Automation and autonomy are key elements in realizing the vision for space exploration. Constellation systems that would benefit from automation and autonomy include crewed vehicle systems, surface robots, habitats, and infrastructure (in situ resource utilization, power systems, etc.). Needed capabilities range from decision support systems in Mission Control to autonomous robotic operations for the Moon and Mars. These capabilities will be instrumental for decreasing workload, reducing dependence on Earth-based support staff, enhancing response time, and releasing crew and operators from routine tasks to focus on those requiring human judgment. In addition, significant reductions in Mission Risk can be achieved through the use of automated checking and enforcing of flight rules and constraints.

The NASA Exploration Technology Development Program (ETDP) has been developing a set of core autonomy capabilities that can adjust the level of human interaction from fully supervised to fully autonomous. To further the application of adjustable automation and autonomy, development is needed in three broad areas:

- Execution tools;
- Decision support systems;
- Trustable systems.

Execution Tools

Executives are a key autonomy capability. However, support tools are needed to facilitate the authoring and validation of execution scripts. Tools that are not tied specifically to one executive would provide NASA the most flexibility in applying such tools across projects. Examples of needed capabilities include:

- Graphical tool for monitoring and debugging plan execution;
- Graphical tool for creating and editing execution scripts;
• Tools for authoring and validating execution plans;

• User friendly abstraction of low-level execution languages by adding syntactic enhancements.

**Decision Support Systems**

Decision support systems amplify the efficiency of operators by providing the information they need when and where they need it. As the complexity of the constellation system increases, so must the capabilities of decision support systems. Decision support tools are needed that:

• Command and supervise complex tasks while projecting the outcome of actions and identify potential problems;

• Understand system state, including visualization and summarization;

• Allow the system to interact with a user when generating the plan and allow evaluation of alternate courses of action;

• Integration of a planning and scheduling system as part of an on-board, closed loop controller;

• Scale up existing techniques to larger problem applications.

**Trustable Systems**

Systems that support or interact with crew require a very high level of reliability. Tools are needed that improve the reliability and trustworthiness of autonomous systems. These include:

• Ability to predict what the system will do;

• Guarantees of behavioral properties;

• Other properties that increase the operator’s trust;

• Verifiability (e.g., restricted executive languages that facilitate model-based verification).

To enable the application of intelligent automation and autonomy techniques, the technologies need to address two significant challenges: configuration management and software validation.

Reusable automation software must be adaptable to new applications without undue difficulty, and easily adjusted as the application operations change. The overhead of applying automation techniques to new applications is one of the two key obstacles to acceptance of such techniques in operations. A variation of the same issue is that of adjustment as requirements and application contexts change, which is inevitable in spacecraft operations.

The software and the adaptation to a given application must also be trusted before it can be accepted. Testing and other techniques are keys to establishing such trust and ensuring the correct function of automation systems. However, in both testing and validation, the complexity of intelligent software has proven to be a major obstacle. This has led to trust and correctness issues being another key obstacle to adoption of intelligent automation.
systems in both unmanned, and most importantly, in crewed vehicles.

Proposals in this area should address the definition of autonomy and automation software architectures that facilitate adaptation and ensure correctness.