MAGNETOMETER (MAG)

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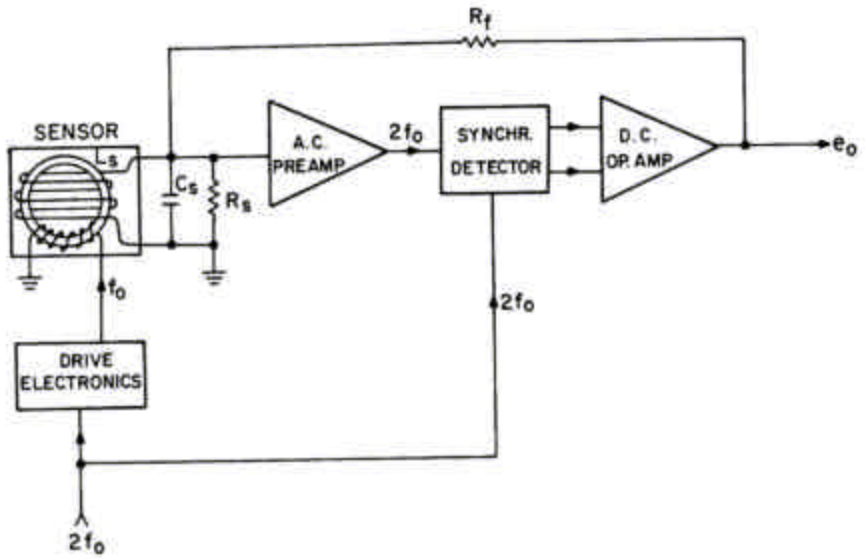
Magnetometer (MAG)

Instrument Characteristics:

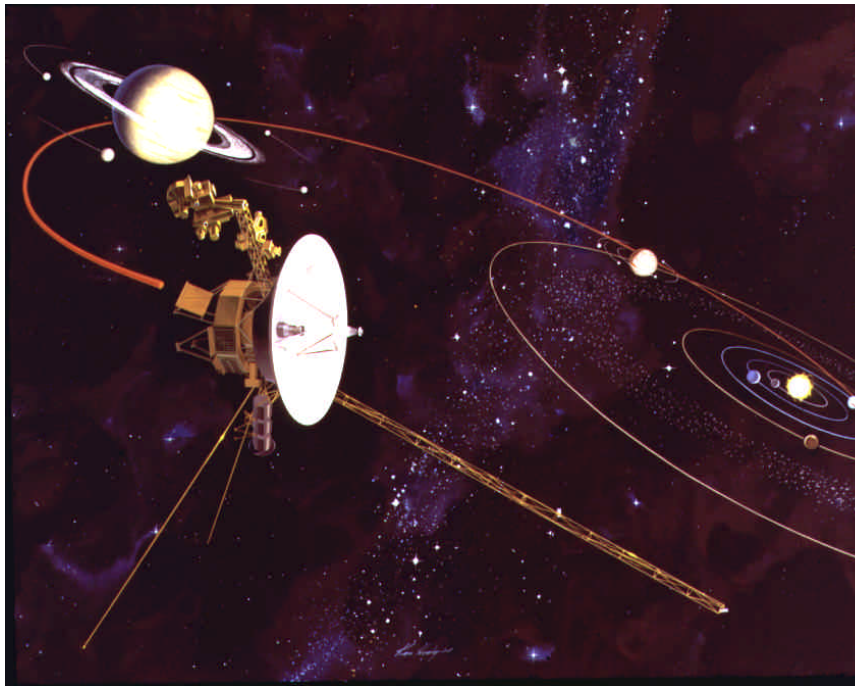
- **Dual-range, single triaxial fluxgate magnetometer**
- **Wide dynamic range: ± 0.01 nT to ± 65,536 nT in two dynamic ranges: ± 512 nT and ± 65,536 nT**
- **Allows for testing in the Earth's field without special equipment – significant simplification and cost savings**
- **Instrument heritage spans > 30 years and > 40 instruments including VOYAGER, WIND, NEAR, ACE, DMSP, LP and MGS**
- **Fluxgate sensor & electronics manufactured and tested at GSFC and integrated into IMPACT IDPU and Boom**
- **Fold-back current limiting isolators to protect IDPU power supply in case of failures**
- **MAG software already developed by UCB for MGS and LP**

Magnetometer (MAG)



FLUXGATE MAGNETOMETER SIMPLIFIED BLOCK DIAGRAM

COMMON DESIGN WITH VOYAGER AND OTHER FLIGHT INSTRUMENTS. STILL OPERATIONAL 25 YEAR AFTER LAUNCH



MAG Performance Requirements

CDR

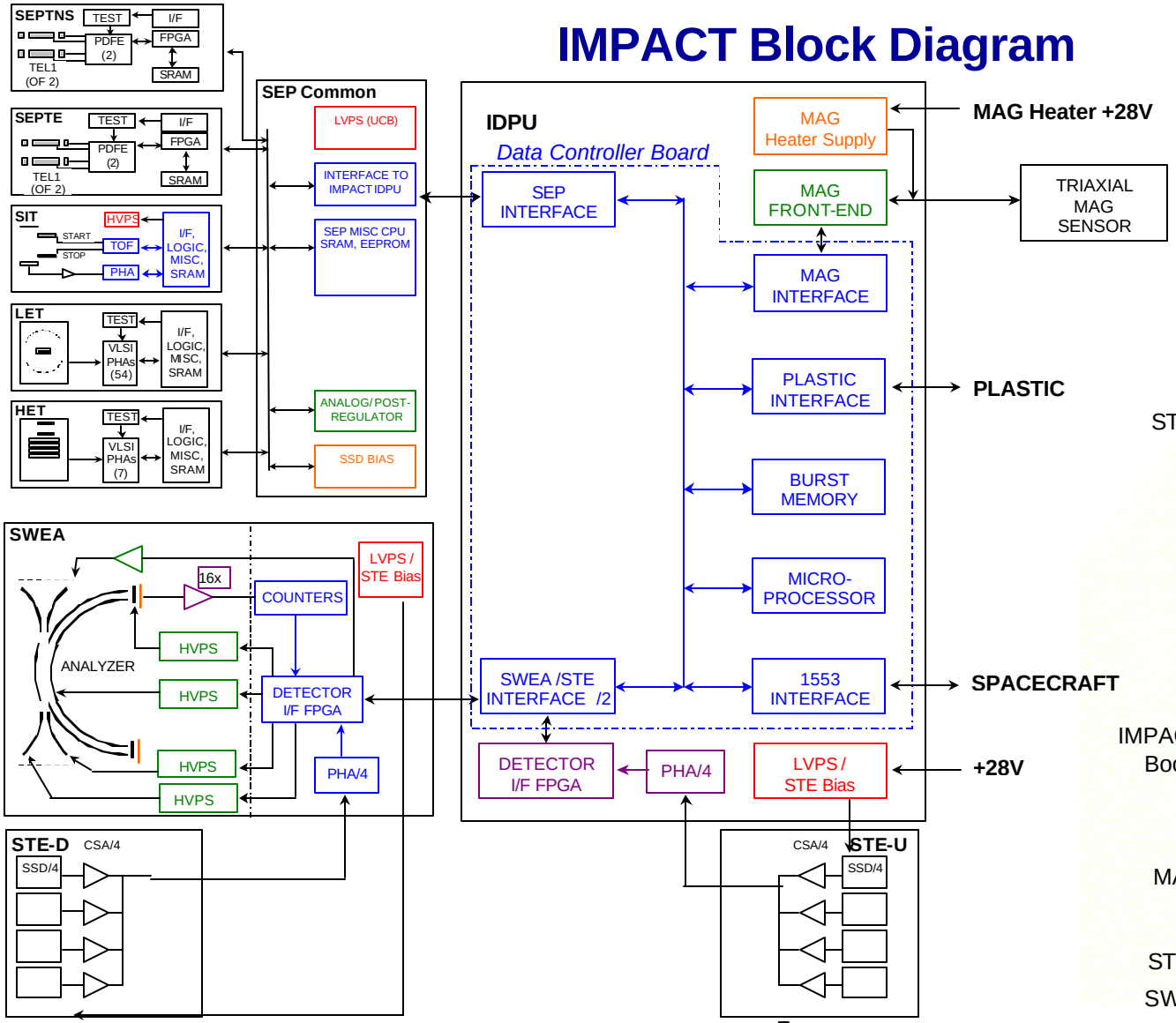
Description	Goal	Requirement	Source
Noise level	0.01 nT	0.05nT	Derived from MRD 4.7(K) and solar wind charateristics
Absolute Accuracy	+/- 0.1 nT	+/-0.1nT	MRD 4.7(K)
Range	+/-512 nT, +/-65536 nT	+/-512 nT	MRD 4.7(K)
Drift	+/-0.2 nT/yr	+/-0.2nT/yr	Derived from Absolute accuracy & MRD 4.6.2.6.1
Time Resolution	1/4 sec. 1/32 sec. (Burst)	1 sec	MRD 4.7(K)

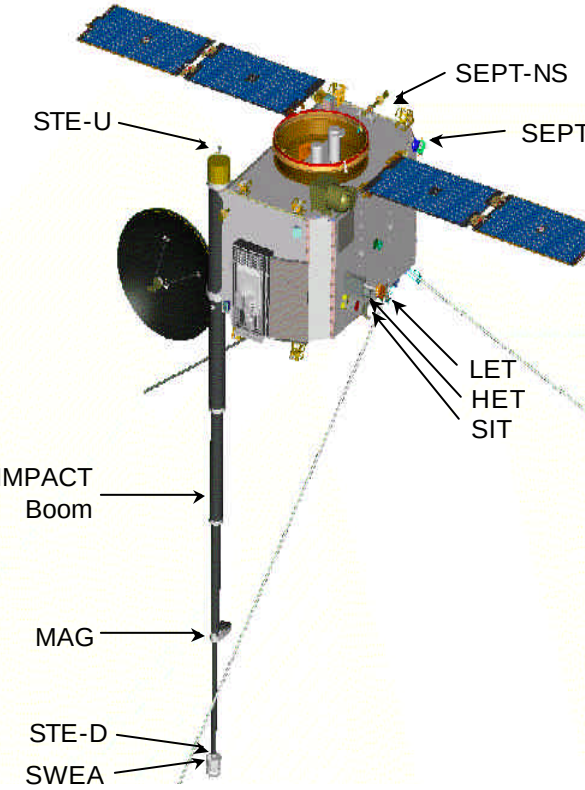
PDR

Description	Goal	Requirement
Noise level	0.01 nT	0.01 nT
Absolute Accuracy	+/- 0.1 nT	+/- 0.1 nT
Range	+/-512 nT, +/-65536 nT	+/-512 nT, +/-65536 nT
Drift	+/-0.2 nT/yr	+/-0.2 nT/yr
Time Resolution	1/4 sec. 1/32 sec. (Burst)	1 sec.

MAG addresses mission level 1 requirement 01.01.0008, Magnetic Field Measurement, which in turn is related to Science Objective 4, Improved determination of the structure of the ambient solar wind.

IMPACT Block Diagram

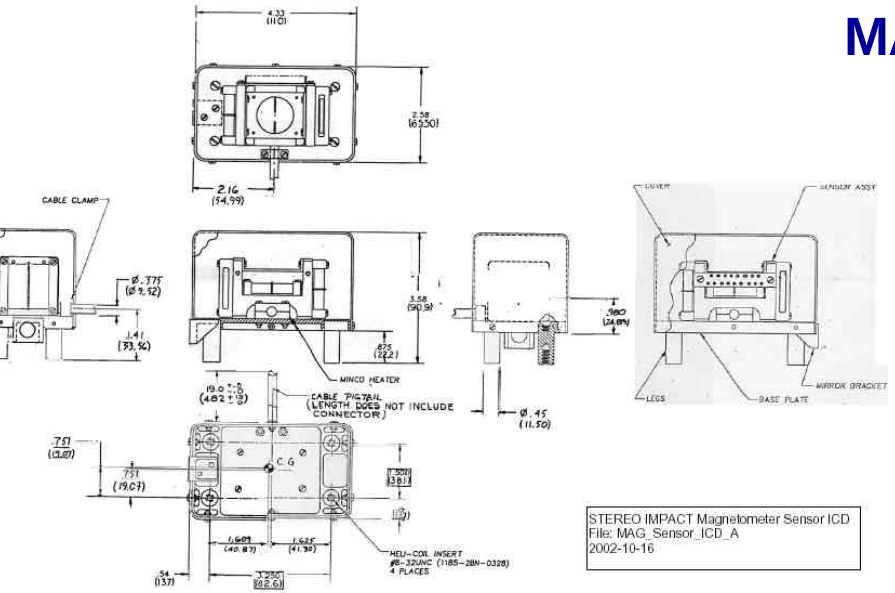




MAG Resources

- MAG Sensor
  - 0.25Kg
  - 0.5W Operational/Survival heater
- MAG Front End (in IDPU)
  - 0.30kg (excluding tray)
  - 0.38W
- MAG Heater Control (in IDPU)
  - 0.07kg
- Telemetry:
  - 398bps
    - 8Hz 16-bit 3-axis vectors plus overhead

MAG ICD



STEREO IMPACT Magnetometer Sensor ICD
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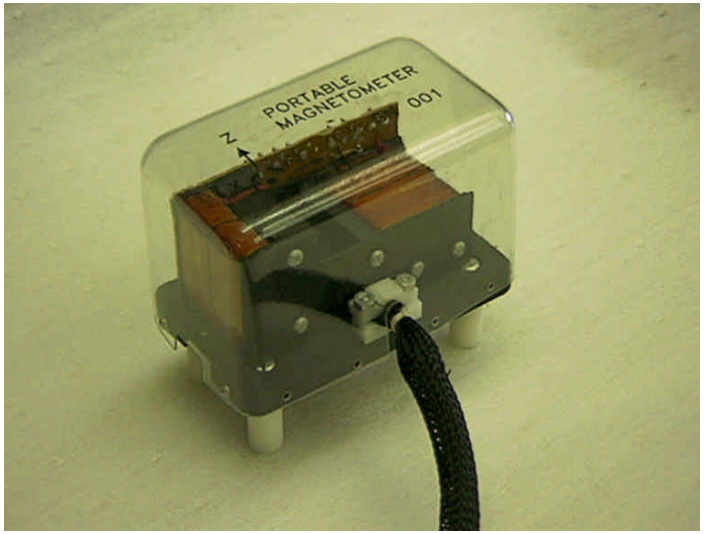
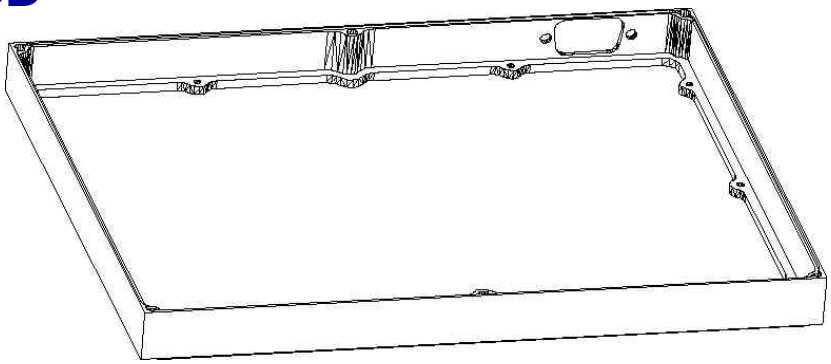
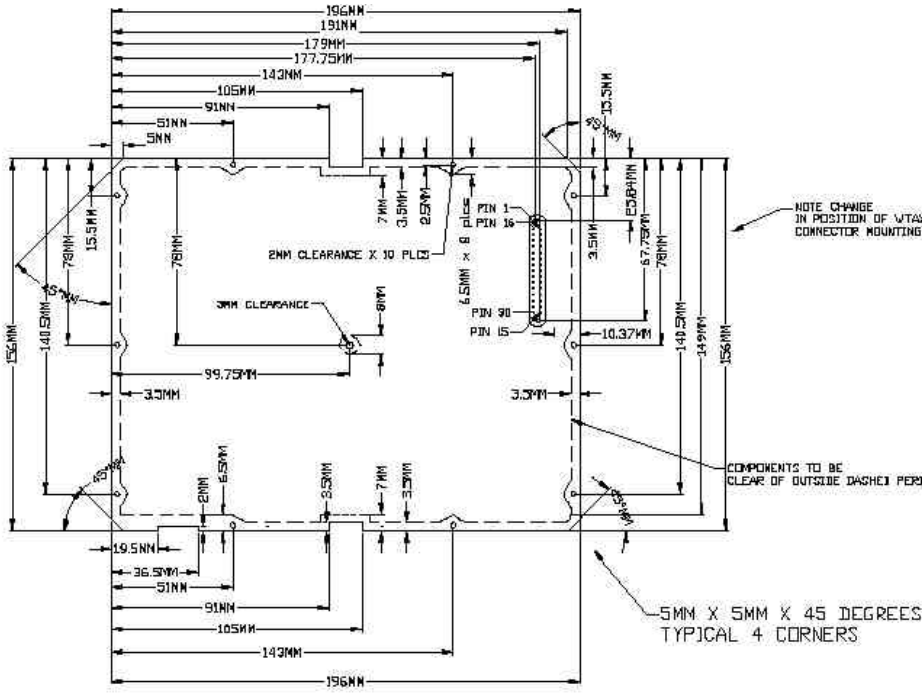
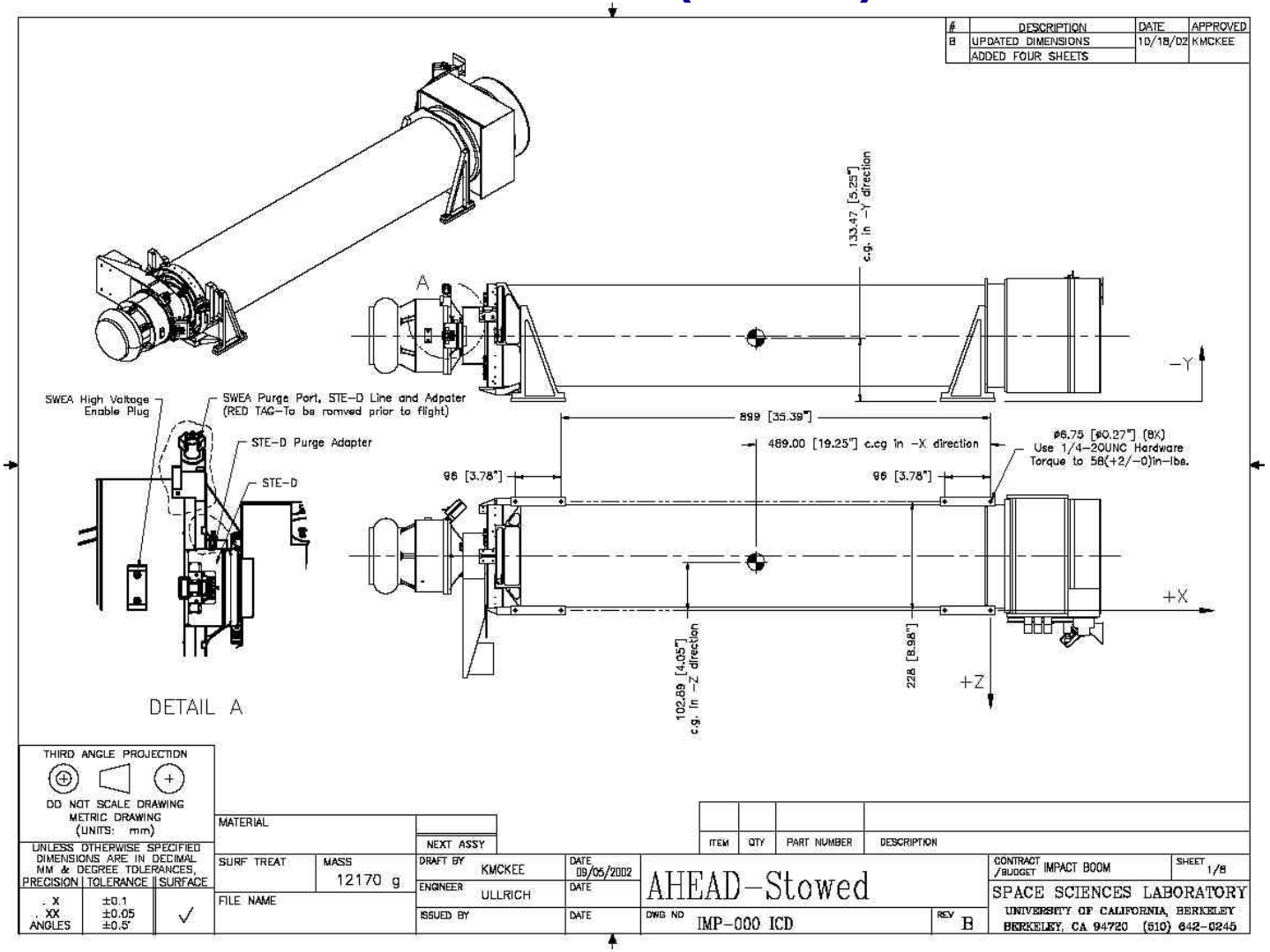


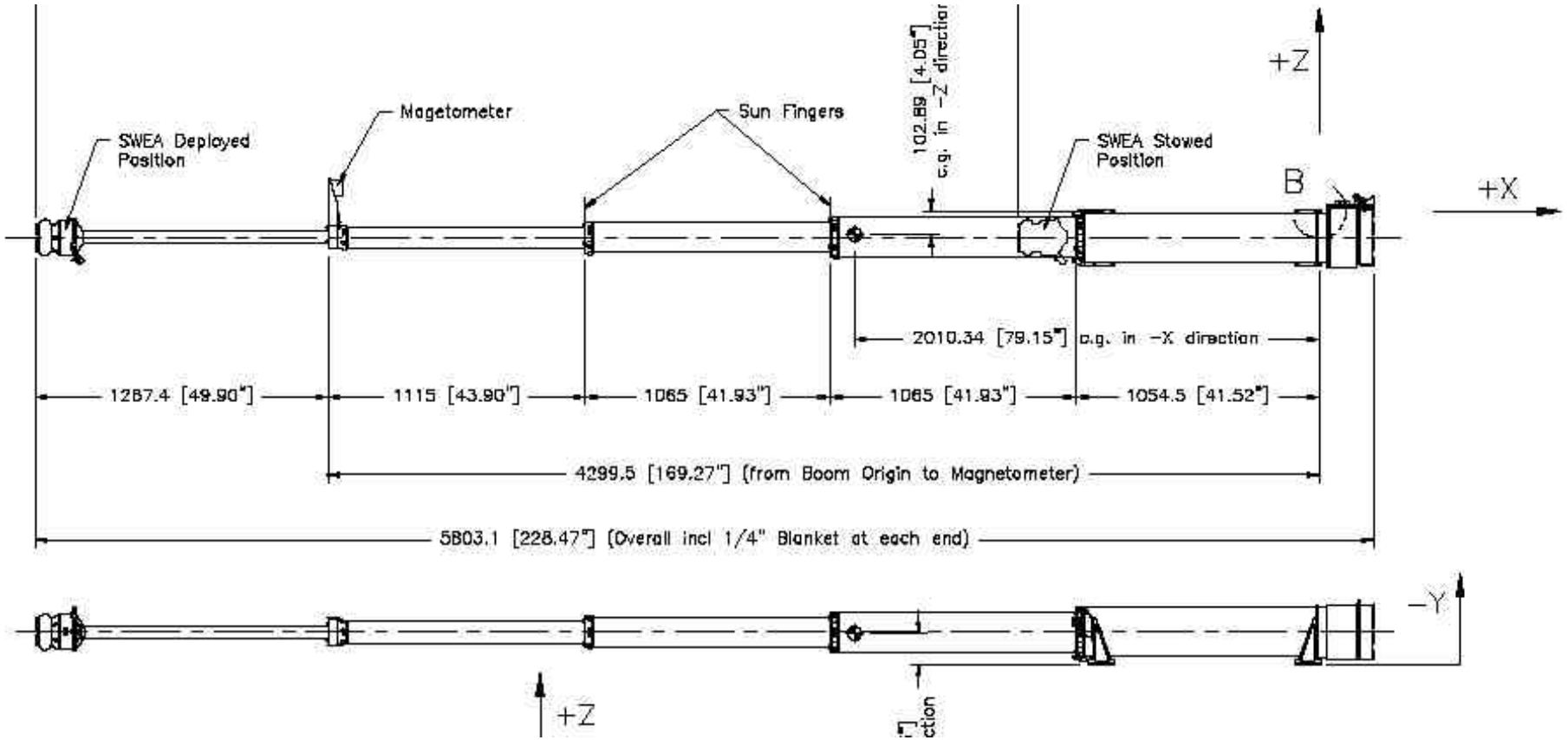




Boom Suite (Stowed)



Boom Suite (Deployed)



MAG Sensor Alignment

IMPACT/MAG has a modest alignment requirement:

- ±1° alignment
- ±0.5° knowledge
- Should be obtainable by mounting tolerances
- MAG sensor axes should be aligned parallel to the S/C maneuver (principal) axes.
- In-flight roll calibrations will be used to determine final alignment

On-Orbit MAG Commissioning Phase

- Would like IMPACT/MAG powered on and the IMPACT boom deployed as soon as possible after launch. This will provide valuable data for modeling of the spacecraft field, and can a provide deployment engineering confirmation/diagnostics
- Perform calibration roll maneuvers 30+ days after launch

Rolls

- Slow spacecraft rolls about the sun-line are required to calibrate the MAG DC offsets during the commissioning phase
- Rolls are also desirable for the other IMPACT instruments, to separate spatial effects from spacecraft effects in the measured particle distributions
- Rolls should occur in a low field region such as the solar wind
- Several rolls are desirable in case the ambient magnetic field is active during the measurement
- Rolls later in the mission, every six months, will measure the drift in the spacecraft DC fields and MAG sensor offsets

Magnetics

- Magnetic Goals, as measured at the MAG sensor:
  - ±0.03nT Dynamic
  - ±1nT Static
- Magnetics Control Plan to be implemented using GSFC instrumentation and support. Objective: minimize dynamic fields from S/C and instruments
- Use of magnetic materials avoided/controlled
- Current loops need to be eliminated/compensated
- Items close to MAG sensor of particular concern (since field falls off at least as $1/R^3$)
- MAG team working closely with APL to help meet these requirements at minimum cost
  - Magnetics Control Seminars at APL
  - Screening of spacecraft components
  - System level magnetic tests during I&T to verify performance
- Mission Requirements: (a) Periodic (monthly) Spacecraft rolls, (b) MAG ON during boom deployment to calibrate spacecraft generated DC magnetic fields

Magnetics Hot List

Magnetics Hot List					
SubSys	**Item**	**Mag Problem**	**Actions**	**Status**	**Notes / Possible Plans of Attack**
COMM	TWTA	Hot			TWTA can withstand 182dB pT at the tube (12.6 Gauss). Mario has data on tube and model of field from Vendor
			Judi - find out maximum external field that would not effect TWTA Performance	Complete	
			Mario - model TWTA in simple spacecraft model	Complete	**PLAN: Compensate with External Magnet**
			Ken - Provide Mario with S/C configuration drawings to view TWTA mounting and also view potential locations for compensating magnet	Complete	Drawings to Mario on 7/9/02
	Isolator	No (from Hot)			Magnetically-representative isolator tested at 200nT at 1 m. Isolator becomes mag problem. **PLAN: Talk to Vendor about changing design** Vendor improved design tests at 0.05 A-m2. < 0.32nT at mag sensor...acceptable
			APL - contact vendor to see if would allow APL to borrow a unit to "sniff"	Complete	
			Mario - Test Unit	Complete	
			APL - get vendor improved design to GSFC for Test	Complete	
			Mario - Test Improved Unit	Complete	
	RF Switches	Possible			RF Switch sent to GSFC for testing on 6/6/2002. Tested at 100nT at 1 m. **PLAN1: Compensate** **PLAN2: Try to Cancel with other switch when in HGA position (TBR)** **PLAN3: Shield**
			APL - order sample part to test	Complete	
			Mario - perform test of switch	Complete	
	Coax	No			coax runs from diplexer to transponder and from transponder to TWTA. Not an issue as long as copper-weld center conductors are not used.
	Waveguide	No			Not an issue as long as nickel-plating is not used.
PWR	Battery	No?			Wire battery similar to MESSENGER; latching relay selection and location being monitored by Brian Anderson
	Solar Arrays	Possible			Array can be forward biased
			Mike - Provide Mario with Solar Array layout drawings	by CDR	
			Mike - Check with vendor if array diodes can be forward biased	Complete	
	Solar Array Junction Box	No?			Design similar to MESSENGER; Brian Anderson to monitor design
	PDU	No?			Design similar to MESSENGER; Brian Anderson to monitor design

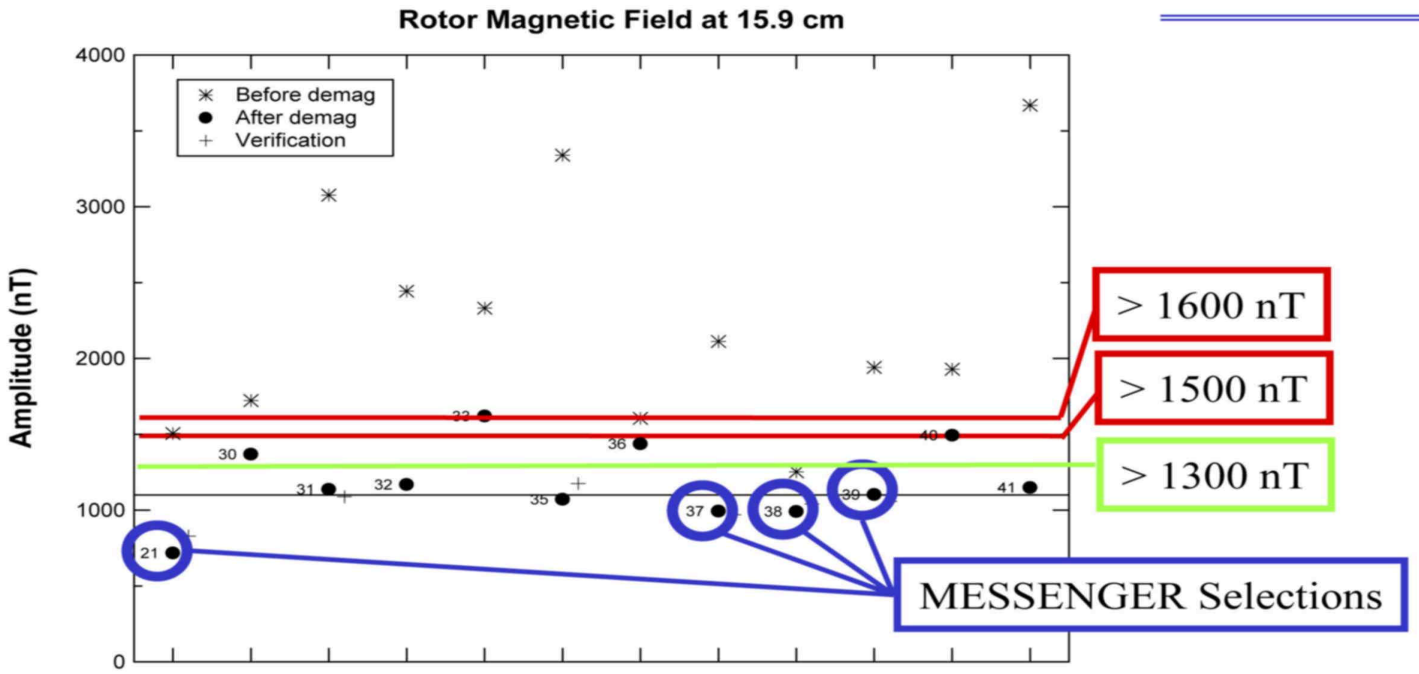
Magnetics Hot List (continued)

GNC	Reaction Wheels	Possible			~~Reaction Wheel RFP out.~~ Teldix Selected **PLAN1: Wait for Wheel Selection and attempt to work with Vendor to reduce mag by deguassing components** **PLAN2: Met-Glass Shielding (2kg allocated)** MESSENGER Data shows plan and allocation of MET glass is sufficient.
	IMU	No			~~Use MESSENGER Measurements~~ Same IMU as CONTOUR, waiting on Mag measurements
MECH	Clamp Band	No			SAAB-Ericsson Selected. Data received from vendor on previous band (1194 vs 937 diam). Springs located on S/C A and band on S/C B. S/C B field at sensor < 0.1nT. S/C A field (worst case) at >0.5 nT at sensor. **PLAN: Request changing of spring assembly to A286**
	HGA Actuator	No?			Estimated at 20nT @ 1 m, using worst case test data of larger actuator from Moog (Type 5 vs. Type 3)
	Fasteners	No			Magnetic stainless fasteners should be avoided, but there use is not prohibited due there small size.
PROP	Latch Valves	Possible			Messenger data shows Mag moments of 19.7 nT m3 along tubing and 81.2 nT m3 perpindicular to mount, both in open configuration. ~~**PLAN1: Try to Cancel Out 1 LV w/ another and mount 3rd to reduce field at Mag sensor**~~ ~~**PLAN2: Shield**~~ Drawings to Mario on 7/9/02; No Difference in open and closed position **PLAN: Compensate with Mag on s/c structure**
			Carl- Get Valve Mag data from MESSENGER	Complete	
			Carl/Ken - Provide Mario with S/C configuration drawings to view latch valve mounting	Complete	
			Carl - Order Latch valve for Testing	Complete	
			Mario - Test Unit in open and closed configurations	Complete	
	Thruster	No			~~**PLAN: Deguass nozzles prior to s/c integration**~~ **PLAN: Compensate with Mag on s/c structure**
THERM	Heaters	No			Project to not use Nichrome heaters
	Thermostats	No			No Change

Magnetics Hot List (continued)

I&T	Tools	No			Project to not use Magnetically attached tools; All tools degaussed on a regular schedule
	Load Cells	Possible			Keep load cells away from spacecraft.
	Vibe Table	No			Vibe Table to be compensated
	Lifting Eyes, Shackles	No			
SCI	PLASTIC	No			
	IMPACT	No?			the heater field meets the 0.05nT requirement. The heater is run by a PWM running at 100kHz with duty cycle programmable by the processor in a closed loop by the processor in 10% increments.
			SWEA heaters to be examined - Mario to work with Dave Curtis. **Mag field simulated - get data to Mario**	Complete	
	SECCHI	Possible			SCIP telescope tubes are coated with Aluminum. SECCHI to order non-inductive heaters
			SCIP telescopes - coating of instrument tubes needs to be non-magnetic	Complete - No Issue	
			L. Spinger - get Mario data on hollow core motors and motors in door mechanisms. **RESEND DATA**	?	
	SECCHI - PWM Heaters	No			**PLAN: Order all heaters "non-inductive"**
			PWM heaters - SECCHI to provide details of design	Complete	
	SECCHI - SCIP CCD/Mirror	No			**PLAN: Deguass Invar Parts prior to instrument assembly**
	SECCHI - Cover Motor	No?			
			Provide Mario with sample unit for Test		
	SWAVES	No			

Wheels (Analysis of Teldix Data)



	Reaction Wheel Rotor # From Messenger Buy	Distance from Sensor (m)	Mag Field Measured at TELDIX (nT @ Xm)		Estimated Mag Field at Sensor (nT)	Dynamic Amplitude Goal (nT)	Shielding attenuation Required to Reach Goal -	Field at sensor with one layer of Met Glass (nT)
Reaction Wheels	#33, 40	3.429	1600	0.159	0.099	0.050	0.50	**0.059**
	#30, 36	3.429	1500	0.159	0.093	0.050	0.54	**0.056**
	#31, 32, 35, 41	3.429	1300	0.159	0.081	0.050	0.62	**0.048**

STEREO

Telecom -TWTA

- Plan:
  - Compensate with external magnets
- Work Done:
  - Initial analysis of TWTA magnetic field resulted in > 2.5nT at sensor
  - Examined effect of compensation magnet near TWTA. Vendor can withstand max field of 182dBpT (12.6 Gauss) or a 100nT-m3 magnet 10 cm away.
- Analysis:
  - Mag PI to model TWTA and compensation magnets in simple spacecraft model to determine field and compatibility.
- Additional Point
  - Data presented at KO meeting shows a AC Magnetic field generated by EPC of 0.3 nT at sensor. Frequency has been pushed up to 50 KHz.

Magnetometer Parts Engineering and QA

The overall applicable document is the IMPACT/PAIP

- **Code 695 Parts Engineer to Verify Quality Level, Radiation Tolerance, Operating Temperature, and GIDEP Alerts Before use or Procurement for Flight**
- **EEE Parts Selected and Tested per 311-INST-001, Quality Level 2 (or PPL21)**
- **Plastic Encapsulated Microcircuits (Not Listed in 311-INST-001) are Allowed if Equivalent Hermetic Parts are not Available. Plastic Parts to be Tested per IMPACT PAIP, which Includes DPA, Temperature Cycling, Burn-In, and Highly Accelerated Stress Testing (HAST)**
- **Radiation Effects: All MAG parts have been characterized to a total dose >10Krad without shielding. Shielding does not make much sense for STEREO.**
- **SEU's – MAG is not sensitive to SEUs and uses latch-up proof CMOS ICs.**

QA:

- **Manufacture, assembly and inspections by pre-qualified GSFC support contractors compliant with S311 requirements and/or ISO9001**
- **Electrical adjustment and testing, qualification, environmental testing performed in house at GSFC – Only manufacturing and assembly services provided by support contractors**
- **Identical materials, processes and parts used in >30 flight projects**

Magnetometer Calibration, Integration and MO&DA

- MAG calibration will take place in house at GSFC if the MAG Test Facility becomes available in the near future. Currently non-operational
- Backup plan is to use the Wallops Island Magnetic Test Facility which is fully operational and has adequate performance to fully verify IMPACT/MAG performance
- Other calibrations/characterizations performed within Code 695
- MAG will be integrated with the IMAPCT IDPU and boom at UCB/SSL
- Initial checkout performed using IDPU simulator and boom test cables
- Procedures similar to those used for the MGS/MAGER and Lunar Prospector MAG/ER are being updated

MO&DA: Other than discussed previously (rolls) the MAG is a fully automatic instrument that requires little commanding and MO planning during routine operations. At most a few commands per week which will be integrated with other IMPACT activities

Magnetometer Verification Matrix

		Verification Matrix for STEREO/IMPACT/MAG																Revision Date: 9/7/01
																		Revision Number: 1
Hardware Description		Test																
Level of Assembly	Item	Elect. test, rm. Temp	Bench Calibration	Elect. Test, hot	Elect. Test, cold	Vibration, Sinusoidal	Vibration, Random	Shock	Acoustics	Thermal Vacuum	Voltage margins	Thermal cycle	Thermal balance	>100 hours Operation	EMC/EMI	Magnetics	Bakeout	Contamination	Comments
C	Sensor, EM	X	X																
C	Sensor, F	X	X	X	X	H	H	H		X		X	H	H	H		H	X	
C	Electronics, EM	X	X	H	H									H					
C	Electronics,F	X	X	X	X	H	H	H		H	X	H	H	H	H		H	X	

Legend:

Level of Assembly	Unit Type		X =	Test required	
			A =	Analysis	
C = Component	BB	Breadboard	H =	Test at higher level of assembly	
I = Instrument	EM	Engineering Model		(Boom for sensor, IDPU for electronics)	
	PT	Prototype			
	PF	Protoflight			
	F =	Flight			

Magnetometer System Level Tests

Spacecraft system level magnetic testing is a MUST and will involve two main tests:

1. **Static test to determine the residual magnetic field of the spacecraft. This will require that the spacecraft be suspended form an overhead crane or mounted on a non-magnetic handling fixture. Special ground based magnetometers will be used to measure the field**

2. **Dynamic test to determine the magnetic fields generated by currents circulating in the spacecraft and the actuation of motors and relays. Field is measured with MAG and ground based magnetometers**

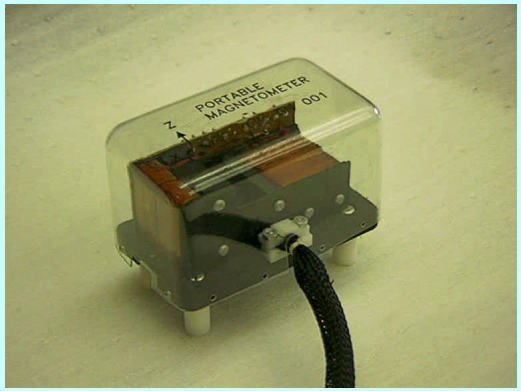
These tests are *verification test* and not "discovery" tests of the magnetic performance of the spacecraft

IMPACT/MAG Current Status

- Baseline design was optimized for surface mount components to miniaturize instrument electronics. Surface mount inductors successfully built and tested for MESSENGER ETU
- 90% of engineering schematics and drawings completed
- Miniature coaxial cables provided by UCB were tested successfully on fully functional MAG breadboard
- Flight fluxgate sensors have been fabricated and assembled. Ready for integration with MAG electronics
- 16-20 bit sigma-delta low power A/D converter(s) selected for implementation. Identical to NEAR, MESSENGER
- Interfaces to IDPU and Boom defined. IDPU MAG simulator is being tested
- Magnetics Workshops and characterization efforts for spacecraft and instrument components conducted on a regular basis
- Manufacturing contracts in place for flight electronics

IMPACT/MAG Current Status

- Procurement of surface mount components ~75% complete
- Heater board layout is complete and board is being manufactured
- Thermal design update conducted by UCB – consistent with previous results on similar missions. Heater board sized to deliver 1W max but expected level is within allocation (0.2W)



TRIANA PLASMAG ELECTRON SPECTROMETER
INSTRUMENT THERMAL DESIGN AND ANALYSIS

August 1999

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MAG - Magnetometer

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