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CATEGORY 5 - SUPPORTING INFRASTUCTURE

Six-Degree-of-Freedom Test Facility

by Michelle Bittel, Lockheed Engineering & Sciences Company

Shuttle to Space Station docking has become an important issue in the last few years. Docking sensors have been proposed that will provide the high precision measurements required for the fuel efficient rendezvous and docking of space vehicles. These sensors also will be used for satellite servicing and orbital assembly. The performance of the docking sensors must be tested before they are implemented in a space environment. A 6-DOF test facility has been developed at the Tracking and Communications Section, Johnson Space Center, to test the static and dynamic accuracies of docking sensors. A candidate sensor is evaluated by comparing the sensor's static position and velocity measurements to the more accurate 6-DOF system.

The facility comprises very robust hardware. An air-bearing 12-meter granite rail system highlights the system. Five rotary stages provide rotational movement. Additional hardware supporting the facility include a GPS time receiver, a rate meter, and a metrology system. A centralized computer with associated software controls the facility. The 6-DOF facility can provide one degree of translation (range) and five degrees of rotation (bearing angles and attitude). Range accuracies are 10.0 microns/meter while rotational accuracies are $\pm$ 0.001 degrees.

The 6-DOF Test Facility hardware is fully integrated. Software has been developed in-house to support system operation. The system has been tested statically and the operational parameters verified. System accuracies remain to be determined. Dynamic testing of the facility is expected to begin shortly. Several companies (such as McDonnell Douglas, Autonomous Technologies, and General Dynamics) are scheduled to test sensors in the next few months. The 6-DOF facility will be available for use in November 1991.

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Soviet Automated Rendezvous and Docking System Overview

By Elaine M. Hinman and David Bushman/MSFC

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The Soviets have been performing automated rendezvous and docking for many years. Its has been a reliable mode of resupply and reboost for years.

During the course of the Soviet space program, the autodocking system has evolved. The earlier IGLA system has been replaced with the current KURS system. Both systems are radar-based. The variation in strength between antennas is used for computing relative positions and attitudes. The active spacecraft has a transponder. From discussions with Soviet engineers, it seems the docking process can be controlled either from the ground or from the active (docking) spacecraft's onboard computer.

The unmanned Progress resupply ships regularly dock with the current MIR Space Station. The Soyuz T spacecraft incorporated the IGLA system, and the later Soyuz TM and Progress M Series spacecraft incorporated the KURS. The MIR Complex has both systems installed. The rear port and the KVANT docking port have the IGLA system installed to support earlier Progress ships that uses the IGLA. The first Soyuz TM docking occurred In May of 1986, while the first Progress M docked in September of 1989.

Questions addressed during the presentation: How is Attitude Determined? Roll is sensed using directional antennas and both chase vehicle and Station is held in attitude hold.

What optical targets are used for contingency? The MIR optical target appears to be similar to the Apollo docking target.

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.

Supervised Autonomous Rendezvous and Docking System Technology Evaluation

by Neville I. Marzwell, NASA JPL

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 rangers, and considerable work is on-going 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