Policy-based Coverage Scheduling for Mission Analysis and Operations: NI-SAR, ECOSTRESS, OCO-3 and EMIT

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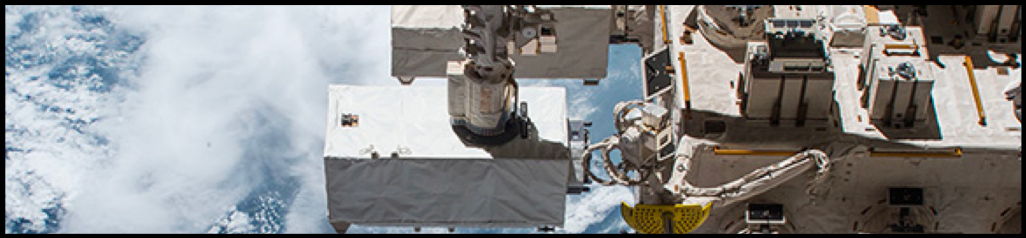
Coverage Scheduling

- Take measurements of points or regions
- Often geometric constraints (viewing, illumination)
- Often temporal constraints (cadence, response, interferometric pair)
- Can be classified as
  - Agile - cover in single overflight
  - Non-Agile – cover in multiple overflights

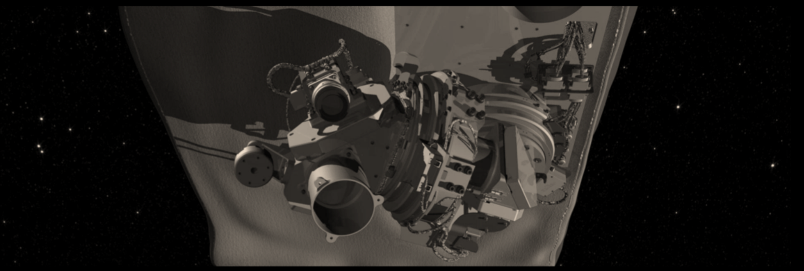
Example Missions:

NISAR (2021)

ECOSTRESS (2018)



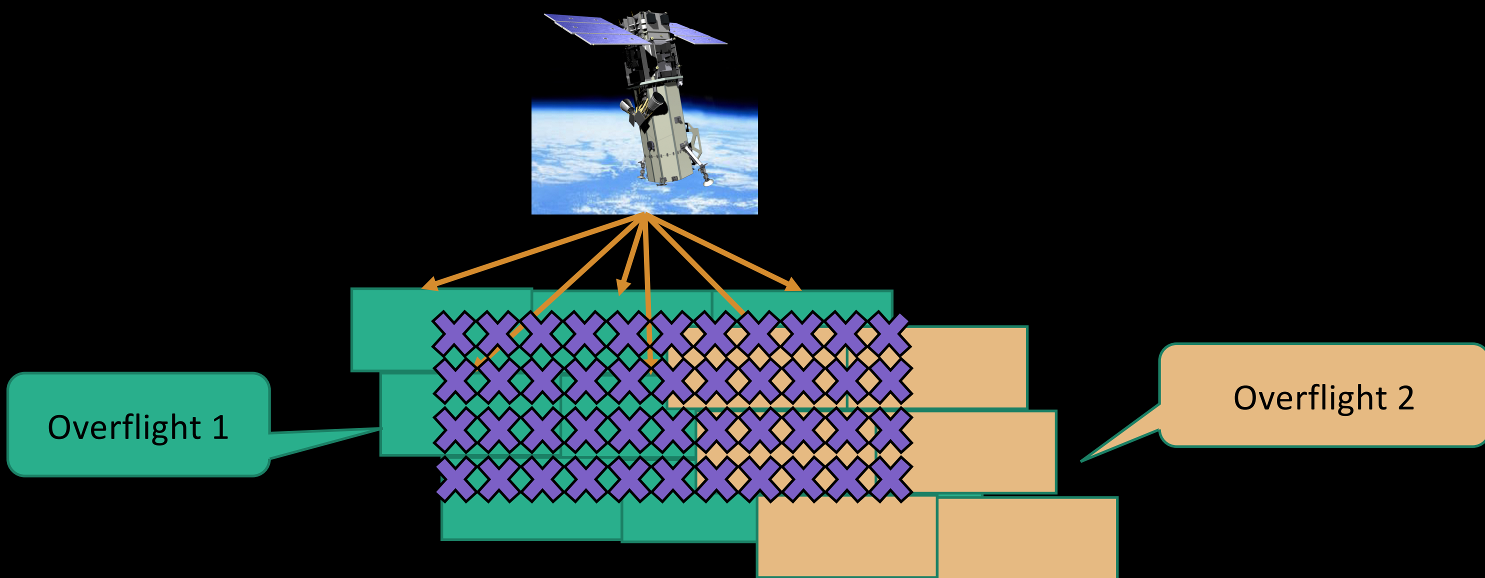
OCO-3 (2019)



Coverage Scheduling - Problem Formulation

- Cover regions
- Temporal frequency
- Geometric constraints
- Aggregate score
- Side constraints
  - data volume
  - instrument thermal
  - downlink
  - keepouts

Problem Definition



Model coverage as ticking off grid marks.
Subset selection of all possible observation records.
Maximize scored ticking off of grid marks.
Alternative – shard based methods.

Solution Definition

Solve w. domain specific search or SWO

Given

a set of potential observation records $O = \{o_1 \ldots o_n\}$

a set of regions of interest $R = \{r_1 \ldots r_n\}$

a set of instrument swaths $I = \{i_1 \ldots i_n\}$

Where $\forall\, o_i \in O\ \exists(r_i, i_i)\ \mathrm{grid}(o_i) \in \mathrm{grid}(r_i) \wedge \mathrm{grid}(o_i) \in \mathrm{grid}(i_i)$

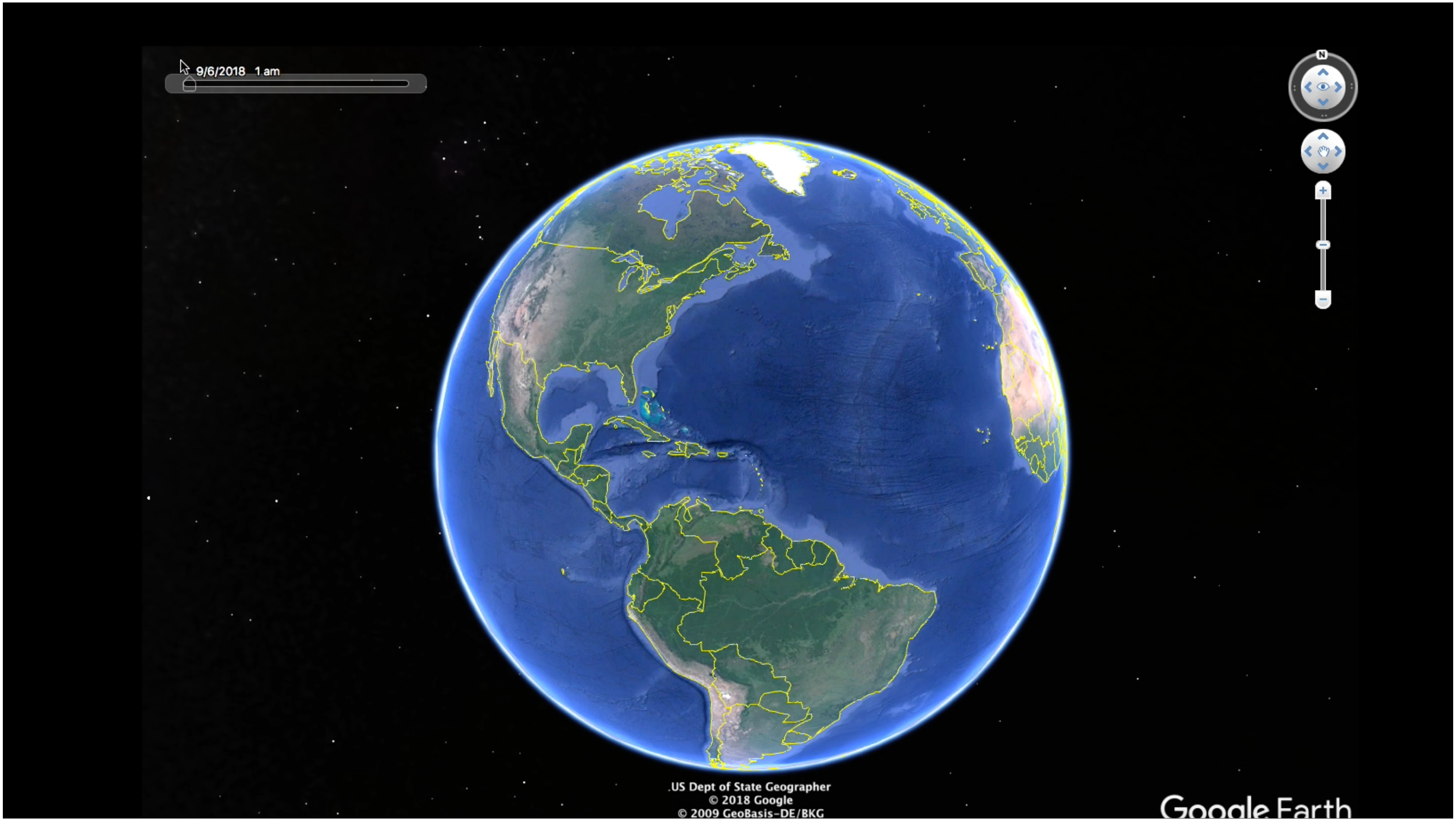
a scoring function $U(r_i) \rightarrow$ real

a constraint function $C(S) \rightarrow T,F$

where $S \subseteq O$ and C is True if S satisfies spacecraft constraints

Select a set of observations A

To maximize $\Sigma_{a \in A} U(a)$ subject to $C(A) \rightarrow T$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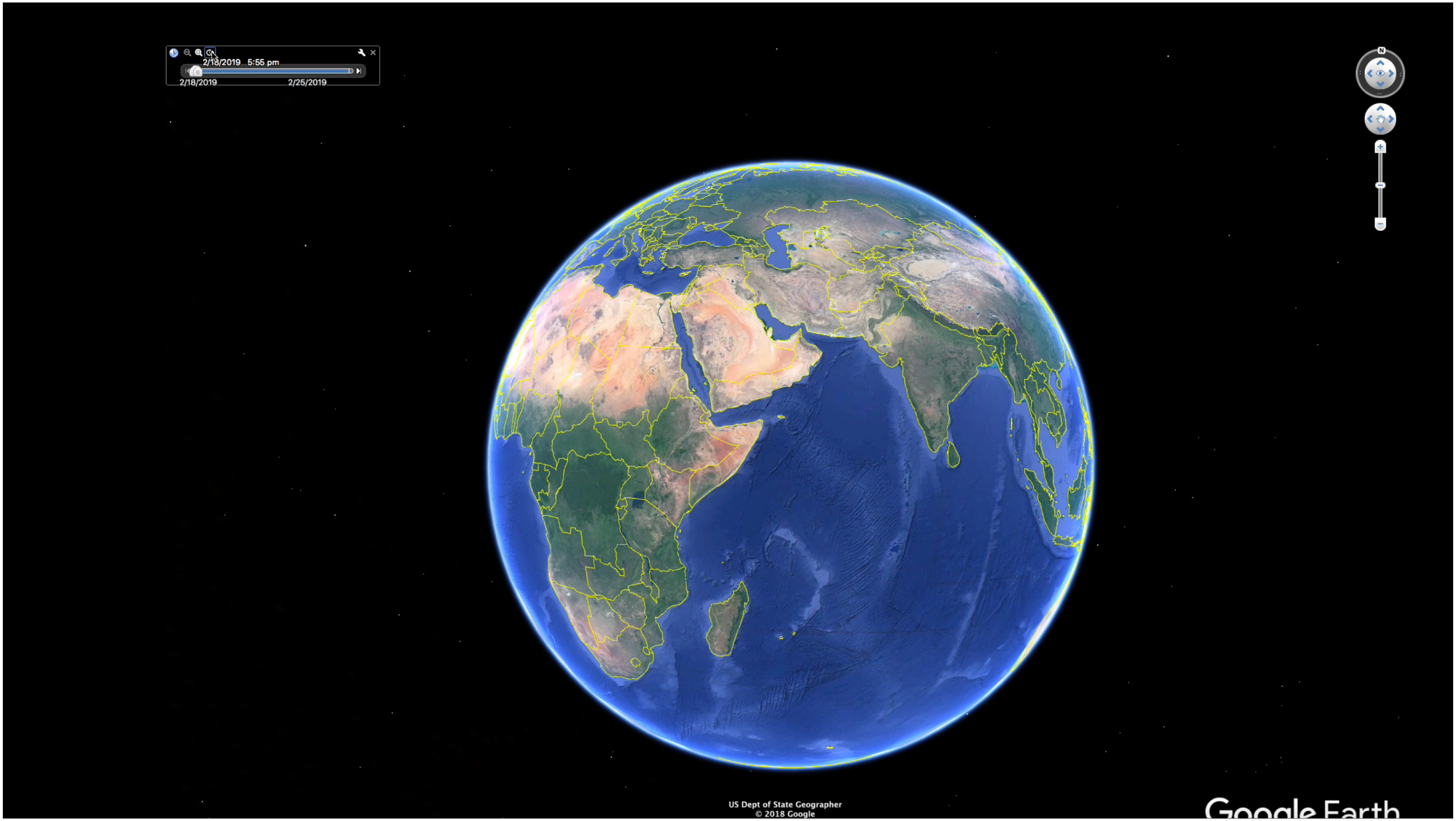
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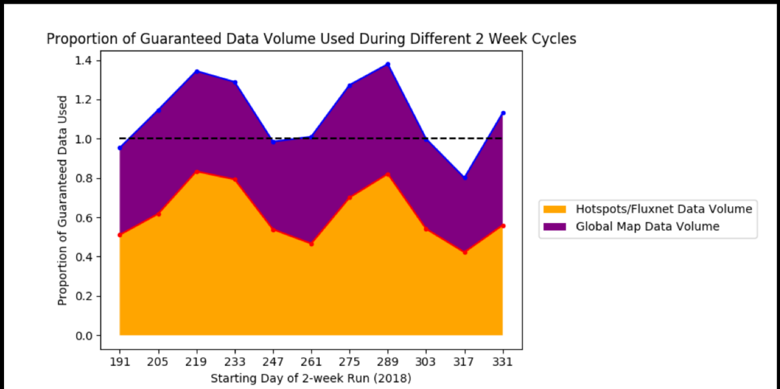
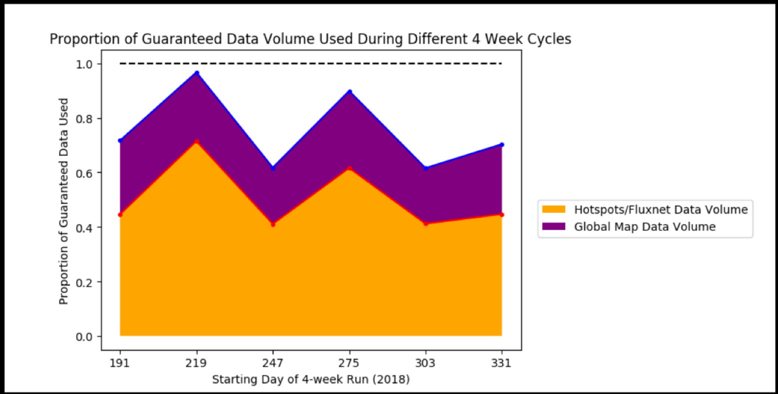
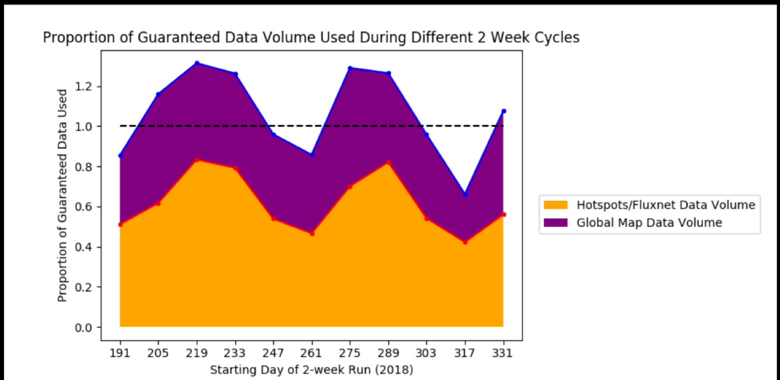
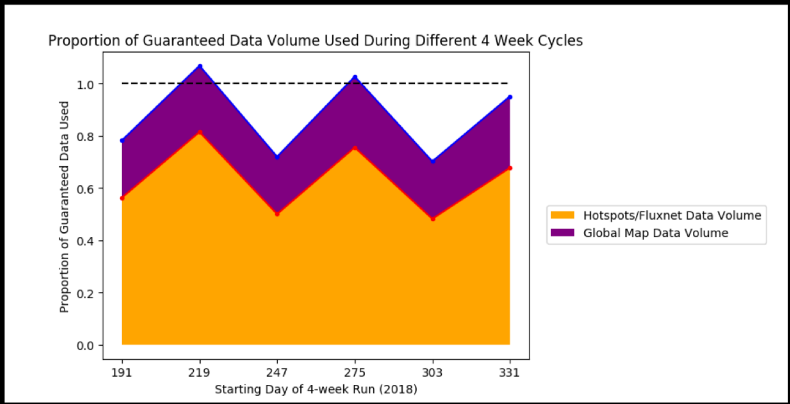
Automated Scheduling for Mission Analysis ECOSTRESSS Global Map v. Data Volume







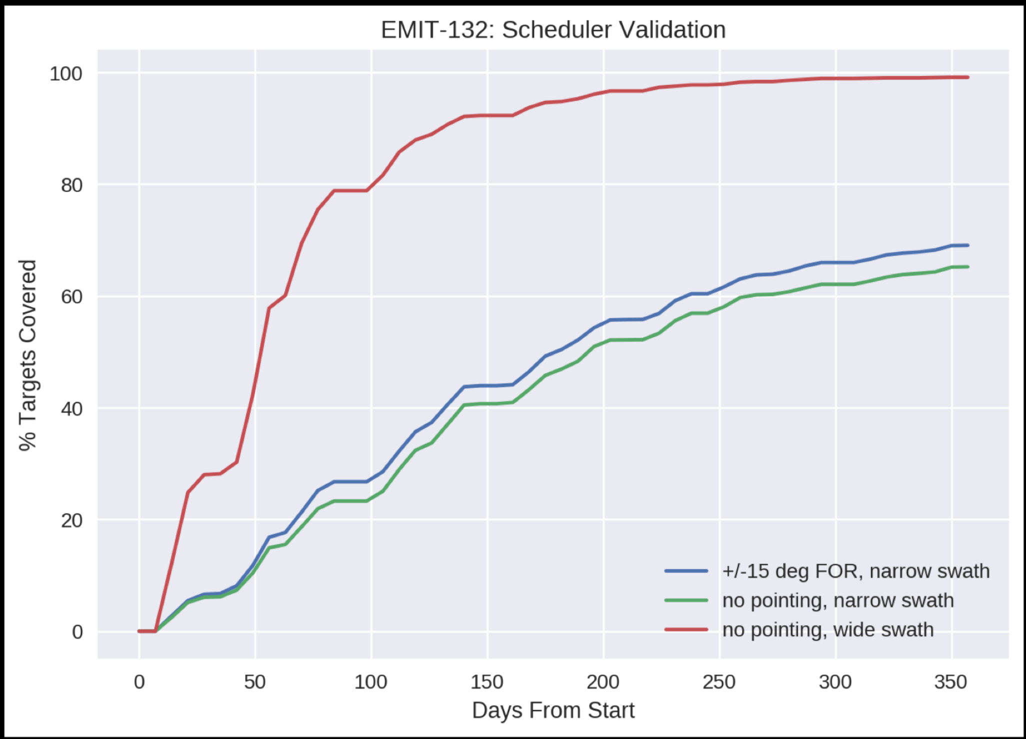


2 week global map 90 SZA v 70 SZA

4 week global map 90 SZA v 70 SZA

POC: A. Yelamanchili, S. Chien

Automated Scheduling for Mission Analysis: EMIT - Pointing Impact on Coverage Rate



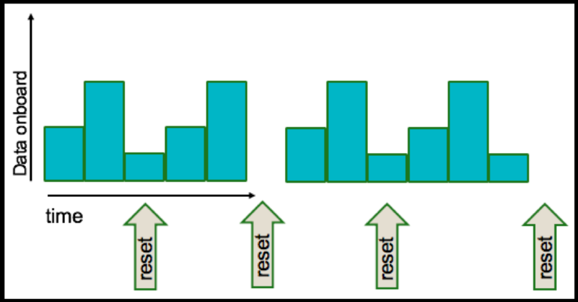
- Analyze impact of swath coverage via pointing access for specific coverage criteria
- Specific analysis shows that pointing control is not majority effect on coverage rate, swath is dominant

POC: A. Yelamanchili, S. Chien

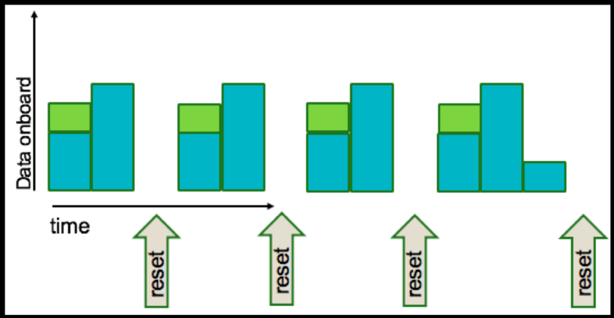
Automated Scheduling for Operations

Ability to adapt to changing operations conditions - ECOSTRESS

- Ability to address operational issues – MSU Ring Buffer Issue



High priority targets are initially scheduled to determine natural places where resets of the ring buffer should occur – when the amount of data onboard will be low and the end of the buffer has not been reached.



High and low priority targets are then scheduled, accounting for the times the ring buffer resets occur.

POC: A. Yelamanchili, S. Chien

Automated Scheduling for Operations
Ability to adapt to changing operations conditions - ECOSTRESS

- Ability to assess and implement radiation keepout zones

ECOSTRESS
Science Targets

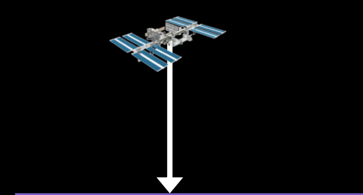
POC: A. Yelamanchili, S. Chien

Reset keepout zones – CPU powered down – no acquisition, no downlink, …

Automated Scheduling for Operations
Complex Geometric Criteria – OCO-3

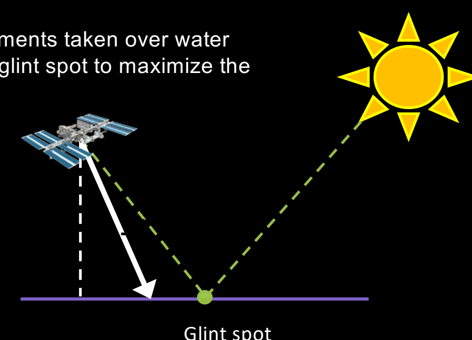
Operational Modes

Default mode over land in the daytime



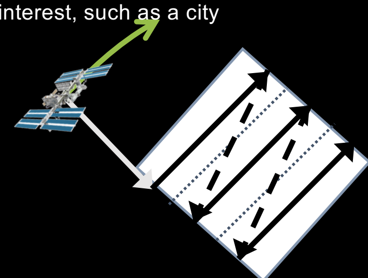
Glint mode

Measurements taken over water near the glint spot to maximize the signal



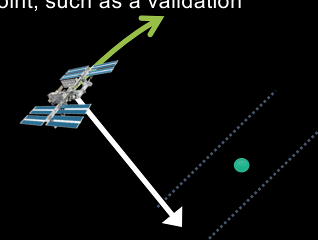
Area Mapping mode

Measurements taken over regions of interest, such as a city



Target Mapping mode

Measurements taken over a specific point, such as a validation site

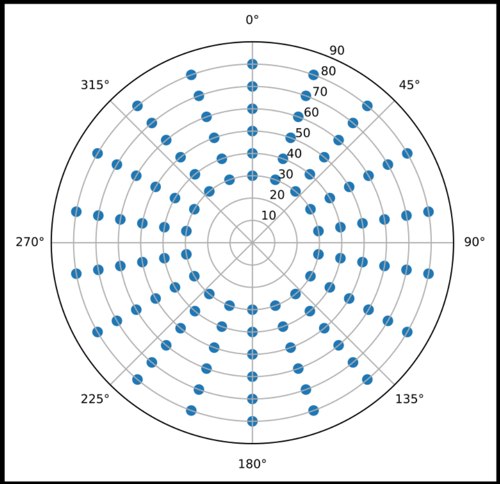


Observe a single stripe over the target point repeatedly

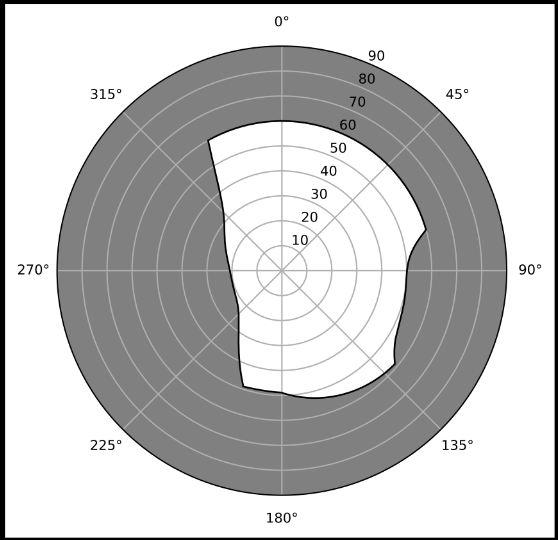
POC: A. Yelamanchili, S. Chien

Automated Scheduling for Operations
Complex Geometric Criteria – OCO-3

- Calibration scheduling
  - Cover pointing grid
  - Calibration at land
  - Minimize repointing time (TSP)



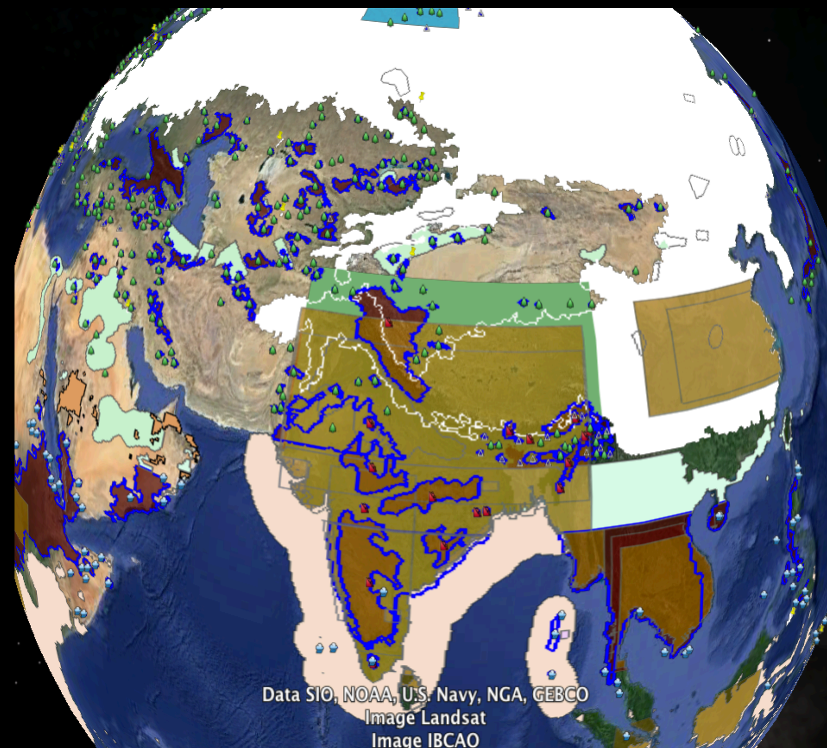
ISS Avoidance



POC: A. Yelamanchili, S. Chien

Automated Scheduling for Operations
Complex Campaigns– NI-SAR

- Numerous science campaigns
  - Callout campaigns
  - Varying observation modes
  - Trades with Data Volume



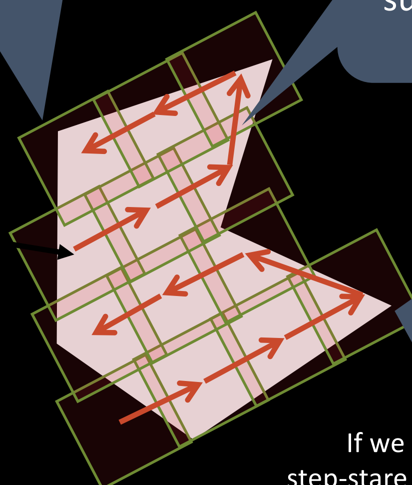
POC: J. Doubleday, P. Rosen

Agile Framing Coverage Problem

Must cover polygon with overlap. Imager footprint varies as a function of spacecraft position (e.g. acquisition time)

Tile to Tile slew time is function of when successive images are acquired

Individual instruments have side constraints or preferences (e.g. look angle)



If we use a step-stare tiling concept

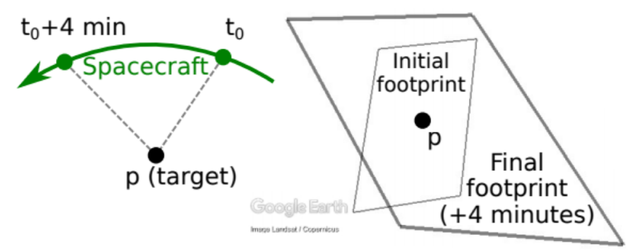


Figure 3: Imager footprint changes size and shape

POC: R. Knight, M. Trowbridge

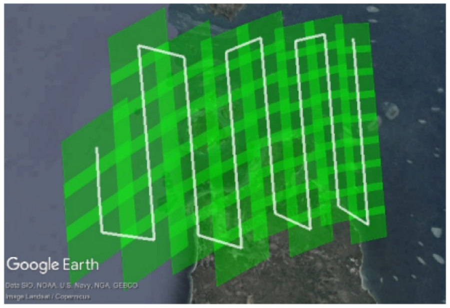


Figure 8: Replanning Sidewinder: adaptive row width

Figure 12: Grid Nibbler: Radial distance heuristic.

Figure 11: Online Frontier Repair. Note suboptimal repairs on the right side (final leg).

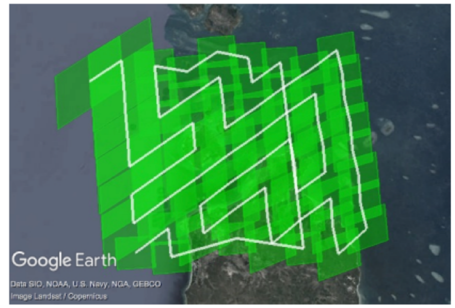


Figure 5: Milling (Knight 2014) algorithm [redacted] (connected by white line) and footprints (g [redacted] division causes excessive overlap and some s [redacted]

See [Shao et al. 2018].

[redacted]

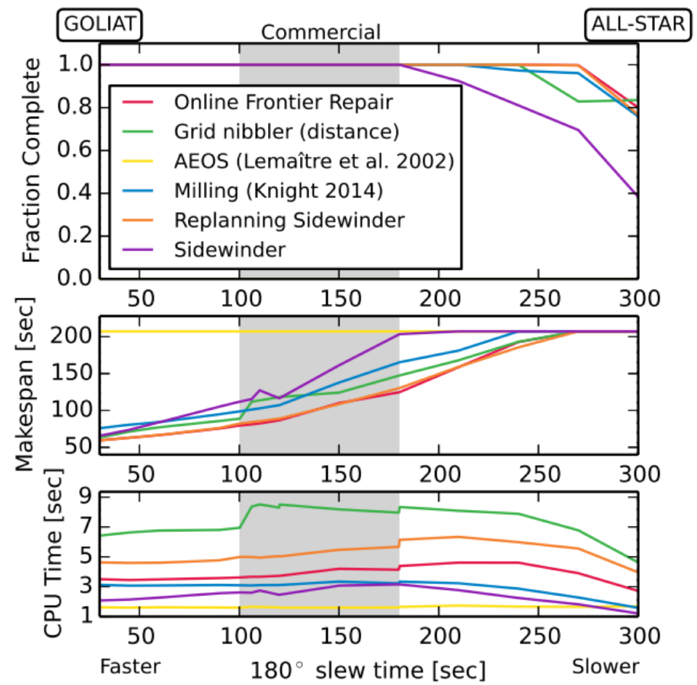


Figure 13: Performance under varying observer agilities

Conclusions

- Coverage scheduling is frequently a major part of many Earth Science Missions
- AI based heuristic search can represent and solve a rich range of such problems
  - Benefits: easily modified constraints and formulation, potential for explanation
- Heuristic search is being used for mission analysis and operations for the NI-SAR, ECOSTRESS, OCO-3, and EMIT missions.

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DARE MIGHTY THINGS