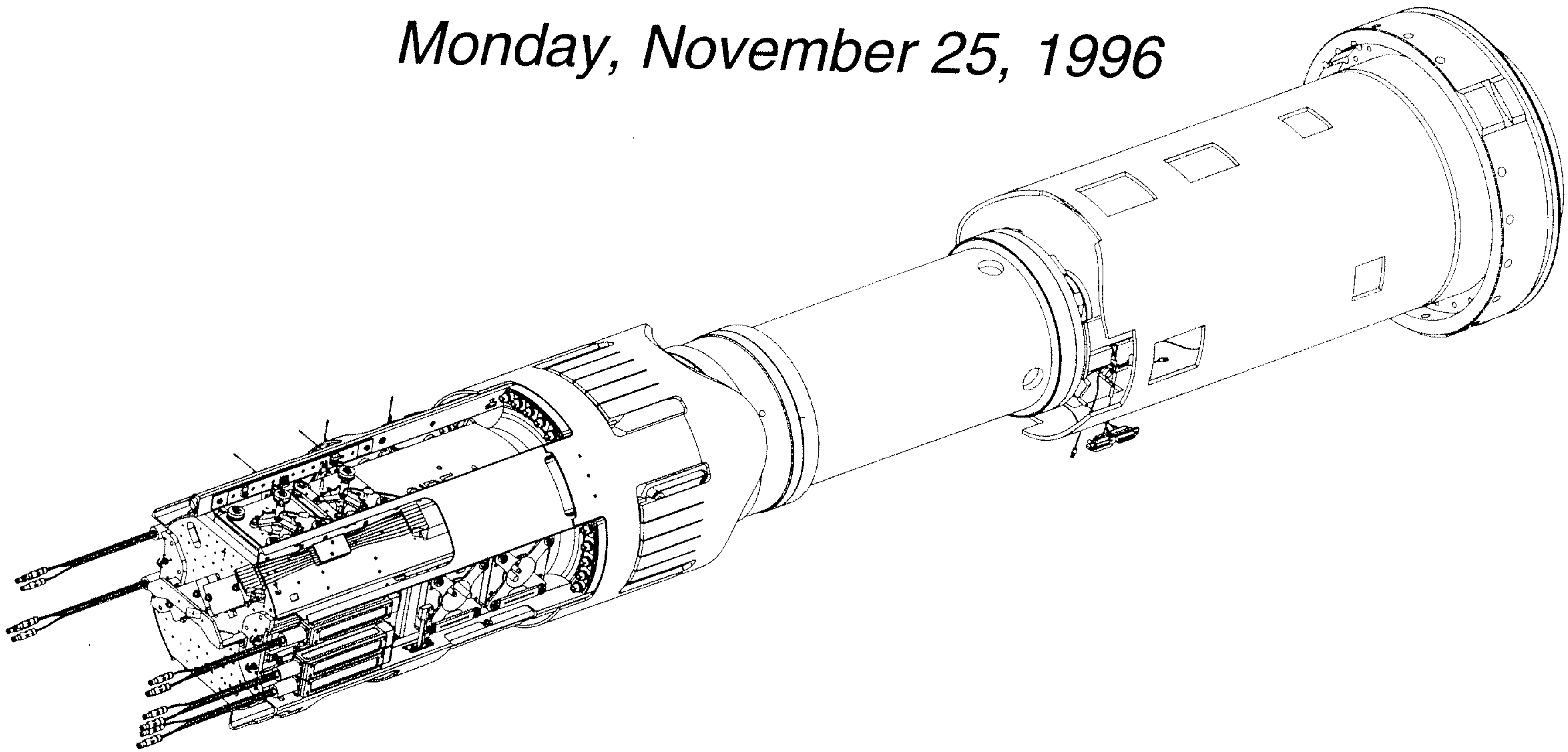
GRAVITY PROBE B RELATIVITY MISSION

SCIENCE INSTRUMENT ASSEMBLY CRITICAL DESIGN REVIEW

Monday, November 25, 1996



STANFORD

Lockheed

SIA CRITICAL DESIGN REVIEW AGENDA

Time	Subject	Person
9:00	Overview	J. Turneaure
9:25	Design Overview Mass Properties	M. Sullivan
9:45	Quartz Block	M. Sullivan
10:00	Caging Mechanism	M. Sullivan
10:15	Gyroscope Retention	D. Bardas
10:35	Magnetics Testing	J. Mester
10:55	Telescope / QB Integration	J. Gwo
11:20	SIA Integration	D. Bardas
11:40	Probe/SIA Interfaces	D. Bardas
11:50	FMECA & Critical Items List	D. Maxwell
12:10	QA / Reliability	B. Taller
12:20	SIA Schedule Overview	J. Burns
12:25	Wrap-up	J. Turneaure

SIA CRITICAL DESIGN REVIEW

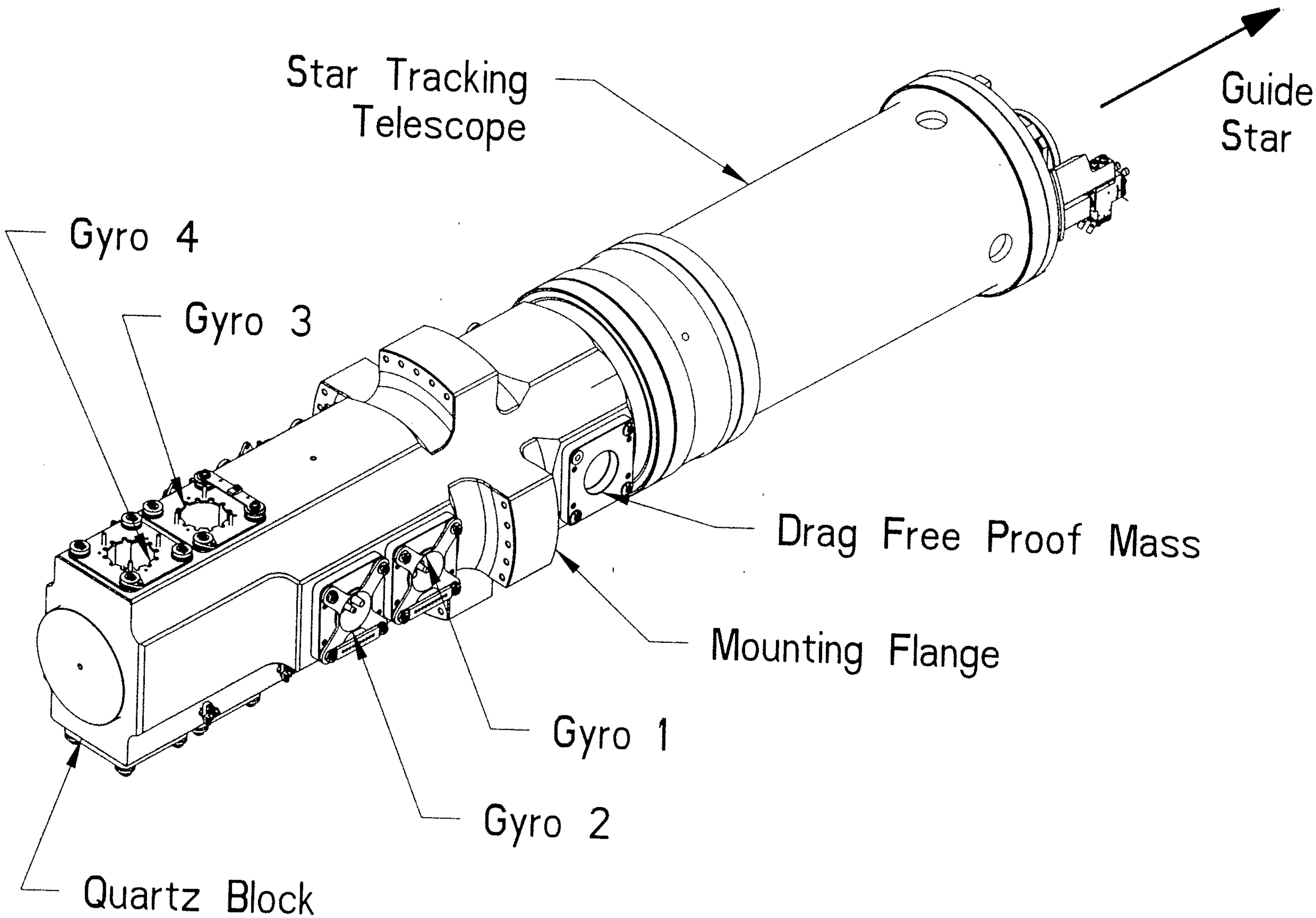
OVERVIEW

John Turneaure

SIA DESIGN REVIEW STATUS

TOPIC	RR	PDR	CDR
SIA	11/22/94	9/20/95	11/25/96
GYRO & PROOF MASS	11/15/93	6/16/94	12/1/94
GYRO READOUT	5/5/94	4/20/95	1/18/96
TELESCOPE	11/11/93	5/19/94	4/11/95

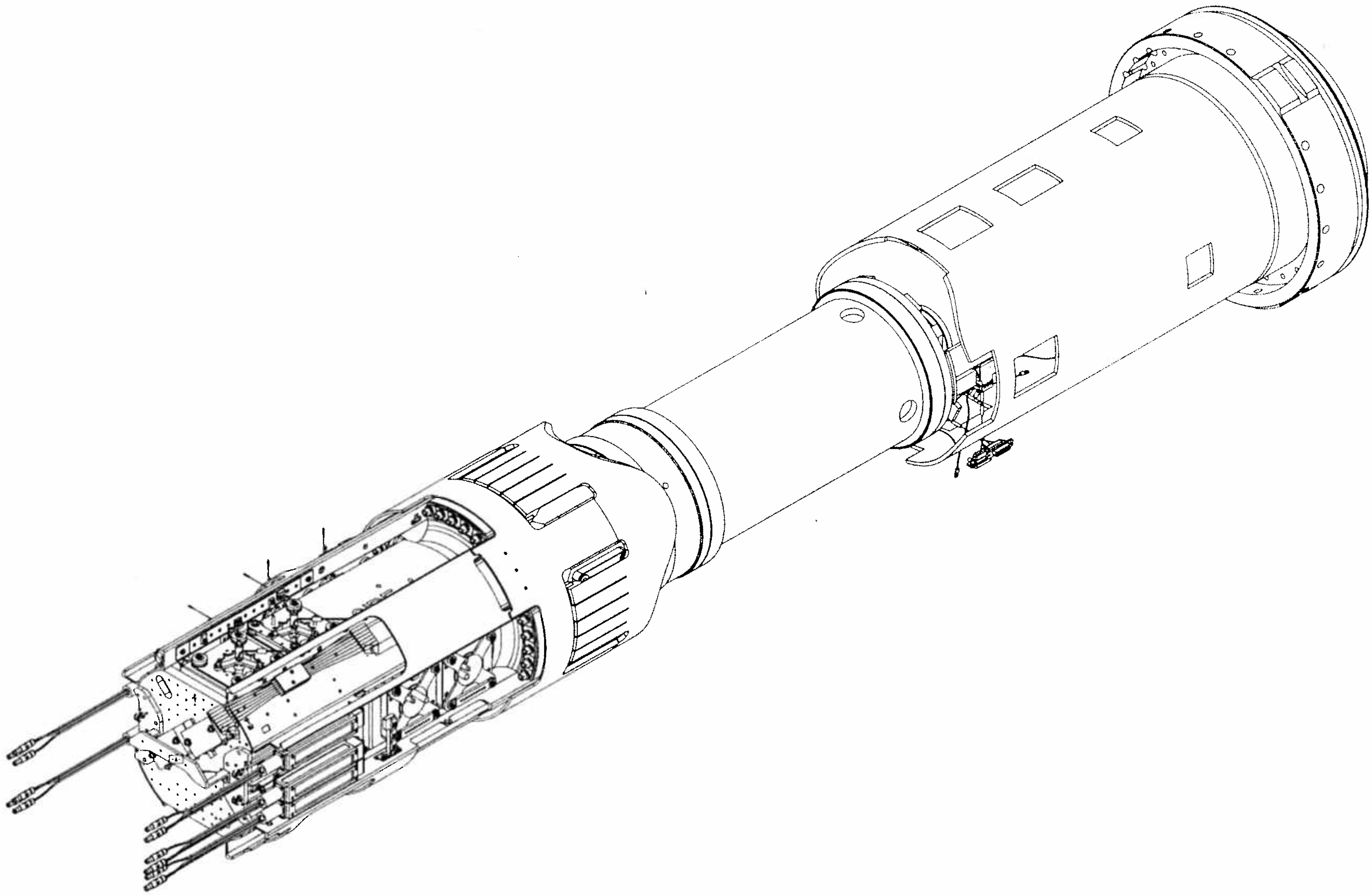
SCIENCE INSTRUMENT ASSEMBLY



SIA DESIGN FEATURES

- **QUARTZ BLOCK**
  - ALIGNMENT & POSITIONING FEATURES
  - FLANGE FOR DEMOUNTABLE JOINT TO PROBE QBS
- **TELESCOPE MOUNTING AND ALIGNMENT**
- **LOCAL SUPERCONDUCTING MAGNETIC SHIELDS**
- **DEMOUNTABLE INSTALLATION OF GYROSCOPE & PM ASSEMBLIES**
  - ALIGNMENT OF READOUT LOOP & SUSPENSION ELECTRODES
  - POSITIONING OF THE CENTER OF GYROSCOPE & PM
- **PLUMBING ASSEMBLIES (1/GYRO)**
- **CAGING ASSEMBLIES (1/GYRO & PROOF MASS)**
- **SQUID PACKAGES MOUNTED ON BRACKETS WITH TEMPERATURE CONTROL**
- **CAPACITOR BANK**

SIA WITH BIRD CAGE & QBS I/F



STATUS OF SIA DESIGN & VERIFICATION

- **HERITAGE FROM FIST-A/B, GTU-0, STU, GTU-1 (no telescope) and GTU-2 (telescope mass model)**
  - DESIGN, FABRICATION, INSPECTION, ASSEMBLY, INTEGRATION, TEST
- **SIA DRAWING STATUS - 408 DRAWINGS (including gyro, R/O, telescope)**
  - 89 % OF DRAWINGS ARE RELEASED
- **MAJOR DEVELOPMENT TESTING COMPLETE**
  - SHAKE, STATIC LOADS, FUSED QUARTZ FAB, CAGING, MAGNETICS, GYRO POSITIONING & ALIGNMENT, SILICATE BONDING, CLEANING, INTEGRATION

SIA REQUIREMENTS — 1

- **SIA SPECIFICATION — PLSE12**
  - NO TBDs IN SPECIFICATION
  - READY FOR SUBMITTAL TO PCB FOR INITIAL RELEASE
  - IN GP-B DATABASE & PROVIDED AS DELIVERABLE
- **SIA VERIFICATION MATRIX DEVELOPED & REVIEWED**
  - IN GP-B DATABASE & PROVIDED AS DELIVERABLE
- **SIA SPECIFICATION TRACEABILITY**
  - TRACEABILITY TO PL SPEC. AND T003 ANALYZED
  - DOCUMENTED & PROVIDED AS DELIVERABLE

SIA REQUIREMENTS — 2

- **T003 & PL SPEC. VERIFICATION AT SIA LEVEL ANALYZED**
  - DOCUMENTED & PROVIDED AS DELIVERABLE
- **SIA DESIGN COMPLIANCE ANALYZED**
  - DOCUMENTED & PROVIDED AS DELIVERABLE
- **T003 & PL SPECIFICATION THERMAL REQUIREMENTS NEED UPDATING FOR FULL SIA DESIGN COMPLIANCE**
  - NO IMPACT TO EXPERIMENT ACCURACY
  - NO DESIGN CHANGE REQUIRED
  - SUBMIT PCB CHANGE REQUEST IN JANUARY 1997

SIA ACTION ITEM STATUS — 1

REVIEW	TOTAL	CLOSED	RECOMMEND CLOSURE	OPEN
RR	34*	33	0	1
PDR	9	7	0	2
TOTAL	43	40	0	3

*36 prior to two Action Items being withdrawn

SIA ACTION ITEM STATUS — 2

OPEN ACTION ITEM STATUS

- **RR ACTION ITEM 32 — Conduct stress analysis of SIA components and prepare formal report**
  - Stress analysis presented at SIA PDR
  - Formal report to be submitted in March 1997
- **PDR ACTION ITEM 6 — Use GTU-1 thermal data to verifiy thermal SIA thermal model**
  - Liz Osborne has begun analysis & Mike Taber has provided GTU-1 data
  - Response by Dec. 15, 1996
- **PDR Action Item 8 — Ensure that instrumentation in FIST lab used during GTU-2 is calibrated traceable to NIST on an appropriate recalibration cycle**
  - Mike Taber is providing list of instruments to QA (Ben Taller)
  - Response by Dec. 15, 1996

DELIVERABLE DOCUMENTS

- SIA CDR PRESENTATION
- SIA SPECIFICATION
- SIA VERIFICATON MATRIX
- SIA DESIGN COMPLIANCE & SPEC. TRACEABILITY
- SIA MASS PROPERTIES REPORT
- SIA DRAWING PACKAGE
- SIA STRESS ANALYSIS EMs (12/15/96)
- SIA STRESS ANALYSIS SUMMARY REPORT (3/97)
- PL FRACTURE CONTROL PLAN UPDATE (3/97)

DESIGN ISSUES

- **NEED FOR CAPACITOR BANK**
  - AGSU MAY ALLOW ADEQUATE EMI FILTERING AT PROBE TOP HAT
  - CONDUCT TRADE STUDY

SIA CRITICAL DESIGN REVIEW

DESIGN OVERVIEW & MASS PROPERTIES

Mark Sullivan

NOTES:

1. IMPORTANT: THIS ASSEMBLY IS EXTREMELY SENSITIVE TO VERY SMALL RESIDUES OF MAGNETIC MATERIALS.
   - USE ONLY PARTS & BULK MATERIALS PROVIDED, OR SPECIFICALLY APPROVED, BY STANFORD.
   - THE USE OF STEEL TOOLS IS PROHIBITED. BERYLLIUM COPPER, CARBIDE, OR OTHER NON-MAGNETIC TOOLS ARE REQUIRED.
   - USE ONLY NON-SILICONE BASED LUBRICANTS.

   ANY MAGNETIC RESIDUES THAT MIGHT BE IMBEDDED INTO THE ASSEMBLY MAY CAUSE SCRAPPING OF THE ASSEMBLY. STANFORD MUST APPROVE THE USE OF ANY OTHER TOOL MATERIAL, CUTTING FLUID, OR LUBRICANT.

2. △ PRIOR TO ASSEMBLY, STANFORD SHALL SUBMIT FIVE MATERIAL COUPONS, TAKEN FROM EACH BULK MATERIAL, TO CRYOGENIC MAGNETIC TESTING AND APPROVAL PER SPEC P0080. TEST COUPONS SUBMITTED FOR SCREENING SHALL BE AS SPECIFIED IN SUGPB DWG 22400, MAGNETIC SAMPLE ENVELOPE.

3. PRIOR TO ASSEMBLY, PARTS SHALL BE CLEANED PER THE GP-B CONTAMINATION CONTROL PLAN P0059.

4. DIMENSIONS AND TOLERANCES PER ASME Y14.5M - 1994.

5. ASSEMBLE PER PROCEDURE P0092.

6. PROCEDURES SHALL BE USED TO MAINTAIN CLEANLINESS OF PARTS DURING AND AFTER ASSEMBLY. CLEAN ASSEMBLY AS REQUIRED PER THE GP-B CONTAMINATION PLAN P0059.

7. ASSEMBLY SHALL BE PROTECTED DURING FABRICATION, SHIPPING, RECEIVING, HANDLING, INSPECTION, AND STORAGE TO PREVENT CORROSIVE, PHYSICAL, AND CHEMICAL DAMAGE.

8. AFTER ASSEMBLY AND INSPECTION, ASSEMBLY SHALL BE MAGNETICALLY SCREENED BY STANFORD PER SPEC P0057.

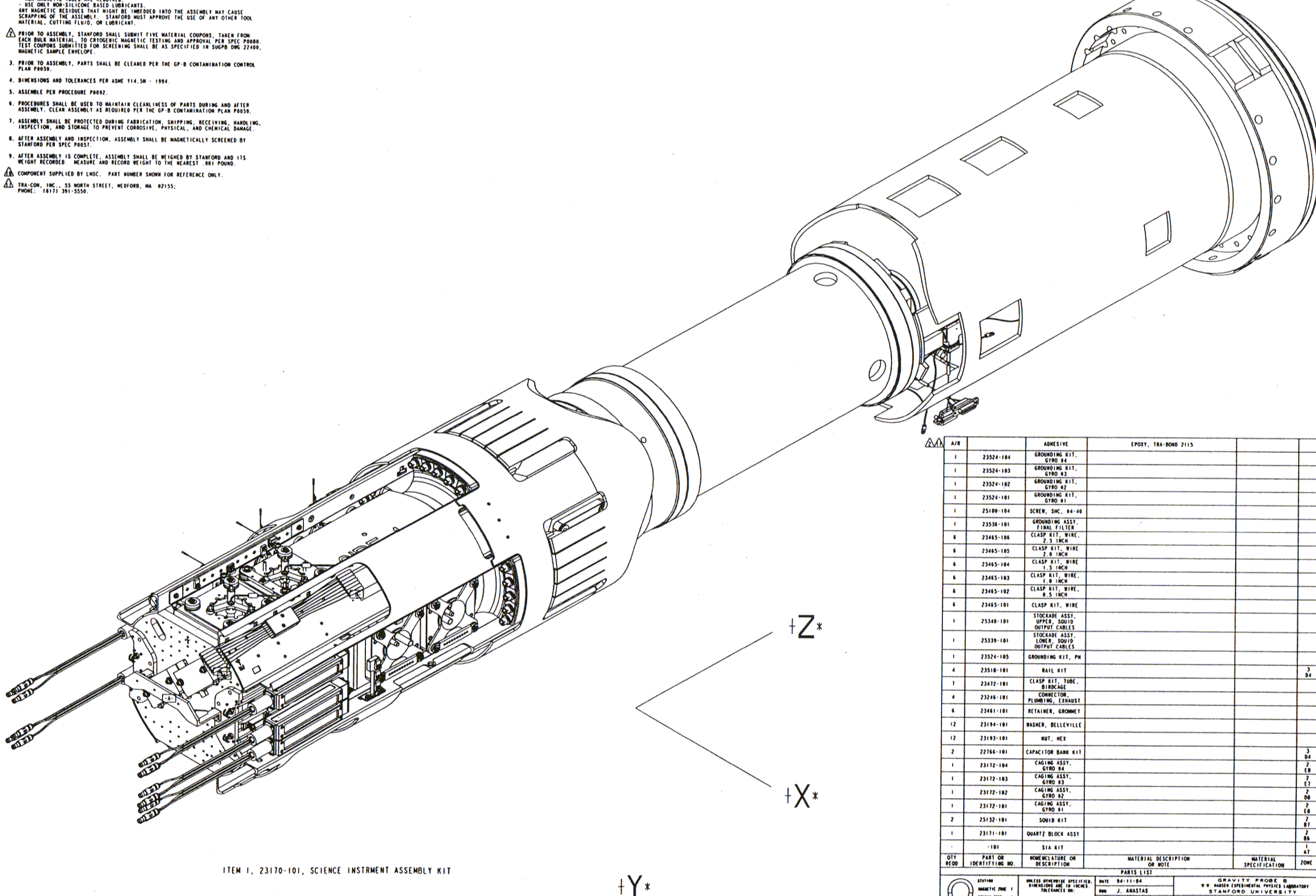
9. AFTER ASSEMBLY IS COMPLETE, ASSEMBLY SHALL BE WEIGHED BY STANFORD AND ITS WEIGHT RECORDED. MEASURE AND RECORD WEIGHT TO THE NEAREST .001 POUND.

10. △ COMPONENT SUPPLIED BY LMSC. PART NUMBER SHOWN FOR REFERENCE ONLY.

11. △ TRA-CON, INC., 55 NORTH STREET, MEDFORD, MA 02155; PHONE: (617) 391-5550.

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APVD



ITEM 1, 23170-101, SCIENCE INSTRMENT ASSEMBLY KIT

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL DESCRIPTION OR NOTE	MATERIAL SPECIFICATION	ZONE	FIND NO
A/R		ADHESIVE	EPOXY, TRA-BOND 2115			30
1	23524-104	GROUNDING KIT, GYRO #4				29
1	23524-103	GROUNDING KIT, GYRO #3				28
1	23524-102	GROUNDING KIT, GYRO #2				27
1	23524-101	GROUNDING KIT, GYRO #1				26
1	25100-104	SCREW, SHC, #4-40				25
1	23536-101	GROUNDING ASSY, FINAL FILTER				24
6	23465-106	CLASP KIT, WIRE, 2.5 INCH				23
6	23465-105	CLASP KIT, WIRE 2.0 INCH				22
6	23465-104	CLASP KIT, WIRE 1.5 INCH				21
6	23465-103	CLASP KIT, WIRE, 1.0 INCH				20
6	23465-102	CLASP KIT, WIRE, 0.5 INCH				19
6	23465-101	CLASP KIT, WIRE				18
1	25340-101	STOCKADE ASSY, UPPER, SQUID OUTPUT CABLES				17
1	25339-101	STOCKADE ASSY, LOWER, SQUID OUTPUT CABLES				16
1	23524-105	GROUNDING KIT, PM				15
4	23518-101	RAIL KIT			3 D4	14
7	23472-101	CLASP KIT, TUBE, BIRDCAGE				13
4	23246-101	CONNECTOR, PLUMBING, EXHAUST				12
6	23461-101	RETAINER, GROMMET				11
12	23194-101	WASHER, BELLEVILLE				10
12	23193-101	NUT, HEX				9
2	22766-101	CAPACITOR BANK KIT			3 D4	8
1	23172-104	CAGING ASSY, GYRO #4			2 E8	7
1	23172-103	CAGING ASSY, GYRO #3			2 E7	6
1	23172-102	CAGING ASSY, GYRO #2			2 D8	5
1	23172-101	CAGING ASSY, GYRO #1			2 E8	4
2	25132-101	SQUID KIT			2 B7	3
1	23171-101	QUARTZ BLOCK ASSY			2 B6	2
-	-101	SIA KIT			1 A7	1

PARTS LIST

STATION
MAGNETIC ZONE 1
CONTAM ZONE 1

NEXT ASSY	USED ON
IC34103	SM

APPLICATION

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ON:
FRACTIONS: ± 1/16
DECIMALS: .X ± .1
.XX ± .01
.XXX ± .005
ANGLES: ± 15 ARC MIN

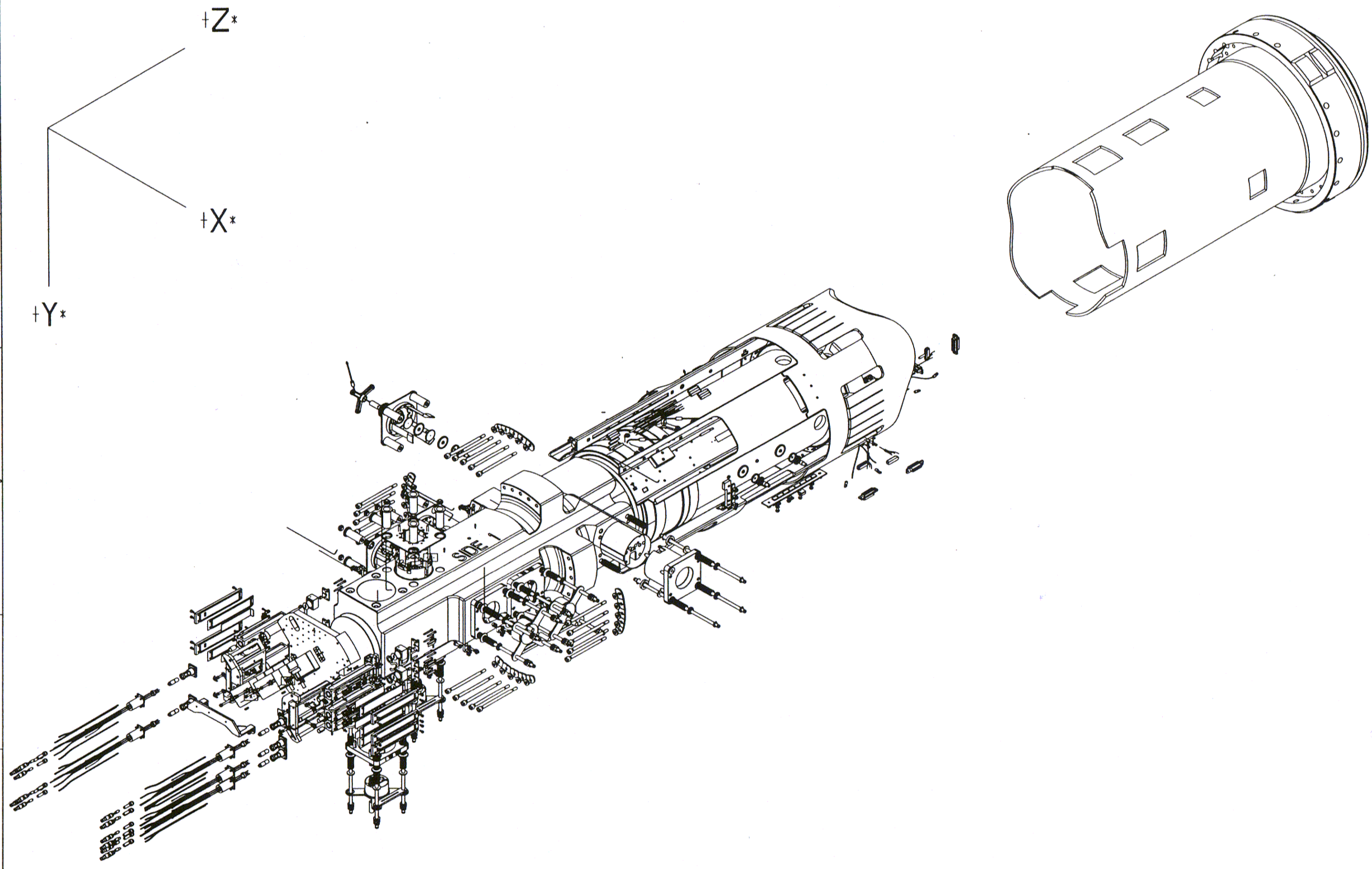
DATE	94-11-04
DWN	J. ANASTAS
ENGR	M. SULLIVAN
CHKD	M. SULLIVAN
RE	D. BARDAS
APVD	J. TURNEAURE
APVD	
APVD	

GRAVITY PROBE B
W.W. HANSEN EXPERIMENTAL PHYSICS LABORATORY
STANFORD UNIVERSITY

SCIENCE INSTRUMENT ASSEMBLY KIT

SIZE E | SUGPB | DWG NO. 23170 | REV -

SCALE: 3:8 | EST WEIGHT: 85.94 LB. | SHEET 1 OF 8



SEE SHEET 1 FOR REVISIONS

SIZE		DWG NO.	REV
E	SUGPB	23170	-
SCALE: DRAWING SCALE		SHEET <CURRENT SHEET> OF <TOTAL SHEETS>	

DWG NO. 23170 <CURRENT SHEET>

NOTES:

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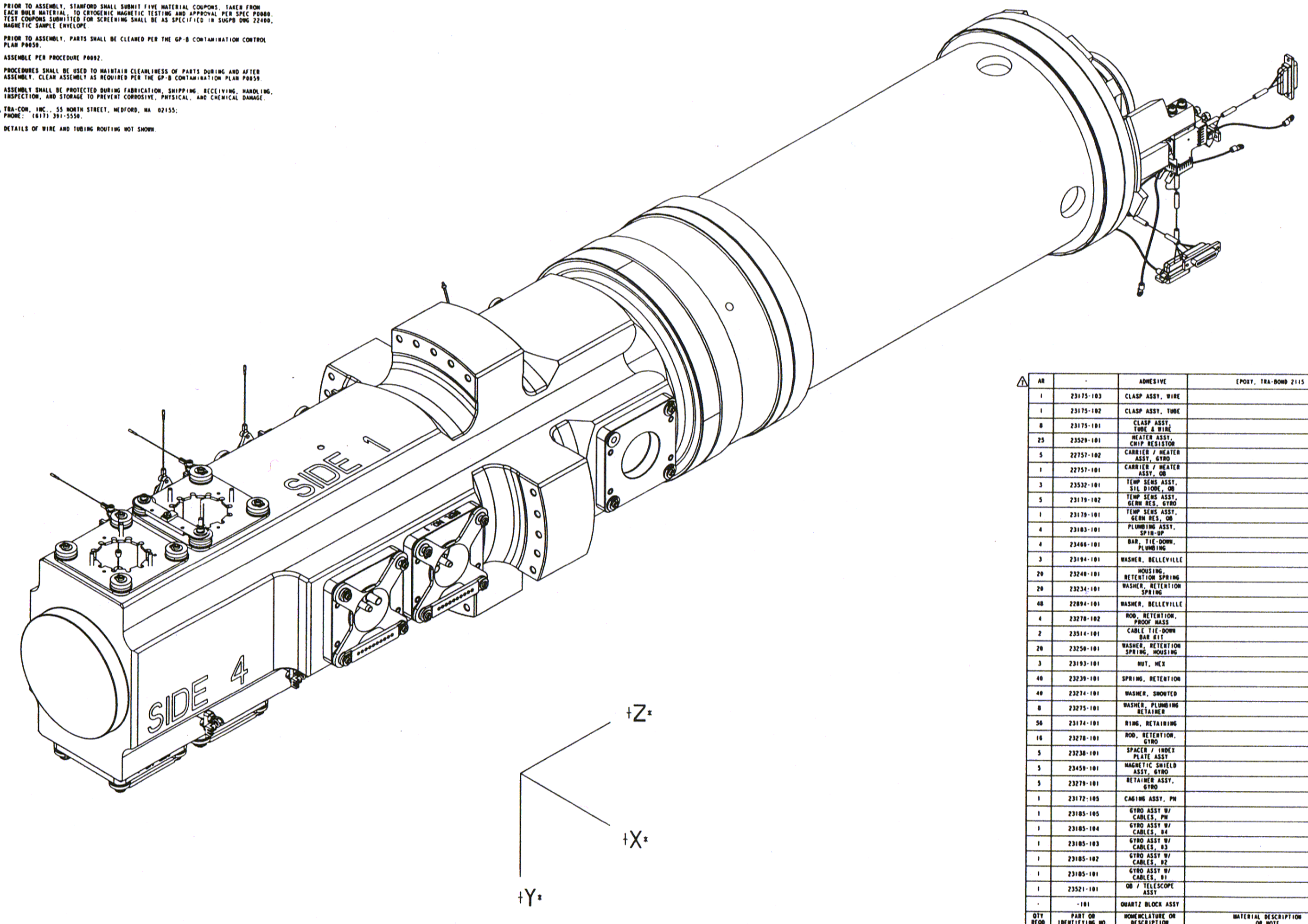
△7 TRA-CON, INC., 55 NORTH STREET, MEDFORD, MA 02155; PHONE: (617) 391-5550.

8. DETAILS OF WIRE AND TUBING ROUTING NOT SHOWN.

ZONE	REV	DESCRIPTION	DATE	APVD



QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL DESCRIPTION OR NOTE	MATERIAL SPECIFICATION	ZONE	FIND NO
AR (△7)	-	ADHESIVE	EPOXY, TRA-BOND 2115			36
1	23175-103	CLASP ASSY, WIRE				35
1	23175-102	CLASP ASSY, TUBE				34
8	23175-101	CLASP ASSY, TUBE & WIRE				33
25	23529-101	HEATER ASSY, CHIP RESISTOR				32
5	22757-102	CARRIER / HEATER ASSY, GYRO				31
1	22757-101	CARRIER / HEATER ASSY, QB				30
3	23532-101	TEMP SENS ASSY, SIL DIODE, QB				29
5	23179-102	TEMP SENS ASSY, GERN RES, GYRO				28
1	23179-101	TEMP SENS ASSY, GERN RES, QB				27
4	23183-101	PLUMBING ASSY, SPIN-UP			6 D7	26
4	23466-101	BAR, TIE-DOWN, PLUMBING			5 D7	25
3	23194-101	WASHER, BELLEVILLE			7 H5	24
20	23240-101	HOUSING, RETENTION SPRING			6 G5	23
20	23234-101	WASHER, RETENTION SPRING			6 G5	22
48	22894-101	WASHER, BELLEVILLE			6 B8	21
4	23278-102	ROD, RETENTION, PROOF MASS			7 F6	20
2	23514-101	CABLE TIE-DOWN BAR KIT			8 H8	19
20	23250-101	WASHER, RETENTION SPRING, HOUSING			6 F6	18
3	23193-101	NUT, HEX			7 H5	17
40	23239-101	SPRING, RETENTION			6 G5	16
40	23274-101	WASHER, SHOUTED			6 B8	15
8	23275-101	WASHER, PLUMBING RETAINER			5 D5	14
56	23174-101	RING, RETAINING			6 G5	13
16	23278-101	ROD, RETENTION, GYRO			6 G6	12
5	23238-101	SPACER / INDEX PLATE ASSY			2 C5	11
5	23459-101	MAGNETIC SHIELD ASSY, GYRO			2 D7	10
5	23279-101	RETAINER ASSY, GYRO			2 E7	9
1	23172-105	CAGING ASSY, PM			7 H3	8
1	23185-105	GYRO ASSY W/ CABLES, PM			2 E3	7
1	23185-104	GYRO ASSY W/ CABLES, B4			2 C6	6
1	23185-103	GYRO ASSY W/ CABLES, B3			2 D5	5
1	23185-102	GYRO ASSY W/ CABLES, B2			2 D5	4
1	23185-101	GYRO ASSY W/ CABLES, B1			2 D4	3
1	23521-101	QB / TELESCOPE ASSY			2 F2	2
-	-101	QUARTZ BLOCK ASSY			-	1

PARTS LIST

STATION
MAGNETIC ZONE 1
CONTAM ZONE 1

NEXT ASSY	USED ON
23170	SM

APPLICATION

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ON:
FRACTIONS: ± 1/16
DECIMALS: .X ± .1; .XX ± .01; .XXX ± .005
ANGLES: ± 15 ARC MIN

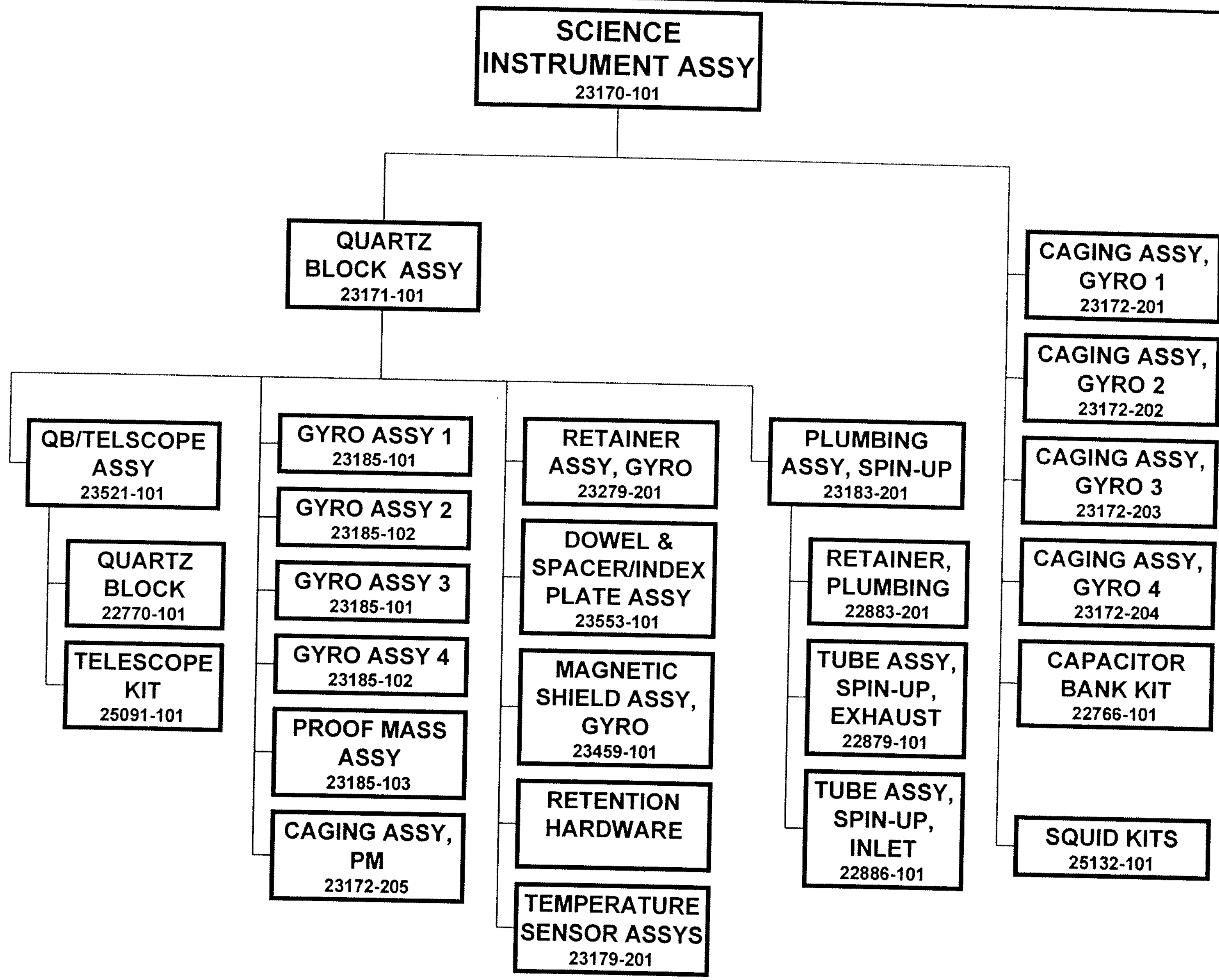
DATE 94-07-25
DRN J. ANASTAS
CHKR M. SULLIVAN
CHKR M. SULLIVAN
RE D. BARDAS
APVD J. TURNEAURE
APVD
APVD

GRAVITY PROBE B
W.W. HANSEN EXPERIMENTAL PHYSICS LABORATORY
STANFORD UNIVERSITY

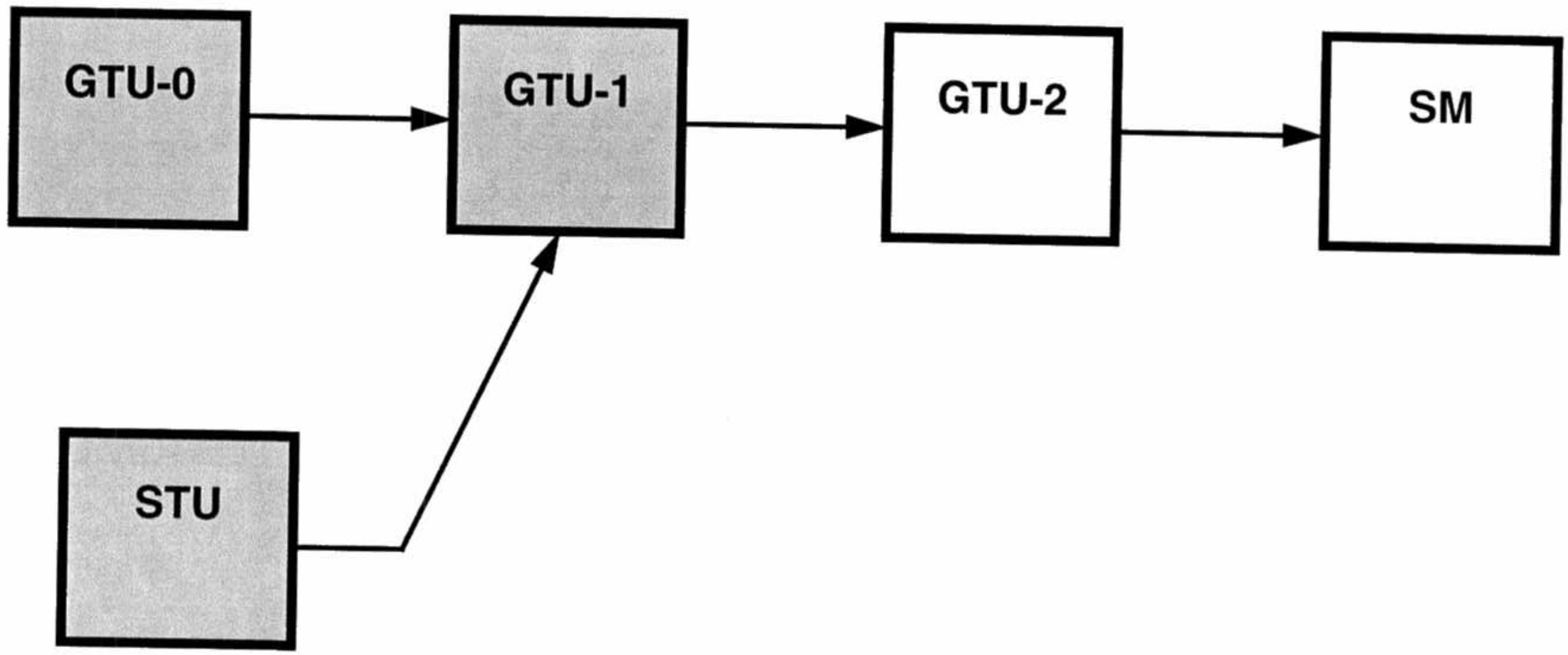
QUARTZ BLOCK ASSY, SM

SIZE E | SUGPB | DWG NO. 23171 | REV -

SCALE: 1:1 | EST WEIGHT: 60.49 LB. | SHEET 1 OF 8


SCIENCE INSTRUMENT ASSY
23170-101
QUARTZ BLOCK ASSY
23171-101
QB/TELSCOPE ASSY
23521-101
QUARTZ BLOCK
22770-101
TELESCOPE KIT
25091-101
GYRO ASSY 1
23185-101
GYRO ASSY 2
23185-102
GYRO ASSY 3
23185-101
GYRO ASSY 4
23185-102
PROOF MASS ASSY
23185-103
CAGING ASSY, PM
23172-205
RETAINER ASSY, GYRO
23279-201
DOWEL & SPACER/INDEX PLATE ASSY
23553-101
MAGNETIC SHIELD ASSY, GYRO
23459-101
RETENTION HARDWARE
TEMPERATURE SENSOR ASSYS
23179-201
PLUMBING ASSY, SPIN-UP
23183-201
RETAINER, PLUMBING
22883-201
TUBE ASSY, SPIN-UP, EXHAUST
22879-101
TUBE ASSY, SPIN-UP, INLET
22886-101
CAGING ASSY, GYRO 1
23172-201
CAGING ASSY, GYRO 2
23172-202
CAGING ASSY, GYRO 3
23172-203
CAGING ASSY, GYRO 4
23172-204
CAPACITOR BANK KIT
22766-101
SQUID KITS
25132-101

SIA DESIGN HERITAGE



SIA DRAWING STATUS

Sub-system	Remarks	Parts/Assys in Design ❶	Drawings in Review ❷	Drawings Released ❸	ECOs Expected	Total Number of Drawings ❶+❷+❸
Caging	Δ design for GTU-2 complete	0	0	29	6	29
Common Parts	design complete	1	0	12	1	13
Detector Package Assy	GTU-2 design complete	15	0	31	4	46
Gyroscope / Proof Mass	design complete	0	3	101	5	104
Quartz Block	Δ design for SM in progress	11	0	17	2	28
Retention Hdwr, Plumbing, etc.	Δ design for GTU-2 complete	9	2	66	1	77
SQUID	Δ design for GTU-2 complete	2	0	79	4	81
Telescope Optics	GTU-2 design complete; Δ design for SM in progress	1	0	29	8	30
TOTAL		39 (10%)	5 (1%)	364 (89%)	31 (8%)	408

SIA DESIGN

STATUS

- **Overall design defined**
  - 89% of SM drawings released (was 60% at SIA PDR)
  - Top-level Assembly solid model (ProEngineer) functional
    - ➤ Performs interface check
- **Incremental Δ Designs ongoing or completed in all major areas**
  - 90% of SM drawings have achieved “In Review” status

ISSUES

- **Reliable sources of magnetically clean materials**
  - Copper alloys somewhat unpredictable
  - Magnetic screening of all SM materials continues

SIA FABRICATION

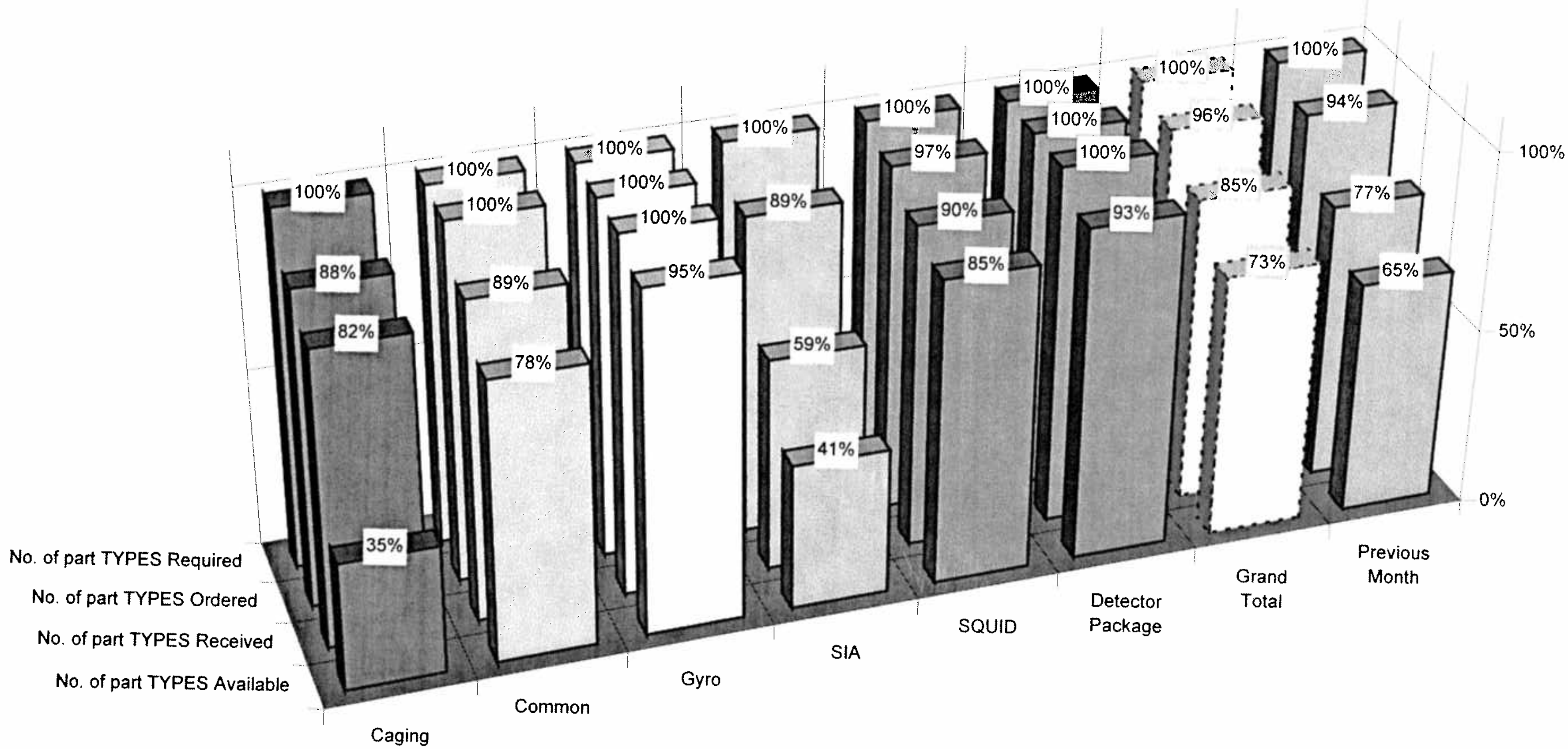
STATUS

- **GTU-2 SIA parts were built to SM standards**
  - Extensive vendor search
  - Magnetic & cleanliness requirements EMPHASIZED
  - Stanford supplied all material from pre-screened lots
  - ☆ GTU-2 parts are Flight Spares (where form, fit, & function still exist)
- **Science Mission SIA parts' fabrications to follow same procedures**
  - Design, Quality, Magnetic, & Contamination requirements well defined
- **Some SM hardware fabrication begun**
  - Quartz Block, Gyroscope, SQUID, & Telescope hardware already being made

ISSUES

- **Consistent production of magnetically clean SM parts**
  - Procedures in place require continued attention

GTU-2 SIA Parts Status, percent



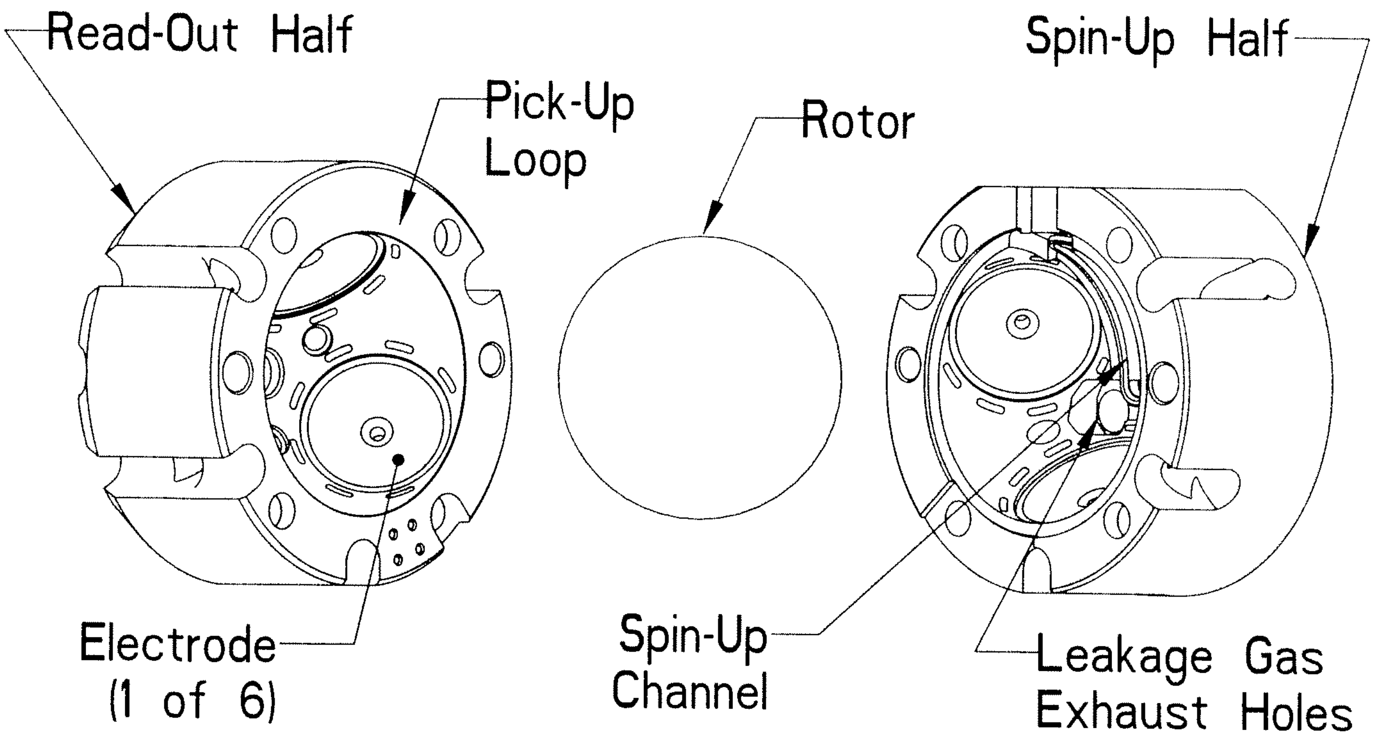
SIA MASS PROPERTIES

	Current Mass, kg (lb)	Center of Mass, mm (in)			Moments of Inertia, kg-mm^2 (lb-in^2)		
		x	y	z	x	y	z
SIA	**40.08** (88.36)	**-0.48** (-0.02)	**1.70** (0.07)	**-26.77** (-1.05)	**2.52E6** (8620)	**40.2** (0.137)	**-1660** (-5.69)
					40.2 (0.137)	**2.51E6** (8580)	**-1020** (-3.48)
					-1660 (-5.69)	**-1020** (-3.48)	**0.159E6** (543)
Requirement	**< 41.0** (< 90.4)	**0.0±20.3*** (0.0±0.8*)	**0.0±20.3*** (0.0±0.8*)	**-31.2±20.3*** (-1.23±0.8*)	**Analytically calculated based on as-built information**		
		*Center of Mass tolerance is a 20.3 mm (0.8") radius sphere around nominal					

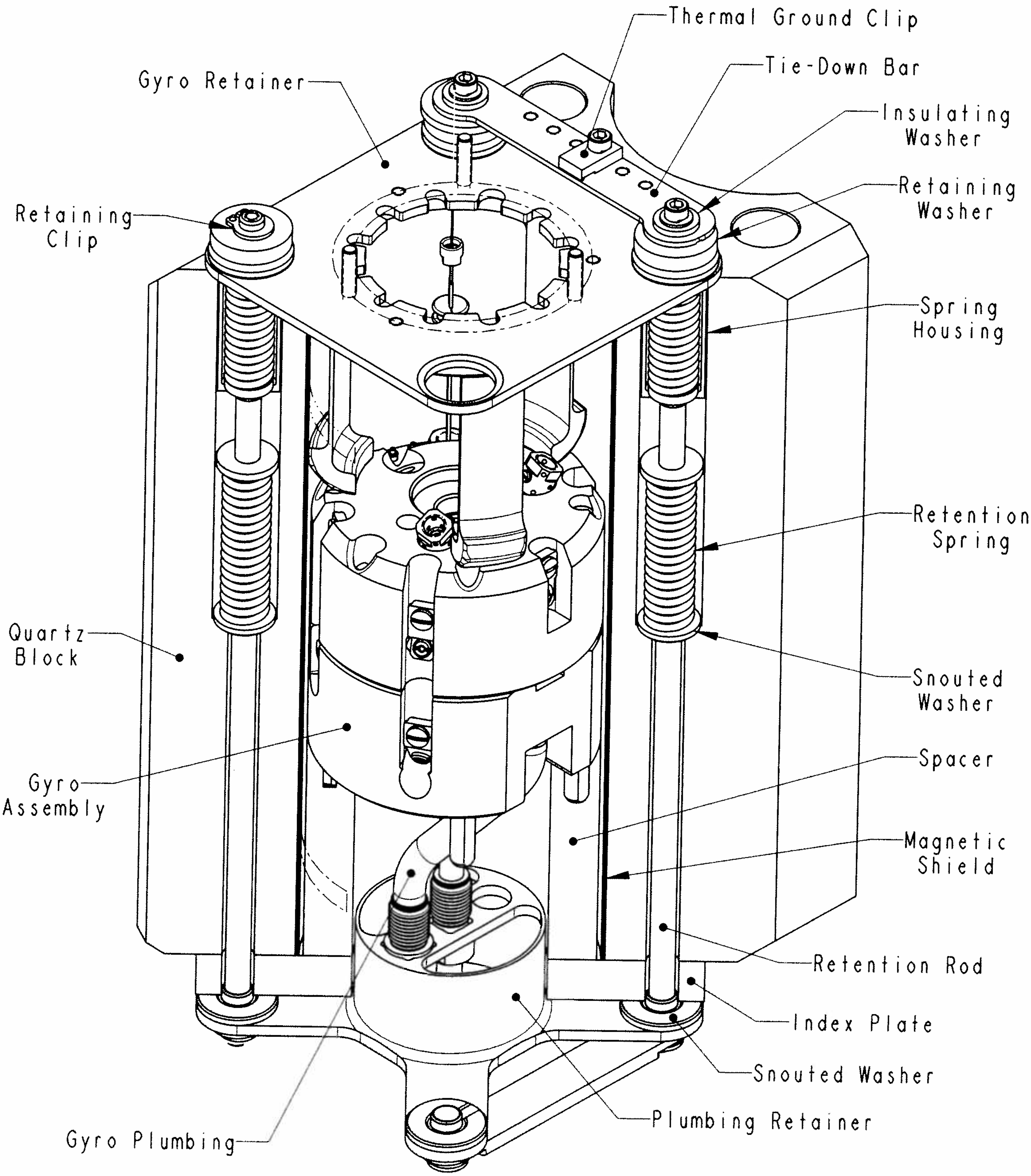
VERIFICATION

- **GTU-2 and Science Mission Assemblies to be weighed**
  - Results will be incorporated in future Mass Properties Reports
    - ➤ Mass contingency reduces as actual hardware masses are known

GRAVITY PROBE B GYROSCOPE

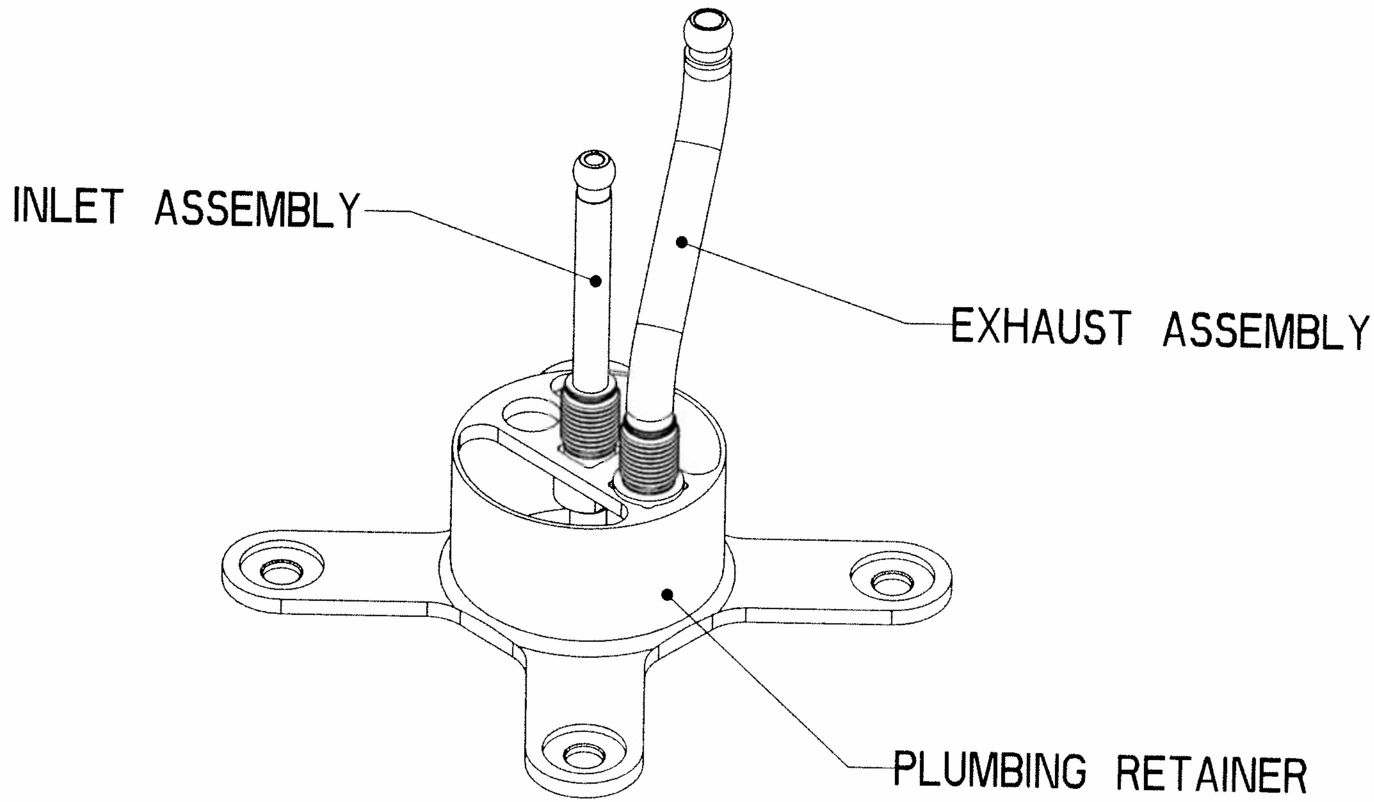


Retention Hardware w/Gyro

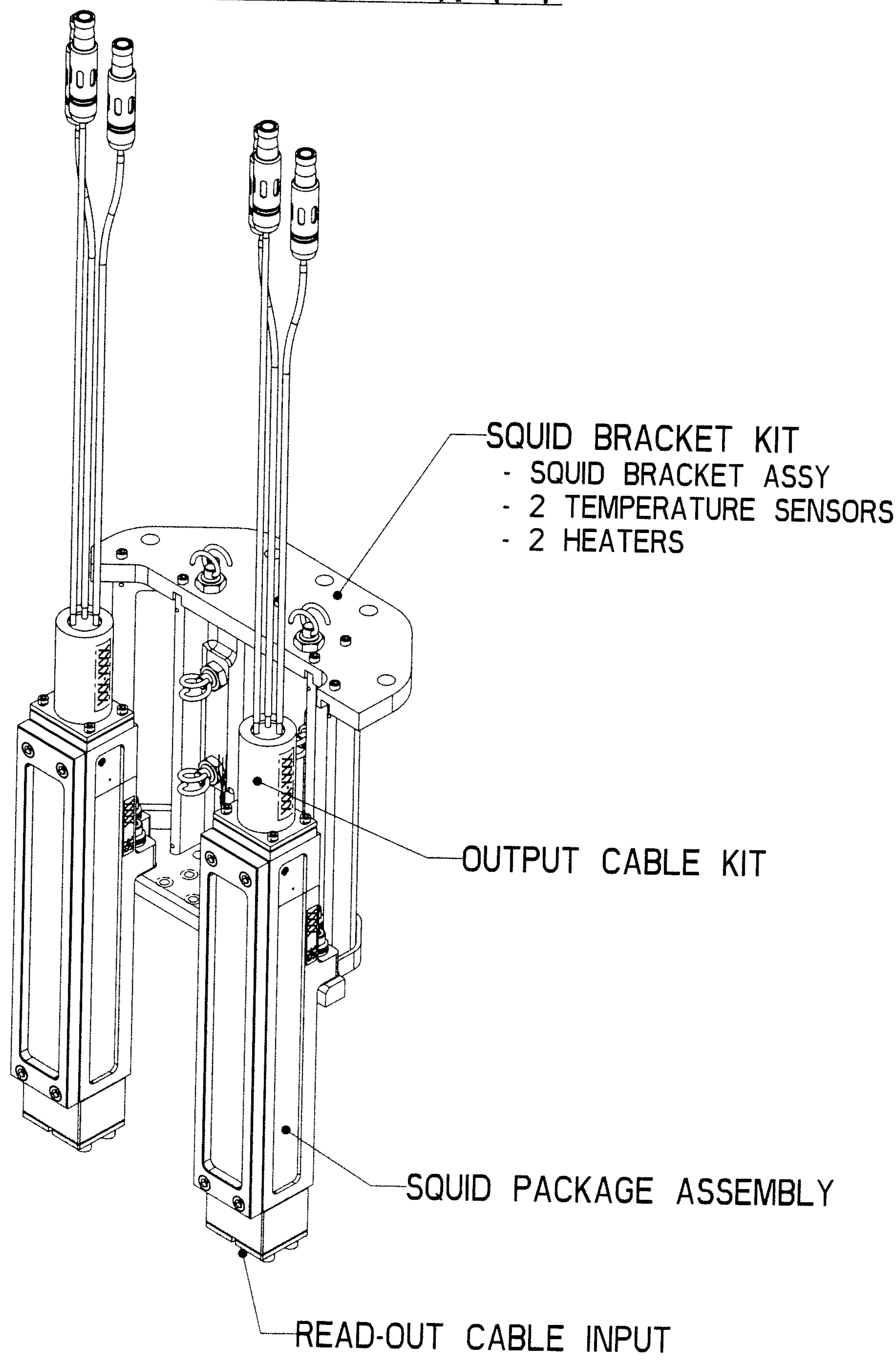


5-31-96

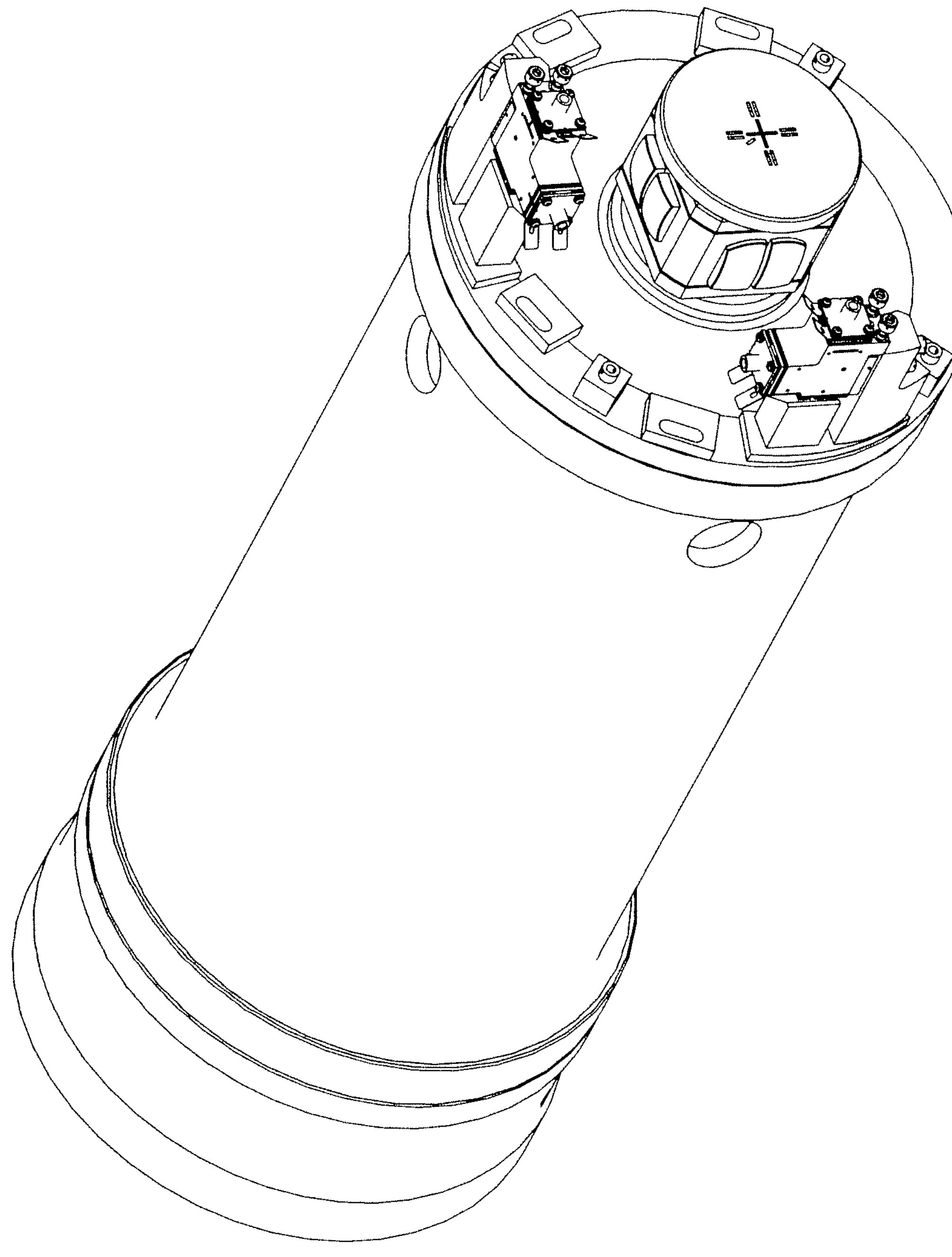
GYROSCOPE SPIN-UP PLUMBING ASSY



SQUID KIT



SQUID BRACKET KIT
- SQUID BRACKET ASSY
- 2 TEMPERATURE SENSORS
- 2 HEATERS
OUTPUT CABLE KIT
SQUID PACKAGE ASSEMBLY
READ-OUT CABLE INPUT



SIA CRITICAL DESIGN REVIEW

QUARTZ BLOCK

Mark Sullivan

SCIENCE MISSION QUARTZ BLOCK

OVERVIEW

- **Six prerequisites for a successful Relativity Mission**
  ❶ a drift-free gyroscope
  ❷ a gyro read-out
  ❸ **a stable reference**
    ➤ **a means (telescope and *mechanical structure*) of referring the gyro read-out to the guide star**
  ❹ a trustworthy guide star
  ❺ a technique for separating relativity effects
  ❻ a credible calibration scheme

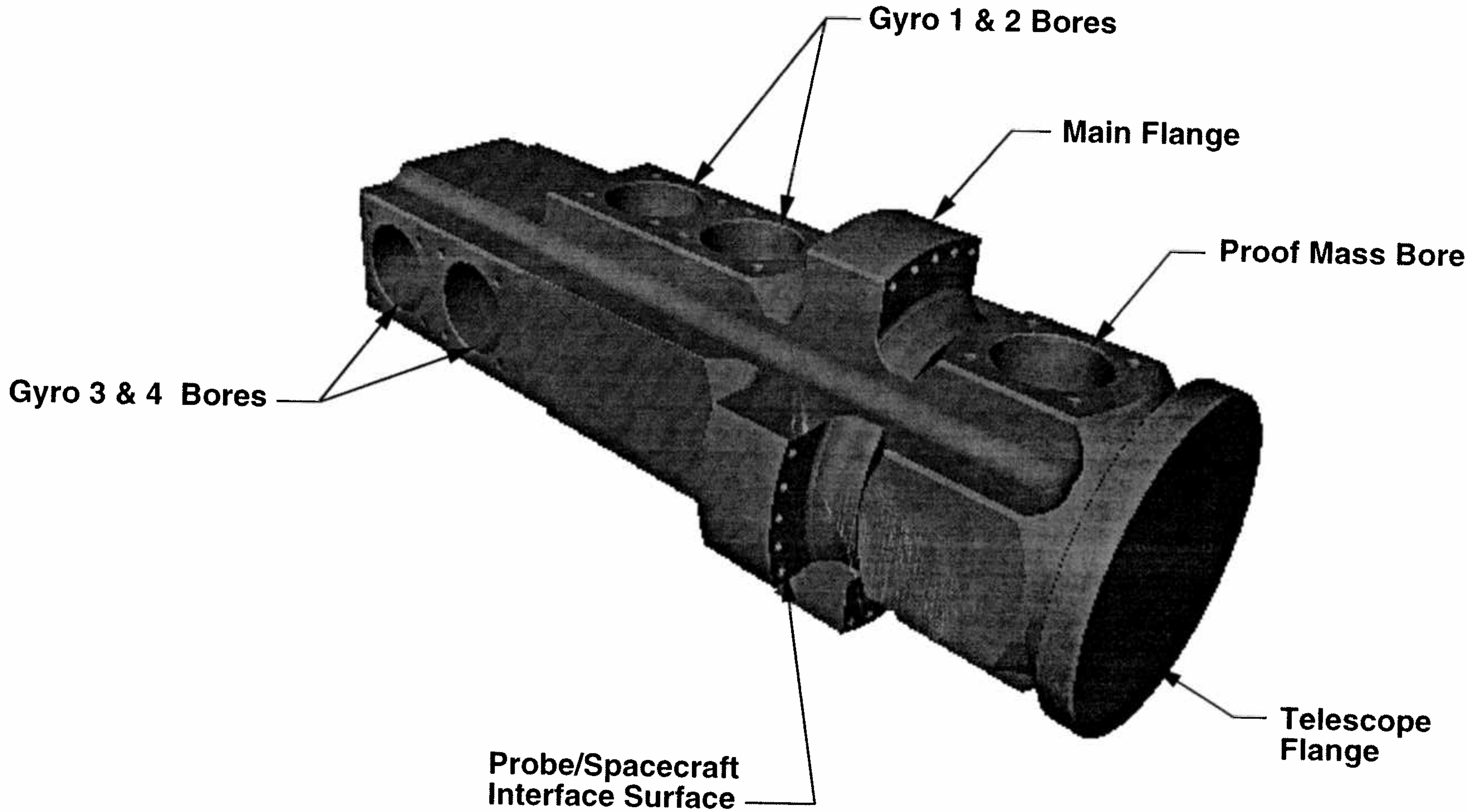
- **The Quartz Block is the <u>mechanical structure</u> which aligns the Telescope with the Gyroscopes**

SCIENCE MISSION QUARTZ BLOCK (SMQB)

OVERVIEW (cont'd)

- **Factors making the Quartz Block "a stable reference"**
  - Material: Solid fused quartz, Herasil 1 Top
    - ➤ Quartz Block and Telescope made from <u>same boule</u>
    - ➤ Special annealing process produces ΔCTE ~1 ppb/K
  - Environment: 2 K operating temperature
    - ➤ Mechanical stability is improved by low temperature operation
      - ◆ Very small temperature variations
      - ◆ CTE essentially constant
    - ➤ Increased ultimate strengths

SCIENCE MISSION QUARTZ BLOCK



SMQB DESIGN STATUS

- **Major features of overall design complete**
  - Geometric dimensioning & tolerancing (GD&T) defined & implemented
  - Top-level drawing being readied for review
- **Phase 1 & Phase 2 Process Drawings released**
- **Phase 3 Process Drawings in work**

SMQB FABRICATION STATUS

SCIENCE MISSION QUARTZ BLOCK 2

- **Refurbished SMQB2 has been received at Stanford**
  - Ready for final cleaning & integration into GTU-2

SCIENCE MISSION QUARTZ BLOCK 5 (FLIGHT ARTICLE)

- **Phase 1 machining completed at Speedring**
- **SMQB5 being sent to University of Arizona for polishing (Phase 2)**
- **SMQB5 will return to Speedring for Phase 3 machining**

SCIENCE MISSION QUARTZ BLOCKS 6 & 7 (FLIGHT SPARES)

- **Material sent from Heraeus, Germany to Atlanta office**
- **SMQB6 will begin Phase 1 machining at Speedring in January**

SIA CRITICAL DESIGN REVIEW

GYROSCOPE CAGING

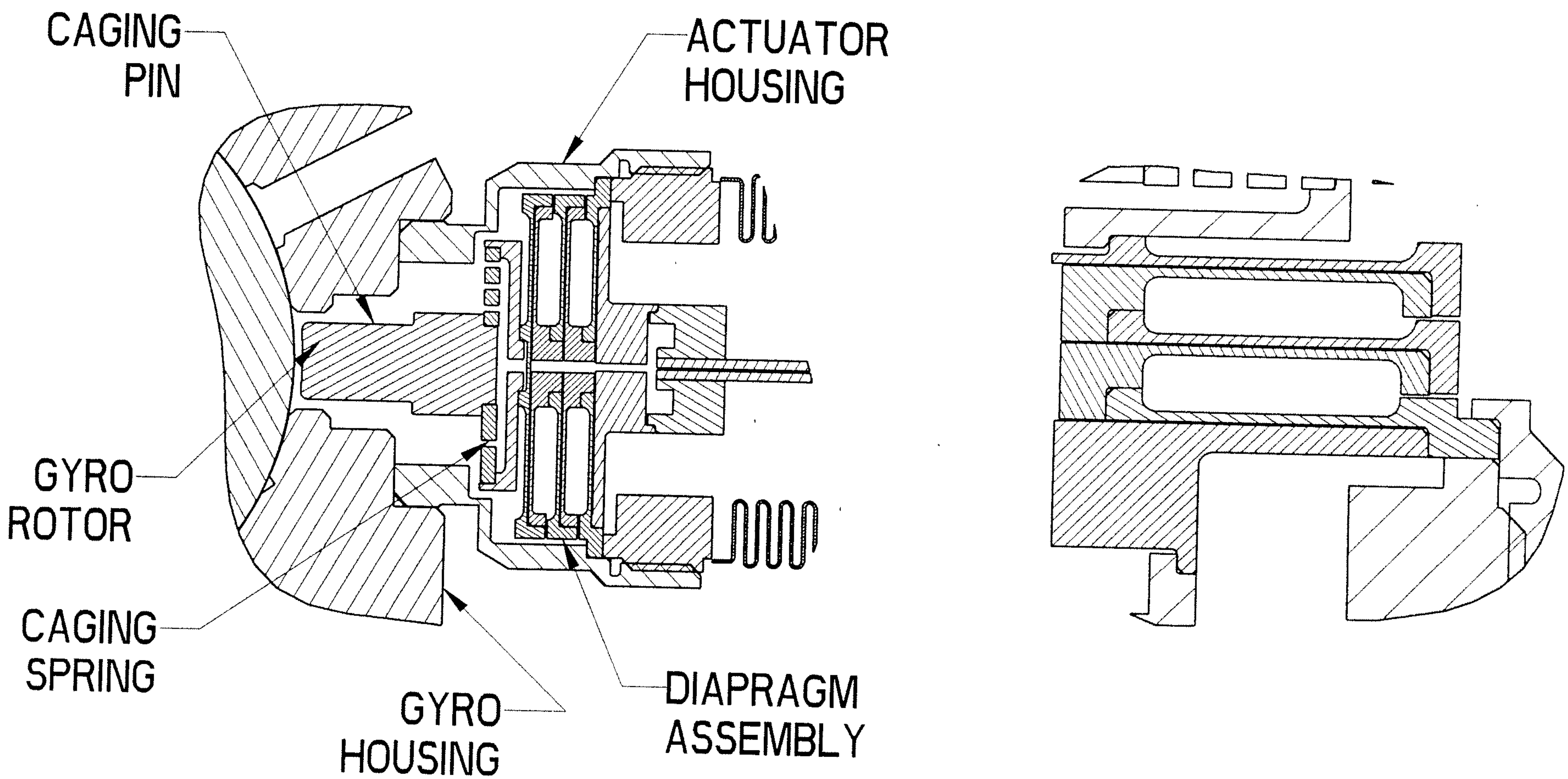
Mark Sullivan

GYROSCOPE CAGING ASSEMBLY

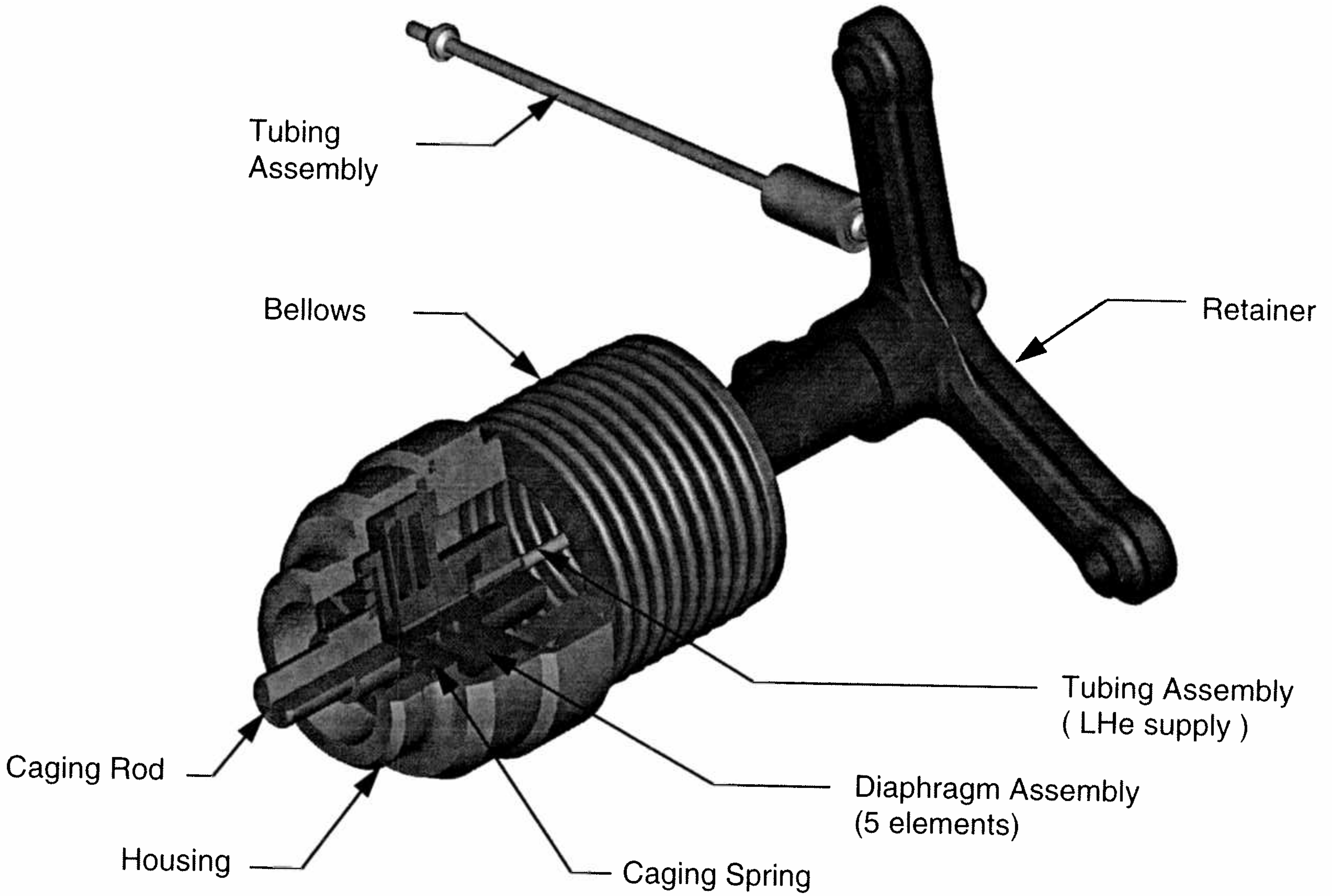
OVERVIEW

- **Design goal**
  - Prevent movement of the Gyroscope Rotor during launch
- **Approach**
  - Secure each Rotor against 3 smooth pads in Gyroscope Housing
- **Implementation**
  - Provide axial force of 13 lb to the Rotor
  - Use He pressure to actuate a Diaphragm set
  - Diaphragm set translates a spring-mounted rod .008" to produce the 13 lb force

CAGING ACTUATION



CAGING ASSEMBLY



CAGING ASSEMBLY DESIGN

STATUS

- **Overall design complete**
  - 26 Part and Assembly drawings released
- **Ternary beryllium copper Diaphragm material is good magnetically**
  - Special run of Ternary Beryllium Copper (BeCuCo) identified
- **All GTU-2 parts fabricated**
- **Laser welding of Diaphragm Assemblies currently underway**

ISSUES

- **Phosphor bronze Tubing has not passed magnetic screening**
  - Etching of ID being investigated
  - Special fabrication of Tubing being considered
- **Caging Assembly fabrication & integration near GTU-2 critical path**
  - Extra effort being made to run fabrication, assemblies, and tests in parallel

DIAPHRAGM MATERIALS

TERNARY BERYLLIUM COPPER SELECTED

Material	Yield Strength, Syt, kpsi	Shapes Available	Remanent Moment, emu	Comments
Requirement	100		~1 x 10^{-7}	Good weldability needed
Ternary BeCu	180 (HT),	Rod	3.8 x 10^{-8} – 1.7 x 10^{-7} (BC01X)	Alloy 125; ∅1/2 & ∅1 rod looks good
	165 (AT)	Rod	N/A	Alloy 125; investigating cold work effects on remanent moment
	N/A	Rod	3.7 x 10^{-8} (JM046)	Limited-run material; 50 lb heats available from Brush Wellman
Binary BeCu	130	Rod	4.0 x 10^{-8} (JL316)	GTU-1 material; no usable stock remains; 50 lb heats available from Brush Wellman
BeCu	150	Many	1.6 x 10^{-7} – 6.6 x 10^{-7} (JL327, JM0087-M)	Commercial product
TiCu, EHT	110	.036 Sheet only?	1.0 x 10^{-7} (LS005)	Made by Yamaha, Tokyo; works well for Lead Bag Fingers

CAGING ASSEMBLY FABRICATION

FABRICATION PLAN

❶ Parts fabrication
- ➤ Precision Diaphragm components
- ➤ Other Mechanical components

❷ Tubing cut to length by Electrical Discharge Machining (EDM)
❸ Magnetic inspection of all parts
❹ Laser weld Diaphragm Assemblies & Tubing Assemblies
❺ Weld penetration tests
❻ Mechanical & magnetic inspection of welded assemblies
❼ Testing & measurement of Diaphragm Assemblies
❽ Final machining of Housings & Rods
❾ Test & verification of completed Caging Assemblies
❿ Integration into SIA

STATUS

- **GTU-2 Caging Assemblies are in Step ❻**

SIA CRITICAL DESIGN REVIEW

GYROSCOPE RETENTION

Doron Bardas & Efrain Alcorta

GYROSCOPE RETENTION – 1

- **NEW RETENTION METHOD FOR GYROS IN QB TO BE USED FOR GTU-2 & SM**

  ⇒ BACKGROUND:

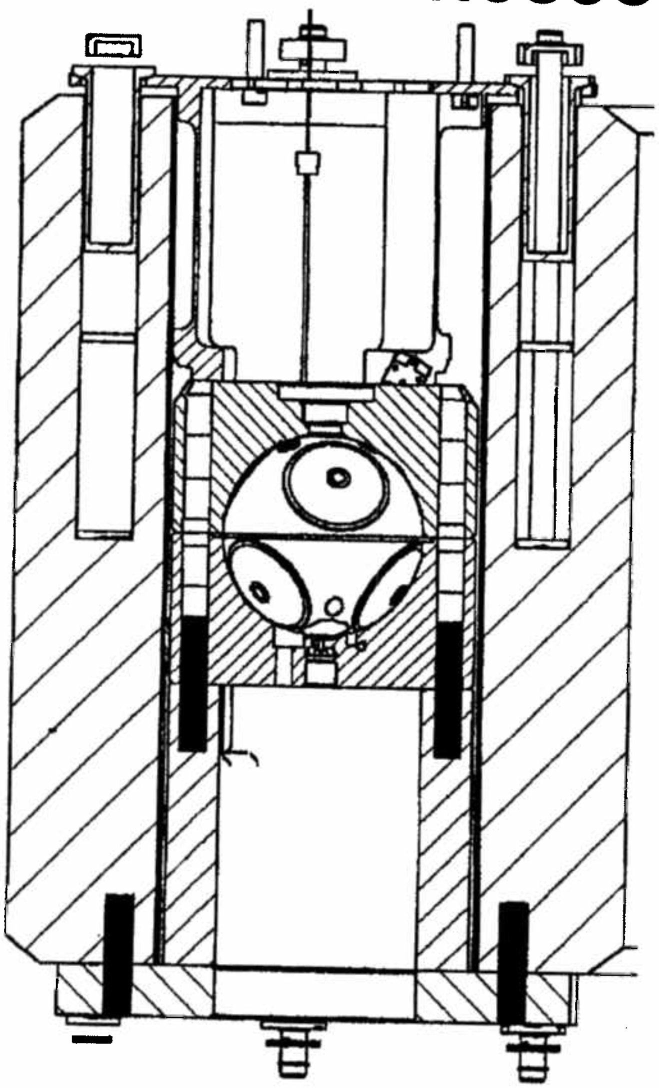
  - **In Recent QB Integrations (STU & GTU-1) it has been difficult to Achieve the Required Tilt and Centering Alignments *Simultaneously* due to several factors:**
    - ◊ Shield bumpers, limiting gyro motion during shake, cause over-constraint
    - ◊ Installation of gyro from readout side of bore requires hard-to-handle fixtures
    - ◊ Securing tapered retention fingers onto gyro chamfer frequently causes tilting
    - ◊ Gyroscopes have become more complicated with many cables attached

GYROSCOPE RETENTION – 2

⇒NEW SYSTEM SECURES GYRO TO SPACER WITH FOUR QUARTZ DOWELS

- ♦ **Precise Dowel Holes Are Machined in Gyro and Spacer**
- ♦ **Prototype Assembly Fabricated From STU Parts Has Been Successfully Shaken**
  - ◊ 10 to 100 Hz at ~5g along bore axis; ~10g in cross-bore direction (launch)
  - ◊ No damage at all; microscopic examination showed dowels/chamfers pristine
  - ◊ Tilt (< 3 arc-s) before and after shake was within SM spec (< 5 arc-s)
- ♦ **Centering of gyro in bore using latest machining methods shown to be < 0.003 dia**
- ♦ **Currently investigating installation of plumbing assembly *before* integ into QB**
- ♦ **New system required modifications to spacer, index plate, and gyro retainer**
  - ◊ also minor modifications to many other retention hardware pieces.
- ♦ **PAYOFF IS EXCELLENT CENTERING, TILT ALIGNMENT, AND INTEGRATION EASE**
- ♦ **THIS HAS BEEN ONE OF EFRAIN ALCORTA'S PRIMARY TASKS FOR 1.5 YR.**

GYROSCOPE RETENTION – 3

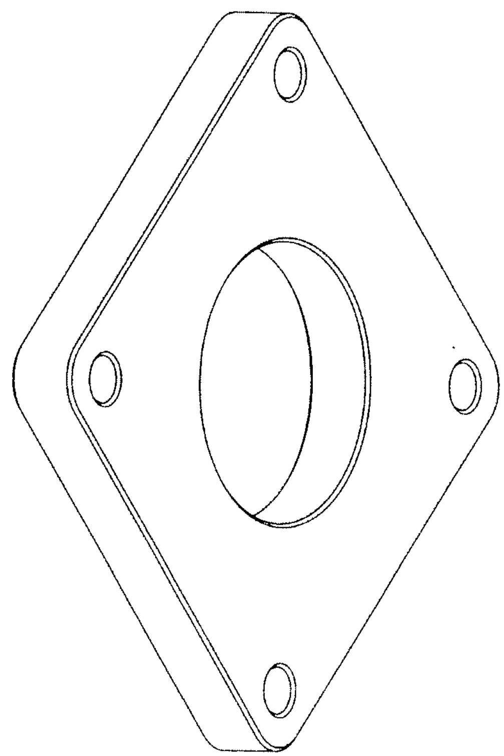


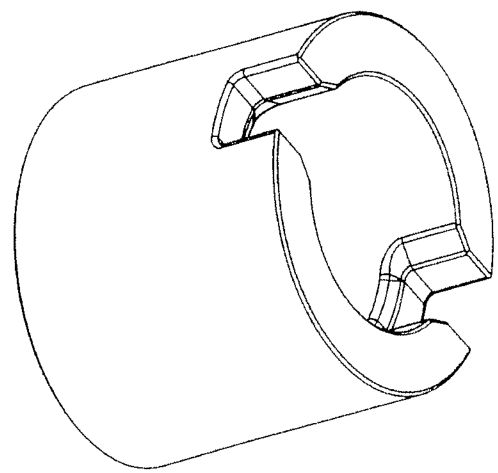
CUTAWAY VIEW OF NEW RETENTION IN TEST FIXTURE

- THE NEW GYRO RETENTION SYSTEM LOCATES THE GYROSCOPE ONTO THE SPACER USING 4 PRECISION QUARTZ DOWELS.
- THE INDEX PLATE IS SIMILARLY DOWELED TO THE QB BY 4 OTHER PRECISION DOWELS
- THE SPACER AND INDEX PLATE ARE BONDED AT STANFORD PRIOR TO THE MACHINING OF THE EIGHT DOWEL HOLES IN THE SPACER AND THE INDEX PLATE, THUS ALIGNMENT OF THESE TWO PARTS TO EACH OTHER IS NOT CRITICAL
- GYRO RETAINER PUSHES BUT DOES NOT WEDGE GYRO IN SHIELD
- RECENT PRECISION MEASUREMENTS AT SLAC USING THE CMM HAVE NOW CONFIRMED THAT THE 4-HOLE PATTERN ON EACH OF THE SPACER AND THE INDEX PLATE ARE < 0.0001 FROM THE IDEAL RECTANGULAR PATTERN.
- THE PATTERN OF SPACER HOLES WAS DISPLACED 0.0001 OF ITS IDEAL LOCATION RELATIVE TO THE CENTER OF THE SPACER, WHILE THE INDEX PLATE DOWEL HOLE PATTERN WAS WITHIN 0.0003 OF SAME
- **EXPECTED CENTERING < 0.003 DIA VS SM REQUIREMENT OF ≤ 0.004 DIA**

GYROSCOPE RETENTION – 4

- **ONE SIGNIFICANT CHANGE IN RETENTION HARDWARE COMPONENTS IS THE CONFIGURATION OF THE INDEX PLATE AND SPACER**
  - ⇒ THE INDEX PLATE AND SPACER ARE DIMENSIONALLY SIMILAR TO THE OLDER TYPE EXCEPT THAT THE SPACER IS NOW SLIGHTLY LARGER IN DIAMETER TO MATCH THE DIAMETER OF THE GYROSCOPE

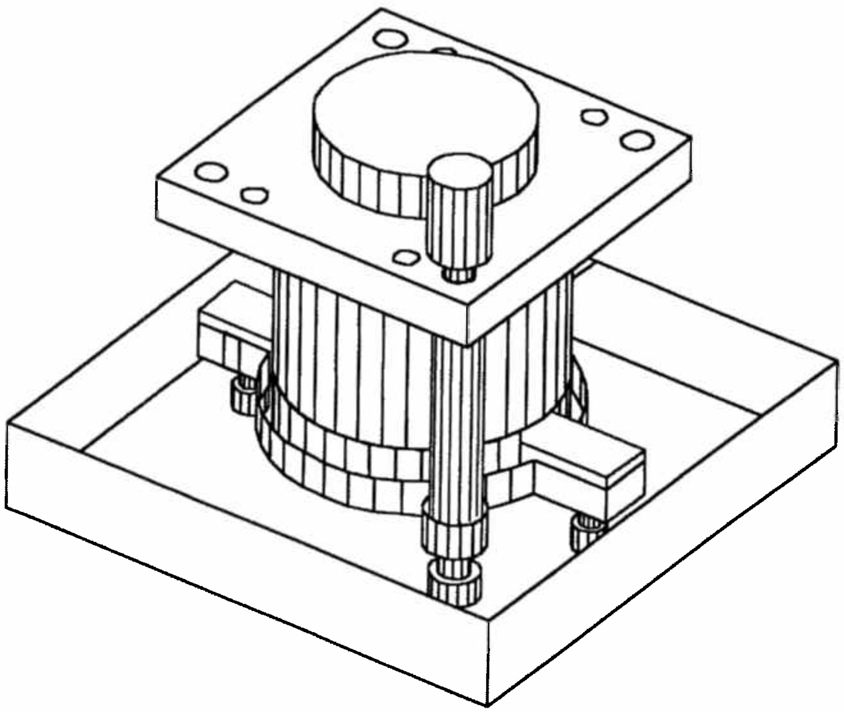


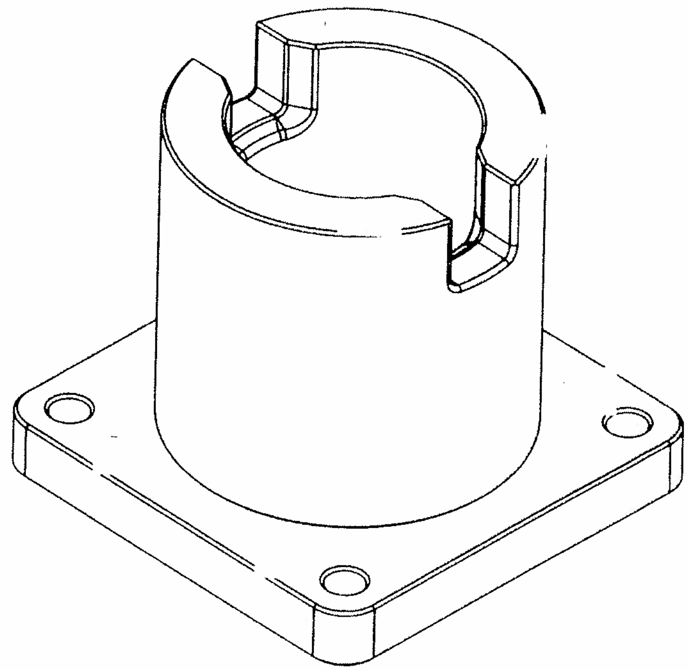


GYROSCOPE RETENTION – 5

- **A NEW BONDING FIXTURE IS BEING DESIGNED TO FACILITATE EASIER SILICATING AND PRECISION ROTATION ALIGNMENT OF THE GYRO WITHIN THE BORE.**

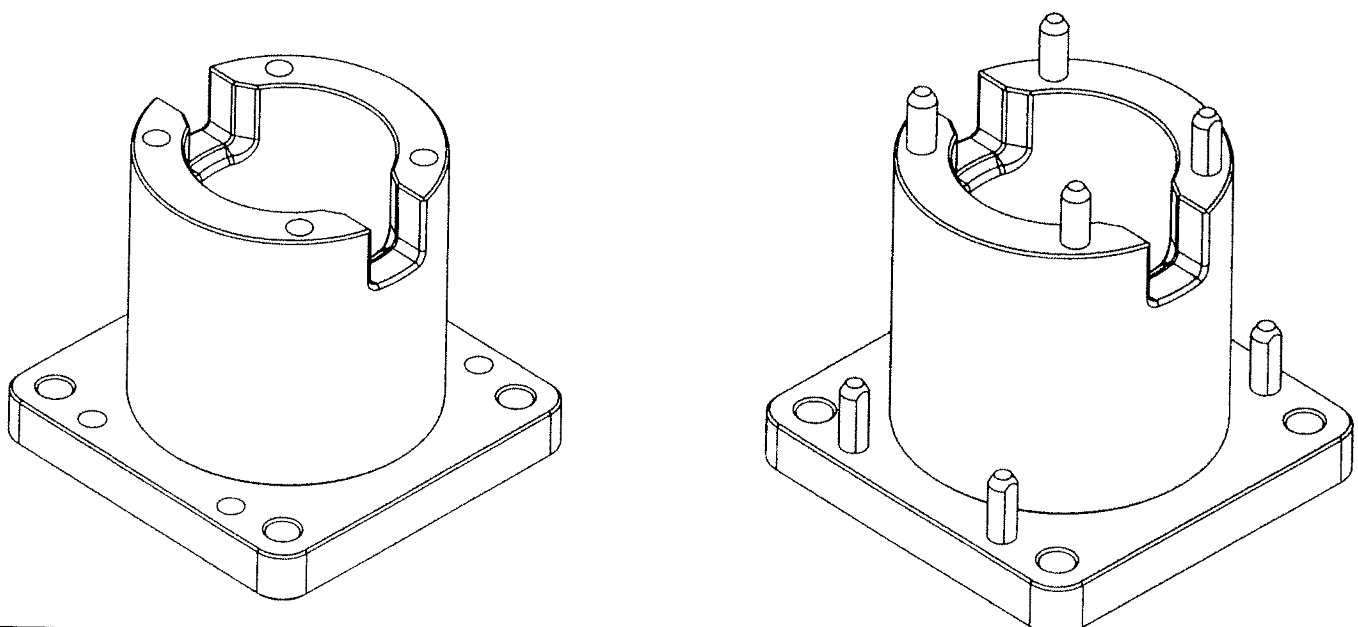
  ⇒ Similar to previous contacting fixture, bond should have tilt < 1 arc-s



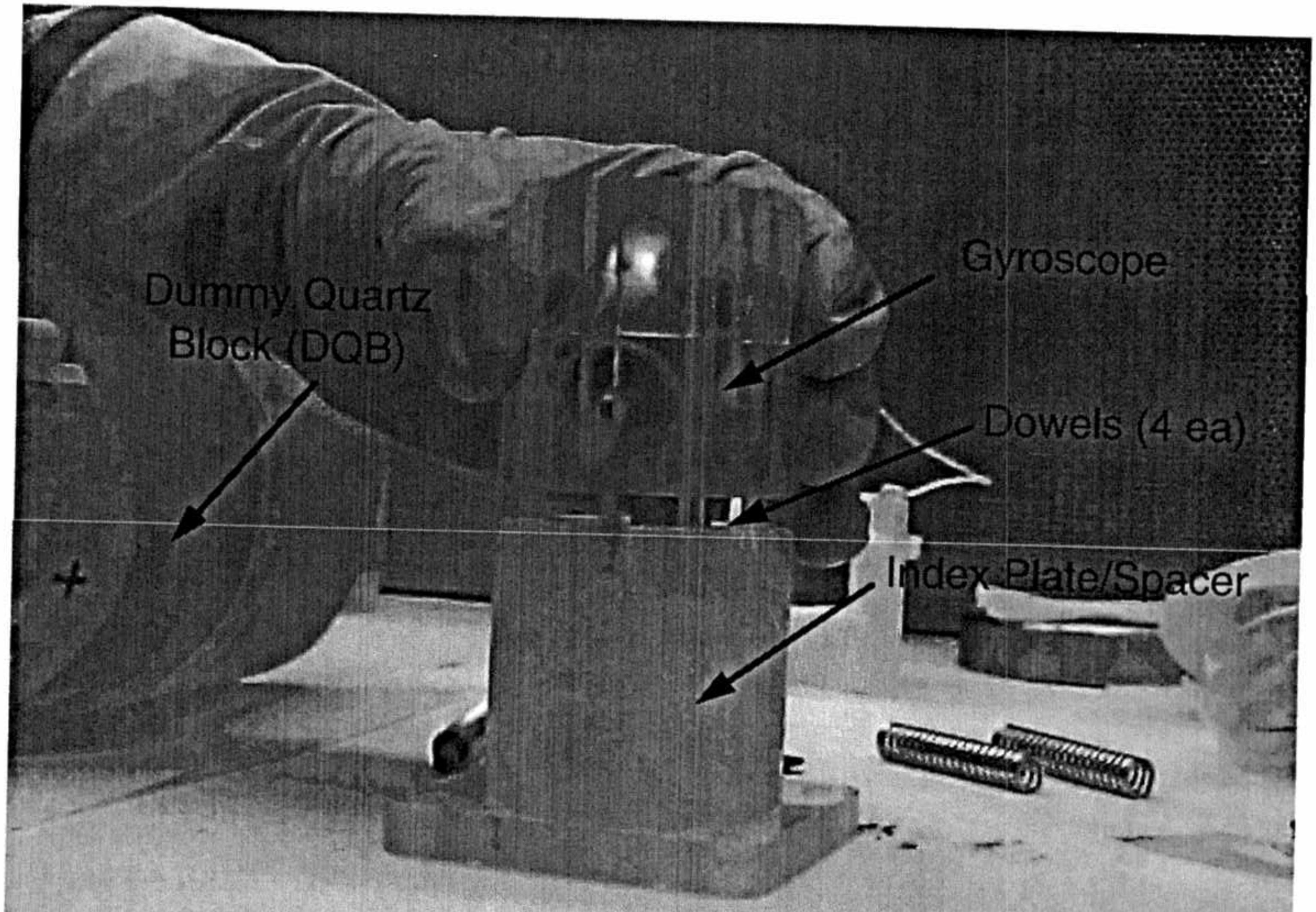


GYROSCOPE RETENTION – 6

- **BONDED ASSEMBLY IS RETURNED TO SPEEDRING FOR INSTALLATION OF DOWEL HOLES IN ONE SET-UP**
  - ⇒ PRECISION DOWELS, WITH ~ 0.0005 DIAMETRICAL CLEANCE TO HOLES ARE FABRICATED TO PROVIDE FOR GEOMETRICAL INTERFACE TO GYRO AND QB ENSURING REQUIRED CENTERING AND ROTATION
  - ⇒ MAINTENANCE OF NEAR ZERO TILT AT GYRO SPACER INTERFACE



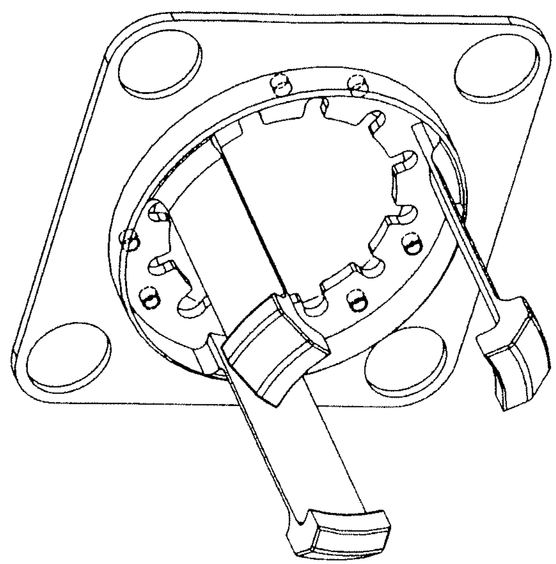
GYROSCOPE RETENTION – 7



LOWERING GYRO ONTO FOUR DOWELS INSTALLED INTO SPACER

GYROSCOPE RETENTION – 8

- **THE GYRO RETAINER HAS BEEN MODIFIED TO ONLY PROVIDE A FORCE TO HOLD THE GYRO AGAINST THE TOP OF THE SPACER**
  - ⇒ IT NO LONGER IS USED TO CENTER THE GYRO WITH TAPERED FINGERS WEDGING BETWEEN THE GYRO CHAMFER AND THE SHIELD
  - ⇒ INSTEAD THE FINGERS END IIN FLAT PADS, EA 0.055 SQ IN, WHICH PRESS ON THE TOP OF THE GYRO, HOLDING IT AGAINST THE SPACER
  - ⇒ THIS AVOIDS OVERCONSTRAINTS ON THE GYRO LEADING TO LARGE TILTS OR MISCENTERING



SIA CRITICAL DESIGN REVIEW

MAGNETICS TESTING

John Mester

SIA Magnetics Testing Objectives

- Ensure SIA Meets GP-B Magnetics Requirements.
- Ensure Fabrication, Cleaning, And Assembly Follow Magnetics Guidelines.
- Determine Magnetic Field Noise Sources; Minimize Impact.

Magnetics Requirements

Hardware Requirement: Rotor Trapped Flux < 10^{-6} Gauss

⇒ SIA Contribution to field at gyroscopes ≤ 1×10^{-7} Gauss

Magnetics Requirements And Verification Procedures Follow

Stanford GP-B Procedure P0057: Magnetic Control Plan

Magnetic Control Issues Guide
All Phases Of SIA Construction

Design	Material Selection	Fabrication	Assembly
GPB Document *Drawing Notes For Magnetic Control of Parts*	GPB Document *GPB Candidate Materials List*	GPB Document *Guidelines for Non-magnetic Fabrication Practices*	GPB Document *GPB Procedure for Magnetic Control of Tools, Fixtures, and Support Equipment*
Magnetics zones specified in drawing notes	Material Coupons submitted for mag approval as outlined in Control Plan	Fabed Parts submitted for mag approval as outlined in Control Plan	Nonmagnetic tool sets maintained by magnetics group
Dimension Specs should account for Chem. Etch Cleaning	Inventory control of approved materials	Inventory control of approved parts	Critical Assemblies submitted for magnetics approval

Magnetics Control Zones

Zone 1: Regions inside each local superconducting shield.

Zone 2: Region inside lead bag shield (not already including zone 1) extending From the bottom of the lead bag to 25 cm above the uppermost gyro.

Zone 2A: Portion of zone 2 within 9 cm distance from the center of any gyro.

Zone 2B: Remaining portion of zone 2.

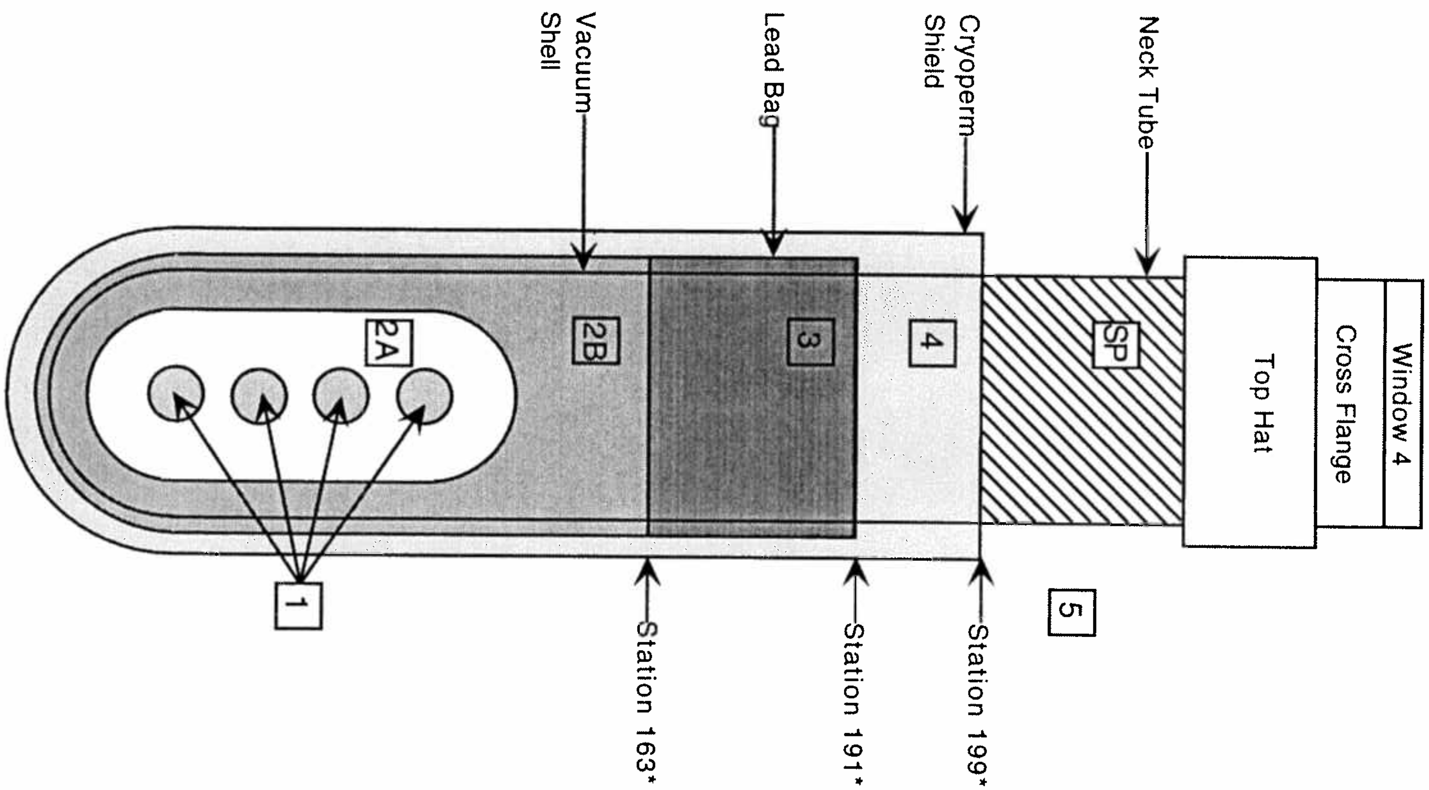
Zone 3: Region inside lead bag extending from the top of Zone 2 to the top of the lead bag.

Zone 4: Region inside the Cryoperm shield but not within the lead bag.

Zone 5: All regions not included in other zones.

Zone SP: Region within probe above top of Cryoperm shield and region between probe and dewar well.

Magnetics Control Zones



Material Qualification

Material Characteristics Considered:

A. Remanent Moment ⇒ DC field at gyro. Minimize.

B. Susceptibility ⇒ Allows sensitive test for magnetic contamination. Minimize.

C. Superconductivity ⇒ Can flux trap or distort fields. Use only as required.

D. Electrical Resistivity ⇒ Large volumes of material with low resistivity produce Johnson noise which can interfere with readout. Minimize use of high conductivity materials.

Material Magnetics Standards By Zone

Magnetic Zone	Rem. Moment	Susceptibility	Superconductivity	Resistivity
1	$< 1 \times 10^{-7} d^3$ emu	$< 5 \times 10^{-6}$ emu/G/g	Only as required	$> 1\ \mu\Omega$-cm @ 2K
2A	$< 2 \times 10^{-6}$ emu	$< 5 \times 10^{-6}$ emu/G/g	Only as required	$> 0.2\ \mu\Omega$-cm @ 2K
2B	$< 4 \times 10^{-6}$ emu	$< 1 \times 10^{-5}$ emu/G/g	Only as required	$> 0.1\ \mu\Omega$-cm @ 2K
3	N/A; field req.	N/A	Only as required	N/A
4	N/A; field req.	N/A	N/A	N/A
5	N/A; field req.	N/A	N/A	N/A
SP	Particulation req.	N/A	N/A	N/A

d = distance from rotor surface in cm.

Finished Part Magnetics Standards By Zone

Magnetic Zone	Avg. Rem. Moment	Rem. Field @ 3.5 cm	Rem. Field @ Sta. 199
1	$< 1 \times 10^{-7} d^3$ emu	$< 1\ \mu G$	N/A
2A	$< 2 \times 10^{-6}$ emu	$< 1\ \mu G$	N/A
2B	$< 4 \times 10^{-6}$ emu	$< 1\ \mu G$	N/A
3	N/A	$< 10\ \mu G$	N/A
4	N/A	< 10 mG	N/A
5	N/A	N/A	< 0.1 G
SP	Particulation req.	Particulation req.	< 0.1 G

d = distance from rotor surface in cm.

GP-B Magnetics Committee may review Waiver applications for parts not meeting standards. Approval decisions based on fundamental magnetics requirements.

Magnetics Verification Procedures

Magnetic Zone	Coupon Testing	Finished Part Testing
1	Cryogenic	Cryogenic
2A	Cryogenic	Cryogenic
2B	Cryogenic	Cryogenic / Gradiometer
3	optional	Room Temp
4	optional	Room Temp
5	none	Survey by material type
SP	no particulation potential — material or permeability particulation potential — zone 2A standards	

Zone 2 parts too large for cryogenic test apparatus treated on individual basis. Acceptance based on Gradiometer test combined with coupon result analysis.

Entire SIA to be tested at AMES facility using Gradiometer and room temp apparatus.

GTU Magnetics Testing Heritage 1

Some commonly considered nonmagnetic materials were found highly lot and heat dependent. e.g.

Phosphor Bronze
BeCu

These require careful selection (Chem. analysis of Fe+Ni+Cr+Co <0.01%) and Magnetic screening, sometimes on rod by rod basis.
High variability and high failure rate.

Other Materials had high rate of Magnetic acceptance:

Quartz	high homogeneity and purity
Ti	Goodfellow, TiCo grade 2
TiCu	Yamaha Metals
Nb	high purity, Teledyne Wah Chang, B-J Scientific
Al 6061	industrial grade

GTU Magnetics Testing Heritage 2

Testing Revealed Proper Surface Procedures of Vital Importance.

Etching: Shown to be necessary even when clean materials and clean fabrication procedures are used. Must be considered in design phase!

Plating: Strict control of plating bath solutions important even when no understrike is used. Plating test coupon samples are required to approve each procedure.

Tiodize: Only approved vendor, Tiodize Inc., should be used. Other vendors have contaminated fabricated parts.

GTU Magnetics Testing Heritage 3

- GTU1 Closely Followed GP-B Magnetics Control Plan. Achieved trapped flux level of $7x10^{-7}$ Gauss, meeting req.

- GTU2 magnetics testing thus far has yielded > 90% acceptance rate.

Major SIA Sub-Assemblies

Quartz Block Assy

QB/Telescope Interface: No GTU1 heritage but silicate bonding tests passed zone requirements with large margin.

Gyro Retention Hardware/ Index Plate: Large parts close to gyro. All parts to be tested in Large Cryoscreener, good GTU1 and 2 acceptance rate.

Plumbing: Several large parts close to gyro, e.g. Plumbing retainer, Spinup hardware. Some special items e.g. spinup bellows. All parts to be tested in Large Cryoscreener, good GTU1 and 2 acceptance rate.

Local Magnetic Shields: Geometry and superconductivity complicate test procedures. High GTU1 acceptance rate after chem. etch.

Temp Sensors: Special run Lakeshore Cryo. Inc. Ge sensors tested individually and selected according to gyro proximity. Si Diode sensors tested for zone 2B.

Major SIA Sub-Assemblies 2

Caging Assy

Several large parts close to gyro.

No GTU1 magnetics heritage.

Special cleaning/etching procedures required for 5mil id Tubing Assembly.

Hi quality Tiodize coating on Caging Rod required to exclude dissimilar metal contact.

Materials selected with very low remanence.

Several finished parts tested for GTU2 pass zone 1 reqs. including: all 5 BeCu diaphragm types, BeCu Springs, Phos Bronze Keepers.

Major SIA Sub-Assemblies 3

SQUID Kit

SQUID Bracket parts cryoscreened.

Complete SQUID Bracket assemblies Gradiometer screened. All 5 assemblies tested for GTU2 meet magnetics requirements.

Temp Sensors tested individually as for QB Assy.

Capacitor Bank

Major parts, Plate (#22761), Lid (#23516), Approved since 11/94

Major SIA Sub-Assemblies 4

Misc. Hardware:

Clasp Kit, Rail Kit, Grounding Kit,

Some parts remain to be tested. Similar parts previously passed.

SIA CRITICAL DESIGN REVIEW

Telescope/ Quartz Block Integration

Jason Gwo

SIA SPECIFICATION (Doc. No. PLSE-12)

3.7.1.4.2.1.1 Accuracy of Perpendicularity

The axes of all readout loops shall be perpendicular to the Science Telescope axis within the error given in 11.2.1 of T003 ($\leq$ 55 arc-sec). The allocations are: (a) $\leq$ 15 arc-sec between Telescope axis (including windows) and readout loop plane, and (b) $\leq$ 40 arc-sec due to stray area of readout loop connections.

3.7.1.4.2.1.2 Stability of perpendicularity

The orientation of the Science Gyroscope readout loops with respect to the Telescope axis shall be stable as stated in section 11.2.1 of T003.

3.1.7.4.2.1.3 Rotation

The Science Gyroscope and Science Telescope readout axes shall be aligned in rotation about the z-axis with the accuracy given in section 11.3 of T003 ($\leq$ 0.02 rad., i.e. 1.1 degree).

Allocations for < 15 arc-sec between Telescope axis (including windows) and Gyro R/O plane

* Window: < 4 arc-sec (~5 waves)

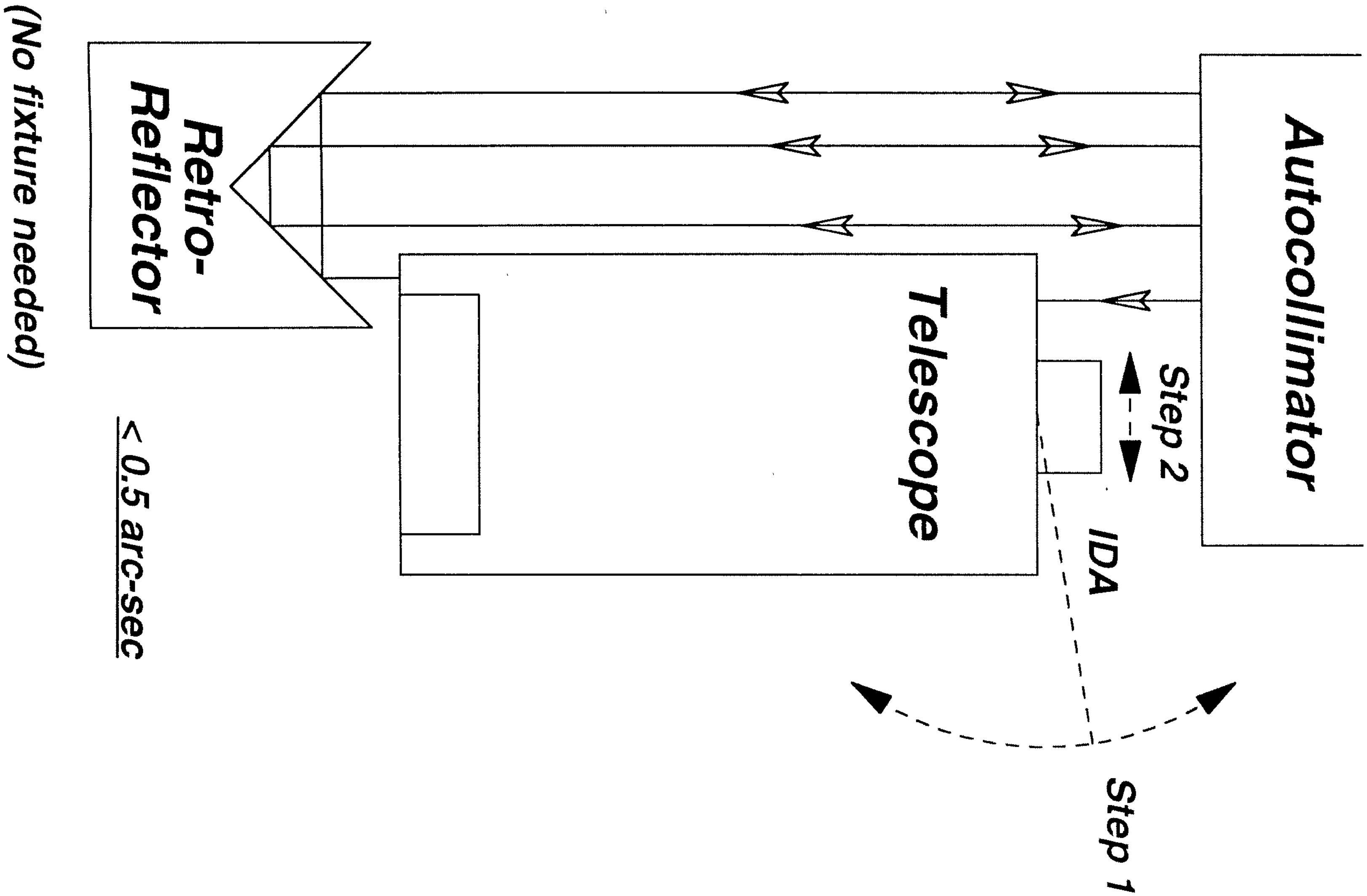
* Perpendicularity bt Telescope optical axis & its base plate: < 3 arc-sec

* Perpendicularity bt Gyro R/O plane & QB top flange: < 5 arc-sec

* Telescope/QB interface wedge: < 1 arc-sec (dominated mostly by measurement accuracy, not by bonding)

Worst-on-worst total: 13 arc-sec (<15 arc-sec)

Alignment Scheme for Telescope Optical Axis w.r.t. Telescope/QB Interface



Allocations for < 1.1° clocking between Gyro R/O plane & Telescope R/O axes

* Orthogonality bt two Telescope R/O axes:	< 0.3°
* Clocking transfer from Telescope R/O axes to Telescope base plate:	< 0.5° (0.009" w/ length of Channel B roof-edge as lever arm)
* Clocking transfer from Gyro R/O plane to QB top flange:	< 0.25 arc-sec
* Telescope/QB interface clocking:	< 0.2° (0.013" on circumference)

Worst-on-worst total: <1.1°

TELESCOPE/ QUARTZ BLOCK INTERFACE REQUIREMENTS:

- No impact on Telescope performance
- Monolithic solid structure
- Interface wedging < 1 arc-sec
- Clocking < 0.2°

BASELINE JOINING TECHNIQUE:

Hydroxide/Silicate bonding + Spring clamping (Sealing unnecessary)

ADVANTAGES OF HYDROXIDE/SILICATE BONDING:

- Strength comparable with that of fused quartz

Launch load	Safety factor
5.2 psi shear	~ 760X (Conservative)
6.2 psi tension	> 670X

- Survives ~ -200 K/ 10 min. cooldown rate to 77 K and
  ~ -100 K/ hr. cooldown rate to ~ 10 K.

- Nominal interface thickness: ~ 200 nm (limited by filter element)
  (corresponding to Telescope/QB interface wedge: ~ 0.2 arc-sec)

ADVANTAGES OF HYDROXIDE/SILICATE BONDING (contd):

- Almost no detectable optical figure distortion (even at 10 K)
- No degradation observed in accelerated life tests
- No outgasing and magnetic contamination problem
- Settling time: 30-40 minutes

ALIGNMENT VERIFICATION SCHEME

[SIA Req. Review, Action Item #5]

Requirements:

(1) Top surfaces of two adjacent (or all four preferably) QBS flanges & QB top flange shall be parallel to < 15 arc-sec. However, none of them is parallel to another within 5 arc-sec.
(2) Area of the reflecting surfaces shall be > 2 cm^2.
(3) Autocollimator with an aperture > 5 inches

Before bonding

(1) Using autocollimation, creat a "constellation" from Telescope:

(a) the **optical axis**, (room temperature readout electronics needed)
(b) the normal of the bottom surface of the **baseplate,**
(c) the normal of the **IDA top** plate (or the reticle plate), and
(d) the normal of the **corrector plate** (edge area for Telescope #2, full area for Telescope #3). (In case it coincides with the normal of the IDA top plate, a ~1 cm o.d., 5-10 arc-sec wedged flat can be bonded to the corrector plate)

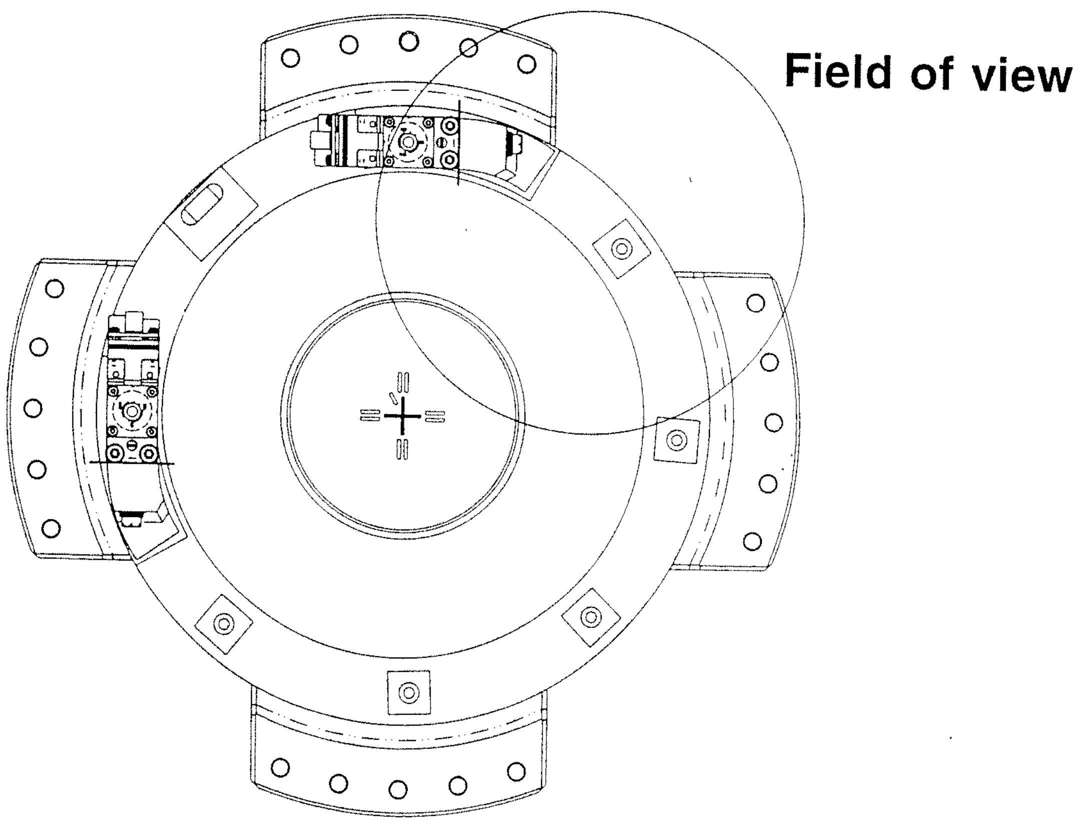
(2) Using autocollimation, creat a "constellation" from QB:

(e) the normal of the **QB top** surface,
(f) and **(g)** the normals of two adjacent **QBS flanges.**

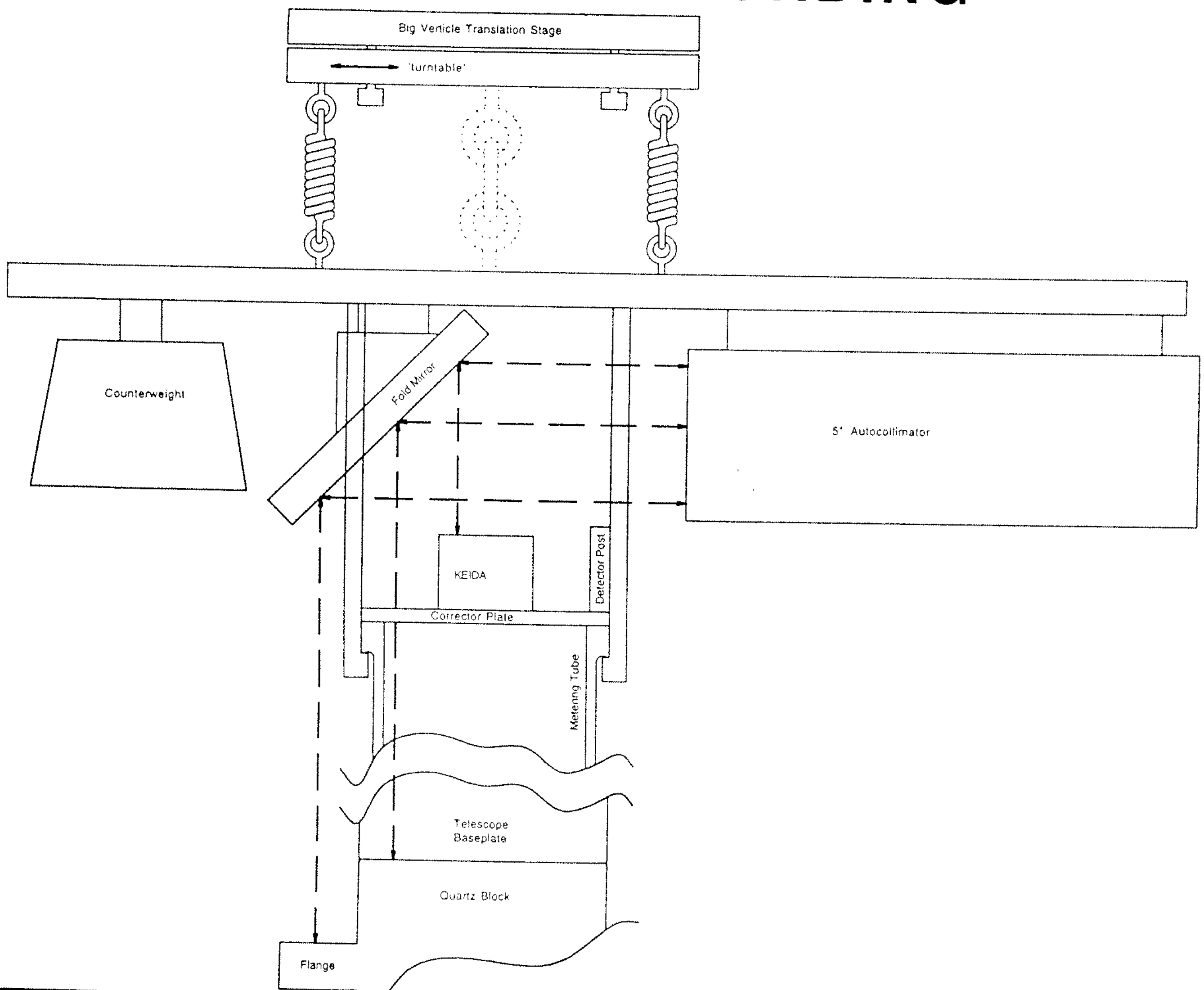
After bonding (c), (d), (f), & (g) ---> (a), (b), & (e) --->

* **Wedge & clocking due to Telescope/QB bonding**
* **Perpendicularity bt optical axis & hidden top surface of QB.**

AUTOCOLLIMATION CONCEPT FOR TELESCOPE/QB ALIGNMENT/BONDING



MECHANISM CONCEPT FOR TELESCOPE/QB ALIGNMENT/BONDING



ADVANTAGES OF THE ALIGNMENT VERIFICATION SCHEME

* Reliability & repeatability
  - --- Reference coordinate system optically established by probe geometry
  - --- No indirect metric transfer
  - --- No external attachment (w/ limited lever arm), no surface damage

* Reasonable QBS fabrication specifications
  - --- Parallelism bt QB top flange & QBS's: [5, 15] arc-sec
  - --- Interim check w/ the 12" ring-shaped flat can be conducted outside cleanroom
  - --- Figure: $\lambda / 4$ tilt within the illuminated area (~0.6"X0.6") w/ negligible second & higher order Zernike terms

* Compatible w/ vertical configuration
  - --- No structural sagging due to gravity
  - --- Allows alignment monitoring during Telescope/QB bonding
  - --- If misaligned, within 10 minutes good chance to debond successfully

* Hidden surface normals may be reestablished after bonding
  - --- Probe monolithicity may be monitored optically

TEST PLAN FOR COMBINED TELESCOPE/QB
(before installation into probe)
[SIA Req. Review, Action Item #1]

(1) Three wedge alignment verification measurements, one, three, and ten days after Telescope/QB bonding. [SIA Spec. 3.7.1.4.2.1.2] (See Action Item #5.)

(2) Three measurements on clocking between Gyro readout loops and Telescope readout axes, one, three, and ten days after Telescope/QB bonding. [SIA Spec. 3.7.1.4.2.1.3]
(Clockings of Telescope readout axes will be transferred to IDA edge during IDA assembly process, and then compared with index plate bonding surfaces on QB optically.)

(3) Characterization of Telescope image size to better than +/-50%
(Room temperature readout electronics and a near-diffraction-limit autocollimator with an aperture of 6 inches or more are needed.)

(4) Measurements on reticle plate
- X-Y location of reticle center [SIA Spec. 3.7.1.4.3.1]
  (Referenced to nominal Roll Axis, defined by two nominally perpendicular index plate bonding surfaces. Metric transfers will be made between all adjacent subsystems from QB to reticle plate.)
- Z location of reticle reflecting plane [SIA Spec. 3.7.1.4.3.2]
  (Summation of Z dimensions of all subsystems from centers of gyro housings to retical plate)
- Rotation of reticle pattern [SIA Spec. 3.7.1.4.3.3]
  (Referenced to clocking of Telescope readout axes. See (2).)
- Orientation of reflecting surface [SIA Spec. 3.7.1.4.3.4]
  (See Action Item #5.)

OTHER TEST PLANS:

- **Bonding characterization for GO/U of A surfaces**

  - * U of A surface cleanliness
  - * Strength
    - --- Including 60°C vacuum bakeout in horizontal configuration w/ static torque load

- **Alignment & bonding/debonding rehearsal in Class 10 cleanroom**

  - * Surface cleaning facility
  - * Using Telescope Mass Model to simulate mass and dimension
  - * Modification of Telescope Mass Model to interface interchangeable practice bonding flat

ISSUE(S)

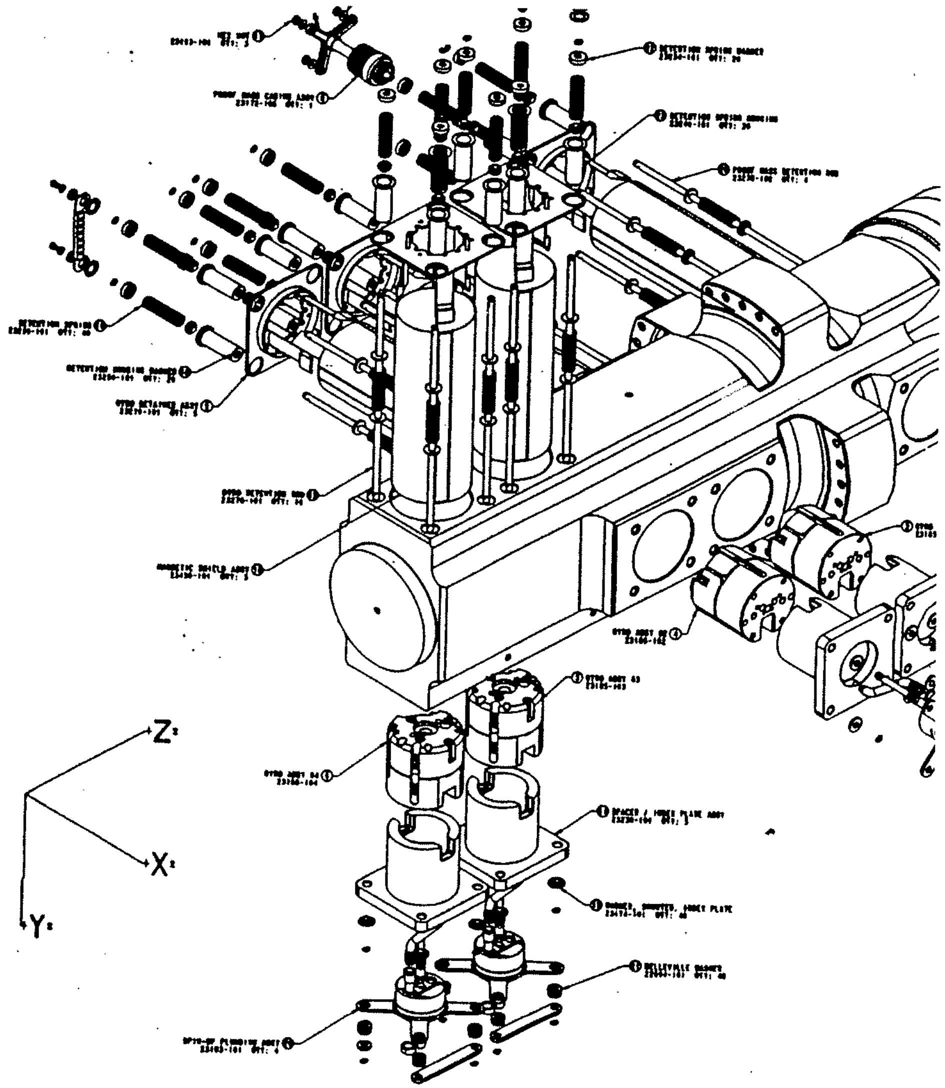
- Finalization on alignment verification scheme for Telescope/QB
  * Separation bt bonding & alignment?

SIA CRITICAL DESIGN REVIEW

SIA INTEGRATION

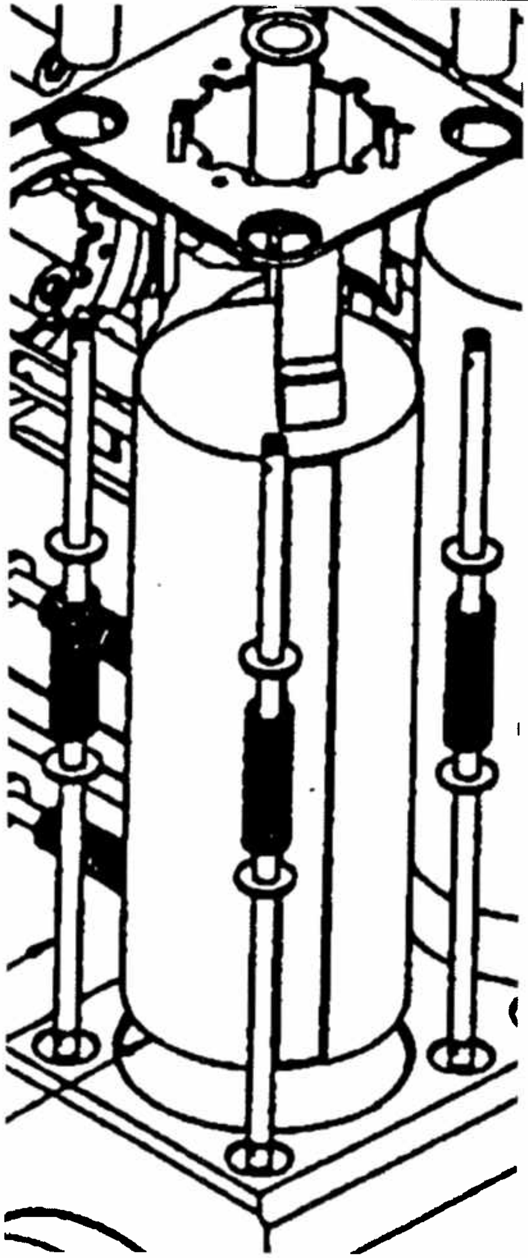
Doron Bardas & Efrain Alcorta

INTEGRATION OF QBA - 1



THE DIAGRAM SHOWS A BLOWN UP VIEW OF GYRO AND RETENTION HARDWARE COMPONENTS THAT ARE INTEGRATED INTO THE QB.

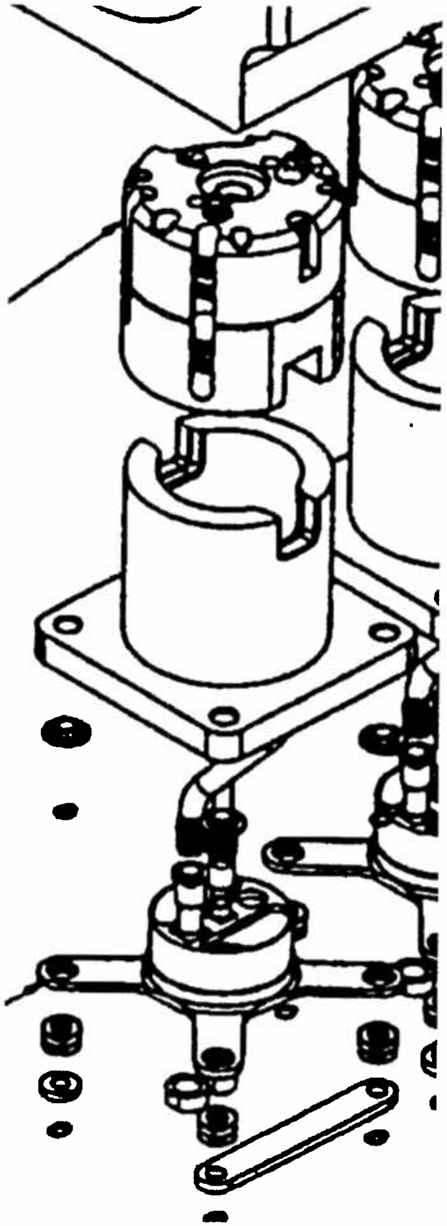
- NOTE TELESCOPE WILL ALREADY BE BONDED TO THE QB AT THIS STAGE
- INSTRUMENTATION INSTALLATION IS NOT SHOWN IN THIS DRAWING
- INTEGRATION CONSISTS OF INSTALLING 4 EA. GYROS AND A PROOF MASS INTO THE QB PLUS ALIGNMENT MEASUREMENTS FOR TILT OF THE GYRO WRT THE BLOCK'S Z* AXIS IN PITCH & ROLL
- WITH THE NEW RETENTION HARDWARE THE GYRO IS HELD AT THE CORRECT AZIMUTHAL ANGLE WITHIN ITS BORE BY THE PRECISION DOWEL PIN SYSTEM. THIS EASILY MEETS THE REQUIREMENT OF $\leq 0.25^{\circ}$
- TILT IS MEASURED WITH A COMPARISON AUTOCOLLIMATOR; ACCURACY $\leq$ 0.5 ARC-S



INTEGRATION OF QBA - 2

- **PROPOSED NEW ORDER OF INTEGRATION**
  - **WILL BE CHECKED OUT IN DECEMBER '96**

1) **INSTALL LOCAL MAGNETIC SHIELD**
2) **PRE-ASSEMBLE GYRO RETAINER WITH CUPS, SPRINGS AND SNAP CLIPS**
3) **LOWER ASSEMBLY INTO QB, WITH EACH ROD IN ITS RESPECTIVE HOLE**
4) **OTHER END OF RODS WILL NOT PROTRUDE AT THIS TIME-BUT WILL BE RE-ENTRANT APPROX. 0.5 IN**



INTEGRATION OF QBA - 3

5) INSTALL GYRO/INDEX PLATE/SPACER/PLUMBING ASSEMBLY INTO BORE FROM BENEATH THE QB

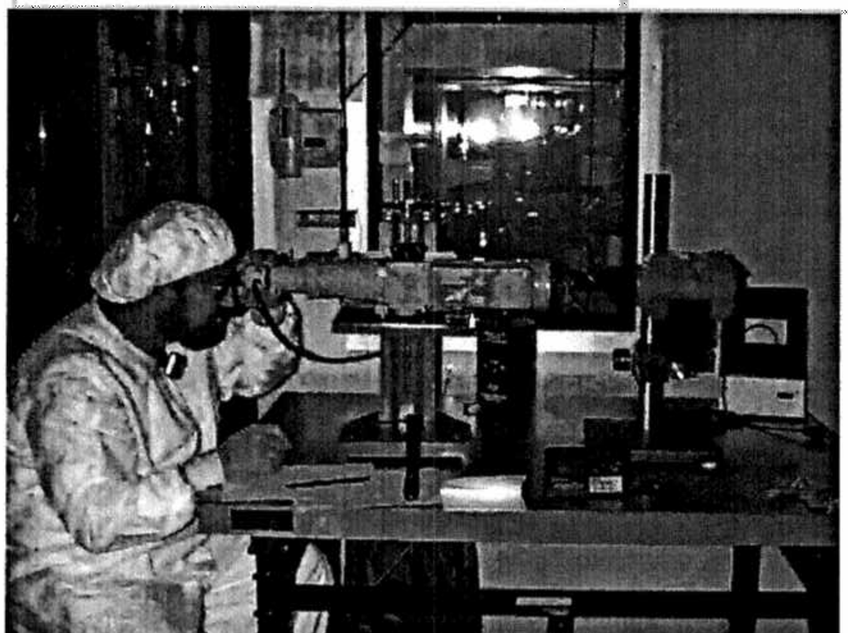
6) HOLD IN PLACE WITH JACK

7) PULL RODS THROUGH WITH 4 EA. NEW SNAP CLIP ASSEMBLY TOOLS

8) INSTALL SNAP CLIPS TO HOLD COMPLETE UNIT IN PLACE

INTEGRATION OF QBA - 4

	CURRENT SM REQUIREMENT	FIST THRU GTU-1	NEW RETENTION (ESTIMATE)
GYROSCOPE TILT (WRT QB)	≤ 4 arc-s	3 to 7 arc-s typ.	≤ 2.5 arc-s typ.
ALIGNMENT OF SPINUP CHANNEL TO TELE AXIS	≤ 0.2°	≤ 0.2°	≤ 0.05°
CENTERING OF GYROSCOPE IN SUPERCONDUCTING SHIELD	≤ 0.008 (dia.)	≤ 0.004 (dia.)	≤ 0.003 (dia.)



CHECKING THE TILT ALIGNMENT OF NEW RETENTION HARDWARE ASSEMBLY USING COMPARISON AUTO-COLLIMATOR. THE BORE AND FACES OF THE QB SECTION ARE ESSENTIALLY IDENTICAL TO THOSE OF A FULL SIZED QB

SIA CRITICAL DESIGN REVIEW

PROBE/SIA INTERFACES

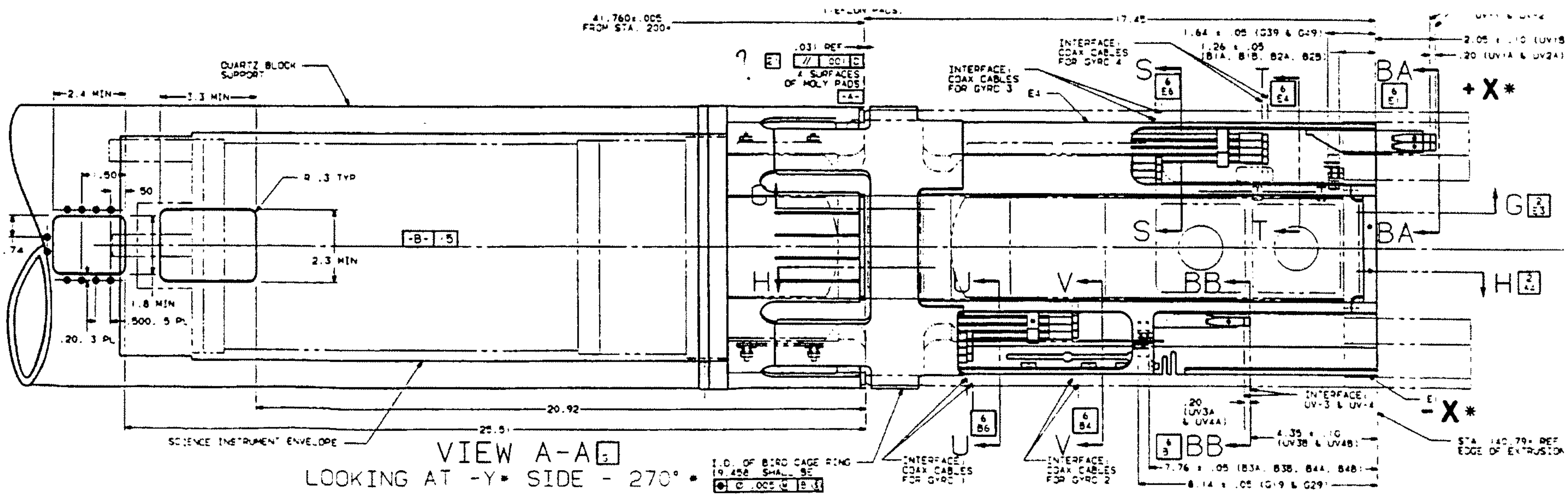
Doron Bardas

PROBE/SIA INTERFACES -1

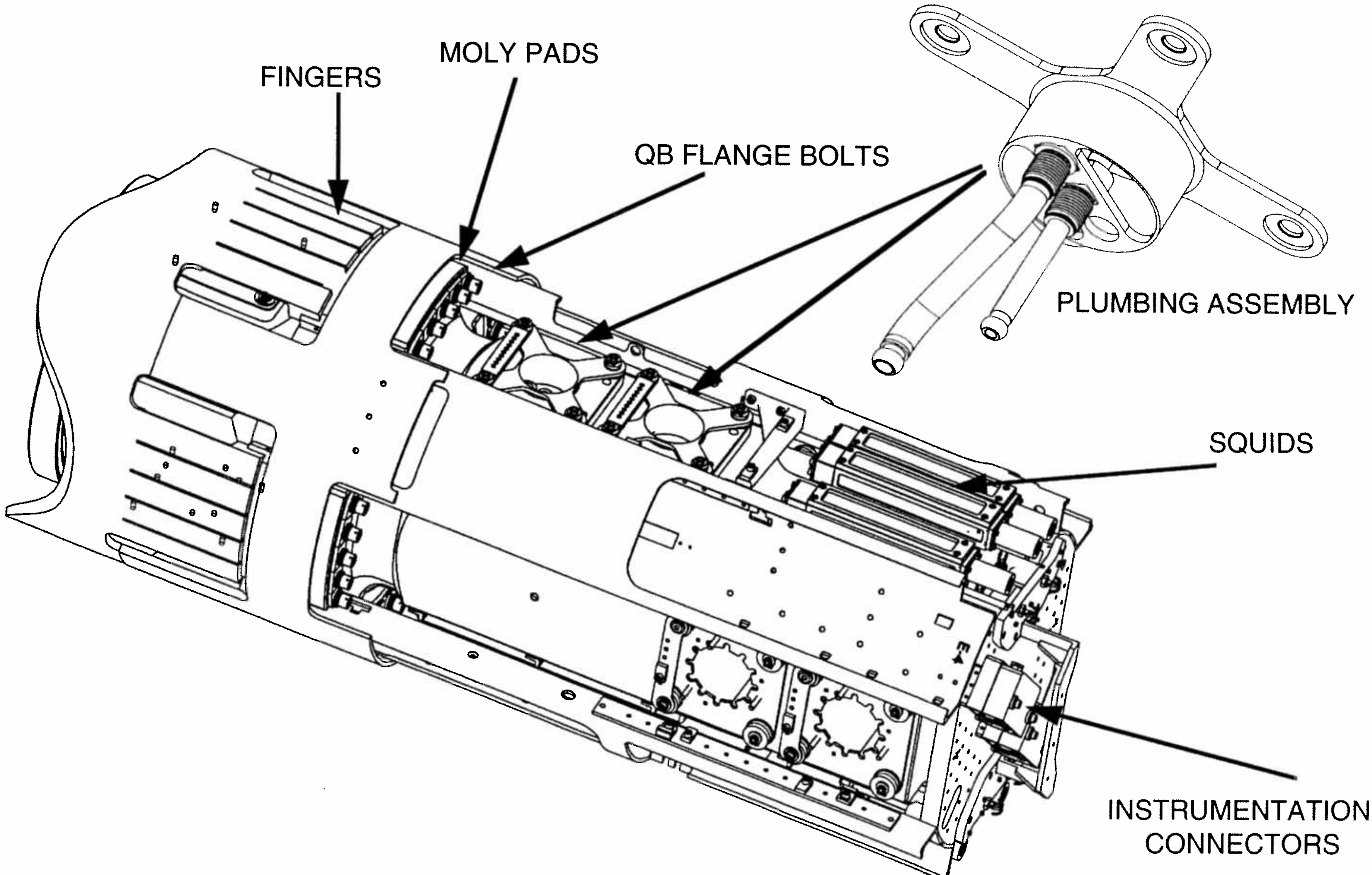
- **PROBE/SIA INTERFACES HAVE EVOLVED AND IMPROVED OVER 8 YEARS**

⇒MAJOR INTERFACES:

- **SIA TO QBS VIA 20 BOLTS AT QB FLANGE INCLUDING THERMAL INTERFACE**
- **RING BUMPER AT QB FLANGE LIMITS QB MOVEMENTS ON SHAKE TO < 0.005**
- **GYRO, SQUID, TELESCOPE, INSTRUMENTATION CABLING TO PROBE**
- **SPIN-UP INLET AND EXHAUST GAS INTERFACES FOR EACH GYRO**



PROBE/SIA INTERFACES - 2



PROBE/SIA INTERFACES - 3

- **INTERFACE AT EACH OF THE FOUR QB FLANGE CONSISTS OF:**
  - ⇒ THE QBS FINGERS CONSTRAINED WITHIN A FIVE SECTOR MOLY PAD
    - ♦ **THIS STRUCTURE IS BONDED IN A PRE-LOADED CONDITION SO THAT THE GROUP OF FIVE BOLTS IS DISPLACED RADIALLY INWARDS BY 0.014 IN RELATIVE TO THE QBS OD**
    - ♦ **DURING SIA TO PROBE INTEGRATION , THE MOLY PADS ARE DISPLACED INWARDS AN ADDITIONAL 0.004 IN TO MATCH QB FLANGE BOLT HOLES**
      - ◊ *I.E. IN THE WARM CONDITION THE FINGERS ARE PRE-LOADED INWARDS BY 0.018*
      - ◊ *THIS DISPLACEMENT DROPS TO NEAR ZERO AT CRYOGENIC TEMPS*
      - ◊ *THIS METHOD, DEVELOPED AFTER INITIAL SHAKE TESTS WITH THE STU QB HAS PROVEN FULLY RELIABLE IN SHAKE AND CRYO TESTS*
    - ♦ **THE BOLTS AT THE QB FLANGE ARE EACH PRE-LOADED USING A GAUGE FIXTURE TO SET THE SQUEEZE OF 6 BELLEVILLES SUCH THAT AFTER DIFFERENTIAL CONTRACTION EACH PROVIDES A FORCE OF ~ 90 lb.**

PROBE/SIA INTERFACES - 4

- **DURING INTEGRATION OF PROBE TO SIA, THE RING BUMPER IS SHIMMED SO THAT THE REMAINING GAP IS ABOUT 0.023 IN**
  - ⇒ WHEN THE RING CONTRACTS AT CRYO TEMPS THE GAP IS ~ 0.005 IN
- **SUSPENSION INTERFACE CONNECTORS AND MOST INSTRUMENTATION CONNECTORS ARE LEMOS OF A COAX OR 4-PIN VARIETY RESPECTIVELY**
- **PLUMBING INTERFACES ARE VIA TEFLON TUBES FROM THE HEATER/ FINAL FILTER IN THE QBS EXTRUSION.**
  - ⇒ THESE ARE CONNECTED TO THE INLET/OUTLET PLUMBING ASSEMBLY ON EACH GYROSCOPE
  - ⇒ THIS INTERFACE IS CAREFULLY MONITORED FOR CLEANLINESS BECAUSE THE PIPES LEAD DIRECTLY INTO THE GYROSCOPE

SIA
FMECA & Critical Items List

GP-B SIA CDR

November 25, 1996

Dick Maxwell / LMMS

SIA FMECA

- SIA FMECA consists of the following component and interfacing FMECA's.
  - Probe C (interface), dated 8/28/96.
  - Gyro Readout, dated 2/16/96.
  - Telescope, dated 2/22/96.
  - Gyro & Proof Mass, dated 11/15/96.

FMECA Methodology

- The SIA worst case credible failure modes are enumerated.
- Mil-Std-1629A, Task 102 is used as the FMECA model.
- Each failure mode risk is measured by a numerical criticality value.

Criticality Table For Critical Items

Risk	P(M)	β	Sev 1	Sev 2	Sev 3
				Criticality	
	A	1	1	5	9
	A	2	2	6	10
	B	1	2	6	10
Unacceptable	B	2	3	7	11
	C	1	3	7	11
	C	2	4	8	12
	A	3	6	10	
	B	3	7	11	
	D	1	7	11	
	D	2	8	12	
Undesirable	C	3	8	12	
	E	1	10		
	E	2	11		
	D	3	12		

Failure Mode Criticality Value Selection Considerations

P(M)	Severity	ß
A = Frequent--------- 0.2	1 = Catastrophic - 1000	1 = Actual Loss -------- 1.0
B = Probable--------- 0.1	2 = Critical ----------100	2 = Probable Loss --- 0.5
C = Occasional-----0.05	3 = Minor ------------- 10	3 = Possible Loss -- 0.05
D = Remote-------- 0.005	4 = Other ---------------- 1	4 = No Effect ----------0.0
E = Improbable--- 0.001		

Critical Items List (CIL)

- Failure modes with criticality values ≤ 12 are critical items.
- Table that lists the critical items follows.
- There are 18 Telescope critical items and 4 Readout critical items .

CIL

COMPONENT	ASSEMBLY	FAILURE MODE	CRITICALITY
Telescope	Telescope Assembly	a) Bond failure between the base plate and the quartz block due to thermal or launch loads.	10
Telescope	Telescope Assembly	b) Bond failure between the mounting tube and the base plate due to thermal or launch loads.	10
Telescope	Telescope Assembly	c) Bond failure between the corrector plate and the telescope tube due to thermal or launch loads.	10
Telescope	Telescope Assembly	d) Bond failure between the base plate and the primary or third mirrors due to thermal or launch loads.	10
Telescope	Telescope Assembly	e) Bond failure between the corrector plate and the secondary mirror interface due to thermal or launch loads.	10

CIL (cont.)

COMPONENT	ASSEMBLY	FAILURE MODE	CRITICALITY
Telescope	Image Divider Assembly	a) Bond failure between the beam splitter mounting block and the corrector plate due to thermal or launch loads.	10
Telescope	Image Divider Assembly	b) Bond failure between the beam splitter and the beam splitter mounting block due to thermal or launch loads.	10
Telescope	Image Divider Assembly	c) Bond failure between the knife edge and the corrector plate due to thermal or launch loads.	10
Telescope	Image Divider Assembly	d) Bond failure between the turning mirror and the top plate due to thermal or launch loads (two places).	10
Telescope	Image Divider Assembly	e) Bond failure between the turning mirror and the corrector plate due to thermal or launch loads (two places).	10

CIL (cont.)

COMPONENT	ASSEMBLY	FAILURE MODE	CRITICALITY
Telescope	Image Divider Assembly	f) Bond failure between the knife edge and the top plate due to thermal or launch loads.	10
Telescope	Image Divider Assembly	g) Bond failure between the ring and the corrector plate due to thermal or launch loads.	10
Telescope	Image Divider Assembly	h) Bond failure between the ring and the top plate due to thermal or launch loads.	10
Telescope	Image Divider Assembly	i) Bond failure between the lens and the ring due to thermal or launch loads (four places).	10

CIL (cont.)

COMPONENT	ASSEMBLY	FAILURE MODE	CRITICALITY
Telescope	Detector and Preamplifier Assembly	a) Bond failure between the corrector plate and the detector support block due to thermal or launch loads (2 places).	10
Telescope	Detector and Preamplifier Assembly	b) Bond failure between the corrector plate and the detector turning mirror due to thermal or launch loads (2 places).	10
Telescope	Detector and Preamplifier Assembly	c) Failure of the clamp which fastens the detector subsystem to the mounting block due to thermal, fatigue, or launch loads.	10
Telescope	Detector and Preamplifier Assembly	g) Defocused lens (breakage) due to thermal or launch loads (2 places).	10

CIL (cont.)

COMPONENT	ASSEMBLY	FAILURE MODE	CRITICALITY
Readout	SQUID super conductive input cable	c) Loss of super conductivity due to poor or intermittent connections.	11
Readout	SQUID jumper cables	a) Broken cable or open connection due to environmental stress.	11
Readout	SQUID super conductive input cable	b) Short to ground from damaged insulation due to environmental stress.	12
Readout	SQUID jumper cables	c) Partially open connection (high resistance).	12

Critical Item Mitigation

- BOND FAILURES
  - Interfaces are joined by a silicate bonding process developed by SU.
  - Tests demonstrate bonds are as strong as parent material.
  - Bonds are readily evaluated by visual inspection for bond quality and area coverage.
  - Each bond is subjected to a 2X shear limit load proof test during component assembly.

Critical Item Mitigation (cont.)

- PREAMP & DETECTOR CLAMP
  - Previously qualified design. Shake tests at flight limit loads will verify assembly.
- DEFOCUSED LENS
  - Shake tests at flight limit loads will verify assembly.
- READOUT
  - Ground testing and QA to minimize connection problems.

Science Instrument Assy Critical Design Review

Quality Assurance / Reliability

Ben Taller

1. Quality Provisions per SU's "Science Mission Quality Plan" P0108

2. Configuration Control per "Science Mission Configuration Management Plan" P0098

- Drawings Release through Drawing Release Review
- Changes of requirements through Program Change Board (PCB)
- Changes of Drawings, Drawings Trees and P-Documents through Engineering Change Board (ECB)

3. Fabrication Control:

- Identification, Traveler, As-Built Configuration.
- Standard Processes: Per Standard Materials and Processes Plan, P0145
- Special Processes: Per written procedures.

4. Contamination Control:

- Per Relativity Mission Contamination Control Plan, P0147

5. Inspection and Tests:

- Per written procedures, by certified personnel

6. Configuration and Test Database

- Database includes:

  Requirements, Reviews and Action Items, Drawings Configuration, P-Documents, PCBs, ECOs, DRs, Dwgs/Parts Tree, Components, Purchasing, Receiving, Calibration, As-Built Configuration, Tests Plans, and Tests Results and more.

7. Nonconformance Control:

- Discrepancy Reports including Analysis and Corrective Action.
- Disposition by Material Review Board (MRB).

8. Reliability

- Per SU Reliability Plan, P0146 (Revised)
- FMECA completed and is included in the package

9. Procurement Control

- Vendors selection from SU Approved Vendors List
- Vendors Quality System meets the requirements of MIL-I-45208A
- Procurement document reviewed by the Quality Engineer

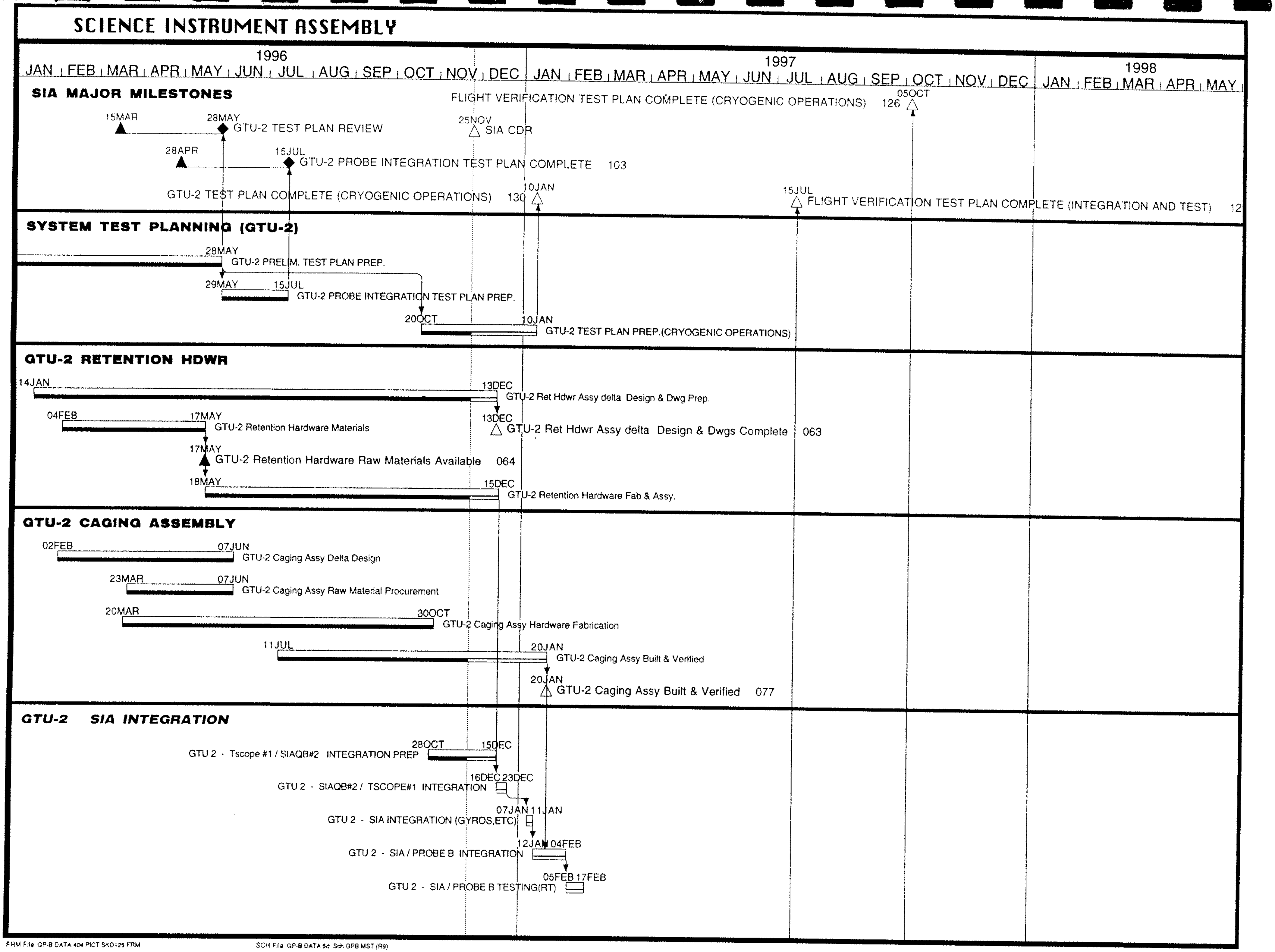
11. Reports:

- All Discrepancy Reports (DRs) and Engineering Changes ECOs are reported to NASA in the Monthly Reviews
- ECOs and PCBs in the Database can be reviewed through the Web site.

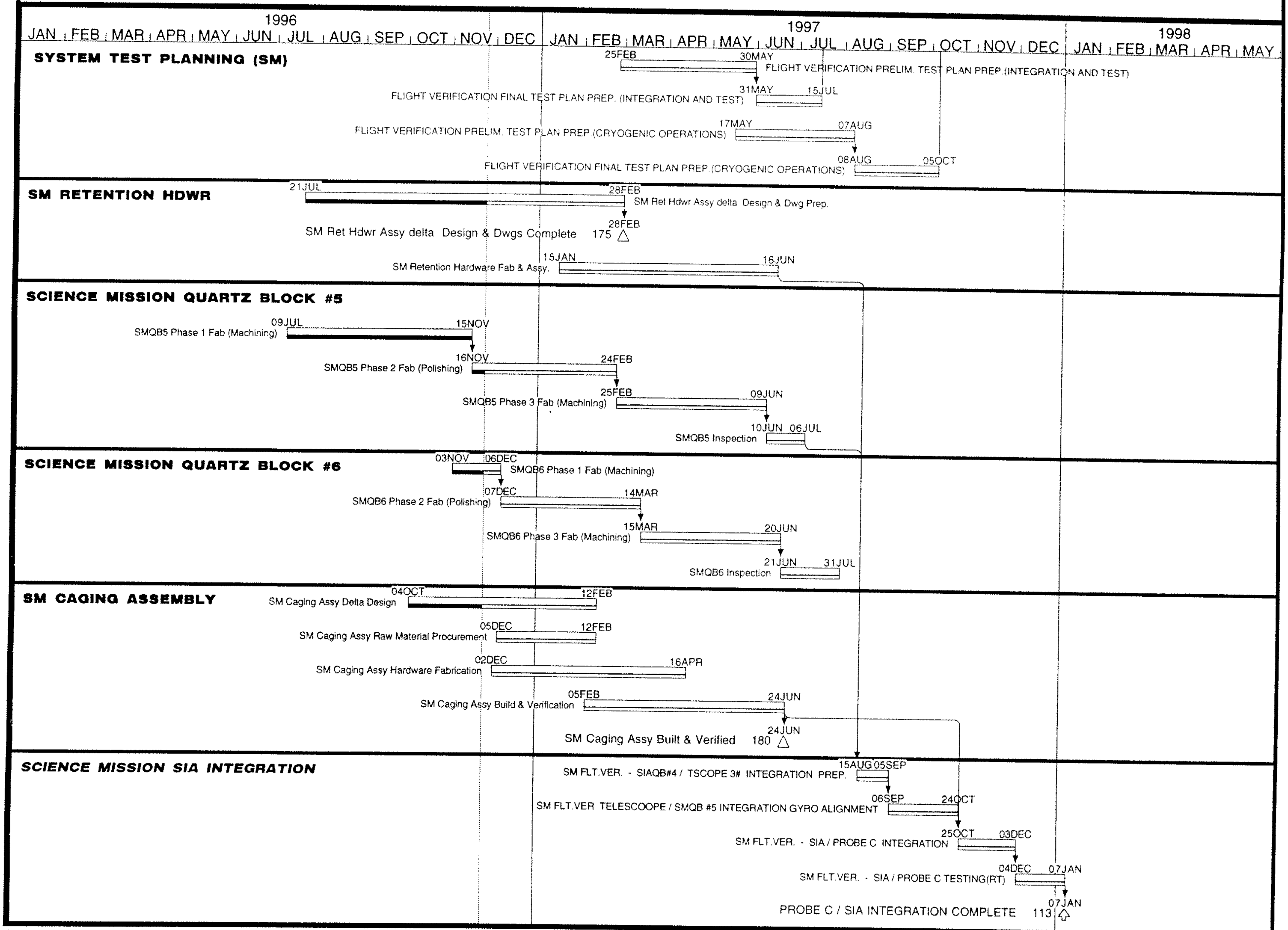
SIA CRITICAL DESIGN REVIEW

SIA SCHEDULE

Jim Burns


SCIENCE INSTRUMENT ASSEMBLY
1996
1997
1998
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
SIA MAJOR MILESTONES
FLIGHT VERIFICATION TEST PLAN COMPLETE (CRYOGENIC OPERATIONS) 126
05OCT
15MAR
28MAY
GTU-2 TEST PLAN REVIEW
25NOV
SIA CDR
28APR
15JUL
GTU-2 PROBE INTEGRATION TEST PLAN COMPLETE 103
10JAN
GTU-2 TEST PLAN COMPLETE (CRYOGENIC OPERATIONS) 130
15JUL
FLIGHT VERIFICATION TEST PLAN COMPLETE (INTEGRATION AND TEST) 12
SYSTEM TEST PLANNING (GTU-2)
28MAY
GTU-2 PRELIM. TEST PLAN PREP.
29MAY
15JUL
GTU-2 PROBE INTEGRATION TEST PLAN PREP.
20OCT
10JAN
GTU-2 TEST PLAN PREP.(CRYOGENIC OPERATIONS)
GTU-2 RETENTION HDWR
14JAN
13DEC
GTU-2 Ret Hdwr Assy delta Design & Dwg Prep.
04FEB
17MAY
GTU-2 Retention Hardware Materials
13DEC
GTU-2 Ret Hdwr Assy delta Design & Dwgs Complete 063
17MAY
GTU-2 Retention Hardware Raw Materials Available 064
18MAY
15DEC
GTU-2 Retention Hardware Fab & Assy.
GTU-2 CAGING ASSEMBLY
02FEB
07JUN
GTU-2 Caging Assy Delta Design
23MAR
07JUN
GTU-2 Caging Assy Raw Material Procurement
20MAR
30OCT
GTU-2 Caging Assy Hardware Fabrication
11JUL
20JAN
GTU-2 Caging Assy Built & Verified
20JAN
GTU-2 Caging Assy Built & Verified 077
GTU-2 SIA INTEGRATION
28OCT
15DEC
GTU 2 - Tscope #1 / SIAQB#2 INTEGRATION PREP
16DEC
23DEC
GTU 2 - SIAQB#2 / TSCOPE#1 INTEGRATION
07JAN
11JAN
GTU 2 - SIA INTEGRATION (GYROS,ETC)
12JAN
04FEB
GTU 2 - SIA / PROBE B INTEGRATION
05FEB
17FEB
GTU 2 - SIA / PROBE B TESTING(RT)

SCIENCE INSTRUMENT ASSEMBLY



FRM File GP-B DATA 404 PICT SKD125 FRM   SCH File GP-B DATA 5d Sch GP8 MST (R9)

CDR 11/25/96