Cumulative Measurement Errors for Dynamic Testing of Space Flight Hardware

Located at the NASA Johnson Space Center in Houston, TX, the **Six-Degree-of-Freedom Dynamic Test System (SDTS)** is a real-time, six degree-of-freedom, short range motion base simulator originally designed to simulate the relative dynamics of two bodies in space mating together (i.e., docking or berthing). The SDTS has the capability to test full scale docking and berthing systems utilizing a two body dynamic docking simulation for docking operations and a Space Station Remote Manipulator System (SSRMS) simulation for berthing operations. The SDTS can also be used for nonmating applications such as sensors and instruments evaluations requiring proximity or short range motion operations. The motion base is a hydraulic powered Stewart platform, capable of supporting a 3,500 lb payload with a positional accuracy of 0.03 inches. The SDTS is currently being used for the NASA Docking System testing and has been also used by other government agencies. The SDTS is also under consideration for use by commercial companies.

Examples of tests include the verification of on-orbit robotic inspection systems, space vehicle assembly procedures and docking/berthing systems. The facility integrates a dynamic simulation of on-orbit spacecraft mating or de-mating using flight-like mechanical interface hardware. A force moment sensor is used for input during the contact phase, thus simulating the contact dynamics. While the verification of flight hardware presents unique challenges, one particular area of interest involves the use of external measurement systems to ensure accurate feedback of dynamic contact. The measurement systems for the test facility have two separate functions. The first is to take static measurements of facility and test hardware to determine both the static and moving frames used in the simulation and control system. The test hardware must be measured after each configuration change to determine both sets of reference frames. The second function is to take dynamic measurements during hardware motion and contact. While performing dynamic testing of an active docking system, researchers found that the data from the motion platform, test hardware and two external measurement systems exhibited frame offsets and rotational errors. While the errors were relatively small when considering the motion scale overall, they substantially exceeded the individual accuracies for each component. After evaluating both the static and dynamic measurements, researchers found that the static measurements introduced significantly more error into the system than the dynamic measurements even though, in theory, the static measurement errors should be smaller than the dynamic. In several cases, the magnitude of the errors varied widely for the static measurements. Upon further investigation, researchers found the larger errors to be a consequence of hardware alignment issues, frame location and measurement technique whereas the smaller errors were dependent on the number of measurement points. This paper details and quantifies the individual and cumulative errors of the docking system and describes methods for reducing the overall measurement error. The overall quality of the dynamic docking tests for flight hardware verification was improved by implementing these error reductions.

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