SYNOPSIS: Addressing the Data Bandwidth Barrier for Interplanetary Missions

Science Yield improvemeNt via Onboard Prioritization and Summary of Information System

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Improving Mission Science Yield

Onboard science autonomy can improve science yield for interplanetary missions (by summarizing/prioritizing data when transmission bandwidth is low). However, there is no system to coordinate data prioritization across multiple autonomy algorithms.

SYNOPSIS is a reusable framework for multi-instrument data prioritization. It enables a transition from "collect some, return all" to "collect much, return best" with:
1. Content-based prioritization
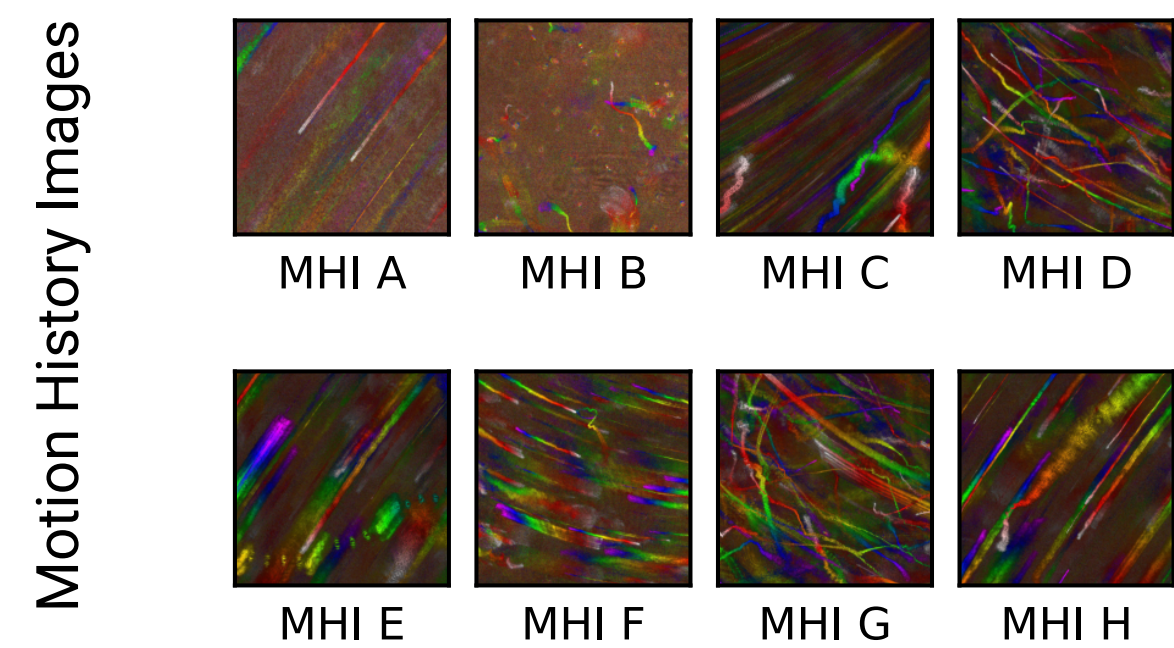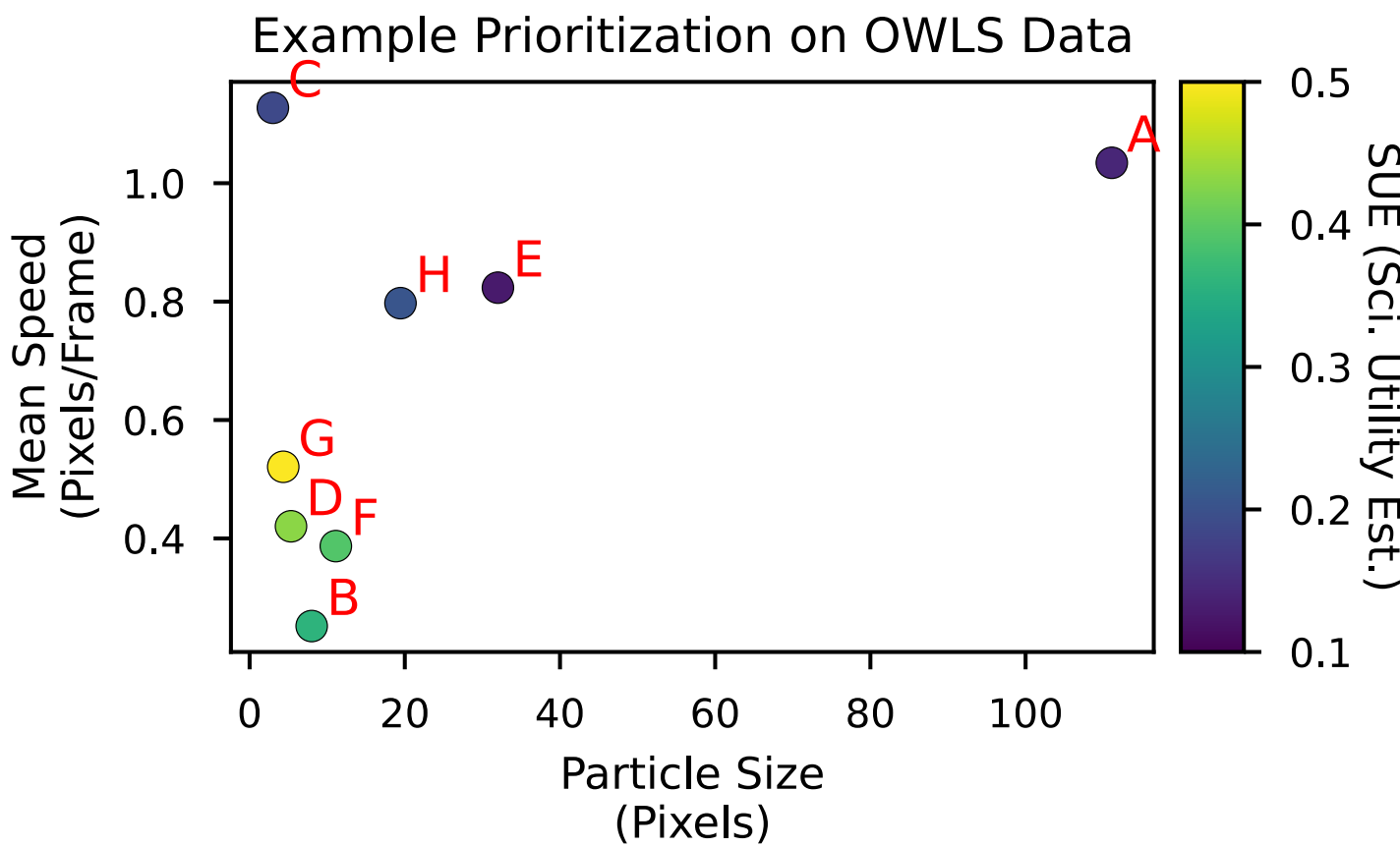2. Rules-based prioritization

System Diagram
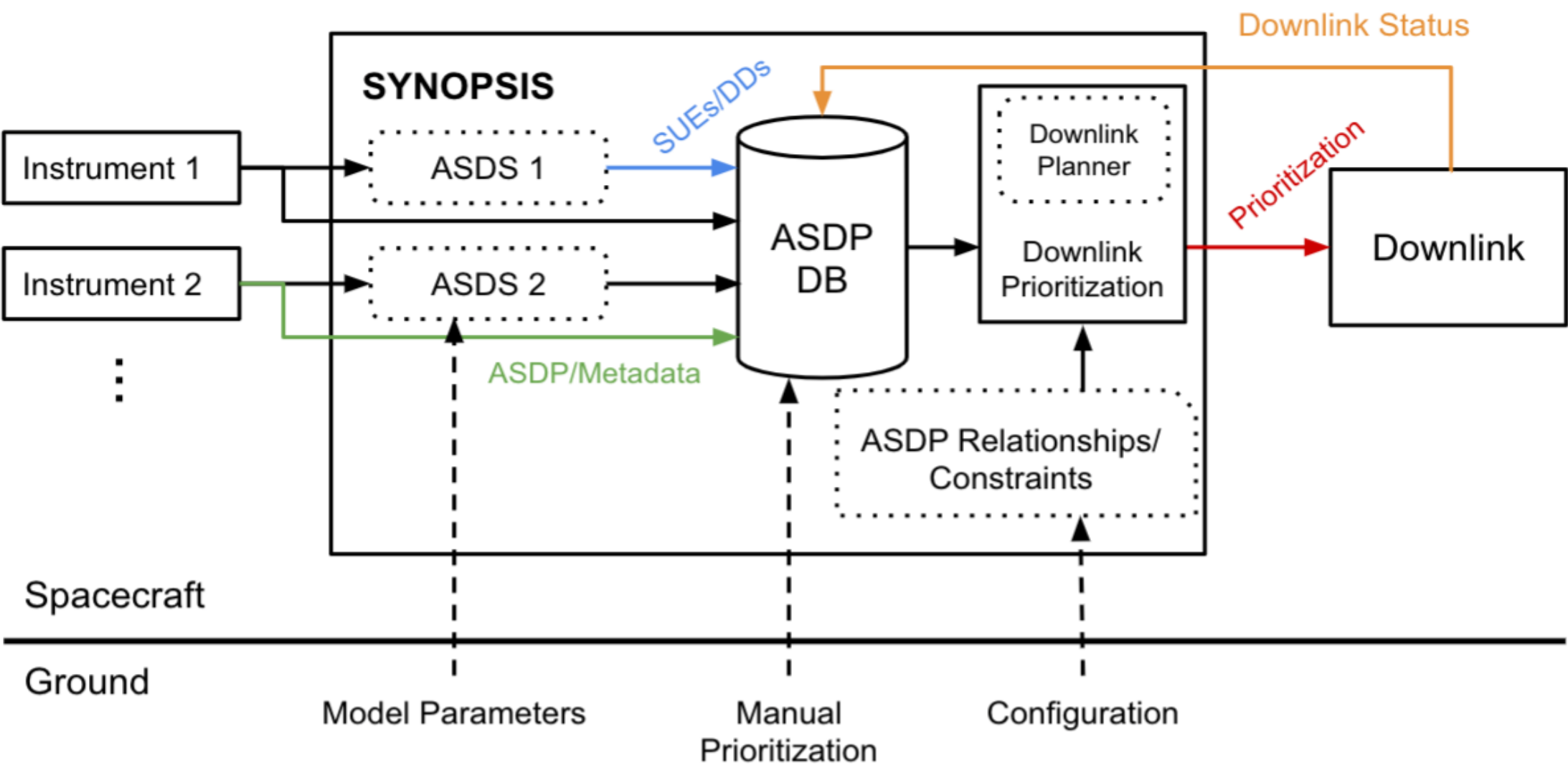
SYNOPSIS collects, stores, and prioritizes data for downlink. Autonomous Science Data Systems (ASDSs) process science data to produce ASDPs (green) with associated SUEs, DDs, and DQEs (blue) for prioritization. Directly before downlink, data is prioritized (red) to to determine a downlink sequence that maximizes science yield. Science/Ops teams can customize dashed components.

Content-based Prioritization

SYNOPSIS uses three products to rank science data for downlink. Any science autonomy algorithm that generates these quantities is SYNOPSIS-compatible.

1. **Science Utility Estimate (SUE)**: Float providing a quantitative estimate of scientific value
2. **Diversity Descriptor (DD)**: Vector describing content and providing a method to compare science observations
3. **Data Quality Estimate (DQE)**: Float value capturing any data quality problems identified through a battery of onboard checks

Example Prioritization on OWLS Data

Motion History Images

MHI A   MHI B   MHI C   MHI D

MHI E   MHI F   MHI G   MHI H

| Ranking	Utility Only	Balanced	Diversity Only
0	G	G	G
1	D	F	A
2	F	H	F
3	B	C	C
4	H	B	B
5	C	A	H
6	A	D	D
7	E	E	E

Three Prioritizations

SYNOPSIS applied to life detection task. Microscopy observations containing evidence of swimming microorganisms can be prioritized in different ways.

Rules-based Prioritization

SYNOPSIS permits use of arbitrary rules to shape prioritization order. These rules embody constraints and/or cross-instrument instrument relationships.

SYNOPSIS rules use the following inputs:

- **Variables**: Autonomy products/metadata
- **Application expression**: when to apply a rule
- **Adjustment rule: how to quantitatively adjust the SUE**
- **Constraints**: limits on the size/number of downlinked products
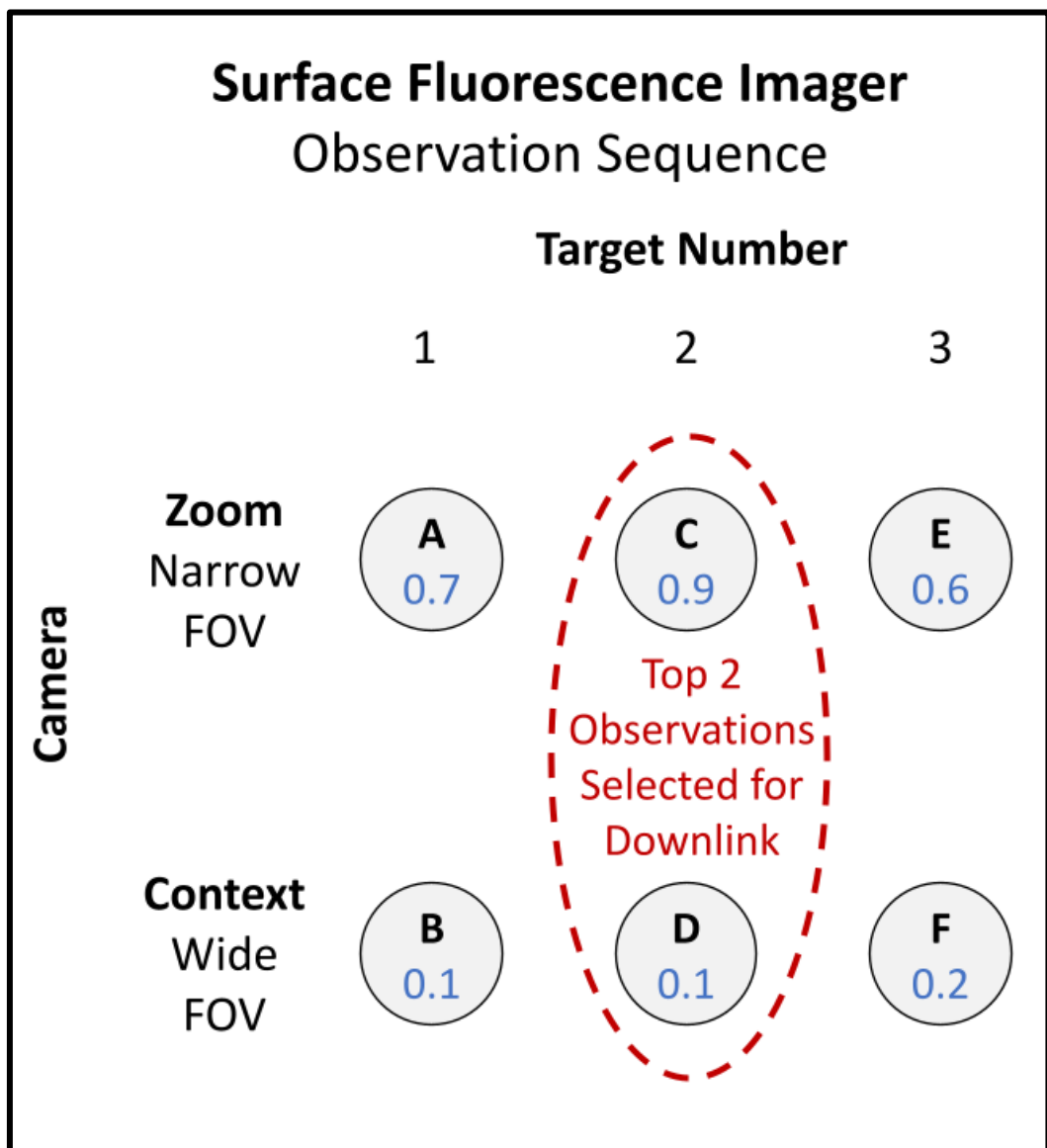
Prioritization rules can be used to enact cross-instrument relationships and change downlink order.

Enabling the Science Autonomy Community

The SYNOPSIS project aims to help deploy science autonomy through a:
- Reusable framework for prioritizing data products produced by one or more autonomy algorithms
- C-based library (and Python wrapper), which facilitates integration with existing flight software packages
- Algorithm zoo that serves as a community-driven collection of science autonomy algorithms

Flight Software Integration

To ease infusion into missions, we are integrating SYNOPSIS into:
1. cFS [1] – a generic flight software architecture framework used on flagship spacecraft, human spacecraft, and cubesats. This integration is led by NASA's Jon McBride Software Testing and Research (JSTAR) team.
2. F Prime [2] – a software framework for the rapid development and deployment Jef spaceflight applications

SYNOPSIS Website

Acknowledgements and References

[1] core Flight System; Overview: https://cfs.gsfc.nasa.gov/ Code: https://github.com/nasa/cFS
[2] F Prime; Overview: https://nasa.github.io/fprime/ Code: https://github.com/nasa/fprime