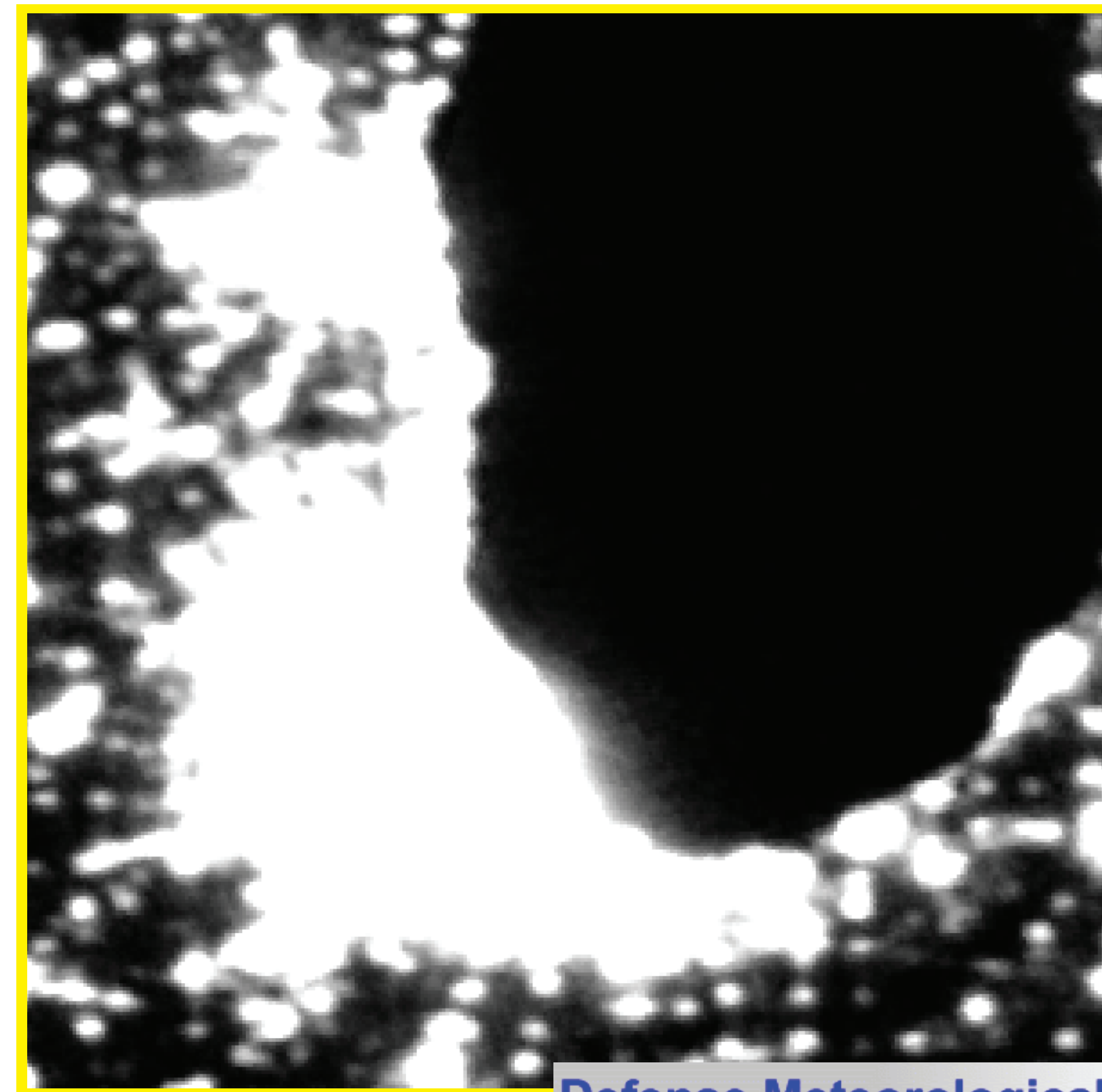


Abstract

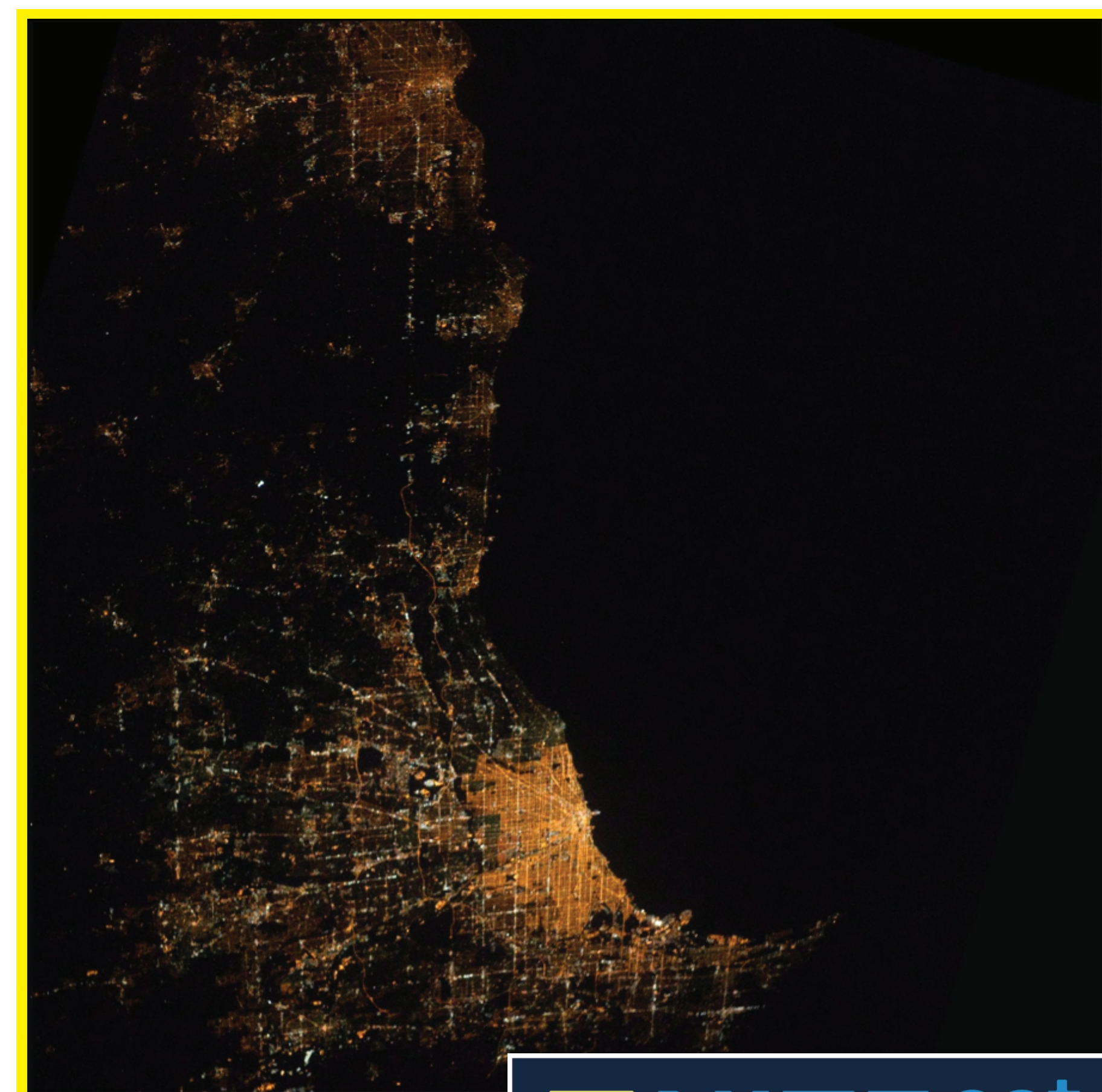
The Far Horizons space program at the Adler Planetarium is designing, building, and will operate NITESat (Night Imaging and Tracking Experiment Satellite), a 2U CubeSat mission supported by a robust education and public outreach effort. The primary science mission of NITESat is to capture high-resolution, three-color, nighttime imagery of the Midwestern United States to quantify and characterize the nature and intensity of light pollution across the region. The motto of the Adler Planetarium is "Join Us In Exploring Space," and the NITESat mission firmly embraces this concept with students, interns, and volunteers embedded in every stage of the design, build and outreach process. This is an overview of the NITESat mission including the opportunities and challenges of engaging participants and the public in an authentic scientific research CubeSat program.



1973-present
Defense Meteorological
Satellite Program



2011-present
Suomi NPP
VIIRS



2018 launch
NITESat

Light Pollution from Space

Satellites can provide invaluable data about the quantity and quality of light pollution across the world. NITESat will provide resolution and saturation improvements over OLS³, resolution and more favorable overpass times than VIIRS⁴ and spectral data both cannot provide.

Science Background

Light pollution (LP) has a variety of impacts on the natural world from health effects in humans, the disruption of bird migration and other adverse environmental impacts.¹ Light projected into the sky is effectively lost energy. The quantification of atmospheric light can be equated to wasted expense by a community. Careful studies have led to the discovery of correlations between light pollution and social-economic indicators such as poverty, effective energy policy and gross domestic product (GDP).¹ One of the most apparent impacts of light pollution in our daily lives has been the loss of our connection to the night sky, and thus our connection with the Universe. It is estimated 60% of the population of the European Union and the 80% of North Americans cannot see the Milky Way from where they live due to excessive light pollution.² As an astronomy education institution, this has a direct impact on the mission of the Adler Planetarium.

NITESat Mission Goals

The NITESat mission will:

1. Acquire night images of artificial light in a 1000km x 1000km region centered on Chicago with:
 - 1.1. a resolution $\leq 200\text{m/px}$,
 - 1.2. a sensitivity $\leq 10^{-8}$ Watts cm^{-2} sr^{-1} ,
 - 1.3. RGB information and,
 - 1.4. Varied overpass times.
2. Create a network of citizen-run ground-based observing stations (GONet) to provide synchronized observations for calibration and ground truthing of NITESat data.
3. Provide opportunities for hands-on STEM participation in the mission for a minimum of 50 students and volunteers per year throughout the mission life cycle.
4. Expose a significant percentage of the Adler Planetarium's 500,000+ visitors per year to information pertaining to the value of CubeSats in general and the NITESat mission specifically through programmatic and museum content.
5. Be a means for outreach, education and awareness of light pollution and light pollution issues.

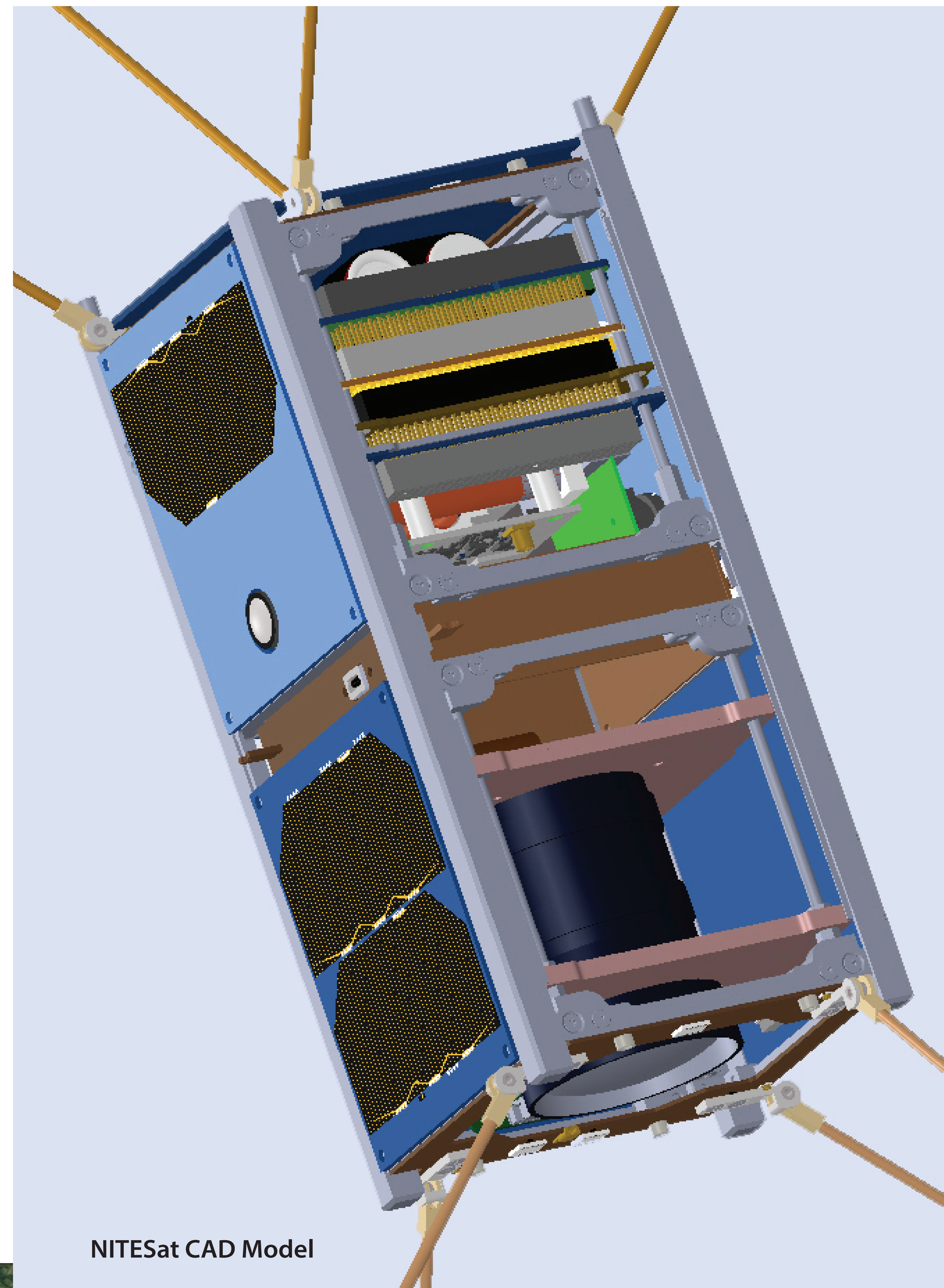
Far Horizons Program Assets

NITESat will be designed as part of the Far Horizons program. Far Horizons is the Adler Planetarium's hands-on space program. Scientists and engineers work directly with students, amateurs and volunteers in a peer and mentor structure. The program has ten years of experience designing and building experiments for High Altitude Balloon missions.

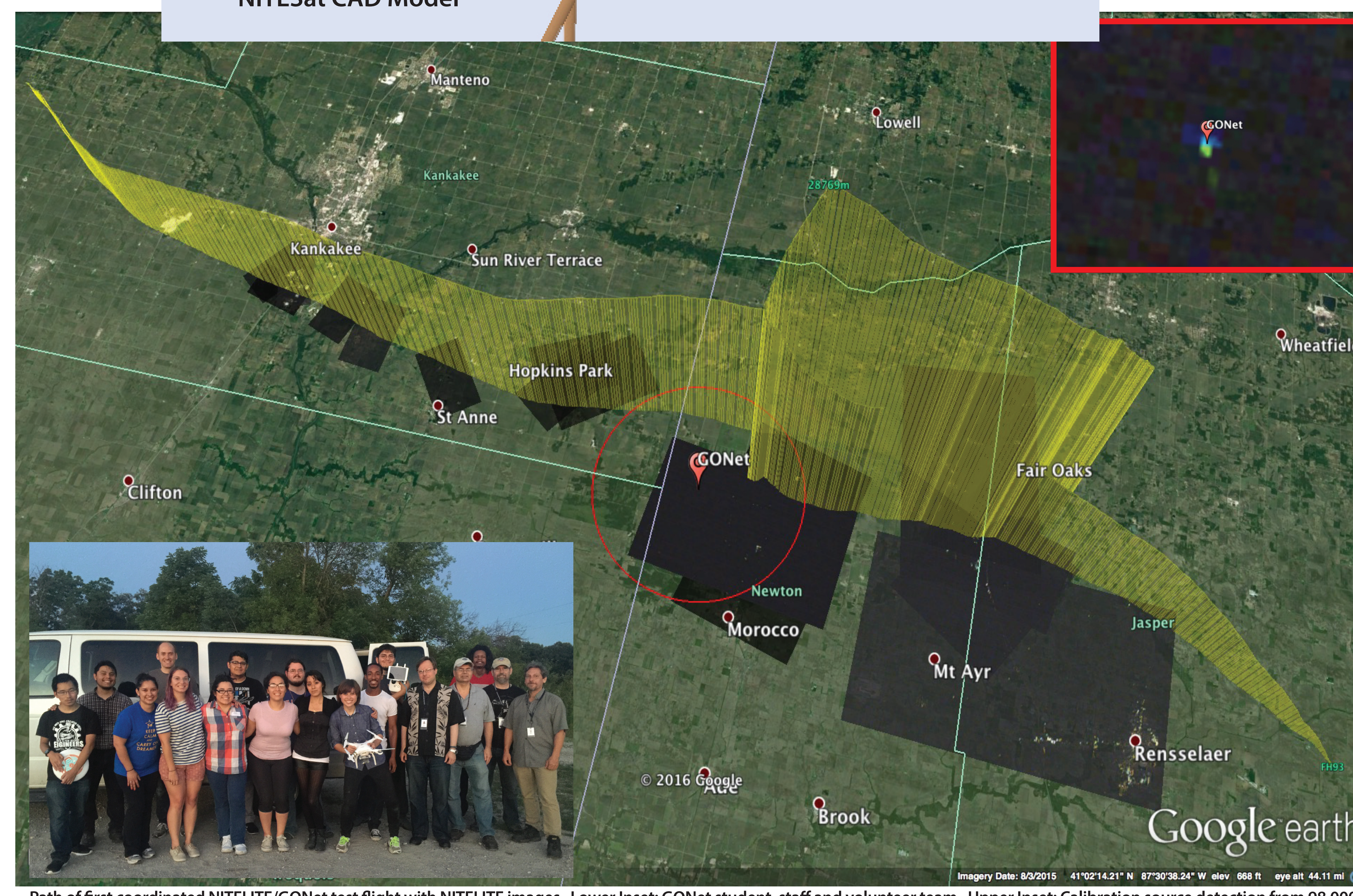
The program has a lab equipped with electronic benches, a machine shop, work and meeting spaces. A satellite communication ground station has recently been installed on the roof of the Adler Planetarium.

An enthusiastic and dedicated volunteer base is at the core of Far Horizons. In 2015, 37 volunteers contributed over 1,200 hours to the program. Over 300 teachers and students were involved in Far Horizons HAB flights or in the design of experiments for stratospheric flight in 2015. A staff of four full-time and three part-time scientists, engineer, manager and educators provide structure and expertise.

Staff have designed the program to allow multiple entry points based upon participant's skills. More advanced participants typically assist mentoring students to help develop new skills. A scaffolded program for teens is used to introduce them to subjects such as electronics, programming, communications and CAD. As their skills grow participants in turn work with higher level projects and assist in the mentoring of new volunteers and students.



NITESat CAD Model



Path of first coordinated NITELITE/GONet test flight with NITELITE images. Lower Inset: GONet student, staff and volunteer team. Upper Inset: Calibration source detection from 98,000

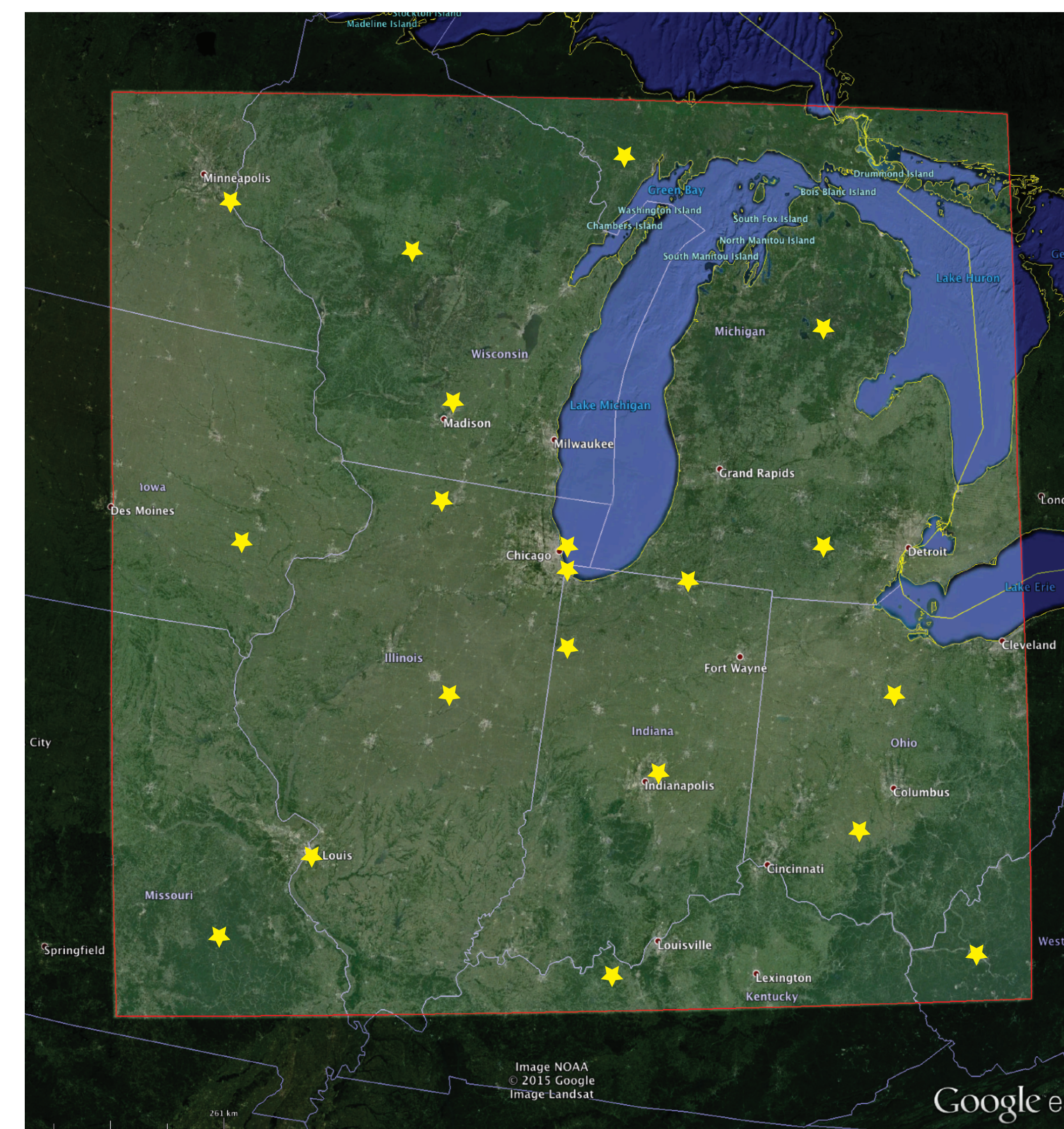
NITESat E/PO

An important aspect of the NITESat mission plan is the involvement of students, volunteers and the public. Far Horizons is primarily a hands-on program for science education. The development, design and achievements of the NITESat mission will be driven by the participation of these participants. Additionally, an active ground network (GONet) of citizen scientists trained through the NITESat program will provide correlated observations to help support the orbital mission. Students, amateur astronomers and the public will collect data coinciding with overpasses of opportunity by NITESat over their area. The data collected on orbit will be coordinated with synchronized ground station readings. These observations will provide a unique opportunity to engage the participants in:

1. Scientifically relevant observations;
2. Awareness of light pollution;
3. Education in the impact of artificial light on their community; and
4. Opportunities for citizen activism regarding light pollution in their own backyards.

Providing correlated data from the ground has been attempted on occasion.⁵ A series of outreach events led by researchers at the Loss of the Night Network (LoNNe) in the EU used the public and off the shelf (OTS) components to attempt to collect ground samples of light pollution to correlate with VIIRS data.⁶ A goal of GONet is to extend this work into a semi-permanent array of LP monitoring stations akin to what has been established in Hong Kong.⁷

This ground-based data collection network will be developed via outreach to schools and community groups through existing Adler Planetarium relationships in addition to developing new collaborations with groups such as the International Dark-Skies Association, Audubon Society, National Parks Service and other organizations who share a common interest and concern about light pollution as an environmental and cultural issue. We plan to use our decades of educational experience in creating an outreach program - including sky monitoring hardware, instructions for proper data collection and information about light pollution - to engage a broad community in joining the mission proper. The data collected by these groups will be pipelined directly to the NITESat database for mission support through an on line



Simulated GONet array across the NITESat imaging footprint

GONet - A Ground-based Observing Network

A unique part of the NITESat mission is the implementation of an array of ground-based light pollution observing stations for "ground truthing" the data supplied from orbit. These stations will collect valuable data not only for general light pollution research but also provide imagery synchronized with NITESat overpasses. These "Citizen Scientist" run stations will engage a diverse community with the NITESat mission as well as hands-on science, light pollution awareness and activism.

The first prototype GONet stations are being developed and tested in a partnership with Chicago City Colleges. Students there have been given design goals, work with experts and have tested their first model of a ground-based light pollution monitor that will cost $\leq \$500$. The eventual goal is to refine and harden the system and produce them in quantity as an affordable LP monitoring station for distribution across the NITESat imaging footprint.

NITELITE/GONet Test Missions

We are utilizing our experience of a decade and near nearly 100 high altitude balloon (HAB) missions as a testbed for components and mission concepts of NITESat. NITELITE is a stratospheric borne imaging system being used to test the NITESat mission assumptions. On July 8, 2016 a team of 34 staff, students, professors and volunteers performed the first coordinated test flight of a down-pointing imaging system with a ground-based sky monitoring station. The camera - an industrial grade, CMOS imager from Point Grey - imaged light pollution sources from the stratosphere as the GONet test station below recorded light contamination of the night sky from a relatively dark sky location. The GONet system also provided a calibrated light source for the in flight camera.

The initial test flight resulted in:

1. Stratospheric images of identifiable artificial light sources with color data
2. Calibrated ground light source detection from 28,000 meters
3. Images of sky quality from GONet
4. Confirmation of the broad mission concept

Additional test flights are scheduled for early Fall of 2016.

Collaboration?

We are interested in collaboration with anyone interested in the development of the science, outreach or STEM opportunities provided by the NITESat mission. Want to learn more? Please email me at kwalczak@adlerplanetarium.org

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