IMPACT Boom

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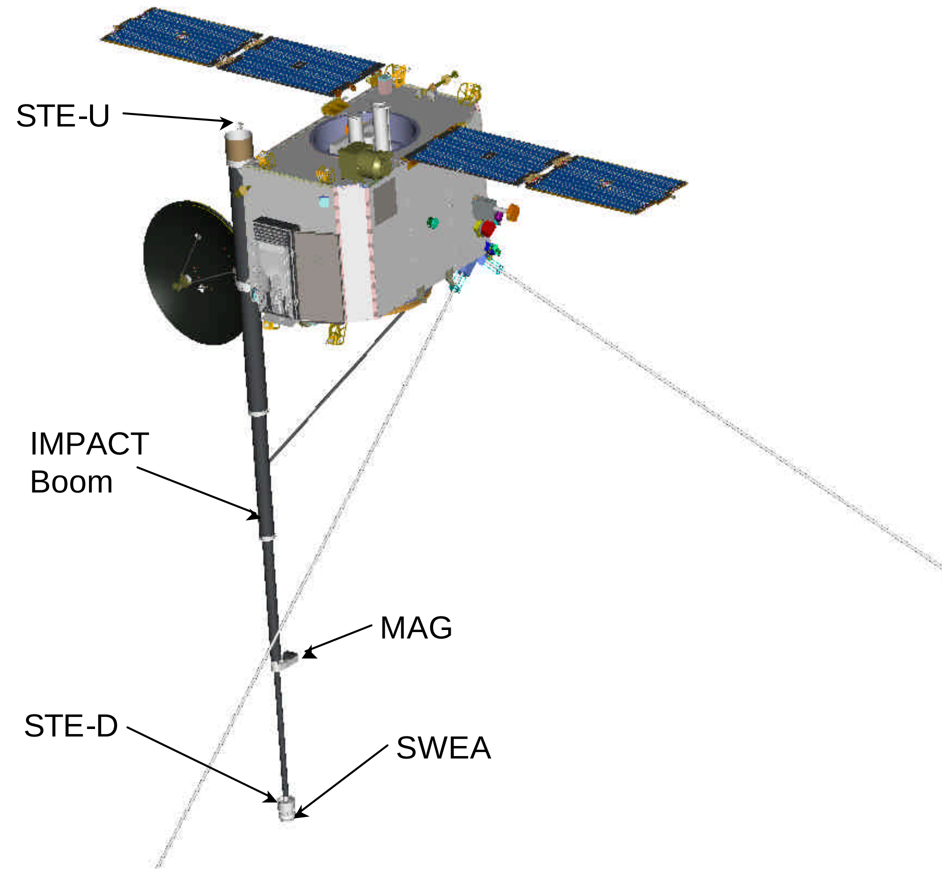
IMPACT Boom

- **The IMPACT Boom is a 5.8m (4.26m stroke) deployable boom**
- **Carries the Magnetometer sensor, and the SWEA/STE-D/U analyzers**
  - **MAG needs to be ^{3}3m from the spacecraft to minimize stray fields**
  - **SWEA needs to be far from the spacecraft due to its large (almost 4p) FOV and to minimize ESC issues**
  - **STE-D needs a glint-free FOV and passive cooling**
- **Designed and built at UCB**

Ahead Spacecraft



System Requirements

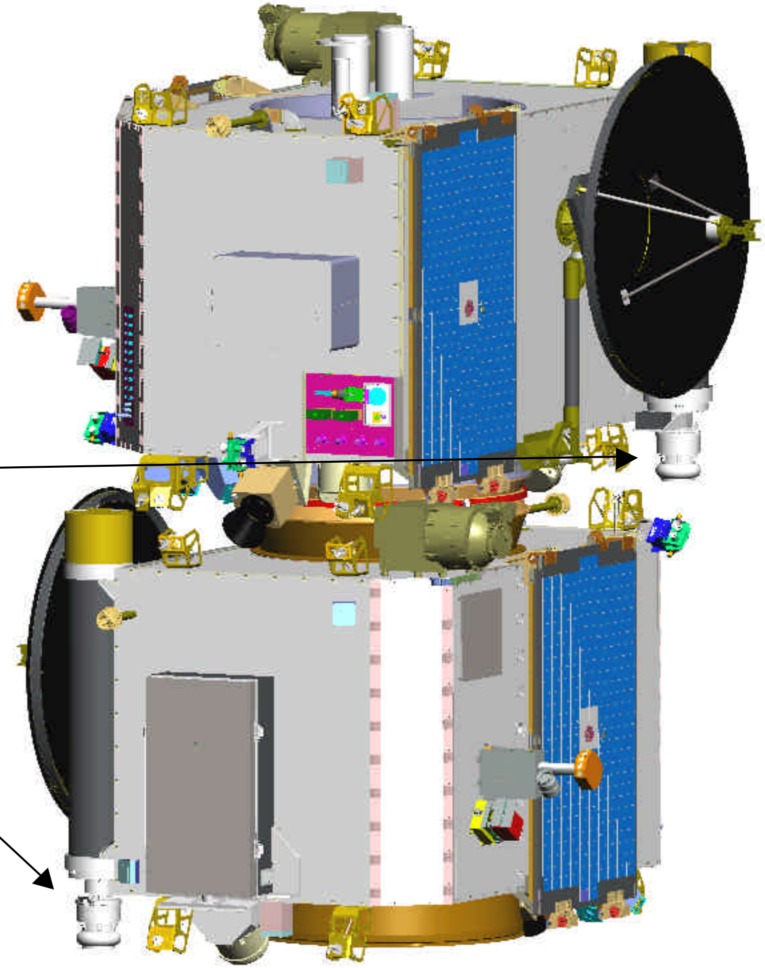
- Materials, Methods and Processes: Complete.
- EMC / EMI
  - Per Program Specification, in accordance with APL Document No.7831-9030
  - Boom surface statically dissipative: < 10^3 ohms / sq. measured.
  - Harness double shielded:
    - Outer shield: Stacer + braid (in final segment of boom).
    - Inner shield: aluminized kapton (TBC)
  - Harness specified in Impact Harness Document.
- Cleanliness
  - Fabrication: Class 100,000.
  - Integration: Class 10,000 (TBC).
- Product Implementation and Assurance Plan
  - Per Impact PAIP.

Resource Requirements

- **Total Boom Mass (less instruments): 9.5kg**
- **Power:**
  - **Deployment heater, 5W**
  - **SWEA op heater, 1W; non-op heater 2W**
  - **MAG Heater 0.5W**
- **Actuator service: TiNi P50-810-1RS**
- **Spacecraft temperature sensors:**
  - **Boom @ deployment mechanism**
  - **STE-U @ preamp**
  - **SWEA @ thermostat**

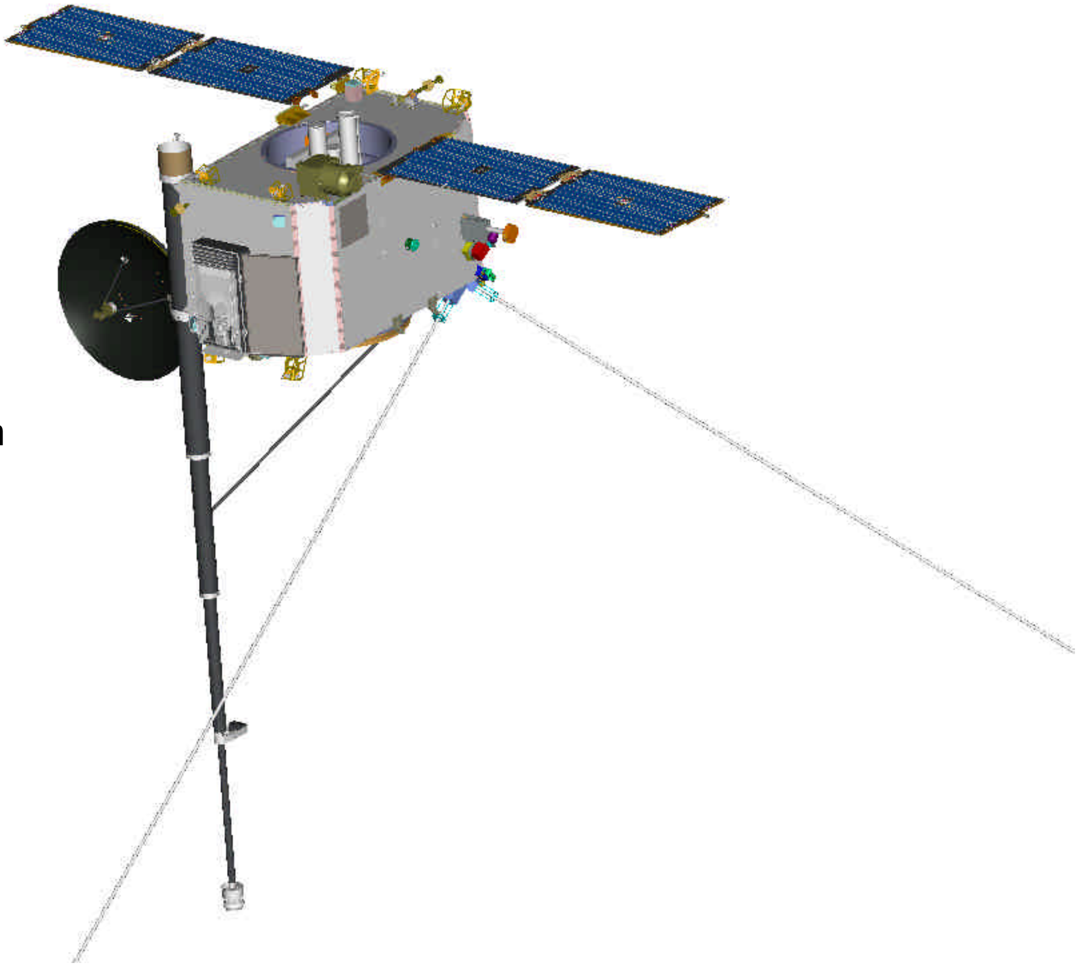
IMPACT Booms, Stowed for Launch

Stowed IMPACT
Booms

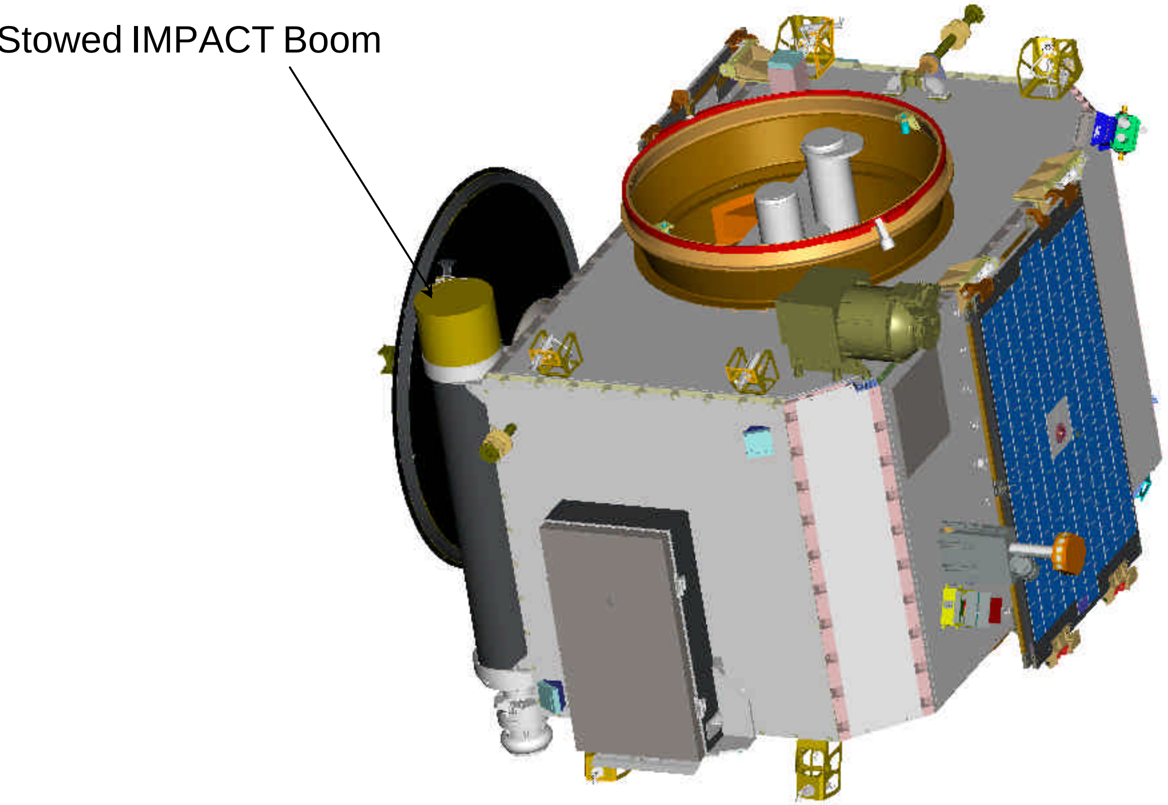


IMPACT Boom Deployed (Ahead Spacecraft)

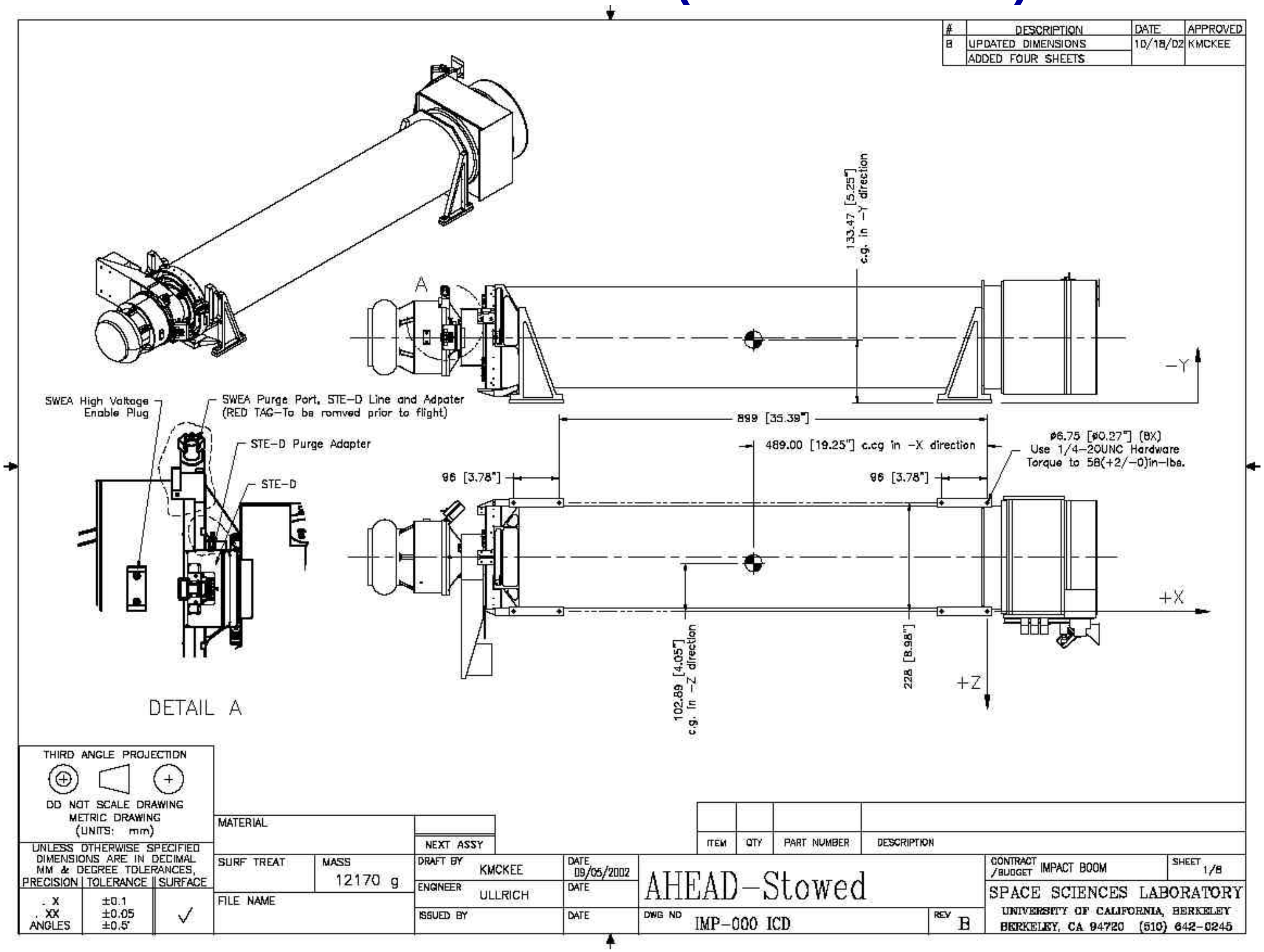
IMPACT Boom deployed



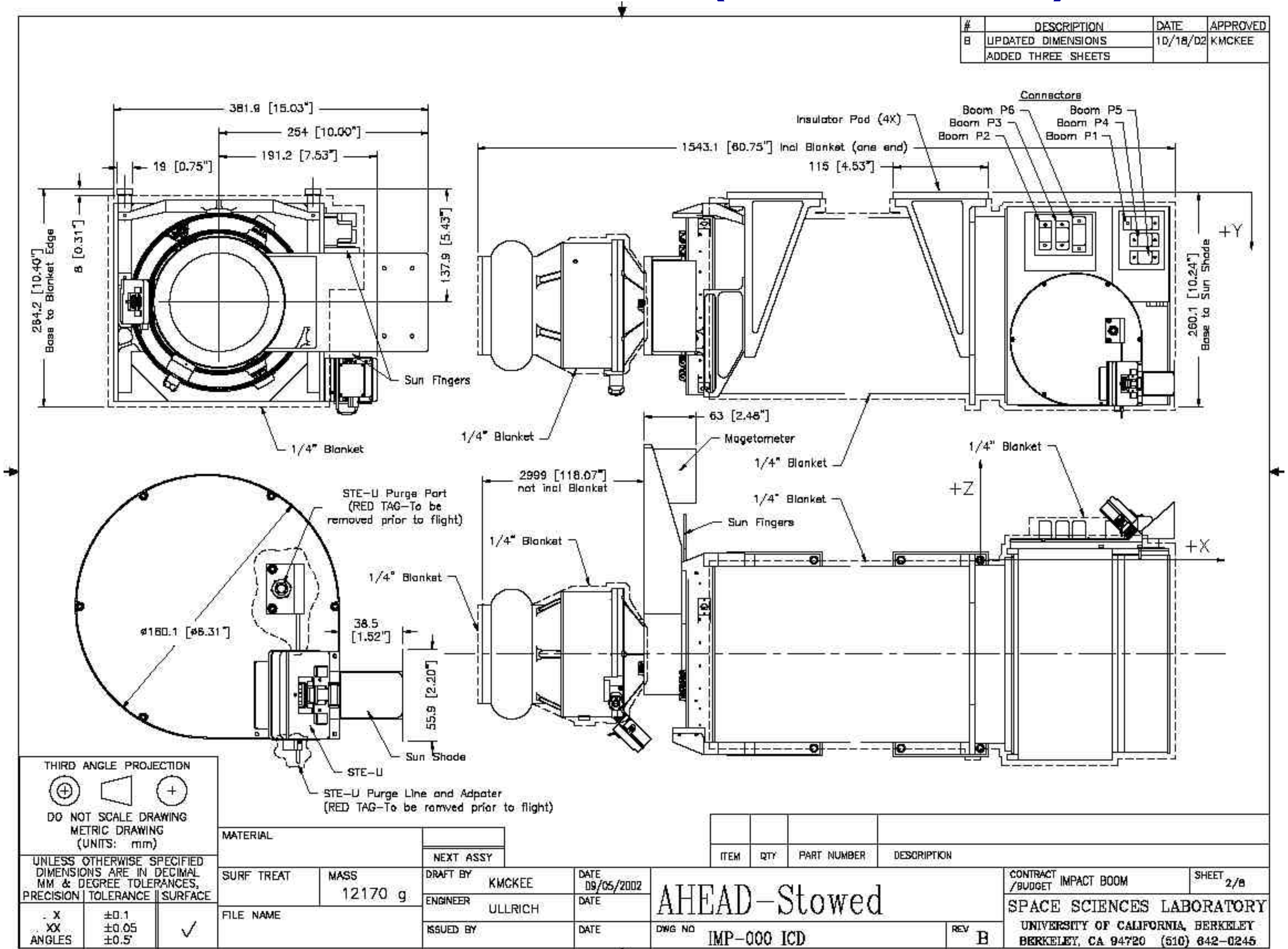
IMPACT Boom Stowed (Behind Spacecraft)



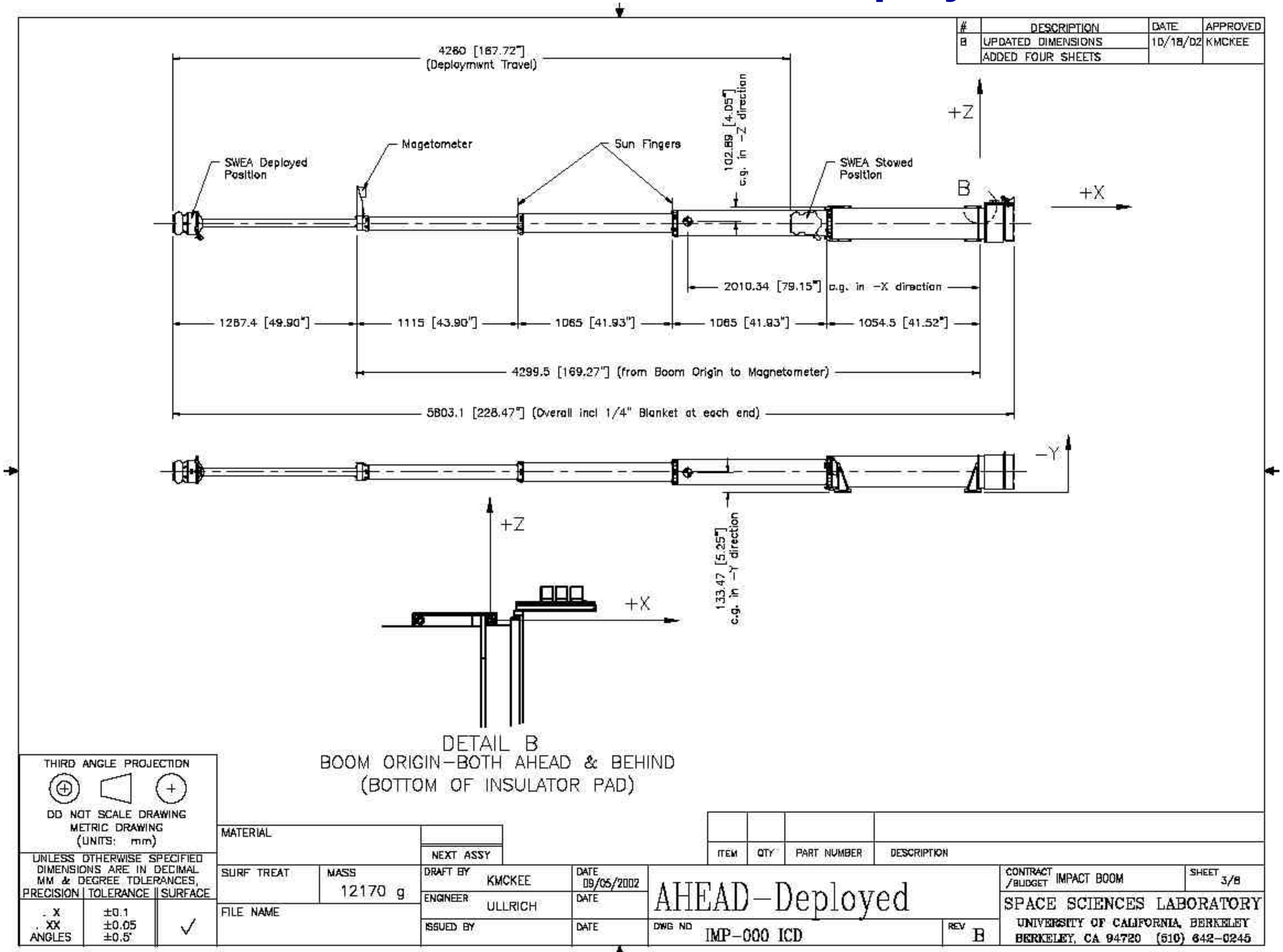
IMPACT Boom ICD (Ahead Stowed)



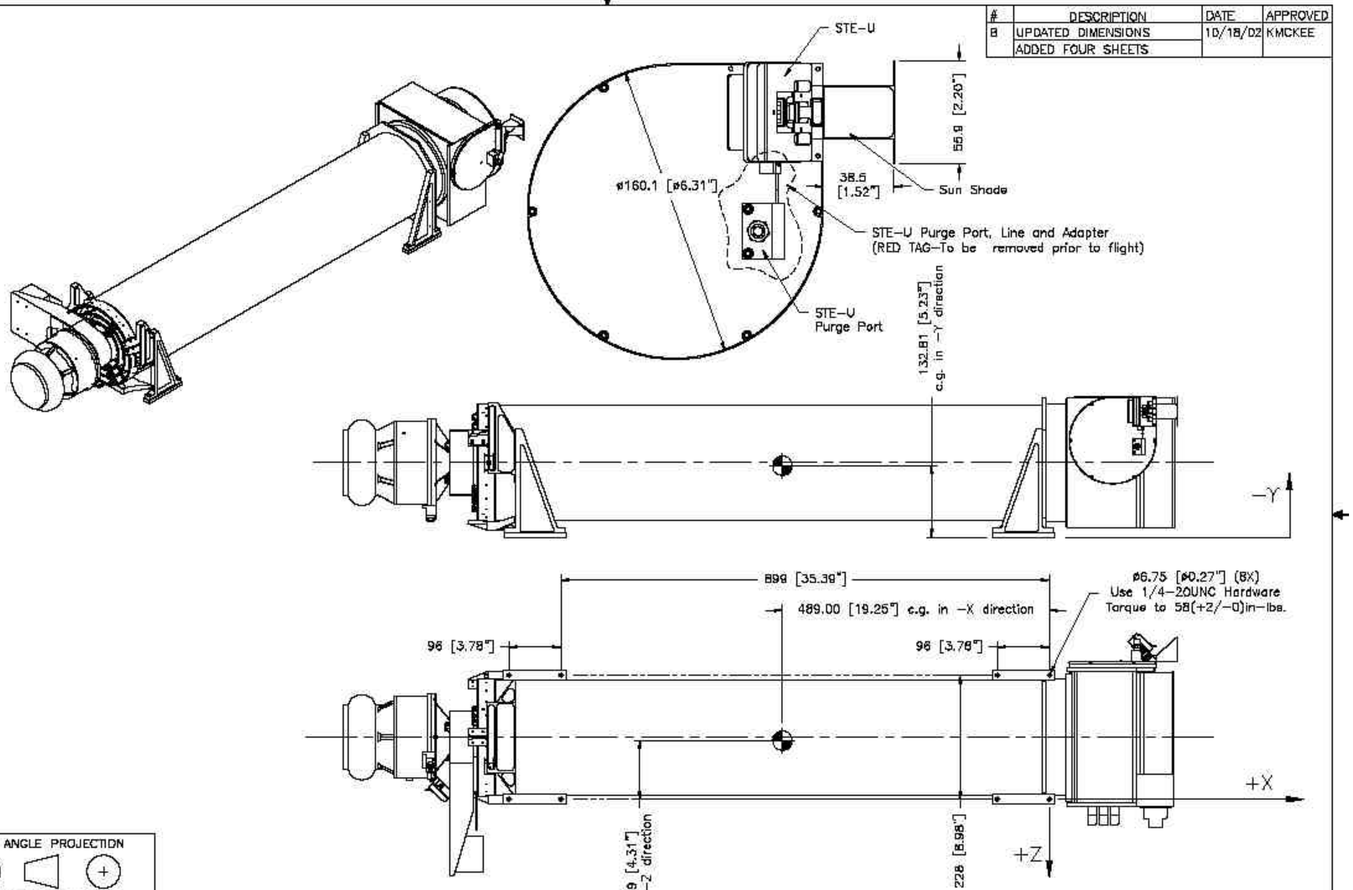
IMPACT Boom ICD (Ahead Stowed)



IMPACT Boom ICD, Ahead Deployed



IMPACT Boom ICD, Behind Stowed



#	DESCRIPTION	DATE	APPROVED
B	UPDATED DIMENSIONS	10/18/02	KMCKEE
	ADDED FOUR SHEETS		

THIRD ANGLE PROJECTION
DO NOT SCALE DRAWING
METRIC DRAWING
(UNITS: mm)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN DECIMAL MM & DEGREE TOLERANCES,

PRECISION	TOLERANCE	SURFACE
.X	±0.1	✓
.XX	±0.05	
ANGLES	±0.5°	

ITEM	QTY	PART NUMBER	DESCRIPTION

MATERIAL
NEXT ASSY
SURF TREAT
MASS 12170 g
FILE NAME
DRAFT BY KMCKEE — DATE 09/05/2002
ENGINEER ULLRICH — DATE
ISSUED BY — DATE

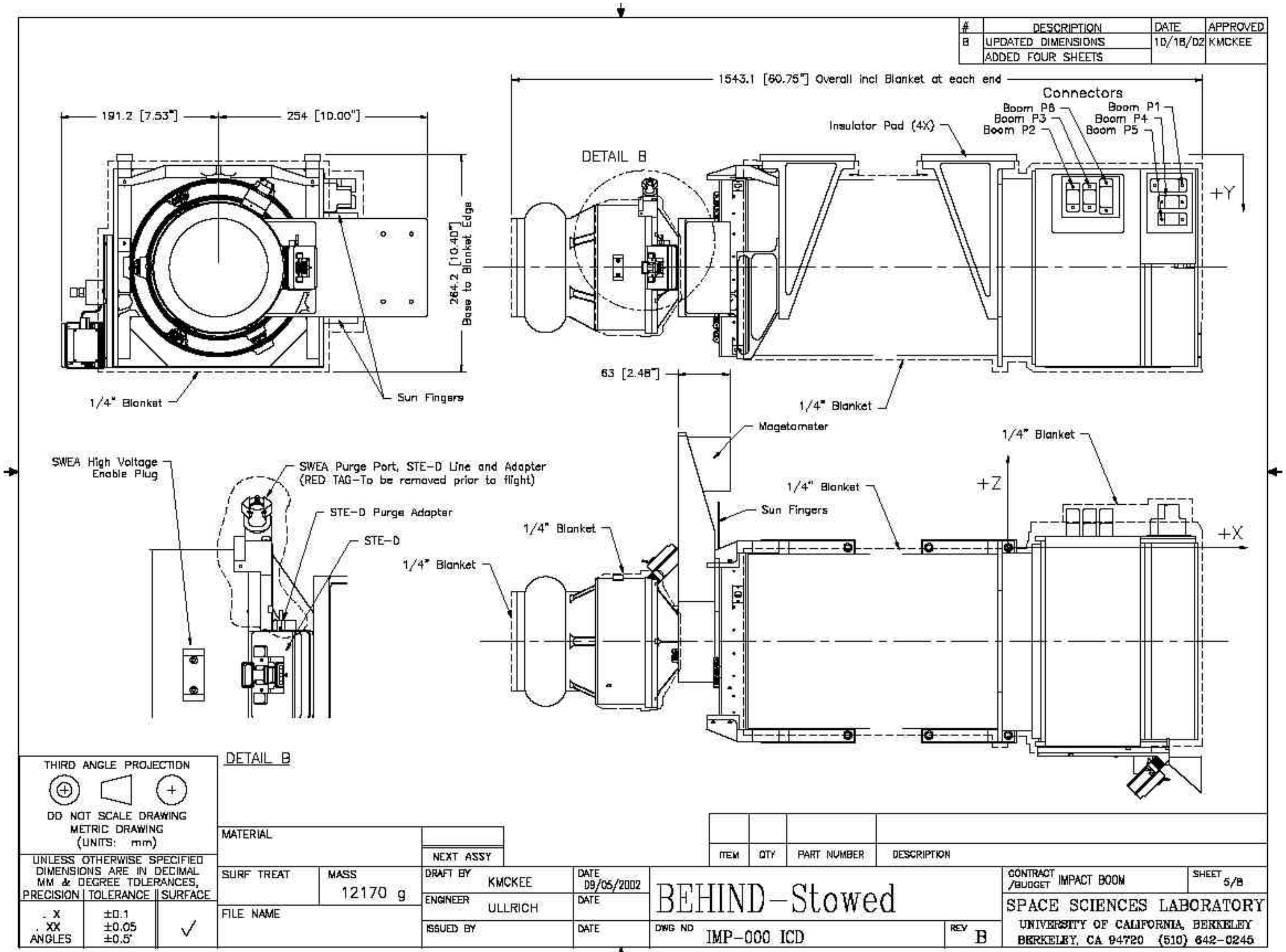
BEHIND–Stowed

DWG NO IMP–000 ICD — REV B

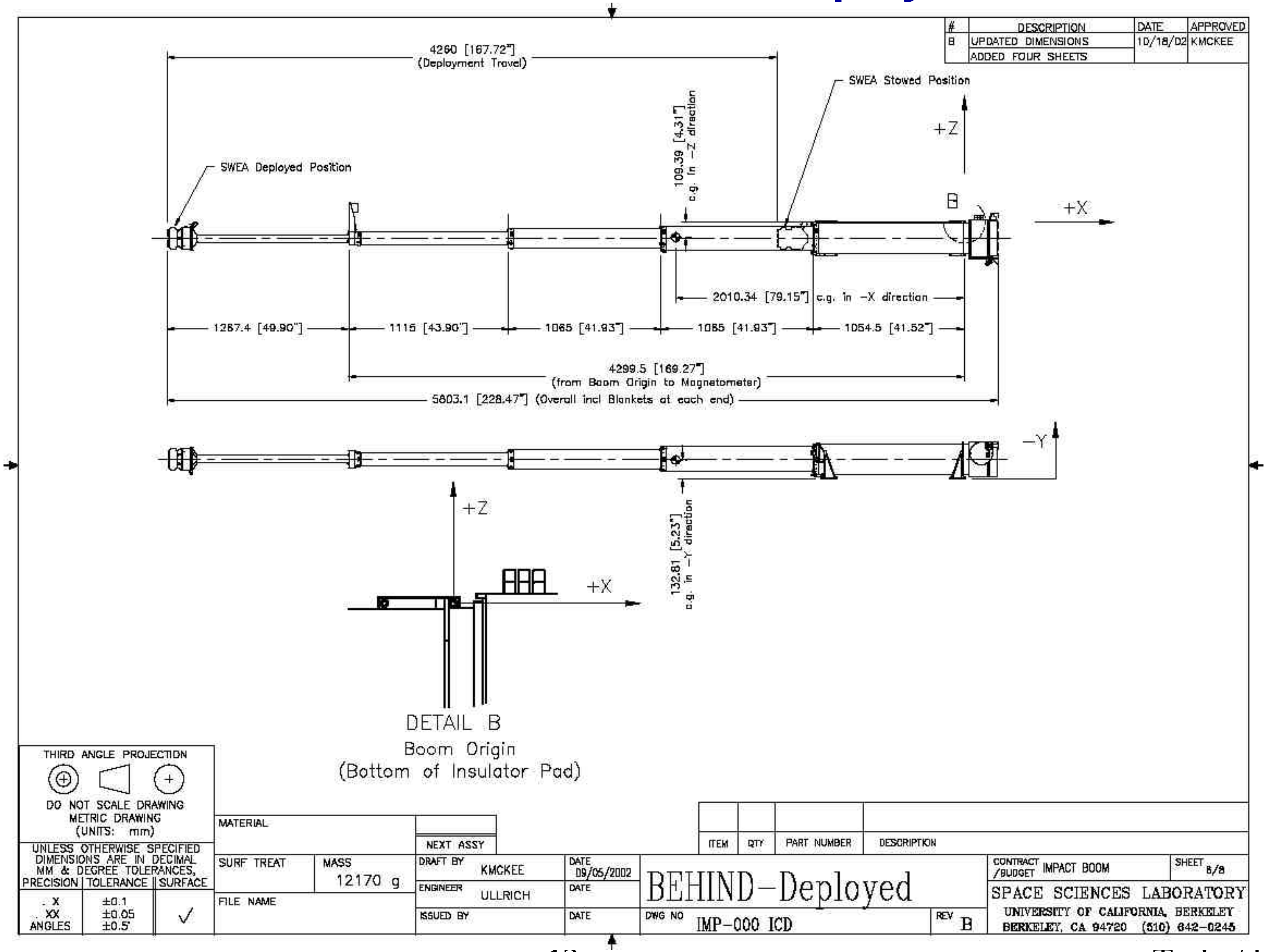
CONTRACT /BUDGET IMPACT BOOM — SHEET 4/8

SPACE SCIENCES LABORATORY
UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELEY, CA 94720 (510) 642–0245

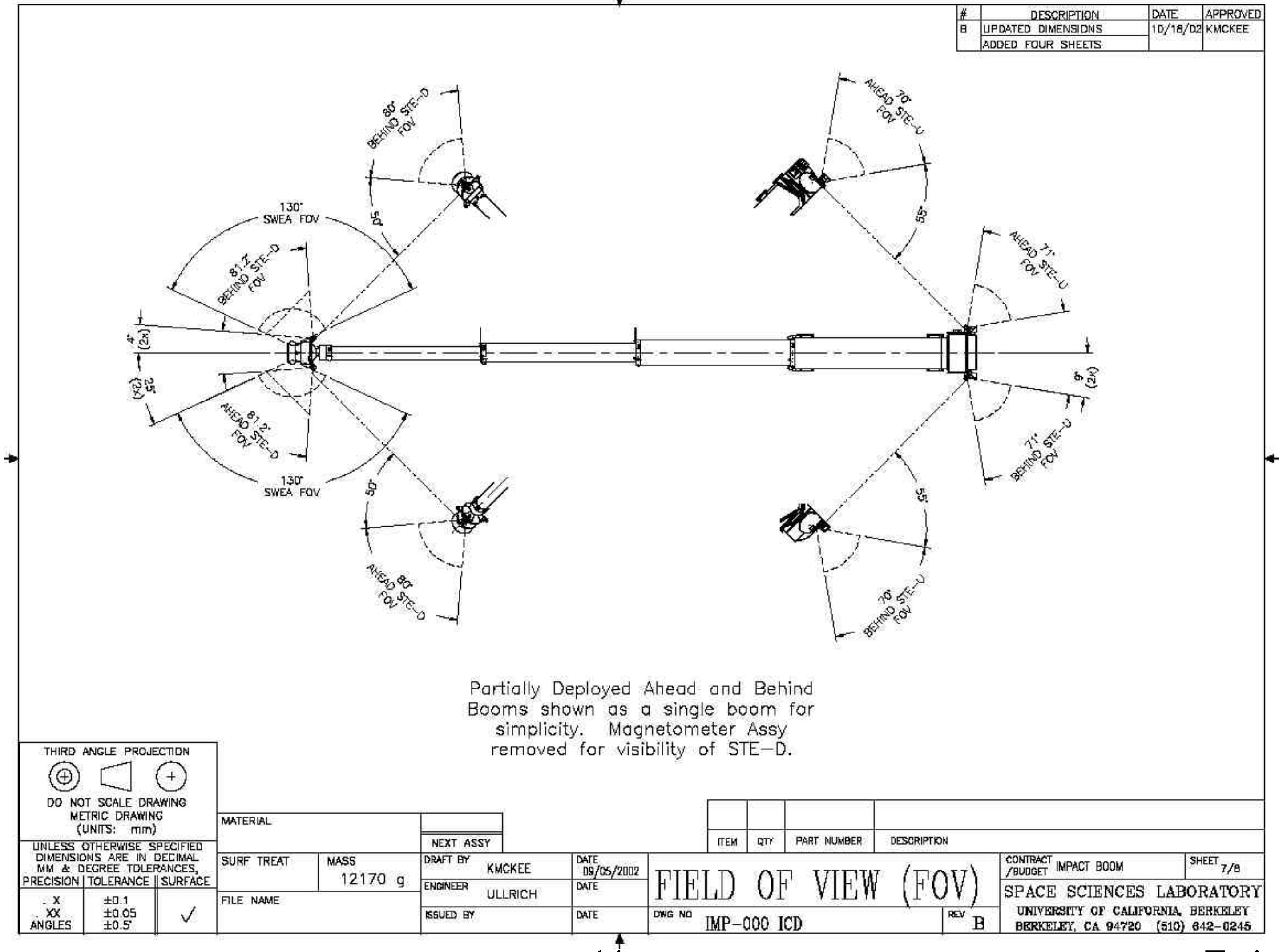
IMPACT Boom ICD, Behind Stowed



IMPACT Boom ICD, Behind Deployed



IMPACT Boom ICD, Fields of View



IMPACT Boom ICD, Properties

AHEAD BOOM

mary: AHEAD BOOM - Stowed Position
s 12170.22 g

roid
-489.00 mm
-133.47 mm
-102.89 mm

ipal mass moments and axes about CG
105286067.13 g mm^2
is
X 1.00 mm
Y -0.00 mm
Z -0.00 mm

3771464261.64 g mm^2
is
X 0.00 mm
Y 1.00 mm
Z 0.06 mm

3746829444.57 g mm^2
is
X 0.00 mm
Y -0.06 mm
Z 1.00 mm

Summary: AHEAD BOOM - Deployed Position
Mass 12170.22 g

Centroid
X -2010.34 mm
Y -133.47 mm
Z -102.89 mm

Principal mass moments and axes about CG
I 105168242.02 g mm^2
Axis
X 1.00 mm
Y 0.00 mm
Z -0.00 mm

J 56487023311.56 g mm^2
Axis
X -0.00 mm
Y 1.00 mm
Z 0.05 mm

K 56462305952.70 g mm^2
Axis
X 0.00 mm
Y -0.05 mm
Z 1.00 mm

BEHIND BOOM

Summary: BEHIND BOOM - Stowed Position
Mass 12170.22 g

Centroid
X -489.00 mm
Y -132.81 mm
Z -109.39 mm

Principal mass moments and axes about CG
I 104537537.85 g mm^2
Axis
X 1.00 mm
Y 0.00 mm
Z -0.02 mm

J 3772877266.96 g mm^2
Axis
X -0.00 mm
Y 1.00 mm
Z -0.10 mm

K 3747184240.79 g mm^2
Axis
X 0.02 mm
Y 0.10 mm
Z 0.99 mm

Summary: BEHIND BOOM - Deployed Po
Mass 12170.22 g

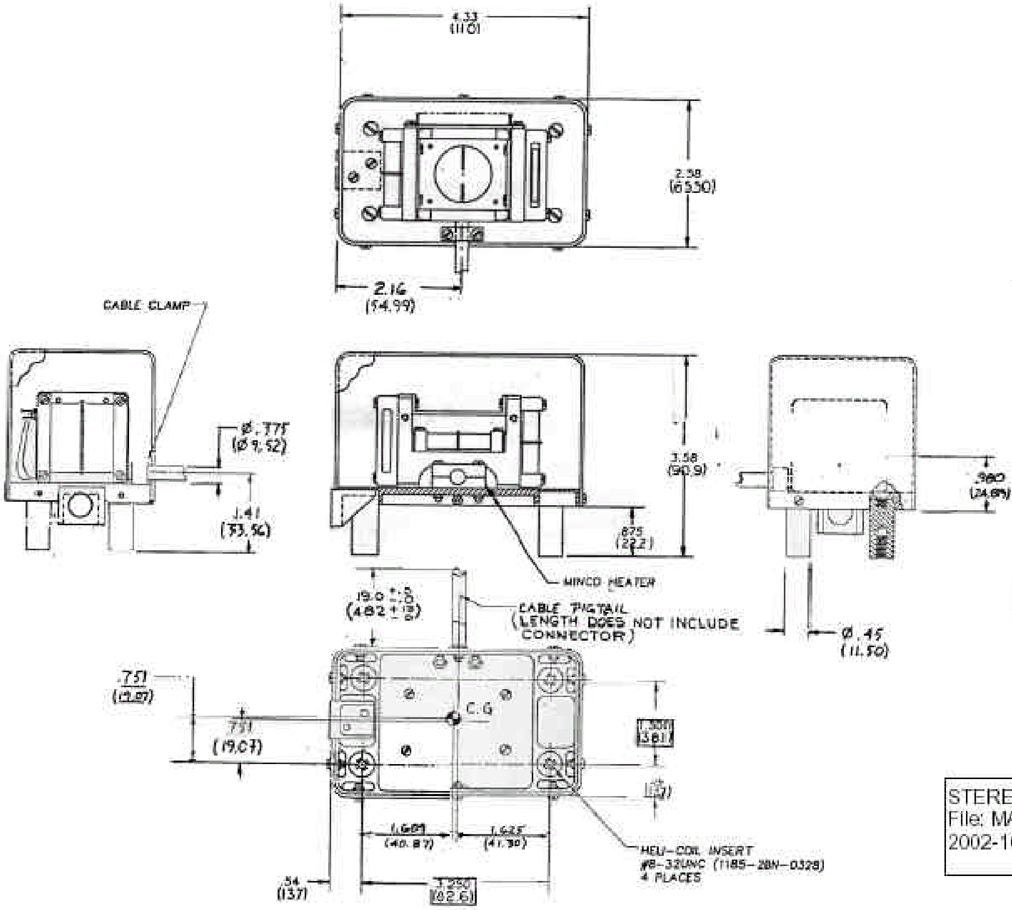
Centroid
X -2010.34 mm
Y -132.81 mm
Z -109.39 mm

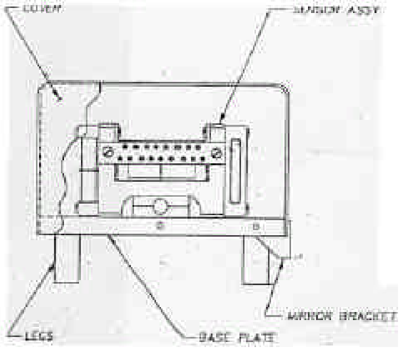
Principal mass moments and axes about CG
I 104496798.45 g mm^2
Axis
X 1.00 mm
Y 0.00 mm
Z -0.00 mm

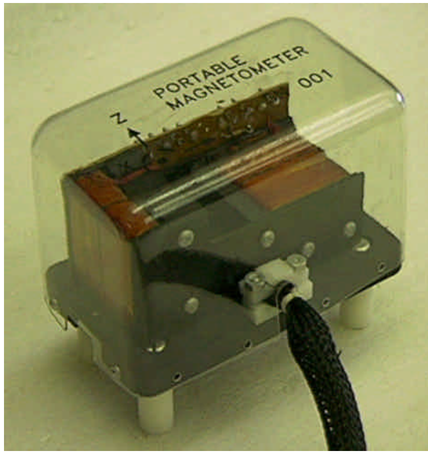
J 56488573352.46 g mm^2
Axis
X -0.00 mm
Y 0.99 mm
Z -0.11 mm

K 56462448260.95 g mm^2
Axis
X 0.00 mm
Y 0.11 mm
Z 0.99 mm

Magnetometer ICD

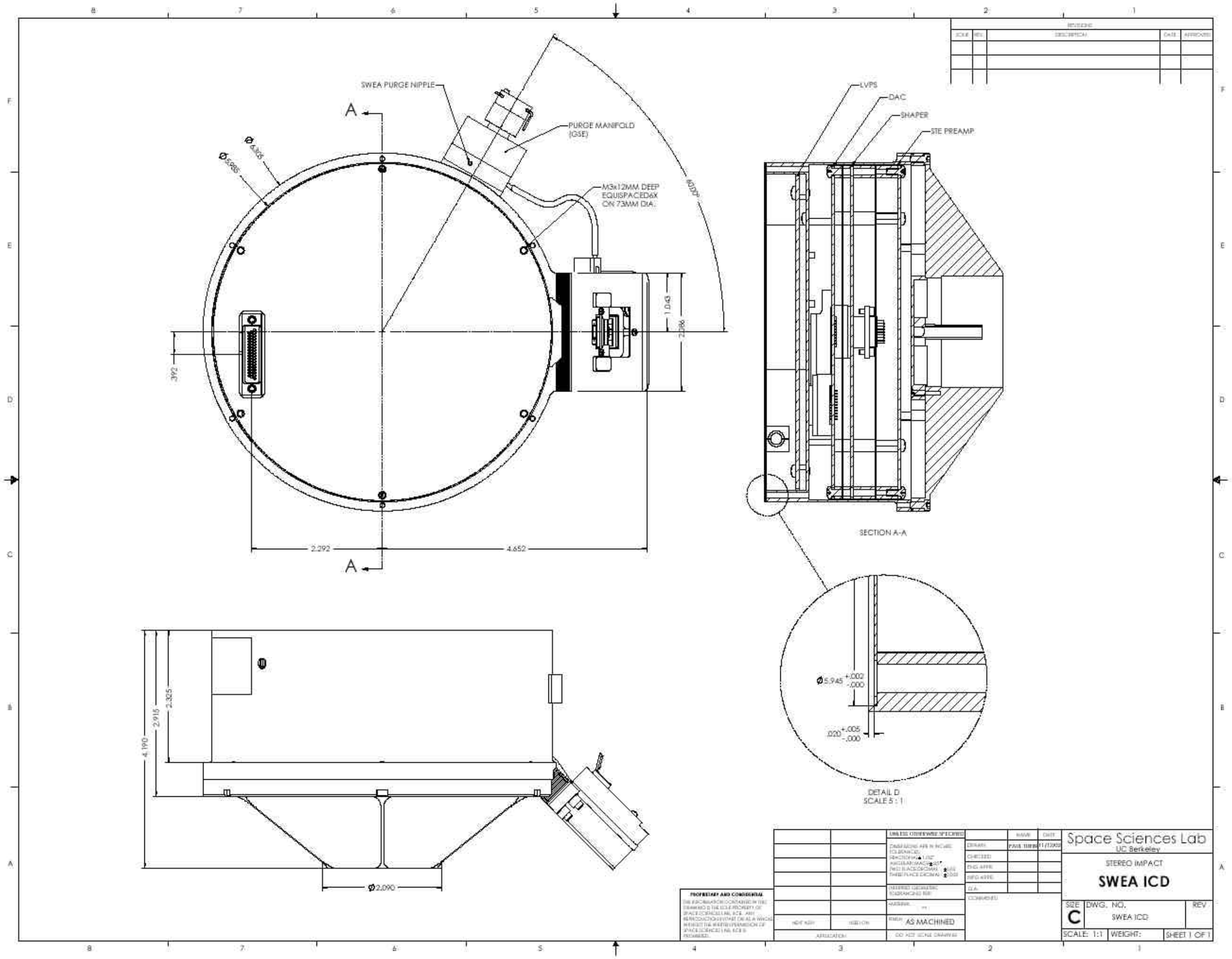






STEREO IMPACT Magnetometer Sensor ICD
File: MAG_Sensor_ICD_A
2002-10-16

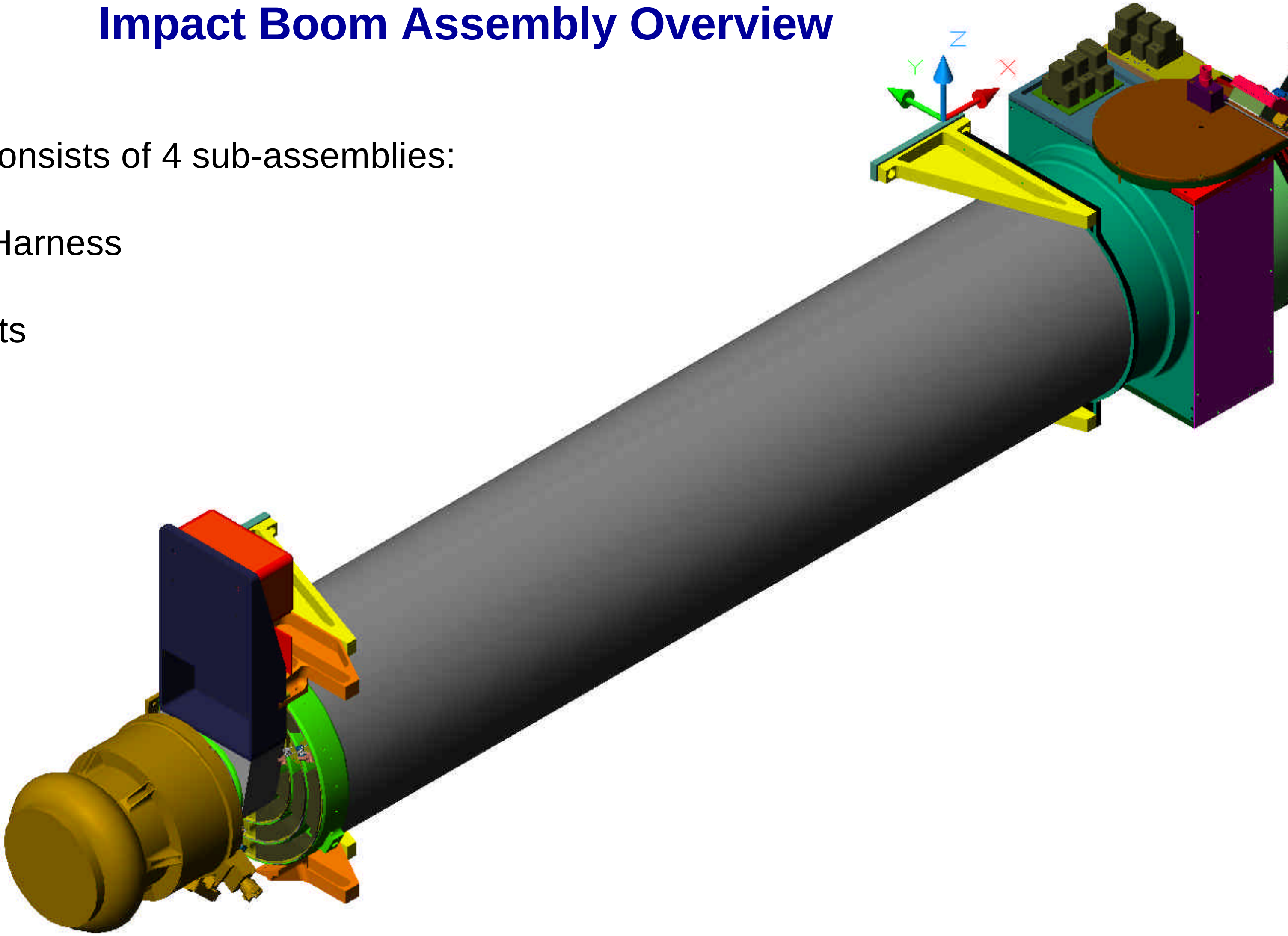
SWEA/Pedestal ICD



Impact Boom Assembly Overview

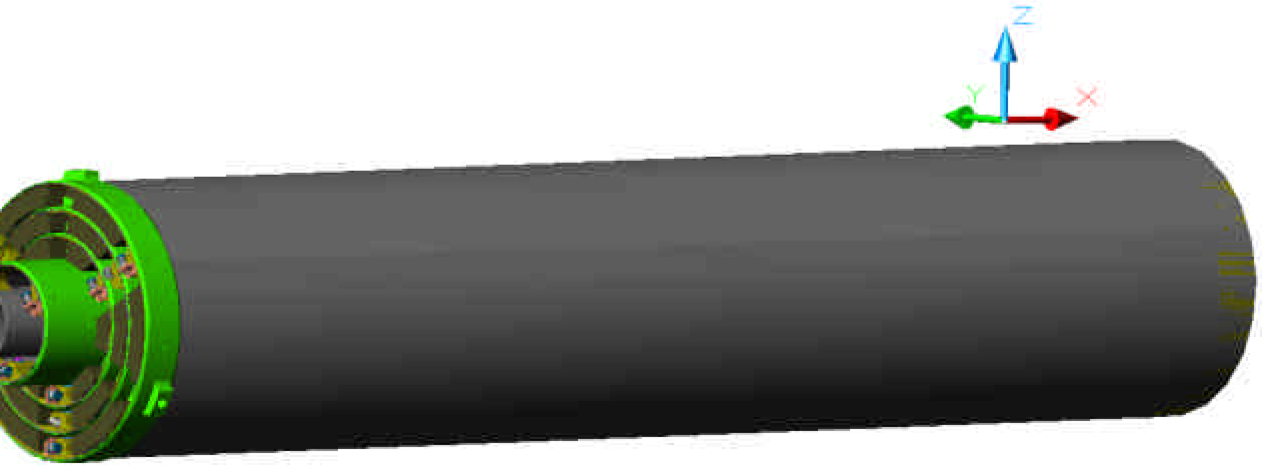
Impact Boom consists of 4 sub-assemblies:

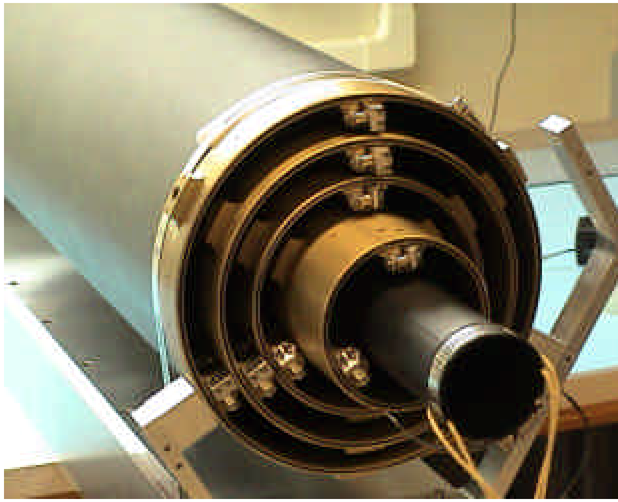
1. Tube
2. Stacer & Harness
3. Mount
4. Instruments



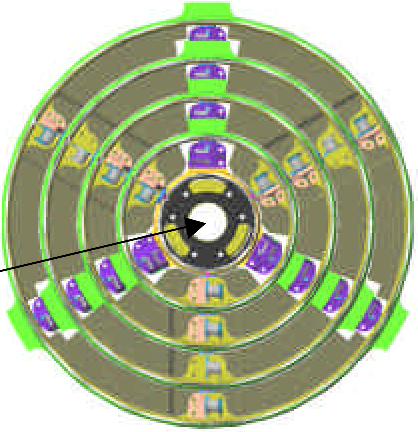
Boom Tube Assembly

Overview





Tube Assembly: stowed position, no instrument brackets shown. Rollers in tips of pins rest on tube surfaces. During deployment, pins roll along tubes until aligned with sockets, then extend 8mm radially to mate with sockets, both have an included cone angle of 10^0 to provide a 'self-locking' interface. An offset of 0.25mm of 2 of the 6 sockets takes up the play from clearances between the pins and sockets, providing a kinematic mounting.

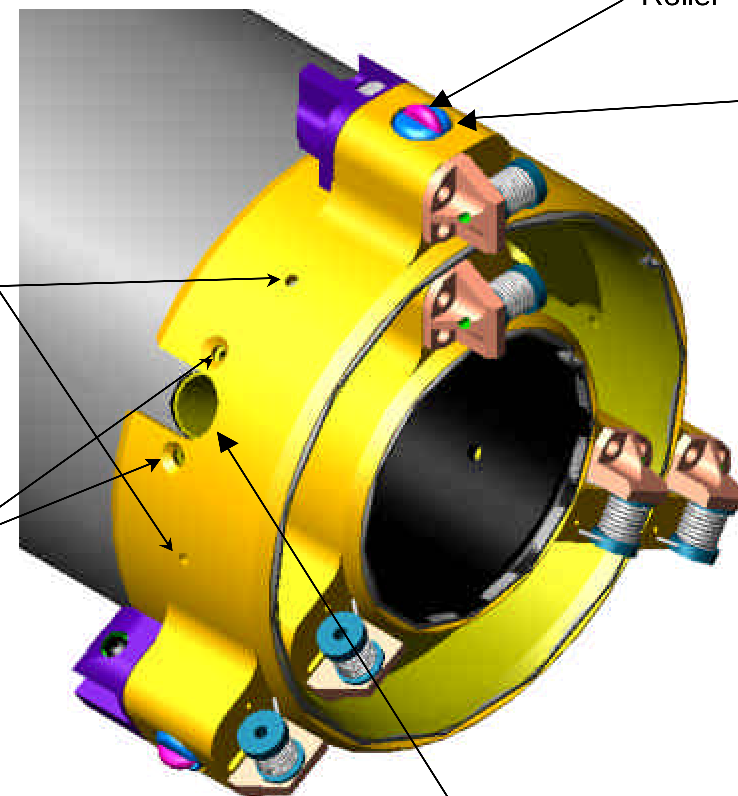


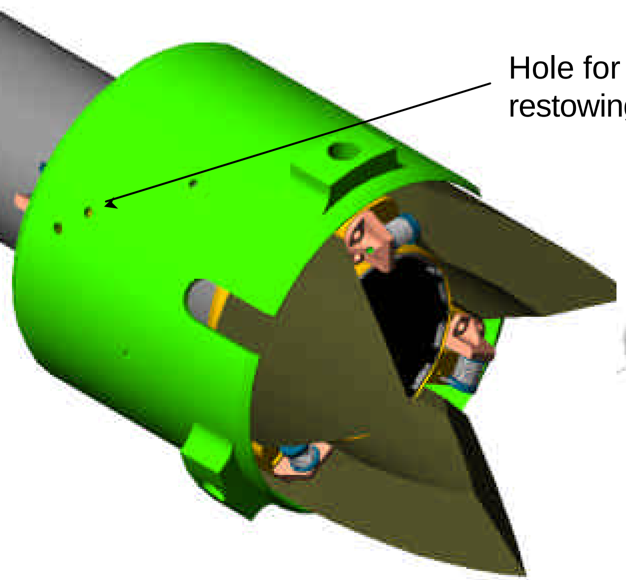
Harness Assembly (including the Stacer) interfaces to the tube assembly here via screw plate.

Tube Assembly

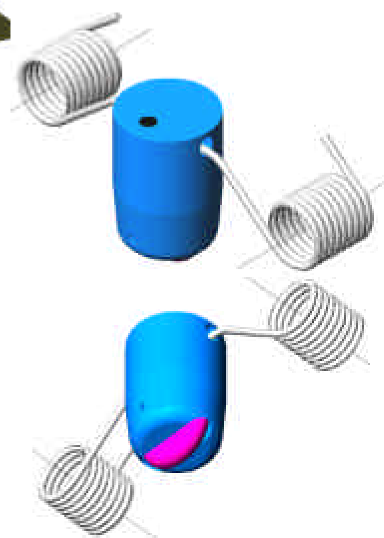
tube end / pin detail

Roller: Al 6061-T6xx; alodine.
Springs: BeCu full hard torsional.
Locking pin: 6061-T6xx Al; alodine taper; hard anodize sliding portion.
Ring: 6061-T6xx Al, hard anodize in guide socket, alodine external surfaces.
Rings bonded to Gr/E with Hysol 9309NA structural epoxy, reinforced with 6 screws





End of travel stop, alignment guides shown (90mm tube hidden). Forces inner rollers to align with holes, prevents overtravel with hard stop.



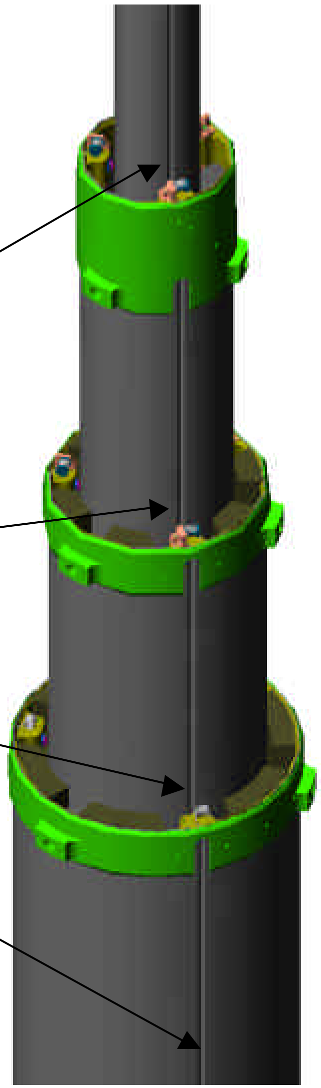
Tube Assembly

Deployment Detail

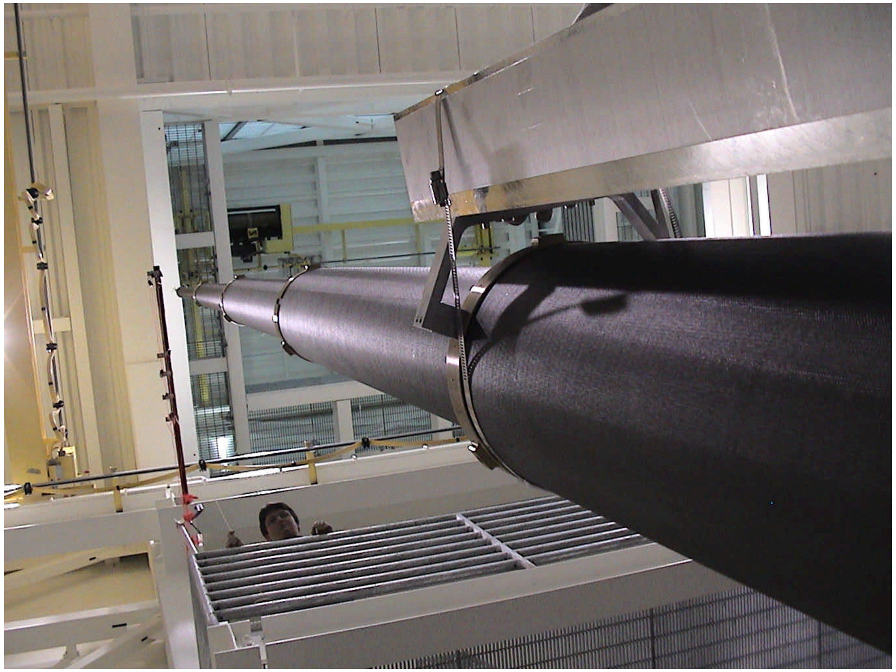
- Mid-deployment of boom is shown.
- 6 rollers ride on tube surfaces. 3 outside rollers follow grooves fabricated into the surface of the carbon fiber tube.
- Drag of rollers in grooves on tubes: measured to be 3.9N (.88lbf)

Upper rollers travel on outside of inner tube in grooves.

Lower rollers travel on inside of outer tube (not visible).



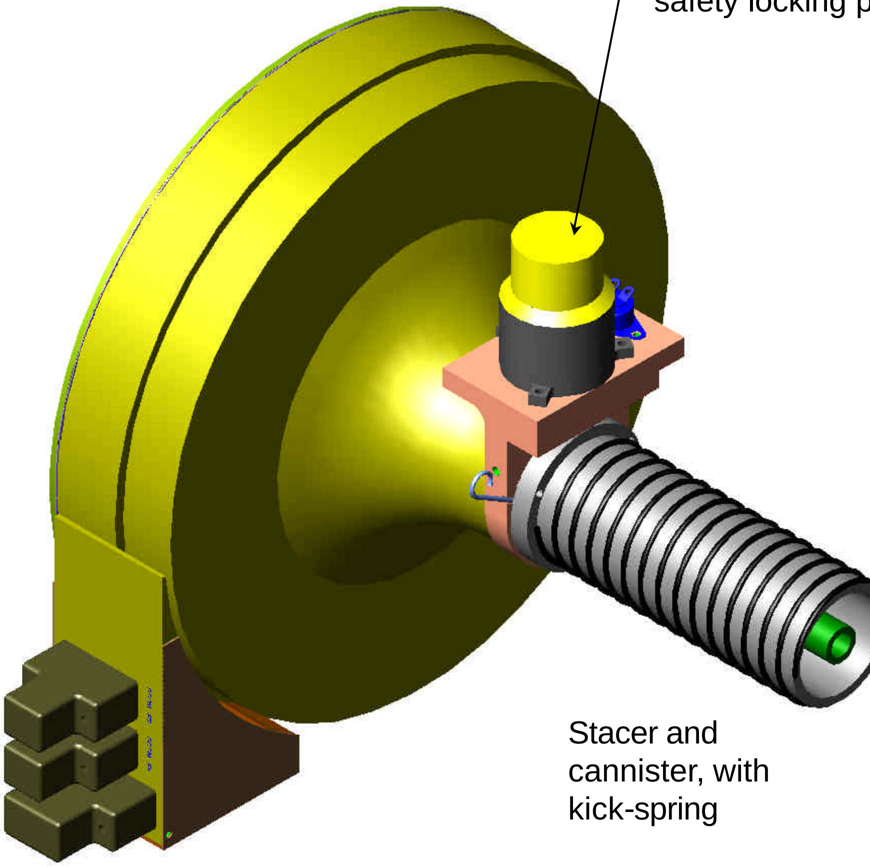
Deployed Tube Assembly



Tube fully deployed, pins inserted into sockets. Boom stiffness calculated from force displacement measurements.

Stacer and Harness Assembly

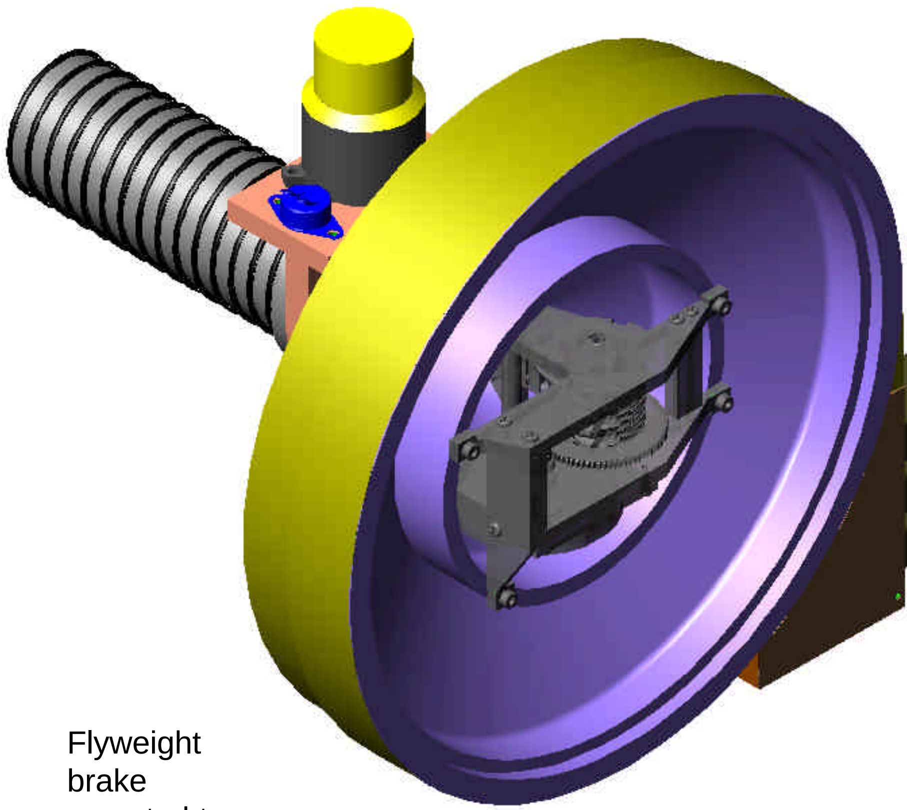
- Stacer canister fits inside of the 50mm diameter tube end.
- Tip piece projects through back of Stacer can to receive pinpuller.
- The harness is stored on a bobbin at the base of the boom assembly.
- Flyweight brake serves as deployment velocity control, is located inside of inner bobbin.
- The Stacer is a helically wound, 6.15m (242") long by 127mm (5") wide strip of Elgiloy: cold rolled, buffed, and coiled with a helix angle of 55^0 and a final tip diameter of 14mm (0.56"). The strip thickness governs the deployment force, and is dependent on harness cable measurements. It is stowed inside a canister for launch, and when released, transfers the stored strain energy into kinetic energy, thus deploying with great force.
- The 3 connectors from the S/C to the SWEA/STE science, power and Mag are attached to the base plate of the bobbin assembly.
- This is a separate assembly, withdrawn from the mount assembly for restowing.



Stacer and Harness Assembly

- Abbreviated Stowing Procedure:
  - Open SMA Release cover plate
  - Remove radial screws from Harness Assembly
  - Collapse tube sections, demate deployed Stacer from boom assembly
  - Stow and safety lock Stacer
  - Reset SMA Release
  - Remove inner bobbin from outer bobbin
  - Withdraw harness and brake lanyard through outer bobbin
  - Wind harness onto inner bobbin
  - Install inner bobbin
  - Wind lanyard onto brake spool, lock into tail of tip piece
  - Reconnect Stacer to tube assembly
  - Replace radial screws from Harness Assembly
  - Preload tube sections
  - Close Cover

End cover removed

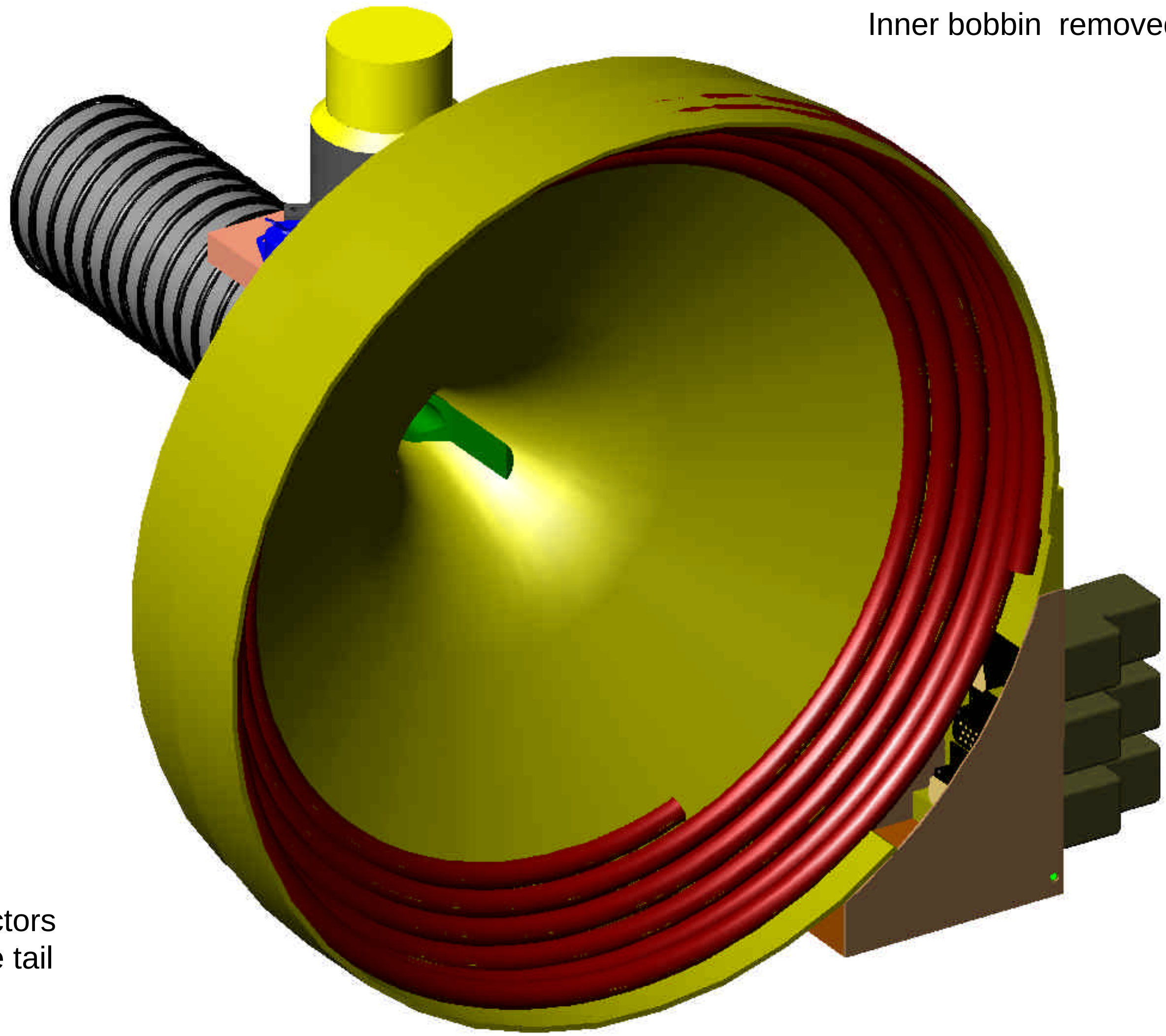


Flyweight brake mounted to inner bobbin

Stacer and Harness Assembly

- Bobbin:
  - Funnel shape give larger bend radii for harness
  - PTFE impregnated anodize coating interior, conductive alodine exterior

Inner bobbin removed

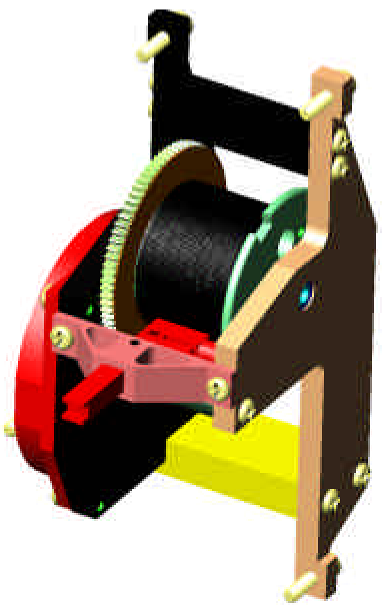


Harness stowed, access to connectors visible. Tip piece tail visible.

Stacer and Harness Assembly

Flyweight brake

- Limits velocity of tubes over wide range of forces
- Spool clamped for launch, no 'birdnesting' of lanyard
- Current deployment time: 6 secs



deploy velo (Vd)	spool diam Ds	gear ratio G	flyweight CG diam (df)	flyweight mass	flyweight radial (rf)	spring k	f_0	sprin
m/s	m		m	kg	movement m	N/m	N	assoc
1.00	0.0295	4.00	0.02654	0.0108	0.00283	1500	0.8	e0063-0

Force to engage brake with drum (Feb) = m*a; a=v^2/r; v=ωr; r=df/2+rf.
Feb=m*ω^2*(df/2+rf) df/2+rf= 0.0161 m

Spring force (Fs) at brake engagement= 2*(k*rf + f_0) Fs= 10.090 N Fg (=m*g) = 0.106 N
min Feb=Fs set Feb=Fs
solve for ω :
ω=sqrt(2*(k*rf+f0)/(m*(df/2+rf)))

Intial Brake engagement at ω=	240.9	rad/s
brake rotor speed=	38	rps
spool speed=	10	rps
Brake engages at deploy speed=	0.89	m/s

Force Balance: brake force >= stacer thrust?

	273.3	301.6	rad/sec - brake speed **- GUESS THIS VALUE**
	0.0108	0.0108	kg - mass per brake shoe
	0.0133	0.0133	m - shoe CG radius
	10.70	13.04	N - shoe centripetal force (m r ω^2)
	10.09	10.09	N - **chosen** brake spring engagement force
	0.3	0.3	Shoe coefficient of friction
	0.05	0.05	m - Brake Drum Radius
	0.018	0.088	Nm - Brake Torque (2 μ (m r ω^2 - Fo) Rd - 2 shoes)
	0.073	0.354	Nm - Spool Torque = Brake Torque x Gear Ratio
Stacer Force (Init: 24N, Fin: 5N) =>	5.0	24.0	N- String Tension = torque / spool radius
	68.3	75.4	rad/sec - Spool Speed = Brake Speed / Gear Ratio
	1.01	**1.11**	**meters/sec - string velocity = Rs ω**

stacer force Fst= G*2*Fb*rd/(Ds/2) 24.0
Force brake F_b = μ*(m*ω^2*r_{cg}-2*(k*r_f+f_0)) 0.884 N
F_s=(m*ω^2*r_{cg}-(F_{st}/(2*μ*D_s/2*r_{dr}*G)))/2

ω desired=	271.2		
Stacer Initial F	24	Fs =	4.83 N
Stacer Final F	5	Fs =	5.18 N
spring k= (avgFs-f0)/rf			1485 N/m

Stacer and Harness Assembly

Harness Description

- The harness consists of a custom fabricated wire bundle routed up the center of the boom.
- The bundle contains 7 coaxial cables, 5 twisted shielded pairs.
- A common, taped, over-shield of the wires extends from inside the boom base to MAG-J1 and SWEA-P1, and will be tied to chassis ground at both ends (the bottom of the boom and SWEA; MAG).
- This assembly is additionally shielded by the Stacer (grounded at boom base), and will have a braid over-shield from the exit of the Stacer up to the SWEA / STE.
- The thermal blankets will be connected to the over-shields' ground.
- The design of the spool and bobbin are dependent on the 'hand' of the cable, so a preliminary mock-up is being built up to get a baseline for stiffness.
- The coaxial wires are a custom fabrication and are the same as used for Cluster, Polar, FAST and other space applications. These have been selected for their ability to carry the high data rates required, while minimizing size.

Stacer and Harness Assembly

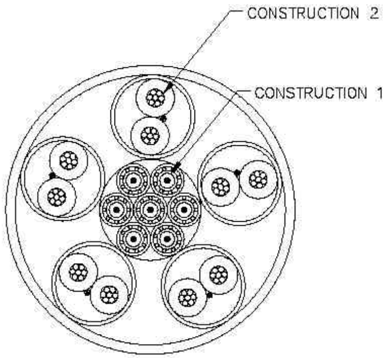
Harness Specification

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED

REVISIONS			
REV	DESCRIPTION	DATE	CHG'D BY
A	INITIAL RELEASE	8/6/02	
B	Change drains to 36(7/44) to 28(19/40), signal: 26(19/48)		

DRAFT WAITING APPROVAL
8/15/02

DESIGN: HYBRID ROUND CABLE
CONTRUCTION 1: 7–55 OHM COAXES
- CONDUCTOR: AWG 36(7/44) SPC
- DIELECTRIC: .005" THK. GORE–TEX EPTFE
- SHIELD: .0015" X .012" AL/KAP (ALUM OUT) 50% OVERLAP
- DRAIN WIRES: 8–AWG 38SPC
- JACKET: 0.003" WALL GORE–TEX EPTFEWRAP, HEAT SEALED, COLOR CODED/STRIPED: BLK, RED, ORG, YEL, GRN, BLU, WHT.
- CAPACITANCE: 22.2 pF/ft NOMINAL



CONTRUCTION 2: 5–SHIELDED TWISTED PAIRS
- CONDUCTOR: AWG 26 (19/38) SPC
- DIELECTRIC: .011" GORE–TEX EPTFE, COLOR CODE; BLACK, WHITE.
- DRAIN WIRES: AWG 28 (19/40) SPC
- TWIST: 1–1.5 PER INCH
- SHIELD: AL/KAP (ALUM IN) 50% OVERLAP
- TWISTED PAIR DIAMETER: .089" NOMINAL
- CAPACITANCE: 15 pf/ft (NOMINAL (SIG–SIG)

OVERALL JACKET: GORE–TEX EPTFE/ FEP LAMINATE WRAP,HEAT SEALED, COLOR CODE: WHITE.
OVERALL DIAMETER: .295" NOMINAL
VOLTAGE BREAKDOWN: ALL SIGNAL LINES TESTED AT 500 VDC MINIMUM

CABLE CONFORMS TO REQUIREMENTS DETAILED IN IMP–031 REV. XXX

GORE Creative Technologies Worldwide

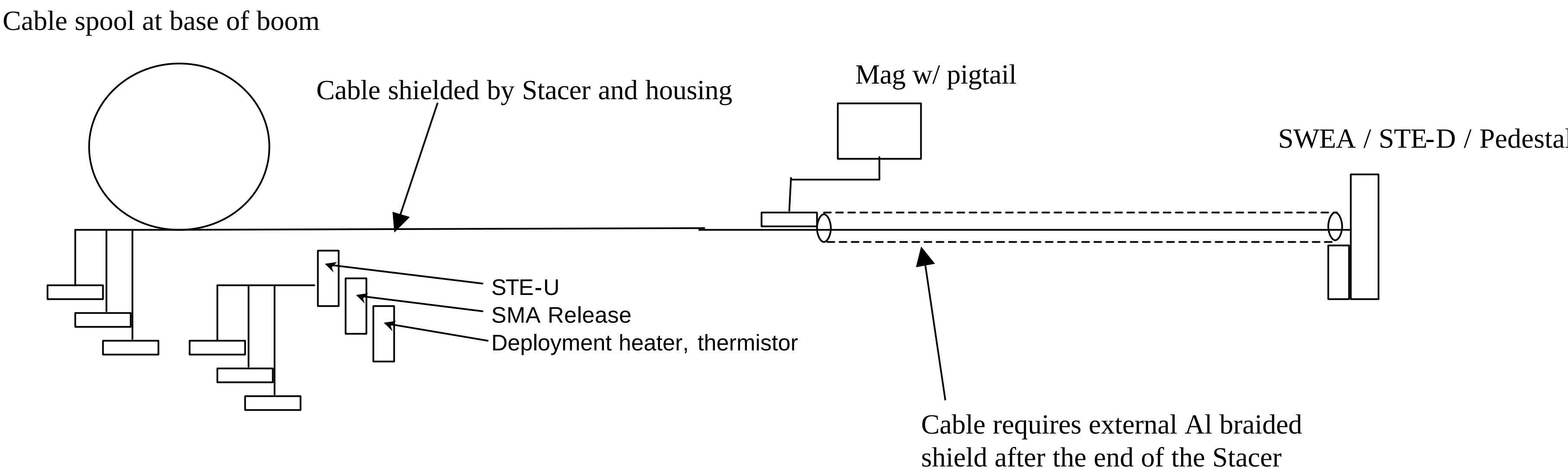
W.L. GORE & ASSOCIATES, INC.
ELECTRONIC PRODUCTS DIVISION
NEWARK DE 19711
302/738–4880

TITLE	HARNESS CABLE SPEC.			
SIZE: A	DWG NO.: RCN8389	DRW'N BY: ED KOZ	APPV'D BY:	REV: B
SCALE	DATE: 08/05/02		APPV'D BY:	

Stacer and Harness Assembly

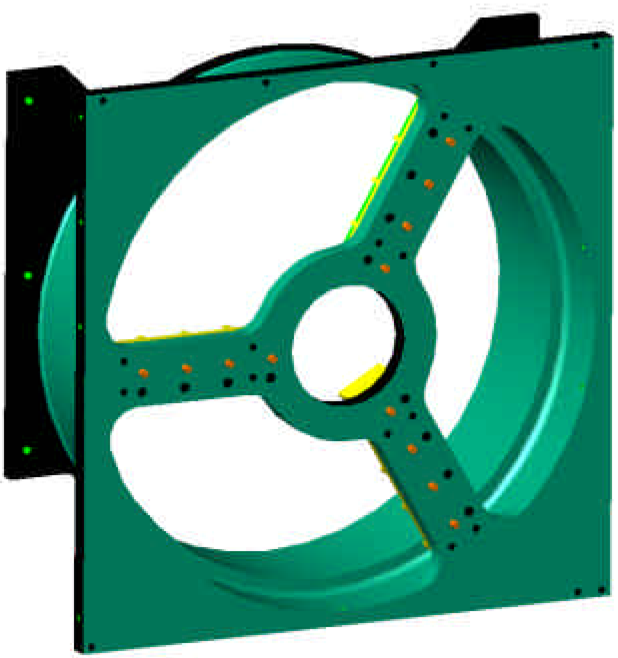
Harness Schematic

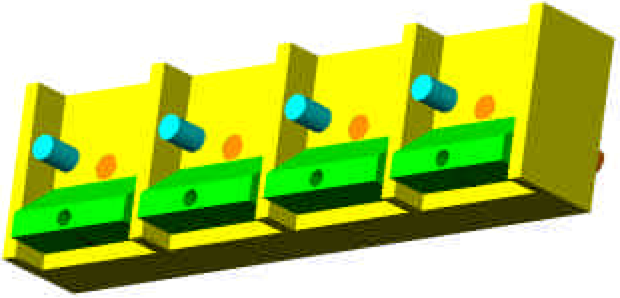
- **The Magnetometer ‘pigtail’ is connected past the end of the Stacer. The remainder of the harness, no longer surrounded by the Stacer, is sheathed in a Ag plated copper braid, and captured in the final tube. It is routed to the SWEA mount, where the harness is terminated at the connector. The harness will be fabricated as a separate entity, and installed into the boom complete with connectors. The shields will be attached at both ends to ground.**



Stowed (Launch) Configuration

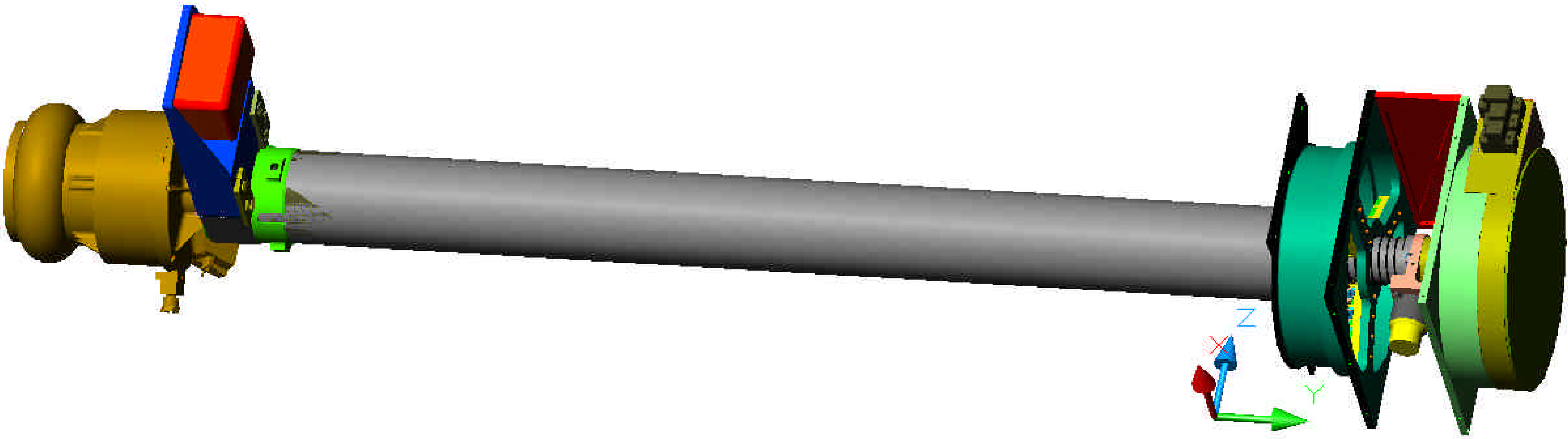
- **For launch, the center tube segment is retained by a Shape Memory Alloy pin puller through a hole in the tail of the Stacer tip piece, which in turn is connected via a swivel to the innermost (50mm diameter) tube. The tubes are held in place for launch by comb-like devices attached to the magnetometer mount. The spool end incorporates adjustable preload / kick spring devices for each tube, allowing tolerances to be taken up due to manufacturing tolerances.**





Deployment Initiation

- **Kick springs located in the spool mounting plate initiate deployment when the SMA is triggered. The Stacer provides the extension force. As the Stacer deploys, the harness is withdrawn from the spool and pulled into the center of the Stacer / tube assembly. A swivel is incorporated into the Stacer attachment at the joint of the smallest diameter tube to relieve the accumulated turns from the Stacer's deployment.**



TiNi AEROSPACE, Inc.
Innovative Mechanism Solutions

TiNi Actuator

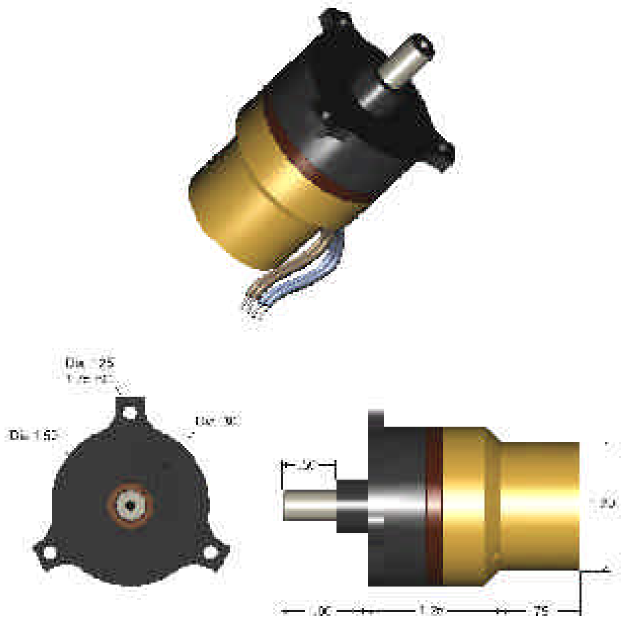
Pinpuller

(Model P50-810-1RS)

The model P50-810-1RS is a stronger derivative of the Pinpuller used by NASA on the HESSI satellite. This embodiment uses TiNi's patented trigger mechanism to retract the engagement Pin with 50 lbs of force and 0.50" of stroke [1]. The extra pull force makes the P50 capable of releasing sheer loads above 100 lbs.

As with all TiNi Pinpullers fatigue life is in the 100s of cycles allowing numerous acceptance and system level testing. The P50 is reset by manually re-extending the Pin using the reset tool provided. This can be carried out in a matter of seconds after actuation, often with the Pinpuller still attached to its mounting structure. This model also incorporates integrated and redundant switches for auto shut-off.

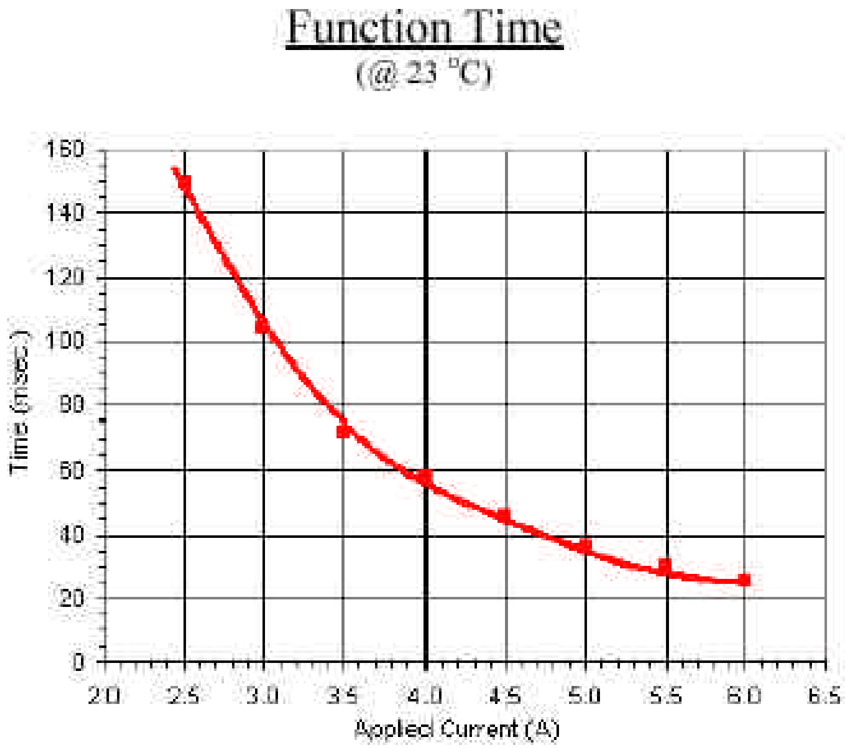
[1] Custom configurations as to pull force and stroke are readily attainable.



Dimensions shown in inches

Rev. 5/02

Actuator Electrical Characteristics



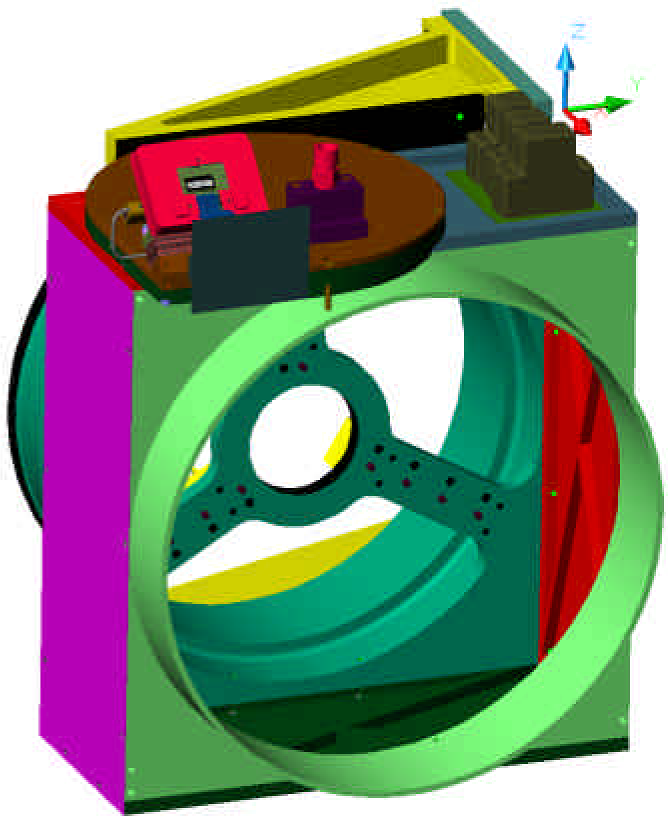
Specifications

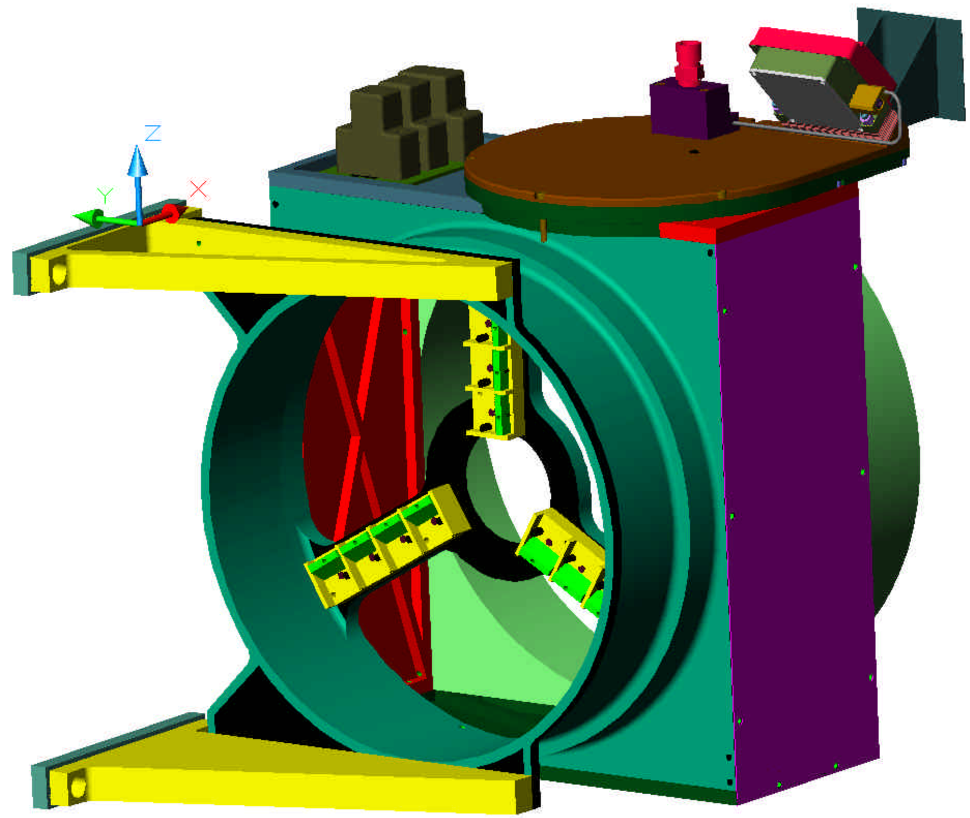
Pull Force	222 N	(50 lb-f)
Pull Stroke (minimum)	1.27cm	(0.5 in)
Operational Current	2.5 to 6.0 amps	
Actuator Resistance	1.2 Ohms	
Min. Power Consumption	7.5 Watts @ 2.5 Amps	
Mass	95 gm	(0.21 lb)
Life	100 Cycles Min.	
Max. Shear Load	445 N	(100 lb-f)
Max. Axial Load	223 N	(25 lb-f)
Min. Operating Temp.	<-60 °C	(<-76 °F)
Max. Operating Temp.	+70 °C	(158 °F)

Features:	Redundant SMA Circuit
	Reusable
	Auto Shut-Off Switch

Mount Assembly

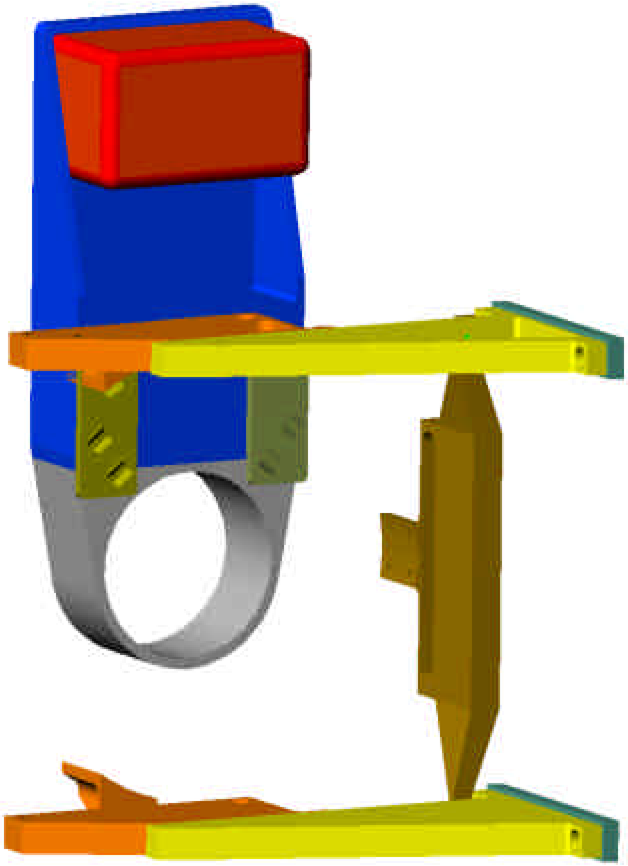
- **Thermal isolators, mounting brackets, tube assembly interface**
- **Stacer & Harness Interface**
- **STE-U mount**





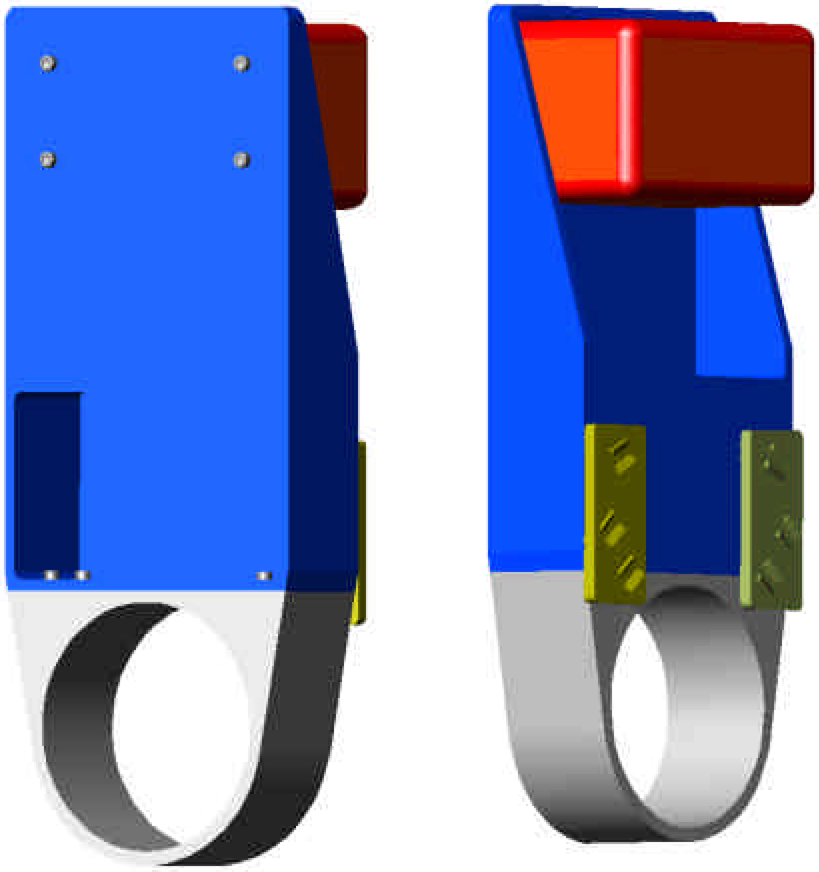
Mount Assembly

- **Magnetometer mount**
- **SWEA/STE/Pedestal interface**



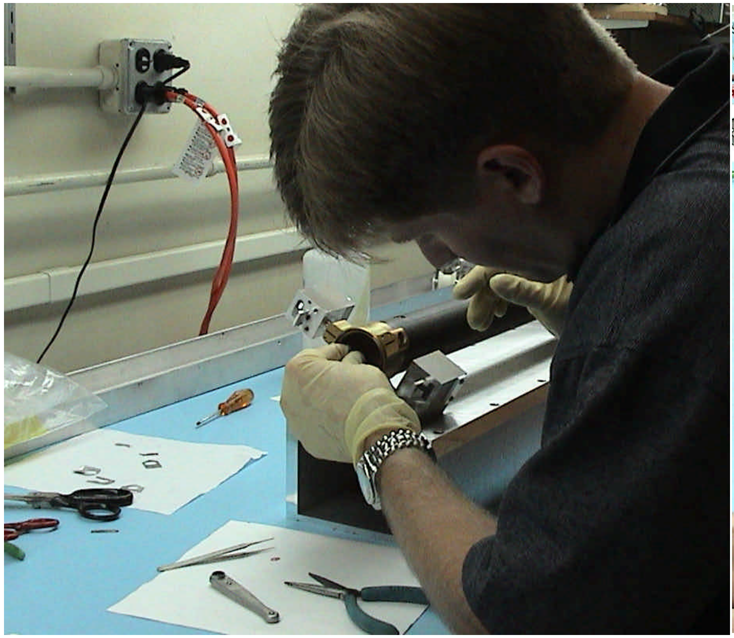
Magnetometer Mount

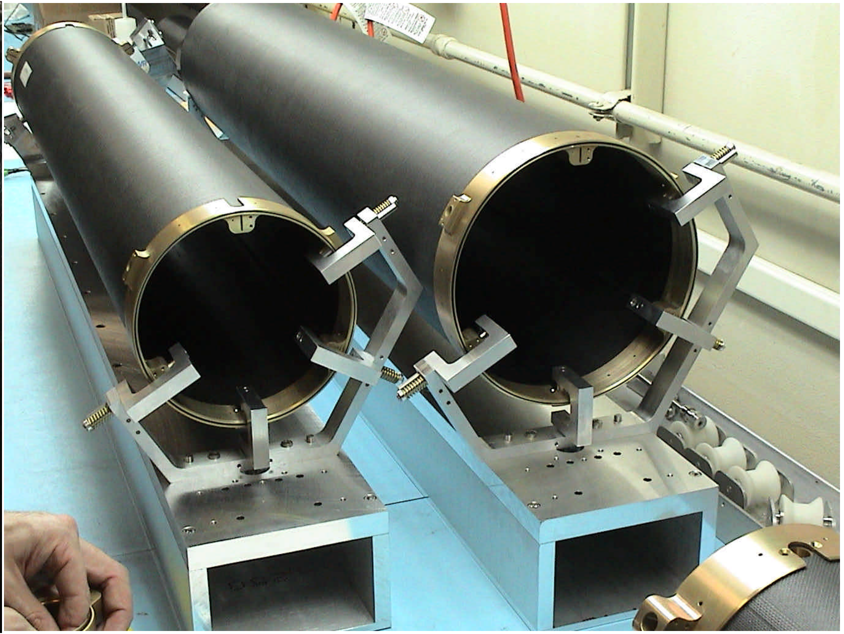
- Mag tray fabrication of carbon filled PEEK high performance engineering plastic.
- Mag tray mounts to 90mm diameter aluminum tube ring with 4 screws with belleville washers and 2 locating pins
- Locates 'comb' for capturing tubes for launch.
- Magnetometer is mounted via 4 screws with belleville washers through the base of the tray.
- Mag is delivered blanketed
- Tray used as 'sunfinger' for 4th joint.



Mechanical GSE

- **Tube / ring bond assembly fixtures**
  - **Worked adequately, but will modify to provide 3-point support (per ring) for next units to improve alignment**



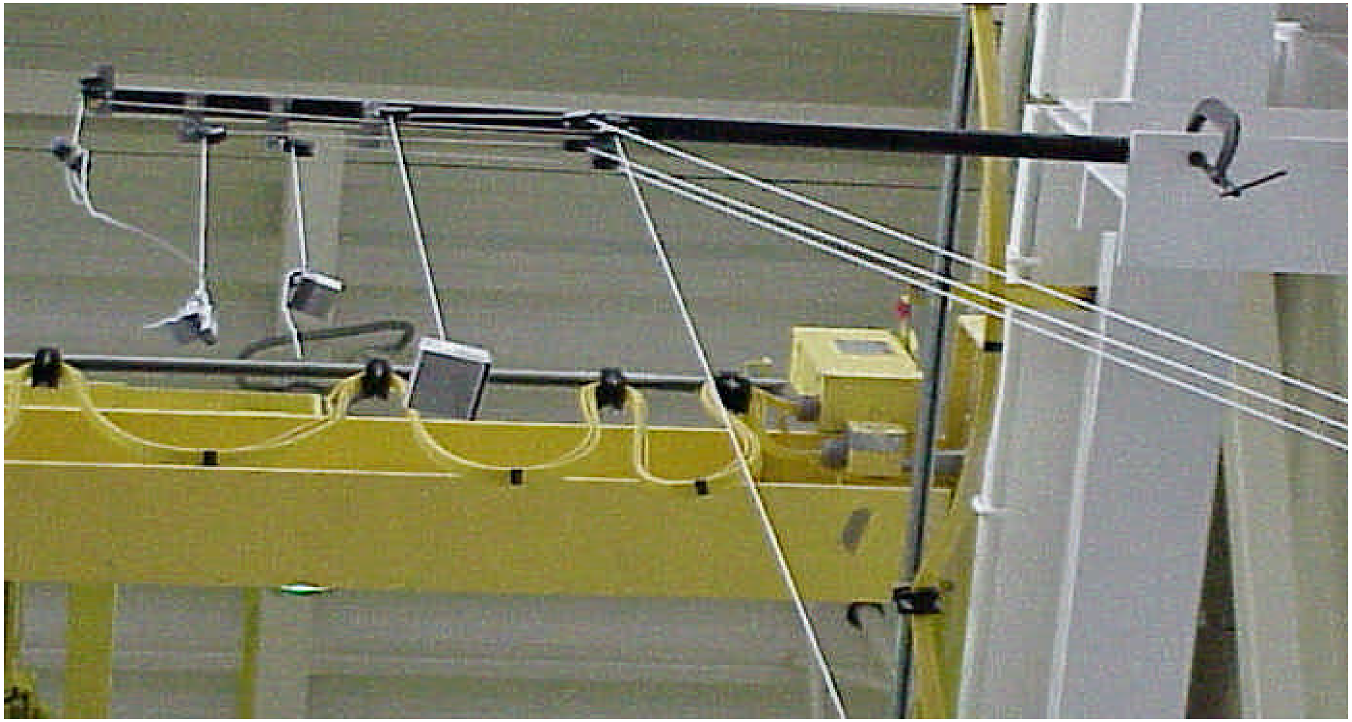


Mechanical GSE cont.

- **Deployment Fixture**
  - **For ambient vertical deployment testing, to check:**
    - **Joint lock up**
    - **Deployed stiffness**
    - **Pointing requirement**
  - **Provides:**
    - **Stable, rigid base**
    - **Leveling legs for vertical alignment**
    - **Lockable turntable for runout measurement**

Mechanical GSE cont.

- **Offload fixtures (compensate for 1g environment)**
  - **Ambient deployment**
    - **Counterweight for each tube section**
    - **Increasing counterweight to compensate for Stacer extension**



Mechanical GSE cont.

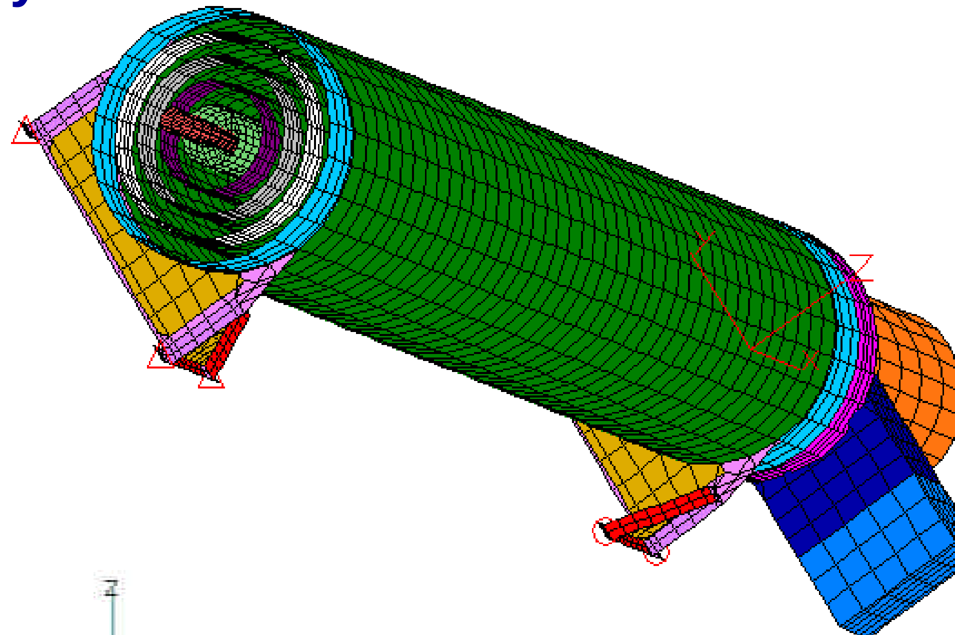
- **Offload fixtures cont.**
  - **EMC characterization**
    - **If horizontal, will supply stands to support boom after manual deployment**
    - **If vertical, need pulley 5m above boom end. We can supply gantry, or use existing crane or lift at facility**
    - **Test-fire SMA boom release since we are deploying anyway**
  - **Qualification Thermal vacuum deployment**
    - **In-house TV chamber:**
      - **Vertical chamber has off-loading system built in**
    - **Outside TV facility:**
      - **We supply off-loading gantry**
  - **Acceptance First motion at S/C integration – 4” travel to verify proper deployment initiation**
  - **Lockdown pin to prevent boom deployment in SMA firing test performed during post S/C integration functional checkout**

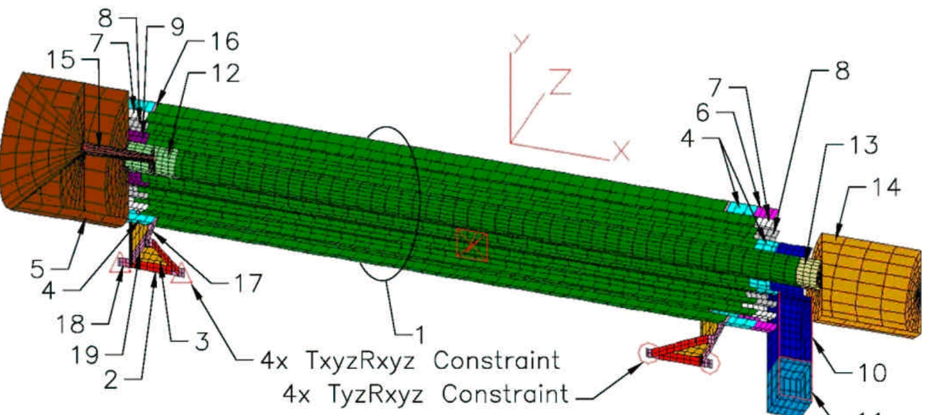
Mechanical GSE cont.

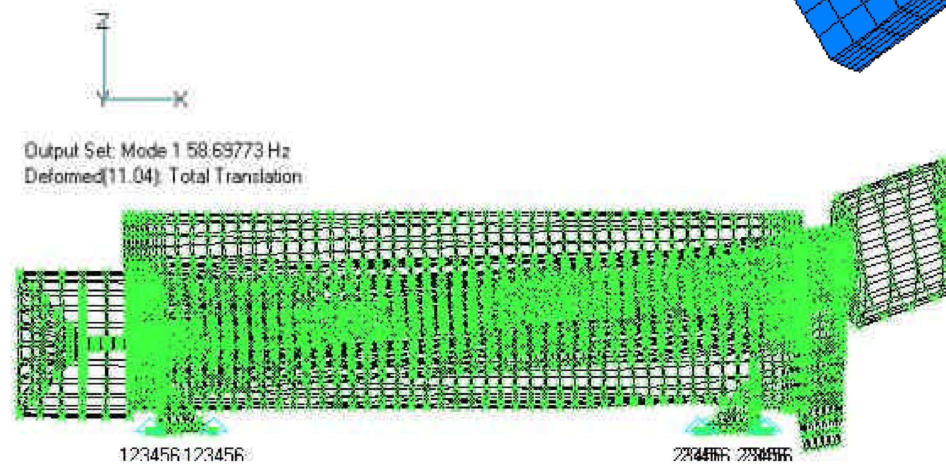
- Shipping containers
  - Vented Aluminum shipping crates
  - Instruments mounted on shock-isolated platforms
  - Instruments grounded to boxes
  - Instruments in clean, anti-static, sealed bags back-filled with dry N_2
  - Bags partially inflated to allow for altitude cycling

Analyses

- **Finite Element Modal Analyses Deployed Case**
  - **Fundamental mode: 58.7 Hz.**
  - **Magnetometer torque load on launch lock pins: Ok to 50 Gs**

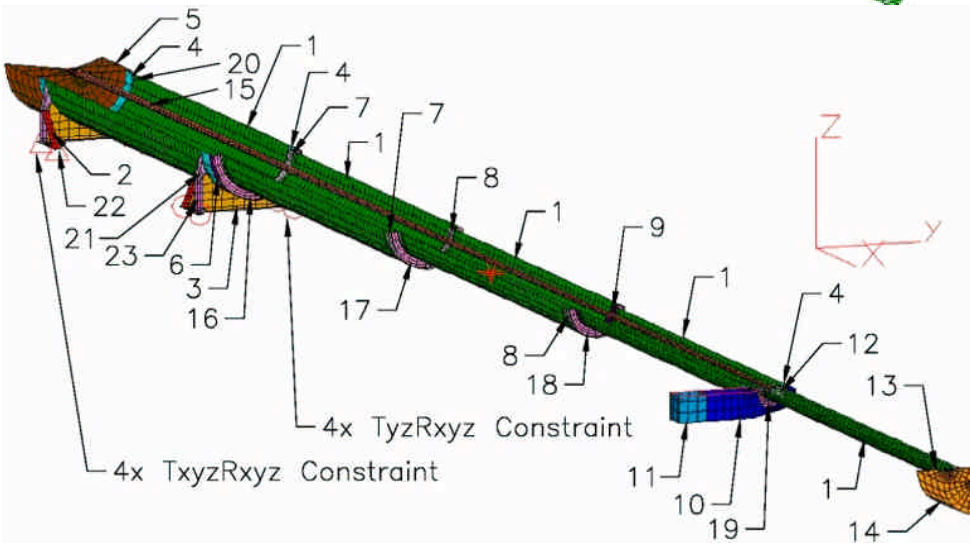






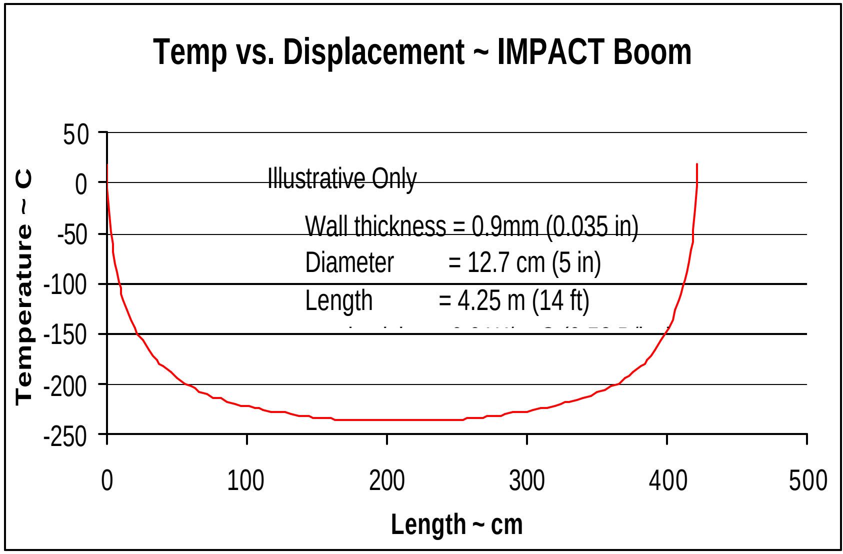
Analyses

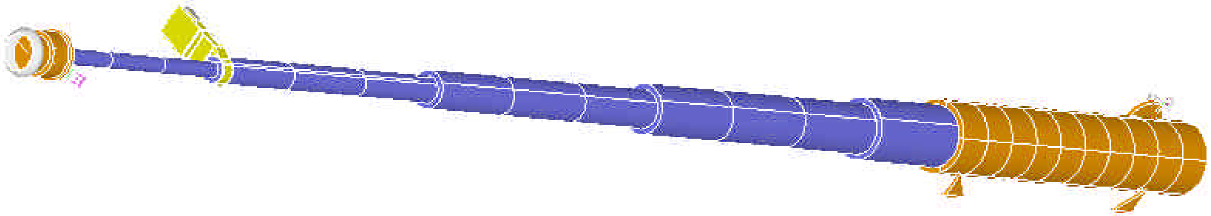
- **Finite Element Modal Analyses Deployed Case**
  - **FEA predicted a fundamental frequency of 1.3 Hz.**
    - **Joint behavior based on measurements of prototype: joint not glued to tube.**
  - **Calculated (from measured force deflection) F.F. is 1.8 Hz.**
    - **Glued joint of EM much stiffer than prototype.**
  - **Direct measurement of actual frequency on test schedule, waiting for accelerometer delivery.**
    - **Measurement will include mass dummies for mag and SWEA/STE/pedestal**



Analyses

- **Thermal FEA performed by Swales**
  - **Stowed temperature range: +16 ^{0}C, -70 ^{0}C (no heater)**
  - **Deployment temperature : 0 ^{0}C (thermostat controlled 5W deployment heater)**
  - **Deployed temperature range: see chart, minimum: -230 ^{0}C**
  - **More details in Thermal presentation**



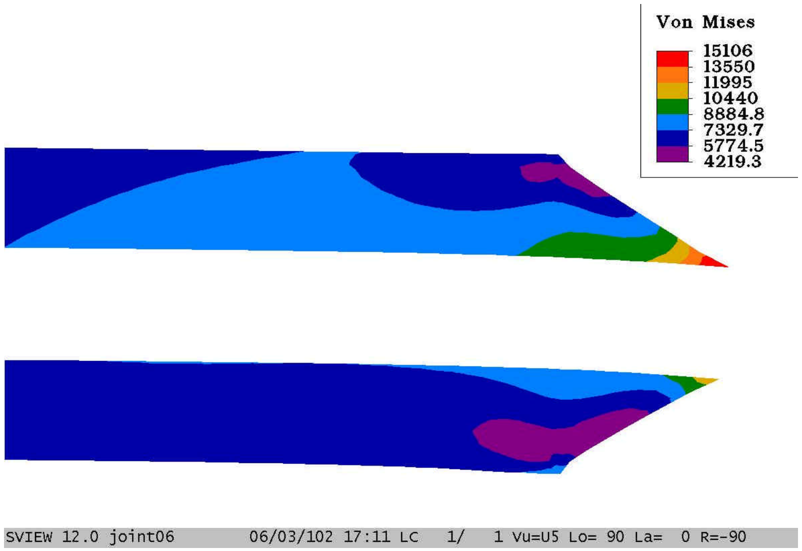


Analyses

- Glue joint thermal FEA
  - Showed glue strength exceeded, based on extrapolated C.T.E. data
  - Glueline thickness determined to be a minor effect for bounded ring arrangement (compared to monolithic bonding)
  - Failure mode of glue needed evaluation

- Verification Thermal Test at 25^{0}K
  - Mock up of ring and tube made, tested; slight crazing of glue seen. No observable weakening of assembly noted during or after thermal test proof loading.

Joint 06 Von Mises stresses, epoxy bonds only



Analyses

- **Analyses performed**
  - **Stacer thrust:**
    - **Current force requirement for deployment:**

      3.9N roller friction + 1N friction and bending losses from harness (value estimated, derived from FAST Axial Boom)
    - **Range sufficient to meet force (torque) margin of 3X: current (in-house) Stacer yields 4.9N, can obtain 18N with a new design.**
  - **Flyweight Brake: deployment speed set at 1 m/s**
  - **Velocity / Momentum imparted to spacecraft:**

BUS RESPONSE ESTIMATE

1.50 m Width — Uniform Density Bus
1.50 m Height — 188 kgm^2 = Box MOI [$M*(W^2+H^2)/12$]
500 kg Mass — 0.8 m = Boom Offset from Bus CG

NOTE: The Stacer is pushing against the bus to accelerate the Boom
9.07 Nm = Boom Acceleration Induced Torque (Γ) ...*average*
0.048 rad/sec^2 = Bus Angular Accel. ($\alpha = \Gamma / Izz$)
in degrees — 0.132 rad/sec = Final Angular Velocity ($\omega = \alpha\ T$)
20.80 — 0.363 rad = Bus Rotation Angle ($\theta = \alpha\ T^2/2$) =
0.027 G's = Boom Coriolis Bending (2 * Rdot *omega)

With Flyweight Brake - Force Equilibrium occurs when the brake engages @ $T_e = f(V_e)$
Bus rotation accelerates only during the Initial Force Imbalance
1.00 m/sec = **selected** brake engagement velocity (boom)
0.26 sec = Time to engage Brake ($T_e = V_e / a_l$)
in degrees — 0.013 rad/sec = Bus Angular Velocity at engagment ($\omega_e = \alpha\ T_e$)
2.20 — 0.038 rad = Bus Rotation Angle ($\theta = \alpha\ T_e^2/2 + \omega_e\ T_{total}$)
0.003 G's = Boom Coriolis Bending (2 * Rdot *omega)

Comment: In both cases conservation of momentum says the bus rotation stops when the boom stops

Analyses

- **Other analyses performed:**
  - **Thermal strain input to S/C –Y deck from rigid tube limited by flexure in front mount: force input for 50 ^{0}C delta is 360N along boom axis.**
  - **SMA Release force margin:**
    - **Sum of preload: Stacer + kick springs = 730N**
    - **Release bushing m=0.05**
    - **Release force needed: 36N**
    - **Release pull force 222N**
    - **Fs = 6**
  - **Mounting bolts: Boom subjected to 50 Gs loads bolts to 5% of yield.**
  - **Thermal standoffs: Area in contact with deck, 8mm thick gives 27 ^{0}C / W**
  - **Alignment Error: Worst case, all pin offsets sum, gives mag mount 0.35^0 angle from boom centerline; RMS value is 0.12^0 angle.**

Status

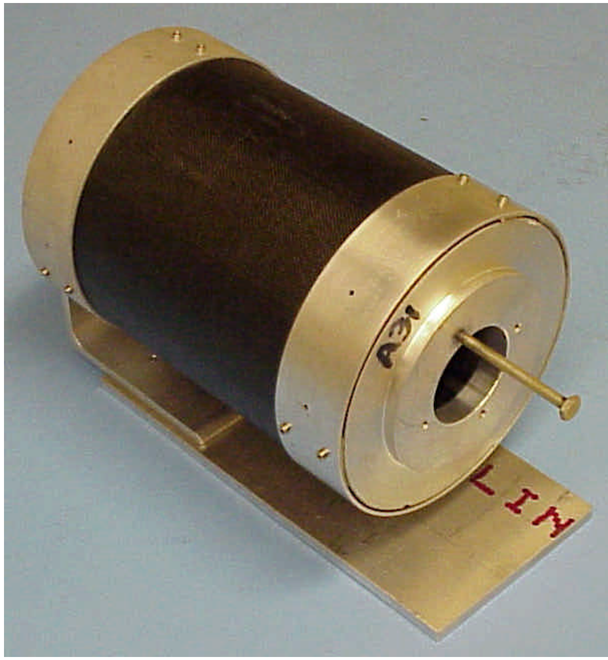
- **EM development status**

Status

- EM development status
  - Design status
    - Telescoping tube section design complete, drawings 100%
    - Mounting section design complete, drawings 80%
    - Harness section design complete, pending cable stiffness/deployment testing, drawings 80%
    - Stacer final design (required force) dependent on harness stiffness
  - Fabrication status
    - Telescoping tube portion complete
    - Mounting section – fab not started – waiting for completion of harness section
    - Harness section – cable testing subset complete, awaiting cable for harness deployment force test
      - Cable delivery ~11/25

Status

- **EM development status**
  - **Tests performed**
    - **Joint cold test**
      - **Achieved 25K for 5 cycles**
      - **Withstood 7.8 Nm torque during test, no deformation**
      - **Withstood 35 Nm torque after test (room temp)**
      - **Localized crazing of glue, no particulates formed**



Cold Test Sample

•Tube extension friction test

–Measured force required to extend each tube

»Max force was 3.9 N

•Groove friction test

•Measure extension force with roller in and out of groove. Results were identical, showing friction not greater in groove

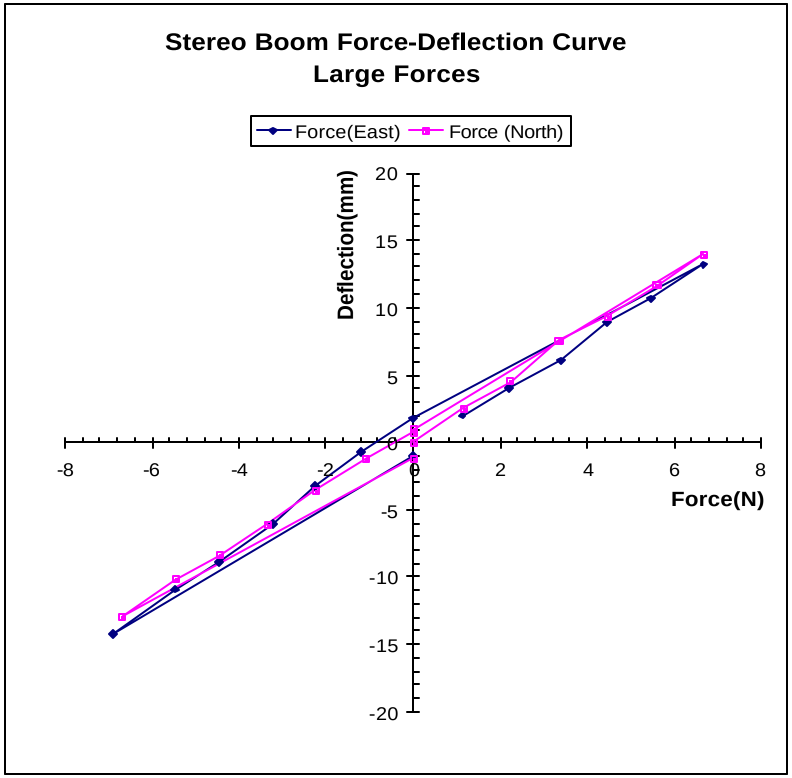
Status

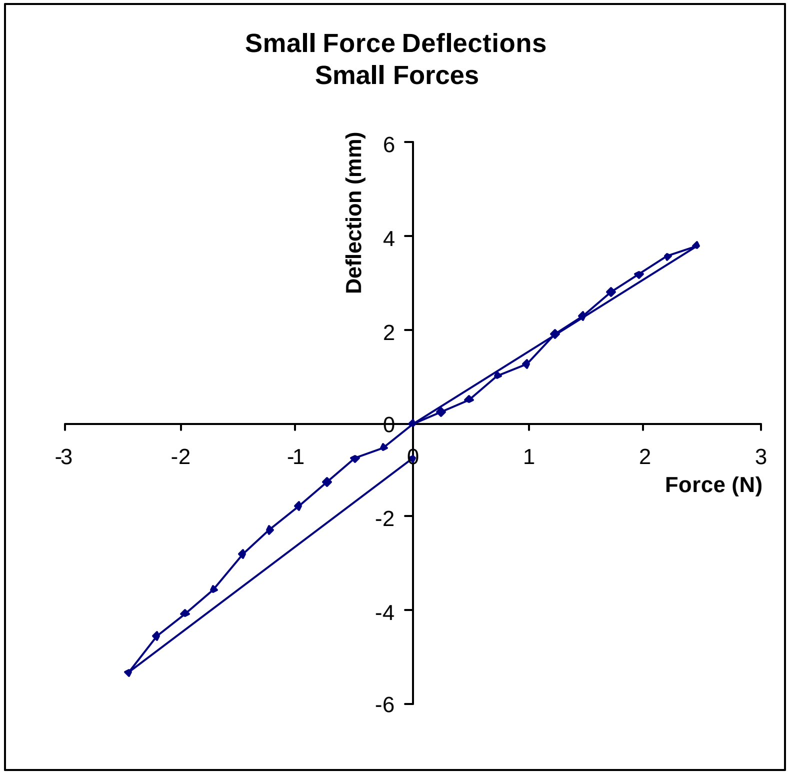
- Torque-out test
  - Applied 1.7 Nm torque to end tube during deployment. Wheels stayed engaged in tracks. This was max load we were comfortable applying.

- Deployment test →
  - Deployed telescoping tube vertically with Stacer and counterbalance
  - Deployed to full extension
- Proof load test (deployed)
  - Applied 40N side load at boom end, no damage
- Graphite Conductivity Test
  - <1 kW/sq

Status

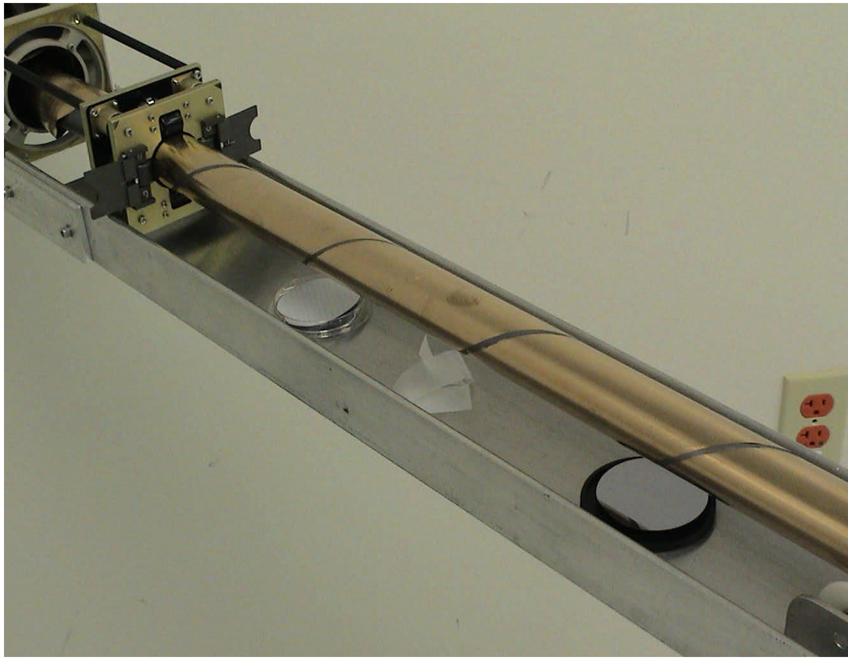
- **Force deflection test**
  - **For large forces (~200N), ~3mm hysteresis**
  - **For small forces(<2.5N), <1mm hysteresis (none?)**





Status

- **Contamination Test**
  - **Performed horizontal deployment (let out by hand) with Stacer above 5” channel**
  - **Tape lifts before test and background witness plates during test**
  - **Silicon and Teflon witness plates, tape loops, particle counter under boom during test**
  - **Deployed 3 sections of boom while guiding by hand**
  - **Preliminary results look good. Opinion of Contamination Engineer that boom appeared to generate very little debris, and that judging by witness plates, should have no problem beating 300-400 spec.**



SWAVES test shown. Same facility, test track, and collection methods used for IMPACT.

Performance Issues

- Thermal (joint test)
    - Withstood 10kg side load, no deformation
    - Achieved 25K
    - Localized crazing of glue, no particulates formed
    - Test joint far stronger than needed post test
- Boom Deploys fully
    - During repeated testing, the boom deployed fully and smoothly and most of the pins locked positively.
- A few pins fail to lock during deployment
    - Due to design error, too many offsets added, preventing typically one pin per joint from aligning with its hole well enough to engage. This introduces a small amount of deadband. Problem cause is well understood, easily fixed on next unit.
    - Pins can all be made to engage by manually aligning, allowing stiffness test.
- Deployment pulley friction
    - Ball bearing pulleys exhibited friction equal to about 1/3 the counterweight – had to increase the counterweights to overcome. Will switch to bicycle wheels to reduce friction.

Performance Issues

- Stiffness (with all pins locked)
  - Higher than predicted by FEA (1.8 vs. 1.3 Hz predict) Considerably better than requirement of >0.5 Hz.
- Inadequate margin on Stacer force
  - POLAR Stacer Has 4.9N push force at end of travel, less than 3X boom rolling friction of 3.9N. Cannot determine required force until completion of harness deployment force test. We can build Stacer with up to 80N force if necessary (pending harness drag measurement).
- Tube concentricity
  - Tubes could be easily pushed out of concentric until parts came in contact causing rubbing friction, possible misalignment of pins and sockets. Also possible to pop guided roller out of its groove.
    - Added pin travel limiters to prevent the rollers from forming a circle more than 0.25mm larger than the tube they ride on.
      - Keeps tubes concentric, prevents rubbing contact, ensures pins are aligned with sockets.
    - Adding two additional grooves (three symmetric) on tube exteriors for better guiding, equal pin stroke and spring forces, and to force concentricity. Combined with travel limiters, rollers cannot come out of grooves and pins cannot go out of alignment with sockets.

Performance Issues

- **Contamination test**
  - **Preliminary results look very good – low particulate generation.**
- **Roller and tube wear**
  - **Microscopic inspection of wheel tracks on carbon fiber tubes shows no crushing or wear of epoxy matrix or fibers.**
  - **Aluminum rollers wearing on tubes**
    - **Aluminum deposited on tracks, slight wear observed on rollers**
      - **Switch to harder material (hardened BeCu)**
      - **Change free-running rollers from small transverse radius to radius matched to tube curvature. Changes from point contact to line contact.**
- **ESC (surface conductivity)**
  - **Graphite tubes measure <1kW << 10^8W requirement**

Peer Reviews

- **PDR open RFAs**
  - **2 open action items for boom mechanism**

    4) Partial Deployment analysis
      - **Submitted**

    18) Test Plan submission and boom stiffness analysis/measurements
      - **Test Plan Submitted**
      - **Boom stiffness calculations and Force Deflection tests complete**
      - **1.8Hz first-mode resonance calculated from stiffness**
      - **Need to perform accelerometer test to verify frequency**

IMPACT PDR RFA CLOSURE STATUS (10/23/02)
(PDR DATE: SEPT 11-13, 2001)

RFA No.	RFA TITLE	ORIGINATOR	STATUS	DATE CLOSED
1	C&T EGSE Software	Mocarsky	Submitted 01/09/02	1/14/02
2	Software Development Plan	Whitley	Submitted 11/16/01	1/16/02
3	FSW Review Schedule	Whitley/Ballard	Submitted 11/16/01	1/16/02
4	Boom Un-locked	Gold	Submitted 01/09/02;Response accepted pending results of analysis in May	
5	Minimum Science Requirements	Sizemore/Gold	Submitted 11/30/01 Sizemore Rejected 01/04/02, Resubmitted 10/22/02	Gold 1/11/0
6	Boom Cold Survival Test	Nguyen	Submitted 01/09/02	1/30/02
7	Thermal Analysis on Magnetometer	Nguyen	Submitted 01/09/02	1/30/02
8	IDPU Thermal Analysis	Nguyen	Submitted 11/16/01	01/03/02
9	Stacer Deployment Mechanism	Betenbaugh	Submitted 01/09/02	1/29/02
10	Boom Testing	Devine	Submitted 01/09/02	2/07/02
11	VLSI Delivery	Sizemore	Submitted 09/17/02	
12	SIT Grounding	Shue	Submitted 01/09/02	01/29/02
13	SEPT Magnetic Emissions	Gold	Submitted 01/09/02	02/05/02
14	Level 1 Requirements Flowdown	Gold/Sizemore	Submitted 11/30/01	01/04/02
15	Limiting Resistor For Boom Actuator	Butler	Submitted 01/09/02	01/29/02
16	LVPS Short	Hynes/Hunter	Submitted 07/24/02	
17	Secondary power grounding	Butler	Submitted 06/14/02	
18	Boom Analysis & Test Plan	Eng	Submitted 01/09/02 Rejected; 1/30/02	
19	SIT Foil Breakage	Sizemore	Submitted 01/09/02	1/12/02
20	L1 Detectors	Sizemore	Submitted 08/29/02	
21	PHA ASIC	Shaw	Submitted 01/09/02	1/29/02
22	SEP Software Resources	Mocarsky	Submitted 01/09/02	1/14/02
23	SEP Instrument Test Environment	Mocarsky	Submitted 01/09/02	1/14/02
24	SEP System FMEA	Ho/Venator	Submitted 08/29/02	
25	SEP Power Supply	Shue	Submitted 11/16/01	11/17/01
26	Processor Margins	Ho	Submitted 01/09/02	1/22/02
27	Time Tagging	Bay	Draft response	
28	SEP Survival Heaters	Venator	Submitted 06/14/02	
29	Glint onto SEPT Detectors	Gold	Submitted 06/14/02	

Peer Reviews

- **Peer review open RFAs**
  - **1) Submitted**
  - **2) Complete**
  - **3) Complete**
  - **4) Complete**
  - **5) Complete**
  - **6) After CDR**
  - **7) Risk Mitigation; Project plan**

IMPACT BOOM Review CLOSURE STATUS (10/29/02)

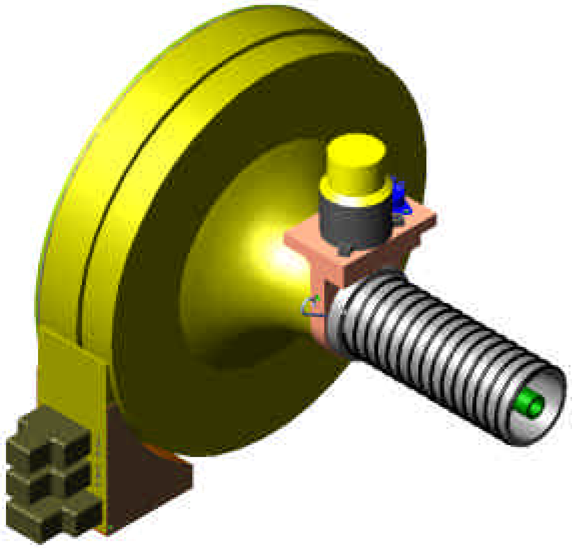
Action No.	Action Item TITLE	ORIGINATOR	STATUS	DATE CLOSED
1	Test Plan	Cliff Willey		
2	Analyze Magnetometer Mount	Cliff Willey		
3	Accelerometer Test	Brian Kemp		
4	Add brackets to analysis	Alphonso Stewart		
5	Verify rotational loads	Alphonso Stewart		
6	Generate a new schedule	Alphonso Stewart		
7	Alternative boom	Alphonso Stewart		

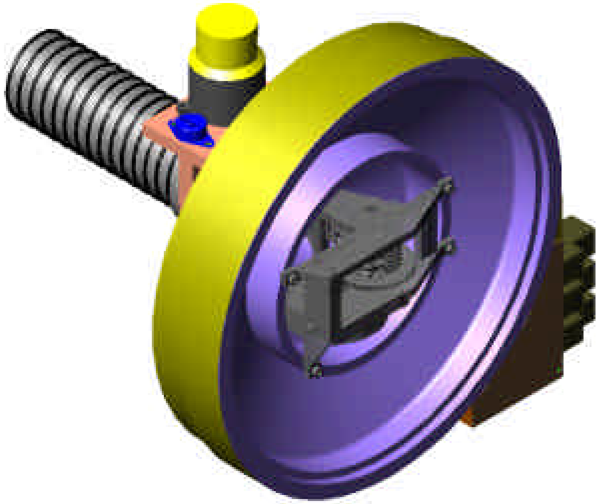
Manufacturing Plan

- **All assembly/test (except cabling) performed by designing engineers with QA oversight**
- **Telescoping Tube Assembly**
  - **Receive carbon fiber tubes and inspect**
  - **Receive, inspect, clean machined parts**
  - **Assemble wheels, axles, pins, spring subassemblies**
  - **Pre-fit shims**
  - **Glue and bolt rings to tubes in gluing fixtures**
  - **Glue mounting rings to outer tube**
  - **Inspect ring alignment, glue joints**
  - **Assemble pins and spring assemblies into rings**
  - **Assemble concentric tubes**
  - **Install pin travel limiters, cow catchers**
  - **Install tube closeouts**
  - **Install magnetometer mount**
  - **Hand deployment to test pin lockup**

Manufacturing Plan

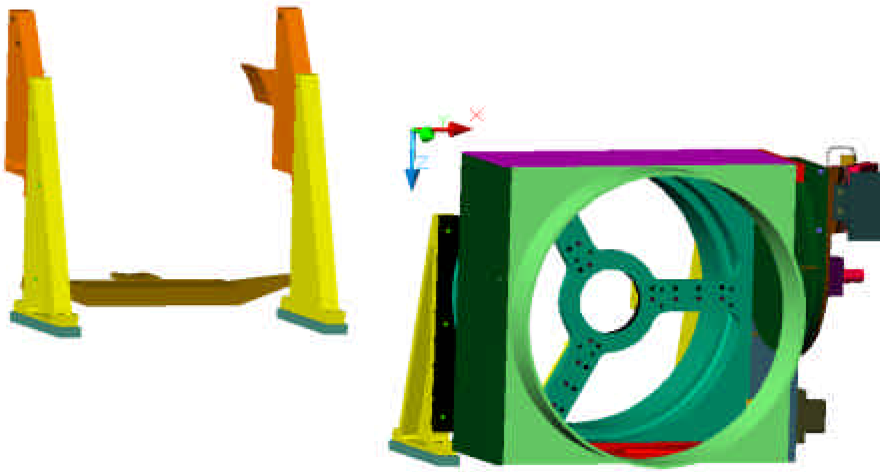
- **Harness/Stacer assembly**
  - **Receive Stacer**
    - **Deploy and inspect**
    - **Clean, apply Perma-Slik RMAC**
    - **Cut to length**
    - **Rivet to can and tip piece**
  - **Receive, inspect, clean machined parts**
  - **Receive, inspect Gore cable**
    - **Fab harness and inspect**
  - **Assemble and test flyweight brake**
  - **Assemble spool**
  - **Add flyweight and Stacer**
  - **Test deploy stacer and harness with SMA release**





Manufacturing Plan

- **Mounting Assembly**
  - Receive, inspect, clean machined parts
  - Assemble Mounting assembly
- **Integrate components**
  - Assemble mounting assembly to telescoping tube assembly
  - Install harness/Stacer assembly
- **Performance checkout**
  - Deploy boom vertically to verify proper deployment and pin lock up
  - Measure forces, calc margin
  - Measure stiffness



Boom Verification Plan

- **EM Qualification (per GEVS-SE Rev. A; APL# 7381-9003)**
  - **Proof Load: 1.25 times expected load. (Tested to 200N side load at SWEA)**
  - **Vibration: 14.1 Grms ; facility: GSFC or Wyle Lab (TBC).**
  - **Thermal Vacuum / balance: 6 cycles @ +26^{0}C / –80^{0}C in < 10^{-5} Torr vacuum; facility: UCB or GSFC(TBC).**
  - **Deployment + boom characterization: length, mag mount angle (3/4 deg budget), stiffness, mass properties @ UCB.**
- **FM1 & FM2 Acceptance (per GEVS-SE Rev. A; APL# 7381-9003; TBC)**
  - **a. Proof Load: 1.25 times expected load.**
  - **b. Vibration: 10.0 Grms**
  - **c. Thermal Vacuum: 6 cycles @ +16^{0}C / –70^{0}C (TBC) in < 10^{-5} Torr vacuum**
  - **d. Deployment + boom characterization: length, mag mount angle (3/4 deg budget), stiffness, mass properties @ UCB, EMI (TBD).**

Boom Verification Plan

- **Contained in UCB Verification Plan Document**
- **Analysis**
  - **Engineering Calculations: Stress, Dynamics, Force Kinematics, Margins**
  - **Data from Previous Flight Designs and Heritage**
  - **FEM Model for Dynamics Characteristics**
    - **Modal Determination**
    - **Stowed and Deployed Configuration**
    - **Worst case partial deployment also analyzed**
    - **Mass Properties**
  - **FMEA**
    - **Survey of Failure Modes**
    - **Risk Mitigation Strategies at UCB Project Management Level**
    - **Trade Studies**
  - **Thermal stress analysis of joints**
  - **Full boom thermal analysis (described in another presentation)**
- **Documentation and Control**
  - **Drawing Release and Control System per IMPACT Configuration Management Plan**
  - **Assy. Procedures, Test Plans and Procedures**

Boom Verification Plan

- Qualification of EM Unit
  - Functional Testing
    - Deployment Characteristics and Rate
  - Measured Properties
    - Mass Properties
      - Mass
    - Deployed Stiffness
    - Alignment
    - Repeatability
    - Force Margins
    - Contamination
    - Surface Resistivity
  - Vibration Testing
    - Modal Survey
    - Sine Sweep (Strength)
    - Random

Boom Verification Plan

- Qualification of Protoflight Unit
  - Functional Testing
    - Min 5 Deployments
    - Deployment Characteristics and Rate
    - Self-shock
  - Measured Properties
    - Mass Properties
      - Mass, CG
    - Deployed Stiffness
    - Alignment
    - Repeatability
    - Force Margins
    - Surface Resistivity
  - Vibration Testing
    - Modal Survey
    - Sine Sweep (Strength)
    - Random
  - Thermal Vac
    - Thermal Cycling
    - Hot, Cold Deployment

Boom Verification Plan

- Acceptance of Flight Units
  - Functional Testing
    - Min 3 Deployments
    - Deployment Characteristics and Rate
    - Self-shock
  - Measured Properties
    - Mass Properties
      - Mass
      - CG
    - Deployed Stiffness
    - Alignment
    - Repeatability
    - Surface Resistivity
  - Vibration Testing
    - Modal Survey
    - Sine Sweep (Strength)
    - Random
  - Thermal Vac
    - Thermal Cycling
    - Hot, Cold First Motion Deployment

IMPACT Boom Verification Matrix

Verification Matrix for STEREO/IMPACT/Boom

Revision Date: 11/05/02
Revision Number: 2

Hardware Description		Test																
Level of Assembly	Item	Deploy Test, Room Temperature	Deploy test, Thermal Vac	First Motion, Thermal Vac	Stiffness, Proof Load	Vibration, Sinusoidal	Vibration, Random	Shock	Acoustics	Thermal Vacuum	Thermal cycle	Thermal balance	EMC/EMI	Magnetics	Bakeout	Deployment contamination	Contamination Inspection	Comments
C	Proto	X			X													
C	EM	X			X	X	X	X								X		Qual levels
C	PF/FS	X	X		X	X	X	X		X	X			X				Protoflight levels
C	FM1	X		X	X	X	X	H		X	X	X	X	X	H		X	Acceptanec levels
C	FM2	X		X	X	X	X	H		X	X			X	H		X	Acceptance levels

Legend:

Level of Assembly	Unit Type		Test
			X = Test required
			A = Analysis
C = Component	BB =	Breadboard	H = Test at higher level of assembly (with instruments)
I = Instrument	EM =	Engineering Model	
	PT =	Prototype	
	PF/FS =	Protoflight / Flight Spare	
	FM1 =	Flight unit #1	
	FM2 =	Flight unit #2	

Flight Units Test Flow Diagram

FLIGHT ASSY →
- CLASS 10,000 CLEAN ROOM
- STOWED

DIMENSIONAL INSPECTION →
- OVERALL
- INTERFACES

MASS PROPERTIES →
- MASS
- CG

→ **DEPLOYMENT (AIR)** →
- MEASURENTS

STOW (MANUAL) →

CLEAN/INSPECT →
- ALCOHOL WIPE
- BLACK LIGHT

VIBRATION TESTING →
- MODAL SURVEY
- SINE BURST

THERMAL VACUUM →
- HOT SOAK
- COLD SOAK

VACUUM DEPLOY →
- FIRST MOTION

STOW (MANUAL) →

THERMAL BALANCE →

→ **THERMAL BAKE** →
- TQCM
- LONG DURATION BAKE

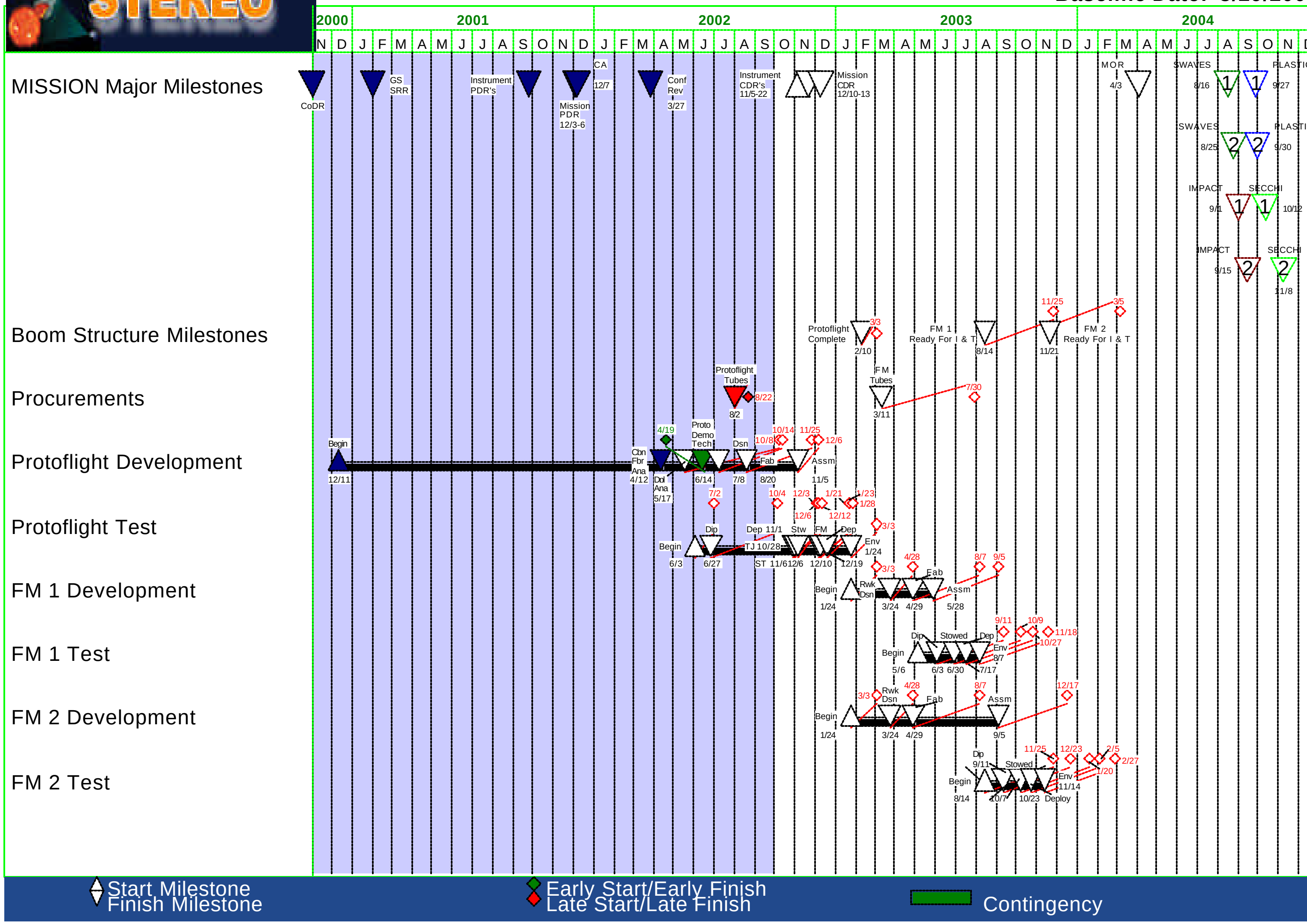
BAG AND SHIP

Risk Assessment

- **Risk Item; mitigation.**
  - **Tube jam; Ensure clearances, Add two additional roller grooves, add pin travel limiters to prevent contact, use harder roller material, material compatibilities, verify by testing.**
  - **Incomplete tube travel; Design Stacer for 3X needed force, 'kick' spring deployment initiator, low friction rollers.**
  - **Pin(s) not locked; Ensure clearances, Design offsets properly, material compatibilities, verify by testing.**
  - **Cryogenic temperature issues; Perform LHe thermal test of glue joint (done) – design is valid, include mechanical fasteners as redundant retainers for critical glue joints. Glue showed no bonding failure after 5 cycles to 25^0K**
  - **Loss of rigidity due to incomplete tube travel; Restoring / centering moment given by offset between pairs of rings: worst case - pins at sockets, not engaged, restoring moment, at any pin / socket location, is 0.04 kg-m; for a zero-extension situation, i.e. release operates but Stacer does not deploy, the restoring moment is 4.95 kg-m.**

BOOM - BOOM Structure

Status Date: 9/30/02
Baseline Date: 3/29/2002



Schedule Analysis

- **ETU slightly behind schedule**
- **Late FM deliveries driven by tube procurement**
  - **Caused by fixed lags in schedule**
  - **Can also improve tube delivery time significantly**
  - **Should be able to move this up by 2-3 months**
- **Even as is, boom is not on critical path**
- **Boom schedule needs some rework (planned for December)**
  - **Staggered/overlapped schedule for EM / FS / FM**
  - **Some EM qualification tests put off to FS**

Issues and Concerns

- **Harness stiffness and its effects**
  - Cannot finalize bobbin design until EM is tested with flight cable
  - Cannot size Stacer until harness pull-out force known
- **Pin Lockup**
  - Correct pin offsets
- **Stacer Sizing**
  - 12 week delivery
  - Can test rest of boom using weaker stacer + external force
- **EM of limited use for further deployment testing**
  - Pin misalignment problem difficult to fix on EM
  - Pin travel limiters difficult to implement well on EM
  - Not possible to implement three tracks – requires new tubes
  - EM will be used for testing of harness/Stacer section and vibration testing
- **Protoflight / Flight Spare for final design qualification**
  - Plan to order long lead parts (tubes) in December
- **Schedule need rebaselining**