W. W. Hansen Experimental Physics Laboratory
STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305-4085

Gravity Probe B Relativity Mission

Gyroscope Simulator Commissioning Procedure

GP-B Procedure
P0749 Rev A

The activities described herein are not intended to stand-alone; they are written to be called from a higher-level test procedure. Note the calling procedure below:

○ P0769 Rev________ ○ Other:___________________

____

Prepared by: David Hipkins Date
RE, Gyroscope Suspension System (GSS) Group

____

Approved by: William Bencze Date
Payload Electronics Manager

____

Approved by: Dorrene Ross Date
GP-B Quality Assurance

1.0 Revision History

Rev Level	Comments/notes	Date	Revised By
-	First release of this test procedure	03-April-2002	D Hipkins
A	Incorporate redlines from April 14, 2002 run of this procedure ECO #1387	20 Sept-2002	D Hipkins

2.0 Scope:

This procedure provides the following calibrations supporting the results of tests involving the Gyroscope Simulator Test Facility.

2.1. Gyroscope Simulator Calibration

2.1.1. *CalSteppy*; Provides a capacitance to voltage measurement needed for the closed loop control of the Gyroscope Simulator acuators.

2.1.2. *V_detrend* ; provides a better than 1% calibration of the voltages commanded by the FSU and read into the gyroscope simulator model.

2.1.2.1. Low Voltage

2.1.2.2. High Voltage

2.1.3. *Calibration of Gyroscope Simulator to Standard Dummy Load;* The dynamic response of the FSU controllers depend on the capacitive load presented to it. Performing this calibration provides a direct comparison of the Gyroscope Simulator performance with that of a standard "dummy load".

3.0 Reference Documents

3.1. Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment, MIL-STD-1686

4.0 Test Facilities

4.1. HEPL Room 127, Stanford University

4.2. Other:___________________________

5.0 QA Provisions:

5.1. Upon completion of this procedure, the GSS manager and the GP-B QA manager shall certify her/his concurrence that the procedure was performed and accomplished in accordance with the prescribed instructions by signing and dating his approval at the end of this procedure.

6.0 Test Personnel

This test procedure is to be conducted only by the following personnel:

6.1. William Bencze

6.2. David Hipkins

6.3. Yoshimi Ohshima

6.4. Other: ______________________

7.0 General Instructions

7.1. Redlines can be initiated by the test personnel listed in Section 6.0 and must be approved by QA.

7.2. Test operators shall read this procedure in its entirety and resolve any apparent ambiguities prior to beginning this test.

7.3. Any nonconformance or test anomaly should be reported by a Discrepancy Report. Refer to the Quality Plan, P0108, for guidance. Do not alter or break test configuration if a test failure occurs; notify quality assurance.

7.4. Only the following persons have the authority to exit/terminate this test or perform a retest: test operators listed in Section 6.0 and GP-B QA.

8.0 Hardware Safety Requirements:

8.1. This assembly is ESD sensitive; special care shall be exercised per the “Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment”, MIL-STD-1686

8.2. Ensure that power is removed from cable assemblies before connecting or disconnecting cable connectors.

8.3. Connector savers are to be used on all flight connector interfaces unless otherwise specified.

8.4. Examine all mating connectors before attempting to mate them. Remove any foreign particles. Look for any damaged pins or sockets. Do not force the coupling action if excessive resistance is encountered. Ensure that key-ways are aligned when mating connectors.

9.0 Test Equipment

The following support hardware, test equipment, or software will be used and the applicable information for the instruments shall be recorded below. Hand-written additions to this list may be made in the space provided.

9.1. Hardware:

Equipment Description	Make	Model	SN	Cal Due
1. 6-digit multimeter	HP	3478		
2. Reference Dummy Load	SU	-	1	N/A
3. DSP board	dSPACE	Ds1005	N/A	N/A
4. 32-channel A/D board, 16-bit	dSPACE	Ds2003	N/A	N/A
5. FSU Engineering Unit	SU	N/A	N/A	N/A
6. Power supply	HP			
7. Precision Capacitance Bridge	Andeen /Hagerling	2500A	129	8 Jun 2003
8. Gyroscope Simulator Testbed	SU	N/A	N/A	N/A

9.2. Software:

Code Description	Version Information	Build Date
1. Matlab application	Release 12 or later	NA (COTS)
2. dSPACE Control Desk	Version 3.2	
3. SU developed apps for Control Desk	N/A	

10.0 Test Configurations

10.1. *V_detrend*; Calibration of the interface between the FSU and the Gyroscope Simulator.

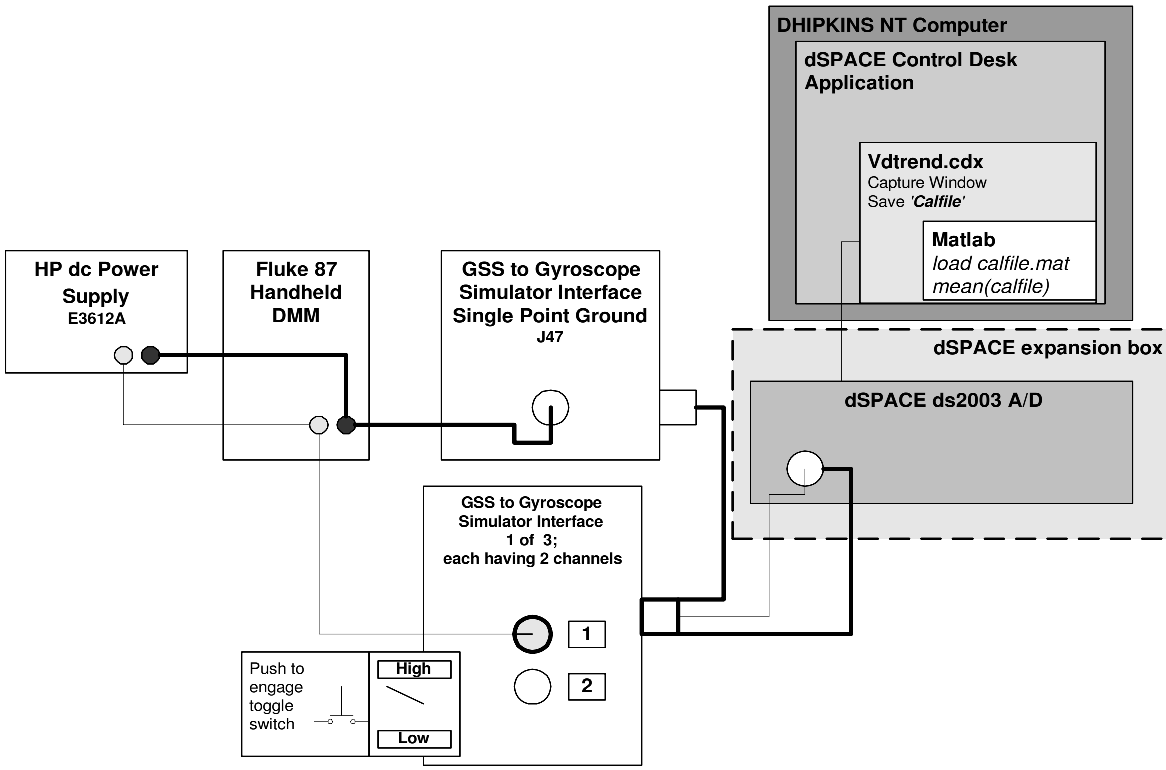

Figure 1. Setup for calibration of FSU to Gyroscope Simulator Interface.

Note: There are in reality (3) GSS to Gyroscope Simulator Interface boxes each having 2 input channels and (6) inputs to the dSPACE A/D, one for each channel. There was only one shown on the diagram for clarity.

10.2. *CalSteppy*; Calibration of the Gyroscope Simulator Actuators.

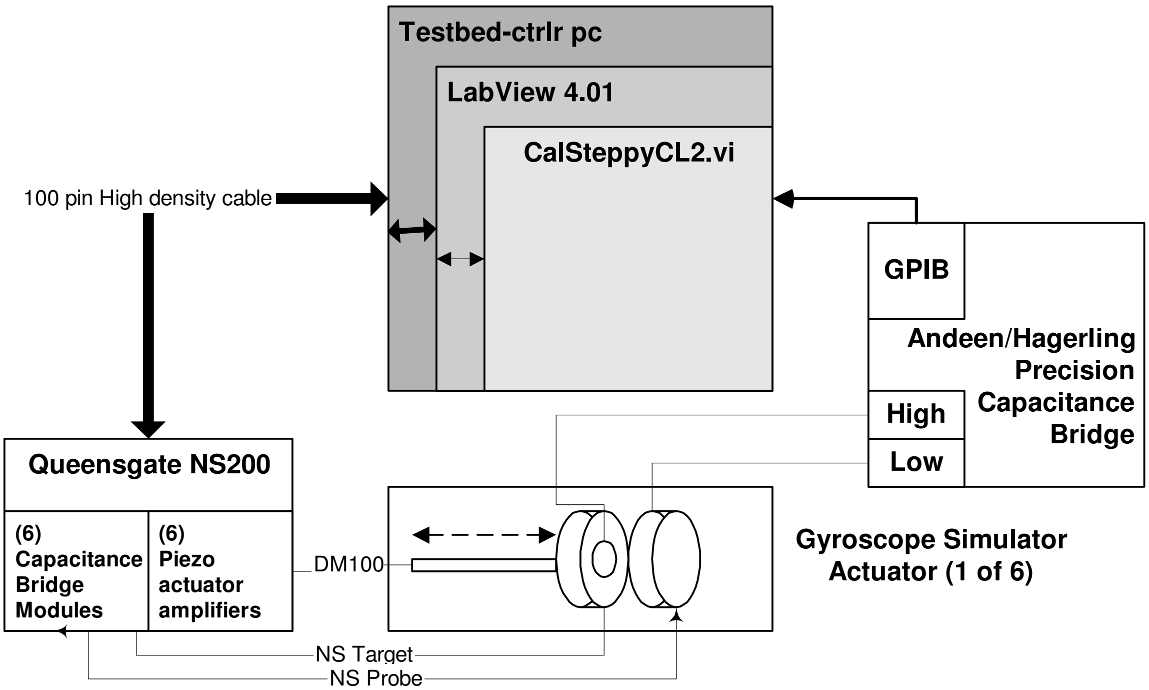

Figure 2. Setup for calibration of FSU EU to Gyroscope Simulator Interface.

10.3. Calibration of Gyroscope Simulator to Standard Dummy Load

10.3.1. FSU to Dummy Load Setup– Part A

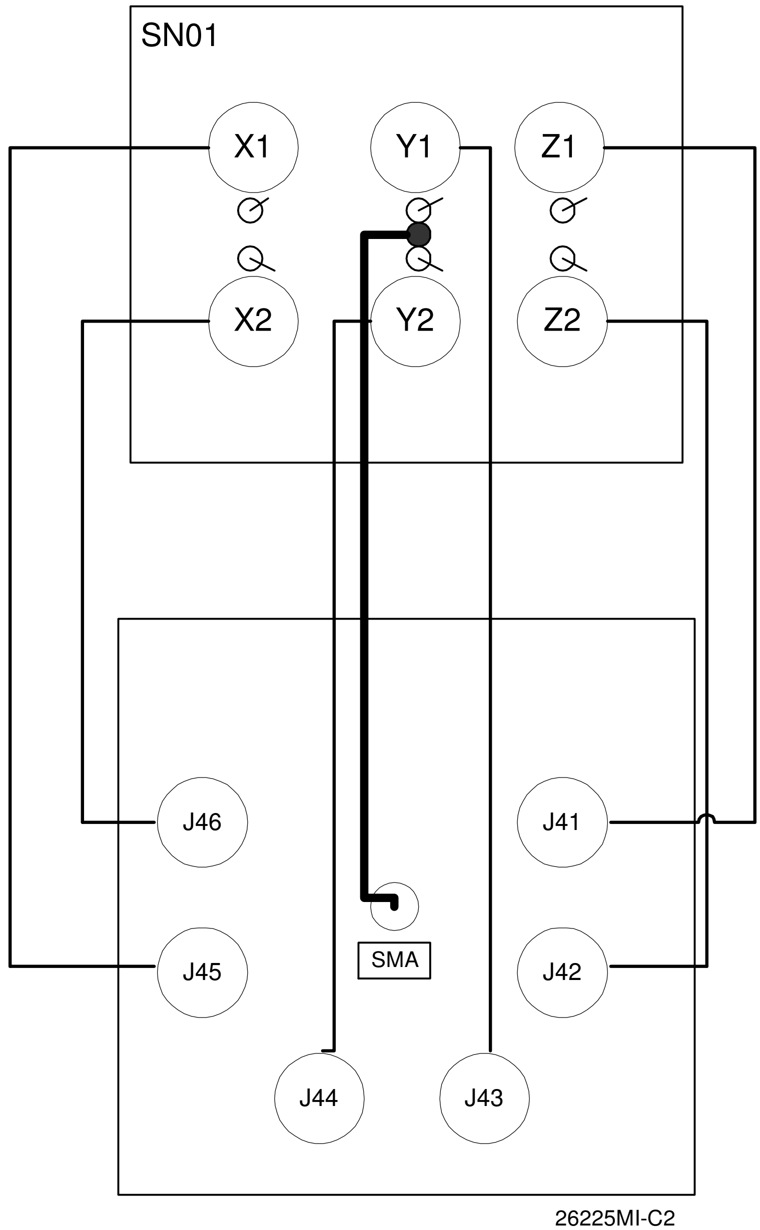

Figure 3. Connection of the FSU EU to Sn01 “Dummy Load”.

Note that the “center positions of the toggle switches is shown in the diagram above. For offsets leave one side in the center position and toggle over the other.

10.3.2. FSU EU to Gyroscope Simulator setup – Part B

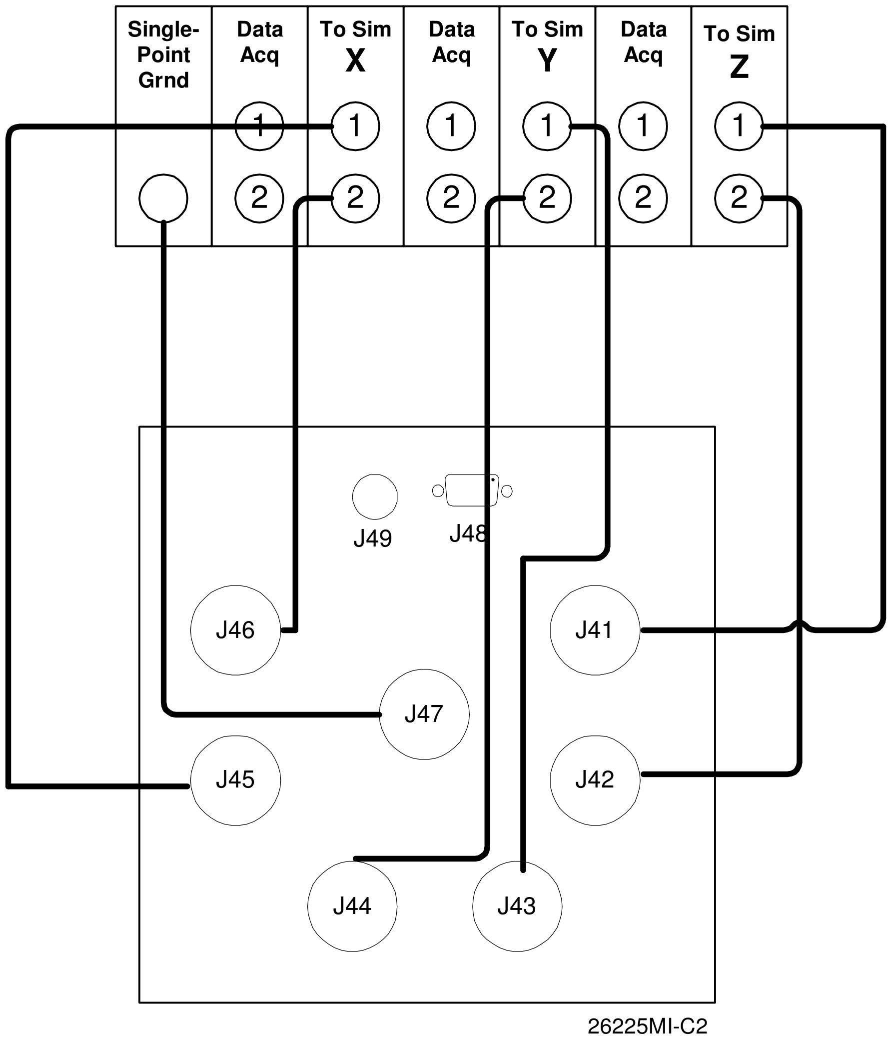

Figure 4. Connection of the FSU EU to Gyroscope Simulator Interface.

11.0 Test Setup:

11.1. *V_detrend*; Calibration of the interface between the FSU and the Gyroscope Simulator.

Description		Completed
11.1.1.	Using cables with MHV connectors, connect each of the data acquisition inputs with the suspension line inputs. There will be (6) in all.	
11.1.2.	There are 2 toggle switches on the back of each of the 3 data acquisition boxes. Put each in the “up” position.	
11.1.3.	Use the BNC connectors near these toggle switches to input the voltage from the HP dc supply.	
11.1.4.	Connect the 3 data acquisition interface boxes with the “single point ground” box on the end using a special daisy-chained banana connector string. The inputs are on the front of each box.	

11.2. *CalSteppy*; Calibration of the Gyroscope Simulator Actuators.

Description		Completed
11.2.1.	Start the LabView program from the shortcut on the desktop.	
11.2.2.	Turn on the Andeen/Hagerling Capacitance Bridge. Press “Continuous” followed by “Enter”.	
11.2.3.	There are (2) LEMO connectors attached to the High and Low BNC cables coming from the back of the A/H bridge. Connect the Low to the LEMO feedthrough labeled “rotor”. Connect the High to the actuator being measured.	
11.2.4.	Disconnect the (6) cables connecting the ds2103 to the Queensgate DM100 modules.	
11.2.5.	Disconnect the (6) cables connecting the ds2003 to the Queensgate NS modules.	
11.2.6.	Make sure the Queensgate NS2000 is turned off. If not, do so now.	
11.2.7.	Connect the high density flat cable from the Testbed-cntrlr pc to the parallel interface of the Queensgate NS2000.	
11.2.8.	Turn on the Queensgate NS2000	

11.3. Calibration of Gyroscope Simulator to Standard Dummy Load;

(Part A)

		P/F	Notes
11.3.1.	Verify that power to FSU EU is **OFF.**		
11.3.2.	Disconnect FSU EU from testbed, if required, at testbed interface box end.		
11.3.3.	Connect the FSU EU ground to the dummy load case.		
11.3.4.	Connect FSU EU J41 to load J41 (Z1)		
11.3.5.	Connect FSU EU J42 to load J42 (Z2)		
11.3.6.	Connect FSU EU J43 to load J43 (Y1)		
11.3.7.	Connect FSU EU J44 to load J44 (Y2)		
11.3.8.	Connect FSU EU J45 to load J45 (X1)		
11.3.9.	Connect FSU EU J46 to load J46 (X2)		
11.3.10.	Set all toggle switches to “zero” position on dummy load (6 places)		

(Part B)

		P/F	Notes
11.3.11.	Verify that power to FSU EU is **OFF.**		
11.3.12.	Disconnect FSU EU from the standard dummy load		
11.3.13.	Connect FSU EU J41 to GSS-Gyroscope Simulator Interface J41 (Z1)		
11.3.14.	Connect FSU EU J42 to GSS-Gyroscope Simulator Interface J42 (Z2)		
11.3.15.	Connect FSU EU J43 to GSS-Gyroscope Simulator Interface J43 (Y1)		
11.3.16.	Connect FSU EU J44 to GSS-Gyroscope Simulator Interface J44 (Y2)		
11.3.17.	Connect FSU EU J45 to GSS-Gyroscope Simulator Interface J45 (X1)		
11.3.18.	Connect FSU EU J46 to GSS-Gyroscope Simulator Interface J46 (X2)		
11.3.19.	Connect FSU EU single-point SMA cable to GSS-Gyroscope Simulator Interface Single-Point Ground box		

12.0 Execution of Tests:

12.1. *V_detrend* ; FSU EU to Gyroscope Simulator Interface Box Calibrations

Task		Pass / Fail
12.1.1.	Configure the test setup per figure 1.	
12.1.2.	Set the Interface for low voltage operation. Be sure to press the momentary switch on the opposite side of the box to activate the latching relay.	
12.1.3.	Open the V_detrend.mdl model in Matlab and set the gains to 1 and the biases to 0.	
12.1.4.	Each of the 6 channels of the FSU EU to Gyroscope Simulator interface needs to be calibrated one at a time. Beginning with X1, apply 0.00 volts using the HP Power Supply.	
12.1.5.	Capture the data in the V_detrend.cdx experiment.	
12.1.6.	Load the file into Matlab and calculate the mean value.	
12.1.7.	Determine the adjustment to the bias and enter it into V_detrend.mdl. . If no adjustment is needed go to 10.1.10	
12.1.8.	Build the V_detrend.mdl and return to 10.1.5	
12.1.9.	Repeat 10.1.5-10.1.8 until there is better than 1% agreement between your measured value and that of the Fluke 87.	
12.1.10.	Apply a 10.0 volt offset from the dc power supply.	
12.1.11.	Capture the data in the V_detrend.cdx experiment.	
12.1.12.	Load the file into Matlab and calculate the mean value.	
12.1.13.	Determine the adjustment to the gain and enter it into V_detrend.mdl. If no adjustment is needed go to 10.1.15	
12.1.14.	Build the V_detrend.mdl and return to 10.1.5	
12.1.15.	Apply –10.0 volts and capture the data in the V_detrend.cdx experiment. Load the file into Matlab and calculate the mean value. If it agrees to within 1% then continue to 10.1.16. If not start over with the same channel at 10.1.5	
12.1.16.	Change the title of the calibrated V_detrend simulink block to reflect today's date and place a copy of it in the EFT library.	
12.1.17.	Record the bias and gain in table 1.	
12.1.18.	Repeat 10.1.5 through 10.1.17 for each of the 6 channels.	

FSU EU to Gyroscope Simulator Interface Box Calibrations (continued)

Task	Pass / Fail
12.1.19. Set the Interface for high voltage operation. Be sure to press the momentary switch on the opposite side of the box to activate the latching relay.	
12.1.20. Repeat steps 10.1.5 through 10.1.18 replacing +/- 60.0 volts for the offset values.	

Table 1.

FSU EU to Gyroscope Simulator Interface Calibration (*V_detrend*)

Channel	Low Voltage		High Voltage	
	Gain	Bias	Gain	Bias
X1 (J45)				
X2 (J46)				
Y1 (J43)				
Y2 (J44)				
Z1 (J41)				
Z2 (J42)				

Created by David Hipkins
01/24/10

12.2. *CalSteppy*; Calibration of the Gyroscope Simulator Actuators.

Task	Pass / Fail
12.2.1. Configure the test setup per figure 2.	
12.2.2. Open the LabView application using the shortcut on the Testbed-ctrlr desktop.	
12.2.3. Choose to open a file. Go to the user.lib directory and from there open LeoCalibration. This will bring up a menu of .vi applications. Select the CalSteppyCL2.vi.	
12.2.4. Configure the variables shown here to the right. V_{max} = 4.90 volts V_{min} = -2.50 volts deltaV = 0.20 DeltaT = 40 Commanded Voltage = 0.00 (starting value) Loop Gain = 0.50 Filename : c:\labview\calibrations**TB#***date***#**; where the **#** will be substituted with the actuator **#** and *date* is a 7 digit representation of today's month, day and year.	
12.2.5. Clear the charts if they are not already. Right click in the chart and select "Data Operations" and from that selection choose "Clear Chart"	
12.2.6. From the Windows drop down menu choose "Show Diagram". This will open another window showing the diagram of the signal paths. Wire the input channel you are going to calibrate. (i.e. NS-1 for actuator 1) This will determine which of the Queensgate bridge measurements to use for the calibration.	
12.2.7. In the same window connect a wire to the PIO96-out block of the same number (i.e. if you are calibrating the #1 actuator connect a wire to the #1 block of the PIO96-out block. Each of the other 5 PIO96-out blocks should have a constant 0.0 wire to them.	
12.2.8. Go back to the previous window and select start. This is the icon looking like 2 arrows in a circle.	
12.2.9. Let the program run as long as you like however it is only necessary to have (1) full cycle. Zero volts to +4.80 volts to –2.50 volts and finally back to zero.	
12.2.10. Once the data acquisition is complete choose stop by clicking the stop symbol.	
12.2.11. From the Windows Explorer find the data file just completed and move it to the dhipkinsNT computer either using a floppy or any other means available.	
12.2.12. Repeat 12.2.4 through 12.2.11 for each of the (6) actuators.	
12.2.13. If all (6) are complete move to the Dhipkins-NT to reduce the data.	

Calibration of the Gyroscope Simulator Actuators.(continued)

Task	Pass / Fail
12.2.14. Start Matlab from the desktop.	
12.2.15. Move each of the data files taken in CalSteppy to \\Dhipkins-nt\ ***c:\FSU_Acceptance_Test\Calibrations\TB_Actuator_Raw_Calibration_Data***	
12.2.16. Record the filenames in Table 2.	
12.2.17. Load the raw data file into the Notepad application	
12.2.18. Select the range of data points representing the full range of Queensgate bridge analog output values. *(Each position has 5 data points taken. For the first set of 5 use only points 2,3,4 and 5. This is necessary to conform with the "super-parse" .m file used for data reduction.)* Copy this selection to the clipboard.	
12.2.19. Paste this data into the Matlab workspace. Use the date of the data collection to name the variable; i.e. sept2002_1 for a file collected September 20, 2002 and the "1" designates this as the first file collected in case there is a need to repeat the data collection.	
12.2.20. Type [c2v,v2c] = super-parse(***enter variable name from 12.2.19***) .	
12.2.21. Print the plot results in Figures 1 and 2 generated by super-parse.	
12.2.22. Open the eft.mdl library located in ***C:\ TestbedCalibrations\Current\T003 Apps .*** Make a copy of the "Calibrations" Simulink block. Save the new block replacing the block title using the current date. Open the voltage to position block labeled "*Vm (x6) to Position (x3)*" . Double-click on the Lookup table to open the dialogue box so you can enter the new values for the lookup table.	
12.2.23. Type *v2c* in the Matlab command window. Cut and paste the voltage values into the box labeled "Vector of input values" and the capacitance values into the box labeled "Vector of output values". Click save,	
12.2.24. Open the voltage to position block labeled "*Position to NS Voltage)*" . Double-click on the Lookup table to open the dialogue box so you can enter the new values for the lookup table.	
12.2.25. Type *c2v'* in the Matlab command window. Cut and paste the capacitance values into the box labeled "Vector of input values" and the voltage values into the box labeled "Vector of output values". Click save,	
12.2.26. Attach copies of the calibration results generated in super-parse.m	
12.2.27. Drop a copy of eft.mdl library into this folder on the release site ***\\GSS-SERVER\Release\FSU_acceptance_testing\calibrations\Testbed Calibrations***	

Table 2.
Gyroscope Simulator Actuator Calibrations (*CalSteppy*)

TB Actuator	Calibration Date	Filename [1] (Raw Data)	Calibration Results Attached
1			
2			
3			
4			
5			
6			

[1] *The files are to be archived on the \\GSS-SERVER\Release\FSU acceptance testing\Calibrations*

12.3. Calibration of Gyroscope Simulator to Standard Dummy Load

Task	Completed
12.3.1. Complete sections 10.3.1 and 11.3 (Part A). Set the toggles on the dummy load for a "centered" or balanced capacitance load.	
12.3.2. Turn on the power to the FSU EU.	
12.3.3. Connect SMA to BNC cables to each of the three position outputs on the test card. Connect one at a time or all three to a calibrated voltmeter.	
12.3.4. Read the output voltage for each of the three channels x, y, and z and record these as Bias values in Table 3.	
12.3.5. Determine the sensitivity for x, y and z and record it in Table 3.	
12.3.6. Turn OFF the FSU EU and disconnect from the "Dummy Load"	

Table 3. Measurements of FSU EU on Dummy Load SN01.

Channel	Bias	Offset position (in "2" direction)	Sensitivity [1]
X	millivolts	Volts	millivolts / µm
Y	millivolts	Volts	millivolts / µm
Z	millivolts	Volts	millivolts / µm

[1] See appendix A for the centered and offset capacitance values as well as the offset capacitance to displacement conversion for the SN01 dummy load.

Task				Completed
12.3.7. Complete sections 10.3.2 and 11.3 (Part B).				
12.3.8. Start the Control Desk application. Open the ***TB_cable_cap_calib.cdx*** experiment.				
12.3.9. Set the positions for x, y and z to the values below:				
Dummy load (#1)Center	X = -0.069 (μm)	Y = 0.181(μm)	Z = 0.020 (μm)	
12.3.10. Turn on the power to the FSU EU.				
12.3.11. Using the adjustments in the ***TB_cable_cap_calib*** experiment determine the undriven capacitance that matches the biases at center for each of the three axes. Record the values in Table 4.				

Table 4. Undriven Capacitance values, differential mode (Bias determination)

Axis	Difference [E(1)-E(2)] in pF
X	
Y	
Z	

Task		Completed
12.3.12. Move the positions of each axis to the values on the right;	μm	
	μm	
	μm	
12.3.13. Adjust the capacitance as a pair of undriven cables maintaining the Difference [E(1)-E(2)] recorded in Table 4. until the sensitivity for each channel is equal to that recorded in Table 3.		
12.3.14. Record the undriven capacitance values in Table 5.		

Table 5. Undriven Capacitance values, common mode (Sensitivity adjustment)

Axis	Undriven Cap. "1"	Undriven Cap. "2"	Bias	Sensitivity
X	pF	pF	mV	mV/μm
Y	pF	pF	mV	mV/μm
Z	pF	pF	mV	mV/μm

Task	Completed
12.3.15. Open the Windows Explorer and go to the following directory : ***C:\Testbed_Applications\Testbed_Models\TB_Controller***	
12.3.16. Open the file "***Setup_Old_Controller.m***"	
12.3.17. Replace the current vector, **C_TB_Cables = [X1 X2 Y1 Y2 Z1 Z2]** with the corresponding values in Table 5.	
12.3.18. Save "***Setup_Old_Controller.m***" and place a copy of it in ***\\GSS-SERVER\Release\FSU_acceptance_testing\calibrations\Testbed Calibrations***	

13.0 Completion of procedure:

	P/F	Notes
13.1. Close ***TB_cable_cap_calib.cdx*** and shut down dSPACE application as well as the DSP.		
13.2. Disconnect EU from the Gyroscope Simulator		
13.3. Archive calibration files on the GSS release site		

I certify that this procedure was performed in whole and that the data recorded above is complete and accurate.

Test Engineer		Date	

This is to certify that the information obtained under this test procedure is as represented and the documentation is completed and correct.

GSS Representative		Date	
Quality Assurance		Date	

Appendix A – Dummy Load Calibration

Dummy Load S/N #1

	X1	X2	Y1	Y2	Z1	Z2
[1]Capacitance @ Center (pF)	136.37	136.51	136.72	136.35	136.46	136.42
[1]Capacitance @ Offset (pF)	172.67	173.40	173.33	172.48	174.84	172.70
[2]Displacement @ Center (μm)	-0.069		0.181		0.020	
[2]Displacement @ Offset (μm)	-8.617		-8.353		-8.244	

[1]Capacitance measured using Andeen/Hagerling Precision Capacitance Bridge. Calibration certificate attached.

[2]Displacement is determined using the shaded columns from Table 6. below. For the "Offset" measurement we have adopted the "2" direction to be the standard for this calibration.

Table6. Displacement to Capacitance for GP-B gyroscopes

Displacement	C1 (d_0 = 32μm)	C2 (d_0 = 32μm)	C1 (d_0 = 33μm)	C2 (d_0 = 33μm)
0	73.3205	73.3205	71.0556	71.0556
0.5000	74.4117	72.2608	72.0800	70.0599
1.0000	75.5359	71.2314	73.1343	69.0918
1.5000	76.6946	70.2308	74.2199	68.1501
2.0000	77.8893	69.2580	75.3383	67.2336
2.5000	79.1219	68.3117	76.4909	66.3415
3.0000	80.3941	67.3910	77.6792	65.4728
3.5000	81.7080	66.4947	78.9051	64.6265
4.0000	83.0654	65.6220	80.1703	63.8018
4.5000	84.4687	64.7719	81.4768	62.9979
5.0000	85.9203	63.9435	82.8265	62.2140
5.5000	87.4226	63.1360	84.2217	61.4494
6.0000	88.9784	62.3487	85.6647	60.7034
6.5000	90.5906	61.5808	87.1580	59.9752
7.0000	92.2622	60.8316	88.7043	59.2643
7.5000	93.9968	60.1004	90.3065	58.5701
8.0000	95.7977	59.3865	91.9676	57.8919
8.5000	97.6691	58.6894	93.6910	57.2293
9.0000	99.6150	58.0085	95.4801	56.5816
9.5000	101.6400	57.3432	97.3390	55.9485
10.0000	103.7491	56.6930	99.2716	55.3293
10.5000	105.9476	56.0574	101.2826	54.7237
11.0000	108.2412	55.4358	103.3767	54.1313
11.5000	110.6364	54.8279	105.5592	53.5515
12.0000	113.1399	54.2332	107.8359	52.9840