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To: Barbara Askins, NASA/HQ, Code MD, AR&C Review
Chairperson

From: Andrew Dougherty, NASA/Goddard, Code 441, Mission
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Subject: Abstract Submittal for AR&C Review

Title: The Real-time Operations of the Space Shuttle
Orbiter during Rendezvous and Proximity Operations

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Details: The Space Shuttle Orbiter is the only U.S. spacecraft in operation today that routinely performs an orbital rendezvous with another spacecraft. The trajectory planning and training of both flight crews and ground operations personnel required to achieve a 100% success rate is considerable. The preflight planning and training can be reduced through very simple design considerations of a new space vehicle.

History: The rendezvous capability of the Space Shuttle Program was inaugurated in 1983 with the successful deployment and retrieval of the SPAS-01 satellite. The capability to rendezvous with, capture, and then repair a satellite in-orbit was demonstrated in 1984 with the repair of the Solar Maximum satellite. The program expanded the capabilities of the Orbiter with the successful SPAS/IBSS STS-39 mission. This mission demonstrated the flexibility of the software onboard the Orbiter during the 38 hour free flight of the SPAS/IBSS satellite which contained more than 20 orbital burns to study the plume contours of the Orbital Maneuvering Engines of the Orbiter. The Orbiter remained in the close vicinity of the SPAS during the entire freeflight while performing these precise maneuvers.

Maturity: The flight software of the SSP Orbiter is very mature and under configuration control at the Johnson Space Center. It is extensively tested with each new OI software delivery. It uses the Lambert targeting methodology.

The ground software used by controllers in the Mission Control Center also uses Lambert Targeting, but contains many features not found in the flight software. It allows much greater flexibility in planning and trajectory redesign than the onboard software. Few enhancements to either the flight or ground software have been made. Mostly due to the complexity of the change process and the significant cost of those changes.

Results: The successful operation of the Space Shuttle Orbiter are accomplished by utilizing both the onboard and ground software, but the software is different. There is little commonality between the software, different user interfaces (the very same software used for premission planning and real-time operations have vastly different interfaces), significantly different capabilities. This means maintaining two or more sets of software. Much can be gained by unifying the software used in flight and premission operations.

The knowledge and techniques required to execute an orbital rendezvous and capture is vastly different than the ascent, aborts, and re-entry phases. Specialization to an on-orbit pilot and reflight of crews with rendezvous experience would reduce the amount of training required.

In ground operations, a specialized cadre of controllers is used in Shuttle operations during rendezvous operations. The responsibilities and functions of the controllers is still spread among several positions. This is due to the decades old software and hardware used in the Mission Control Center. A modern, distributed, workstation based control center should be mandated. The ability to easily and quickly upgrade both the software and the hardware it is hosted on should be designed into the infrastructure of the program. The use of graphical displays and expert system-like software to assist the controllers in fault detection, isolation, and reconfiguration should be used. The premission planning and onboard software should be similar, if not identical, to enable the premission design team and the real-time controllers to be the same people and reduce the amount of software configuration management required.

Spacecraft operations must be included in the design requirements of any new spacecraft capable of Rendezvous and Capture operations. Unless considered early in the design phase, these requirements impose very costly redesign efforts or very restrictive limitations on the operations of the vehicle. You could end up like Space Station Freedom whose solar arrays are damaged during an Orbiter approach due to plume impingement effects. Another example of plume effects was on the OMV, where the short range radar and

communication antennas were in the direct flowfield of the orbit transfer engines, probably with the same result as the SSF solar arrays.

Another example from OMV was the requirement for a high level of autonomy in the onboard rendezvous software, but the solar array/battery combination was so underpowered that the vehicle had to be 'put to sleep' for so much of the orbital mission that little of the autonomy was ever realized by the program. The OMV is a pretty good place to look to find out how not to build a new vehicle for rendezvous and capture operations.

Funding: All the experience gained of the Rendezvous and Proximity Operations capabilities of the Space Shuttle Orbiter were gained at the Johnson Space Center.