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Gravity Probe B Relativity Mission

Science Gyro Spin Up

GMA Valve Sequences

S0633, Rev. A

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1. Purpose

This document will outline , the series of actions required to initiate gyro spin up [SU] for the 0 Hz, low-speed [1 Hz], and high-speed [>80Hz] spins. Spinning up the gyros carries with it a high degree of risk. The purpose of this document is to provide a reliable reference for doing so safely and reliably. The final revision will include exact details, commands and telemetry required for the entire SU process.

2. Entry Criteria

The spacecraft will be in a nominal pre-configured condition prior to SU. This entry criteria is detailed in *Gyro Spin Up Science Document 635.* In addition to the state of the spacecraft being established as nominal, adequate ground support shall be available in the MOC, including full TDRSS coverage, and spin up will not commence until the Flight Director has polled all subsystem managers for a "go/no-go" decision for SU.

3. Subsystems

GMA – valves, pressure transducers
ECU – GIF heaters, Vatterfly valves

4. Related Documents

MOOG GMA Schematic – Drawing #SUGPB-26273 (See Appendix A)

5. Discussion

5.1. ***Nominal valve states for mission phases other than spin-up.*** This includes initialization, launch, pre-SU and post-SU. The GMA valves should be in this state prior to SU.

Phases	Valve	Normally Open [NO]	Normally Closed [NC]
Initialization, launch and pre-SU	Supply Valves		V1,V2,V3,V4,V5,V6
	Gyro "quad" Valves	V7,V8,V11,V12,V15, V16,V19,V20	V9,V10,V13,V14,V17, V18,V21,V22
	Flux Flush "quad" Valves	V23,V24	V25,V26
	Vent "quad" Valves	V27,V28	V29,V30
Post-SU	Supply Valves		V1,V2,V3,V4,V5,V6
	Gyro "quad" Valves	V7,V8,V11,V12,V15, V16,V19,V20	V9,V10,V13,V14,V17, V18,V21,V22
	Flux Flush "quad" Valves	V23,V24	V25,V26
	Vent "quad" Valves	V27,V28,V29,V30	

5.2. ***Venting the GMA prior to SU.*** The GMA is assumed to have already been vented prior to any gyro SU at any speed. The venting takes place in event 0890.0

5.2.1.	Open V29
5.2.2.	Wait 30 min
5.2.3.	Close V29

5.3. ***0 Hz SU.*** These operations will not flow any gas to the gyros, but instead test the integrity of all supply valves, and both high-speed (725 SCCM) and low-speed (2.0 SCCM) supply lines for each gyro. For gyros 1&2 ECU A-side will be used and for gyros 3&4 ECU B-side will be used. The evacuation sequence will be concatenated after the last gyro (Gyro 1). For the table below RR = Roll Rate (in RPM). The roll rate is assumed to be 0.1, 0.2, or 0.3, rpm, and will not be the same for all 4 gyros.

Phase	Step	Gyro: 12xx	Gyro: xx34
Setup	5.3.1.	Open V29	Open V30
	5.3.2.	Wait 180 sec	Wait 180 sec
	5.3.3.	Open V1	Open V2
	5.3.4.	Wait 30 sec	Wait 30 sec
	5.3.5.	Open V3	Open V4
	5.3.6.	Wait 30 sec	Wait 30 sec
	5.3.7.	Close V3	Close V4
	5.3.8.	Wait 180 sec	Wait 180 sec
	5.3.9.	Open V5	Open V6
	5.3.10.	Wait 180 sec	Wait 180 sec
	5.3.11.	Close V5	Close V6
	5.3.12.	Wait 30 sec	Wait 30 sec
	5.3.13.	Close V29	Close V30
Spin Up	5.3.14.	Enable	Enable
	5.3.15.	Open V29	Open V30
	5.3.16.	Wait 180 sec	Wait 180 sec
	5.3.17.	Open V3	Open V4
	5.3.18.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev
Reconfig	5.3.19.	Close V3	Close V4
	5.3.20.	Wait 60 sec	Wait 60 sec
	5.3.21.	Close V1	Close V2
	5.3.22.	Wait 60 sec	Wait 60 sec
Post-Reconfig	5.3.23.	Close V29	Close V30
	5.3.24.	Reserved	Reserved

*5.4. **Low-speed SU.*** These operations will flow gas to individual gyros down the low-speed (2.0 SCCM) supply line. In general, the A-side gas supply path will be used. However, redundant valves can be used and are shown below in brackets.

5.4.1. Gyro 1 low-speed SU

Phase	Step	Gyro: 1
Setup	5.4.1.1.	Open V29
	5.4.1.2.	Wait 60 sec
	5.4.1.3.	Open V1
	5.4.1.4.	Wait 60 sec
	5.4.1.5.	Open V5[1]
	5.4.1.6.	Wait 60 sec
	5.4.1.7.	Close V5
	5.4.1.8.	Wait 60 sec
	5.4.1.9.	Close V29
Spin Up	5.4.1.10.	Enable
	5.4.1.11.	Open V29
	5.4.1.12.	Wait 60 sec
	5.4.1.13.	Open V3
	5.4.1.14.	Wait 60 sec
	5.4.1.15.	Open V9
	5.4.1.16.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.4.1.17.	Close V29
	5.4.1.18.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev [2]
	5.4.1.19.	Open V29
	5.4.1.20.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig ure	5.4.1.21.	Close V9
	5.4.1.22.	Wait 60 sec
	5.4.1.23.	Close V3
	5.4.1.24.	Wait 60 sec
	5.4.1.25.	Close V1
	5.4.1.26.	Wait 60 sec

[1] Verify that path is clear and gas is venting, high speed path chosen to get better reading
[2] This wait time can be changed by changing "1 rev" to "N rev" where N is an integer

Post-Reconfig	5.4.1.27.	Close V29
	5.4.1.28.	Reserved

Note:
The wait time for slow SU is critical since too long wait can overheat the gyros since the GIF heaters are on and just a little bit of gas flowing. This comment is outdated since the GIF's probably won't be used.

5.4.2. Gyro 2 low-speed SU

Phase	Step	Gyro: 2
Setup	5.4.2.1.	Open V29
	5.4.2.2.	Wait 60 sec
	5.4.2.3.	Open V1
	5.4.2.4.	Wait 60 sec
	5.4.2.5.	Open V5
	5.4.2.6.	Wait 60 sec
	5.4.2.7.	Close V5
	5.4.2.8.	Wait 60 sec
	5.4.2.9.	Close V29
Spin Up	5.4.2.10.	Enable
	5.4.2.11.	Open V29
	5.4.2.12.	Wait 60 sec
	5.4.2.13.	Open V3
	5.4.2.14.	Wait 60 sec
	5.4.2.15.	Open V13
	5.4.2.16.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.4.2.17.	Close V29
	5.4.2.18.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev
	5.4.2.19.	Open V29
	5.4.2.20.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig ure	5.4.2.21.	Close V13
	5.4.2.22.	Wait 60 sec
	5.4.2.23.	Close V3
	5.4.2.24.	Wait 60 sec
	5.4.2.25.	Close V1
	5.4.2.26.	Wait 60 sec
Post-Reconfig	5.4.2.27.	Close V29
	5.4.2.28.	Reserved

5.4.3. Gyro 3 low-speed SU

Phase	Step	Gyro: 3
Setup	5.4.3.1.	Open V29
	5.4.3.2.	Wait 60 sec
	5.4.3.3.	Open V1
	5.4.3.4.	Wait 60 sec
	5.4.3.5.	Open V5
	5.4.3.6.	Wait 60 sec
	5.4.3.7.	Close V5
	5.4.3.8.	Wait 60 sec
	5.4.3.9.	Close V29
Spin Up	5.4.3.10.	Enable
	5.4.3.11.	Open V29
	5.4.3.12.	Wait 60 sec
	5.4.3.13.	Open V3
	5.4.3.14.	Wait 60 sec
	5.4.3.15.	Open V17
	5.4.3.16.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.4.3.17.	Close V29
	5.4.3.18.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev
	5.4.3.19.	Open V29
	5.4.3.20.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig ure	5.4.3.21.	Close V17
	5.4.3.22.	Wait 60 sec
	5.4.3.23.	Close V3
	5.4.3.24.	Wait 60 sec
	5.4.3.25.	Close V1
	5.4.3.26.	Wait 60 sec
Post-Reconfig	5.4.3.27.	Close V29
	5.4.3.28.	Reserved

5.4.4. Gyro 4 low-speed SU

Phase	Step	Gyro: 4
Setup	5.4.4.1.	Open V29
	5.4.4.2.	Wait 60 sec
	5.4.4.3.	Open V1
	5.4.4.4.	Wait 60 sec
	5.4.4.5.	Open V5
	5.4.4.6.	Wait 60 sec
	5.4.4.7.	Close V5
	5.4.4.8.	Wait 60 sec
	5.4.4.9.	Close V29
Spin Up	5.4.4.10.	Enable
	5.4.4.11.	Open V29
	5.4.4.12.	Wait 60 sec
	5.4.4.13.	Open V3
	5.4.4.14.	Wait 60 sec
	5.4.4.15.	Open V21
	5.4.4.16.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.4.4.17.	Close V29
	5.4.4.18.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev
	5.4.4.19.	Open V29
	5.4.4.20.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig	5.4.4.21.	Close V21
	5.4.4.22.	Wait 60 sec
	5.4.4.23.	Close V3
	5.4.4.24.	Wait 60 sec
	5.4.4.25.	Close V1
	5.4.4.26.	Wait 60 sec
Post-Reconfig	5.4.4.27.	Close V29
	5.4.4.28.	Reserved

5.4.5. ***Gas Evacuation, low-speed***. Executed when all gyros have been spun.

Corresponds to Event 0890.0 in the timeline.

Commands:
Evacuation after Slow Spin-up
Open V29 [V30]
Wait 30 min
Close V29 [V30]

5.5. ***High-speed SU.*** These operations will flow gas to individual gyros down the high-speed (725 SCCM) supply line. In general, the A-side gas supply path will be used.

5.5.1. ***Gyro 1 high-speed SU***

It is assumed that the command sequences for Setup, Spin Up and Reconfigure for low speed SU have been run prior to the execution of the commands listed here, see S0635.

Phase	Step	Gyro: 1
Setup	5.5.1.1.	Close V29
	5.5.1.2.	Wait 60 sec
	5.5.1.3.	Open V1
	5.5.1.4.	Wait 60 sec
Spin Up	5.5.1.5.	Enable
	5.5.1.6.	Open V29
	5.5.1.7.	Wait 60 sec
	5.5.1.8.	Open V5
	5.5.1.9.	Wait 60 sec
	5.5.1.10.	Open V9
	5.5.1.11.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.5.1.12.	Close V29
	5.5.1.13.	Wait (60 sec/min) * 1/(RR rev/min) * N rev[3]
	5.5.1.14.	Open V29
	5.5.1.15.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig ure	5.5.1.16.	Close V9
	5.5.1.17.	Wait 60 sec
	5.5.1.18.	Close V5
	5.5.1.19.	Wait 60 sec
	5.5.1.20.	Close V1
	5.5.1.21.	Wait 60 sec
Post - Reconfig	5.5.1.22.	Close V29

[3] Here N is a positive integer

	5.5.1.23.	Reserved

5.5.2. Gyro 2 high-speed SU

It is assumed that the command sequences for Setup, Spin Up and Reconfigure for low speed SU have been run prior to the execution of the commands listed here, see S0635.

Phase	Step	Gyro: 2
Setup	5.5.2.1.	Close V29
	5.5.2.2.	Wait 60 sec
	5.5.2.3.	Open V1
	5.5.2.4.	Wait 60 sec
Spin Up	5.5.2.5.	Enable
	5.5.2.6.	Open V29
	5.5.2.7.	Wait 60 sec
	5.5.2.8.	Open V5
	5.5.2.9.	Wait 60 sec
	5.5.2.10.	Open V13
	5.5.2.11.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.5.2.12.	Close V29
	5.5.2.13.	Wait (60 sec/min) * 1/(RR rev/min) * N rev
	5.5.2.14.	Open V29
	5.5.2.15.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig ure	5.5.2.16.	Close V13
	5.5.2.17.	Wait 60 sec
	5.5.2.18.	Close V5
	5.5.2.19.	Wait 60 sec
	5.5.2.20.	Close V1
	5.5.2.21.	Wait 60 sec
Post – Reconfig	5.5.2.22.	This would normally be "Close V29". However, it is intentionally **not** run. It is intended that V29 will be left open for the duration of the science mission.
	5.5.2.23.	Reserved

5.5.3. Gyro 3 high-speed SU

It is assumed that the command sequences for Setup, Spin Up and Reconfigure for low speed SU have been run prior to the execution of the commands listed here, see S0635.

Phase	Step	Gyro: 3
Setup	5.5.3.1.	Close V29
	5.5.3.2.	Wait 60 sec
	5.5.3.3.	Open V1
	5.5.3.4.	Wait 60 sec
Spin Up	5.5.3.5.	Enable
	5.5.3.6.	Open V29
	5.5.3.7.	Wait 60 sec
	5.5.3.8.	Open V5
	5.5.3.9.	Wait 60 sec
	5.5.3.10.	Open V17
	5.5.3.11.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.5.3.12.	Close V29
	5.5.3.13.	Wait (60 sec/min) * 1/(RR rev/min) * N rev
	5.5.3.14.	Open V29
	5.5.3.15.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfigure	5.5.3.16.	Close V17
	5.5.3.17.	Wait 60 sec
	5.5.3.18.	Close V5
	5.5.3.19.	Wait 60 sec
	5.5.3.20.	Close V1
	5.5.3.21.	Wait 60 sec
Post - Reconfig	5.5.3.22.	Close V29
	5.5.3.23.	Reserved

5.5.4. Gyro 4 high-speed SU

It is assumed that the command sequences for Setup, Spin Up and Reconfigure for low speed SU have been run prior to the execution of the commands listed here, see S0635.

Phase	Step	Gyro: 4
Setup	5.5.4.1.	Close V29
	5.5.4.2.	Wait 60 sec
	5.5.4.3.	Open V1
	5.5.4.4.	Wait 60 sec
Spin Up	5.5.4.5.	Enable
	5.5.4.6.	Open V29
	5.5.4.7.	Wait 60 sec
	5.5.4.8.	Open V5
	5.5.4.9.	Wait 60 sec
	5.5.4.10.	Open V21
	5.5.4.11.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
	5.5.4.12.	Close V29
	5.5.4.13.	Wait (60 sec/min) * 1/(RR rev/min) * N rev
	5.5.4.14.	Open V29
	5.5.4.15.	Wait (60 sec/min) * 1/(RR rev/min) * 1 rev * ½
Reconfig ure	5.5.4.16.	Close V21
	5.5.4.17.	Wait 60 sec
	5.5.4.18.	Close V5
	5.5.4.19.	Wait 60 sec
	5.5.4.20.	Close V1
	5.5.4.21.	Wait 60 sec
Post - Reconfig	5.5.4.22.	Close V29
	5.5.4.23.	Reserved

Appendix A - MOOG-GMA Schematic