

Is override of automation by Cosmonauts cultural? Seemingly yes, since all unmanned vehicles sent to Mir have successfully docked automatically.

What is the terminal velocity at docking? The terminal velocity is 0.2 m/sec.

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Supervised Autonomous Rendezvous and Docking System Technology Evaluation
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P. V.

Technology for manned space flight is mature and has an extensive history of the use of man-in-the-loop rendezvous and docking, but there is no history of automated rendezvous and docking. Sensors exist that can operate in the space environment. The Shuttle radar can be used for ranges down to 30 meters, Japan and France are developing laser rangefinders, and considerable work is ongoing in the U.S. However, there is a need to validate a flight qualified sensor for the range of 30 meters to contact. The number of targets and illumination patterns should be minimized to reduce operation constraints with one or more sensors integrated into a robust system for autonomous operation. To achieve system redundancy, it is worthwhile to follow a parallel development of qualifying and extending the range of the 0 - 12 meter MSFC sensor, and simultaneously qualify the 0 - 30+ meter JPL laser ranging system as an additional sensor with overlapping capabilities. Such an approach offers a redundant sensor suite for autonomous rendezvous and docking. The development should include the optimization of integrated sensory systems, packaging, mission envelopes, and computer image processing to mimic brain perception and real-time response. The benefits of the Global Positioning System in providing real-time positioning data of high accuracy must be incorporated into the design. The use of GPS-derived attitude data should be investigated further and validated.

In the guidance and navigation area, algorithms for the design of homing trajectories for rendezvous and docking include techniques such as proportional navigation and those based on trajectory optimization using the Clohessy-Wiltshire equations. While being more fuel optimal, the latter techniques generally lead to non-intuitive trajectories not suitable for supervised rendezvous. However, a new technique (Olszewski, 1990) which allows optimized trajectory design wherein the trajectory profile can be prescribed, promises to alleviate this shortcoming.

In the control area, a variety of feedback compensator design techniques are available. While the design issues for the Linear Quadratic Gain (LQG) and H-infinity type controllers are well understood, the specific choice can be determined only on a case by case basis. The tradeoff among the methods is between performance and compensator complexity.

Fuzzy control theory remains an area needing further research, and has the potential of providing simpler controllers.

Neural networks offer tremendous potential but further development is needed. The objective of neural network implementation is to enhance the performance of existing classical model-based and adaptive schemes. Enhancement of system performance will be a result of neural network based identification of nonlinear effects such as actuator saturation and backlash and onboard control correction, including design aids to help control engineers rapidly select optimal control parameters. The neural network program is justified based on the fact that classical model-based and adaptive approaches do not compensate for nonlinear effects for areas such as actuators, contact dynamics, sensor errors, and sensor failure, and therefore system performance is degraded. Recent results indicate that neural nets are excellent nonlinear estimators, with good fault tolerance properties due to the internal redundancy in information storage. Also, since the conventional selection of correct control parameters is a very time intensive process, any updating

of control parameters during a mission would be extremely expensive. Neural nets have already been applied to numerous pattern recognition problems, and therefore their application to the gain scheduling problem is relevant. The synthesis of neural networks can lead to better interactions with the unknown environments and responses that can be expected with classical control methods and is ideally suited for the AR&D problem. Neural nets provide an efficient way to implement nonlinear estimators and do not require explicit information about the environment.

As with other elements of AR&D, the recursory capture mechanisms are available or under development, but flight credibility is yet to be established. A number of significant test beds exist in support of AR&D at government-owned foreign and contractor facilities. Full credibility is yet to be earned for ground supervised AR&D flight systems to demonstrate sensors, software, mechanisms, and proximity operations. A flight validation program should be our top priority in support of validating these test beds and methods.

The presentation and discussion afterwards brought out that there are about 40 sensors applicable to AR&D. On the open market there are many more sensors described in classified documentation.

Questions addressed include: Has a study been conducted on managing the AR&D system during communications blackout and is there onboard software to handle this contingency? There is onboard software, but ground intervention is allowed since unforeseen, unplanned events always occur. The study aspect of the question was not answered.

What type of learning is used with neural networks and where does the data come from? The data comes from computer simulation. The type of data includes the impact of various spacecraft masses, sizes, etc.

The main point of Marzwell's presentation was that the technology is available to develop an AR&D system. However, we need to do the system engineering to integrate it.

Autonomous Rendezvous and Capture Development Infrastructure

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In the development of the technology for autonomous rendezvous and docking, key infrastructure capabilities must be used for effective and economical development. This need involves facility capabilities, both equipment and personnel, to devise, develop, qualify, and integrate ARD elements and subsystems into flight programs. One effective way of reducing technical risks in developing ARD technology is the use of the Low Earth Orbit test facility. Using a reusable free-flying testbed carried in the Shuttle, as a technology demonstration test flight can be structured to include a variety of sensors, control schemes, and operational approaches. This testbed and flight demonstration concept will be used to illustrate how technologies and facilities at MSFC can be used to develop and prove an ARD system. p. 2

To maximize on-flight experiment experience and qualified equipment and minimize program risk and agency costs, the concept uses the existing Spacelab Multi Purpose Experiment Support Structure (MPRESS), as a deployable/retrievable target vehicle (by adding a cold-gas three-axis stabilization system) with accommodation for assorted sensors and subsystem tests. A small automated chase vehicle can be adapted from a Lightsat to carry ARD equipment and can fly various 6-DOF separations and approaches. The GPS can be used for rendezvous, MSFC video guidance sensor can be used for final approach, the OMV-derived three point docking mechanism for docking, and the Automated Fluid Interface system for umbilical connection. The chase vehicle is docked and locked onto the pallet after testing and integration, allowing the shuttle crew and the ground processors to handle the experiment as a single integrated payload.