Intelligent Long Endurance Observing System (ILEOS)

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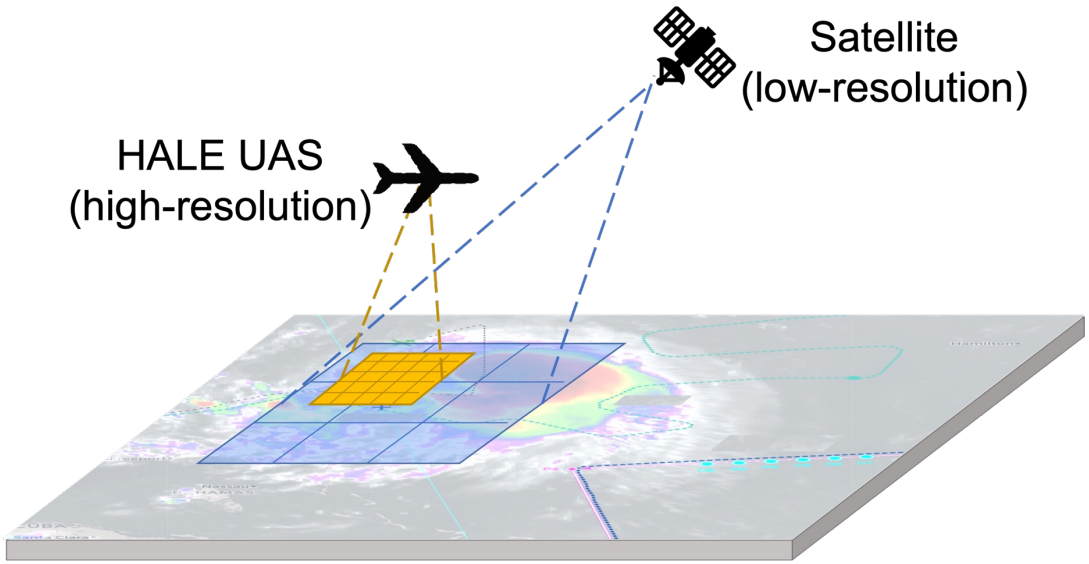
Concept of Operations



- 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

Relevance to Earth Science

- ILEOS will focus on use cases related to NO_2 and CH_4, which both high relevance to the science and application priorities presented in the 2019 Decadal Survey:
  - NO_2, here a proxy for combustion emissions (e.g., CO_2), over oil and natural gas extraction areas of the Gulf of Mexico.
    - Estimation of these emission sources(e.g., point - large rigs, line - shipping lanes, and area - small wells and support ships).
  - NO_2 down to the city block level in urban environments
    - Human health (unhealthy to breathe) and environmental justice
  - NO_2 generated from lightening (collected from above storm clouds)
    - Important ingredient in formation of upper tropospheric ozone, expensive to collect with crewed aircraft
  - CH_4 over Artic-Boreal zone
    - Characterize how the water table and air temperature affect the rate of emission
  - CH_4 from various anthropogenic sources such as industrial processes and leaky natural gas distribution pipelines, in complex urban environments
    - Pinpoint sources needing migration for safety reasons or to reduce the GHG footprint of urban areas

Team Members

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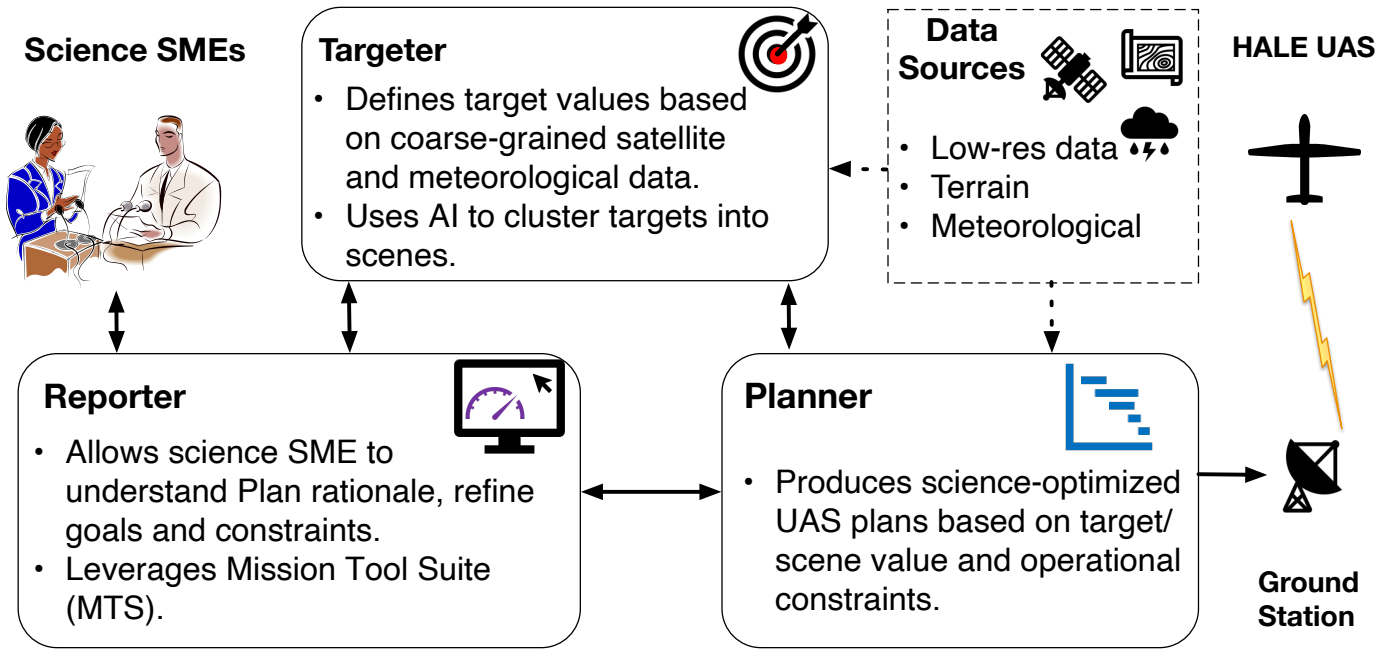
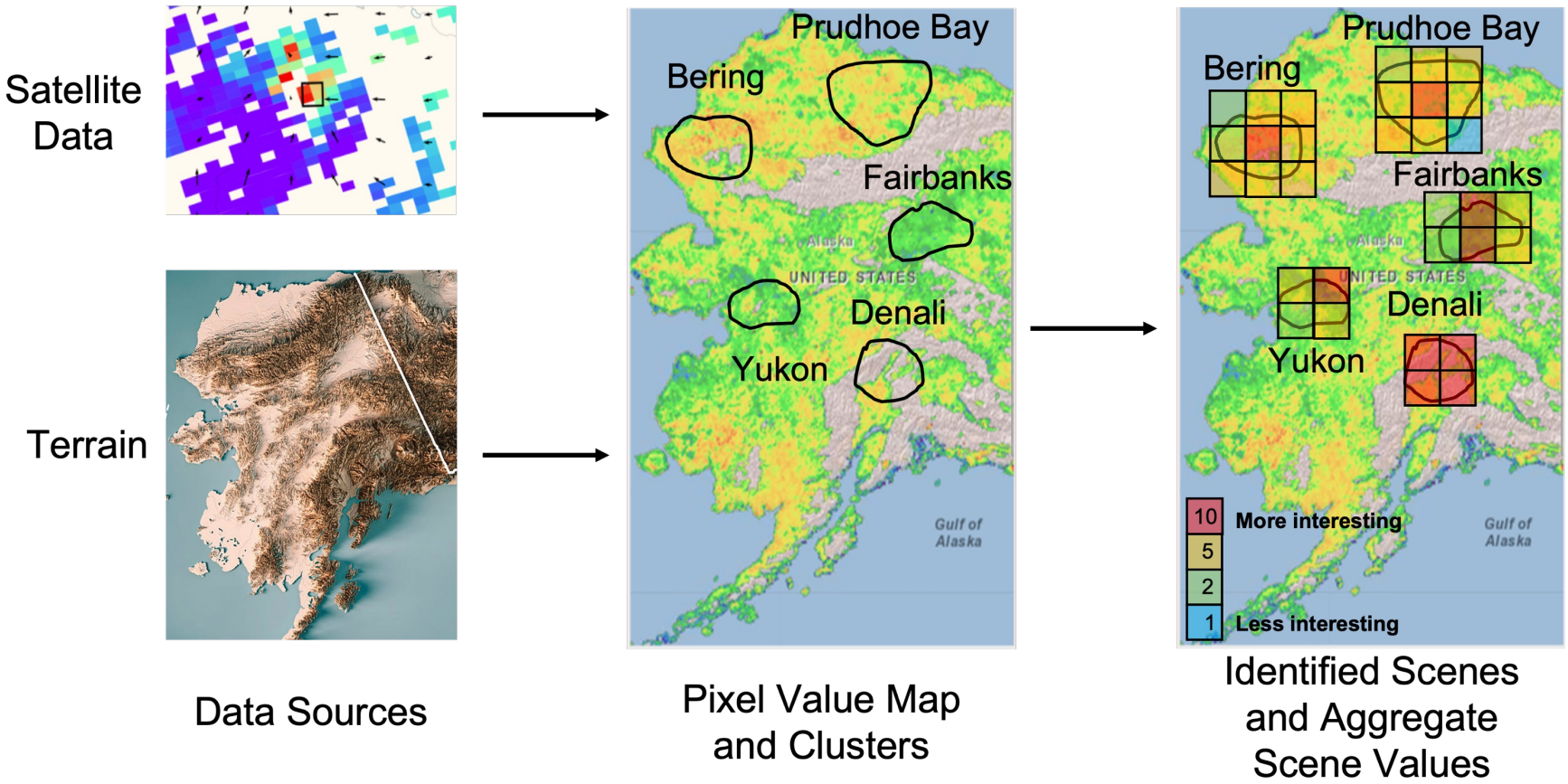
ILEOS Architecture



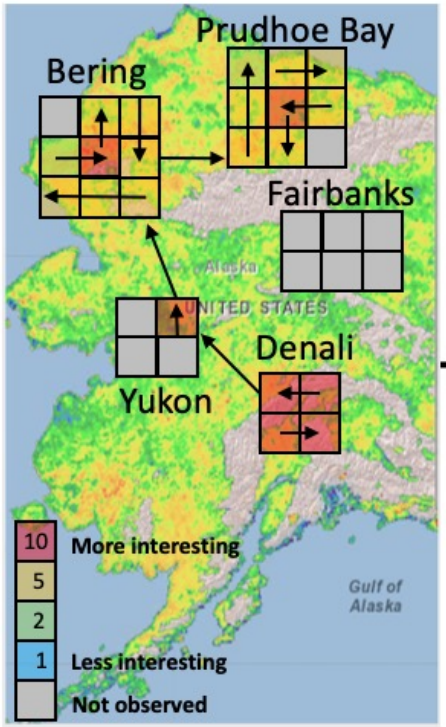
- Targeter – leverages Science SME domain knowledge to fuse available coarse-grained data into pixel value maps to generate target scenes
- Planner – generate flight plan to observe best identified target scenes while enforcing HALE UAS operating constraints
- Reporter – allow users to configure Targeter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

Targeter



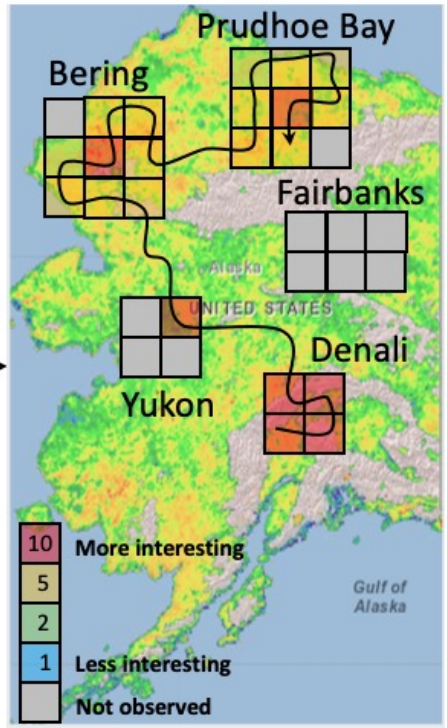
The Targeter leverages a pixel value module to assign pixel values from varying inputs (left). It then groups similar pixels (middle), and then breaks these groups into scenes with values aggregated from the pixels within them (right).

Planner



Scene Selection and Sequencing

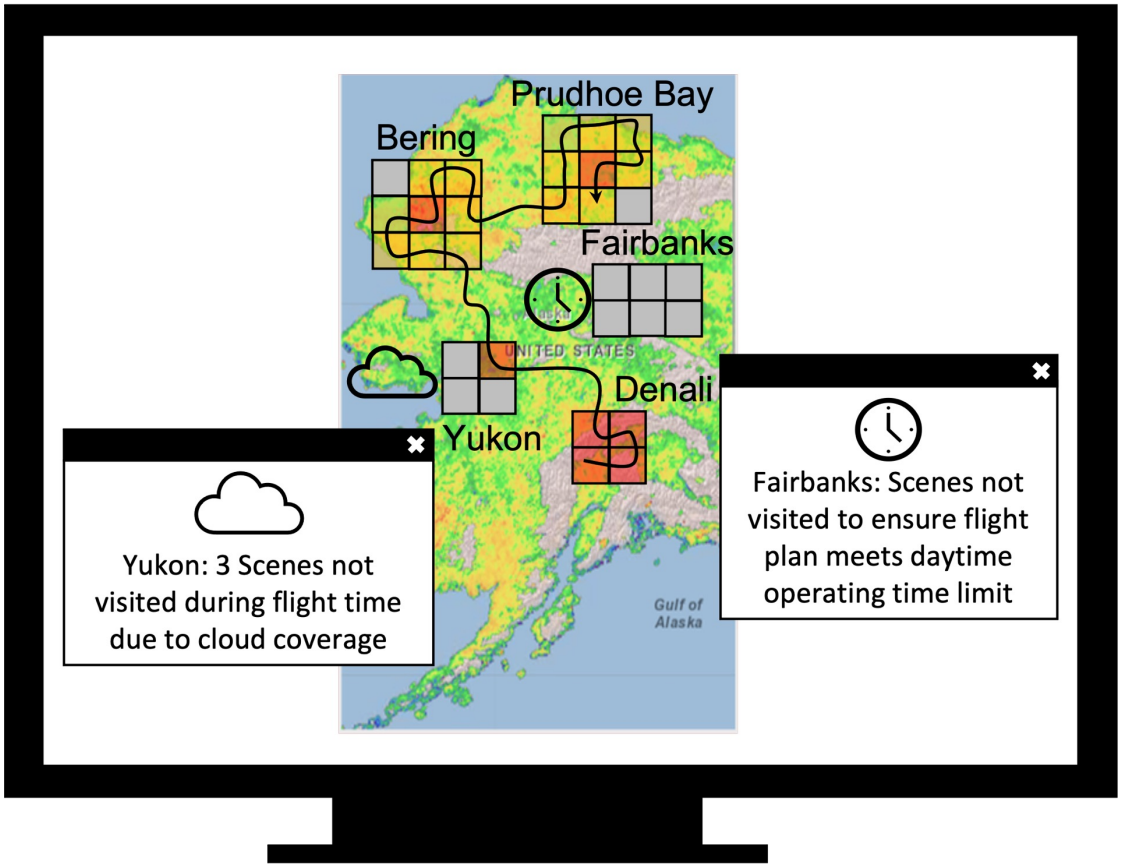
Route + Motion Planning Output (UAS plan)		
Plan Step	**Action**	**Duration**
1	Observe Denali 3	30 mins
2	Observe Denali 4	30 mins
3	Observe Denali 2	30 mins
4	Observe Denali 1	30 mins
5	Traverse Denali to Yukon (Avoid T-Storm)	120 mins
6	Scan Yukon 2	30 mins
5	Traverse Yukon to Bering (Strong Headwind)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



Detailed Flight Planning

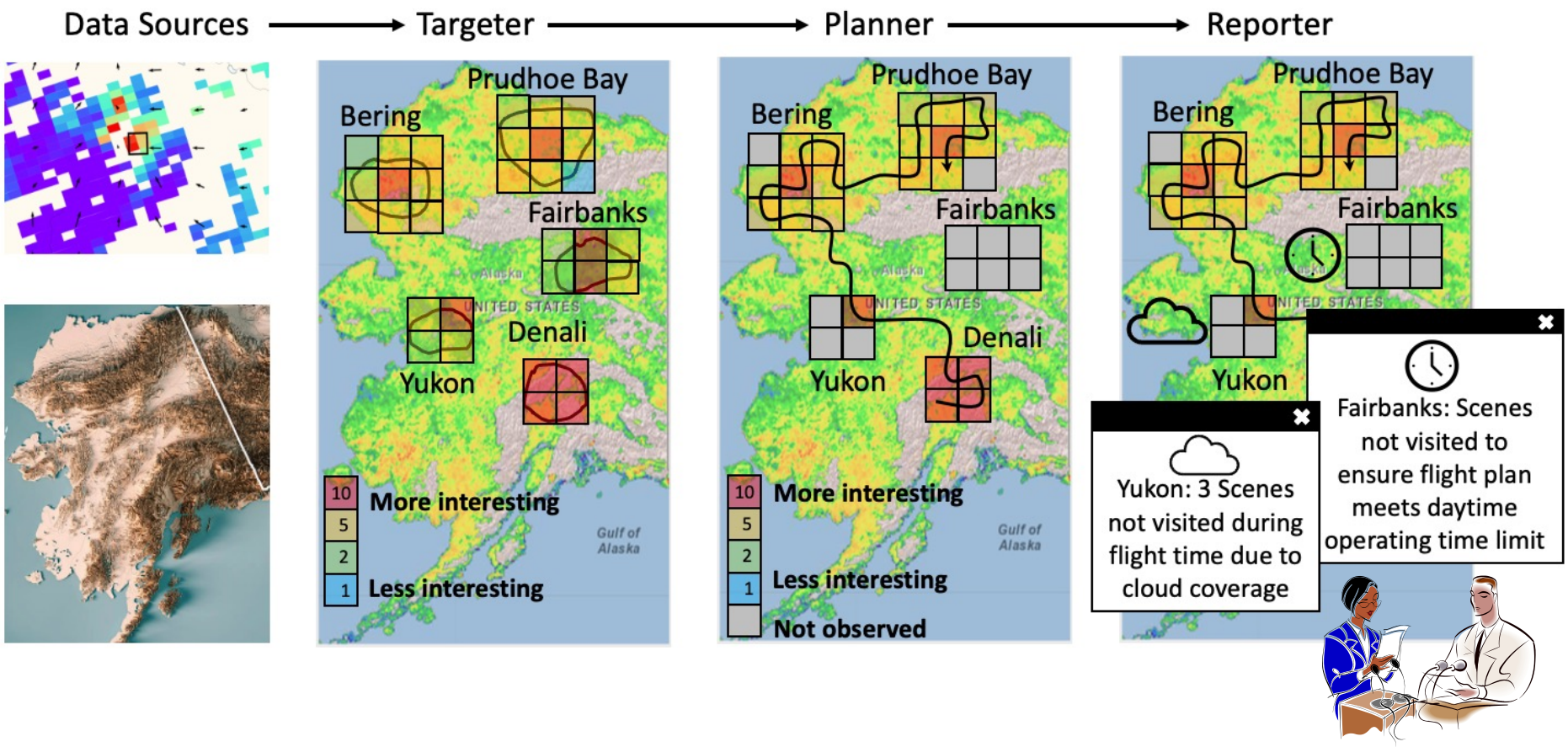
The Planner determines which scenes should be visited and in which order (left), detailed behaviors within each scene (middle), and refines routes for traveling between and within scenes with wind speed and velocity and HALE UAS operating constraints (right).

Reporter



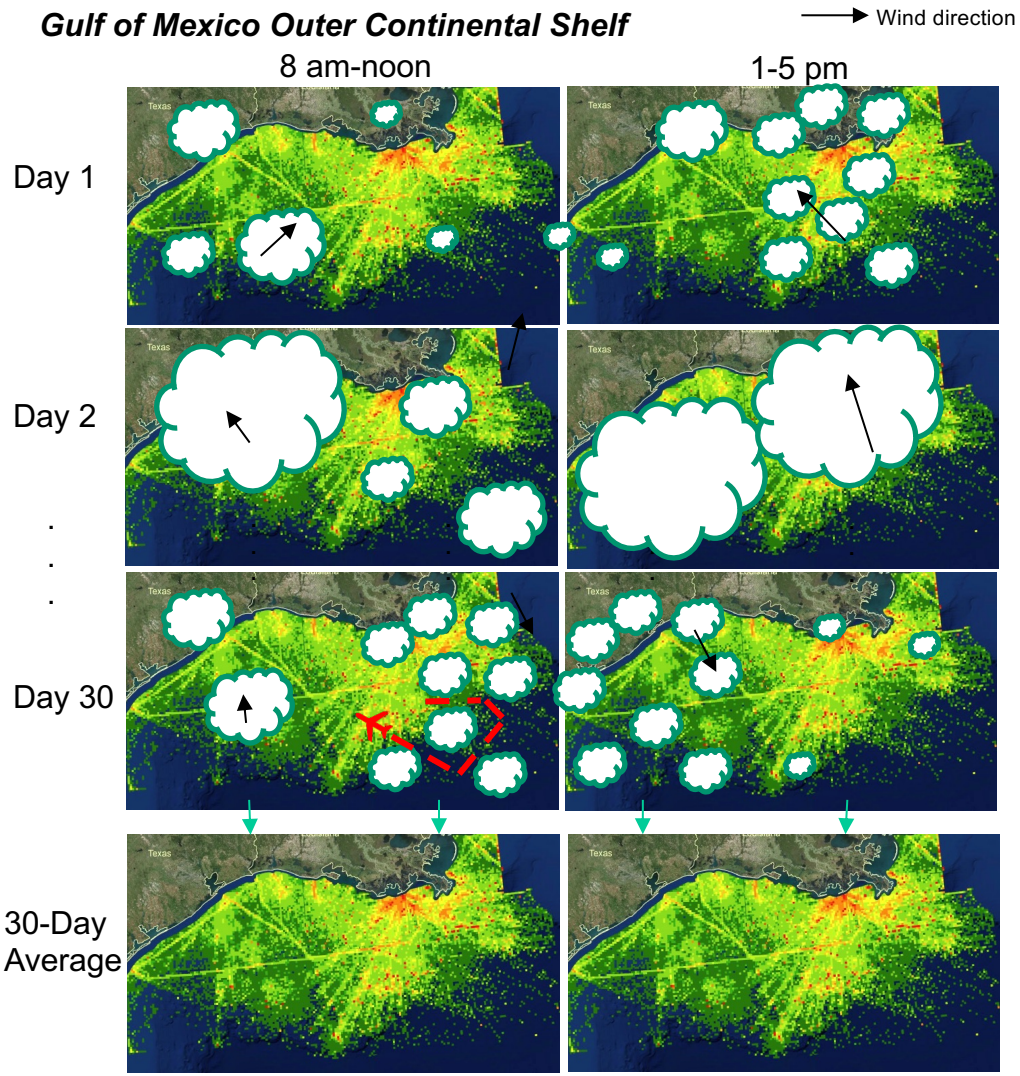
The Reporter provides explanations for Targeter and Planner outputs to the user. For example, explanations include icon and popout descriptions of why scenes were not included in a flight.

Full ILEOS Pipeline



Example NO_2 Use Case

Gulf of Mexico Outer Continental Shelf



Duncan BN. 2020. NASA resources to monitor offshore and coastal air quality. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2020-046. 32 p. https://espis.boem.gov/final%20reports/BOEM_2020-046.pdf

Intelligent Long Endurance Observing System (ILEOS)

ILEOS is a data collection planning system that generates optimal flight tracks based on mission parameters and various input datasets. It may be applied to numerous aircraft platform-instrument configurations, including in the use case study presented next.

ILEOS Use Case Study Example – Offshore Oil & Natural Gas Operations

The Outer Continental Shelf Lands Act (OCSLA) requires the US Dept. of Interior Bureau of Ocean Energy Management (BOEM) to ensure compliance with the National Ambient Air Quality Standard (NAAQS) so that Outer Continental Shelf (OCS) oil and gas exploration, development, and production do not significantly impact the air quality (AQ) of any state. BOEM has partnered with NASA to explore the use of satellite data to meet this goal.

One air pollutant, nitrogen dioxide (NO_2), is emitted during fossil fuel combustion, including during oil and natural gas extraction activities (e.g., from ships, platforms, flaring), and is readily detected from instruments on satellites. Therefore, it is an excellent tracer of anthropogenic activities.

ILEOS would use data of offshore and onshore NO_2 sources (in figure at left) with weather data to efficiently generate optimal flight plans, such as for a HALE UAS fitted with a NO_2 sensor. The NO_2 sensor, with its small pixel size (30x30 m^2; 4.5 km swath), can easily collect data at the platform-scale, including between broken clouds that stymie coarsely-resolved satellite instruments (e.g., TROPOMI; 3.5x7 km^2 pixel size). Therefore, in this configuration, ILEOS would enable the efficient collection of data for BOEM's applications, including spatio-temporal emission quantification.

System Evaluation

- ILEOS' first 2 years will culminate with a capstone demo featuring simulated observing campaigns overseen by SMEs
  - Evaluated on at least 2, ideally 4 climate-relevant gas sensing science use cases

Sensing Domain	Use Case Type	
	Nominal	Stressing
Methane	Urban emissions	Artic permafrost thaw
Nitrogen Dioxide	Urban emissions	Upper atmospheric lightening

- Assess users' ability to generate desired plans and understand relationship between scenes, priority, constraints, and their impact on plan
  - Human-in-the-loop evaluation

Technology Infusions

Tentative 3rd Year

- Technology infusion into NASA Airborne Sciences Program (ASP) via integration with:
  - Heritage Mission Tool Suite (MTS) application
  - Upper-E Traffic Management (ETM) Project

Thank You

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