

SPHERES 25TH ISS Test Session

Version XX, 2010/12/16

Abstract

The SPHERES Test Session 25 occurred on 2010-October-28. The session lasted two hours and a half due to a 15 minutes delay in the starting time and a premature end, almost 30 minutes in advance. Despite the time constraints the group A success marker was reached and the first 3 tests belonging to group B were successfully run. Group C was not expected to take place due to the limited time available while the remaining tests in group B, that correspond to the ZR test, were postponed because of the unexpected time reduction.

The 3 group B tests run, corresponding to relative control, provided valuable data for evaluating the coupled dynamics architecture performance. The fuel consumption and maneuver time were compared to the same metrics found in similar tests in TS20 using independent architecture. The data analysis from the stop and stare test has shown how the maneuver time is reduced using a Phase-Plane control system combined with coupled dynamics. However, the fuel consumption was increased. We believe that future improvements can lead to a reduction in the fuel consumption. The spiral test pointed out that a tradeoff between fuel consumption and tracking precision must be done by tuning the gain configuration of the control system.

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1 Test Session Objectives

The session included the following research topics:

(a) Fluid Slosh

- i. Obtain data on the effects of slosh due to the liquid in the gas tanks of a SPHERES satellite.
- ii. Excite and measure fluid slosh in the tank by a fast X-axis and a fast Z-axis rotation start & stop.
- iii. Excite and measure fluid slosh in the tank by a fast X-axis translation and a fast Z-axis translation & stop.
- iv. Differentiate slosh effects between the short and long axes of the tank.

(c) Spiral Maneuvers

- i. Test a new optimal formation flight control algorithm for relative positioning using a spiral maneuver.
- ii. Test a new optimal formation flight control algorithm for relative positioning while performing a Stop and Stare maneuver
- iii. Obtain data to compare performance of decentralized controllers while following continuous and piecewise spiral trajectories.

(d) ZR 2010

- i. Validate the different phases of the Zero Robotics 2010 competition: "search" and "docking".
- ii. Validate the satellite interaction features of the Zero Robotics 2010 competition
- iii. Test the game rules at the game boundary lines and the boundary lines themselves for the Zero Robotics 2010 competition.
- iv. Test game rules at the boundary lines for the Zero Robotics 2010 Competition
- v. Perform a trial run of a complete Zero Robotics 2010 game

(b) Interact

- i. Collect data on high level human-machine interaction for collision avoidance under the influence of communication delay in two different scenarios
- ii. Measure the effects of communication delay and collision configuration scenario on human-machine interaction for collision avoidance.

To achieve these goals the session test plan was divided into three groups:

- Group A: "25A (1 Sat): Fluid Slosh"
- Group B: "25B (2 Sat): Spirals and ZR"
- Group C: "25C (3 Sat): Interact"

2 Timeline Summary

The MIT team was on console at approximately 2:00 PM GMT on October 28th, 20010, and setup began at approximately 3:15 PM. Setup was completed at approximately 4:15 PM. Eleven tests were run during the session in a total time of 1:22 hours. The session started with 15 minutes delay and ended at approximately 5:45 PM, almost 30 minutes before the scheduled end (6:15 PM). The team was of console at approximately 7:00 PM.

Table 1 below shows a summary of the tests run during this session, which lasted approximately 3.15 hours.

Table 1. Test Summary

Program	Test	Description	Start time	Interval
P311	T1	Quick Checkout	4:24 PM	8:46
	T2	Fluid Slosh: Z Translation	4:32 PM	7:58
	T2	Fluid Slosh: Z Translation	4:40 PM	0:36
	T2	Fluid Slosh: Z Translation	4:41 PM	5:51
	T3	Fluid Slosh: X Translation	4:47 PM	8:46
	T5	Fluid Slosh: X Rotation	4:56 PM	14:34
P312	T1	Quick Checkout	5:20 PM	1:24
	T1	Quick Checkout	5:22 PM	4:50
	T2	Spirals Stop and Stare	5:27 PM	5:32
	T2	Spirals Stop and Stare	5:32 PM	7:24
	T3	Spirals Relative Control	5:39 PM	6:20
		<i>End Time</i>	<i>5:46 PM</i>	
#tests	11			
total	1:22:44			
avg / test	7:31			

3 Operations

3.1 Operational Anomalies

During this test session, two anomalies were encountered. The first involved difficulties figuring out when the gas is either off or out. The second involved errors in the data received.

3.1.1 Gas status

During tests T2 and T3 in P312, “Spirals and ZR”, the Blue SPHERE seemed to underperform. During the test run MIT was not able to determine whether the gas was off, out or none of them. This led to confusion since the underperformance could not be explained and the test T2 had to be rerun.

3.1.2 Received data bugs

The data received from the blue SPHERE during tests T2 and T3 in P312, “Spirals and ZR”, contained a number of bugs, where the most significant was the huge number of the Blue SPHERE tank counter, well above possible values. This event combined with the aforementioned fact of being unable to see when the gas is off or out during a test, the uncertainty in the gas status.

3.2 Consumables Consumption

During the test session, the consumables specified in Table 2 and Table 3 were used.

Table 2. Test Session 25 battery usage

Batt	Sat	In/Out	Status
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PSI02202J	Orange (1)	Out Used	Used
PSI02202J	Orange (1)	In New	New
PSI02203J	Orange (1)	In New	New
PSI02203J	Orange (1)	Out Used	Used
PSI02225J	Blue (3)	Out Used	Used
PSI02222J	Blue (3)	Out Used	Used
PSI02209J	Blue (3)	In New	New
PSI02210J	Blue (3)	In New	New

Table 3. Test Session 25 tank usage

Tank	Sat	In/Out	Status

4 Results Analysis

4.1 Program P312 “Spiral and ZR”

5 Conclusions

Concerning the Coupled Dynamics architecture and the development of precise formation flight algorithms the Session resulted very successful. Two different scenarios were proposed for evaluating this relative control architecture and both tests were successfully completed, corresponding to tests T2 and T3 in P312. Profitable data was obtained that will certainly contribute for further developments in the field of research. The Stop and Stare test resulted in partial improvements when compared to equal tests running independent control algorithms in the Diamond tests in TS20. While the Phase-Plane controller algorithm with coupled dynamics happened to be more time efficient, it is unfortunately also more fuel consuming. The slow control period and the wrong estimation of the mass of the satellite seem to be causing the overconsumption. Solving these problems can lead to a noticeable improvement of the maneuver’s metrics. In the Spiral test the gains were modified to have a less reactive behavior compared to the previous Spiral tests in TS19 and TS20. The results were a 50% reduction in fuel consumption but an important decrease in the tracking accuracy. From the 3 last spiral tests we can say that a tradeoff must be done between the fuel consumption and tracking precision as no test has shown an improvement in both metrics.

Finally, while group C tests were not expected to take place during this test session due to time constraints, the ZR test couldn’t be run because of an unexpected time reduction of approximately forty-five minutes in the allocated

time. They will be soon run in the next test session, TS25a, since they will allow testing the game features of the Zero Robotics competition, scheduled for December 2010.

6 Lessons Learned

Some important lessons were learned from the two operational difficulties encountered this test session:

- The crew does not always realize when the gas is low or out. They need to learn how to recognize the thruster sound when is firing out of gas.
- It is not easy to figure out at MIT whether an underperformance on a satellite is due to low gas or to any other reason.
- It is important to know the tank counter status for a more accurate data analysis. The counter should be reset by the crew after each tank change.

7 Future Actions

This session did not have any difficulties that required the team to have to take future actions.

8 SPHERES Team

The SPHERES team members who played a direct role in the preparation, operation, and data analysis part of Test Session 25 are identified in Table 4. This group is in addition to the support of the SPHERES sponsor at JSC, the DoD Space Test Program.

Table 4. SPHERES Team Members for TS25

Principal Investigator		
Prof. David W Miller	ScD '88	
Lead Scientist		
Dr. Alvar Saenz Otero	PhD '05	
MIT Graduate Students		
Jakob Katz	PhD Candidate	Zero Robotics
Martin Azkarate	Visiting Student	Spirals, Editor
Brent Tweddle	PhD Candidate	Operations
Sreeja Nag	Masters Student	Operations
David Pascual	Visiting Student	Operations
Aurora Flight Sciences		
John Merk	Program Manager	

9 Revision History

Date	Version	Notes	Released by
10/12/16	0.1	Initial draft	

