Facility (PABF), using a MMU qualification-unit and EVA Retriever, can support physical integration of the MMU and AR&C systems.

Questions were addressed at the end of the presentation: Can the range of the MMU extend beyond 300 feet? Yes, but at this time a mission rule limits the range to 450 feet. Can an unmanned MMU be considered for an AR&D demonstration flight? Yes, but we want to make sure to provide safety/override capability in the event of an anomaly. What is the astronauts' reaction to the Auto R&D scenario? They do support the effort, but when safety reviews come up, the job of selling the idea gets harder.

S32-16
N93-21439
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p. 2

The Realtime Operations of the Space Shuttle Orbiter during Rendezvous and Proximity Operations

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The Shuttle first demonstrated the capability to perform precision proximity flying in 1983 when the SPAS-01 satellite was deployed and subsequently retrieved. This flight was intended to validate the capability of the Shuttle to perform proximity operations with a co-orbiting vehicle in preparation for the Solar Maximum Repair mission of the next year.

STS-39 was flown in April 1991 and contained the most complex relative trajectory flown by the Shuttle yet. Existing onboard targeting algorithms were used to plan and execute the complex flight profile. New techniques for using the software had to be developed to support the trajectory and they proved to be more accurate than the ground software in executing maneuvers.

Shuttle rendezvous operations have two segments: phasing and "the day of rendezvous." Phasing begins at lift-off and ends when the range to the target is approximately 40 nmi. The "day of rendezvous" phase of operations covers the last 40 nmi to the target. The name comes from the fact that most of the maneuvers executed during that last day are computed onboard, providing a functional difference.

Shuttle proximity operations cover the final phase of the rendezvous. The phase is characterized by crew control of the trajectory based on radar data and out-the-window viewing of the target. It begins immediately after the last rendezvous burn and ends with the successful grapple of the target. A subsection of proximity operations involves the deployment and separations. There are two phases of proximity operations, the standardized transition trajectory and the final approach. As the name implies, transition trajectory is a well known and standard trajectory flown by the crew to transition the Shuttle from an interception trajectory to formation flying with the target some 130 meters in front of it on the velocity vector. The approach, however, is not as standard because it depends on the characteristics of the target. Some targets are Local Vertical/Local Horizontal (LVLH) stabilized and some are inertially stabilized. The Shuttle program prefers the target to be in a LVLH stabilized configuration for grapple and places tight restrictions on the attitude and attitude rates of the target for nominal operations via the PIP.

Many significant lessons can be learned from the Shuttle program that can reduce mission planning costs for future vehicles; for examples: unify flight design and real-time operations software, integrate the flight design and real-time operations personnel, provide a control center and flight vehicle that allows for quick software upgrades, and use new state-of-the-art software development tools to reduce configuration control.

Significant benefits to both the Shuttle and Cargo Transfer Vehicle programs could be realized by co-developing rendezvous and proximity operations software because of the commonality of the algorithms.

In summary, any vehicle that is designed to perform rendezvous and proximity operations must consider at least the following conditions in the design of the vehicle: plume impingement and contamination, sensors, visual cues, data transmission times, data presentation to the pilot, flying qualities from jet placement, and grapple operations.

S33-18
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Autonomous Rendezvous and Docking - A Commercial Approach to On-Orbit Technology Validation

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14 N93-21440

P. 7

SpARC, in conjunction with its corporate affiliates, is planning an on-orbit validation of autonomous rendezvous and docking (ARD) technology. The emphasis in this program is to utilize existing technology and commercially available components wherever possible. The primary subsystems to be validated by this demonstration include GPS receivers for navigation, a video-based sensor for proximity operations, a fluid connector mechanism to demonstrate fluid resupply capability, and a compliant, single-point docking mechanism.

The focus for this initial experiment will be ELV based and will make use of two residual Commercial Experiment Transporter (COMET) service modules. The first COMET spacecraft will be launched in late 1992 and will serve as the target vehicle. After the second COMET spacecraft has been launched In late 1994, the ARD demonstration will take place. The service module from the second COMET will serve as the chase vehicle.

The ARD mission begins with the validation state, in which the ARD payload is powered up and the payload controller (a 286 running VRTX and the Spacecraft Command Language) starts executing tasks. GPS almanac data is uploaded from the ground station and loaded into the GPS receivers on COMETs 1 and 2, allowing GPS data collection to begin.

In the ready state, COMET 1 is maneuvered into velocity vector mode in preparation for ARD, via commands from the ground station. At this point the RF link is activated and time stamped GPS and ACS data is transmitted through the link. COMET 2 begins monitoring the RF link for COMET 1 transmissions.

In the rendezvous state, ephemeris data for COMETs 1 and 2 (based on ground tracking and on-orbit GPS data) are used to compute the targeting commands required for COMET 2 to rendezvous with COMET 1. The resulting command sequence is then uploaded into COMET 2 from the ground station. The COMET 2 Orbital Adjust System (OAS) begins executing the commands to reach a station keeping state near COMET 1. While still several kilometers away from COMET 1, COMET 2 will be able to receive data through the RF link.

Relative position and velocity can then be used to keep COMET 2 in a station keeping state approximately 1 km from COMET 1.

Upon successful validation of system operations by the ground station, COMETs 1 and 2 are set into the proximity operations state. Using a combination of relative GPS information, a video tracker, and video-based proximity sensor, the Translation Maneuvering System (TMS) on COMET 2 executes commands to place COMET 2 within approximately 1 m from COMET 1.

At this point, the two spacecraft enter the docking state. COMET 2 instructs COMET 1 to shut down its ACS, allowing docking to take place with a stable, yet passive, spacecraft. The docking