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CATEGORY 3 - INTEGRATED SYSTEMS

Proximity Operations Considerations Affecting Spacecraft Design

by Steven K. Staas, McDonnell Douglas Space Systems Company

Proximity operations can be defined as the maneuvering of two or more spacecraft within 1 nautical mile range, with relative velocity less than 10 feet per second. The passive vehicle is non-translating and should provide for maintenance of the desired approach attitude. It must accommodate the active (translating) vehicle induced structural loads and performance characteristics (mating hardware tolerances), and support sensor compatibility (transponder, visual targets, etc). The active vehicle must provide adequate sensor systems (relative state information, field-of-view, redundancy), flight control hardware (thruster sizing, minimal cross-coupling, performance margins, redundancy) and software (reconfigurable, attitude/rate modes, translation and rotation fine control authority) characteristics, and adequate non-propulsive consumables such as power. Operational concerns must be considered. These include: (1) the desired approach trajectory and relative orientation; (2) the active vehicle thruster plume effects (forces, torques, contamination) on the passive vehicle; and (3) procedures for contingencies such as loss of communications, sensor or propulsion failures, and target vehicle loss of control.

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Guideline Requirements for Serviceable Spacecraft Grasping/Berthing/Docking Interfaces Based on Simulations and Flight Experience

by A. B. Thompson, Martin-Marietta

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The described efforts support a NASA Space Assembly and Servicing Working Group activity to draft guideline interface standards. The general requirements are to provide a simple, reliable, and durable system. Interface requirements developed include lateral position offset, axial and lateral velocities, and angular misalignment. A survey of concepts and simulation studies of spacecraft docking, existing docking/end effector performance criteria, and space proven, qualified docking data was conducted and evaluated, in order to provide recommended mechanical interface guidelines and interface tolerances for manual and autonomous capture operations. The criterion for the selection of the guidelines was maximum capability to handle malfunctions. Originally the guidelines for a zero velocity docking were considered to be covered within the grasping/berthing definition. It is acknowledged that perhaps a separate category needs to be established for this option. The draft standard has been delivered to the AIAA for review, revision, and issuance as the first U.S. national standard guideline on interfaces. The intent is to develop the guidelines into an International Standards Organization standard.

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Autonomous Docking Ground Demonstration

By S.L. Lamkin, T.Quan Le, L.T. Othon, and J.L. Prather/NASA JSC
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The Autonomous Docking Ground Demonstration is an evaluation of the laser sensor system to support the docking phase (12 ft to contact) when operated in conjunction with the guidance, navigation and control software. The docking mechanism being used was developed for the Apollo/Soyuz Test Program. This demonstration will be conducted using the 6-DOF Dynamic Test System (DTS). The DTS simulates the Space Station Freedom as the stationary or target vehicle and the Orbiter as the active or chase vehicle. For this demonstration, the laser sensor will be mounted on the target vehicle and the retroflectors will be on the chase Vehicle. This arrangement was chosen to prevent potential damage to the laser. The laser sensor system, GN&C, and 6-DOF DTS will be operated closed-loop. Initial conditions to simulate vehicle misalignments, translational and rotational, will be introduced within the constraints of the systems involved.

The laser sensor system being used is a brassboard version of the Laser Docking Sensor that was being developed for application in the Lunar/Mars Programs. The laser sensor being used has been tested in the 6 DOF Sensor Test Bed (Granite Rail) in Building 14 at NASA/JSC. The Shuttle and Station models are pared down from existing models and will be validated from existing test cases. The integrated test runs currently are delayed by DTS controller hardware problems. Difficulties have been encountered thus far, but progress is continuing.

An Overview of Autonomous Rendezvous & Docking System Technology Development

by Kurt D. Nelson, General Dynamics

The Centaur upper stage was selected for an airborne avionics modernization program for many reasons. The parts used in the existing avionics units were obsolete and continued use of existing hardware would require substantial redesign yet result in the use outdated hardware. Manufacturing processes also were out of date with very expensive and labor intensive technologies being used for manufacturing. The Atlas/Centaur avionics were to be procured at a fairly high rate that demanded the use of modern components. The new avionics also reduce size, weight, power, and parts counts with a dramatic improvement in reliability. Finally, the cost leverage derived from upgrading the avionics as opposed to any other subsystem for the existing Atlas/Centaur was a very large consideration in the upgrade decision. The upgrade program is a multiyear effort begun in 1989. It includes telemetry, guidance and navigation, control electronics, thrust vector control, and redundancy levels.

The new INU combines the inertial measurement system with the flight control system into a single radiation hardened package including ring laser gyros, accelerometers, processors, and electronics. This new system resulted in a weight savings of over 100 pounds and a four-to-one cost reduction. The new Remote Voter Unit (RVU) receives commands and performs a 2 out of 3 vote on the discrete commands with a center select on the analog signals. The RVU is fully internally redundant, has been developed, breadboarded, and demonstrated. The integration of a Global Positioning System receiver into the inertial navigation system has been accomplished for both the advanced Centaur and the cruise missile programs. The capability provided by this system will meet the accuracy requirements for low earth operations independent of mission duration time. It provides precision position and velocity measurements and it can be configured to provide attitude information.

An Image Processor Assembly (IPA) is in flight test and an earlier model IPA was used in a successful proof of concept AR&D ground demonstration in November 1990. This adaptable embedded processor (of Cruise Missile heritage) is modular and can be reconfigured in real-time to perform a variety of mission functions. A unit is being built for the Autonomous Rendezvous, Docking and Landing System Test Program. A typical submodule contains a 32-bit microprocessor with four megabytes of memory. Each board can accept up to eight submodules providing processor capability of eighty 32-bit microprocessors and 320 megabytes of memory with a throughput of 800 MIPS. Modular functions include frame grabbers, graphics display drivers, interface adapters, video processors, and MIL-STD-1553 and other system interfaces. The modular parallel processor approach provides performance and flexibility to rapidly reconfigure for changes in the application environment.

The Centaur modern avionics components can be combined with the Cruise Missile image processing system and GPS to provide a fully autonomous rendezvous and docking system using off-the-shelf technology. The autonomous capability provides collision and hazard avoidance in all