Space Shuttle Program - Automatic Rendezvous, Proximity Operations, and Capture (Category 3)

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Abstract:

The NASA Johnson Space Center is actively pursuing the development and demonstration of capabilities for automatic rendezvous, proximity operations, and capture (AR&C) using the Space Shuttle as the active vehicle. This activity combines the technologies, expertise, tools, and facilities of the JSC Tracking and Communications Division (EE), Navigation, Control and Aeronautics Division (EG), Automation and Robotics Division (ER), and Structures and Mechanics Division (ES) of the Engineering Directorate and the Flight Design and Dynamics Division (DM) of the Mission Operations Directorate.

Potential benefits of AR&C include more efficient and repeatable rendezvous, proximity operations, and capture operations; reduced impacts on the target vehicles (e.g., Orbiter RCS plume loads); reduced flight crew work loads; reduced ground support requirements; and reduced operational constraints.

This paper documents the current JSC capabilities/tools/facilities for AR&C and describes a proposed plan for a progression of ground demonstrations and flight tests and demonstrations of AR&C capabilities. This plan involves the maturing of existing technologies in tracking and communications; guidance, navigation and control; mechanisms; manipulators; and systems

management and integrating them into several evolutionary demonstration stages.

The systems/disciplines which are key to AR&C include: tracking and communications, GN&C, docking mechanisms, manipulators, operations management, systems management, and system integration. The white paper describes the current capabilities and associated technology readiness levels, system tradeoffs, key development needs, tools and facilities (in place and needed), development schedules, and related industry activities for each of these systems and disciplines.

The key technology needs for each of these systems for the proposed set of AR&C demonstrations are summarized as follows:

Tracking and Communications:

- Development of laser sensors (e.g., range finder, proximity operations sensors, and capture/release sensors)
- GPS development, ground test, and flight test

GN&C:

- Selection of applicable proximity operations translational state targeting and guidance
- Upgrade of Orbiter proximity operations navigation (e.g., incorporate GPS and/or laser sensor)
- Upgrade of Orbiter On-Orbit Flight Control System for automatic stationkeeping and blended translation/rotation control

Docking Mechanisms:

- Increased sophistication in controllers/sensors (e.g., active docking mechanisms, contact sensors, mechanisms controllers)
- Integration of sensors and controllers with mechanisms

Manipulators:

- Addition of real-time sensors (e.g., point of resolution position and attitude, force and torque sensors, proximity operations sensors) to support an enhanced autosequence mode
- Automated track and capture capability for SRMS

Systems Management:

- Enhanced displays for monitoring and control during proximity operations (e.g., Crew Optical Alignment Sight (COAS)/Target icon display, relative motion trajectory plots)

- Real-time collision risk assessment for capture/release operations

Operations Management:

- Flight qualifiable automatic mission replanning expert system

The key AR&C system development and integration needs include:

- Development of operations ground rules and flight rules for candidate automatic systems

- Merging software point designs and related hardware prototypes into integrated systems
- Incorporation of AR&C demonstration hardware and software into the host vehicle (e.g., Orbiter) without compromising the integrity of the operational flight system

- Development of a Rapid Integrated Prototyping Environment (RIPE) Lab for integrating AR&C analyses

- Establishment of criteria and plans for system verification methods (e.g., engineering analysis/simulations, ground demonstration, and flight demonstrations)

Source / Sponsorship:
The proposed demonstration activity is being sponsored by NASA/JSC with the lead integration and GN&C development effort being sponsored by the Navigation, Control and Aeronautics Division. Other JSC divisions including the Tracking and Communications Division, Automation and Robotics Division, Structure and Mechanics Division, and the Flight Design and Dynamics Division are sponsoring their contributing activities.