Automated Rendezvous and Proximity Operations

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Overview

IR&D efforts in recent years have focused on effective means of performing automated rendezvous and proximity operations. The primary focus for application has been to the Space Shuttle Obiter and potential derivations, such as the Reusable Cargo Vehicle (RCV), studied in FY 1990. All candidate vehicle mission scenarios have included approach to docking or berthing with the Space Station Freedom (SSF). Results to date indicate that application of appropriate guidance algorithms can reduce docking contact or relative offset conditions, resulting in potential simplification of capture systems.

Historical Development

Mr. G. Carden/Rockwell-SSD developed guidance algorithms for a controlled approach to target vehicles under 1988 and 1989 IR&D studies to review the contact conditions expected for Orbiter-SSF docking. These candidate algorithms (Guided V-Bar, Guided R/V-Bar, Range Gate, Parallel V-Bar, and Bearing Guidance) were incorporated in the Docking and Berthing Simulation (DBSIM) and executed using a "paper pilot." In order to assure equivalence between the guidance computations, a nominal relative navigation state was used, equivalent to the assumption of a laser-based docking sensor (LDS). Figure 1 presents an overview of the simulation configuration.

The resulting contact conditions were then compared to determine the algorithms exhibiting at least acceptable performance relative to the docking contact or stability conditions for berthing as defined at that time (see Figure 2). As a rule, automated control achieved or significantly improved upon the desired contact or stability criteria.

Additional considerations for automated docking or berthing included Reaction Control System (RCS) propellant consumption an plume impingement. Runtime orbiter-equivalent thruster firings were recorded and assessed using a plume impingement program to determine the total forces and moments applied to the target vehicle. Total delta velocity (delta-v) was also recorded and totalled for the approach profile to estimate the equivalent propellant requirements. This was of additional benefit in determining the sensitivity of the approach technique while demonstrating recovery to the desired approach profile given dispersed initial conditions.

Future Application

Current plans are to incorporate the automated rendezvous and proximity operations guidance algorithms into the Avionics Development Laboratory (ADL). The commands will then be used to drive ADL hardware, emulating the relative translational motion of an approaching vehicle to a capture mechanism. This provides for a three degree-of-freedom (3 DOF) motion assessment of the contact conditions, with later incorporation of an air-bearing device to provide the remaining capability to assess 6-DOF relative dynamics. ADL capability to integrate LDS hardware and incorporate sensed relative navigation signals is also under consideration in order to demonstrate fully closed-loop proximity operations with candidate sensor suites.

The ADL provides a future host site for assessing and/or validating candidate guidance and navigation concepts during rendezvous and proximity operations. Present IR&D efforts, while focused on utilization in the RCV, are applicable to studies of other potential vehicles and missions, such as lunar return, Mars visit, or even unmanned transfer vehicles. Incorporation of the driving algorithms into the ADL will provide rapid study of approach and separation techniques where the level of automation or autonomy require system level definition.

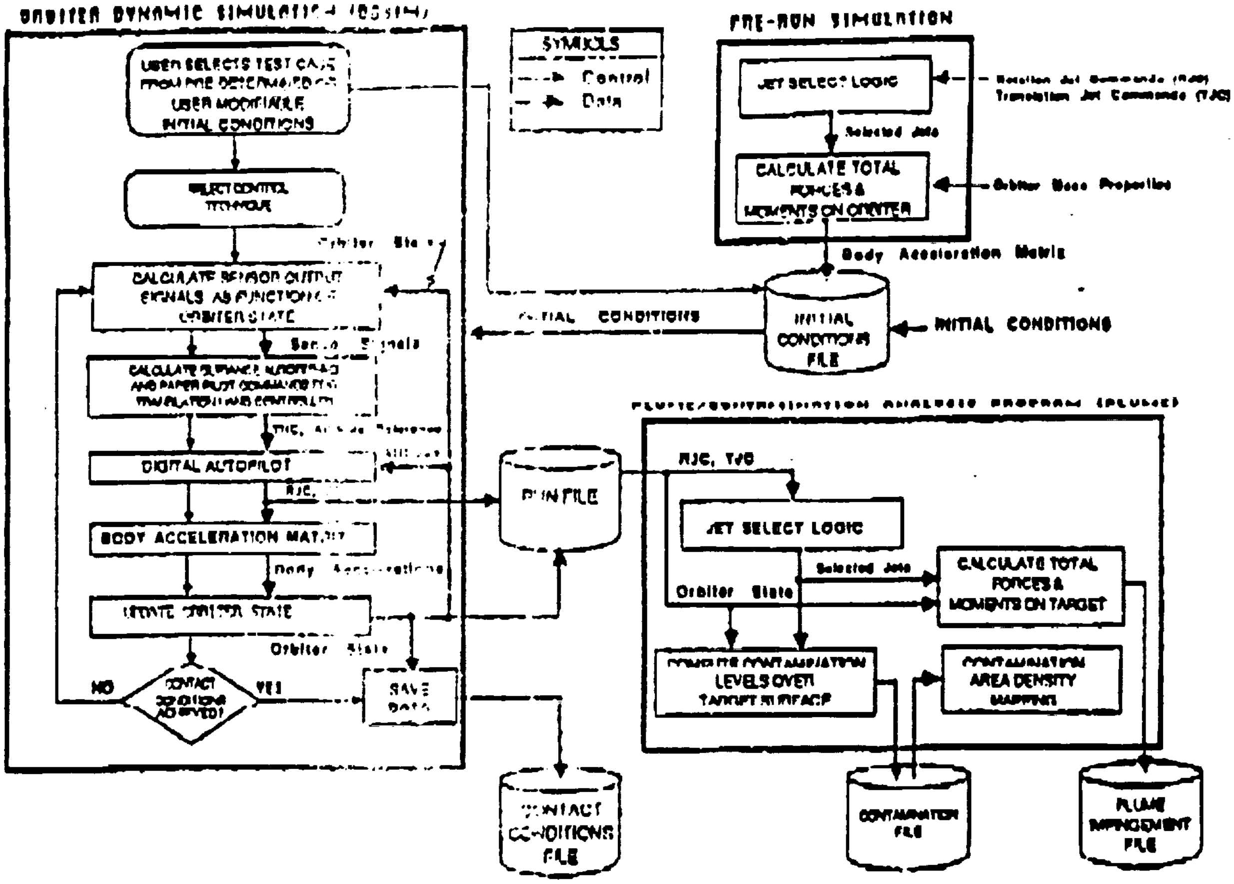
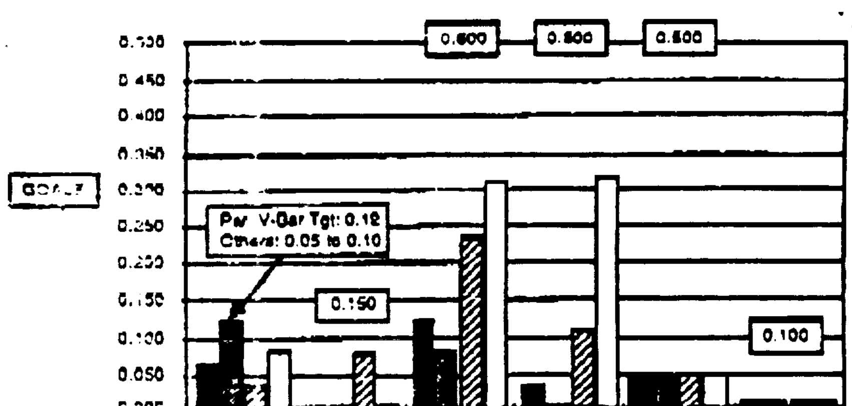


Figure 1. Docking/Berthing Simulations



CRITERIA / TRAJECTORY	CLOSING RATE (ft/sec)	LATERAL RATE (ft/sec)	LATERAL MISALIGN (Y) (feet)	LATERAL MISALIGN (Z) (ft/sec)	ANGULAR MISALIGN (deg)	ANGULAR RATE (deg/sec)
RANGE GATING	0.066	0.005	0.120	0.034	< 0.050	< 0.010
PARALLEL V-BAR	0.120	0.005	0.084	0.006	< 0.050	< 0.010
GUIDED V-BAR	0.034	0.079	0.237	0.111	< 0.050	< 0.010
GUIDED R-BAR	0.084	0.007	0.310	0.320	< 0.050	< 0.010

Figure 2. Contact Conditions vs. Selected Trajectory

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