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Leveraging Planning Tools to Demonstrate the Feasibility of the OpTIIX Public Outreach Mission

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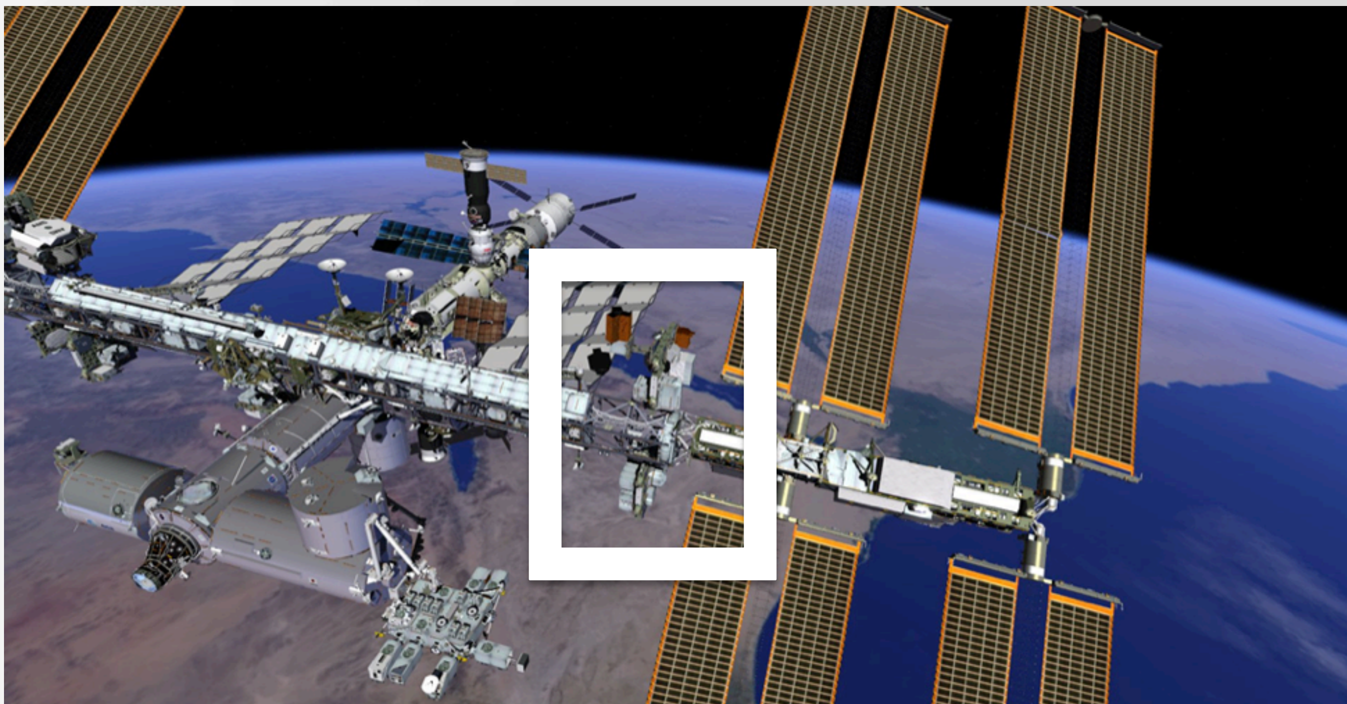
OpTIIX

- **Op**tical **T**estbed and **I**ntegration on **I**SS e**X**periment
- Proposed mission to put a 1.5 meter-telescope on ISS.
- Launch ~ Spring of 2015



OpTIIX Goals

- Experiment and demonstrate the technologies for future large space telescopes
  - Robotic assembly of the telescope
  - Laser metrology and wavefront sensing and control
- Education and public outreach
  - Amateur astronomers
  - Middle- and high-school students

OpTIIX Goals

Robotic assembly of the telescope

James Webb Space Telescope

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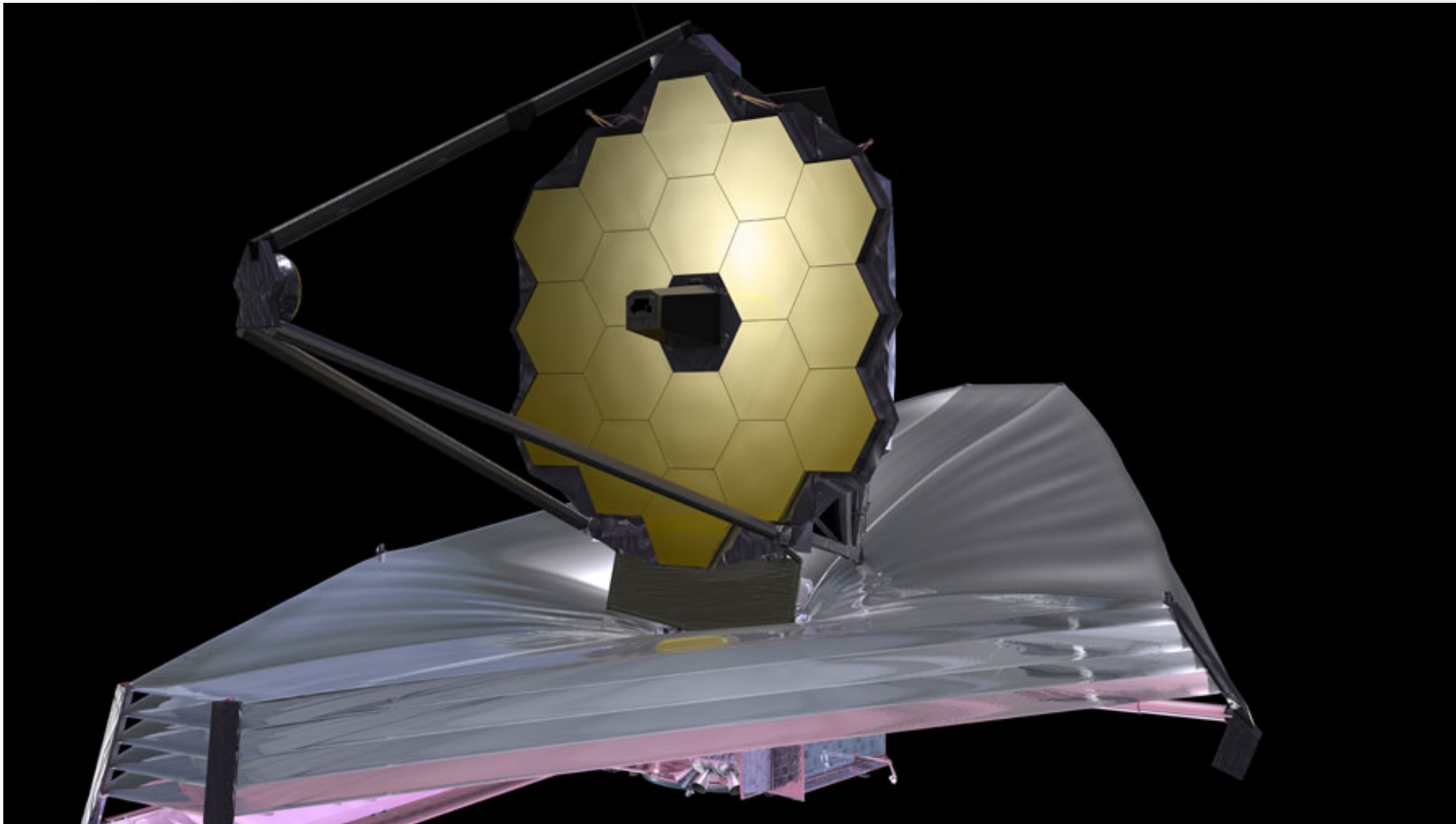

OpTIIX Goals

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3-4 months

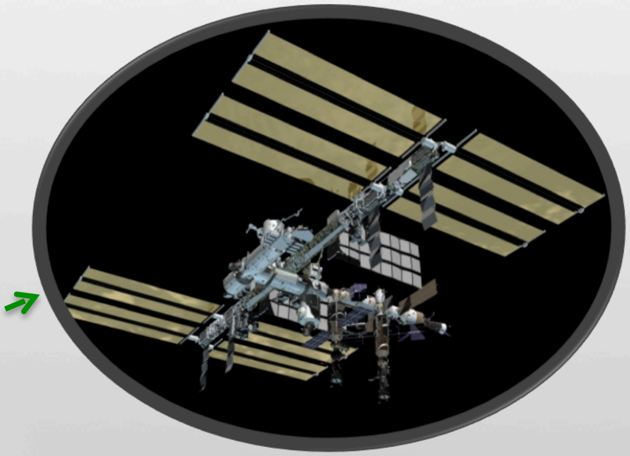
- Experiment and demonstrate the technologies for future large space telescopes
  - Robotic assembly of the telescope
  - Laser metrology and wavefront sensing and control

3 months

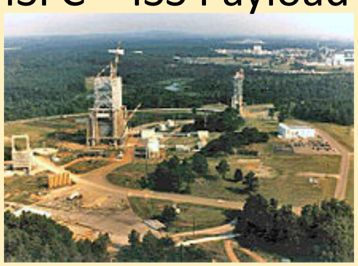
- **Education and public outreach (EPO)**
  - **Amateur astronomers**
  - **Middle- and high-school students**

OpTIIX Operations

JSC – ISS Mission Control



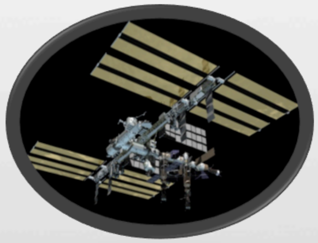
MSFC – ISS Payload Operations



JPL

STScI

OpTIIX Operations



JSC

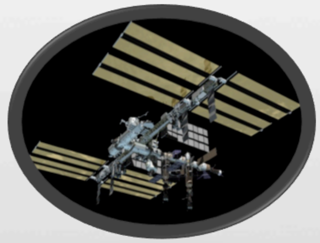
MSFC

JPL

OpTIIX operation
- Command generation
- Calibration
- Raw data archive

STScI

OpTIIX Operations



JSC

MSFC

JPL

STScI

EPO operation
- User interface
- Observation scheduling
- Data processing
- Image archive

Outline

- Education outreach program requirements
- Feasibility analysis
  - Proof of concept system implementation
    - Telescope scheduling constraints
  - Scheduling simulation
  - Results
- Comparison with another EPO mission

Education Outreach Requirement

- **50 targets within a 3-month period**
  - ~4 targets per week
  - Planets, galaxies, globular clusters, and nebulae
- **Time between observation request to image retrieval ≤ 1 week.**
  - Too short to let students select actual observations that get scheduled.

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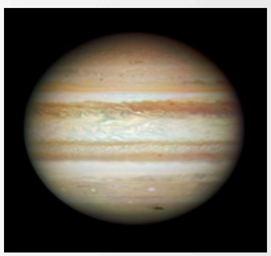
Planet

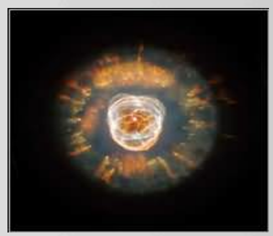


Jupiter

Galaxy

M87

Planetary Nebula



Eskimo Nebula (NGC 2392)

Non-planetary Nebula

NGC2261

Globular Cluster

M53

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EPO Challenge

Time between observation request to image retrieval ≤ 1 week.

- If we are to schedule based on the students' selection, it would require at least 3 uploads/week.
- We want the students to feel they have the control of the telescope
  - Do not want to let them choose from archived images.

➡ Pre-schedule observations but the images are generated based the exposure time and filters picked by the students.

- Students can only pick targets from the upcoming observations.

EPO Challenge

40-min exposure

40-min exposure

40-min exposure

20-min exposure

60-min exposure

20-min exposure

20-min exposure

EPO Challenge

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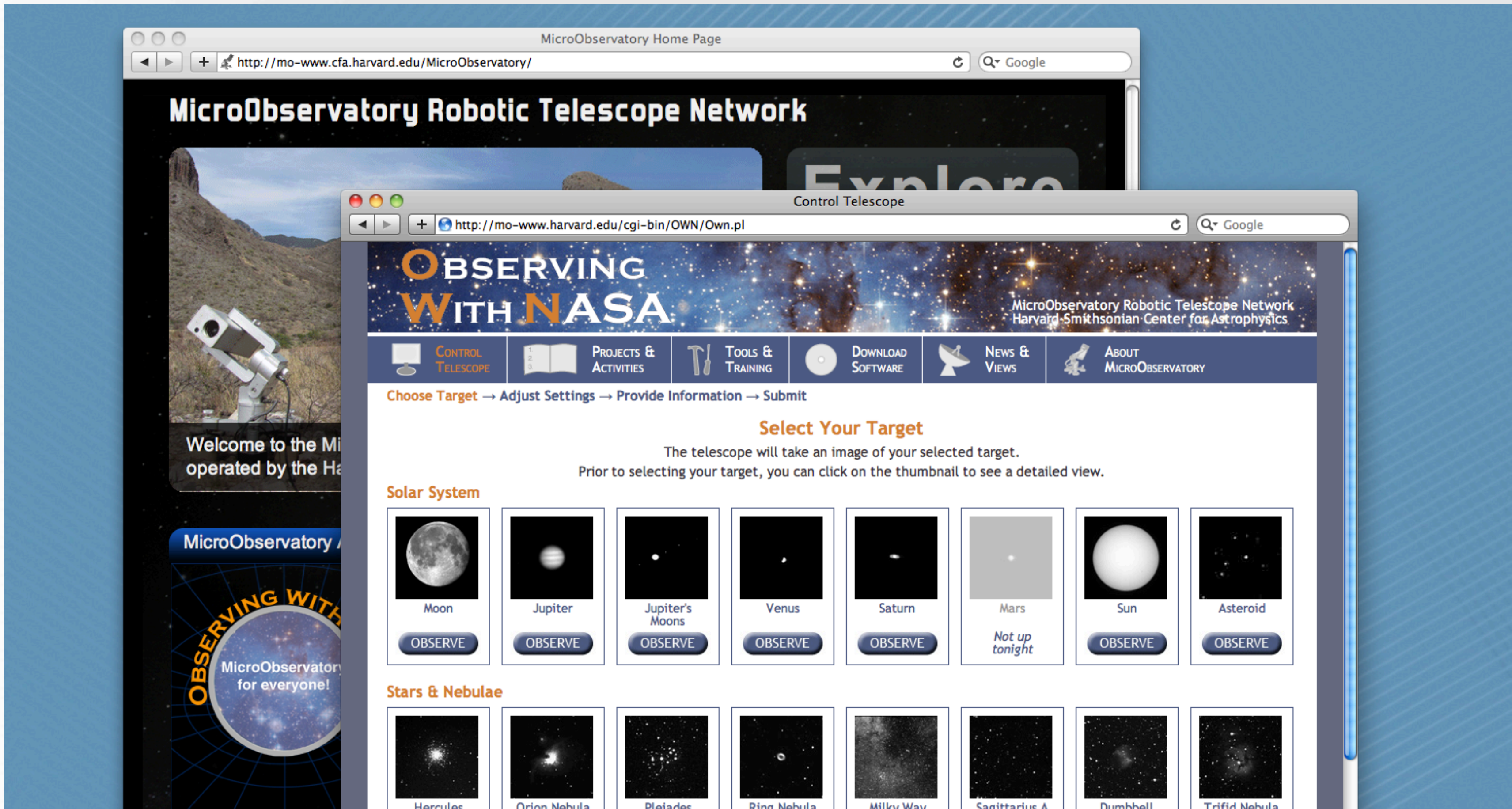
Web-based Interface

MicroObservatory at Harvard (http://mo-www.cfa.harvard.edu)



Proof of Concept System

- Coded a proof of concept system using Spike.
- ISS orbit modeled using the existing Spike orbit modeling utility.
  - Target visibility calculated (Used for the telescope gimbal flexibility analysis).
- Simulated scheduling of the EPO observations
  - Planning system used in feasibility analysis
    - Other mission feasibility study using planning system: CLASP used for DESDynI (Knight et al., 2012)

Spike

- Scheduling system
  - Used for long-range planning of HST and JWST as well as Spitzer, FUSE, Subaru & Chandra.
  - Has a suite of support modules for astronomical observation; orbital calculation, coordinate conversion, etc.
  - 2 scheduling engines: Least-commitment scheduling and CSP scheduling.
    - CSP scheduling engine is used for OpTIIX.

OpTIIX scheduling constraints

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- **Field of regard**. Targets in the area of the sky that the telescope can point to at the time.
- **Sun occultation**. No target can be observed unless the Earth occults the sun from ISS's point of view. The telescope has to be pointed to a safe position during the sunny portion of the ISS orbit.
- **Moon avoidance**. The target has to be separated from the moon by a TBD amount.
- **South Atlantic Anomaly (SAA) avoidance**. No observation can be performed while ISS crosses over the high radiation region near South America.
- **Guide star availability**. A guide star has to be available on a fine guidance sensor to track the target.
- **ISS exclusion**. OpTIIX cannot be used during certain ISS activities (e.g. Soyuz dockings).
- **Calibration activities.** A one orbit calibration every day and a six orbit calibration once a week.

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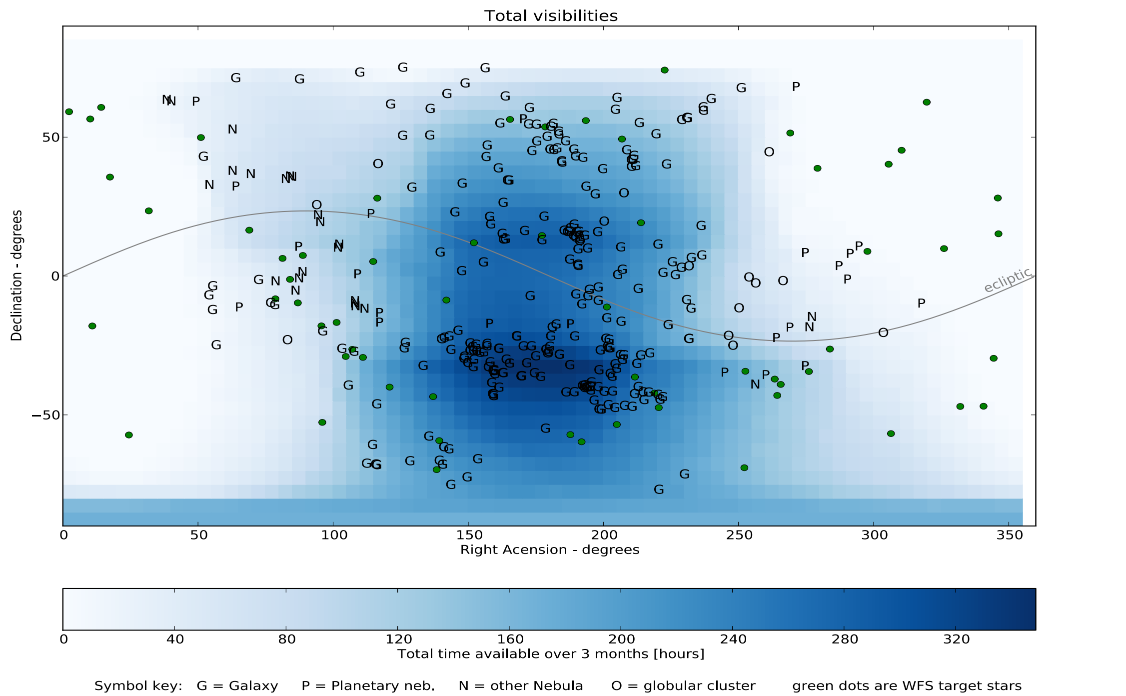
Visibility Duration and Potential Outreach Targets



- The target locations plotted.
- The total visibility duration calculated for the 3 month period starting Feb 1, 2016.

Potential EPO Observations

Type	#observations	Duration per observation (in seconds)
Planet	2	600
Galaxy	257	12000
Globular Cluster	14	1000
Planetary Nebulae	23	8000
Other Nebulae	24	5000

- The period used for study: Feb 1, 2016 – Apr 30, 2016
  - 1383 physical orbits in the 89 days
  - 1203 usable orbits after assumed ISS exclusions taken out
  - Scheduling all the targets requires 2835 orbits.

Simulation

- Mars and Jupiter scheduled once a week, if observable.
  - Requires one orbit. Easy to schedule.
- Calibration activities scheduled
  - Goal is to plan a one orbit wavefront sensing observation every day and a 6 orbit wavefront sensing observation once a week
  - Spike can pick which orbit to use for calibration activities.

Multi-objective Scheduling

- Evaluation criteria
  - Maximize the time on target.
  - Maximize the number of wavefront calibration observations scheduled.
  - Maximize the number of science observations that are fully scheduled.
  - Minimize the number of orbits scheduled from partially scheduled observations
  - Maximize the number of orbits scheduled from fully scheduled observations.
  - Minimize the schedule gap time

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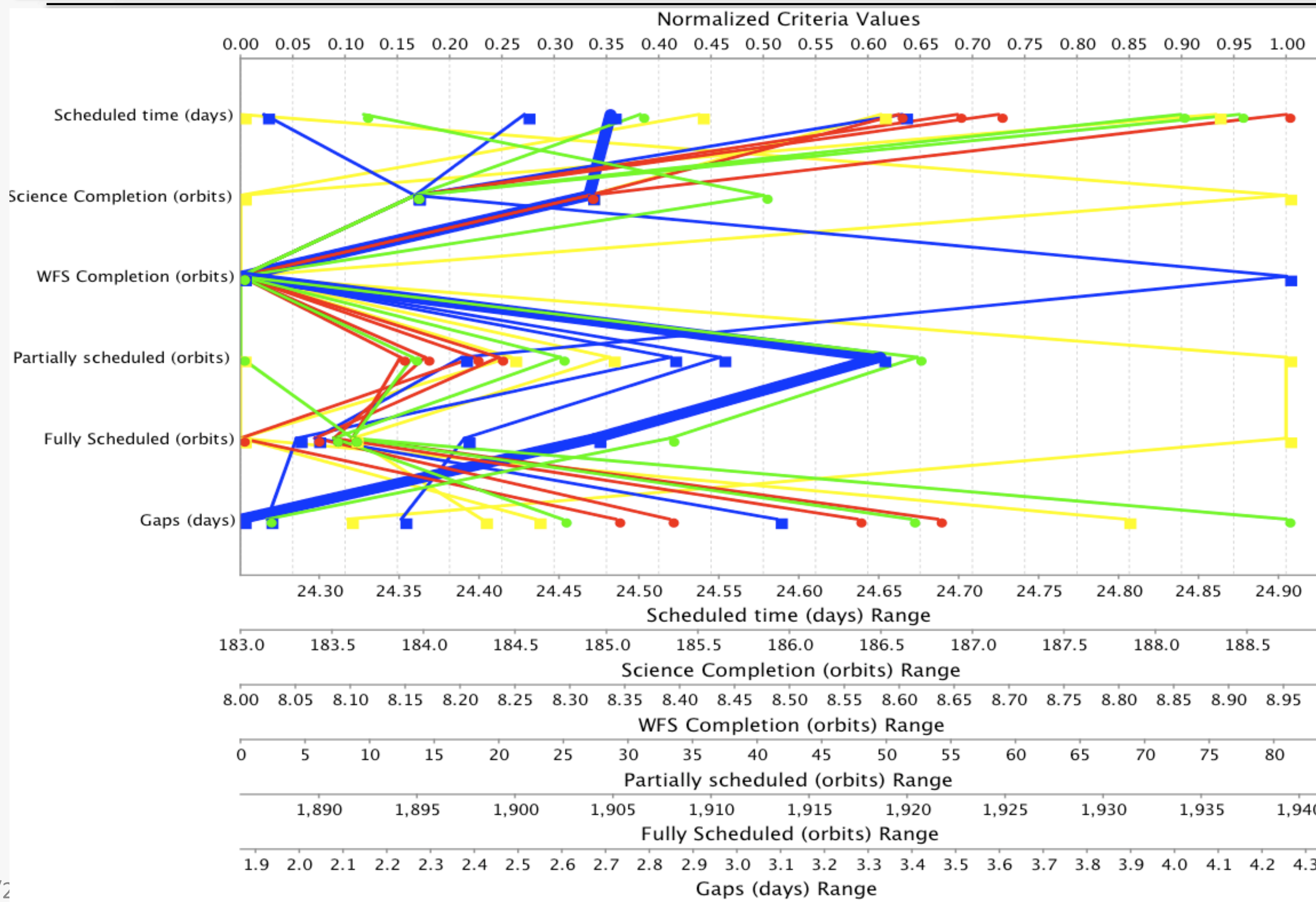
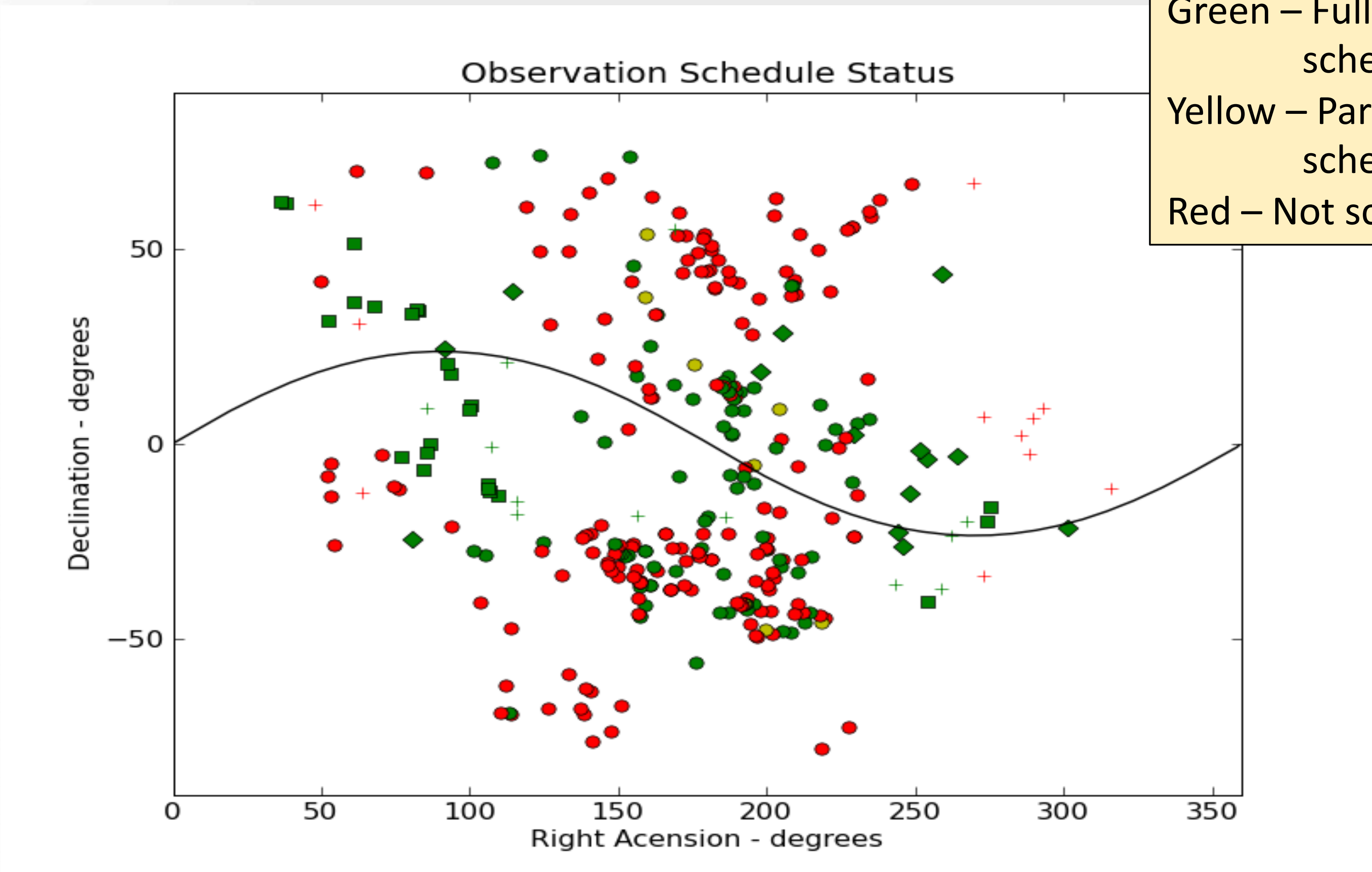
Pareto Optimal Solutions



Scheduling simulation results

- All schedules but one completed all of the wavefront calibration activities.
- From 129 to139 outreach observations fully scheduled (= average of ~12 obs per week)
  - All moving targets were scheduled once a week.
- Schedule gaps ranged from 2-5%.

Solution target plot



Green – Fully scheduled,
Yellow – Partially scheduled,
Red – Not scheduled.

Feasibility Analysis Results

Q: Can we accomplish the education outreach mission goal?

A: Yes. The OpTIIX mission can achieve its goal of 50 outreach targets in a three month interval with significant margin.

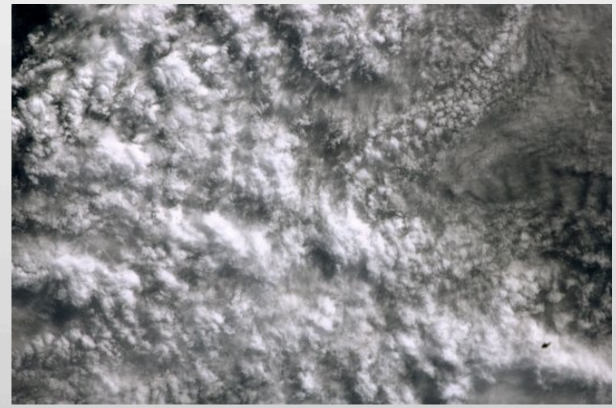
- The scheduling simulation gave us information to help us build the public and education outreach program.
  - Better idea of what observation can be scheduled.
- The proof of concept system gives us a head-start on the actual planning and scheduling system development.

OpTIIX status

- Preliminary Design Review (PDR) completed in September 2012.
- Not fully funded.
  - EPO system development suspended

EarthKAM
(www.earthkam.ucsd.edu)

- Looking down from ISS
- Program for middle school students to take pictures using a digital camera on ISS.
  - Students specify the coordinate of the location directly underneath the ISS.
  - Successful program since 2001.



- Can send a request as little as 2 hours in advance and can receive the resulting image within 5-10 minutes after.

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Questions?

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