TEACHING SCIENCE THROUGH LITERATURE

BY

DANIEL BARTH

A Dissertation submitted to the Faculty of Claremont Graduate University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate Faculty of Education

Claremont, California
2007

Approved by:

John O. Regan

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Abstract of the Dissertation

Teaching Science Through Literature

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Claremont Graduate University: 2007

The hypothesis of this study was that a multidisciplinary, activity rich science curriculum based around science fiction literature, rather than a conventional text book would increase student engagement with the curriculum and improve student performance on standards-based test instruments. Science fiction literature was chosen upon the basis of previous educational research which indicated that science fiction literature was able to stimulate and maintain interest in science.

The study was conducted on a middle school campus during the regular summer school session. Students were self-selected from the school’s 6th, 7th, and 8th grade populations. The students used the science fiction novel *Maurice on the Moon* as their only text. Lessons and activities closely followed the adventures of the characters in the book. The student’s initial level of knowledge in Earth and space science was assessed by a pre test. After the four week program was concluded, the students took a post test made up of an identical set of questions. The test included 40 standards-based questions that were based upon concepts covered in the text of the novel and in the classroom lessons and activities. The test also included 10 general knowledge questions that were...
based upon Earth and space science standards that were not covered in the novel or the classroom lessons or activities.

Student performance on the standards-based question set increased an average of 35% for all students in the study group. Every subgroup disaggregated by gender and ethnicity improved from 28-47%. There was no statistically significant change in the performance on the general knowledge question set for any subgroup.

Student engagement with the material was assessed by three independent methods, including student self-reports, percentage of classroom work completed, and academic evaluation of student work by the instructor. These assessments of student engagement were correlated with changes in student performance on the standards-based assessment tests. A moderate correlation was found to exist between the level of student engagement with the material and improvement in performance from pre to post test.
Dedication

For Dominique:

Quaerendo Invenietis
Acknowledgements

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The author also acknowledges a professional debt to the legions of astronomers, both professional and amateur who have inspired, and instructed him for more than four decades; and to the students who have in turn, challenged him to engage and inspire them in the classroom and under the starry sky. First among them is Reverend Theodore A. Bessette, who gave a nine-year old boy his first glimpse of Saturn on a cold winter’s night, and ignited a life long passion to explore the sky and open the way for others to follow.
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CHAPTER ONE

Overview

Introduction

The impetus for this study springs from two decades of practical experience in the secondary science classroom and a life long fascination with science fiction, first as a consumer, later as a writer. My parallel interests in science and science fiction have leapfrogged together for most of my life. Interests sparked by a Sci-Fi story or film were pursued in the classroom or independently. Later, as a writer, science fiction was an avenue to explore the creative possibilities of new ideas learned in the science classroom. The study of physics, astronomy, microbiology and genetics, furnished ideas for use in short stories written for magazines and anthologies. In the experience of the researcher, science in the classroom and the laboratory and science fiction, especially written science fiction, are inextricably linked. The idea of researching the use of science fiction literature as a primary text in a science class and how students responded to it academically seemed quite a natural topic for investigation.

It must be noted that when referring to “Sci-Fi” in this paper, the researcher is referring to the sub-genera of hard Sci-Fi, which is the most closely wed to current science as we know it and makes every effort not to contradict the laws of nature as we currently understand them. Science fiction writing comprises a very wide gamut of material, not all of this material is useful or useable in the classroom. Hard science fiction, by contrast, is generally written by authors with solid science backgrounds, many of whom work professionally as scientists. Some science fiction authors simply introduce fantastic events, technologies, or events which could not exist in nature as we
understand it; a hard science fiction author, by contrast, sticks much closer to the rules of nature as we currently understand them. Because of this, the hard sci-fi author is less likely to introduce concepts which sound scientific to the lay reader, but are actually more fantastic or even scientifically impossible. In using science fiction in the classroom, it was very desirable to have a hard science fiction text so that students would not have to wonder which of the ideas presented in the book were based upon actual scientific knowledge and which were purely imaginary. The goal of the study is to investigate pedagogic methods which can help students improve their performance on standards-based exams, this goal could not be advanced unless the science fiction text in use presented scientifically accurate facts and information in the context of the story itself.

There have been some previous studies by Dubeck, Moshier, Freudenrich and others using science fiction in the classroom. Some authors used modern science fiction books, others used films or a combination of mixed media. Moore and Bintz found that literature in the form of stories or novels used in the classroom helped put science concepts in social and cultural perspective. Putting difficult concepts in perspective in this way helps students to construct their own meaning and understanding of these scientific ideas. Wiley found in his study that the use of literature in conjunction with other classroom activities helped to prevent students from forming misconceptions of scientific concepts.

Many authors have found that science fiction literature is effective as a motivational tool for stimulating and maintaining student interest in, and positive student attitudes toward, science in the classroom. The great majority of these studies involved
graduate students, specifically students who were non-majors in the sciences. The intent of this study was to try using a science fiction text in conjunction with an inquiry based curriculum in middle school. In reviewing the literature, the researcher discovered nothing regarding the use of science fiction in the middle school classroom. However, for several reasons, it was middle school science that became the focus of this study.

According to a recent study by Lieberman, up to 25% of all teachers nationally teach out of their subject area at some time during the day. (Lieberman 2001) This often occurs because of growth in enrollment or the difficulty of finding teachers in certain specialties, such as in mathematics and science. The current difficulty in finding science teachers can be seen by examining the EdJoin.org website, which is a central clearing house for job seekers and employers in education in the state of California. During the week of December 15th, 2006; EdJoin.org posted over 4,000 job openings at almost 3,000 schools for K-12 teachers in science and mathematics. There is a severe shortage of science and mathematics teachers in California, and similarly across the nation. To compound this difficulty, studies by Grasmick, Thomas, and Pederson indicate that K-8 Teachers are the least well prepared in specific subject areas, including science and mathematics. A recent survey of over 2500 new teachers found that only 17 were certified in physics, astronomy, Earth or space science, 13 were certified in chemistry, 65 in mathematics, and none in computer science. (Grasmick 2001) Overall, less than 4% of the new teachers in this study were certified in science or mathematics. Teacher shortages are also borne out by a recent trend in districts across California to compete for science and mathematics instructors by offering signing bonuses as well as salary bonuses and perquisites. These trends put severe pressure on the teaching of science in
middle school. And yet, high school and college science programs depend upon the results and effectiveness of these middle school science programs to provide them with sufficient numbers of successful students to fulfill the needs of society for scientifically literate workers in all fields, including teaching.

Part of the difficulty in teaching science to young people comes from confronting cultural barriers to scientific learning in the classroom. Virtually every culture has its own stories and myths that help explain the Earth and its place in the Universe, the existence of life on our planet, etc. When a science teacher broaches these subjects, research by Bruner, Lee, Thompson, and others indicates that challenging cultural preconceptions must be done sensitively if the teacher is to be effective in getting the student to incorporate the new knowledge successfully. Indeed, the inquiry method itself can be very challenging for students from cultures which place a high value upon respect and obedience to adults and people of authority, such as teachers. For such students, to publicly test what the teacher has told you by doing an experiment can be seen as disrespectful, it is difficult to persuade such students to pursue a scientific investigation with vigor if the teacher is culturally insensitive to these issues in the classroom.

Studies by Moore and Bintz have shown that science fiction literature is particularly effective in putting science concepts into a cultural context that helps students construct meaning and integrate these new scientific ideas successfully. Bruner, Marzano, and others have done many studies regarding the use of effective and varied pedagogic methods including the use of a paired text to improve learning and the retention of science concepts. The investigator considered whether a science fiction novel could be used as a primary text for a science course with an activity-rich
curriculum incorporating reading, writing, and visual art strands, with traditional Earth
and space science curriculum.

A review of the literature revealed no studies using science fiction literature with
middle school or younger students. Certainly one difficulty with using existing science
fiction literature and film with middle school students is the prevalence of adult themes in
books and films of this type. With older students in college, scenes with sexual or violent
content, or morally ambiguous characters can be passed over and the instructor can focus
on a scientific principle at work in the story. There is no such option with young
students; all content must be age appropriate throughout the story. Reading level is
likewise an issue, most market science fiction is written for adults or young adults. Hard
science fiction for emerging young readers is a very small niche, indeed.

Research Study Design

In setting up an in-classroom study, it was necessary to work closely with a local
school district in Riverside, County, California. The Superintendent's office agreed to
fund the proposed study by providing classroom space, employing the instructor, and
supplying classroom materials in exchange for sharing the data from the study with the
district. Initial discussions had focused upon a plan with three campuses offering one
section each of the “Summer Science Enrichment” course; this plan would have three
independent instructors and a total sample of 75-100 students. Unfortunately, changes in
funding made this impossible, and the plan was reduced to a single campus. The district
chose to implement the study at the campus where the need for improvement was the
greatest. The course would be offered to all the students at the middle school and the
class would be made up of a self selected group of 6th, 7th, and 8th grade students. All students were to get the same curriculum, regardless of age or grade level. Approximately half of the instructional time would be spent doing a variety of hands-on activities, with the remaining time split approximately equally between reading and writing activities. All students would take a pre test of 50 questions and take part in a pre program survey. After the four week program was complete, all students would take at 50 question post test and take part in a post program interview. The results of the tests and surveys before and after the program would be compared to determine if there had been any change in student responses.

The pre and post tests were all composed of the same group of fifty questions. The order of the questions and of the answers for each question were scrambled into four versions to help prevent copying or cheating. The test questions were further divided into two sub groups: standards-based questions and general knowledge questions. The forty, standards-based questions cover topics that are dealt with in the text of the novel and in the lectures and activities the students participate in. The ten general knowledge questions are based upon science concepts and standards in the same area of Earth and space science, but these particular standards are not dealt with in the book, nor are they covered in any of the lectures or activities. The pre and post test results allow us to compare any effect size that may be observed on knowledge about the specific standards that are covered in the class in detail, as well as any effect size on the general knowledge portion of the test.

It is also part of the study to measure student engagement, and to attempt to relate measures of student engagement to changes in performance on the standards-based
portion of the pre and post test exams. Measuring engagement is difficult; it is not easy to quantify internal mental activity. The study called for three independent measures of student engagement; the first measure would be taken by the student’s themselves. Twice each day, at a random time, students would be asked to make a short entry into a daily journal. Each time, the students were asked to consider three questions: What are you doing? What are you thinking about? Do you have any questions about today’s lessons? Students were asked to respond in short, complete sentences. The researcher took sufficient time on the first day to insure that every student understood that the response journals were confidential, and that except for the researcher, neither their teacher, nor anyone else would read the journals.

The second measure of engagement was the percentage of daily assignments each student finished by the end of the day. In order to finish an assigned task, a student must be physically and mentally engaged with the task to some significant degree. Each day the work was collected, and the researcher checked the collected work each week and evaluated each assignment for completeness. Academic quality, neatness and other factors were not considered; only the percentage of the assignment completed was evaluated. This assessment was made by the researcher independently, without any input from the instructor.

The third measurement of engagement was to measure the academic quality of the work completed by the students and turned into the instructor. In order to produce work of satisfactory academic quality, the student must be engaged with the material at some academic and physical level. The academic assessments made by the instructor were done independently, without any input from the researcher. The finished workbooks and
journals were evaluated twice during the program by the instructor. These academic evaluations were turned over to the researcher after the course was over.

These measures of engagement would be correlated with any measured changes in the number of correct responses to either standards-based questions or general knowledge questions within the exam. It was the intention of the researcher to measure if such a quantitative correlation existed between measurements of student engagement and changes in student performance on content-based questions in the pre and post program exams, and if so, to quantify this relationship and provide a baseline for further research in this area.

It was also the intent of the researcher to compare changes in student performance on content-based questions to similar changes in student performance on the general knowledge questions in the pre and post program exams. Because the reading and classroom instruction are interwoven in nature and closely coordinated by design in regards to the academic standards which are addressed, it is hypothesized by the researcher that the targeted learning addressed by the Science Through Literature, or STL pedagogy will be effective in promoting student learning and improved mastery as measured by the changes in performance on the pre and post program exams. It is further hypothesized that there will be no change in student performance on the general knowledge question set over the course of the pre and post program exams. Because of the pace and intensity of the program, involving students five hours per day for just four weeks, plus homework and observation sessions in the evenings, there will not be a great deal of time for the student to absorb all this new knowledge, much less integrate it, and branch off independently such as finding a book on a related topic, or seeing a program
or movie on a related topic. While it is hoped that the exposure to Earth and space
science in an intensive, and varied activity rich program will have long lasting effects on
student interest in science, and learning and performance in math and science classes in
the future, any longitudinal study was beyond the scope of this project.

Limitations and Biases of the Study

First and foremost is the researcher’s own author bias regarding the science
fiction text, Maurice on the Moon. Writing curriculum is a skill which all teachers
develop to some extent, and a common job experience for almost every educator at some
time during their careers. Writing a novel is rather different and crosses the line from
technical writing into artistic endeavor at some point, even when one of the principle
intents of the author is to educate and inform the reader. As an author of a science fiction
novel, there is great personal motivation on the part of the researcher to please the
intended audience of children and their teachers. One of the fundamental assumptions of
this study is that if one is to use a fictional novel as the principle text in a science class,
then the book must be a good novel, and the children must like it. The contrapositive
argument is easier to make; it would be difficult to found an academically successful
curriculum on a bad book. The idea of planning a research study to use a science fiction
novel to increase student engagement and performance in science presupposes a good
novel in the literary sense. Perhaps a best seller which has been enjoyed by millions of
children for many decades would be a reasonable choice, sitting down to write a new
novel custom for the purpose, rather less so. It certainly could be argued that the
researcher has a good deal personally invested in the outcome of the study. The
researcher prefers to view the artistic excellence of the novel as a hypothesis subject to support or rejection by the data from the study. While the success of the study may be indicative of the book’s literary quality, that relationship is not readily quantifiable and lies beyond the scope of this study.

In any case, for the designer of the study, the researcher conducting the study, and the author who wrote the book and the curriculum to be one and the same person must be seen as a major weakness of this research. In very preliminary work, this problem is sometimes unavoidable. This study must be considered as early work in this area; arranging for independent researchers to repeat the study with larger and more diverse groups of students will be essential to confirming or rejecting results from this study.

There is also bias involved with the district and school which hosted the research study. The school which was used as the site for the study has been under program improvement status for five years, and there are powerful pressures on the school teachers and administration to find ways to increase student performance in the classroom. As such, the school had a great incentive for a positive result on this study. However, the ability of the school’s staff or administration to influence the outcome was minimal. No one from the school’s own staff was involved in the daily operation of the Summer Science Enrichment class, and no faculty or administrators visited the classroom personally during the time when class was in session. No one from the school’s faculty or staff had substantive contact with the researcher or teacher during the four week class, nor was there any attempt to influence or control the outcome of the study. There was one classroom visit by a school district official; this occurred in the course of a tour of the
summer school sites district wide and lasted less than five minutes. There was no attempt to influence the researcher, instructor, or students in any way during this visit.

A major weakness of the study is the small number of student participants that completed the initial study. The study was originally conceived on a substantially larger scale with approximately 100 participants on three different campuses with different instructors. This sample size would likely have given a greater ethnic and socioeconomic diversity to the sample population. It would have also put any statistical analysis of the resulting data set on a much better foundation.

Financial considerations made it impossible for the school district which hosted the study to fund more than one class. The choice of the campus to host the study was also in the hands of the district. While there is some evidence from discussions and interviews with various district staff that there may have been more interest in the Summer Science Enrichment program at some campuses than at others. The choice of campus may have impacted the sample size substantially, given that only a single campus was used for the study. While the reasons for the small sample size may be debated, the results of a small N on the study is more clear. Results from this study must be considered as preliminary. The small size of the N limits the confidence level of the conclusions that can be drawn from this study. The results can, however indicate directions in which future work may be profitably pursued.

The limited demographic breadth of the student sample is also a limit to the study's broader applicability. The relatively narrow demographic sample is due primarily to restricting the study to one class of students drawn from a single campus. The middle school which hosted the study has a student population of 1076; with 361 6th graders,
339, 7th graders, and 376 8th graders. The student population demographic breakdown is 46.6% Hispanic or Latino, 40.0% White, 9.6% African American, 1.0% Filipino, 0.9% Native American, 0.8% Asian, 0.8% multiple or no response, and 0.3% Pacific Islander. The median income of the families served by Santa Fe is approximately $32,000.00 per year. (All data taken from the school district’s website.)

School wide in 2005, the most recent year for which data is available, 41% of students score at or above the 50% percentile in reading, and 37% in mathematics. Of the two subgroups that were represented in our study, 33% of Hispanic students school wide scored at or above the 50th percentile in reading and mathematics, while 55% of White students scored at or above the 50th percentile in reading, 47% in mathematics. For English Learners or ELD students, only 23% score at or above the 50th percentile in mathematics, just 17% in reading. Reading scores for boys over all show 35% scoring at or above the 50th percentile on norm referenced tests, 47% for girls school wide. The average class size for mathematics is cited at 25.4, with 11 classes over 33 students per class; science classes are the most crowded with an average 30.5 students per class and 19 classes at 33+; English classes average 25.4 students per class, with 7 classes at 33+ students per class.

This middle school has not met its annual AYP goal in any of the last three years for which data is available. Neither Hispanic, White, or ELD students met their AYP goals for proficiency or participation rates in 2005, the most recent year for which data is available. The 2004 API score for the middle school was 687 with 99% of students tested. The school’s statewide rank is 5, and its similar schools rank is 9. The API for subgroups represented in our study are: Hispanic = 650, White = 719, Socioeconomically
disadvantaged = 656; all scores are from 2004, the most recent data available. This middle school is in year 4 of its Program Improvement Implementation.

Only Hispanic and White students were included in the self-selected student body in the study. This was not especially surprising, as these two groups comprise over 86% of the student body at the campus from which the students were drawn. The socioeconomic level of all the students in the study was also very similar. The study group was representative of the campus from which the students were recruited, but the weakness remains. Again, this is primarily a function of the small sample population, taken from a single campus.

The remedy for this limitation is obviously further research. Three schools have agreed to run the Maurice on the Moon curriculum as part of their regular classroom instruction in the spring semester of 2007. This should give us a sample population of well over 100 students and a much broader demographic and socioeconomic base for the follow up study. Results of that research should do much to confirm or falsify the original conclusions of this preliminary study.

Obtaining Final Approval for the Study

Obtaining final approval for the study was an involved process requiring the researcher to negotiate the terms of the study with the district officials individually and in committee. It also required the researcher to gain the approval of the parents, teachers and administrators in the district who chose to involve themselves in the local political and educational process.
The initial outline of the study was submitted to, and approved by the district superintendent. Once the outlines of the study had been agreed to by the Superintendent, the plan for a pilot course and research study was submitted to the district’s Curriculum Council, where it was given initial approval. Initial approval is only a stepping stone, and all that is actually approved is that the course materials would be put on display for public viewing and comment for 30 days. The district regularly notifies parents and teachers of curriculum council meetings and invites members of the district staff as well as members of the public to view new potential course offerings including such materials as textbooks and curriculum.

Following the review period, the council discussed the materials again, and the researcher made a short presentation discussing the course itself, and the academic goals of the course.

Members of the district staff, as well as members of the public present at the meeting were deeply interested in the issue of improving student performance in the sciences, there were also many concerns regarding the use of a non-standard text for the program. Several parents and teachers present voiced concerns about using science fiction in a science class. The researcher was asked to summarize the plot and to discuss the characters and what “principals and moral standards” these characters represented and promoted in the book.

The author described the plot briefly and read short selections from the text. Some of these discussions continued long after the hearing. Several parents were very interested in what social values the book presented and supported; the details of the plot and the meta-content or ‘messages’ of the text were reviewed in some detail. The author
took some pains during these meetings to present and defend his conception of the Maurice character and the use of the science fiction novel in a science class. Over the course of the discussion, each of the questions and objections were satisfied, although it was clear that some parents still did not favor the science fiction format of the story.

Some board members inquired about the nature of the activities in the classroom; interest particularly focused on hands-on learning and project-based learning methodologies. District policy places a high value upon student engagement with the material and upon having all students engaged actively in learning for more than 90% of their time in the classroom. Using materials from the book and the *Maurice on the Moon* curriculum, the author was able to demonstrate that the consistent dramatic theme of the book tied all the learning activities together. Several projects, such as *Understanding the Moon in Orbit* or *The Lunar Surface and Landscape*, are multi-layered in nature; students are introduced to the key ideas early on while layers of detail and analysis are added as they return to study new aspects of the topic as the story progresses. The process of critical thinking, scientific and mathematical analysis becomes progressively more sophisticated each time the students return to the topic.

The academic goals of the project as presented to the district, were:

- Students will engage in long term projects closely tied to California state educational standards
- Students will participate in multi-disciplinary projects which require them to use and integrate skills across the four core areas of curriculum: science, mathematics, language arts, and the social sciences.
• A substantial portion of the project-based learning should involve group work to stimulate collaboration and teamwork.

• Projects should help all students, including English learners, acquire a broadly based academic vocabulary.

• Projects should help students prepare for, and improve performance on, standardized examinations such as the STAR test and SAT.

The curriculum as presented to the Curriculum Council contained 27 major hands-on projects ranging from simple 15-minute demonstration exercises intended to amplify a particular concept to complex activities that would be revisited over several days; each time adding a new layer of conceptual or academic challenge. Questions regarding the standards-based content of the activities were rather extensive. Administrators, teachers, and parents were all keen to know that the activities were well grounded in the California state standards and that these activities were appropriate to the age and skill level of the students who would be participating in the program.

Selection of students for the study

A few days after the book, curriculum program, and research proposal were presented to the Curriculum Council, the Hemet District School Board formally adopted Maurice on the Moon and its curriculum for a pilot program and study to be run during the summer school term. The program was entitled “Summer Science Enrichment”, and would be offered by letter, to every 6th, 7th, and 8th grade student at the Santa Fe Middle School. The researcher drafted a letter describing the “Summer Science Enrichment” course and also the research study. The brochure for the class described the integrated
curriculum and hands on activities and the science fiction book. The research project letter described the project, that test and survey data would be taken, and that participation was completely voluntary. There were also permission forms for both parents and students to sign and return. This packet was approved and distributed by the school district to the families of approximately 1100 students who attended the campus where the program would be offered.

Thirty nine families returned completed paperwork signing their children up for the Summer Science Enrichment program. Although detailed contact information was included in the letter and brochure, encouraging parents and students to contact the researcher if they had questions, only two parents contacted the researcher with questions. Both of these questions were rather trivial in nature and concerned the location and starting time of classes for summer school, etc.

Of the original 39 students who signed up, only 24 ever appeared in class. Several district officials commented that this initial attrition rate between the number of students who sign up for a summer program and the number who initially show up for that program was very consistent with their experience and expectations. One school official who asked not to be named in this report said: “If you want to have 30 students complete a summer school program, you must sign up 75 kids. Of these 75, perhaps 45 will show up on the first day, and of these, 25-30 students will finish the program. This makes things very difficult for summer school administrators and teachers. We have to staff the program for a large number of kids initially, and we set class limits very high. Even so, we almost always have to collapse classes and dismiss teachers. There is a lot
of pressure on teachers to keep kids attendance up and promote student success so that they don't lose their jobs.”

Of the 24 students who showed up on the first day of the Summer Science Enrichment program, two students dropped almost immediately upon getting more information on the class and what was actually involved. Three students dropped out over the first half of the program when their families withdrew them so the students could go on an extended vacation, causing them to miss 7-12 days of instruction time. District rules for all summer school programs require that any student missing more than three school days be dropped from the program. The last student to leave departed just two days before the end of the program, because his family was moving out of the community. Eighteen students completed the full program and are included in this study.

Physical environment of the study

This research study utilizes mixed methods, employing both qualitative and quantitative methods to gather and analyze data. It has been argued that everything in the classroom where the teaching event takes place is semiotically significant; that the arrangement of the student desks with respect to the teacher’s desk, where the blackboard and the computer and the projector were located in the room were all significant data worthy of study. While the researcher makes no claims or pretense to being a semiotician, the diagram of the classroom below is presented to offer a rigorous description of the environment in which the study was conducted.

The classroom used was a standard laboratory / classroom type common to many secondary and middle school campuses. The classroom was equipped with seven
laboratory tables large enough for 4-6 students to work together comfortably, 30 student desks, a teacher’s desk, and a lab demonstration table with a sink. Behind the demo table, a double-height chalkboard runs the width of the room with a ceiling mounted screen above. The counters running around the perimeter of the room had sinks with water and gas available, storage cabinets below deck and bookcase / storage cabinets above the counter. A storeroom and a laboratory prep room with a full lab sink opened off the room as well, greatly simplifying access to lab supplies. The classroom was also
equipped with a single computer with internet access, other computers normally available in the room for students had been stored for the summer. The classroom was fully equipped for the classroom and laboratory portions of the study.

Selecting the classroom instructor

With the conditions of the study established and the venue chosen, it remained only to select the instructor for the summer program. The position was posted by the district on their web site and the position was ‘flown’ along with all other normal summer school positions during the district’s normal hiring cycle. By the end of the interview process, the evaluators were unanimous in selecting one candidate for the teaching position.

The selected teacher, who we will call “Linda”, is a veteran teacher in her 7th year in the classroom. The teacher agreed to interviews which would be conducted before the study, at midpoint, and again after the study. The first interview focused on the instructor’s background and pedagogic practices and beliefs. The information presented here is a summary of the first interview.

Linda has a B.A. degree in education, and a minor in chemistry. She explains that she had been a pre-med major who transferred to education in her junior year. She also has 35 hours of biology, just short of a double major in Education and Biology. Linda confesses that chemistry is her favorite science, closely followed by biology. While she did take a physics class in college, Linda remembers it as an “insane class” which was crammed into a four-week summer term. While Linda is obviously well trained in the
laboratory sciences, she reports that teaching physics and Earth and space science, is definitely outside her comfort zone.

Linda describes herself as a “practical, hands-on” science learner who relates science concepts in class to real world examples; she also carries this into practice in the classroom. Linda favors activity based, and long term project based learning in her science classroom.

“I find that [when using active learning] the kids remember it better, compared to a ‘here’s what we have to learn’ approach. They are able to discover it [science concepts], and take ownership of it, which helps, because they are able to grasp the concepts, even some of the higher level concepts. This makes it easier with some of the more difficult topics such as physics.... It makes some of the tough stuff easier.

“As a science teacher, I am very much into projects. You know, units that flow through the whole year. Starting out with scientific method, where we do light, the process into photosynthesis, and from there into cells, and then on to genetics.... I would make sure we go from micro to macro, too.”

Asked to consider what she would do if she had complete academic freedom in the classroom, Linda replies: “That would be great! While I would still use project-based methods, there would be a lot more lessons taking the kids out into the world outside the classroom and showing them how things work. I think there is a lot more science in the world than you can show someone just in the classroom. If money was no object, there would be a lot more field trips, taking kids out to areas where kids could build and plant their own garden, or construct their own trebuchet!”
When I asked Linda about her knowledge of the *Science Through Literature* concept, she indicated that she considered literature to be "a huge part of middle school", and indicated that she had taken a class on exploring science through literature as part of her writing class sequence at the University of Missouri, at Saint Louis. Linda indicated that even though she had never done a science and reading combined curriculum before, she had high expectations for the program. "I think it’s a great concept; a wonderful idea! The kids are able to read and actually apply [what they learn.] It’s more of an inquiry – what I like about it is that the kids are able to ask their own questions. By reading a story and then applying a curriculum with it; the kids get excited about what’s going to happen next [in the story]. It gives the science learning more meaning than just doing a classroom science project."

The researcher also asked Linda about her knowledge of, and expectations for, the students in our summer program. "Since this is just the kids in my district, I feel that these kids will be pretty much the same demographic as I’m used to at my school. We are ethnically and socioeconomically diverse, and we have a very broad range of students; from those who have a very strong knowledge of science to those who basically have no ideas about science. I think it will be very interesting to see how the various age groups are working together. Actually, I think that this will be one of the stronger points [of the program] because they can actually help each other. I think the mix of ages will be a good thing..... Actually, I’m very excited because this is the first time that I’ve taught a science course through a science fiction book and had the kids tie in the classroom activities to that book..... I’m curious to see how the kids will respond to Maurice and his adventures – will they see themselves as Maurice and Cassie? I’m thinking especially of..."
some of the little boys and girls who like to go out and throw rocks and play rough and have adventures on their own. I wonder how many of them are going to connect with Maurice and Cassie?"

Conducting the Summer Science Class

While some of the data from the study is quantitative in nature, there is also a qualitative portion which involves a thick description of the environment and daily routine of the science through literature classroom in action. The purpose of this qualitative description is to better inform the interested reader as to the conditions under which the instruction was delivered, and how the class functioned on a daily basis. It is also essential to convey that this study was not conducted as part of the school's regular term classes. The study was conducted as part of the school's summer school program. Class convened at 8:00 each morning and ran until 12:00 with just two five minute breaks. Because of the extended sessions, the instructor was more free to schedule reading, lecture, writing and activities. There was no concern that a particular project or activity would extend beyond the 50 minute limit imposed by a traditional daily school schedule.

The first day of the summer term is best characterized as organized chaos. Over 800 students and their parents descended upon the campus. More than 100 students were there to attempt to sign up for summer classes at the last minute. A team of administrators and secretaries helped to get the students organized and to get new students registered for the summer term. The teacher collected her students from each of the three grade levels and brought the students together for the first time. Linda then took
the students to an assembly where the Principal explained the rules and expectations for the summer term to everyone. After the assembly, Linda escorted all of her new students to the classroom.

Linda’s first priority was to establish a seating chart for class and for lab. Linda later confided that although she did not know these children, her experience in the middle school classroom had taught her that a well structured environment helped students to feel secure and also was instrumental in limiting undesirable behavior in class. Once seating had been established, Linda introduced the Researcher and allowed him to address the class. During this talk, which lasted most of an hour, the researcher outlined the Science Through Literature concept, discussed the idea of a research study, and reviewed the goals of the study and the concept of confidentiality and its importance to the study. The researcher also discussed the daily notebooks used for gathering data during the study and introduced the students to these notebooks for the first time. The students were told that the researcher and the teacher were acting independently of each other and that the communication between the students and the researcher in their notebooks were confidential and would not be shared with the teacher and would not be part of their grade for the summer term. The concept of confidentiality was again emphasized and questions from the students were encouraged and entertained until the researcher was confident that all the students understood this.

The method of using notebooks to ask study participants to record thoughts or experiences in order to provide a statistically significant data sample has a rich history. The researcher developed his own method independently, although it was informed by reading other studies which used similar methods.
The students were told that random times during the day, they would be asked to stop and write a few sentences in their notebook before resuming their work. The students were told that the questions they would answer each day would always be the same. What are you doing now? What are you thinking about or feeling now? Do you have any questions about things we have read about or done in class?

Other response sample methodologies use sophisticated methods such as beepers, alarm watches programmed to go off at random times, or text messages to inform study participants when it is time to record a response. Working with 11-13 year old students, it was necessary to simplify the process; the researcher predetermined the times when the notebook responses would be called for and simply announced them in class each day. For the purposes of this study, the researcher divided two, 2-hour blocks of each day into five minute intervals. Eliminating the first and last ten minutes of the school day as impractical for notebook responses due to the predominance of practical, non-academic matters such as attendance, startup and clean up activities; the researcher focused on the remaining twenty, 5-minute periods of time as appropriate possibilities for a notebook response. The researcher used a 20-sided die, which was rolled twice each morning to randomly determine the time at which the notebook response was called for. The notebook response times were determined each day before the start of school and were not shared in advance with either the teacher or the students.

The intent of the researcher in regards to the first question was to establish physical engagement at the sample time by asking what the students were actually doing. It was emphasized that it was important to answer briefly and honestly, and that the teacher would not be privy to the notebooks. Students were asked to limit their answer to
a single sentence if possible, or a list of points if they preferred. These responses would be used to document discrete events of students being physically engaged or not engaged with the curriculum materials. Each response was compared to the daily log to determine whether or not it represented on task activity.

The researcher emphasized that students should consider each question carefully, and record a primary, secondary, and tertiary answer (if any). For instance, when answering the question: “What are you doing?”, students were told to consider their activities carefully before answering. Numerous examples were given and discussed, and the researcher emphasized that each student must prioritize their answers for themselves. For instance, if a group of four students were working together on a lab exercise calculating the speed of a ball rolling down a ramp; the students involved might be doing a variety of things ranging from timing the ball, calculating its speed, recording data, fooling around, listening to an i-Pod or MP3 player, writing a note to a friend, even sleeping in class. Each student might give a different answer of what thing most engaged their attention at the time the notebook response was called for. The researcher also went to some pains to indicate that the responses were confidential and would not be shown to the teacher and would not be part of the grading process.

The intent of the second question was to document the student’s mental engagement with curriculum by asking them to describe what they had been thinking about when the notebook response was announced. The initial conception of the responses to this question included a range of possible results from detailed on task replies about thoughts regarding the reading or activities to off task replies such as a student thinking about after school activities, dating, or family. In fact, this question
proved very problematic for most of the students in the study, who were unable or unwilling to frame a cogent reply about their own internal mental or emotional state of being.

Abstract thinking about internal mental states was clearly difficult for many of the students in the study group. The problem of speaking and writing in English further complicated the problem for those participants who were identified as English language learners. The researcher quickly discovered that to expect the students to provide a detailed written expression of an internal mental state in an emerging second language was not always realistic. Few, if any of the students in the study were consistently able to express their internal states of thinking and feeling in an organized, hierarchical manner that the original research protocol called for.

The following dialog was recorded in writing from memory immediately after the interview occurred, and represents a typical exchange.

Researcher:  (Noticing a child was not recording anything in his notebook) “Roberto, are you having trouble with your notebook response?”
Student:  “Yeah.”
Researcher:  “Don’t you want to tell me what you are thinking about or feeling?”
Student:  “I don’t care about that.”
Researcher:  “Then go ahead and write it down. It doesn’t have to be long, just a short sentence or even a few words are o.k.”
Student:  “What am I supposed to write about?”
Researcher:  “What were you thinking about when I asked you to start writing?”
Student:  “What do you mean?”
Researcher: “Tell me what was going through your head; you know, what thoughts were you having when you were doing the activity?”

Student: “I wasn’t thinking anything!”

Researcher: “You weren’t thinking about anything?”

Student: Shrugs.

Researcher: “Ok, why don’t you tell me what you were feeling about the activity?”

Student: “Feeling? I guess I feel hungry.”

Researcher: “I meant for you to tell me about how you felt about what we were doing in school today.”

Student: “I know I’m in school... I just feel hungry.”

This conversation was typical on a number of levels. Many students were not unwilling to relate their internal states, but appeared to be unable to describe them. When asked to describe what they thought or felt when an notebook response exercise was called for, many students were only able to describe their internal physical states, not their internal mental states. Responses such as: “I’m tired,” or “I am sleepy now,” or “I feel hungry and I am thinking about what is for lunch,” were common. When the researcher tried to clarify his request to have the students focus on how they were feeling about or thinking about the school activities going on at the time, this produced little or no improvement in the quality of the responses. On the other hand, a few students were almost always able to describe their mental states and able to successfully relate how they felt about an activity or what they were thinking about during the activity.

In some cases, the expression of thoughts and feelings were intensely personal. It became clear that outside factors in the home or in the personal lives of the students had a
great impact on their mental states during the course of the class. One student repeatedly described feelings of sadness and rage after learning that a cousin had been shot and killed during a gang conflict in Los Angeles. Another described despondency upon the loss of a family dog, the hopelessness of waiting for someone to respond to “lost dog” posters around the neighborhood, and later elation at going to adopt a new puppy at the local animal shelter. Several students described feelings of love and reported thinking about a boy or girl friend often during the school day. In spite of all these complex feelings, it is remarkable that the students were able to concentrate on the academic activities at hand and make substantial progress in the acquisition of math, science, and language skills. Most, but not all of the students made some progress in the quality of their self expression and self awareness of internal mental states during the program, but it is beyond the scope of this study to analyze the cause of improvement.

The notebook responses made it clear that even an orderly, well managed classroom’s calm and productive appearance conceals a complex network of relationships, feelings, and mental states being experienced by learners at every level of academic achievement. Almost every student reported some personal upheaval during the four-week study; from the tragic-comedy of adolescent love to extreme disasters of crime, death and dislocation. The resilience of the students emotionally, intellectually, and academically was extremely impressive.

The third thing that the students were asked to do during each notebook response break, was to ask any questions that had occurred to them since the last break regarding the story or the activities that were being done in class. Once again, the researcher emphasized that the questions communicated in the notebooks were confidential, and that
questions should be academically appropriate, and not personal. When discussing this in
class, several students wanted to know how their questions would be answered; and if
they would not be answered, why they should write them down? Thus, the third
notebook response task: “What questions do you have about what we are reading or
doing in class?” evolved into a written dialogue between the researcher and the students
in the class. At the end of each day, the response notebooks would be collected and
reviewed, and any appropriate questions asked by the students would be responded to by
the researcher.

Initially, the idea of having students record questions was conceived of as an
additional measure of intellectual engagement with the material being presented.
Generally speaking, only a student who is actively engaged with intellectual material is
able to ask pertinent and appropriate questions about that material. While the nature of
the written question and answer dialog between student and researcher blurred the line
slightly between observer and participant in this study, the questions were not discussed
verbally with the students during the class day, so as not to interfere with the teaching
process. While every student asked at least one pertinent question during the term of the
study, the content and focus of the questions varied widely. The questions asked by the
students broke down into three major categories. Many students were fascinated by the
writing process involved in creating the *Maurice on the Moon* story, others focused upon
the aspects of space travel and colonization of other planets, while others focused upon
technical aspects of astronomy such as the physical nature of the Moon and other planets
and how scientists acquired such knowledge. The tone of the questions varied from
wonder (Is this *really* true?), to skepticism (If the Earth is like this, how can the Moon be
so different?), to denial (My Dad says you are wrong about this!) In some cases, follow up questions were asked over a period of days until the student was satisfied as to the answers given. In other cases, students asked questions whose answers were clearly beyond their cognitive grasp (How does gravity work so that the Earth’s gravity holds the Moon in the right place all the time?) Regardless of their particular content, these questions were clearly a good indicator of a student’s intellectual engagement with the material being presented in the classroom.

Daily Classroom Routine

The instructor chose to implement the *Maurice on the Moon* curriculum in an activity rich format. While the curriculum allows the teacher to customize the delivery of instruction from either an activity rich or text rich perspective; the instructor chose to emphasize the science and mathematics based activities, and spent an average of 11.8%
of the available classroom time on reading, 10.5% of available time on writing, 15.8% of available time on class or group discussion, and 45% of available time on hands-on activities.

During discussions between the researcher and the instructor, it became clear that Linda’s pedagogical choices in the classroom were informed by her core beliefs about children and how learning occurs in a science classroom. Linda is a classically trained chemist first, and an educator second. She studied science at the University of Missouri, Saint Louis where her program emphasized a hands-on laboratory curriculum. Laboratory research delighted Linda as an undergraduate, and still fascinates her today. During her interview for the position, Linda noted that the emphasis on science activities and possibilities for students to use inquiry methods and do real research in the classroom was the primary reason for her interest in teaching the program in the first place. Linda believes that students learn science best when they have the opportunity to explore and experience science concepts first hand, rather than reading about them in a book. “Reading is O.K. as an introduction, a demonstration is better, but actual hands-on inquiry is the best method for teaching kids science.” (Personal communication).

Linda was also insistent that she be allowed sufficient freedom to schedule and alter activities as she saw fit, and made it clear that she would not be interested in teaching a ‘canned’ program where each day’s lesson and activities were highly scripted in advance. In fact, Linda was rather dismissive when discussing such programs, and indicated that she thought it was impossible for someone to design a completely scripted lesson for children they had never met, and whose needs and strengths were unknown.
Linda indicated that she believed that good teachers were flexible, and able to adapt their lesson content, difficulty, and mode of presentation ‘on the fly’ in the classroom.

One challenge for Linda was the substantial socioeconomic differences between the children in the study and the students at her own school. More than one third of the students in the study were identified as English Learners, or ELD students. While Linda had taken CLAD training and was aware of SDAIE strategies, she was not used to applying them regularly in class. The lessons and activities of the Maurice on the Moon program were, however, developed with SDAIE strategies in mind. The lessons emphasized group work to help students acquire both social and academic English vocabulary, as well as extensive use of hands-on activities, as well as using diverse strategies for concept acquisition by students within the program.

The general pedagogical method for the program started with students reading together from the story. This allows students to be introduced to concepts in a way that is natural for them. Following reading, students discussed the ideas from the chapter or section that had been read in small groups, and then related the results of their discussion to the class as a whole. This discussion helped to formalize the scientific concepts that had formed the foundation of the action in the story. After reading and discussion, a small group activity would follow that allowed students to use other modes of learning such as drawing and model making along with further group discussion. These hands-on activities access student’s multiple intelligences to deepen their understanding of the scientific concepts. Finally, a laboratory activity allowed students to apply what they had learned to investigate or solve a scientific problem. It was usually at this stage that mathematics related to the scientific concept were introduced; usually as part of the
analysis section of the lab activity. The use of mathematics helped students to expand their understanding of the science involved, and allowed them to improve their mathematical skills by applying them in a concrete manner to understand a now-familiar scientific concept. Often, a single general scientific topic, such as gravitation and orbital mechanics, would be touched upon again and again, creating a learning spiral that deepened understanding and further cemented gains in mathematics and academic English vocabulary by giving the students an opportunity to use the knowledge they had so recently gained. Further, because each activity produced a physical product that the students could see and share with their peers and their families; the students were able to see immediate physical results based upon their newfound learning. The students all took great pride in the products of their efforts in the laboratory, such as star maps, a lunar landscape model, calculations and plots of the Moon’s orbit, even astrophotographs and moon maps.
A Crisis of Knowledge

There is a crisis in science education today. Although economic growth, societal stability, and environmental health all depend upon a culturally broad based and rigorous scientific literacy, science education does not provide our young people with the science education that our 21st century culture will require of them. There is a shortfall in the pool of scientifically literate workers required by our culture, and the problem is not a new one. (Schaefer 1990; Schmidt 2004) The problem is a complex one, and will require all of our ingenuity and dedication to solve; as H. L. Mencken says, “For every complex question, there is a simple answer—and it’s wrong.”

As a language of inquiry and discovery, “science is too little spoken in the nation’s households and there are too few role models for young people to emulate.” (Tobias 1990) This problem is a long standing one. Between the years of 1966 and 1988, the number of students planning to major in the mathematical or scientific disciplines dropped by 50%. (Green 1989) The problem continues today. Reformulating science education in the K-12 arena has been an issue of pressing concern since the days of Sputnik I in the late 1950’s, obviously we need to continue to attack this issue with new vigor and continue to attempt new strategies. (Schaefer 1990; Tobias 1990)

How are we to address this problem? An essential technique in any scientific inquiry is to break the problem down into discrete steps. We can begin to analyze this problem by examining the K-12 educator who must deliver the science instruction. While it may be obvious to most acute observers, that knowledge must predicate
teaching, never the less it is helpful to know that even this discrete point is backed by educational research. Subject content knowledge is acknowledged to be an essential part of the cultural toolkit of anyone wishing to teach science and mathematics effectively. (Grasmick 2001) However, teachers at the elementary and middle school level are very seldom masters of the science curriculum that they must teach. According to Nancy Grasmick, a recent (2000) study of all education students in the State of Maryland found that of 2550 teacher education candidates, only 4 were certified in physics, 4 in Earth/space science, 13 in chemistry, 65 in mathematics, and none in computer science. This, even though subject knowledge is acknowledged to be the most important variable affecting student achievement. (Grasmick 2001; Schmidt 2004)

According to Professor William Schmidt, director of the 1999 TIMSS study, “If you are going to have a challenging curriculum [in math and science], then you also have to have teachers who have enough of the mathematical and mathematical-pedagogical knowledge in order to pull off that curriculum.” (Schmidt 2004) In high poverty schools, rural schools, and inner city schools, the problem is accentuated by the shortage of qualified educators. Nation wide, up to 25% of all educators teach out of their subject area during some part of the teaching day. (Lieberman 2001)

In fact, teachers (especially elementary educators) as a group tend to be poorly trained in the sciences and poorly prepared to teach them. (Grasmick 2001; Thomas and Pedersen 2003) In spite of this need, teacher education programs as they exist across the nation are often poorly structured to help educators remediate their deficiencies, even though a variety of organizations including the American Council on Education (ACE), the American Association for Higher Education (AAHE), the Council of Colleges of Arts
and Sciences (CCAS), and the American Association of Colleges for Teacher Education (AACTE) all indicate that more and better content in science and mathematics must be added to teacher education programs. (Carriuolo 2001) Additionally, there is a lack of professional development courses available during evenings and over weekends or summers when currently employed educators are able to take them. Further, science faculty that might be best able to teach such courses tend to be occupied with research of their own or other subject specific professional development activities. (Shaffer 2001)

For those students currently pursuing certification as educators, it is clear that powerful teacher preparation must include subject specific content in mathematics and science to make them more effective in the classroom. To prepare a powerful science teacher requires not just strong pedagogy taught by professional educators but science knowledge taught by a scientist. (Carr 2002) Collaboration is a powerful tool for change in education, but there are many barriers to this collaboration. Scientists and teachers tend to have very different cultures, although, both tend to reflect the philosophy that “science is hard—teaching is easy.” Both groups suffer from failing to understand that knowledge isn’t enough to create effective education. (Carr 2002) Other barriers to this collaboration stem from language difficulties. It is not that both groups do not use the same terminology; rather that they both have specific and conflicting definitions for similar or identical terms. The programs also tend to be geographically isolated on campuses – even if a university offers both programs to equal numbers of students. The professional expectations each faculty has for their respective students in terms of success and career goals also differs significantly, creating very different cultures between the two departments that would otherwise benefit greatly from working together. Carriuolo
refers to this as “academic silos.” (Carriuolo 2001) This cultural divide does not end when teachers move out into the field. In schools where faculty is divided into departments or disciplines, there is a continued lack of teacher cooperation between teachers of science and teachers in other disciplines – to the detriment of both groups. (Hanson 2002)

A Conflict of Cultures

It is important as educators to do our utmost to provide equal access to scientific knowledge and science education to all students regardless of color or socioeconomic status. The 21st century economy demands that new workers entering the field must be scientifically and technically literate. There has been a shortfall of well trained employees in fields where science and technology know how are considered gateways to improved socioeconomic status. (Schaefer 1990) The challenge for educators is to help students build a cultural toolkit that includes scientific knowledge and skills. However, building this toolkit and expanding it requires a knowledge of the existing culture of the students in the classroom. (Bruner 2003)

While science as a professional activity is essentially inquiry based, inquiry as a classroom method can be problematical for students who find questioning authority a cultural problem. Some students, especially from Hispanic cultures, place great cultural value on respecting adults, educators, and authority figures whether in person or in print. (Lee 2003) For these students, the idea of challenging a hypothesis or testing a theory declaimed in a textbook can be very intimidating, even impossible. Such students
may also react very negatively if the teacher challenges scientific preconceptions or even misconceptions that come from adults in the child’s family or home environment.

In these cases, the teacher must enable the student to cross barriers between the cultural world at home and the culture of scientific literacy at school. Using alternative modes of learning and promoting alternative ways of knowing such as inquiry, discovery, reading, and discussion may help students make the knowledge culturally relevant and improve the retention of science concepts. (Bruner 2003; Lee 2003)

While there is some research to suggest that students learn better when they are of the same culture as their teacher, there is often little choice available to parents and students with regard to who teaches the student science or mathematics. Studies of folk pedagogy suggest that teachers tend to teach as they have been taught and that their classroom methodologies stem from deeply held beliefs about how students learn and how children’s minds work. (Bruner 2003; Thomas and Pedersen 2003) Further, there is research to suggest that teacher education programs have little impact on this folk pedagogy, that is upon teacher’s beliefs and practices in the classroom. (Goodman 1988; Raizen and Michelsohn 1994; Ulrich 1999) This has been found to be true even though Dewey’s doctrine that teacher education must be based upon and extend the previous educational experiences of the student has been understood and accepted for almost a century. (Dewey 1904; Dewey 1938)

There is serious concern over the content and quality of these ‘previous educational experiences’ as Dewey puts it, that prospective teachers are bringing with them into their teacher education programs – at least in terms of subject content knowledge in science and mathematics. A recent survey of 150 prospective elementary
education teachers found that although most expressed concern over their own limited content knowledge and many reported that they had had negative science learning experiences, virtually all of the prospective teachers also proclaimed that 'fun' was a critical factor in good science learning experiences and that 'fun, hands-on learning' was the best possible pedagogy. (Thomas and Pedersen 2003) Clearly, these prospective teachers had a strong folk pedagogy favoring inquiry based learning in science, and yet they shared a sense that their own subject content knowledge would be a barrier to achieving the powerful learning environment they wished to create in their own classrooms.

The teachers in Thomas and Pedersen's study echo many other studies that suggest "teachers' subject-specific knowledge, especially math and science knowledge, is the most important variable affecting... student's achievement." (Thomas and Pedersen 2003) Other authors go even further, claiming that it is our teacher educational practices, which are flawed. Teachers teach pedagogy, but it is the scientists who must deepen and extend the subject knowledge of new educators.

"Powerful preparation of elementary educators in teaching science involves significant contributions from both scientists and teacher educators. Ironically, faculty and students in science and teacher education departments are often isolated from one another not only across the physical boundaries of the university, but across the cultural boundaries of academe. Coordination and collaboration between science and education faculty and students
requires a careful negotiation of these cultural boundaries.”(Carr 2002)

As we know from our own educational experiences, collaboration is a powerful tool for change in both methodologies and in shaping future practices in teacher education. It is also true that subject content knowledge is not enough to make a good teacher. If effective collaboration between science and education departments is to be established and the subject content preparedness of new teachers is to be advanced, then means of bridging the culture gap between science educators and teacher educators must be explored vigorously. The elementary and middle school teacher must be competent enough in the subject area to help identify the students' cultural preconceptions and scientific misconceptions. “Teachers must enable students to confront, shift, and define knowledge values and assumptions that form their own personal theories.”(Thomas and Pedersen 2003) These challenges to students’ preconceptions must be culturally sensitive, however, if the teacher is to help the student to explore alternative views without alienating the student or making them hostile to science education.(Goodman 1988)

To accomplish this goal, a new culture must be established in the classroom. This new culture must be one that encourages free inquiry and exploration of theories and hypotheses in an open and non-judgmental manner. Such a new classroom culture becomes a culture that the student and teacher build together and share with each other. Using differentiated learning techniques based upon free scientific inquiry, students immersed in such classroom environments learn new language and new cultural rules together with their classmates and teacher. This classroom methodology can successfully
help challenge student preconceptions and misconceptions and change negative self-statements into positive self-statements. (Lee 2003)

In sciences and mathematics classes, building a new culture in the classroom is dependent upon breaking out of the cycle of read-lecture-quiz that many teachers of science fall back on because they feel that they lack sufficient subject content knowledge. (Shaffer 2001; Burns and Price 2002) While inquiry based pedagogy can be culturally challenging for some students, building a new culture of free inquiry in the classroom helps students learn to negotiate border crossings between home culture and classroom culture. Such strategies also increase a sense of shared culture between student and teacher, which enhances learning and improves student attitudes toward science classes and concepts. (Lee 2003) Such a new exploration of the language of science and mathematics also gives students a new role model for inquiry and helps them learn to ‘speak science’. 

New Pedagogies

Hanson showed in her study that by interventions as simple as integrating visual art into science and math lessons that learning and retention could be increased as much as 90% (using pre and post test methodologies) over students who received only traditional read-lecture-quiz style lessons. Hanson also sites the lack of teacher cooperation across disciplines as a strong factor that limits student learning, along with misalignment of curriculum, lack of variety of teaching method, and failure to use alternate assignments to help students access various modes of learning in the classroom. (Hanson 2002)
Dr. Eugene Shaffer, Education department chair at the University of Maryland at Baltimore testified before congress that new pedagogies need to be explored that will enable teachers to move away from expository methodologies to more student centered and inquiry based methodologies which helped students make meaning from the instruction they receive. (Shaffer 2001) Shaffer, like many others advocates “meaningful curricular integration” between science and literacy standards. In his testimony, he indicated that his experience and research has shown that science and literacy are both better understood when “intertwined in teaching methodologies.” (Shaffer 2001; Hanson 2002; Lee 2003) This is succinctly summarized by Grim, “Education is best served when students and teachers work together to create a culture of inquiry in the classroom where scientific failure is a motivational factor, an invitation to further exploration; a culture where no one is personally afraid of failure or wrong answers. Ultimately, Nature never gives the wrong answers, and our job as educators is to teach our students that science consists primarily of learning to formulate the right questions.” (Grim 2004)

Some teachers of science who do not vary their teaching method find that some students become unresponsive over time. This is often indicative of a folk pedagogy where students are classified as VS (very smart), KS (kinda smart), or KD (kinda dumb). (Matsui 2004) However, lack of an effective pedagogy in class or the presence of an ineffective folk pedagogy is no excuse for poor student performance and failure to learn. The teacher is not entitled to assume that irresponsiveness in a student is indicative of stupidity or inability to learn. Increasingly, it is apparent that to increase student achievement, we must create a different context for science learning in the classroom and create different methods based on inquiry and differential instruction to take advantage of
diverse cultural experiences and diverse modes of learning in our classrooms. (Moore and Bintz 2002)

Some effective methodologies that have been explored in the classroom are broadly applicable; others are more focused on specific areas of scientific study. Some of the broader methods include the *paired text* method. This method involves teaching reading and science together. Young students are given texts such as *Mr. Archimedes Bath, Galileo, or Maurice on the Moon.* (Allen 1980; Fisher 1992) Students read the books together in class or independently. These paired texts set the cultural context for the science concepts in the curriculum and reinforce both the literature and science standards. (Moore and Bintz 2002) Shaffer recommends intertwining science and literacy standards, especially in elementary and middle school classrooms. (Shaffer 2001)

Chessin and Moore have recently written about expanding the 5-E model. The 5-E stands for *Engage, Explore, Explain, Expand,* and *Evaluate.* Engagement relates to student involvement in the concept being taught. To engage a student effectively, the teacher must understand the student’s culture and establish the cultural context for the learning. (Bruner 2003; Lee 2003) Exploration relates to the inquiry method of pedagogy; allowing the student to work with equipment and materials to make the learning personally important and relevant. Explanation is a literary and communication skill. All science and math relies upon good communication skills. Explanation also allows the teacher to access different modes of learning and to have alternate modes of assessment as a ready tool in the classroom. Students who can explain a concept have not only mastered the core ideas, but made the concepts personally meaningful and incorporated them into their own personal cultural toolkit. (Bruner 2003) Expand refers to expanding
the context of the learning across more than one area of the curriculum. Expanding a concept across the curriculum helps children to link and integrate concepts into their own cultural toolkit. Evaluation is a comparative skill which Marzano demonstrates is highly effective in increasing retention and learning in the classroom. (Marzano, Pickering et al. 2001) The sixth E that Chessin and Moore have added to this regimen is the E-Search. Using electronic media such as CD-ROM’s, DVD’s, internet research and other resources allows the student to expand their horizons and access more knowledge than any teacher or school library could possibly have access to. (Chessin and Moore 2004)

Teaching Science Through Literature

There is a large body of anecdotal evidence available through National Science Teachers Association and other similar organizations, which indicates that teachers and students are having success in achieving greater conceptual understanding by integrating science and literature standards. While magazines like Science Scope and The Science Teacher are peer reviewed journals, they are generally qualitative in their research and primarily concerned with pedagogy and method in the individual classroom. These journals are active forums where experienced educators share with their colleagues techniques and pedagogies that are effective in the classroom. When common themes recur in these and other similar publications, the active researcher in education can spot trends and patterns in educational practice and methodologies. Such magazines are also useful as they provide definitive insights into the folk pedagogies of teachers who are educational leaders and influential among their colleagues.
One theme that is apparent is the increasing interest nationwide in using literature to enhance the teaching of science. When educators desire to use literature to broaden their approach and diversify their methodologies in science classes, however, they do not turn to professional science journals or peer reviewed science publications. A recent study of scientists as writers revealed that scientists do not write in a manner that is compatible with educational and pedagogical needs in the K-12 classroom. When scientists write, they tend to target very narrow audiences and use a dense vocabulary that is highly specialized within their research discipline. The audiences that the professional scientist targets tends heavily toward interdisciplinary colleagues and students or narrowly focused journals that address their own subgroup or niche research discipline.(Yore, Hand et al. 2002) When interviewed and surveyed about their writing and communication styles, Yore, Hand, and Prain found that scientists perceive writing as a knowledge-telling activity as opposed to a knowledge-building activity. Most professional research scientists see educational and teaching duties as secondary at best and teaching and tutoring duties are generally perceived as interfering with their primary job of research science. Although I have extensive experience in science research inside organizations such as the U.S. Department of Agriculture, Cal Tech, Research Corporation, National Science Foundation, and various other university environments, I have never met or worked for any research scientist who considered his or her primary duty to be educational. Every one of the scientists I worked with and for considered tutoring and teaching duties to be an onerous and even degrading part of their work. It is not surprising therefore, that teachers make little use of professional science literature in classes.
Never the less, teachers who do make use of science oriented books in their classrooms find that science learning activities based on books do in fact deepen conceptual understanding. Using such books by science writers or popular children’s authors enhances student activity and discovery, and leads students naturally into inquiry based learning and helps them to construct useful personal and cultural connections to the new scientific concepts to which they are exposed. Using activities and methodologies based upon stories and articles they have read helps students to see patterns and cycles in science. Such literature based or literature enhanced activities assists students in constructing their own knowledge while helping them to understand the phenomena at hand. Such literature based and literature enhanced activities also help to prevent the student from developing damaging misconceptions of science concepts. (Moore and Bintz 2002; Wiley 2004)

We know that literature puts science concepts into cultural perspective and that this cultural perspective enhances student learning. (Dubeck 1994; Dubeck, Moshier et al. 1995; Freudenrich 2000) Not all genres of literature are equally effective, however. While books oriented strictly toward scientific concepts can be interesting, it is science fiction, or SF that many researchers find most effective in terms of enhancing classroom learning. Freudenrich advocates using SF literature “...to stimulate and maintain interest in science,” and “set a contextual framework for learning.” SF literature “readily captures the interest of students, even those who are not SF enthusiasts. The approach is easily adapted for use in a variety of science courses and helps students maintain a high level of interest and a positive attitude toward science.”(Freudenrich 2000) The incorporation of SF in the form of film, visual art, and literature brings literature strands.
and varied educational approaches into the classroom, enhancing student learning and retention. (Dubeck 1990; Dubeck 1994; Dubeck, Moshier et al. 1995; Freudenrich 2000; Marzano, Pickering et al. 2001; Burns and Price 2002; Hanson 2002) In order to make the best use of SF literature and film in the classroom, students must learn to be active consumers of media.

Active reading and observing with teacher guidance, note taking, and written and discussed questions are essential threads in weaving SF material into classroom pedagogy. Science is, by its nature, story driven. (Butterfield 2002) As noted by Carl Sagan: “I was positive from my own experience that an enormous global interest exists in the exploration of the planets and in many kindred scientific topics—the origin of life, the Earth, and the Cosmos, the search for extraterrestrial intelligence, our connection with the Universe. And I was certain that this interest could be excited through that most powerful communications medium, television.” (Sagan 1980)

Exploring science through literature is also an excellent medium to help the educator identify the preconceptions and misconceptions that his students may be bringing into the classroom. Exploring science through literature also helps the educator challenge these misconceptions in a non-threatening way. (Cavanaugh 2002; Hanson 2002) It is almost impossible to give students a deep and accurate scientific conception of the world around them if you do not understand the misconceptions that they bring to the classroom. Misconceptions are the hidden landmines that can destroy the effectiveness of a lesson and prevent the student from making progress. It has long been a personal maxim of the researcher that in order to teach new things, you must first destroy your student’s old modes of thinking. This is not as vicious or destructive as it
sounds, but in fact a blunt recognition that people tend to think now as they have done in the past. The perpetuation of thinking patterns is not just the province of the mature adult, it applies equally (perhaps more so) to adolescents who are strongly peer influenced in their thinking and behavior. In the experience of the researcher, one cannot teach physics, a science whose understanding is dependent upon realistic measurement and mathematical modeling/prediction of physical objects and systems, if students persist in thinking of the calculator as an infallible computer of limitless accuracy and confuses the mathematical-Platonic concept of number with the much more limited, but realistic concept of the quantified measurement.

While directly challenging a student’s prior concepts of science may be effective, it can also be perceived as hostile to the student’s culture. Some beliefs about the world transcend science and are bound up in culture and religion. Personal theories about the age, size, and origin of the Universe, the origin of life, even the causes of physical phenomena are bound up in cultural education that a child receives at home from family and peers. Mention origins or evolution in the classroom without understanding a student’s preconceptions and you will be on the road to disaster. It matters little whether you are speaking of the evolution of stars and the origin of the Universe or the origin of life and its speciation into the modern forms. Certain concepts are so deeply rooted in cultural and religious education outside the classroom, that the successful educator must tread carefully and take time to explore preconceptions before marching ahead with new learning. While Copernicus understood this intuitively and refused to publish his De Revolutionibus until he was on his deathbed, Galileo Galilei refused to acknowledge preexisting cultural norms and demanded that his students and peers accept his teachings
on evidence alone. While I greatly admire the work of both of these scientists, and what they did teach us about science and the Universe, I cannot endorse either one as a sound model of effective pedagogy. As Copernicus knew, and Galileo discovered; veritas non suficiat, the truth is not enough.

Science Fiction in the Classroom

If it is our desire to use literature in the classroom to sound out student’s preconceptions of science and to gently and effectively challenge these cultural and scientific preconceptions, in what manner should we proceed? Science fiction offers a literary mode that is uniquely suited to the task. In point of fact, this type of literature was invented for this very purpose. The first science fiction story was written by Johannes Kepler. Somnium (The Dream) is a story of a young man who journeys to the moon where he learns what the heavens look like from that lofty perspective. Kepler wrote the work in his youth and continued to work on it throughout his life. It was actually published only posthumously by his son. We know from Kepler’s correspondence that he wrote the story specifically to educate and chose the format of fictional literature in order to help challenge and overcome the cultural prejudices of his contemporaries.

"There can be little, if any, doubt that Kepler selected the framework of the Dream to satisfy two major demands: first, fewer objections could be raised among the ranks of those still within the Aristotelian orbit by passing off this Copernican treatise as a figment of an idle slumberer’s uncontrollable imagination; and secondly, it enabled
Kepler to introduce a mythical agent or power capable of transporting humans to the lunar surface. In fact to the cursory reader, Kepler must have appeared more mythographer than speculative scientist, and this is the very impression the author intended."(Christianson 1976)

Kepler not only invented the genera of science fiction, he contrived it for the purpose that it still serves today – the education of the non-scientist in scientific matters. Kepler’s colleague, Galileo Galilei continued in this theme when he wrote The Dialogues Concerning the Two Chief World Systems. Unlike Kepler, Galileo wrote a play instead of a story, wherein his three characters dispute the validity of Aristotelian science and the Copernican view of the solar system. Galileo’s characters perform scientific experiments, explaining to the reader how the experiment was set up and operated in such a way that almost anyone who was interested could perform the same experiment with common household materials. Where Kepler wrote in Latin for a select, educated and literate audience, Galileo wrote in Italian for the common man in the street. Fragments of Kepler’s work were released prematurely and caused him great distress – some even claim that the work was instrumental in fomenting accusations of witchcraft against Kepler’s mother.(Christianson 1976) Galileo did not learn from Kepler’s mistakes (if indeed he was aware of them) and the publication of The Dialogues saw Galileo arrested for heresy and condemned to a life in prison.

Despite its rocky start, it became clear that fiction could be used to introduce scientific concepts to non-scientists in a manner, which allowed the reader to explore new ideas that challenged his preconceptions in a culturally non-threatening way. Jules Verne became one of the first modern authors to pursue science fiction as an educational genera
of literature. Verne wrote under the tutelage of such writers as Victor Hugo and
Alexandre Dumas, whom Verne knew personally, and influenced by Edgar Allen Poe.(Liukkonen 2000) Verne’s works became the foundation of the science fiction as
science education movement. Such works as *A Drama in the Air, A Journey to the Center of the Earth, From the Earth to the Moon, Round the Moon, 20,000 Leagues Under the Sea, Around the World in Eighty Days*, and *The Adventures of Doctor Ox* were all written with a mind to introduce and explain scientific concepts to the average reader;
and this at a time when the average educational level of the reader of one of his books
would probably have been 8th grade or less.(Verne 1851; Verne 1864; Verne 1865; Verne 1869; Verne 1869; Verne 1872; Verne 1874) These works used the fantastic and
futuristic concepts of submarine, space, and air travel among others to educate the reader
and introduce new scientific concepts to the reading public. In an age when scientific and
technological progress, and the public’s faith in it, was high, Verne’s works were
enormously popular. His work became, and continues to be, a common subject for film
makers beginning in 1902 with *Le Voyage Dans la Lune* (A Trip to the Moon) by French
director George Méliès.

Jules Verne was almost unique in his field until H.G. Wells came along at the end
of the 19th Century. Unlike Verne, Wells was a trained scientist who studied biology and
evolution. Like Verne, Wells used literature to introduce new scientific concepts to the reader. Wells’ works such as *The Time Machine, The Island of Dr. Moreau, The War of the Worlds*, and *The Invisible Man* not only introduce scientific concepts from subjects such as atomic physics, microbiology, evolution, and astrophysics; Wells attempts to put these ideas into social context for the reader.(Wells 1895; Wells 1896; Wells 1897; Wells 1898)
H.G. Wells is not the eternally optimistic proponent of science and technology that Verne was; rather, he sees and tries to help the reader to see that scientific achievement occurs in a societal context with impending consequences for good and ill. Whether it was the concept of microbiological immunity that saves the Earth in *The War of the Worlds*, or the devastation of atomic war and radiation that splits humanity into two competing species in the far future of *The Time Machine*; Wells is keenly aware that the blessings of science and technology are mixed. He challenges the cultural assumptions of the reader directly, and the events of the early 20th century proved that he was a more accurate judge of the cultural effects of science upon society than the optimistic M. Verne.

A century of science fiction has seen both literary highs and lows in this genre; however, we must explore the consequences for the 21st century educator. When it comes to introducing new concepts in the classroom and putting these ideas into cultural context for the student, science fiction has been shown to be uniquely suited to the task. SF literature creates a cultural context for the reader that helps them to explore new ideas and integrate them into their preexisting 'cultural toolbox' of concepts and ideas; it does this by creating a contextual framework in which new ideas and concepts can be explored in a non-threatening manner. (Trent 2001; Cavanaugh 2002; Halpern 2002) Because the SF universe the writer creates is familiar enough to be understandable, but different enough for us to consider ideas without cultural conflicts, SF is admirably suited to the science classroom where culturally challenging ideas are regularly presented.

Interestingly, our modern society is not so different in some ways from that of the 19th century society of Verne and Wells. Studies indicate that SF literature and films is
where most of the population gets their most regular exposure to new scientific ideas and concepts. (Science 1994; Cavanaugh 2002) This in itself should not be surprising, since studies show that attendance in science classes of every discipline declines rapidly after school mandated classes are finished. This trend continues through high school and college level. (Tobias 1990) In spite of this tremendous decline in attendance, science fiction programs on television and SF based movies continue to be a perennial favorite with a broad demographic appeal. One only has to look at the success of the *Star Trek* and *Star Wars* franchises for evidence of this.

This appeal reaches into the science classroom as well. Science fiction materials are easily adaptable to a variety of science and mathematics classroom situations and there is a wide variety of books, film, drama and art available to support academic goals and standards. Teachers who are experienced at using SF materials in the classroom find that the films and books in the science fiction genre create 'teachable moments' that the adroit educator can capitalize upon. In his research, Cavanaugh further notes that it is science fiction in both books and film that is the single most powerful influence on students who choose to pursue science beyond the required minimum for graduation. (Cavanaugh 2002)

When watching Stanley Kubric's classic adaptation of Arthur C. Clark's *2001: A Space Odyssey*, my students have often noticed that all of the exterior shots of ships moving in the vacuum environments of space and the lunar surface are filmed in complete silence. We are greatly conditioned by our galaxical environment to expect a soundscape and film score to accompany every moment of a visual environment. Silence is a rarely used device in film (outside of suspense films, anyway) and almost never seen
in television. To see an action sequence of ships flying, astronauts moving, explosions happening — all in complete silence is jarring to us; just as Kubric knew it would be.

Kubric’s creative use of silence; his fidelity to the experience of nature, create the perfect teachable moment. A discussion of sound waves propagating in air and a demonstration of a loud buzzer growing rapidly silent as the air is pumped out of a bell jar become powerful enhancements to the film. Just as the film becomes a powerful enhancement to the teaching of physics in the classroom. If SF films and books have such a powerful effect on students both in and out of school, it would seem foolish to keep this powerful teaching medium out of the classroom.

Science fiction becomes a powerful tool for almost any science related topic. From environmental warming and over crowding, dealt with so powerfully in such classic films as *Soylent Green* and *Silent Running*; to the results of powerful scientific technologies gone wrong in *The China Syndrome*, or *The Omega Man*. The educator must be careful to choose wisely, however. Writers, actors, and film producers often are not concerned with scientific accuracy if it conflicts with an exciting tale or good box office. Teaching about the asteroid that destroyed the dinosaurs in the Chixulub impact and enhancing that educational experience with a film like *Deep Impact* would be beneficial. Matching the academic lesson to a laughable, bad-science clunker like *Armageddon* would be far worse than using no matching film or reading at all. Alas, the educator must be a film critic in the galaxical teaching environment of the modern classroom!

Sociologically, science fiction media offers benefits beyond the enhancement of simple science concepts in the classroom. While using literature in the science classroom
is beneficial, studies show that SF literature and films appeal to, and motivate a far more
diverse cultural audience than other forms of literature. (Freudenrich 2000; Cavanaugh
2002) This should not be surprising when we examine science fiction’s broad box office
appeal worldwide. Further, DVD format films often offer the choice of Spanish, French,
and English vocal tracks on films. It becomes a simple matter to offer the program in a
language, which enhances the cultural connections of the student audience.

In addition to its broad cultural appeal, we also find that the use of SF materials in
the classroom improves student attitudes toward the study of and content of science
classes. (Freudenrich 2000; Cavanaugh 2002) This is not surprising as the use of science
fiction as a medium for teaching science follows the drama → inquiry → lecture model
expounded by Marzano and utilized by Freudenrich in his research. (Freudenrich 2000;
Marzano, Pickering et al. 2001) The use of drama, including dramatic literature and
films is also found to enhance learning across the curriculum. (Marzano, Pickering et al.
2001; Halpern 2002) Some instructors have even moved further by having their students
produce their own dramatic works to enhance their understanding of curriculum
concepts. (Lauritzen and Jaeger 1992; Lake 1993; Trent 2001; Burns and Price 2002;
Schmidt 2004)
CHAPTER THREE

Methodology

Introduction

It will be useful here to outline the basic procedure of the study before expanding upon the details of the methodology and its limitations. The basic method of the study involves using a pre and post test composed of both standards-based and general knowledge questions. Standards-based questions were designed to test student’s knowledge of those science standards which were explicitly taught in the text, lectures, and activities of the Summer Science Enrichment class, while the general knowledge questions were designed to test the students' general knowledge of the subject of Earth and space science. The concepts upon which the general knowledge questions were based were explicitly not taught during the class, either through the text, lectures, or activities. The working hypothesis of the study was that the students would show improvement from pre to post test on the standards-based questions, but that the performance on the general knowledge questions would remain essentially unchanged.

The second part of the method of the study was to compare the change in student performance upon the standards-based questions to student engagement with the curriculum. In order to do this, student engagement was measured in three different ways: self-reporting by the students in response logs, evaluation by the researcher of the percentage of class work completed by each student, and evaluation of the academic quality of each student’s individual work by the instructor. Using three different methods of evaluating student engagement allowed the researcher to obtain a more accurate and
quantitative evaluation of what is essentially an internal mental process for each student. The third part of the study was implemented at the request of the research client school district. This involved a general survey of the students' opinions and attitudes with regards to their interest in school, and the students' self opinions as learners.

One of the primary limitations of this study is the small sample size. Working with a single school district was essential in order to be able to successfully negotiate the terms of the initial study. The study size was limited by both the size of the district and the financial support that the district was willing to contribute to the study. Initial discussions with the district superintendent focused upon running the program simultaneously at three school sites across the district, using three different instructors, with the researcher splitting time between the three campuses. However, the financial resources of the district were not sufficient to implement this ambitious program. Part of this was due to changes in the way that the state of California funds summer school programs. In the end, a single site program operated in one classroom with a single teacher was all that the district was able to afford. A letter describing the Summer Science Enrichment program was sent out to over 700 families with students attending the middle school which was selected to host the program; this was the only publicity the Summer Science Enrichment program was to receive. Thirty nine families responded and sent in all the required paperwork to enroll their children in the study and participate in the study; twenty four students actually showed up for the summer program, and 18 completed the class and the study.
Standards-based Testing

Student performance on standards-based tests was a major concern of the host school district. The No Child Left Behind Act, or NCLB places heavy emphasis upon student performance on standardized examinations, as does the State of California Department of Education. Improving student scores on such standardized tests was perhaps the primary goal of the district for the Summer Science Enrichment program. Several schools in the host district have been designated as "Program Improvement" schools by NCLB and the State of California. Program improvement status brings with it many penalties, both financial and otherwise, as well as a public stigma and perception of lack of academic quality and accomplishment that the district is anxious to avoid. The single most important measure by which this status is assessed is by student body performance on standardized tests given each spring.

The Summer Science Enrichment program likewise included a standards-based testing instrument that was developed for the program and used as a pre and post test instrument. Questions for the test were based upon a question set originally developed for astronomy and Earth science students in 9th – 11th grade. The questions were carefully edited and reworded where necessary to insure that they were both comprehensible to the younger reader and that they reflected science standards which were covered in the text of the book or the activities in the curriculum. Forty such questions were developed to test the students knowledge of the standards covered in the core curriculum of the class. These forty questions formed the "standards-based" question set. The students' initial knowledge of these science standards would be tested
during the pretest, and then tested again during the post test. Any change in the number of correct responses would be noted.

In addition to the forty standards-based questions, an additional ten questions were written which covered standards that were *not* covered in either the text of the novel or the activities in the class. These questions also focused upon science standards for Earth and space science, and were written and reviewed just as the other questions were. These ten questions (20% of the exam questions) formed the “general knowledge” question set. As with the standards-based question set, these questions would be given to the students as a pretest and again as a post test. The intention of these questions was to measure any change in the student’s general knowledge of the topic before and after the exam.

The general knowledge question set served a dual purpose within this study. The first was to measure the level of general knowledge on the class topic before and after the class to determine if there had been any enhancement or degradation in general knowledge over the course of the study. There is some concern in general folk pedagogy that ‘going deep’, or making an intense and multistranded study of a particular focused topic will degrade a student’s general knowledge in other areas. Another common belief is that going deep in a particular topic somehow endows a student with enhanced abilities in other similar areas. It is the hypothesis of the researcher that deep study in a particular area neither enhances or degrades general knowledge in similar areas except to the extent that new learning may modify or improve a student’s understanding of pre-existing known concepts.
Secondly, the general knowledge question set serves as an experimental control for the 40 questions from the standards-based question set. The intended purpose of the STL curriculum is to intensely focus the student on science standards in Earth and space science by integrating reading, direct instruction, and inquiry based, hands on activities. Because all programmed classroom activities target student learning on a specific set of science and mathematics standards, the hypothesized outcome is that the standards-based questions which are targeted by the curriculum will show greater change than the general knowledge questions which were not target by the curriculum. An outcome of this sort would demonstrate that the targeted learning in the curriculum was effective in improving student responses on standards-based exams. An outcome where the change in general knowledge questions was similar to or greater than the change in the standards based question set responses would indicate that the targeted learning envisioned by the researcher was not effective, and that student knowledge and understanding of the targeted standards was not improved more than the students general knowledge of the subject matter.

Neither the instructor nor the students were informed of the presence of the control question set in the pre and post tests. By comparing the change in the percentage of correct responses between the experimental and control question set, it would be possible to determine how much of the change in the number and percentage of correct responses was due to the curriculum and instruction in the class. Since these topics were not part of the reading, discussion, or activity sets, it was predicted that there would be no substantial change in the level of the responses to the control questions, but that the experimental question set would show measurable improvement from pre test to post test.
The researcher used the Exam View program to prepare and print the test instruments. Three versions of the pre and post tests were used. Each version was composed of identical questions, but the order of the questions in the test and the order of the multiple choice answers was randomized for each version. The multiple versions of the exam were used to insure that no cheating occurred. Any student who copied an answer from their neighbor would find that they had copied an incorrect response for their own exam. With three versions of the test, the odds of getting a correct response by copying were negligible. The instructor also spoke to the students about copying on exams, and reminded them that their scores on the pre and post tests were not part of their grade for the summer school program. Every effort was made to make sure that the students understood that there was no advantage in copying answers. The instructor also made sure that she was an active proctor during the exam, and took great care to circulate around the room and make herself visible to discourage any copying by students. When the test were analyzed, no evidence was found that students had copied from one another.

At the end of the pre and post tests, the students were asked to rate the exams for their difficulty, and for the student's own prior experience with the material. For this brief, two question survey, a 1-10 Lickert scale was used. For the test difficulty rating, students were asked to rate the material where a ranking of 5 indicated the test was at their own grade level, and each number above or below 5 indicated a whole grade level of difficulty. In other words, a ranking of 4 by a student indicated that they thought the test was appropriate for a student one year behind them in school, while a rating of 7 would indicate that the student believed the test was appropriate for someone two years ahead of them.
For the experience rating, students were told that the rating of 1-10 represented how much of the test material they had been exposed to during their regular education in science or math class or during their own reading and experience. A rating of 5 indicated that the student had experienced or encountered 50% of the material before, a rating of 8 would indicate that the student had experienced or encountered 80% of the material before. The researcher took substantial time and effort to explain to the students that experiencing or encountering material was very different from understanding or mastering the material. If there was a question about the origin of the lunar craters, for example; students should only consider whether they had read or heard about this topic, not whether they had understood the material, or done well on a previous test concerning the material.

The purpose of these two survey questions was to measure the change in students’ perceptions about the material’s difficulty and their experience with the total content of the pre and post tests before and after the program.

Measuring Engagement

With a small sample size, it was clear that some standard statistical methods of analysis would not be feasible. Simply looking at pre and post test results and providing statistical analysis on the change in scores would leave the results open to question due to the small number of participants involved. An additional methodology for correlating results with student engagement in the classroom would lend weight to the results.

The experience sampling method or ESM as used by many researchers involves using a signaling device and a notebook or ESM log. The signaling device used by
various researchers in the field has varied from beepers, to cell phones, text messages, even watches with alarms programmed to go off at random times during the workday. When the ESM signaling device goes off, the participant in the study stops what they are doing and records their present actions, thoughts, and feelings, emotional state, etc. in the log. The participant may be asked to respond in the ESM log several times a day for weeks or months at a time. The ESM log then becomes a snapshot of the participants activities, internal mental and emotional states during the workday. The researcher then is able to track the log and provide a statistically significant analysis of the participants ongoing mental and emotional states during significant tasks which are frequently repeated during the work day. ESM based studies typically involve sample sizes from a few dozen participants to many hundreds, even thousands of participants.

Traditional experience sampling was not feasible for this study for a variety of reasons. It was impractical to signal students individually to record experiences in a log book, and having individuals in a classroom do this at independent times would very likely be a disruptive influence in the classroom environment. It was therefore necessary for the researcher to develop a methodology specifically for this study that would answer the purpose of enabling the researcher to quantify and measure engagement events in the classroom in such a way that normal operation of the classroom would be disrupted as little as possible.

Due to the low level of funding for this project, it was impossible for the researcher to provide each student with a cell phone, beeper, or an alarm watch programmed to go off at random times. There were also strong objections to having individual students record in their ESM logs at different times from the instructor, who
pointed out that middle school students as a group have trouble focusing upon academic
tasks for long blocks of time. The instructor further indicated that if students were being
individually taken off task, even momentarily, to record in daily experience logs, that this
would seriously impinge upon the academic performance of the entire class. Simply put,
if one student went off task to record in an experience log, that would rapidly draw others
off task as well. The instructor indicated that the emotional maturity of students at the 6th
to 8th grade level was insufficient to allow them to concentrate on their own task while
someone else stopped to write in an experience log. If the class was to remain
manageable, then recording experiences in any sort of logbook would have to be
performed for the entire class at one time.

With this in mind, the researcher and the instructor developed the idea of the
“notebook break”, during which all students would be asked to stop what they were doing
and record their responses in the provided notebooks. In order to keep the times random,
so as to get a good sampling of the students’ engagement with the material across the
school day, it was important to look at the structure of the students’ day in the summer
school program. The summer school day began at 8:00 AM and ran until 12:05 PM
every afternoon. The day was divided into two 2-hour blocks, with a 10 minute break
between them. Each block included an optional 5-minute break in the middle of the
block. Most of the students in the summer program were taking both mathematics and
language arts classes; each class was two hours long and students would change classes
in the middle of the day. Linda decided that she would not schedule the 5-minute breaks
and stick to the single 10-minute break period between the two blocks; this gave two
blocks of 115 minutes each.
I divided the blocks into twenty three, 5-minute time periods. By excluding the first ten minutes and last 5 minutes of each block, I was left with twenty, 5-minute periods; the notebook break could feasibly be taken during any of these 5-minute periods. I excluded the first ten minutes of each block because this was most often the time when the teacher would introduce the class to the next activity, take attendance, and deal with classroom management issues such as tardies and absences. I excluded the last 5-minute period of each block because this was generally used as clean-up time for the students to put materials away. In each case, these small periods of time at the beginning and end of the period were not primarily academic time, but primarily devoted to administrative and classroom management tasks.

In order to randomize the selection of the twenty remaining blocks of time during which a notebook break would be reasonable, I purchased a 20-sided die. In addition to the classic 6-sided die which most people are familiar with, die with 4, 8, 12, 16, 20, 24, 36, 50, and 100 sides are available at shops which cater to gamers. With the advent of more sophisticated computer games, the need for physical devices such as dice for generating random outcomes is substantially less than it once was; never the less, it is still possible to find unique dice such as these relatively easily. The 20-sided die was thrown twice each morning at the start of the day to determine when the notebook break would be announced; each number on the die indicated a 5-minute period during the school day. For instance, a throw of 8, indicated $8 \times 5 = 40$ minutes into the first block period. With the first ten minutes excluded for administrative tasks, that meant that the morning’s notebook break occurred at 8:50 AM. At 8:50 the researcher would call for an notebook break and students and the instructor would stop whatever they were doing and take 2-3
minutes to write in the daily notebooks before resuming the lesson or activity they had been doing.

In order to record a snapshot of each student's engagement with the material, the researcher asked the students to consider three questions during each break. First: what are you doing? Students were asked to explain what they had been doing when the break had been called. Each student was asked to record a primary, secondary, and tertiary activity. In order to explain the idea of primary, secondary, and tertiary activities, the researcher discussed the idea that at any given time, a person may be engaged in a variety of tasks. For instance, my primary activity might be reading a book, secondarily, I might be occasionally taking notes occasionally, and a tertiary activity might be listening to a radio in the background. Distinguishing secondary and tertiary activities was clearly very difficult for most of the young students. Early responses included such tertiary activities as "I am scratching my foot," or, "I am sitting in my chair." There were several discussions with the class which tried to clear up the idea of a tertiary activity, none of which was very successful. Eventually, the concept of tertiary activities was dropped and students were asked to mention secondary activities only when they did not involve bodily functions such as scratching, etc.

The second question that the students were asked to consider each day was "What are you thinking about or feeling?" This question was much more difficult for most of the students than the question about concrete activities. It became clear after days of examining the response notebooks that many of the students had difficulty forming metastatements about their own internal mental processes. The thinking/feeling question was often unanswered, or answered with little or no detail. The researcher attempted to
discuss the concept of internal mental and emotional states with these students on a number of occasions without much success. The skill of being aware of internal mental and emotional states and then reporting on them in writing was beyond many of these students. The responses of such students was often to report internal physical states such as pain, hunger, sleepiness, etc. This problem was certainly compounded for those students in the study group who were not native English speakers.

It was not uncommon for the students in the study to write partial statements such as “I am doing...”, and “I am feeling...” in their notebooks at the beginning of the day and then fill them in with a word or two when the notebook break was called. After the researcher had held several conversations with the students trying to get them to report what they had been thinking about, one student asked, in obvious annoyance:

“Why do you keep asking what I’m thinking? I’m not thinking, I’m just here doing school work!”

“If you have trouble telling me what you are thinking, then tell me what you are feeling as you do your work.”

“What do you mean how I’m feeling?”

“How does the work make you feel?”

“Well, I feel hungry, but that isn’t the work; it is just because I’m waiting for lunch.”

Some students were indeed able to report internal emotional states, but these states generally had little to do with the activities in the classroom. These students usually reported emotional states that had to do with events happening in their lives outside the classroom, such as arguments with friends, emotional entanglements with the
opposite sex, or anger and frustration with family life. Most of these students were unable or unwilling to analyze and report on internal emotional responses to the learning environment.

The third question that the students were asked to consider in the notebook break was: "What questions do you have about what we have read or done in class?" It was explained to the students that this was an opportunity to ask questions that occurred to them while reading the story or doing activities in class. The rationale for this question in terms of measuring engagement is simple. In order to frame and ask a cogent and appropriate question on a topic presented in the classroom, the student must be mentally engaged with the material in a significant and active way.

The third daily question was much more successful than the previous question on thinking, and every student was able to ask a focused, pertinent question about the material from the book or the classroom at least once during the research study. Students in the study group were told that the questions they had recorded were, like all notebook responses, completely confidential. During discussion of the study methods on the first day of the term, a student asked why they should ask questions if no one would see them or answer them? Many students agreed with this and the class demanded that their questions should be answered if they took the time and effort to record them. The researcher agreed to answer the questions in writing as long as the questions were appropriate and on topic. In many cases, students asked follow-up questions and a running dialog was established over a course of days on a specific topic until the students questions had been answered completely or their interest in the topic had been exhausted.
The second method of measuring student engagement with the curriculum was to measure the percent completion of each daily classroom assignment. This measure of engagement is to some extent grade-driven, rather than internally motivated through the desire to learn about the topic as with questions recorded in a daily response notebook. Irregardless of the exact individual motivations, the physical record of a completed classroom assignment indicated that the student had indeed been significantly mentally and physically engaged with the task at hand during the class time.

The researcher kept a careful log of assignments given to the students by the instructor. The log included the title and a description of the assignment, as well as a description of what was expected of the student by the teacher. This log was then compiled and used to evaluate the percent completion of each assignment. The academic quality of student work was not considered in this assessment. Instead, a rubric for each assignment was developed and used to evaluate how complete the assignment was.

For example, an assignment might include a labeled sketch with key, a written component, and calculations. The percentage of the total that each comprised was assessed according to the amount of time and effort required to complete that section of the assignment and a completion score from 0-100% was assigned. The average completion rate of all assignments over the summer term could then be assessed for individuals and groups within the study population. The advantage of this method of determining student engagement was that it did not require any meta analysis by the student, nor did it require the student to report and discuss internal mental and emotional states to the researcher, as the daily notebook response did. This measurement was also independent of any input from the instructor. The students were provided with sufficient
time each day to finish work in class. The instructor was careful to actively monitor student progress when they were working. It was common practice to schedule more time, or continue an assignment to the following class period rather than cut the time short. Students at every ability level within the study population had sufficient classroom time, or in rare cases homework time, to finish every assignment. This is important and strengthens the measurement of the percentage of work completed as a measurement of student engagement with the curriculum.

The third method of measuring student engagement was to record the academic achievement score given to each student by the instructor. The instructor developed her own rubrics for grading the assignments and recorded them separately. The grading by the instructor was done on her own time away from school and no part of this procedure was discussed with the researcher. At the end of the class, the instructor gave the researcher a copy of her evaluations of the students’ work, listed by assignment. While the academic grade for the assignment is not a pure measure of engagement, it must be noted that without substantial engagement with the material being presented, academic achievement is not possible. Academic achievement also requires an understanding of academic vocabulary, scientific method, mathematical operations, and skill in observing / drawing, as well as skill in writing and recording observations in written English. Some of these tasks were more difficult than others for individual students. Assignments in written English were more difficult for ELD students than for native English speakers. Assignments requiring scientific acumen or mathematical skill likewise varied in difficulty depending upon the academic level and to some extent grade level of the individual student concerned. The assignments requiring scientific and mathematical
skills showed little correlation to the student’s native language, but varied substantially from student to student. A complete analysis of the student’s academic performance correlated to the student’s ELD level was beyond the scope of this study, however.

The three measures of engagement, student reported notebook responses, researcher recorded percentage of class work completed, and instructor recorded academic achievement grades represented independent attempts to measure and quantify an internal mental event which is difficult to observe and record in real time without disrupting the educational process. An agreement of results between three independent measurements also lends credence to the data, while a disparity in results may indicate poor experimental design. It is the agreement between these disparate data sources that lends weight to the results of the study in spite of the small sample size.

The Survey Instrument

The researcher also prepared a pre and post program survey instrument for the students. The purpose of the survey instrument was to assess student opinions regarding how well they liked school in general, their attitudes toward math and science, and their own self assessment of their math, science, reading and language arts skills. The survey instrument used a Lickert scale from 1-5; 1 = strongly disagree, 2 = slightly disagree, 3 = neutral or ‘don’t know’, 4 = slightly agree, and 5 = strongly agree. Students were asked to respond to a variety of statements such as: “I enjoy going to school each day,” or, “I like the way science is taught in my school,” by selecting a value of 1-5 on the Lickert scale. The key for the scale was printed at the top of each page of the survey instrument, and the researcher spent approximately 20 minutes before each survey to properly
prepare the students and be sure that they understood the survey instrument and how it worked. The researcher also made every effort to insure that the students knew that the survey instrument was part of the research project, but not part of their grade for the course. The researcher also emphasized to the students that the survey responses were confidential, and that the instructor would never see their responses to the survey.

The surveys were evaluated and pre and post program responses were cataloged and measured.

In addition to questions which were repeated in the pre and post program surveys, the post program survey also included a set of questions that asked the students to evaluate their own level of academic improvement in science, mathematics, language arts, and the acceptability of the *Maurice on the Moon* curriculum. Students were asked to respond to statements such as: “My reading skills have improved this summer,” or “My mathematics skills have improved this summer.” Responses were again based on the now familiar 1-5 Lickert scale. In the case of questions about science or mathematics skills, students were asked to list, if they could, actual academic skills that they thought had improved over the summer. Greater weight was given to students who could actually cite specific examples of improvement in their own skills as opposed to students who indicated that there was improvement, but could not be specific as to what skills they had acquired or improved.

Methodological limitations and biases

For the researcher, measuring and quantifying student engagement with the curriculum must remain the most problematic aspect of the study. As a physical scientist,
the measurement of what amounts to an internal mental event that occurs in a crowded, dynamic environment so rich in stimuli and responses must remain extremely problematic, both practically and philosophically. Justice Potter Stewart defined obscenity with what he referred to as the "Casablanca test", or "I know it when I see it." The same may be said of "engagement"; every experienced teacher knows it when they see it, measuring engagement is another matter, however.

The study uses three different measures of engagement, each of which indicates student engagement with the curriculum in a different manner, each measured or recorded independently by a different observer. The strength of this interlocking method is that any alignment of results among three disparate measurements made by different observers must more strongly indicate real events and lend credence to analysis made based upon these results. The weakness of the method lies in the concept of the "independent observer." When an instructor, researcher, and 24 children share a room together for 25 hours a week for four weeks, the concept of 'independence' in certainly stretched significantly. Furthermore, the classroom is a complex environment where the researcher, instructor, and students all have independent and interlocking reasons for wishing to please or displease each other in their social and academic interactions. The effect of these biases on the study data is undoubtedly real and will not be entirely cancelled out by the independent nature of the three measures of student engagement. The quantitative effect is believed to be small, but in fact would be very difficult to quantify in this small study.
CHAPTER FOUR

Pre and Post Intervention Data

Introduction

The data given here comes from three sources; pre and post test data, student survey data, and student engagement data. Pre and post test examinations were given to students in the classroom on the first and last day of the summer term. Each student was given their own exam paper and exams were identified only by the student's ID number. The exams were designed as a multiple choice instrument, with four choices per question; there was always a correct answer available. Student survey responses were made on a 1-5 Lickert scale indicating that a student agreed or disagreed with a particular self referential statement. Student responses to pre-survey and post-survey questions were tracked and any changes in the responses were noted. Student engagement data was less quantitative and consisted of free responses in the provided notebooks. These responses, which were categorized into several different types, were recorded as evidence of student engagement. Responses which were considered indicative of student engagement included statements about relevant activities such as "I am reading about Maurice" or, "I am working out a math problem." Other responses which indicated student engagement were on topic questions stimulated by the reading, discussion or activities in the classroom. These responses were all generated by the students themselves in response to a request for information by the researcher. This data is certainly subject to some bias because students are highly motivated generally to give responses that will please the teacher. Never the less, if the researcher wishes to know what a subject is thinking, the
question must be asked. Some research techniques help remove some of this bias by
disengaging the researcher personally from the process by telling the subject to answer a
question when given an impersonal signal such as an alarm watch going off, a beeper
chirping or a text message on a cell phone. In a classroom with 25 students, a teacher and
a researcher present, there is no such possibility of separating the researcher from the
subject under observation.

Because of this bias in student’s responses, two other independent methods of
gathering engagement data were used. The percent completion of academic work which
was analyzed by the researcher after students had turned in all their class work to the
instructor was used to measure engagement. Measuring the percentage of work
completed is a secondary indicator of engagement; that is, it is not a direct response from
the participant saying “Yes, I am engaged with this material,” rather it is a product of that
engagement process. To the extent that completing the classroom assignments requires a
student to be engaged with the material, a completed assignment indicates that such
engagement has indeed taken place.

This type of data was helpful because it was not subject to the bias inherent to the
process when a researcher asks a subject for information. Neither the instructor, nor the
students were not told that this data was being collected. This both sharply reduced the
bias present in the first method and provided a means to begin quantifying the amount of
bias in the first method. If the engagement data were very similar, this would indicate
that the bias present in the first method did not greatly affect the data collected and would
strengthen the case in any analysis of that data. This is not to say that the second method
eliminates such bias; anytime that a teacher asks a class to do an assignment, there is both
internal desire to please the teacher by completing the assignment, and external pressure from parents, administrators, and others to do well. It is also obvious that every student understands by middle school age that they are constantly being observed and evaluated; academic grades are a constant reminded of this.

The third method of gathering engagement data sought to balance any bias that the researcher may have had in evaluating the students’ work by using the academic achievement grades which were assigned to each assignment by the instructor independent of the researcher’s input or oversight.

It is the intention of this study to examine the effectiveness of the *Maurice on the Moon* curriculum and Science Through Literature pedagogical method in improving student performance on standards-based assessments in a brief, intense summer school format. A successful intervention curriculum should show substantial increases in student performance on standards-based academic assessments, improvements in students self perceptions as effective learners, and such improvements must be cross cultural and beneficial to all students as much as possible without regard to a student’s particular gender, ethnicity, native language, or national origin.

In order to determine if the experimental curriculum and pedagogy met the goals of the study, several analyses were made. Pre and post test data for each student was assessed for both the standards-based and general knowledge question sets and changes in performance were noted. Pre and post survey data for each student was assessed, and changes in responses to self referential statements were noted. Because of the small sample size, student engagement data was also used and correlated to the students
changes in performance on the pre and post test instruments and to the changes in responses on the survey instruments.

Pre and Post Test Data

For each question, the maximum number of correct or incorrect responses was 18 (the number of students who completed the study.) For each question number, the table shows the number of students who answered correctly and incorrectly on the pre and post test instruments. The raw data is available in appendix A, table 1. This data shows the breakdown of correct and incorrect responses by individual question number for both the standards-based and general knowledge question sets. The table also shows the change in the percentage of the number of students answering the question correctly. Negative percentages are highlighted in red. At the bottom of the column, the table shows the total number of correct and incorrect responses to the standards-based and general knowledge question sets, as well as the average change in the percentage of students answering each question set correctly.

The group of student participants in the study made a total of 229 correct responses out of a possible 720; this gave a cumulative score for the group of 30.5% correct. Individual questions varied considerably. Some of them were correctly answered by every student in the group, other were not correctly answered by anyone in the group. In the post test, the students as a group more than doubled their number of correct responses and gave 481 correct answers for a group percentage of 66.8% correct.

The data for the general knowledge questions was much more consistent from the pre test to the post test. The students in the study managed 84 correct responses out of a
possible 180, for an initial group score of 46.7% correct. On the post test, the number of correct responses changed very little; the group scored 90 correct responses out of 180 possible for a final group score of 50.0%.

For the standards-based question set, the average increase in correct responses from pre to post test was +6.3 questions, an increase in correct responses of 35.0%. Also of note is the fact that, in the standards-based question set, 38 of 40 questions showed an improvement in the number of correct answers from pre to post test. The two questions that did not show an increase, #25 and #44, declined by only one answer each. On average, the number of correct responses to questions in the standards-based set increased by 35%; individual questions saw changes in correct responses ranging from -5% to +78%.

The general knowledge questions were not as consistent, and seemed to show a more random fluctuation. Half of the general knowledge questions stayed the same or actually decreased in the number of correct responses, while the other half increased only slightly. Individual questions saw changes in correct responses ranging from -11% to +22%. For the general knowledge question set, the total number of correct answers also increased from 84 correct responses on the pre test to 90 correct responses on the post test; an increase of only 6 correct responses. The average question in the general knowledge set increased by only 0.6 correct responses, for an average change of +3.3%.
Increase in Correct Responses to Standards Based Question Set

Figure #3: Increase in correct responses to the standards-based question set.

Increase in Correct Responses to General Knowledge Question Set

Figure #4: Increase in correct responses to the general knowledge question set.

Notebook Response Data

The response notebooks were distributed to each of the students on the first day of class; each notebook had been pre-coded with a four-digit code number written in base 6.
The code numbers were generated randomly using a set of four color coded dice (one each of red, yellow, green, and blue.) The dice were thrown from a cup and the numbers recorded from the red, yellow, green, and blue dice, (in their spectral order) to make a 4-digit ID code for each notebook. This 4-digit code became the students’ ID numbers once the notebooks were distributed.

The researcher took pains to explain the response procedure and concept to the students. Twice each day, the researcher would call for a ‘response break’ at a random time. Once again, the random times were determined using dice; this time a 20-sided, or isocohedral die. The first and last ten minutes of each two-hour block were ruled out for student responses, as this time was often partially or totally occupied with taking role, getting students started, giving instructions for the day, or cleaning up after a day’s activity. This left 20, five-minute time periods in the time block, one for each number on the die. A roll of 6 indicated 6 x 5 minutes = 30 minutes after the introductory 10 minutes, or 8:40 AM. A roll of 12 would indicate 9:40 AM, etc. One die roll was made to randomly determine the response break time for the morning and afternoon session each day. These times were not revealed to the instructor or the students in advance.

In the notebook, the students were asked to respond to three questions: First: What are you doing? Second: What are you thinking or feeling? Third: What questions do you have about the material we are reading or studying? For the first question, the response was decoded (some responses from ELD-2 and ELD-3 were in broken English), then the response was checked against the log of classroom activities to determine if the response was appropriate to the situation at hand. Non-responses, inapplicable responses, and absences were all noted in the summary of the responses. The number of
appropriate, or ‘on task’ responses were compared to the total possible responses to calculate an *active engagement* percentage. The active engagement percentage reflected the number of times that the student reported being ‘on task’ when asked to record a response in their notebooks.

The analysis of the second and third questions proceeded in a different manner. Many students were unable or unwilling to express their own internal mental or emotional states on paper. Many of the students were only able to describe internal *physical* states, or very simple emotions such as hunger, anger, sleepiness, boredom, etc.

As with the first question response, the responses to the thinking / feeling question were compared to a log of classroom activities and determined to be either *on task* (engaged mentally with the material) or *off task* (not mentally engaged.) The number of on task responses was then compared to the number of opportunities to be on task and a *mental engagement* percentage was determined.

The third question response was not initially planned for the study, but arose from initial discussions with the class about the student response process and response notebook. Many of the students were quite emphatic about including a questions section in their notebooks; they were not interested in just asking questions, they wanted a response to their questions from the researcher. Cataloging these responses was somewhat more complex than for the previous two questions. It was decided to categorize the questions as follows: 1: Questions about the book itself. These included questions about the characters, plot sequence, themes, and location descriptions in the text of the story. 2: Questions about the writing process. These questions included queries about the writing and publishing process, science fiction, etc. 3: Questions about
the solar system. These included questions about the actual locations on the Moon where the action in the book takes place, general questions about the Moon, Mars, or other planets, the Sun, etc. 4: Questions about space exploration. These included questions about historical or future space exploration, space travel, colonization of other planets, etc. Questions about activities and assignments in the class. These included questions about the process and content of lessons, the meaning of data from classroom projects, as well as questions about the upcoming tests or assignments. 5: Inappropriate or off-topic questions. These included diverse and generally innocuous topics ranging from “What kind of music do you listen to?”, to “Why would anyone want to be a teacher?” These questions, along with non-responses, were all categorized as off-task. Once all the questions had been categorized, the on task questions were divided by the possible number of opportunities to create a mental engagement percentage. For the purposes of this study, the second two responses were considered together, because either a self report of thinking about an on task topic, or asking a question about an on task topic indicated that a student was mentally engaged with the material on some level.

The process of creating a book and a curriculum fascinated some students in the class. 33% of the students asked one or more questions about writing a book or story; of those who asked such questions, 83% were female. These questions indicated a high level of metacognition; specifically, questions about how the material was created. Questions on the writing process ranged from how long it took to write the book, where the ideas had come from, and how the author decided to get the characters into and out of difficulties. Half of those responding indicated an interest in writing their own stories. The progress of the story including plot details, outcomes of certain adventures, and
resolution of conflicts within the book was also a major topic of interest. 75% of the students asked one or more questions about the story itself.

Table #1 below, shows the data gathered from the response notebooks, summarized as on task activity, off task activity, on task thinking, and off task thinking. For the thinking section, either an on-task thinking report, or an appropriate question related to the topics of interest in the class were sufficient to mark the student as

Table 1

Physical and Mental Engagement of Male and Female Students

<table>
<thead>
<tr>
<th>ID</th>
<th>On Task Activity</th>
<th>Off Task Activity</th>
<th>On Task Thinking</th>
<th>Off Task Thinking</th>
<th>Active Engagement</th>
<th>Mental Engagement</th>
<th>Avg. Daily Engagement</th>
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<td></td>
<td></td>
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<tr>
<td>1144</td>
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<td>1</td>
<td>18</td>
<td>15</td>
<td>97.0%</td>
<td>54.5%</td>
<td>75.8%</td>
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<td>18</td>
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<td>45.5%</td>
<td>72.7%</td>
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<td>1</td>
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<td>2</td>
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<td>92.6%</td>
<td>94.4%</td>
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<td>0</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
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<td>6</td>
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<td>5</td>
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<td>6</td>
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<td>18.8%</td>
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<td>2.9%</td>
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</tr>
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<td>51.5%</td>
<td>75.8%</td>
</tr>
<tr>
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<td>11</td>
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<td>68.6%</td>
<td>84.3%</td>
</tr>
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<td>Female Students</td>
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</tr>
<tr>
<td>1336</td>
<td>34</td>
<td>1</td>
<td>30</td>
<td>4</td>
<td>97.1%</td>
<td>88.2%</td>
<td>92.7%</td>
</tr>
<tr>
<td>5342</td>
<td>31</td>
<td>4</td>
<td>18</td>
<td>17</td>
<td>88.6%</td>
<td>51.4%</td>
<td>70.0%</td>
</tr>
<tr>
<td>5613</td>
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<td>19</td>
<td>15</td>
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<td>55.9%</td>
<td>72.1%</td>
</tr>
<tr>
<td>1523</td>
<td>31</td>
<td>2</td>
<td>20</td>
<td>13</td>
<td>93.9%</td>
<td>60.6%</td>
<td>77.3%</td>
</tr>
<tr>
<td>Hispanic</td>
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<td>14</td>
<td>20</td>
<td>82.4%</td>
<td>41.2%</td>
<td>61.8%</td>
</tr>
<tr>
<td>1214</td>
<td>35</td>
<td>0</td>
<td>30</td>
<td>5</td>
<td>100.0%</td>
<td>85.7%</td>
<td>92.9%</td>
</tr>
<tr>
<td>4366</td>
<td>32</td>
<td>1</td>
<td>13</td>
<td>20</td>
<td>97.0%</td>
<td>39.4%</td>
<td>68.2%</td>
</tr>
</tbody>
</table>

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‘mentally on task’ for that response period. For some students, on task reports were almost all based upon questions asked, rather than reports of on task thinking about classroom topics; for other students this was almost the reverse, with on task thinking being predominant, and on task questions rarely being recorded.

Student Survey Data

The student pre and post survey instruments varied slightly in their form, with the post program survey also including a series of questions on the students’ self-assessment of their improvement (or lack thereof) during the program. Most of the questions were identical, however. The students were given a series of self-referential statements and asked to rate their agreement or disagreement with the statement by choosing a number on a 5-point Lickert scale, where 1 = strongly disagree, 2 = slightly disagree, 3 = neutral or don’t know, 4 = slightly agree, and 5 = strongly agree. The students responses to identical questions were recorded and compared from the pre program survey to the post program survey. The pre program survey included only these general statements. The post program survey included statements such as: “My math skills have improved this summer.” Students who answered affirmatively were also asked to give a specific example of skills they felt that they had improved in if they could. The post program survey also included two questions about their acceptance of the Maurice on the Moon curriculum and text. The questions from the pre program survey are listed below.

1. I enjoy going to school each day.

2. I like the way science was taught in my school last year.

3. I like the way math was taught in my school last year.
4. I enjoy using math to solve problems in class.
5. I am a good problem solver.
6. Math is easier to understand when I do ‘real life’ problems.
7. I can find more than one way to solve a problem.
8. I have mastered multiplication.
9. I have mastered fractions and decimals.
10. I have a strong command of algebra.
11. Math was my worst subject last year.
12. Science was my worst subject last year.
13. I like to read.

The post program survey updated these questions slightly to reflect the students’ experiences in the summer school program. For instance, question #1 became: “I enjoyed coming to summer school each day,” and question #2 became: “I liked the way science was taught in summer school this year,” etc. In addition, the post program survey included these additional questions:


15. I will do better reading and discussing books next year because of the work I did this summer.

16. My reading skills have improved this summer.

17. My vocabulary has improved this summer.

18. My math skills have improved this summer. (If yes, can you give a specific example?)
19. My science skills have improved this summer. (If yes, can you give a specific example?)

20. I would recommend the Summer Science Enrichment program to my friends next year.

The raw data results of the thirteen identical pre and post program survey questions are gathered in appendix A, table 2. It should be noted that statements 11 and 12 are negative, and that disagreement with them indicates a positive response toward science and math classes by the student. Statements 14-20 of the survey were presented to the students only once, during the post program survey. These survey statements asked the student to assess their own progress in academic areas over the summer. The results of these statements are presented collected in table 3 in appendix A.

The final survey result concerned the pre and post test examination itself. At the end of the pre test and again at the end of the post test, students were asked to rate the test on two points. First, rank the difficulty of the test on a 1-10 Lickert scale, where a score of 5 indicated that the exam was at their own grade level, and each number above or below 5 indicated a difference of one year. For example, if a student thought the exam was as difficult as a typical science exam in their own grade, they would post a difficulty score of 5, if the student thought the exam would be appropriate for someone one year ahead of them in school, they would post a difficulty of 6, and so on.

The second point the students were asked to consider, was how much of the test material they had seen covered in class before. In this case, each point on the 1-10 scale was to be considered as 10%; a score of 5 would indicate that the student had seen 50% of the exam material in class before. It was emphasized that this was an experience
rating, not one of mastery or understanding of the material; they were simply to rate how much of the material that they had been exposed to in a class before they took the exam.

For the pretest, the students rated the difficulty of the exam with an average score of 6.89, indicating that the students, on average, believed the exam to be almost two grade levels too difficult for them. Four weeks later, the students took the same exam and rated its difficulty with an average score of 4.28, indicating that they now saw the exam as being almost one year below their own grade level.

The experience rating of the pretest averaged 6.28, indicating that the students reported having been exposed to approximately 63% of the material on the exam on average. By the time of the post test, the students indicated that they now had been exposed to an average of 81.1% of the material on the exam. In fact, the text and curriculum had exposed them to exactly 80% of the test material, as 20% of the exam material consisted of general knowledge questions which were not addressed either in the text of the novel or in the classroom activities or lessons.
Overview of Findings

The quantitative results of the pre and post tests were encouraging. Student performance on the standards-based question set showed marked improvement for every subgroup in the study population. Hispanic females showed a 32.5% average increase in the number of correct responses, with an effect size, or gain of 13 additional questions correct on the post test instrument. Hispanic males also increased, but did not match their female classmates rate of improvement with an average increase of 27.5% and an effect size gain of 11 questions. White males improved their correct responses by 37.5% with an effect size gain of 15 questions. There was only one White female student in the study group, she improved her performance by 47.5% with an effect size gain of nineteen questions.

The gains in student performance on the standards-based question set correlated well with the degree of student engagement measured by student self-responses, percentage of class work completed and the academic quality of the work done. The use of the three measures of engagement allowed the researcher to ascertain an average daily engagement percentage that included active engagement such as performing required tasks during class time and mental engagement based upon student self reports and questions asked and recorded in student notebooks. While moderate correlations were found between changes in student performance from pre to post test and the average daily

89
engagement percentage, the strongest correlation was found between actual on task activity and test performance, while the correlation between student-reported mental engagement and test performance improvement was much weaker, though still positive.

The student survey results were also positive, indicating that the students in the sample population attitudes toward attending school had improved moderately (+22%), while the students self perception as science and mathematics learners had increased substantially. The number of students who enjoyed the way that science was taught in the summer class climbed to 83%, those who enjoyed the way math was taught showed less increase, rising from 36% to 56% over the course of the summer. Student attitudes about themselves as capable learners in science showed substantive gains, however the students did not view themselves as significantly more capable in mathematics at the end of the study. Most students however, claimed that their skills in science (89% agree) and mathematics (78% agree) had improved to some degree over the summer. Approximately 90% of those who said their skills in science and mathematics had improved were able to cite a specific skill or area in which the improvement had occurred.

The survey also addressed the literature and reading component of the study. Students who reported that they liked to read rose 23 points to 67% over the course of the study. Students also overwhelmingly reported that they believed their reading and vocabulary skills had improved over the course of the summer, with 78% and 89% respectively agreeing with that statement in the post program survey.
The Research Question

A diverse group of 18 students self selected from the 6th, 7th, and 8th grade population of a California middle school are given a 4-week long summer school program entitled Summer Science Enrichment. The program consists of the science fiction novel *Maurice on the Moon*, paired with a diverse, activities-rich curriculum that combines science and mathematics with literature, art, drama and model making. The program is taught using the Science Through Literature pedagogy by a certificated, middle school science instructor who has received 4-6 hours of training in the curriculum and the science through literature method.

Student assessment in this program includes identical, pre and post tests containing a standards-based set of 40 questions and a set of 10 general knowledge questions. The general knowledge and standards-based questions were intermixed randomly throughout the test; the presence of the general knowledge questions was unknown to either the students or the instructor of the program. Standards-based questions were based upon science standards that were covered in the text of the book as well as the activities of the class. General knowledge questions were based upon science standards relating to the Earth-Moon system that were not covered either in the text of the novel or the activities within the class. How does the change, if any, in student performance on the general knowledge questions compare to the change, if any, in student performance on the standards-based question set? Is the difference in pre and post test performance, if any, statistically significant?

Student engagement with the material is measured in three different ways, including student notebook responses, percentage of assigned work completed, and
academic achievement grades assigned by the instructor in the course. Is there any correlation between measures of student engagement with the material and a change in performance on the standards-based question set? If so, is this correlation significant?

Student self perception as effective learners is a critical measure of program success for the research client. Is there any measurable change in student self perception as effective learners as measured by a pre and post survey instrument? Is there any correlation between changes in self perception as measured by the survey instrument and change in student performance on standards-based assessment as measured by the standards-based question set? If so, is this correlation significant?

Null Hypothesis #1: The change in the number of correct responses to the general knowledge question set is not affected by the student’s exposure to the *Maurice on the Moon* curriculum. H₀ : Δ Correct = 0

Null Hypothesis #2: The change in the number of correct responses to the standards-based question set is affected by the student’s exposure to the *Maurice on the Moon* curriculum. H₀ : Δ Correct ≠ 0

Test Data Analysis

Using the change in correct responses taken from table #1 in chapter 4, the researcher used ΔCₓ for the standards-based question set as the sample population and the change in correct responses, or ΔCₑ for the general knowledge question set as the control population; a t-test was performed to determine if the change in response was significant. The following data was calculated for the sample and control populations. This analysis showed that the effects of the program on the students’ change in performance from the
pre test to the post test were statistically significant, and that the probability of such a result being a result of random effects was exceedingly small, on the order of one chance in one million. In fact with the total number of correct answers more than doubling from pre test to post test, and the fact that no student showed a decrease in their total number of correct answers from pre test to post test on the standards-based question set, and the fact that the average effect size for the standards-based question set was more than ten times the average effect size for the general knowledge question set, there was little doubt that the effect of the program on the change in student performance on the pre and post test standards-based question set was statistically significant. The statistical analysis shows that null hypothesis #1 and #2 are both disproved. The change in performance on the standards-based question set was strongly influenced by the *Maurice on the Moon* curriculum; and the change in the number of correct responses on the general knowledge question set was not affected by the curriculum. The change in correct responses on the general knowledge question set was statistically insignificant, as seen in table 2 below.

**Table 2**

**Tests of Statistical Significance on the Improvement of Student Scores**

<table>
<thead>
<tr>
<th>Sample Population Data</th>
<th>Control Population Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu$</td>
<td>6.3</td>
</tr>
<tr>
<td>$\delta$</td>
<td>3.6176</td>
</tr>
<tr>
<td>Variance</td>
<td>13.08718</td>
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<tr>
<td>Maximum</td>
<td>14</td>
</tr>
<tr>
<td>Minimum</td>
<td>-1</td>
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<tr>
<td>N</td>
<td>40</td>
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<td>$\alpha$</td>
<td>0.0005</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
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</tr>
<tr>
<td>Z-critical</td>
<td>3.965</td>
</tr>
<tr>
<td>Z-obtained</td>
<td>-9.965</td>
</tr>
</tbody>
</table>
Disaggregating the data by gender and ethnicity illustrates that the achievement gains from the pre to post test in the standards-based question set were not confined to, or limited by a student’s gender or ethnicity. Table 3 below, shows that male students as a group improved the number of their correct responses to the standards-based question set by an average of 33.9%, with White male students doing somewhat better than their Hispanic classmates. Each group increased substantially in their correct responses, and no male student showed a decrease in the total number of correct responses to the standards-based question set. An increase in the percentage of correct answers on a standards-based exam such as the SAT-9 or CAT-5 exam of 34% would be sufficient to move a student from a ranking of “basic” to “advanced”.

Table 3
Improvement in Test Performance for Male Students

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Pre test Correct</th>
<th>Post test Correct</th>
<th>Δ Correct</th>
<th>Δ % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1144</td>
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<td>26</td>
<td>18</td>
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<td>6246</td>
<td>12</td>
<td>25</td>
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<tr>
<td>2626</td>
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<td>32</td>
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<td>5153</td>
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<td>4256</td>
<td>18</td>
<td>35</td>
<td>17</td>
<td>42.5%</td>
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<tr>
<td>3612</td>
<td>15</td>
<td>24</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Effect Size</td>
<td>+15.0</td>
</tr>
<tr>
<td>6215</td>
<td>9</td>
<td>24</td>
<td>15</td>
<td>37.5%</td>
</tr>
<tr>
<td>1634</td>
<td>6</td>
<td>15</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6166</td>
<td>15</td>
<td>26</td>
<td>11</td>
<td>27.5%</td>
</tr>
<tr>
<td>6112</td>
<td>16</td>
<td>25</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Effect Size</td>
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</tr>
<tr>
<td>Average Effect for All Male Students</td>
<td>13.45</td>
<td>27.00</td>
<td>+13.55</td>
<td>33.9%</td>
</tr>
</tbody>
</table>
Examining data for all female students in table 4 below, shows similar results. It must be noted that in the category of White, female student, there was only one individual in the research sample group. This individual demonstrated an unusual level of improvement from pre test to post test that appears to be anomalous, however the performance for the female students as a group shows similar improvement to their male counterparts in the classroom. Female Hispanic students showed an average improvement of 32.5% over their pre test results, with the average student improving her score by almost 14 questions out of the 40 question standards-based set. As with the male students, an improvement of this magnitude on a standards-based state exam would be sufficient to raise that student from a ranking of basic to advanced. As with the male students, every individual showed a substantial increase in the number of correct responses to the standards-based question set and no student showed a decrease in correct responses.

Table 4
Improvement in Test Performance for Female Students

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Pre test Correct</th>
<th>Post test Correct</th>
<th>Δ Correct</th>
<th>Δ % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1336</td>
<td>17</td>
<td>36</td>
<td>19</td>
<td>47.5%</td>
</tr>
<tr>
<td>5342</td>
<td>7</td>
<td>22</td>
<td>15</td>
<td>37.5%</td>
</tr>
<tr>
<td>5613</td>
<td>11</td>
<td>26</td>
<td>15</td>
<td>37.5%</td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1523</td>
<td>16</td>
<td>32</td>
<td>16</td>
<td>40.0%</td>
</tr>
<tr>
<td>5664</td>
<td>13</td>
<td>22</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td>1214</td>
<td>11</td>
<td>23</td>
<td>12</td>
<td>30.0%</td>
</tr>
<tr>
<td>4366</td>
<td>11</td>
<td>22</td>
<td>11</td>
<td>27.5%</td>
</tr>
<tr>
<td>Effect Size</td>
<td>+19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td></td>
<td>+13.0</td>
<td>32.5%</td>
</tr>
<tr>
<td>Average Effect for All Female Students</td>
<td>12.29</td>
<td>26.14</td>
<td>+13.86</td>
<td>34.6%</td>
</tr>
</tbody>
</table>
An examination of data for all Hispanic students again shows that the performance of this group varied little from other disaggregated groups. In table 5 below, we see that Hispanic students as a group increased their percentage of correct responses on the standards-based question set by 30.5%. Among the Hispanic students, there was less variation between males and females; however, as with their White counterparts, we see that female students improved more than their male classmates. Hispanic females improved an average of 32.5%, compared to Hispanic males, who improved by 27.5%. As with all the other groups, there were no individuals who saw a decrease in correct responses. Here, as with other disaggregated groups, the average improvement in the performance on the standards-based question set would be sufficient to increase a student's rank on a SAT-9 or CAT-5 examination from basic to advanced.

Table 5

Improvement in Test Performance for All Hispanic Students

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Pre test Correct</th>
<th>Post test Correct</th>
<th>Δ Correct</th>
<th>Δ % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5342</td>
<td>7</td>
<td>22</td>
<td>15</td>
<td>37.5%</td>
</tr>
<tr>
<td>5613</td>
<td>11</td>
<td>26</td>
<td>15</td>
<td>37.5%</td>
</tr>
<tr>
<td>1523</td>
<td>16</td>
<td>32</td>
<td>16</td>
<td>40.0%</td>
</tr>
<tr>
<td>5664</td>
<td>13</td>
<td>22</td>
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<td>22.5%</td>
</tr>
<tr>
<td>1214</td>
<td>11</td>
<td>23</td>
<td>12</td>
<td>30.0%</td>
</tr>
<tr>
<td>4366</td>
<td>11</td>
<td>22</td>
<td>11</td>
<td>27.5%</td>
</tr>
<tr>
<td>Effect Size</td>
<td>+13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6215</td>
<td>9</td>
<td>24</td>
<td>15</td>
<td>37.5%</td>
</tr>
<tr>
<td>1634</td>
<td>6</td>
<td>15</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td>6166</td>
<td>15</td>
<td>26</td>
<td>11</td>
<td>27.5%</td>
</tr>
<tr>
<td>6112</td>
<td>16</td>
<td>25</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td>Effect Size</td>
<td>+11.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Effect for All Hispanic Students</td>
<td>11.50</td>
<td>23.70</td>
<td>+12.20</td>
<td>30.5%</td>
</tr>
</tbody>
</table>

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In the next table, we see the disaggregated data for all White students in the study. The White students in the study improved 7% more than their Hispanic classmates. Every White student in the study was a native English speaker, which may have had some effect on the ability of the students to comprehend and answer the questions on the test instrument. However, the use of SDAIE techniques, such as group work, emphasis on vocabulary development in social and academic English, use of shared reading techniques to improve comprehension, and an activity rich curriculum which helps to improve a student's comprehension of scientific and mathematical concepts as they develop appropriate academic and social vocabulary and speaking skills was effective for the Hispanic students in the study. All students were able to operate in the intelligence mode that suited them best, and improve their comprehension of scientific and mathematical standards while improving their skills in written and spoken English. The average improvement among the White students in the study was 38.8%. Again, there was only one White female student, whose improvement on the standards-based question set in the pre and post test instrument was anomalous for the study group as a whole. In the group of White students, this individual was only one among eight and her contribution only changed the average of the group by 1.3%. As with every other disaggregated group, no individual showed a decrease in correct responses to the standards-based question set, and five of the eight students increased their score on the standards-based question set by over 40%. An improvement of almost 39% on a standardized test instrument such as SAT-9 or CAT-5 would raise a child's rank from 'below basic' to 'advanced'.
### Table 6

**Improvement in Test Performance for All White Students**

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Pre test Correct</th>
<th>Post test Correct</th>
<th>Δ Correct</th>
<th>Δ % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1336</td>
<td>17</td>
<td>36</td>
<td>19</td>
<td>47.5%</td>
</tr>
<tr>
<td>1144</td>
<td>8</td>
<td>26</td>
<td>18</td>
<td>45.0%</td>
</tr>
<tr>
<td>3355</td>
<td>15</td>
<td>33</td>
<td>18</td>
<td>45.0%</td>
</tr>
<tr>
<td>6246</td>
<td>12</td>
<td>25</td>
<td>13</td>
<td>32.5%</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2626</td>
<td>15</td>
<td>32</td>
<td>17</td>
<td>42.5%</td>
</tr>
<tr>
<td>5153</td>
<td>19</td>
<td>32</td>
<td>13</td>
<td>32.5%</td>
</tr>
<tr>
<td>4256</td>
<td>18</td>
<td>35</td>
<td>17</td>
<td>42.5%</td>
</tr>
<tr>
<td>3612</td>
<td>15</td>
<td>24</td>
<td>9</td>
<td>22.5%</td>
</tr>
<tr>
<td><strong>Effect Size</strong></td>
<td></td>
<td></td>
<td>+19</td>
<td>47.5%</td>
</tr>
<tr>
<td><strong>Average for All White Students</strong></td>
<td>14.88</td>
<td>30.38</td>
<td>+15.50</td>
<td>38.8%</td>
</tr>
</tbody>
</table>

The concept of engagement is a difficult one to measure quantitatively. The attempts to measure engagement with the material made in this study were indeed quantifiable, but they relied upon three different observer/reporters of engagement criteria: engagement reports generated by the students themselves in their daily notebooks, percentage completion of work observed and reported by the researcher, and academic achievement observed and reported by the instructor. It was initially hypothesized that the correlation of student reports of engagement would correlate closely with improvements in test scores from the pre test to the post test. When these data were correlated, however; only a weak correlation between the two data sets was observed; and that relationship was not consistent among all the major subgroups in the study. The only measurement in this area that showed any reasonable correlation to improvement in test scores was the student...
Table 7

**Student Notebook Response Data Analysis**

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Male Students</th>
<th>Active Engagement</th>
<th>Mental Engagement</th>
<th>Average Daily Engagement</th>
<th>Δ Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On Task Activity</td>
<td>On Task Thinking</td>
<td>Off Task Activity</td>
<td>Off Task Thinking</td>
<td>Students On Task Thinking</td>
</tr>
<tr>
<td>1144</td>
<td>32</td>
<td>1</td>
<td>18</td>
<td>15</td>
<td>97.0%</td>
</tr>
<tr>
<td>3355</td>
<td>33</td>
<td>0</td>
<td>15</td>
<td>18</td>
<td>100.0%</td>
</tr>
<tr>
<td>6246</td>
<td>26</td>
<td>1</td>
<td>25</td>
<td>2</td>
<td>96.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2626</td>
<td>31</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>100.0%</td>
</tr>
<tr>
<td>5153</td>
<td>27</td>
<td>6</td>
<td>28</td>
<td>5</td>
<td>81.6%</td>
</tr>
<tr>
<td>4256</td>
<td>26</td>
<td>6</td>
<td>6</td>
<td>26</td>
<td>81.3%</td>
</tr>
<tr>
<td>3612</td>
<td>16</td>
<td>16</td>
<td>15</td>
<td>17</td>
<td>50.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6166</td>
<td>33</td>
<td>0</td>
<td>17</td>
<td>16</td>
<td>100.0%</td>
</tr>
<tr>
<td>6112</td>
<td>35</td>
<td>0</td>
<td>24</td>
<td>11</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

notebook reports of active engagement. When on task activity and on task thinking reports are plotted against test score improvement, we find a weak correlation between on task activity as reported by the students in their notebooks and test scores for White male students and for female students, but a slight negative correlation for Hispanic males. Examining the graphs in figure 5 below, we see that the changes in on task activity roughly parallel changes in test performance, while there is little or no correlation between reports of on task thinking and test score improvement. When statistical analysis is performed, the correlations are found to be statistically significant.
analysis was performed on these correlations, only weak relationships were found between the two sets of data, with r-values between 0.04 and 0.10. A moderately strong correlation would have an r-value between 0.3 and 0.5.

Even so, when scatter plots and linear regression is performed, we can see in figure 5 that there is a modest fit between reported time on task in the student notebooks and improvement in test scores. The data indicates that the correlation is strongest among the White male students in the study, moderate to weak correlation among all female students, and that the correlation is negative among the Hispanic male students in the study. However, if one data point among the Hispanic male population is considered to be an outlier, then the correlation between reported time on task and improvement in test scores is similar for all three groups. While there are some observational reasons to consider this to be the case, they must be considered to be non-quantitative, at best.

Certainly, the greatest difficulty in disaggregating the data in this manner is the small sample size in this study, which makes it very difficult to draw any definitive conclusions of correlation between reported on task time from student generated engagement data and changes in test score performance on the standards-based question set. There is also the question as to whether the students are reporting honestly, or reporting what they believe the researcher wants to hear. Whereas an adult who has volunteered to participate in a study may be more generally relied upon to understand the needs of the researcher for honest reporting and comprehend that their responses are confidential and will not be shared with others. It is very difficult to ascertain whether or not the students in the study fully understood this point, or whether they believed that the data was truly confidential and would not affect their grade in the summer course.
Figure 5: Comparing Increase in Test Performance to On Task Reports from Notebook Responses.

This portion of the research hypothesis cannot be considered proved by any means. Although the evidence below indicates that there was a high level of student
engagement with the material, and an effective use of classroom instructional time by the instructor, the relationship between engagement and improvements in test performance is not convincingly demonstrated. Nevertheless, it can be said that there is enough evidence of a relationship between student engagement with the material and improvement in test performance to warrant further study. It is likely that a much larger sample of students would be needed to demonstrate this hypothesis.

Figure 6: Correlation between the number of on-task reports and improvement in test performance. Note the second chart of data for Hispanic males which excludes the purported outlier.

One of the goals of the research client was to demonstrate that the experimental curriculum and Science Through Literature pedagogic methodology created student engagement within the classroom for all students regardless of their socioeconomic status or demographic origins. This hypothesis was effectively proven to be true. Students self-
reported active engagement with the material 91.4% of the time on average. Engagement as measured by percentage completion of work in the classroom averaged 84.4% as measured and reported by the researcher. Engagement as measured by academic success in the program as measured and reported by the instructor averaged 76.2% with a failure rate of 11.1%. This is extraordinarily successful. The student population from Middle School that the study subjects were drawn from feeds the community high school, where the failure rate in 9th grade Earth and space science class has remained consistently at 45-50% for the past decade. The curriculum covers the same standards as the *Maurice on the Moon* curriculum, but it is not presented as a laboratory course, and there are no activities presented with the material, and there is no paired text available. The differences in pedagogy and in success rates for essentially identical populations are very stark indeed.

Survey Data Analysis

The survey instrument, which was not part of the initial design, was included at the request of the research client. The school district was interested in student attitudes toward school and their self perception as learners. One measure of success that the research client defined, was improvements in how students perceive themselves as learners. Measuring any change in student attitudes was the function of the student survey instrument. This survey instrument was initially developed by the researcher at the research client’s request, and later approved by the district’s curriculum council as part of the research study and the Summer Science Enrichment pilot program. The first part of the survey was designed to examine students attitudes toward school in general,
and to measure student attitudes towards science, mathematics and problem solving prior to their participation in the STL curriculum. The second part of the survey instrument, which was administered only after the program was over, was designed to examine how the students viewed their own success, or lack thereof, in the Summer Science Enrichment program.

In order to accomplish this task, student responses to identical questions asked before and after the program were compared for individual students, and compiled per question for the group. The complete data table of responses can be seen in table #4, in Appendix A.

Breaking down the survey instrument, it was found that the students’ attitude toward going to school each day improved moderately, increasing by 22%, while the number of students who actively disliked going to school each day declined to just 11% of the survey group.

Examining the students’ attitudes toward math and science pedagogic method, the survey statement was “I like the way science / math is taught in [summer] school.” It was found that the number of students who actually enjoyed the way that science was taught climbed to 83%, and the number of students who disagreed and disliked the way in which science was taught fell to 0%. This is a strong vindication of the activity rich, Science Through Literature methodology. The improvement in students’ attitudes toward the way in which mathematics it taught also saw gains, but not as strong as in science. The number of students who enjoyed the way in which math was taught increased modestly from 39% to 56%; perhaps more importantly, the number of students who disliked the way math was taught declined substantially from 44% to just 11%.
Mathematics, along with English and language arts form the primary emphasis of the current California state testing which determines API and AYP ratings for schools. Several of the survey statements dealt with students’ self perceptions regarding their mathematical skills. It is also seen in the Hemet district as one of the most problematic areas. The first statement, “I enjoy using math to solve problems in school,” initially showed a poor result in the pre program survey, where only 17% of the students agreed with this statement and 39% disagreed. In the post program survey, the number of students agreeing with this statement had climbed to 67% and the number who disagreed had fallen to just 11%; a very powerful result which seems to be attributable to the activity rich nature of the program, as well as integrating math with science and literature. This is only surmise at this point, however, and indicates a direction for further research in the future.

This interpretation is bolstered, however, by the survey statement, “Math is easier with real life problems.” This statement was included because of the researcher’s own experience with teaching physics, chemistry, and astronomy over the last two decades, whereas the researcher has consistently found that students report that good grades and perceived math skills do little to improve their chances to succeed in these applied science classes. The reverse, in fact, has consistently been reported to the researcher by his students. These students find that their experience in physics, chemistry, and astronomy helps their performance in math classes far more than good scores in math help them in science. In this survey, the number of students who agreed with the statement; “Math is easier with real life problems” climbed from 44% to 89%, and the number who disagreed fell to just 11% by the end of the program.
Interestingly, students' self perceptions of themselves as mathematicians did not change much. The survey statements, "I am a good problem solver," and "I can find more than one way to solve a tough problem," changed very little on the positive side. The first statement saw an increase in those who agreed of just 5%, while the second statement saw an increase of 11% in those who agreed. The number of students who disagreed with the second statement, "I can find more than one way to solve a tough problem," did decline by 17%. Students in the survey did not become more positive about themselves as mathematicians, but they did become somewhat less negative.

This perception is also reinforced by the next three statements, which targeted students' self perceptions of their abilities in specific mathematical skill sets; multiplication and division, fractions and decimals, and algebra. For these three statements, the number of students who agreed with these statements increased by an average of only 3.7%; the number of students who disagreed declined by an average of 13%. Once again, the students did not become more positive about their mathematical skills as a group, but their self image did seem to be less negative, at least as far as their mathematical skills were concerned, after the program was over.

The next two statements were focused on student's resistance to math and science classes as they move through middle school. It has been documented that the numbers of students who voluntarily take science classes continues to decline as a percentage of the student body from 9th grade through graduate school. The statements in the survey were: "I think math will be my worst class next year," and "I think science will be my worst class next year." These statements were added to the survey because, although the district Superintendent reported that many parents were interested in a summer science
enrichment program, there is little similar interest on the part of the students’ themselves. For these statements, a positive result would be a decline in agreement, rather than an increase. The survey results found a modest 11% and 22% decline in agreement with these negative statements respectively. Similarly, the amount of disagreement with these statements increased modestly by 5% and 22% respectively. The change in student attitudes toward science classes in particular was not as strong as hoped for, but the direction of the change was a positive one.

The last statement on the pre and post program survey was; “I like to read.” Reading level among students is a prime concern for the research client school district, and in many districts across California and the nation. Studies have found that encouraging students to read almost any type of material will increase reading levels and proficiency. Students who enjoy reading are more likely to continue to read on their own and improve their reading level and keep pace with the expected increase in reading proficiency as they advance through school. In the researcher’s own classroom, student resistance to reading text books has increased noticeably over the past two decades. Student responses to the “I like to read,” statement were positive, but not overwhelmingly so. The change in the percentage of students who agreed with this statement increased from 44% to 67%; likewise, the percentage of students who disagreed with this statement declined from 28% to just 11%. Given the high percentage of ELD students in the program, this result must be considered to be a moderately strong result.

In addition to the survey statements that were in both the pre and post program survey, the post program survey also included a series of statements that asked students to assess their academic gains over the summer and whether they would recommend the
program to peers in school. The results of these survey statements are listed in the table below.

Table 8

Student Responses to Post Program Survey Statements

<table>
<thead>
<tr>
<th>Post Program Survey Statement</th>
<th>Total Agree</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Neutral Agree</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
<th>Total Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I will do better reading books in Eng. next yr.</td>
<td>11.11</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>77.78</td>
<td>11.11</td>
<td>88.89</td>
</tr>
<tr>
<td>I enjoyed reading Maurice on the Moon</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>33.33</td>
<td>61.11</td>
<td>94.44</td>
</tr>
<tr>
<td>My reading skills have improved this summer</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>50.00</td>
<td>27.78</td>
<td>77.78</td>
</tr>
<tr>
<td>My vocabulary has improved this summer</td>
<td>11.11</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>61.11</td>
<td>27.78</td>
<td>88.89</td>
</tr>
<tr>
<td>My math skills have improved this summer</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>61.11</td>
<td>27.78</td>
<td>77.78</td>
</tr>
<tr>
<td>My science skills have improved this summer</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>66.67</td>
<td>22.22</td>
<td>88.89</td>
</tr>
<tr>
<td>I will tell others to take summer science</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>11.11</td>
<td>38.89</td>
<td>50.00</td>
<td>88.89</td>
</tr>
</tbody>
</table>

The first statement was: “I will do better reading and discussing books in English class next year because of the experience I had in the summer science enrichment program.” The response to this statement was overwhelmingly positive with 89% agreeing with the statement, 11% neutral, and none disagreeing. The related second statement was: “I enjoyed reading *Maurice on the Moon.*” Again, the response was overwhelmingly positive with 94% agreeing, 6% neutral, and none disagreeing.

The next four statements targeted the students’ self perceptions of their improvements in reading skills, vocabulary, mathematics, and science. The statement, “My reading skills have improved this summer,” found 78% agreeing, 22% neutral, and none disagreeing. The second statement, “My vocabulary has improved this summer,” found that 89% agreed, 11% were neutral, and none disagreed.

The next two statements; “My mathematics skills have improved this summer,” and “My science skills have improved this summer,” also had follow up questions with them. If a student agreed with this statement, they were asked to provide an example of
an area in which their skills had improved. For the first statement, 78% agreed they had improved, 11% were neutral on the subject, and 11% disagreed. Of the students who agreed with this statement, 93% were able to cite a specific math skill or skills where they felt they had improved. The most common responses were improvement in basic multiplication and division skills and working with decimal values in problems.

For the second statement concerning improvement in science skills, 89% of the student population agreed that their science skills had improved. Of those who agreed with this statement, 69% were able to cite a specific skill or science knowledge area where they had improved. Unlike the mathematics responses, students did not often cite a particular skill set such as multiplication, division, or working with decimal values; rather the students who responded tended to cite areas of scientific study where they felt they had improved. Responses to this follow up question were more varied than those for the math follow up question, and included using math and science together, problem solving, accurate measurement, and the ability to perform lab activities independently. By far the most common response was improvement of their knowledge in the areas of astronomy and space science, which was cited by over half of the respondents.

The very strong positive response to the survey questions about students’ improvement in math, science, reading and vocabulary is one of the most encouraging results of the entire program. An average of 86.6% of the students in the sample population reported an increase in reading, vocabulary, mathematics, and science skills. This is also an area for further research. The researcher plans to follow the progress of these students during the next semester in math, science, and English / Language Arts to see if the students’ self perception of improved skills is reflected in an increase in
academic performance in these areas. Members of the Hemet district administration have already indicated that they are interested in further research in this area as well.

Conclusions

There were two sets of research goals for this project, those set by the researcher, and those set by the research client school district. The researcher set out to demonstrate the viability of the Science Through Literature concept; specifically, that teaching science concepts using a literary science fiction text could be as effective, or more effective than using a standardized school text. Secondly, to confirm that science fiction literature easily crosses cultural boundaries in the classroom and empowers the learning of diverse groups of students within a classroom without excluding students based upon gender or ethnicity. Third, that using science fiction literature as a primary text could be as effective a tool in the middle school classroom as it has been in the secondary and undergraduate classroom. For the research client school district, the goals were to develop a powerful intervention curriculum that could be administered flexibly either in summer school or in the regular classroom; a program that would be useful for a variety of grade levels from 6th through 9th grade. The school district also desired a curriculum that would not just improve science scores on standardized tests, but also improve mathematics, literacy and reading skills. The district is also very concerned with at risk populations and desired a program that would be highly palatable to middle school students who do not traditionally have high success rates in science, mathematics, and English / language arts programs. According to the school district’s own criteria, the program would not be fully successful unless it also increased student confidence in their
own abilities. The district’s “Believe and Achieve” motto is taken very seriously at all levels from the Superintendent’s office down to the classroom level on individual school campuses.

Data from this study confirms the researcher’s hypothesis that using a Science Through Literature based pedagogy with a science fiction novel as a primary text was more effective than using a standard science text. When compared to similar populations in 6\textsuperscript{th} - 9\textsuperscript{th} grade, the four-week summer school intervention population had a higher academic passing rate (100% of the study group passed the course with scores of 60% or higher, while the average passing rate in 9\textsuperscript{th} grade Earth science using Holt, Rinehart, and Winston’s *Modern Earth Science* as a primary text in a 6-week unit covering the Earth-Moon system at district high school whose students come from the middle school that hosted the study has averaged just 56% over the last seven years. The population of the middle school which was the source for the volunteers in the study is the feeder school for the high school in question, and the populations are essentially identical. In fact, all of the 8\textsuperscript{th} grade students from the study group are now attending this high school.

There are substantial differences in the pedagogy between the two classes that also account for the success of the Science Through Literature program. The high school Earth Science class is not a laboratory science class. The reasons for this are various, but primary among them is the fact that the University of California system and California State University system do not accredit 9\textsuperscript{th} grade science classes for lab science credit when students apply to college. Because of this, the district and site administration dictates that Earth science classes, which are offered as a standard 9\textsuperscript{th} grade science class, are not taught as a laboratory science. The classes in Earth science typically run 40+
students per class, even in rooms that are designed for no more than 24 students. Over crowding also severely limits the ability of the instructors to offer any lab experiences, even if they had the budget to do so. Most of the teachers at the high school campus offer optional labs before or after school, but these sessions are poorly attended and do not affect the overall passing rate of the classes. The class is taught from the Holt-Reinhart text with reading, lecture, some occasional demonstrations, and standards-based test instruments to assess student learning. As the Earth Science master teacher for this high school campus, the researcher has developed and refined the curriculum in the Earth science classes to meet or exceed California State Educational standards for Earth science.

Despite the differences, the fact remains that with students from essentially identical populations, a literature-based, activity-rich curriculum produced a passing rate nearly double that of the high school classroom which taught the same standards over the same period of time. Obviously, further research is needed, and the idea of using the *Maurice on the Moon* test and STL-based methods in a traditional classroom setting has been discussed at the district level. The first implementation of this is planned for another middle school in the client district, and at a private Girls Academy in Pasadena; both are to occur in the spring, 2007 semester. There have also been discussions considering implementation of the *Maurice on the Moon* curriculum at the district's high school which serves at-risk students who have not been successful in standard high school classrooms. No definite time has been set for this implementation.

The results of this study also confirm earlier research by Butterfield, Cavanaugh and others that science fiction literature successfully crosses cultural barriers in the
classroom, and mirrors the wide multicultural appeal of science fiction literature and film world wide. Every subgroup in the study broken down by either gender or ethnicity were extremely successful in mastering the material and substantially improving their scores on standards-based exams. Pre and post test scores showed almost identical 32% gains for girls and boys, and every ethnic subgroup improved at least 28% on scores from pre test to post test. While it is true that White males improved substantially more than their Hispanic classmates, it is also true that every White male in the class was a native English speaker, while the majority of Hispanic males in the classroom were non-native speakers with ELD level average for the group of 2.6. It is the opinion of the researcher that the actual improvement of the Hispanic males is of far more significance than the difference between the various ethnic groups.

Hispanic females were also very successful, increasing their scores from pre test to post test by an average of 32.5%, and every student in this subgroup improving by at least 22.5%. There was only one White female student in the study group; she improved more than anyone else in the entire study, raising her score over 47% from pre to post test. No conclusions can be drawn from this single data point. There were also no African American students who completed the study, nor any other ethnic groups represented.

This matter is obviously an avenue for further study in the future; it is hoped that the additional implementations of the *Maurice on the Moon* curriculum and STL pedagogy in various school districts will help answer these questions. The success level of every student in this small study group is highly encouraging, however.
The use of a general knowledge set of 10 questions intermixed with the standards-based set of 40 questions to make up the pre and post test instruments was crucial in demonstrating the effectiveness of the *Maurice on the Moon* curriculum and the STL pedagogy. By using a general knowledge question set, the researcher had access to an independent measure of student improvement that clearly demonstrated the effectiveness of the program. The general knowledge question set, when disaggregated from the standards-based question set showed only an average 3.3% increase in performance; a gain of just 4 correct answers of 720 possible responses on the test for the entire study population. Three of the questions showed a decrease in the number of correct responses from pre to post test, two showed no change, and five questions showed some increase; this is typical of the change expected in random variance in test answers where no learning has occurred. Statistical analysis showed these changes to be insignificant; in other words typical of random fluctuation. Comparing the 35% increase in correct answers for the average question in the standards-based question set to the 3.3% average change in the general knowledge question set shows the dramatic effect that the curriculum and pedagogy had upon the students' learning. Statistical analysis confirmed that this result was significant with a confidence over 99.9999% and showed that the chances of this being a random response was far less than 1:1,000,000. This was a powerful confirmation of the research hypothesis that the Science Through Literature pedagogy would be effective in the classroom.

The school district's research goals for the pilot Summer Science Enrichment program were also fully realized. The intervention curriculum was successfully administered in a summer school setting to a diverse group of students that reflected the
population demographics of the district, and proved to be effective for all the major demographic groups that the district ordinarily serves. The program was effective for boys and girls, regardless of their ELD level, and every student in the program showed substantive gains in science and mathematical proficiency as measured by standards-based exam instruments.

The district’s secondary goal of improving student’s self image as learners in accordance with the district’s own ‘Believe and Achieve’ motto was also strikingly successful. As demonstrated by the pre and post survey instrument, students enthusiasm for going to school each day improved, as did their approval and enjoyment of the method of teaching that was employed. Students in our study clearly enjoyed the activity rich method compared with the text rich method commonly used in the district’s middle and high school classrooms. While the student’s self opinions as science and math learners did not improve significantly, it did become less negative.

The survey results were much more positive when students were asked to asses not themselves as learners, but their own improvement in specific skill areas. 78% - 94% of the student population in the study reported that they had improved their reading and vocabulary skills, and 89% said they felt that the Summer Science Enrichment would improve their ability to read, discuss, and study literature in English / language arts classes next year. The great majority of students who reported that they had improved in math and science skills also were able to cite specific areas of improvement when asked to do so. This specific and focuses awareness of their own improvement exceeded every expectation of the program and was hailed as a tremendous success when the results of the study were presented to the School Board and Curriculum Council in public meetings.

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in November, 2006. The fact that 94% reported enjoying the *Maurice on the Moon* book and that 89% said that they would recommend the program to their friends and peers at school encouraged the district to adopt the text officially as a classroom supplement and permanently adopt the Summer Science Enrichment program for Middle School Summer School. Plans are currently being discussed to more broadly implement the program in next year’s summer school program and possibly offer the Summer Science Enrichment at more campuses in 2007. In doing so, the research client school district has joined other districts in California, Illinois, Tennessee, and New York that have officially adopted the *Maurice on the Moon* curriculum.

Implications for Pedagogy and Practice

There are several implication for pedagogy and practice from this research. Primary among these is the recognition that students must be actively engaged with the curriculum presented in the classroom. Curriculum that is conveyed to students in a variety of modes, including visual, aural, written, and manipulative modes among others encourage students to engage with the material that the teacher presents in a variety of ways and offers avenues to success for students irregardless of where their own individual strengths and weaknesses lie.

When comparing the pedagogic design of this project to the methods employed in teaching very similar curriculum and science standards to students in the district’s high school, the differences are very stark. The STL curriculum integrates reading, writing, mathematics, and science in an activity rich curriculum which encourages students to express what they learn individually and in groups in a variety of modes. Every student
in the study was able to express what they had learned in a variety of modes that were not, for the most part, language dependent. Investigating scientific and mathematical concepts and creating documents, artwork, mathematical analysis, and physical apparatus helped these students to engage with and integrate that knowledge.

There were no sharp divides between the success levels of native English speakers, and English language learners, as is often found in 9th grade classrooms in which a textbook-lecture-test methodology is instituted from the top down and imposed upon the classroom teacher and students alike. In this, this research confirms and extends the previous results of Marzano, Pickering, and others who have found that active modes of instruction and learning outstrip passive modes in virtually every instance. The results of the student survey also support this by showing that the students’ satisfaction with the learning process, and their self evaluation as learners all increased over the term of this study. It was beyond the scope of this brief study to determine if these improvements in student performance and attitudes were long lasting; this work requiring a longitudinal study remains a prospect for future investigations.

This study also supports previous work by Freudenrich, Dubeck and others indicating that science fiction literature is effective in the classroom as an educational tool that supports student inquiry into scientific and mathematical concepts and has broad cultural appeal which is not limited to certain ethnic, socioeconomic, or cultural groups in a classroom setting. The survey results from this study indicate a very high level of student satisfaction with the *Maurice on the Moon* text, and with the use of a science fiction work as a primary text in a science class.
As previously noted, the implications for this study may be more important for older students than for middle school students due to the small number of works in this genera that would be appropriate for use with middle school children. However, the effectiveness of the concept in action indicates that there is great utility in such works as may be found appropriate, or for other works yet to be written for the purpose. A second work in the Maurice series, entitled *Maurice and the Doomed Colony of Mars*, including a full curriculum that emphasizes ecological, environmental, and biological science has been commissioned by a group of school districts in several states and will be the focus of future research along these lines. While it is not reasonable to presume that using works of science fiction as a primary text will become a widespread practice, there is a clear implication for general educational practice that using a paired fictional text can increase student engagement in the classroom and can have very beneficial effects that are not limited to small demographic segments of school populations. This implication has far broader ramifications for general educational and pedagogic practice in middle and high school classrooms; it is also a clear indication of a possible direction for future study and investigation.

Specific Recommendations for Further Research

Primary among the concerns about this study is the small size of the student population upon which this data is based. While the strong, universal improvements among every gender and ethnic subgroup in this study is highly encouraging, a larger study is obviously called for. In particular, the lack of any African American students, only one White female student, and no other minority groups at all being represented is a
major problem that can only be remedied with further study including larger groups of students.

The instructor who implemented the Summer Science Enrichment program is now planning to implement the program in three classes of 7th grade students at another middle school this spring. This study group of approximately 110 students should offer much more diversity than the original group of 18 students and will be a welcome addition to the study data concerning the program's effectiveness. A second implementation and study of the Science Through Literature curriculum as a two year program with 5th grade students receiving the original *Maurice on the Moon* curriculum concerning the Earth-Moon system, and 6th grade students receiving a new ecology/biology oriented curriculum based upon a second book in the Maurice series is planned for the 2007-08 school year. The new curriculum will focus upon Mars, and be more ecologically/environmentally based than the original curriculum which focuses heavily upon the Earth-Moon system, gravitation, orbital mechanics, and the formation of the solar system. This additional implementation of the Science Through Literature concept should provide much needed data to further refine the research results that have been shown in this initial study.

In addition to further implementation of the Science Through Literature concept in other classrooms and districts, it will also be necessary to follow the study participants as they progress through school and determine if their participation in the program transfers to improvements in science, mathematics, and English/language arts classes. It is planned to follow these students during the current school year and compare their grades in these core subjects to their grades before their participation in the program. The
researcher will also examine the standardized exam scores of these students in science, mathematics, and English / language arts when those scores are available from the California Department of Education in fall, 2007. It is hypothesized that participation in the program will result in long term gains in academic performance in these areas, but this has yet to be tested. Obviously, the performance of the original study group on future tests and in future classrooms will be the first step in following a larger group of participants in a longitudinal study that will take several years to complete. It is hoped that future study will confirm the tremendous potential of the Science Through Literature pedagogy and the *Maurice on the Moon* curriculum.
BIBLIOGRAPHY


### Table 9

**Pre and Post Test Analysis Breakdown by Question**

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Total number or correct and incorrect responses in each category

Students were asked to rate the test on a 1-10 scale for difficulty (5 = at grade level for them) and for experience with the material (1 = no experience with this, 10 = I have seen all of this material in class before)

Pretest Ratings:
- Difficulty Average = 6.889
- Experience Average = 6.278

Post Test Ratings:
- Difficulty Average = 4.278
- Experience Average = 8.111

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Table 10

Student survey results – pre program vs. post program responses

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Table 11

Student Survey Results: Post Program Self Assessment Survey Questions

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Table 12

Change in Student Responses to Pre and Post Survey Statements

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<th>Somewhat Agree</th>
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<tr>
<td>Enjoy going to school each day</td>
<td>27.78%</td>
<td>5.56%</td>
<td>22.22%</td>
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<td>33.33%</td>
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<tr>
<td>Enjoyed going to summer school daily</td>
<td>11.12%</td>
<td>5.56%</td>
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<td>27.78%</td>
<td>55.56%</td>
<td>5.56%</td>
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<td>-16.66%</td>
<td>-5.56%</td>
<td>22.23%</td>
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<td>22.23%</td>
</tr>
<tr>
<td>Like the way science was taught last year</td>
<td>22.22%</td>
<td>11.11%</td>
<td>11.11%</td>
<td>27.78%</td>
<td>38.89%</td>
<td>11.11%</td>
<td>50.00%</td>
</tr>
<tr>
<td>I like the way science was taught in Sum Sch.</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>16.67%</td>
<td>38.89%</td>
<td>44.44%</td>
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<td>0.00%</td>
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<tr>
<td>Like the way math was taught last year.</td>
<td>44.46%</td>
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<td>27.78%</td>
<td>16.67%</td>
<td>27.78%</td>
<td>11.11%</td>
<td>38.89%</td>
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<tr>
<td>I like the way math was taught in Sum Sch.</td>
<td>11.11%</td>
<td>0.00%</td>
<td>11.11%</td>
<td>33.33%</td>
<td>38.89%</td>
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<tr>
<td>Enjoy using math to solve problems.</td>
<td>38.89%</td>
<td>22.22%</td>
<td>16.67%</td>
<td>44.44%</td>
<td>16.67%</td>
<td>0.00%</td>
<td>16.67%</td>
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<tr>
<td>I enjoyed using math to solve probs in S.S.</td>
<td>11.11%</td>
<td>0.00%</td>
<td>11.11%</td>
<td>22.22%</td>
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<tr>
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<td>-22.22%</td>
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<td>-22.22%</td>
<td>38.89%</td>
<td>11.11%</td>
<td>50.00%</td>
</tr>
<tr>
<td>Am a good problem solver</td>
<td>27.78%</td>
<td>5.56%</td>
<td>22.22%</td>
<td>38.89%</td>
<td>33.33%</td>
<td>0.00%</td>
<td>33.33%</td>
</tr>
<tr>
<td>Am a good problem solver</td>
<td>22.22%</td>
<td>0.00%</td>
<td>22.22%</td>
<td>38.89%</td>
<td>27.78%</td>
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<tr>
<td>Math is easier with real life problems.</td>
<td>22.22%</td>
<td>11.11%</td>
<td>11.11%</td>
<td>33.33%</td>
<td>22.22%</td>
<td>22.22%</td>
<td>44.44%</td>
</tr>
<tr>
<td>Math is easier with real life problems.</td>
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<td>22.22%</td>
<td>22.22%</td>
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<tr>
<td>More than one way to solve a tough problem</td>
<td>22.23%</td>
<td>16.67%</td>
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<td>27.78%</td>
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<tr>
<td>More than one way to solve a tough problem</td>
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<tr>
<td>Have mastered multiplication &amp; division</td>
<td>16.67%</td>
<td>5.56%</td>
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<td>Have mastered multiplication &amp; division</td>
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<tr>
<td>Have mastered fractions and decimals</td>
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<td>27.78%</td>
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<td>44.44%</td>
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<tr>
<td>Have mastered fractions and decimals</td>
<td>22.22%</td>
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<tr>
<td>Have a strong command of algebra</td>
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<tr>
<td>Math was my worst class last year</td>
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<td>Math will be my worst class next year</td>
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Maurice on the Moon -- Annotated Contents:

Stowaway
We meet Maurice Haberman and his friend Cassie Metis horsing around at the local spaceport. Maurice puts a crazy plan to get to Earth into action. Cassie saves him from stowing away on a space liner and getting into big trouble.

Life on the Frontier
Life on a lunar colony is vastly different from Earth. Every portion of the environment must be brought in or created from scratch, including air, water, and a food chain. Some of Maurice's daily chores involve helping with recycling and environmental maintenance, the trouble is, Maurice sometimes neglects his responsibilities!

A New Plan
Maurice hatches a new plan to get to Earth — go prospecting and strike it rich! Maurice talks Cassie into helping him take a broken down old rover from his father's mining company without permission.

Up and Over
Maurice and Cassie head for the Sea of Moisture in their stolen buggy, but first they must get the dilapidated vehicle over the formidable rim of the Gassendi Crater. Driving uphill turns out to be easier than driving down, when the buggy starts a small avalanche in the soft soil of the crater rim.

Helium Prospectors
Maurice and Cassie venture out onto the Sea of Moisture, prospecting for helium-3, a valuable isotope used for fusion power. Prospecting is more work than they had expected and success is not quick to find them. Trouble comes when Cassie pushes Maurice and he trips, ripping his suit.

Small Crater — Big Trouble
Cassie is driving Maurice back to Gassendi LEX, unfortunately, the battery on the old buggy is low and may not make it all the way back. Cassie is furious at Maurice; arguing loudly, they drift off track and crash into a crater, ruining the buggy and sealing Maurice's fate.

Reckoning
Maurice and Cassie are returned safely to Gassendi, but they must face the consequences of their actions. The only bright spot in this mess is that Maurice may have found a real deposit of helium-3 which could save his father’s job, ironically keeping his family on the Moon.

Jump Like an Earthman
Maurice joins the track team to help him forget about going to Earth. Cassie finds out that she and her parents will be returning to Earth soon. Cassie must wear a heavy 'Earth Suit', so that she can get used to Earth normal weight again. Maurice borrows the E-suit for yet another crazy scheme.
Arrivals and Departures
Maurice is doing well on the track team; the coach suggests he may be able to earn a place at the All System Track Finals in Chicago – a possible ticket to Earth! Mike Evans, an older boy on the track team is angered when the coach insists that he adopt Maurice’s unorthodox training method.

The Leap to Earth
Maurice and his rival get into a fight over the theft of the E-suit. The coach helps the boys reconcile their differences and learn to respect one another. Maurice competes in the big track meet and manages second place, good enough for a ticket to Earth!

Flight to Earth
Maurice finally gets to fly to Earth on a space liner. The observation deck shows impressive views of the lunar landscape, where Maurice watches Earthrise for the first time! Maurice experiences higher ‘acceleration gravity’ as the ship accelerates away from the Moon and zero gravity in free flight on his way to Earth.

High Gravity Planet
Maurice lands on Earth, where everything weighs too much and falls too fast! Air pollution, humidity, and the lack of air purification are a real surprise. Open land and ‘wild trees’ are mysteries without answers, and no one seems to bury their houses properly to protect them against radiation and meteorites, either. Trying the high jump in high gravity is a shock, but not as much as playing a game of pickup basketball with several Earth kids.

Lost in the Wilderness
The mysteries of Earth get deeper as Maurice visits an aquarium in Chicago. A camping trip on a local lake shore with boating and swimming in water where wild fish live and mosquitoes feed on you is utterly alien. A violent storm with lightning and hail lets Maurice experience real weather after a lifetime of watching clouds from the Moon.

The Big Meet
Maurice travels to Chicago to compete in the All System Track and Field Finals. Crowded Earth with traffic jams, air pollution, and its millions of people and their strange culture is beginning to wear on Maurice. Another boy from the Moon befriends Maurice, making him very homesick.

Citizen of the Moon
Maurice returns to Gassendi to a hero’s welcome. Returning to low gravity, clean air, and comfy underground housing feels wonderful! On Citizenship Day, Maurice and his parents go to Eagle Stadium on the Sea of Tranquility where they take the oath of citizenship to the Lunar Union and become permanent citizens of the Moon.
Maurice on the Moon – Curriculum Masters:

Maurice on the Moon

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Chapter 1 Questions:

1. Maurice and Cassie both wear pressure suits. What is a pressure suit and why is it an important garment for Maurice and Cassie?

2. Maurice and Cassie would never dream of letting the sun shine on their bare skin on the Moon. Why is lunar sunshine so different from Earth sunshine?

3. Maurice and Cassie were able to jump completely over people! Do you think this is realistic? How could this be done?

4. If you were building a spaceport, how would you make sure that kids couldn’t go jumping over people there?

5. How do you know that the same side of the Moon always faces the Earth? How could you prove this to a friend who didn’t believe you?

6. When Maurice looks at the Earth in the lunar sky, why does it appear so much larger than the Moon does in our skies here on Earth?

7. Why does the Moon appear to move across the skies on Earth each night?

8. Why does the Earth hang in one place in the lunar sky without moving across it at all?

9. What cities in your area are large enough that Maurice might see them by the glow of their night time lights?

10. The Moon revolves around the Earth once every 29.5 days. How long would it be from sun up to sun set on the Moon?

11. If Maurice did make it to Earth, he would find that he weighed six times more than usual (his 17 pounds would become 102 pounds!) Figure out how much you would weigh if you were on the Moon.

12. The Moon is 385,000 kilometers away from Earth. If you flew there in a space liner at 40,000 kilometers per hour (the minimum speed needed to escape Earth’s gravity!) how long would the trip take you?

13. Maurice and Cassie don’t believe there was a real lunar astronaut named ‘Buzz’. Are they correct? Look up the names of the Apollo astronauts on-line and see.

14. If Maurice successfully stowed away on the space liner, what do you think the consequences of his actions might have been? Can you think of a better plan to get to Earth?

15. Most of the Aldrin spaceport is built underneath the rim of the giant crater Gassendi, why did the lunar colonists build it there instead of out on the surface?
16. How was Cassie able to lift Maurice over her head? Was this realistic? If Cassie is six times lighter than she would be on Earth, how come she isn’t six times weaker?

17. Why couldn’t Maurice and Cassie hear the space liner take off as they left the spaceport to go home?

18. If you watched a rocket blast off from the lunar surface, would you expect to see smoke? Explain why or why not.
Chapter 1 Activity

Drawing Moon Phases:

As the Moon orbits around the Earth, the geometry of the Earth/Moon/Sun alignment changes daily. Now it’s your turn to see how the Moon’s orbit around the Earth creates the phases we see.

1. On a piece of paper, draw a circle representing the Earth and a circle around the Earth representing the Moon’s orbit.

2. Across the page, draw the Sun. Shade in the ‘dark side’ of the Earth (the side that faces away from the Sun!)

3. Sketch the Moon so that it is directly between the Earth and Sun. Don’t forget to shade in the ‘dark side’ of the Moon! What phase would we see from Earth?

4. Sketch the Moon in 4-5 other positions in its orbit around the Earth. Remember to shade in the dark side each time and tell what phase we would see from Earth.

Use the example below to help you!
Chapter 1 Activity

Charting the Moon’s Phases:

As the Moon orbits the Earth each month, we see the phases of the Moon change. That is, the shape of the lighted portion of the Moon’s globe we see each night changes. By observing the Moon for several days just after new moon (the night when no Moon is seen in the sky at all), you can chart the phases as the Moon orbits our planet!

1. Use a ruler and a pencil to divide a sheet of paper into 8 boxes as shown below.

2. Start just after the new moon, look for the Moon in the western sky just as the Sun is setting.

3. Sketch the shape of the Moon in the sky in the first box. Shade in the dark areas of the Moon’s disk, and then record the time and date of your observation in the box.

4. Make a new observation and sketch each successive night until all 8 boxes are full. You should begin to see a pattern developing! Remember to record time and date each night.

Use the diagram below to help you! Make your full-size observation record from a full sheet of paper. Sketch carefully – you will see more detail if you take your time! Describe any pattern you see on the back of the sheet.
Chapter 1 Activity

**Moon Ballet:**
Every planet and moon dances their own ballet in orbit. The Earth whirls almost thirty times faster than the Moon spins on her axis. Choose a partner, one of you will be the Earth and one the Moon. Whoever plays the Moon should ‘orbit’ about ten feet away from the person playing the Earth. Earth begins to turn around in place, timing their spin to make about one turn per second. The person playing Moon always faces the Earth and takes one step each time the Earth turns once. Trade off and practice until the person playing the Moon can orbit Earth perfectly in 28 Earth days (28 spins for the person playing Earth!) Try not to get dizzy in orbit!

**Spaceport Model:**
What do you think Aldrin Spaceport looks like? Have you been to an airport? What would the lounge area or the big observation port window where Maurice and Cassie watched the Earth be like? Make a drawing or model of Aldrin spaceport in the Gassendi Crater. You can use clay or paper maché, maybe cardboard or construction paper. Be creative and have fun!
Chapter 2 Questions

1. Maurice’s apartment is dug deep into a hillside to protect it from falling meteorites and radiation. What protects your home and mine from these hazards here on Earth?

2. Maurice needs protection from dangerous radiation on the lunar surface. Where does this radiation come from?

3. Kids at Maurice’s school sometimes call someone “dumb enough to sit in a sunny window.” Why is sitting in a nice sunny window so dumb on the Moon?

4. How do the lunar colonists in Gassendi crater produce the food and oxygen they need to survive? How does this compare to the way we do things on Earth today?

5. Why is real meat a treat for Maurice? Why would it be so hard to get on the Moon?

6. What are “krill”? Are these real animals? Are they edible? Look on-line and see what you can find out about them.

7. Maurice is familiar with the saying “Apathy kills.” What do you think this means? Would it be as true on Earth as it is on the Moon? How so?

8. Maurice watched his plastic bag of shrimp inflate as the airlock depressurizes. Why do you think this happens? How does this relate to Maurice wearing a pressure suit?

9. Maurice’s home is full of plants, why do his parents have so many of them?

10. Taking care of plants is one of Maurice’s chores around the house. What chores do you have? Which ones would be the same if you lived on the Moon? Explain how the others would be different.

11. The air quality police had the right to come into Maurice’s home because he didn’t change a CO$_2$ filter. Why do you think the lunar citizens gave their police this much power?

12. When the Air Quality police came to the house, they gave Maurice a breath test. What do you think they were checking for?

13. Maurice’s parents have to pay an oxygen bill every month. What kind of utility bills do your parents have to pay? Explain how these would be the same or different on the Moon.

14. This chapter is titled *Life on the Frontier*, how is living on the Moon like living on the Old Western frontier that Maurice likes reading about so much?
15. Maurice’s parents are excited about gaining lunar citizenship. What benefits does citizenship give them? How is this similar to having citizenship in a country on Earth?

16. What did Maurice’s parents have to do before they would be considered for citizenship? Tell why you think each of those things are important for a citizen to do.

17. Why does Maurice hate the idea of lunar citizenship?

18. If you were Maurice’s parent, and you caught him like his father did at the end of the chapter, what would you say to him? What would you do to make sure it didn’t happen again?
Chapter 2 Activities

Planning a lunar farm:

Imagine that you are given responsibility for planning a lunar farm. All you have to start with is a small circular crater 100 meters across and 10 meters deep, where your farm will go. Choose groups of three students for this activity.

1. Lunar soil is just powdered rock with no organic nutrients or water in it (think very dry sand). What will you need to bring from Earth to start your farm in the way of planting soil? How deep must the soil be? Use the size of your crater to calculate area and volume of topsoil you need.

2. An average corn plant will use a gallon of water a day. If you plant corn plants 25 cm apart in every direction, how many plants will you have? How much water will you need every day?

3. Recycling is important on the Moon. You can’t let your valuable water run down into the lunar soil and disappear forever! How will you recycle the water that you put on the soil? How will you recycle the water your corn plants ‘exhale’ into the air?

4. Corn plants can’t grow in hard vacuum! How will you make sure your plants have air? How much air will you need to start your farm? How can you reduce the amount of air you need?

5. Earth plants are used to a 24-hour day/night cycle. How will you help your plants deal with the long lunar day and night? How will you help your plants cope with the powerful lunar sunshine and the extreme cold of lunar night?

6. Make a poster or model of your lunar farm. Label and explain each special feature that helps your farm prosper! Considering how hard it is to grow food ‘on the frontier’, how expensive do you think it would be to buy groceries on the Moon?
Chapter 2 Activity:

How do we know the Moon isn’t flat?

In the time of Galileo and Copernicus, many people thought that the Moon was a flat disk, some even taught that the moon was smooth, polished and featureless. They probably needed some glasses, but these were a new high-tech invention in the 1400’s and only the very rich could afford them!

The fact that the Moon obviously shows dark areas (the flat lava basins called maria) and light areas (the mountainous highlands) was generally ignored by these people. One fact that everyone recognized was that the Moon had phases, and changed from a thin crescent, to half full, gibbous (¼ full), and to full Moon, and then back again. Phases actually prove to us that the Moon is round!

This experiment was first described by Galileo in his book Dialogues Concerning the Two Chief World Systems. Galileo’s experiment proves that the Moon must be round for phases to exist – as you will see for yourself!

You will need:

1. A yogurt cup lid (or similar flat, round object)
2. Markers or crayons
3. light-colored construction paper
4. Tissue paper and glue (for making small amounts of paper mache
5. A strong flash light or projector

Begin by cutting out a circle of construction paper the same size as your yogurt lid. Draw or color maria onto this circle – you don’t have to worry if your ‘moon’ doesn’t look much like the real one here!

Next, paste the circle securely onto your yogurt cup lid. When this is dry, you are ready to begin. Darken the room and turn on your flashlight or projector. Have someone point this in one direction and hold it steady – this represents light from the Sun.

Work with a partner, one will be the Earth and stand in one place, the other will hold our flat moon and walk slowly around the ‘Earth’. Remember, the Moon’s flat face must face the Earth at all times. The Earth person must turn slowly in place so that they always face the Moon!
Begin with the Moon person standing between the Earth person and the light source. This is “new moon”, no light falls on the Moon’s flat face. The Moon now travels slowly around the Earth ‘in orbit’. How far around the orbit does the Moon go before light falls on the surface? Notice that once the light falls on the flat face, the entire surface is illuminated at once! Instant full Moon! For half the orbit, the Moon is full, for the other half, the Moon is ‘new’ and its face is totally dark. There is no way to create realistic phases using a flat Moon! Galileo’s experiment proves the Moon is spherical, just like the Earth!

Once you have tried this experiment several times, mix up some paper mache and form small ‘mountains’ on your lunar surface, and let them dry completely overnight. With mountains on your lunar surface, try the experiment again. Notice the shadows from the mountains on your lunar surface as the Moon travels around the Earth. The shadows change shape and length as the Moon moves in orbit around the Earth. Not only did Galileo prove the Moon was round, he also measured changes of the shadows on the lunar surface and determined the height of the mountains on the lunar surface. Apollo astronauts measured several of these mountains 350 years after Galileo did and found the Italian astronomer was very accurate. Some of his measurements differed from NASA measurements by less than 2%!
Chapter 3 Questions

1. Describe what Maurice and Cassie do in order to have a private conversation together. Would this be completely private on Earth? Explain your answer.

2. What does Cassie think would have happened to Maurice if he had been caught stowing away on the space liner? What do you think would happen to him?

3. What chore did Maurice get in trouble for forgetting? Why was it important?

4. How is carbon dioxide (CO\textsubscript{2}) removed from Earth’s atmosphere?

5. Maurice claimed his parents forced him to stow away on the space liner. How does he explain his thinking to Cassie? Tell why you agree or disagree with Maurice’s thinking.

6. Maurice picks up a rock during the daytime. Why was that a dangerous thing to do?

7. Maurice thinks the buses we use on Earth are silly. Explain why Maurice is sure they wouldn’t work well on the Moon; can you add any more reasons?

8. What does Maurice’s father have to do with lava beds? What is the other name for these volcanic formations?

9. Why is helium-3 so valuable? What do people do with it?

10. What is Maurice’s new plan for getting to Earth?

11. How does Maurice plan to pay for his new plan?

12. Would Maurice’s plan work if he were on Earth? How would you change the plan to make it work?

13. Why is working on the breccia fields dangerous? What kind of accident is Cassie worried about?

14. Parents on the Moon tell their kids not to take their helmets off ‘until you feel the air hug you;’ what do you think they mean by that?

15. Maurice has sent you a note asking you to go prospecting in that buggy he found. Write him a note back telling him if you will go or not and explain your answer to him.

16. The prospecting buggy had a cracked solar panel, what was it supposed to do in the first place? Why would it be a problem if it didn’t work correctly?

17. Maurice thinks that everyone on Earth is a farmer, where do you think he got such a crazy idea?
18. What do Cassie and Maurice think the grass in your yard is for? Why do they think it would be crazy to just grow grass out in the open like that?
Chapter 3 Activities

Sound Transmission through Air:

This activity is planned as a teacher-operated demonstration.

Materials:
- One vacuum pump – electric or hand operated
- One vacuum jar with base – glass or plastic
- One battery operated buzzer, bell or similar noisemaker
- Light string or strong thread
- One suction cup hook

Procedure:

1. Make sure the vacuum jar is clean and free of cracks, chips or serious scratches. A cracked, chipped, or badly scratched vacuum jar is not safe to use!
2. Use several inches of string to attached your buzzer to the suction cup hook as shown below.
3. Attach the suction cup to the top of the vacuum jar. The buzzer should not touch the vacuum jar or its base when it is in place!
4. When you are sure everything is ready, turn on the buzzer and place the jar securely on the base and begin pumping the air out.
5. Observe what happens to the sound of the buzzer as the air is removed from the bell. Try to explain what you see and hear.
6. Once the air is completely removed from the jar, tilt the jar carefully so that the buzzer rests against the side of the jar. Observe what happens as you tilt the jar back and forth, allowing the buzzer to touch the side of the jar and move away again several times.
7. Slowly let the air back into the jar and see what happens to the sound of the buzzer.
8. Explain how this demonstration relates to Maurice and Cassie having a private conversation by clicking their helmets together.
Chapter 3 Activity

The Lunar School Bus:

This project can be done alone or with a partner. Imagine what the perfect lunar school bus would look like! Wire wheels, an open top, no windows! What other cool features would your perfect lunar school bus have? You can choose several different ways to go with this project.

   a) Draw and label your lunar school bus. Label the features that make it perfect for taking kids to school on the Moon. Describe how each special feature works or what it is for.

   b) Make a poster! Draw the lunar school bus in action driving over craters or through deep moon dust. Use references pictures you find in books or on the internet to help you draw a realistic setting for your bus to travel through!

   c) Make a model! Build the perfect lunar school bus. What would it look like? How large would it be. Use a small action figure to help you scale the size of your model. Have a display card to go along with the model to explain all of its features. You can also construct a diorama to put your model in, if you want!
Chapter 4 Questions

1. Where does Maurice plan to go prospecting? Find this location on a lunar map.

2. Why did early observers call the dark areas on the Moon the *maria*? What convinced them the Moon was actually waterless?

3. How were the maria formed? When did this happen? Describe this process in a short paragraph.

4. What is Maurice prospecting for? Why is this substance valuable?

5. Why is the solar panel important for the buggy? What is it supposed to do?

6. Why is the solar panel important for the plot of the story?

7. Why is Maurice having so much trouble avoiding rocks and other obstacles in their path?

8. Maurice and Cassie have to drive around heavy steel fences at the bottom of the crater rim. What are these fences for? Why aren’t there any on the outer side of the crater rim?

9. Maurice and Cassie start two avalanches as they drive over the crater rim. Explain how these avalanches started, and tell why one of them is much more dangerous than the other.

10. What argument does Maurice use to convince Cassie to drive down the far side of the crater rim? Would you be convinced by this? How would you respond to this argument?

11. What is the ‘ting-ting’ sound Maurice and Cassie keep hearing on the way down the crater rim. Why didn’t they hear this sound on the way *up* the crater rim?

12. Why is the ‘ting-ting’ sound *dangerous*? What damage could it do?

13. What is Maurice’s diagnosis of the ‘ting-ting’ problem? How does he choose to solve this? What would you do instead?

14. Maurice and Cassie end up outrunning a boulder ‘as big as Maurice’s living room’. How did their little buggy manage to move such a huge rock? Is this realistic? What happens in an avalanche on Earth?

15. Why is Cassie stunned to be alive after driving over the crater rim?
Chapter 4 Activity

Making a Lunar Landscape:

This activity is can be performed in small groups, or one demonstration activity can be run which everyone observes. The supplies and materials will be given for a single setup and can be expanded to cover multiple groups if needed.

Materials:

- Plaster of Paris mix, 1 5lb bag
- Dry sand – equal in volume to dry plaster mix
- A shallow container 30-40 cm on a side, at least 10 cm deep
- A plastic dishpan
- 1 gallon of clear water for mixing the plaster
- 1 can dark grey spray paint
- 15-20 pebbles (two rocks 5-7 cm, three rocks 3-5 cm, remainder are 3cm or less)
- (optional) A plastic liner for the dishpan (this can be cut from a plastic trash sack)

Procedure:

1. Mix equal volumes of dry sand and dry plaster together; stir well. The dry mix should fill the plastic pan about 10 cm deep.

2. Add water slowly, stirring well. Mixture should be about the consistency of cake batter. If you use the plastic liner, mix the plaster in a separate bucket before pouring into the plastic pan.

3. With the well mixed plaster in the pan, shake the pan back and forth gently to level it, then spray the surface with the dark grey paint. The grey paint of the ‘lunar surface’ contrasts with the white ‘ejecta’ blasted from the Moon’s interior during a meteor impact.

4. Rocks are now tossed into the pan of plaster mix, starting with the large rocks. Students throwing rocks should wear a ‘trash-bag apron’ or old clothes to protect themselves from splashed plaster material.

5. When all rocks are thrown, leave plaster mold alone for 1 hour to allow it to harden completely.
Chapter 4 Activity

Mapping Your Lunar Landscape:

Make a full scale “Moon map” of your crater landscape. Begin by taping or gluing light string or thread every 5 centimeters horizontally and vertically. Recreate these lines on paper and use them to plot each crater in its correct size and position on the map. Choose a theme and name every crater larger than 3cm wide. (Name them after Presidents, comic book heroes, etc.) Mark the white ejecta blasted from each crater and shade in an ‘ejecta blanket’ around each crater on your map!

Use string or large rubber bands to divide the Lunar landscape for mapping!

A Finished Lunar Landscape Map!

Map Legend:

1. Sagan
2. Asimov
3. Quinn
4. Herbert
5. Burroughs
6. Wells
7. Hope
8. Grim
9. Niven
10. Pournelle
11. Bradbury
12. Verne
13. Barth

Map Theme: Famous Writers

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Chapter 4 Activity

Crater Analysis

Craters can be somewhat oval in shape. Measure every named crater and find the *semi-major axis* (the longest axis of the oval) and the *semi-minor axis* (the shortest axis of the oval). Plot the semi-major and semi-minor axes on your Moon map. Prepare a table of craters showing name, major and minor axis size, and the *eccentricity*. Eccentricity = minor axis / major axis. Eccentricity runs from 0.0 (the oval is stretched into a flat line) to 1.0 (perfectly circular).

Measure each of your named craters and record the major and minor axis in a table like the sample one below. Calculate the eccentricity by dividing the minor axis by the major axis and record it to two decimal places. Plot the eccentricity numbers on your crater map ($E = .85$ etc.) next to the crater name.

In nature, almost all craters are circular, or nearly so. In order to make a significantly oval crater, the asteroid or meteor must impact the surface at a very low angle (usually 10 degrees or less). Because almost all the craters on the Moon are circular, and because few craters are visible on Earth, many scientists believed that the extensive cratering seen on the Moon was volcanic in nature. Apollo astronauts proved that almost all lunar craters are impact scars, not volcanic. Would your lunar landscape agree with the Apollo findings, or not? How would you judge your landscape model? Does it accurately model lunar impact craters? Explain your answer!

Sample Crater Analysis Table

<table>
<thead>
<tr>
<th>Crater Name</th>
<th>Semi-Major Axis</th>
<th>Semi-Minor Axis</th>
<th>Eccentricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagan</td>
<td>12 cm</td>
<td>8 cm</td>
<td>0.67</td>
</tr>
<tr>
<td>Asimov</td>
<td>9.5 cm</td>
<td>7.9 cm</td>
<td>0.83</td>
</tr>
<tr>
<td>Quinn</td>
<td>3.2 cm</td>
<td>2.9 cm</td>
<td>0.91</td>
</tr>
</tbody>
</table>
Chapter 5 Questions

1. Why does Maurice want to drive out on the maria and take samples from many different locations instead of taking many samples from one area? Does this make sense scientifically?

2. What is the “large black crate” on the back of the buggy? Why did Maurice want to bring it along?

3. Maurice and Cassie use a “Lunar Positioning System” or LPS on the Moon to find out exactly where they are. We have a similar system on Earth – what is it called and how does it work?

4. Why does the box shake and bounce the buggy so much when it is working? What is it doing to cause so much vibration?

5. The sample processor reads out the helium-3 levels in the rocks in ‘PPB’ or parts per billion. What does this term mean?

6. If a sample of rock was found to have 5 PPB of helium-3, how many tonnes of ore would you need to process in order to get one tonne of helium-3?

7. Why do you think the mining company won’t pay for a helium strike if the helium-3 level in the ore is less than 50 PPB?

8. Cassie warns Maurice that they could get lost. Both children find this funny; explain why no one on the Moon is ever afraid of wandering away from home and getting lost. Why is the Moon so different from Earth where people get lost all the time?

9. Maurice reminds Cassie that an old fashioned compass would not work on the Moon like it does on Earth – why not?

10. Would the old fashioned compass point to the nearest large piece of metal like Maurice said? If so, why does it work that way?


12. What is Cassie’s real name? Who is she named after?

13. What happens to Maurice when Cassie pushes him? What are the ‘red rubies’ Maurice sees flying away from his suit?

14. Maurice gets very cold when his suit starts to lose air; this is called adiabatic cooling. Can you think of any situations on Earth where things get cold when they lose pressure?
15. Cassie seals off the rip in Maurice’s suit with tape and glue. Why does the tape change colors?

16. What would happen to Maurice if the tape *didn’t* work?

17. Cassie tells Maurice that they have to tape his suit ‘just like we practice at school every week.’ What kind of things do you practice at school that could save your life?

18. What other danger does Maurice face besides too little air? How does this relate to Maurice’s failure to change the scrubbers in his apartment?
Chapter 5 Activity

Learning About Carbon Dioxide:

Carbon dioxide is a natural part of Earth’s atmosphere. It is a large gas molecule with one carbon atom in the middle and an oxygen atom on either side, these three atoms bond together to form one molecule of gas. Carbon dioxide molecules weigh 30% more than oxygen gas and almost 40% more than nitrogen gas (nitrogen and oxygen make up almost all of Earth’s atmosphere). The activity below will show several things about carbon dioxide gas. See if you can discover evidence for each of these special properties of carbon dioxide.

1. Carbon dioxide is a fluid. A fluid is any substance that can flow like water through a pipe and takes the shape of its container the way milk does when you pour it in a glass of any shape.

2. Carbon dioxide is heavier than air, heavier than oxygen and nitrogen gas, anyway. Salad oil and vinegar are both fluids, just like carbon dioxide and air. What happens when you mix oil and vinegar for salad dressing?

3. Carbon dioxide blocks oxygen. If you breathe too much CO₂, your body wouldn’t get enough oxygen. Just a few minutes without oxygen and most animals will suffer permanent injury, or even die. What evidence do you see that carbon dioxide blocks oxygen?

4. Carbon dioxide is an acid. When carbon dioxide mixes with water, it turns the water into an acid solution. Acids taste sour to us and can cause things like metals to corrode or rust. You should NEVER test any chemical by tasting! However, you can test for an acid using litmus paper. Your teacher will show you how.

Materials:

- Two plastic soda bottles with caps
- Several feet of plastic tubing
- A sink or large dish pan half-full of clean water
- One cup each of baking soda and household vinegar
- A small amount of household bleach (perhaps a teaspoon)
- Several strips of litmus paper
- A large beaker or clear glass jar (a large mayonnaise jar works well)
- Three birthday candles, cut to different lengths (one is full length, one 1/3 shorter, the other is 2/3 shorter)
- Some clay (for sticking down the candles)
- A long match or similar lighter

Preparation: Make sure the soda bottles are clean and dry. Drill a hole in one of the bottle caps large enough for the tubing to fit through. Put one end of the tubing in the hole and secure it with silicone glue or epoxy. Set this cap aside for later. Fill your dish pan half-full with water. Use the clay to
stand the candles up in the bottom of the large beaker or jar, but do not light them yet! Put ¼ cup of baking soda into one of the dry soda bottles.

1st Procedure

1. Light the candles in the jar
2. Add vinegar to the soda bottle with the baking soda in it
3. Quickly attach the cap with the plastic tube to the soda bottle.
4. Hold the tube near the top of the jar, allow the CO$_2$ to flow into the jar with the lit candles.
5. Observe and record the results carefully. If you wish to repeat the experiment, you must tip the jar and allow the CO$_2$ to flow out and be replaced by oxygenated air. Otherwise you will not be able to relight the candles!
Chapter 5 Activity

Carbon Dioxide as an Acid:

2nd Procedure
1. Fill an empty soda bottle with fresh water.
2. Rinse out the baking soda bottle and add ¼ cup of fresh baking soda. The bottle need not be dry.
3. Take the full bottle and turn it over in the tub of water. A helper will hold this bottle in position.
4. Add vinegar to the baking soda bottle and attach the cap with the tube.
5. Allow the tube to bubble under water for a moment (to clear the tube of air) then put the tube up into the bottle full of water. Allow the tube to bubble until the bottle is half-full of gas.
6. Without removing the bottle from the water, cap it securely. Once it is capped, remove the bottle from the water and shake vigorously for one minute.
7. Pour out a sample of the water shaken with CO₂ into a beaker. Pour a similar sample of fresh water.
8. Put a litmus strip in each sample of water and compare the results.
Chapter 6 Questions

1. How did Cassie’s driving hurt Maurice’s arm again? Why did this happen if the Moon’s gravity is so low and Maurice weighs so little?

2. One kilometer is equal to 0.62 miles. Change the 25 kph top speed of the buggy into miles per hour. Is this a reasonable top speed for a lunar buggy? Explain your answer.

3. Why did the battery on the buggy run down so quickly? How could this dangerous situation be avoided?

4. How did Cassie end up putting their buggy into a crater? How could she have avoided this?

5. The kids’ suits contain ankle lights as well as helmet lights. Why would the ankle lights be needed on the Moon?

6. Maurice violated many basic safety procedures on this adventure. Make a safety poster that features rules that Maurice and other kids on the Moon should remember.

7. Cassie refuses to leave her friend out on the maria while she goes for help. Was this a good plan? Explain what you would have done in Cassie’s position and why.

8. Maurice comes up with a plan for a “smoke signal”. How does this work if it isn’t possible to bum anything on the airless Moon?

9. Why did Maurice and Cassie have to disconnect the electrical power to three of the four buggy wheels? Could Maurice’s idea have worked if they didn’t do this?

10. Where did Maurice get his inspiration for the lunar smoke signal? Have you ever got an idea this way? If so, describe one of these ideas.

11. Cassie quotes her mother, saying: “Desperate men clutch at the thinnest straws.” What does this mean? How does it apply to their predicament in this chapter?

12. How does Maurice expect anyone to see his smoke signal? What makes him believe that such a signal would be reported?

13. Maurice keeps asking Cassie about the time; why is time so important in this situation? How many different reasons can you think of?

14. Who discovers Maurice’s signal? Who comes to rescue them?

15. Why does Maurice have mixed feelings about being rescued?
16. Maurice does two things before he leaves the damaged buggy behind, what are they? Why do you think Maurice did these things?
Chapter 6 Activity

Lunar Survival Hike:

You and a friend are driving across Mare Humorum in a small buggy during the early afternoon. The buggy crashes into a crater and is disabled. After you determine that there is no way to get the buggy working again (not even enough to make a lunar smoke signal.) You check the emergency compartments in the buggy and make a list of your possessions. (see below)

Checking your map, you realize that it will take you 36 hours to hike to the nearest colony. Your belt and backpack together can only carry 25 kilograms of supplies each. Use the list below and decide what you would take along for your hike back to civilization at Gassendi LEX. After you make your list, explain your choices.

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Oxygen bottles – Each bottle has enough oxygen for 15 hours resting, 8 hours walking, 3 hours running or working hard.</td>
<td>2.5 kg per bottle</td>
</tr>
<tr>
<td>20 Food ration packs – Each pack gives enough food for an average meal. Most people eat three meals per day. You must be in a shelter to eat the meal (no opening your helmet to stuff in a candy bar!)</td>
<td>0.5 kg per package</td>
</tr>
<tr>
<td>Water rations – One liter packs of water can be used to refill your in-suit drinking system. Empty packs can be used for waste disposal. An average person uses 2-liters per day in light exercise or walking, 4 liters per day for heavy work.</td>
<td>1.1 kg per one-liter package</td>
</tr>
<tr>
<td>Two-person survival shelter. This is an air-tight tent with sun and radiation shielding and thermal protection from high or low surface temperatures. The shelter has its own air and water supply for four days and the stranded traveler can relax inside without a helmet or pressure suit and comfortably wait for rescue.</td>
<td>32 kg (this can be carried by 2 people!)</td>
</tr>
<tr>
<td>2 Magnesium picks. Good for breaking up rock or prying.</td>
<td>2.5 kg each</td>
</tr>
<tr>
<td>2 Magnesium shovels. Good for digging, shoveling, etc.</td>
<td>2.5 kg each</td>
</tr>
<tr>
<td>Two-person solar shelter. This is a lightweight mat that gives protection from high or low surface temperatures. It has a ultra thin shade that can block the sun so a person can rest and allow the suit cooling system to work less.</td>
<td>15 kg</td>
</tr>
<tr>
<td>6 CO₂ Scrubber packs. Each scrubber pack will neutralize CO₂ for 24 hours of moderate activity (walking or similar activity.)</td>
<td>1.0 kg each</td>
</tr>
<tr>
<td>3 coils of nylon rope, 100 meters long, each.</td>
<td>3.5 kg each</td>
</tr>
<tr>
<td>3 coils of Spidersilk rope, 100 meters each. Spidersilk is very strong, resists high temperatures and abrasion.</td>
<td>5.5 kg each</td>
</tr>
<tr>
<td>Lamont LaRue Edition Six-Shooter with 12 cartridges and holster.</td>
<td>3.5 kg</td>
</tr>
<tr>
<td>5 rolls of SuitSealer tape, each with a tube of SuitSealer glue. Each roll can do one repair only.</td>
<td>1.5 kg each</td>
</tr>
</tbody>
</table>
Emergency Tool Kit. Various wrenches, pliers, screwdrivers, and a hammer.

Geology Tool Kit. Sampling hammers, Power R.A.T. (rock abrasion tool – like a drill or grinder), brush, tweezers, sieve screens, sample washer, mini-spectrometer (for identifying different minerals) and sample bags.

Emergency Signaling Radio. Quitter! Well... ok, but only if you really need to use it! A radio like this can reach anywhere on the Moon by using the LPS satellite network. This one's out of batteries, but you never know...

2 Flashlight/Lanterns. This two million candlepower monster can be seen for miles in spotlight mode or can light up large areas to make walking and exploring on the surface much safer. Battery provides 48 hours continuous use, solar cell on top will recharge battery in less than one lunar day, so it never runs out of batteries!

Solar Furnace. This large (50 cm x 50 cm) lens can focus sunlight to cut or melt almost any materials. The beam of concentrated sunlight focuses one meter away from the lens. Anything from cooking food in the can to light welding is easily accomplished with a practiced hand.
Chapter 6 Activity

Emergency Drills on the Moon:

When his suit ripped, Cassie kept Maurice calm by reminding him to do things “...just like we practiced in school!” How do you think a suit rip drill would go if your teacher was in charge of it?

a) Make an emergency poster for the kids at Maurice’s school.
   a. Give it a cool title!
   b. The poster should tell what to do if your suit rips!
   c. The poster should tell how to avoid rips.
   d. Make it colorful and fun, and chock full of information!

b) Do a skit of a suit rip drill
   a. Choose someone to play teachers, students, and any others that might be present at a suit rip drill.
   b. The skit should show someone learning to fix a suit rip
Chapter 7 Questions

1. The doctor removed bits of lava rock from Maurice’s wound, how do you think they got there?

2. The doctor uses a hemostat to help her treat Maurice’s injuries. Look up the word hemostat in a dictionary or on line. Explain what you think a hemostat is for.

3. Maurice’s doctor prescribed an antibiotic injection for him after his wound was cleaned and dressed. What does an antibiotic do and why would Maurice need one?

4. Maurice said the lunar soil was sterile. What does sterile mean, and how would Maurice know the lunar soil was indeed sterile?

5. Maurice feels conflicted because his parents love living on the Moon and he hates it. If you were Maurice’s friend, how would you advise him to resolve this family conflict?

6. Maurice gives his father the data cartridge from his prospecting trip. What do you think was on this data cartridge?

7. How do Maurice’s actions threaten his family’s place on the Moon? Do you think this is fair? Explain how you would change the law to make it better if you think it is unfair.

8. How does the data cartridge and the sample save Maurice’s family? How do you think Maurice feels about this?

9. Mr. Haberman questions Maurice about how deep he and Cassie were digging. Explain why this is important.

10. Why is a smooth maria like Humorum a better place to look for helium-3 than the heavily cratered highland areas?

11. Who or what is CMP? What to they have to do with Maurice’s family?

12. Mining towns were common in the 1800’s and early 1900’s. What relationship did the mining company have with the town and the workers who lived there?

13. How does the prospecting law protect Maurice and his family from being expelled from the Moon?

14. Maurice and Cassie are ‘sentenced’ to scrubbing odor filters as punishment for their bad behavior and poor choices. Why would odor filters be needed on the Moon? What does that job here on Earth?
15. Do you think Maurice’s punishment was fair? What would you do if you were Maurice’s mother or father?

16. Scrubbing the odor filters uses lots of expensive water. What do you think the colony does with the dirty water? Where does it end up?

17. How is dirty water processed on Earth? Would that be an option on the Moon?

18. Maurice wants to invent a power scrubber to help him clean odor filters. Cassie isn’t interested – explain why you would or wouldn’t be interested in this idea.

19. If you were Maurice’s parent, how would you react if Maurice did build and use a power scrubber to help him finish the odor filters faster?
Chapter 7 Activity

The Mining Town:

Maurice and his family live in a mining town, Gassendi LEX. In a mining town, the mining company is very powerful. The company generally owns all the buildings, including public places like schools and stores, even private homes where families live. Some company towns were built around other industries besides mining, such as textiles (cloth making), and stockyards (cattle and sheep), to name a few.

1. You may have had mining or factory towns in your state or region. Research a mining town in your area. Find out when it was founded, what company (or companies) ran the town and who lived and worked there. What was produced in the town? How has the town changed over the years?

2. The economics (the exchange of money, goods, and services) of a mining town are different from a regular city. Make a chart or poster showing how money and goods flow in a mining town and in a regular city.

3. Mining towns tend to change over time. How does this change occur, what drives it? Some mining towns don’t survive, what factors can destroy a mining town? Do you think these factors apply equally to such towns on Earth as well as Lunar colonies? Discuss in class and explain your thinking.

4. Mining and factory towns often have to live with environmental consequences long after the original industry is gone. What are some of the environmental consequences of large factories, mines, or other industries in your area. What changes would you make to limit the environmental impact of large local industries? Keep in mind that most plans cost money! If the cleanup costs more than the finished goods are worth, the industry collapses and the community loses many important jobs!
Chapter 8 Questions

1. Why couldn’t Maurice or Cassie sign up for track before now?

2. Maurice’s dad has decided that Maurice is a ‘prospecting whiz’. What does he decide to do about it? Why do you think Maurice’s dad is doing this? Is there more than one reason?

3. Why is Maurice interested in trying out for the track team? Do you think this is a good reason to try out for a sport?

4. What is Maurice’s favorite event? What inspired him to try out for the event?

5. Making the high jump squad at Gassendi Middle School requires a jump of 24 feet. How could anyone expect a middle school kid to jump that high?

6. If you adjust the minimum height of 24 feet for Earth gravity, how high would you have to jump to make the team? Is this reasonable?

7. People on the Moon must stay in shape. Why is this so important on the Moon? How many reasons can you think of?

8. What device have the lunar colonists invented to help people get in shape for returning to Earth’s higher gravity? Explain how this device works.

9. What event does the coach want Maurice to try out for? Why doesn’t he think Maurice is suited for the high jump?

10. How does Cassie suggest Maurice solve his problem? Why won’t Maurice take her suggestion?

11. Why does Maurice get so mad at Cassie when she shows up in an Earth suit?

12. What crazy idea does Maurice get after seeing Cassie’s Earth suit? How does Maurice think this will help him? Explain why you think this scheme will (or won’t) work.

13. If you had a lead suit that made you six times heavier, how heavy would the suit be by itself? How heavy would you be with it on? Could you jump or exercise in this suit?

14. Why does Maurice refuse help from other team members while he is training for the high jump?

15. What happens when the coach sees Maurice working on the high jump? Why was the coach surprised by Maurice’s method?
16. Why does the coach refer to Maurice's training method as 'trying to jump like an Earthman'?
Chapter 8 Activity

Modeling the Orbit and Phases of Luna

Modeling the phases of Earth and Moon can easily be done using materials available from any hobby or craft store. You can make your models more realistic by painting continents and oceans on your ‘Earth’ and painting your ‘Luna’ grey, with black maria and white rings of various sizes representing craters. You may wish to use the internet to find pictures or maps of the lunar surface to help you.

1. The ball you use for Earth must be about 4x larger than the one you use for Luna! You want to make your model completely to scale, so choose the smallest ball you can get (about 1/4” – a plastic or wooden bead works well for this) for Luna and a 1” Styrofoam ball for the Earth. Use a toothpick and some clay to make a base for your Earth and Luna.

2. Use a large square of butcher paper or cardboard to draw out a lunar orbit; the square should be about 45” wide.

3. Near the center, mark two points, exactly two inches apart, these are the foci of the Moon’s orbit. We will use them to draw the shape of Moon’s elliptical orbit in space.

4. Make a loop of string, the loop should be 20” long when stretched out between two pencils. A drop of glue on the knot will insure the loop will not stretch out as you use it.

5. Thumbtack your paper square securely to the wall. Place a push pin at each of the two focal points you marked earlier and place your loop of string over both push pins. If you can’t attach the paper to the wall, tape it securely to a smooth surface such as a table or tile floor. Someone can hold two pencils (eraser side down) on the focal points while a partner draws the orbit in step 6.
6. Put a marker or crayon inside the loop and pull it taut, then trace around the two pins keeping the string loop tight. This is just like drawing a circle with a piece of string, but the two pins will change the shape into an ellipse or oval shape. All orbits in space are elliptical; this is the first law of planetary motion!

7. Choose one of the two focal points you labeled earlier and mark it “Earth”, this is where your model planet Earth will go. Using this point as the center, take a meter stick and draw lines dividing the ellipse into 8 equal parts. Label these points 0°, 45°, 90°, 135°, and 180° on each side of the orbit as shown.

8. Darken the room and use a powerful flashlight (or an overhead projector!) to represent the sun. Your ‘sun’ should shine as close to the flat plane of the Moon’s orbit as possible.

9. Place your Moon at the 0° point of its orbit. Tie a red thread to the moon base, run it around the Earth base, then back to the ‘sun’ and tape it in place there. Leave some extra thread at the ‘sun’ end so that you can adjust the length of the thread as the distance between Earth and Luna changes during its orbit! This thread shows your line of sight between Earth and Moon.

10. With the ‘sun’ turned on, look along the thread past the Earth and toward the Moon. The brightness of the ‘sun’ makes it impossible to see the lunar surface and the lighted side of the Moon faces completely away from Earth. This is the phase of New Moon. Sketch the phase and label it on your orbit paper.

11. Move your Moon to the 45° point of the orbit and adjust the red thread so it is tight again. Now look past the Earth along the red thread again. How much of the Moon’s lighted surface can you see? This is the Waxing Crescent phase (‘waxing’ means the moon’s phase appears to
be getting larger each night.) Sketch and label it on your orbital map. Repeat this for the 90° point (First Quarter phase), 135° point (waxing gibbous), and 180° point (full moon.) Continue to move and plot the moon’s phase around the orbit. All points past the 180° mark are **Waning** phases, meaning the lighted portion of the moon appears to be getting smaller each night.

12. Repeat this process, but this time, look along the line of sight (the red thread) from the Moon toward the Earth. This shows the phase of Earth that Maurice and others on the Moon would see at that time. Students should notice that when you start at 0° (new moon), Earth is Full, and completely lit from the Moon’s point of view and that the Earth’s phase is always opposite of the Moon’s phase as seen from Earth!
Chapter 8 Activity

Orbital Mathematics

A German astronomer and mathematician, Johann Kepler discovered the three laws of planetary motion in the mid-1600's. Kepler's first law was that all orbits are elliptical, with the main body located at one focus of the ellipse. Kepler's idea overturned the idea of perfectly circular orbits which had been in use for over 25 centuries!

We used Kepler’s idea of elliptical orbits in the last activity when we drew the Moon’s orbit as an ellipse, a curved shape that has two center points, instead of just one like a circle does. The center points of an ellipse are called focus points, or foci. Kepler also realized that a body in orbit, like the Moon around the Earth, does not always move at the same speed, although he did not understand why this was true.

Today we know that gravity is the force which holds the Moon in orbit around the Earth. In fact, wherever any object is traveling through space, it is gravity which controls its path and speed of travel. Although gravity is the weakest force known, it has the longest reach: gravity is the only known force which reaches across the entire Universe! Isaac Newton taught us that gravitation increases in strength as you get closer to the source. Earth’s gravity pulls more strongly on you than it does on the Moon, which is 40 times farther away from the center of the Earth than you are. Newton realized that the Moon speeds up in orbit as its elliptical orbit carries it closer to the Earth, and slows down as it moves farther away.

1. Measure each quarter of the circumference of the lunar orbit you drew in the last activity. You need to find the distance from the 0°—90° point, and from 90°—180° point on each side of the orbit. There are a variety of methods to do this, use your own creativity to come up with the most accurate measurement you can. Write down your method so that someone else could follow your instructions and come up with the same answer you did!

2. Although the distances you measured were different, the Moon takes the same amount of time to travel over each quarter of its orbit – approximately seven days. Divide each distance by 7, since it takes the Moon almost 28 days to orbit the Earth just once, this answer will tell you how far your model Moon will travel each day. Start at the 0° point and mark off the orbit to show where the Moon will be at the same time each day.
3. Measure the distance from the Earth’s position to each of these points on the lunar orbit. It is important to measure as accurately as you can. Record your data in a table like the one below, we’ll see how to fill in the rest of the table later.

<table>
<thead>
<tr>
<th>Day #</th>
<th>Map Distance (mm)</th>
<th>Orbital Dist (km)</th>
<th>Δx (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>508 mm</td>
<td>406,000 km</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>496 mm</td>
<td>396,410 km</td>
<td>-9,590 km</td>
</tr>
</tbody>
</table>

4. The Moon’s most distant point from the Earth is called the **apogee point**, the closest point in orbit is called **perigee**. Label these points on your lunar orbit diagram.

5. At apogee, the Moon is approximately 405,000 kilometers away. Use this distance with the measurement on your diagram to set up a ratio. What is the scale on your diagram in km / millimeter?

6. Now use your ratio to find the Earth—Moon distance at each of the 28 orbital points you marked on the diagram and record them in your table.

7. According to Kepler and Newton, the Moon should be speeding up as it gets closer to Earth (just like coasting down hill!) Calculate the Δx (the change in the Moon’s distance from Earth) by subtracting each new distance from the previous distance. If the Moon is getting closer, the Δx value should be a negative number, and the Moon will be speeding up. If the Moon is getting farther away from Earth, the Δx value will be a positive value and the Moon will be slowing down. Label each position with a color-coded arrow. Green for speeding up, and red for slowing down. Make the arrows bigger for larger Δx values and smaller for smaller values.

8. Once you have plotted all the arrows on your diagram, what pattern do you see? Describe this pattern and write your conclusions in a short paragraph.
Chapter 9 Questions

1. Why do you think Mike Evans was so unhappy with Maurice? Could Maurice have done anything to change this?

2. Maurice is having more success with his high jumping – what has Maurice done to make himself more successful?

3. The coach advises Maurice to spin in flight on his way up to the high jump bar. What other things spin in flight like this?

4. What does Mike Evans do to try to handicap Maurice’s attempt to make the team? What would you have done instead?

5. How did Mike’s plan backfire?

6. How did the coach figure out that Maurice hadn’t done the damage to the ceiling in his office? Would you accept this ‘proof’?

7. What does Mr. Haberman offer to Maurice to make him feel better about Cassie’s departure?

8. Cassie got Maurice a going away present. Why do you think she chose that particular item to give to Maurice?
Chapter 9 Activity

Freefall Parabolas

All objects in free fall, such as a thrown baseball, a bullet, or a high jumper travel through the air in a curved path called a parabola. Parabolas can be tricky mathematically, but they are easily described, and even easier to draw and study. The reason any object freely falling through the air (like a well-kicked soccer ball) travels in a parabola is that \textit{horizontal and vertical motion are independent}. This is one of the most important ideas in physics!

When you kick a soccer ball, for instance, the horizontal speed is constant, that is the speed of the ball as it travels across the field stays the same. The ball doesn’t have a rocket motor to speed it up, nor brakes to slow it down. Once you kick it and the ball leaves your foot, the ball is going as fast as it will ever go. The horizontal speed cannot change. (We will ignore wind resistance here, Maurice certainly isn’t troubled by it on the airless Moon!)

Vertical speed is different; the ball’s vertical speed is strongly affected by gravity. Anyone who has ever jumped off a diving board knows that you speed up all the way down until you hit the water! It is gravitation that causes you to accelerate, that is to steadily increase in speed as you fall. So while horizontal speed never changes, vertical speed never stays the same! By using some marbles, graph paper, and finger paint, we can see for ourselves that everything falls in a parabolic path.

1. You will need a flat board, some graph paper, marbles and a ‘marble launcher’ (a common ruler with a groove down the center works well for this.) Set your board on an angle by propping it up with sticks or some text books as shown below.

![Marble launcher diagram]

2. Roll the marble lightly in some water-based paint, or on a stamp pad, then let it roll down the marble launching ramp and across the graph paper. Be sure that the marble launcher points directly across the paper before you release the marble! The marble will trace out a parabolic curve across the graph paper!

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3. The launcher assures you that the speed of the marble across the paper (horizontal speed) will be constant – marbles don’t have brakes! This means that time needed for the marble to cross each square of the graph paper horizontally is the same. We will call the time it takes the marble to cross one square horizontally one “Tic” of time. Our unit of time is certainly less than a second.

4. The slope of the large board provides the gravitational force that accelerates the ball as it rolls down the graph paper vertically. Acceleration means that the ball is always moving faster, gaining more speed for every second of travel.

5. Take a marker and make a dot on the graph paper to mark the curve’s position at each “tic” of time. If your graph paper squares are small, you may wish to place a dot at every other square.

6. Measure the change in horizontal distance between each dot and record it on a data table as shown below. Label this column “Δx”, the symbol for “change in horizontal distance.” Similarly, measure and record the change in vertical position between each dot. You can measure this distance in millimeters with a ruler. Record it as “Δy” in your data table.

<table>
<thead>
<tr>
<th>Δx</th>
<th>Δy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>1.0</td>
<td>0.4</td>
</tr>
<tr>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>1.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

7. Notice that the change in the horizontal distance is always the same (constant horizontal speed), while the vertical distance always increases each time (vertical acceleration due to gravity.) You can use the marble and ramp and adjust the angles any way you wish, but the results will always be this way. The path of every free falling object is a parabola!

8. You can repeat the experiment by rolling a golf ball off a table and video taping it as it falls in front of a large sheet of graph paper drawn on butcher paper. Pause the tape and mark the position of the ball on the TV screen with an overhead marker. You will see the same parabolic curve!
Chapter 9 Activity

Freefall Time and Speed

Calculating freefall time and speed is part of the science of physics. Modern physics is a mathematical science that uses mathematical formulas to predict how things act in nature, such as how long it takes to fall or how fast something is moving when it strikes the ground. The part of physics that deals with objects in motion is called kinematics. In its modern form, it was developed by Galileo in the 1630's and perfected by Isaac Newton in the 1760's. Scientists still use the ideas of Galileo and Newton today to predict how an airplane will fly or how to aim a spaceship to successfully reach another planet.

In the story, Maurice manages to jump 24 feet, 11 inches to qualify for the track team. Let's see how physics uses mathematical equations to find out how long Maurice's jump takes and how fast he hits the ground.

1. The first step is to convert the distance into meters. While some sports still use English measurements, all scientific measurements are done in metric units. To convert into meters, first change the distance into inches.
   \[
   24 \text{ feet} = \text{ _____ inches} + 11 \text{ inches} = \text{ _______ inches total}. \]

2. Next, to get meters, divide the total inches of Maurice's jump by 39.37, this will give you meters.
   \[
   \text{_______ inches} \div 39.37 = \text{_______ meters}. \]

3. Isaac Newton's formula for falling time is listed below. It may look complex, but it really isn’t hard if we do this one step at a time! All Newton says is: 'multiply the height by two, then divide by the acceleration of gravity. Then take the square root of your answer to get the time to fall any distance.'

   \[
   \text{Falling Time} = \sqrt{\frac{2 \times \text{Height}}{\text{Gravity}}} \]

4. Start by multiplying Maurice’s height in meters by 2. Easy, right? Now divide your answer by 1.6 – on the Moon, everything falls at 1.6 meters per second per second.

5. The last step is easy, find the square root of your last answer. You can use a calculator to help you. Enter your number, then press the square root key. It usually looks like this:

   \[
   \sqrt{x} \]

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6. Now the last step. Newton's formula is for falling time, and as they say, what goes up must come down! It takes the same amount of time to rise to the highest point of a parabola as it does to fall back down to the surface again. Since the time going up and the time going down are the same, the total time in the air, is twice the falling time. We must multiply our last answer by two to find Maurice's total jumping time.

\[ \text{Total Time} = \text{Falling Time} \times 2 \]

7. We can also use physics to figure out how fast Maurice is moving when he hits the ground from that height. Once again, we will rely upon the equations of Isaac Newton to guide us!

\[ \text{Final Speed} = \sqrt{2 \times \text{Gravity} \times \text{Height}} \]

8. Once again, we will take the equation by parts to make our job easier. Begin by multiplying the Lunar gravity by two \((1.6 \text{ m/s}^2 \times 2 = ?)\)

9. Next, multiply your last answer by Maurice's maximum height in meters. You figured this out earlier and you can use the same number again. Once you have this answer, use a calculator to find the square root of your last answer.

10. Now try the calculation again, but this time, use Earth gravity, which is \(9.8 \text{ m/s}^2\), six times larger! You will find that Maurice lands moving 2.5 times faster!
Chapter 10 Questions

1. Maurice tells his father that he can't go work with him in the Geology lab – why do you think his father accepts this?

2. What did Mike Evans plan to do to keep Maurice from competing after his plan to steal the E-suit failed?

3. Mike Evans' second plan to knock Maurice down the stairs also fails – but why? Shouldn't a bigger boy be able to knock a smaller boy down? Why did Mike bounce off of Maurice?

4. Maurice and Mike get caught fighting. Violence is never the answer to your problems! What happens at your school if someone is caught fighting? Why is this a bad choice?

5. How does Coach Rosales solve the fighting problem between Maurice and Mike?

6. Why do you think that Mike gains respect for Maurice after Coach Rosales is finished with them? What do you think of the coach's solution?

7. Even after the Coach is through with them, Mike keeps on calling Maurice, squirt. How is a nickname different from calling names? How do you tell the difference?

8. Maurice wins a medal for second place at the Procellarum Invitationals. Why wasn't he disappointed at not taking first place?

9. Coach Rosales and Principal Sato tell Maurice that the school can't afford to buy him a ticket to Earth, how do they explain this?

10. The coach and the principal hope that Maurice's parents can buy him a ticket, but Maurice won't even ask them for the money. Why not? Would you make the same decision?

11. What is Maurice's reaction to the disappointing news about the ticket? What would you have done?

12. Maurice grumbles that his parents don't even have to tell him to come back inside – how do they control when he comes in?

13. Maurice's parents decide to allow Maurice to buy his own ticket to Earth. Why didn't they tell him he had all that money in the first place?

14. Do you think Maurice's parents were right not to tell him about the money? What would you do if you were the parent and Maurice was your child?
Chapter 10 Activity

Studying Inertia and Collisions

Mike's plan to knock Maurice down the stairs failed because Maurice and the E-suit had more inertia than Mike expected. You can study inertia by colliding different weights together and seeing how they react.

You will need:
1. Several small toy cars like HotWheels® or Matchbox® cars and some track for them to run on. All cars should be about the same size and weight.
2. 20-30 pennies
3. Several textbooks
4. Paper, masking or duct tape, and scissors

What to do:
1. Tape the pennies together to make several weights of 2, 5, and ten pennies each. It may be easier to wrap bundles of pennies with tape before attaching them to the cars!
2. Use textbooks to make a ramp at each end of your track as shown below.
3. Tape a weight to one of your cars, and set it on the track as shown.
4. Allow the unweighted car to run down into the unmoving weighted car.
5. Measure how far each car goes after the collision, and in which direction.

Inertia is the property of matter that makes it hard to start or stop a moving object. If you help with the grocery shopping, you know that the grocery cart gets harder to start, stop, and turn as you fill up the cart with groceries. The more groceries you put in the cart, the more difficult it is to change speed or direction. Interestingly, inertia is not the same as weight. Weight changes with gravity, such as when someone goes from Earth to the Moon. Inertia never changes with gravity. Even in deep space, your grocery cart would be harder to speed up, slow down, or turn as it filled up with boxes, bags and canned goods. This idea comes from Sir Isaac Newton, we call inertia the First Law of Motion. As Newton said: “An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless acted on by an outside force.”

After you have tried your experiment with weighted and unweighted cars as many ways as you can think of – and recorded results for each run – think about how your
experiment proves or disproves Newton's ideas about inertia. Present your results to the class or make a poster to show what you have learned about inertia!
Chapter 10 Activity

Making a budget

Making a budget is important, it helps you know how much money you have to spend each month so you don’t run out of money! It also requires good math skills. For this activity, you will need just pencil and paper, some dice, and a daily newspaper.

1. Your newspaper will have a ‘help-wanted’ or ‘employment’ section. Look through the ads and pick a job you might like to have. Be sure the advertisement tells the salary or hourly pay that your job offers. Some ads tell the salary by the month, some give a yearly salary, if you are not sure which, ask your teacher for help. Hourly pay can easily be changed into monthly pay by multiplying it by 40 hours per week and again multiplying by 4 weeks per month. (For this activity we will happily ignore taxes!) Cut the ad out and paste it to your paper in the “My Job” section as shown.

<table>
<thead>
<tr>
<th>My Home</th>
<th>My Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Car</td>
<td>Food Costs</td>
</tr>
<tr>
<td>Energy Costs</td>
<td>My Savings Plan</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>My Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Income</td>
</tr>
</tbody>
</table>

2. Next, you have to find a place to live. The newspaper will have lists of apartments for rent. To make sure you have enough money for other expenses, your apartment should not be more than 1/3 of your monthly income! If your apartment is too expensive, you may not have enough for food! Cut the ad out and paste it to your paper in the ‘My Home’ section.

3. Energy like electricity and natural gas are used to heat and light our homes and cook our food. Energy costs vary – to get your monthly cost, roll two
dice and multiply by 10. Repeat this 12 times and average the results. This represents your average monthly energy cost. Do the work in the ‘Energy Cost’ section.

4. Food costs vary from one family to the next. Ask your parents how much they spend on food each week. It isn’t necessary to have an exact answer, an estimate will do. Multiply your weekly cost times four to get your food cost for the month. Do this work in the ‘Food Costs’ section.

5. Do you want a car? Most adults need one for going to school and work, getting groceries and running errands. Look to the paper again, this time in the automotive section. Many companies will show a car for so much per month, there may also be ads for used cars as well. Used cars are often much cheaper than new ones! If you choose a used car, divide the cost by 24 to get a monthly payment. Add $200 per month to the cost of the car for gas, oil, and repairs! Paste the ad and do the figures in the ‘My Car’ section.

6. How much money would you like to save each year for vacation? (or for an emergency!) Divide that amount by 12 and put this in your budget for savings. Do the work in the ‘Savings Plan’ section.

7. Now it is time to draw up your final budget. List your income on one side of a paper and your expenses on the other. Total up your expenses for each month. If expenses are less than income, you have money left over for movies, eating out and having fun. If your expenses are bigger than your income, you are in trouble! You must go back and choose a cheaper car or apartment, perhaps save money on energy by cutting down on lights, heating and air conditioning. Most families can save up to 10% on energy or food, but it is very difficult to save more than this. In many families, both parents work (Maurice’s parents both work for the same company.) You can find a second job and add it to your worksheet if you need to.

8. Another way of balancing your budget is to get a better job. But better, higher paying jobs usually take more education and experience. Staying in school and getting good grades now is one of the best ways to balance your budget later!
Chapter 11 Questions

1. Maurice’s seat number on the space liner isn’t an accident. What connection does number ’39-A’ have to space exploration? Internet research may be helpful here!

2. Maurice will travel approximately 380,000 kilometers in ten hours. How fast is the spaceship moving?

3. How long did the Apollo astronauts take to go from Earth orbit to the Moon?

4. Maurice feels himself sinking into the cushions as the space liner takes off, what causes this feeling? Have you ever felt something similar? Describe the situation!

5. Many of the features on the Moon’s far side have Russian names while many features on the near side have Latin names. How do you explain the difference in the use of the two languages?

6. The captain of the space liner talks of ‘accelerating to escape velocity’. What is escape velocity? Can you find out how fast it is for Earth and Moon?

7. Maurice notices that acceleration gravity in the space ship is very different from wearing the E-suit. What differences does Maurice notice? How do you account for these differences?

8. While looking out from the observation deck, Maurice sees the Big Dipper constellation for the first time. Why wouldn’t he normally be able to see the Big Dipper from home?

9. Maurice sees Earthrise for the first time from the space liner. Why would this be his first time?

10. Under two gravities of acceleration, Maurice weighs 228 pounds – 12 times more than he is used to on the Moon. Why would moving around under two gravities be considered dangerous?

11. The space liner orbits the Earth at 17,000 miles per hour, 250 miles above Earth’s surface. How long would it take the ship to circle once around Earth at this speed?

12. Maurice docks at the Yuri Gagarin Spaceport – who is Yuri Gagarin? Why would anyone name a space station after him?
Chapter 11 Activity

Internet Research: Discovering Resources on the Moon

1. The Aitken basin is the home of the only water on the Lunar surface. Use the Internet to research this. How and when was the water discovered? How was the huge Aitken basin crater discovered? Make a poster showing what you learn about this exciting topic.

2. Why would a ‘local’ source of water be important for a lunar colony? Think about how much water a person would need each day and where it would have to come from!

Mapping the Lunar Maria

The first known scientific map of the lunar surface was made by Galileo himself, in 1609. Galileo named the dark regions on the lunar surface Maria (Latin for ‘Seas’), because he originally believed them to be bodies of water. Although Galileo quickly realized his mistake (he saw no clouds or storms over these ‘seas’), the name stuck. Scientists later discovered that these Maria were actually seas of frozen lava left behind from huge asteroid impacts that happened billions of years ago. Mapping the Maria is the first step to mapping the Moon properly.

Sketching the lunar surface is easily done using the Clock Method. Picture the Moon in the sky as a clock face. To locate any feature, just imagine what ‘hour’ the object is closest to, and then determine how far from the center it is. Examine the drawing below:

The circle on the left simulates a moon or asteroid with various markings on its surface. We imagine the object to be divided up like a clock face into 12 equal parts. The circle on the right is our sketch of the object. We divide it up into 12 parts, just as a clock is divided. We use these lines to help us sketch accurately. Take a look at the mark on the moon that stretches between 11 and 12 ‘o clock, about ¾ of the way out from the center. On our drawing, we sketch in a similar shape. The hour lines we have drawn help us make sure the mark is in the correct place and the correct size. Practice copying this drawing before you try your hand at sketching the real moon!

Use the circles below to practice sketching the Moon. Bring your best effort back to
class and compare your drawing with a map or picture of the Moon from a textbook or the internet. How many Maria can you identify accurately in your drawing? Outline the Maria you are sure of in red, number them on your map and make a key!
Chapter 12 Questions:

1. Maurice lands in Chicago, why would the weather be a surprise for him?

2. What advice would you give to Maurice to make his first day on Earth easier? What do you think would be the toughest adjustment Maurice would have to make?

3. Someone at the Air and Space Port is selling gravitational aides. Who would buy such a thing and why would they need one?

4. When Maurice trips in the airport, some kids call him a neo. How would they be able to tell Maurice was new to the Earth?

5. Maurice notices the difference between the filtered, recycled air he is used to on the Moon and the humid, odor-laden air of Earth. Which would you prefer? Explain why!

6. Maurice is amazed at the colors, sounds, and smells of Earth. Take a look at some pictures of the Moon and see if you can tell why.

7. Cassie complains about her dad’s hobby of watching old-fashioned black-and-white television shows. What ‘old fashioned’ hobbies do your parents have? What hobbies do you think your own kids will complain about someday?

8. Maurice thinks Cassie’s house in Milwaukee is very weird! What is so strange about it? If Maurice were your guest, how would you change things to make him more comfortable?

9. Maurice is fit and athletic, so why do you think he has so much trouble playing basketball with Cassie’s friends?

10. Why did Maurice freak out when he ripped his blue jeans?

11. In many ways, chapter 12 is all about gravity. How many ways can you think of that gravity plays a role in the events of this chapter?
Chapter 12 Activity

**Lunar and Terrestrial Culture:**

1. Maurice uses *Black and Whites*, glasses that filter some or all of the color out of what you see to help him adjust to the Earthly landscape. If you could invent a device to help Lunar residents adjust to Earth, what would it be? What similar devices do you think might help first time visitors to the Moon feel more comfortable?

2. Your *culture* is a combination of the people you know, the customs and habits you have, and the unstated rules that tell you how to behave in different situations. Why is Maurice’s culture on the Moon so different than the culture on Earth? Besides habits and customs, what else do you think makes up a *culture*?

3. Pretend you are a travel agent arranging trips to Earth for people who have grown up on the Moon. Design a poster or a pamphlet to help Lunar folks know what to expect when they get to Earth and feel more comfortable when they arrive.

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*Welcome to Earth!*

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Chapter 12 Activity

Killer Meteor Research

Large meteoroids from space can cause tremendous destruction on Earth. Fortunately, these impacts are quite rare, but not unknown in modern times. Use the library or the internet to research and learn what you can about these four major impacts. You can check all four, or focus on just one if you wish. Make a poster showing what you learned and share it with the class!

1. The ‘Dinosaur Killer’ meteor. This meteor is thought to have been only 10-12 km wide, and yet it destroyed the dinosaurs and changed the course of evolution forever. What evidence led to the discovery of this giant impact 65 million years ago? How could the evidence survive that long? Where did it strike the Earth, and why can’t we see the crater today? How did something that small destroy all the world’s giant reptiles?

2. The Barringer meteor. The Barringer meteor created the famous Barringer Meteor Crater in Arizona. This meteor was much smaller than the famous ‘dino killer’, and much more recent. How big was it, and when did it strike? How large is the crater, and why did this crater survive when the much larger dino-killer crater did not? What would such a strike do if it happened today?

3. The Vladivostok meteor. This meteor exploded over the Russian city of Vladivostok in 1947, how big was it? Thousands of eye-witnesses saw this event, how did they describe it? What did these witnesses see? What were the effects of the Vladivostok impact? Why didn’t it leave a giant crater like the Barringer crater in Arizona? The Vladivostok impact didn’t kill anyone – why not?

4. The Tunguska impact. This event happened over the Siberian wilderness in Russia in 1908. It was fundamentally different from the previous three meteor impacts, why? What were the effects of this impact from space? People across the world were affected by the Tunguska impact; people in England called it “the year without a summer.” How did this impact affect the weather world wide?
Chapter 13 Questions:

1. Maurice is amazed at a tub full of hot water ($7,000 dollars worth on the Moon!) What things do you use regularly that are expensive where you live? How would your life be different if these things were suddenly easy to get and very cheap?

2. Trade between nations is based on selling things you have a lot of and using the money to buy things that are in short supply at home. What major items do you think would be traded between Earth and Moon?

3. Can you see a beam of light in the air, say from a car’s headlights or from a flashlight beam? Maurice never has! What does this tell you about air quality on Earth?

4. Large aquariums are fun to visit and can teach you a great deal about life in the lakes, rivers and seas. What is the only thing similar to the Shedd Aquarium that Maurice might see on the Moon?

5. The Chain 'o Lakes is an important habitat that people, plants, and animals share in Illinois and Wisconsin. What natural waterways are located in your area? How do ea

6. Maurice takes his first boat ride in Mr. Metis' powerboat. Write a note to Cassie describing the boat as you think Maurice would. What would he compare it to?

7. Maurice reacts with horror when he sees he has gotten a sunburn. Why do you think he feels this way?

8. How does the Earth protect us so that a little extra sun is just uncomfortable - not deadly! Is there any way that Luna could use the same protection system that Earth uses?

9. Maurice is very impressed that he gets to eat real beef hot dogs. Would you be just as impressed with the food Maurice usually eats every day? Explain why or why not!

10. Why is Maurice so enchanted with the rain?

11. What kind of storms do they have on the Moon? (Hint: there are two kinds!)

12. What kinds of clouds produce the rain with thunder and lightning that Maurice and Cassie experience? What conditions are required to produce such clouds?

13. Cassie explains to Maurice that every three seconds you count between the flash of lightning and the boom of thunder is another kilometer between you and the lightning strike. Can you use this information to determine how fast sound travels through air on Earth?
Chapter 13 Activity

Build a Particular Pollution Detector:

Beams of light in the air tell Maurice that Earth’s air is full of dust, humidity, and even pollution. You can use a beam of light to help you determine how clean or dirty the air is at your school!

What you need:
1. A battery powered laser, such as a laser pointer
2. A small solar cell
3. An oatmeal can or small shoebox
4. A *Volt meter* (a device for measuring electric current)

What to do:
1. Punch two small holes in the bottom of the oatmeal can to fit the wires from the solar cell
2. Glue the solar cell to the bottom of the oatmeal can with the wires sticking out the holes
3. Cut a hole in the top of the can so light can shine through and fall onto the solar cell
4. Attach the wires from the solar cell to the volt meter. Use double stick tape to fix the volt meter onto the bottom of the oatmeal can.

Your finished pollution detector must be placed in a steady location so the laser beam can shine steadily into the can and onto the solar cell. You should try to have the laser at least 15 feet away from the pollution detector (farther is better). Make sure the beam and the detector are as steady as you can while you read the meter.
Chart your readings each day and see if they go up and down with the air quality index. You can get air quality information from the daily paper, or over the internet from your local weather service. You can also try to measure air quality several times per day. Is the air cleaner in the morning or in the afternoon? Does the air get dustier after recess? Does the relative humidity (the amount of water vapor in the air) affect the readings? Find out what your state or local community is doing to help improve air quality in your area!
Chapter 14 Questions

1. Maurice experiences a *three second delay* when he is talking by phone with his parents on the Moon. What causes this?

2. What is the largest delay you would find acceptable before conversation would become impossible? Use the speed of light (3 million meters per second) and your maximum acceptable delay time to see how far away someone could be and still conduct a conversation with you by phone.

3. Maurice seems to be having second thoughts about the Earth as he talks with parents on the phone. Would these same thoughts make you more or less likely to return to a place you had visited? How do you think Maurice would feel?

4. Maurice gets stuck in traffic on the way to the big meet. Do parents in your area get stuck in traffic? How do you think this crowding affects resources like time and energy?

5. Maurice failed on his first attempt at jumping over the high bar. What kind of qualities does it take to keep trying after that? Does this make you feel differently about Maurice?

6. When Maurice injures himself on his last jump, he gets help from an unexpected source. How does Randolph Scott let Maurice know that he is on his side?

7. Maurice wanted to escape the Moon and get to Earth more than anything. How do you think watching the Moon rise over the athletic field made him feel?

8. How do you think Maurice’s feelings about his home on the Moon have changed over the course of the story? Why did this happen?
Chapter 14 Activity

Looking for Tycho’s Rays:

Rays on the Moon are streaks of dust blasted out of craters as large meteoroids comets crash into the lunar surface. Seeing these pale streaks requires a small telescope and sketching them can be rewarding and fun. You can even measure your drawing and calculate the length of the rays you see and record. This activity must be run within 48 hours of the full Moon; this gives you almost 4 nights when you can see rays on the Moon. The closer you are to true full Moon night, the better your results will be. Nights before the full Moon will find the Moon rising before sunrise (you can work earlier in the evening). Nights after the full Moon will find the Moon rising after sunrise – almost an hour later for every night you go past full Moon. Working after the full Moon has passed will find you staying up later in order to see the Moon in the sky.

You will need a small telescope (50 – 60mm will do fine) set up to view under moderate power (75-100x). Most common 60mm telescopes will do fine with a 10-12 mm eyepiece, giving you a comfortable view at about 70x magnification. Don’t try to view at very high power! This will restrict your view to only a small area of the Moon’s surface and make the image you see dimmer and grainier. The telescope is also harder to aim and control when it is at higher power making your observation more difficult and less fun. The lowest power that will show you the details you want is the best magnification to use.

The map below shows only the Highlands (light) and Maria (dark) on the Moon; it does not show any craters. First, sketch the craters in their correct positions and sizes while the telescope is on its lowest power. After you have located the major craters, use a higher power eyepiece (one with a lower number on it) to look more closely at the craters you’ve seen. You may now be better able to sketch in the rays you see. Don’t worry about the many smaller craters you will see on higher power, just work on sketching in the rays!

Knowing that the Moon’s diameter is 3500 kilometers, can you measure and estimate the length of the rays you have sketched? You will need to use your ratio and proportion skills from math class to do this! Ask your math teacher for help with this part of the project. Can you think of a way to take the curve of the lunar surface into account when measuring your rays on your drawing? One way to do this is to use a basketball and some string… but I’ll leave that for you to work out! Above all, have fun gazing at Maurice’s beautiful home!
The map above is designed to be used with a **reflecting telescope**. The reflecting telescope is easy to recognize because it has a mirror in the bottom of the tube instead of a clear glass lens. These telescopes, also called **Newtonian** telescopes flip the image upside down and reverse it left to right. The map above has been printed with North at the bottom and West on the right to match the image you will see.

Notes:
The second map show above is designed to be used with a refracting telescope. These telescope are easily recognized by the clear glass lens in one end of the tube. These telescopes usually display an upright image (North is up on the map above), but they still reverse the image from left to right. The image above should match what you will see in a refracting telescope!

Notes:
Chapter 15 Questions

1. How would you react to a big welcome home party like the one Maurice got when he returned to the Moon?

2. Mr. Haberman is convinced the 14th place medal says something special about Maurice. What do you think is says about him?

3. Why doesn’t Maurice seem to mind when a kid in the spaceport concourse calls him a neo, especially when it seemed to bother him so much in Chicago?

4. How do you think Maurice’s ideas about the Earth have changed since he went away? Would this make you like the Earth more or less?

5. What are some of the small things that remind Maurice he is home safe on the Moon?

6. If you had to go far away from home for a couple of weeks, what are the things you would miss most and be happiest to get back to?

7. Maurice looks back to Earth and sees that Cassie will soon be experiencing sundown. A short time later, he experiences a lunar sunrise. How would the two experiences be different? What causes these differences?

8. Maurice grumps about wearing a tie to Citizenship Day; Mr. Haberman calls it tradition. What are some traditions in your school or family that you like or dislike? What is tradition supposed to do for us?

9. How do the lunar citizens protect their heritage at the Apollo 11 landing site? Why is it important to preserve such sites?

10. What happens on Citizenship Day? Why would that be important to the young Lunar Union? How would it affect their culture?

11. How is Eagle Stadium different from a sports stadium here on Earth? Are these differences necessary? Explain why.

12. Maurice used to see the swearing in ceremony as a great time to go to the bathroom or to get something to eat. How do you think this day will change his opinion? Do you think the change will last, or will it be temporary?

13. Maurice gets the Robert Goddard Medal for young inventors. Who was Robert Goddard? Why did they name an inventor’s medal after him?
Chapter 15 Activity

Challenges of Citizenship:

People move all over the globe every day. Some decide to stay in a new area and become citizens. For those that choose to pursue it, citizenship is an important concept and a key accomplishment in their lives.

1. Find out what is required for citizenship in your town, state, and country. Why are the requirements different for each level of citizenship? Make a chart or a poster showing the path that someone must go through to achieve citizenship at each level. What makes each level meaningful to you?

2. See if you can find someone in your area who has struggled to gain their citizenship. Interview them and then do a presentation to your class or group on the personal struggle and achievement that citizenship represented to that person. Ask your parents if they know someone who gained citizenship after immigrating to your country – there may even be someone in your own family!

3. Citizenship isn’t a one-way street. A city, state or country usually asks citizens to uphold special responsibilities as part of duties of citizenship. What are some of the responsibilities that go along with being a citizen at each level? Do you think that citizenship is a good deal?
GLOSSARY

All terms are real unless marked with a ® to indicate a thing or idea that doesn’t exist... yet!

**Acceleration**: A change in speed or direction. A vehicle like a car or spacecraft accelerates when speeding up, slowing down, or turning. [See: *Acceleration Gravity*.]

**Acceleration Gravity**: A reaction force that feels just like gravity. Acceleration gravity is caused by a vehicle such as a car or spacecraft accelerating. It may pull in any direction (not just down), and lasts only as long as you continue to accelerate. You feel no acceleration gravity when moving at a steady speed. [See: *Acceleration*.]

**Air Pressure**: A constant squeezing force your body experiences when you live in an atmosphere. On Earth, this pressure is naturally maintained by the weight of 125 kilometers of air pressing down on you. On the Moon, this pressure is created artificially by pumping air into a dome or a pressure suit—just like inflating a basketball! [See: *Airlock, Atmosphere, Oxygen, Pressure Suit*.]

**Air Quality Management**: An organization that monitors and protects the quality of the air we all breathe. On Earth, AQM workers monitor things like air pollution and car exhaust. On the Moon, AQM workers monitor other things like carbon dioxide and oxygen levels in the indoor air. [See: *AQ Cops, CO₂, CO₂ Sensor*.]

**Airlock**: A special room with two doors, one opens ot handle the outside environment, the other opens to the living area. Both doors are NEVER open at the same time! The airlock will pressureize to allow you to take your helmet and pressure suit off when you come indoors. It also pumps the air back indoors before you leave so that the air isn’t wasted. [See: *Air Pressure, Atmosphere, Oxygen*.]

**Aitken Basin**: Aitken is the largest impact site in the solar system. This 2200 kilometer wide crater is centered roughly on the Moon’s south pole. It was discovered in 1998 by the Clementine Lunar orbiter. The Clementine Lunar Prospector, as it was also known, was the first craft to discover water on the Moon, deep within craters within the Aitken basin. Aitken is also one of the states of the Lunar Union. [See: *Asteroid, Impact Crater*.]

® **Aldrin Spaceport**: A small spaceport serving the Gassendi LEX area named for Edwin “Buzz” Aldrin, the second man to walk on the Moon in 1969. Often called ‘Buzzport’ by children, it is one of Maurice’s favorite places to hang out. [See: *Gassendi LEX, Spaceport*.]

**Algae**: Single-cell plants that use chlorophyll to produce food from sunshine and carbon dioxide. Common on Earth where ever there is abundant water. Algae are efficient producers of atmospheric oxygen on both Earth and Moon. [See: *Carbon dioxide, OK Corral, O/K Farm, Oxygen*.]

® **All System Track Finals**: A track and field tournament held for all students 12th grade and younger. The All System Finals are held on Earth and Moon alternately. Because of vastly different gravity and other conditions, scores are averaged and the tournament trophy is awarded every other year. [See: *Bi-annual, High Jump, JV Division, National Lunar Track Team, Soldier Field*.]

® **Ambush at Coyote Canyon**: A novel of the Old West by Maurice’s favorite author, Lamont LaRue. Don’t look for this one in the local library, Lamont LaRue is a fictional character!

® **Ankle Lights**: Ankle lights are installed in your boots that shine down on the ground around your feet so you don’t have to hold a flashlight. Ankle lights are standard equipment in lunar pressure suits because the Moon has two weeks of uninterrupted darkness every month. [See: *Lunar Day, Pressure Suit*.]

**Antibiotic**: An antibiotic is a medicine that destroys infection causing bacteria, it does no good against viruses, though. [See: *Hypodermic Syringe*.]
Apathy: Apathy is an 'I don't care' attitude. In a rugged frontier environment like the Moon, Apathy kills people who don't care enough to be careful about pressure suits, air supplies, etc. [See: *Pressure Suit, Suit Discipline*]

Apollo Monument: The Apollo Monument is a building and statue commemorating humanity's first steps upon another world in 1969-72. There are six Apollo Monuments on the Lunar near side; one for each of the six successful Apollo landings. [See: *Apollo Park, Schmidt-Sabine LEX*]

Apollo Park: Apollo Park is a sports complex in Schmidt-Sabine LEX, in the state of Tranquilitatus. This sports complex was named in honor of Apollo-11, the first successful manned landing on the Moon. [See: *Apollo Monument, Eagle Stadium, Lunar Citizenship*]

AQ Cops: A common name for the Air Quality Police. On the Moon, air quality is crucial. Fouling the air or failing to maintain the filters and air scrubbers in your home can get you a citation and a fine. [See: *Air Quality Management, Atmosphere, Carbon Dioxide, CO₂ Sensor*]

Asteroid: Asteroid is another name for meteoroid. Essentially a large rock in space, the word asteroid literally means “star-like object.” Asteroids come in three basic varieties: S-type, made of stone; M-type, made of metal (mostly iron); and C-type, made of carbon. Asteroids are usually found in the asteroid belt, a region of space between Mars and Jupiter. Although they range in size from small particles up to almost 1000 miles across, the name asteroid is usually reserved for objects large enough to be seen from Earth. Very large asteroids have impacted the Moon in the past, creating more than 20 maria which we still see today. Asteroids were able to do this because these huge objects struck the near side where the lunar crust was only 50 kilometers thick. There are only four maria on the far side because the crust there was 150 kilometers thick! There have been no impacts of this size on the Moon for billions of years. [See: *Impact Crater, Lunar Crust, Maria*]

Atmosphere: The atmosphere is the blend of gases that make up our air. The Moon has no natural atmosphere because its gravity is too low to hold air down on the lunar surface, so gases escape into space. [See: *Airlock, Air Pressure, Air Quality Management, Carbon Dioxide, Oxygen, Pressure Suit, Twilight*]

Axis: The axis is the imaginary line around which a planet spins. It is rotation on its axis which causes a planet to experience the regular cycles of day and night.

Bi-Annual: Anything that occurs once every other year is considered to be bi-annual. [See: *All System Track Finals*]

Big Dipper: The big dipper is part of the constellation *Ursa Majoris*, or the ‘Great Bear’; it is also known as ‘The Plough’ in England and much of Europe. [See: *Constellation*]

Black and Whites: Black and whites are special glasses that replace colored light with tones of black and white. The amount of color you can see can be adjusted, helping lunar visitors to Earth deal with ‘color shock’. [See: *Color Shock*]

Booster: A booster is a large rocket engine used to help get large ships and cargoes into space. [See: *Passenger Liner, Spaceport*]

Breccia Field: Breccia is mixed rock that is fused together with glass. This happens when a meteor impact makes temperatures high enough to melt rocks together and change sand into glass. Common on the Moon, breccia is rare on Earth except in volcanic regions such as Hawai’i. Because they are composed partly of glass, breccia can shatter into dangerous, razor-sharp pieces. [See: *Asteroids, Ejecta, Ejecta Blanket, Impact Crater, Rays*]

Buggy: [See: *Lunar Buggy*]

Burrows: Burrows are rooms or buildings on the Moon that have been dug into the ground or into the side of a large crater rim. Most of the South Gassendi Complex where Maurice lives is composed of burrows dug into the Gassendi Crater rim. [See: *LEX, Radiation, Radiation Damage, and Shielding*]
Carbon Dioxide: Carbon dioxide is a naturally occurring gas that humans and other animals breathe out as part of the respiration process. Earth atmosphere is roughly 0.5% carbon dioxide. Concentrations of CO\textsubscript{2} over 2% are considered toxic. Plants ‘breathe in’ carbon dioxide, scrubbing it from the air and turning it into sugars and cellulose (plant fibers). [See: Atmosphere, Air Quality Management, AQ Cops, CO\textsubscript{2} Scrubber, CO\textsubscript{2} Sensor.]

Cassiopeia: Cassiopeia is a large constellation in the northern sky near the Big Dipper; it is also called ‘The Queen.’ [See: Big Dipper, Constellation.]

Celsius: A unit of temperature used in the metric system, Celsius is also sometimes called ‘Centigrade.’ [See: Fahrenheit.]

Ceramic Turbo-Diesels: Engines are more efficient when they are very hot. Modern ceramics can withstand both the heat and shock needed to make ultra-efficient diesel combustion engines. At present, ceramic engines are considered experimental and are not found in everyday applications like cars or boats.

Chain 'o Lakes: The Chain 'o Lakes is an area with dozens of small lakes connected by shallow channels. Stretching from southern Wisconsin into northern Illinois and Indiana, the Chain 'o Lakes is part of the Fox River system and drains into Lake Michigan. The lakes and river are home to many species of wildlife, all harmless with the exception of the Cottonmouth Snake. [See: Lake Catherine, Cottonmouth.]

Chicago Port Authority Police: The Port Authority Police is a real-life police force that patrols the Chicago harbor and airport transportation system, including O'Hare International Airport (the future O'Hare Air and Spaceport!) Port Authority Police are now part of the Department of Homeland Security. [See: O'Hare Air and Space Port.]

Chicagoland LEX: A large metropolitan combination of more than a dozen cities bordering southwestern Lake Michigan. The cities are technically separate, but work together for shared government functions. [See: LEX.]

Chronometer: A chronometer is simply a watch or a timepiece.

Citizenship Day: July 20\textsuperscript{th} of each year is the Independence Day celebration for the Lunar Union. This is also the one day each year when qualifying new citizens are sworn in and take their oath of allegiance to the Moon. [See: Apollo Park, Lunar Citizenship, Lunar Union.]

CO\textsubscript{2}: This is the chemical formula for carbon dioxide gas. [See: Atmosphere, Carbon Dioxide, Scrubbers.]

CO\textsubscript{2} Sensor: This is a chemical sensor that can detect the level of CO\textsubscript{2} gas in the air and protect people against accidental carbon dioxide poisoning. [See: Atmosphere, Carbon Dioxide, Scrubbers.]

Color Shock: People on the Moon live in a very monochrome environment, virtually everything outside is either black, white, or grey. For lunar residents, traveling to the Earth with its very colorful environment is hard on the eyes, just as bright lights can sting your eyes when you are not used to them. [See: Black and Whites.]

Concourse: A concourse is a large public area in an airport or space terminal. This is where passengers walk to and from their boarding areas, lounges, and baggage claim areas. [See: O'Hare Air and Space Port, Aldrin Spaceport.]

Constellation: A constellation is a group of bright stars in the sky that make a familiar pattern. There are 88 internationally recognized constellations. People on the Moon see the exact same constellation patterns as we do on Earth. How many of the 88 constellations you see depends on where you live. People living on the equator see virtually all of them, while people on the poles see only half of them. [See: Big Dipper, Cassiopeia.]

Copernican Stock Exchange: Like the Tokyo and New York Stock Exchanges, the Copernican Exchange, located in Schmidt-Sabine LEX, is a major economic trading house. People on the Moon buy and sell stocks there. [See: Water Futures, Water Stocks.]

Cottonmouth Snake: The Cottonmouth is a large (1-2 meters long) and aggressive poisonous snake native to wetland areas from the northern Midwest to the Southeastern seaboard of the United States.
Dark brown or black with small tan stripes, they often show off their spectacular white mouths when angry or striking. Sometimes referred to by locals as the ‘Water Moccasin’. [See: Chain 'o Lakes.]

Crater: [See: Impact Crater.]

Crawler-Miner: A crawler-miner is a very large vehicle that slowly crawls over the land on massive treads (like tank treads.) These vehicles scrape rock off the surface, grind and heat it to release helium-3 as they go. There are also versions of this machine that mine metals. They are very efficient, but they leave ugly scars upon the landscape. [See: He-3 Mining Company, Helium Analyzer, Helium Prospecting, Helium Reserve.]

Crescent: The crescent is a thin, curved shape that is thickest in the center and tapers to a point on the ends. [See: Crescent Phase, Gibbous Phase, Phase of the Moon, Quarter Phase. Also see: Appendix—A: Lunar Orbit and Phases.]

Crescent Phase: The crescent is one of the five distinct phases of the Moon as seen from Earth (or the Earth as seen from the Moon.)

Dark Side: The ‘dark’ side is the side of the Moon that people on Earth never see. The Moon’s core is off-center, and the Earth’s gravity always holds the ‘heavy’ side down; that is, toward the Earth. This means that only one side (the heavier side) is ever seen by Earth dwellers. It also means that people living on the dark side (or far side, as residents there prefer to call it) never see the Earth in their sky. People living on the far side consider the term to be an insult. [See: Far Side, Near Side.]

Data Cartridge: A data cartridge is a high-capacity data storage device used in computers and field equipment like helium analyzers. Essentially a disk drive with no moving parts, similar devices are now common in digital cameras, MP3 players, and other devices. [See: Helium Analyzer.]

Dehumidifier: A dehumidifier is a device made to extract water from air or clothing. Think of a clothes drier that would capture both the lint and water from your wet laundry and you have the right idea. [See: Water Reclamation.]

Dirt Suckers: Dirt sucker is an impolite term for people who have never flown in space. Often, it is used for those who are afraid or uncomfortable with space flight.

Domes: Domes are large plastic covers that are fitted over crater rims. Craters fitted this way can hold air an water, even buildings and people. Very simple to build, but offering little protection from sun, radiation, or meteorite exposure, they are generally used for storage, not for living or working in. [See: LEX, Habitat.]

Dustboard: Similar to a terrestrial snowboard, the dustboard allows kids on the Moon to ‘catch some powder’ when they travel to the highlands. The best part is that the dust is always there, so there is no need to wait for snow! Dustboarding is enjoyed year-round on the Moon.

Eagle Stadium: Eagle stadium is an underground stadium in Apollo Park in Schmidt-Sabine LEX, this is one of the places where citizenship ceremonies are held each year. [See: Apollo Park, Citizenship Day, Lunar Citizenship.]

Earth Standard Gravity: One standard gravity makes you fall at 9.8 meters per second, per second, or 9.8 meters per second squared. This is roughly three times faster (and heavier) than Martian gravity, and six time more than lunar gravity. [See: Acceleration Gravity, Gravitational Aides, Gravitationally Challenged.]

Earth Suit: An Earth suit consists of a lead lined jacket and pants; this allows people on Mars or the Moon to exercise at their ‘normal’ weight (in Earth gravity.) Failing to exercise rigorously in low gravity causes loss of bone mass and muscular weakness that may make it impossible to return to Earth safely. [See: Earth Standard Gravity, Gravitational Aides, Gravitationally Challenged.]

Earth Transit: Earth transit is the portion of a space flight that takes you from the Moon to Earth. [See: Lunar Escape Trajectory, Passenger Liner, Trans-system Trajectory.]
**Earthman:** Earthman is a slang term for someone who is a citizen of Earth. Sometimes used as an impolite term for someone who is snobbish about being from Earth. [See: Loonie, Moon Man, Terran, Terrie.]

**Earthrise:** The rise of the Earth over the lunar horizon is called Earthrise. This only happens if you live in a narrow band on the Moon that separates the near side from the far side. Earthrise times are irregular, and the speed and length of the event varies greatly. [See: Far Side, Lunar Day, Near Side, Synchronous Orbit.]

**Ecologist:** An ecologist is someone who studies the complex interactions of living species in their natural environment. [See: Oxygen/Krill Farm.]

**Ecosystem:** An ecosystem is a community of living things and their environment interacting together. A healthy ecosystem is balanced between plant and animal; as well as between predator, prey, and scavenger. [See: Ecologist, Oxygen/Krill Farm.]

**Ejecta:** Material blasted out of a crater during an impact is called ejecta. This may include rocks, dust, and if the impact is large enough, brecciated rock – pieces of different types of rock fused together by the heat of the impact blast. [See: Breccia, Ejecta Blanket, Impact Crater.]

**Ejecta Blanket:** The ejecta material that covers the ground around an impact crater is called the ejecta blanket. The size and composition of the ejecta blanket varies with the size of the impact, and the type of object that struck the surface. Sometimes the crater rim will be jagged, making, ejecta spray out in straight lines called rays, which can extend for thousands of kilometers. [See: Breccia, Ejecta Blanket, Impact Crater.]

**Emergency Radio:** The emergency radio is a battery operated radio with very simple controls. It communicates wirelessly with your pressure suit com system, so you don’t need a microphone. Kids and adults on the Moon consider it a personal failure to have to use one. [See: Lunar Buggy.]

**Escape Velocity:** The speed you need to break free of a planet’s gravity. About 25,000 mph for those of us on Earth. If you do get up to escape velocity, any path you take will eventually lead you back to the home planet – often with a crash landing! [See: Earth Transit, Lunar Escape Trajectory, Trans-System Trajectory.]

**E-Suit:** [See: Earth Suit.]

**Faceplate:** The transparent part of a space helmet that allows you to look out at the planet you are exploring is called the faceplate. [See: Fittings, Helmet, Pressure Suit.]

**Fahrenheit:** Fahrenheit is an English unit of temperature, not commonly used anywhere except the United States. Fahrenheit is not longer used by scientists anywhere in the world. [See: Celsius.]

**Fenders:** Curved pieces of metal or plastic that prevent rocks or dust kicked up by the wheels of a vehicle from flying up and hitting the driver. [See: Lunar Buggy, Smoke Signal.]

**Fittings:** Usually made of aluminum rings, fittings allow you to put the pants, shirt, helmet, and gloves of a pressure suit together so they don’t lose air. [See: Faceplate, Helmet, Pressure Suit.]

**Fusion Power:** Unlike current fission powered nuclear plants, fusion power produces only helium, and very little radioactive waste. Very efficient and using super-abundant fuel, fusion reactors promise inexpensive power for all of society. They are still in development and not currently in commercial use. [See: He-3 Company, Helium-3, Isotope.]

**Gagarin Spaceport:** Gagarin spaceport is an orbiting space station and rocket port named for the first human being in space – Yuri Gagarin. [See: Spaceport, Orbit.]

**Gangway:** A gangway is a flexible, covered ramp that allows passengers to get on or off an airplane or space liner safely. On the Moon these are air tight structures, while on Earth, they are not. [See: Passenger Liner, Spaceport.]
Gantry: A gantry is a large tower that stands next to a space vehicle ready to be launched. Used for boarding, maintenance, and fueling. [See: Passenger Liner, Spaceport.]

Gantry Crane: A large crane attached to a gantry tower. Gantry cranes are used to load cargo, fuel, and to assemble rockets and boosters. [See: Gantry.]

Gassendi Complex: An interconnected set of living quarters, businesses, and schools all dug into the south rim of the Gassendi Crater. Home to Maurice and his family, Gassendi LEX as it is also called, is Maurice’s home town. [See: Burrows, Gassendi Crater, LEX.]

Gassendi Crater: Gassendi is a very large crater north of Mare Humorum with a flat, lava-filled floor. Roughly 110 kilometers wide (70 miles), the rim measures over 350 kilometers around. [See: Gassendi Complex, LEX, Mare Humorum.]

Gassendi Giants: The Gassendi Giants are the team mascot for Gassendi Middle School. [See: Gassendi Middle School.]

Gassendi Middle School: Maurice’s school on the Moon is Gassendi Middle School, home of the Gassendi Giants! [See: Gassendi Giants, Gassendi Complex.]

Geiger Counter: Invented in the first half of the 20th century, the Geiger-Muller tube counts radioactive particles. [See: Gene Therapy, Hard Radiation, Radiation Damage, Radiation Exposure, Shielding.]

Gene Therapy: Gene therapy is a long, but not particularly painful procedure that allows doctors to repair or replace DNA that has been damaged by radiation or certain toxic chemicals. The process is under development, but is considered experimental – not commonly used as a medical practice in our time. [See: Geiger Counter, Hard Radiation, Radiation Damage, Radiation Exposure, Shielding.]

Genetically Engineered: Genetically engineered organisms have had their natural genes (their DNA) altered in a scientific way to make them stronger, healthier, or otherwise superior. This technology has been in use in one way or another since people first began selectively breeding plants and animals over 5000 years ago. [See: Oxygen/Krill Farm.]

Geochemist: A geochemist studies the chemical and physical processes that shape and form rocks and minerals in a planet’s crust. [See: Geology.]

Geology: Geology is the study of the movement, shaping, and evolution of a planet’s crust. Since the word ‘Geology’ technically means “Study of the Earth”, some scientists in Maurice’s time prefer the term Lithology or Lithologist, meaning someone who studies rocks. [See: Geochemist.]

Geyser: A geyser is a natural eruption of water, steam, and other gases caused by volcanic heating. Geysers on other planets and moons are not always erupting water, sulfur and liquid nitrogen geysers are also known. Since the Moon is geologically dead (no volcanic activity exists there), it is impossible to have a geyser on the Moon today.

Gibbous: From a word meaning ‘fat’ or ‘rounded’, this refers to seeing a moon or planet more than half lit by the Sun. [See: Gibbous Phase. Also see: Appendix A—Lunar Orbit and Phases.]

Gibbous Phase: A phase of the moon between full and quarter moon. [See: Gibbous. Also see: Appendix A—Lunar Orbit and Phases.]

Global Positioning System: A series of satellites used to compare and identify your position on the Earth; accurate to within one meter, the system has been in widespread use since the late 20th century. [See: LPS.]

GM Reading: A reading from a Geiger-Muller tube (a Geiger counter) which tells how much radioactivity is present. [See: Geiger Counter, Radiation, Radioactivity.]

GPS: [See: Global Positioning System, LPS.]

Gravitational Aide: Any cane, walker or wheelchair used to help those not ready to handle Earth’s powerful gravity is a gravitational aide. [See: Earth Standard Gravity, Gravitationally Challenged.]

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Gravitationally Challenged: Someone who is gravitationally challenged is not ready for strong terrestrial gravity; they may require a gravitational aide to help them get around. [See: Earth Standard Gravity, Gravitational Aide.]

Habitat: 1. Any structure or shelter that helps keep people alive in a hostile environment is a habitat.
2. The natural environment of any plant, animal, or microorganism. [See: Burrows, Domes, Gassendi Complex, Survival Shelter.]

Hard Radiation: Sometimes called ‘ionizing radiation’, hard radiation will penetrate your body and disrupt molecules inside your cells. Very large molecules like DNA, RNA, and proteins tend to absorb more damage because they are thousands of times larger than smaller molecules found in your cells. Damage to these important molecules can cause cancer and other genetic diseases. Sometimes, if you get enough radiation damage, too many cells in your body will be damaged beyond repair – this can cause severe radiation sickness and even death. These severe cases are very rare, however. [See: Gene Therapy, Radioactivity, Radiation Damage, Shielding.]

Hard Vacuum: A ‘hard’ vacuum is a complete absence of air (or nearly so.) These conditions are found on the Moon and in space. [See: Habitat, Pressure Suit.]

Hatch: A hatch is a door into another part of a ship that can be closed and sealed air and water tight if need be. [See: Passenger Liner.]

HE-3 Mining Company: HE-3 is the mining company that employs Maurice’s parents. A subsidiary of the Consolidated Mines and Petroleum company which owns most of Gassendi LEX and is heavily invested in colonies all over the solar system. [See: Fusion Power, Mining Town.]

He-3 Deposits: Pockets of helium-3 gas trapped inside bubbles in lava and sometimes other types of rock; helium-3 deposits are usually found on the lunar maria. [See: HE-3 Mining Company, Helium Analyzer, Helium Prospecting.]

Helium Analyzer: A helium analyzer is a buggy-portable device that will grind a rock sample to powder and then heat it to release any trapped helium gas; the analyzer then uses a Geiger counter to determine how rich the sample is. [See: He-3 Deposit, Helium Prospector.]

Helium Prospecting: Prospectors typically work alone or in pairs, traveling the vast maria of the Moon, sampling rock and trying to find the next big helium strike. Secretive and suspicious as a rule, prospectors are always wary of someone else trying to steal their claim. [See: Fusion Power, HE-3 Mining Company, He-3 Deposit, Helium Reservoir.]

Helium Reservoir: A particularly large and rich deposit of helium-3 is called a reservoir. [See: He-3 Deposit, Helium-3.]

Helium-3: Helium-3 is a radioactive isotope of helium. Common helium is actually helium-4, with two protons and two neutrons in the nucleus of each atom. Helium-3 is lighter because it has only one neutron per atom instead of two. He-3 is particularly good fuel for fusion reactors which supply clean, efficient power to most of the Earth, Moon, and the outer colonies in Maurice’s time. [See: Fusion Power, HE-3 Mining Company, Helium Prospecting.]

Helmet: Slang for ‘space helmet’, it is an air-tight helmet that locks into a set of rings in a pressure suit. Usually solid except for the faceplate, the helmet provides shielding against impact and radiation. The faceplate is so strong as to be virtually bullet proof, because any crack or break would be fatal. [See: Faceplate, Fittings, Pressure Suit.]

Hemostat: A grasping tool that doctors use, the hemostat looks like a combination between a pair of scissors and a needle-nose pliers. [See: Sterile, Suture.]

Hidden Glaciers: In 1998, the spacecraft Clementine was sent to the Moon on a mapping and prospecting mission. Clementine discovered large amounts of water present at the bottom of perpetually dark craters near the Moon’s south pole. These ‘hidden glaciers’ are believed to be left over from comet impacts, they have survived because these craters deep within the Aitken basin never see sunlight. [See: Aitken Basin, Impact Craters.]
High Jump: High jump is a track and field sporting event. Competitors keep jumping over the bar at ever greater heights until they have missed the same jump three times in a row. [See: All System Track Finals, Lunar Finals.]

Horizon: The horizon is the farthest distance you can see. On a planet, this is limited by the curvature of the surface. On Earth, the horizon is about 50 miles away, on the Moon, the horizon is less than 5 miles away.

Hypodermic Syringe: A tube of medicine with a plunger on one end and a hollow needle on the other. The doctor or nurse uses them to give you vaccinations, allergy shots, antibiotics, etc. The needle lets the doctor inject the medicine under the skin and directly into your body. [See: Antibiotic.]

Impact Craters: Holes in the surface of a moon or planet left over when an object falls in from space are called impact craters. Bodies with no atmosphere (like the Moon) have huge numbers of craters in all sized from microscopic to continent sized. On Earth, our atmosphere burns up most objects before they can strike the surface, so we have relatively few craters. Meteors hit Earth and Moon at speeds averaging 50,000 kilometers per hour! The meteoroid’s great speed causes the explosive impact that makes a crater. Most craters are about 10 times larger than the meteoroid or comet that made them. This means that the asteroid that made the Gassendi crater where Maurice lives was probably about 10 miles wide — about the same size as the one that killed the dinosaurs. [See: Asteroid, Breccia, Ejecta, Ejecta Blanket, Gassendi Crater, Maria, Meteoroid, Rays.]

Insect Larvae: Larvae are immature insects, often called maggots or grubs. Mosquito larvae live underwater; they are fed on blood that female mosquitoes get when they bite you!

Isotope: An atom that is chemically identical to other atoms of its type, but weighs more or less than they do. Isotopes occur naturally, some are radioactive (they give off radiation) others are not. An isotope has a different number of neutrons in the nucleus than is usual for that element. ‘Normal’ helium is helium-4, the isotope of helium Maurice and his father are interested in is helium-3, which has one less neutron than helium-4. Helium-3 is used to power fusion reactors, whereas ‘normal’ helium-4 would not work. [See: Fusion Power, Helium-3, Radioactivity.]

JV Division: JV stands for ‘junior varsity.’ This is a sports division for younger, less experienced players. [See: Track and Field, High Jump.]

K-Beef: A meat product commonly served on the Moon, K-beef is made from krill, tiny shrimp-like creatures common in Earth’s oceans. They are processed, flavored, and textured to resemble beef. K-meats come in chicken, pork, and fish flavors as well. [See: Meatless Diet, Oxygen/Krill Farm, Vegetarian.]

Kilometers: A kilometer is a common metric unit of measure, equal to 1000 meters or about 6/10th of a mile. To change miles into kilometers, divide miles by 0.62. To change kilometers into miles, multiply kilometers by 0.62. [See: Klicks, Metric System.]

Kiosk: A kiosk is a small stand where vendors sell anything from hotdogs to souvenirs.

Klicks: Klick is a slang term for kilometers.

Krill: Krill are tiny, shrimp-like creatures that live in the open ocean and feed on plankton. [See: K-Beef, Oxygen/Krill Farms.]

Lake Catherine: A small lake in northern Illinois; Lake Catherine is part of the Chain ’o Lakes region. [See: Chain ’o Lakes.]

Lamont LaRue: Maurice’s favorite author, Lamont LaRue writes adventure stories set in the Old West. Sorry, Mr. LaRue is a fictional character, so you won’t find Ambush at Coyote Canyon in your local library or bookstore. [See: Ambush at Coyote Canyon.]
**Landing Tax:** Lunar authorities charge all ships a fee to use their landing facilities. The landing tax is usually payable in water or air. [See: *Spaceport.*]

**Latitude:** Latitude is a system of lines on a planet or moon that measure distance north and south of the equator all the way to the poles. [See: *Global Positioning System, LPS.*]

**Lava Beds:** An area where lava has erupted and then frozen into vast layers of rock. [See: *Maria, Lava Types.*]

**Lava Types:** There are two major types of lava: *Felsic Lava* is made mostly of silicates (stone) and has very little metal in it. Felsic lava is generally lighter in weight and color; pumice, a common felsic lava is often used as an abrasive for scrubbing or sharpening tools. *Mafic Lava* is rich in iron, magnesium, aluminum, and other metals. Mafic lava tends to be runny and flows easily down hill; it is darker in color and cools faster than other lavas. [See: *Maria, Lava Beds.*]

**LEX:** [See: *Local Economic Exchange.*]

**Liter:** The liter is a metric unit of volume. You may buy drinks in half-liter to three-liter sizes; one liter is about the same as an American quart. [See: *Metric System.*]

**Local Economic Exchange:** A group of facilities, buildings and living quarters shared by a group of colonists on the Moon is referred to as a LEX. Every person and company contributes to the LEX by investing in the building of the housing, schools, roads, hospitals, air and water plants, etc. In a Lunar colony, the economic health of your LEX controls how well you live – even if you can survive. [See: *Chicagoland LEX, Gassendi LEX, and Schmidt-Sabine LEX.*]

**Longitude:** A system of lines on a planet or moon that measure distance east and west from a line designated as the “Prime Meridian.” On Earth, this line runs through the city of Greenwich, England. [See: *Global Positioning System, GPS, LPS.*]

**Loonie:** An impolite term for someone who lives on the Moon. [See: *Moon Man, Terran, Terrie.*]

**LoPOR:** Low Pressure—Oxygen Rich. LoPOR environments include habitats and suits that are pressurized to about 1/3 normal Earth air pressure. The low pressure is compensated for by making the air richer in oxygen. This allows people to breathe normally and reduces problems due to leaks. LoPOR systems also take 2/3 less gas to pressurize any given volume. [See: *Atmosphere, Air Pressure, Gassendi Complex, Habitat, Pressure Suit.*]

**LPS:** Lunar Positioning System. A system of satellites orbiting the Moon that allow people on the lunar surface to measure their location with great accuracy. [See: *Global Positioning System.*]

**Luna:** Luna is the proper name for Earth’s moon. Technically, the word ‘moon’ refers to any object in orbit around a planet. The name of Earth’s moon is Luna. [See: *Terra.*]

**Luna Net:** The Luna-net is the Moon's version of the internet.

**Luna Flight:** A company that flies passenger space liners from the Earth to the Moon.

**Lunar Buggy:** A buggy is a small, 4-wheel, low power vehicle for carrying up to two people. The buggy has a limited range and cargo capacity, and only moderate climbing ability.

**Lunar Citizen:** A sworn citizen of the Lunar Union. The Lunar Union represents most of the near side and the Aitken basin near the south lunar pole. Most of the far side is still independent with no national affiliation. [See: *Citizenship Day, Lunar Citizenship, Lunar Union.*]

**Lunar Citizenship:** Citizenship in the Lunar Union is not free, it must be bought and paid for by investing in a LEX. Citizenship investment is usually about $100,000 per person. Citizens are expected to be productive and contribute actively to society. The unemployed have very few rights on the Moon because a frontier colony cannot afford to pay for the air and water to keep them alive. There is no such thing as welfare in the Lunar Union.

**Lunar Crust:** The upper 50-150 kilometers of rock forms the lunar crust, the last 5-10 meters have been pounded into dust and crushed rock called regolith. [See: *Impact Craters, Maria.*]

**Lunar Day:** The lunar day is defined as the time from sunrise to sunrise on the Moon, approximately 708 hours. The length of the lunar day also varies significantly due to inconsistencies in the Moon's orbit. Lunar colonies still use Earth time which is based upon a 24-hour day and 365-day year for things like school, work, and business. On the Moon, there is no real match between time of day
and the presence of daylight or darkness outside. Nor is there any match between the time of year and the seasons, because there are no seasons and no weather on the lunar surface. [See: Orbit, Synchronous Orbit.]

Lunar Dust: Lunar dust is part of the regolith layer, the uppermost 5-10 meters of the Moon’s crust. Rocks in this layer have been pounded to dust by meteor impacts from space.

Lunar Escape Trajectory: An escape trajectory is a path in lunar orbit that will take you completely out of the Moon’s gravitational influence. In order to go from Moon to Earth or Mars, you must first take a lunar escape trajectory. [See: Escape Velocity, Orbit, Passenger Liner.]

Lunar Finals: Slang for Lunar Track and Field Finals, this event decides which athletes will represent the Moon in the All System Track Finals. [See: All System Finals, Track and Field.]

Lunar Gravity: Lunar standard gravity is roughly 1/6th that of Earth’s. Low gravity makes everything weigh six times less than it would on Earth. Athletes can perform incredible feats in lunar gravity due to reduced weight. Low gravity causes problems for lunar residents, who must exercise strenuously to keep fit enough to return to Earth one day. If you are lazy in Lunar gravity, you will quickly lose bone mass and muscular strength – so much so that you may be unable to return to higher gravity planets like Mars or Earth. [See: Acceleration Gravity, Earth Standard Gravity, Gravitational Aides, Gravitationally Challenged.]

Lunar Independence Day: The Lunar Union declared independence on the 100th anniversary of the first manned Moon landing; July 20th, 2069. Each July 20th is celebrated as Lunar Independence Day; it is also Citizenship Day for the Lunar Union. [See: Citizenship Day, Lunar Citizenship, Lunar Union.]

Lunar Positioning System: A system of satellites orbiting the Moon that allow people on the Lunar surface to determine their exact location with the help of an LPS receiver. [See: Global Positioning System, Latitude, Longitude.]

Lunar Smoke Signal: Using the spinning wheel of a buggy to throw dust high into the sky where it is visible from great distances and casts huge shadows on the lunar surface. Because the lunar horizon is much closer than on Earth, you cannot see long distances, making search and rescue operations much more difficult. The lunar smoke signal dramatically increases the distance from which you can be seen. Invented by Maurice Haberman, for which he received the Goddard Medal for young inventors. [See: Helium Prospecting, Robert Goddard Medal.]

Lunar Soil: On the Moon, there is no true ‘soil’ as we know it on Earth. True soil consists of minerals, clays, organic matter (decaying plants, etc.), thousands of different microbe species, insects, and other animals. So-called lunar soil is simply a mixture of crushed rock and dust for the most part, and contains no water or organic matter at all. [See: Lunar Crust, Regolith.]

Lunar TV: Maurice and Cassie’s name for old 20th century black and white television shows. They say that the old TV shows look like the lunar surface – black, white, and grey.

Lunar Union: The only declared nation on the Moon. The Lunar Union includes most of the near side and the Aitken basin on the Lunar South Pole. Citizenship in the Lunar Union must be earned; people who qualify must swear an oath of loyalty and productivity in addition to making an investment in their local LEX and banking a year’s worth of water and air. Currently, the total cost of citizenship is about $100,000 per person. [See: Citizenship Day, LEX, Lunar Citizenship, Schmidt-Sabine LEX.]

Lunar Union Flag: Three vertical bars, black, white, and grey, with an image of the lunar near side in the center surrounded by 21, five-pointed stars for the original 21 Apollo astronauts and the 21 states of the Lunar Union. [See: Lunar Union.]

Magellanic Clouds: Two small dwarf galaxies that orbit our own Milky Way galaxy. These bright clouds of stars are only visible in the southern hemisphere of Earth or Moon. They were first reported to European astronomers by survivors of Ferdinand Magellan’s voyage around the world in the 1500’s.
Magnesium: Magnesium is a strong, lightweight metal plentiful on both Luna and Mars. A principle building material on those planets, magnesium also has the property of being flammable! On Earth, it was used in flashbulbs until the late 20th century.

Magnetic Field: Planets with a molten iron core will produce a magnetic field if they rotate fast enough. None of the other inner planets has a significant magnetic field; they either lack a molten metal core or rotate too slowly. This is one of the reasons that Mars and Luna rely on a satellite positioning system rather than traditional magnetic compasses. [See: LPS.]

Mare Cognitum: The Sea of Knowledge, it borders Mare Humorum on the northeast; it is also called the Known Sea. [See: Impact Crater, Lava Bed, Maria.]

Mare Humorum: The Sea of Moisture, Gassendi crater sits on the northern edge of the sea. South Gassendi Complex (where Maurice and his parents live) is part of Gassendi LEX and looks out over this ancient sea. [See: Impact Crater, Lava Bed, Maria.]

Maria: From the Latin word for ‘sea’, a maria is a very large impact crater that actually punctured the crust of the primordial Moon, allowing the impact crater to fill up with lava. This lava is richer in iron and other metals than the rest of the lunar crust and darker in color. The maria are the dark areas you see on the Moon from Earth. [See: Impact Crater, Mare Cognitum, Mare Humorum.]

Martian Gravity: Martian standard gravity is about 1/3rd that of Earth, or about double that of Lunar standard gravity. As on the Moon, people living on Mars must continue to exercise to be able to return to Earth with its higher gravitational pull. [See: Earth Standard Gravity, Lunar Gravity.]

Meatless Diet: On the Moon, soil, air, and water are expensive and hard to come by. Without a ranch environment that provides open space, food, water, air, and soil essentially for free, raising livestock such as cattle, sheep, or pigs is terribly expensive and impractical. Most Lunar colonists eat a diet which is very low in meat products. Most dietary protein requirements come from processed krill-foods and vegetable protein from lentils and beans. The lunar diet is essentially ‘meatless’ as most Earth people would consider it. There are some animals raised for food on the Moon, but only species that take up little space, air, or water and eat most everything that people throw away are kept. Rats and chickens are the most common animals raised as livestock on the Moon. [See: K-Beef, Oxygen/Krill Farm, Rat Dogs, Vegetarian.]

Meteor: A piece of space debris in the process of entering a planetary atmosphere. When a bit of space debris hits the air at speeds from 15,000 to 70,000 kph, it immediately heats up and begins to glow brightly. On Earth, we see these streaks of light across the night sky and call them ‘falling stars’ or meteors. While in space, the object is a meteoroid or asteroid; once on the ground, the object becomes a meteorite. Most meteors burn up at an altitude of 15-40 miles above Earth’s surface, few leave any trace on the ground. Atmospheres protect planetary surfaces from impacts from space by burning up most meteors in this way. It would be virtually impossible for any rock smaller than a school desk to penetrate the atmosphere and strike the Earth’s surface without burning up. On the other hand, planets and moons without any atmosphere have no protection, so there is never a meteor streaking across the sky on an airless world like Luna. [See: Asteroid, Meteorite, Meteoroid, Micrometeorite, Regolith.]

Meteoroid: A piece of space debris orbiting the Sun is called a meteoroid. After an object enters a planet’s atmosphere, it may be incinerated in a short, brilliant streak we call a meteor. If any pieces survive the difficult passage through the atmosphere, they are called meteorites. [See: Asteroid, Meteor, Meteorite, Micrometeorite, Regolith.]
and professionals. The United States is the only country in the world that still uses the old
‘English’ system of measuring in yards, inches, and pounds, etc. [See: Kilometer, Meter.]

Micrometeorite: A microscopic particle that has survived impact with a planet or other object.
Micrometeorites cause wear and surface pitting of objects in Earth orbit and on the lunar surface.
[See: Impact Crater, Meteorite.]

Milky Way: Our home galaxy is called ‘the Milky Way.’ You can see it arch across the sky in fall and
winter months if you have dark skies and a clear view. [See: Magellanic Clouds.]

Millennia: The plural of millennium, thousands of years.

Mining Town: A town focused on one essential industry. The company that owns the industry not only
employs the people of the town, but owns the housing the workers rent and runs the grocery and
other stores where the workers buy food and other supplies. [See: HE-3 Mining Company,
Gassendi LEX, LEX.]

Mole: A quantity of measure commonly used in chemistry. One mole is about
600,000,000,000,000,000,000,000 atoms or molecules. A mole of water is about enough to make
one ice cube. [See: Oxygen.]

Moon Dust: Dust made from rocks and lava that has been crushed and pounded by meteoroid impacts from
space. Moon dust is also part of the regolith layer of the Moon. [See: Ejecta, Impact Crater,
Regolith.]

Moon Man: A slang term for a lunar citizen or other person who makes their permanent home on the
Moon. [See: Loonie, Terran, Terrie.]

Moss Mower: A small, hand-held mower used to trim moss that is grown in homes all over Luna for the
oxygen it produces.

National Lunar Track Team: A team of students from 6th to 12th grades who compete in track
and field events at the All System Finals. [See: All System Track Finals, Track and Field.]

Near Side: The side of the Moon that always faces the Earth. This happens because the Moon is lop-sided
(the side nearest the Since you can’t see one when wearing a pressure suit, they are not worn by
Moon men except for special formal occasions like the Citizenship Earth is heavier.) Eventually,
the ‘heavy side’ ended up pointing ‘down’ or toward the Earth all the time so the Moon now
rotates on its axis in the same amount of time it takes for the Moon to go around the Earth. This is
called Synchronous Rotation. [See: Far Side, Synchronous Rotation.]

Near Side News: The largest print and electronic news service in the Lunar Union. NSN has a
circulation of about 1.5 million readers / viewers daily.

Necktie: An antique item of men’s clothing. A colorful piece of cloth, ritually tied around the throat with a
knot facing forward. Day ceremonies.

Neo: Latin for ‘new’, the word neo is an impolite term for someone who has just arrived to your planet;
often used for people who are having trouble adjusting to different gravity and atmosphere.

O. K. Corral: Maurice’s name for the oxygen/krill farm where his mother works. [See:
Oxygen/Krill Farm.]

O₂: Oxygen gas. [See: Atmosphere, Mole.]

Oath of Loyalty: Similar to the American Pledge of Allegiance, the oath of loyalty is given to all
people who want to become official citizens of the Moon on Citizenship Day. [See: Citizenship
Day, Lunar Citizenship, Lunar Union.]
Observation Deck: The part of a space liner with a clear plastic roof where travelers can look out and see the broad vista of space. Originally developed for passenger trains, they still prove to be popular today. [See: Passenger Liner.]

Oceanus Procellarum: The Ocean of Storms. The largest maria on the lunar surface; located northwest of Humorum and Gassendi Crater. [See: Impact Crater, Maria.]

Odor Scrubber: A special filter designed to remove odors from recirculated air, they are in use in submarines and other closed environments. Odor filters require periodic cleaning to function properly. [See: Air Quality Management, Scrubbers.]

§ O'Hare Air and Space Port: The interplanetary port for air and space travel, it is located outside Chicagoland LEX on the site of the old O'Hare Airport. [See: Spaceport.]

Orbit: A curving path in space around a planet or star. The gravitational pull of the planet or star keeps your ship or satellite—even your planet—from flying off into space. While in orbit, objects are always falling (really!) and so objects appear ‘weightless’, this is not true ‘zero-gravity’, but it is true weightlessness. In fact, you couldn’t orbit a planet without gravity; if a planet’s gravity suddenly disappeared, all its satellites and moons would fly off into space—a real disaster! [See: Satellite, Spaceport.]

Orbital Escape Acceleration: The final burst of speed needed to get you free from a planet’s gravity and send you on your way to another moon or planet. [See: Escape Velocity, Passenger Liner.]

® Oxygen/Krill Farm: A hydroponic farm (everything grows in water instead of soil) that is a self-contained ecosystem of plants and animals. The animals, tiny shrimp-like creatures called krill, produce carbon dioxide and feed off the plants and each other. The plants, tiny one-celled creatures called algae and plankton, produce oxygen and consume carbon dioxide. Humans (like all animals) need oxygen to survive. Green plants produce oxygen as part of their natural life processes. Without plants to replenish our supply, all the oxygen in Earth’s atmosphere would be lost within a few years. Surplus oxygen produced by the plankton is harvested for human use. The larger krill species are also harvested for protein that is processed to resemble beef, chicken, and other meats. [See: Atmosphere, K-Beef, Meatless Diet, OK Corral.]

Palm Lock: A modern door lock that reads the finger and palm prints from your hand. No losing your key with this lock!

Parts Per Billion: A measure of very dilute concentrations. If the helium-3 concentration is 50 ppb (parts per billion), that means that one billion tonnes of ore would yield only 50 tonnes of helium-3. [See: Helium Analyzer.]

Passenger Liner: A space transport for taking passengers from Terra to Luna and back again. Very similar to a modern passenger jet, crowded, noisy, and the food is terrible! [See: Orbit, Spaceport.]

Phase of the Moon: The portion of the sunlit Moon that can be seen from Earth. Phases are: new moon, waxing crescent, first quarter (this is actually a half-lit Moon), waxing gibbous, full moon, waning gibbous, last quarter, waning crescent, and new moon again. [See: Crescent, Gibbous, Waning, Quarter Moon. Also see: Appendix A – Lunar Orbit and Phases.]

Pit: The padded area where jumpers land in track and field competition. Used in high jump, long jump, pole vault (Earth only), and other events as well. [See: High Jump, Track and Field.]

Polar Orbit: An orbital path that takes a ship or satellite over the north and south polar regions, as opposed to around the equator. [See: Lunar Escape Trajectory, Orbit.]

Polaris: The star closest to the north celestial pole. Also called the ‘North Star’, every star in the northern sky appears to turn around Polaris. If you live in the northern hemisphere, and you can find the North Star, you always know what direction you are going. [See: Constellation.]

PPB: [See: Parts Per Billion.]

Pre-Dawn: The time on Earth before the sun comes up and the sky begins to get brighter. This effect is caused by Earth’s atmosphere catching sunlight and bending it around the curve of the planet’s...
horizon. Pre-dawn brightening of the sky does not happen on the Moon, due to its lack of atmosphere. On the Moon, dawn arrives like flipping on a light switch. [See: *Atmosphere.*]

**Pressure Suit:** An air-tight suit complete with gloves and helmet that allows you to go out on the airless surface of the Moon safely. Pressure suits contain heating and cooling technology that helps to protect you against extreme temperatures on the lunar surface and radiation shielding to protect you against hard solar radiation. Since there is no air on the Moon to carry sound, the suits must also have a communications system, or com-system, sort of a built-in walkie-talkie. The suit must also carry all your air and water (you can’t just take your helmet off and get a drink from the water fountain, can you?). Because you carry all these supplies with you, the pressure suit’s backpack is rather large and bulky, fortunately, lunar gravity makes them easy to carry! Pressure suits must also be very tough; a rip can be fatal! Everyone carries a ‘rip kit’ with glue and an oxygen sensitive bandage that changes color to let you know you’ve sealed the leak completely. [See: *Atmosphere, Habitat, Helmet, Faceplate, Fittings, LoPOR, Safety Bandage, Suit Discipline.*]

**Pristine:** A completely natural state. Untouched by man.

**Procellarum:** One of the states of the Lunar Union, also the name of the largest maria – Oceanus Procellarum – the Ocean of Storms. [See: *Lunar Union, Maria.*]

**Procellarum Invitational:** A major track and field meet for students on the Moon. It is held in Schiaparelli LEX each summer – almost 1500 kilometers north of Gassendi LEX. [See: *All System Track Finals, Lunar Finals, Track and Field.*]

**Prospecting:** The ancient art of searching out valuable ores in the soil and underground. Prospecting has been a human activity for at least 5000 years, probably longer. On the Moon, prospectors look for metals, water, and helium-3 deposits. [See: *Helium Prospecting.*]

**Protein:** A very large molecule made of amino acids; proteins are assembled by DNA in animal cells (some plant cells, too.) Proteins are the main components of muscle tissue and meat. Your body needs plenty of protein to grow strong muscles as well as other organs and tissues in your body. On the Moon, most food protein comes from processed krill, although there is some ranching of both chickens and rats for food as well. [See: *K-Beef, Krill, Meatless Diet, Oxygen/Krill Farm, Vegetarian.*]

**Quarter Phase:** The phase of the Moon that is less than half-lit as it is seen from Earth. Sometimes called a ‘young moon’ or even ‘fingernail moon’, it occurs just before and after the new moon. [See: *Crescent, Gibbous. See Also: Appendix A – Lunar Orbit and Phases.*]

**Radiation:** Naturally occurring, high-speed particles and rays that come from unstable isotopes of atoms as they decay. Radiation also comes from fusion processes such as the process that powers our sun. Because radiation is a natural part of our environment, all plants and animals on Earth have evolved to handle small amounts of radiation without ill effects. Even your own body is naturally radioactive and gives off very small amounts of natural radiation! Earth’s thick atmosphere, ozone layer, and magnetic field all screen out harmful radiation before it reaches the surface of the Earth. The Moon has no such natural protection, so anyone living or working there must put living quarters underground and wear foil layers in their clothing to protect them from harm. Being exposed to excess radiation can cause cancer and other diseases. In Maurice’s time, people can get ‘gene therapy’ from their doctor to correct most damage caused by excess radiation. [See: *Gene Therapy, Isotope, Pressure Suit, Radiation, Radioactivity, Shielding.*]

**Radiation Damage:** Not all radiation is harmful to humans; some types of radiation will not even penetrate your skin, other kinds (low energy ultraviolet) helps your skin make vitamin-D and keeps you healthy. You have probably had radiation damage at some point in your life – the kind we call sunburn! As you know, your body heals this minor damage very well on its own. [See: *Gene therapy, Hard Radiation, Isotope, Radiation, Radioactivity, Shielding.*]
Radioactivity: The natural emission of energy and particles from decaying atoms. Radioactive decay, as it is also known, happens when an unstable nucleus of an atom kicks out energy and particles in order to become a smaller, more stable atom. As odd as it seems, this process makes one element change into another! Radioactive uranium, for instance, always decays into lead after a succession of radioactive changes. [See: Fusion Power, Isotope, Radiation, Radiation Damage.]

Rat-Dogs: Hot dogs made from rat meat. Not much different from our hotdogs on Earth where pork, beef, turkey, and chicken hot dogs are all available. Rat meat is commonly referred to as 'scurry', just as pig-meat is referred to as 'pork' and cow meat is called 'beef'. [See: Meatless Diet.]

Regolith: The outermost layer of the lunar surface, the regolith is a layer made of crushed rock, sand, gravel, and dust. It was created by four billion years worth of impacts from space crushing and remixing the upper surface rock. In most places, the regolith is from 2-10 meters deep. [See: Impact Crater, Lunar Dust, Meteor, Meteorite, Rays.]

Relative Humidity: A measure of how dry or moist the air is. Technically, relative humidity is the ratio of the amount of water vapor in the air divided by the total amount of water vapor the air could carry at that temperature and pressure. Lunar environments tend to be very low humidity, just like any desert environment on Earth. [See: Atmosphere.]

Rip: A catastrophic and life threatening tear in a pressure suit. If your suit tears and you do not fix it quickly, you will lose all your air and die. A cry of "RIP!" is an emergency call for immediate help. [See: Pressure Suit, Safety Bandage, Spacing.]

Robert Goddard Medal: A medal awarded to students on the Moon for exceptional skill in inventing new technology or new uses for existing technology. The prize includes the medal itself and a one-year scholarship to the Lunar University of choice. [See: Lunar Smoke Signal.]

Roll Maneuver: A controlled rolling over of a ship in space. Sometimes used to properly orient a ship for accelerating or braking when entering or leaving orbit. [See: Lunar Escape Trajectory, Passenger Liner.]

Safety Bandage: A safety bandage is a special bandage that goes on the outside of your pressure suit to seal a rip. The bandage goes on white, and then turns blue as it hardens and seals your pressure suit. The safety bandage is also oxygen sensitive; and it will turn bright orange if your suit is still leaking oxygen. [See: Pressure Suit, Rip, Spacing.]

Satellite: Any object in orbit around another body in space. Planets are satellites of the Sun, just as moons are satellites of various planets. Artificial satellites were conceived in the 15th century by Johannes Kepler, who discovered the laws of planetary motion. The first artificial satellite of the Earth was Sputnik I, launched by the Soviet Union (Russia) in October of 1958. By the beginning of the 21st century, Earth had hundreds of artificial satellites, as did Venus, Mars, Jupiter, and Saturn. [See: Orbit, Space Station.]

Schmidt-Sabine LEX: The capital of the Lunar Union, also the state capital of Tranquilitatus. [See: LEX, Lunar Union.]

Scratch: A term from track and field competition meaning a missed jump because of a technical foul or disqualification. [See: Track and Field.]

Scrubbers: Chemical filters designed to pull certain impurities from the air without removing useful components. CO2 scrubbers chemically remove carbon dioxide from the air, leaving useful oxygen and nitrogen untouched. Scrubbers must be replaced regularly, failure to do so can lead to a visit from the AQ Police, a fine, or even death if the problem is not fixed quickly. Everyone takes scrubber maintenance seriously on the Moon! [See: Air Quality Management, Atmosphere, Carbon Dioxide.]

Sea of Moisture: Also called Mare Humorum, the Sea of Moisture is one of the Moon's smaller maria; Humorum is also one of the states of the Lunar Union. Gassendi LEX, where Maurice and his family live, is the state capital of Humorum. [See: Impact Crater, Lunar Union, Maria.]
Shedd Aquarium: A major aquarium and museum located in Chicago, Illinois. Shedd is one of the oldest public aquariums in the United States. [See: Chicagoland LEX.]

Shielding: A layer of material intended to stop radiation. Some radiation has very low penetrating power, clothing or skin will stop most alpha and beta radiation. Other radiation, called ‘hard radiation’, is made of gamma rays, x-rays, or even cosmic rays. Hard radiation can penetrate many meters of rock or metal; this radiation is dangerous to people, as well as damaging electronics and weakening most materials. Lunar habitats are built underground; most are formed in burrows dug out of crater rims, allowing many meters of lunar soil and rock to act as shielding for the people inside. Pressure suits on the Moon and Mars are also lined with metal foils to help limit personal exposure. [See: Burrows, Habitat, Ionizing Radiation, Pressure Suits, Radiation, Hard Radiation.]

Solar Panel: A panel that produces electricity when light shines on it. Typically, solar panels are not very efficient, but they are attractive because they are non-polluting, light weight, and do not require any fuel or other resources than sunlight to generate electric power. Solar panels are also fragile, damage from impacts or micrometeorites can reduce their electrical output or disable them altogether. [See: Lunar Buggy.]

Soldier Field: A sports stadium in Chicagoland LEX, originally built in the mid-1900’s, Soldier field is still used in Maurice’s time for major sporting events like the All-System Track and Field Finals. [See: All-System Track Finals, Track and Field.]

South Gassendi Complex: A large group of homes and businesses burrowed into the south rim of the Gassendi Crater, home to Maurice and his family. [See: Gassendi Crater, Gassendi LEX.]

Southern Cross: A constellation of stars near the south celestial pole. [See: Constellation.]

Spaceport: A spaceport is similar to today’s airports, but with take-off and landing facilities for orbital transports and other space craft. Some are combined transportation hubs, like the O’Hare Air and Space Port in Chicagoland. Kennedy Spaceport in southern Florida was the world’s first spaceport. [See: Aldrin Spaceport, Gagarin Spaceport, O’Hare Air and Space Port, Space Station.]

Spacing: Exposing someone or something to vacuum, spacing is also used to describe leaving an airlock without a helmet or removing your helmet in vacuum conditions. [See: Air Pressure, Pressure Suit, Rip, Safety Bandage.]

Space Station: A large installation in permanent orbit around a planet or moon. The International Space Station, also known as Space Station Alpha or the ISS, is currently orbiting the Earth and under construction. [See: Gagarin Spaceport, Space Station Alpha, Spaceport.]

Space Station Alpha: A large space station and docking port in high Earth orbit. The ISS is used as a transfer point between deep space and Earth’s surface as well as an experimental platform for current scientific work. [See: Spaceport.]

Speed of Light: The speed of light in a vacuum is the fastest possible speed in the Universe. Light, radio, television signals, and radiation from the sun are all forms of light (also called electromagnetic radiation.) These light waves travel 300,000 kilometers per second (186,000 miles per second.) In one minute, a flashlight beam travels 11.2 million miles; in one year, light will travel over 6 trillion miles. This is still less than 1/4th the distance to the nearest star. The speed of light also affects the time delay when talking to someone on the Moon (or another planet.) The communication delay to the Moon and back is about 3 seconds; this represents the time between ‘How are you?’ and ‘I’m fine!’ Communication delays to Mars run between 6 and 45 minutes! [See: Three Second Delay.]
Sterile: Sterile items are germ free; no life of any kind can exist in a sterile area. The presence of any type of life makes an object or area non-sterile. The term sterile usually refers to being free of microorganisms. [See: Antibiotic.]

Strewn Field: An area where meteorites have landed on the ground is a strewn field. On Earth, strewn fields are often created when a meteor breaks up in the atmosphere, scattering pieces over a wide area. On the Moon, strewn fields occur because a meteorite explodes on impact, scattering debris in every direction. This is technically called an ejecta blanket. [See: Ejecta, Ejecta Blanket, Impact Crater, Regolith, Rays.]

Strike: 1) A place where a meteorite has hit the surface of a moon or planet, creating an impact crater. 2) The discovery of a deposit of valuable ore or minerals. [See: Helium-3 Deposit, Helium Prospecting, Prospecting.]

Sub-Crater: A small crater that was made inside of, or overlapping a larger one. [See: Impact Crater, Maria.]

Suit Discipline: The regular routine of checking your suit before you go out on the lunar surface. Suit discipline also refers to cleaning and replacing scrubbers, air and water supplies to make sure your suit is in working order before you go out. [See: Air Pressure, Apathy, Pressure Suit, Spacing.]

Survival Shelter: A self-inflating dome about two meters in diameter that allows a wounded or stranded traveler on the Moon or Mars to eat and drink without a helmet. A survival shelter generally contains enough air, water and food to provide 48-72 hours. [See: Habitat.]

Suture: A strong, sterile, surgical thread that doctors use to sew bad wounds closed – also called ‘stitches’. Synchronous Orbit: A natural process that occurs when a satellite slows its own rotation enough so that the same side of the satellite always faces the planet it orbits. Like all natural objects, moons and asteroids are not perfectly balanced; over time, the heavier side will come to rest perpetually facing the home planet. If the planet is large (strong gravitational field) or if the satellite forms in orbit around the home planet, the process happens more rapidly. For Luna, its rotation time to spin on its axis and its revolution time around the Earth is the same – 27.3 days. This means Luna has a far side that never faces Earth as well as a near side that never turns away from Earth. There are many examples of synchronous rotation in our solar system. [See: Far Side, Near Side, Orbit.]

Terminator: The line between light and darkness on a planet’s surface. The line moves as the planet or moon rotates on its axis in space. People standing on the terminator are experiencing either sunrise or sunset. [See: Appendix I – Lunar Orbit and Phases.]

Terra: The proper Latin name for Earth. [See: Earthman, Terran, Terrie.]

Terrans: A term for people who live on (or are loyal to) the Earth. The impolite form of this word is Terrie. [See: Loonie, Terra, Terran.]

Terrestrial: On, part of, or having to do with the Earth. Terrestrial planets or terrestrial gravity, for example.

Terrie: The impolite way to refer to someone living on, or loyal to, the Earth. [See: Loonie, Terran.]

Three-Second Delay: The time delay between speaking and hearing a reply when telephoning someone on the Moon from Earth or vice-versa. [See: Speed of Light.]

Track and Field: A series of athletic competitions that emphasize running and jumping. [See: All System Finals.]

Tram: A low-speed transport for carrying people and luggage; often used where there are large parking lots such as at airports and amusement parks.

Tranquility Base: The site of the first manned lunar landing by Neil Armstrong and Edwin ‘Buzz’ Aldrin on July 20th, 1969. Also the first place any human had set foot on another world. [See: Apollo Monuments, Schmidt-Sabine LEX.]

Trans-System Trajectory: A path that takes a ship from Earth to the Moon or vice-versa. [See: Escape Velocity, Passenger Liner.]
Twilight: The time of day when the sun has set, but the sky is not yet dark. Twilight occurs because the Earth’s atmosphere bends light around the curve of the planet. Twilight occurs immediately after sunset or before dawn and can last up to an hour. This effect only occurs on planets with atmosphere, such as Earth and Mars. Twilight never occurs on the Moon because there is no air there to create it! [See: Atmosphere, Terminator.]

Tycho Crater: A large and recently formed crater on the Moon. Tycho was formed well after the maria and most cratering took place. Tycho is only a few tens of millions of years old! [See: Ejecta, Impact Crater, Rays, Tycho’s Rays.]

Tycho’s Rays: Rays are dusty streaks left on the lunar surface after the creation of a crater. Because the Moon has no atmosphere to scatter and suspend dust in clouds, the dust from the explosion travels in straight lines for thousands of kilometers. The dust is deposited in straight lines that may be many kilometers wide, but only a few millimeters thick. These dusty streaks reflect more light than surrounding, older dust and show up as bright lines radiating away from the crater. Tycho’s rays can only be seen within a day or two of the full moon; since the rays are too short to cast shadows, they cannot be seen at any other time. [See: Ejecta, Ejecta Blanket, Impact Crater, Rays.]

Tycho’s Rim South: A LEX that is built into the south rim of the crater Tycho. [See: LEX.]

Ultraviolet: A type of sunlight or solar radiation. Ultraviolet rays can cause damage to skin, resulting in sunburn or even skin-cancer. Earth’s atmosphere shields all life there from excessive UV radiation. On the Moon, homes built into the ground or covered with soil perform the same function. Lunar clothing has foil layers inside the fabric to give the same protection when you are outdoors. [See: Gene Therapy, Ionizing Radiation, Radiation, Radiation Damage.]

Ursa Majoris: Latin for ‘the Great Bear’, Ursa Majoris is a constellation in the northern sky. In America, it is known as the ‘Big Dipper’, while in England and much of Europe, it is known as ‘the Plough’. [See: Constellation.]

Vegetarian: Someone who doesn’t eat meat. On the Moon, this also means someone who restricts themselves to K-products such as K-Beef, which is made from krill. [See: K-Beef, Krill, Oxygen/Krill Farms, Meatless Diet.]

Videophone: Similar to our present-day telephone, except with a camera and screen on each end. You can see the other person talking and listening to you. [See: Three Second Delay.]

Waning: 1) Getting smaller, shrinking. 2) Refers to the phases of the Moon between full and new where the Moon’s lighted portion visible to the Earth is shrinking day by day. [See: Appendix I—Lunar Orbit and Phases.]

Water Futures: Similar to stocks, bonds, and commodities traded on Earth. Water futures are a way for people to invest their money in the water market. [See: Copernican Stock Exchange, Water Stocks.]

Water Reclamation: Comprehensive water recycling. Water from every human and industrial use is recycled, even wet trash such as food scraps would have water reclaimed from it.

Water Stocks: Investments in companies that buy, sell, treat, distribute, and reclaim water. [See: Copernican Stock Exchange, Water Futures.]

Waxing: Growing larger or increasing in size. Waxing phases of the Moon occur between new moon and full moon when the lighted portion of the Moon is getting larger as seen from Earth. [See: Appendix I—Lunar Orbit and Phases.]

X-Radiation: A powerful ionizing radiation, strong enough to penetrate the human body and do damage to internal organs. Medical uses of x-rays use ultra-low doses of x-rays that are not harmful, but uncontrolled exposure to x-rays on the lunar surface can be far more dangerous than
ultraviolet rays because the x-ray has much greater penetrating power. [See: Gene Therapy, Ionizing Radiation, Radiation, Radiation Damage, Shielding.]

X-Rays: [See: X-Radiation.]

Zero Gravity: Being in free-fall. Technically, there is no zero gravity location anywhere in our solar system because the Sun’s gravity affects everything in our solar system! In free-fall, everything in your ship is falling at the same rate, therefore you experience no force of gravity pulling you ‘down’ in one direction or another. Objects seem to float and appear weightless, but zero-gravity does not affect inertia, or how difficult it is to stop or start an object moving. An asteroid hitting the Moon in free-fall is ‘weightless’, but not massless: it still has tremendous inertia that does the work of carving out the impact crater. [See: Acceleration Gravity, Orbit, Passenger Liner.]

Zero-Gee: A slang term for zero gravity. [See: Zero Gravity.]
Appendix C: Test and Survey Instruments

Student Pre-program Survey

Student Number: _________

Read each statement carefully, then circle the number below that tells how you feel about that statement. Answer as honestly as you can. No one will know which survey was yours, and no one will see your individual answers.

For each statement: 1 = Strongly disagree, 2 = Somewhat disagree, 3 = neutral or “don’t know”, 4 = Somewhat agree, 5 = Strongly agree.

1. I enjoy going to school each day.  
   1 2 3 4 5

2. I like the way science was taught in my school last year.  
   1 2 3 4 5

3. I like the way math was taught in my school last year.  
   1 2 3 4 5

4. I enjoy using math to solve problems.  
   1 2 3 4 5

5. I am a good problem solver.  
   1 2 3 4 5

6. Math is more understandable when I’m solving a real-life problem.  
   1 2 3 4 5

7. I can think of more than one way to solve a tough problem.  
   1 2 3 4 5

8. I have mastered multiplication and division.  
   1 2 3 4 5

9. I have mastered fractions and decimals.  
   1 2 3 4 5

10. I have a strong command of algebra.  
    1 2 3 4 5

11. Math was my worst class last year.  
    1 2 3 4 5
12. Science was my worst class last year.

13. I like to read.
Student Post-program Survey

Student Number: _________

Read each statement carefully, then circle the number below that tells how you feel about that statement. Answer as honestly as you can. No one will know which survey was yours, and no one will see your individual answers.

For each statement: 1 = Strongly disagree, 2 = Somewhat disagree, 3 = neutral or “don’t know”, 4 = Somewhat agree, 5 = Strongly agree.

1. I enjoy going to summer school each day.
   1  2  3  4  5

2. I like the way science was taught in summer school.
   1  2  3  4  5

3. I like the way math was taught in summer school.
   1  2  3  4  5

4. I enjoy using math to solve problems.
   1  2  3  4  5

5. I am a good problem solver.
   1  2  3  4  5

6. Math is more understandable when I’m solving a real-life problem.
   1  2  3  4  5

7. I can think of more than one way to solve a tough problem.
   1  2  3  4  5

8. I have mastered multiplication and division.
   1  2  3  4  5

9. I have mastered fractions and decimals.
   1  2  3  4  5

10. I have a strong command of algebra.
    1  2  3  4  5

11. Math was my worst class last year.
    1  2  3  4  5
12. Science was my worst class last year.
13. I like to read.
14. I will do better reading and discussing books in English class next year because of the work I did this summer.
15. I enjoyed reading *Maurice on the Moon*.
16. My reading skills have improved this summer.
17. My vocabulary has improved this summer.
18. My math skills have improved this summer.
19. My science skills have improved this summer.
20. I will tell others to take the Summer Science Enrichment program next year.
Maurice on the Moon – Pre / Post Test

Multiple Choice
*Identify the letter of the choice that best completes the statement or answers the question.*

1. Examine the diagram above: What is illustrated here?
   - a. A lunar eclipse
   - b. The sun is in conjunction with the Moon
   - c. A solar alignment
   - d. A solar eclipse

2. What is the orbital period of the Moon?
   - a. 27.3 days
   - b. 33.8 days
   - c. 29.5 days
   - d. 25.6 days

3. The Earth has a radius of 6000 km, what is its approximate circumference?
   - a. 18,840 km
   - b. 1911 km
   - c. 37,700 km
   - d. 12,000 km
4. Examine the drawing above. When the Moon is in the position shown, what phase would we see from Earth?
   a. Gibbous Moon
   b. Quarter Moon
   c. Full Moon
   d. Crescent Moon

5. Some gases, like carbon dioxide, trap solar heat and cause the air to get warmer. What is this process called?
   a. The greenhouse effect
   b. Atmospheric carbon loading
   c. Solar heating
   d. Natural gas heat

6. Examine the diagram above: Which letter represents the 5.2° tilt of the lunar orbit?
   a. Letter J
   b. Letter V
   c. Letter X
   d. Letter R
7. How can you tell the Moon isn’t flat?
   a. You can see different sides of the Moon if you watch steadily day to day
   b. The Moon could not have phases if it were flat
c. We didn’t know this for certain until we flew spacecraft around the Moon in the 1960’s
d. You have to use 3-D glasses for that

8. Magnification in a telescope trades:
   a. brightness for magnification
   b. information for clarity
c. magnification for clarity
d. aperture for brightness

9. What is a meteor?
   a. A bit of matter burning up in the atmosphere as it strikes the Earth
   b. A piece of iron or stone left over on the ground from a ‘shooting star’
c. A piece of rock or ice floating in space
d. A hole in a planetary surface left over from an impact from space

10. How long would it take for a flashlight beam to reach the Moon?
    a. light reaches the Moon instantly, it doesn’t take any time at all.
    b. 10 seconds
c. 1.5 seconds
d. light from a flashlight could never reach the Moon, it is much too weak to go that far.

11. What is an isotope?
    a. If two atoms of an element have different numbers of neutrons - then they are isotopes
    b. Any atom with neutrons in the nucleus is an isotope
c. An atom with NO neutrons in the nucleus is an isotope
d. Any radioactive atom is an isotope

12. Examine the diagram above. What kind of telescope is shown here?
    a. A Galilean telescope on a dobsonian mount
    b. A Newtonian telescope on a dobsonian mount
c. An equitorial telescope on a Newtonian mount
d. A reflector telescope on an equitorial mount

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13. A heavy object, such as a bowling ball, tends to resist changes in motion; it is difficult to speed it up, slow it down, or change its direction of travel. What do we call this resistance to change in motion?
   a. inertia c. mass
   b. weight d. momentum

14. The size of the primary lens or mirror that gathers light for a telescope is called the:
   a. opening c. diameter
   b. aperture d. apparatus

15. What shape is common to every natural orbit for planets, moons, and asteroids?
   a. circular c. elliptical
   b. oval d. eccentric

16. How did the ancient meteor impact actually kill the dinosaurs?
   a. Dust and smoke from the impact blocked the sun for decades freezing the Earth and disrupting the food chain. Without plant life, most dinosaurs starved to death.
   b. The impact created a crater so large that most of the world’s shallow seas drained into it (this is now the Pacific Ocean). This dried the climate, destroying the dinosaurs on land.
   c. Scientists now believe that an early ice-age killed the dinosaurs. The meteor hit at the same time, but really had nothing to do with their extinction.
   d. Radiation from the impact killed many dinosaurs and mutated the rest into birds and mammals we see today.

17. A telescope gathers light into a single point - this point of light is called:
   a. The point c. The focus
   b. Information d. The primary

18. Why are astronauts weightless when they are in orbit around the Earth?
   a. Earth’s gravity stops when you leave the atmosphere c. The astronauts in orbit are in free-fall and cannot feel their own weight
   b. The astronauts are too far away from Earth for its gravity to work d. The pull of the Moon’s gravity cancels the Earth’s pull while you are in orbit

19. If you and a friend were in pressure suits exploring the Moon, and your radio went dead, how could you talk to each other?
   a. There is no way you could communicate except to use hand signals c. Open your helmet very quickly and shout
   b. Yelling loudly enough inside your helmet would let your friend hear you d. Touch your helmets together - the sound would travel through the plastic shell

20. If you throw a ball straight up in the air, what factors control how high it will go?
   a. how fast it moves and how smooth its surface is c. how long you push upward on the ball and the air temperature at the time
   b. only the speed of the ball makes any difference to the height d. how fast the ball is moving and the strength of Earth’s gravity
21. The Moon is 385,000 kilometers away from Earth. If you flew there in a space liner at 40,000 kilometers per hour (the minimum speed needed to escape Earth’s gravity!) how long would the trip take you?
   a. just over one day  
   b. 10 days  
   c. about 9.6 hours  
   d. over 95 hours

22. Examine the diagram above: What event is represented here?
   a. A lunar transition  
   b. Partial solar eclipse  
   c. Solar eclipse  
   d. Lunar eclipse

23. What is the actual cause of sunburn?
   a. Ultra violet radiation from the sun damages cell tissue (and DNA) in your skin.  
   b. Too much sunlight causes your blood vessels to expand, making your skin feel tight and hot to the touch.  
   c. Heat from the sun builds up in the skin and causes a burn - similar to holding your hand too near a hot stove for a long time.  
   d. X-rays and gamma radiation from the sun damage cell tissues (and DNA) in your skin.

24. How old is the Moon?
   a. at least 10 million years  
   b. over 4 billion years  
   c. at least 100 million years  
   d. over 500 million years

25. If there is too much carbon dioxide in the air you breathe (more than 4%) it is deadly. How is this gas naturally removed from the atmosphere on Earth?
   a. Burning (such as forest fires) removes carbon dioxide from the atmosphere  
   b. Carbon dioxide gas naturally becomes part of the rocks  
   c. Plants remove carbon dioxide from the air as they grow  
   d. Many animals inhale carbon dioxide, removing it from the air as they breathe
26. If you could see the Earth from the lunar surface, how would it compare to our view of the Moon?
   a. The Earth would look the same size as the Moon, but would be a colorful blue
   b. The Earth would appear almost identical to the Moon, a small, grey ball in the sky.
   c. The Earth would appear 4x larger than the Moon, with oceans and continents easily visible
   d. Earth would be more than 10x larger than the Moon in our skies, even small cities and roads would be easily visible

27. What is a pressure suit and why is it an important garment for space exploration?
   a. A pressure suit protects people who work in high pressure environments
   b. all of these are true
   c. A pressure suit controls the air pressure inside a spacecraft
   d. A pressure suit protects people from the airless vacuum of space

28. Examine the diagram above: Which letter represents the Moon in the Full phase?
   a. Letter J
   b. Letter R
   c. Letter M
   d. Letter K

29. Why is lunar sunshine so different from Earth sunshine?
   a. Lunar sunshine is much hotter than on the Earth
   b. Lunar sunshine includes deadly radiation that Earth’s atmosphere filters out
   c. Earth’s atmosphere adds color to sunshine on our planet (this is why the moon appears mostly black and white)
   d. There is no difference between sunshine on the Earth and on the Moon

30. What are the brighter areas on the lunar surface called?
   a. bright lands
   b. craters
   c. highlands
   d. maria

31. Why do meteors burn as they enter the atmosphere?
   a. Meteors are combustable like charcoal
   b. Meteors ionize the air they pass through, producing a glowing light
   c. Friction with the air heats the meteors to thousands of degrees, destroying them
   d. Meteors don’t burn, they just get hot and glow slightly
32. What is the rotational period of the Moon?
   a. 29.5 days  
   b. 27.3 days 
   c. 24.7 days  
   d. 28.6 days 

33. A student who weighs 120 pounds on Earth travels to the Moon. How much will they weigh on the Moon?
   a. 120 lbs  
   b. 20 lbs  
   c. 60 lbs  
   d. 240 lbs 

34. Why does the Moon appear to move across the skies on Earth each night?
   a. The Moon’s apparent motion is an illusion, it actually doesn’t move at all  
   b. The Moon appears to move because the Moon orbits the Earth 
   c. The Moon appears to move because the Earth moves around the sun 
   d. The Moon appears to move across the sky because the Earth spins rapidly on its axis 

35. The lunar surface changes temperature by 500 °F as it goes from day to night - why doesn’t Earth’s surface change that much?
   a. Air and water absorb much of the sun’s energy, keeping our temperature more steady 
   b. It does, but only at the equator  
   c. Earth gets only a fraction of the sunlight that reaches the Moon 
   d. Because Earth’s diameter is 4x larger than the Moon, our surface heats up only 1/4 as much as the Moon’s does 

36. When the sun goes down below the horizon, it takes almost an hour for the sky to become completely dark. How can you explain this?
   a. Sunlight reflects off of high clouds and shines down for awhile, even after the sun has actually dropped below the horizon 
   b. The Earth’s atmosphere acts like a lens and bends the light around the curve of the Earth 
   c. All of these are true  
   d. The sunlight travels along the Earth’s surface for awhile before the air absorbs it completely 

37. Which of these is NOT a real lunar phase?
   a. gibbous  
   b. quarter  
   c. garrolous  
   d. crescent 

38. Why does the Moon speed up, and then slow down in its orbit around the Earth?
   a. Luna speeds up as it moves closer to Earth and then slows down as it moves away, due to Earth’s gravity 
   b. Luna slows down due to atmospheric drag when it gets closer to the Earth, and then speeds up again as it moves farther away 
   c. Luna is slowly speeding up as it moves closer to Earth each year, but it never slows down 
   d. Luna is speeding up as it gradually moves away from the Earth each year, but it never actually speeds up 

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39. Plant life requires carbon dioxide gas to live - where does this essential gas come from?
   a. All of these are sources of carbon dioxide gas
   b. Volcanoes produce carbon dioxide
   c. Chemical reactions between ocean water gas and rocks produce carbon dioxide
   d. animals produce carbon dioxide as they breathe

40. Why do we only see one side of the Moon from Earth?
   a. the Moon never actually rotates on its own axis in space
   b. it is because we live in the Northern hemisphere, the Southern hemisphere sees the other side of the Moon
   c. the Moon rotates once in 27.3 days, the exact amount of time it takes to go around the Earth once
   d. all of these are true

41. Animals on Earth need oxygen to survive - where does this essential gas come from?
   a. The Earth’s entire atmosphere is oxygen
   b. Oxygen comes from chemical reactions in the Oceans
   c. Oxygen is produced by green plants
   d. Oxygen comes from volcanoes

42. Why does the Moon suffer hundreds of times more impact craters than the Earth?
   a. The Earth gets just as many craters as Luna, our weather just erases them
   b. Luna is Earth’s “outer defense shield” blocking most meteors from space
   c. Earth’s atmosphere vaporizes most meteors before they can create impact scars on Earth
   d. The moon attracts most meteors before they hit the Earth

43. What are the two major types of lava?
   a. continental and oceanic
   b. liquid and solid
   c. metallic and silica based
   d. red and black

44. Examine the diagram above. The primary mirror is represented by Letter _____.
   a. letter W
   b. letter T
   c. letter Z
   d. letter R

45. Which of these two lunar periods are equal?
   a. rotation and revolution
   b. rotation of apsides and rotation of nodes
   c. rotation of apsides and precession
   d. revolution and solar day
46. How long is a solar day on the Moon (sunrise to sunrise)?
   a. 96 hours - exactly 4x Earth   c. 24 hours - just like Earth
   b. over 700 hours               d. 36 hours

47. Examine the diagram above. What does letter Z represent?
   a. The azimuth control          c. The RA setting circle
   b. The secondary mirror        d. The focuser and eyepiece

48. How long is a solar day on the Earth (sunrise to sunrise)?
   a. 23 hours 56 minutes          c. 24 hours
   b. it depends on the time of year d. 12 hours

49. What is the first thing that happens when carbon dioxide mixes with water?
   a. The water becomes more caustic (less acidic)  c. The water volume expands to make room for the dissolved gas
   b. The water becomes more acidic                 d. The water begins to evaporate rapidly

50. How were the craters on the Moon made?
   a. they are ancient lake beds    c. all of these are true
   b. they are old volcanoes       d. they are places where meteorites and asteroids have hit the Moon
Maurice on the Moon – Pre / Post Test
Answer Section

MULTIPLE CHOICE

1. ANS: D
   General Knowledge Question
   This diagram shows the Moon’s **umbra**, or dark shadow crossing the surface of the Earth, creating a total solar eclipse.

2. ANS: A
   The siderial orbital period averages 27.3 days -- 360 degree rotation around the Earth as seen from space.

3. ANS: C
   Circumference = \(2 \pi R\) or approximately 37,700 km

4. ANS: A
   To determine phase, draw a line through the centers of the two bodies (Terra and Luna), then draw a second line, perpendicular to the first through the Moon’s center. This reveals the phase to be **gibbous**

5. ANS: A
   General Knowledge Question
   All atmospheric gases trap heat to a greater or lesser degree. Carbon dioxide is somewhat more efficient at this than oxygen or nitrogen, resulting in the epithet “greenhouse gas”. This is much more a political term than a scientific one.

6. ANS: B
   General Knowledge Question
   Letter-V shows the angle of the lunar orbit.

7. ANS: B
   The Moon’s round shape and orbital motion around the Earth combine to produce phases

8. ANS: A
   Magnification is accomplished at the expense of brightness and limits light to the eye

9. ANS: A
   Meteors are burning objects in the atmosphere - they last only seconds

10. ANS: C
    At the speed of light, the Moon is just 1.5 seconds away. Communication by radio between Earth and Luna suffers from a 3-second delay, time for the signal to go out and back to the Moon.

11. ANS: A
    General Knowledge Question
Isotopes are atoms with identical Z-numbers (same # of protons, or same 'element'), but different numbers of neutrons (different atomic masses). The change in neutron # leaves chemical properties identical, but changes nuclear properties, especially stability and radioactivity.

12. ANS: B
This is a Newtonian reflector telescope on a Dobsonian Alt-Az mount.

13. ANS: A
A resistance to a change in the state of motion is called *inertia*. Inertia is a property of *mass*. The effect of gravity on mass is called *weight*. The product of mass and velocity for an object in motion is called *momentum*.

14. ANS: B
The diameter of the primary lens or mirror is the *aperture*.

15. ANS: C
Kepler’s first law of planetary motion.

16. ANS: A
**General Knowledge Question**
The 100-million megaton Chixulub impact created a ‘nuclear winter’ scenario. 95% of the biomass on Earth was burned, producing large volumes of smoke, ash, and dust which was lifted into the stratosphere, where it blocked the sunlight for up to a millenia. The extreme cold that followed the burning times disrupted the food chain and lowered atmospheric oxygen, destroying almost all large species on Earth.

17. ANS: C
Light gathers at the *focus*, from the Latin term for “burning place”.

18. ANS: C
Free fall creates weightlessness in orbit. This is also described as ‘Geodesic free float’ by John Wheeler. What we call ‘weight’ is actually a body’s resistance, or inability to follow its local spacetime geodesic.

19. ANS: D
Sound waves are the mechanical vibration of air molecules, creating pressure and density differences in the atmosphere. No air - no sound waves!

20. ANS: D
Newtonian mechanics (gravitation) \[ h = \left(\frac{v^2}{2g}\right) \]

21. ANS: C
\[ \frac{385000}{40000} = 9.6 \]

22. ANS: D
**General Knowledge Question**
The Moon is about to travel through the Earth’s shadow (first penumbra, then umbra, then penumbra again!), creating a lunar eclipse.

23. ANS: A
UV-a and UV-b rays (longer and shorter wavelengths, respectively) damage large molecules in the skin's dermis layer; including proteins, cell walls, capillary vessels, and of course, DNA. The body shunts additional blood to the skin to speed healing, causing swelling (skin tightness) and the feeling of heat that we experience with mild sunburn.

24. ANS: B
Radio dating from Apollo samples indicates the Moon is at least 4.2 billion years old. It was created when a Mars-sized planet (sometimes referred to as Nemesis) impacted the Earth in the later period of planet formation.

25. ANS: C
Animal respiration adds CO₂ to the atmosphere; while photosynthesis removes carbon dioxide from the air and ‘fixes’ this carbon into plant tissue, principally cellulose and related molecules. Fixed carbon can be liberated back to the atmosphere by digestion/respiration or combustion.

26. ANS: C
Earth's radius is 4x larger than Luna's, and if seen from the same distance would appear 4x larger than Luna does in our skies.

27. ANS: D
A pressure suit maintains normal atmospheric pressure in airless environments such as space or the lunar surface.

28. ANS: B
Full phase occurs when the Moon is on the opposite side of the Earth from the Sun. This occurs at point-R in the diagram above.

29. ANS: B
Earth's atmosphere acts as a filter, blocking deadly X-rays and Gamma radiation.

30. ANS: C
Highlands tend to be richer in aluminum and magnesium (light colored metals and ores), compared to the basaltic rock of the maria, which are rich in iron (dark colored metal and ore).

31. ANS: C
General Knowledge Question
Atmospheric friction causes the meteoroid to slow from an average speed of 40,000 kph to 500 kph (freefall terminal velocity in air) in less than 5 seconds for most meteors. This lost kinetic energy is turned into heat, vaporizing virtually all meteors less than 1-meter in diameter before they strike the Earth. Meteoroids < 1m constitute more than 99.9% of all such objects to strike the Earth.

32. ANS: B
The moon's rotational period is exactly the same as its orbital period because the moon is tidally locked in a synchronous orbit around the Earth.

33. ANS: B
Lunar gravity is 1/6th of Earth's.

34. ANS: D
Most of the Moon’s motion across the sky each night is due to Earth’s rapid rotation (30x faster than the Moon’s orbital speed). The Moon’s own orbital motion accounts for the difference in rise and set time we see each night, and for the phases of the Moon we see in the sky.

35. ANS: A
The heat capacity of water is primarily responsible for keeping temps steady on Earth. The Cp-value of water is 5-10x higher than that of soil or rock.

36. ANS: B
atmospheric refraction - air acts as a lens to bend light beyond the horizon, or terminator creating twilight. The Moon, lacking any atmosphere, has no twilight, sunrise and sunset are effectively instantaneous.

37. ANS: C
“Garrolous” is not a phase

38. ANS: A
Kepler’s second law of planetary motion

39. ANS: A
**General Knowledge Question**
All these sources produce atmospheric carbon dioxide, in addition of course, to industrial processes.

40. ANS: C
**General Knowledge Question**
Synchronous rotation, the Moon’s orbital period is identical with its rotational period on its axis

41. ANS: C
Photosynthesis produces oxygen as a waste by-product

42. ANS: C
Luna lacks an atmosphere. Earth’s atmosphere vaporizes 99.9% of impactors before they strike the surface. Erosion also erases craters over millions of years, but this effect is much less important to the actual number of craters on the surface.

43. ANS: A
**General Knowledge Question**
Mafic lava is metal rich, low viscosity and gas poor (similar to the lava that flooded the lunar maria). Felsic lava is rich in gas, but poor in metals, highly viscous and explosive, such as that which caused the Mt. St. Helen’s disaster in 1980.

44. ANS: D
The primary mirror rests in the end of the telescope tube opposite the focuser and eyepiece. This is shown as Letter-R above.

45. ANS: A
The moon is locked in a synchronous orbit where rotation and revolution are equivalent

46. ANS: B
The lunar rotation period is 27.3 days, resulting in a solar day = 29.5 Earth-days, or approximately 708 hours. Due to the Moon’s extensive libration (orbital wobble), the length of the lunar day would vary by as much as 12 hours from one solar day to the next. This complex effect ties in with the Moon’s synchronous orbit about the Earth.

47. ANS: D
   Letter-Z in this diagram represents the focuser and eyepiece of a ‘Dobsonian’ mount, reflector telescope.

48. ANS: C
   Earth’s solar day is always 24 hours

49. ANS: B
   Carbon dioxide + water = carbonic acid

50. ANS: D
    Virtually all craters are from impactors. This hypothesis was first presented by the University of Ireland in the 1950’s, it was not generally accepted until after the Apollo missions of the 1960’s and ‘70’s proved the point beyond doubt.
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Introduction:

Back in the last millennium when I was a boy, I used to watch a lot of science fiction shows on TV, and read every sci-fi story I could get my hands on. The news of the day was hardly less fantastic than the stories and programs I watched by the hour. We were reaching for space; brave men climbed aboard towering rockets and blasted into orbit for the first time in history. The Mercury and Gemini programs led to Apollo 11, and the first men set foot upon the Moon in 1969. Reality had outstripped fantasy; science fiction had become science possible, and I wanted more.

If I couldn’t get to the Moon myself, I at least wanted a book that would take me there and show me what it would be like on the day after tomorrow, when families would live and work on the Moon. After waiting 35 years for that book, I realized I would have to write it myself. I was a bit more ambitious than NASA, though. I didn’t want to put a few men on the Moon, I wanted to put a whole nation there – and I wanted to make it real.

Everything about the Moon and its surface that you read in this book is as true and accurate as I could make it. The crater called Gassendi where Maurice lives lies on the north edge of a frozen sea of lava called Mare Humorum or ‘The Sea of Moisture’. If you go out on a clear night when the Moon is mostly full, you can see the sea and its giant crater with any small pair of binoculars. The same goes for the other locations like the Sea of Tranquility and the double crater Schmidt-Sabine. I don’t think there’s such a place as the Buzz Aldrin Memorial Spaceport yet, but I’m sure that there will be someday. And yes, Maurice, there really was an astronaut named Buzz who walked on the Moon with Neil Armstrong!
I think it is time for us to get used to the idea of people living and working in space and on other planets in the solar system – and time to stop listening to people who say it isn’t possible. My generation invented an entirely new technology, went to the Moon, walked around and came back with some really cool rocks, and loads of scientific information. It was a fun trip and we learned a lot, but we’ve been back home for a long time. Now we must return to the Moon and learn to live there permanently. We will need someone smart, tough, creative, and adventurous – I think you’re just the person for the job.

It is your generation that will explore the Moon and start the first colonies there. You will be pioneers, like your grandparents and ancestors before you. You are the people your own great grandchildren will brag about and do book reports on. You will establish the new outposts of civilization on the high frontier… and Maurice will be one of your children. As for me, well, I’ll see you on the Moon!

Daniel Barth
Gassendi LEX,
January, 2006
Chapter 1:

**Stowaway**

Maurice crouched by the chairs and peered down the hallway. There were a dozen different people in sight, some pushing large trolleys of luggage, others carrying a small bag, or nothing at all. One or two of them may have noticed a young boy in a pressure suit so dusty, you couldn’t tell what color it used to be. But Maurice was a boy many people would not look at twice. He had grey eyes and a round face without a single freckle and was as pale as a cave dweller. He wore his brown hair short, because there was no such thing as a good hair day in a space helmet. People tended to overlook Maurice as just another skinny kid in a pressure suit – until he got one of his wild ideas.

“Okay, it’s my turn. We’ll do three jumps this time.” Maurice grinned wickedly at Cassie, and pointed down the concourse. “First jump is that old guy over there with the briefcase, then across the hall and jump over the lady in the pink pressure suit pushing the trolley... the long way.”

“You’re crazy, Maurice,” said Cassie. Cassie was even skinnier than Maurice, and at least five centimeters taller. Her black hair was cut short like a boy’s and her green eyes flashed whenever her parents or teachers would speak to her about dressing or acting more feminine.

“I may be a girl, but I won’t be a girly-girl!” she would declare. Cassie had one feature that made most of the girls in her class jealous; dark skin. On the Moon, sunlight was considered deadly radiation. With no atmosphere overhead, lunar sunlight was full of ultra-violet light, x-rays, and even gamma rays. No one on the Moon exposed themselves to the sunlight, so everyone’s skin tended to get paler over time. Everyone it seemed, except Cassie. If Cassie’s dark skin make the kids at school envious, her
friendship with Maurice did not. Nearly everyone thought Maurice was crazy. Today, like most days, Maurice was doing what he could to prove them right.

Maurice grinned at Cassie, “The third jump is over that row of chairs into the lounge area.”

Cassie shook her head, “If someone sees us, we’ll have to jump out again. Could be tough.”

“You chicken?” Maurice smiled again; Cassie hated to be called a chicken.

Cassie grinned back, “No way, let’s go on three!”

Maurice nodded, “One... two... three!” The pair sprinted off toward the old man in the conservative grey pressure suit. He heard their pounding feet and saw them coming right toward him.

“What the?” The old man put his briefcase up to protect himself.

“First jump!” cried Maurice as he and Cassie leapt up and over the old man easily.

“Come on, faster!”

The woman in the pink jump suit had seen the two kids leap over the old man and realized they were headed in her direction. She tried to maneuver her large luggage trolley out of the way, but the wheels were balky and didn’t turn very well. “Oh, my!” She crouched down behind the trolley’s handle the best she could.

“Second jump!” Cassie whooped as she cleared the luggage trolley.

“Young hooligans!” the woman shouted, shaking her fist at the pair.

“Head for the chairs!” Maurice shouted.

By now, the commotion in the concourse was considerable and people who had been sitting comfortably in the chairs that separated the concourse hallway from the...
lounge began to get up and move away quickly. Many of them had seen the pair bounding over innocent passengers and had no desire to be the next human hurdle.

None of the passengers getting off the liner and walking slowly into the lounge had any idea of what was going on. A large man carrying an awkward, old suitcase bounced on his heels and laughed giddily.

“Look at this, Victor, I bet I don’t weigh more than 30 pounds!” The man laughed and took an experimental hop, then a higher one, and another. “Whoa!”

“Watch out, Alexi!” cried his friend, who was pointing to a Port Authority Officer in his blue pressure suit and badge. None of that mattered; it was too late. The stranger was going too fast and couldn’t stop. Maurice was approaching from around the corner and could not see the man coming. The two met in mid-air and crashed. The big man sprawled into the officer, spilling his suitcase all over the two of them in the process. Being half his size, Maurice caromed off, bouncing to a stop in the middle of the concourse hallway.

The officer pushed the big man off, and sat up without realizing there was a pair of purple underwear draped over his hat. He scowled fiercely at the big man sitting next to him.

“No running or jumping in the concourse, sir.” said the officer coldly, pointing to a sign that showed a jumping figure in a circle with a red slash through it.

“Sorry, officer!” stammered the man. “It wasn’t me; that young kid crashed into me!” The man pointed across the concourse hallway where Cassie was pulling Maurice to his feet.

“Hey!” the officer yelled. “You kids come here!”

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Cassie yanked on Maurice’s arm, “Let’s go!” She ran off laughing with Maurice in pursuit.

The Port Authority man moved to get up and follow the children as they ran off down the hall.

“Officer, wait! Those are mine!” The big man pointed at the policeman’s hat.

“What?” He felt atop his hat and produced the pair of purple underwear. “Ugh!” By the time the ugly purple shorts were removed and tossed back to their owner, Maurice and Cassie were nowhere to be seen.

The two fugitives raced to the end of the long hallway and thumped into the giant observation port window. The pair slumped to the ground panting for breath; Cassie started to snicker and couldn’t stop laughing.

“Well, I guess you won that game!” she chuckled. “If you get five points for jumping over one person and fifteen points for jumping that lady and her luggage, just how many points do you get for crashing into some old geezer and then knocking him into a spaceport cop?”

“With or without the purple underwear on his hat?” Maurice asked. They both laughed again. Maurice let his gaze travel up and out the observation window to the beautiful blue Earth hanging in a velvet black sky. Since the same side of the Moon always faced the Earth, the blue globe of Earth just hung in the lunar sky, unmoving. Everyone arriving on the Moon was stunned when they saw it for the first time; the brilliant Earth in the black lunar sky was five times larger than the little silver Moon they were used to on the Earth. It usually took visitors a little while to realize that the Earth didn’t drift across the sky here, like the Moon did back on Earth.
Maurice looked for awhile, and then sighed, "It must be a beautiful day down there."

"Yeah, I guess so." Cassie replied. Cassie and Maurice had been friends since the fourth grade at Crater Rim Elementary. They liked to look up at the home planet and imagine going outside without a pressure suit and helmet on, smelling the air and rolling on the grass.

Maurice had been born on Earth where the tremendous gravity of the home planet helped his bones develop strong and straight. His parents had brought Maurice to the Moon when he was just two years old. He didn't remember Earth at all, but Maurice had read everything he could lay his hands on about the home planet. Cassie didn't always understand Maurice's obsession with Earth. Since her father was an engineer, who traveled to Earth and back again fairly regularly, Cassie had made several trips to the Earth. It was always humid and generally too hot or too cold for comfort. Mostly, it was crowded and smelled bad all the time. Cassie was happy that her parents had decided to make their permanent home on the Moon, even if her father did have to travel a lot for his work.

Maurice looked out the window at the brilliant blue and white globe in the northwestern sky. The Earth hung in the same place as it always did. Spinning on its axis and revealing continents, oceans, deserts and even glowing cities on the dark side.

The lit portions of the globe were almost cloudless today. Maurice could make out the coast of South America almost to the tip of Tierra del Fuego at the southernmost end, and a slice through the middle of North America that ran up through northern Canada.
“Cool! Look, Cassie, you can see the Rocky Mountains. Dawn in the Old West,”
Maurice sighed, “I wonder what Hector Wrathburn would be doing right now?”

“Jeez, Maurice! Hector Wrathburn is a guy in a book. Did your dad give you
another one of those Larraby LaGrange novels?”

“His name is Lamont LaRue, why can’t you get it straight, Cassie? Dad gave me
Avalanche on Apache Mountain last week!” Maurice pulled out his ever-present book
player. “See, it’s all about this prospector—”

“Hey look, that must be Los Angeles!” said Cassie, cutting him off. The city on the
edge of the Pacific was still in darkness. A large, glowing spider web of light connecting
San Diego to the south and San Francisco to the north outlined the edge of the Pacific
Ocean.

Maurice reached out and traced the coast of North America with his finger. “It
must be almost dawn there. It sure would be weird seeing the sun come up and go down
every single day, huh?”

Cassie shrugged, “The sun comes up and goes down here on the Moon, Maurice.”

“Yeah… once a month, anyway.” Maurice sighed. He glanced briefly up at the sun
through the tinted glass. It was mid-afternoon today on the Moon, the sun would not set
for another four days or so, and Maurice wouldn’t get to see the dawn until early next
month. Because of the Moon’s slow rotation, it took over seven hundred hours for the
Moon to turn once on its axis. The Earth spun almost thirty times faster, turning once
every 24 hours. One sunrise and one sunset per month was all you got on the Moon.

Maurice had often watched the Earth spinning in space, envying dawns and sunsets
that arrived each day like clockwork; a place where the sun, moon, and stars all sped
across the sky. The idea of a rapidly spinning world fascinated Maurice; he liked to track
the movements of oceans and continents across the lighted portion of the globe and the
spider-web glow of cities as they moved across the Earth’s dark side. The Earth was
almost a quarter million miles away and looked just about close enough to touch... if you
could only jump high enough.

Maurice tore his eyes away and looked out across Aldrin Spaceport to where the
sleek passenger liners and blocky orbital freighter ships stood ready for launching, the
kids all called this place ‘Buzzport’, but neither Maurice nor Cassie really ever believed
that there was a real astronaut with the name ‘Buzz’.

Maurice looked out across the passenger terminal; most of it was dug into the north
rim of the Gassendi crater. From the outside, you would never know it was there except
for a couple of dinky service domes. The spaceport concourse was busy, just like any air
or spaceport on Earth. There were hundreds of people hurrying different directions to
catch flights or pick up passengers or cargo. This was Maurice and Cassie’s favorite
place to hang out after school.

“Come on, let’s go see if the passenger liner’s boarding.”

“Yeah,” said Cassie, “maybe we can see it take off before we have to go home for
dinner.”

The pair bounded off down the corridor taking long leaps and watching for security
officers who would kick them out of the spaceport for sure if they saw them fooling
around; especially after all the excitement earlier.

“Watch this!” Cassie leapt up and over a large woman and her luggage cart with a
whoop.

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“Knock it off!” hissed Maurice. “Everybody’s going to be watching for someone jumping over passengers now! You want to get us kicked out before I even have a chance?”

Cassie looked closely at Maurice. “A chance for what?”

“Um, to see the liner take off, of course!” Maurice ran off down the hall toward the boarding area again to avoid any other questions.

Maurice and Cassie fetched up against the railing separating the real passengers from the families and others who were there just to wave goodbye. Maurice watched all the people getting ready to board very closely.

“Man, I can’t wait ‘till I get to go back again someday,” Cassie sighed.

“You’re always complaining about how rotten it was after you get back,” Maurice grumped. “I think Earth must really bring out the girl in you.”

“Knock it off, Maurice,” Cassie warned.

Maurice sensed Cassie’s irritation and continued teasing her. “If Earth makes you all whiney like a girley-girl… whoa!”

Cassie was a member of the judo club at school and an expert in low-gravity wrestling. She had grabbed Maurice by his helmet ring and his belt and hoisted him easily over her head. In the low lunar gravity, Maurice weighed just 17 pounds, about the same as a year-old infant on Earth.

“Hey! Lemme down!”

“Who’s squeaking like a girl now, Maurice?”

“You there, put that boy down!” It was one of the port authority police, yelling at them from across the concourse.
Cassie reluctantly set Maurice on his feet again, but punched him in the arm for good measure. It didn’t make much of a dent through the stiff pressure suit fabric.

“You’re such an idiot sometimes, Maurice.”

Maurice pointed at the crowd waiting to board the space liner. “I just want to be where they are, Cassie. I just want to go to Earth.”

Cassie shrugged and patted his shoulder, “Don’t worry, Maurice. You’ll get there someday.”

Maurice smiled. “Well, Dad always says that luck never just happens, you have to make your own.” He opened the small gate into the passenger area and stepped through. “I’ll send you a vid from Earth, Cassie!”

“Maurice!” Cassie hissed; her eyes went wide as she saw her friend get in line behind a family with twin squalling babies and two other children besides. The father was fumbling for all the tickets while the gate agent frowned at the screaming babies. One of the babies spat up on him, which made him frown even more.

“Here we go!” said the man, handing the agent a hand-full of tickets and passports.

“Yeah, ok, go ahead,” grumped the agent, who was very anxious to have the two screaming babies out of his way. He didn’t notice that he had only six tickets while seven people walked past him onto the gangway.

Once inside the gangway, the family moved to the access hatch of the ship and stepped inside. The babies were still howling; more than ever if that was possible.

“Can I have a window seat?” whined the little girl.

“No, I get the window seat!” shouted her brother.
“Don’t worry,” said the steward, “the ship isn’t very full today, I’m sure you can all spread out and have window seats if you want.”

Maurice smiled to himself, he really had picked the right day. He was going to Earth! Maurice made his way down the ladder to find a compartment near the engines. He had heard that these seats were quite noisy and not very popular. He wanted to get away from the family and find a seat, and then pretend to be asleep until they were well clear of lunar orbit.

Pulling aside the curtain, he saw two chairs wedged in a small closet-like space. “Man, this is tiny!” Maurice said to no one in particular. Once he climbed into the seat and fastened his seat belts, the chair automatically rotated backward until Maurice was flat on his back in the best position for takeoff. The butterflies were doing orbital maneuvers in his stomach now. As hard as it was to close his eyes, Maurice had to pretend to be asleep if this was going to work.

“Maurice Haberman?” The voice was tiny, but seemed to be coming closer.

Maurice closed his eyes even tighter. The curtain that separated his little space from the hallway slid aside. “Maurice Haberman?”

“Um?” said Maurice.

“Oh! You are on board!” The steward smiled at him. “You’re really not supposed to come on board to say goodbye to anyone, you know. We’re going to take off in just a few minutes; you have to get off the ship right away!”

“Sorry,” Maurice mumbled. “I was just pretending I was flying to Earth and I must have fallen asleep.” Maurice gave the steward a toothy smile and hoped it didn’t look as fake as it felt.
“Your sister is worried sick. We better get you off right away!”

Sister, eh? Maurice arched an eyebrow, “Right.” He sighed as he moved to follow the steward back up the ladder to the hatchway. When they reached the end of the gangway, Cassie was waiting for him, looking worried.

“I found your brother for you,” said the steward, looking from Maurice’s pale face to Cassie’s dark one, and then back again. “He... um, doesn’t look very much like you.”

“Adopted,” Maurice almost spat. “I told the folks it was a huge mistake, but they never listen to me.”

Maurice and Cassie glared at each other. “Come on, Maurice. Our folks will be waiting for us.”

The steward patted Maurice on the head. “Bye now, come fly with us again some day,” he said just a little too sweetly.

“Sure,” Maurice said. He glared at the steward for treating him like a dumb kid, and then he scowled at Cassie again. “Thanks a bunch.”

At the airlock, Maurice and Cassie finished fastening their helmets in silence, and prepared to go outside and catch the tram back to Gassendi Crater Complex where they both lived and went to school.

When they were outside, Cassie keyed her helmet-com and turned to Maurice.

“I swear, Maurice, you’re dumb enough to sit in a sunny window. Stowing away on a space liner? Are you CRAZY!?” Cassie shouted. The curved faceplate of her helmet magnified her face a little, making her look even angrier than she really was.
"Me crazy!" Maurice shouted back. "If you hadn't interfered, I'd almost be breaking orbit by now! That's the only 'liner this month that makes a direct flight to the surface of Earth instead of stopping off in orbit first. I could've been on my way!"

"On your way? On your way without me, you mean! You didn't even tell me you were planning this dumb stunt!"

"I didn't tell anybody, Cassie!"

"Not even your best friend?"

The rumble could not be heard, but both kids felt it beneath their feet. It stopped their argument cold. They turned together and watched the graceful passenger liner climb out over the domes of the spaceport on an almost invisible column of silent flame and head out to space – and the Earth. The ship looked so close, Maurice wanted to throw a rock and knock it out of the sky. He felt a tear begin to slide down his cheek inside his helmet. Since he couldn't wipe it off, Maurice kept his face turned away from Cassie all the way home.
Chapter 2: Life on the Frontier

The tram slowed to a stop, Maurice moved to get off.

"I'll see you Monday... ok?" Cassie asked.

Maurice shrugged his shoulders, but didn't turn back toward Cassie. "Guess you made sure of that, alright."

He hopped off the tram and headed for the orange and white airlock set into the stark hillside of the Gassendi crater rim. Like most of the Gassendi Complex, this apartment block was built into the hillside to protect it from radiation and micrometeorites. With no atmosphere to screen out damaging rays, the Sun's ultraviolet and X-radiation were many times stronger than what people on Earth received. Instead of a hundred and fifty kilometers of air, people on the Moon used 10-15 meters of soil and rock to screen out harmful radiation. Some of the windows Maurice could see glowed softly with light. Every window on the Moon was deeply set into the side of a hill or covered with a strong magnesium awning to protect against punctures from meteorites. There weren't any windows facing east or west either. The direct sun was more than hot enough to start a fire inside, not to mention the radiation exposure. Calling someone 'dumb enough to sit in a sunny window' was a common expression at school.

Near the airlock, there was a chalkboard where Maurice saw his name.

'Maurice, come and see me at work if you have enough air. Love, Mom.'

Maurice checked his wrist display and trudged off along the rim roadway toward the O.K. Corral, where his mother worked. The O.K. Corral, as Maurice called it, was actually the Oxygen/Krill farm, station #28. His mother had her office there and was in
charge of 18 such stations along the rim, which produced over 70% of the oxygen, and protein-based food needs for the greater Gassendi Complex itself.

Maurice could make out the brilliant maze of green tubes that emerged from the lunar soil on the crater rim hillside and ran along above the surface for a time before diving back into the lunar soil again. It was a complete ecosystem in a tube, which was pumped around in a big circle once every 24 hours.

Maurice was very proud of his mother and her important job as chief ecologist. Ruth Haberman kept the whole ecosystem balanced. What Nature did effortlessly back on Earth required deft management and tireless effort here on the Moon.

Maurice stepped into the airlock and closed the door. He felt the pressure change as the air hissed into the lock and removed his helmet when the indicator said 2/3 atmosphere. Almost all environments on the Moon were low pressure, oxygen rich or LoPOR environments. It took only 2/3 as much gas to fill any given living space with low pressure air.

The lock cycled, and opened. The interior spaces of the farm were very dimly lit with pale red lights.

“Hello, Maurice!” His mother’s voice came out of the darkness. She soon followed and stepped into the circle of red light.

“Hi, Mom.” Maurice gave his mother a hug and submitted to a kiss on the cheek.

“How was your day?”

“It was ok. Cassie and I went down to Buzzport for awhile after school.”

“I’m glad you had a good day.” She reached into a nearby tank and pulled up a large plastic sack. “Here, I want you to take these home right away while they’re fresh.
We’re having a special dinner tonight.” She handed Maurice a clear plastic bag filled with seawater and dozens of thumb-sized shrimp.

“Real meat?” Maurice held the bag up and peered into it, poking the shrimp through the plastic with his finger. “Cool!” Maurice was excited; most of the meals on the Moon were vegetarian. Growing your own food was simply much cheaper than importing it from a quarter million miles away. Meat once or twice a week was considered living very well in most circles on the Moon.

The O/K farm workers harvested krill of all sizes and processed them for protein. The protein could be shaped, textured, and flavored any way you liked. There was krill-beef or K-beef as it was known, along with K-chicken, K-pork, and even K-salmon. Many long-time lunar residents were squeamish about eating food that once walked around. “Our Beef Never Said ‘Moo’!” was the popular slogan of one fast food chain here.

Maurice squinted at his mother through the plastic bag as if it were a lens; squeezing it and making her change shape as she talked.

“Your father and I have a surprise we want to share with you.”

“Like what?”

“You’ll see.” She leaned forward and kissed him on the cheek again. “On your way, now, and straight home, please!”

Maurice sighed and rolled his eyes. “Go straight home, watch your air, and don’t dawdle along the way.”
His mother smiled at him and took his helmet from his hand. “That’s right.” She fitted it over his head like she used to do when he was little, twisted it until it snapped home, and sealed his pressure suit. She double checked the fittings.

“How’s your air?” She took his arm and checked his wrist display. Maurice pulled his arm back.

“It’s fine, Mom. Really.”

“Maurice, you have to be careful...”

“I know, Mom! Why, just last week, the Dorkleson boy, Jeb, took off his helmet to spit his tabaccy juice and spaced his self, so you best be careful!” Maurice mocked her and rolled his eyes dramatically. He stopped short when he saw his mother’s hands on her hips.

“Ok, I know.... Suit discipline saves lives.”

“That’s right, Maurice. Apathy kills.” She arched an eyebrow and eyed him carefully. “Straight home, please. And put those shrimp right in the refrigerator.”

“Yes, Ma’am.”

Maurice carried his bag of shrimp down the hall. He peered inside the bag and poked it experimentally.

“C’mon, ‘lil doggies! Time to hit the trail for home.” He stepped into the airlock and hit the button. As the air was pumped out, the small plastic bag began to inflate like a balloon until it was almost the size of a basket ball. As the air was drawn out of the airlock and the pressure dropped, the water began to churn as low pressure boiling competed with adiabatic freezing. As the airlock neared zero pressure, the water began to freeze with a crunching sound that faded to nothing as the last of the air was removed.
His sack was now a large ball with a shallow pool of water and shrimp frozen in the bottom. Maurice dropped the sack and let the ice shatter, then allowed the sack to deflate. It was much easier to carry a sack of broken ice than a lopsided basketball.

He walked up to residence block and passed through the airlock. Once inside, Maurice found his door, removed his gloves, and held his palm to a small plate on the wall until the door recognized him and opened up. The lights came on automatically as he entered. Like every home on the Moon, there were green plants everywhere. Potted plants, flowers, vines in window boxes that climbed trellises up the walls, any way you looked at it, every apartment was full of plants. Up near the ceiling, where the light and humidity was the best, a shallow tray ran around each wall in the house. These were the moss trays. The genetically engineered moss produced more oxygen than most plants, but it grew like crazy and had to be trimmed regularly.

Taking care of the plants in the house was one of Maurice’s chores each day. After putting the frozen shrimp in the refrigerator, he moved around the apartment from one room to the next, testing the soil, watering and feeding where necessary. The moss in his room also needed trimming. Maurice used the hand-held moss mower to trim the green stuff and catch the clippings. The clippings went into the green recycling bin to be composted and reused. Everything was recycled here.

Ding-dong! Ding-dong! Bam-bam-bam! Someone was ringing the bell repeatedly and banging on the door at the same time.

“What the heck?” Maurice headed for the front door.

“Air Quality Management! Open up! We have a CO₂ sensor alarm, is anyone there?”
Maurice looked over at the scrubber panel in the kitchen. The indicator light above the access hatch was flashing. “Oh, man! Why didn’t I change those first and mow the moss later!” The two cartridges inside the panel were supposed to turn from white to cherry red, as they got full. The cartridges had gone a sort of angry purple color, like pickled beets.

Maurice got to the door and tried to smile and look innocent. “Yes?”

A serious looking man in a lime green pressure suit with an official “Air Quality Management” patch on his chest shoved a black tube with a mouthpiece at him. It looked like the back half of a clarinet, but without any holes or keys.

“Lieutenant Ramirez, Air Quality Management. Breathe into this, please.”

Maurice took the tube and blew into the mouthpiece. It made a harsh hissing sound, like an angry snake.

“Again, and harder, please.” The man was studying a handheld display intently.

“Anyone else home?”

“Phew!” Maurice saw spots briefly swimming in front of his eyes.

“You didn’t have to blow that hard, kid. Your CO₂ is fine, don’t worry. Anyone else at home?” The man’s companion moved past them into the living room and made straight for the scrubber panel in the kitchen. Maurice turned his head and watched him go and cringed.

“Hey, kid, I’m talking to you! This is important, is anyone else home?”

Maurice answered without taking his eyes off the kitchen door. “Um... no. Just me.”
“Found it, Fred!” The second AQ officer came into the room holding two cylinders that appeared to be filled with purple jam. “There was a pair of new filters right there in the closet, so I already installed ‘em. Be sure you bill them for the maintenance on the ticket.” He glared at Maurice. “Changing these wouldn’t be one of your chores, would it now? Filters and plants scrub CO\textsubscript{2} out of the air, you know. That’s why everybody’s supposed to take care of their own air supply at home.”

Maurice saw the lecture coming, but there was nothing he could do about it. It would be just his luck for these two to babble on until his parents arrived.

The officer continued, “You can’t see carbon dioxide, kid. It’s colorless, odorless, and toxic. If you don’t change these filters, it can build up and kill you!”

“Plant’s make oxygen, too,” said the lieutenant. “Oxygen’s sold by the mole here, and a mole of oxygen is only enough to keep you alive for about 10 minutes, you know. Didn’t your parents ever show you the O\textsubscript{2} bill?”

Maurice nodded. His parents were always complaining about bills. He checked the oxygen bill every month himself. It usually said something like: ‘Your houseplants saved you $32.57... Congratulations!’ Maurice got half this amount as his allowance for taking care of the household plants. It wouldn’t cover the cost of the fine, though. He was sure of that.

“How much is the ticket?”

“Don’t worry, kid,” the lieutenant grinned wickedly, “we’ll mail it to your folks.” He took out a citation book and pressed it against the door’s palm lock. Their names and home address appeared on the screen. He looked up at Maurice, “So I’m going to write this ticket to you, is that it?”
"Depends. How much is it?"

"Seventy five bucks. And I didn’t charge you for Johnny putting in your new filters, either. Can you pay that much?"

Maurice felt a little sick. There went his new dustboard. He looked at the clock and cringed; either Mom or Dad could be home any minute.

"Yeah, I’ve got the money.” He sprinted back to his room and found his secret cache of bills hidden in his copy of *2001: A Space Odyssey*, the $75 fine left little behind. "It’ll be worth it if I get rid of them before Mom and Dad get here,” he mumbled as he headed back to the living room.

"Here. Um, can you go now?"

"Take it easy, gotta count this first...” The man seemed to take forever counting and rearranging the bills. He was finally satisfied, put the money into an envelope, and sealed it. "Right. Seventy five dollars received.” He tapped on the citation pad again. "Now, which one are you?"

"Maurice. Can we finish this quicker, please?” Maurice was practically hopping from one foot to the other and watching the clock.

"Hey, kid, if you gotta use the bathroom or something, we’ll wait.” The two officers smirked at each other; Maurice was sure they were just trying to hang around until his parents got home so they could see him get into more trouble.

"NO! Just hurry up!"

"Ok, ok, take it easy.” The Lieutenant tapped the screen with his stylus and wrote quickly. He handed Maurice the citation book and his stylus. "Sign here... and across the envelope flap, please.”
Maurice did as he was told and handed everything back. “Here. Are we done, now?”

A couple more taps on the screen and the book printed a receipt.

“Now we are.” He handed Maurice the neatly printed receipt, and gestured toward the purple scrubbers on the coffee table, “Better get those turned in right away too, eh?”

“Thanks a bunch. See ‘ya!” Maurice practically shoved them out the door and turned to look at the over-full scrubber filters. “I better hide those, and quick!” He took them to his bedroom and buried them in his school back pack and stuffed his smelly gym uniform back on top of it. That ought to keep anyone from taking too close a look! He picked up his watering jug and finished up with the last of the potted plants before he went out to the living room to put away the step ladder and the moss mower. Maurice was startled by his father’s voice.

“Anyone home?”

“Hi, Dad!” Maurice hollered from the hall closet. He had gotten rid of the AQ guys just in time!

“What’s for dinner?” his father asked.

Maurice stared at his dad closely for a second before answering; there was no sign on his face that anything was wrong. Maurice remembered to breathe.

“It’s real shrimp! I would have rather had rat, but real meat is great any day.” Maurice loved crispy orange-peel rat with braised vegetables, but he knew his father hated rat and wouldn’t have it in the house. Parents are so weird.
“Ah, your mother sent the pick of the herd from the O.K. corral, did she?”

Although he knew Maurice would like to have rat once in awhile, Mr. Haberman couldn’t stand the thought of it. Unlike Maurice, he hadn’t grown up here. He still grumbled about the mostly vegetarian diet. Instead of asking ‘What’s for dinner?’, he would often say ‘What meat’s for dinner?’ But he would cringe visibly when anyone ever mentioned rat.

Rats and chickens were the only two animals commonly raised for food on the Moon. They were practical because they didn’t take up much space or use too much air or water. Rats were especially cheap to raise because they bred like crazy and ate almost everything people threw away. Rat meat was cheaper than anything except processed K-beef cold cuts.

Although he considered himself a Moon man through and through, Ivan Haberman still thought like an Earthman in one way; he hated rats, and had never allowed them to be served at his table.

Still, he smiled at his son and tried to change the subject, “Did you have any exciting adventures on the frontier, today?”

“Yeah, we were pretending to stow away on a liner bound for San Francisco so we could go be prospectors.... Cassie kind of ruined the game, though.”

“Don’t let it worry you, Maurice. Besides, we have a surprise for you tonight!”

“Well, I see everyone’s here already,” Ruth Haberman entered the room.

“Hey, Mom, what’s the surprise?”

Ruth looked at Ivan, who smiled and nodded.
“Sweetheart, we’re finally going to become lunar citizens—our whole family. We’re going to stay on the Moon, isn’t that great! That’s why we’re having a special dinner to celebrate.”

Maurice just looked at his parents. The most impossible, horrible thing in the universe was happening... and, of course, being parents, they were happy about it.

“But... how can you afford it? You have to bank a year’s worth of oxygen and water for each of us!”

“That’s why your father’s been working so much overtime this last year, Maurice.”

“I know you didn’t like it at the time, son, but I told you it would all be worthwhile,” said his dad, slapping him on the shoulder. “I used most of my overtime pay to buy oxygen and water on the Procellarum exchange. We made our final quota earlier this month.”

Maurice felt as though things were beginning to swirl around him, threatening to drag him down into some terrible vortex.

“But, we have to buy our apartment... and make an investment in Gassendi Complex, too. That’s going to cost a ton!”

“A little over $300,000, but it’s still quite a bargain, no matter how you look at it. The bank approved our loan yesterday afternoon; I got the call at work. We’re all set.”

Maurice could see the excitement in his father’s eyes. His mother was thrilled, too.

“Just think, honey, in a couple of months we’ll all be citizens and we won’t ever have to worry about being forced to leave the Moon,” said his mother.
“Really?”

“That’s right, son. We’re going to stay on the Moon... permanently!”

Maurice sat down at the table. “Boy... that’s great.” His dad sat down across from him as his mother was busy in the kitchen.

“So. Anything else happen today while I was out?”

Maurice saw that his father’s face was very bland. This was bad. “Like what?”

“Dunno. Get the moss trimmed like I asked you to?”

“Uh, huh.”

“Anything else exciting? Any... visitors?”

Maurice saw his father wasn’t blinking, now. This was very bad.

“Well,” Maurice smiled self consciously, “there was that guy who came to check the filters.”

“Ah. Yes. What did Lieutenant Ramirez have to say while he was here? Anything interesting?”

“What’s that?” Ruth Haberman walked into the room at that moment and looked from Maurice to her husband, and back to Maurice again. Maurice reflected that she, like all mothers, had perfect mother-timing. Perfectly disastrous.

Mr. Haberman raised an eyebrow. “Maurice was just going to tell us about the rest of his day,” he said dryly.
Chapter 3:  
A New Plan  

Cassie saw Maurice on Monday while waiting for the tram to take them to Gassendi Middle School. She tapped him on the shoulder and touched her helmet to Maurice’s so they could talk without being overheard. Since there wasn’t any air to carry it, sound didn’t travel on the Moon. By touching helmets, the sound was able to travel right through the plastic bubbles. This let friends have complete privacy, even in a crowd.

“Are you still bugged about Friday?” Cassie asked. When she heard no answer, Cassie moved her helmet away from Maurice’s so she could look at her friend. Maurice glared at her through the plastic faceplate.

“I guess you are,” Cassie mumbled to herself. She put her helmet next to Maurice’s with a click and spoke to her friend again.

“Look, Maurice, I’m sorry you didn’t get to go to Earth, ok? But, jeez, you’d probably still be in a jail somewhere waiting for your parents to come and have the guards unlock the door so they could kill you.”

“Yeah,” Maurice grumbled. “I guess that was a pretty dumb stunt... at least that’s what my Mom said, anyway.”

“You’re mom knows about stowing away on the ship to Earth?”

Maurice startled, “What? Heck, no! She said... uh, that’s what she would have said if she knew. Anyway.”

Cassie shook her head inside her helmet and started to snicker. She thought Maurice couldn’t hear her. She was wrong.

Maurice heard the laugh and grumped, “She said that about something else,
"Forgot to change the scrubbers, didn’t you?” Cassie asked.

“Who told you?”

“Jeez, it figures, Maurice. For being the ‘lived here all my life’ Moon man, you are the sloppiest guy I know when it comes to maintenance. Hey, what did your dad say when he got the ticket?”

“He didn’t get it. I paid it off out of my dustboard money and sent the AQ cops away. They met dad coming out of the building.”

“The creep blabbed, of course,” Cassie sympathized.

“Naturally. Dad’s not paying me back for the ticket, either.”

“That all?”

Cassie heard Maurice take a deep breath, and felt his shoulders sag a little.

“Gotta clean out all the moss trays in the apartment and repot the moss.”

“Ewww!”

“Yeah. Hey, about Friday, I suppose I should say ‘sorry’... and thanks, too.”

“S’okay. Hey, you’d do the same for me if I tried something really dumb.”

Maurice chuckled a little. “Thanks... I think.”

Cassie just shook her head inside her helmet. “Did you really think you could get to the Earth that way?”

“I dunno. I just want to get there so bad; I’m willing to try just about anything. Besides, my parents kind of forced me into it....” Maurice trailed off.

“Your parents forced you into trying to stow away on a space liner?” Cassie was used to Maurice’s somewhat odd way of looking at things, but this one was a real winner,
even for him.

"Yeah. My folks have been hinting for weeks now that something was up, I kind of suspected it was about our residency here on the Moon. That's why I just had to try and get off Luna now or I figured I'd never make it. Turns out, I was right. After you pulled me off that space liner Friday, I got home and my folks gave me the 'big surprise'. Because of my Dad's promotion at the Helium mining company, we will be eligible for Lunar citizenship in just a couple of months... And that will mean we're staying here permanently."

"First you got a ticket, and then your parents told you you're never leaving the Moon, and after all that you got caught by your dad? Man, what a day!"

"Yeah." Maurice looked like he wanted to spit, but in a pressure helmet that just wasn't a good idea. Instead, he picked up a large rock and juggled it quickly before hurling it as hard as he could. Maurice watched it sail a few hundred yards over the next crater rim.

"Aren't you afraid you're going to bum through your gloves that way?" Cassie asked. When the sun was up, lunar rocks quickly hit almost 400 Kelvin, over 250 degrees Fahrenheit. Everyone's boots and helmets were thick and well insulated, but the 'casual' pressure suits most kids wore to school didn't have insulated gloves - it made it too hard to carry books and things.

"You shouldn't throw rocks, Maurice. You never know what's beyond the next crater rim!" said Angelina Santiago over the public com channel.

"Shut up, Angelina! You're such a goody-goody," snarled Cassie. She felt bad for Maurice, and now this dumb girl was picking on him!
“Yeah, why don’t you go see what’s on the other side of that crater yourself,” said Maurice. “Better yet, go find that rock and put it back where it belongs!”

Cassie looked at Maurice and silently mouthed the word: ‘Girls!’ and made her worst broccoli-eating face. Maurice laughed at this, which made Cassie feel better too.

Angelina merely sniffed and turned off her intercom. They could see her talking to herself inside her helmet as she stalked off.

The school tram soon arrived to pick up the children. It was a large yellow vehicle with no top and eight wheels made of steel wire mesh. Maurice had seen pictures of school buses on Earth with their hard tops, windows, windshields, and big tires made out of rubber. On the moon, there wasn’t any air, so no wind, rain, or snow, either. Since everyone was inside a helmet, what good would windows do anyway? Rubber tires would be a joke here, too. Most of the moon didn’t have paved roads, just graded paths across the strewn fields and lava beds. These open areas exposed to the harsh sun did not have a hundred miles of atmosphere in a blue sky above to protect them. The surface here reached 250° F, and stayed this hot constantly during the two week long lunar ‘day’. Once the sun fell, the whole surface quickly cooled to 275 below zero for the duration of the long lunar night. Some regions at the lunar poles never saw the sun at all. Here, where miners tapped ancient glaciers for water, temperatures never rose above -300° F.

Maurice shook his head. Rubber tires. If the heat and cold didn’t get them, the sharp volcanic rocks on the open lunar plains would tear them to pieces. Maurice had been to the ancient lava beds with his father, who called them breccia fields. His father would hire prospectors to test the shattered volcanic rocks for helium-3 deposits. The breccia rocks were sharp as knives, but the special isotope of helium in them was used to
power fusion power plants here and on Earth which gave electricity to almost everyone in
the solar system. Helium-3 was one of the moon’s most valuable products and his
father’s important part in this industry was one of the reasons his family was being
considered for Lunar citizenship.

Thinking about the lava fields gave Maurice another idea. “Hey!” Maurice poked
Cassie in the arm.

“What?”

“Know why my plan didn’t work on Saturday?”

“Which plan? The plan to get thrown in jail by the orbital patrol? That one didn’t
work because I was there to save you... as usual.”

“No! My plan to get to Earth!”

“Oh, that plan.” Cassie waited for the joke, but Maurice was clearly expecting her
to take this seriously. “That didn’t work ’cause you were trying to sneak onboard a space
liner without a ticket like a jerk.”

“Exactly! So the thing to do is buy a ticket!”

Cassie glared at him, she was thinking about the trouble they would have gotten
into if Maurice had succeeded in stowing away on that liner. Her parents would never
believe that she had nothing to do with it. “I don’t even want to hear about it, Maurice.”

“That’s not what you told me yesterday. Or were you talking about some other
best friend of mine?”

“You know I’m not talking about anyone else, Maurice. Just think about what you
were doing for a minute; that was a really stupid stunt.”

“Hey! The stowaway thing was a really great plan. I would have been free and
clear on Earth if... well, if things had worked out better. Anyway, that doesn’t matter because the buy-my-own-ticket plan is even better, and I’m telling you in advance so you can help.”

“Oh, yeah, Maurice. I’m sure your parents wouldn’t care if you just went to Earth for the weekend without them or something.” Cassie rolled her eyes. “Besides, how are you going to get the money? Do you know how much those tickets cost? I suppose you’re going to start robbing banks or something now!”

“Of course not, that’s silly,” Maurice said.

Cassie laughed. With Maurice, nothing was too silly to be dismissed out of hand.

“Helium prospecting, Cassie! That’s the ticket. You can help, it’ll be fun!”

“Fun? Out on the breccia fields? If you fall, that stuff will cut you to ribbons; not to mention letting all the air out of your suit.”

“Who’s going to fall?” Maurice laughed.

Cassie just shrugged. Helium prospectors did make a lot of money if they hit a big strike, but who would let them use a buggy and testing gear? The plan sounded crazy; but then, with Maurice, you never knew.

* * * *

Two days later on the ride home from school, Maurice tapped Cassie’s helmet.

“Let’s get off here,” Maurice said.

“This isn’t our stop, Maurice.”

“Today it is, and the next stop after that is the Earth!”

“Are you sure about this?”

“Hey, was that you I heard grumping about wanting in on the next plan, or was that
just a lot of gas escaping from your leaky helmet?"

"Alright, I'll come along, but this had better work, Maurice!"

Maurice led Cassie down inside a large sub-crater on the floor of Gassendi near the south rim. It was filled with industrial domes and garages.

"What is this place, Maurice?"

"I was here sometime last week with my Dad. You'll see, this is it...." Maurice tapped out a code on the door lock; it opened obediently. "Come on, before somebody sees us!" The two scrambled inside the airlock. With the door closed, there was the familiar 'whoosh' of air as the airlock pressurized and the squishy feeling that you were being hugged all over as the increasing air pressure forced your pressure suit tight against your skin. Parents on the Moon always drilled their kids not to take their helmets off until you 'felt the air hug you'.

Cassie and Maurice removed their helmets and went inside the building. It was a garage of some sort with lots of rovers and buggies, some appeared to be in working order, some were half disassembled and still others were obviously being cannibalized for spare parts.

"This one over here. Isn't she a beauty?" Maurice asked. The buggy was a four-wheeled open cart with one front fender missing and a cracked solar panel.

"Maurice, you have got to be kidding!" Cassie looked the buggy over, scowling as she did so. She pointed to the cargo rack on the back, which held a large black box with "Property of HE-3 Mining Inc. Official Use ONLY!" stamped on it.

"What's that?" Cassie wondered aloud.

"That's our helium prospecting rig. It breaks up the rocks and reads out helium-3
Maurice patted the buggy as if it were a favorite dog. No one had dogs on the moon of course, where would you take it for a walk when everything was inside and no there no trees to pee on?

“I don’t know Maurice; this thing is probably here because it’s broken.”

“Just a few scratches, Cassie.” Maurice moved to stand in front of a crack that seemed to run all the way across the solar panel.

“That isn’t going to work! It’s nearly sunset today, Maurice; are you sure the positioning arm works? This panel won’t do any good if we can’t point it toward the sun.”

“Where’s your sense of adventure, Cassie? Besides, I threw in a fresh battery anyway, so who cares?”

“My sense of adventure is fine, thanks; I’m still friends with you, aren’t I? And if we’re going to get stuck out on the breccia fields, Maurice, I care!”

“Well, I guess that means I get your half of the money from the helium strike, too. That means I’ll be traveling first class on a nice liner instead of going economy on some old dumb freighter!” Maurice slapped Cassie’s shoulder. “Are you coming or not?” Cassie closed her eyes for a minute and shook her head in disbelief, but when she didn’t say ‘No!’ or start running away, Maurice smiled. “Right! Let’s get going, daylight’s burning!”

Cassie sighed and started climbing into the buggy. “‘Daylight’s burning’? What the heck is that supposed to mean? The sun won’t set for five or six hours, and it’s free. You don’t have to burn anything.” Cassie looked at her friend sort of sideways, as if he
were some weird bug or something.

“It’s an Earth farmer saying. I decided I’m going to land in Chicago and visit my cousin George in Illinois. Have you ever looked at the middle of North America with a telescope, Cassie? There’s so much green everywhere you look! I think everybody there must be a farmer or something. So if I’m going to where everyone’s a farmer, I figure I gotta speak the lingo or I’ll look like a real neo for sure.”

“Everybody’s a farmer, Maurice?”

“Yeah. I heard from my cousin George that most everybody grows grass in the front of their houses. The only people who do that stuff here are farmers, it can’t be that different in Chicago, can it?”

Cassie wasn’t sure; the only times she had been back to Earth, her father had been working on large engineering projects in the great cities. She had never been to a farm on Earth.

“They grow grass in front of where they live? That’s crazy, Maurice! What would they do that for? All the oxygen would be wasted. Do you think they harvest it somehow?”

“I dunno. Maybe it’s for their cows to eat or something.”

Cassie shook her head again. “Cows, huh? Let’s just go, Maurice. Before this gets any weirder.”
Chapter 4:
Up and Over

“Where are we going, Maurice?” asked Cassie.

“Out over the rim of Gassendi, and down onto the floor of Mare Humorum. I’ve got a spot all picked out.”

“Out onto Mare Humorum, the Sea of Moisture? Are you sure, Maurice? I thought most of the prospectors were working out on Procellarum or Mare Cognitum.”

“Exactly! That’s why we’ll make a major strike before they do, Cassie. Just wait till we come back rich; won’t our folks be surprised!”

“Yeah... one way or the other, anyway.”

“C’mon, Cassie, you’ve got to love the sea! It’s beautiful the way it rolls out all the way to the horizon!” Maurice laughed, “You know what I mean, don’t you?”

“No, I’ve never been to the sea before.”

“You’re kidding! You have never left Gassendi crater the whole time you’ve lived on the Moon? Living in a crater is like living your whole life inside a castle without ever going outside the walls.” Maurice thumbed in the direction of the nearby crater rim.

“There’s a whole frontier out there, Cassie!”

“The frontier, is it? Lance LaGrange strikes again; which book is it this time?”

“Avalanche on Apache Mountain! And the author’s name is Lamont—”

“Yeah, whatever. So big deal if I’ve never been to the Sea of Moisture, I’ve seen it from the Earth!”

“Really? What does it look like?”
"The Moon is very bright, but almost all one color. It's sort of silvery white, not much different from the color of the soil here, I guess.

"Mare Humorum is almost circular, you can see it as a dark area on the left side of the Moon's face, just a bit below the equator."

"Of course we're below the equator, Gassendi is in the southern hemisphere," Maurice noted.

"Right. It's neat when you see it in a telescope, you can see the central mountain and lots of the surrounding craters, too. I tried to see some of the city structures that are above ground, but I couldn't."

"Someone told me that you can't see anything smaller than a kilometer across from Earth," Maurice replied. "Something about the thick atmosphere interfering with telescopes. I don't see how it would, I don't have any trouble with seeing through the air up here."

Cassie laughed and tapped on his faceplate, "Completely transparent, eh?"

"Thanks," grumped Maurice. He changed the subject, "You know, they used to think that the maria were real oceans of water like those," Maurice pointed at the Earth again. The slices of the southern Atlantic they could see were a brilliant blue under cloudless skies.

"Oceans of stone, more like," said Cassie.

"Well, those old astronomers were right in a way; the maria were liquid once!"

"Of course they were liquid once... three and a half billion years ago! Every kid on the Moon knows that asteroids slammed into the surface and punched holes in the
crust that filled in with lava from the Moon's interior. Blah-blah, Maurice, they teach you that from the time you're in third grade.”

“I know, but it's really cool! Just think of it, giant oceans of lava! Gassendi crater here was a one hundred kilometer wide sea of lava, and Mare Humorum is about four times wider than that! And all that lava is rich in metals from deep within the moon. It is the metals in the rock make it much darker than the rest of the Moon's surface. That must be why you saw the maria as dark spots on Moon's face when you were down on the Earth.”

“I guess so.” Cassie looked at their meager supplies, just a few liters of water, no food, and no personal shelter, either.

“Hey, Maurice, how far out into the sea do you plan on going?”

“Well, I figured this new battery should take us about 200 kilometers round trip, so we'll go about 100 klicks out, do our sampling, then come back.”

“One hundred kilometers out... and back? We are coming back before dark, aren’t we? Besides, we can’t go that far, we won’t have any juice to drive around and collect samples that way. And what if we decide to bring back samples; that adds weight to our buggy, too.”

“Don’t be such a worrier, Cassie! That’s what the solar panel’s for.”

Cassie looked back at the solar panel with the large crack that ran almost from one corner to the other and grimaced. “I hope you’re right about this, Maurice, it might be a long walk back!”

Maurice and Cassie double checked each other’s air supplies and put on heavy duty gloves that would allow them to pick up and handle rocks in the sun without burning
their hands. Maurice then hopped on the buggy and pressed the starter, the electric motors whined and the buggy rolled forward into the garage airlock. The door thumped closed behind them and the hiss of air being pumped out of the airlock came through their helmets. The sound of the hissing air and the motor noise from the buggy faded away to nothing as the last of the air was pumped back into the building. No one wasted air on the Moon.

The outer door opened at last. “Here we go!” Maurice pushed the throttle forward and the buggy lurched into motion. “Open sea and helium-3, here we come!”

The ride to the Gassendi crater rim was just over a kilometer, and a chance for Maurice to get used to the controls. The buggy bounced and rolled on its wire mesh wheels, taking bumps and holes in stride without trouble. The sun sat on the horizon casting long shadows. Maurice had to be careful; a shadow could conceal a dangerous rock or hole with equal ease.

“This is GREAT!” shouted Maurice. “We should have taken one of these out for a spin a long time ago!”

Cassie gritted her teeth and held on tightly as Maurice crashed over another large rock in their path. She wondered if she would get a chance to try driving while the buggy was still working. “Hey, when’s it going to be my turn to drive?” Cassie complained. She was sure that Maurice would let her sit in the driver’s seat and wiggle the steering after the little buggy conked out, but she wanted more than that! She held on as the buggy drove through another shadow and hopped over a large, but invisible, stone.

“Why don’t you flip the lights on?” Cassie asked. Maurice ignored her.
“When we get past that, you can drive.” Maurice pointed ahead where Cassie could see the long line of hills that must be the Gassendi crater rim.

“Man, that looks really high.” Cassie said quietly. “Isn’t there a pass or something around here?”

“Find a pass? Turn on the lights? Why don’t you just post our schedule on the Luna-net so everyone knows where we’re going prospecting! Heck, Cassie, in the old days on Earth, prospectors never told where they were going. Otherwise, claim jumpers might sneak up on you in the middle of the night, ambush you and leave you for dead; they’d jump your claim and take all your gold, too!”

“Sneak up in the middle of the night? It won’t be night for hours, Maurice! How long did you plan on being out here? I want to be home in time for dinner.”

Maurice laughed at this. Normally, when Cassie was bugged with him, she would be confronting him with her hands on her hips, just like his mother did. The wild bouncing of the buggy denied her this.

“Well, if you want to get home in time for dinner, then we better get going!”

Maurice put the buggy into low gear, headed for the crater wall. Ahead, they saw massive fences made of interlocking metal bars as thick as your arm. Maurice slowed down and drove carefully through a gap where two fences overlapped.

“What are those things?” Cassie wondered aloud.

“Avalanche fences. With all the digging and excavating of the crater wall a colony does, every once in awhile you get an avalanche. Those fences are supposed to stop the rock slide from damaging buildings and stuff.”

“How come we don’t have them back at the living complex?”
“There isn’t much danger where we live, the slope of the crater wall is a lot less, so there’s less chance of a slide.”

“Any slide would probably be a lot slower, too,” Cassie noted. “Hey, Maurice? If they only put fences where the crater rim is really steep, why did we pick the really steep place to try and drive over the rim?”

“Whiners never settled the West, Cassie,”

“Oh yeah? Well I’ve seen vids of some of those Larraby Lagrange stories—”

“It’s Lamont, LaRue!”

“—and I’ll have you know that wackos never settled the Old West, either, but they sure made the coyotes happy!”

“Thanks a bunch.” Maurice stomped on the pedal and lurched the buggy to full speed again.

Beyond the fences, the ground began to rise. The way was easy at first, but quickly became steeper. The little electric motor in the buggy began to strain and slow down.

Maurice drove over a rock as big as their tires. The wire wheel slipped off the rock surface and dropped Cassie’s side of the rover down with a crash that jarred her teeth. To Cassie’s horror, the small boulder began to wobble and roll slowly backward.

“Watch out, Maurice!” Cassie shook his arm and pointed, “You’re going to start an avalanche!”

Maurice jerked the buggy to the left in time to miss the rock, which bounced in the slow-motion of lunar gravity and gathered speed down the hill. Maurice and Cassie watched from the safety of the buggy as the bigger rock started other rocks rolling and
crashing down the hill. Only a few rocks moved at first, but more soon joined the cascade, as their one boulder became a small avalanche of sharp volcanic rocks and dust that reached the bottom of the hill and crashed silently into the avalanche fences, making them ring and quiver in perfect lunar silence.

"Man, I’m sure glad were up here and not down there!" Maurice laughed with relief. "Besides, it’ll cover our tracks!"

"Sure, as long as no one comes out to investigate what idiot was starting landslides on the crater rim in the first place."

"Don’t be such a worry wart, Cassie. Look, the top of the crater rim’s just a little ways ahead, then on to the sea! Let’s go!"

As the buggy struggled its way silently up the hill, they saw the top of the crater rim at last. Maurice stopped the buggy on the peak, and both children looked out in wonder. Although they had been many places in the domes and burrows that lined the south rim of Gassendi crater complex and had been out on the crater floor many times, neither Maurice nor Cassie had ever been up on the rim before.

500 meters below them, the Sea of Moisture, Mare Humorum stretched out to the horizon. The rolling volcanic plain’s rippled surface was covered in a coating of dust, and pocked with small craters. Stray rocks and boulders cast giant shadows in the low light. From here, it really did look like a gray, ancient sea that had somehow frozen in time some billions of years ago and slowly fossilized from frozen ice into a wasteland of dust and stone.

Maurice looked down the steep hill that led to the plain below. "Your turn to drive!"
Cassie hesitated, “You’re kidding, right? What if I start an avalanche like you did?”

“What do you mean, avalanche? There’s no avalanche fences on this side are there?”

“Of course not, but—”

“Exactly! No avalanche fences means no avalanches! It’s perfectly safe.”

Maurice hopped in the passenger’s seat and buckled in. “C’mon, Cassie, a couple of pebbles and some dust don’t scare real Moon men!”

“I’m not a Moon man, Maurice, and that has nothing to do with being afraid of real danger. That has to do with your common sense.”

“Common sense? Cassie, you aren’t chicken, are you? You can do this! Hey, I drove up here ok.” Maurice smiled inside his helmet. Cassie hated to be called ‘chicken’ and could be dared into trying almost anything at least once. Maurice had once dared her to sneak into the teacher’s locker rooms at school and put moon dust in the shower heads so they would spray mud instead of water. They both had to scrub out the whole locker room after one of the gym teachers had tried to take a shower, but it was worth it.

Cassie took the driver’s seat, fastened her seat belt and started the buggy. She eased it up to the edge of the hill until she could no longer see any ground out in front of them. It looked like they were going to drive off a cliff.

“Well, here goes!” The buggy tipped forward and started slowly down the hill.

“Whoa!” Maurice hollered. Both kids felt as though they were hanging from their seatbelts as they headed down hill, but the buggy seemed to be handling things all right as they moved slowly down slope.
“What’s that, Maurice?” Cassie asked. “We shouldn’t be able to hear any motor noise out here.”

Cassie and Maurice looked at each other.

Ting!....ting, Ting!

Maurice looked behind the buggy, too. The dust and gravel surface of the hillside above them was beginning to slump like ice cream left in the sun. The whole hillside seemed to be following them slowly down the hill. The sand and dust was trying to swallow up the rear tires of their rover as it went. Bits of gravel were beginning to bounce freely and were hitting the back of the rover. Some were bouncing high enough to hit the kid’s helmets where they stuck up over the backs of the seats. Ting! Ting, BONK! This one hit Cassie’s helmet and made her yelp with fear.

“It’s gonna be a landslide! Run for it Cassie!” Before Cassie could say anything, Maurice reached over and threw the buggy’s transmission from “Low” into “Cruise”.

The rover lunged forward and began accelerating down the hill. The sudden loss of support from the back of the rover caused the rock and dust above them to begin sliding in earnest. It quickly gathered speed and power, even in the slow motion of lunar gravity.

The rover was really picking up speed. Cassie hung on to the steering joystick with all her strength; trying to guide the rover around large boulders without crashing or
turning over. She felt the thump! and whack! of rocks hitting the underside as they sped
down the hill and the occasional shock of a rock from uphill catching up to them and
bouncing off the back of the rover.

The stone floor of the maria was coming up fast now, and with a bone jarring
thump they hit the level plain and continued racing out across it. Maurice watched the
growing cloud of dust and rock running downhill after them. Just when it seemed they
would be safe, a ten-meter wide boulder leapt out of the slowing cloud of dust,
outrunning the cloud and now gaining on them. It looked about as big as Maurice’s
whole living room.

“Boulder! Go left!”

Cassie yanked on the joystick and the buggy swerved, bouncing wildly on two
wheels for an instant before crashing down on all four again. Maurice watched the
boulder go rolling by in destructive silence just a few meters away, crushing small rocks
and throwing up more dust which sparkled like diamonds in the sun as it settled. Cassie
allowed the rover to roll to a stop, then just sat there in silence.

Maurice grabbed Cassie’s shoulders and shook them, laughing. “That was the
most amazing driving I’ve ever seen! We made it!”

Cassie looked a bit stunned to be alive and out on the surface of the maria. “My
first time, too,” she mumbled.

“On to the mother lode!” Maurice shouted.

“Ok,” said Cassie, “but you drive for awhile.”
Chapter 5:

Helium Prospectors

Maurice drove out across the surface of the maria, enjoying the view and freedom of having the buggy all to themselves.

“How far do you want to go before we start taking samples?” Cassie asked.

“I figure we’ll stop every 10 kilometers or so and see what the helium level is like. We can try our first sample any time now.” Maurice brought the buggy to a stop; he and Cassie climbed out and began opening the black crate on the back.

“Cool!” Cassie reached out to the machine that looked sort of like an overgrown home food processor with a computer screen and keyboard attached. She touched the power button and the screen came to life.

“Ok,” Maurice said, “first we press the LPS button like this to see where we are. The Lunar Positioning System, like the GPS system on Earth, used a set of satellites orbiting overhead to find their exact position on the Moon. The whereabouts displayed themselves as longitude and latitude numbers as well as a glowing dot on a map that showed them just beyond the Gassendi Crater rim and on the edge of the Sea of Moisture.

“Well, at least we know you drove the right way, anyhow.” Cassie joked.

“Thanks!” Maurice tried to punch Cassie in the arm for good measure, but Cassie hopped sideways and dodged just in time.

“Quit fooling around! Now what are we supposed to do?”

Maurice gathered up a double handful of rocks and dust and dumped it all into the analyzer. “We put a few rocks in the hopper here, close the lid, and push this red button.”

The red button started the box shaking and bouncing hard enough to shake the
whole buggy on its tires.

Maurice bent over and touched his helmet to the processor. A loud grinding, crunching noise filled his ears. “Man, put your helmet against this thing!”

Cassie tried with similar results; she took her head away after a moment. “That’s too loud! My ears are ringing now.”

The machine continued to grind the rocks down to a powder, eventually slowing down to a gentle vibration, then stopping all together.

“What’s it doing now?” Cassie wondered. As if in answer, the screen lit up, flashing the word ‘HEATING’ in green letters. After a minute, the screen changed to flash ‘GM READING’ as the Geiger counter began trying to detect the subtle radioactivity of helium-3 atoms.

The screen stayed unchanged for so long that both of them thought it might be broken. ‘Helium-3 level: 0.27 PPB’.

“Less than one part per billion. We need at least a score of 50 PPB for a worthwhile strike,” Maurice grumbled.

Cassie snorted as if to say ‘I told you so’ to another of Maurice’s crazy schemes. “C’mon, lets head out, Maurice. Daylight’s burning, remember?”

The pair continued on their trek across the desolate maria, pausing every 10 kilometers or so to take another sample of the local rock. Each time they would stop the buggy, get out, and dig some loose volcanic rock out of the dusty soil and throw it into the analyzer and wait while it shook and then meditated in perfect silence. The numbers were getting a bit better, 1.5 PPB, 2.8 PPB, 7.5 PPB, but never the score of 50 or better Maurice insisted they needed to make a successful strike the mining company would pay
By the fifth stop of the day, Maurice and Cassie were both tired and sore. Digging rocks and dust with short folding shovels and a pick was still lots of work, even in low gravity. The bulky pressure suits didn’t help much, either. They were mostly designed for walking here to there, not for digging and working out on the surface. They were rubbing Cassie and Maurice raw in spots both inconvenient and unmentionable.

Their casual suits had rather bulky backpacks that held their air supply along with an air scrubber, cooling system, heater, and communications gear. They were simple to fill and maintain, but they were nothing like the sleek, high-pressure jobs the professional miners and prospectors wore. The bulky backpacks weren’t heavy, lunar gravity took care of that. A ten pound box the size of a small suitcase on your back just makes it hard to balance. Especially when you weigh only about 17 pounds yourself.

Cassie took a break, and tossed down the pick and sat down in the buggy.

“Whew! You never told me this was such hard work. What about all that stuff about the romance of the Old West and the wiley prospector who talked to his mule and then struck it rich?”

“Well, the romance part is supposed to happen after you’re rich. And I didn’t have a mule handy, so I brought you to talk to!”

Cassie laughed and hopped out of the buggy again.

“Oh, yeah? Well look, Mr. Prospector,” Cassie pointed out into the sea of growing shadows, “we can’t see the crater rim anymore. We’re probably lost now! Got your old-timey compass to help us find our way home?”

Maurice was laughing too, now. “Old timey compasses won’t work on the Moon,
you dork! We haven’t got any magnetic field here, so it’ll just point to the nearest metal—like maybe the metal plate in your head!” He punched Cassie in the arm again for good measure.

“Ha! Maybe you should have bread crumbs so we could leave a trail to follow back home!”

Both children were howling with laughter now. They knew that the Moon’s only source of weather and erosion was rocks falling in from space, and most of them were microscopic in size. Unless someone else walked or drove over them, the tracks and footprints they left would be there for millions of years to come.

“And this is for punching me in the arm all the time!” Cassie shoved Maurice up and backward. It was a favorite school yard trick. Tripping people didn’t work on the Moon, the low gravity usually gave you plenty of time to recover your footing. But if you pushed somebody up, they couldn’t do anything once their feet left the ground. Since most of your friends weighed just 15 to 20 pounds, getting them airborne wasn’t hard at all. Teachers always hated the game, even though it was rare for anyone to get hurt. Their home room teacher, Mrs. Stratford, would send you to the office for something as minor as throwing someone across the lunch table. What a grouch!

Cassie laughed as Maurice left the ground at a satisfying angle.

Maurice wiggled his feet and shook his fist in the air, still laughing, “I’m gonna get you for this Cassini Theresa Metis!”

“If you keep calling me Cassini, Maurice, you’re going to end up walking home! My name is Cassie!”

Maurice only laughed as he continued to move backward another meter or two
before his feet touched the ground again. He tried to catch himself and land on his feet – that was part of the game, after all – but his ankle caught on a protruding rock and flipped him backward.

Maurice put his hands back to catch himself and felt them squoosh into the lunar dust. The sharp pain and sudden cold in his left forearm made Maurice feel faint. He pulled his arm from the soil and saw dust, gas, and tiny red rubies of ice puffing away from his arm. The cold was becoming intense, now.

“RIP! Help me, Cassie! QUICK!” Maurice tried to squeeze the fabric of his suit shut around his elbow to reduce the air loss.

Cassie leapt over to Maurice in a single bound and knelt beside him.

“Hold still, Maurice!”

“It HURTS! It’s freezing my arm off!” The little rubies were getting larger now, and there were more of them.

Cassie took a red tube from her belt and broke the end off. She squeezed black goo from the tube onto the white fabric of the suit, smearing it all around the quarter-inch tear. Next, a roll of white plastic tape was wrapped completely around the arm, starting below the tear and working up toward the elbow. Maurice could hear Cassie mumbling inside her helmet as she wrapped the bandage; he wondered why she sounded angry when he was the one who was hurt.

“Not so tight!”

“You want an air leak? Maybe you just want to bleed to death before we get back, is that it? When you wrap an air leak, your suit becomes your bandage, remember? Don’t panic on me, Maurice, we gotta do this just like we practice at school every week!”
Cassie continued to wrap the tape as she talked.

"Ok, Cassie, ok. I ... I'm ok." Maurice tried to move his arm a little, but cringed and let it go limp again. "Man, it's really sore, and I'm cold all over now." Maurice began to shiver slightly. Both he and Cassie stared intently at the safety bandage; it hardened as they watched, changing color from white to a bright blue. If any oxygen were leaking out, the bandage would turn orange in that area, indicating an air leak. The wrapped forearm remained a comforting blue.

"You did it, Cassie! I'm not going to decompress!"

"You're welcome," she grumped. "Ok, Maurice, let's check your air supply."

Cassie took Maurice's good arm that had his communications keypad and a data screen strapped to it. Cassie held his arm still and punched out the code for suit functions.

"Let's see..." Cassie continued to tap on the touch screen of Maurice's data readout, "It took us 32 seconds to seal the leak—"

"Hey, that's not bad!"

"Better than we usually do in school, anyway. Mrs. Stratford would be proud of us!"

"No kidding! How's my air holding out?"

Cassie tapped on the display again. "You lost... gee, Maurice, you lost 30 minutes of air! That means you have a little less than three hours of air left. We have to head back now, it's going to take us at least two hours to drive back over the rim and get to the garage. Plus we might need some extra time to sneak this buggy back where it belongs."

"Don't worry about that, no one works in that storage garage usually."
“I hope you’re right, Maurice,” Cassie looked at the Sun, which was actually touching the horizon now. “Look how low the sun is, it’s going to be dark by the time we get to the garage. We’ve got to get going, I don’t want to have to drive over the Gassendi rim in the dark!” She tapped on Maurice’s data display a few more times. “Let me finish checking these readouts and then we can get going.”

Cassie shook off a feeling of panic as she scrolled through the other readouts, then she stopped short and tried to sound casual about what she saw.

“Hey, your CO₂’s too high. All your yelling ‘ow!’ and stuff pumped too much bad breath into your suit, but this CO₂ reading is still higher than it should be. When’s your next scrubber change supposed to be?”

“Day before yesterday.”

“What? For heaven’s sake, Maurice, don’t you ever learn from your mistakes?” Cassie could feel her temper rising again.

“It’s just a stupid scrubber! I was busy, ok?”

Cassie started to grab Maurice’s arm to shake him, but stopped herself in time when she looked at the blue bandage.

“Arrrrgh! You are such an idiot! It’s not just a scrubber, Maurice; it removes poisonous carbon dioxide from your air supply.” Cassie let Maurice’s arm go and paced back and forth to keep herself from tossing him into the nearest crater. “Suit maintenance keeps you ALIVE!” She grabbed Maurice’s helmet and clicked her faceplate against his, “If you weren’t hurt right now, I’d kill you!”

“Sorry, ok?” Maurice shrugged.

Cassie scowled at him.
"I'm the one who's hurt here!"

Cassie was unimpressed. "It's getting dark. Let's get back before anything else happens."

"Hey, it's just a rip, it will be alright. I've got enough air to get back to the garage, right?" Maurice reached for his data display with his injured arm, "OW! With my arm all bandaged like this, I can't work my display! Hey, Cassie, I've got enough air to get back... right?"

"Just get in the buggy Maurice. Now."
Chapter 6:  
Small Crater – Big Trouble

Cassie helped Maurice climb aboard the buggy and saw that his belt was fastened.

“We gotta get you back as quick as we can. What if the repair doesn’t hold?”

“Cassie, relax. Don’t panic, remember? I’m fine, just drive.”

“Oh, sure. I can just see explaining your dead body to your parents. Gee, sorry about Maurice, folks. But it was such a nice day for a drive, and Maurice did say to take my time!”

Cassie threw the buggy into high gear and stomped on the accelerator, snapping Maurice back in his chair.

“Ow! Hey, watch it! My arm!”

“Sorry!” Cassie slammed on the brakes, throwing Maurice forward again.

“OW!!! Geez, Cassie. If you’re going to kill me, just take my helmet off and space me right now, would ‘ya? This way’s too painful and slow.”

“Slow!? We can’t be slow! We’ve gotta get you back to Gassendi!” Cassie stomped on the accelerator again and lurched off back along the same tracks they left coming out. Maurice was ready for her this time and managed not to get thrown around.

The buggy lurched and bounced along at its top speed of 25 kilometers per hour. Cassie watched the landscape crawl by slowly, she was sure that she could run faster.

“Hey, Cassie, we’ll have more battery life if you slow down. I don’t want to have to hike over the Gassendi rim, ok?”

“Battery... right.” Cassie tapped on the driver’s console display several times, then frowned. “Maurice! The battery’s down to just 40% capacity, we won’t make it home!”
"We’ll make it if you slow down!"

"Why is the battery so low?"

"I dunno, Cassie, maybe the rock crusher back there doesn’t have its own power supply like I thought."

"You didn’t check! You said that’s what the solar panel was for." Cassie was staring at him in disbelief now.

"Sure, that’s what the solar panel’s for... but ours has this big crack in it, see?" Maurice thumbed toward the back of the buggy. “Besides, it was almost dark, so I threw in a new battery instead.”

Cassie was frightened and shouting at him by this time.

"I don’t BELIEVE you!"

"Hey, look out! A rock!"

Cassie was so busy being mad at Maurice; she hadn’t been paying attention to where she was going. She drifted off their previous track, straight into the path of a meter high boulder. Maurice reached over and yanked the joystick hard to the right. They managed to avoid the boulder and drove straight into a small crater just a few meters across hidden in the shadow of a low hill to the east of them. It was only two or three meters deep, but the buggy landed almost nose first and dug itself into the pulverized dust at the bottom with a sudden Crunch!

For a moment, all was dark and silent, except for the noise of quiet breathing. Maurice and Cassie snapped on their helmet lights. “You all right, Cassie?”

“Yeah.”

“Bet you think this is my fault, too.”
“Yep.”

Maurice sighed. “C’mon, let’s check for damage.”

The buggy was tipped forward at almost a 40-degree angle. Maurice and Cassie carefully got out and hopped to the crater floor.

“It’s pitch black in here. Better turn on your ankle lights, Cassie.”

“Right.” The ankle lights shone down from your boot tops and lit the ground all around your feet for a distance of a couple of meters or more without you having to hold a flashlight or watch your feet all the time.

Maurice activated his ankle lights as Cassie climbed underneath the buggy.

“How bad does it look?” Maurice asked.

“Not too bad, no real damage to the front that I can see. Maybe if we’re lucky, we can just back it out of here and keep going. Let’s give it a shot.”

With both of them securely back in their seats, Cassie started the motor and put it in reverse. The buggy whined and strained with the front tires. The back tires only slipped in the dust.

“It doesn’t seem to have any power up front.” Cassie tapped buttons, and checked the driver’s display again. “The battery’s down to just 15% capacity! What happened?”

“Maybe it just got partially disconnected, I’ll check.” Maurice hopped out as Cassie killed the power. He pushed away some dust and sand from the front of the buggy, and opened the hood.

“Well, Cassie, I think it’s time to break out the emergency radio.”
“It figures,” Cassie grumped. Both kids hated to give up and call for help. Parents and teachers alike had drilled self-reliance into them from a young age. Asking for aid felt like quitting... or cheating.

“Are you sure we can’t fix it?” Cassie hopped out and came around to join Maurice in peering down into the motor compartment. It was immediately obvious what was wrong. A large and pointed rock was sticking up through the bottom of the motor compartment and had broken open three of the five battery cells. The thick fluid from inside the batteries had oozed out and frozen in mid-boil. The hard vacuum and frigid temperatures of the sunless crater bottom had combined to destroy it.

“Right. I’ll get the radio.” Cassie moved off as Maurice continued to stare at the torn up front end of a buggy that wasn’t even his.

“My dad’s gonna kill me,” he mumbled to no one in particular.

Maurice looked up; Cassie was opening one compartment after another on the buggy and slamming them closed with increasing force.

“They’re all empty, Maurice! This buggy’s been stripped. No radio, no air canisters, no scrubber packs, no shelter, no rations or water.” Cassie looked at Maurice with her hands on her hips. “Nothing. And you don’t have enough air to get back, Maurice.”

“You still have enough air to hike back,” Maurice said quietly. “It’s almost dark; you better get going so you can send somebody back to find me.”

Cassie shook her head. “No way. We hike together or stay here together, but we don’t split up.”

Maurice smiled. “Right. Thanks.”
“Come on,” Cassie said, “They always say stay with the vehicle; it’s bigger and easier to see than you are. Let’s see where we’re at.” She pointed up at the crater rim and began to climb.

Maurice struggled with his injured arm. The soft dust and sand that lined the crater’s sides seemed to grab his boots and tug him backward. He stumbled and almost fell just a meter or so from the top. Cassie grabbed Maurice’s good hand and pulled him up over the edge and onto the level plain of the maria. They walked a couple of meters away, and then turned around to survey the crater and buggy and saw... nothing. The low rim of the small crater was lost in the growing shadows. The lunar landscape and the crater had completely swallowed the buggy.

“You’d have to be practically on top of it before you spotted anything. Maybe they’ll search for us by air.”

Cassie squinted at the sun, low on the horizon. “Sure, Maurice, it’s going to be dark in a half hour or so. And maybe our parents won’t just think we’re hanging around at the spaceport again when we’re late for dinner. It’s what they always do, Maurice. It will be hours before anyone thinks to start a search. Besides, by the time they check all the obvious places, you’ll already be—”

“Hanging around the spaceport and late for dinner!?” Maurice looked at his chrono display, but it was covered by the blue tape. “What time is it exactly, Cassie?”

“Time? You don’t need to worry about what time it is, Maurice. Better worry about how much time you’ve got left!”

“What TIME is it!?”

“You don’t have to yell at me! It’s 5:48.”
"That gives us fifteen minutes; we can make it if we hurry!"

"Make what?" Cassie called after Maurice as she watched her friend hop down into the crater again.

"A smoke signal! Just like the old-time prospectors did, Cassie! C’mon!"

Cassie walked to the crater’s edge. "What are you talking about? Your CO₂ levels must be higher than I thought; you're hallucinating."

"I’m NOT crazy! I read about it once in a Lamont LaRue story—"

"Maurice!"

"Come on, Cassie, you’ll see how it works as we go. Now help me disconnect all these front wheel motors... hurry!"

Cassie watched Maurice stumble down into the crater in amazement. "Desperate men clutch at the thinnest straws, I guess," she mumbled to herself.

"What was that?"

"Never mind, I was just thinking of something my mom always says."

"You can tell me all about how I’m a bad influence later. Right now there’s work to do and I need your help!"

Cassie checked her own air and sighed. Whatever Maurice had in mind, he didn’t have much time. No matter what happened, she figured she would have enough air left to make the hike back to Gassendi alone... afterwards. She felt a tear start down her cheek and sniffed loudly.

"Cassie? Where are you?"

"Coming!" she said, and jumped into the crater after her friend. Maurice had the hood of the buggy open and was busy doing something inside the motor compartment.
“Look, each wheel of the rover has its own electric motor. These wires power the motor and run back to the battery and controller over here.” Maurice took his pocketknife out of his belt and began cutting at the tough wire coverings on the nearest motor.

Maurice pointed at the opposite motor, “You take that one, Cassie. We only want to leave power to that one motor back there.” Maurice indicated the left rear wheel half buried in dust, three quarters of the way up the crater wall.

“I still don’t get it, Maurice.”

“There’s a space liner leaving from Buzzport at 6:03 tonight and heading south into a polar orbit. We were going to go see it blast off; remember? It will pass almost right over us, so if we can get our smoke signal ready, maybe the rangers can come save us two prospectors in the nick of time after all!”

“Would you knock it off with that old-time prospector bit?” Cassie made a grab for his injured arm, “Let me check your CO₂.”

Maurice pulled away before she could grab him, “Stop it, will you? This is serious!”

“I am serious, Maurice! How do you expect to make smoke for a smoke signal when you can’t burn anything?”

Maurice smiled and reached down, grabbing a handful of dust from the crater floor, then held his hand out toward Cassie. “Smoke is just dust that got carried up to the sky, Cassie.” Maurice tossed up a handful of dust that sparkled brilliantly when it broke into the sunlight above the crater rim.
“Cool,” said Cassie. “Daylight’s burning! But how do we get your so-called smoke into the sky?”

Maurice thumbed at the back of the buggy. “That’s what the wheel’s for. What time is it now?”

“Man, it’s already 5:53, we gotta hurry!”

Both of them renewed their attacks on the motor cables, which parted with silent snaps.

“Got it.”

“Mine, too. You get those two fenders off while I get the last motor wires cut.”

Maurice yanked hard on the knife trying to cut through both wires at once. When the first one parted, his hand flew up and rapped against the motor hatch and the knife went spinning up and out of the crater.

“My knife!”

“Take mine.” Cassie folded her pocket knife, tossed it to Maurice and continued to tug on the wrench to loosen the last fender. Maurice opened the knife carefully.

“Time?”

“Six o’clock.” With a grunt, Cassie freed the last fender bolt. “Now what?”

“Bolt those two fenders together so they make a three-quarter circle.” Cassie started attaching the two fenders together with the wrench and bolts. “We’re going to take that fender and hold it up to the spinning wheel while we shovel dust into the other end. The wheel will spin and throw the dust up into the air – instant smoke signal!”

Cassie raised an eyebrow. “Who gets the job of holding the fender?”

“It’s gotta be me. With my arm, I can’t shovel fast enough.”
“You? Maurice, if you let go of that fender...”

“Yeah. I get a face full of wire wheel at full speed. But this is the only chance we’ve got, that liner launches in just two minutes.”

They began to dig a space out from the crater wall behind the one working wheel until it was big enough for Maurice to climb in and hold the fender in place with the top edge pointing almost straight up.

“Ok, Cassie, I’m in. Start up the buggy and get shoveling!”

Cassie turned the key in the buggy, and then grabbed a basketball sized rock and used it to hold down the accelerator pedal. Maurice felt the wheel start to spin and grabbed the bolts protruding from the back side of the fender more tightly. He felt the fender shudder as the first shovel full of dust and dirt hit it and was caught by the wheel, spun against the plastic shield, and hurled up and out of the crater.

“Whoa! Look at that stuff go!”

“Just keep shoveling!”

Cassie hurled shovel after shovel of dust and sand onto the fender where the spinning buggy wheel whirled madly and hurled it up into the sky where it formed an arching column over a hundred meters high. The giant arch sparked and dazzled under the intense lunar sun; it cast a huge shadow many kilometers long in the dying sunlight.

“Six...Oh....Three!” Cassie puffed without stopping her shoveling.

“Doing great, Cassie! Keep going, they’re sure to see us now!”

Cassie kept shoveling and Maurice struggled to keep hold of the fender as it shook and wobbled with each shovel full of dust and dirt. More than once, Maurice felt the wheel catch the fender and almost take it away from him.
“Six...... ten.” Cassie threw another shovel full. She was slowing down, so was the wheel. Cassie noticed that the dust, which had at first flung itself over a hundred meters into the sky, was now a gentle arch less than half that size.

“Just ten minutes to sunset! You’ve got to keep going, Cassie!” Maurice pleaded. His arm had gone numb from the cold that seemed to seep in from the rip. He could see orange spots through the dust and dirt on his bandage. The stress of holding the fender in place against the whirling wheel had damaged the bandage and caused several small air leaks. The sight of the orange spots sent a jolt of fear through him. Maurice tried to ignore it. Either this stunt would work, or a little leak here or there really wouldn’t matter much anymore.

High above the struggling children and their stranded buggy, a lunar patrol flyer cruised southward. There had been a report of an eruption or geyser out on the Sea of Moisture. As unlikely as a geyser was, it had to be checked out.

“Gassendi control, this is patrol flyer 14 south of Gassendi rim. I’ve spotted your geyser the liner pilot reported. It’s not a hundred meters high, maybe 20 if that, but casting quite a shadow. Looks like its fading even as I’m watching, over.”

“Roger that flyer One Four. Investigate further and report.”

“Heading in.” The pilot slowed forward speed and dropped his altitude. “Gassendi Control, this is flyer 14, the geyser or whatever it was seems to be coming from a crippled prospecting rig crashed in a small crater. There are two occupants coming up out of the crater now. One has a blue bandage on the left arm. Repeat, a blue bandage. We have a rip and possible injuries. Will pick up the survivors and transport to Gassendi Med-Complex, ETA in ten minutes. Fourteen out.”
Cassie spotted the patrol flyer first.

"Maurice! A ship... a patrol flyer! We're saved!" Cassie was jumping up and down as Maurice tried to work his way out from under the wheel of the buggy. Cassie pulled on his good arm and helped Maurice get out.

"Your plan worked, Maurice. You're not going to die!"

"Yeah." Maurice contemplated the ruined buggy. "At least not until I get home."

Before he left the small crater, Maurice grabbed the data cartridge from the helium analyzer and pocketed it. Without thinking about it, he also grabbed a fist-sized rock from the bottom of the crater. "Our last sample," he thought to himself.

The last of the sunlight vanished instantly, plunging him into darkness. There was no air to bring color or twilight to the moon as the sun dipped below the horizon. Maurice glanced up at the Earth, half in sunshine, half in darkness, spinning serenely above the northwest crater rim. He shook his head and began to climb out to where the patrol vehicle would be waiting to take him home. Back to Gassendi Complex. Back to the Moon.
Chapter 7:
Reckoning

“Hold still, please.” The young doctor stared intently at the wound in Maurice’s arm. She did not look up at Maurice or at the nurse helping her. “Quite a few bits of broken lava rock and some dust in the wound,” she said to no one in particular.

“Hemostat.”

Maurice couldn’t see what was going on behind the blue sheet, but he could hear the plink!... plink! as pieces of the lunar surface were pried out of his arm and dropped into a metal basin the nurse held. When the doctor asked for suture, the nurse moved to throw the contents of the pan away.

“Um... can I have those?” Maurice asked.

“Souvenir of your big adventure?”

Maurice nodded.

“You bet. The nurse rinsed the pieces off, and then he poured them deftly into a small plastic tube and capped it securely. “Here you go, Tiger!”

“Hmmph!” snorted the doctor, “You’re lucky to be alive after a stunt like that.”

“Maurice?” His mother’s voice coming from somewhere beyond the curtain chilled him to the bone.

Maurice sighed, “I think that’s about to change.”

The doctor finished putting on the bandage, and removed the blue sheet so Maurice could see her handiwork. “Well, whatever sort of firing squad they have dreamed up for you, I’m pretty sure you deserve it from what the officer told me,”

“Thanks.” Maurice looked at the bandage a moment longer. “Am I going to have a scar?”
“Probably.”

“Well, at least that’s something.”

The doctor raised an eyebrow, but said nothing as she walked out. The nurse looked like he wanted to laugh, but didn’t dare. Maurice could hear the doctor speaking quietly with his parents on the other side of the curtain. The nurse grinned at him again.

“Prospecting, eh? Find anything?”

Maurice pulled the data cartridge out of his pocket. “Maybe so.”

“Been out a few times myself. If you get any good at it, let me know. Folks are always looking for prospectors with a nose for helium.”

Maurice’s smile faded as his mother pulled aside the curtain around his bed.

“Darling, are you alright?”

Maurice permitted the hug, and as the relief of seeing his parents sunk in, he hugged back harder. Then he caught a glimpse of his father over his mother’s shoulder; standing with his arms crossed and a very set expression on his face. This was very bad.

His father caught his eye. “You’ve got some pretty good explaining to do, Maurice.”

Maurice let go of his mother and dropped his eyes. “Yeah. I know.”

“Oh, Ivan, it’s late, he should be home in bed. Can’t this wait ‘till tomorrow?”

“No, but I suppose it can wait until we’re in the buggy.”

The nurse returned carrying a small metal tray with a hypodermic syringe in it.

“The doctor’s prescribed an antibiotic injection for you, Maurice. I need you to roll over and show me your hip.”

“But lunar rock is all sterile! How could I get an infection?”

300
“You suit wasn’t sterile, was it?”

Maurice grimaced and rolled toward his father.

“Is it going to hurt?”

His dad nodded. “You bet.”

He was right.

* * * *

“... and that’s when we saw the patrol flyer and knew we were safe.” Maurice had told everything – except why he had really done it in the first place. He couldn’t tell his parents about how he really hated the Moon and wanted more than anything to leave this place and go back to the Earth. They both loved the Moon. Maurice was certain that they would never understand.

He looked at his father for sign of a reaction to his tale. His mother had alternately grimaced or covered her mouth smothering an ‘Oh, dear!’ . She had even smiled at some of the funny parts. His dad listened patiently, but said nothing and his face revealed little more.

“Well, at least my plan worked...” Maurice trailed off.

“Which one?” His father eyed him carefully. “The plan to take mining company property without permission? The plan to get lost in the dark, out on the sea without telling anyone where you were going? Or maybe the plan to get you and your best friend killed in some nameless crater where you might never have been found again?”

“I was thinking more like the plan to help the lunar patrol find us... and maybe this plan, too.” Maurice got the data cartridge and the fist sized rock out and handed them to his father. “The numbers kept getting better, but they never got much over 10...
parts per billion. Nothing like the 50 PPB you told me real ore has to have.”

“Oh?” His father’s face changed for the first time in over an hour and he turned his intent gaze on something else besides Maurice’s face. It felt as if he had been standing under a cutting laser that had finally been turned off.

Ivan Haberman took the cartridge and snapped it into the slot on their computer terminal. He stared at the charts and graphs it made for several minutes before turning back to Maurice.

“How deep were you digging?”

“Just scraping through the surface dust and breaking a few of the surface rocks up and tossing them in, why?”

“Prospectors normally use cutting tools to get samples from a meter or two down. Surface rock is often porous and loses much of its helium over the millions of years.”

“I know. But there weren’t any cutting tools I could lift by myself in the garage.”

“Hmmm. Since you came back with all four limbs intact – or nearly so – I suppose we should consider that fact a small mercy and leave it at that. These data…” he pointed at the screen, “and this rock might just save us, Maurice.”

“Save us? What’s us?” Maurice looked at his mother, “What is Dad talking about?”

“Oh, Maurice, your father’s company was talking about dismissing him because of this. Stealing that buggy and then wrecking it, how would you expect them to act?”

His mother nodded as she spoke.

“What?”

“Oh... yes, dear. I’m afraid it’s true. Of course, you took the buggy, not your
father. But to the company, it’s all the same thing. I didn’t have the heart to tell you, but we may have to pack up and be off the Moon by the end of the week over all this.”

“Yes,” his father interrupted. “But if these numbers are correct,” he looked closely at Maurice again, “You’re sure you were only digging on the surface and not using any cutting tools?”

“Positive.”

“Well, I may be able to work something out. I’ll need to take these down to the office tonight and look over the data in more detail before my boss comes in with the morning shift. You see, Maurice, if your surface numbers are good, then it may indicate a big helium reservoir out on the Sea of Moisture no one knew about before.

Consolidated Mines and Petroleum—”

“That’s the company that owns most of Gassendi colony,” said Maurice.

“That’s right. CMP is very strict with their employees, but that’s our parent company. Your mother and I work for HE-Three Mining, and fortunately, the mining company is pretty lenient with prospectors, especially as they tend to be quite an odd lot.” Mr. Haberman ruffled Maurice’s hair and smiled for the first time that night.

“Prospectors tend to be very independent and not much for work-a-day rules.” He looked at the rock and then his son again with both wonder and frustration on his face. “I’d better get these down to the office quickly if I’m going to get this all straightened out. It looks like maybe your nose for helium might just manage to keep us on the Moon after all.”

His mother hugged him hard. “Isn’t that wonderful, Maurice?”

Maurice was speechless. His great helium discovery was going to keep them on
the Moon!? Whatever punishment his parents dreamt up for him now could never hold a candle to this. He began to wish the space liner had never seen their smoke signal after all.

* * * *

Maurice walked down the hall of the HE-Three company offices with his father. He saw Cassie and Mr. Metis up ahead waiting for them.

"Hello, Ivan."

"Afternoon, Bob. I see you’ve brought Cassie." Mr. Haberman opened a door and motioned them inside. "After you."

Inside the room was a row of large stainless steel sinks on one wall and rack after rack of odor scrubber filters on the other wall. The commercial scrubber-filters were designed to remove odors from the recirculated air in the domes and burrows. From the look of the piles of the things along the far wall, Maurice and Cassie were certain Mr. Haberman had asked that every air scrubber the HE-Three company owned be pulled for cleaning.

Mr. Haberman took one of the filters off the rack. "They open like this..." a flip of a latch on one side and the filter opened like a book, revealing many flat plates stained a brownish yellow. Maurice grimaced at the sight. Mr. Haberman threw it in the sink and sprayed it with water, then scrubbed one corner vigorously. The water and soap caused the filter to release its odors. The steam coming off the sink smelled like B.O., rotten cabbage, curry powder, and week old French fries.

"Ewww!" Cassie wrinkled her nose and took a step back.

"When you’re done with it, the filter should look white like this." He held up the
filter and showed one corner clean and gleaming, then tossed it back in the sink.”

“How long do we have to do this?” Maurice moaned.

“That depends on you two. When that pile is clean,” Mr. Haberman pointed to the far wall, “you’re done. If you show as much initiative with this as you did with your prospecting scheme, you might be done in a day. On the other hand, if it takes you more than two weeks, the cleaning crew will bring in another batch.”

“You mean we’d have to do those, too?” Maurice asked.

His father raised an eyebrow. “You’re done when the pile is gone. If it takes you a year, at least I’ll know where you are after school and that you’re not experimenting with anything more dangerous than soapsuds.”

Bob Metis laughed at this. “C’mon, Ivan. Let’s go get a cup of coffee and let the young prospectors have at it. We’ll be back in three hours to pick you up, kids. Have fun.”

Maurice and Cassie each took a filter and made their way over to the sinks. The stinky steam rose as they poured water on the open filters.

“Ugh!” Maurice wrinkled his nose. Cassie actually gagged a little.

“Hey, Cassie.”

“Yeah.”

“My dad was pretty impressed that we managed to find a real helium strike out on the sea by ourselves.”

“Sure, Maurice. And we got paid real good, too. Just like you promised.”

“Just think of it as an adventure, Cassie. Isn’t that payment enough?”

Cassie dunked another filter into the soapsuds and choked on the foul smell. “My
dad thinks this is payment enough for our adventure, Maurice. ” she stopped scrubbing and glared at him.

Maurice grabbed another filter off the rack. “Hey, I gotta scrub them, too, you know.”

“Yeah, but that’s just your dad getting even with you, and he can’t space you ‘cause you’re his son. As for me, I haven’t decided what I’m going to do to get even yet, but kicking you out of an airlock without your helmet isn’t off the list by a long shot.”

“At least when we get done with the filters, you’re done with all this. My dad thinks I’m some sort of geology whiz, now. He’s talking about making me study to learn to do it for real so I can go out on a prospecting crew part time as an after school job. He says it’ll keep me out of mischief.” Maurice rinsed the filter off, put it on the drying rack and got another. This one smelled like an old miner’s boot liner mixed with moldy cheese when the water hit it. Maurice wrinkled his nose again.

Cassie laughed at him, “Serves you right.”

“Come on, Cassie,” Maurice whined. “You’ve got to help me come up with a plan so I don’t have to spend all my free time digging up rocks.”

Cassie glared at him. “Well, I guess you shouldn’t have shown your dad how good you were at it, eh?” Cassie grabbed another filter.

“Yeah.” Both children scrubbed in silence for a few moments.

Maurice grabbed another filter and opened it. He stopped for a moment and examined it carefully. His eyebrows rose and a wild sort of look came into his face.

“Hey, Cassie... I’ve got an idea! I bet we could hook up a motor and a round brush to make an automatic scrubber to clean these things faster.”
Cassie splashed a handful of soapsuds at him without bothering to look up from her scrubbing. “Shut up, Maurice.”

Maurice sighed. “Yeah.” He went back to scrubbing filters with a vengeance.
Chapter 8:
Jump Like an Earthman

“Our last announcement for the day, Coach Rosales will be holding tryouts for the track team. Everyone who is interested is invited to attend practice after school.”

“Did you hear that, Maurice?” asked Cassie excitedly. “Now that we’re finally in 7th grade, there’s going to be a real track team with uniforms and everything! Lunar mile, here I come! Come and sign up with me.”

“Yeah, I might as well. I gotta quit messing around with weird plans to go to Earth.” Maurice looked up to the blue orb in the sky. It was midnight on the moon today. The Earth, which is always at the opposite phase as the Moon, blazed full and round above them. “I’m never gonna get there, it might as well be Pluto as far as I’m concerned.”

“Yeah. Well, at least track practice will give you something else to do after school.” Cassie saw Maurice get that far-away look in his eyes which usually meant trouble.

“After school.... You’re right Cassie! This gives me a great idea.”

“Now what? If it involves rovers or prospecting, Maurice, leave me out of it!” Cassie looked at her hands. She had been sure that the pruney feeling from washing all those smelly filters would never go away.

“I don’t want to be a prospector, Cassie! Doing it for awhile with the chance to go to Earth as a payoff was ok, but digging rocks every day as a job stinks. Ever since our helium strike, my dad thinks I’m going to be the next great prospecting whiz or something. We spend two or three hours every day working on geology, lava types,
crater profiles... I'm really sick of it! Maybe if I'm doing track practice every day, my dad will drop the prospecting thing after awhile.”

“Yeah, well, maybe. If you make the team, that is. You should probably talk to your dad first about whether he’ll let you go to practice instead of just working after school all the time. It would be great if you didn’t have to pound rocks every day. Man, we haven’t been to the spaceport in at least a month.”

Maurice nodded, “Yeah, and it’s midnight today, so the Earth is full and everything. Since Maurice and Cassie lived on the near side of the moon, the lighting of the face of the Earth was always opposite that of the Moon’s. When the Moon’s face was the darkest, it flew over the noontime skies of the Earth and looked down on a fully lit globe. ‘The Earth is always brightest at midnight!’ was a popular saying intended to cheer up the gloomy.

Still, there was always the track team. Apart from wanting to get out of the extra work his dad had him doing, Maurice really liked track and field competition. He had wanted to compete in the high jump ever since he had seen the 2088 Olympics on television. But it wouldn’t be easy, you had to be able to clear 24 feet to make the school team. Maurice’s best jump ever had been just 19 feet, and on the Moon, that just wasn’t good enough.

Living on the moon wasn’t a permanent thing for most people and almost every adult on the moon wanted to return to Earth some day. Going back meant keeping in shape. Being healthy enough to go back to a place where you weighed six times more than normal meant you needed strong bones and muscles.
If you got lazy, your bones would gradually get thinner and lighter and muscles would get weaker. After all, an adult who weighed 180 pounds on Earth weighed just 30 pounds on the moon. Maurice weighed just over 17 pounds. He had figured it out once, that would have made him 104 pounds on Earth. Maurice found it hard to imagine he could weigh more than his whole soccer team put together!

At afternoon practice, Maurice met Coach Rosales.

“Alright everyone! Line up at the table under the lights, give me your name and tell me what event you want to try out for.”

At last it was Maurice’s turn.

“Name?”

“Maurice Haberman,” said Maurice quickly.

“Event?” asked the coach.

“High jump, Sir,” said Maurice proudly. “At least this will solve my problem and get me out of prospecting!” he mumbled to himself.

“High jump, huh? Don’t look like you’ve got the legs for it to me. What about the 100 meter dash? You’re light enough to be really fast.”

Maurice frowned. “High jump.”

“Really? Well, how high do you want to jump?”

Without thinking about it, Maurice pointed to the Earth, brilliant and full above them: “I want to jump there,” he said seriously.

Mike Evans, one of the teams best jumpers snorted. “Well, it seems like Superman’s going to be jumping for the Gassendi Giants this year!”
Everyone laughed at this for some time. Maurice blushed and grimaced all at once. It was the start of a very long afternoon.

Maurice worked all through practice on sprinting and jumping form. After a dozen or so jumps he was up for his last turn at the bar.

*O.K.,* he thought, *right foot planted, crouch low, sprint, hit your mark and...*

"Arrrrghh!" Maurice exploded into the air, raking and clawing with his arms as if he could pull himself higher by sheer force of will. An ungraceful roll over the light bar and tumbling down to land with a loud, belly-flop *Splat!*

"Twenty feet, six inches," said the computer flatly. A personal best! Even so, that jump still left him three and a half feet short of making the team.

The coach shook his head. "Doesn’t seem like you’re going to make the height, Maurice. Are you sure you won’t try the sprint?"

Maurice just shook his head.

"All right then," said the Coach. "Final cut is in two weeks; the track area is open after school ‘till six every day. I suggest you get some practice time in."

Cassie walked up to him. "Sure you don’t want to try out for the mile with me or maybe something easier?"

"What could be easier than flying like a bird in lunar gravity?"

"Sure," replied Cassie, "flying like a bird where there isn’t any air. What could be easier?"

When Maurice sat down at lunch with his friends the next day, he had almost given up hope. "I don’t see how I’m going to make the team! How am I going to get strong enough to jump 24 feet?"
At that moment, Cassie sat down with a crash that shook the table and nearly knocked Maurice’s milk into his lap.

“Hey! Watch out!” Maurice punched his friend in the arm and then yelped in pain. “Ow! What the heck?”

Cassie laughed. “Thought you might try that! Hah!”

Maurice rubbed his hand and stared at Cassie with a mixture of horror and disbelief while Cassie kept speaking the words Maurice was afraid to hear.

“We’re going back to Earth in just one week.” Cassie watched as Maurice’s face fell. “Sorry, Maurice. I just found out for sure yesterday when Mom took me to the doctor for a checkup and to get fitted for this.” Cassie took off her school jacket to reveal a bright yellow Earth-suit. It was sort of like the lead-filled apron the dentist puts over your lap when he takes X-rays of your teeth. But the lead-filled E-suit and pants Cassie wore weighed 5 times more than she did, over 80 pounds.

“Yes, I weigh 110 pounds exactly with this thing on, but I’ve got to wear it until we leave for Earth.”

“What’s it like?” asked one of the kids.

“Hot and heavy, mostly. And stairs are the worst! I can’t jump worth beans with this thing on!”

Maurice shoved his lunch tray away and got up from the table and stalked off. Cassie followed him after a moment of struggling to get up from the table with the heavy E-suit on. She jogged after Maurice, huffing and puffing.

“Maurice, wait!”

Maurice stopped and glared back at Cassie.
“You’re really going, aren’t you,” Maurice accused.

“It’s not my choice, Maurice. My dad got transferred back, I have to go. But you’ll get there, too. I know it.”

“No, I won’t. I’m never going to get down to the Earth, Cassie.”

“Besides, Earth isn’t really all that big a deal. You just weigh more and get to go out without a suit, that’s all.”

“You just don’t get it!” Maurice yelled. He stopped and stared red-faced at Cassie, then he turned away for a moment and rubbed his eyes with his knuckles.

“You were born there, just like me, Cassie. But you grew up there and remember everything... and you’ve been back! Sure, you’ve been here on the Moon for four years, and now you’re going home. But it’s different for me.

“I left Earth before I was two years old. That was TEN YEARS AGO!” Maurice was starting to shout and get red in the face again.

“Take it easy, ok?” Cassie looked worried and began to look around to see if anyone was watching. This was starting to get embarrassing.

“Look, practically the last thing you did was stop me from stowing away on a space liner—”

“Which you agreed was a stupid thing to do!” interrupted Cassie.

“—and now you waltz in here with an E-suit on and a ticket to Earth practically in your back pocket. It’s not fair!”

Maurice looked to Cassie as if he might start to cry again. Cassie thought she might die of embarrassment if her friend started crying here in the lunch yard. Then she put her hand on Maurice’s shoulder, “Look, Maurice...”
“Ow!”

“Sorry! This suit is the worst! I feel all clumsy and everything.” Cassie looked down at the yellow suit. “And it’s all yellow, too. I hate yellow! Not to mention looking like the Moon’s fattest clown with the world’s most boring costume on.” Cassie looked at her friend again. “You’re not getting the worst of the deal, believe me. I’ve got to wear this thing for at least a week until Dad’s transfer is approved and we get our tickets and stuff.... This thing really stinks, Maurice.”

“'S your own fault. The suit wouldn’t be stinky if you weren’t in it.” Maurice chuckled a little in spite of himself, then took a deep breath. He looked at Cassie again, suddenly appraising.

Cassie took a step back, “Oh, oh. I don’t like that look, Maurice. It usually means you’ve got something in mind.”

Maurice looked at Cassie and smiled. “How would you like a little break from wearing that nasty, hot and heavy E-suit this afternoon? I think I’ve got a plan to make the cut for the high jump!”

After school, wearing an oversized sweat suit to cover up the yellow E-suit, Maurice struggled out onto the track and huffed and puffed over to the high jump pit. Maurice watched Mike Evans make his last attempt of the day. Mike made his sprint and when he was still 15 feet away from the bar, he sprang into the air. Mike rose up, holding his hands out like a diver ready to plunge into deep water. He seemed to pause at the top of his arc, then gracefully turned over and cleared the bar. A soft summer salt down to the mat returned him to terra firma.

“Twenty seven feet, 10 inches,” droned the computer voice.
“All right!” said Mike, leaping up with a raised fist. “Procellarum Invitationals, here I come!” His friends shouted in glee. No one from the Gassendi Giants had ever gone to the Lunar Track Finals before.

“Hey!” called one of the boys to Maurice. “Didn’t you try out for high jump today? Do you want us to watch your form and give you some help?”

Someone else laughed. “What are you gonna do, throw the little dork over the bar?”

“Um... no thanks, fellas. Coach wants me to run the sprint,” Maurice fibbed. There was no way he wanted to try this crazy scheme while the bigger kids watched.

At last, the other boys left and Maurice was able to pace off his mark. From his starting point, the bar looked impossibly high. His sprint seemed more like trudging through deep water. When he leapt off the ground, he expected the usual 6 seconds in the air and the view from 20 feet up. Instead, the E-suit kept Maurice from jumping more than a few feet off the ground.

Maurice wondered about the kids who actually did the high jump on Earth. Not only would they be six times heavier, but they fell six times faster! The best thing about jumping on the moon was the wonderful feeling of flying so high you could sail over a two story house! On Earth, the whole jump would be over in less than a second! Besides, if you couldn’t jump much higher than you were tall, it hardly seemed worthwhile.

The next try was no better than the first. “Oooff!” Maurice landed at least 10 feet away from the bar. The added weight of the E-suit made it feel like a pro wrestler just landed on his back. Groaning, Maurice rolled over and looked up at Coach Rosales.
“You OK, Maurice?” Coach held out a hand to help him up, but Maurice refused to take it.

“I’m alright. Just tripped, that’s all.” Maurice said, not meeting the coach’s eye.

“Let’s go back to your mark and try again.”

Maurice wished there was a deep crater he could fall into. More attention from the Coach was the last thing he wanted.

“Starting the high jump is just like starting the sprint. Speed’s the thing, Maurice. Get into your starting position.”

Maurice crouched as best he could with the suit on.

“Start a little lower,” Coach Rosales insisted. He pushed down on Maurice’s shoulders. It was just a bit too much and Maurice toppled over with a crash. This time the Coach was too fast and had a hold of Maurice’s arm to help him up.

“Urk!” The coach wasn’t expecting the extra weight and fell over on top of Maurice. “What the....?” He patted down Maurice’s arm and torso. “You’re wearing an E-suit?”

Maurice blushed furiously, but could only nod.

“Interesting training technique. Did you read about it somewhere, or did you think this up yourself?”

“One of my friends showed up at lunch with the E-suit. I got the idea and borrowed it from her.”

“Well,” said the coach smiling, “if you’re going to jump like an Earth man, you need to know how. I’ve got some old training films from when I was in college at Iowa
State back on Earth. And don’t worry, Maurice. Your secret is safe with me. C’mon, let’s try that jump again.”

The next two weeks were busy ones for Maurice. Each day he would borrow the E-suit from Cassie, then report to Coach Rosales at the high jump pit after the older boys had finished. Each day Maurice noted how the lighted portion of the Earth he could see through the high jump uprights kept shrinking. Like his own personal blue hourglass in the sky, it had traded its blue and white sand for the velvet blackness of space. But the sands had run out, the Earth was new today and completely invisible to him under the noonday sun.

Progress seemed slow, but Maurice gradually increased his jump height from three and a half feet to 5 feet, 2 inches! Maurice was pleased with his performance, but practicing with the E-suit was terrifically difficult. It left him sore and covered with bruises from bad landings. At least his father had stopped bugging him about doing prospecting work – after he had called the coach to make sure Maurice was really attending practice. In its own way, the track practice was actually harder than the geology studies.

At last, the big day arrived for Maurice. Today, he would have to make his qualifying jump or wait until next year to join the team. When his name was called and he stepped up to his mark, Mike Evans spotted him.

“Hey, short stack! I thought you were trying out for the sprints! You weren’t anywhere close to making the minimum height two weeks ago.”

Maurice just smiled. “We’ll see,” he said. Without the E-suit, he felt like he could run a hundred miles an hour. He could hear Coach Rosales in his ear again; ‘Get as
much speed as you can, then explode into the air!’ Maurice hit his jumping mark and
leapt with all his strength. It was like being a bird! He folded his arms tight against his
sides and sped upward into the sunshine, then arched over gracefully and drifted down to
the mat with a soft plop.

“Twenty four feet, eleven inches,” said the computer evenly.

Cassie and the rest of Maurice’s friends erupted in cheers. Best of all was Coach
Rosales offering a quiet handshake and a smile.

“I knew you could do it, Maurice,” said the coach.

Cassie broke away from her friends and bounded over to Maurice, she was all
smiles.

“Maurice! You did it!” Cassie threw her arms around Maurice and gave him an
enthusiastic hug.

“Hey! Knock it off, Cassie!”

Cassie let Maurice go, but didn’t stop grinning at him. “Sorry, Maurice! I
couldn’t help it, I’m so proud of you for making the team that I feel like celebrating!”

“Well, pick some other way to celebrate besides going all girlish on me, ok?”

Cassie arched an eyebrow, “Ok,” she smiled, “how about this?” She seized
Maurice by his jacket, pivoted neatly and tossed him over her hip.

“Yeow!” Maurice arced neatly toward the high jump landing pit where he landed
with a Splat!

“Metis!” yelled the coach. “Stop throwing Haberman around, we need him on the
high jump squad!”
Everyone laughed at this as Maurice sat up, red faced, on the crash mat. Almost everyone, anyway. Mike Evans, the teams best jumper was red-faced himself – with fury.

"NO way!" he spat. "That little squirt couldn’t even clear 20 feet two weeks ago!" Mike began to march toward Maurice with his fists balled up at his sides. "Hey, squirt, how did you improve that much so quickly?"

Cassie moved to stand next to Maurice as he got off the mat. She pointed at Mike Evans, who was approaching quickly. "Trouble, Maurice."

"What the heck did I do?"

Mike was stopped short when the coach clapped a hand on his shoulder.

"Hearing footsteps behind you, Mike?" asked the coach. Maurice and Cassie saw the coach steering Mike forcefully toward the showers while still talking to him. "Don’t sweat it, Mike. Maurice is in the junior division, he doesn’t compete directly with you."

"Yeah, but if he can improve that much in such a short time, what about next year?"

"It’s all in the training techniques, Mike," said the Coach. Mike nodded, still looking over his shoulder at Maurice as if he expected him to put on a cape and fly away. "C’mon, I’ll teach you to jump like an Earthman. Maybe you’ll still have a chance for a medal at the Lunar Finals next month! And if you do well there, the All System finals are in Chicago down on the Earth this year. If you want to have a chance at that, maybe you and Maurice should train together."

"Me, train with the shrimp? We’ll see about that." Mike buried his fist in his other hand and stalked off to the showers.
“You gotta be kidding me, Coach!” Mike Evans looked with disbelief when the coach held up the yellow E-suit. “There’s no way I’m going to train in that thing. I couldn’t jump for anything wearing an E-suit.”

“You’re going to have to wear one sooner or later, Mike.”

“Well, it’s not going to be today, and it’s not going to be because some stupid 7th grade twerp gets a bright idea, either.”

“Suit yourself.” The coach looked at the E-suit again and raised an eyebrow, “or not. It’s your choice Mike, but the Lunar Finals are only three weeks away. Your current heights aren’t good enough in your division to win a medal, much less go on to the All System finals on Earth next month.”

“Yeah... well, we’ll see about that.” Mike stormed out of Coach Rosales’ office muttering under his breath, “If I don’t get to go, the shrimp won’t either!”

“Man, that Evans kid sure wasn’t happy you made the high jump squad.” Cassie said around her sandwich the next day at lunch.

“Why should he care? I don’t compete with him anyway.”

“Yeah, well, just watch out for him, ok?”

“Sure, Cassie, I’ll be careful. And besides, what’s he going to do, plot against me or something? That would be crazy.”

“A crazy plan, huh? And this from the guy who hijacks prospecting rovers and sneaks on board space liners without a ticket?”

* * * *

“Ok, Maurice. Last jump of the day. Let’s really punch it, ok?” The coach stood
by his jumping mark and Maurice backed up to his starting place. “Really plant that left foot before take off this time!”

Maurice ran as fast as he could, hit his mark and leapt, then landed with a thump! He still hadn’t quite gotten used to the hard landings from wearing the E-Suit, but it sure did help improve his performance.

“Five feet, eight and one half inches,” droned the scoring computer.

“Hey, that’s a personal best for you, Maurice! Great job! Let’s try one more without the suit.”

“Ok. I haven’t jumped without it since Monday afternoon.”

“Looks like you’ve been doing weight training, too.”

“Sort of. My dad had me doing a lot of geology and prospecting training. I got to lift a lot of rocks.”

The coach laughed. “I heard about your prospecting adventure, is this another new training method, Maurice?”

“I wouldn’t really recommend it, coach.” Maurice shucked off the rest of the bulky E-suit and dropped it with a thump. Maurice didn’t notice Mike Evans watching with a couple of the older boys a few meters away.

“Ok, now. Reset your mark, you wouldn’t want to try jumping from the same place without your suit, you’d miss the landing pit entirely. That hurts from 20 feet up.” Neither Maurice nor the coach saw Mike Evans smile broadly at this remark.

Maurice used a white plastic circle he set on the ground to show him where to jump. Since lunar gravity was so low, high jumpers had to leap in the air while still more than fifteen feet away from the bar in order to clear the light bar at their maximum height.
On Earth, jumpers rarely leapt more than two or three feet from the bar. In high gravity, the jump was almost perfectly vertical, while on the Moon, the best jump was a gentle arch that peaked just as you crossed the uprights.

Maurice sprinted hard and shot into the air, arms flat to his sides to cut air resistance like the coach had taught him. He leapt with a slight spin that allowed him to spiral upward without tumbling or losing control of his direction of flight or orientation in the air. ‘Fly like a football does, Maurice’ the coach had said more than once. ‘You’ll be more stable in the air and that means more height.’ Maurice timed his spin so that after two and a half revolutions he lay over on his back and crossed the uprights, kicking his feet as he did so. And then, a soft summersault down to the mat in the landing pit and hit with a soft plop! on his back.

“Twenty seven feet, three inches,” said the computer.

Coach Rosales helped Maurice off the mat. “You know what that means, Maurice?”

“The best jump I’ve ever had!” said Maurice excitedly.

“You’re going to the Lunar Finals! If you can jump like that in the junior division, you could end up going to the All System Finals in Chicago.”

“Me? The Lunar Finals? Go to Chicago.... On Earth?”

“Yep. Good day’s work, seems like you’ve finally arrived. Go hit the showers.”

Maurice practically hopped and bounced all the way to the locker room, the extra weight of the E-suit he carried didn’t seem to slow him down at all. After Maurice had stored the suit and gone in to take his shower, Mike Evans came out from around the corner where he had been watching.
Taking a small pry-bar from his pocket, he quickly popped open the locker where Maurice had stored his things.

"Let's just see how well he does without his favorite toy!" Mike took the E-suit out with a grunt. "Man, that's heavy!" The Earth suit was too bulky and heavy to carry far. Looking around quickly for a place to hide the thing, Mike spotted the table in the corner of the room. He let his gaze travel up to the ceiling tiles and smiled. Climbing up quickly onto the table, he lifted a large tile and shoved the pieces of the E-suit into the ceiling and up over the wall divider that separated the locker room from the next room. Mike didn't realize he had pushed the E-suit over the divider and stashed the 80 pound lead lined suit above the ceiling tiles in the coach's office. With a smile, Mike left the locker room whistling off-key.

Maurice came out of the shower wrapped in his towel and spotted the broken locker almost immediately.

"Oh, NO!" While his clothes were still there, the E-suit was not. "Cassie's gonna kill me!" A frantic search of the locker area after he was dressed revealed nothing. The E-suit was gone. Maurice's father had warned him; any more foolishness on his part would surely find him back in the little room scrubbing out odor filters again. Maurice also knew the E-suit didn't really belong to Cassie. No one actually bought one, you just rented a suit for a week or two to help you stay in shape for passing the physical to go back to Earth.

Someone had taken the E-suit on purpose – and Maurice thought he knew who did it. The only problem was, there wasn't any way to prove it.

"Heading home, Maurice?" Coach Rosales asked.
“Um...”

“Hey, what happened here?” The coach ran his finger along the damaged locker door.

“Somebody broke into my locker while I was in the shower.... It looks like they took Cassie’s E-suit. If I don’t find it, she’s gonna get in loads of trouble with her folks. She’s not even supposed to be lending it to me.”

The coach frowned at the broken locker. “Come to my office, we’ve got to fill out a report.”

Maurice dressed quickly, then followed along, dragging his feet and wondering what he would tell Cassie. It was bad enough his best friend was leaving in a few days, but having Cassie leave mad at him and in trouble as well was just too much.

Coach Rosales plopped down into his chair, scooted it back to a file cabinet in the corner, and began rummaging in one of the drawers. “I’ve got the forms in here somewhere...”

There was a groaning noise above them. Both Maurice and the coach looked up at the ceiling and watched a bulging white tile break loose with a loud ripping sound. Broken pieces of tile and 80 pounds worth of yellow E-suit dropped down on top of Coach Rosales. It knocked him out of his chair, burying him in yellow vinyl, white tile fragments, and clouds of puffy pink insulation.

“Coach! Coach, are you ok?” Maurice raced around to the other side of the desk and began pulling tile pieces and insulation off Mr. Rosales. He pulled the yellow E-suit jacket away to reveal the angriest face Maurice had ever seen.

“Haberman! If this is your idea of a joke, I’ll...”
“NO sir! I wouldn’t, I mean I couldn’t.... I didn’t! Really!” Maurice looked up in the hole in the ceiling. “How’d it get up there anyway?”

Coach Rosales followed Maurice’s gaze up into the ceiling and saw where some of the insulation had been dragged over the wall from the other side. Without saying a word, he took the E-suit and left the office and went to the other side of the wall where the table stood.

“Haberman, get over here!”

Maurice came cautiously around the corner and looked at the coach without saying a word.

“Hop up here,” the coach pointed to the table. When Maurice had climbed up, the coach pointed at the ceiling tile above him. “Get that tile down, I want to see what’s inside there.”

Maurice reached up, but he was several inches shy of reaching the tile. He flexed his knees to jump but the table wobbled under him precariously.

“Don’t jump, Maurice, it’s not necessary. Come on down from there.”

“You were seeing if I could have done it myself, weren’t you?”

“Sorry, Maurice. Kids lie to teachers all the time. It’s nice to know you’re being honest with me.”

“Man, I wouldn’t lie to you, coach! If my dad found out, it would be back to scrubbing odor filters for sure.”

Coach Rosales smiled, “I guess it would at that.” He looked up at the ceiling tile again. “Best take the E-suit and head home Maurice, and don’t tell anyone about our little adventure here. Act as if nothing happened. But the next time you take a shower,
stash the E-suit in my office. It’ll probably be safe there.

Maurice just nodded. “Hey coach, who do you think took the suit and stashed it in the ceiling in the first place?”

“Dunno. Had to be somebody pretty tall to reach those tiles and then reach up into the ceiling as well.”

“Yeah.” Maurice was sure they were both thinking about the same person.

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“Hurry up and finish getting dressed, Maurice! We don’t want to be late getting to the space port!” Maurice’s mother called down the hall.

“I’ll go see to him, Ruth,” said Mr. Haberman. “Maurice?” Ivan Haberman poked his head around the corner of Maurice’s room and saw him sitting on the bed with his chin on his hands. “Looks like you’re all ready to go. You haven’t been to the space port in quite awhile, aren’t you excited?”

“I’d rather be heading back to scrub air filters again.”

“It won’t be so bad, Maurice. Cassie may not be on the Earth forever after all, and there’s always the vid and e-mail.”

Maurice looked up at his father who was offering a rather sad smile. Part of living on the Moon where most people didn’t stay forever was frequently saying goodbye to friends.

“You can even send a real letter now and again if you like.”

Maurice’s eyes widened. “A real letter? With an envelope and everything?” Sending actual delivered mail from the Moon to the Earth was very expensive – much more so than just making a vid call. However, when you received a real letter, you had
something personal in your hand you could hold and read over again when ever you
liked.

“Sure.” His dad smiled again and ruffled his hair, something Maurice normally
did not like much. It didn’t feel so bad this time. “C’mon, let’s go. Cassie will be
wondering where you are.”

The drive to the spaceport was a quiet one. The crowds didn’t seem so cheery,
and Maurice didn’t feel like jumping over anyone. The sight of rockets, freighters, and
sleek space liners didn’t seem to inspire him this time. They all seemed poised to take his
best friend and drag her away to the one place he wanted most to get to, but never seemed
able to reach.

When he got to the departure gate, he saw Cassie and her parents waiting in the
lounge for the boarding to begin.

“I thought you’d never get here!” Cassie jumped up and slapped Maurice on the
back.

“Yeah.” Maurice shrugged. “Me too.”

“We’re going to North America. Some place called Milwaukee or something.”

“What kind of a name is Mill-wok-key?”

“Who knows. Probably the same people who came up with ‘Chicago’ named it.
It’s supposed to be near there.” Maurice only shrugged at this. “Hey, cheer up, I got you
a present for when I’m gone.” Cassie nudged a large box at his feet with his toe.

“What’s this?”

“Open it and see.”

Maurice lifted the flap and saw the yellow E-suit inside.
“The rent is paid up for another week, so I talked my folks into letting you use it. Just don’t lose it, ok? I promised my folks you’d be good. Besides, the Lunar Finals are just a week away. If you make it there, maybe you can come visit me!”

“Yeah, that’d be cool,” Maurice said quietly, still staring at the E-suit.

“Last call for boarding Luna-Flight Six-Five-Two!”

“Better get that thing on, you don’t have much time to train, eh?”

“Thanks. I’ll put it on as soon as you’re aboard so you can recognize me waving from your port window.” Maurice put out his hand to shake, but Cassie grabbed him in a big bear hug and lifted him off the ground briefly.

“See you on Earth, Maurice.”

“You, too.” Maurice watched Cassie walk away and wave once more over her shoulder as she entered the gangway. Then she was gone.

Maurice quickly put on the E-suit and walked over to the observation window were he could see the sleek liner waiting to take off. The port windows were so small and dark, there was no way he could know which one was Cassie’s, or even if she was on this side of the ship. He waved anyway as the gantry crane removed the fueling hoses and vapors began to pour out of the rocket engines. Then there was the silent burst of almost colorless flame and the spreading cloud of dust as the rocket lifted up. It rose slowly at first, then gathered speed and shrunk quickly into the dark sky until it was just one more point of light lost among the stars.

Maurice looked up at the blue Earth. He could see the entire globe from the Norwegian coast to the edge of the Antarctic ice shelf south of Africa. The Earth was full and bright, but it was midnight on the Moon, and in Maurice’s heart as well.

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“I’ll get there, Cassie. Just you wait.”
Chapter 10:
The Leap to Earth

Maurice wore the E-suit from Cassie for the rest of the weekend. He put it on again Monday morning and prepared to wear it to school under his sweat suit.

“You going to wear that over your pajamas, Maurice?” his father asked.

“I tried it; it’s too uncomfortable and I sink too far into the mattress with it on. It kind of feels like you’re Dracula in his coffin or something.”

“I see.... Going to go out to the geology lab with me this afternoon?”

“I can’t, Dad. The Lunar Finals are next week, I’ve got to practice. Coach Rosales thinks I might be able to earn a medal!”

“And the All System Finals are on Earth this year, aren’t they?”

Maurice smiled, “Yep.”

* * * *

Mike Evans watched as Maurice rounded the corner and headed for the stairs to go down to the lunch area.

“There’s the twerp, now!”

“What are you going to do, Mike?” said one of his friends.

“Watch and see. If the little twerp sprains an ankle on the stairs, that’d be just too bad for him, wouldn’t it?”

Mike headed for Maurice from behind, setting out at a run.

“Man, look at him! He’s going to knock that kid down the stairs!”

Maurice didn’t see Mike coming and practically didn’t feel him either. When Mike hit Maurice, he wasn’t expecting to run into someone who weighed six times more than he did. It was like a one-year old running into a 12 year old – Mike bounced off.
Maurice stumbled forward slightly, but all his practice and work out time in the E-suit made it relatively easy for him to keep his balance.

“What the?” Maurice turned around and saw Mike on the ground and realized instantly what had happened. “You!” First there had been the teasing, then the business with the stolen E-suit, and now this! Maurice leapt for Mike and fell on him with a crash and began to flail away with his fists. Fortunately for Mike, trying to hit someone while you have an E-suit on doesn’t work very well. With the E-suit’s bulky, stiff sleeves, it’s more like having a pillow fight where the pillows are sewn to your arms. But unfortunately for Mike, these pillows weighed eight pounds each, about the same as a gallon of milk did on Earth.

“Oooff! OW! Get him off me!”

Maurice felt himself being lifted by the arms and looked up to find Mrs. Stratford and another teacher pulling him off the Evans boy.

“What’s going on here? Fighting on campus? You’ll have to see the principal about this, gentlemen!”

“I’ll take care of them, Mrs. Stratford.” It was Coach Rosales. They’re both my boys, and I think I know what this is about.”

“Are you sure, Mr. Rosales?”

“Oh, yes,” he said with a smile. “I’ll make sure it doesn’t happen again.” He grabbed each boy by his collar and marched them off. “Come with me, gentlemen. Since you have so much energy, let’s burn a little off.”

“But coach, he was on top of me with that stupid suit, pounding me! I shouldn’t be in trouble with you!” Mike whined.
“In a way, you’re right, Mike. In fact, since I saw the whole thing from start to finish, you shouldn’t be in trouble with me. By all accounts, you should be off the team and headed for the principal’s office right now. You’ve broken into school facilities, stolen property, tried to kill me by having that E-suit stashed above my ceiling where it could fall down when I least expected it.” The coach glared at Mike. “On top of all that, you deliberately tried to injure another student because you were afraid his success would make you look bad. You haven’t acted like a team player at all. Whether or not you stay on the team will depend on how you handle yourself today.”

The coach looked at Maurice. “As for you, jumping on someone while wearing an E-suit is very dangerous, it may have been richly deserved, but it was dangerous. Here on the Moon, dangerous horseplay gets people killed, if anyone should have known that, It was you, Maurice.”

“Yes, sir.”

They arrived at the track and field stadium with its many rows of bleachers.

“All right, since you both have so much energy and we have a big meet coming up, let’s start with some stair climbing. Mike, since you seem to have such an interest in Maurice’s E-suit, you can wear half of it. Maurice, give Mike your jacket.”

Maurice grimaced, but began unfastening the yellow E-suit jacket.

Mike Evans’ face reddened with anger, “What? No way!”

“Mike, you either put it on or turn in your uniform and head for the principal’s office. There’s no third way.”

Mike said nothing more but began putting on the heavy jacket. “Geez, this thing weighs a ton!”
“Um, just 45 pounds, actually.”

“That’s more than double my weight!”

“Enough talk! Up those stairs, double time!”

Maurice started up the stairs with a hop. Mike tried to take two stairs at a time to show him up but banged his shin on the second stair and stumbled.

“Oh!”

“Run it off. Get going.”

Mike struggled up the stairs after Maurice. It was the start of a very long afternoon for him. Maurice, working with half his usual load, found the workout rather easy and didn’t break stride once. Mike continued to struggle and puff as they went up and down the stairs. After their tenth time up and down the stadium steps, the coach blew his whistle.

“Take off practice. Stand on the bottom step with your feet together and hop up each step. Double quick! Let’s GO!”

It was the hops that did Mike in. After his third trip to the top, he sat down involuntarily.

“Gotta..... hand it..... to ‘ya..... Haberman.” He took a swallow of water. “You gotta be pretty rugged to train in this darn thing. How did you do it with both halves on?”

Maurice shrugged. “I wanted to jump as high as you. I figured a squirt like me needed an edge.”

Mike laughed and wiped the sweat away from his eyes. “Let’s go, squirt. Victory’s waiting.” It was one of Coach Rosales’ favorite sayings. Mike hopped off down the stairs and Maurice followed quickly. The coach was waiting for them at the
bottom of the stairs.

“Well, if you two are still interested in fighting, I can get out the boxing gloves and you can go a couple of rounds.”

Mike sagged a little. “No thanks, Coach.”

Maurice wiped the sweat from his face with his jersey. “Me neither.”

“Good. Go shower up, and don’t let me hear of anything stupid like this again, ok?”

“Yes, sir.”

“Right, Coach.”

“Hey, Mike, while you’re at it, Haberman’s locker has a broken door. See what you can do to help him fix it, eh?”

“Right. C’mon, squirt.” Mike looked down at the heavy yellow jacket, “Let’s get out of this rig and get cleaned up.”

“Fine, just quit calling me squirt, ok?”

“Sure, squirt. Anything you say!” Mike laughed and jogged off toward the locker room with Maurice in hot pursuit.

* * * *

“All right, squirt. Last jump coming up. Stretch out a little bit... breathe... good!”

The day of the Lunar Finals had finally arrived. Maurice had ridden the bus with all the rest of the team. He sat around for much of the time waiting for high jump to start, and for the older boy’s division to finish before he would get his try. In the JV division, Mike finished with a jump of 28 feet, one inch. Good enough for 6th place, but not good enough to get to go to Earth for the All System finals. Maurice was in third place with a
jump of 27 feet, 2 inches.

"Man, I'm never going to catch that kid from Tycho's Rim South. 28 feet, three inches!"

"Yeah. We'll have to find out how he trains, eh? But don't worry about him now, just think through your jump, hit your mark, and explode with everything you've got. The team's counting on you, Maurice."

Maurice took a deep breath and looked up at the glowing bar of light.

"I'm ready." Maurice walked to his jump mark and checked its position, then paced back to his starting spot and got into his crouch. From here, if he looked up between the upright posts of the high jump, he could see the Earth, a brilliant blue crescent, tipped with white.

"Earth, here I come!" Feet pounding, arms pumping, head down, Maurice sprinted toward the bar. He hit his mark and exploded upward into a graceful arc. Flying, hands against his sides, eyes looking ever upward. He twisted in a slow spiral, which revealed the whole stadium and its crowds from an ever higher vantage. Still, Maurice's eyes never left the blue crescent of the Earth above. Slowing down, reaching near the top of his arc, the last half-twist and arching back. kicking his feet gracefully over the light bar.

"I made it!" After a slow tumble down Maurice landed with a loud plop!, sinking into the soft cushions of the landing pit.

Maurice climbed off the mat and walked over to where Mike and the coach were standing.

One of the judges carefully checked the display and announced: "For Maurice
Haberman of Gassendi Middle School... twenty seven feet, eleven inches.”

“Great job, Maurice,” said the coach.

“Thanks! Hey, what about the final results?”

Mike thumbed over at the judges huddling over their clipboards. “They’re tallying the points now.”

Maurice wandered over to try and look over one of the judge’s shoulders, but he was shooed away impatiently. After a wait that seemed to take forever, one of the judges checked the tally sheet carefully for the last time, then moved to the microphone.

“For Tycho’s Rim South... Randolf Scott, first place. For Gassendi Middle School... Maurice Haberman, second place.”

“Yes!” Maurice jumped up and down and hollered until he was hoarse. Mike Evans and the rest of the Gassendi Giants were cheering at least as loud as the kids from Tycho’s Rim South who had taken the first place prize. Ruth Haberman had her video recorder up to her eye, but she was jumping up and down so much that the pictures would be a worthless blur. Ivan Haberman hollered too, and kept clapping until his hands were red and sore. Coach Rosales was all smiles.

Maurice looked up at the beautiful blue Earth. I’m coming, Cassie! See you in Chicago! he thought to himself, then he moved off to find the podium and accept his medal for second place.

* * * *

“Go right on in, Maurice,” said Coach Rosales. The sign on the door said ‘Dr. Masaki Sato, Principal’. Maurice had managed, incredibly, to avoid going in this door so far, in spite of some of the stunts he and Cassie had pulled. The Procellarum Invitationals
had been five days ago, Maurice wondered why the principal wanted to talk to him about it now. He opened the door and went in. The office was small, all chrome and black. Many pictures of Gassendi Crater and the Mare Humorum adorned the wall, all of them framing a large poster of Albert Einstein, which said: 'Great spirits are often violently opposed by mediocre minds.' Doctor Sato was tall and thin, with narrow shoulders and spider-like, long-fingered hands. He had a penchant for suits with well padded shoulders. Instead of making him look more fit or masculine, they had the unfortunate effect of making his head look two sizes too small for his long body.

"Welcome, Maurice, and congratulations!" said the tiny head in a surprisingly deep voice. "You're the first student from Gassendi Middle School to be going to the All System finals. That's quite an accomplishment."

"Thank you very much, sir."

"Yes, um... let's not be thanking me just yet, Maurice. There's still the matter of your ticket. That's really why we asked you to come up here."

"Ticket?" Maurice felt the butterflies wake up and prepare for takeoff in his stomach.

"The ticket... yes, the ticket. You see Maurice..."

"We don't have a ticket for you to go, Maurice," the coach finished for him.

"No ticket?" Maurice was starting to feel sick. The butterflies were practicing barrel rolls and loops, now.

"The school district will pick up your hotel and meals, of course!" Interrupted the principal. Coach Rosales scowled at him and then continued.

"Usually, the team pays for transportation, Maurice. But at the start of the season,
I considered our chances to be next to zero for having anyone go to the All-System finals on Earth. I didn’t budget for it. The ticket is nearly two thousand dollars. I spent that money on uniforms and other things at the beginning of the season.”

Maurice couldn’t help it. A small tear trickled slowly down his cheek.

“I’m sorry, Maurice.”

“We hoped maybe your parents could afford to send you, Maurice,” offered Dr. Sato.

“They’re saving up to buy our Lunar citizenship later this year. I don’t think they can afford it.”

“Of course, that’s a big expense,” said Sato.

Lunar citizenship was actually a partnership in the local economic exchange or LEX. Maurice’s family LEX was the South Gassendi Complex. It included not only their apartment, but a share in the ownership of the domes, burrows, factories, and public facilities like schools and parks. If your LEX prospered, so did you. It cost about $100,000 per family member and wasn’t offered to just anybody. Every citizen pledged their loyalty and fortune to ‘A united Moon, one land over the Earth, with equality and productivity for all.’ The Habermans had been saving for this opportunity for years, he couldn’t ask his parents to sacrifice the citizenship they had worked so hard to get for a ticket to Earth just because he wanted it. That would be too selfish.

The walk to the tram stop was a long one and Maurice stared at his boots the whole way home. For the first time he could remember, the stark gray landscape didn’t hold any fascination for him. The tram dropped him off in front of his housing block. Like all the housing in Gassendi Complex, Maurice’s home was built into the side of the
crater rim to shield it from radiation and meteorite impact. Maurice didn’t go inside. Instead, he climbed the crater rim. Almost 500 meters up, he reached the top and found a boulder big enough to sit on.

The Earth was gibbous, little more than half full, and getting smaller as they moved toward lunar dawn. It had never seemed so far away.

“Stupid planet!” Maurice shouted into the darkness. He picked up a rock and threw it up at the blue Earth and watched it travel toward the globe for a moment as if it were a Christmas ornament he might break with a lucky throw. But then lunar gravity claimed the rock and bent it’s path downward until it landed with a silent puff of dust somewhere out in the darkness.

“Stupid Moon!” Maurice choose another rock and threw it after the first. Then another, and again. Rocks flew into the darkness toward the Earth. One after the other, they were claimed again by the Moon, as was Maurice himself. Exhausted, he sat down on the boulder and scuffed his toe in the dust and gravel until his suit began to beep that he was low on air.

As he got up to go inside, he mused to himself, “Parents don’t even have to tell you what time to come back inside here, they just have to control how much air you get to take with you.” When your suit said ‘Low air!’, coming back in was automatic. He trudged and scuffed his way down the rim’s inner slope and found his way into the complex. When he palmed the door lock open and went inside, his mother was there. She seemed unconcerned with his distress. Moms just didn’t get it.

“Good heavens, Maurice! You’re all dusty, what on Earth were you doing out there?”
Maurice snorted at this, "Not going to Earth, that's what." He glared at his mother and ignored her puzzled look. He was mad at everyone.

"Well, be that as it may, it's off to your room to get cleaned up for supper, young man."

"Yes, ma'am."

Maurice showered, spraying himself once with water, then soaping up carefully before another brief spray to rinse off. The water reclamation system chugged and hummed, separating the soap, dirt, and salt before putting the former shower water back in the drinkable tank. Maurice put his towel in the dehumidifier, even this water would be reclaimed. Water was the most precious resource on the Moon. Many times more expensive than air, every ship that came to the Moon paid its landing tax in water and oxygen. Many ships carried extra water to sell at the spaceports. For a small freighter, a couple thousand liters of water could almost pay for the fuel for the trip from the Earth to the Moon.

Maurice sighed, there was one last thing to do. He went to the videophone and dialed Cassie's number in Milwaukee. "It is 9 PM where you are calling," said a computer voice on the 'phone.

"Hello? Hey! Maurice!" Cassie’s smile was a big as ever.

"Hey, Cassie."

Cassie noticed Maurice’s long face immediately, "What's the matter?"

"I'm not coming."

"What!? Why not!"

"Coach didn't budget any money for travel this year. He didn't figure anybody
would make it this far... ‘specially not me. My folks don’t have the money either, so I’m not coming.”

Maurice felt a tear waiting to fall and sniffed. A knock at the door surprised him. “I gotta go.” He turned away from his friend and broke the connection quickly before Cassie could reply.

“Hello, son. Sorry I’m late.”

“Hi, Dad.”

Ivan Haberman looked at his son for a moment. “Maurice, I had a chat with your track coach and principal earlier this afternoon. I heard they couldn’t pay for you to go to the All System meet in Chicago. Your mother and I have talked about this, too. With our citizenship coming up, we can’t afford to buy you a ticket either.”

Maurice sniffed and scrubbed his cheek with his knuckle to prevent a second tear from following the first. “I know.”

“But you can afford it.”

“Me? Where am I gonna get two thousand dollars for a ticket?”

“From your helium strike money.”

“...Helium strike?”

“That’s right. The company always pays their prospectors, it’s the law. That last rock you brought back had a concentration of 63 parts per billion. It was from the bottom of that little crater you crashed into, not a surface rock like your other samples. It’s a pretty rich strike, apparently. There have been prospecting teams out on Humorum ever since the analysis came in.

“Your mother and I talked with Cassie’s parents, and we decided you shouldn’t be
encouraged in your reckless behavior by getting well paid for almost getting yourselves killed. So we and the Metis’ split the earnings and put them into college funds for each of you. Even after the company deducted the cost of the buggy damage you each had a little over fifteen thousand dollars in your new college funds.”

Maurice was grinning broadly now. “We made money?”

“Hmmm, yes. That’s the reaction we didn’t want.” Ivan Haberman smiled briefly. “But your mother and I think this ticket would be a good use for some of the money. We’ve already talked to Cassie’s family. You’ll be spending a week with Cassie and her family in Milwaukee before the All System track meet. You’ll have a chance to get used to the gravity and practice before the big day arrives.” Ivan Haberman held out a large red envelope with ‘Aldrin Spaceport’ stamped on it in gold letters, and ‘M. Haberman’ printed in the corner.

“I bought the ticket this morning. Looks like you’re going to Earth after all, son.”

Maurice was hugging his dad so hard he hardly heard him.
"Good luck, Maurice," said Coach Rosales. "And remember, victory is waiting!".

"Go show 'em how to really jump like an Earthman, Maurice!" Said Mike Evans with a smile. He looked out the observation port at the sleek liner waiting on the pad.

"Man, wish I was going with you."

"Next year," Maurice assured him as he waved goodbye and entered the boarding area with his parents.

"Now don’t forget to watch your step, and don’t talk to any strangers!" Ruth Haberman sniffed and wiped away a few tears.

"Mom? It’s a whole other planet. There are seven billion strangers and only about 3 people I know. It’ll be kind of hard not to talk to some of them." Maurice shrugged.

“Oh, Ivan...” she looked at her husband and then turned back to her son. She smashed Maurice in another bear hug and planted too many kisses on his cheeks and forehead. He was sure he must be dripping with drool and lipstick by now.

“Mom!”

His father offered a more manly handshake, but then put his arm around his shoulder and gave him a squeeze anyway.

“Make us proud son. Here’s the boarding gate.”

“Back to see us again?” It was the same steward who had found him stowing away on the space liner some weeks ago. “Where’s you sister today?”

“Um... she’s already on Earth. I’m going to go see her for a few days.” Maurice saw his dad raise an eyebrow at this comment but he said nothing. “Here’s my ticket.”

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“All in order today, I see. Welcome aboard, you have seat 39-A, on the window.”

“Thanks.”

“Alright, Maurice, time to go.” His father gave him a hug and a stern look to go with it. “No urgent phone calls or weird messages on your behalf, hmm?”

“Yes, sir. I’ll be good.”

Maurice’s mother did not content herself with just a hug but insisted on kissing him – twice – and in front of everybody, too. “Be a good boy, Maurice, and mind Mr. and Mrs. Metis, won’t you?”

“Yes’m.” Maurice started backing down the gangway and away from any more embarrassing parental affection.

“Good luck at the track meet, son. Do your best!” His father called after him.

Maurice went through the hatch and was directed to his seat on the mid-deck of the ship. He climbed down the ladder and pushed aside the blue curtain separating his seat from the aisle. Fortunately, he had no seatmate, he had the tiny closet the stewards called a ‘cabin’ all to himself. He strapped himself in and felt the seat rotate back into takeoff position automatically.

Maurice looked out at Aldrin spaceport from his viewport. He was really going to Earth! He waved to his parents, even though he knew they couldn’t see him through the polarized glass. He saw them waving back. His mother pointed to the ship and put her hand to her mouth. Maurice could almost hear the ‘Oh, dear!’

Then he felt the sharp ‘clunk!’ that must have been the fuel lines detaching.

“Good afternoon ladies and gentlemen. I’m captain Femmel. Along with Sub-Captain Goodman, I will be piloting your ship to the Earth today. Our trip will take just
about 10 hours from the lunar surface to Earth orbital transfer station Alpha where we’ll be docking at the Gagarin spaceport. On behalf of Luna Flight, we thank you for flying with us today!”

A moment later, Maurice heard a thunderous rumble and felt himself being pushed down into his seat. It was about the same feeling as when he wore his E-suit in bed. There was the same sensation of sinking into the cushions of the chair that felt like he was suddenly much too heavy. He was on his way to Earth at last!

From out of the viewport he could see the Gassendi crater suddenly in all its size and glory with the Sea of Moisture stretching away to the south. The ship was gaining altitude now and heading south.

Maurice tried to see where he and Cassie had crashed the buggy, but he could not. The long shadows of the lunar sunset made spotting things on the ground rather difficult. There were signs of prospecting activity out on the sea now, though. Tracks and roads being cut and a large He-3 crawler-miner was making its slow way out onto the sea to where he and Cassie had discovered their helium strike.

This too, faded quickly as the ship gained altitude and passed over the lunar south pole and the Aitken basin, a huge impact scar over 2000 kilometers across. It was the largest impact site in the solar system and averaged six miles deep. Maurice tried to look for the famous hidden glaciers that lay in the bottom of some of the deeper impact craters peppering the bottom of the huge basin, but he couldn’t make out any glints of blue ice hidden in the black shadows.

The ship was still accelerating, heading into a higher lunar orbit from which it would leave for the Earth-Moon transit portion of the flight. The dark side of the moon
was coming into view now. It wasn’t entirely dark, of course, it had been named by the people on Earth who had never seen it. The far side was pretty bland compared to the near side where Maurice and his parents lived. There were only four tiny seas and none of the vast plains of lava and dust that were common on the near side. Maurice watched the unfamiliar terrain pass by for a few minutes, and then he started watching the horizon for signs of Earthrise.

The cabin speakers crackled to life again, “This is Captain Femmel, ladies and gentlemen. We will be accelerating to escape velocity and trans-Earth injection for the next fifteen minutes or so until we will reach our cruising speed of approximately 50,000 kilometers per hour. If you need to use the facilities, it’s much easier to use the standard lavatory while we have acceleration gravity. Once we hit cruising speed we will be in zero-gravity for the next seven hours and 48 minutes while we make our transit to Earth orbit and dock with spaceport Alpha.

For those passengers who are interested, the observation deck is now open and we will be seeing Earthrise in just about 4 minutes.”

“That’s for me!” Maurice unbuckled his seat belt. It didn’t feel much different under acceleration gravity than it did to be on the Moon. Then there was a bump and a dull rumble he could feel more than hear. He felt himself pushed back in his seat a little harder.

“Ladies and gentlemen, this is Sub-Captain Goodman. We are now accelerating at two lunar gravities. And for those of you away from home that’s about 1 Martian gravity or one third Earth standard. In just 7 minutes we will be making full acceleration into our lunar escape trajectory where we will be pulling two standard gravities, six times our
current acceleration. At that time all passengers, crew, and cargo must be strapped in and secured. Crew members, prepare for escape acceleration. Goodman, out.”

Maurice felt odd. It wasn’t as much work as wearing the E-suit. The yellow monster made him pull around 114 pounds of weight – the same as he would weigh in Earth standard gravity. But even weighing that much (Maurice normally weighed 17 pounds on the Moon); if you tripped, you still fell as slow as ever. Maurice figured he must weigh about 34 pounds now, but he could feel that everything wanted to fall faster! It was really weird, as if everything started falling twice as fast as it should and weighed twice as much, too... and they were going to weigh and fall six times more than this?! Maurice could hardly believe it.

He climbed out of his chair and made his way to the ladder in the passageway, then climbed up toward the front of the ship. Stewards were hurrying here and there securing luggage and helping people to seats. Maurice could catch snatches of conversations as he moved up the ladder, the ship was full of activity.

The observation deck access was through a glowing green hatch. It looked just like any other part of the cabin, except it was very dark. Two rows of large, comfortable seats ran the length of the dark cabin, which was lit by a row of tiny red lights that ran down each side of the aisle. Maurice saw a boy about his age who was sitting by himself; there was no one else on the deck.

“Can I sit down?”

“Sure.”

Maurice hopped in the seat next to the boy. “I’m Maurice.”

“Enrico.”
Maurice looked around and shrugged, what gives?

"I dunno. It sounded like fun when that captain said we could see stuff, but this seems kind of dumb now."

"Ready to open observation hatch," came the voice from the speaker. There was a sharp 'clank!' above them and a crack opened up in the darkness letting in moonshine and starlight. The crack continued to get wider as the large two halves of the roof continued to separate and open up, leaving nothing between them and the stars but a clear plastic bubble. The stars were brilliant.

"Cool!" said Enrico. I can see the Big Dipper and Cassiopeia!"

"Where? I've lived in the southern hemisphere all my life, I've never seen them."

Enrico pointed the constellations out and traced the stars with his finger. "And if you follow the front edge of the Big Dipper like this... you get to Polaris just about... there! If you're on Earth and you see that, you know which way's north."

"That's cool. We don't have a pole star in the south, just the Southern Cross. And that's more confusing than helpful for finding directions unless you really know what you're doing."

The speaker crackled to life again, "This is Sub-Captain Goodman, all crew stations check in..."

Maurice and Enrico could hear the voices of the different stewards over the cabin speaker; "First class cabin, Go!"

"Coach cabin, Go!"

"Galley, Go!"

A head popped in the observation deck hatch. "You boys all strapped in?"
Maurice snapped his buckles, “Yep.”

The woman keyed her wristlink, “Observation deck, Go!”

“Cargo master, here. All secure for lunar escape acceleration!”

Maurice and Enrico looked at each other with excitement.

They heard the sub-captain’s voice again, “Captain Femmel, we are secure to maneuver.”

“Secure to maneuver, aye! Prepare to initiate roll maneuver on my mark... three... two... one... MARK!”

The great liner hissed quietly and the stars in the sky above them began to roll to the left. The liner was rolling to be in proper position to fire their main engines and escape the Moon’s gravity and begin the journey to the Earth. The Moon came into view over the right side of the roof and continued to rotate until it was directly overhead. The dark line of the terminator cut the Moon in half.

“Everyone living on that line is seeing sunset right now!” marveled Maurice. The ship hissed again and the rotation stopped with the Moon hanging above their heads.

“Whoa!”

“Awesome!”

“Hey weird, if I squint one way, it looks as if the Moon is hanging above my head. But if I blink another way it feels like I’m hanging upside down over the surface!”

Maurice squinted, “Yipes!” For a minute, he was hanging, head down and impossibly high over the lunar landscape. He blinked again and the Moon was still enormous, but remained safely over his head instead of seeming to be far beneath him. The shift in perspective made him dizzy.
A bright flash on the northern horizon of the Moon caught his eye.

“What’s that?”

“Hey! It’s Earthrise!”

Maurice could only stare in silence. He had lived almost his entire life on the Moon and had never seen Earth anywhere near the horizon, much less rise above it. Since one side of the Moon always faced the Earth, the lunar view of the Earth never changed much. The Moon’s own tilting or libration and irregular changes in the lunar orbit did make the Earth seem to wobble around the sky some, but like a marble spinning at the bottom of a bowl, it never seemed to wander very far from its usual position. Now it was rising, blue and beautiful, over the limb of the moon.

“I can’t believe I’m on my way to Earth!”

“Yeah, me too. I’ve been here for two weeks, I’m ready to go home.”

“I’ve been here since I was two years old, about ten years, I guess.”

“Ten years! How did you stand it? The low air pressure always gives me a headache and all the fiddling with suits and helmets all the time makes me crazy. The low gravity’s cool, but I just want to go out and run over the grass and smell green things again.... And I miss my dog.”

“You have a dog?”

“Sure. He’s a tiger-striped Akita, his name is Jishin. He’s a big fuzzball though, about a hundred pounds.”

“A hundred pound dog? He must be as big as a truck!”

Enrico laughed. “Naw.” He held his hand out by his waist, “About this tall. Standard gravity, remember?”
“All hands, this is the captain, prepare for orbital escape acceleration in 10 seconds! All passengers should have heads back on the headrests and arm and legs firmly against the seat cushions.”

Maurice and Enrico arranged themselves in their seats.

“It’s not as bad as going into Earth orbit, you get almost three gees there!”

There was a rumble somewhere behind them. It was as if a giant hand were pushing Maurice hard back into his chair.

“Oh my gosh!” Maurice now weighed over 200 pounds. Twelve times more than was normal for him. He strained to raise his hand off the armrest.

“Oooff! I can hardly lift my arm!”

“Don’t try that with your head, you can hurt you neck if you do.”

“I won’t!” Maurice’s cheeks sagged. Maurice felt as if someone had a hold of his ears and was trying to stretch his face too tight over his skull. He tongue felt like it was made of lead. It kept trying to fall to the back of his throat. It even made talking difficult.

“This... is... terrible!” Maurice groaned.

“...Yeah.”

Maurice thought how odd this was. Gravity had always kept him from reaching the Earth before, now this strange acceleration gravity was moving him toward the Earth at almost thirty thousand miles per hour!

“All hands, this is Sub-Captain Goodman, prepare for acceleration cutoff in one minute.” The sub-captain’s voice didn’t sound like the gravity was affecting him at all.

“How does he do that?” Maurice croaked.

352
“Dunno,” Enrico grunted back.

As abruptly as it began, the great rumble from the back of the ship ceased, it felt like they had topped a big hill and started down a long drop on a roller coaster. Both boys felt themselves rise back up and float freely against their straps.

“Zero-Gee!” they chorused.

“This is so cool!” Maurice grinned at his new friend.

“I don’t think everyone thinks so... listen.”

Maurice could hear sounds of people groaning and getting sick in the cabin below.

Enrico laughed. “Dirt suckers!”

Maurice grinned weakly. “Yeah....” he felt a little ill, himself, but wasn’t about to admit that to Enrico, who seemed not to notice the change from two gravities to weightlessness at all.

“Attention passengers and crew, this is Captain Femmel. We are now on our trans-system trajectory. We will be increasing pressure and oxygen content from LoPOR standard to Earth standard gradually over the duration of the flight. Please inform the crew immediately if you have any difficulty breathing. The increased pressure and oxygen should help those of you with nausea to feel better soon.”

Maurice hoped he was right.

* * * *

The Earth, half lit like the Moon behind them, seemed to grow gradually larger over the next several hours until it filled the entire view out the roof of the observation deck. The Moon had diminished to a tiny half-disk the size of an aspirin tablet held at arm’s length. The Earth was never that small when Maurice looked at it from the lunar
surface. It made him feel somewhat lost and very far away from home. Everyone he had ever known, everywhere he could ever remember going to; they were all on that tiny gray ball floating in space behind him.

The view of the Earth was spectacular. Maurice could make out continents, shorelines, bays, coral reefs off shore in tropical waters, and the delicate spider-web tracings of cities and highways on the dark side.

“The home planet...”

“Yeah,” Enrico said. “See there, in the Mediterranean? You can see the coast of Italy traced out in lights. That bright area in the north is Milan, that’s where I live.”

Maurice nodded, staring at the edge of the terminator, which separated the dark of night from the light of day. It was sweeping over Greece and Turkey, moving toward Europe as they hurled westward high above the Earth at 17,000 miles per hour.

“Boys?” It was one of the stewards. “You’ll have to return to your seats now. The captain is shutting down the observation deck and closing the hatches so we can make final orbital maneuvers and dock at Gagarin Spaceport. You’ll be debarking and catching your shuttle connections down to the surface from there within the hour.”

“Right. Earth, here I come!” Maurice loosened the straps that held him to his seat and floated down the aisle toward the hatch, his seat, and the Earth!
Chapter 12:

High Gravity Planet

“Ladies and gentlemen, welcome to O’Hare Air and Space Port. On behalf of our crew, we want to thank you for flying Trans-Orbital Transport today. Our weather outside is hot and muggy, 35 degrees Celsius or 94 degrees Fahrenheit. The relative humidity is 87 percent. We caution all of our passengers when getting items down from overhead storage. We are now in standard gravity and your bags may be much heavier than you remember! Please ask a crew member for assistance if you need help.”

Maurice unfastened his seatbelts and stood up carefully. All 114 pounds of him. It was very strange to feel this heavy with nothing on except his clothes, not even a pressure suit or helmet. Just pants and a cotton T-shirt sporting “Property of Gassendi Giants Track Team” on the front. He tried dropping a coin from one hand into the other and watched in wonder as it raced downward, falling six times faster than normal. It was so strange. Maurice was very glad he had a week to get used to this place before the All System Finals.

He cautiously made his way up the aisle toward the door with the rest of the crowd. His breathing felt a little funny. It was sort of like breathing syrup, the air felt very thick and humid. Earth’s atmosphere was 50% thicker than the air in any lunar environment. He saw the open door to the gangway and noticed there were gaps in the flexible structure where air must be rushing out!

Maurice tapped the steward on the arm and pointed anxiously, “How can you maintain pressure with those gaps? Shouldn’t someone do something?”

The steward looked to where he was pointing and then sighed.
“Look, kid. This is Earth, we have atmosphere here, ok? Nobody has to buy air to breathe and we don’t have to live our lives in plastic bags, either, so just relax.”

“Sorry.” Maurice walked slowly down the gangway, he could see that other people from the Moon who weren’t in quite as good a shape as he was were having a bad time of it. Some of them were hobbling along, bent over like they were a hundred years old or something. It was easy to tell the lunar natives from those who had just been visiting. The real Terrans were walking quickly around their slower lunar cousins, sometimes with annoyance, but mostly ignoring them.

Maurice emerged from the gangway and looked around for a familiar face. Cassie’s family was supposed to meet him here. A hawker at a nearby kiosk was selling plastic canes and walkers for the gravitationally challenged.

“Get your gravitational aides here! Canes, walkers, chairs... rent or buy! Don’t risk a fall that could spell disaster...”

“Maurice!”

He quickly located the familiar voice in the crowd, “Cassie!”

The two rushed toward each other and collided in a bear hug. Maurice tried to lift Cassie off the ground this time, but grunted and found he couldn’t.

“Man, you weigh a ton!”

“Yeah, just like you!” The friends smiled at each other. “C’mon. My folks are over there.” Cassie pointed to her parents, waiting beyond a row of seats separating the waiting lounge from the main concourse.

Maurice waved at them, “C’mon, Cassie, let’s go!” Before Cassie could say anything, Maurice turned and tried to hop over the row of seats and join Cassie’s folks.
Even weeks of practice with the E-suit didn’t prepare Maurice for the tremendous speed of terrestrial gravity. Falling six times faster than he was use to, Maurice caught his shin on the edge of the seat with a whack! and tumbled over the chair onto the tile floor.

“OW!” Maurice came up from behind the chair with a drop of blood trickling from the corner of his mouth.

“Are you ok?”

“Think I split my lip. I’m not sure I like this place...”

Maurice overheard a couple of kids laughing as they went by. One of them poked his friend in the ribs and pointed, “What a neo!”

Maurice blushed in spite of himself. A pair of hands hoisted him bodily up onto his feet. Maurice looked up at a blue uniform and a shiny badge that said: ‘Chicago Port Authority Police’ on it. Upon seeing that he wasn’t really injured, the policeman frowned at him and pointed to a sign showing a jumping figure in a red circle with a slash through it. “No running or jumping in the concourse, young man,” he said firmly.

Maurice just nodded his head and rubbed his lip some more.

Mr. Metis had reached them by this time.

“You alright, Maurice?” Bob Metis inspected his charge and dusted him off a bit. “Cassie did the same things when she got here. Seemed to think she could still jump over the house – or off the roof – if I’d let her. Don’t worry, you’ll get use to it pretty quickly. Heck, it’s a lot easier coming from the Moon than it was when I came back from my mining tour on Saturn!”

The family retrieved Maurice’s suitcase and headed for one of the exits.
“C’mon everybody. Stay together, the car’s this way,” Mr. Metis called over his shoulder.

Maurice stopped and looked at the exit dubiously. It was just a glass door. No seals, and no airlock he could see, either. Each time someone went up to the door, it simply hissed opened and let them in or out of the building. The air that came into the building smelld thick, humid, and laden with the petroleum smell of car and jet exhaust.

“It’s really ok, Maurice,” said Cassie. Even so, it was several minutes before Maurice could work up the courage to walk through the door and into the outdoors without his helmet on.

Walking outside was like walking into a wall of heat and humidity. There was nothing on the Moon like this unless you went into the bathroom just after someone had finished using the shower, and even that didn’t smell like jet exhaust. Maurice kept looking at his arm to find the environmental controls for his suit, but there weren’t any there.

Cassie saw him looking at his arm. “Hot, huh?”

“Yeah. I’m not sure I like it here.”

“Don’t worry, you’ll get used to it. The car’s air-conditioned anyway.”

“Does it condition away the smells?”

Cassie shook her head. “’Fraid not. But, hey, at least there aren’t any odor scrubbers to clean out, eh?”

* * * *

The drive back to Cassie’s house in Milwaukee was one surprise after another. The number of people and cars continually amazed Maurice. The Chicagoland area, as the
natives liked to call it, or Chicago LEX, as Cassie referred to it, extended around the southern shore of Lake Michigan. From Milwaukee on the north, to Chicago in the center, and then east around the point of the lake to Gary and Ann Arbor, the giant city crossed four states and contained over 20 million people. This was more than twice the population of the entire Moon with the near and far sides put together. Maurice had often looked at Chicagoland from the Moon using his telescope. It had never looked so intimidating through the eyepiece.

They passed a sign saying: 'Welcome to Wisconsin, Dairyland of the Americas!'

"I don't get it. If it's all one city, why do they have all these names?"

"It wasn't always one city, Maurice," said Mr. Metis. "They started out as separate towns and grew together over time. In my grandfather's day, there were farms between the cities, and quite a bit of open land, too."

"Was it more like the Moon, then?"

"Even open land here has trees and grass and animals living on it, Maurice."

"Trees grow wild around here? That's weird! If they grow wild, who gets to keep the oxygen, and for that matter, how do they harvest it?"

"No one harvests it, Maurice," said Mr. Metis. "It just goes into the environment."

Maurice sat back in his seat and rolled his eyes at Cassie. "Oh, sure. Like if I owned a whole field of grass, with wild trees on it no less, there's no way I'd let everybody come sniff all the Oh-two they wanted for free!" He looked around some more at the green hillsides he could see between housing tracts and squinted. "How do you stand all the colors?"
“I know!” Cassie handed Maurice a pair of very dark glasses. “Black and Whites. They filter out about 90 percent of the colored light and replace it with shades of gray. You can adjust them to let in more color as you get used to it. They really help with the color shock.”

Maurice put them on. They made everything look, well... a lot more lunar.

“I can’t stand those darn things,” said Mr. Metis. “They make it look like you’re living in an old TV show.”

“TV show?” Maurice asked.

Cassie poked Maurice in the ribs and shook her head no as if to say ‘don’t get him started!’

“They used to have lunar TV here,” she whispered.

“Lunar TV?”

“Shhh! Yeah, even the people were gray.” Cassie wasn’t quiet enough. Mr. Metis overheard them.

“It wasn’t lunar TV, Cassie. It was just black and white, that’s all. They didn’t know how to make colored pictures then.”

“Nothing had color then?” Maurice asked.

“NO! Just the TV was black and white.”

“Why couldn’t you paint the TV box any color you wanted? Was it a law or something?”

“Only the pictures were black and white, Maurice.”

Cassie looked at Maurice’s puzzled expression and put her finger to her lips.
“Don’t get him going on his primitive art stuff or we’ll all have to sit down and watch hours of the junk when we get home,” she hissed.

“Parents are so weird!”

“Yeah.”

* * * *

Cassie’s house was a stand-alone (!) building with a large green lawn out front and more space and grass out back. The house wasn’t under a dome or built into a hillside or even covered with a meter or two of soil to shield out the hard radiation. Maurice wondered if the living quarters were underground and they used the above ground areas for storage.

“This place must be huge, Mr. Metis. How far underground does it go?”

“Underground? Sorry, Maurice, but this is it.”

“Aren’t you worried about radiation exposure? You don’t even have any dirt on the roof.”

“There’s a hundred miles of atmosphere to filter out all that; no need to worry.”

Maurice looked up at the impossible blue above him.

“Hey! The sun’s moved!”

“Sure! Sunrise and sunset – a twice daily show at no extra charge.”

“Ah...” Maurice couldn’t stop staring at the neatly trimmed grass on the lawn and the small maple tree growing in it. He wondered if Cassie had to cut it, and how long it took her to do it with a hand-held moss mower.

Maurice pointed to the grass, “Where’s your cows?”

“Cows, dear?” asked Mrs. Metis.
Mr. Metis laughed. “We use a lawnmower to keep that trimmed up, Maurice.” He winked at him. “I might even let you and Cassie talk me into trying it out this weekend... it’s easier to run than a moon buggy on a crater rim, anyway!”

Cassie groaned at her dad’s bad jokes, “Come on, Maurice! Let me show you the back yard. We’ve got a surprise for you!”

Cassie ran off and Maurice jogged along behind her. When he rounded the corner of the house, Maurice saw what must be the world’s shortest high jump. The makeshift wooden uprights and plastic bar were hardly taller than he was, maybe seven or eight feet tall. The pit cushions were just a couple of mattresses piled on top of one another.

“We built this so you could practice everyday before the big meet.”

Maurice couldn’t resist. He started to run up to the bar, but in the thick air and heat, he quickly slowed to a trudge. By the time he jumped, he barely left the ground, and whacked into the bar with his shoulder and crash-landed on the mattresses.

Maurice reddened slightly. “Guess I must be tired from the trip!”

Cassie’s mom helped him up. “Of course you’re tired, it’s your first day in high gravity, dear. You’ll get used to it.”

Maurice walked toward the house with Cassie. “Everybody keeps saying that.”

Cassie shrugged. “I know.”

When they got to the porch, Maurice opened the screen door, stepped inside and stood waiting in front of the main door to the house.

Cassie whispered in his ear. “There’s no pressure change to wait for, it’s not an air lock.” She reached past him, opened the door and went inside.
Maurice sighed and followed her in, mumbling to himself, “Don’t worry, Maurice, you’ll get used to it!”

* * * *

The next morning found Maurice and Cassie out in the back yard practicing the high jump. Cassie had appointed herself as Maurice’s coach. Maurice did his best to ignore Cassie and instead remembered the lessons Coach Rosales had taught him about jumping in Earth gravity. He set his jumping mark within arm’s reach of the bar and paced off the distance to his starting position.

Maurice crouched at the start and sprinted toward the bar. Everything seemed to hold him back, from the extra-heavy shoes to the thick and humid air. He leapt and rolled in the air, bumped the bar off the uprights and landed with a thump on the mattresses. The whole thing had taken less than a second.

“Man, you fall so quick here! It’s hard to time your jumps.”

“I know. Don’t worry, you’ll...”

“Don’t say it! I’ll never get used to it!”

“Okay, let’s just try again.”

The morning progressed a bit better, but Maurice still wasn’t able to get his timing right and his best jump of the day was just 5 feet, 4 inches.

“Hey, Cassie!”

Maurice looked over to the gate in the fence. There were three boys standing there, one was holding a battered orange basketball.

“Want to go to the park and shoot a few?”

Cassie looked at Maurice, who nodded.
"It’s gotta be better than this!" Maurice thumbed at the high jump pit.

"Can my friend come?"

The other boys waved them on, "Sure! Come on."

Cassie introduced Maurice to her friends as they walked to the park.

Ted, the boy with the basketball, said casually, "So you’re another loonie, huh?"

"Loonie?"

"Yeah. You know, a lunar colonist."

"We’re not colonists. We’re a nation now."

"Sure. And all anyone would have to do to conquer you is just go up and shut off your air!" Several of the boys laughed at this.

Maurice bristled. "Maybe you should come up and try it, then!"

"Oh, yeah?"

Cassie stepped between the two. "Hey, knock it off, guys. We just came out to play some basketball, remember?"

Ted sneered. "Fine, let’s play. Us against you two loonies."

"Three on two isn’t fair!" Maurice complained.

"Fair is for colonists. You’re a whole nation now, remember?" Ted tossed Maurice the ball, "Here, you can have the ball first so you can quit whining about fair."

Maurice passed the ball to Cassie then ran toward the basket. The pass came back and hit him with a lot more force than he was expecting. Most of the rocks on the Moon didn’t weigh as much as that basketball seemed to. Maurice took his shot... and watched the ball drift through the viscous air, far too low and too slow to make it to the basket. It flew directly into Ted’s arms instead.
“Was that supposed to be a shot?” He laughed and ran for the other basket and scored easily. Ted’s team quickly ran the score up to 12 to 4. It would have been worse except that Cassie was a pretty good shot – even three against one. Maurice was determined to score on the next play and drove hard under the basket and jumped up to shoot. One of the other boys jumped with him to block the shot and Maurice fell sideways and landed on his knee, ripping his jeans and scraping his knee.

Maurice looked down at the ripped pants and the scrape on his knee and felt the panic begin to rise. “RIP! Help me Cassie, I’ve got a rip!” Quickly he gathered the pants leg and pressed it hard against his thigh above the knee to prevent the air from leaking out of his suit... except he wasn’t wearing a suit.

Cassie knelt down beside him, “It’s ok, Maurice.”


“Better head back to the Moon, Loonie. The colony may need you, but the Earth sure doesn’t!” All three boys left amid lots of laughter at Maurice’s expense.

Cassie sighed. “Let’s go home. We can practice for the meet some more after lunch.”
Chapter 13:
Lost In the Wilderness

“All right, you two!” said Mrs. Metis. “We need to get cleaned up so we can go into the city tonight. I’ve drawn a bath, who’s going to go first?”

“Maurice can go first!” smiled Cassie. Maurice glared back at her.

“Go ahead Maurice. Cassini, show him where towels and soap and things are, okay?”

Maurice grinned, Cassie hated it when her mother used her real name.

Cassie scowled, “Yes ma’am.” She lead the way into the bathroom. “Here you go.”

Maurice looked at the tub full of soapy water with amazement. “What’s this?”

“It’s a tub,” Cassie laughed. “You get undressed and sit in it...”

“You sit in the water? C’mon, Cassie, you can do better than that! There must be 40 gallons of water there... that would be...” Maurice did the math in his head, “Gaah! Over seven thousand dollars! I’ve never seen that much water in one place in my life!”

“C’mon, what’s it for really?” Maurice was fascinated by the large tub of hot water. “Man, if you really could!” he mumbled to himself.

“You get in and wash yourself off, Maurice,” Cassie said laughing. “Why do you think it’s all hot and full of soap bubbles? Have fun.” She closed the door on her way out.

Maurice couldn’t believe it, it was like a dream come true! He stepped into the tub carefully. It was hot! As he sat down a little water sloshed over the side.

“Oh NO!”

Cassie’s voice came through the door. “What’s wrong now?”
“I spilled some!”

“Maurice, just relax! This isn’t the Moon, water doesn’t cost forty dollars a liter here. Most of the planet’s covered with the stuff, miles deep in places, ok? If you spill a little, just wipe up after your done. If you spill too much, just add some more,"

Maurice reached over and turned on the tap, releasing a gushing flood of water into the tub. “Whoa!” Maurice played with the taps a bit changing the flow from a drip to a forceful spray.

Cassie’s voice came through the closed door again, “Like I said, have some fun, just don’t flood the place... and don’t take too long!”

Maurice splashed and played until Cassie was bugging him to get out already. The Earth was really cool, Maurice decided as he pulled the plug on the tub. “I could get used to it here!

An hour later, they were all in the car again, heading south.

“Where are we going?” Maurice asked. They were headed into Chicago again. Maurice watched the sun setting over the houses and rolling hillsides. With the sun this close to the horizon, you could even see it move. Weird.

“It’s a surprise, Maurice,” said Mrs. Metis. “I think you’ll like it!”

Driving into the city at night amazed Maurice. The lights and colors didn’t stop just because the sun had set. If anything, the city was busier than ever. Up ahead there were huge rays of light waving about in the air.

“What are those?”

“Searchlights. Probably a car dealer or a grand opening of some store or other.”
“They’re lights? Pointed up in the sky? How can we see them? You can never see a flashlight beam like that anywhere on the Moon, the beam is always invisible.”

Mr. Metis thought about it a moment. “I guess you’re seeing light reflecting off of dust particles or water vapor in the air.”

“Dust particles just floating in the air?” Maurice wrinkled his nose. “And we’re all breathing that stuff?”

“Sure, everybody on Earth breathes in a little smog everyday. It’s ok, you’ll get used to it. Everyone does.”

When they finally arrived, they parked near an ancient complex of brick buildings.

“That one, over there,” said Mr. Metis.

“Shedd Aquarium? Is it Latin? Let’s see... little house with water in it? I don’t get it.”

“You’ll see. I love this place!” said Cassie. “Race ya!” She ran up the stairs with Maurice and her parents following after.

“Welcome to Shedd Aquarium, ticket please?”

Maurice gave the woman his ticket and stepped in side, then stopped cold. It was as if someone had transported him into a fabulous treasure house. On the Moon, water was one of the most expensive quantities in daily use. People traded water stocks and water futures on the Copernican Stock Exchange. Everyone used it very sparingly because the Moon was many times drier than the most arid desert on the face of the Earth. Here in Chicago, they had so much water, they could have a building with glass tanks of every size full of the stuff just for pretty fish to swim in. He tried to calculate the
value of the water in just the first display gallery and quit when he lost track of the millions of dollars.

“Chicagoland must be one of the richest cities in the universe!” Maurice exclaimed after they had toured another gallery with colorful salt water fish from the tropics. Maurice was aghast. “They put salt in it on purpose?”

“These fish couldn’t live in fresh water, Maurice,” Mr. Metis explained. “Come on, I’ll really show you something!” Mr. Metis walked down to the end of the hall and out the exit. Maurice followed with Cassie and her mom not far behind. The door opened out onto a cement terrace. At the end of the terrace was a railing where Mr. Metis was standing. Maurice could hear soft splashing sounds in the distance.

“What the...” Maurice walked to the railing and looked out onto an infinity of black water, softly lapping the concrete of the terrace he stood on.

“Welcome to Lake Michigan, Maurice.”

“I can see lights!”

“Yes, there are quite a few boats out there tonight,” said Mr. Metis.

“Those are boats? You mean that all the way out there is still water? How far does it go?”

Mr. Metis pointed out across the lake, “Almost two hundred kilometers that way...”, he pointed north along the lake shore, “and several hundred kilometers that way. And it’s all fresh water, too.”

Maurice stared in wonder. “Yes sir, Chicagoland must be the richest city in history!”

* * * * *
“Get up, lazybones!” Cassie shook Maurice again. “Come on! Dad’s taking us camping!”

“Really?”

“Yeah! Sort of like the old west and out on the range, except with no cactuses, or Indians, or horses, and more water and fun things to do... Midwestern style, you might say.”

When they finally found the little gravel road with the beat up sign that said ‘Lake Catherine Resort and Campground’, it was already mid-morning.

“Here we are!” said Mr. Metis, pulling into a space under a group of large elm trees.

Maurice got out and saw the small sandy beach and glassy lake that stretched a kilometer or two across, but wound out of sight to the north and south.

Mrs. Metis pointed to the lake shore a few meters away. “This is Lake Catherine, Maurice, what do you think? It’s not as grand as Lake Michigan, of course.”

“Lake Catherine is part of the Chain o’ Lakes, Maurice,” said Mr. Metis. “There are dozens of lakes like this, most of them are connected by shallow channels that eventually lead to the Fox river about 40 kilometers south of here.”

Mrs. Metis led him down to the water’s edge. In the shadow of the dock, the water was the color of green olives, but where the sun shone on it, Maurice could see the sandy bottom. The slope was very shallow and he saw the lake didn’t get deep very quickly. Mrs. Metis took off her shoes and waded in a few meters until the water was half way up to her knees.

“Ah! That feels very nice. Come in if you like, Maurice. The water’s very cool.”
Maurice took off his shoes and socks and waded in carefully, watching the water lap around his ankles. It seemed very cold.

“It’s kind of green.”

“That’s algae, dear, this is a real live lake.”

“Algae? Eewww!” A group of small, silver fish swam by him; several circled his ankles. Maurice was fascinated until one of them pecked at his ankle.

“Yeeeaah! He bit me!” Maurice hollered and scrambled out of the water.

“What bit you, dear?”

“The fish!”

Mrs. Metis laughed. “Oh, yes! They seem to like the salt on your skin or something. But don’t worry, they’re too little to have any teeth. They can’t hurt you.”

“Are there bigger ones with teeth?”

She laughed again. “Not in this lake, dear.”

“Gangway!” Cassie ran past him in her swimming suit and splashed out a few meters, and jumped in with a holler. Maurice contented himself with sitting on the sand in the sun while Cassie and her mom splashed about and had fun. Swimming in water full of algae... and live fish. This place was too weird. The day didn’t get any better.

After lunch, Cassie dragged Maurice to the boat house, where a small boat bobbed quietly, tied to the pier. Titanic II was painted neatly across the stem of the boat.

Maurice shook his head. “Titanic eye eye? I admit I don’t know much about boats, but isn’t this a little dinky to be called titanic?”

“Trust me, don’t ask! If you do, dad will make you sit through all four versions of the movie when we get back home.”
"They made a movie... four movies about your dad's dinky little boat? Come on, Cassie, quit kidding!"

"Shush! Dad's coming!"

"Want to go for a boat ride, kids?" Mr. Metis asked cheerfully.

Maurice watched Mr. Metis step carelessly off the pier onto the boat, which bobbed and sloshed as he hopped around removing the covers from the seats and checking the engine and fuel tanks. Cassie and Mrs. Metis followed and stepped onto the boat after him.

"Come on, Maurice, get in," Mr. Metis pleaded.

"It'll sink." Maurice said stubbornly.

"There are seats for eight, Maurice," Cassie said, "and there's only four of us. Besides, I've been out in this thing lots of times, it's perfectly safe."

"It better not sink..." Maurice said as he grabbed Cassie with one hand and Mr. Metis with the other and stepped into the boat. It rocked and bobbed beneath him and Maurice went pale with fear.

"Sit down, son," said Mr. Metis, "it won't bother you so much that way."

Maurice sat down and clutched onto the seat cushions.

Mr. Metis grabbed what looked to be a large orange pillow that someone had tried to cut in half and proceeded to wrap it around Maurice's neck and tie it on with a confusing set of straps and buckles.

"What the heck is this thing?"

"It's a life jacket, silly!" said Cassie.

"Life jacket? I thought you said this thing was safe!"
“It’s the law, Maurice; everyone under 15 years old has to wear a life jacket in a boat. No exceptions,” said Mr. Metis. He watched Cassie put her life jacket on and then checked to see that everything was fastened securely. “Good, we’re all set to go!”

Maurice looked around frantically on the seat cushion, “Wait a minute, there’s no seat harness?”

“It’s just a small ski boat, dear, it’s supposed to be fun,” said Mrs. Metis.

Maurice tried to breathe deeply and relax. He was hot and thought about putting his hand out in the water, but he remembered the algae and the fish that didn’t (maybe) have teeth and thought better of it. He startled at the violent rumble beneath his seat.

“Twin engine,” Mr. Metis shouted over the noise. “Propane burning, intercooled, ceramic turbo diesels! Watch this!” He shoved the throttle forward and the boat shot out into the lake, throwing Maurice back in his seat. He turned to see the dock shrinking behind them and saw the stern of the boat was running very low in the water. He watched a large wave from the wake of another ski boat come at them from astern. It caught up to them and slopped over the low stern, wetting the seats in the back.

“Sinking!” Maurice shouted, cringing away from the water as if it were acid. It had made quite a puddle in the back on the floor.

“Don’t worry, Maurice,” Mrs. Metis patted his arm, then reached down into the bottom of the boat and pulled a small rubber plug from a hole near the rear of the boat.

“Aaah!! NO!” Maurice leapt to somehow plug the hole in the bottom of the boat, but miraculously, the water drained out the hole instead of rushing in to kill them all. Maurice felt he could breathe again only after Mrs. Metis replaced the plug. He sat back down in the wet seat and felt his pants get damp. Maurice looked down at his wet
pants, then up at Mrs. Metis who nodded and smiled at him. Earth was so weird. On the Moon, nobody smiled at you if you had wet pants. Not even your best friend’s mom.

As the morning wore on, more boats appeared on the lake and the temperature continued to rise.

“Dad, when can we go skiing?” Cassie asked.

“We?” Maurice wondered aloud.

“I’ll go first and show you how!” said Cassie.

“Alright,” said Mr. Metis, “you can give it a try.” He pointed the boat to a quiet area near shore and killed the engine. “Hop out, sweetheart!”

“Yippee!” Cassie hollered as she vaulted over the side into the dark water and swam a few meters away from the boat. Maurice wondered what kind of maniac would jump out of a perfectly good boat, with or without a life jacket.

Mr. Metis pulled up a seat cushion and rummaged around, pulling out a long thin board with a mangled rubber boot fastened to it. He waved at Cassie, “Here you go!” and tossed the board at her. He pulled another board out from under the seat and looked to see where Cassie was.

“What are you doing?” Maurice asked, grabbing his arm before he could throw another board at Cassie.

“My daughter’s pretty good, Maurice, but I don’t think she is ready to try skiing with just one ski!” Mr. Metis tossed the other board at Cassie, who caught it deftly. Shesplashed around trying to get her feet into the rubber boots attached to the skis. Mr. Metis grabbed a rope out of the compartment under the seat and attached one end to the
stern of the boat and tossed the other end out to Cassie. Cassie took hold of a small wooden bar on the end of the rope and made a thumbs up sign.

Maurice had seen tethers before, spacers used them all the time when they had to work outside their ships in orbit or deep space. At least Mr. Metis wasn’t going to let Cassie drift away and drown.

“All ready, Dad!” Cassie shouted.

Mr. Metis touched the throttle lightly and moved the boat slowly away from Cassie until the rope was taut.

“I don’t get it,” said Maurice, “how is Cassie supposed to swim with those boards on her feet?”

Mr. Metis laughed, “Swim? I don’t think so!” He hollered to Cassie, “Here we go!” and slammed the throttle forward, throwing Maurice back into his seat with a wet splat!

Maurice turned to see the rope go tight and begin dragging Cassie through the water. Oddly enough, she did not drown, but rose out of the water, standing up on the improbable skis and skimming over the surface of the lake for a short distance before she lost her balance and fell with a whoop and a loud splash.

Mr. Metis slowed the boat and turned around, heading back toward Cassie who was swimming about, trying to retrieve her missing ski.

“Well, at least now I know,” said Maurice.

“Know what, dear?” asked Mrs. Metis.

“Now I know what kind of maniac jumps out of a perfectly good boat... the kind who thinks she can walk on water.”
By the time the boat pulled back into the dock that afternoon, Maurice had had enough of water to last him a lifetime. He climbed out of the boat onto the solid dock and then the beach itself. He stood perfectly still and yet felt the earth swaying and bobbing beneath his feet. All the while, his eyes told him everything was standing perfectly still. It seemed like one more evil trick of the mysterious green water.

"Too bad you didn't try skiing, Maurice," said Cassie.

"Yeah. I'm devastated."

"Let's go eat, I'm starved!" Cassie slapped him on the shoulder.

"Ow!"

"Looks like you got some sun," said Mr. Metis cheerfully.

Maurice looked at his reddened arms in horror. "Radiation damage! Oh my gosh! I'm going to start to blister and get sick and then all my hair will fall out and I'll need to have gene therapy for weeks!"

"It's just a sunburn," Cassie assured him. "Your skin will be red and sore for a day or so, and then you'll have a nice tan when you go back to the Moon."

"A tan? I'm going to change color?" He looked at his bright red arm. "Again?"

"All we get here is a little nice UV," said Mr. Metis. "Everyone doesn't have to wear layers of foil sewn into their clothing and you don't have to crinkle like a candy bar wrapper every time you walk down the street."

"Yeah, I noticed nobody sounds normal when they walk around here. I was wondering what that was.... Ow!" Maurice slapped his arm. "Something bit me!" He raised his hand and saw a red splatter mark about the size of a fingernail.
“‘Skeeter,” nodded Mr. Metis. “At least you got ‘em. That’s one whose babies will go hungry.”

“IT feeds my blood to its young?”

Mr. Metis nodded. “Insect larvae. They live...”

“In the lake?”

“How did you know?”

Maurice shrugged his shoulders. “It figures.” He scratched at the growing welt on his arm. “Man, this itches!” Then he began to notice other spots. There were three on his other arm and several itchy welts up and down each leg, he wasn’t sure how many were on his back. “They’re eating me alive!”

“Here you are, dear, this will stop the itching.” Mrs. Metis proceeded to use a bottle with a foam sponge in the top and began dabbing him on each spot, leaving a sticky pink circle.

“What the heck is that stuff?” Maurice pulled his arm away.

“It’s bug-bite lotion, dear. It’ll stop the itching.”

He looked at his arms as Mrs. Metis continued working with the blotter-spotter bottle of lotion. He could hear the squishy sound and feel the lotion cool his skin in spots as it dried.

“This is great, Cassie. What’s red and white and covered with pink polka-dots? Maurice the Moon man, that’s what.” Cassie laughed at this. “Hey, what’s to stop more of them from having me for lunch, anyway?”

“Try some of this, it’ll help.” Cassie sprayed him with a foul smelling liquid from an aerosol can, covering his arms and chest before Maurice could stop her.
“Bleach! Stop that! What is that stuff, anyway?”

“Bug repellent.”

“It’s repellent, all right, ugh!” Maurice held his arms out away from himself, but he couldn’t get away from the smell.

“You could go wash off in the lake.”

“Thanks,” Maurice frowned at her.

“It’s your choice. Arms and legs and back full of those,” Cassie pointed to the welt on his arm (which had begun itching again), “or arms and legs and back covered in this.” She held up the aerosol can.

Maurice suffered himself to be covered in the stinky stuff. “If rocks had noses, this stuff would stop a landslide.”

Cassie continued to spray her own arms and legs, “I know.” She passed the can to her dad. “There, now we’ll all stink. Pretty soon you’ll stop smelling it so much.”

“Yeah. I’m sure my nose will go numb any minute now.”

“Come on, Maurice, you can help me start the fire for dinner,” offered Mr. Metis.

“A real fire? Cool! Are you going to use two sticks to start it like the prospectors did in the Old West?”

“ Heck, no!” “I spray the wood with this stuff before I light it.” Bob Metis held up the bug repellent can, “This stuff would make wet peat bum like newspaper!”

Maurice sniffed his arm again and shuddered.

In spite of everything, the hot dogs roasted on sticks and served on buns with ketchup and bags of potato chips were delicious.

“Hey, these are great! Did you get real rat-dogs?”
“For heaven’s sake, Maurice, those are all-beef hot dogs!” said Mr. Metis.

“Doesn’t taste like K-beef, these are great!”

“No, Maurice, real beef hot dogs.”

“Whoa!” Maurice stared at the rest of his hot dog with awe.

Mr. and Mrs. Metis had gotten several lake perch from some fishermen who were using the dock. But after seeing Bob Metis scale and clean them, then prepare the filets, neither of the kids would have anything to do with the fish.

After dinner, Maurice even tried his hand at roasting marshmallows for S’mores. All he managed to do was sacrifice a dozen or so perfectly good marshmallows to the fire before giving up and confining himself to eating instead of burning his food.

The sun was getting lower in the west and there were large shapes looming on the horizon.

“Those must be clouds!” Maurice said with delight.

“It’s supposed to rain tonight, but don’t worry. I’ve checked both tents, you’ll be fine and dry as long as you stay inside.”

When it came time to go to bed, Cassie climbed into the tent first with a flashlight. Maurice was right behind her, stooping to enter the small dome tent.

“Isn’t this cool?”

Maurice nodded. “Yeah. It’s just like a survival shelter... except it’s not a matter of survival.” He poked the thin nylon wall of the tent, “And apparently not much shelter, either.”
Everyone got ready for bed and climbed into their sleeping bags. As soon as Maurice and Cassie were quiet, they noticed a rhythmic ‘skreek-skreek-skreek’ that seemed to come from all around them.

“What’s that?” Maurice asked.

“Frogs are singing,” Cassie said. “Aren’t they cool?”

“Get serious, is it something dangerous?”

“I am serious. Most of the noises you hear are frogs and toads singing for mates in the shallow water. Some folks around here go hunting them at night by wading along the reeds with a spear and a flashlight. But you have to watch out for cottonmouths.”

“What are those?”

“Poisonous swimming snakes. About a meter and a half long. Mostly black and brown, kind of hard to see, but when they try to bite, you can see the inside of their mouths are pure white, just like cotton.”

Maurice scrunched up in his sleeping bag and looked around the floor of the tent for unknown spots of black and brown. There seemed to be many of them that might be vaguely snake-shaped. “You’re just trying to scare me, huh?”

“It’s all true,” insisted Cassie.

The tent wall behind Cassie began to flicker with light.

“What’s that? Something’s burning!”

Cassie and Maurice stuck their heads out of the tent and looked toward the west, over the lake. The last shades of purple were draining from the sky, the shapes of a tall row of clouds marched across the horizon.

“It looks like a huge crater rim.”
“You’re right.”

The wall rippled with colors from blue to pink that seemed to flicker and run along inside the wall before them. Flash after flash chased themselves across the sky in perfect silence, seemingly in time to the eerie music of the frogs. Finally, a low rumble sounded for several seconds before fading away. The frogs became strangely silent. The marching wall of clouds covered up the Moon and made the night suddenly much darker. The temperature was dropping quickly now and the wind was picking up.

“You kids get inside!” Bob Metis poked his head out of the next tent. “Seal the flaps like I showed you, it’s going to rain pretty hard, but it shouldn’t last long.”

The first big drops were beginning to patter on the tent now and the embers of the fire were starting to hiss-hiss-hiss as more drops struck the burning wood.

Maurice stuck his face into the wind and felt the drops on his hair. “RAIN!” He had heard about it all his life, and now he was out in the rain feeling water fall on him from out of the sky. A moon man’s dream come true. The drops came suddenly faster, plastering his hair to his scalp. The fire gave a last fizz and went silent.

Maurice pulled his head back inside and sealed the flaps. The drumming of the rain became suddenly much louder. He grinned at Cassie as drops of water rolled down his face.

“Rain, Cassie!”

“Neat, huh? We get it all the time.”

Thump! Thump... thump, ping! It sounded as if someone had begun throwing rocks at their tent.

“Meteorites, Cassie! We’ve got to take shelter!”

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"We’re in a shelter, Maurice, and it’s not meteorites, either.” Cassie moved over to the tent flap and unzipped it. She stuck her hand out groping for a minute, then pulled it back in and handed Maurice several small, round chunks of ice about the size of marbles.

“Ice meteors?”

“ Heck, no. It’s hail, look.” Cassie took a pocket knife and deftly split one of the ice balls in half while Maurice held the flashlight. She held the split ice-ball up for inspection.

“Cool, it has rings!”

“Yeah. Dad says they circle up and down through the clouds adding new ice layers each trip until they’re too heavy to stay up anymore.”

There was a flash of light that illuminated the entire tent. Cassie started counting, “One.. two.. three.. four..”

“What are you doing?”

“five.. six..” BOOM!

“What was THAT?”

“Thunder and lightning. You count the seconds between the flash and the boom and you can tell how far away the lightning strike was. Every three seconds is a kilometer. That one was about two kilometers away.” There was another flash.

“....seven.. eight.. nine..” BOOM! This one was louder and rumbled for some time. “Three kilometers away.”

Maurice huddled down in his sleeping bag, staring up at the dark fabric of the tent with his knees drawn up, his fists clutching the fabric of the bag.
“How big are those bolts?”

“Dad says about a billion volts on average.”

“We’re gonna die!”

“No way. They usually don’t get much closer than that, anyway.”

Flash! CRAAACK! RRRUMMMMBLE!

“Aaahh!” Cassie and Maurice screamed together.

“That was too close, Cassie!”

“No kidding!”

They both scrunched into their bags and watched the wind and rain shake the tent until they were sure it was going to blow away with them in it. The peak of the storm lasted twenty devastating minutes. By the time it was over, Maurice had fallen asleep from fear and exhaustion and dreamt of sinking ships and crashing storms on the high seas until he woke just after dawn.
Chapter 14:
The Big Meet

"Today’s the big day, Maurice," said his mother.

“That’s right, son. Just do your best and you’ll do us all proud! Getting this far has been a tremendous accomplishment. We’re both proud of you."

"Thanks Mom and Dad. I’ll do my best today." Maurice stared at the tiny videophone screen, missing his parents terribly. Talking to them on the ‘phone’ was ok, but the three second delay between ‘Hello!’ and ‘How are you?’ every time someone took turns to speak was annoying. But when you were calling someone a quarter million miles away, even the speed of light (or in this case, radio waves) took some time to get to the Moon and back. It was worse for people on Mars. The delay averaged about 20 minutes each way making real conversation impossible.

“How are you enjoying the Earth, son?” asked his father.

Maurice felt the cut on his lip with his tongue and looked at his sunburned arms, skinned knees and elbows. “It’s ok, I guess. Everybody says I’ll get used to it.”

“Is it nice for you to go around without a pressure suit? I’ll bet you’re glad you don’t have to fiddle with environmental controls on your suit all the time,” said his mother.

Maurice looked to the open window, a hole in the wall still made him shudder some. The day promised to be very hot and humid again. He could see little streamers of vapor coming off the morning dew on the grass and felt the first drop of sweat trickle down his back.
“It’s great, Mom. Not quite what I imagined it would be, I guess, but nice just the same.” Another drop of sweat began to race the first down his back. “I better get going, we have to get to Chicago so I can check in and get ready for my event.”

“Good luck, darling! We’ll see you soon!”

“Coach Rosales sends his best, too, son.”

“Thanks, Dad. You too, Mom. I’ll see you soon.” Maurice broke the connection with a sigh.

“Ready to go, Maurice?” asked Mr. Metis.

“Sure, let me get my helm... um, my duffle bag and I’ll be right with you. Hey, why do we have to leave so early? It only took an hour to get here from the spaceport. I don’t have to be there for over three hours.”

“Well, this morning, we’re going into the city with the morning traffic, not coming out of the city in mid-day.”

“What difference does that make? It’s still the same distance, isn’t it?”

Mr. Metis only laughed.

* * * *

“Why are we stopping? Isn’t this an expressway?” Maurice asked. They had been sitting in a solid block of cars and barely moving for nearly an hour now, and they seemed to be getting no further. “Isn’t there another road we can take?”

Mr. Metis just turned up the radio, which was tuned to a news station.

“The Eisenhower expressway is jammed this morning with a stall near the state street exit. Lake Shore Drive is moving at about 10 to 15 miles per hour and the Cross-town expressway is jammed with a jackknifed truck in the center lane. It’s a slow
commute all over Chicagoland today, and the extra traffic with the All System track and
field meet downtown at Soldier Field today isn’t helping matters.”

“That’s you!” cried Cassie.

“No, I think that part about the non-moving traffic is us,” complained Maurice.

“Don’t worry, we’ll get you there.”

“This is nuts. There isn’t this much traffic at Apollo Park on Lunar Independence
Day!”

* * * *

The day had gone slowly for Maurice. Once at the famous Soldier Field, he
checked in and had an enormous number 815 pinned to the front and back of his jersey.
He moved to an empty area and warmed up and then waited... and waited.... He knew
things would be like this, Coach Rosales had briefed him about it before hand. He had
brought along his electric book and a novel disk by his favorite western author, Lamont
LaRue. *Ambush at Coyote Canyon* distracted him until his event was called. The waiting
was difficult, especially since Cassie was not allowed to accompany him onto the field.
Coach Rosales would have been able to be with him, but since the coach couldn’t afford
to come to Earth, Maurice had to endure the waiting alone.

At last, his event was called, the big moment had come.

“All high jump competitors for the Junior division, report to the pit and check in
immediately!”

“Guess that’s me,” he said to no one in particular.

Maurice jogged over to the pit area and checked in with the judge.

“Number eight-fifteen, Haberman, competing for the Lunar near side, right?”
“Yes sir.”

“You’ll be jumping fourth. Don’t miss your turn when you’re called, or it’s scored as a failed jump. Three failed attempts at any height and you’re done. Got it?”

“Right.” Maurice gave the ‘thumbs-up’ sign and tried to look more confident than he felt. He saw the judges set the bright orange bar at 5-feet, 2-inches.

“Ok. This should be easy enough to start with.” He felt if he could make the first jump, all the others would be all right. He knew he would fail eventually. In high jump, you weren’t done until you couldn’t jump any higher without failing. At last, it was his turn for the first jump. The first three boys had made the height easily – he wasn’t sure if any of them were from the Moon or not.

Maurice reached his hand out to the bar and placed his jumping mark, then paced off his steps and crouched down. The sprint felt as slow as ever in the high terrestrial gravity; just as he was about to hit his mark, he tripped, crashed through the bar, and hit the mat face first with a splat. The painful impact and the laughter he heard made him cringe.

“Scratch!” said the judge. “Missed jump.”

Maurice cleared the beginning height on his next try, but it was an omen of things to come. The day progressed slowly, there were so many jumpers in the beginning, it took more than 30 minutes between turns. This gave the jumpers time to worry and fret about their technique, which did not help anyone’s performance. Maurice watched Randolf Scott, number 711, the jumper from Tycho’s Rim South. Scott was still jumping well, but the strain of the increased gravity was beginning to tell on him, too.
Maurice had missed twice at 5-foot, 7-inches. It was his last try and there were still many jumpers in the field. He crouched at his starting mark and looked at the bar. Not even six feet, it had never looked so high before. Maurice sprinted with all his strength, holding nothing back. He hit his mark and exploded in the air, feeling something tear and go painfully wrong in his left calf. Ignoring the pain, he rolled over perfectly and arched over the bar on his back, kicking his feet and clearing the bar by almost 2 inches. But he landed badly off balance on the pad and lay there holding his calf.

One of the trainers came over and looked to his leg.

“Pretty bad muscle pull by the looks of things. I think you’re done for the day, son.”

Maurice could only grimace and nod.

“Got someone to help you get back to the locker room and carry your stuff?”

“I’ll do it.” It was Randolf Scott, the boy from Tycho’s Rim.

“You’re not on his team...”

“Of course I am, we both jump for the Moon.” Randolf offered Maurice a hand.

“My friends all call me Ray.”

Maurice smiled. “Tycho’s Ray?”

The boy grinned. “That’s right. It’s a Moon joke, no one around here gets it.”

Tycho’s rays were streaks of dust left on the face of the Moon after crater Tycho was formed perhaps a billion years ago. You could only see them from Earth with a good telescope, and only on a full moon night.

“C’mon, Moon man! Pretty good jumping today for old Luna.”

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“Pretty good?”

“Yeah. You’ll end up with 14th or 15th place, looks like.”

“That’s not so great in my book,” Maurice said sadly.

“Not to worry. This is a two-year tournament, one year here and one year on the Moon. Best total points takes the bi-annual trophy. You should have seen some of these clowns on the Moon last year. Scared of any real height to start with, and then half of them jumped out instead of up and cleared the pit and landed in the turf instead.”

Maurice laughed in spite of himself and took Ray’s hand. “Ooo!” He quickly took the weight off his injured leg.

“Careful, gravity’s terrible when you’re hurt. But don’t worry, you’ll get used to it.”

“Somehow, I knew you were going to say that.”

Together, they hobbled off the field. It was getting dark; the Moon was nearly full and rising over the rim of the old stadium.

“Look at that!” Ray said.

Maurice felt suddenly homesick for the Moon. “Yeah. I’m ready to go home.”

* * * *

Later that evening, his leg was taped securely and feeling better, Maurice walked toward the boarding area of the space liner that would take him back to the Moon. He was disappointed that Ray Scott, the boy from Tycho’s Rim would be flying home on a different ship.

“Well, what do you think of Earth now that you’ve had a visit?” Cassie wondered.

“It was... different than I expected. I never did get used to it.”
“Would you want to come back again some time?”

“As long as we don’t have to go camping again, sure.”

“Boy, howdy, Dorothy, I bet its time to click your ruby slippers three times and say ‘There’s no place like home!’” said Bob Metis with a big smile and a look that said he expected Maurice to get the joke.

He didn’t.

Cassie stood behind her father and silently waved him off, mouthing: “Don’t ask!”

She walked over and put her arm over Maurice’s shoulder and led him away from Mr. Metis.

“Let’s get you on board now, Maurice!” she said over her shoulder.

“You’re dad’s a real wacko, Cassie.” Maurice whispered.

“I know... have a good trip back. Write me one of those ‘for real’ letters on paper some time.”

“Sure will. See ‘ya.”
Chapter 15:
Citizen of the Moon

“This place is packed!” Maurice looked out the port window as his liner was dropping down tail-first, to land on the pad at Aldrin spaceport. Maurice had never seen so many buggies in the open parking above ground. The observation dome seemed to be full of people, too. “How many people are on this thing?” he wondered aloud.

By the time he debarked and headed up the gangway, he could hear the noise of too many people all trying to have conversations at once. He thought he was through with crowds when Cassie and his parents had put him on the space liner at O’Hare and waved goodbye.

He emerged from the gangway. Somebody was having quite a party; there were balloons and things everywhere.

“Look, there he is, Ivan! Maurice! Over here, darling!”

Maurice smiled broadly when he saw them, “Mom! Dad!”

“It’s Maurice!” shouted someone from across the concourse. A band started into a scratchy rendition of a popular tune, Living on the High Frontier. Several kids lifted banners that said ‘Welcome Home Maurice’, and ‘All System Track Star!’

Someone was waving at him, Maurice waved back.

“Smile!” FLASH! “Hey there, Maurice! Winston Grimes with the Near Side News, got a minute?”

“Congratulations, Maurice!” Coach Rosales shook his hand as the news camera flashed again. Mike Evans and many of the other team members were slapping him on the back – his sunburn was still a little sore.

One of the cheerleaders came up to him, “Hi, Maurice, how was the Earth?” she
tilted her head and smiled brightly until her hair was pulled hard from behind by another cheerleader.

“Quit trying to hog him, Marcia!”

It was all a bit too much. He started to run to his parents, but the low gravity fooled him and Maurice stumbled into his father.

Ivan Haberman caught his son easily. “Feels like you maybe gained a little weight on Earth, son. You might be over 20 pounds now. I guess he’s getting bigger, Ruth.” Ivan smiled at his wife with pride.

“Hey, let’s see that medal, boy!”

“Sure, Dad.” Maurice reached into his shirt and pulled out the small bronze medallion with a runner embossed on the front and the legend: ‘All-System Track and Field Finals – Chicago, 2092’. The back said: ‘High Jump – Junior Division’ around the edge with ‘14th Place’ in the center. The news camera flashed once more.

“Thanks, folks!” His father pretended not to notice. It made Maurice feel as if he were the most important person in the world.

“Boy, I bet there aren’t many people on the Moon with one of these, son.”

Maurice snorted just a bit. “Sure, Dad, how many people would keep a 14th place medal?”

“I was thinking more of what it said on the front side... and what it says about you. Your friend Cassie worked hard, but she doesn’t have one of these. Neither does that Evans boy you were always trying to beat. Competing for the national Lunar Track Team, even in the junior division is quite an honor as well as an accomplishment to be proud of.”
Maurice looked at the runner on the front of the medallion. He decided he would wear it outside of his shirt for awhile as they headed out and waved to all his well wishers and shook hands or chatted briefly with some of them.

At last, they got away from the crowd and reached the garage where the buggies were parked. He did little experimental hops and jumps in the low gravity just to feel himself falling at normal speed instead of six times too fast. He didn’t even mind when some kid pointed at him from across the concourse and laughed, calling him a neo.

Putting on the pressure suit felt like heaven. Maurice was smiling to himself as he checked the fittings.

“You know, dear,” his mother was saying, “the last time I went to Earth, I never really felt fully dressed without it on.”

Ivan nodded, “I remember. You spent the whole vacation in the Bahamas wearing those tight jump suits... in the 40 degree heat, no less.”

“Yes, well, the only time I felt comfortable on that planet was when we went scuba diving. Nice bottled air and that wonderful wetsuit. But most of all...”

“I know, it feels like zero gravity when your under water.

Ruth Haberman smiled at both of her ‘men’ and fitted her helmet with a sharp click, then turned on the com-system as she stepped into the air lock.

“Let’s go home, gentlemen!” She took one of them on each arm as the lock depressurized and their suits inflated to their full volume. Maurice walked out into the hard vacuum of the Lunar landscape lit only by the lights of the spaceport. The soothing grays and blacks of the silent landscape were a welcome change from the riot of color and sound in Chicagoland. The occasional white airlock or orange sign stood out instead
of being lost against a busy background. For some reason, this pleased Maurice immensely. The buildings were all safely covered with several meters of lunar soil or were actually underground. Only the entrances or a sign above ground showed they were there at all.

Most of the landscape was pristine, as it had been for millennia. The sky was a beautiful velvet black, just like everyday. The sky was orderly too, the sun and Earth stayed put in the sky like they were supposed to. The stars were brilliant points of light of many colors. Wispy glows from nebulae and the Magellanic Clouds were sprinkled across the sky, with the glowing arch of the Milky Way above them.

The Earth was just a day or two past new and showed a waxing crescent face. The black disk of Earth's night side was picked out in lights from the cities of the Americas. Maurice could make out the blue spider-shape of the lights of great lakes region beginning to glow. Cassie would be seeing sundown now; on a planet where everything weighed too much, fell too fast, landed too hard, and things in the sky never stayed where they belonged. He shuddered a little bit to think of his friend sleeping next to an open window under a roof without a single centimeter of radiation shielding.

Ivan Haberman drove confidently through the darkness along the illuminated roadway. “It'll be dawn soon,” he noted. “Let's get home before the sun rises, eh?”

“Look, Maurice, here we are.” Said his mother.

The white and orange garage entrance was built into a semi-circular tunnel that went straight back into the huge rim of Gassendi Crater.

‘Residence Block – 1026, Gassendi Complex’ said the sign in front of the door.

The door recognized their buggy’s radio signature and opened automatically. Mr.
Haberman drove the buggy inside. The steel mesh tires buzzed on the rough concrete surface.

"It won't be too many years before you'll be driving the family buggy for yourself, Maurice!"

"Legally, that is, dear," added his mother with a smile.

Mr. Haberman parked the buggy in their assigned space; everyone climbed out, and headed for the airlock and stepped inside. Maurice felt the air pressure increase and hug his whole body. He felt secure and at home for the first time in a week.

They exited the airlock and headed down the long curving hallway toward dwelling number 383. Maurice pressed his palm to the lock pad and the door slid open quietly.

"Home at last!" he said as he stepped inside. The windows were all sealed tight and shielded against direct impact by meteors and the bright daytime sun. Maurice looked out at the stark lunar landscape. The softly rolling plains of the Sea of Moisture, ancient and unchanging, fading away into darkness away from the lights of the windows looking out from the Gassendi Crater rim.

Suddenly, the scene was starkly illuminated in the harsh light of the dawning sun. Long shadows and sharp beams of light instantly blazed across the harsh surface. There was no gradual twilight or pre-dawn light here on the moon. There was no air to carry the sun's light around the curve of the planet. They had just crossed the terminator into the light.

* * * *

"Come on, Maurice... we don't want to be late!"
Maurice heard his mother’s voice and continued to struggle with his necktie.

“Need some help, son?” asked his father.

“Why do we have to wear these antiques anyway?” Maurice grumped as he started to tie the necktie from scratch for the fifth time.

“It’s tradition, Maurice. It’s important to keep in touch with your history sometimes.” Mr. Haberman took the ends of the tie from his son’s hands.

“Around once... around twice... up through the back... and down through the loop like this!” A quick tug and the tie cinched tight around Maurice’s neck.

“Ack!” Maurice put his finger in his collar and tried to loosen the tie some.

“Let it alone. It looks fine.”

“Okay.”

“Here, I think this will give it the finishing touch.” Ivan Haberman placed the bronze track medal around Maurice’s neck and laid it neatly against the white tie.

“Perfect.”

“My, how handsome my men are today!” His mother smiled broadly and bestowed a kiss on each cheek.

The ride to Aldrin Spaceport was quick, but there was no sleek space liner this time. The Habermans boarded a local shuttlecraft headed for Schmidt-Sabine Complex; the closest LEX to Apollo Monument and Eagle Stadium. The six Apollo Monuments commemorated humanity’s first steps on the Moon, over one hundred years ago. Local shuttle flights over the parks were prohibited to prevent damage from exhaust blasts or possible crashes or forced landings. With care and stewardship, the Apollo craft and the first footprints on the Moon should be available for future generations to marvel at for
millions, even billions of years. There was no weather or erosion on the Moon to speak of that would ever erase them. Visitors to the park could walk above the original landing site in an enclosed walkway raised up off the surface on stilts. One of the original builders had gotten the idea from a park in the cypress swamps of central Florida where visitors strolled through the swamp on walkways elevated a meter or so above the water and the wildlife. The Apollo monuments drew millions of visitors from around the solar system each year. In an age where humans took space travel for granted and millions lived in colonies from the Moon to Saturn, most people still wanted to see where Man had first walked on another world.

Unlike Soldier Field in Chicago where Maurice had competed, Eagle Stadium wasn’t built open to the sky, rather it was built completely underground to shield the occupants from radiation and meteorites. The domed roof of the stadium was painted white and could be made to appear any color you could imagine. Often, blue lights would be turned on to make it appear Earth-like, but for other events, the ceiling illumination was simply turned off, making it appear a lovely lunar black, complete with softly glowing stars in realistic constellations.

Today, the stadium wasn’t the site of an exciting ball game or a concert, today was citizenship day. Once a year, on July 20th, Lunar Independence Day, those who had qualified for citizenship would take the oath of loyalty and productivity and be sworn in as citizens of the Lunar Union, which encompassed all of the lunar near side and the Aitken impact basin on the lunar south pole. Most of the far side was still fiercely independent, and few of the inhabitants there wanted anything to do with citizenship in any group.
Ceremonies like this one were to be held all over the near side of the Moon today. Their nation would add about ten thousand citizens on an average independence day. The ceremony at Eagle stadium near the Apollo Monument at Tranquility Base was an especially important one. Ivan Haberman’s contributions to the mining industry had earned them a spot of honor here today.

“I wouldn’t be surprised if they considered your accomplishments as well, son,” Mr. Haberman said.

“Remember to stand up straight, dear,” his mother reminded him for the third time.

“I will, Mom.”

As they entered the stadium, they saw many rows of chairs had been set up in front of a small raised platform containing a podium and a few other chairs. Behind the chairs, the Lunar Union flag was flanked by the flags of the various lunar seas and oceans. On the Moon, most of the settlements tended to be concentrated in large craters on the edges of the lunar seas. These huge, relatively flat areas of frozen lava were easy to build on and travel across; this made them choice sites for new colonies. When the Moon became independent and the Lunar Union was established, these maria became the natural states of the Union. Tranquility was the largest such state, but sparsely populated.

“Cool! Look at the state flags, they’re just like my mini-flag set at home on my desk.” Maurice looked around the stadium; most of the good seats were already taken as more people continued to arrive for the Independence Day festivities. “Where do we get to sit?”

“Down there,” his father pointed, “in those chairs in front of the platform.”
“Down on the field?”

They proceeded to the rows of chairs where an usher showed them their seats.

Soon after everyone was seated, a line of people entered from the end of the stadium and proceeded to the platform. The last to step up to the platform was the President of the Lunar Union, Liu Chen Ho. President Liu stepped to the podium. Lights sprang into life and reporters with small video pickups and microphones closed in for any special word or nuance. Maurice and his family listened intently, too.

“People of the Moon, welcome to our 23rd celebration of Lunar independence, and perhaps just as importantly, the 50th anniversary of permanent Lunar settlement.” Much cheering erupted at this; many people were looking forward to the entertainment to come. Maurice had been to several of these events in the past. He had always seen the swearing in of new citizens as boring, a great time to get a hot dog or go to the bathroom. Today, his attention was riveted.

“...The Moon has always called to the people of Earth. Over a century ago, in 1969, men first rose up to answer that call and stride forth on the surface to claim it for all of us. Fifty years ago, in 2042, we first came here to live permanently in answer to that call. Twenty three years ago, in 2069, on the one hundredth anniversary of the first man’s footprint on this surface, we declared our independence and brought forth a new nation in answer to that call. The Moon still calls to Earth, and as long as people like these before us rise up to answer that call with their ingenuity, courage, and productive skills, the Lunar Union will never fail!”

Everyone stood and clapped and cheered. Many waved the Lunar flag in black, gray, and white.
"Fix your hair, dear," his mother ran her hands through his short hair. "Use your comb."

Maurice glared at his mother. "Guess I'll have to now," he grumped.

Starting at the front, each person went up on the platform and gave their oath of allegiance to the Lunar Union, and then had their picture taken shaking hands with President Liu who said a few words to each one. When it was Maurice's turn, he raised his hand and promised to serve the Moon with courage, ingenuity, and productivity.

President Liu took his hand and shook it warmly. "Ah, the young Mr. Haberman! I've heard great things about you." The president brought a small blue box out of his pocket and turned again to the crowd. "As a special part of our citizenship ceremony today, I am pleased to announce the presentation of the Robert Goddard Medal for young inventors to Maurice Haberman for his development of the emergency smoke signal for disabled lunar rovers. Maurice invented this new signaling method when he and a friend became stranded while prospecting on Mare Humorum. Because of his ingenuity, this new technique is being incorporated into standard training and will save many lives in the future, I am sure."

President Liu turned to Maurice again, "On behalf of a grateful Lunar Nation, I thank you." He placed the large silver medallion around Maurice's neck. It looked like a map of the nearside with a stylized rocket ship across the front. The president placed his hand on Maurice's shoulder. "You have quite a list of accomplishments, young man. Inventor, track star, helium prospector.... buggy pirate." The President raised an eyebrow. "The Moon needs creative and ambitious people like you, Maurice. But maybe you should focus on just three out of four. Better results if you don't spread
"you're discussion, you know."

Maurice's eyes went wide. Wait 'till Cassie hears about this!