Intelligent Long Endurance Observing System (ILEOS)

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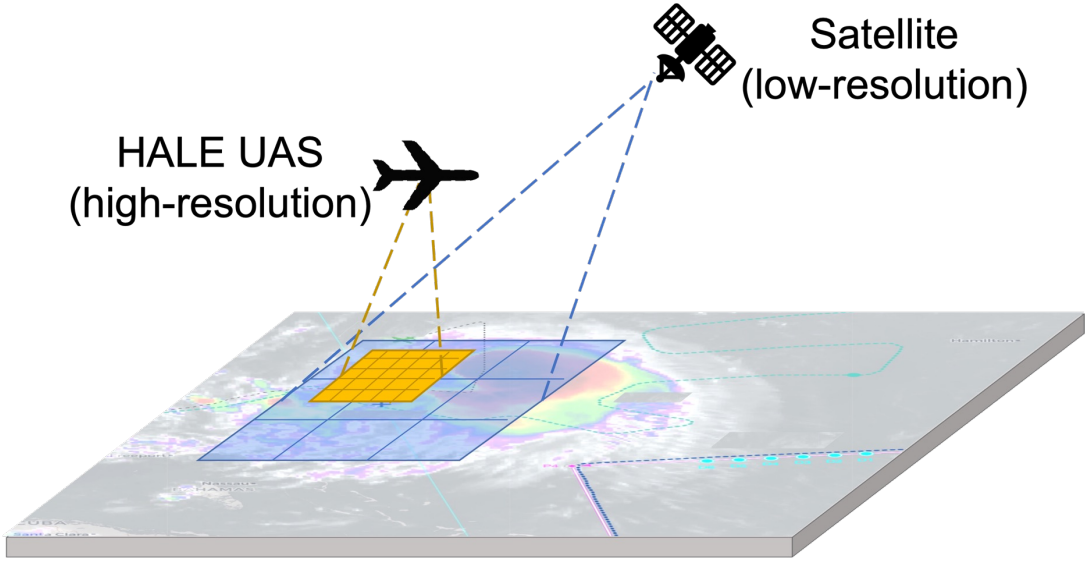
Concept of Operations



- Current satellites and fine-pointing aircraft do not provide sufficient spatio-temporal resolution to observe stochastic, ephemeral events between observations

- HALE UAS provide mechanism for collecting higher spatio-temporal data
  - Operate for months and loiter over targets

ILEOS will provide a science activity planning system to enable NOS
  - Fuse coarse-grained sensor data to target and plan HALE UAS flights

Objectives

- Optimize fine-grained spatio-temporal resolution data collection of Earth observations, such as GHG-relevant gases

Novel automated target generation technology

- Incorporates *coarse-grained satellite data* and near real-time environmental (e.g., wind, weather, airspace constraints) data to generate high-value fine-grained resolution data collection plans.

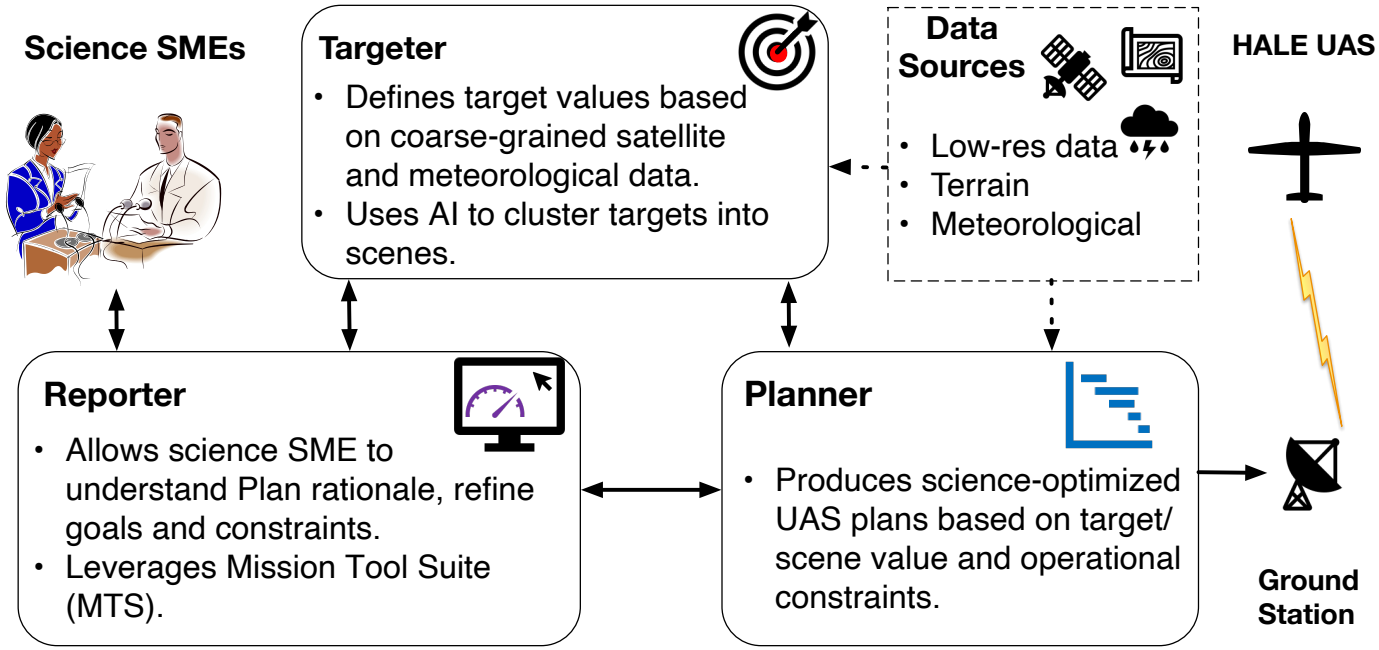
State-of-the-art automated planning and scheduling algorithms

- Designed for human operators; *plan explanation and data provenance features* will ensure science mission planners understand all key choices made while generating targets and plans.

Innovative techniques for user control and review of decision making

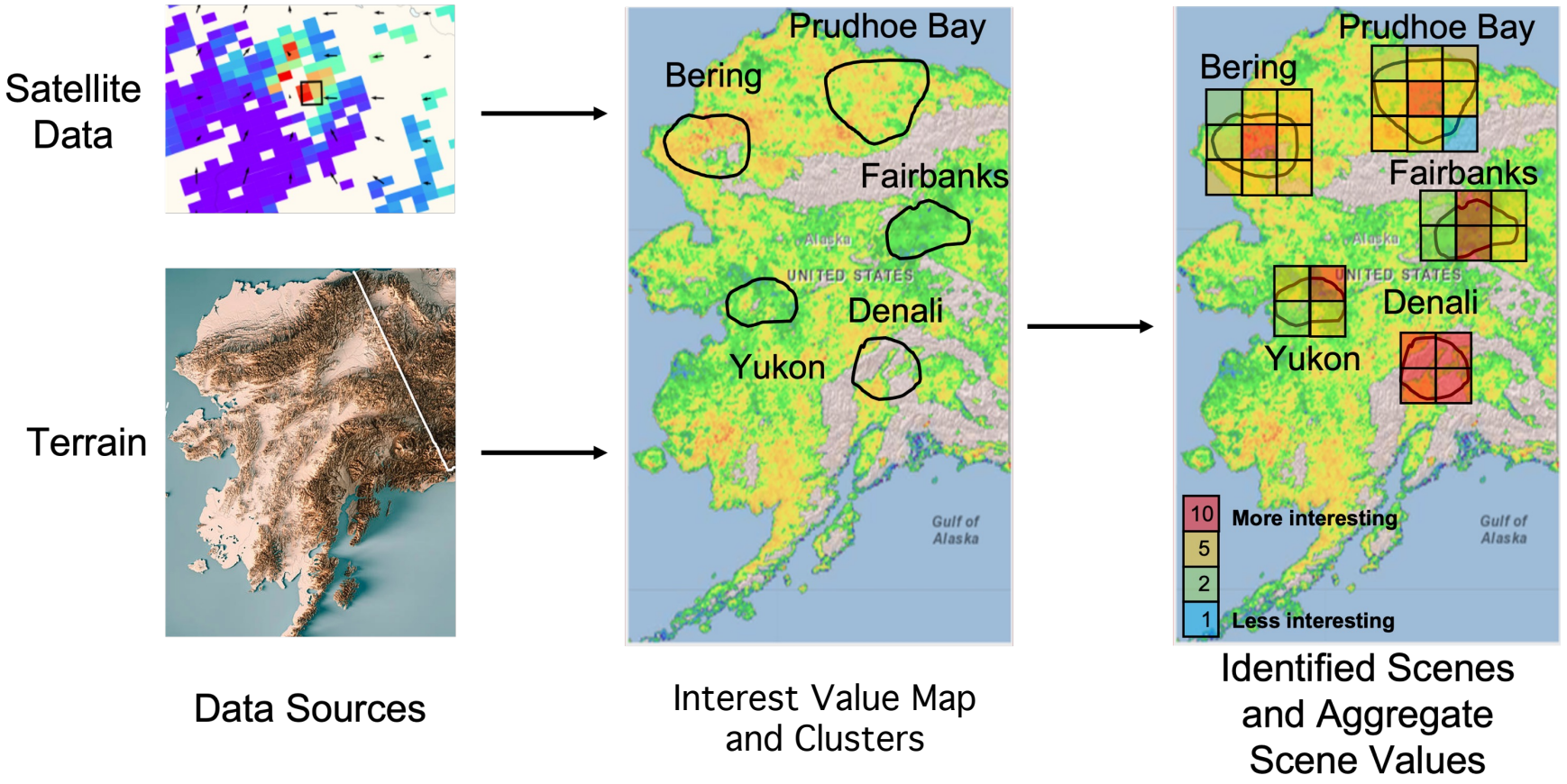
IMPACT: Reduced cost for Earth observations in environments ranging from arctic to urban to offshore (some previously inaccessible), continuous observations not possible for current field/in-situ campaigns, improved science outcomes

ILEOS Architecture



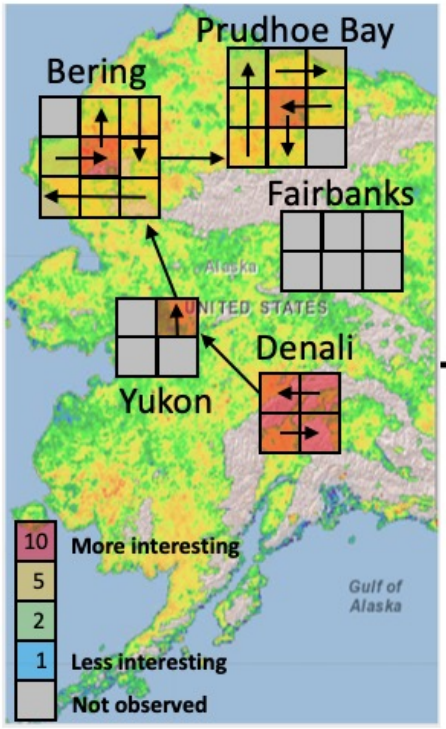
- Targeter – leverages Science SME domain knowledge to fuse available coarse-grained data into pixel value maps to generate target scenes
- Planner – generate flight plan to observe best identified target scenes while enforcing HALE UAS operating constraints
- Reporter – allow users to configure Targeter and Planner, visualize all data and outputs, and request explanations

Targeter



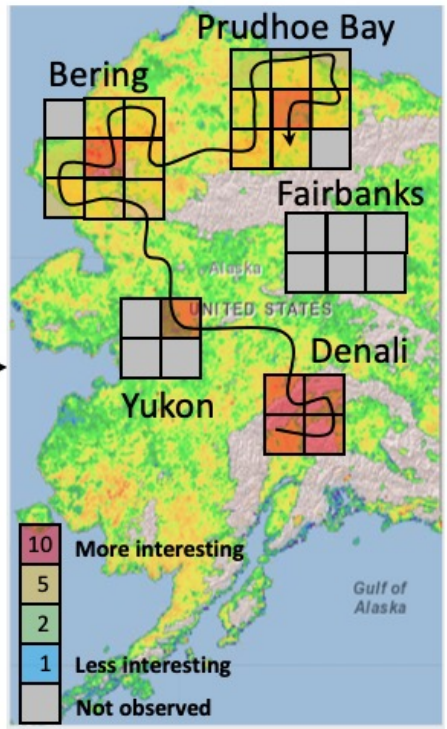
The Targeter leverages a science pipeline to assign interest values from varying inputs (left). It then groups similar pixels (middle), and then breaks these groups into scenes with values aggregated from the pixels within them (right).

Planner



Scene Selection and Sequencing

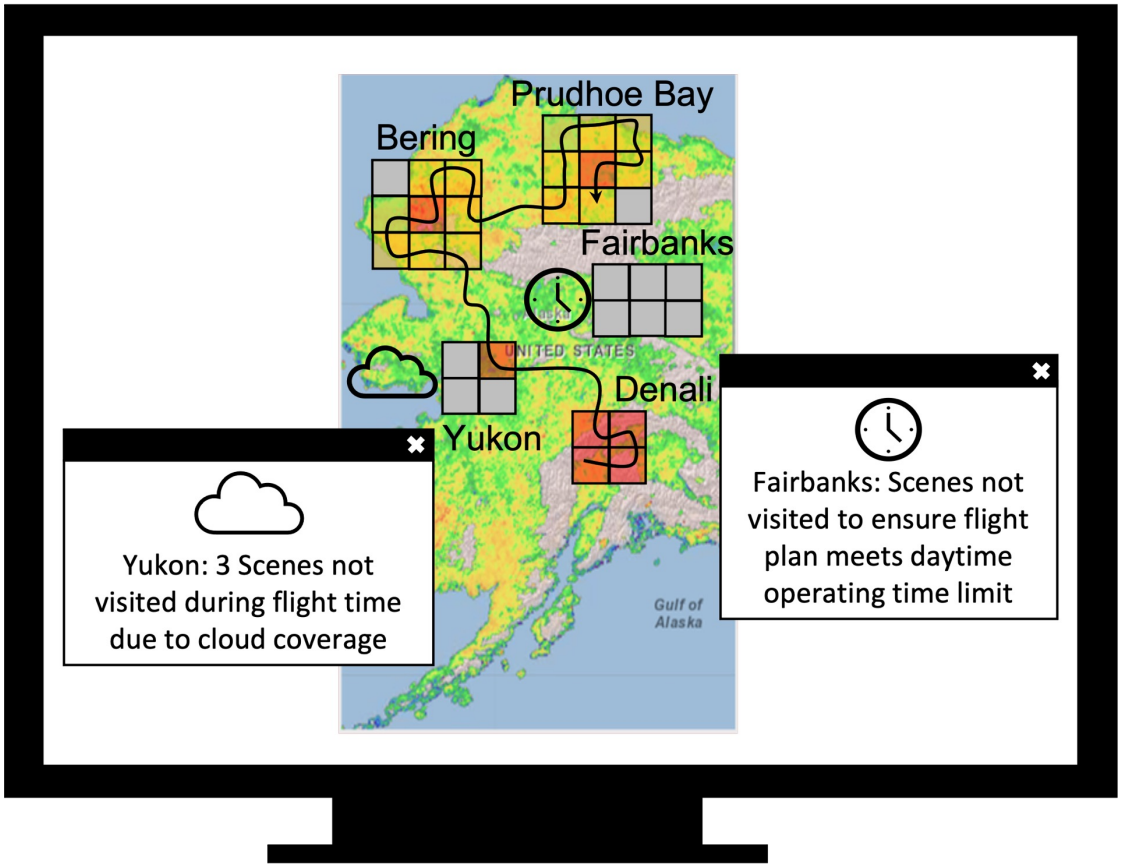
Route + Motion Planning Output (UAS plan)		
Plan Step	**Action**	**Duration**
1	Observe Denali 3	30 mins
2	Observe Denali 4	30 mins
3	Observe Denali 2	30 mins
4	Observe Denali 1	30 mins
5	Traverse Denali to Yukon (Avoid T-Storm)	120 mins
6	Scan Yukon 2	30 mins
5	Traverse Yukon to Bering (Strong Headwind)	180 mins
6	Scan Bering 9	30 mins
...	...	...



Detailed Flight Planning

The Planner determines which scenes should be visited and in which order (left), detailed behaviors within each scene (middle), and refines routes for traveling between scenes based on environmental and HALE UAS operating constraints (right).

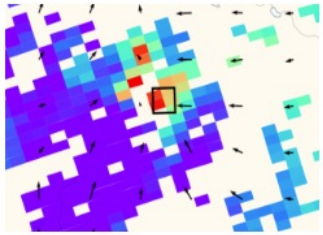
Reporter

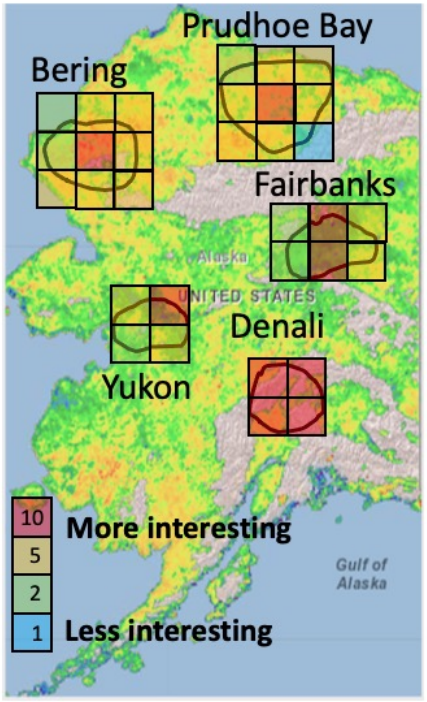


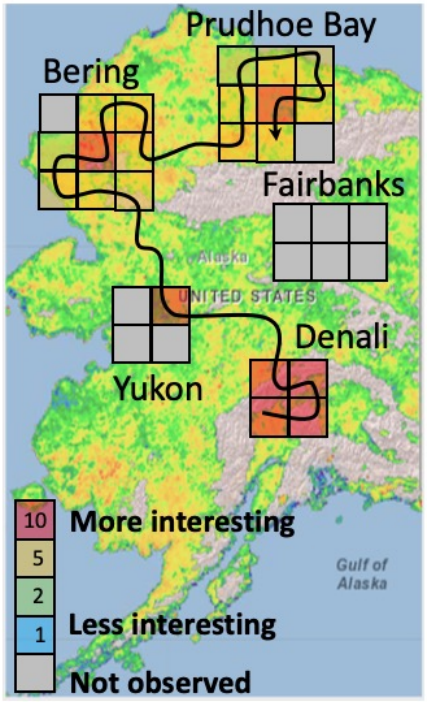
The Reporter provides explanations for Targeter and Planner outputs to the user. For example, explanations include icon and popout descriptions of why scenes were not included in a flight.

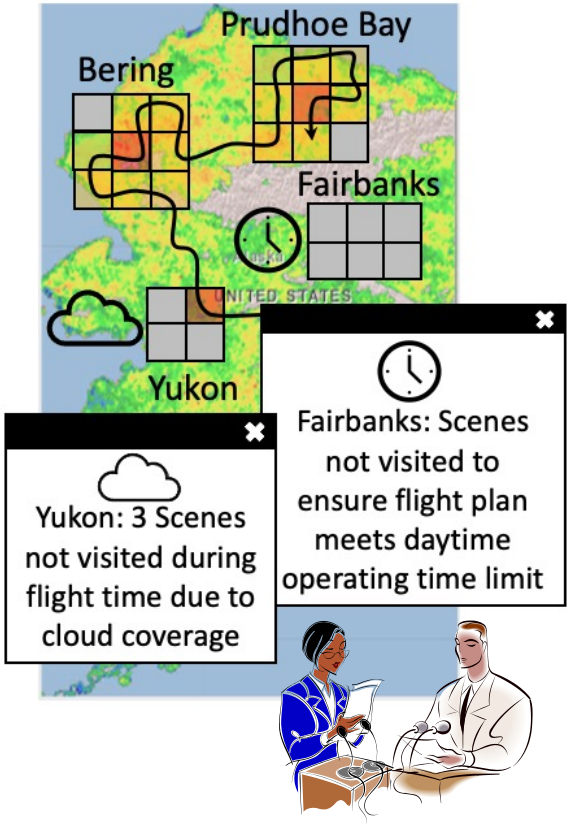
Full ILEOS Pipeline

Data Sources → Targeter → Planner → Reporter









Targeter Interest Values

Interest values:

- Unique for each use case
- Based on available coarse-grained data (satellite measurements, meteorological, etc.)
- Leverage Science SME domain knowledge to provide priority

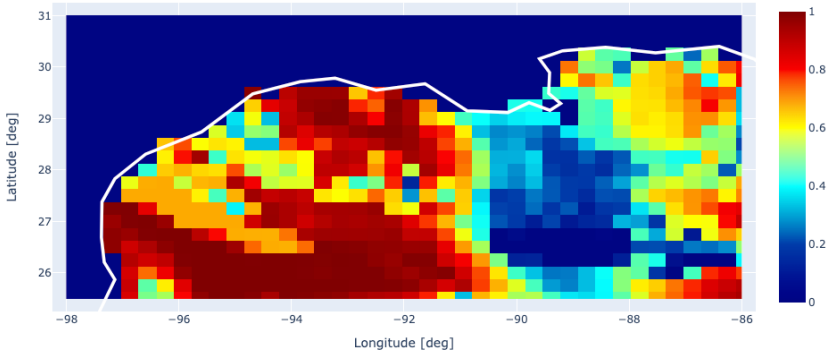
NO_2 Use Case Coarse Grained Data:

- Land cover (target water)
- Measured satellite NO_2
- Cloud cover
- Aerosol optical thickness

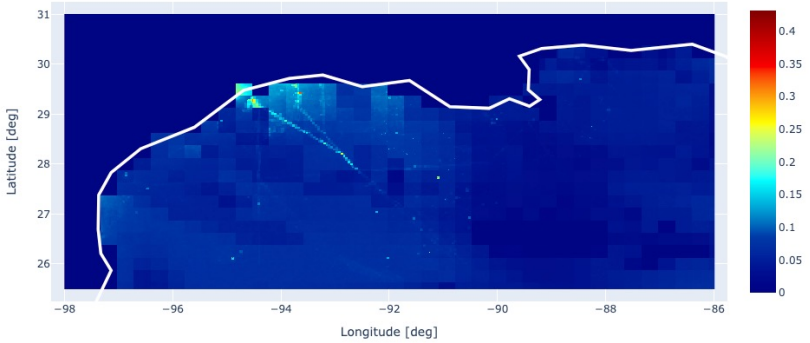
Methane Use Case Coarse Grained Data:

- Land cover (target wetlands)
- Cloud cover
- Inundation
- Measured Methane

Sample Value Map for NO_2 BOEM Inventory Use Case



Cloud Cover



Interest Values

Planner Objectives

Goal: Maximizes the total science rewards for all selected targets.

Planner decides:

1. Which targets to visit
2. How many targets can be visited
3. When to visit each target

Constraints:

- Mission duration
- Vehicle constraints
  - Speed
  - Turn dynamics
- Environmental constraints
  - Wind

Search space is huge:

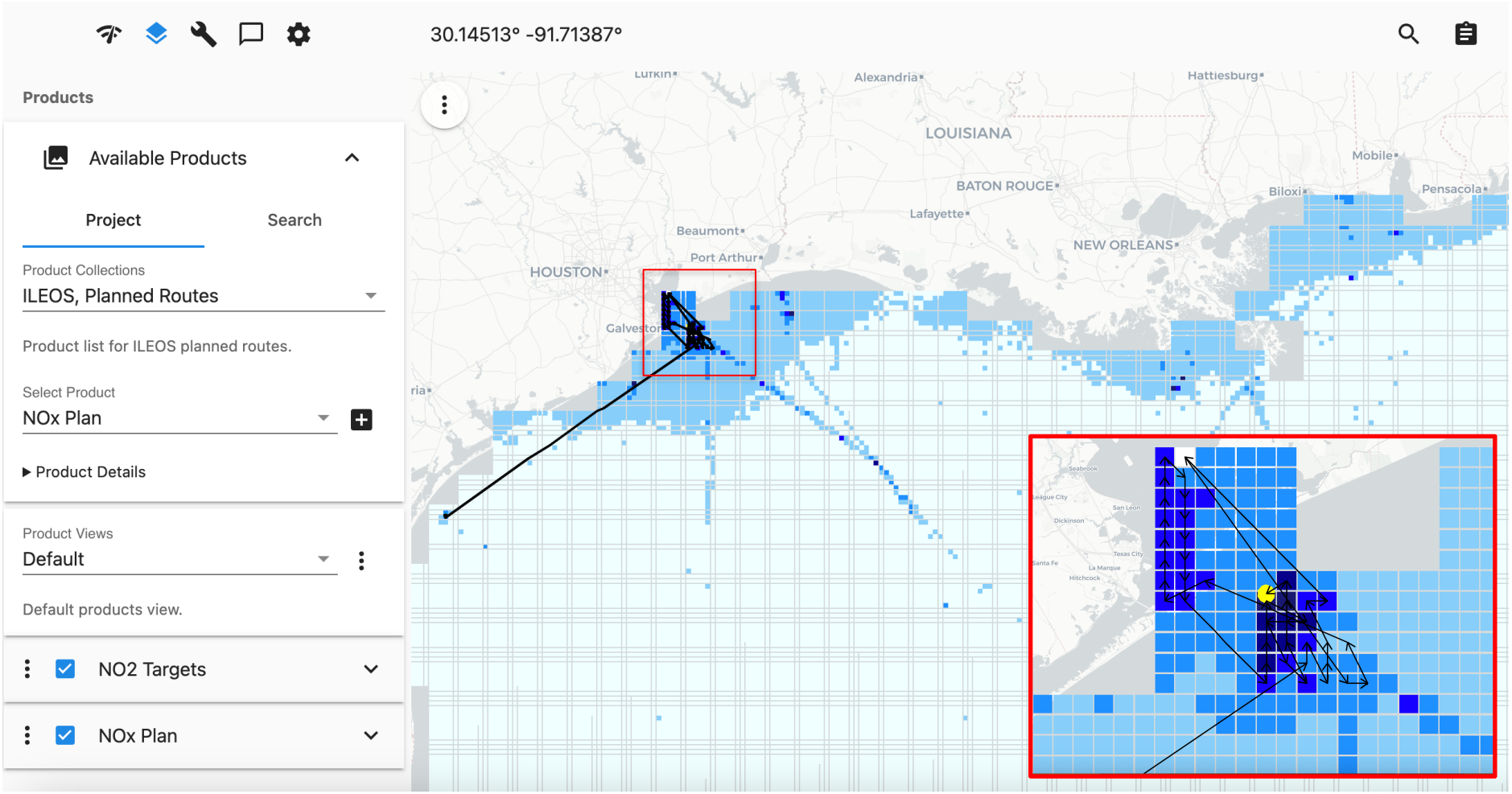
Ex: Find 30 targets out of 15,000 possible.

Assume 3 time window options (cloud data at different times of the day)

=> 1.86×10^{125} options

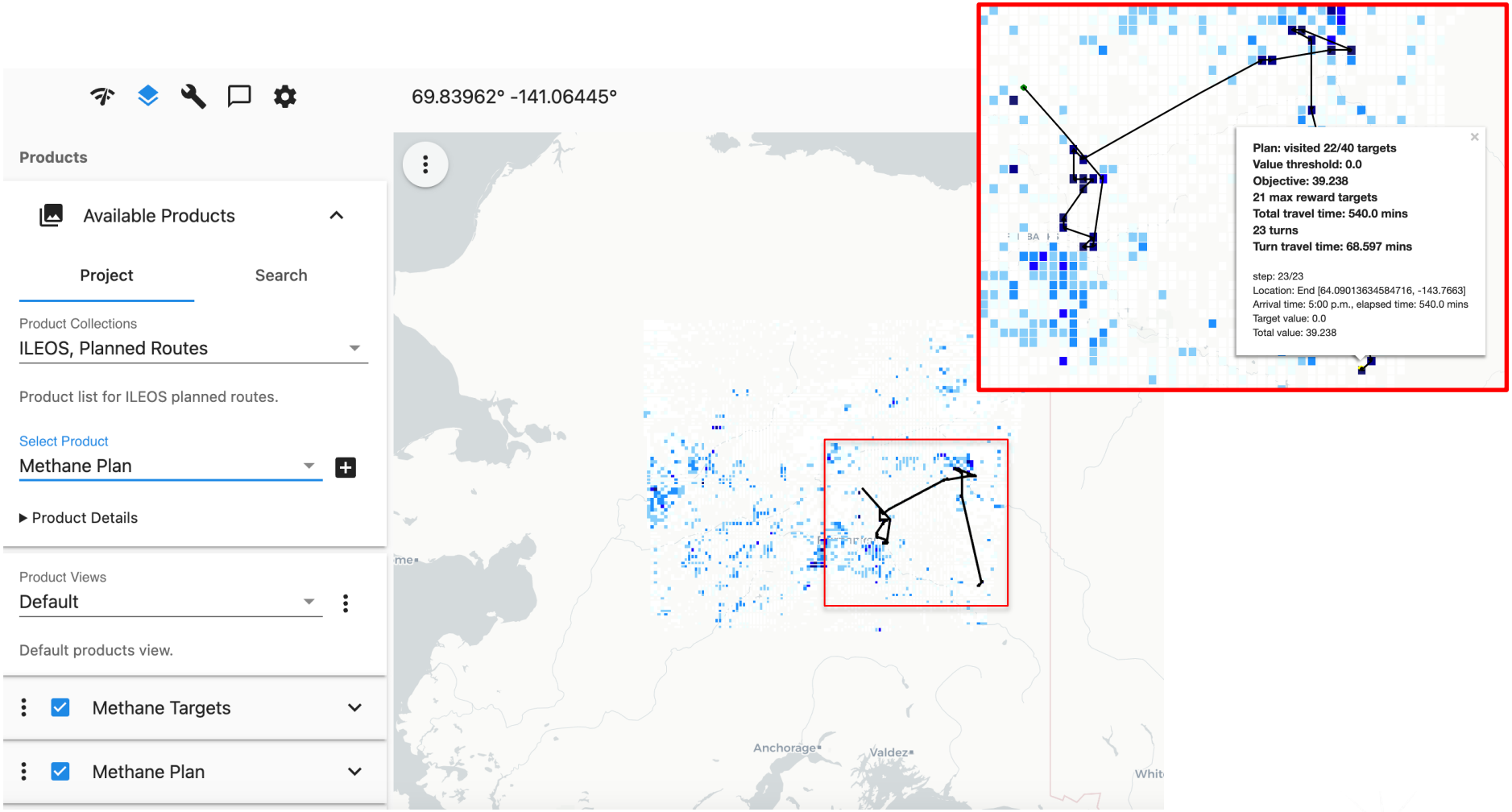
NO_2 Use Case

Use Case 1: BOEM Inventory Verification of NO_2 in the Gulf of Mexico



Methane Use Case

Use Case 2: Methane in Interior Alaska



Future Work

- Targeter
  - User defined target prioritization
- Planner
  - Improve efficiency
  - Add environmental constraints
  - Detailed motion planning
- Reporter
  - Improve input data layer visualizations
  - Targeter and Planner parameter updates
- Explainability
  - Associate coarse-grained data with Targeter produced interest values
  - Constraint-based reasoning for Planner not choosing segments
- System evaluation: Plan quality, Explainability, Usability
- Multi-day missions
- Multi-vehicle missions

Thank You

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