Proposed "Mini-Study" for the Stereo Impact Boom

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Summary

As the Impact program has progressed, the budgetary and physical constraints of the Impact Science Suite have become more codified. To respond to these changing requirements, UCB SSL proposes to develop a flight ready deployable boom to meet the stated requirements.

The purpose of this mini-study is to ascertain the viability of a telescoping deployable boom, its characteristics and requirements, and to give the needed confidence to proceed. As Impact's scope and budget have incorporated the deployable boom, and vendor quotes have climbed, leveraging the SSL Mechanical Engineering department's experience in successful spacecraft deployables is the best way to fulfill the project in a cost effective and timely manner. The method is to bring together several previously flown technologies as the Impact Boom.

A basic overview of the proposed boom technology is:

Tubes: Fabricated from carbon fiber woven, epoxy pre-impregnated cloth. UCB has an excellent CF background on site, and has utilized it for major scientific structural members of the Lunar Prospector, FAST and Polar spacecraft.

Stacer spring deployment device: Used many hundreds of times from sounding rockets to Polar and FAST axial booms.

Lock pins: This arrangement is standard hardware for any moving part that needs to be locked. This design needs to be self-locking, therefore it will be over constrained mechanically.

SMA Release Mechanism: Used as a replacement for the old electro-explosive (pyro) device, this allows the actual unit used for flight to be verified and tested environmentally in place, and doesn't depend on statistics methods for proof of usability. These have been used on Mars Global Surveyor, Lunar Prospector and HESSI here at Berkeley.

The following pages identify the areas of investigation: physical description (requirements); manpower estimate; schedule; a proposed budget; major risk issues and their mitigation; a brief trade study; and some preliminary design sketches.

The product of this "mini-study" is agreement between NASA Stereo Project and the Impact team that the best instrument available for the mission is being developed.

Required Physical Specifications

Static

- Stowed Size: 300mm diameter X <1400mm overall
- Deployed Length: 4 + meters from spacecraft
- Environmental
  - Magnetics / ESC: < 0.1 nT @ magnetometer, $<10^8$ ohm/sq (conductive)
  - Thermal: TBD
  - Materials: low B field / eddy current, cost effective, meet NASA flight requirements including CV and TML outgassing specifications

Dynamic

- Frequency stowed (launch vibration): per GEVS-SE (or transmissibility spectrum from coupled loads)
- Frequency deployed (stiffness): >0.5 Hz
- Pointing accuracy/knowledge: tip within 50mm radius circle, 1.5 degree pointing
- Dead band: minimal but specification TBD
- Deployment Method (redundancy / safety factor): 5X power ratio
- Deployment Release Method (redundancy): SMA single action (2 parallel devices, TBD)
- Deployment Time: <2 min.
- Deployment Awareness: Cam activated deployment switch

Interfaces: requiring definition, fed back to design

- S/C: Mechanical ICD: attachment points, coupled load, Science harness supports
  - Electrical ICD: release harness, Deployment Sw., Science harness
- IMPACT
  - Mechanical: TBD, internal @ UCB SSL
  - Electrical: TBD, internal @ UCB SSL

Power Requirements: deploy device(s) only: 5A for <500 msec

Mass: <= 12kg.

Proposed Design

The design under evaluation consists of several well established, flight heritage technologies in combination with a telescoping tube. This system can be divided into the following categories: commissioning, and data collection. For the commissioning of the Impact boom, there must be a release device, a deployment motivational force, and feedback for confirmation that the boom has been deployed successfully. Data collection requires that the instruments be in the correct location, and able to deliver their information to the spacecraft.

Commissioning

Release Mechanism

The release mechanism is a device produced by TiNi Aerospace, San Leandro, CA, among others, and utilizes a resetable, flight qualified, Shape Memory Alloy (SMA) pin puller. These devices have been well received by the space "deployables" community as they are non-explosive, require few special safety precautions, tested then the exact unit is flown, cost effective and quick acting. The first use at UCB SSL was on the Mars Global Surveyor, where the initiator was qualified. Since then these devices have been used on Lunar Prospector and HESSI at Berkeley, and have been qualified or flown on 10 other missions.

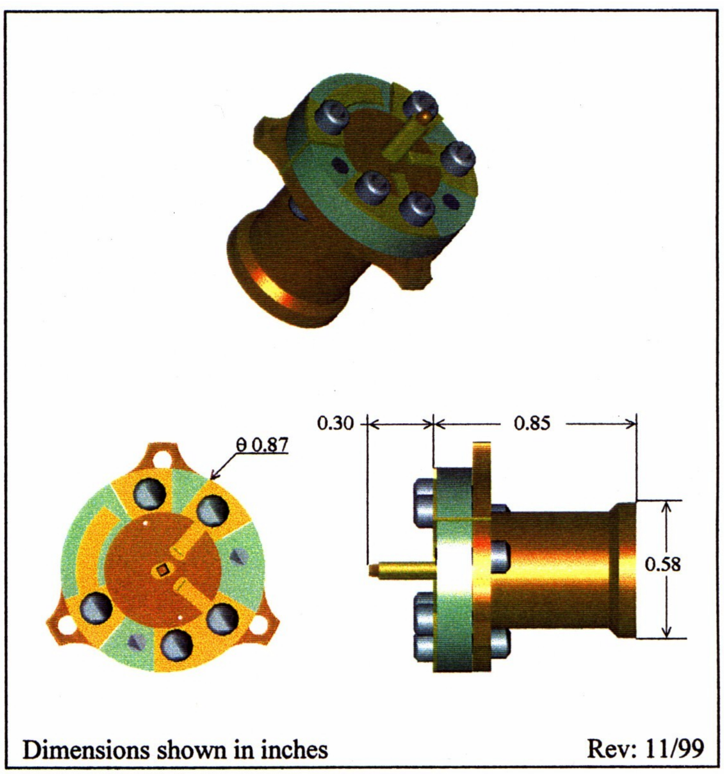


Figure 1 Release Device: SMA Pin Puller (thanks to TiNi Aero)

Deployment Mechanism

The force to deploy the tubes is provided by a Stacer, well known in the aerospace industry, and a long time staple product for antennas. This application is less demanding than usual, as the only function is as a spring, and the Stacer will carry no instruments directly. The element will be fabricated of Elgiloy, a magnetically clean, high strength material, with excellent spring properties.

The Stacer design will be tailored to give the required deployment force, but initial calculations show that a force of up to 450N can be easily achieved. The Stacer spring is packed in a canister for launch, and the SMA initiator, when triggered, will release the Stacer, which will then push the tubes out. The deployment velocity is limited by a lanyard attached to a flyweight brake spool, and will be selected to account for the tube sliding friction, and desired dynamic input to the system. This is the same arrangement as was used on the Polar Axial booms, and many other programs, with good result.

The Stacer technology has been flown on literally hundreds of space missions over the last 25 years, from short 1m length antennas to 7m long gravity gradient booms, and is being utilized for the Stereo Waves experiment antennas.

Deployment Feedback Mechanism

The deployment progress will be monitored by a rotating cam mounted to the brake spool activating a sealed 1HM19 microswitch. The resolution is selectable, to give enough information without a large data transmission requirement. This is traditional mechanism, used at UCB on Polar, FAST, numerous rocket flights, and most recently on Cluster 2.

Data Collection

Telescoping Mast

The main structural member of the Impact suite is this assembly of 5 sections of carbon fiber / epoxy concentric tubes. The size is determined by the required fields of view of the SWEA and STE instruments and the available area for the stowed unit. The material selection is driven by the magnetic 'cleanliness' requirement. The length that has been previously identified for the stowed condition is ~1.5m, see Figure 2, and the length overall needed to meet the F.O.V. requirements is ~6.3m, therefore 5 sections are needed. The 50mm diameter of the inner tube is chosen to allow the STE a clear view, each section diameter is then established by the lock pin mechanism requirements. The final tube has an O.D. of 300mm, see Figures 3 and 4.

The lock pins will be set into post bonded rings at the ends of the tubes, similar to Polar and FAST mounting rings, and the path of the pins in the tubes during extension will be guided by grooves integral to the tube inner wall. This prevents cantilever binding and provides correct orientation of the instruments at full extension. Once the pin ring reaches its end of travel, the pin spring will force the conical pin into its conical socket. The pin to housing clearance required for functionality over a large temperature range allows a certain amount of 'play' in the joints. This can adversely affect the pointing accuracy and increase the 'dead-band' of the boom. This effect will be nullified by the use of designed in offsets of pairs of pins, each pin axis slightly offset with respect to the socket axis. The long engagement of the conical pin in the socket will force the tube to ‘take a set’, and finally lock into a fixed position.

This type of mast has been developed at Astro Aerospace / TRW, and a prototype has been developed at AEC Able Engineering as well.

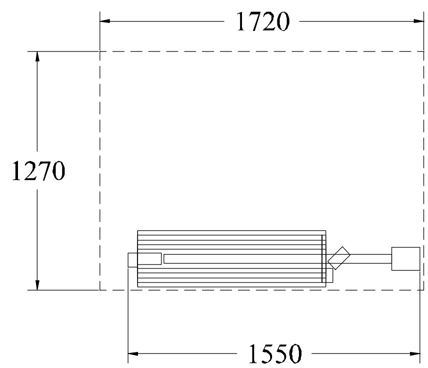


Figure 2 Stowed Side View

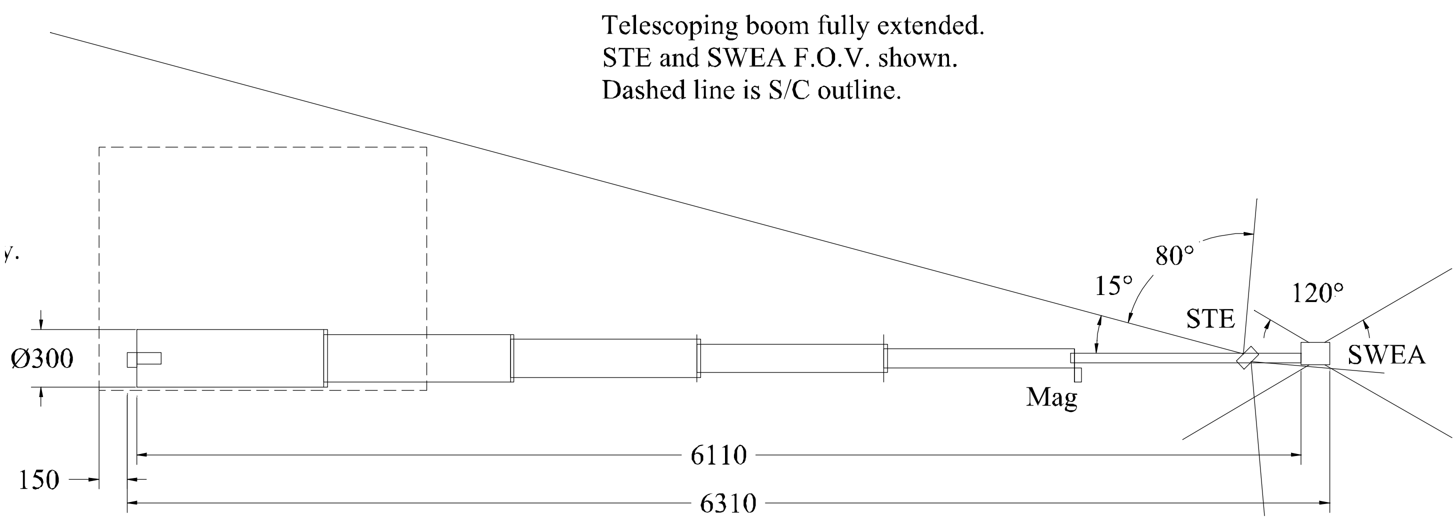


Figure 3 Deployed Side View

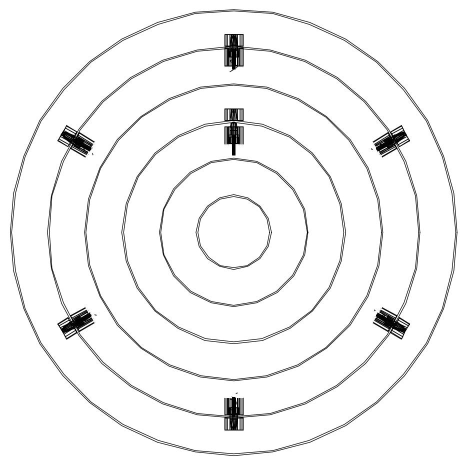
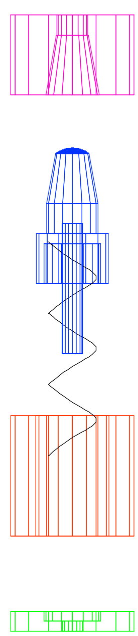


Figure 4 End View, Stacer Spring Assembly Not Shown

There are 6 of these pin assemblies per ring: one set of inner and outer rings for each of the 5 moving tubes. Rings are bonded to tubes.



Socket – mounted in outer end ring

Pin – carried in guide body

Spring – provides locking force. Coil spring shown, leaf spring also possible.

Guide Body – mounted on inner ring

End Cap - holds assembly together

Figure 5 Lock Pin Assembly, Mounts in Ring

Magnetometer Mount

The magnetometer will mount to the end of the second smallest diameter tube, fastened to its locking ring. It will incorporate the sunshade for the STE instrument, and be fabricated of carbon fiber epoxy. The design will be optimized for the new location, but the basic layout is the same as proposed: a reinforced, cantilevered plate.

SWEA Mount

The SWEA is mounted to the end of the inner tube, using a carbon fiber plate post bonded to the tube. This is the same as proposed.

STE Mount

This will be identical to the proposal, a polyether-ether ketone engineering plastic, post bonded to the tube.

Harness

The harness will be stowed on a bobbin for launch, located beneath the mast assembly. The bobbin diameter will be chosen to provide an acceptable bend radius for the cable. The Stacer will pull the cable off the bobbin and guide it through the center of the Stacer / tube assembly, as was done for the FAST Axial booms. This allows the Stacer to act as the outer shield, saving mass and lowering the complexity of the harness. The harness will be split to attach to the SWEA and mag at the end of the Stacer, at the base of the smallest diameter tube.

Schedule Overview: see IMPBoom.pdf for details (Study must be completed by PDR at latest)

Design:	1½ mo
Tubes: prototypes of each size, 3 styles;	2 mo
EOT Lock up: prototype ring set, mods.;	2 mo
Spring:	TBD, 15 week ARO
Characterization, Analysis: (including proto results)	3 mo

Estimated Fabrication Costs including limited testing

Tubes: prototypes of each size, 3 styles;	$10k
EOT Lock up: prototype ring set, mods.;	$8k
Stacer Spring:	$5k

Identified Risk Areas: Estimated Risk Level / (mitigation method):

Release: SMA actuation: Low Risk / (full acceptance test of devices to be flown)

Deployment:

Inter-tube travel resistive forces: friction: Moderate Risk: / (mock-up, testing; redesign, qualification)

Power Margin of spring, force to cause extension divided by resistive forces: Low Risk / (calculation + testing)

Spacecraft attitude requirements, allowable angular rotation rates Low Risk / (analysis, testing)

End of Travel (EOT) Lock up:

Lock Rings, reliability of locking, dead-band: Moderate Risk / (early proto, protoflight testing, flight environmental)

Deployment switch, accuracy, reliability: Low Risk / (acceptance testing)

Deployed location knowledge: repeatability, stability, stiffness: Low Risk / (analysis, testing)

B field, boom degrades magnetometer sensitivity: Low Risk / (analysis of materials, inspection)

Thermal, positional stability, suitability for science suite: Low Risk / (analysis of coatings, thermal modeling, environmental testing)

End of Life margin on above requirements: Low Risk / (analysis)

Mini Trade Study

From Proposal	New (Pre-Phase A/B)
Deployable longeron mast (AEC, TRW)	Telescope tubes (SSL)
$1.4M total	~$500k
Indeterminate deployment path issue	fully constrained deployment path
Flight ready from manufacturer	full testing @ UCB
52 week lead minimum	TBD (shorter though)
Separate ICD, SOW, Specifications	Internally controlled
Large Contract Office involved	Design, Purchased Parts only, low overhead
Fixed science mast	(included)
Man power estimates Summary	
6 m-m requirements development, design and test specification, contract oversight	4 m-m full up design
3 m-m design, fabrication	4 m-m fabrication
2 m-m fixed boom test	3 m-m boom test

2 m-m project support (reviews)	2 m-m project support
1 m-m ADP	1 m-m ADP

Equipment, consumables estimates (computer, T/V maintenance, shipment, etc)

$50k test hardware incl. off-load fixture	same
$15k shipping crate, insurance, misc.	same