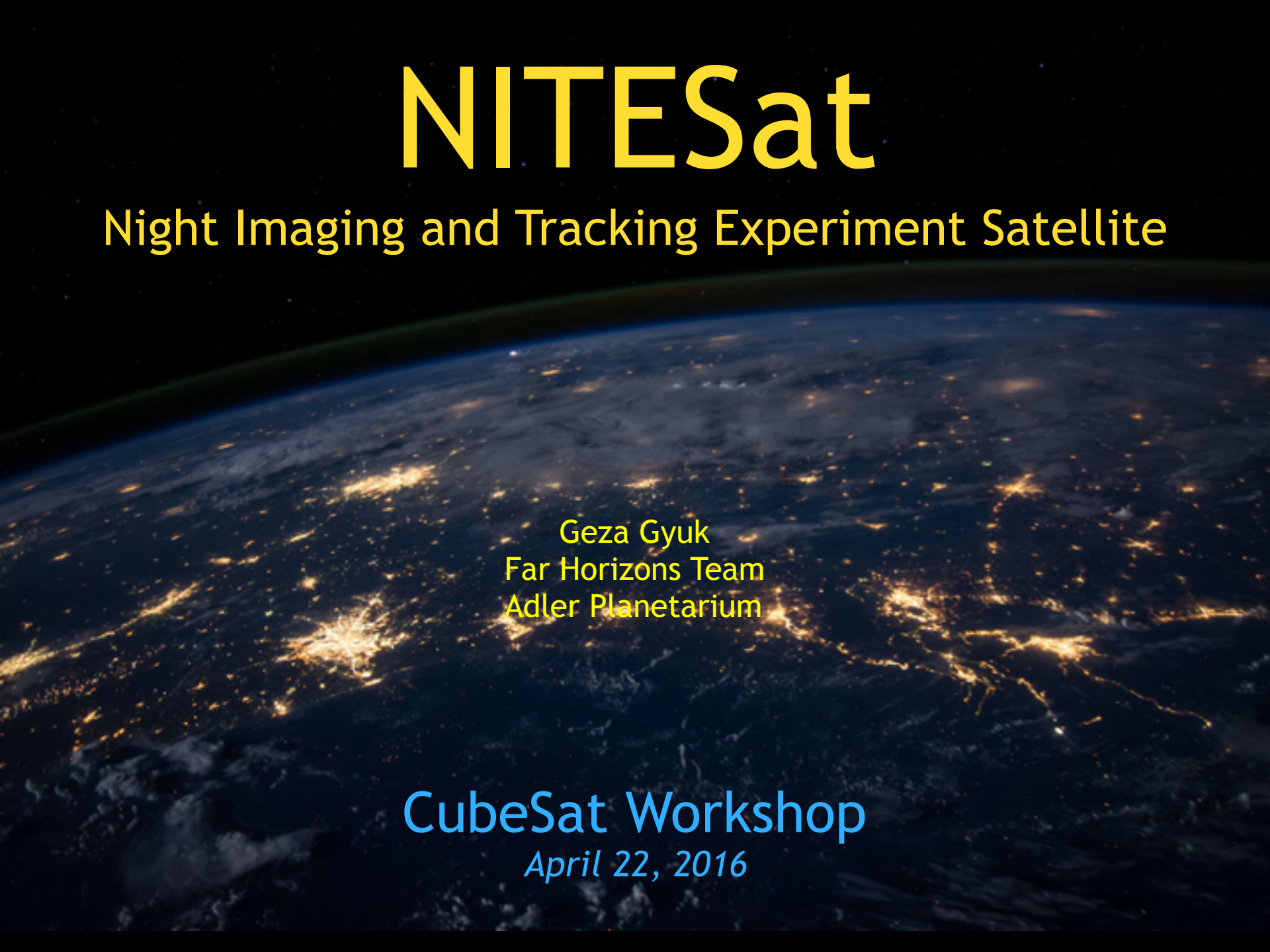
NITESat

Night Imaging and Tracking Experiment Satellite



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Far Horizons Team
Adler Planetarium

CubeSat Workshop

April 22, 2016


Chicago


Chicago

Why do we care about light pollution?

1. **Science** - Negative impact on astronomical research
2. **Education** - Loss of night sky = public disconnect w/ science
3. **Culture** - Loss of celestial heritage
4. **Economy** - Inefficient lighting systems waste energy
5. **Ecology** - Adverse effect on natural systems
6. **Health** - Possible adverse effects on human health

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→ Economic effects alone are many billions of dollars

On-Orbit Measurement of Night Lighting

Sensor	Years	Description	Platform	Resolution (m/px)	Detection Limit
Operational Linescan System (OLS)	1973-present	Scanning telescope with three single detector focal planes. Light intensification achieved with a photomultiplier tube (PMT).	Defense Meteorological Satellite Program (DMSP)	2700	10^{-9} W cm^{-2} sr^{-1}
Visible Infrared Imaging Radiometer Suite (VIIRS)	2011-present	Day-Night Band (DNB): radiometer with a single broad low-light imaging band employing time-delay integration (TDI) on a charge-coupled device.	Suomi National Polar-orbiting Partnership (Suomi-NPP)	742	10^{-11} W cm^{-2} sr^{-1}
Kodak-Nikon 760	2002-present	Color digital camera with image motion compensation device. Requires complex post-processing.	International Space Station (ISS)	60–100	Varies
Nightsat	2007 (proposed)	Multispectral low-light imaging from low-altitude near-synchronous orbit during early evening overpasses.	Proposed: not launched	50-100	2.5E^{-8} W cm^{-2} sr^{-1} (or better)

The VIIRS instrument is presently the best and most complete dataset available

Elvidge, C.D., et al. (2007). The Nightsat Mission Concept. *International Journal of Remote Sensing*, 28(12), 2645-2670

NITESat Mission Objectives

NITESat will be a 2U CubeSat with the following Scientific and Educational focus:

- Acquire high quality data of regional (Midwestern) **light pollution** from orbit
- Organize synchronized **ground observations** of sky brightness
- **Raise awareness** of the impact of light pollution
- Provide **authentic** science and engineering experience to participants

➔ And do this all with a community of volunteers!

Imaging Requirements

Resolution:

Sufficient resolution is required to distinguish major roads, commercial centers, dimly-lit residential neighborhoods, and lighting in sparse undeveloped areas. NITESat will provide a ground resolution of 200m/px.

Spectral Information:

Color imaging data will allow distinction between most common sources of artificial night-time lighting, a level of data not provided by the OLS or VIIRS instruments. Useful distinction between major types of artificial illumination sources will be achieved with RGB information available from a standard OTS CCD or CMOS camera.

Sensitivity:

To obtain a valuable data product, the imager must be have sufficient sensitivity and SNR to detect dim illumination sources. The recommended minimum detectable signal is $1E^{-8}$ Watts cm^{-2} sr^{-1} with a signal-to-noise ratio (SNR) of 5 or better.

Coverage:

The imaging data products will produce a 1000x1000km map nominally centered on Chicago with a minimum of 90% cloudless coverage across that footprint throughout the mission lifetime.

Pointing:

Absolute pointing adequate to provide >=90% overlap with intended target. Relative pointing drift smaller than 1 px during exposure.

Night Imaging and Tracking Experiment Satellite

	NITESat	VIIRS
Resolution	**200 m/px**	742 m/px
Spectral range	**Multispectral (0.4-0.5, 0.5-0.6,0.6-0.7μm)**	single band (0.5-0.9μm)
Sensitivity	$1x10^{-8}$ W/cm^2/sr	**$5x10^{-11}$ W/cm^2/sr**
Nighttime Overpass	**Varied**	1:30 a.m. (local time)
Ground Calibration	**Yes**	No
Coverage*	1000km x 1000km	**Global**


Minneapolis
Wisconsin
Madison
Milwaukee
Michigan
Grand Rapids
Des Moines
Chicago
Detroit
Cleveland
Illinois
Fort Wayne
Indiana
Ohio
Indianapolis
Columbus
St Louis
Cincinnati
Missouri
Springfield
Louisville
Lexington
Kentucky
Image NOAA
© 2015 Google
Image Landsat
Google ear

Mission Design

- 2U cubesat
  - Nadir pointing – active pointing
- Orbit
  - 450-500 km
  - 50-55° inclination
- 2 min overpasses
  - Stacking exposures
- Low duty cycle!

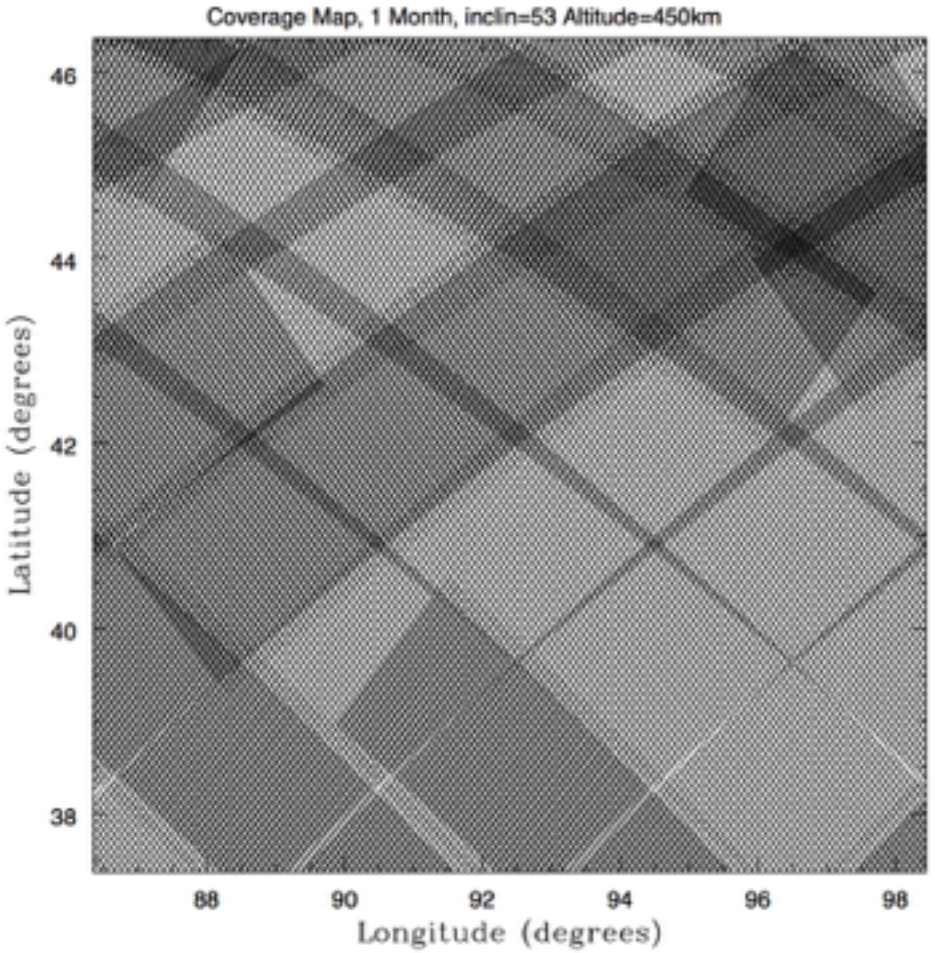
Coverage

Spatial:

9pm-midnight passes provide almost complete double coverage every other month

inclinations below 45° do not reach target latitudes

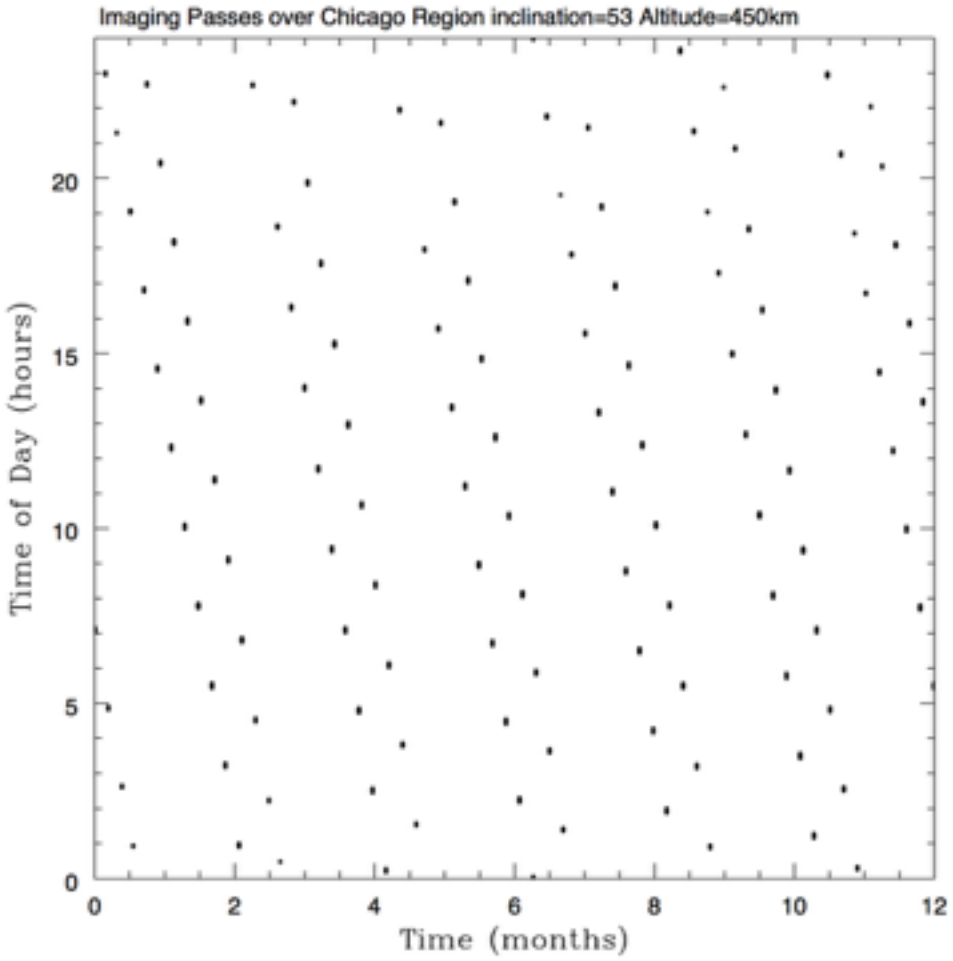
Inclinations above ~60° leave coverage gaps

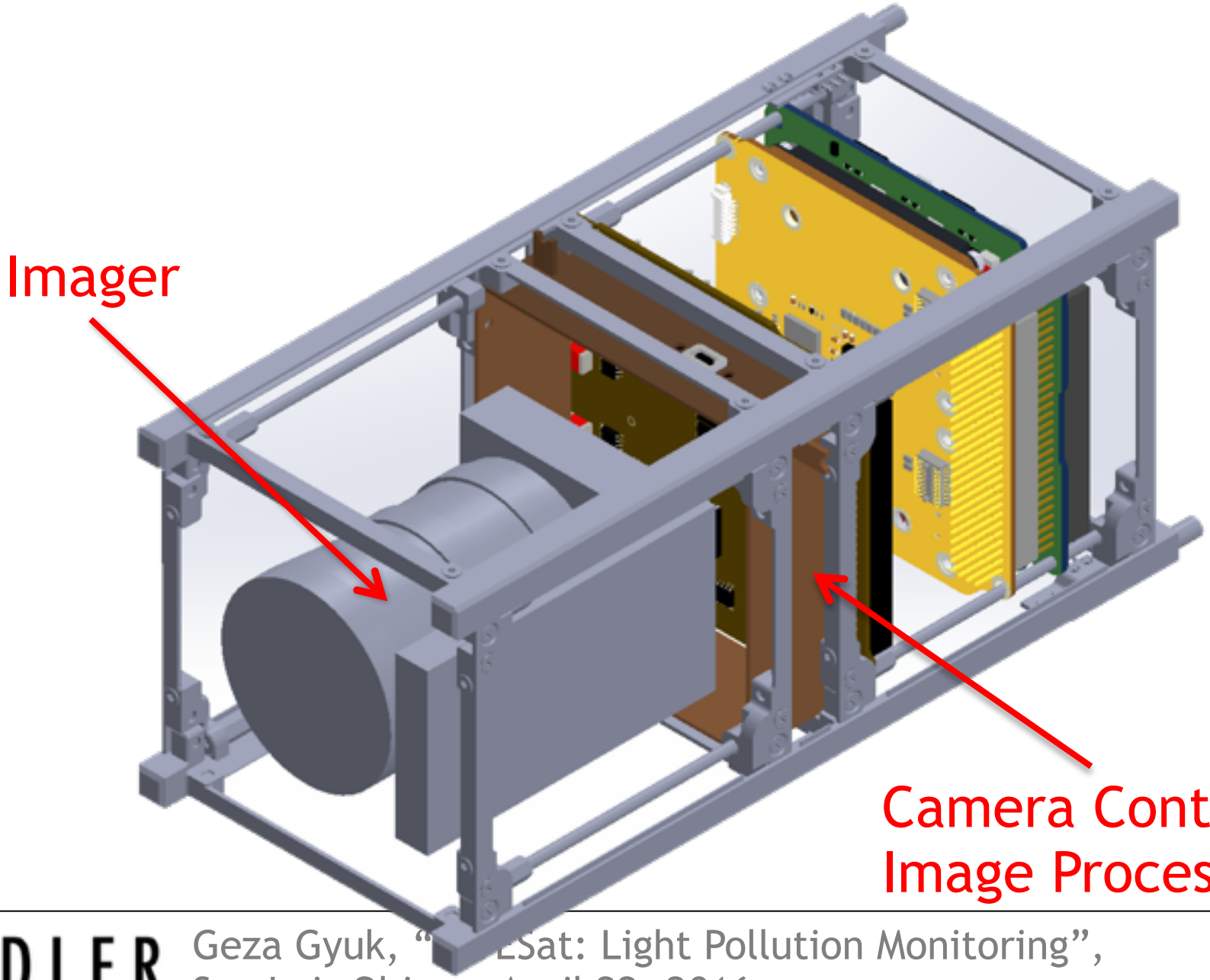


Coverage

Temporal:

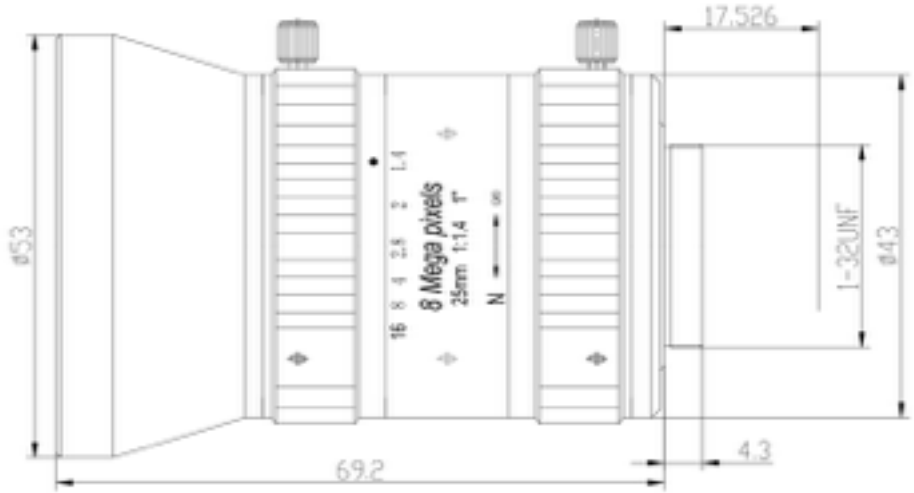
Passes during the 9pm-midnight period occur in clusters of duration approximately 1 month, separated by 1 month periods of no imaging passes




Imager
Camera Controller/
Image Processor

Imager

The imaging subsystem consists of a lens, a camera, a focuser and an image processor/controller.



Lensation C8M2514GSV2

PCO edge 3.1 scmos

Imaging Performance

Plate scale: 117m/pixel (at 450km)

Field of view: 29.8° = 240 km (at 450km)

Exposure time: 1/50th sec (x20)

Sensitivity: 2-5 x 10^{-9} W/cm^2/sr

Dynamic range: 15 bits

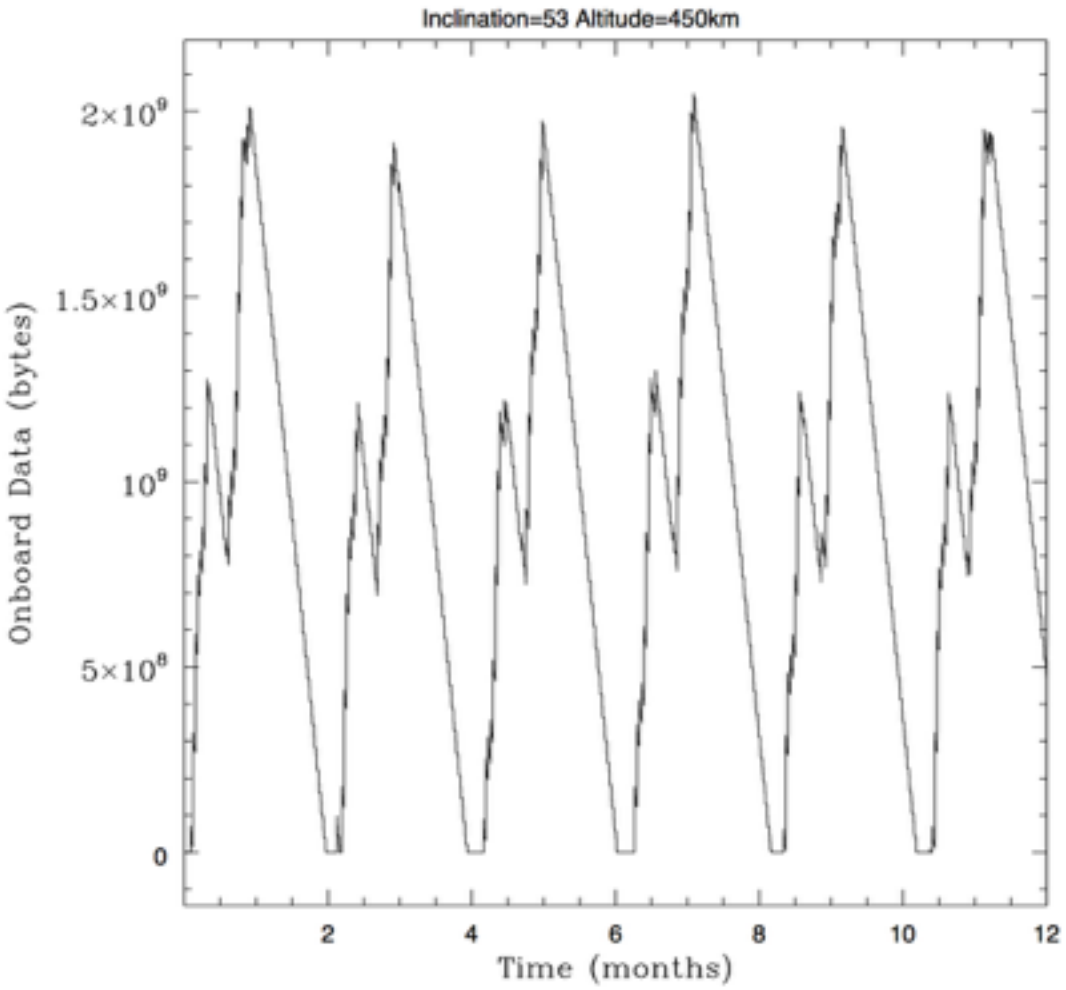
Comm. System Performance

Data Storage & Downlink:

- Downlink range: 1700 km
- Downlink data rate: 2.4kB/s **
- compression 10:1
- Single ground-station
- no adaptive data rate

➡ 8GB on-board storage is more than adequate

** 17% lower than link calculation



Operational Notes

- Imager operated only over target region at night resulting in an average duty cycle of ~0.1% during orbit
- Images taken in rapid stacking pairs (stored in in-camera buffer) and transferred to image processor/storage separated by 0.1 sec
- ~14GB of data transferred to processor during imaging passes
- “Realtime” stacking reduces long-term storage requirement to ~100MB/pass
- Imager requires nadir pointing accuracy to 5-10°, pointing drift below 1°/s and roll less than 4.5°/s

Simulated NITESat Image

VIIRS Image

NITESat E/PO Thematic Strands & Major Elements

- Far Horizons build community
- Light pollution data collection as part of '*Scopes in the City* telescope outreach and sky observing events that coincide with Globe at Night data collection campaign dates;
- Development and facilitation of light pollution-themed Service Learning Project available to middle and high school students.
- NITESat Mission Operations and Control exhibit

The Adler Planetarium will partner with Globe at Night, the International Dark-Sky Association, and local and regional astronomical societies, school districts, and other organizations.

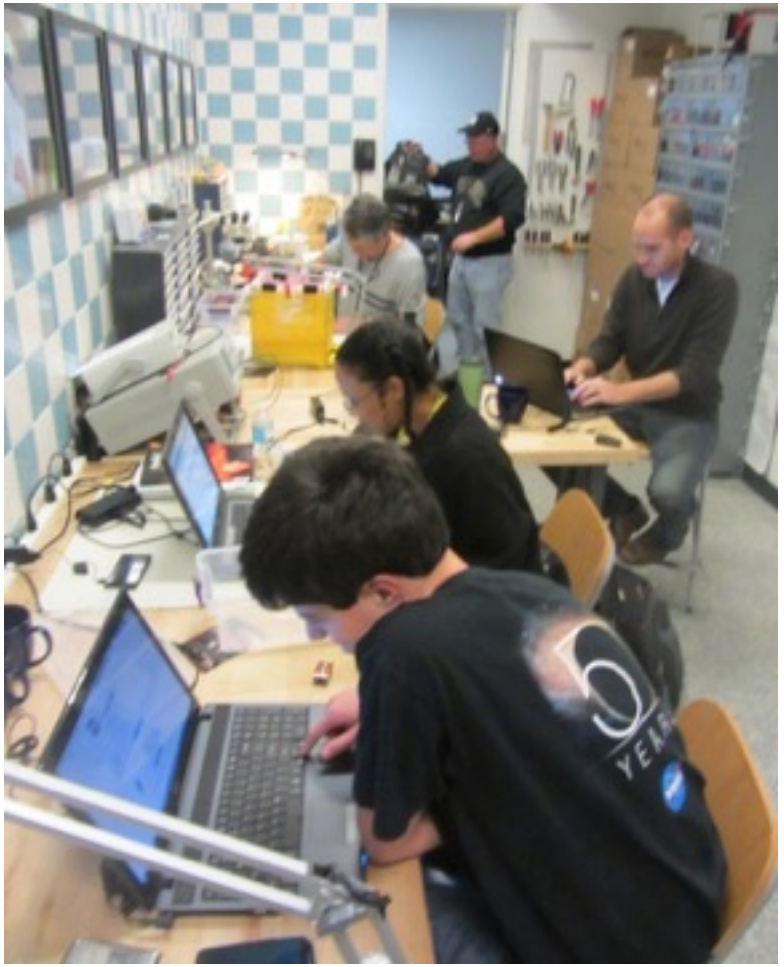
Simulated Ground Observing Network Coverage

Far Horizons

- Relatively new program aimed at actively involving the public in space exploration
- We want to enlist the public in performing cutting-edge science in space

  BUT…

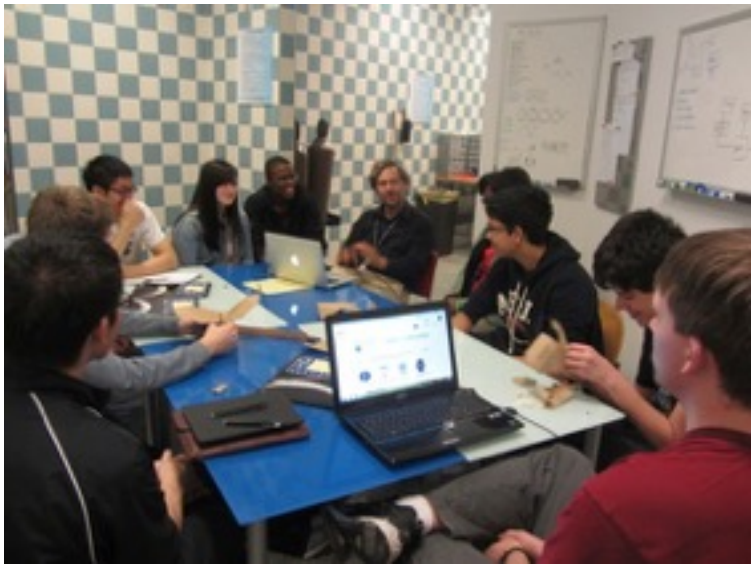
- Steep learning curve
  - Institutionally
  - Individually
- Ballooning as “on-ramp” to space
  - “NASA” model



FAR
HORIZONS

Far Horizons (cont.)

- Healthy Design/Build/Fly Community
  - Volunteers
  - Students
  - Interns
  - Planetarium members
  - Online and physical community
  - ~100 missions



- Stepping up to satellite missions

Summary

- Interesting science case
- NITESat design is maturing
- Expecting early 2018 launch
- Integrated informal education/outreach

Schedule

Preliminary Design Review	Dec. 2015
Critical Design Review	Sep. 2016
Engineering Model Completed	Apr. 2017
Flight Model Complete	Jun. 2017
EPO Program Implementation	Sep. 2017
Launch	Mar. 2018
On-orbit Checkout Complete	Jun. 2018
Flight Operations	2018-19
End of Mission	Jun. 2019