range, velocity, and bearing information. Multiple targets are utilized to provide relative attitude data. The design requirements were to utilize existing space-qualifiable technology and require low system power, weight, and size yet operate from 0.3 to 150 meters with a range accuracy greater than 3 millimeters and a range rate accuracy greater than 3 mm per second. The field of regard for the system is +/- 20 degrees. The transmitter and receiver design features a diode laser, microlens beam steering, and power control as a function of range. The target design consists of five target sets, each having seven 3-inch retroreflectors, arranged around the docking port. The target map is stored in the sensor memory. Phase detection is used for ranging, with the frequency range-optimized. Coarse bearing measurement is provided by the scanning system (one set of binary optics) angle. Fine bearing measurement is provided by a quad detector. A MIL-STD-1750 A/B computer is used for processing. Initial test results indicate a probability of detection greater than 99% and a probability of false alarm less than 0.0001. The functional system is currently at the MIT / Lincoln Lab for demonstration.

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Contact Dynamics Testing of Automated Three-Point Docking Mechanism
by Kenneth H. Rourke, TRW

An evaluation of an OMV docking mechanism, based on an adaptation of the Shuttle Flight Support System Pallet Berthing Mechanism has been completed. The mechanism uses automatically actuated motorized latches to engage towel bars on the target satellite. LED sensors establish the towel bar position within the capture envelope and the latch capture commands are issued. Then, locking pawls engage the bar, locking and pre-loading the mechanism. Two series of tests were conducted to test nominal and failure mode captures and to evaluate design parameters such as LED sensor locations, automatic closure algorithms, latch closure velocity, position/velocity entry envelopes, and closure method. The first test series involved single latch testing on the Flat Floor Facility, 6 DOF Facility and an analytic simulation model. The intent was to compare results in order to validate the various facilities. Reasonably good agreement was achieved. The second test series repeated the single latch testing on the refurbished 6 DOF Facility to validate the facility modifications. The individual latches were tested under free-drift conditions for functionality and performance. Next, the three-latch configuration underwent parametric testing. Test results validated the improved fidelity of the 6 DOF Facility and verified successful docking at the required entry velocity. The tests determined the "best" design parameter definitions and concluded that the locking pawls should not lock until all three latches completely close.

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TRAC Based Sensing For Autonomous Rendezvous
By Louis Everett Texas A&M University, and
Leo Monford, NASA JSC

The Targeting Reflective Alignment Concept (TRAC) sensor is to be used in an effort to support an Autonomous Rendezvous and Docking (AR&D) flight experiment. The TRAC sensor uses a fixed-focus, fixed-iris CCD camera and a target that is a combination of active and passive components. The system experiment is anticipated to fly in 1994 using two Commercial Experiment Transporters (COMETs). The requirements for the sensor are: bearing error less than or equal to 0.075 deg; bearing error rate less than 0.3 deg/sec; attitude error less than 0.5 deg. and; attitude rate error less than 2.0 deg/sec. The range requirement depends on the range and the range rate of the vehicle.

The active component of the target is several "kilo-bright" LEDs that can emit 2500 millicandela with 40 milliwatts of input power. Flashing the lights in a known pattern eliminates background illumination.

The system should be able to rendezvous from 300 meters all the way in to capture.

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A question that arose during the presentation: What is the life time of the LEDs and their sensitivity to radiation? The LEDs should be manufactured to Military Specifications, coated with silicon dioxide, and all other space qualified precautions should be taken. The LEDs will not be on all the time so they should easily last the two-year mission.

Applicability of Relative GPS to Automated Rendezvous between the Space Shuttle and Space Station

by Fred D. Clark and Ann Christofferson
Lockheed Engineering and Sciences Co.

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The purpose of this study is to determine the adequacy of the Global Positioning System (GPS) in providing relative navigation for automated rendezvous and proximity operations. The study was performed using the Proximity Operations Simulator (POS), Lockheed's high-fidelity, six-degree-of-freedom simulation of the Space Shuttle and Space Station.

This simulation includes identical models of GPS receivers for each vehicle. The navigation software in each vehicle includes identical Kalman filters. Each vehicle estimates its own state, and the relative state vector is obtained by simply subtracting absolute states.

The GPS model includes errors in the ephemeris and clocks of the GPS satellites. Receiver clock errors and receiver noise are modeled, as well as ionospheric errors. Multipath and obscuration effects are not modeled. The receivers are modeled to provide either the precise positioning service (p-code), or the standard positioning service (C/A code). Both filters include three state vector components for position, velocity, and unmodeled acceleration bias, one component for clock bias, and one component for clock frequency error.

The Shuttle Operational Rendezvous (SOR) profile was simulated with two exceptions. First, the orbiter was targeted to cross the +Rbar below the station and intercept the +Vbar 500 feet in front of the station, rather than targeted directly to the station. Second, when the angle between the line of sight to the station and the +Vbar reached 45 degrees, the orbiter was commanded by the guidance to remain on a 45-degree glideslope for the remainder of the trajectory.

In the simulations, five different dispersions in position and velocity were used to initialize the orbiter at a range of about 100 nautical miles from the Station. Simulations were run with both p-code and C/A code models. Also, in one set of runs, estimated orbiter Reaction Control System (RCS) delta-v was used instead of Inertial Measurement Unit (IMU) data, which has a quantization level of 0.0344 ft/sec. As expected, relative position is estimated better using p-code. Relative velocity estimation is nearly identical regardless of whether p-code or C/A code is used. If delta-v is estimated without IMU, and additional process noise is added during RCS firings, relative velocity errors are halved.

Relative GPS is adequate for controlling the trajectory of the shuttle along a 45-degree glideslope until a few hundred feet from the station. A sensor capable of estimating range, range rate, and bearing would be needed to complete the final phase of an automated rendezvous and capture.