Education and outreach using the falcon telescope network

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**Abstract**

The Falcon Telescope Network (FTN) is a global network of small aperture telescopes developed by the Center for Space Situational Awareness Research in the Department of Physics at the United States Air Force Academy (USafa). Consisting of commercially available equipment, the FTN is a collaborative effort between USafa and other educational institutions ranging from two- and four-year colleges to major research universities. USafa provides the equipment (e.g. telescope, mount, camera, filter wheel, dome, weather station, computers and storage devices) while the educational partners provide the building and infrastructure to support an observatory. The user base includes USafa along with K-12 and higher education faculty and students. The diversity of the users implies a wide variety of observing interests, and thus the FTN collects images on diverse objects, including satellites, galactic and extragalactic objects, and objects popular for education and public outreach. The raw imagery, all in the public domain, will be accessible to FTN partners and will be archived at USafa. Currently, there are five Falcon telescopes installed, two in Colorado and one each in Pennsylvania, Chile, and Australia. These five telescopes are in various stages of operational capability but all are remotely operable via a remote desktop application. The FTN team has conducted STEM First Light Projects for three of the US observatories, soliciting proposals from middle and high school students and teachers that suggest and then become what is observed as official STEM first-light objects. Students and teachers learn how to write and submit a proposal as well as how telescopes operate and take data, while university-level students at the U.S. Air Force Academy and The Pennsylvania State University learn how to evaluate proposals and provide feedback to the middle and high school students and teachers. In this paper, we present the current status of the FTN, details of and lessons learned from the STEM First Light Project, and feedback from middle and high school students and teachers.

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1. Introduction

The Department of Physics at the United States Air Force Academy (USafa) is developing a global network of small aperture telescopes called the Falcon Telescope Network (FTN) [1]. Led by the Department's Center for Space Situational Awareness Research (CSSAR), the FTN will provide USafa cadets and faculty with world-class capability to conduct research in satellite characterization and astronomy. Partnering with USafa are educational institutions around the world consisting of two- and four-year colleges as well as major research universities. USafa provides the equipment (e.g. telescope, mount, camera, filter wheel, dome, weather station, computers, network and storage devices) while the educational partners provide the building and infrastructure to support an observatory. The formal partnership framework is the Cooperative Research and Development Agreement (CRADA) which allows USafa to provide the equipment and share the raw image data with every partner.

2. Falcon telescope network

The FTN, in full operations, will be a global network of 12 small aperture telescope observatories for the purpose of conducting research in astronomy and satellite optical characterization, as well as supporting science, technology, engineering and...
mathematics (STEM) activities. All the FTN equipment is commercially available and exportable to international partners. The cost of the equipment provided by USAFA is approximately $165,000 U.S. dollars per observatory. Table 1 lists the specific equipment (hardware and software) currently being utilized.

Each FTN site is equipped in a nearly identical manner in order to achieve consistency, ease of use, and simplicity when developing automation techniques. This design concept has also been helpful during troubleshooting, as a direct comparison to another site can provide insight into the issue. The one negative impact of this concept is the potential for failures at multiple sites due to global hardware or software problems.

Key to the successful operations of the FTN is the myriad of educational partners in the network. Table 2 shows the educational institutions that are, or will be, hosting observatories. The specifications of the telescope and camera provide a plate scale of 0.65″ per pixel and a field-of-view of approximately 11″.

Table 1: Current hardware and software used by the Falcon Telescope Network.

<table>
<thead>
<tr>
<th>Equipment description</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ritchey-Chrétien 20 in., f/8.1 Telescope</td>
<td>Officina Stellare</td>
</tr>
<tr>
<td>Paramount ME2 Telescope Mount</td>
<td>Software Bisque</td>
</tr>
<tr>
<td>Alta F47 1024 x 1024, 13 μm CCD Camera</td>
<td>Apogee</td>
</tr>
<tr>
<td>9 Position Filter Wheel</td>
<td>Apogee</td>
</tr>
<tr>
<td>Johnson Cousins Filters</td>
<td>Astrodon</td>
</tr>
<tr>
<td>Sloan Filters</td>
<td>Astrodon</td>
</tr>
<tr>
<td>Exoplanet Filter</td>
<td>Astrodon</td>
</tr>
<tr>
<td>Diffraction Grating</td>
<td>Newport</td>
</tr>
<tr>
<td>12-Foot Clamshell Dome</td>
<td>Astro Haven</td>
</tr>
<tr>
<td>Boltwood Cloud Sensor II</td>
<td>Diffraction Limited</td>
</tr>
<tr>
<td>RC637 Symmetrical GPS Antenna/Webcard</td>
<td>Microsemi</td>
</tr>
<tr>
<td>Gen II Computers w/ Intel SSD DC 53700 Series</td>
<td>Advantech</td>
</tr>
<tr>
<td>Network Attached Storage</td>
<td>Synology</td>
</tr>
<tr>
<td>ASA 5005 Router</td>
<td>Cisco</td>
</tr>
<tr>
<td>Small Business 200 Series Switch</td>
<td>Cisco</td>
</tr>
<tr>
<td>UPS SMART 1000 and 2000 Series</td>
<td>Tripp Lite</td>
</tr>
<tr>
<td>Pan/Tilt IP Camera FI8919W and FI9826W</td>
<td>Foscam</td>
</tr>
<tr>
<td>The SkyX Professional Software Suite</td>
<td>Software Bisque</td>
</tr>
</tbody>
</table>

To date, five of the twelve FTN observatories are installed and in some state of operations. They include the OJC-Falcon in La Junta, Colorado; NJC-Falcon in Sterling, Colorado; PSU-Falcon in University Park, Pennsylvania; CBR-Falcon in Canberra, Australia; and the MMO-Falcon in Vicuña, Chile. Pictures of each of these observatories can be seen in Fig. 1.

The remaining seven FTN observatories are in various stages of development. Each partner institution is responsible for providing the land and building infrastructure into which the equipment will be installed and each has taken differing lengths of time to do so. Upon completion of the building infrastructure, USAFA personnel travel to the partner site to install the dome, telescope, and other equipment listed in Table 1.

### 3. FTN first-light project

#### 3.1. Project description

The goal of the Falcon Telescope Network First-Light Project is to provide an opportunity to local K-12 students and teachers, primarily in the schools around the FTN locations, to gain first-hand experience in developing a technically sound proposal.

Working with our FTN higher education partners, we identify prospective schools in their local area and send emails to the appropriate STEM teachers and administrators offering them the opportunity to participate in the FTN First Light Project. To provide a single location for information exchange, we create a CVent information, registration, and submission webpage for each event. A link to the CVent webpage is sent to the prospective teacher participants, allowing them access to all the details, deadlines and documents necessary for writing and submitting a proposal. To aid them, we include a document titled “How to Begin Your Proposal” which contains guiding questions along with their explanations including 1) Is your target (or targets) visible at all from an FTN site?: 2) What time of year and what time of night is best for observing your target (or targets)?; and 3) Is your target (or targets) well matched to the capabilities of the telescope’s camera? We also provide the students and teachers with the following proposal template:

- **Principal Investigator**: Teacher’s name, address, and contact information
- **Co-Investigators**: Class name and grade
- **Proposal title**
- **Proposed object’s name**
- **FTN node to be used**
- **Proposed object’s location in right ascension and declination**
- **Proposed object’s angular size as seen from earth, or apparent dimensions in degrees, arcminutes, and arcseconds**
- **Proposed object’s brightness as seen from Earth, (i.e., apparent visual magnitude)**
- **Desired date(s) and local time(s) of observation for the proposed object**
- **Justification**: Why is this object important? What is interesting about it? Will your class/group study it more or find out something about it after you get the images? Have you studied it before and want more information about it?

Additionally, we provide some astronomy-related resources to the teachers to aid in the proposal preparation. These resources include links to:

- **Amazing Space**: [http://amazing-space.stsci.edu/](http://amazing-space.stsci.edu/), which has astronomy curriculum support tools.
- **Penn State ASTRO 801**: [https://www.e-education.psu.edu/astro801/content/l3_p7.html](https://www.e-education.psu.edu/astro801/content/l3_p7.html) which includes a lesson on telescopes.
- **Stellarium**: [www.stellarium.org](http://www.stellarium.org), which is a free, downloadable software that shows exactly what you see when you look up at the night sky from whatever location you choose.
- **Heavens Above**: [http://www.heavens-above.com](http://www.heavens-above.com), which provides information on satellite passes over any location.
Once the FTN team receives the proposals, undergraduate and graduate students evaluate them and determine the feasibility of each based on location and equipment. We usually accept all proposals unless we absolutely cannot detect the proposed object. After making a schedule for the observations, we call the students to congratulate them on acceptance, discuss astronomy principals and interesting facts about their object, and provide them with the caveat that the observations would all be weather dependent.

3.2. Sample proposals and first-light objects

To date, we have accomplished three First Light Projects for the OJC-Falcon in La Junta, Colorado; NJC-Falcon in Sterling, Colorado; and PSU-Falcon in University Park, Pennsylvania resulting in the participation statistics provided in Table 3.

The proposed first-light objects were stars (5 proposals), solar system objects (11), nebulae (6), galaxies (7), clusters (2), and other more distant exotic objects like pulsars (1) and quasars (1). There was even one proposal from high school students to observe an exoplanet transit (WASP-43). Some examples of the type of uncorrected and un-calibrated images we provided back to the students can be seen in Figs. 2–5.

Fig. 6 is a “light curve” created by students in Vermont from 75 images collected with the NJC-Falcon over 2.5 h while the exoplanet WASP-43b transited the face of its host star. The school procured the astronomical software package required to process and analyze the data. The students then taught themselves how to use it to perform differential photometry and successfully detected the WASP-43b transit signal, as evidenced by the dip in brightness of the blue data series in Fig. 6. They also analyzed NJC-Falcon data collected on the exoplanet TrES-3b, again successfully creating a light curve clearly indicating a transit event. Their results were featured on a poster presented by USAFA faculty members at the Emerging Researchers in Exoplanet Science Symposium (ERESS) at Penn State University in May 2015 [2].

3.3. Lessons Learned and Feedback

After collecting the first-light images, we prepare them for distribution back to the students and teachers. Since the CCD camera taking the images saves the pictures as FITS files, we normally create a JPEG file of the image as well as a text file with all the FITS header metadata, which includes information such as date/time of exposure, exposure duration, filter used, and telescope boresight in RA and Dec. These files are sent to the teachers along with an explanation of the filters used, the conditions of the night, and any information we feel the teacher could use to expand the students’ understanding. We also hold a teleconference with the classes to provide verbal feedback and to answer any questions they might have in regard to the images they received.

Finally, we ask the teachers to provide voluntary, more formal feedback on the educational effects and project design of the First Light Project. We began asking for formal feedback after the NJC and PSU First Light projects, and unfortunately, we only received feedback from five of the nine teacher participants in the PSU

<table>
<thead>
<tr>
<th>Site</th>
<th>Proposals</th>
<th>Classes/teachers</th>
<th>Students involved</th>
<th>Grade levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>OJC</td>
<td>8</td>
<td>5</td>
<td>57</td>
<td>6 – 12</td>
</tr>
<tr>
<td>NJC</td>
<td>9</td>
<td>4</td>
<td>89</td>
<td>10 – 12</td>
</tr>
<tr>
<td>PSU</td>
<td>19</td>
<td>9</td>
<td>202</td>
<td>7 – 12</td>
</tr>
</tbody>
</table>
However, the feedback we received will serve us well as we continue to conduct and improve the FTN first light projects. To assess the educational effects, we asked the following questions:

1. Why did you ask your students to participate in the FTN STEM First Light Project? What were your expectations with respect to educating your students?

2. Did the project help you meet state or national education standards, Yes or No. If Yes, please list those that are applicable.

3. The project improved your students' interest in science, astronomy, or other STEM subjects: Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree. Please share any quantifiable measurements (i.e. improved homework or test scores) or observations (e.g., student attitudes) that support your response.

4. The project met your expectations with respect to educating your students: Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree.

For the first question, all the teachers were either in an astronomy block of lessons or studying technology systems like telescopes. One teacher said “I was hoping they would enjoy the project and learn a bit of how real astronomers request objects to study.”

For the second question, two of the teachers responded ‘Yes’, affirming that the project helped them meet state educational standards in science and provided an explanation. One teacher in particular stated that the project acted to “demonstrate an inter-relationship between the subjects of physics, chemistry, earth science/environmental science, biology and astronomy; and apply knowledge, understanding, and skills of science subject matter/ concepts to daily life.” Another said that the project helped her students “analyze the essential ideas about the composition and structure of the Universe—compare the use of visual, radio, and x-ray telescopes to collect data.”

For the third question, the average response was “Agree” with comments such as: “Students enjoyed looking at taken images that they thought were “cool”; “They learned that telescopes can take pictures of objects in space and we can use those images to study them.”; “My students learned about how to locate an object in the sky by RA and DEC, they researched different objects and presented their individual ideas to the class.”; and “Students were essentially more engaged than with previous projects.”

The average response for the fourth question was also “Agree” with comments such as: “I wanted students to learn how astronomers use telescopes to study objects in space, that they do not look at objects through the telescope, they look at images of the objects taken by the telescope.”; “I think this was a great project for generating interest in astronomy.”; “Students had difficulty identifying why some objects would be more appropriate than others based on angular size and magnitude. In the future, it would be helpful for the introductory materials to more specifically describe the size and brightness limits for the telescope to give students a framework to start researching objects.”; and “Students’ most common complaint was the “low quality” of the pictures. This is completely understandable, and it was a teachable moment, but some info from the FTN would be good.”

As to the project design, it was clear that the interaction with FTN scientists was an important aspect that should be continued. One comment stated “The commentary on the pictures was
ESSENTIAL. Don’t lose that.* Some criticism revealed the need to include more technical detail on the FTN so that the students could properly apply constraints to their proposal. Because this type of information is included in the “How to Begin Your Proposal” document provided on the registration website, it seems that some teachers had not found the resources available. Additionally, there was some interest in doing more quantitative analysis of the data instead of just getting “cool” pictures. This last comment, however, varied depending on the grade level of the students.

In response to this feedback we intend to acquire data in multiple filters to provide higher quality, color stacked images; explain the capabilities of the FTN and why data will not look like Hubble images, for example; modify the registration webpage to draw attention to the resources available; and respond to the proposals in writing, still offering the option of a phone conversation, so the educational information remains available for review.

4. Similar astronomy outreach evaluation

4.1. Worldwide telescope ambassadors

For a quick comparison to other similar outreach projects conducted previously, we reviewed the public literature and, to the best of our knowledge, did not find anything similar to the FTN First Light Project. We did, however, find astronomy-based outreach programs such as The WorldWide Telescope (WWT), a web-based program consisting of an online catalogue of astronomical data arranged into a sky visualization tool. Using astronomical images from all wavelengths and multiple sensors, WWT imbeds images of objects into the proper location within a sky map. WWT also provides a 3-dimensional model of the Solar System, panorama images of the moon and Mars, and automated imagery tours of various object types.

The WorldWide Telescope Ambassadors Program (WWTA) is an astronomy outreach initiative, run by researchers at Harvard University and Microsoft Research, to utilize WWT as a teaching tool. Ambassadors use WWT to create interactive Tours of the Universe that are then shared with schools, public venues and online. In 2010 and 2011, WWTA conducted a program in which partner teachers used WWT with sixth grade students over the course of a 6-week long astronomy unit. The purpose was to analyze the outcome and determine any improvement in understanding and student performance in science and astronomy by those using WWT versus those who did not use the program. The findings from this investigation were reported at the Astronomical Society of the Pacific Conference in 2012 [3].

To evaluate the impact on the students, WWTA used information directly from the students instead of receiving feedback from the teachers. Following the astronomy unit, WWTA administered a “Moon Phases Quiz,” received comments from the students, and conducted a survey for both the WWT users and non-users. The process and survey questions used by WWTA more closely resemble the Program Theory for the Children and Schools Program developed by Chapman et al. [4] for the International Astronomical Union’s Office of Astronomy for Development than those of the First Light Project. The WWTA data indicated a higher level of understanding and interest among those who used WWT for the 6-week course compared to those who did not.

The goals of the WWTA and FTN First Light Project are both to inspire interest, excitement, and learning in astronomy and other science and technology subjects. Overall, both of our results indicate that including an interactive, hands-on experience is beneficial.

WWT is a valuable tool that can be used by teachers and students at any time and can be integrated into the curriculum with regularity, whereas FTN First Light Projects are scheduled events that likely will not occur at regular time intervals. However, there are several aspects of the FTN First Light Project that WWT does not provide. First, the students learn how scientists conduct their work and must complete some prior investigation in order to write a proposal. Second, the process involves a great deal of interaction with FTN scientists and college level students, which gives the students vision for pursuing science. Finally, the students receive a product that they participated in generating and learn how and where astronomical data is produced instead of simply seeing the end result. Based on the teachers’ comments seen in Section 3.3 these aspects were important and provided additional learning potential.

In the future, if a more rigorous evaluation is desired for the First Light Project, surveys given directly to the students would likely be more informative with respect to the students’ development. However, it is also helpful to understand if the program is beneficial for the educators and how they perceive the students’ attitudes in class.

5. Conclusions

Overall, the United States Air Force Academy’s Falcon Telescope Network provides a wonderful STEM opportunity for K–12 students and teachers around the world to propose objects for a telescope’s first light. The K–12 students gain valuable experience in writing a scientifically sound proposal and college-level students gain experience in evaluating them and mentoring younger minds. A First Light Project will be conducted for each newly completed observatory. However, beyond first light, we can periodically conduct alternative proposal projects throughout the lifetime of the FTN. For future events, the projects may evolve to include themes for the proposals, such as galactic comparisons or exoplanets, more rigorous proposal criteria, and more hands-on experiences at the observatories.

References