High Energy Spectroscopic Imager (HESSI)
Mission Requirements
HSI-SYS-021B

LEVEL 1 Science Requirements

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
SCI-1.	**Solar Spectroscopy**					
SCI-1.1.	Energy Range: 3 keV to 20 MeV Goal, 20 keV to 7 MeV Required	T			Spectrometer calibrations with IDPU	Verify in self-compatibility test
SCI-1.2.	Energy Resolution: 3 keV FWHM 20keV to 1MeV Required	T			Spectrometer calibrations with IDPU	Verify in self-compatibility test
SCI-1.2.1.	0.5 keV FWHM at 3keV and 2keV FWHM at 1MeV Goal	T			Spectrometer calibrations with IDPU	Verify in self-compatibility test
SCI-1.3.	Sensitivity Goal: Detect Microflares, 20 keV photon flux 5x10-3 (cm2/sec/keV)-1 for a 10s burst and E-4 power-law spectrum	A, T	Geometric factor calculation	XGCF grid transmission characterization, detector efficiency calibrations	Gridlet Imager test throughput, Spectrometer detector calibration efficiency	
SCI-1.4.	Dynamic Range: Measure Large Flares: Maximum Photon Flux (> 20 keV for E-3 power-law spectrum):					
SCI-1.4.1	High Energy Resolution: 400 (cm2/sec/keV)-1	T			Spectrometer Calibrations with IDPU	
SCI-1.4.2	Broadband: 5,000 (cm2/sec/keV)-1	A, T	IDPU throughput calculatiojs		Spectrometer Calibrations with IDPU	
SCI-1.5.	Background:					
SCI-1.5.1.	Minimize/measure particle-induced background, Goal	A, T	Predict with standard NSSDC model		Particle Detector Calibration	
SCI-1.5.2.	Minimize x-ray background in front segments, Goal	A	Montecarlo simulation of shielding performance			
SCI-1.5.3.	Minimize scatter of flare x-rays into rear segments by the spacecraft and Earth's atmosphere during a flare, Goal	A	Montecarlo simulation of shielding performance			
SCI-1.6.	Photometry: knowledge of absolute intensity of an observed flare in various continuum bands and lines to better than 10% Goal, 25%	A,T	model grid, detector resonse	grid, detector calibration	spectrometer calibrations	not reqd
SCI-2.	**Solar Imaging**					
SCI-2.1.	Angular Resolution: <4 arcsec to 35 keV (goal 2.3 arcsec), 7 arcsec to 400 keV, 36 arcsec above 1 MeV	A,T	geometric analysis	OGCF measurement of grid pitch	gridlet test	not reqd
SCI-2.2.	Angular Coverage: 4 – 180 arcsec	A, T	geometric analysis	OGCF measurement of grid pitch		
SCI-2.3.	Field of View: Full Sun	A	Minimum 1 degree FOV by geometric analysis			
SCI-2.4.	Time resolution: 100 ms for coarse image, 2 s for detailed image	A,T	calculated modulated waveform		IDPU Image Generator GSE tests	Image Generator GSE tests
SCI-2.5.	Image dynamic range 100:1 goal, 10:1 required	A, T	Image background analysis results in error budget; see INS-2.5	grid, detector calibration		
SCI-3.	**Mission Timing (Solar Maximum)**					
SCI-3.1.	Launch mid 2000 Goal, before end of 2001 Required	I	Currently 3/2001			
SCI-3.2.	Mission Life: 1 year Required, 2 year Nominal, 3 year Goal	A	Orbit Analysis (2 year minimum 3 sigma), no expendables, limited life items analysis, aproporiate reliability levels	Cryocooler burn-in, attenuator actuator life test, solar array qual pannel		
SCI-4.	**Data Handling**					
SCI-4.1..	System Capacity: Continuous imaging through large flares, including data collection, storage, transmission from the spacecraft, reception on the ground, analysis, and archiving (Goal), 50% coverage Required	A, T	Analyses of largest and typical flare event rate convolved with modeled instrument response indicates adequate bandwidth and memory; see also SYS-1, GND-1, INS-4, BUS-3		IDPU high rate mode functionals and Image Generator tests, bus high rate mode tests	
SCI-5.	**Secondary Science (Goals)**					
SCI-5.1.	Hard X-ray / Gamma-ray all-sky monitor	A, T	Monte Carlo Simulation		Side-on calibrations of Spectrometer	Side-on calibrations of Spectrometer in Spacecraft
SCI-5.1.1.	Field of view of at least 2 pi steradians	A, T	Monte Carlo Simulation		Side-on calibrations of Spectrometer	Side-on calibrations of Spectrometer in Spacecraft

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
SCI-5.1.2.	Ability to see transient hard x-ray sources down to about 300 mCrab from 30-100 keV in 3 days of integration	A	Extrapolation from BATSE sensitivity			
SCI-5.1.3.	Detection at > 10-sigma significance of gamma-ray lines with flux of a 3E-4 photons/cm2/s in a	A	Extrapolation from BATSE sensitivity			
SCI-5.1.4.	<1ms time resolution for x-ray pulsar period determination	T	See INS-4.1			
SCI-5.2.	Crab Nebula Imaging: view Crab Nebula when within a few degrees of the Sun	A	Analysis indicates sufficient Crab viewing once a year without off-pointing			
SCI-5.3.	High energy & temporal resolution measurements of terrestrial Hard X-ray / Gamma-ray emissions:					
SCI-5.3.1.	Field of view requirement as for cosmic all-sky monitor	A	Monte Carlo Simulation			
SCI-5.4.	Location and Spectroscopy of Gamma-Ray Bursts	A	Monte Carlo Simulation			
SCI-5.5.	Polarization Detector	A, T	Monte Carlo Simulation		Measure with source	
SCI-5.5.1.	Sensitivity to hard x-ray polarization levels < 10% for the largest flares	A	Monte Carlo Simulation			

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Level 2 System Requirements

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
SYS-1.	**Communications**					
SYS-1.1	Ground Station at Berkeley	I				
SYS-1.2	S-Band, STDN-compatible, CCSDS-compatible, COP-1 compatible	T			Berkeley ground system tests by UCB and manufacturer	End-to-end tests with spacecarft and ground system
SYS-1.3	>3.5 Mbps downlink, <10-6 BER, >2.7 dB link margin minimum @ 5deg above horizon	A,T	Link Margin analysis		Berkeley ground system tests by UCB and manufacturer	Tests with in-orbit spacecarft
SYS-1.3.1	Worst case ground station G/T = 19.3dB @ 5deg above horizon	T			Berkeley ground system tests by UCB and manufacturer	
SYS-1.4	2000bps uplink, <10-7 BER, >3db uplink margin @ 5deg above horizon	A,T	Link Margin analysis		Berkeley ground system tests by UCB and manufacturer	Tests with in-orbit spacecarft
SYS-1.4.1	SYS-1.4.1. Transmit EIRP > 58dBW	T			Berkeley ground system tests by UCB and manufacturer	
SYS-2.	**Mission Ops**					
SYS-2.1	Ground station and mission ops co-located at Berkeley	I				
SYS-2.2	Tracking by NORAD	I	Berkeley Ground Station Autotrack can also be used to generate orbital elements			
SYS-3	**Orbit**					
SYS-3.1	Launch sites preclude low-background equatorial orbit. 38 degree orbit maximizes telemetry downlink to a ground station at Berkeley	I	Specified in Launch Services ICD			
SYS-3.2	600 km (TBR) orbit - high enough to meet the lifetime requirement (SCI-3.2), and as low as possible to minimize the background (SCI-1.5) and meet the Debris requirement	I	Specified in Launch Services ICD (currently 580km, since launch dispersion is less)			
SYS-4	**< 333 kg launch mass (now 330kg)**					
SYS-4.1	Spacecraft not-to-exceed = 158 kg (allocated)	T			Measured Bus mass = 161kg (includes balast)	Observatory mass properties after spin-balance
SYS-4.2	Instrument not-to-exceed = 160 kg (allocated)	T			Measured Instrument mass = 130kg	
SYS-5	**I&T**					
SYS-5.1	System integration and test at Berkeley, using the same resources & personnel that will do mission ops	I				
SYS-5.2.	Cleanliness/Contamination: Class 100,000 at system level, as required at subsystem level	T			Facilities testing prior to use and monitor during use	
SYS-5.3	Environmental Tests					
SYS-5.3.1	Subsystem level thermal or thermal vac, vibration	I				
SYS-5.3.1.1	Thermal to stress subsystems at least 10C beyond expected	I				
SYS-5.3.1.2.	At least 4 thermal cycles at acceptance levels	I			Typically more, particularly where thermal rather than thermal vac used	
SYS-5.3.1.3.	Vibration & structural loads levels to be determined from SELVS-II input function and computed coupling through spacecraft, or computed using GEVS-SE Rev A	I				
SYS-5.3.2	System level vibration, thermal vac / thermal balance, EMI	I				
SYS-5.3.2.1.	Vibration level to envelope of SELVS-II launch loads	I				

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
SYS-5.3.2.2.	System level thermal balance to verify thermal model	I				
SYS-5.3.2.3.	EMI to verify no self-interference between subsystems, compatibility with launch vehicle & launch site	I				
SYS-5.3.3	GEVS-SE Rev A test procedures	I				
SYS-6	**Power**					
SYS-6.1	Instrument power Not-to-Exceed 162W orbit average (Allocated)	T,A	Imager Heater & Cryocooler power depends on thermal analysis		CBE=145W, mostly measured	Thermal Balance test will improve thermal analysis fidelity
SYS-6.2.	Spacecraft bus to meet Instrument and Bus Not-to-Exceed power requirements at End-of-Life	T,A	See bus-4.3			
SYS-6.3.	Spacecraft battery capacity sufficient to power Instrument plus Bus through orbit shadows without exceeding battery manufacturer's suggested Depth-of-Discharge for the predicted number of cycles (3 years)	T,A	See bus-4.4			
SYS-6.4.	Spacecraft battery sufficient to power bus through worst case orbit insertion scenario until the bus achieves positive power balance on its arrays.	T,A	See bus-4.5			

Level 2 Bus Requirements

No.	Requirement	Method	Analysis/Inspection	Component Test	Hot Bench or S/S	Bus Level Test	Observatory Test
Bus-1	**Spacecraft Bus**						
BUS-1.1	The total spacecraft bus mass shall not exceed 158.00 kg (SYS-4.1)	T	Current bus mass estimate is 136kg based on individual component weights.				Not Required
BUS-1.2	The spacecraft bus shall be designed to be operated for a minimum of two years following launch.(SCI-3.2)	A	All bus components designed for and analyzed for three year mission life.				Not Required
BUS-1.3	Commandability: The s/c shall be capable of receiving ground commands at all time.	A	Link budget shows 12dB margin for uplink at 5° elevation at worst case spacecraft aspect angle	Transponder receiver sensitivity tested to meet unit requirement of -113dBm	Antenna range testing performed to verify antenna patterns on spacecraft mockup.	Uplink commanding capability verified in bus test with power levels below -113dBm at receiver input in bus telecommunications functional test. RF losses of all passive components verified in RF component integration procedure.	System Compatibility Test to verify no interference from other spacecraft systems
BUS-1.4	All autonomous functions shall be capable of being initiated and disabled by ground command.	T		EPS overcurrent and undervoltage trips tested in PCB board level test to verify enable/disable capability.	Enable and disable capability of flight software fault protection functions verified in FSW acceptance testing on hot bench.		Not Required
BUS-2	**Attitude Control**						
BUS-2.1	The spacecraft shall be spin stabilized. (INS-2.2)	T			ACS spin stabilization verified in closed loop testing on hot bench.		Not Required
BUS-2.2	The nominal spacecraft spin rate shall be 15 RPM. (INS-2.2)	T			ACS performance verified at 15 RPM in hot bench testing.		Not Required
BUS-2.3	Pointing Control: The spin axis shall be within 0.2° of the sun center (INS-2.3).	T			Hot bench performance testing demonstrates pointing within 0.1° in normal mode.		Not Required
BUS-2.4	Spacecraft spin rate shall be stable to 180 arcseconds in 10 spins (INS-2.5.6.1)	A	Analysis demonstrates 125 arcseconds in 10 revolutions while in sun. Baseline procedure is to control spin while in eclipse.				Not Required
BUS-2.5	ACS shall accommodate use of RAS /SAS data for attitude determination as a goal. *Note: Requirement to use RAS data deleted in agreement with UCB.*	T			ACS performance verified in hot bench using simulated SAS data.		Not Required
BUS-3	**Telecommunications**						
BUS-3.1	The uplink antenna coverage shall be 4pi steradian. (SYS-1.4)	T	Analytical modelling of antenna configuration done to predict antenna coverage.		Antenna range testing performed to verify antenna patterns on spacecraft mockup.		Not Required
BUS-3.2	S-band uplink and downlink (SYS-1.2)	T		Transponder uplink frequency verified to be 2039.6458 MHz Transponder downlink frequency verified to be 2215 MHz		Uplink frequency verified to be 2039.6458 MHz and downlink frequency of 2215 MHz verified in bus telecom functional test.	Not Required
BUS-3.3	Downlink Data Rates						
BUS-3.3.1	High Data Rate Downlink: 4 Mbps (SYS-1.3)	T		Transponder and CIB testing verified 4Mbps downlink capability.	Downlink data rate of 4Mbps verified in hot bench testing.	Downlink data rate of 4Mbps verified in bus telecom functional test.	Downlink to Berkeley Ground Station verified
BUS-3.3.2	Low Data Rate Downlink: 32 kbps (SYS-1.3) *Note: Requirement changed by 125kbps prior to CDR per agreement with UCB.*	T		CIB testing verified 125kbps and 1Mbps downlink capability.	Downlink data rates of 125kbps and 1Mbps verified in hot bench testing.	Downlink data rates of 125kbps and 1Mbps verified in bus telecom functional test.	Downlink to Berkeley Ground Station verified
BUS-3.4	Uplink Data Rate: 2000 bps (SYS-1.4)	T		Transponder and CIB testing verified 2000 bps uplink capability.	Uplink data rate of 2000 bps verified in hot bench testing.	Uplink data rate of 2000 bps verified in bus telecom functional test.	Uplink from Berkeley Ground Station verified
BUS-4	**Electrical Power**						
BUS-4.1	Bus Voltage shall be 28 +6/-4 volts D.C.	T		CCB board level test verified that CCB limits maximum voltage to 34V. Battery capacity test verified that battery maintains minimum bus voltage above 24V at maximum power load during eclipse.		Bus voltage range verified in bus EPS functional test.	Verify EPS performance with flight instrument components in observatory test.

No.	Requirement	Method	Analysis/Inspection	Component Test	Hot Bench or S/S	Bus Level Test	Observatory Test
BUS-4.2	Single Point Ground	T	EPS, wire harness and component mounting accommodations designed for single point ground	Isolation of power and signal grounds verified during electrical testing of all boards and electronic boxes.		Component grounding verified during component integration.	Not Required
BUS-4.3	The spacecraft bus shall provide up to 162 Watts orbital average power to the instrument (SYS-6.1, SYS-6.2)	T	Power budget analysis shows 13.9% margin with 173.6W orbit average instrument power.	Solar array LAPSS testing and power analysis verified 505W power EOL. Battery capacity test measured 17A-hr capacity.		Full power operation verified in bus EPS functional test.	Not Required
BUS-4.4	The spacecraft bus shall accommodate full power operation of the instrument during eclipse without exceeding a battery depth of discharge of 50% (SYS-6.3)	T	Power budget analysis shows 13.9% margin with 173.6W instrument power constant throughout orbit. Worst case battery depth of discharge is 37.1% for 15A-hr battery nameplate capacity.	Solar array LAPSS testing and power analysis verified 505W power EOL. Battery capacity test measured 17A-hr capacity.		Full power operation verified in bus EPS functional test. Battery capacity measured 18.25A-hr during battery conditioning.	Not Required
BUS-4.5	Spacecraft battery sufficient to power bus through worst case orbit insertion scenario until the bus achieves positive power balance. (SYS-6.4)	T	Power analysis based on ACS hot bench testing shows marginal performance with worst case sun pointing and above nominal tip-off and spin rate.		ACS hot bench testing demonstrated sun acquisition with above nominal tip-off and spin rates.		Not Required
BUS-4.6	Instrument Power Interface						
BUS-4.6.1	Current limiting on all instrument power services (150% of expected current)	T		Instrument power service current limits verified in PCB board test.	Instrument power service current limits verified in SEM acceptance test.	Instrument power service current limits verified in bus EPS functional test using simulated instrument power loads.	Not Required
BUS-4.6.2	Current monitoring of all instrument power services telemetered in state of health (SOH) telemetry	T		Instrument power service telemetry monitoring verified in PCB board test.	Instrument power service telemetry monitoring verified in SEM acceptance test.	Instrument power service telemetry monitoring verified in bus EPS functional test using simulated instrument power loads.	Not Required
BUS-4.6.3	Cryocooler power will be drawn from the bus as a 60 Hz rectified sinusoidal current waveform.	T		CCB and PCB boards tested with simulated cryocooler power load.	EM EPS components tested with EM CPC to verify design compatibility.	CPC load simulator used for bus EPS functional testing.	Verify EPS performance with flight CPC after instrument integration.
BUS-5	**Command and Data Handling**						
BUS-5.1	Data storage: 2.0 Gbytes of science data storage (INS-4.4)	T		SSR testing verified 4.0Gbytest of science data storage		Science data storage of 4.0Gbytes demonstrated in bus C&DH functional test.	Not Required
BUS-5.2	Microsecond Clock: 2^{20}Hz Clock for performing timing accurate to within +/-1ms over any 15 hour period (INS-4.7, INS-4.8)	T		OCXO testing verified timing accuracy better than ±1ms over 15 hours after 1.5 days run time.		Clock interface and frequency verified in bus C&DH functional test.	Verify clock interface after instrument integration.
BUS-5.3	Telemetry Requirements						
BUS-5.3.1	Provide real-time state of health telemetry at all times when in contact with ground	T		CIB board test demonstrated that CIB always provides real-time SOH telemetry to transponder. PACI board test demonstrated that PACI always generates real-time SOH telemetry.	Hot bench testing verified that real-time state of health telemetry always available whenever in contact with ground.	Bus C&DH functional test verified that real-time state of health available at all times when in contact with ground.	Not Required
BUS-5.3.2	Limited real-time science data to be provided during ground contacts.	T		SSR unit test verified ability to control read pointer.	FSW testing in hot bench verified ability to command SSR to playback a commandable number of most-recently recorded frames of science data and downlink this as real-time science data.	Bus C&DH functional test verified ability to command SSR to playback a commandable number of most-recently recorded frames of science data and downlink this as real-time science data.	Not Required
BUS-5.3.3	All telemetry to be time-tagged with transmission time accurate to within ±1ms	T		Time tagging verified in CIB board testing.	Telemetry time tags verified in SEM box test and hot bench testing. Time tag latency <1ms verified by testing EM CIB in hot bench	Telemetry time tags demonstrated in bus test.	Not Required
BUS-5.3.4	Reed-Solomon encoding of all downlinked data	T		RS encoding verified in CIB board test.	RS encoding verified in hot bench testing	RS encoding verified in bus testing	Not Required
BUS-6	**Structure and Mechanisms**						

No.	Requirement	Method	Analysis/Inspection	Component Test	Hot Bench or S/S	Bus Level Test	Observatory Test
BUS-6.1	Instrument mass capability of up to 160 kg. (SYS-4.2)	T	Structural Analysis performed verifying that structure can accommodate instrument mass of up to 160kg.		Bus structural analysis model verified by modal testing.		Spacecraft vibration testing to provide final design verification.
BUS-6.2	Capability to align spacecraft spin axis with instrument boresight in orbit (INS-2.3)	T	Analysis of IAD design and spacecraft mass properties shows >±1° of spin axis alignment capability.	ADB board test verified stepper motor drive capability. IAD motor function verified.		Bus SMS functional test verified ±4.54° of principle axis alignment capability with ±0.17mrad resolution (based on 4 step minimum increment)	Not Required
BUS-6.3	Moment of inertia ratio: spin axis to transverse axis moment of inertia ratio must be at least 1.10 (for spin stability) (INS-2.2)	A	Solar wing tip masses sized to provide at least 1.10 inertia ratio based on mass properties analysis.				Verify mass properties analysis in spin balance test.
BUS-6.4	Design factor of safety: 2.0	A	Analysis verified positive margin on 2.0 factor of safety for components.				Not Required
BUS-6.5	Instrument radiator of 4450 cm2 to be provided, anti-sun facing orientation	I	Radiator provided by UCB. Bus provides adequate area verified by Pro-E modeling.				Not Required
BUS-6.6	Instrument fields of view to be provided per ICDs						
BUS-6.6.1	Imager FOV: 2π steradian	I	Forward antennas and fine sun sensor bracketry designed to provide clear FOV for imager and verified by Pro-E modeling.				Not Required
BUS-6.6.2	Spectrometer FOV: 2π steradian	I	Spectometer radiator 2.54mm above separation plane.				Not Required
BUS-6.6.3	RAS FOV: ±6° Azimuth, ±15° Elevation	I	RAS FOV verified by Pro-E modeling				Not Required
BUS-6.7	Instrument Alignments						
BUS-6.7.1	Imager aligned concentric to spacecraft Z-axis to 1mm, aligned with Z-axis to ±1°	T	Imager mounting interface designed to meet alignment requirement.		Bus structure alignment measured imager interface alignment.		Verify imager alignment after instrument integration.
BUS-6.7.2	Spectrometer concentric with imager to 1mm, cryocooler free piston aligned with spacecraft Y-axis to ±1°	T	Spectrometer mounting interface designed to meet alignment requirement.		Bus structure alignment measured spectrometer interface alignment.		Verify spectrometer alignment after instrument integration.
BUS-6.7.3	RAS alignment						
BUS-6.7.3.1	RAS boresignt direction 15° up from X-Y plane	I	RAS mounting interface complies with RAS ICD.		Bus structure alignment measured RAS interface alignment.		Verify RAS alignment after instrument integration.
BUS-6.7.3.2	RAS pointing stable to <1.0 arc-minute (INS-2.5.6)	A	Thermal analysis verified worst-case temperature gradient across RAS mounting interface.				Not Required

Level 2 Bus Requirements

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
INS-1.	**Spectrometer**					
INS-1.1.	Detectors: Nine 7cm diameter segmented Germanium detectors cooled to 75degK Goal, 85degK Requirement, meets SCI-1 and consistent with number and placement of grids in INS-2.1	T		Detector Calibrations (prior to installation in Spectrometer) verify detector performance	Spectrometer Thermal Performance: <85K at 70W cooling; Detector Calibrations (with and without IDPU) verify detector performance	Cool-down performance to be measured in Spacecraft thermal vac; Detector Calibrations verify detector performance
INS-1.1.1	Minimize thermal cycling of cryostat to minimize contamination issues to meet SCI-3.2	P	Procedural Constraint on I&T, Ops			
INS-1.1-2	Cool down detectors as soon as possible after launch to minimize radiation at elevated temperatures (more than 1 week above 100degK may require an anneal cycle) to meet SCI-3.2 and SCI-1.1	P	Procedural Contraint; as soon as power-positive, stable			
INS1.1-3	Avoid exceeding 100degK except during a anneal cycle (may require an anneal cycle) to meet SCI-3.2 and SCI-1.1	A	Cryocooler on continuously. See also INS-1.1			
INS1.1-4	Maintain HV on whenever temperature is below 100degK to minimize radiation damage to meet SCI-3.2 and SCI-1.1	P	Procedural Constraint on Ops			
INS1.1-5	INS-1.1.5. Goal: Provide ability to anneal detectors to about +100degC to reduce the effects of accumulated radiation damage or contamination (requires venting the cryostat to space).	T			Spectrometer Anneal cycle test	Spectrometer Warm-up (only to +20C)
INS-1.2.	Shutters (Goal): A system to mechanically insert mass between the imager and detectors to decrease the low energy photon flux in order to increase the counting rate dynamic range to meet/exceed SCI-1.4 Alternatively, must provide fixed mass profile to achieve SCI-1.4.	T		Attenuator performance verified with x-rays at XGCF at GSFC. Mechanisim life-tested at UCB > 10,000 cycles. Mechanisim thermal-vacuum tested at UCB	Mechanisim action verified on Spectrometer	Mechanisim action and operation verified in system tests
INS-1.3.	INS-1.3. Goal: Material in FOV limited to 0.040" thickness beryllium windows, plus 2 x 3mil Kapton caps, plus 39 blanket layers, including front and back of collimators plus inside cryostat; each blanket is 0.25 mil mylar film + 0.3 mil equivalent nylon netting (SCI-1.1,1.3,1.4)	A	Audit of all materials in FOV meets requirement.			Not Requiered
INS-2.	**Rotating Modulation Collimator Imager**					
INS-2.1.	Grids: 9 grids with characteristics indicated in table INS-2.1 (SCI-2.1, SCI-2.3)	T		Grid Characterization (OGCF & XGCF) of all grids at GSFC	Imager Gridlet test	Not Required
INS-2.2.	Spin stabilized spacecraft 12-20RPM (SCI-2.4)		See Bus-2.2, Bus-6.3			
INS-2.3.	Alignment requirement: Telescope axis aligned to sun direction to < 0.2 degrees (INS-2.7.1)		See Bus-2.3, Bus-6.2			
INS-2.4.	White Light Imaging (Goal): measure white light features on the sun to correlate images with ground observations (SCI-6)	T		SAS Functional test, Image mode	Imager Sun-viewing tests with SAS in Image mode	Not Required
INS-2.4.1.	Absolute Solar Aspect Solution 1 arcsecond 3 sigma	T			Imager Sun-viewing tests	Not Required
INS-2.5.	Modulation > 70% (SCI-2.5). Budget: (3sigma Allocations)					
INS-2.5.1.	Relative twist of grid trays: < 1 arcminute	T			Imager CMM measurement and TMS test	TMS tests, pre- & post-environments

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
INS-2.5.2.	Grid Imperfections: < 4.5 microns on finest grids; proportionalely less on coarser grids	T		Grid Characterization (OGCF & XGCF) of all grids at GSFC	Imager Gridlet test	Not Required
INS-2.5.3.	Grid Matching: < 1 part in 3E4	T		Grid Characterization (OGCF & XGCF) of all grids at GSFC	Imager Gridlet test	Not Required
INS-2.5.4.	Solar Aspect solution good to < 1.5 arcseconds	T			Imager Sun-viewing tests	Not Required
INS-2.5.5.	SAS to Grid alignment, knowledge < 3 arcsecond, stability < 1 arcsecond	T		Alignment on CMM	Pre & post imager environments CMM	Not Required
INS-2.5.6.	Roll Phase solution good to < 3 arcminutes	A,T	RAS stability analysis, RAS sensitivity analysis		RAS sensitivity and speed measurements	RAS Alignment (for absolute roll angle)
INS-2.5.6.1.	Spacecraft spin rate stable to 180 arcseconds in 10 spins		see Bus-2.4			
INS-2.6.	Twist Monitoring System to monitor relative grid twist during integration and test (SCI-2.1)	T		TMS system verified against CMM		see 2.5.1
INS-2.7.	Other Aspect Sensor Requirements:					
INS-2.7.1.	Solar Aspect Field Of View >0.8 degrees (Allocated)	T			Imager Sun-viewing tests	Not Required
INS-3.	**Particle Detector (Goal): to measure particle flux that will increase the detector background (SCI-1.5.1)**					
INS-3.1.	Energy range 100keV - > 30MeV	T			Radiation Source Tests	Not Required
INS-3.2.	Dual discriminator (electrons and protons)	T			Pulser Test & Radiation Source Tests	Not Required
INS-3.3.	Count rate capability sufficient to not saturate in SAA	A, T	Compute maximum counting rate expected in SAA		Pulser tests	Not Required
INS-3.4.	Minimum counting dynamic range 100x	A, T	Compute geometric factor		Verify background rate limitation to SNR	Not Required
INS-4.	**Data Handling**					
INS-4.1.	Photon list telemetry, each event containing measured energy, time tag sufficient for imaging (100 us or better for finest spatial resolution grids), detector identification, live time information, and coincidence information. (SCI-2.1, SCI-1.2, SCI-1.6)	T		Board-level functional tests	IMAGE Generator GSE test verifies functionality and throughput with realistic event script	IMAGE Generator GSE test verifies end-to-end functionality and throughput with realistic event script
INS-4.2.	When event rate is too high to do high energy resolution, extend count rate dynamic range by counting events for each detector in broad energy channels with counter readout rate sufficient for imaging (SCI-1.4)	T		Board-level functional tests	Functional Test	Not Required
INS-4.3.	Telemetry storage on board for at least 5E8 photon events (SCI-4.1)		see Bus-5.1 (4 bytes/photon)			
INS-4.4.	Telemetry downlink sufficient to downlink at least 5E8 photon events in 2 days. (SCI-4.1)	A, T	Link margin analysis, downlink window analysis, 4Mbps test (see also Bus-3.3.1)			Not Required
INS-4.5.	Photon decimation scheme to limit data rate if memory approaches full. (SCI-4.1)	T		Board-level functional tests		System-level functional test
INS-4.6.	Take data during quiet time as well as flare times (SCI-1.5.2, SCI-5.1, SCI-5.3)	A	System allways collecting data (unless memory full)			Not Required
INS-4.7.	Relative Timing: relative timing of photon events and aspect sensor data must be known to 60 ms (SCI-2)	A	Common clock used for time-tagging. See also Bus-5.2			Not Required
INS-4.8.	Absolute timing: To correlate with ground observations (SCI-6), need to be able to reconstruct absolute time of event data on the ground to better than 5 ms (Goal).	A	See Bus-5.2			Not Required
INS-5.	**Calibration (SCI-1.1, SCI-1.2, SCI-1.6)**					
INS-5.1.	Laboratory measurements of detector efficiency with calibrated sources at the detector and spacecraft level	T		Calibration with sources	Calibration with sources	Calibration with sources

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
INS-5.2.	Computer simulations of X-ray and gamma-ray response to extend and interpolate between laboratory measurements.	A	Computer modeling in place			Not Required
INS-5.3.	In-flight sensitivity calibration using a low-level radiation source	T			Verify calibration source measureable	Not Required
INS-5.4.	In-flight Roll alignment using Crab data	A	Verify Crab in FOV once a year, has adequate statistics			Not Required

High Energy Spectroscopic Imager (HESSI)
Mission Requirements
HSI-SYS-021B

Level 2 Ground System Requiremenrts

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
GND-1	**Antenna at Berkeley**					
GND-1.1.	Communications Compatibility with Spacecraft	T			UCB and Manufacturer tests	End-to-end test
GND-1.2.	Autonomous Operations, controlled by MOC	T			Test with FAST, IMAGE	
GND-1.3.	Antenna Pointing					
GND-1.3.1.	Track spacecraft: auto (Goal) and programmed (Required) track	T			Test with FAST, IMAGE	
GND-1.3.2.	Support Zenith passes	T			Manufacturer and UCB test	
GND-1.3.3.	Operate at wind speeds up to 40MPH, Survive up to 120MPH	A	manufacturers analysis			
GND-1.3.4.	Pointing accuracy <0.1 degree goal, <0.2 degree required	T			Manufacturer and UCB test	
GND-1.4.	Antenna located where it has an unobstructed view to 5 degrees above the horizon for >90% of HESSI pass time	A	Site analysis			
GND-1.5.	Time-tag Transfer Frame receive time to 1ms accuracy	T			Manufacturer and UCB test	
GND-1.6.	Data Handling: Real time & stored telemetry and command capability between ground station and MOC	T			Tested	End-to-end test
GND-2.	**Backup Antenna Compatibility**					
GND-2.1.	Availability					
GND-2.1.1.	Backup antenna required for Launch and Early Orbit backup	I	Wallops contracted. Others in work			
GND-2.1.2.	Backup antennas may be required later in the mission in case of Berkeley antenna trouble or if it is desired to increase the downlink capability during a large series of flares. These backups will be negotiated as needed, and should take < 24 hours to set up	I	Wallops contracted. Others in work			
GND-2.2.	Compatible with the HESSI spacecraft	A,T	Compatible on paper			CTV test, recorded data test
GND-2.3.	Compatible with MOC; MOC must be able to command spacecraft and	A, T	Compatible on paper		MOC-Wallops compatibility test	
GND-3.	**Mission Operations Center (MOC) at Berkeley**					
GND-3.1.	Compatible with Berkeley and Backup Antennas	T	see GND-1.6, GND-2.3			
GND-3.2.	Real-time monitor and control of spacecraft	T			MOC/Ground system tests	End-to-end test
GND-3.2.1.	Autonomous operations capability with automatic operator dial-up in case of alarm	T			MOC test	
GND-3.3.	Mission Planning (Autonomous)	T			IMAGE autonomous operations	
GND-3.3.1.	Fetch NORAD orbit predicts & generate spacecraft ephemeris to control Antenna pointing and contact schedule	T			IMAGE autonomous operations	
GND-3.3.2	Generate spacecraft command sequences	T				Orbit simulation tests
GND-3.4	Data trending and Analysis	T				Orbit simulation tests
GND-3.5.	Maintain Telemetry and Command Database	I				
GND-3.6.	Pass stored (not real-time) telemetry to SOC	T				Orbit simulation tests
GND-4	**Science Operation Center (SOC) at Berkeley**					
GND-4.1.	Instrument state of health monitoring	T				Orbit simulation tests
GND-4.2	Level Zero Processing (LZP) of telemetry	T				Orbit simulation tests
GND-4.3.	Quick-look & catalog data products generation	T				Orbit simulation tests

No.	Requirement	Method	Analysis/Inspection	Component Test	Subsystem Test	Observatory Test
GND-4.4.	Distribute Level Zero & Derived data to SDAC and ETH	T				Orbit simulation tests
GND-4.5.	Generate Instrument commands and pass to MOC for inclusion in Command loads	X	Now run directly from MOC			