Extending the Earth Observation System System (EPOS) for Coordination of Asynchronous Sensor Webs

NASA ESTF 2014
October 28 2014

Stephan Kolitz (kolitz@draper.com) PI
Mark Abramson (mabramson@draper.com) Co-PI

NASA AIST-11 Project:
EPOS for Coordination of Asynchronous Sensor Webs

Draper Laboratory
555 Technology Square
Cambridge MA 02139

DRAPER LABORATORY

Outline

- Opportunity to increase the overall value gained from Earth observing systems
- Our approach to achieving this through asynchronous distributed coordination
- Application to a NASA mission: HS3
- Conclusion

Problem

- **Use of sensing assets (satellites, UAVs, etc.) for data collection is widespread, e.g.,**
  - Ground images
  - Atmospheric chemistry and weather data
- **Missions using these assets typically are managed independently of each other**
- **Result is less value than if the missions were coordinated**

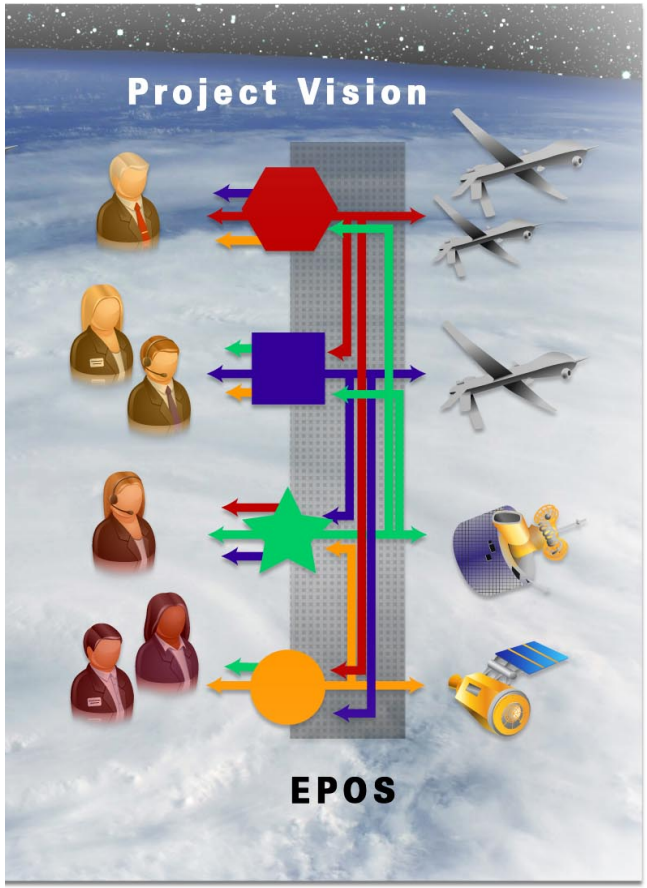
Current Process

DRAPER LABORATORY

Coordination Objectives

- **Use existing infrastructure**
- **Work with a wide array of missions to increase system-wide utility attained**
- **Increase the overall *value* gained from Earth observing systems**
  - Technology development: EPOS Coordination Manager and Data Access Tool
  - Technology infusion: for HS3

Coordination



DRAPER LABORATORY

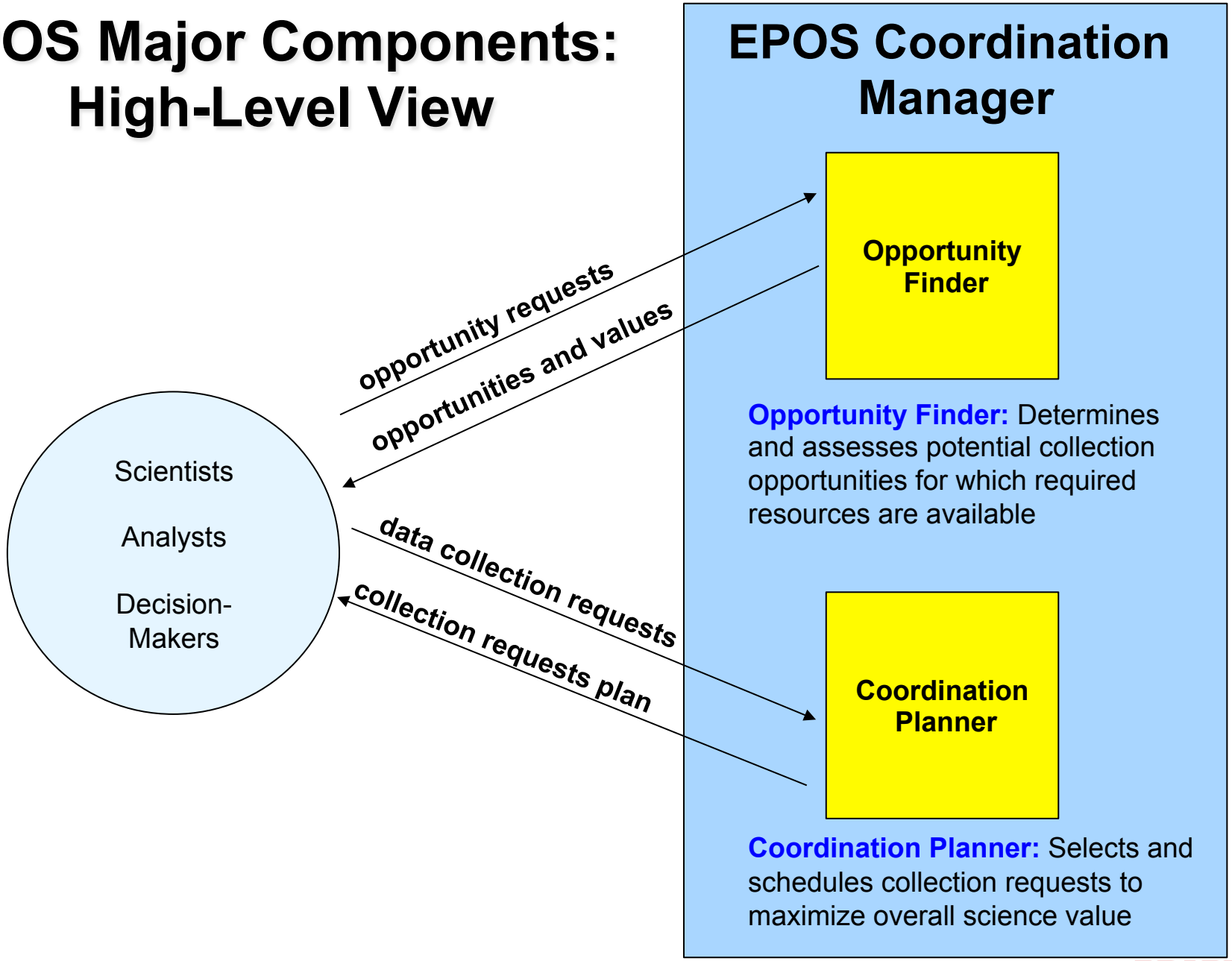
Technology Useful for Multiple User Classes

- **Scientists**
  - Specific science goals
  - Interested in specific characteristics of data (e.g., locations, times, spectral bands, resolution) and/or products that can be generated from the data (e.g., temperature, relative humidity, wind speed)
- **Analysts**
  - Specific goals, e.g., for better forecasts/predictions
  - Value of data is for the analysis and forecasts, not necessarily science
- **Decision-makers**
  - Government
    - Goals: to save lives and preserve property; education
    - More interested in the implications of data, rather than the data itself
  - Public
    - Goal: education; to be properly prepared for their own interests
    - Uses media and the internet to gather information

User Observation Requests

- **Simultaneous measurements, e.g., dual collection**
  - Explicit desire for multiple measurements over an area – e.g., validation, calibration, quality improvement
- **Persistent surveillance to minimize coverage gaps**
  - Desire for maximized coverage over an area of interest
- **Soonest possible observation**
  - Request fresh situation awareness of a target that has likely changed due to movement or process dynamics

EPOS Major Components: High-Level View

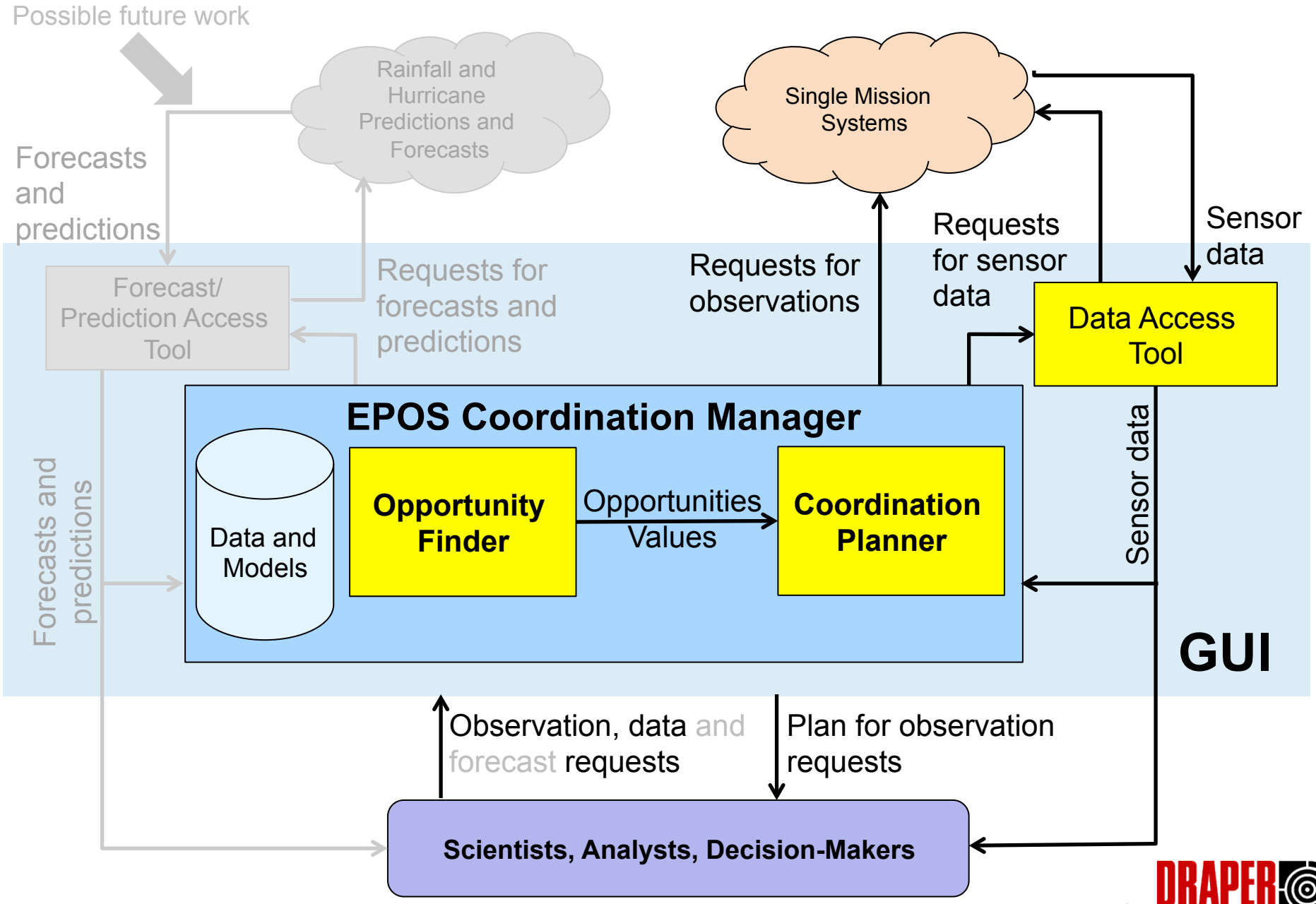


DRAPER LABORATORY

Approach

- **Opportunity Finder**
  - Determines feasible collections that meet user requests using mathematical models of the systems, values and constraints
  - Utilizes these models–in conjunction with a desired collection requirement–*to identify the potential assets that could meet the requirement and assign a value to data collected by the asset*
- **Coordination Planner**
  - Optimization-based planning approach used to identify which data collection *requests* should be sent to which mission/asset at what time
  - The *value* of the collection requests to each user must be known (as input) and is key to optimizing the coordination of requests across all users and all assets
    - ***Uncertainty in the value function presents a key technical challenge***
- **Rolling horizon decomposition**
  - Plan for a given length of time, get feedback during operations and replan as necessary

EPOS Functional Software Architecture

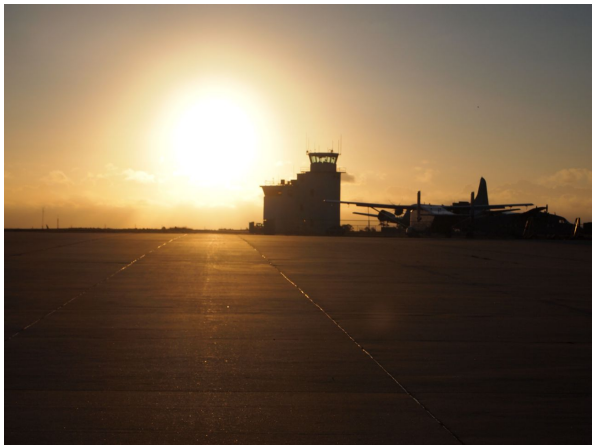


DRAPER LABORATORY

HS3 Mission Background

- The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission specifically targeted to **investigate the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin**

- Objectives achieved using **two Global Hawk Uninhabited Aerial Systems (UAS) with separate comprehensive environmental (AV6) and over-storm (AV1) payloads**



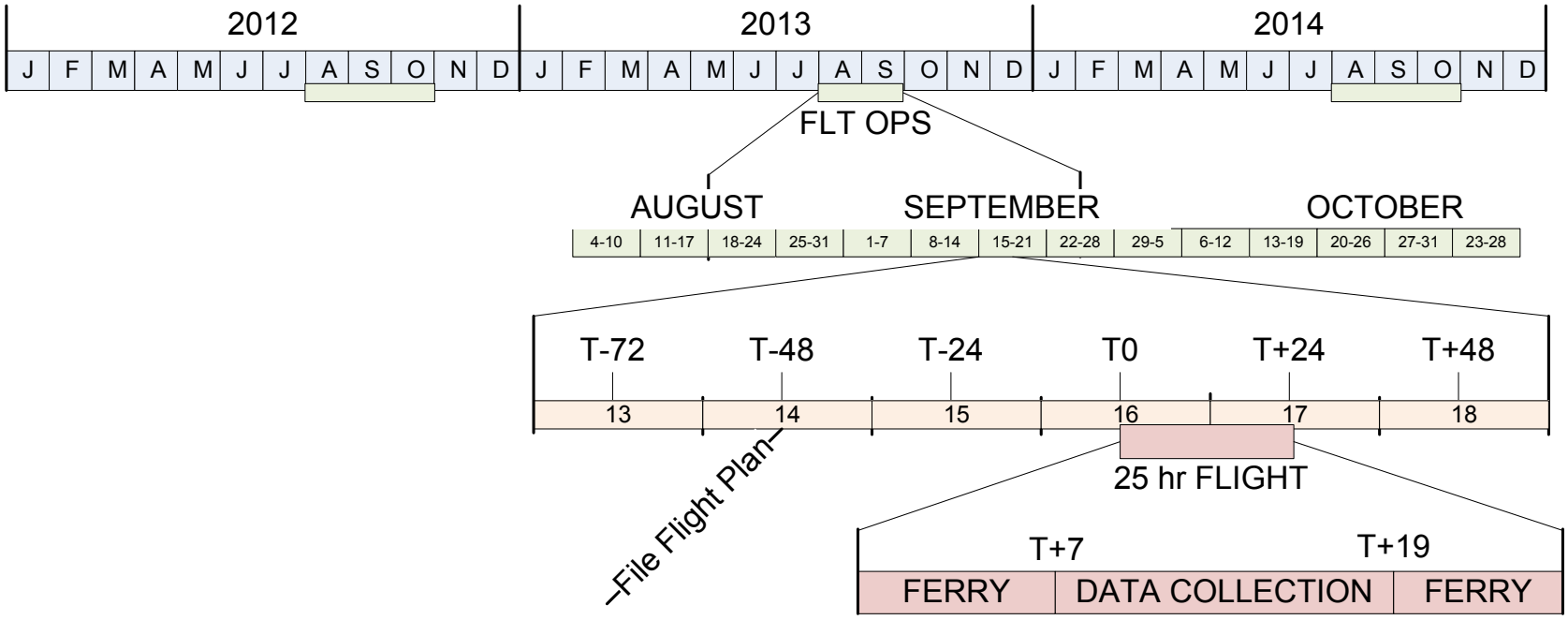
HS3 Measurement Types

Measurements from HS3 Instruments		
Vehicle	Instrument	Measurement Type
AV-6	AVAPS	Temperature
		Pressure
		Wind
		Humidity Vertical Profiles
	CPL	Cloud structure and depth
	S-HIS	Temperature
		Water Vapor Profiles
AV-1 (not flown in 2014)	HAMSR	Temperature
		Water Profiles
		Cloud Liquid Water
	HIRad	Surface Wind Speed
		Rain Rate
	HIWRAP	Radar Reflectivity
		Wind Profiles

HS3 Mission Timelines

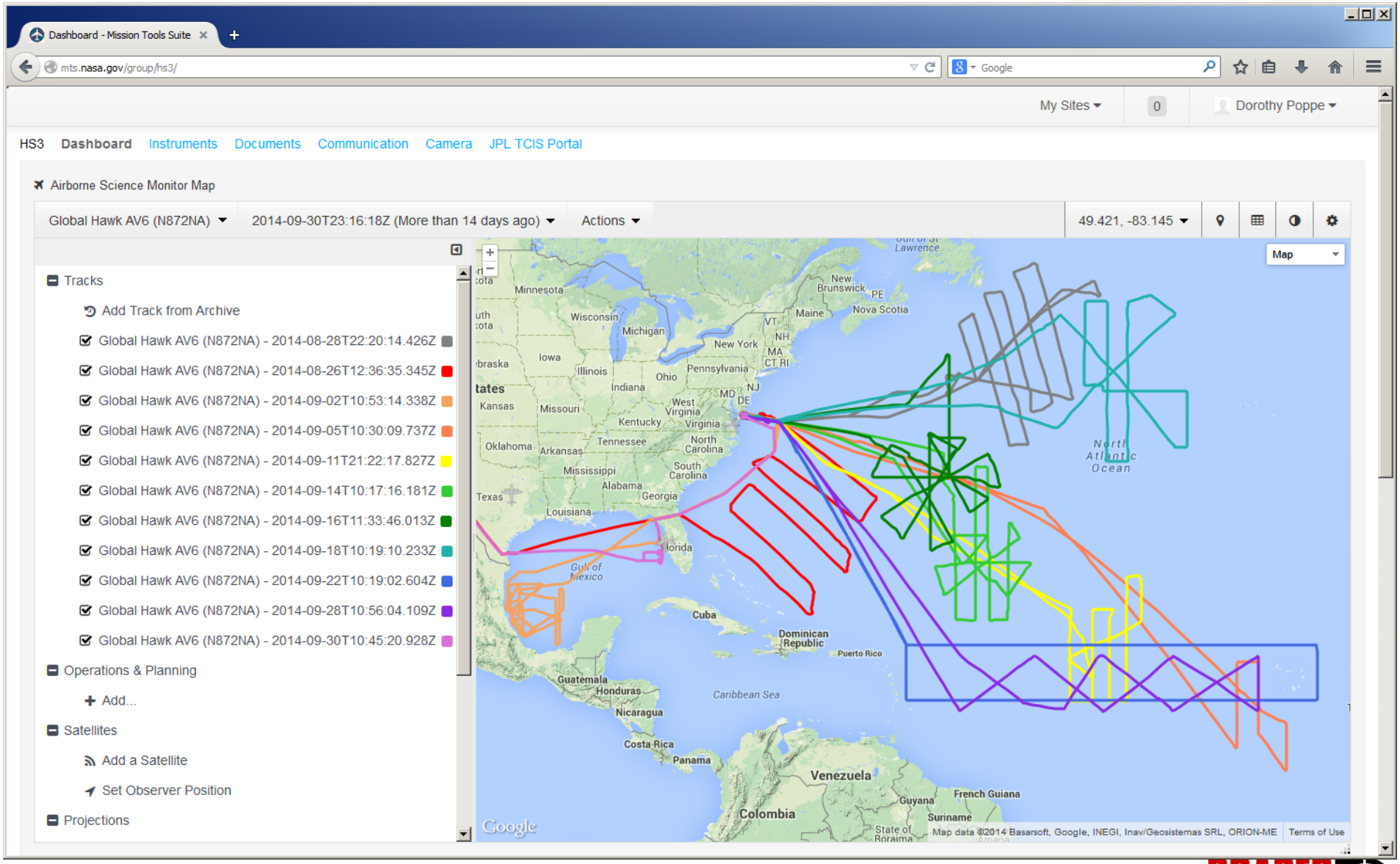
- **Multi-year mission**
- **Flight in late Summer ➔ early Fall**
- **Multi-day time line per flight**
- **25 hour flight duration**

HS3 Timeline



2014 HS3 Missions Flown

Aug 22 - Sep 30, 2014

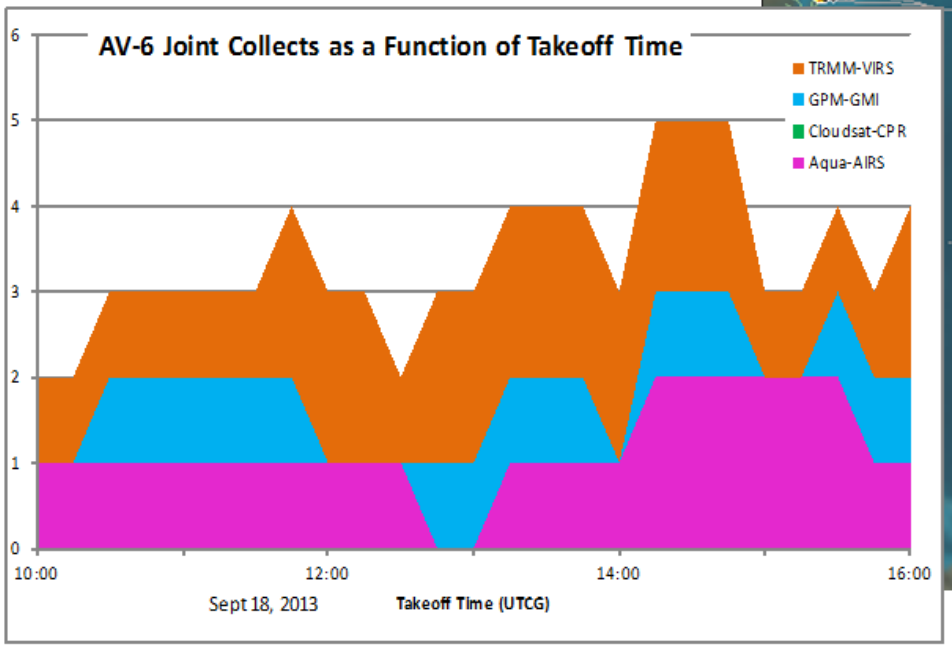


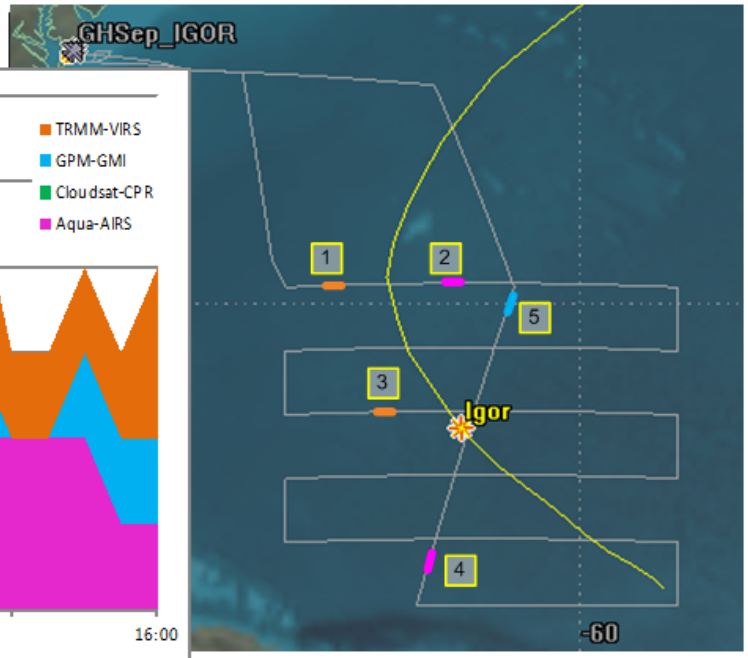
DRAPER LABORATORY

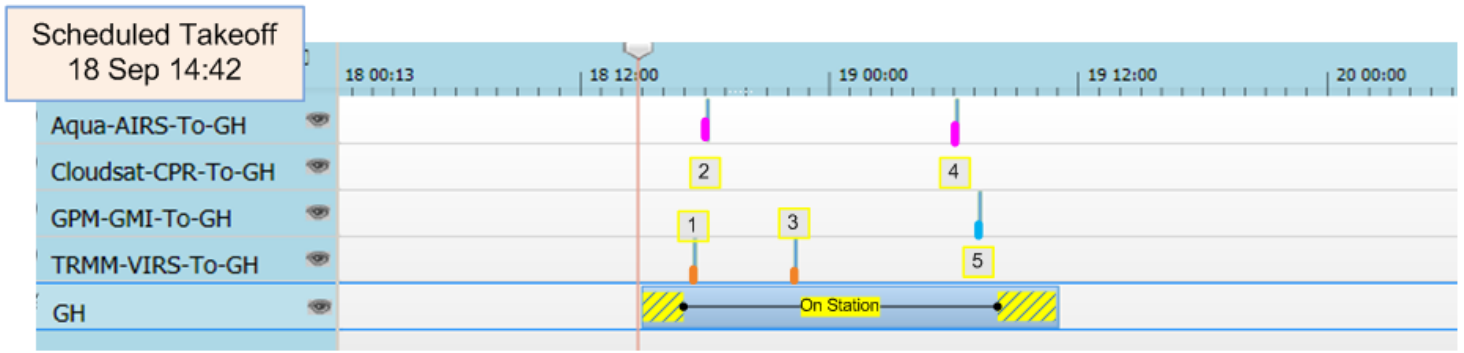
T-1 Days Product Example: AV6

Joint Collection as function of Takeoff Time

Analysis for one day before flight when AV-6 has been selected





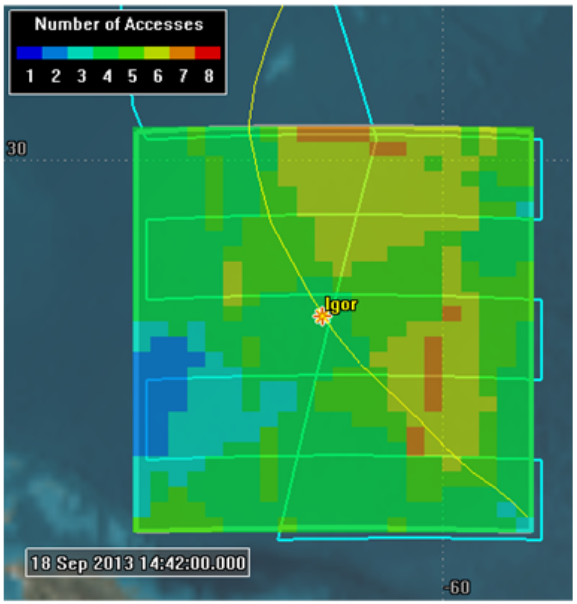


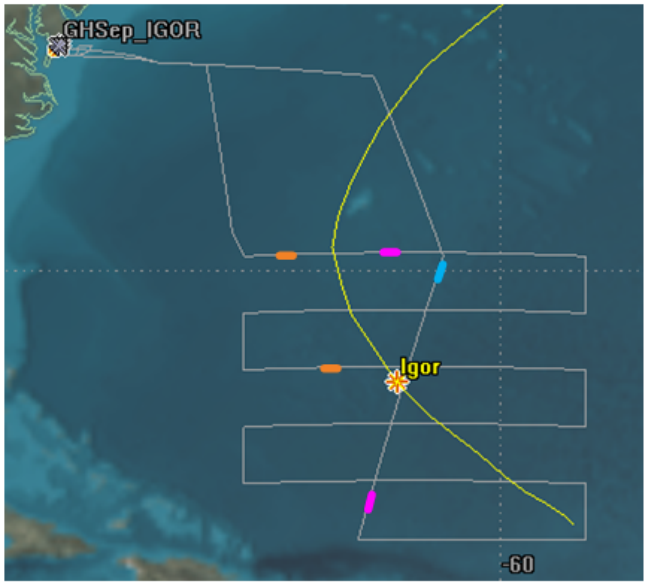
JHAPER LABORATORY

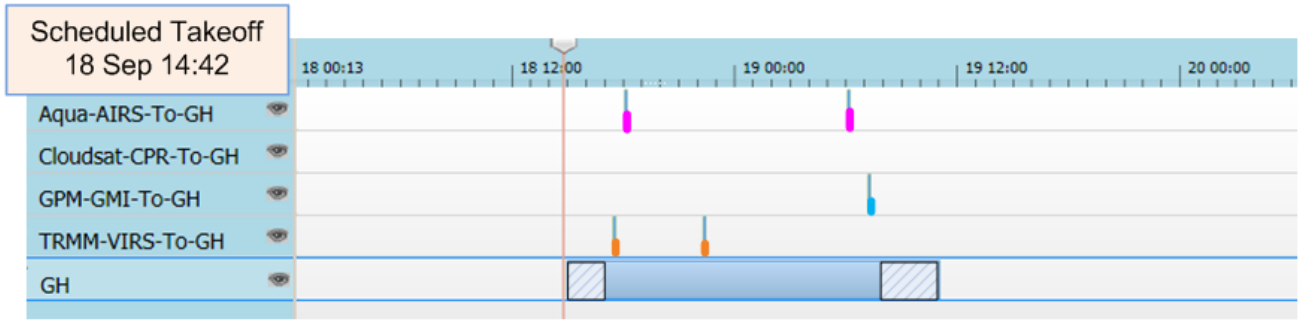
T-0 Days Product Example

Joint Collection and Surveillance for Flight Time

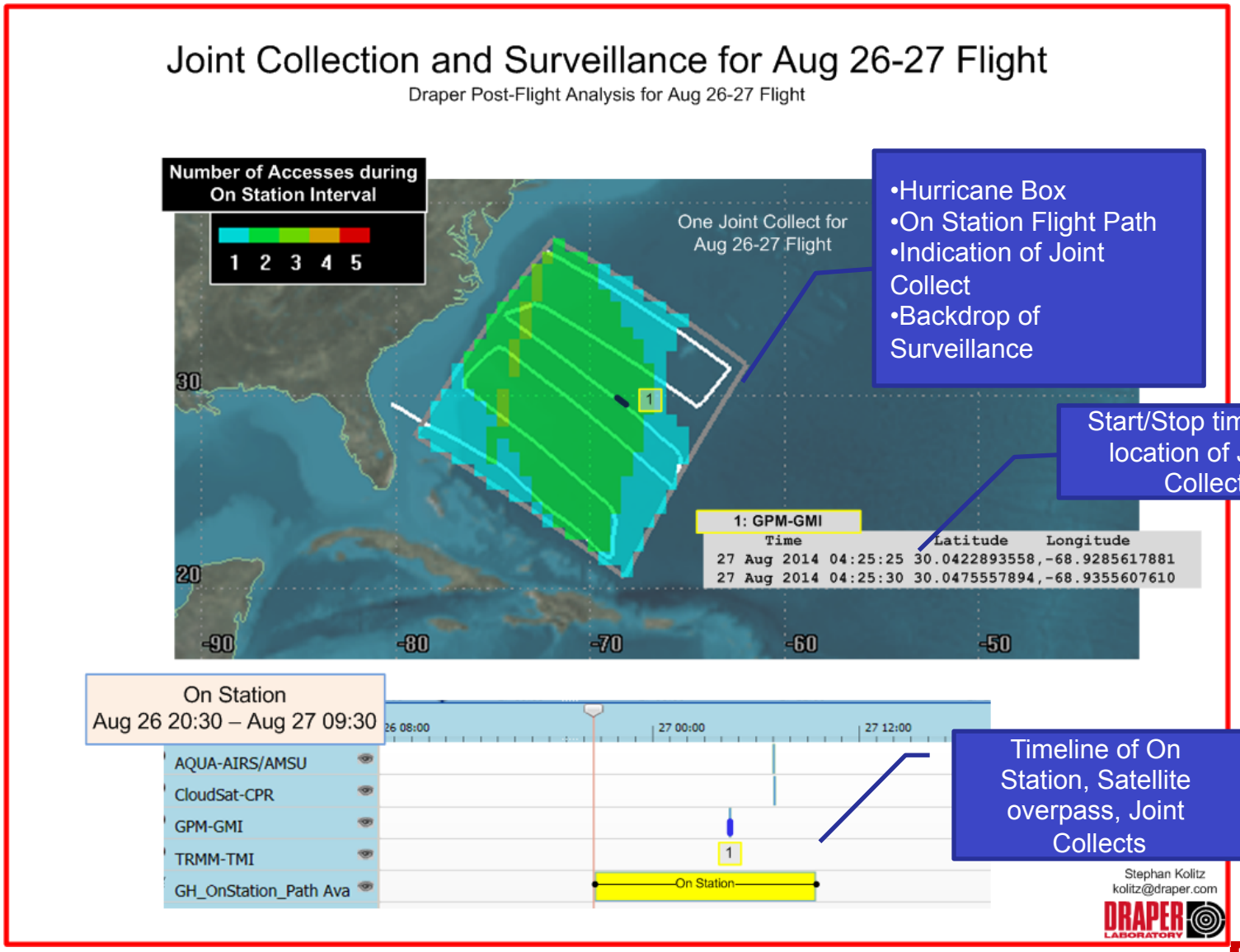
Analysis day of flight – shown for AV-6 example



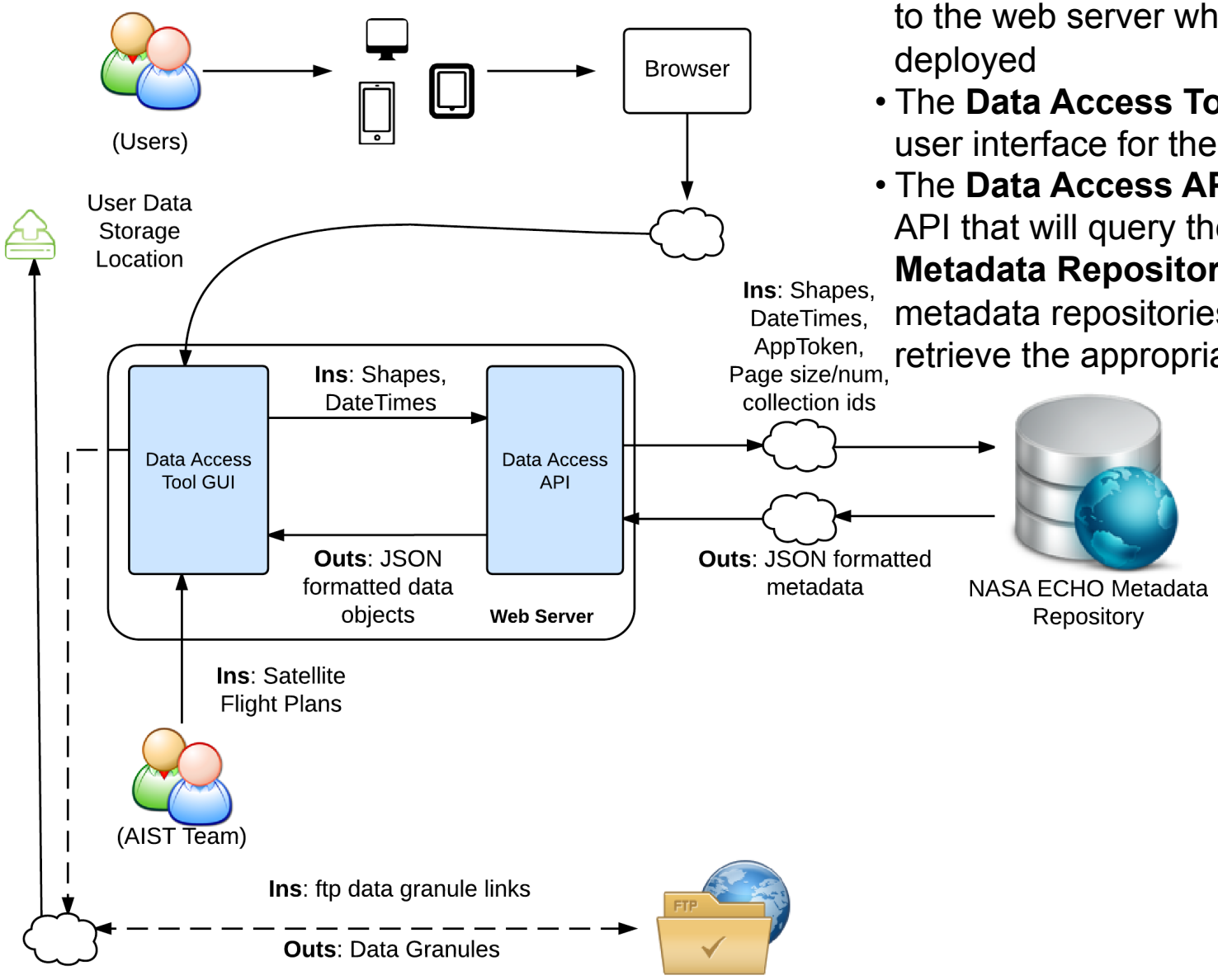




T+1 Product Example

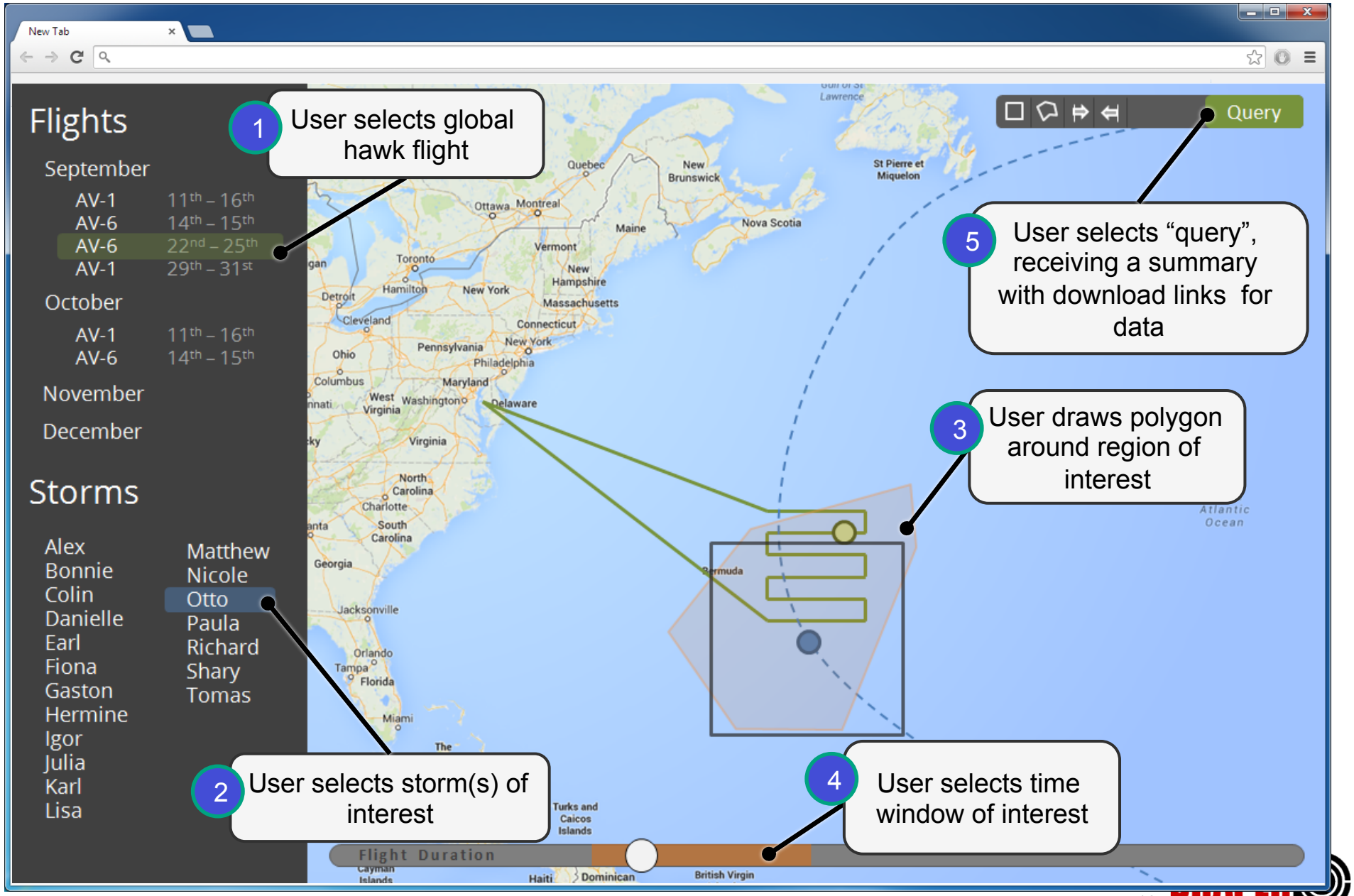


Science Data Access Tool Architecture



- **Users**: any end user who will interact with the system
- **Browser**: the app will be accessible via browser of any device that has a connection to the web server where the app will be deployed
- The **Data Access Tool GUI** is the main user interface for the app
- The **Data Access API** is the data retrieval API that will query the **NASA Echo Metadata Repository** or any other metadata repositories as necessary to retrieve the appropriate datasets

Data Access Tool Workflow



Conclusion

- Identified a need for a broad range of users to acquire valuable timely science data and products derived from the data
- Developed and implemented an approach to achieving this without requiring modifications to existing systems
- Infusing the technology in a NASA mission: HS3
- Identified further capabilities that will add significant value for users