D-SHIELD: Distributed Spacecraft with Heuristic Intelligence to Enable Logistical Decisions

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D-SHIELD + Soil Moisture Monitoring for Uncertainty Minimization

**Product:** Suite of scalable software tools that helps schedule payload operations of a large constellation, with multiple payloads per and across spacecraft, such that the collection of observational data and their downlink, results in maximum science value for a selected use case.

Project Technologies

Basic modules
+ Payload module
+ Ground Module
+ Power/Data module
+ New Science Simulator
+ New Scheduler

Ground Points (GP), Field of Regard (FOR), Current Sat States (S)

Access times (A) per satellite, GP, off-nadir angle

Ground Points (GP), Field of Regard (FOR), Current Sat States (S)

Data bundle priority (BP), Inter-sat distances

Prev GPs seen

Power, Slewing times per satellite (\( \dot{J} \)), Satellite-Ground pairs (s-gp, s-gp)

Bundle delivery latency (L) per satellite pair, per observed GP

Bundle traffic generated (N)

Value i per GP, Spatial \( T_i \), Temporal \( T_i \)

Schedule of pointing commands (\( \Omega = \text{path}_{\text{sat}}[gp, t_i] \))

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Received Bundles (S, \( \Omega \), GP, i )

Satellite ACS characteristics (X) + GP, S

Comm specs (C), Protocol (s ), Contact Plan (\( K = f(S) \))

Bundle Broadcast (i , GP, \( \Omega \), S)

Orbital Mechanics

Attitude Control

Communication

Scheduling Optimization

(Dynamic Programming, validated with Mixed Integer Programming)
Agile Spacecraft Constellations Maximizing Coverage and Revisit

- Small Sat constellation + Full-body reorientation agility + Ground scheduling autonomy = More Coverage, for any given number of satellites in any given orbits
- Using Landsat as first case study (710 km, SSO, 15 deg FOV) w/ a 14 day revisit. Daily revisit needs ~15 satellites or 4 satellites with triple the FOV.
- Assuming a 20 kg satellite platform for option of agile pointing
- Scheduling algorithm allows 2 sat constellation over 12 hours to observe 2.5x compared to the fixed pointing approach. 1.5x with a 4-sat constellation
- Extendable to monitoring applications (e.g. coral reefs)

Agile Spacecraft Constellations Maximizing Coverage and Revisit

*Over 12 hours of planning horizon using 2 satellites, 180 deg apart in the same plane:*

- Using our **proposed DP algorithm**
- Using a **fixed Landsat sensor**, as is

Adding onboard autonomy to flight software + inter-sat communication to the constellation can improve science-driven responsiveness?
If longest latency < shortest gap, for pairs with the same priority
=> each satellite can be considered fully updated with information from all others, i.e. perfect consensus is possible, in spite of distributed decisions made on a disjoint graph.

Appropriately low latency in information exchange enables the onboard scheduler to observe ~7% more flood magnitude than a ground-based implementation.

Both onboard and offline versions performed ~98% better than constellations without agility.
Questions?

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Project Relation to NOS Concept

• Brief description of where your project fits into a NOS concept. For example but not limited to:
  • onboard data understanding and analysis;
  • inter-node coordination (including comms, standards, ontologies, commands);
  • Planning, scheduling and decision making;
  • Interaction to science and forecast models;
  • Cybersecurity

• Include graphics or pictures if appropriate.