Mission Design Evaluation Using Automated Planning for High Resolution Imaging of Dynamic Surface Processes from the ISS

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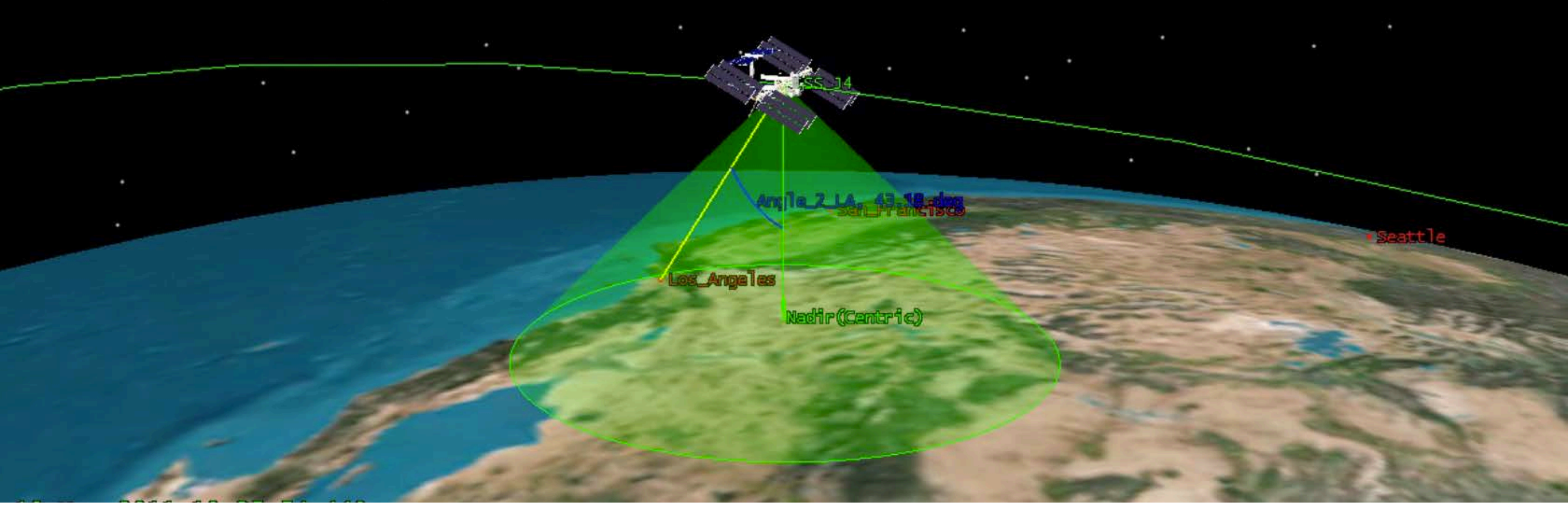

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Proposed Eagle Eye Mission

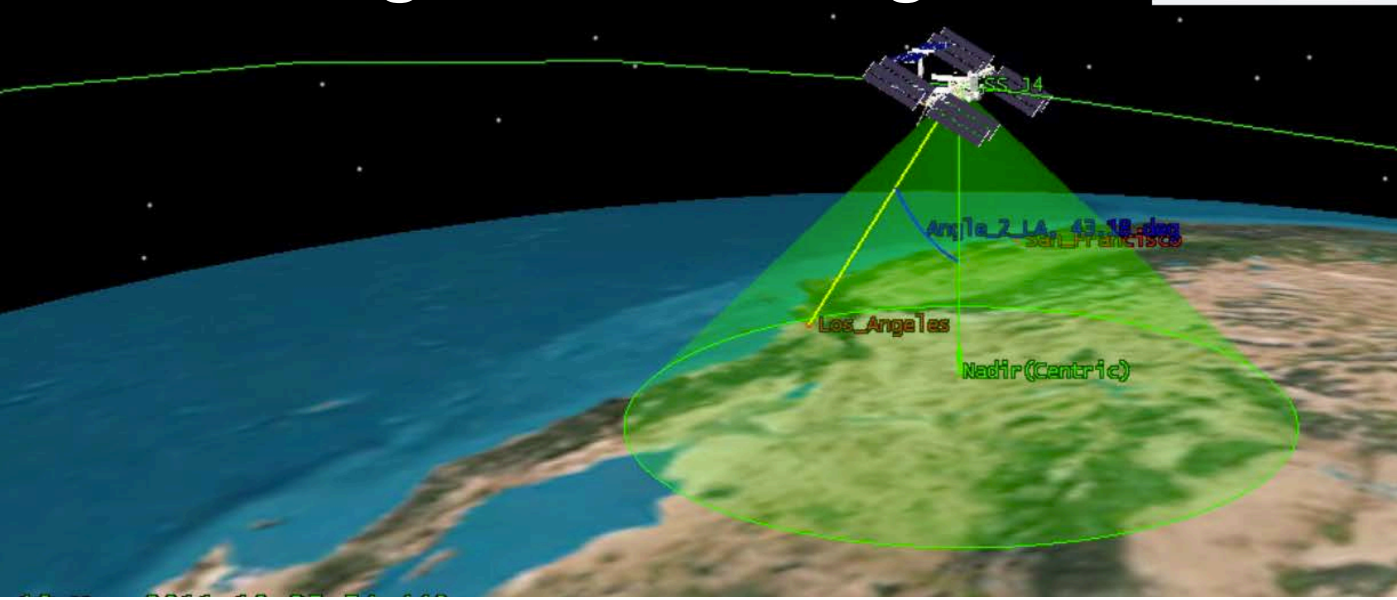
- Understand how Earth's vulnerable systems reflect changes in climate
  - Measure glaciers and sand dunes over time

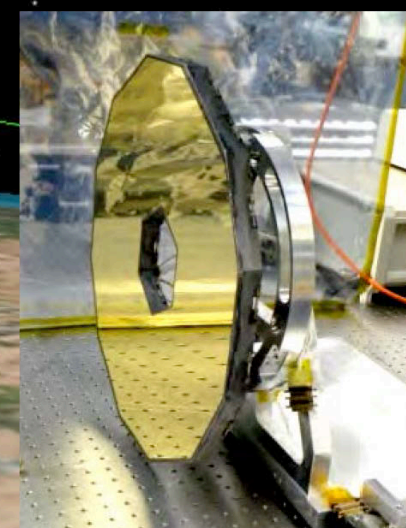
Vegetation changes can mobilize dunes

- Increase understanding of natural hazards
  - Volcanoes, fire, landslides, faults, flooding, coastal change

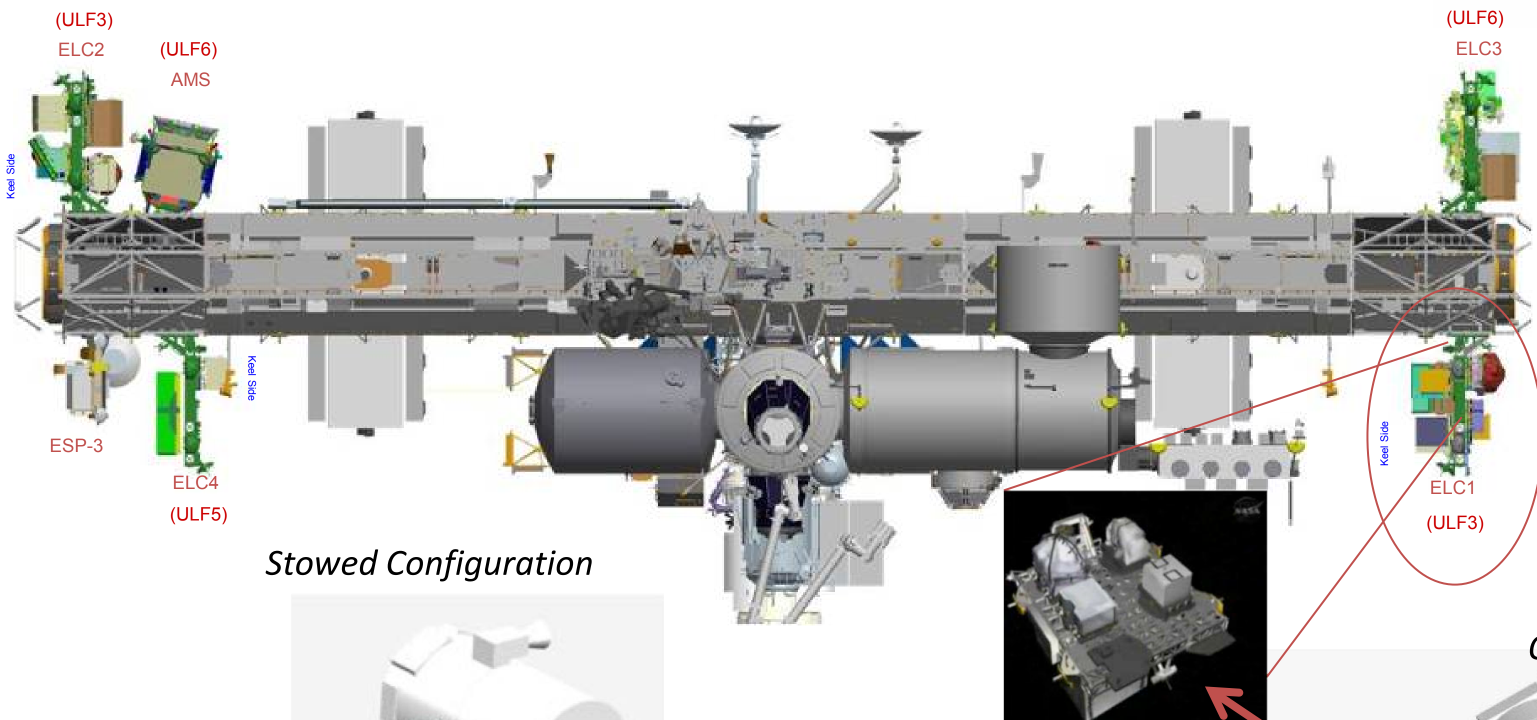
Instrument

- 0.5m integral active control
- 1-2 km^2 visible area
- 45 degree field of regard

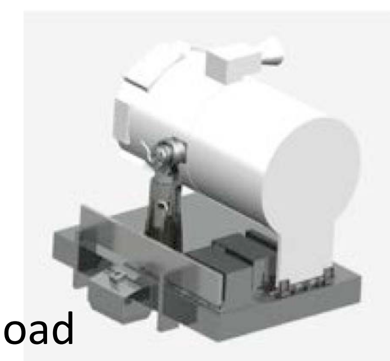




ISS Location

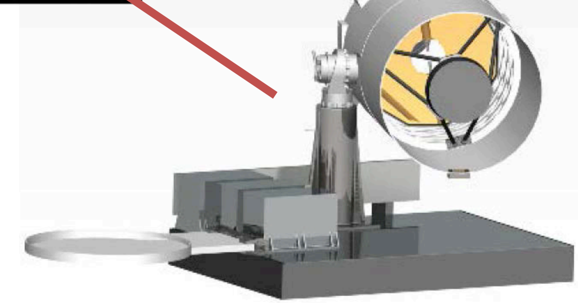


Stowed Configuration



FRAM-based payload
Fits within Dragon capsule

During Operations



Unique Measurement Capability

Current Platforms

- Near nadir view
- Off-pointing single images
(up to 35)
- Push broom technology
- Stereo Imagery
- Difficult retrieval with uniform albedo

Fixed-point retrieval

- Off-pointing up to 45°
- Collect 10X more images
(up to 350)
- Persistence
- 3D recovery
- Take advantage of varying sun angle

Scheduling

- Given
  - Observation targets
    - Lat, Lon, Alt, FPS, Priority
    - based on National Snow and Ice Data Center (NSIDC) glacier inventory
    - Approximately 100,000 points
  - Spacecraft and Instrument description
    - Ephemerides, memory (1Tb), collection rate, downlink rate
    - Slewing is fast (1s), but settle is slow (20s)
  - Communications sites (Synthetic, likely use ISS comms)
    - Lat, Lon, Alt, min. Elevation

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Scheduling (cont)

- Choose a time-stamped ordering of telescope pointing coordinates
  - Cancelling a scheduled lower priority target never enables scheduling of an unscheduled higher priority target
  - Targets are imaged at the optimal times, given a "black box" function that computes quality based on elevation angle, sun angle, and distance to target
  - Twofers are OK

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Algorithm

For each observation point, in priority order

- **Check for feasibility**
  - Memory, Slewing to previous and subsequent points
- If feasible, introduce into the schedule and **propagate**

Extract a solution from the pointing timeline

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Check for feasibility

Check that frame rates and data usage cause no constraint violations, and if they do, return **failure**

Generate the set of reasonable pointings *P*

Remove any member of *P* that is unreachable given the previous or simultaneous pointing

If *P* is empty, return **failure**

Let *nextP* be the subsequent set of reasonable pointings

If the intersection of *P* and *nextP* is not empty, return **success**

If no transition is possible from any member of *P* to any member of *nextP*, return **failure**

Return **success**

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Generate the set of reasonable pointings

- Given a target point *p*
- For all points that are within a reasonable distance to the target point, project the point paths onto the imager
- Convert to rectangles
- *P* = the set of squares that cover at least one point and *p*
- At most quadratic in the number of points simultaneously image-able with *p*

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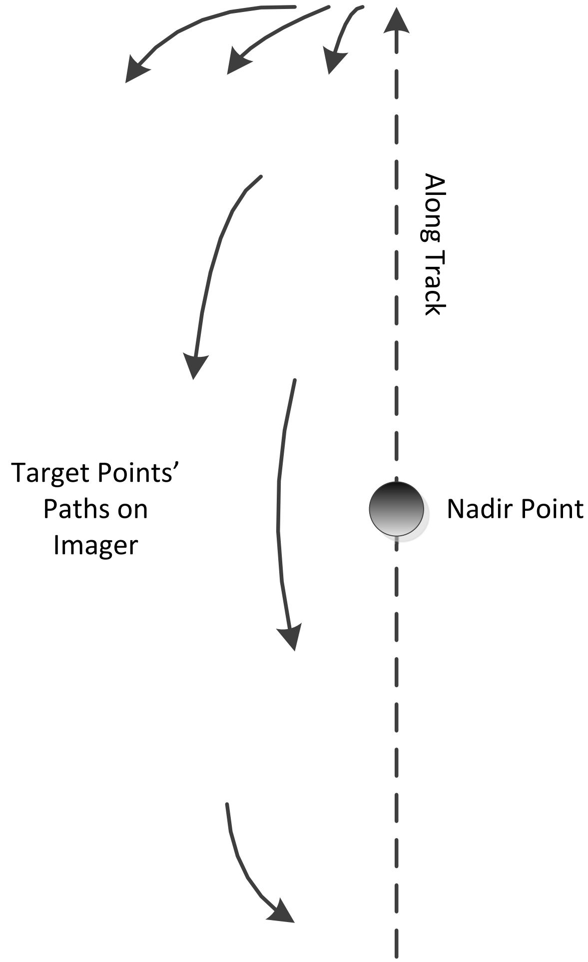
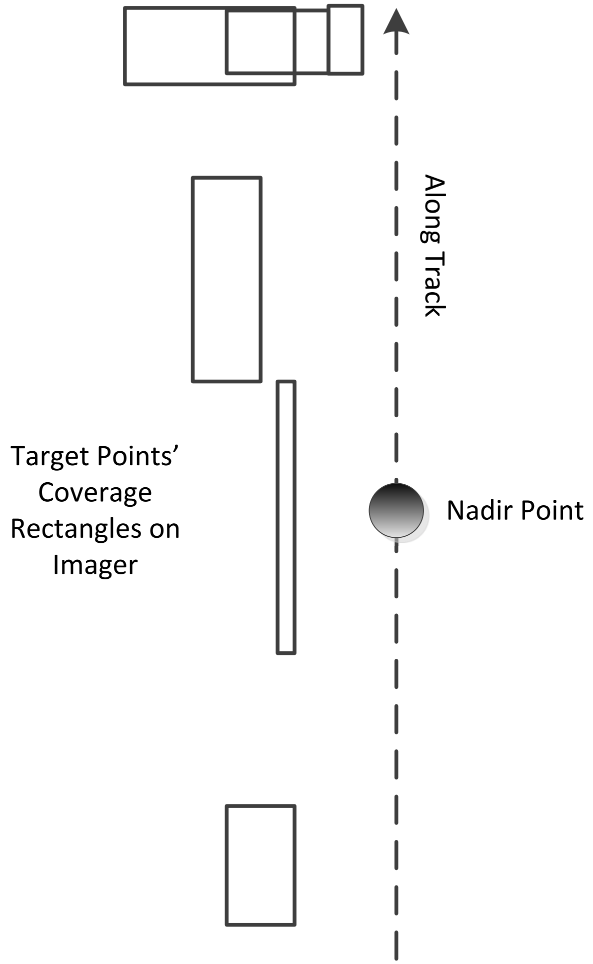
Paths of Points on the Imager



Rectangles on the Imager



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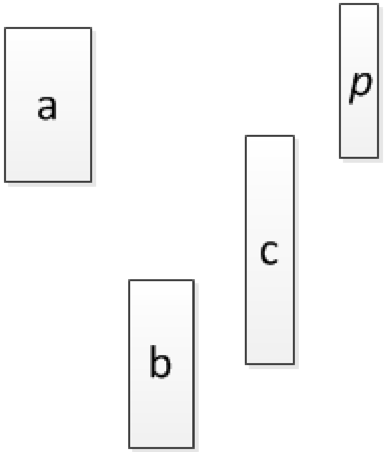
Point rectangles a, b, c and *p*



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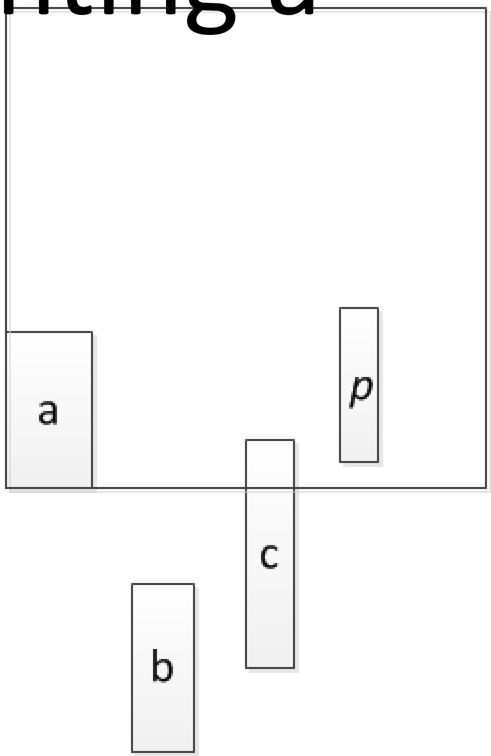
Pointing a



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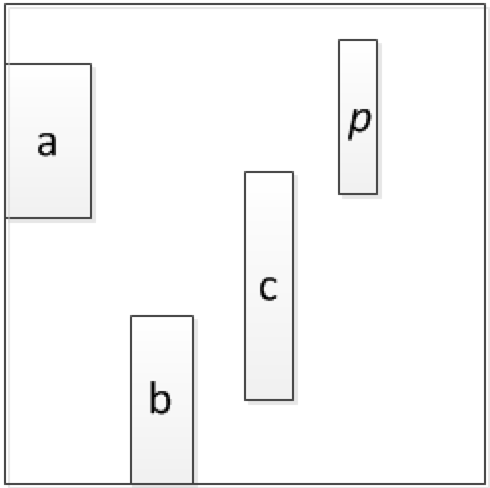
Pointing a,b



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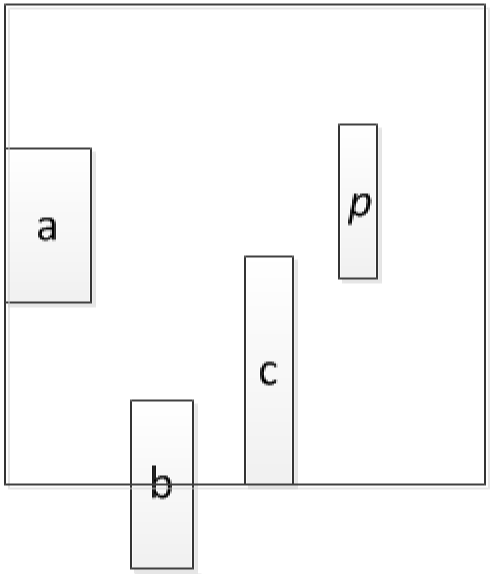
Pointing a, c



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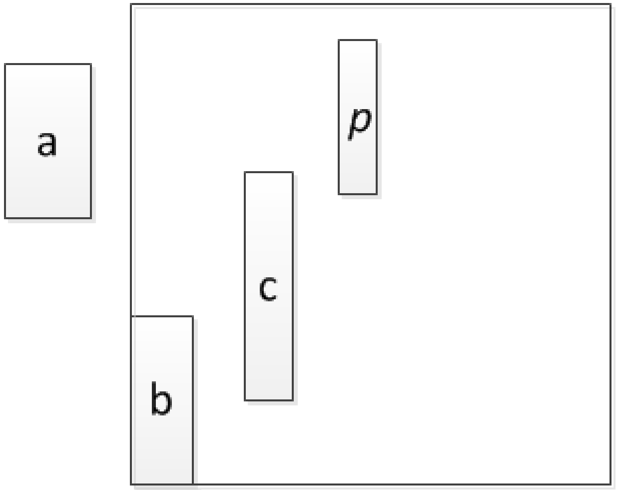
Pointing b



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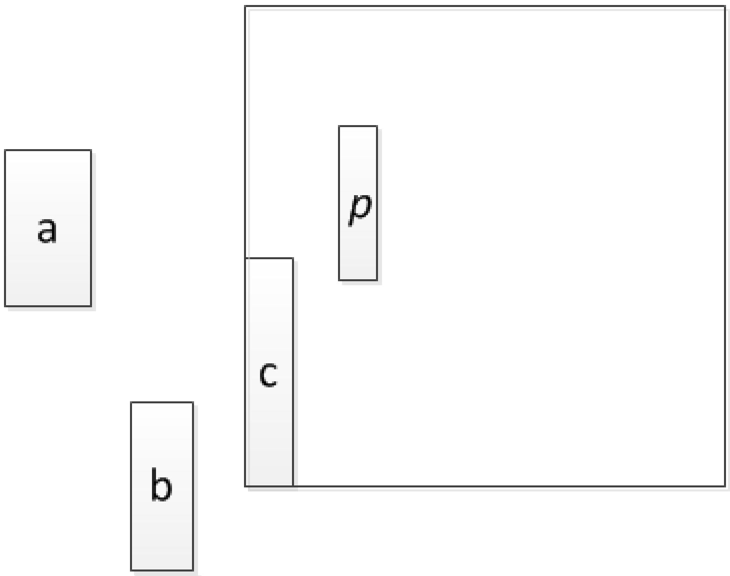
Pointing c



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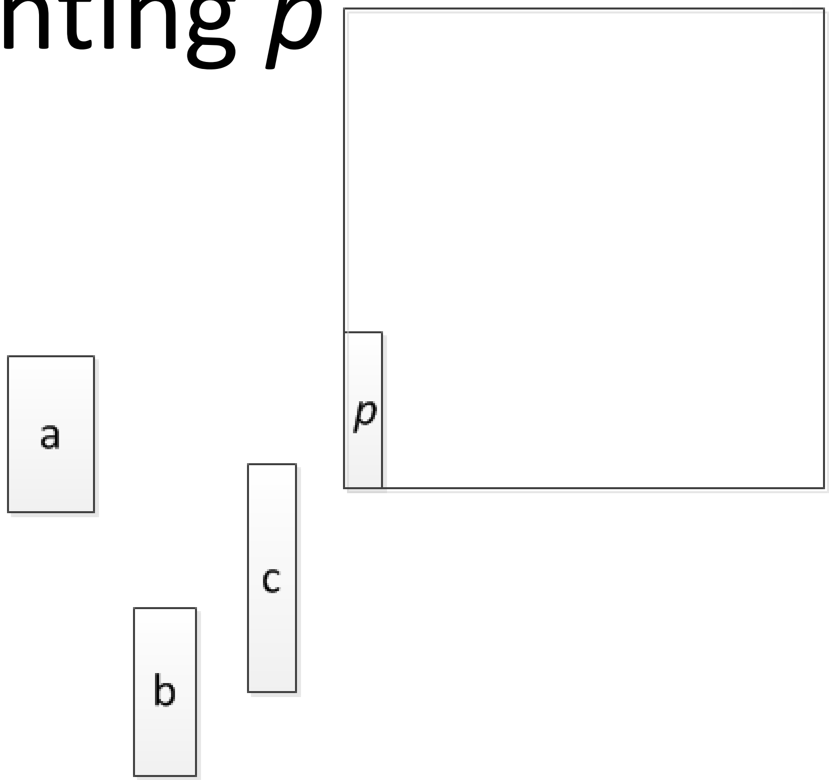
Pointing *p*



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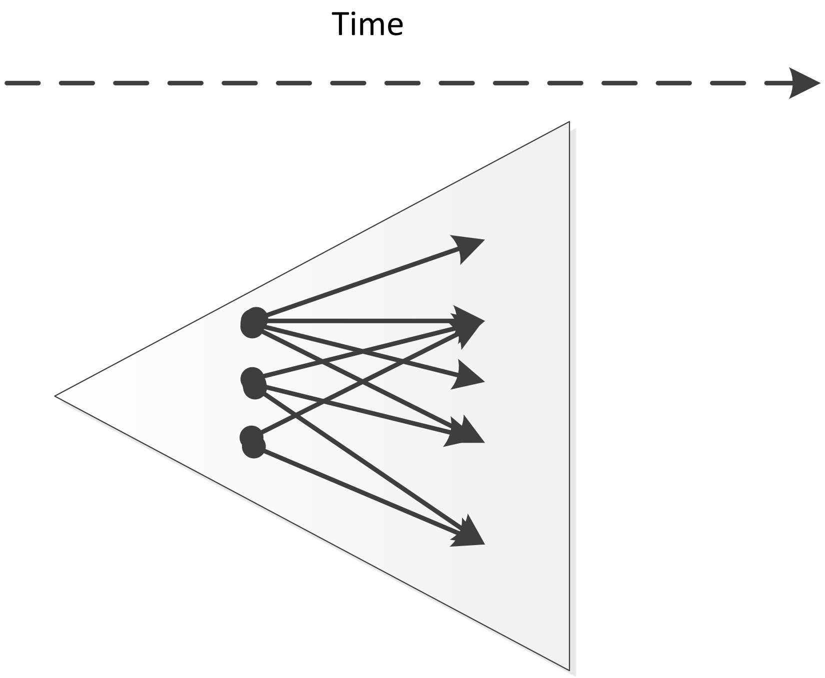
Propagate

- Remove any subsequent pointings that are not compatible with *P*
- Conceptual transition between pointing sets



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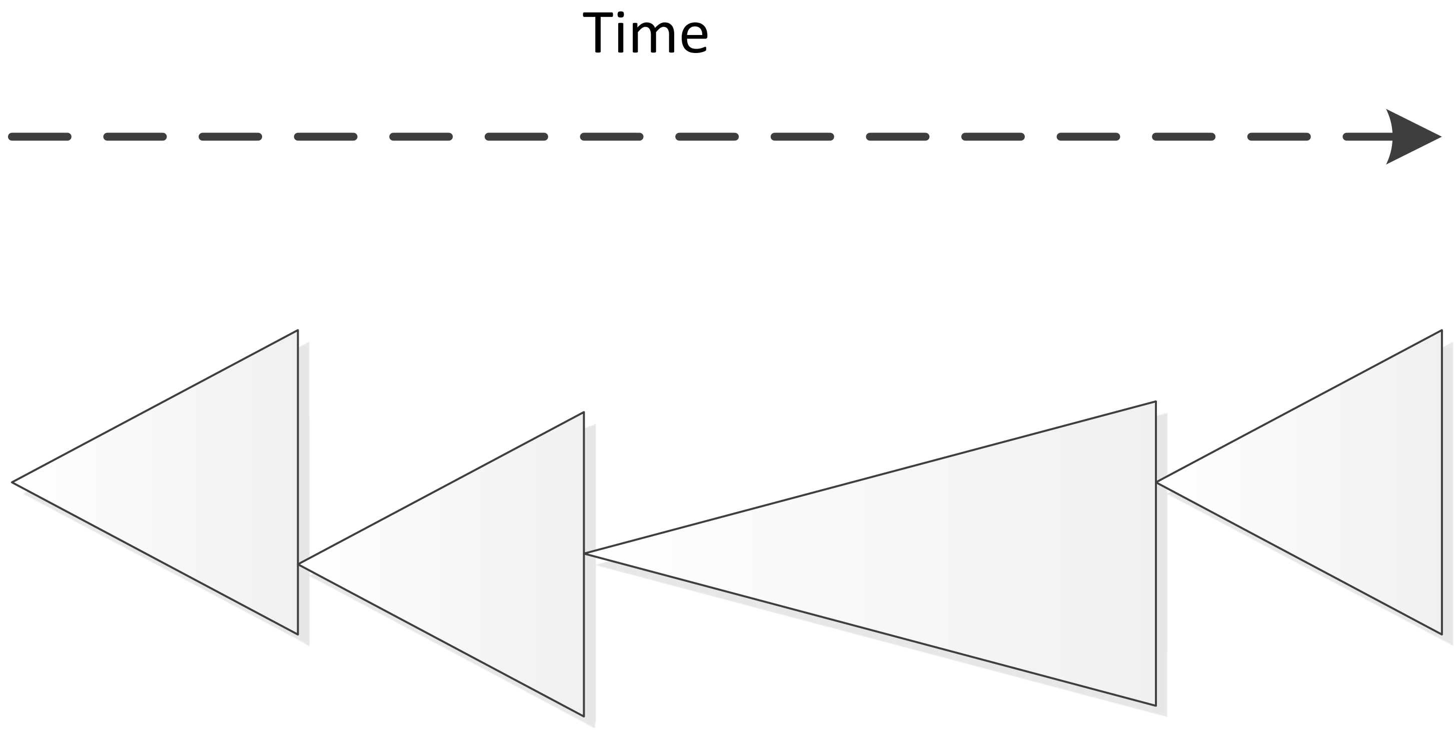
Schedule without the pointing set that contains *p*



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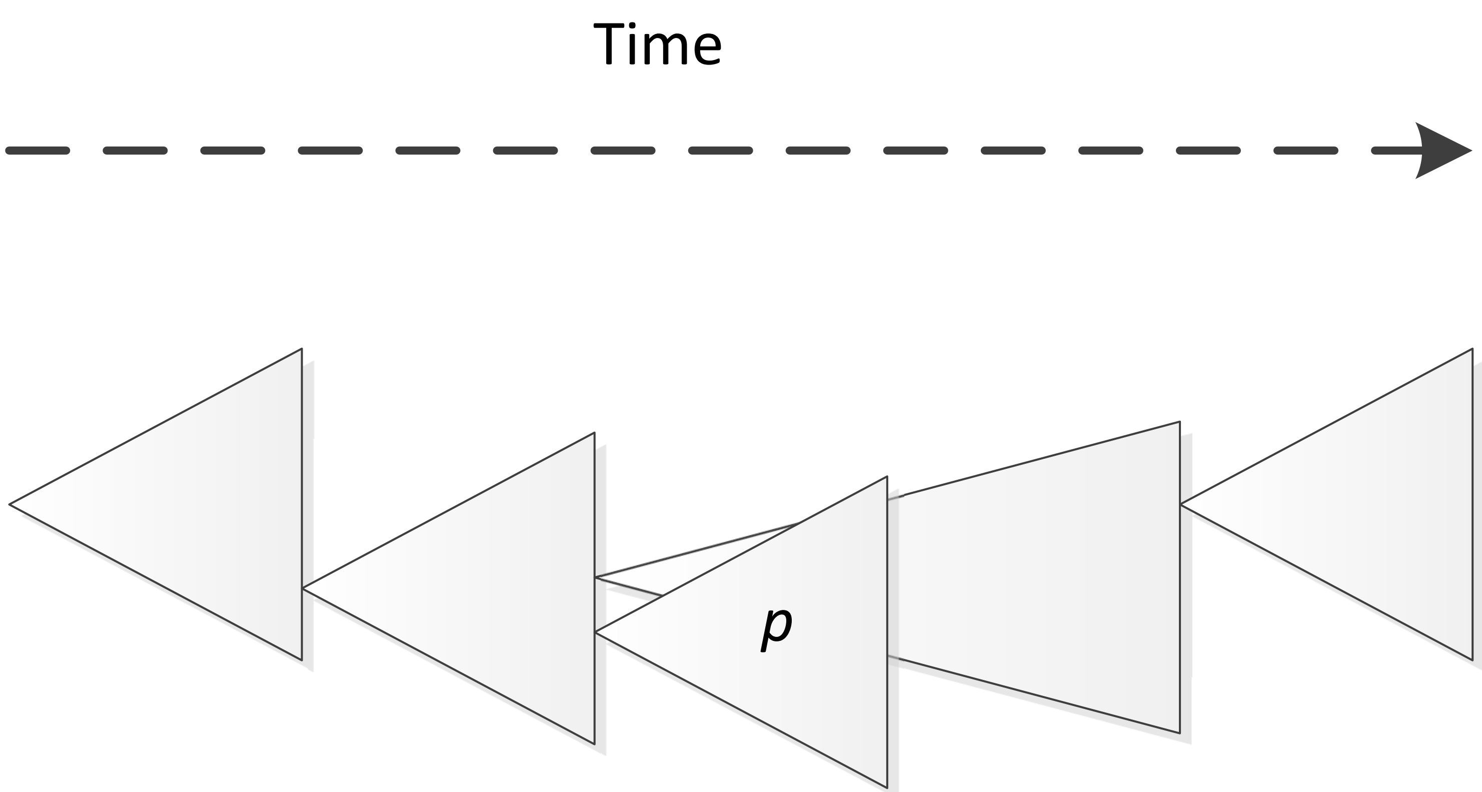
Schedule before propagation



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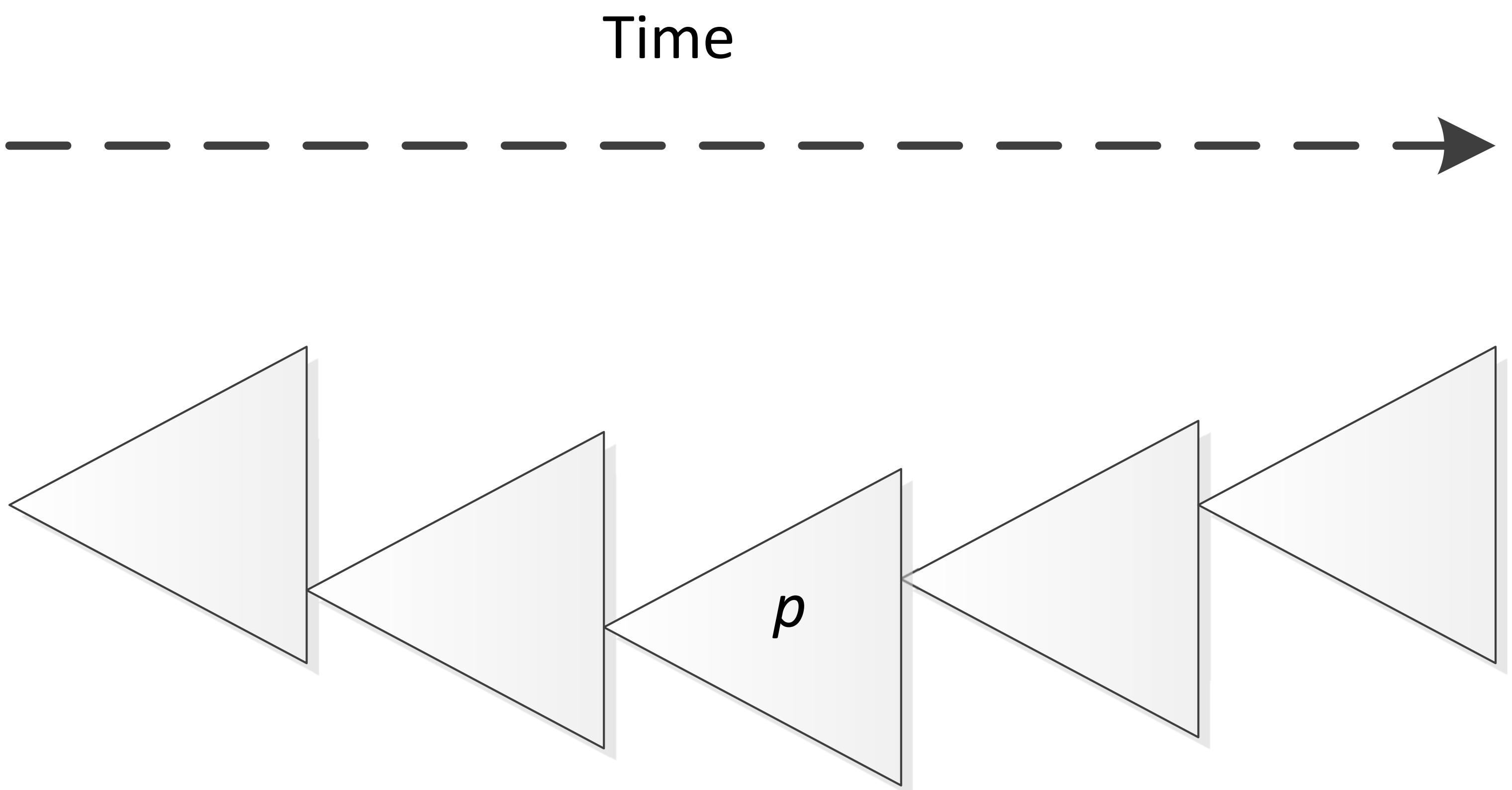
Schedule after propagation



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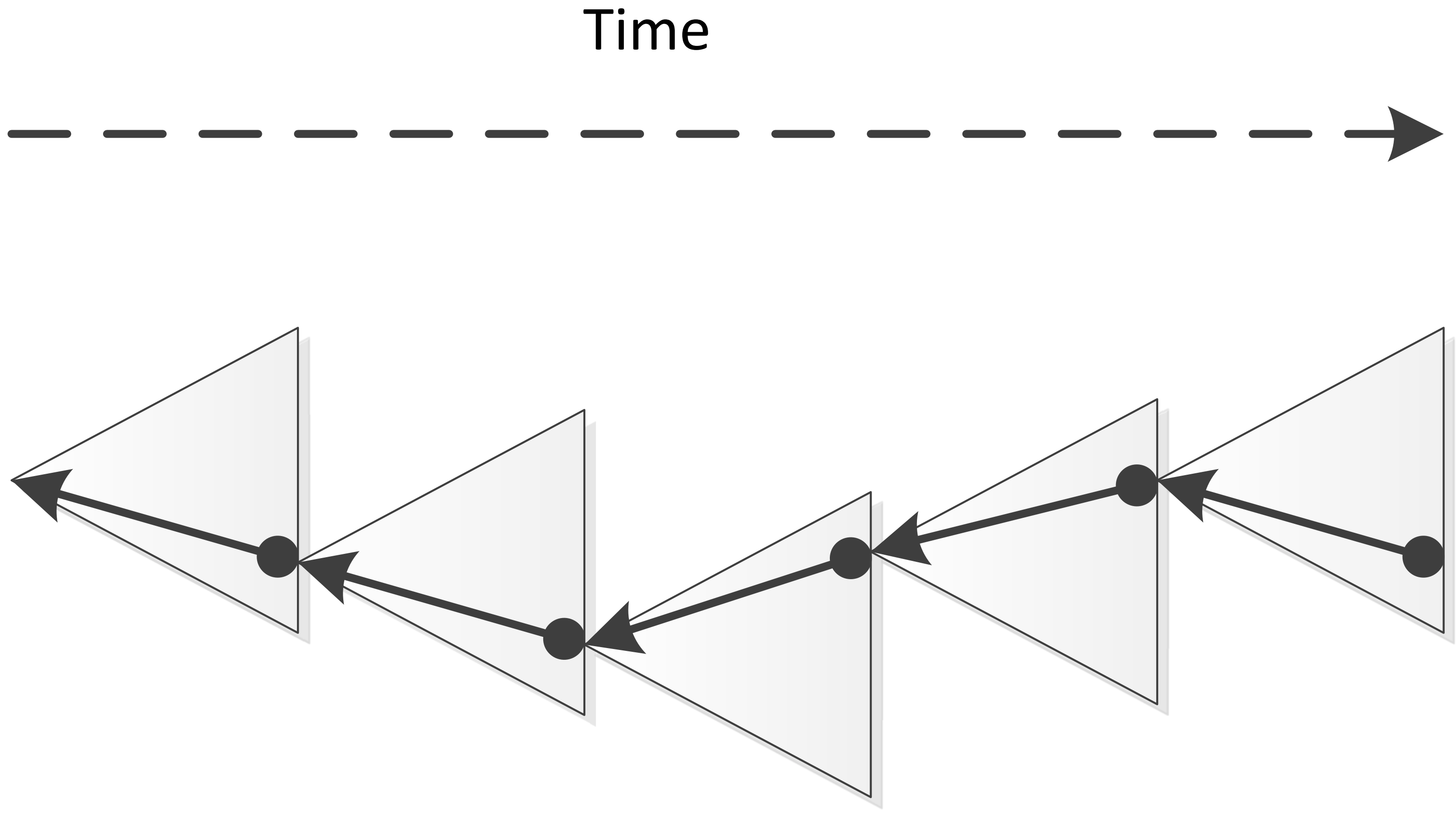
Extract a Solution



Schedule Fragment in KML