2018 Workshop on Autonomy for Future NASA Science Missions

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DRM Breakout Report

Ocean Worlds

Group Members

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Cryobot Concept Mission

ITEM	Question	Response
A	Describe a specific Design Reference Mission objective or mission requirement to be addressed with autonomy.	Detect life in an unknown ocean worlds environment without human in the loop – cryobot mission EA = Engineering Autonomy SA = Science Autonomy
B	Describe an autonomous capability that could be used to accomplish (A).	*EA1: autonomous descent through the ice shell to the ocean* *EA2: autonomous under-ice roving* *SA1: perform real-time adaptive science with limited a-priori knowledge*
C	List the core autonomy technologies needed by (B). Refer to the Autonomous Systems Taxonomy table for technologies.	*EA1: 4.4, 1.4 , 4.1 for autonomy, 2.5, 2.6* *EA2: 2.3, 2.4* *SA1: 1.3,1.5 science, 1.6 ,2.7*
D	List any other supporting technologies needed by (B), including assets from potential commercial partners.	*Decision making algorithms (machine learning) - industry* *Sensor data integration - industry* *Supporting technologies*
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).	*look into this …*
F	Is (B) enabling or enhancing for (A)? Can this capability <u>only</u> be enabled with autonomous technology? Explain.	*Enabling – one way light time prohibits human-in-loop; probe cannot stop; unknown conditions limit predefined sequences, real-time science discovery essential*
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.	*2.6, 4.1 needs long time-frame research for EA* *2.7 needs long time-frame research for SA* *funds TBD*
H	Describe how (B) will increase (or decrease) mission risk (development or ops). Risk can be performance, schedule, etc.	*N/A cannot do A without it*
I	Optionally list any comments, key points, questions, etc. not covered in the sections above.	*Need to clarify V&V for autonomous systems* *EA and SA - Need program to validate autonomous long-lived ops and science in relevant environment like Artic,*

Crevasse Explorer Concept Mission

ITEM	Question	Response
A	Describe a specific Design Reference Mission objective or mission requirement to be addressed with autonomy.	Detect life in an unknown ocean worlds environment without human in the loop – active crevasse entry mission EA = Engineering Autonomy SA = Science Autonomy
B	Describe an autonomous capability that could be used to accomplish (A).	*EA1: autonomous mobility to edge of crevasse* *EA2: autonomous mobility into crevasse* *SA1: perform real-time adaptive science with limited a-priori knowledge*
C	List the core autonomy technologies needed by (B). Refer to the Autonomous Systems Taxonomy table for technologies.	*EA1: 4.4, 1.4 , 4.1 for autonomy, 2.3, 2.5, 2.6* *EA2: 2.3, 2.4* *SA1: 1.3,1.5 science, 1.6 ,2.7*
D	List any other supporting technologies needed by (B), including assets from potential commercial partners.	*Decision making algorithms (machine learning) - industry* *Sensor data integration - industry* *Supporting technologies*
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).	*look into this …*
F	Is (B) enabling or enhancing for (A)? Can this capability only be enabled with autonomous technology? Explain.	*Enabling – one way light time prohibits human-in-loop; probe cannot stop; unknown conditions limit predefined sequences, real-time science discovery essential*
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.	*2.6, 4.1 needs long time-frame research for EA* *2.7 needs long time-frame research for SA* *funds TBD*
H	Describe how (B) will increase (or decrease) mission risk (development or ops). Risk can be performance, schedule, etc.	*N/A cannot do A without it*
I	Optionally list any comments, key points, questions, etc. not covered in the sections above.	*Need to clarify V&V for autonomous systems* *EA and SA - Need program to validate autonomous long-lived ops and science in relevant environment like Artic, Ice sheets …*

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.

- Engineering autonomy for traveling through cryo-ice
  - <White paper abstract>
- Autonomous adaptive science with limited a-priori knowledge
  - Covers both geology and life detection
- Autonomous ocean exploration
  - Covers ice-ocean roving and free-swimming
- Autonomous crevasse exploration

DRM Working Group Guidelines

THIS SLIDE FOR GUIDANCE ONLY – REMOVE PRIOR TO PLENARY REPORT-OUT PRESENTATION

- Three key questions to help guide your autonomy concept brainstorm:
  1. What capabilities that are critical to your DRM can only be accomplished with advanced autonomy?
  2. What autonomous capability would enable expanded mission goals at reduced costs/risk, and/or improved scientific outcome?
  3. Are there any *technical* reasons why your DRMs are not possible today, and can autonomous technologies help to address those challenges?

- Scenarios that demand autonomy include (but are not restricted to):
  - Constrained communications (e.g. light-speed latency, occultations, bandwidth, etc.)
  - Time-critical decisions (e.g. crisis management, fleeting scientific anomalies, etc.)
  - Data-heavy decision processes that exceeds bandwidth (e.g. soft landing final approach)
  - System architecture simplification (e.g. local control-system feedback loops)
  - Situational complexity that exceeds the limits of useful human input

DRM Autonomy Summary

(Single-row summary for each DRM objective or requirement.. duplicate this slide if you need more rows)

DRM Scenario	Autonomy Requirements/Goal	Key Question & Knowledge Gaps	Technology Innovations and Partnerships	Current SOA, Projects and Products
<DRM mission objective or requirement>	<List of all the autonomy capabilities needed to address this DRM requirement>	<Key questions and technical unknowns in developing these autonomy capabilities>	<Key areas of required technology innovation, approach to achieve solutions, including commercial partnerships >	<Current state of the art of technology which constitutes a basis for development, including commercial systems>
<DRM mission objective or requirement>	<List of all the autonomy capabilities needed to address this DRM requirement>	<Key questions and technical unknowns in developing these autonomy capabilities>	<Key areas of required technology innovation, approach to achieve solutions, including commercial partnerships >	<Current state of the art of technology which constitutes a basis for development, including commercial systems>
[…]				
<DRM mission objective or requirement>	<List of all the autonomy capabilities needed to address this DRM requirement>	<Key questions and technical unknowns in developing these autonomy capabilities>	<Key areas of required technology innovation, approach to achieve solutions, including commercial partnerships >	<Current state of the art of technology which constitutes a basis for development, including commercial systems>

<NAME of DRM Autonomy Capability>

→ One slide for each of the autonomous capabilities needed to support a DRM object or requirement. ←
Example…
DRM Requirement: *Fetch-rover to minimize the infrastructure of the Mars sample-return platform*
<NAME of DRM Autonomy Capability>:
Slide 1) *"Long-distance AutoNav for Mars sample-fetch rover"*
Slide 2) "Autonomous reporting of opportunistic science by sample-fetch rover during traversal."

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ITEM	Question	Response
A	Describe a specific Design Reference Mission objective or mission requirement to be addressed with autonomy.	e.g. *Mars sample return: use a "fetch" rover to retrieve previously cached sample by traversing 5+ km.* <Replace this example with your response>
B	Describe an autonomous capability that could be used to accomplish (A).	e.g. *Long-distance / multi-sol autonomous surface navigation.* <Replace this example with your response>
C	List the core autonomy technologies needed by (B). Refer to the Autonomous Systems Taxonomy table for technologies.	e.g. *Sensing and perception (1.1), state estimation and monitoring (1.2), knowledge and model building (1.3), hazard assessment (1.4), motion planning (2.3), execution and control (2.4)* <Replace this example with your response>
D	List any other supporting technologies needed by (B), including assets from potential commercial partners.	e.g. *lidar with 10m range that can be accommodated on a rover, high-performance computer (better than RAD 750).* <Replace this example with your response>
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).	e.g. *"Visual Teach and Repeat (Barfoot / Univ. of Toronto)High-Performance Spacecraft Computing (STMD GCD). With some modifications, flash lidar technology from commercial partners may help to accelerate development of this capability (https://sbir.nasa.gov/SBIR/abstracts/16/sttr/phase2/STTR-16-2-T9.01-9825.html) "* <Replace this example with your response>
F	Is (B) enabling or enhancing for (A)? Can this capability only be enabled with autonomous technology? Explain.	e.g. *Enhancing - autonomous surface navigation could increase the average "speed made good" while traversing from point to point.* <Replace this example with your response>
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.	e.g. *This capability will require investment comparable to the development cost of MSL AutoNav. This capability would decrease the amount of time required for surface operations, with corresponding reduction in mission control cost.* <Replace this example with your response>
H	Describe how (B) will increase (or decrease) mission risk (development or ops). Risk can be performance, schedule, etc.	e.g. *This capability would greatly decrease ground traversal time and therefore mission operational risks associated with the probabilities of encountering rover-disabling metrological/seasonal conditions.* <Replace this example with your response>
I	Optionally list any comments, key points, questions, etc. not covered in the sections above.	e.g. *MER and MSL have previously demonstrated "AutoNav", which is sufficient for short-range waypoint driving with autonomous hazard avoidance.* <Replace this example with your response>