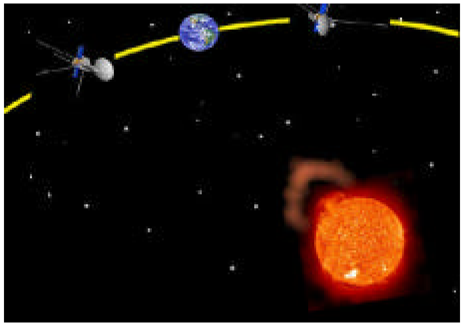

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Stereo Impact Boom

Preliminary Design Review

Johns Hopkins University
The Applied Physics Lab

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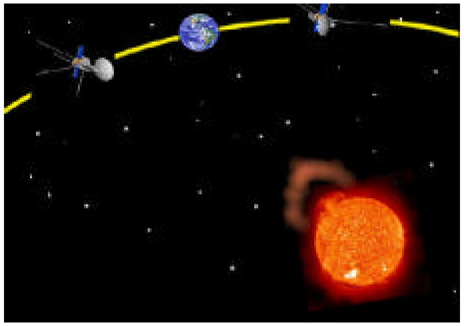


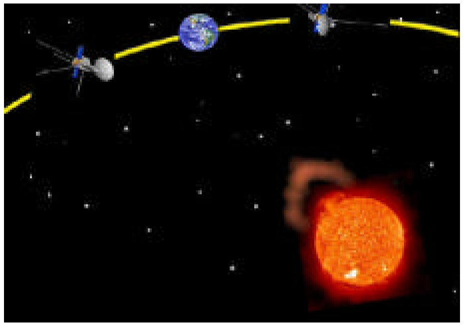
Stereo Impact Boom

Flow down science requirements for the Impact Boom

1) Magnetometer >= 3m from S/C
2) Magnetometer >= 1m from other instruments
3) SWEA 130^0 X 360^0 FOV, clear of S/C.
4) STE
   a. 60^0 X 60^0 FOV (80^0 X 80^0 goal) clear along Parker Spiral both inward and outward looking.
   b. Operational temperature: -20^0C to -40^0C (TBC).
   c. No exposure to Sun, thruster plumes.

Spacecraft Requirements

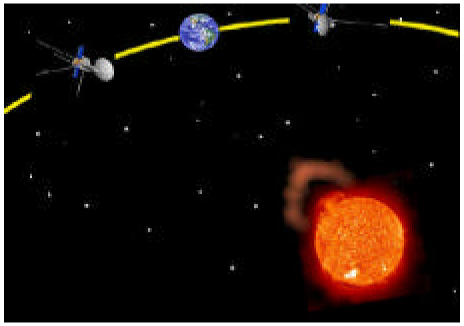
1) Stowed length =< separation plane to separation plane: 61”, 1549mm.
2) Boom doesn’t interfere with HGA: diameter overall including blankets =< 12”, 305mm.
3) Stiffness > 0.5Hz Requirement.



Stereo Impact Boom

System Requirements

1) Materials, Methods and Processes: first revision complete.
2) EMC / EMI
   a. Per Program Specification, in accordance with APL Document No.7831-9030
   b. Boom surface statically dissipative: < 10^8 ohms / sq.
   c. Harness double shielded:
      i. Outer shield: Stacer + braid (in final segment of boom).
      ii. Inner shield: aluminized kapton (TBC)
   d. Harness specified in Impact Harness Document.
3) Cleanliness
   a. Fabrication: Class 100,000.
   b. Integration: Class 10,000 (TBC).
4) Risk assessment: Item; mitigation.
   a. Tube jam; Ensure clearances, material compatibilities, verify by testing.
   b. Incomplete tube travel; Design Stacer for 5X needed force, ‘kick’ spring deployment initiator, low friction rollers.
   c. Pin(s) not locked; Ensure clearances, material compatibilities, redundant pin / socket pairs, verify by testing.
   d. Cryogenic temperature issues; Perform LN_2 dunk of glue joint (done) – design is valid, include mechanical fasteners as redundant retainers for critical glue joints.

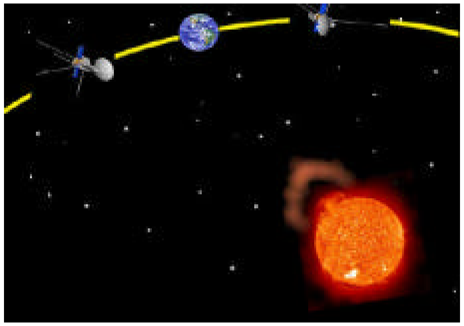


Stereo Impact Boom

- e. 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, ie. release operates but Stacer does not deploy, the restoring moment is 4.95 kg-m.

5) Product Implementation and Assurance Plan
   - a. Per Impact PAIP.
   - b. No EEE parts.

6) Long lead items:
   - a. Stacer: ~26 weeks.
   - b. Gr/E tubes: 15 – 20 weeks.
   - c. SMA releases mechanisms: 8 weeks.

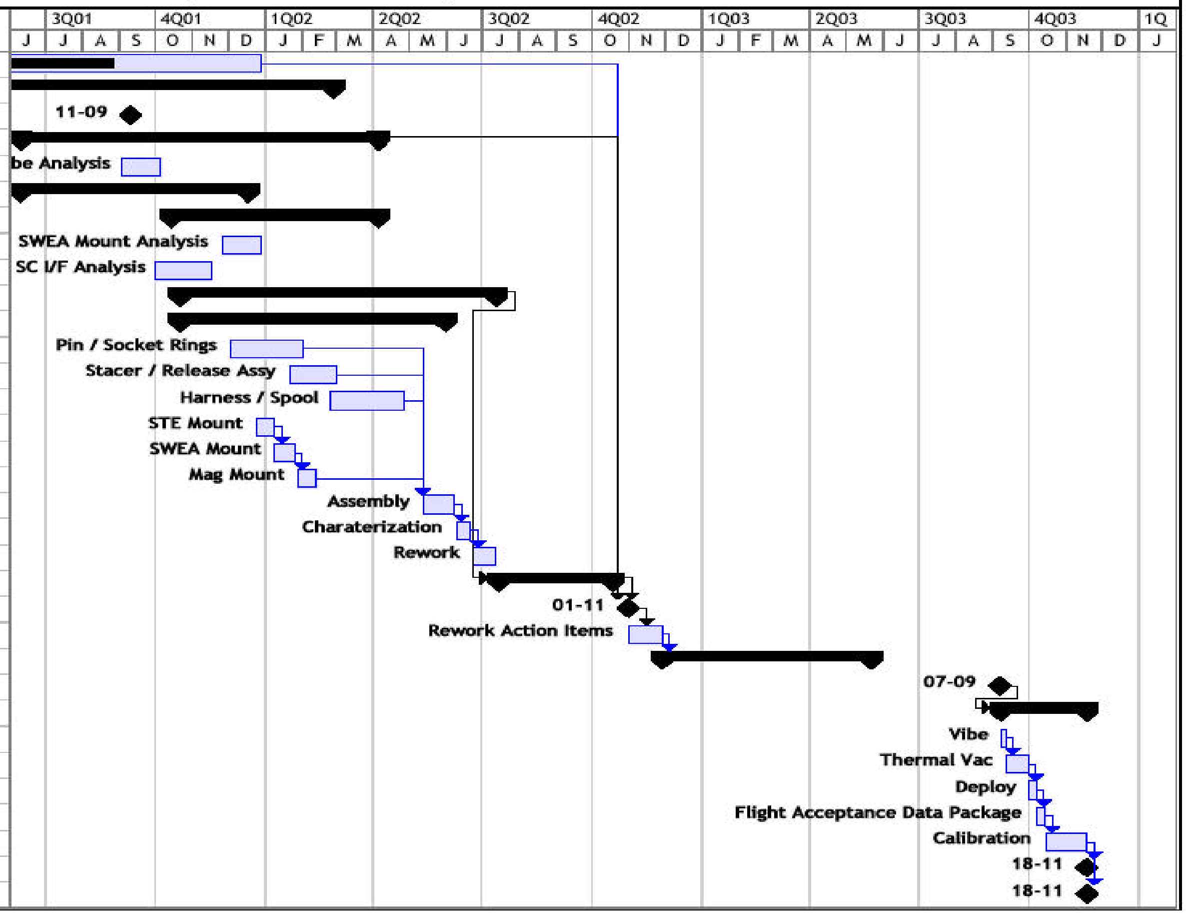


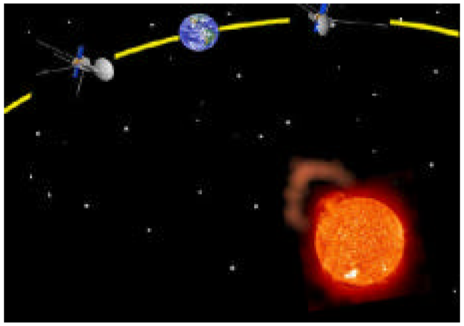
Stereo Impact Boom

Development Plan

Stereo Impact Boom Development Schedule

ID	Task Name
1	Design
2	**Prototype Demonstration Technology**
10	PDR
11	**Analysis**
12	CF Tube Analysis
13	**STE**
16	**Deployment**
21	SWEA Mount Analysis
22	IMPACT / SC I/F Analysis
23	**Proto-Flight Build**
24	**Tubes**
30	Pin / Socket Rings
31	Stacer / Release Assy
32	Harness / Spool
33	STE Mount
34	SWEA Mount
35	Mag Mount
36	Assembly
37	Charaterization
38	Rework
39	**Qualification**
45	CDR
46	Rework Action Items
47	**Flight Build**
56	PER
57	**Boom Flight Acceptance**
58	Vibe
59	Thermal Vac
60	Deploy
61	Flight Acceptance Data Package
62	Calibration
63	FM2 Boom Available
64	FM1 Boom Available





Stereo Impact Boom

Test Sequence

1) EM Qualification (per GEVS-SE Rev. A; APL# 7381-9003; TBC)

   a. Proof Load: 1.25 times expected load. (Design Goal: 100 X)
   b. Vibration: 14.1 G_{rms} ; facility: GSFC or Wylie Lab (TBC).
   c. Thermal Vacuum / balance: 4 cycles @ $+50^0$C / -40^0C (TBC) in < 10^{-5} Torr vacuum; facility: UCB (TBC).
   d. Deployment + boom characterization: length, target accuracy, mass properties @ UCB.

2) FM1 & FM2 Acceptance (per GEVS-SE Rev. A; APL# 7381-9003; TBC)

   a. Proof Load: 1.25 times expected load.
   b. Vibration: 10.0 G_{rms}
   c. Thermal Vacuum: 4 cycles @ $+40^0$C / -40^0C (TBC) in < 10^{-5} Torr vacuum
   d. Deployment + boom characterization: length, target accuracy, mass properties @ UCB, EMI (TBD).

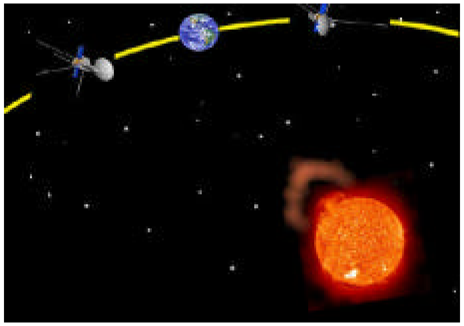
Mechanical GSE

1) Tube / ring bond assembly fixtures

2) Deployment offload fixture(s) for:
   a. EMC characterization
   b. Thermal vacuum
   c. First motion at S/C integration (TBC)

3) Stowing fixture(s) and tools.

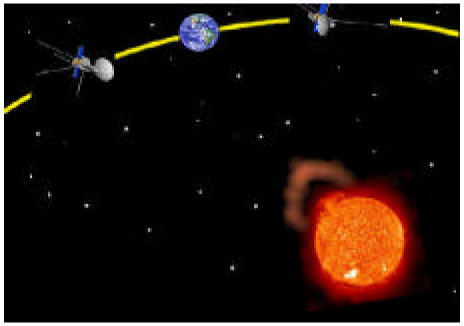
4) Shipping containers



Stereo Impact Boom

Design Trades made

1) Selection of current configuration:
   a. Longeron style: Cost > $1M., exceeds budget; cost over-runs, late deliveries not uncommon.
   b. Swing-arms: Can not meet Magnetometer basic 3m distance requirement without 3 or more pivot joints / arms. Stowing, sequence and reliability of deployment questionable.
   c. Telescoping: New for this application, meets science and budget requirements, combines many heritage technologies.
   d. Stacer only: possible alternative, would require active pointing means with feedback; not as rigid as telescope style.
2) Length: finalized (in wet concrete) for the current spacecraft baseline.
3) Prelim. instrument interfaces: finalized (also in wet concrete) for the current spacecraft baseline.
4) FOV's
   a. STE: split into 2 separate locations: STE-U (up, towards sun) and STE-D (down, away from sun); 80^0 X 80^0 FOV unobstructed. A reduction of the STE-U maybe needed for sun avoidance (TBC).
   b. SWEA: 130^0 by 2**P** radians, impingements by solar arrays, corner of lead S/C. New S/C baseline would require a boom >10m long to avoid these impingements. Current design with impingements is accepted by Co-I's.
5) Lock pin design: includes roller in tip to lower friction, reducing needed force for deployment, lower particle generation.
6) Retraction pin serves provides roller alignment during deployment. Removes multiple guide tracks down length of tube, requires only 1 set per segment, relieving tight tolerance requirements.



Stereo Impact Boom

Current Design Status

Spacecraft baseline design, as of 13 August 2001.

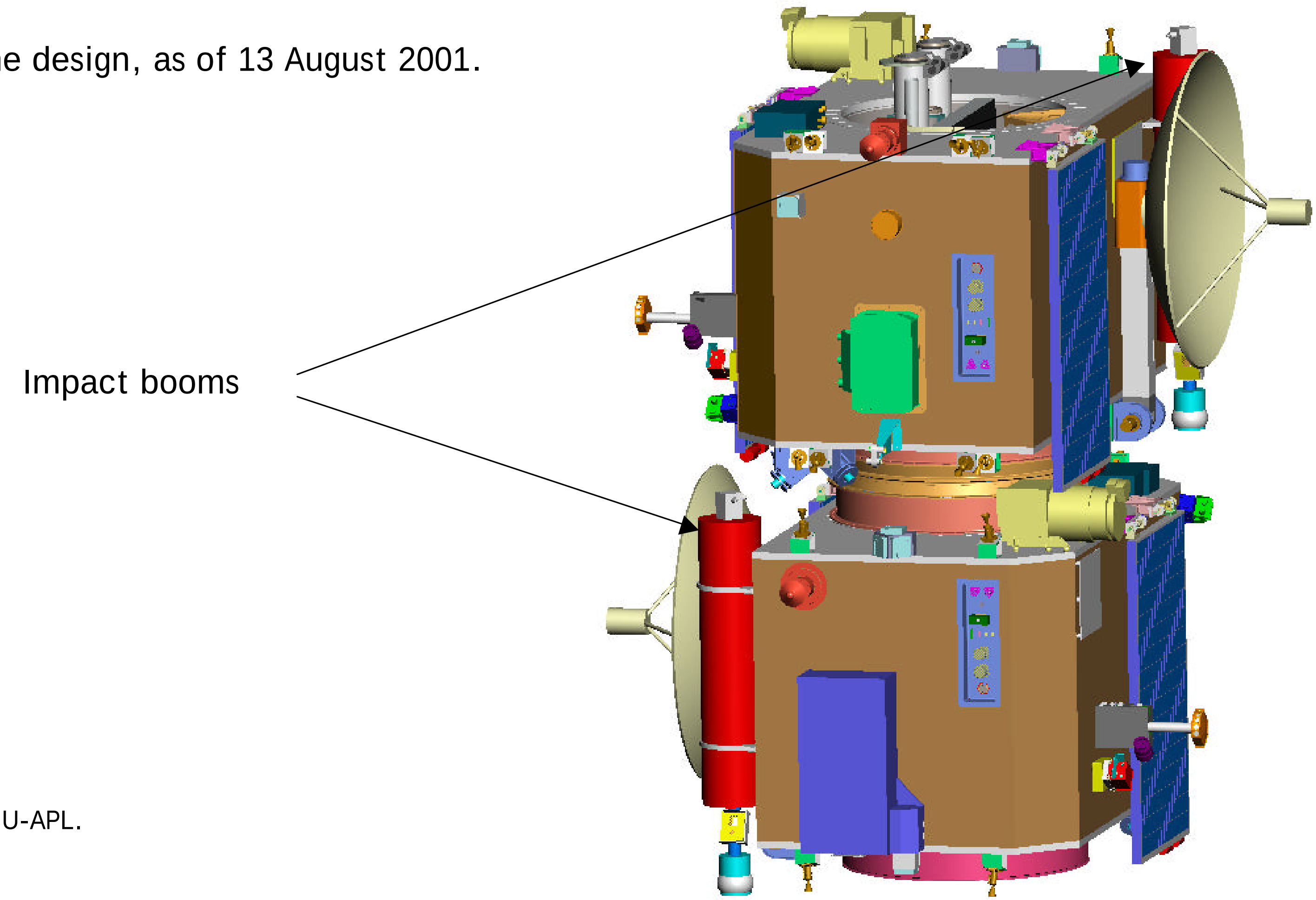


Illustration courtesy JHU-APL.

Stereo Impact Boom

Impact boom deployed, with spacecraft coordinate system

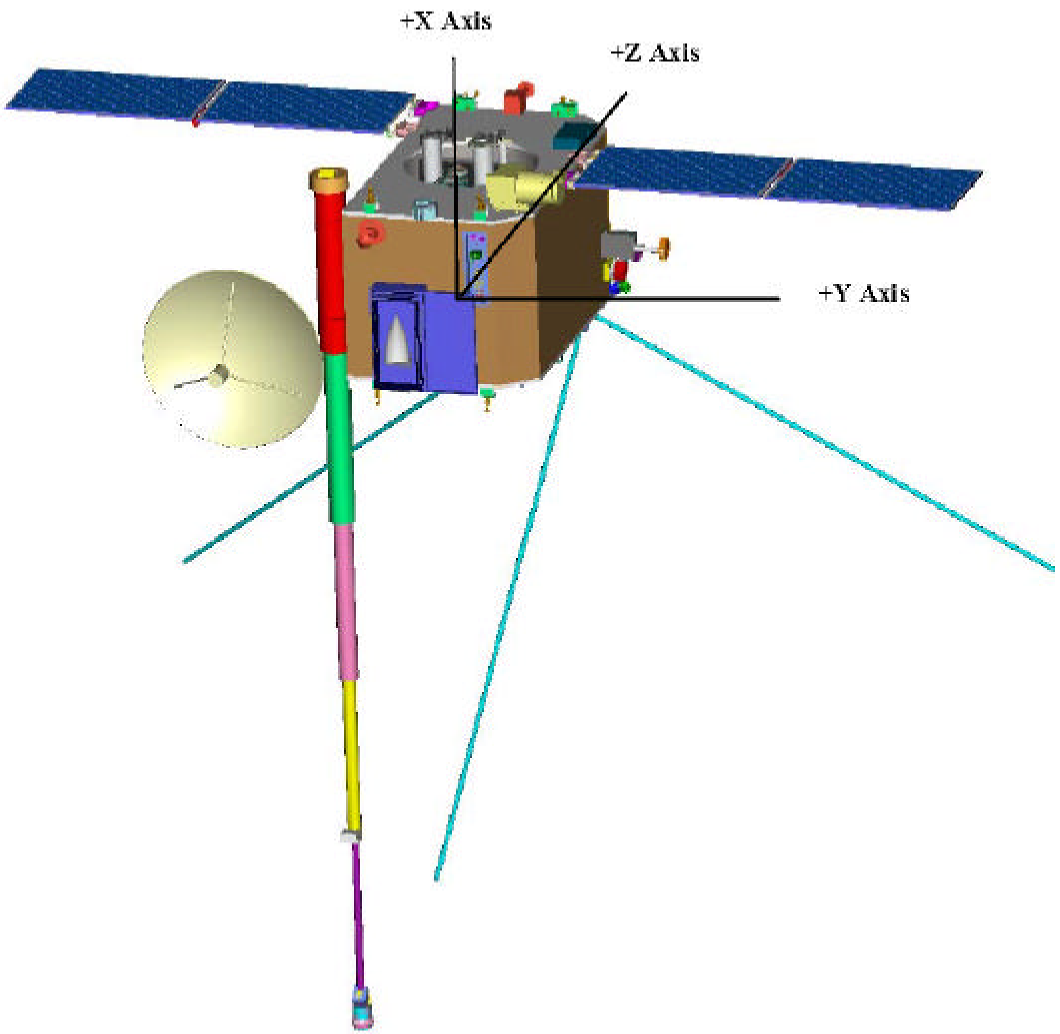
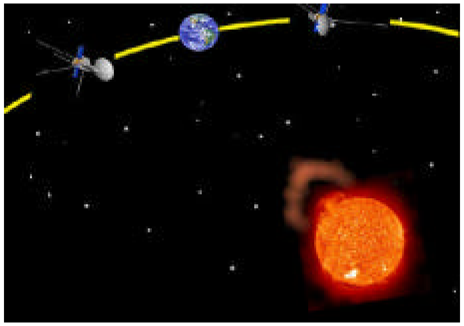


Illustration courtesy JHU-APL.



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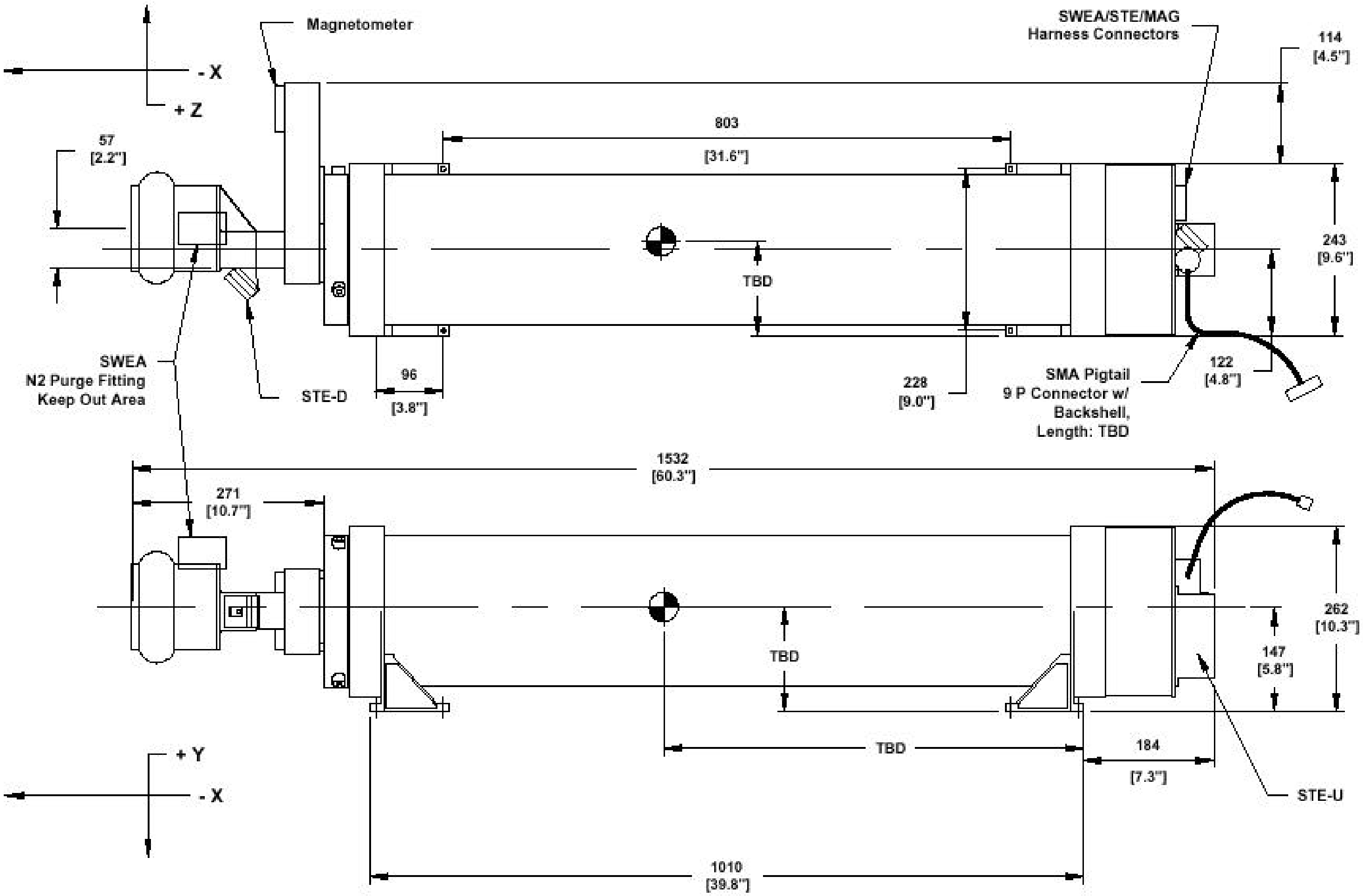
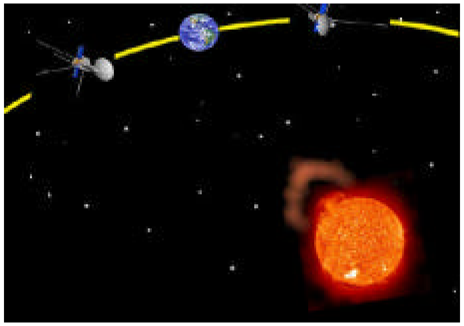
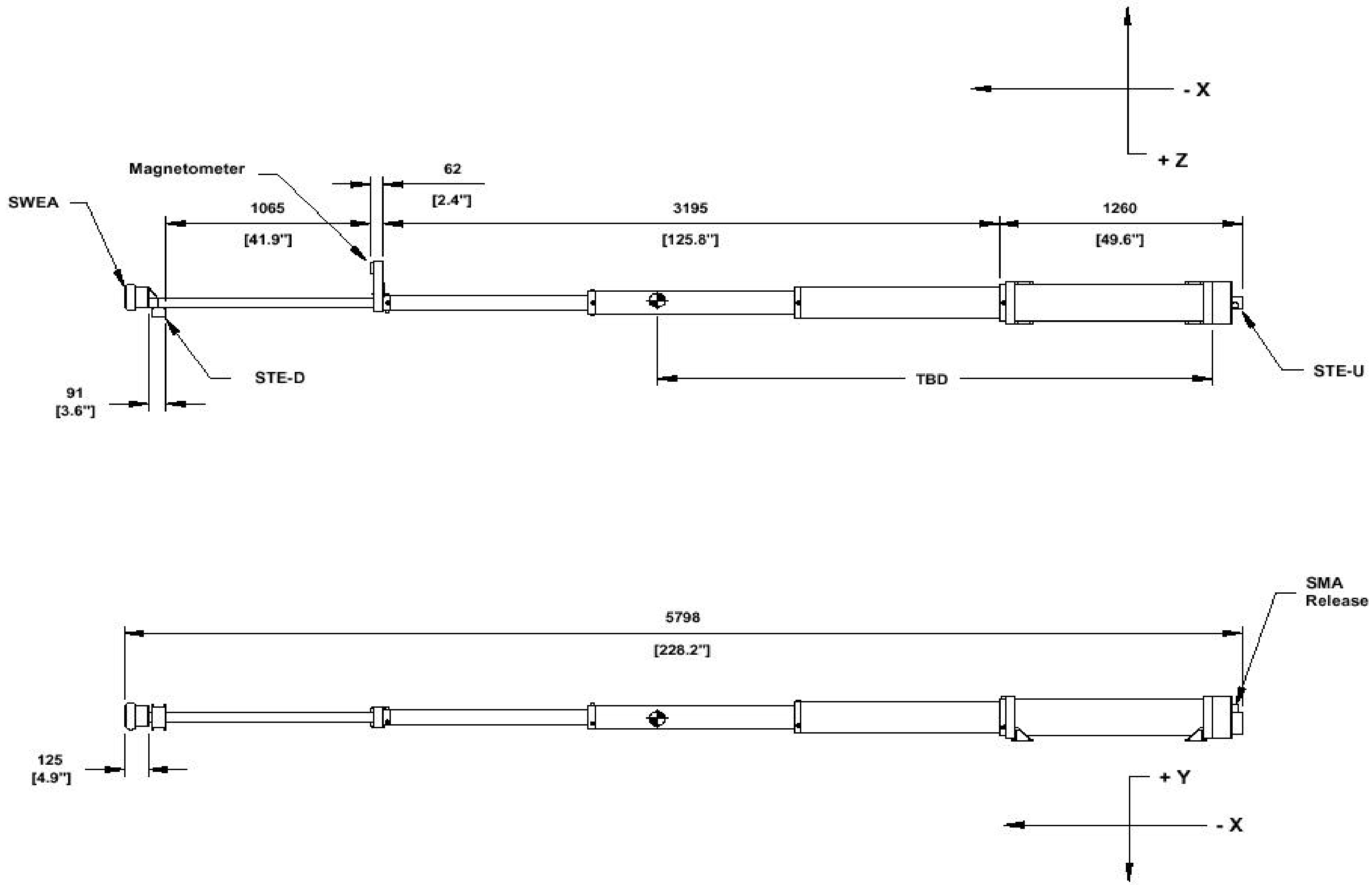
Stereo Impact Boom

Stowed configuration

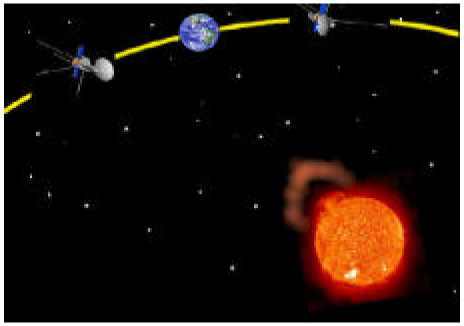




Stereo Impact Boom



Deployed configuration

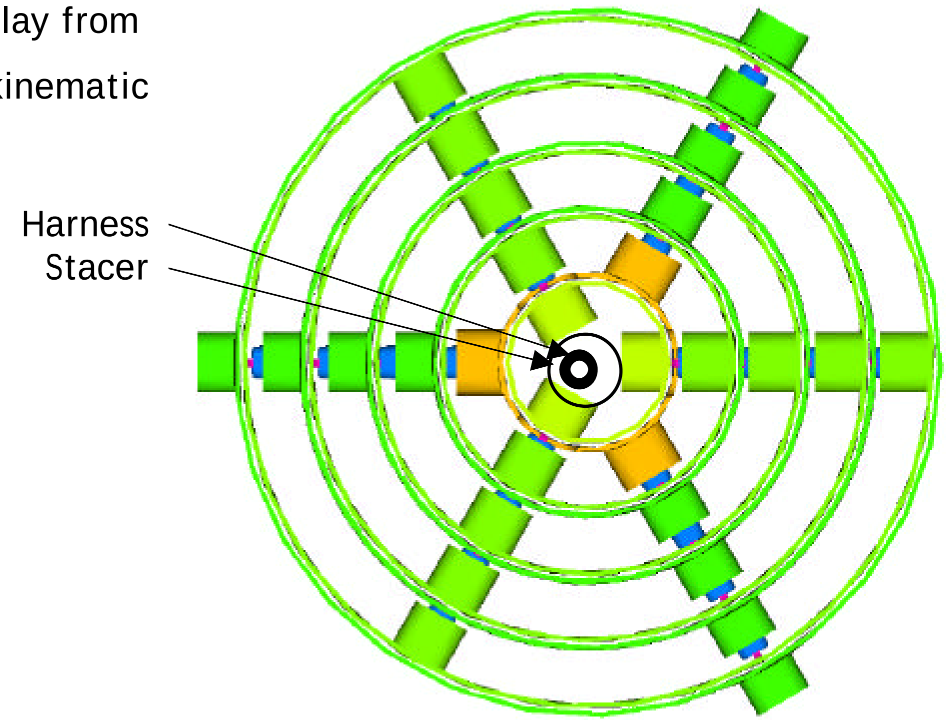


Stereo Impact Boom

<u>Boom Assembly Overview</u>

Top view: stowed position, no instrument brackets shown. Rollers rest on tube surfaces. Lock pins are blue, rollers magenta, Gr/E tubes are thin white rings between green and orange rings. For deployment, pins roll along tubes until end of travel, then extend 8mm radially to mate with sockets, both have an included cone angle of 10^0 to provide a 'self-locking' interface.

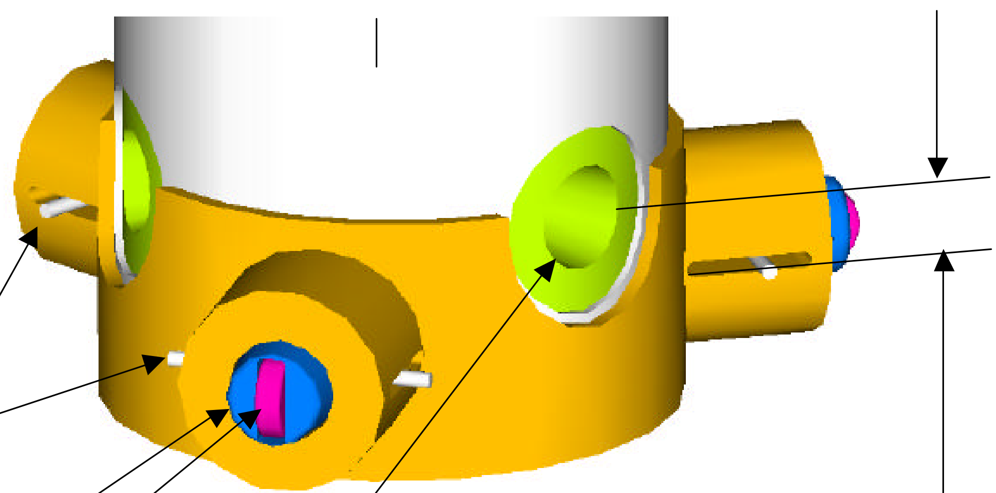
An offset of 1.0mm of 3 of the 6 sockets takes up the play from clearances between the pins and sockets, providing a kinematic mounting. The rings shown are schematic in the sense that the webs, cutouts, covers, and fillets that eventually appear in the final design have not been added. Only the minimum structure necessary to hold the pins in place is included. Manufacturability issues are held as a background consideration, to be folded into the final designs.

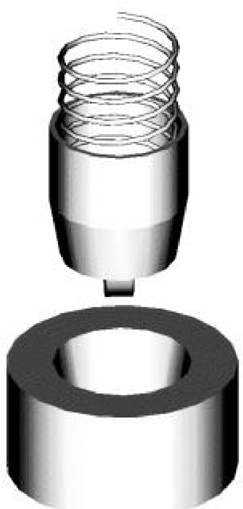


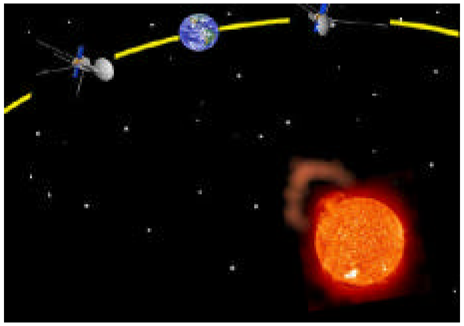
Stereo Impact Boom

Pin detail

Roller: PEEK, roll pins: 300SSt, locking pin: 6061T6xx Al, ring: 6061T6xx Al, adhesive: Hysol 9309NA structural epoxy. Offset between lower and upper lock pin centerlines: 10mm, provides restoring moment.







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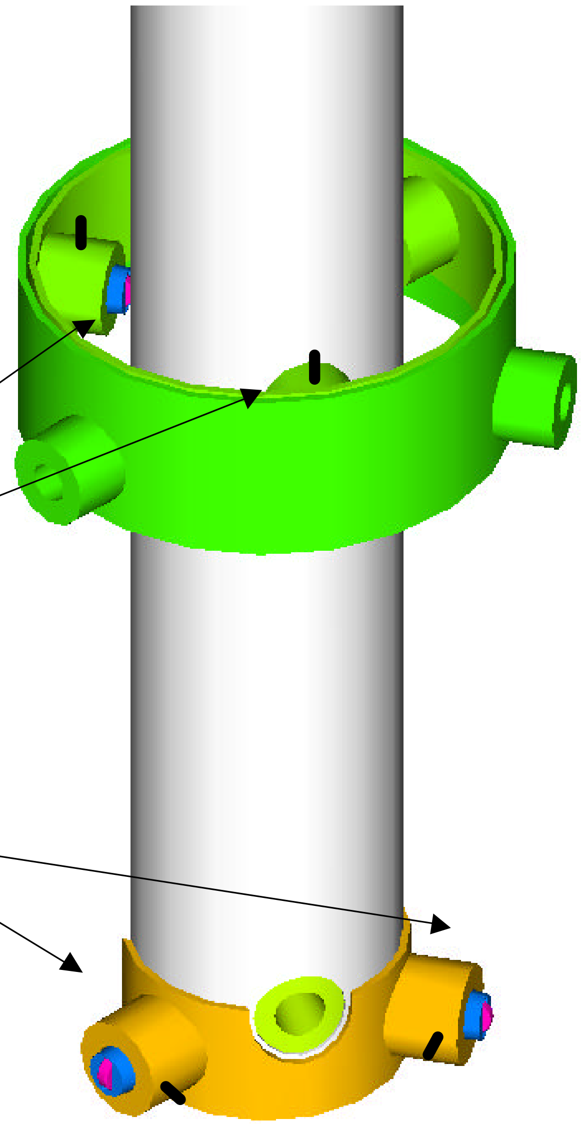


Boom Deployment Detail:

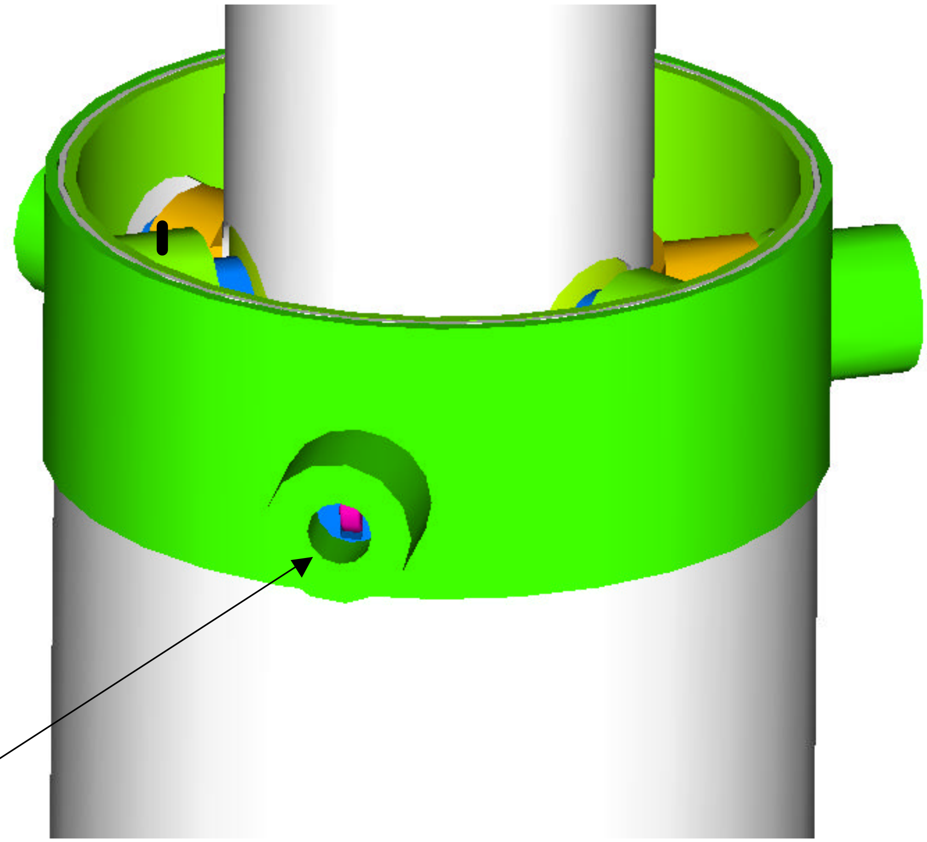
Mid-deployment of inner tube is shown. Outer tube, guide track have been removed. Rollers ride on tube surfaces.

Upper rollers travel on outside of inner tube. End of internal guide pin visible.

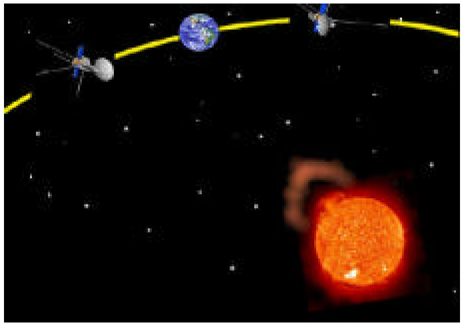
Lower rollers travel on inside of outer tube (not shown).

Stereo Impact Boom

Inner tube fully deployed, pins inserted into sockets. Pattern repeats for each segment. Boom stiffness goal: >0.5 Hz.



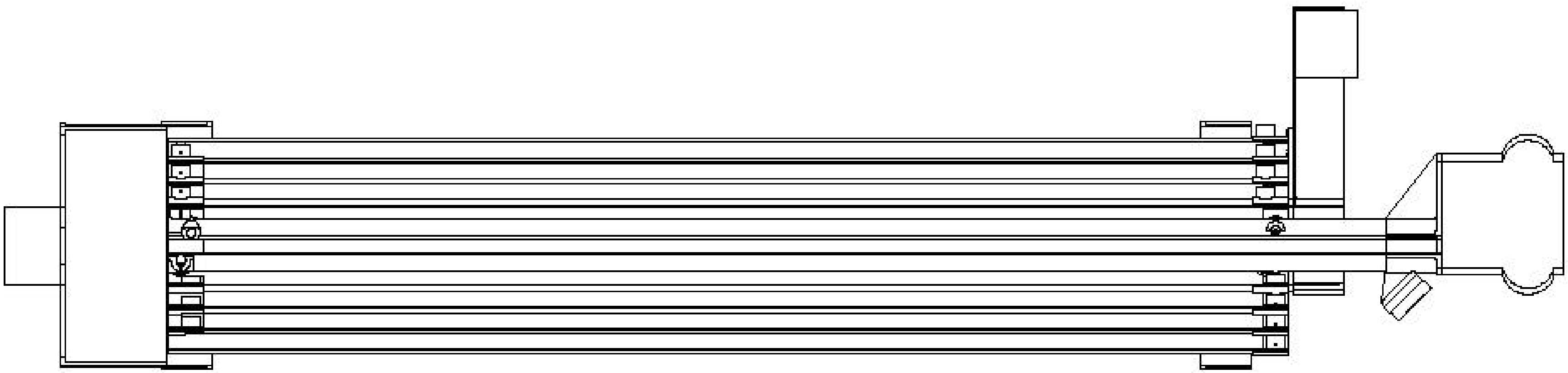
Pin visible through access hole in socket



Stereo Impact Boom

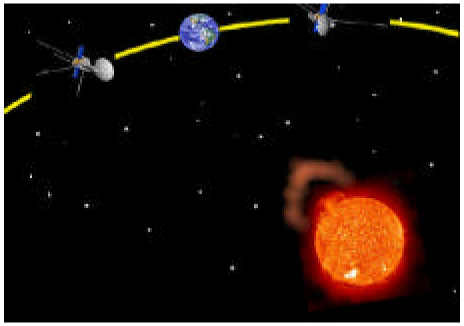
Background information for design:

For launch, the tube segments are retained by an SMA pin puller through a hole in the Stacer tip piece, which in turn is connected to the innermost (50mm diameter) tube. The tubes are held in place for

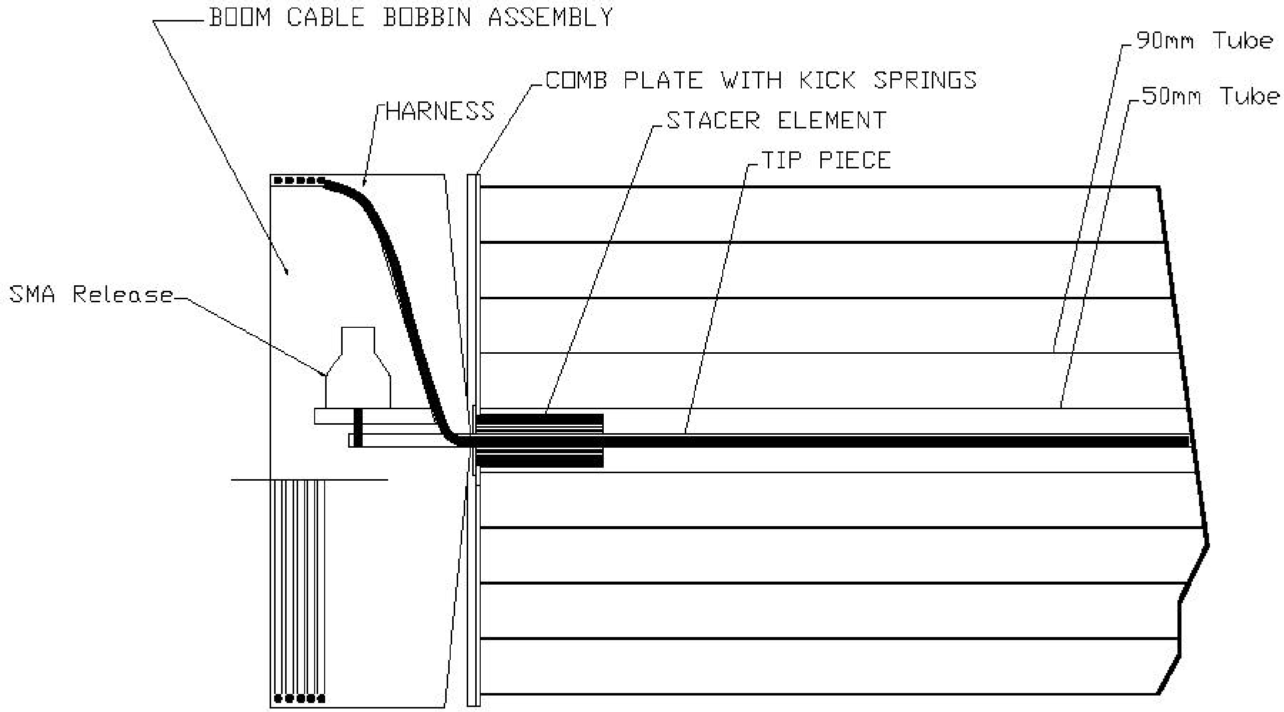


launch by comb-like devices attached to the spool mounting plate and the Magnetometer mount.

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 and the next segment out to relieve the accumulated turns from the Stacer's deployment.



Stereo Impact Boom

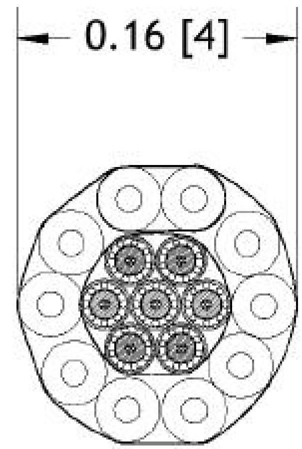


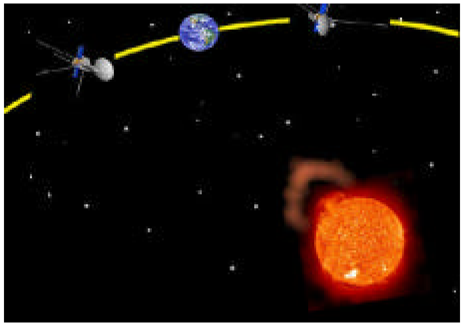
<u>Stacer, spool and harness</u>

Detail section of harness, spool and SMA release. This is almost identical to FAST axial boom harness storage and Stacer release. Stacer is stowed inside of the 50mm diameter tube. Tip piece projects to receive pinpuller. The harness serves as Stacer velocity control, set by the bobbin radii and clearances to the spool wall. The Stacer is a helically wound, 6.02m (237”) long by 100mm (4”) wide strip of Elgiloy: cold rolled, buffed, and coiled with a helix angle of 55^0 and a final tip diameter of 12mm (0.5”). 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 5 connectors from the S/C to the SWEA / STE science & power; Mag; and boom release & thermal are located on the base plate of the bobbin assembly.

Harness

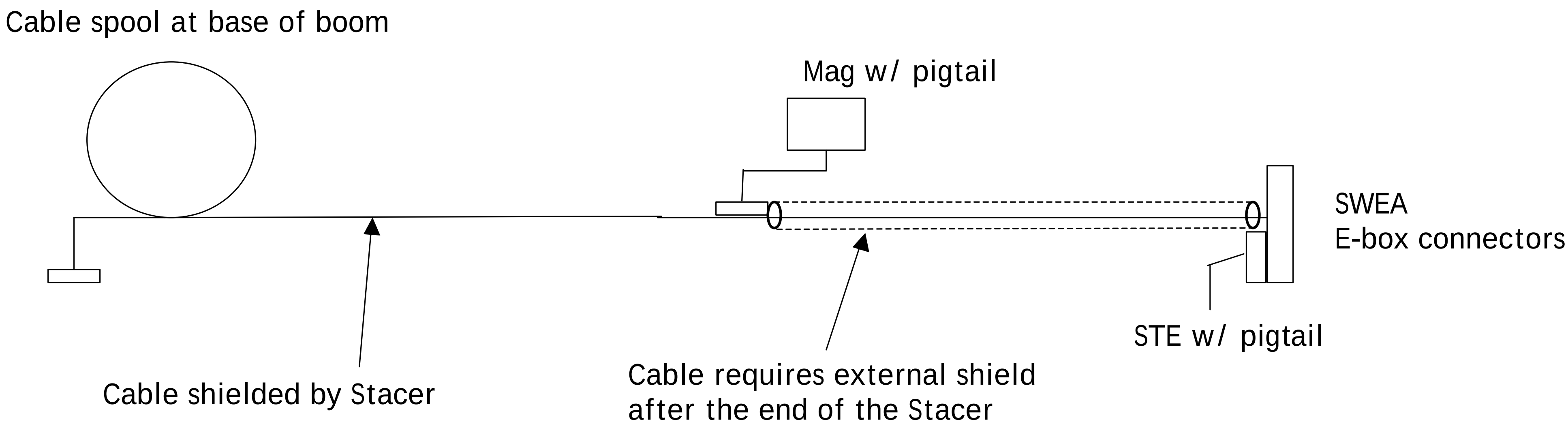
The harness consists of a custom fabricated wire bundle routed up the center of the boom. The bundle contains 7 coaxial cabless, 4 #26 Ga twisted pairs, and a single #26 Ga twisted shielded pair (for Mag AC heater). A common, taped, over-shield of the wires extends from the boom base to MAG-J1 and SWEA-P1, 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 S/C), and will have another 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 coax are a custom fabrication: #36 Ga center wire with E-PTFE jacket. Aluminized kapton wrap with 8 #38 Ga drain wires, and a final E-PTFE wrap jacket. The exterior is expanded PTFE wrapped. The coaxes 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 still fitting in the envelope of the boom.





Stereo Impact Boom

Harness Schematic

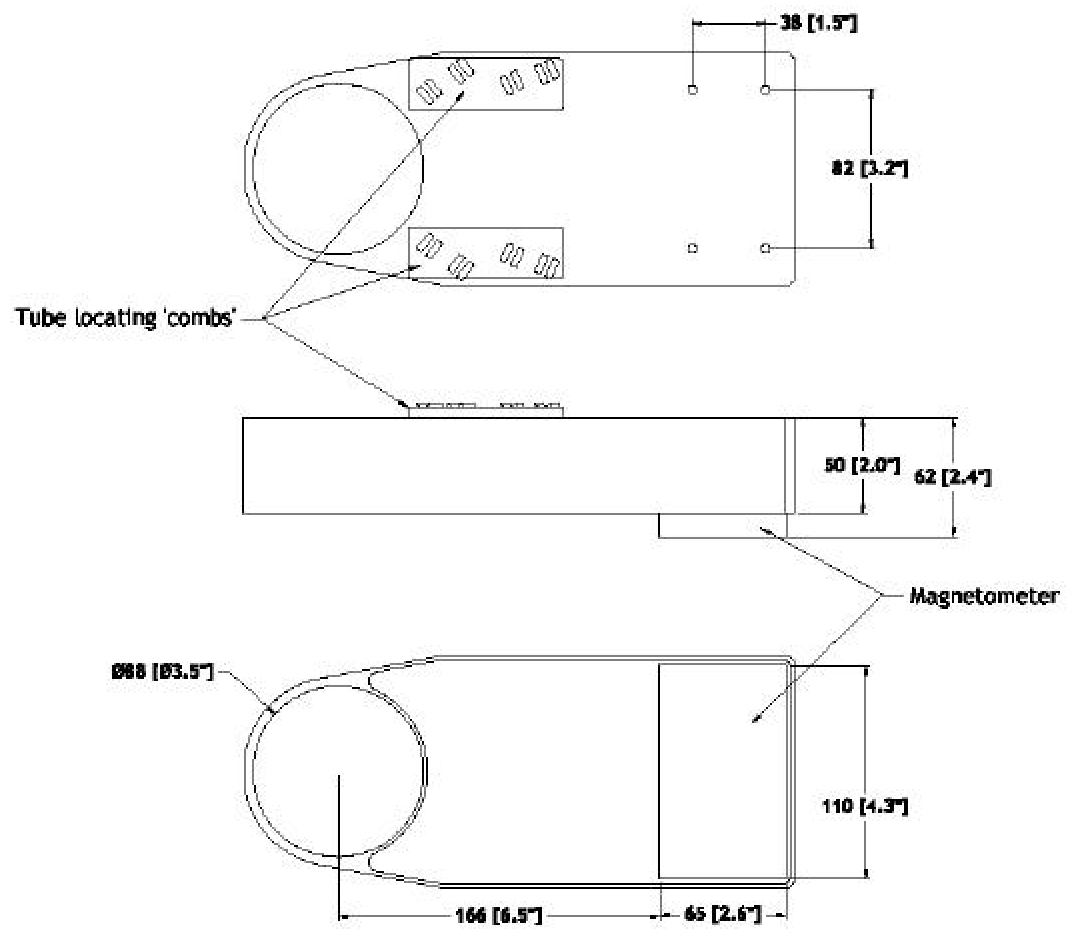


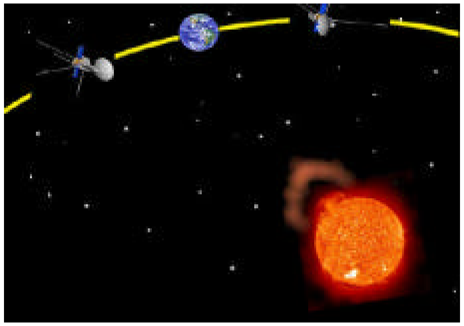
The Magnetometer ‘pigtail’ is connected just past the end of the Stacer. The remainder of the harness, no longer surrounded by the Stacer, is sheathed in a copper braid, and captured in the final tube. It is routed to the SWEA mount, where the harness is terminated at the connector. The harness will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

Stereo Impact Boom

<u>Magnetometer Mount</u>

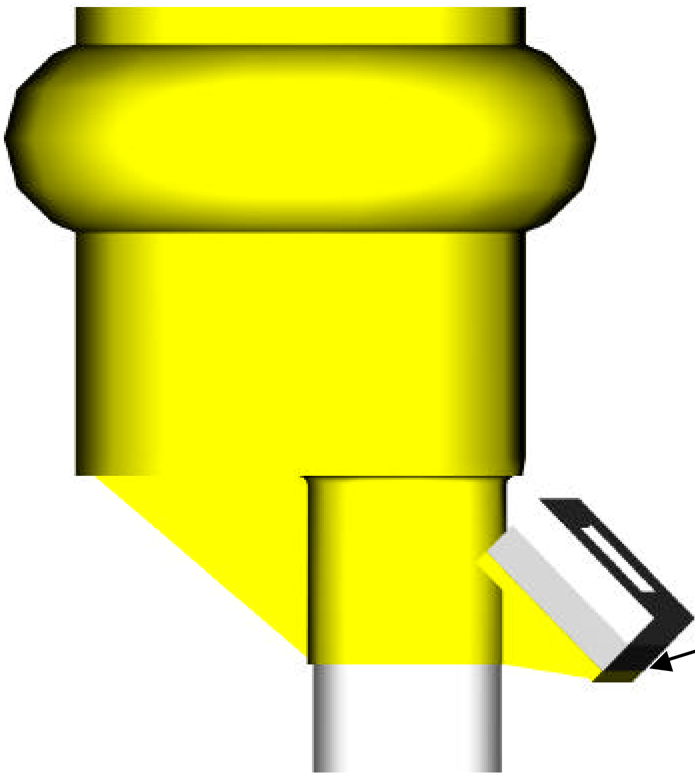
Preliminary design, showing single piece fabrication of PEEK high performance engineering plastic. The second and third views show 'comb' for capturing tube for launch. Magnetometer is mounted via 4 screws through the base of the tray.



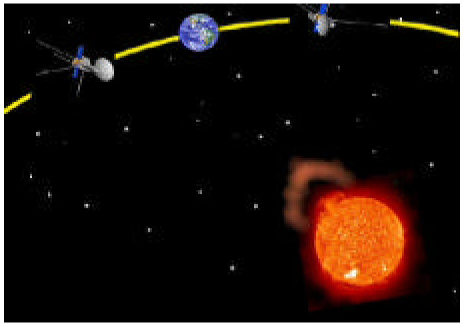


Stereo Impact Boom

STE / SWEA Mount



Fabricated from 6061-T6xx Aluminum, incorporates both instruments in a compact package. Enhances thermal control by increasing conduction, common blanketing. The SWEA is mounted to the extreme end, where its 2P radian FOV is unobstructed, and the STE-D is mounted to the side. The STE reclosable shutter and actuator are not shown.

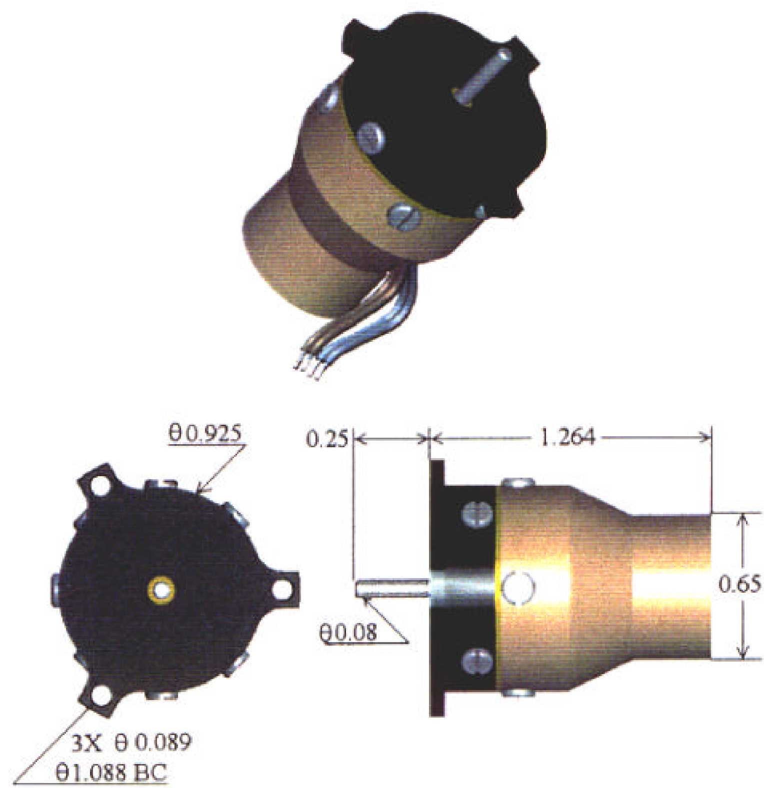


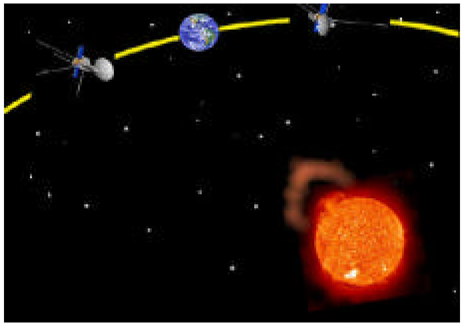
Stereo Impact Boom

Shape Memory Alloy Release

The Model P5-405-6RS is the latest addition to the P5 Pinpuller product line. It was specially designed for the Jet Propulsion Laboratory to be used aboard the Mars 2001 spacecraft. This embodiment incorporates redundant SMA (Shape Memory Alloy) triggers with integrated shut off switches, a convenient 3 ear mounting flange, and optional enclosure (as shown). As with all TiNi Pinpullers the P5-405-6RS uses the same ball-lock trigger mechanism developed under TiNi patent # 5,771,742 issued in June of 1998. Reset is achieved by manual re-extension of the pin via two access holes at the base of the pinpuller.

* Custom configurations as to pull force, retraction stroke, and mounting interface are readily attainable.

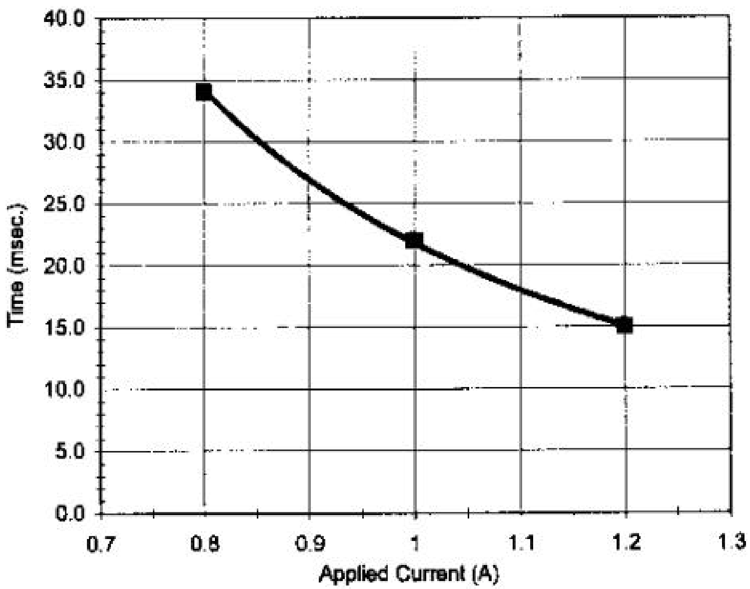




Stereo Impact Boom

Function Time

(@ 20 °C)

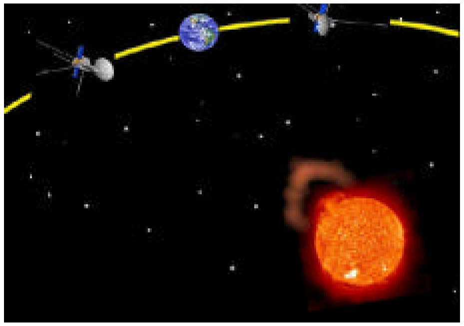


Specifications

Pull Force	22.3 N	(5 lb-f)
Pull Stroke (minimum)	6.35 mm	(0.25 in)
Power Consumption	6 Watts @ 1 Amp	
Operational Current	0.5 to 1.5 Amp	
Actuator Resistance	6.0 ohms	
Life	> 100 cycles	
Minimum Operating Temp.	<-50 °C	(<-58 °F)
Maximum Operating Temp.	+70 °C	(+158 °F)
Mass	30 gm	(1.0 oz)

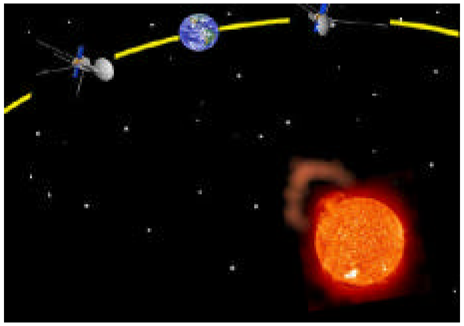
Features:

- Reusable
- Redundant SMA Trigger
- Integrated Shut-Off Switches



Thermal

Initial thermal studies have been made for the boom and some of the instruments. The current estimate for the SWEA / STE shows operational heaters are required. For SWEA, the instrument dissipates ~1.5W, and requires an additional 1W at 50% duty cycle. The STE has a lower desired op-temp and minimal power dissipation, and requires ~0.5W, again at ~1/2 duty cycle. These heaters are software controlled. The Gr/E tube near the SWEA / STE will conduct away ~0.007W at -100^{0} C. The Mag has its own AC heater, and will be fully blanketed. The Gr/E tube section between the Mag and the SWEA / STE has been identified as a possible location for some thermal tape. The details remain to be established. This would keep the heat loss from the tube lower. The midsections of the boom will be radiating to free space, and will drop to an estimated range of -150^{0} C to -200^{0} C. These temperature extremes have led to the inclusion of metal fasteners between the inner and outer rings, capturing the Gr/E tube to prevent loss of rigidity due to possible thermal failure of glue lines. The spacecraft end of the boom has a blanket completely surrounding the outer most tube. The interior of the boom behaves as a black body, so it must be thermally isolated from the s/c deck. There is significant heat input to the STE-U end, temperatures are expected to be in the -20^{0} C. range. This end will be blanketed to keep the STE-U cold.



Stereo Impact Boom

Peer Review Status

6 March 2001 Review

14	**133**	**IMPACT Boom**	Can the boom tube maintain the deployed frequency requirement under expected on-orbit thruster loads without the plungers? The Stacer (deployment force) may provide the required preload (at the end of deployment) to meet this requirement without the complication of the plungers and rails design. A boom frequency requirement should be incorporated into the Instrument Requirements Document. Also, an analysis should be performed to show that the boom design meets the given frequency requirement.	**Action Item / Open**
17	**136**	**IMPACT Boom**	Need to determine co-ax size to determine mechanism used for deployment.	**Action Item /Open**
20	**137**	**IMPACT Boom**	The current understanding is that there is a requirement for this that was provided in the original boom proposal and should be reflected in the design. My understanding is that the stiffness requirement for the IMPACT boom is 0.68 Hz, which matches the stiffness of the earlier proposed Astromast boom. Action to determine what the stiffness requirement is and include the requirement in the IRD.	**Action Item/ Open**

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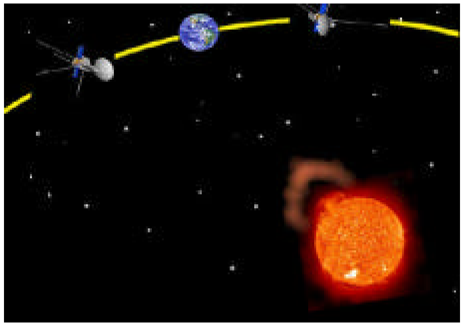
10		**IMPACT**	The thermal testing of the IMPACT booms should be performed at the boom deployment temperatures if possible.	**Action Item /Open**
18		**IMPACT**	Have the contamination control personnel verify that the composite boom material is usable.	**Action Item /Open**



Stereo Impact Boom

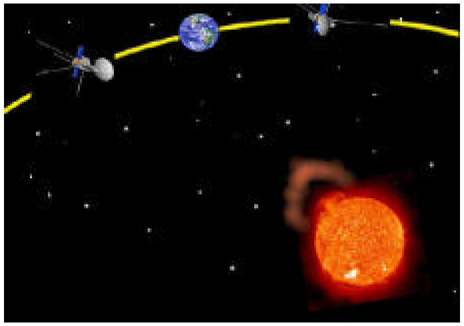
#133: The boom cannot meet the stiffness spec. without full locked deployment. The offset of the rollers provides a centering moment. Current range of moments: 0.04kg-m to 5kg-m. depending on deployment position, based on current spring values.

#136: See page 18.

#137: The requirement is 0.5Hz. A suite of tests to determine the resonance will be performed: vertical, horizontal, (with float tank if needed).

#10: The thermal testing is being planned for nominal deployment temperatures, currently TBC at $+50^0$C / -40^0C. for Qualification and $+40^0$C for Acceptance.

#18: Contamination issues for the Gr/E boom: the sample is ready for inspection.



Stereo Impact Boom

Remaining Issues

Thermal data need to be fed back to optimize designs.

Structural properties need further analysis, testing. Keep APL updated with current design.

Summary

Final design imminent.

Thermal, structural requirements, and initial ICD have been established.

A prototype will be made and tested.

Details for all the different subsystems need to be integrated. The basic subsystems for the Impact boom have a long flight heritage, and are mature technologies: Stacers, GR/E structures, Shape Memory Alloy releases, all are iterations of proven designs. The integration into a telescoping boom is the next step.

Schedule is generous, no time constraints to impede forward progress.