The Pittsburgh Nightscape From Space - A Different Perspective on Skyglow

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I. Introduction

This research project is done for the 99-520 Collection and Analysis of Slyglow Data class at Carnegie Mellon University (CMU), virtually run in summer of 2020. The goal of the class is to bring together students from a multitude of backgrounds and demonstrate the importance of a dark sky as well as the damage done by humanity through urban development. Light pollution not only affects human ability to view the night sky, it also has deleterious effects on wildlife and even human health that are not well understood. Students will gain an appreciation for the night sky, learn basic astronomical terminology, and complete a number of activities to explore light pollution research. Finally, students will contribute themselves to this research.

This report details my summer research, beginning on July 6th, 2020 and concluding on August 8th, 2020 and includes the identification of night time photographs of Pittsburgh in the publically available NASA repository.

II. Background

The International Space Station (ISS) is a multi-national habitable satellite in low earth orbit and has been continuously occupied for nearly 20 years. The ISS is primarily used as a

laboratory to study microgravity effects on humans and many experiments are run on board. Travelling at 17,500 miles per hour, the ISS completes one revolution around the Earth in about 90 minutes with approximately 16 revolutions per day.

Since the Mercury missions in the 1960s, scientists and citizens alike have relied on astronauts for the nearly 1.5 million photographs of Earth that have been taken so far. The ISS has an orbiting altitude between 220 and 286 miles and an inclination of 51.6 degrees. Astronauts have a stunning view of most parts of the world across different ranges of the day along the orbital path. The Crew Earth Observations (CEO) program connects scientists with the astronauts on board to plan out observations and capture photographs of specific locations. Astronauts observe and take photographs with manual cameras through the Cupola, a seven window dome. These photographs are publicly available through the Earth Science and Remote Sensing Unit, NASA Johnson Space Center on this website: https://eol.jsc.nasa.gov/.

For the most part, these photographs are used to evaluate natural disasters and aid ground efforts in near real-time. Most of the photographs are taken during day time. But another huge use for space photography that is necessary for this skyglow research is night photography of city lights. The City of Pittsburgh uses 40,000 street lights, the majority of which are high pressure sodium (HPS) powered. These kinds of lights can be characterized by their orange glow. Starting in 2012, Pittsburgh began to replace these street lights with light-emitting diodes (LED). With reported energy savings and lower maintenance costs, LED fixtures, by the numbers, appear highly favorable. We now know that the brighter, white light currently emitted by most of these installations causes glare, an eerie daytime feel, and harmful impacts to dark sky visibility and the environment (RCI, 2011). Space photography of cities at long focal lengths

allows for a greater overarching evaluation of the type of light being emitted from cities. This helps cities have an understanding of large scale impact, and informs future decisions regarding city lighting.

The skyglow research group at CMU has previously submitted proposals for night time photographs of Pittsburgh for study. These observations are still on the astronaut's schedule at this time. Another student in the course has been tasked with submitting additional proposals for this purpose. My task is to identify and gather existing suitable photographs of Pittsburgh.

III. Project Information

Some photographs in the NASA repository have been cataloged by a machine learning software or through basic categorizations such as mission number, time of day, and spacecraft nadir point. However, the vast majority of the photos do not include any other more thorough categorizations, like the object of the image.

This project will include sorting through and identifying useful images of Pittsburgh at night. The criteria for a photograph that is suitable for skyglow research is as follows:

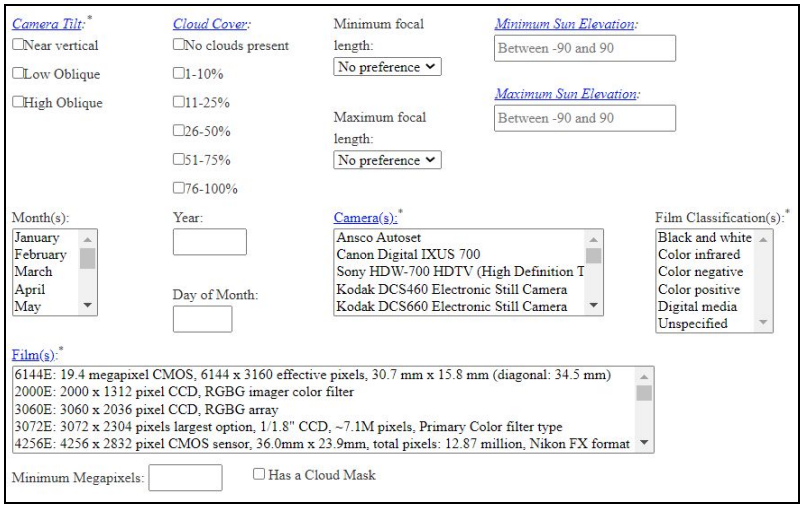
- Night time
- Photo center point close to nadir (straight down)
- Low percentage of cloud cover
- Focused within Pittsburgh city limits (longer focal length preferred)

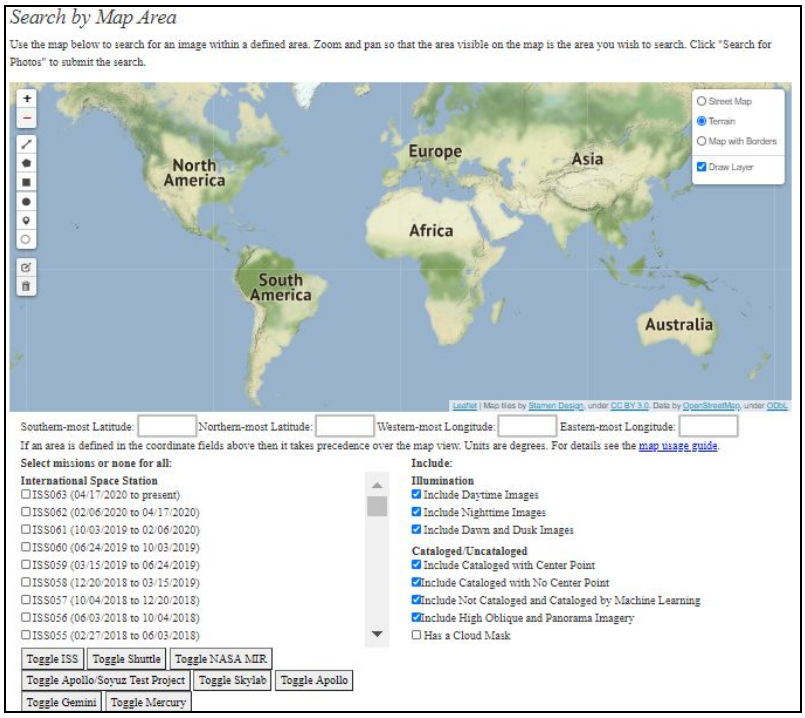
The night time criteria is self-explanatory, as the focus of this project is city light photography. When astronauts look out from the Cupula, they can take photos from a variety of angles. In astronomical terms, the nadir is the point directly below an observer, or the

coordinates on Earth that the ISS is over. This data is recorded for every photograph taken. The photo center point is the coordinates of the photograph, which can be vastly different from the spacecraft nadir if the image is taken at an oblique angle. High angle photos are often used to photograph the horizon. A desirable Pittsburgh image is taken straight down onto the city, so the photo center point is close to the spacecraft nadir point. Cloud cover causes blurs in images by scattering light. This is not ideal for a clear image. The last criteria is for the photo to be centered on Pittsburgh city limits. Pittsburgh is easily recognizable by the three rivers that intersect in downtown. The focal length is a characteristic of the camera lens being used and describes the field of view of the image. It is measured in millimeters, and a larger value corresponds to a smaller field of view. This creates a clearer and more focused image of the downtown area. A focal length longer than 100mm is ideal.

Images matching these criteria will be used to study the effects of LED lighting in Pittsburgh and the damage done to plants, animals, and human health. By identifying major sources of skyglow within the city, CMU researchers can help inform elected officials in Pittsburgh through the decision of changing street lights in the city.

The NASA repository has a multitude of search capabilities that range from a simple text box to more advanced settings. Two of the advanced settings options I used most commonly are pictured below and include options for camera tilt, focal length, and map location.





(Earth Science and Remote Sensing Unit, NASA Johnson Space Center)

An additional goal of this project is to investigate the possible use of programming to develop a method of searching for images that fit the criteria. Though NASA has several

machine learning algorithms used to place labels on the images, currently few contain any for useful searchability.

IV. Internship Role

The basic method of identifying suitable photographs is to manually filter through the images available online. To keep track of the selected images, a spreadsheet with identifying information for searching, such as photo date and number, spacecraft nadir, and focal length was recorded.

In the initial stages of the research project, I aimed to understand the search functionality in the NASA database by trying various levels of searches and examining the resulting photographs. I also reached out to Edward Potosky, a friend of professor Diane Turnshek, who compiled a list of night time Pittsburgh photographs in 2018. He provided various search tools he used to narrow down the images to manually sort through.

One of the most basic search parameters is predetermined labels. Some of the images in the database have been identified through machine learning or human processes and carry tags that can be recalled in search results. My first search was for any photos with the location label of “Pittsburgh”. 170 images were identified for this search query. None of the images were night time photos and though they spanned in time from the mid 1970s to 2018, most were also not centered within the city boundaries which feature the intersecting rivers. Below is one of the clearest of these daytime Pittsburgh images.

(Earth Science and Remote Sensing Unit, NASA Johnson Space Center)

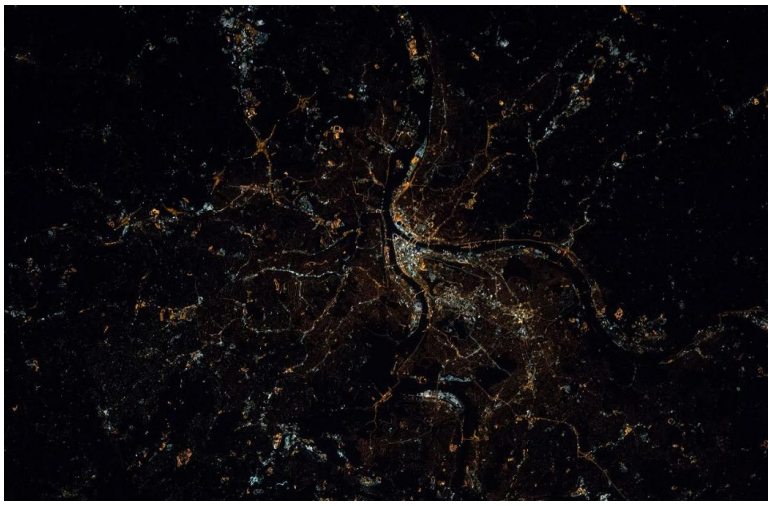
Though it provides a beautiful view of the city, no lights are visible and skyglow effects cannot be evaluated. So, images in the query are not useful for this project's purposes.

Following this basic search, I expanded into manual searching of night time photographs. Because these photographs were not identified in the basic searches, they do not have city labels. I learned how to recognize Pittsburgh in space images. At a close range, the intersecting rivers of downtown are a notable landmark. From afar, the positions of Lake Erie and the cities of Columbus, Cleveland, and Detroit can be used as pointers.

From there, I narrowed the search down based on the map location. The uncategorized images only have records of the spacecraft nadir point. However, for this project, only images close to the nadir are desirable to begin with. This simplifies the manual searching process. I tested several ranges of longitude and latitude values to find a reasonable group of photographs. With a search of 39.2 N to 41.7 N latitude and 81.2 W to 78.7 W longitude, 268 images were found. Of these, only one image has geographical labels or identified features.

A manual visual search through the images resulted in three time frames where close imagery of Pittsburgh was taken: 2012, 2013, and 2016. The list of close range images is presented in Table 1. From those images, the clearest images are from 2012 and 2016. Incidentally, Pittsburgh began installing LED lighting in the downtown area starting in 2012. Comparing the images below, the color difference from an orange dominated glow in 2012 to a more whitish glow in 2016 is evident.

(Earth Science and Remote Sensing Unit, NASA Johnson Space Center, 2012)



(Earth Science and Remote Sensing Unit, NASA Johnson Space Center, 2016)

I was unable to find close range images of Pittsburgh more recently than 2016 from this image repository. So, I took to the Internet to find images that I potentially missed or are from other sources. On Twitter, I found a Pittsburgh space image posted by astronaut Chris Hadfield in 2013, and on Reddit, an image 40,000 feet from an aircraft posted by user jabbs72 in 2018. Both images are presented below.

(Chris Hadfield, Twitter)

(u/jabbs72, Reddit)

In the two images that are not directly from NASA, it is unclear if the images have been edited to change the saturation of colors. However, the differences in color can still be seen, but should not be used in any evaluation of Pittsburgh city color temperature.

Throughout the research for this project, I determined that an algorithm able to accurately recognize the city of Pittsburgh is not viable in such a short time frame. FeatureHunter is a machine learning algorithm developed by students for NASA and is available on the NASA database website. The purpose of the program is to assist scientists in finding useful photographs for use in their research. Machine learning algorithms require an immense amount of training data in order to function reliably. From the search results I produced for this research, no query produced more than 1000 images. The majority of which were duplicates or obviously not of Pittsburgh. In the case of such small amounts of relevant data, occasional manual searches may be quicker and more practical than developing a functional image recognition software.

Across the month duration of this project, I spent 51 hours on this research project out of a total of 103.5 hours spent for this class. Although this is short of the 135 hour goal for the course, I believe this was a realistic amount of time for this specific project. If I had dove into the development of an image recognition program, the time taken would have been much longer. A detailed spreadsheet of the dates and times work was done is attached in a separate document.

V. Experience Description

My project is different from many other student's in the class because the entire project was largely independent work. Many other students collaborated with researchers to complete a small part of a larger goal. As such, I did not have a project team. The main outside interaction

came from the professors and other students with similar projects looking for additional information. Overall, I enjoyed working on this project because I have always had interest in the work that astronauts completed on the ISS. Having to sort through the huge repository of images allowed me to see the scarcity of night time imagery and the general disregard humans have on the impacts of electricity use. If the project could span over a longer period of time, I would have dove deeper into the programming ability to compare the imagery found.

VI. Knowledge Gained

Key knowledge that I gained from this experience is how to narrow down search parameters in large amounts of data to identify the important criteria of a project. Almost all of the available photographs are interesting in some way, but may not be useful for the project at hand. Recognizing which paths are worth the time to pursue in a search is an important skill. Because I am not from the East Coast, I also had to learn about the city locations and sizes as I am not familiar with the area. I also learned the basics of photography and astronomical terms related to identifying images taken from space.

Another takeaway from this experience is a realization of how little information about city lights is available to scientists. From this project, I first-hand experienced the scarcity of night time imagery that is necessary for skyglow research. In the future, I would like to contribute more to citizen science projects and assist in the collection of useful data.

VII. Conclusion

The goal of this project was at a baseline to provide a listing of images of Pittsburgh at night from the NASA astronaut archive. An additional reach goal would be to develop a program that can identify photos of Pittsburgh from a collection. I was able to accomplish the goal of creating a list of existing night images of the city and determined that an image recognition software would be impractical in the short term.

From my research, I identified several additional research topics that could be explored to further knowledge and use the astronaut photography found:

- Color weighted evaluation program that determines percentage of colors in predetermined ranges in an image. This can be used to demonstrate the amount of orange or white light in the city over a range of time.
- Developing programs with future satellites aimed at providing regular imagery of cities at night.

VIII. Tables

The following two tables detail images of Pittsburgh at night at close and far ranges. A close range photo features only the City of Pittsburgh unobstructed, while the far range images include other cities and may feature other objects on the ISS such as solar arrays.

For latitude, positive values indicate degrees North while negative values indicate degrees South. Likewise for longitude, positive values indicate East degrees while negative values indicate West degrees.

Table 1 - Close Range Pittsburgh Images

Photo ID	Date Taken	Nadir Latitude	Nadir Longitude	Focal Length (mm)
ISS030-E-83178	20120202	42	-79.7	85
ISS030-E-83179	20120202	42	-79.6	85
ISS030-E-83180	20120202	40.4	-80	85
ISS030-E-83181	20120202	40.4	-80	85
ISS030-E-83182	20120202	42.4	-78.8	85
ISS030-E-83183	20120202	42.5	-78.8	85
ISS035-E-8017	20130323	41	-79.2	400
ISS035-E-8018	20130323	41	-79.2	400
ISS035-E-8019	20130323	41	-79.2	400
ISS035-E-8020	20130323	41	-79.2	400
ISS046-E-25718	20160128	40.5	-80.6	400
ISS046-E-25719	20160128	40.5	-80.6	400
ISS046-E-25720	20160128	40.5	-80.6	400

Table 2 - Far Range Pittsburgh Images

Photo ID	Date Taken	Nadir Latitude	Nadir Longitude	Focal Length (mm)
ISS030-E-251919	20120414	40.1	-81.2	8
ISS030-E-251941	20120414	39.2	-79.8	8
ISS042-E-156186	20150120	39.9	-80.3	28

ISS042-E-156219	20150120	40.6	-79.2	28
ISS042-E-160740	20150120	39	-81.8	19
ISS042-E-139541	20150117	37.1	-81.6	24
ISS042-E-138103	20150117	37.4	-81.2	22
ISS042-E-138109	20150117	37.5	-81	22
ISS042-E-122060	20150110	37.4	-81.8	32
ISS042-E-122062	20150110	37.4	-81.9	32
ISS043-E-243577	20150522	37.2	-80.2	24
ISS043-E-240953	20150525	37.4	-81.7	24
ISS046-E-22799	20160124	37.4	-80.7	28

X. References

Earth Science and Remote Sensing Unit, NASA Johnson Space Center. https://eol.jsc.nasa.gov/.

Hadfield, Chris. "Pittsburgh, PA - even from orbit it's easy to see the three rivers." *Twitter*, February 24, 2013. https://twitter.com/Cmdr_Hadfield/status/305746440976740352.

Jabbs72. "The Burgh from 40,000ft." *Reddit*, October 28, 2017. https://www.reddit.com/r/pittsburgh/comments/79clcq/the_burgh_from_40000ft/?utm_content=buffer558f3&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

Remaking Cities Institute (RCI). "LED Street Light Research Project." September 2011. https://www.infrastructureusa.org/wp-content/uploads/2011/10/led-updated-web-report.pdf