2018 Workshop on Autonomy for Future NASA Science Missions

October 10-11, 2018

DRM Breakout Report

Earth Science Working Group

Marge Cole, Mike Little, Jacqueline LeMoigne-Stewart, Matthew Tarascio, Joel Johson, Philip Koopman, James Donlon, Eric Frew, Lisa Callahan, Martyn Clark, Sujay Kumar, Gerald Bawden, Mike Seablom, Mahta Moghaddam, Graeme Smith, Lena Braatz, Catherine Pavlov, Mark Cheung, Andrew Sabelhaus, Steve Chien, Jason Hyon, Steve Kepko, Tom Wagner, Barry Lefer, Jared Entin,

DRM Autonomy Summary- Earth Science

DRM Scenario	Autonomy Requirements/Goal	Key Question & Knowledge Gaps	Technology Innovations and Partnerships	Current SOA, Projects and Products
ES-1 (line 8) Demand-driven Observing	• Autonomy algorithms, prioritization, schedulers, instrument control algorithms, aim-able instruments	• Human-machine interface issues • Safety issues • Security issues	• Integration of in situ, airborne and orbital observations along with USGS, EPA, DoD, ESA et al	• Software defined instruments in infancy, previous AIST Sensor Web Projects, AIST18 solicitation, AIST NOS Testbed
ES-2 (line 9) Model-driven Observing Strategy	• Algorithms for autonomy, prioritization,	• How to coordinate output of models with observing system? • Orbital comms	• Integration of models with NOAA, EPA, USGS • Integration of research models inside NASA • NSF modeling technology	• Operational and research models are currently batch and need to be continuous • Internodal comm inadequate
ES-3 (line 10) Phased array station keeping and reconfiguration	• Identification of priority observing opportunities and direction to satellites in formation.	• Latency and response rate for aiming array • How accurately need to keep station? • Can we compensate for relative motion or do we need rigid array (by instrument type)?	• DoD, ESA	• Today, all configuration information is obtained through post-processing of GNC • Intercalibration technologies needed
ES-4 (line 11) String of Observations (observe tornado life cycle)	• Identification of priority observing opportunities and direction to satellites in-trail.	• Data volume for downlinking? • Human-machine interface	• DoD, ESA	• Need Intersatellite comm and, later, need standards for multiparty functions
ES-5 (line 12) Intelligent Observation Strategy (reduce unsuccessful measurements)	• Identify selectively observations to make • Rapidly adjust mission plan	• Identify precluding conditions • Onboard decision making	• DoD, ESA, NSF, ONR	• Same as ES4 • AIST14 – Ball Aerospace

Model Driven Observing Strategy DRM

ITEM	Question	Response
A	Describe a specific Design Reference Mission objective or mission requirement to be addressed with autonomy.	MODEL DRIVEN OBSERVING STRATEGY. In one use case, operational models are used to determine which measurements are needed to improve the forecast skill level of the model. The model identifies a region for forecast skill has deteriorated and will eventually become unacceptable. It identifies the observations needed to regain adequate skill and passes the requirements to the observing system manager which determines what observing assets (in situ, orbital or airborne) can meet the requirements, adjudicates conflicting priorities for tasking and assigns the tasking and verifies the work flow for obtaining the results and inputting into the model and checks the improvement. In a second, research, case, the research model determines what measurements are needed to improve the understanding of the phenomenon.
B	Describe an autonomous capability that could be used to accomplish (A).	*Selection of the appropriate asset, resolving conflicts and issuing the necessary tasking without human intervention. It monitors workflow, detects and compensates for faults and verifies completion of the improved forecast.*
C	List the core autonomy technologies needed by (B). Refer to the Autonomous Systems Taxonomy table for technologies.	*Algorithms for use in autonomy, retasking, optimization of multiple assets, dynamic recalibration on-orbit, intelligent data understanding, low-load algorithms for detecting desired observations.*
D	List any other supporting technologies needed by (B), including assets from potential commercial partners.	*(1) On board processing, (2) adaptive computer security (3) models capable of continuous operations and identifying regional degradations (4) assimilation models supporting irregular input, (5) collision avoidance as collaboration with other assets (i.e., non-NASA), (4) autonomous mission evaluation, including testing, safety evaluation, threat detection.*
E	List any related/relevant R&D projects for (C) and (D). Include references (e.g. citation, URL, name of PI, name of org or private sector company performing the research).	*AIST-18, HPSC, Intercalibration among instruments, DoD security, blockchain logging, legacy AIST projects, SoilScape, TAT-C, Multi-platform mission planning and operations, CYGNSS, TROPIC, ASTERIA, AIST ground test bed*
F	Is (B) enabling or enhancing for (A)? Can this capability <u>only</u> be enabled with autonomous technology? Explain.	*Humans in the loop cannot provide sufficient response to manually task instruments and platforms (need low latency).*
G	Provide a rough estimate of the development costs for (B), and describe how (B) will increase (or decrease) overall mission cost (development or ops). Cost can be $, schedule, staffing, etc.	*$20M in four years, ±$5M, ±2 years to get to a ground-based test bed demonstration*
H	Describe how (B) will increase (or decrease) mission risk (development or ops). Risk can be performance, schedule, etc.	*This represents a major shift in the design of missions, including transient and transitional phenomenon and events and is radically more complex. This would require a progressive demonstration of the capabilities and eventually a demonstration of the science value of such observing strategies which are dependent upon the autonomy. Full implementation would be degradable to a manually operated mission with substantial reduction in science data.*
I	Optionally list any comments, key points, questions, etc. not covered in the sections above.	*See attached*

Implications of Autonomous Missions in Earth Science Observing Strategies

- Prioritization of the observation of transient and transitional phenomena in comparison to global mapping missions. This involves use of multiple platforms to answer science questions.
- Accept more risk
- Observing strategies involving multi-disciplinary science should be prioritized. The relevant science community owns the observing strategy and instruments.
- At Senior Review, consider re-directing satellites for use as technology experiments after initial mission objectives have been met.
- Improve incentives for interorganization collaboration on proposals for flight missions
- Formulate policy about command uplinks without humans in the loop to the ISS
- Explainable AI (XAI) is essential to gaining ES community infusion
  - http://home.earthlink.net/~dwaha/research/meetings/ijcai17-xai/

Near-term experiments in key issues

The number of existing low-Earth orbital assets offers opportunities to run experiments and obtain real world insight into many of the issues

- Using OCO-3, experiment with targeting strategies as a tech demo
  - Apply prototype targeting schemes to see what we might have obtained compared to the one used
- Re-use Tropic and Cygnss to test re-targeting strategies with autonomy
- Provide foundation for autonomy to be called out in next Decadal Survey

Candidate DRM White Papers

Propose one or more white papers that should be published in order to define and promote the key autonomy innovations identified by this working group.

- Autonomy in Model driven Earth Observing Strategies
  - A description of the Design Reference Mission with use cases in both weather and flood forecasting and the functional needs for autonomy to make such a mission yield the science benefits.
- Smart Train Retargeting
  - The A-train demonstrated the value of studying a phenomenon or event with multiple instruments. With more capable satellites and aimable instruments, coordination of these measurements can occur at a higher frequency, providing coverage of more events.
- Policy and cultural implications of the application of autonomy to Earth science observing strategies
  - Many changes to the existing mission and science culture will be needed to realize the science opportunities created by multiple autonomous platforms. Some policy changes will also be needed to enable proposals of multiple platform, autonomous observing missions.