Challenges and Lessons Learned in the Application of Autonomy to Space Operations

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Extended Abstract

NASA's Space Operations Management Office (SOMO) is working toward a goal of providing an integrated infrastructure of mission and data services for space missions undertaken by NASA enterprises. A significant portion of this effort is focused on reducing the cost of these services. We are interested in the potential of autonomy to reduce operations costs. SOMO services support space missions, but are not part of the mission objectives; therefore the level of acceptable risk is very low. In fact, SOMO could be effectively prevented from applying autonomy if customers merely *perceive* it as adding risk to their mission(s). We are interested in this workshop from the standpoint of understanding what can be done to realize the potential cost savings due to autonomy while maintaining acceptable risk and serving the needs of our customers. We would like to present our lessons learned so far in adopting autonomy and automation, which we think will contribute to clarifying the challenges facing the use of such technology.

SOMO provides services to a diverse and ambitious set of mission customers. Many of these missions are groundbreaking missions for which communications, data, and other operations requirements sometimes cannot be clearly articulated early in the program. This motivates a need for systems that are robust in the face of unanticipated situations so that customer missions are not unreasonably constrained or impacted by "shortcomings" in SOMO services.

One of SOMO's primary goals is to realize a paradigm in which SOMO acts as a service provider to organizations that fly space missions for NASA, other government agencies, and even the commercial sector. These organizations purchase SOMO services "by the pound" as customers. We have to provide systems that are not experiments themselves, but rather stable bases from which to do bold experiments. To this end, SOMO also seeks to work closely with industry to see that robust autonomy technology gets infused into products and services for the space industry and beyond.

The potential for application of these technologies spans space-based communications networks (e.g. TDRSS) and ground-based assets including communication and tracking antenna systems, data networks, and control centers. There are several problems that are candidates for the application of autonomy, if it can be made reliable enough, including: antenna control, antenna scheduling, communication link scheduling and operation, navigation, attitude determination, fault detection, isolation, and reconfiguration (for spacecraft or ground assets), and mission-level planning and scheduling.

Some attempts have been made to apply autonomy and automation in these areas in the past with varying degrees of success. We will present relevant case histories and the lessons inferred from them. Combining this past experience with anticipated future needs, we can clarify the challenges that must be met in order to realize the benefits of autonomy.

Related Work

SOMO has established a technology development pipeline to identify, develop, integrate, validate, and transfer/infuse advanced technologies that will increase the performance, provide new capabilities, and reduce the costs of providing data and mission services to customers. Additionally, the pipeline infuses new capabilities into commercial practice for the benefit of both NASA and the Nation. SOMO-funded tasks serve to improve and/or reduce the cost of SOMO-provided services, or provide the technology advancement to enable the introduction of new services. To this end, five campaigns establish the technology development objectives of SOMO:

Advanced Communication
Space Internet

- Virtual Space Presence
- Autonomous Mission Operations
- Advanced Guidance, Navigation, and Control (GN&C)

Of these five, two are relevant to the topics covered in this workshop: Autonomous Mission Operation and Advanced GN&C.

The Autonomous Mission Operations campaign will enable the planning, design, development, and operation of missions with challenging observational or exploration scenarios. These include autonomous decision-making and control for complex navigation and guidance scenarios, collaborative robotic exploration of remote bodies or terrain, autonomous observation planning and optimization of information return, and hazard avoidance and autonomous maintenance of spacecraft operational safety. Model-based system design and operation, goal-oriented planning, and related advanced testing techniques for autonomous systems are essential elements of these approaches. System automation to (1) increase information handling and effective science return, (2) automate system responsiveness to operational activities and spacecraft driven service requests, and (3) automatically detect and respond to unplanned events is an element of this campaign.

The Advanced Guidance, Navigation, and Control (GN&C) campaign focuses on enabling the planning, design, development, and operation of missions with challenging navigation scenarios. Scenarios include (1) autonomous navigation and guidance for entry, descent, precision landing, and rendezvous & docking, (2) autonomous formation flying and constellation operations, and (3) operation in complex gravitational fields such as small body or Europa orbits, and Libration points. Many of these mission scenarios require highly responsive guidance approaches with control loops closed on the spacecraft rather than between spacecraft and ground. Autonomous maneuver decision making, planning, and execution techniques are being extended to enable distributed networks of individual vehicles to interact with one another and act collaboratively as a single functional unit. The activities in this campaign develop the techniques and subsystems to (a) enable the relative positions and orientations of vehicles to be determined; (b) develop formation flying control architectures, strategies, and management approaches; (c) develop inter-spacecraft communication techniques for constellation coordination; and (d) assess ground/flight operations concepts, trades, and accommodation requirements. Global positioning system (GPS) technologies that have been utilized for applications at the Earth are being evaluated and extended to support autonomous navigation for non-low earth orbit (LEO) missions.

By attending this workshop, I hope to enhance the payback of the SOMO technology development pipeline by looking for (1) applications for technology under development in our pipeline (2) new technology and concepts that are applicable to SOMO needs and (3) synergies between developments in our pipeline and other work proposed or on-going in the field.