

Gateway Autonomy for Enabling Deep Space Exploration

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The Gateway spacecraft is an important stepping-stone to exploration of the solar system, integrating commercial and international partners into a tightly coupled system, enabling cislunar activities, and implementing key technologies for missions to Mars. Autonomy is a capability area necessary to handle long communication outages where intervention from Earth is impossible, to prepare to operate with long communication delays that will be common in interplanetary travel, and to make spaceflight more affordable and accessible by reducing sustaining operations costs. The Gateway Concept of Operations states that one of Gateway's goals is to "focus on infrastructure and systems that will allow autonomous operations aboard the Gateway with robotics, automated systems, advanced communications, and distributed computing."

Gateway's Vehicle Systems Manager (VSM) and associated Autonomous Spacecraft Management Architecture (ASMA) are key products towards delivering autonomous capability. The primary functions of the control architecture are Mission Management and Timeline Execution, Resource Management, Fault Management, and Vehicle Control and Operation (VCO). In each of these areas, there is an initial level of capability to be delivered at launch, with plans to continue development and grow to greater capability. The initial deployment of VSM will focus on maintaining vehicle safety by focusing on full fault management capabilities and deploying only enough resource and timeline planning functionality to support that. The final deployment of VSM will add significant planning and control optimization functionality to support nominal operations for up to 21 days without ground support, even accommodating fault and failure conditions. While the VSM is the vehicle-level representation of autonomous reasoning, distributed automation is essential to provide the right scope and abstraction of information to process. Module and system support of automation and simplicity of interfaces are two important design paradigms that Gateway is focusing on to garner a systems approach to autonomy. Distribution of reasoning can increase complexity, so Gateway is also taking a strict hierarchical approach to information flow and decision making.

VSM is not the only capability necessary to achieve an autonomous spacecraft. Robotics support for maintenance of the spacecraft will be essential to provide continued vehicle functionality even when crew is not present. Technical and programmatic challenges exist when implementing autonomous robotics operations. These challenges include sufficient network flexibility to support data transfer to the rest of the vehicle to coordinate module-to-module robotic walk-offs and finding the proper interfaces to allow sufficient dexterity. Communication system upgrades planned for Gateway include Delay Tolerant Networking to best utilize the complex network of relays that will be part of mature cislunar operations. Distributed computing and management will provide failure tolerance, robustness, and growth of capabilities while still allowing significant reuse of heritage software on heritage systems as well as reuse of common applications across a spacecraft to minimize new development, but this requires adherence to key standards and interfaces.

The Gateway program has demonstrated significant progress towards these capabilities and has identified challenges other spacecraft developers should be aware of from the start.