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Arecibo Observatory for All

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Abstract

We describe new materials available at the Arecibo Observatory for visitors with visual impairments. These materials include a guide in Braille that describes the telescope, explains some basic terms used in radio astronomy, and lists frequently asked questions. We have also designed a tactile model of the telescope. Our interest is in enabling blind visitors to participate in the excitement of visiting the world's largest radio telescope.

1. INTRODUCTION

The Arecibo Observatory is a part of the National Astronomy and Ionosphere Center (NAIC), a national research center operated by Cornell University under cooperative agreement with the National Science Foundation. Professor William E. Gordon from Cornell University designed this telescope to have a huge collecting area (305-m spherical dish; see Figure 1). The Arecibo Observatory is the largest single-dish radio telescope in the world. This design means that it can point to objects that are within 18º of the zenith. Its location in Puerto Rico allows for the observation of the planets, stars, galaxies, and other interesting astronomical objects that pass overhead. This radio telescope has receivers that can observe light between 1G and 10GHz and has a radar system, so it can transmit radar pulses to targets in space and receive the echo from these signals as they bounce from the target. It operates 24 hours a day and is used by scientists from all over the world. This instrument is used in radio astronomy, space sciences, and atmospheric sciences. It was declared an IEEE Milestone in Electrical Engineering and an ASME Landmark in Mechanical Engineering in 2001 (Brand 2001; Note 1). These awards recognize the achievements of this facility in electrical and electronics engineering. It is one of eight facilities that have received this joint designation.

Figure 1. The main spherical dish of the Arecibo Observatory radio telescope (below), one of the concrete towers (left) that holds, by means of cables, the triangular platform (above) with the Gregorian dome and the 430MHz line feed suspended below it.

Important discoveries have been made at the Arecibo Observatory. Because of Mercury's size, its distance from Earth, and its orbit so close to the Sun, it was not possible to determine its rotation rate until 1965, when Gordon Pettengill, working with Rolf Dyce, used radar techniques to finally determine how the planet spins. In 1974, Russell A. Hulse and Joseph H. Taylor discovered the first binary pulsar. They were awarded the Nobel prize in physics in 1993 for the discoveries they made studying this pulsar. Their studies served to test predictions made by Einstein's general theory of relativity. It was the first time a Nobel prize was awarded for discoveries that have made use of an astronomical observatory as a research tool. The first extrasolar planets were discovered by Alexander Wolscyan, who was studying a pulsar he discovered in 1990 (the name of the pulsar is PSR 1257+57). Many other discoveries have been made at Arecibo, and surely many more will be made in the future.

The Arecibo Observatory opened the Ángel Ramos Foundation Visitor and Educational Facility in 1997. The center allows visitors to view the largest radio telescope in the world, and it has audiovisual and interactive exhibits that describe how the telescope works and the type of research that is conducted. In addition, the center has exhibits that describe the basic concepts of astronomy. The exhibits are in Spanish and in English. The visitor center receives an average of 110,000 visitors annually, of which 26% are children, 66% are adults 60 or younger, and 8% are adults older than 60. The number of visitors to the Arecibo Observatory peaks in July, with around 20,000 visitors. September has the fewest visitors, around 4,000. It is one of very few places on the island where children and families can learn about science and technology through radio astronomy. The visitor center serves the general Puerto Rican population and is involved in projects with school children and teachers. It offers workshops for science teachers, has a teacher in residence program, and coordinates special science and education workshops. In addition, the center is part of the Arecibo Geoscience Diversity project, which targets high school students, teachers, and undergraduates, among other activities. (See Altschuler 2002 for more information regarding the history and construction of the Arecibo Observatory; also http://www.naic.edu). For information about the visitor center, see Altschuler and Eder (1998).

We have been working at the University of Puerto Rico (UPR) in developing science and mathematics courses that are accessible to students with visual impairments. According to the 2004–2005 statistics from the affairs office for students with disabilities at the UPR-Río Piedras campus, of a total of 3,445 students with disabilities, 1,378 are visually impaired. Of those with visual impairments, 474 students belong to the college of natural sciences (OAPI [Affairs Office for the Handicapped] 2006).

This experience led us, during the summer of 2006 (and with a scholarship from the Fundación Comunitaria de Puerto Rico and support from NAIC/AO), to consider the problem of how to make accessible the impressive view of the telescope, with its enormous reflector set in a sinkhole, and the beautifully diverse vegetation surrounding the observatory in the karst region at Arecibo. We want all visitors to enjoy their experience at the observatory, and we wish to motivate them to explore the universe. How can we do this? How can we allow a blind person to learn and to enjoy a visit to the observatory?

We must keep in mind that persons who are blind from birth acquire a concept of the world and its reality differently than sighted people do. The blind child lives in a world of people who can see and must compete in the world of sighted people. The use of science and technology increases daily. The best way to prepare these children is to allow them to learn as they grow (Grady et al. 2003). The blind child develops an exterior concept of things by the sensation produced by touch. We must help the blind child to form a concept of what surrounds him or her. This mental picture does not necessarily need to be built according to our visual concept, but rather in terms that are comprehensible to the child (see Note 2).

When a blind person encounters unfamiliar surroundings, he or she feels more at ease if guided by the arm of a friend. As the blind person becomes familiar with the place, he or she discovers reference points to help in orientation. We must let them explore and find those objects by themselves. In addition, children who learn by touch and sound prefer activities that are concrete and explained verbally.

2. THE BRAILLE GUIDES

Our first step in developing accessible material for blind or visually impaired visitors was to evaluate the current facilities at the visitor center. These facilities have a deck area adjacent to the main building from which the visitors have a view of the telescope. The center has a 100-person-capacity auditorium where the visitors can view a 15-minute presentation, "A Day in the Life of Arecibo Observatory."

The exhibits are centered on the theme, "More than Meets the Eye: Exploring the Invisible Universe." We classified the exhibits into three groups: *mainly text* are those exhibits that have a panel with text, graphs, and images to explain basic astronomical concepts; *visual exhibits* are those centered on a model that relies mostly on the visual sense; and *audio, text, and visual* exhibits have all three elements (see Table A1 in the appendix).

We found that the exhibits are mostly visual. Some exhibits could be improved by implementing some minor changes. There is one tactile model, a meteorite that visitors are allowed to touch. This exhibit could be improved by adding a brief description in Braille. Other exhibits might be improved if modified to allow a tactile exploration.

One of the biggest obstacles that blind people encounter is accessing information in a written format. For this reason, it is very important to facilitate access to information by sound and touch (Santana & Torres 1983; Torres 2000). Tiflotechnology—technology for the blind—has made it possible to make written communication more accessible to the blind by means of a computer. An example is the JAWS software from Freedom Scientific (http://www.freedomscientific.com). JAWS is a screen reader that allows the user to access the Internet and Windows programs and applications. Another method is to adapt information by means of Braille transcription. To adapt material that is mostly visual, one must think nonvisually and prepare nonvisual material (Torres 2000, 2002). To make reference to shapes or geometric figures, concrete examples are needed.

At present, the Arecibo Observatory visitor center exhibits are not designed adequately for visually impaired visitors. These visitors are currently received by guides who give them an oral description of the site. We wanted to contribute to improving this situation, although we had limited time and a small budget. This work would constitute the summer student project for one of us (GMI) as part of the Arecibo Observatory Summer Student Program (Note 3). We noted during the summer that visitors are most interested in the radio telescope. We decided to focus on giving the visually impaired visitor the opportunity to enjoy the visit by acquiring a better sense of the radio telescope.

We decided to prepare a Braille guide to the observatory. Our guide consists of three Braille documents. The first document, "Parts of the Radio Telescope," is the guide for all visitors and describes the main parts of the radio telescope. The other documents were elaborated for visitors who wish to learn more about radio astronomy. Each document is printed in Braille and in regular text, the idea being that the whole family can enjoy and learn from its contents. The guides are in Spanish and English and are printed in Grade 1 Braille. Grade 1 Braille is the standard Braille alphabet with no contractions or abbreviations, and Grade 2 Braille has contractions. We decided to print the document in Grade 1 Braille, considering the diversity of visitors to the observatory and our desire to ensure that the information is accessible to all, including those who are new to reading by touch. Our goal is that these guides will help the visually impaired visitor to have an idea of what the main tool of research is.

The first guide document consists of a description of each of the radio telescope's parts. It gives details about the primary reflector, the platform, the telescope mount, and the receivers. It includes high-relief diagrams of several parts to give the reader an idea of what is observed when one faces the radio telescope. Figure 2 shows the presentation of the Braille documents and tactile model at the Arecibo Observatory library.

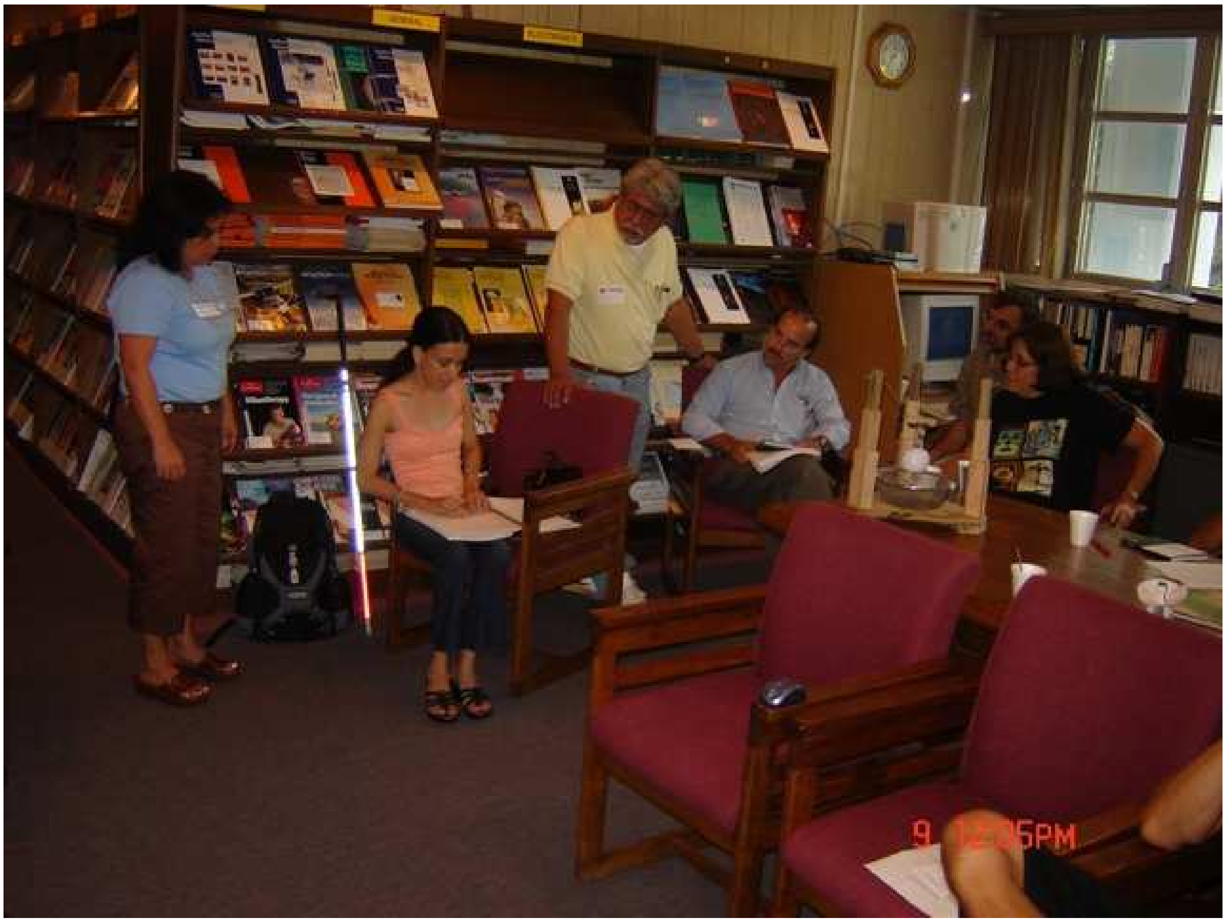

Figure 2. The presentation of the Braille documents and tactile model at the Arecibo Observatory library.

The second document consists of the definitions of important terms used in astronomy, like "radio astronomy," "telescope," "radio waves," and others. We included terms that are commonly used when describing the Arecibo Observatory radio telescope.

The third document is dedicated to frequently asked questions about the Arecibo Observatory. In our experience with guided tours to the Arecibo Observatory visitor center, there are some questions that visitors commonly ask: Why was the telescope built at Arecibo? How much did it cost? What is this radio telescope used for? What discoveries have been made? Among the most interesting questions we have received from our blind visitors is the following: Can a blind person work at the Arecibo Observatory? The answer is, yes, of course they can. Dr. Kent Cullers has a PhD in physics from the University of California, Berkeley. He is the first totally blind physicist in the United States and the first blind-from-birth astronomer. He has worked in the SETI project from NASA, and as part of this project, he worked at the Arecibo Observatory. The fictional character of Kent Clark in the movie *Contact* was inspired by him.

Our goal when developing the guides was to allow visitors to learn about the Arecibo radio telescope with the first document. Visitors who want more information can refer to the other two documents. It is not necessary that visitors read the guide before visiting the observatory; it is intended to be read during the visit.

3. BRAILLE EMBOSSING

Most people understand the basics about Braille: that it provides a reading medium for blind people, using "cells" made up of raised dots in various patterns instead of the characters used in regular print. But many people do not realize that the cells-for-characters substitutions are not typically on a one-to-one basis. The process is especially complicated with languages such as English and French, in which Grade 2 Braille is used (Grade 2 Braille involves contractions that are based in part on pronunciation). Formatting of Braille pages also involves issues beyond those that affect print.

Braille embossers are devices that print out documents in Braille. To make a personal computer capable of producing a Braille printout, software can be used to translate word-processing text files into Braille suitable for embossing on a Braille printer. Braille embossers transcribe print text into embossed Braille output. Braille embossers that are capable of embossing on two sides of a page are referred to as Interpoint Braille embossers. Figure 3 shows embossed graphic and text.

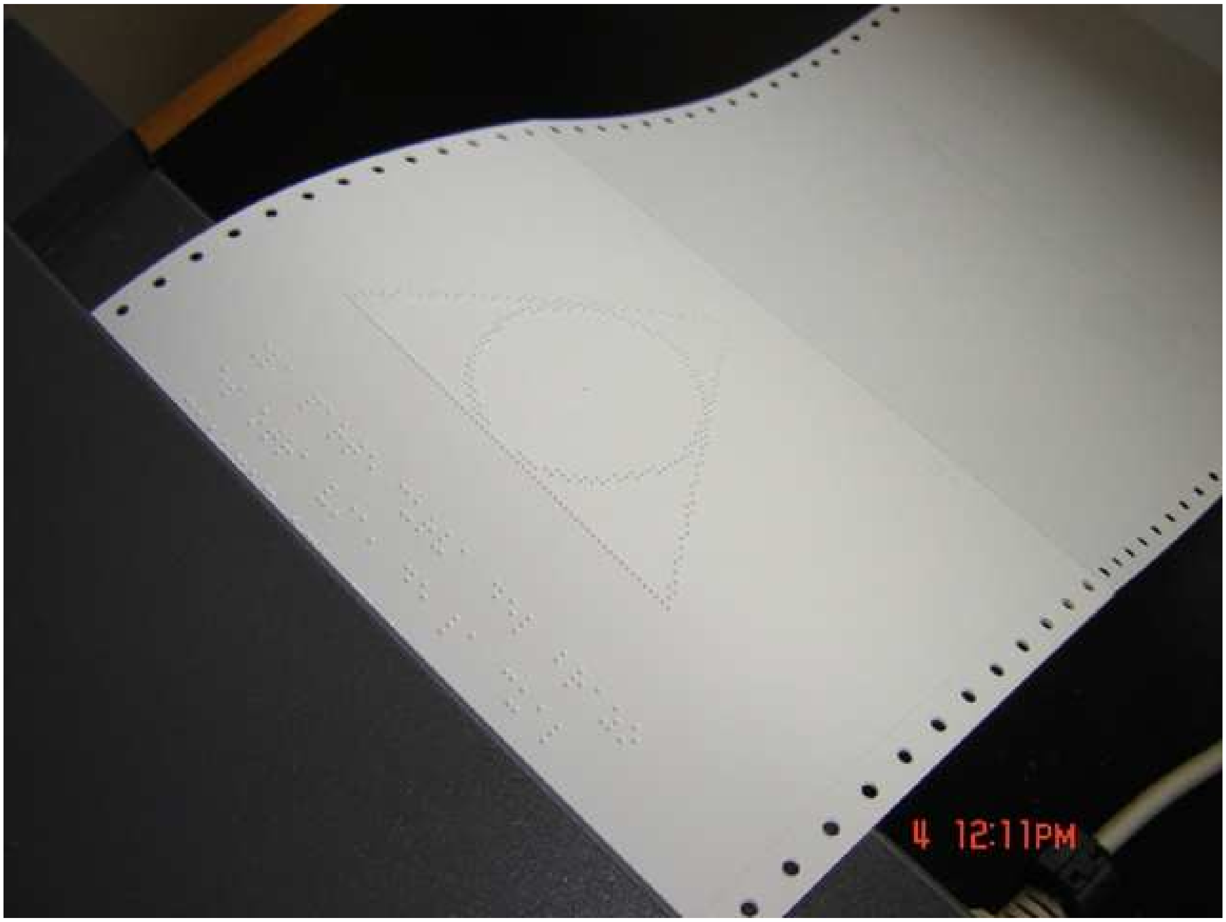

Figure 3. Embossed graphic and text.

We used the Versapoint DUO Braille Interpoint Embosser with Speech to create the documents. Versa Point Duo is an Interpoint Braille embosser capable of printing tactile graphics. It can read text files directly from a computer and has speech capabilities.

We used the Duxbury Braille Translator for Windows software. This software can convert regular print to Braille and vice versa. (See Note 4 for links to more information about embossers and software, including pricing and local distributors.)

The guides were printed on letter-size paper (8.5 x 11 inches). The pages have approximately 28 lines and 35 characters per line, with a net text area of 25 lines per page and 27 characters per line. These characteristics cause the Braille text to occupy more space than regular text, and it also means more difficulty in handling. Depending on the symbols used in the text, a Braille text might require three to five times more space than the regular text version.

4. A TACTILE MODEL

Providing a model made of paper, wood, or another material might give the blind child an idea of shape and form. It is important to present new concepts in different formats. With a model, you allow them to form a concept of what they are learning. Beck-Winchatz and Ostro (2003) have developed three-dimensional asteroid models and used them to develop an astronomy activity for blind students. Their models help blind students perceive spatial structures directly, aid in the development of concepts, and stimulate their interest in science and math.

We have designed a model of the radio telescope that can be assembled with some assistance (see Figure 4). Our first version is a simplified model. The model is not to scale because we were interested in providing a tactile model that could be used to complement our Braille guide describing the parts of the radio telescope. The materials used to build this model are wood, aluminum, plastic, thread, and magnets. The model includes the following parts:

- *Base:* The Arecibo Observatory sits on a 48-hectare (118-acre) site. In our model, the base is made of wood and has an indication as to how it should be set on the table.
- *Three towers:* The telescope has three concrete towers that support the structure. One is 111 m high, and the two others are 81 m high. In the model, the towers are made of wood, and all three tops are the same height. The towers in the model are symmetrical, with only one way to assemble them.
- *Cables with platform and circular track:* The telescope has 18 support cables that run from the towers to hold the platform. In our model, we represent these with three threads. These threads are attached to a triangle and a circle. You must specify the metal circle to be oriented below the triangle. The triangle represents the platform, which weighs 900 tons and is suspended 150 m above the dish. The circular track is 42.7 m in diameter and allows the azimuth arm to rotate.
- *Azimuth arm:* In our model, this part is attached to the circular track by means of a magnet. With the azimuth arm and the circular track, it is possible to show sighted and blind students how this telescope points at astronomical objects. The Arecibo Observatory uses horizon coordinates or the azimuth-altitude system. The Gregorian dome and the carriage house can move along tracks on the azimuth arm to point in altitude while the azimuth arm can rotate around the circular track. The azimuth arm is 93 m long, 3.7 m wide, and 10 m deep.
- *Gregorian dome:* This part is plastic and is attached with a magnet to the azimuth arm. The Gregorian dome contains a reflector system (a secondary reflector and a tertiary reflector). Because the main dish (the primary reflector) is spherical, the light is focused along a line rather than a single point for the Arecibo radio telescope. The Gregorian has two reflectors to focus light to a single point; the receivers are placed at that position. It lies 137 m above the 305-m dish, is six stories high, and weighs 90 tons.
- *Carriage house:* This part is made of wood and is attached to the azimuth arm with a magnet. It represents the carriage house with the 430 MHz transmitter.
- *Dish:* The spherical reflector is fixed in place, and the receivers are moved to observe light that arrives from the astronomical sources. The dish is 305 m in diameter has a surface area of 18 acres (equivalent to 26 football fields).

Figure 4. A view of the concrete tower, cables, triangular platform with circular track, azimuth arm with Gregorian dome, and carriage house (left), and the wooden model of the radio telescope (right).

Our intention was to use the tactile model, in combination with the Braille guides, as an aid to describe the radio telescope. The document that describes the parts of the telescope includes tactile diagrams that can be complemented by the tactile model. The visitor can identify the parts of the telescope and assemble the parts that have been described in the guide. From this concrete experience, the visitor can develop an idea of what is observed from the deck area of the visitor center.

Once the tactile model was completed, we realized that it is useful for teaching blind and sighted students. It can be used to describe the parts of the telescope and to describe the way in which the telescope moves and points. These are topics that are discussed in an introductory astronomy course. At the University of Puerto Rico, this course is ASTRO 3005, and when discussing telescopes, we describe the Arecibo radio telescope. The model helps to emphasize the parts of the telescope and how its design is unique. The topic of coordinate systems is also discussed, and this model allows the students to move the telescope in altitude and azimuth. Part of the course is a visit to the Arecibo Observatory after these topics are discussed.

5. CONCLUSION

After printing the guides, we had two blind students from the University of Puerto Rico assist us with proofreading. They also gave us their impression of the material. One of the students had visited the observatory in the past, and he had an idea of the radio telescope. Our diagrams and detailed descriptions of the parts were a complement to his visit. Among his remarks: "I wish I would have had the guide the day I visited the observatory. Everything would have been different. For me, the visit to the observatory consisted of listening to what my family told me." The second student had a different experience. She had never been to the observatory. She first read the guides, after which we arranged a visit to the observatory, which included a special tour that took us next to the main dish. This allowed her to have an impression of the depth, and she could touch the aluminum panels that make the dish (Figure 5). Dr. Paulo Freire (NAIC/AO) talked to her about pulsars and let her listen to "the sounds" of pulsars. To her, this was very exciting, and she remarked, "It was like a wonderful concert."

Figure 5. A close view of the perforated panels that make up the primary spherical dish. One of our blind students is exploring the Arecibo Observatory site during a guided tour.

The Braille guides are in Spanish and English. Because this was a summer student project for one of us (GMI), we have not yet worked on their implementation and evaluation. We expect that blind visitors will be welcomed to the observatory, after which they will likely want to tour the facility with their families or friends. After listening to the movie, *A Day in the Life of Arecibo Observatory*, one of the visitor center guides will offer blind visitors the Braille document describing the parts of the telescope, and invite them to explore the tactile model. They will be asked if they would like more information and be offered the other documents. We do not want to isolate the blind visitors; we want them to enjoy the visit with their families and to develop a sense of the telescope. The family members may work with the tactile model if they wish. Together, they can share an experience in which they learn about the parts of the Arecibo Observatory radio telescope.

We are planning an activity, in coordination with the Ángel Ramos Foundation visitor center, in which a group of blind students from the University of Puerto Rico can use the Braille guide and tactile model, and participate in the exhibits in a more active way. We are interested in learning from this experience and adapting the materials as necessary for use in our astronomy and mathematics courses at the University of Puerto Rico. Other resources for blind students can be found in Grice (2006).

With the guide and tactile model, blind visitors can experience the excitement of visiting the world's largest radio telescope. We hope that this constitutes a first step in making the Arecibo Observatory an observatory for all.

Acknowledgments

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Notes

Note 1: See http://www.ieee.org/web/aboutus/history_center/arecibo.html.

Note 2: Ideas for adapting learning materials for students with special needs may be found at http://serch.cofc.edu/special/accessscience.htm and http://www.tsbvi.edu/Outreach/seehear/summer98/groovy.htm.

Note 3: The Arecibo Observatory Summer Student Program Web site is http://www.naic.edu/science/summer_set.htm.

Note 4: You can find more information about embossers and software, including pricing and local distributors, at http://www.freedomscientific.com or http://www.duxburysystems.com. In Puerto Rico, you cannot purchase these items directly from these Web sites; you must contact the distributor, Umecco (http://www.umecopr.com/pages/rehab/blind_lowvision.html). For more information on how to select an embosser, see http://www.nfb.org/Images/nfb/Publications/bm/bm01/bm0110/bm011007.htm.

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APPENDIX

Table A1. Qualitative Classification of the AO Visitor Center Exhibits

Visual Exhibits	Mainly Text	Audio, Text, and Visual
A Scale Model of the Solar System	Life of a Star	The Cafe at the End of the Universe
More than Meets the Eye	Changes to Planet Earth	Introduction to the Solar System
Stars and Their Colors	Introduction to Planet Earth	The Sun Our Neighboring Star
The Meteors	Solar Wind	Doppler Effect
The Miller Planisphere	Layers of the Atmosphere	
Palomar Sky Survey	The Moon	
Galaxies Video	What Happened When?	
Tour of the Arecibo Telescope Platform Video	Clouds	
Telescopes around the World	Time Is of the Essence	

X-Rays	Introduction to Stars and Galaxies Exhibit Area	
Ultraviolet Rays	Where Are These Galaxies Going?	
Viewing Earth from Space	The Expanding Universe	
Stars and Their Colors	The Biggest Explosion Ever	
Where Are These Galaxies Going?	Introduction to Galaxies	
Visible Rays	Light and Electromagnetic Waves	
	How We Learn about the Universe	
	The HF Facility, Lidar, and Photometry	
	Radio- Radar telescope	
	X- Rays	
	Ultraviolet Rays	
	Infrared Radiation	
	Radio Waves	
	Astronomical Highlights, Education, and Outreach	