THE MSFC SPACE STATION / SPACE OPERATIONS MECHANISM TEST BED

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The Space Station/Space Operations Mechanism Test Bed consists of a hydraulically driven, computer controlled Six Degree-of-Freedom Motion System (6DOF), a six degree-of-freedom force and moment sensor, remote driving stations with computer generated or live TV graphics and a parallel digital processor that performs calculations to support the real time simulation.

The function of the Mechanism Test Bed is to test docking and berthing mechanisms for Space Station Freedom and other orbiting space vehicles in a real time, hardware-in-the-loop simulation environment. Typically, the docking and berthing mechanisms are composed of two mating components, one for each vehicle. In the facility, one component is attached to the motion system, while the other component is mounted to the force/moment sensor fixed in the support structure above the 6DOF. The six components of the contact forces/moments acting on the test article and its mating component are measured by the force/moment sensor. The force/moment sensor has a dynamic range from less than 1 lb to over 6000 lbs and is interfaced to the real time Alliant computer system. The hydraulic system is capable of generating over 100,000 lbs of force. Each actuator has a closed loop position bandwidth measured at 7 Hz. The test articles are protected with hardware and software safety devices.

The equations of motion describing the berthing or docking process are driven by the measured contact forces/moments, vehicle control system actuators, gravity, and other forcing functions pertinent to the process. These equations are solved numerically for the relative motion between the docking/berthing mechanisms in real time. Actuator leg length commands are computed for the motion system such that the relative motion between the mechanism components in the facility duplicates that of the numerical simulation. In this manner, the general case of two objects moving through space is fully represented.

The numerical docking simulation mathematically models two flexible

bodies moving freely in space. The bodies are acted on by mechanism contact and capture forces/moments, gravity, and vehicle control actuators and thrusters. The code is modular and easily accommodates user defined vehicle control routines. The simulation will also allow man-in-the-loop studies using a control station and a test subject responding to computer driven instruments and computer generated/video images. The non-linear equations of motion were derived using the Boltzmann-Hamel equations, accounting for flexibility through the assumed modes technique.

The numerical berthing simulation is based on a model of the orbiter Remote Manipulator System (RMS). The berthing process is defined by the following scenario. An astronaut will grapple the payload using the RMS and position it within the capture envelope of the berthing mechanism. The RMS will then be placed in limp mode (i.e. power to all motors will be cut off). Capture latches on the active half of the mechanism will reach out, hook the passive mechanism, and pull it towards the active half, thereby back driving the motors of the RMS simulation. The RMS model consists of the controlling flight software modules, joint servo models, and arm/base vehicle dynamics models. The flight software calculates joint rate commands based on tip position and orientation errors. Motor shaft rate errors and simple DC motor models produce resulting actuator torques for each joint. The measured contact forces/moments and simulated motor torques drive the equations of motion describing the flexible RMS and base vehicle. The RMS/base vehicle model is composed of a chain of flexible bodies coupled by torsional springs. These springs simulate flexibility in the joints and the gear boxes between the motors and the joint drive shafts. Body flexibility is incorporated into the equations of motion using a component mode synthesis technique. The payload and base vehicle may also be flexible. The resulting equations are valid for large rotations and translations of each body. Friction/stiction is also included at each joint and motor.

The Mechanisms Test Bed has previously been used to test several docking and berthing mechanisms, ranging in size from a few pounds to large mechanisms weighing in excess of 3500 pounds. These mechanisms include :

- Docking/Berthing Mechanism for Skylab reboost.
- Berthing Mechanism for a 25 KW power module.
- Space Telescope Keel Latch
- RMS Arm End Effector

- Prototype Space Station Docking/Berthing Mechanism with long reach capture latches and electro-mechanical load attenuation devices.
- Docking Mechanism for Orbital Maneuvering Vehicle.
- Prototype Space Station Freedom Docking/Berthing Mechanism

This paper will describe the facility, simulation capabilities, and past test projects.

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