NASA Explorer Platform satellite to minimize new development and accomplish a cost-effective automatic closure and capture demonstration program.

Several RV sensors have been developed at breadboard level for the Hermes/Columbus program by Matra, MBB, and SAAB. For example, the Matra laser proximity operation sensor, developed with Matra and CNES funding is based upon a flight qualified CCD sensor working together with a pulsed laser to illuminate retroreflectors mounted on the target docking side. The CCD operates in a Flash-During-Transfer (FDT) mode, enabling operation even with sunlight in the sensor FOV. The sensor has demonstrated good results at ranges out to 1 km and at proximity operation relative velocities, even with the sun in the FOV. The sensor demonstrated recently at 10 m: range accuracy to 0.8% of range (3 sigma); elevation/azimuth accuracy better than 0.02° (3 sigma); and attitude angles of the target to better than 0.25° (3 sigma) using five optical retroreflectors in a 15 cm wide pattern.

Detailed algorithms for automatic rendezvous, closure, and capture have been developed by ESA and CNES for application with Hermes to Columbus rendezvous and docking. They currently are being verified with closed-loop software simulation. The algorithms have multiple closed-loop control modes and phases starting at long range using GPS navigation. Differential navigation is used for coast/continuous thrust homing, holdpoint acquisition, v-bar hopping, and station point acquisition. The proximity operation sensor is used for final closure and capture. A subset of these algorithms, comprising the proximity operations algorithms, could easily be extracted and tailored to a limited objective closure and capture flight demonstration.

The software to implement the automatic operations has been written in C and Ada. Closed loop performance tests are in progress. These tests include the software for final approach operations (100 m to a few cm), and testing is to be complete by January 1992.

Fairchild and Matra suggest that by combining ESA and NASA resources, a complementary, cost effective flight demonstration program to demonstrate automated closure and capture could be readily structured. This joint, cooperative program would use the automated guidance and proximity operations system developed by Matra for ESA and the existing, on-orbit Explorer Platform (EP) spacecraft developed by Fairchild for NASA. These two system elements would be integrated by Fairchild with an EP-mounted docking module receiver and a maneuvering payload module (PLM) to close with and dock to the EP docking module receiver.

The proposed program would have Fairchild build the docking module to be attached on-orbit to the EP, build the payload module with a maneuvering capability that performs the docking with the EP-attached docking module (using the Fairchild-developed resupply interface mechanism), complete development of the STS procedures for on-orbit EP payload changeout to remove the current EUVE payload and attach the docking module; and accomplish the overall system integration. European Space Agency and Matra would provide the proximity operations sensor and the guidance software as well as verify the satisfactory flight hardware closure and capture on the European Proximity Operations (EPOS) simulator and/or on the CNES 6 DOF Dynamic Docking Test Facility (DDTF).

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A Method for Modeling Contact Dynamics for Automated Capture Mechanisms
by Philip J. Williams, Logicon Control Dynamics Inc.

Logicon Control Dynamics develops contact dynamics models for space-based docking and berthing vehicles. The models compute contact forces for the physical contact between mating capture mechanism surfaces. Realistic simulation requires proportionality constants, for calculating contact forces, to approximate surface stiffness of contacting bodies. Proportionality

for rigid metallic bodies becomes quite large. Small penetrations of surface boundaries can produce large contact forces.

The Method of Soft Constraints is a contact dynamic modeling technique in which surface boundary constraints of contacting bodies are enforced through application of restoring forces to the bodies when contact is detected. This technique allows small violations of the constraints. The advantages of the method are that it is relatively easy to implement and the number of constraints is unlimited.

A disadvantage of the method is that simulation run times are relatively long on most affordable computers. Usually, results are saved from a simulation and then processed by a graphics program to generate an animation. What makes the simulation take a long time? When this type of contact model is used for "force" with the system equations of motion run in a time domain simulation, the integration step must be chosen carefully. Often a very small integration time step is selected to avoid numerical instability even though this makes the simulation run time longer.

Contact force models using the Method of Soft Constraints can help evaluate capture mechanism performance, both before and after hardware production. Engineers can use simulation results in examining loads, and dynamic response characteristics as well as in stress analysis. Data can help determine size and shape of capture envelopes and can evaluate mechanisms and their controllers.

Contact force models were used to validate hardware-in-the-loop tests at MSFC's 6-DOF motion facility. Models included were: OMV, SSF docking, SSF berthing, and Apollo/Skylab. These models were incorporated in time-domain contact dynamics simulations. They were used to generate contact loads and dynamic response data.

The contact force model for Space Station Freedom contains component models for all parts of the berthing system, thus facilitating accurate simulations. Mass properties and initial conditions are given to the contact force models and the hardware in-the-loop simulation. Computer dynamic responses and contact characteristics closely match the actual results. In 1992, this model will support hardware in the loop berthing tests.

After the presentation, two questions were asked. Does the model deal with compliance between the payload and the Remote Manipulator System (RMS)? Flexibility terms were incorporated. Could berthing or docking with Space Station Freedom be accomplished without force feedback? The force feedback discussed in the presentation was only for simulation implementation and the actual docking does not require force feedback.

A Phase One AR&C System Design
By Peter Kachmar, Robert Polutchko, Marty Matusky, and William Chu/C.S. Draper Laboratory
William Jackson and Moises Montez/JSC

The Phase One AR&C System Design integrates an evolutionary design based on the legacy of previous mission successes, flight tested components from manned Rendezvous and Proximity Operations (RPO) space programs and additional AR&C components validated using proven methods.

The Phase One system has a modular, open architecture with the standardized interfaces proposed for Space Station Freedom system architecture.

As of today, the "Phase One" AR&C integrated GN&C system design is complete. The new subsystems are an integrated system executive; laser sensor and laser navigation capability for relative position, velocity, and attitude; auto maneuver execution; and trajectory controller. The