GRAVITY PROBE B

PROCEDURE FOR

PAYLOAD VERIFICATION

P0522 REV A
FAST SPIN IN PROBE C

17 April 2001

Prepared by: B. Clarke
Approvals:

Program Responsibility	Signature	Date
B. Clarke Gyro Verification		
R. Whelan Systems Engineering		
D. Ross GP-B Quality Assurance		
R. Brumley Payload Technical Manager		

NOTES:
Level of QA required during performance of this procedure:
___Stanford QA Representative
___Government QA Representative

All redlines must be approved by QA

Revision Record:

Rev	Rev Date	ECO #	Summary Description
-	11/24/99		Original rev.
A	4/17/01		Include requirements verification section.

Acronyms and Abbreviations:

Acronym / Abbreviation	Meaning

Table of Contents

A Scope

This is a procedure for spinning a gyroscope in Probe C to a high spin speed (>10 Hz) and then slowing the gyro to a slow spin speed (<2 Hz).

B Requirements Verification

B.1 Requirements Cross-reference

Req't Source	Req't #	Requirement (Title and Description)	Achieved (completed during test)
3. PLSE-12	3.2.1.7.1	**Final Gyroscope Angular Velocity** - The science gyroscopes shall be capable of being spun up to 80-180 Hz using pressurized helium gas at a mass flow rate <= 2.8 mg/s of He4 or <= 2.1 mg/s of He3 (both equivalent to 950 scc/m) supplied to the input of each gyroscope spin-up channel. Further, the above required spin speed shall be achieved with a total helium mass per gyro of < 26.5 g for He4 or < 19.9 g for He3. (equivalent to 950 scc/m for 158 min)	
1. T002	6.0	**Science Gyroscope Spinup and Alignment** - The Science Gyroscope rotors shall be spun up to a speed in the range 80 to 180 Hz. After spin up, the spin axes of the gyroscopes shall be aligned in a specified direction with respect to the line of sight to the guide star with an accuracy better than 10 arcsec maximum.	

B.2 Expected Data for Verification per Requirement

- A three-parameter exponential fit to the spin-up data collected in section L4 will verify PLSE-12 3.2.1.7.1 by test and analysis. This data will support an S-Doc which will provide the final buyoff for the asymptotic spin speed requirement. The mass flow rate is scaled from the flowmeter readings taken from GSG-3 during the spin-up. The total helium mass necessary to achieve the required spin speed is a product of the time necessary to achieve the required spin rate (inferred from the exponential fit) and the mass flow rate used during the spin-up.
- A three-parameter exponential fit to the spin-up data collected in section L4 will verify T002 6.0 by test and analysis. This data will support an S-Doc which will provide the final buyoff for the asymptotic spin speed requirement. Spin axis alignment shall be verified by analysis in a separate SDOC.

C Configuration Requirements

Probe C is installed in the dewar and being pumped on by the Leakage Gas Management pumping system.

D **Hardware Required**

D.1 Flight hardware required

Description	No. Req'd
Probe C in Flight Dewar	1

D.2 Commercial test equipment

Manufacturer	Model	Serial Number	Calibr. Exp. Date

D.3 Mechanical/Electrical Special test equipment

Description	Part No.	Rev. no.	Serial No.	Certification Date
Facility Data Acquisition System	N/A	N/A	N/A	N/A
VAT Valve Controller	N/A	N/A	N/A	N/A
Optical readout systems	N/A	N/A		
DDC Suspension system	N/A	B	1,2, or 3A	
FFT Data system	N/A	N/A	GT	
Probe C leakage - gas management pumping system	N/A	N/A	N/A	
Gyro spin-up gas management system	N/A	N/A	N/A	

D.4 Tools

Description	No. Req'd

D.5 Expendables

Description	Quantity

E **Software Required**

No software is required.

F **Procedures Required**

No other procedures are required.

G **Equipment Pretest Requirements**

No equipment pretests required.

H **Personnel Requirements**

This test to be conducted only by the following certified personnel:

- Robert Brumley
- Chris Gray
- Bruce Clarke
- David Hipkins

- William Bencze
- Sasha Buchman

Only the following certified personnel may operate the Facility Data Acquisition System:
- Dave Murray
- Jim Maddocks
- Mike Taber

I Safety Requirements

General
It is important to be cognizant at all times of the position of the probe. Be extremely careful not to accidentally bump into the probe. If any connector does not connect smoothly and securely, do not try to force it. Instead, remove the connector and inspect it to find the reason for the difficulty. Great care must be taken at all times during the performance of this procedure.

Electrostatic Discharge

Grounded wrist straps shall be worn at all times when mating to or demating from an electrical connector on Probe C.

Personnel Safety

All operations shall take place according to Stanford University safety guidelines. Any person observing a situation that they deem unsafe shall report the fact immediately to the test director. The Quality Assurance representative shall be responsible for monitoring that all activities are performed in a safe manner.

Mating and demating of flight hardware electrical connectors

- Connection and disconnection shall be performed only when the equipment involved is in a powered-down state. Note DDC connections should be made according to P0481.
- Connector savers are to be used unless otherwise specified.
- Connectors shall be inspected for contamination and for bent, damaged, or recessed pins prior to mating.
- Grounded wrist straps are to be worn prior to removal of connector caps or covers and during mating/demating operations.
- ESD-protective caps or covers are to be immediately installed after demating of connectors.
- Update all applicable mate/demate log when mating to or demating from any probe connector.

J **General Instructions**

- Redlines can be initiated by B. Clarke or R. Brumley and must be approved by QA.
- 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.
- Only the following persons have the authority to exit/terminate this test or perform a retest: Rob Brumley, Chris Gray, David Hipkins, Bruce Clarke, Sasha Buchman, and QA personnel

K **References and Applicable Documents**

Op. Order No.____________
Date Initiated____________
Time Initiated____________

L OPERATIONS

NOTIFY ONR AND QA PRIOR TO THE START OF THIS PROCEDURE

L1 Pre-Test Checklist

Start Date: ______________________

Start Time: ______________________

Gyroscope # ____________________

Probe orientation: ________________

Orientation of gyro under test: _______________________

Spin-up Position: _______________________________________ (To be supplied by the RE).

L.1.1 Verify that the gyroscope under test has been levitated continuously and spinning in the spin-up position (or in a more aggressive position with regard to rotor freedom of motion, i.e. further off-center) for the last 12 hours. Verify that the spindown rate in this position is acceptable to the RE. Record this spindown rate to two significant figures here and attach a copy of the frequency Vs time plot to the end of this procedure.

df/dt in spinup position = ___________ mHz/hr

S/U Position X ____________uin, Y _____________uin, Z _____________uin

L.1.2 Verify that the rotor has not charged and that the DDC suspension voltages have not shown any anomalous behavior since the rotor was moved into the spinup position.

L.1.3 Verify that the optical spin speed readout system and FFT data system is operating and spin speed data is currently being logged.

L.1.4 Verify that the Leakage Gas Pumping System is operating and that the System Pressure (LGG-1A and LGG1B) < 5×10^{-5}. Both LGP-1 and LGP-2 should be pumping on the probe.

L.1.5 Verify that the Spinup Exhaust Pumping System is operating and that the Exhaust Gas Pressure

(SEG-2) is <5x10 $^{-3}$. If the pumps are not running, pressing the momentary switches on the left side of the schematic will start them. Check that 'Interlock Defeat' flashing light is on.

L.1.6 Confirm the manifold between the Probe C Gyro exhaust VAT valves (V1 & V2, or V3 & V4) and the Gyro Exhaust management manifold (SEV-2) is connected, under vacuum, and leak checked. (Note that only one pneumatic exhaust valve will be used – SEV-2. This valve will serve two gyros that are plumbed in parallel, namely, GYRO #1 and GYRO #2 or GYRO #3 and GYRO #4).

L.1.7 Confirm that the helium spinup gas supply is Grade 6 He and has Conformance Certification available. Check that the spinup gas supply bottle contains > 250psi. Open V5 and V6 at the helium supply bottle.

L.1.8 Start the emergency generator if it is not already running.

L.1.9 Confirm that the manual spinup inlet valves on the probe for the gyro under test and for one other unlevitated gyro are both open (S1 → Gyro #1, S2 → Gyro #2, S3 → Gyro #3 and S4 → Gyro #4). If the P1A valve is connected to the spin-up gas management system, evacuate the volume behind the P1A valve using the spin-up gas management system and open P1A.

L.1.10 Verify that the area around the dewar and probe has been roped off. Only those personnel identified as essential by the RE shall be allowed inside of the roped off area. Those essential personnel working near the probe are to be aware of their motions and avoid causing any mechanical disturbance to the probe.

L.1.11 Set the safety radius on the DDC to 1500 uin. This effectively disables the automatic shut down.

L.1.12 Verify that the addition of exchange gas through an un-levitated gyro (as outlined in steps L.5.9 and L.5.10 of this procedure) has been practiced.

L2 <u>Evacuate Spinup and Exhaust Manifolds</u>

Note: *Refer to Figure 1 for pumping system schematic.*

L.2.1 Open auxiliary valves AXV-8 and AXV-5. This will evacuate the spinup manifold up to the flow controller valves GSV-2 and GSV-3 and up to the gas supply valves (GSV-6, GSV-7, GSV-8, GSV-9 and GSV-10).

L.2.2 Open AXV-6 and SEV-2 to evacuate the exhaust manifold up to the exhaust VAT valve. Note the pressure reading on SEG-2.

SEG-2 = ___________________ torr

L.2.3 Zero the Baratron gauges GSG-4, GSG-5 and SEG-1. Zero the flowmeters GSG-2 and GSG3.

L.2.4 Close SEV-2, AXV-8, AXV-6 and AXV-5.

L.2.5 Confirm that the difference between the probe pressure (PMG-1) and the exhaust pressure

(SEG-2) is not more than 10 torr. While monitoring the suspension on the gyro under test, open the exhaust VAT valve (V1, V2, V3 or V4) for this gyro.

L.2.6 Confirm that the gyro is still levitated and has not charged.

L.2.7 Check that the state of the valves is as follows: All pneumatic valves CLOSED. Exhaust VAT valve OPEN. ('Interlock Defeat' flashing light is ON.)

L3 Start Data Acquisition and Pre-Heat the Quartz Block

L.3.1 Have a qualified operator of the Facility Data Acquisition System start a log file and a strip chart that includes:

Gyro temperature for each gyro	T01Q, T02Q, T03Q, T04Q
Final filter temperature for each gyro	T6P, T7P, T8P, T9P
Quartz block temperatures	T05Q, T06Q, T07Q, T10P, T11P, T17Q, T18Q
Heater power on final filter for the gyro under test	H1P, H2P, H3P or H4P

The strip chart time scale should be set such that a 15-minute interval will be easily discernible.

Record the data filename and path: ____

L.3.2 Have a qualified operator of the Facility Data Acquisition System ramp up the temperature on the quartz block and control it to a set target. The sensor used, target temperature and ramp time should be determined by the RE using P0519 'As Built' as a guide. The heater used should be 'Htr QBS fing/a or /b' (data system designations H05P or H06P). Record the sensor and heater used as well as the ramp time and target temperature below.

Quartz Block Temperature Sensor: _________________________

Quartz Block Heater: _________________________

Initial Quartz Block Temperature: __________________________ K

Quartz Block Target Temperature: _________________________ K

Ramp time: ________________________________ minutes

When the temperature is within 0.1 K of the target and stable to 0.1 K over 3 minutes, proceed to the next step. The Facility Data Acquisition Operator can determine this.

L.3.3 Record the gyro spin speed: _______________ Hz

L.3.4 Restart the FFT routine on the SUN 386i. The sampling rate should be set to 500 Hz. The logging interval should be 60 seconds for now (this should be updated to 3s during spinup).

Channel 0 ____

Channel 1 ____

Path and Filename ____

L.3.5 Open GSV-3 (1000 sccm flow controller) and the Gas Supply Valve Bypass GSV-6. Initiate a substantial bypass flow by rotating the 10-turn pot clockwise on GSV-4 until 800 sccm is displayed on GSG-3. Record the parameters in Table 1.

L.3.6 Turn the flow rate down to 10 sccm.

L.3.7 Record the gyro target temperature (to be supplied by the RE). Based on P0519 'As Built', a final filter temperature needed and the corresponding settings on the HP power supply can be determined. Record these settings here:

Power Supply # _________________ Model # ______________________

Gyro target temperature ______________________ K

Final filter temperature _______________________ K

Heater used ______________________________

Power supply voltage _______________________ V

Power supply current _______________________ mA

Pre-set the desired voltage on the HP power supply but do not enter it yet. Make sure the power supply to heater connection is made. Note that the RE may change the gyro target temperature at any time during the spin-up.

L4 Spin-up

SECTION L4 AND L5 MAY BE REPEATED ANY NUMBER OF TIMES AT THE RE'S DISCRETION.

L.4.1 RE is to confirm the gyro target temperature and that the gyro is in the desired spin-up position.

Record the gyro position: X ____________uin, Y _____________uin, Z _____________uin

Record the gyro target temperature: _______________ K

If need be, move the gyro to the desired spin-up position and pre-load the HP power supply with the correct voltage needed to achieve the gyro target temperature on spin-up.

IF AT ANY TIME DURING THE SPIN-UP THE GYRO SUSPENSION BECOMES UNSTABLE OR THE PROBE PRESSURE AS MEASURED ON PMG-1 > 7 x 10^{-4} torr, STOP THE SPIN-UP BY SKIPPING IMMEDIATELY TO SECTION L.5.

L.4.2 Open Spin-up Exhaust Valve SEV-1, open the Gas Supply Valve to the gyro under test (GSV-7, GSV-8, GSV-9 or GSV-10) then close the Bypass valve GSV-6. This begins the spin-up of the gyro.

L.4.3 Increase the flow rate to 250 sccm. Record parameters in Table 1.

L.4.4 Check the gyro suspension and probe pressure. At the RE's discretion, increase the flow rate to 725 sccm.

L.4.5 Adjust the FFT logging interval to 3 seconds. Apply the appropriate heater voltage by pushing enter on the HP power supply. Record parameters in Table1.

L.4.6 The quartz block heater should now be turned off. The timing of this step relative to step L.4.5 is at the RE's discretion. Have a qualified operator of the Facility Data Acquisition System command the quartz block heater to zero power.

L.4.7 As the spin up proceeds, record parameters in Table 1 once every 2 minutes. Monitor the DDC suspension voltages, the FFT tracking of the gyro spin frequency and the probe and gas management system pressures.

L.4.8 The RE will determine at what point to stop the spin-up and move on to section L.5. At a minimum, it is necessary to achieve a reasonable equilibrium so that relevant parameters (flow rates and temperatures) can be measured. This is typically <10 Hz. If it is desired to directly measure fa (e.g. a spin to >30 Hz), then it is necessary to have Program Manager and Quality Assurance concurrence (due to the risk involved in this procedure).

Circle One: ~10 Hz Spin >30 Hz Spin

__________________________	________________________________
Program Manager (if >30 Hz spin)	QA (if >30 Hz spin)

L.5 Spin-down

THE RE, AT HIS DISCRETION, MAY DECIDE AT ANY STEP IN THIS SECTION TO RETURN TO THE BEGINNING OF SECTION L.4

L.5.1 Turn the heater power off by commanding zero volts on the HP power supply. Turn the flow on GSV-5 down to zero.

L.5.2 Close GSV-3. Pump out the spin-up and exhaust sides by opening AXV-5, AXV-6 and AXV-8.

L.5.3 Carefully and slowly move the gyro up in the housing to +100 uin on each axis. Monitor the probe ion gauge (PMG-1) during this operation to be sure the housing is not flooded with gas that may be left in the spin-up and exhaust lines.

L.5.4 When the probe pressure on PMG-1 drops below 1×10^{-5} torr, close the exhaust valve SEV-1 and the gas supply valve to the gyro under test (GSV-6, GSV-7, GSV-8, GSV-9 or GSV-10). Close the exhaust VAT valve (V1, V2, V3 or V4). Close the auxiliary valves AXV-5, AXV-6 and AXV-8.

L.5.5 Open GSV-2 (100 sccm flow controller) and the gas supply bypass valve GSV-6. Adjust GSV-4 to give 3 sccm on GSG-2.

L.5.6 Open the gas supply valve to the gyro under test (GSV-6, GSV-7, GSV-8, GSV-9 or GSV-10) and close the gas supply bypass valve GSV-6. Closely monitor the probe pressure as the flow is adjusted to give a reading of $\sim 2 \times 10^{-4}$ torr on PMG-1. Continue to monitor the pressure during the spin-down and adjust the flow to give a PMG-1 reading of no more than 2×10^{-4} torr.

L.5.7 Adjust the logging interval on the FFT data acquisition to 300 seconds. Continue to update Table 1 every 15 minutes.

L.5.8 When the spin frequency is no longer decreasing, stop the flow of gas by adjusting GSV-4 to zero. Close the gas supply valve to the gyro under test (GSV-6, GSV-7, GSV-8, GSV-9 or GSV-10).

L.5.9 Close the probe pumping manifold VAT valve (PIV-1 a.k.a LV-1). (Optional)

L.5.10 Open the gas supply valve to an un-levitated gyro or to the P1A valve (GSV-6, GSV-7, GSV-8, GSV-9 or GSV-10). Using GSV-4, add exchange gas through this un-levitated gyro or through P1A until the probe pressure (PMG-1) is $\sim 2 \times 10^{-4}$ torr.

If the pumping VAT valve is closed, then close both the gas supply valve used and GSV-2. Otherwise simply let the gas continue to flow. At this point, all pneumatic valves on the spin-up gas management system should be closed. All VAT valves should be closed. Turn the 'Interlock Defeat' flashing light OFF.

L.5.11 Decrease the DDC safety radius to 350 uin. Continue to monitor the spin-down until the spin frequency is < 0.3 Hz. Then the rotor may be delevitated using P0481.

L.5.12 Open the probe pumping manifold VAT valve (PIV-1). Have the Facility Data Acquisition System operator stop the strip chart and the data log. The strip chart will then be attached to this procedure. The data log will be archived on the Payload Server.

Payload Server path and filename: ____.

L.5.13 Stop the FFT program and archive the data files on the Payload Server.

Payload Server path and filename: ____.

L.5.14 Archive the DDC charge file and any levitation/de-levitation files and/or snapshots on the Payload Server.

Payload Server path and filename: ____.

Payload Server path and filename: ____.

Payload Server path and filename: ____.

Payload Server path and filename: ____.

Payload Server path and filename: ____.

Payload Server path and filename: ____.

L.6 <u>Pass/Fail Criteria</u>

L.6.1 Perform a three-parameter exponential fit to the spin-up data collected in section L.4 and attach a printed copy to this procedure. From this fit record the following values:

This does not constitute final verification of on-orbit spin speed. It is data used to support an S-Document which completes the entire verification. The asymptotic spin speed indicated below is based on a partial analysis and should not be considered final.

Asymptotic spin speed: f_a = ____________________ Hz

Spin-up time constant: Tau = ____________________ minutes

Initial torque: df/dt(t=0) = ____________________ mHz/s

Fit range = __________ Hz to __________ Hz

Peak-to-peak residue to the fit =____________________ mHz

If the initial torque is greater than 33.0 mHz/s the test is passed.

Test passed: Yes No (circle one)

If no, enter D-log # ________________________

L.7 Requirements Verification

L.7.1

3. PLSE-12	3.2.1.7.1	**Final Gyroscope Angular Velocity** - The science gyroscopes shall be capable of being spun up to 80-180 Hz using pressurized helium gas at a mass flow rate <= 2.8 mg/s of He4 or <= 2.1 mg/s of He3 (both equivalent to 950 scc/m) supplied to the input of each gyroscope spin-up channel. Further, the above required spin speed shall be achieved with a total helium mass per gyro of < 26.5 g for He4 or < 19.9 g for He3. (equivalent to 950 scc/m for 158 min)

Enter the helium flow rate used from section L.4.4 : Flow =________________ scc/m He

Enter the asymptotic spin speed from section L.6 : f_a = _________________ Hz

If f_a is between 80 and 180 Hz and the flow rate is less than 950 scc/m then the spin speed and flow rate part of the requirement is met. ***(Not final verification -- See Relevant S-Doc)***

Requirement passed: Yes No (circle one)

If no, enter D-log # ____________________

From the exponential fit to the data in section L.6, estimate the time needed to achieve 80 Hz and record here:

$T_{80\ Hz}$ = ________________ minutes

Calculate the helium mass needed to achieve this speed by multiplying by the flow rate in scc/m (above) and by the factor (26.5/(950*158)) for helium 4 or (19.9/(950*158)) for helium 3. This will give the total helium mass needed in grams.

He mass needed = ___________________ g

If the helium mass needed is less than 26.5 g for helium 4 or 19.9 g for helium 3 then the total helium mass part of the requirement is met.

Requirement passed: Yes No (circle one)

If no, enter D-log # ____________________

L.7.2

1. T002	6.0	**Science Gyroscope Spinup and Alignment** - The Science Gyroscope rotors shall be spun up to a speed in the range 80 to 180 Hz. After spin up, the spin axes of the gyroscopes shall be aligned in a specified direction with respect to the line of sight to the guide star with an accuracy better than 10 arcsec maximum.	

Enter the asymptotic spin speed from section L.6 : f_a = _________________ Hz

If f_a is between 80 and 180 Hz then the spin speed part of the requirement is met. ***Not final verification of this requirement. See supporting S-Doc.***

Requirement passed: Yes No (circle one)

If no, enter D-log # ____________________

Update the Table of Requirement in section B to reflect the results of this procedure as calculated in the section.

Test completed.

Completed by: __________________
Witnessed by: __________________
Date: __________________
Time: __________________

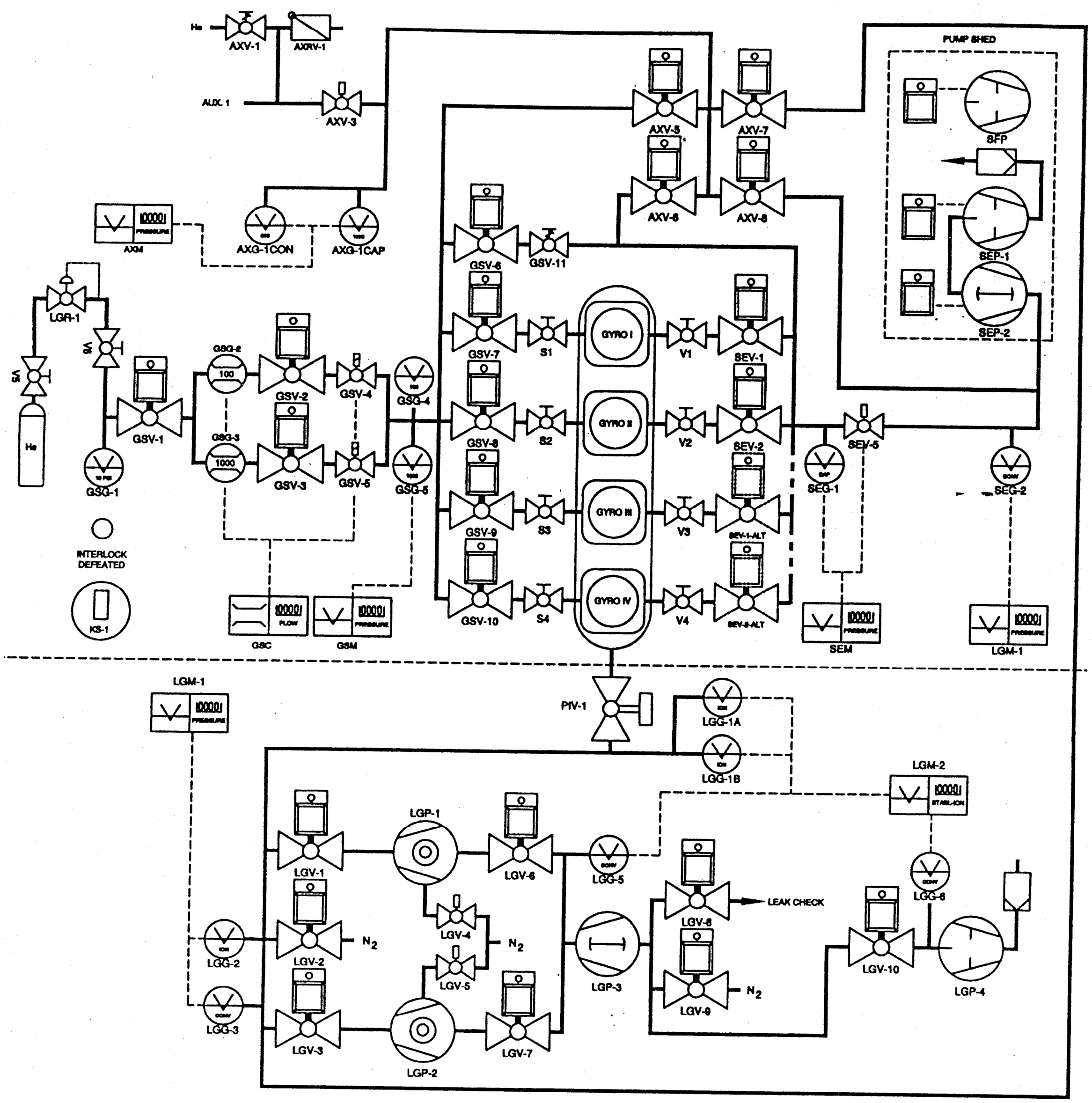

Figure 1: Gyro Gas Management System

TABLE 1 – FAST SPIN RECORD

Date ____________ Position ___________________________ Page ___ of ____

Gyro ____________ Filename __________________________

TIME	*f(Hz)*	*flow (sccm)*	*T gyro (K)*	*T filter (K)*	*PMG-1 (torr)*	*LGG-1 (torr)*	*GSG-4/5 (torr)*	*SEG-1 (torr)*	*Control effort X (g)*	*Control effort Y (g)*	*Control effort Z (g)*	*Control effort net*

TABLE 1 – FAST SPIN RECORD (continued)

Date ____________ Position ___________________________ Page ___ of ____

Gyro ____________ Filename __________________________

TIME	*f(Hz)*	*flow (sccm)*	*T gyro (K)*	*T filter (K)*	*PMG-1 (torr)*	*LGG-1 (torr)*	*GSG-4/5 (torr)*	*SEG-1 (torr)*	*Control effort X (g)*	*Control effort Y (g)*	*Control effort Z (g)*	*Control effort net*

TABLE 1 – FAST SPIN RECORD (continued)

Date ____________ Position ___________________________ Page ___ of ____

Gyro ____________ Filename ___________________________

TIME	*f(Hz)*	*flow (sccm)*	*T gyro (K)*	*T filter (K)*	*PMG-1 (torr)*	*LGG-1 (torr)*	*GSG-4/5 (torr)*	*SEG-1 (torr)*	*Control effort X (g)*	*Control effort Y (g)*	*Control effort Z (g)*	*Control effort net*

TABLE 1 – FAST SPIN RECORD (continued)

Date ____________ Position ___________________________ Page ___ of ____

Gyro ____________ Filename ___________________________

TIME	*f(Hz)*	*flow (sccm)*	*T gyro (K)*	*T filter (K)*	*PMG-1 (torr)*	*LGG-1 (torr)*	*GSG-4/5 (torr)*	*SEG-1 (torr)*	*Control effort X (g)*	*Control effort Y (g)*	*Control effort Z (g)*	*Control effort net*