An Automated Approach to Maneuver Campaign Management for SkySats

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Lake Okeechobee, Florida, USA – July 1, 2016

Planet Labs PBC

“Using Space to Help Life on Earth”

- Leading provider of global daily satellite imagery and geospatial solutions.
- Builds, designs, and operates the largest Earth observation fleet of imaging satellites, (over 200 currently in orbit) capturing over 30 TB of data per day.
- Provides mission critical data and software solutions to over 800 customers in agriculture, forestry, education, finance, and government.
- Makes global change visible, accessible and actionable.

Muir Woods & Mt. Tamalpais, California, USA – December 23, 2015

Planet Dove Satellite

- Always-on, broad-area monitoring
- 3 meter resolution
- RGB and NIR bands

Planet SkySat Satellite

- Custom, targeted monitoring
- 50 centimeter resolution
- RGB, NIR, and Pan bands

Planet Dove Constellation

~98° Sun-Synchronous Orbit

Planet SkySat Constellation

SkySats 1-15

~98° Sun-Synchronous Orbit

SkySats 16-21

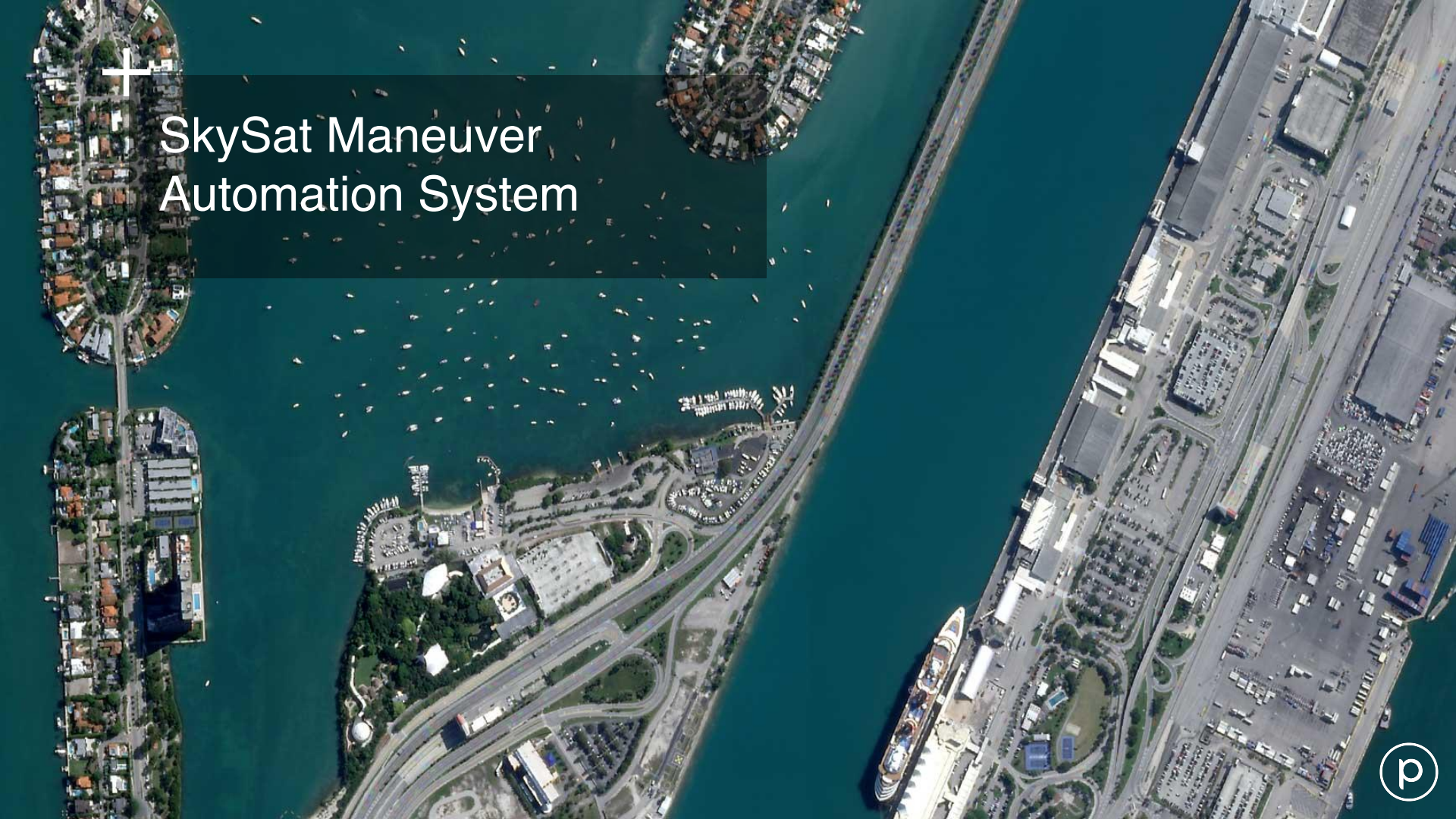
~53° Inclined Orbit

Motivation for Maneuver Automation

So Why Automate?

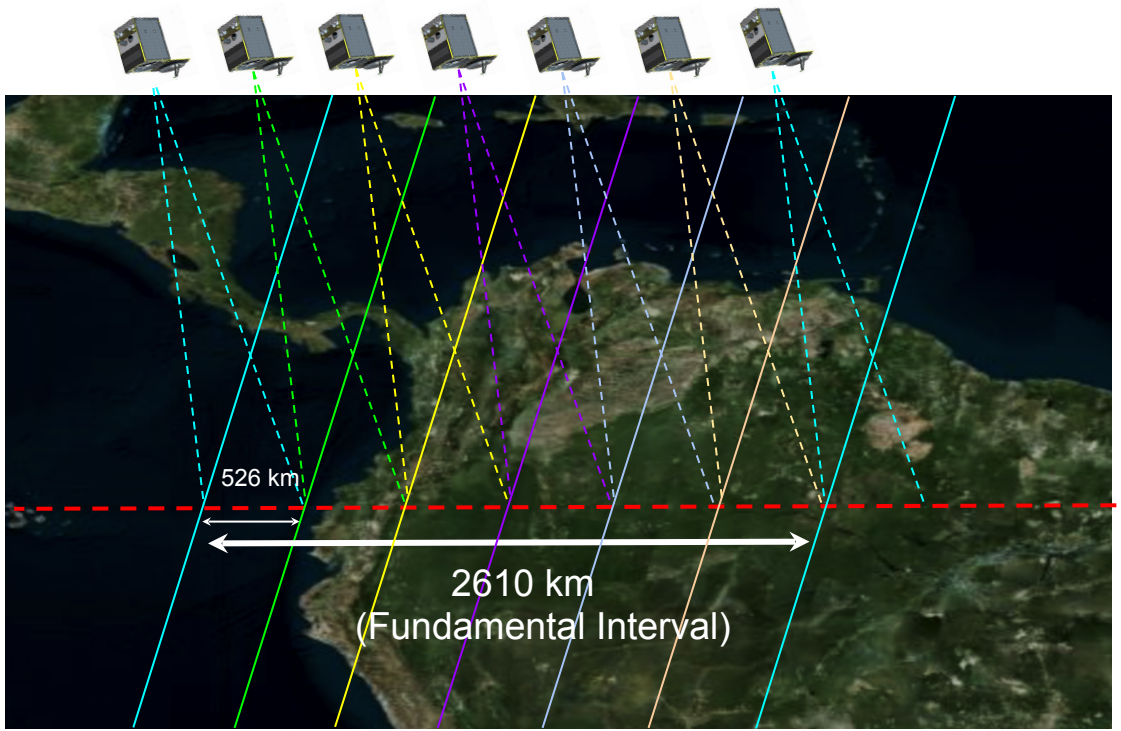
- Many satellites!
- Need routine stationkeeping maneuvers to maintain orbit requirements:
  - Altitude (decays with atmospheric drag)
  - MLTDN (third-body resonances effects cause secular change in inclination)
  - Frozen orbit conditions (long term periodic variations due to J2 and J3)
  - In-plane phasing to have non-conflicting ground contacts and overlap between successive groundtracks
- Reduce operator workload, save time, and focus on innovation and R&D
- Pave the way for scalable operations (multiple missions and constellations)

Provide a reliable, robust, and efficient system with metrics reports and traceable information for the operator/orbit analyst.


SkySat Maneuver
Automation System

Phase by Relative Longitude

- Ensure optimal coverage between successive ground tracks.
- Space satellites in the same orbital plane to have overlapping swaths, spanning the fundamental interval.

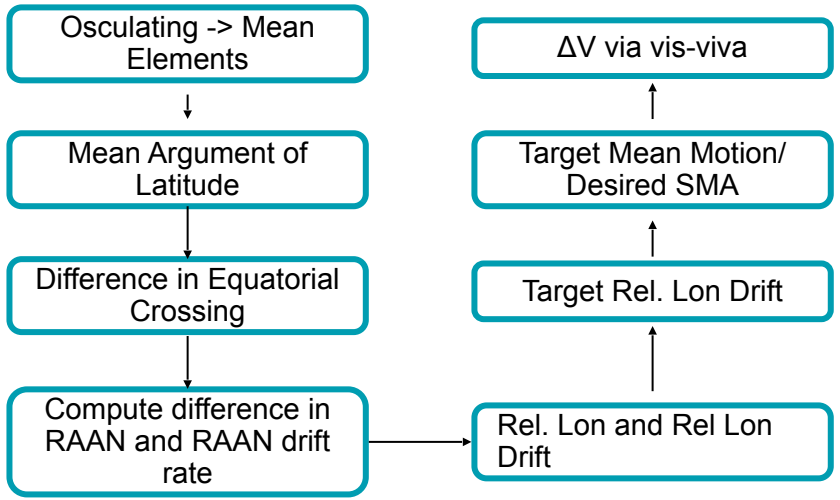


Relative Longitude Stationkeeping Algorithm

- 1 reference satellite for each orbital plane.
- Stationkeeping bounds computed w.r.t reference satellite based on fundamental interval, swath width, and off-nadir angle.
- Reference satellite for one plane can also track reference satellite for the other orbital plane, allowing 1 primary reference satellite for both planes.

Given: Position & Velocity for reference satellite and follower satellite

Compute:



Campaign Planner

The workhorse of the automation system

- Constellation Management and Maneuver Planning Tool
- Utilizes Planet's in-house Astrodynamics/GNC libraries
- Interacts with Planet's Mission Control

Two Key Components

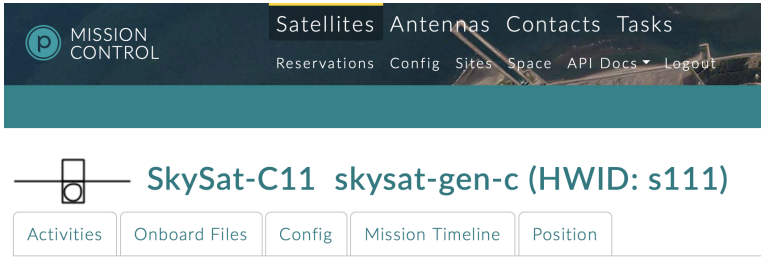
- Maneuver Trigger
  - Assess the need/possibility to maneuver based on
    - Blackout Days
    - Burn Frequency Check
    - Existing Burn Check
    - Stationkeeping Check
- Maneuver Action
  - Runs stationkeeping algorithms to plan maneuver at optimal location in orbit

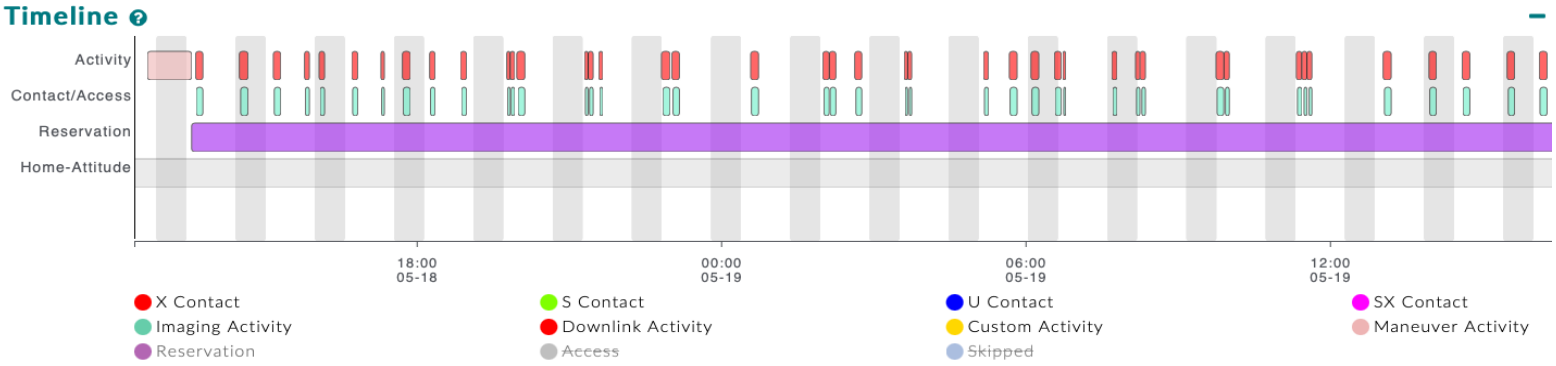
Output

- Constellation wide maneuver plan
- Close Approaches and conjunction anomaly trends

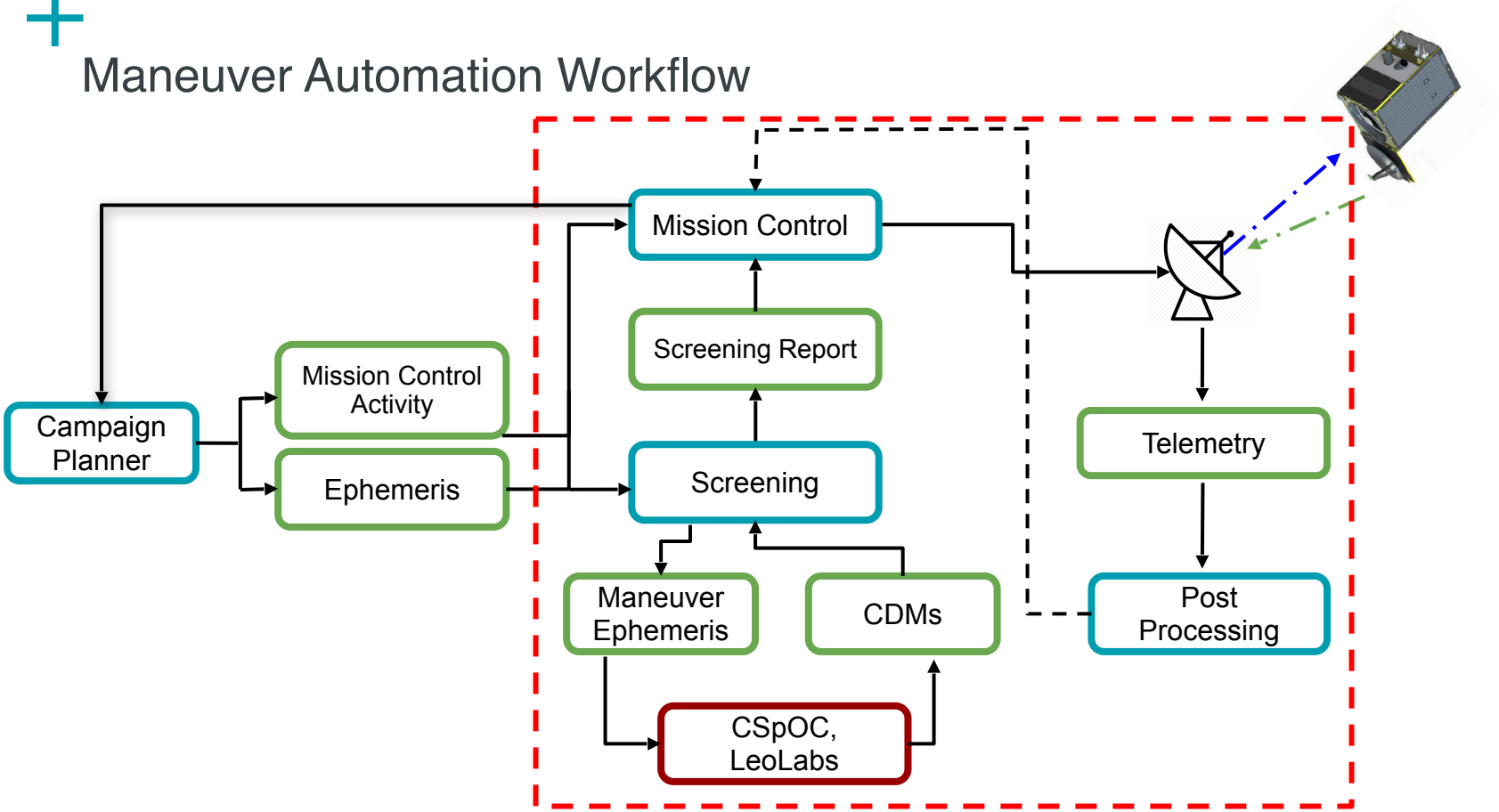
Planet Mission Control

- Cloud based application
- Coordinates the interaction of satellites with ground antennas
- “Source of all truth”
- For each satellite, contains:
  - Scheduled activities
  - Onboard files
  - Configuration settings
  - Mission Timeline



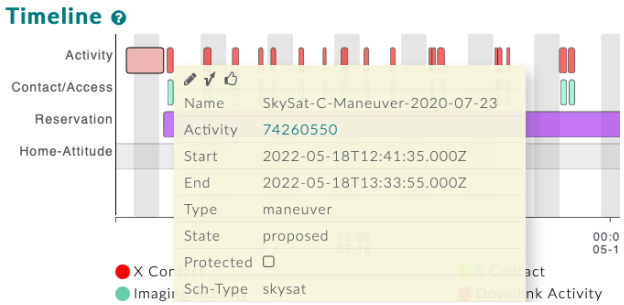


Maneuver Automation Workflow



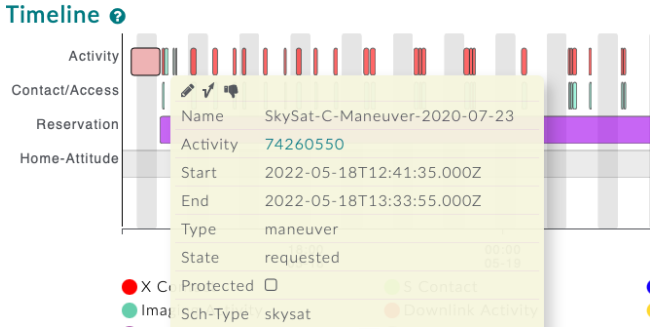
From Delivery to Execution

1. Proposed



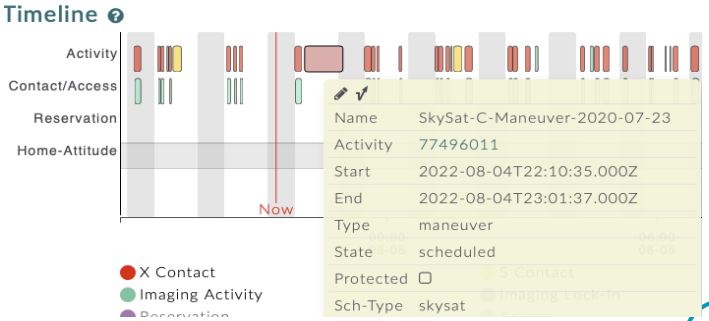
Passes screening,
Gets approved

2. Requested



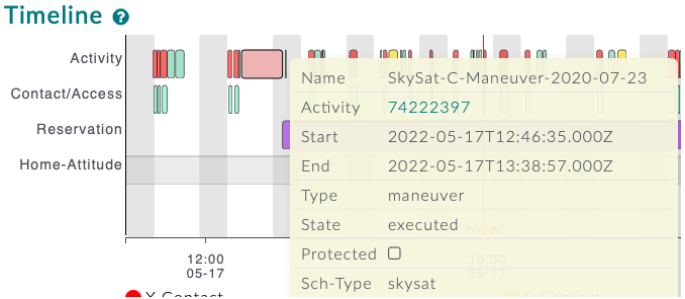
Uplinked

3. Scheduled



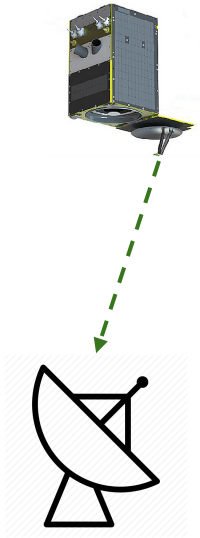
Executed

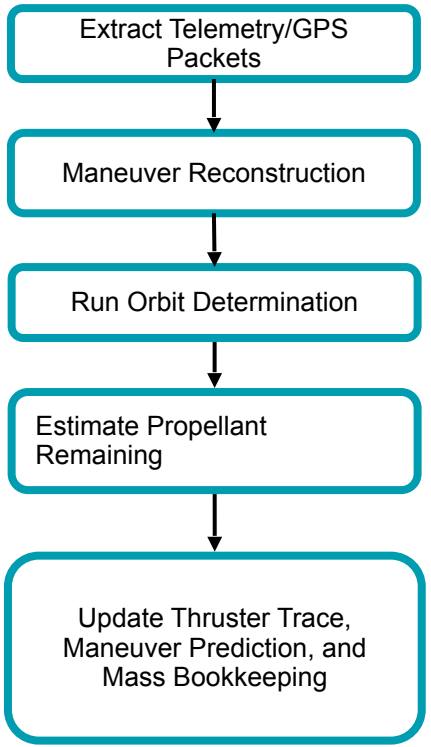
4. Executed



Post Maneuver Processing

- Telemetry packages are extracted from the next post-maneuver downlink.
- Successful receipt of these triggers a series of automated processes.
- Satellite specific files are updated and used for all subsequent maneuver planning.
- Can be manually triggered as well for a specific satellite ID and maneuver activity ID.

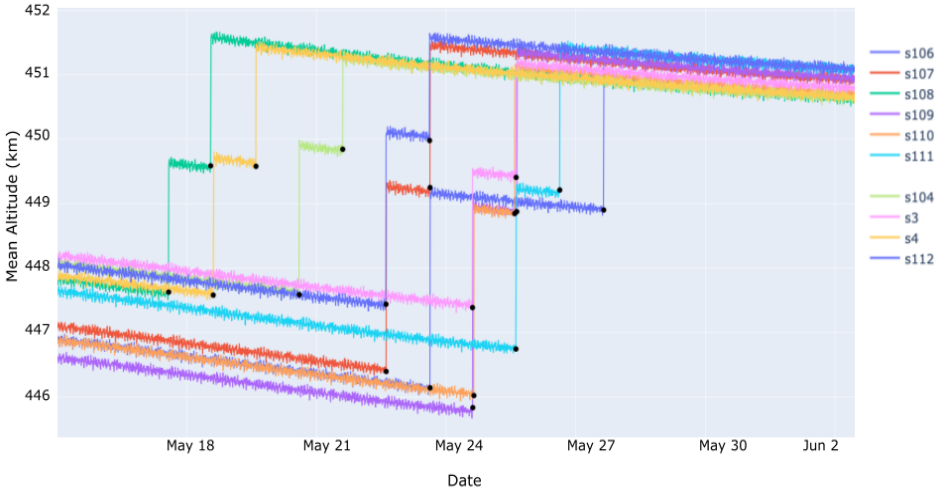




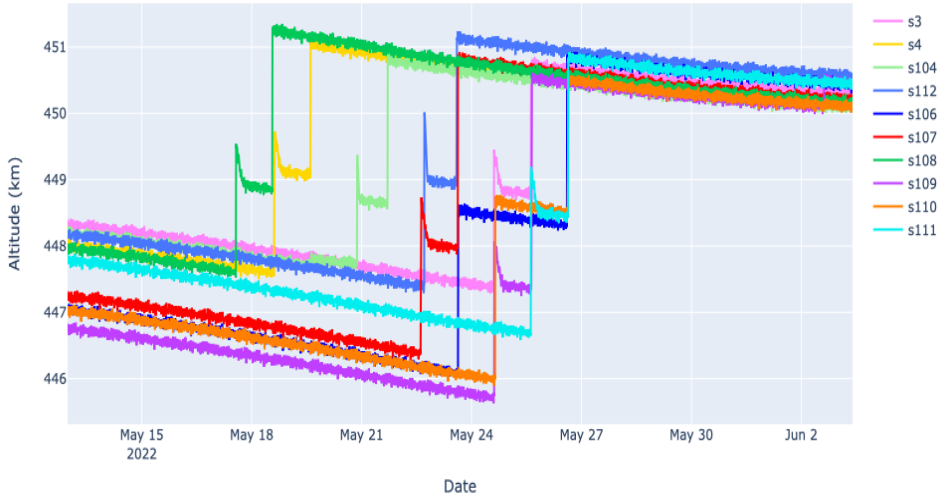
Results from SSO SkySats Stationkeeping Campaign

- CampaignPlanner was used to stationkeeping campaigns in May and July for a subset of Sun-Synchronous SkySats

Mean Altitude Gain Results

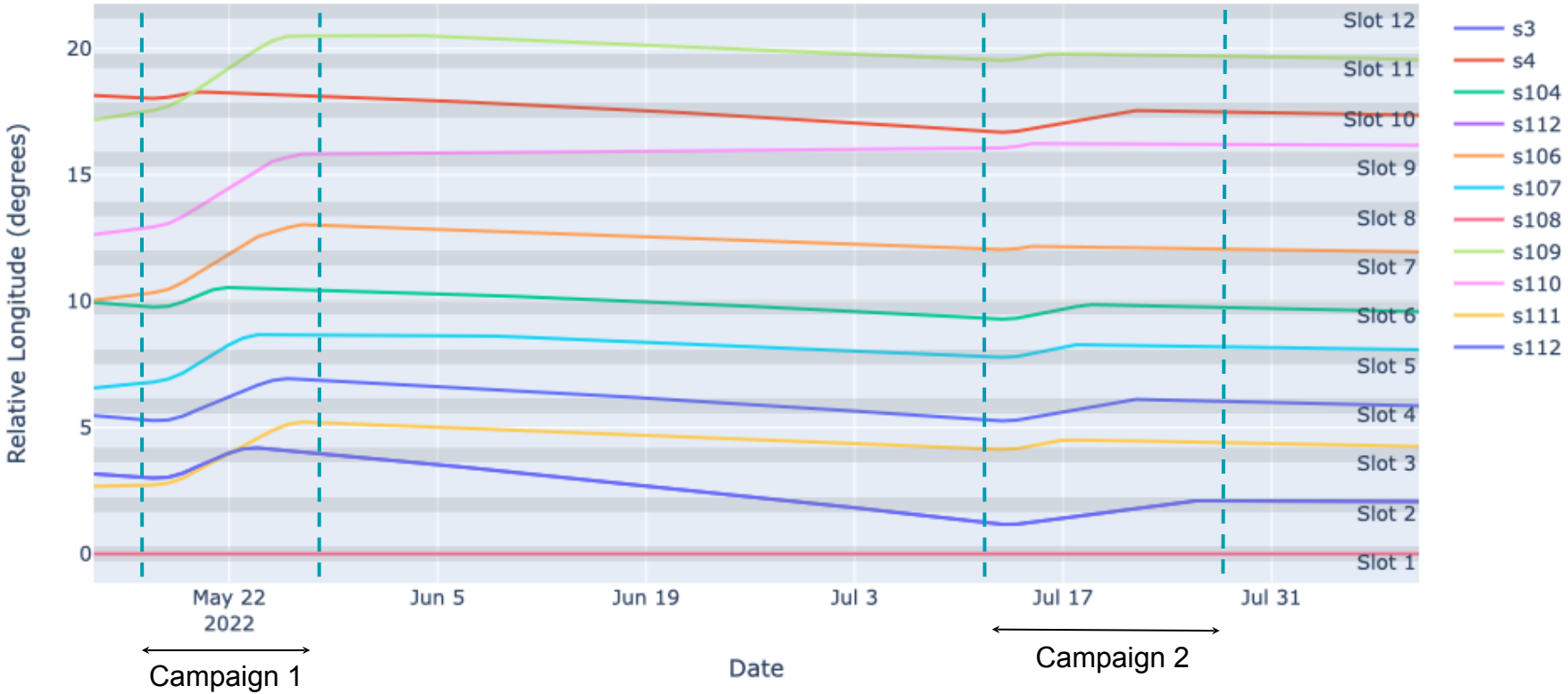


CampaignPlanner Simulation



On-Orbit Results

Relative Longitude Stationkeeping Results



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Small Satellite Conference Committee

Thank you!