(Insert in 699-205, Cassini Orbiter Functional Requirements Book)

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Cassini Orbiter
Functional Requirements Book
Imaging Science Subsystem (ISS), Rev.C

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1.0 PURPOSE AND SCOPE

This document establishes the functional requirements of the Cassini Imaging Science Subsystem (ISS) in response to mission and spacecraft requirements and science objectives. A description of the baseline architecture of the imaging science subsystem with the current configuration (FIGURE 4-2036:-01, "ISS Configuration") is also provided.

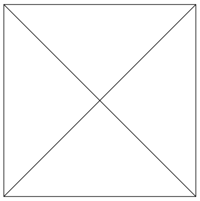

FIGURE 4-2036:-01 ISS Configuration (July 31, 1992)

2.0 APPLICABLE DOCUMENTS

The following documents, revised to the date of this document, form a part of this Functional Requirement to the extent specified herein:

<u>Project Requirements</u>

699-004	Project Policies and Requirements Document
699-565	Navigation Requirements Document
699-050	Science Requirements Reference Document
699-270	Spacecraft Flight Rules and Constraints

<u>System Functional and Design Requirements</u>

CAS-3-100	Orbiter System Requirements
CAS-3-110	Cassini Electrical Interface Listings
CAS-3-160	Maneuver and Control Requirements
CAS-3-170	Accuracy Requirements and System Capabilities
CAS-3-180	Mechanical Configuration Requirements
CAS-3-190	Structural Design Criteria Requirements
CAS-3-200	Inertial Properties Requirements
CAS-3-210	Temperature Control Requirements
CAS-3-220	Electronic Equipment Design Criteria Requirements
CAS-3-230	Mass Allocations
CAS-3-231	Equipment List
CAS-3-240	Environmental Design Requirements
CAS-3-250	Power System Design and Functional Requirements
CAS-3-251	Power/Pyro Users List
CAS-3-260	Electrical Grounding & I/F Circuit Requirements
CAS-3-271	S/C Data System Intercommunication Formats
CAS-3-281	S/C Telemetry Generation and Processing Formats
CAS-3-291	S/C Sequencing and Command Formats
CAS-3-310	S/C Information System Functional Requirements
CAS-3-330	S/C Fault Protection Functional Requirements
CAS-3-350	Power Allocations
CAS-3-360	Safety Requirements
CAS-3-1110	Support Equipment Functional Block Diagram and I/F Listing Requirements

<u>Drawings</u>

10135900	Narrow Angle Camera Imaging Science Subsystem (ISS NAC) Interface Control Drawing

10135902	Wide Angle Camera Imaging Science Subsystem (ISS WAC) Interface Control Drawing
10144252	ISS/Accel Assembly EA12 Arrangement Drawing

Several requirements from JPL PD-699-004 "Project Policies and Requirements", have been incorporated into CAS-3-100 "Orbiter System Requirements". Applicable requirements remaining in 699-004 are direct requirements on ISS.

3.0 FUNCTIONAL REQUIREMENTS

3.1 GENERAL

The instrument subsystem shall provide the capabilities documented herein to support the research needs of the planetary remote sensing community as represented by the ISS Cassini Science Team. The ISS shall also provide the capability to support optical navigation for the Cassini mission. The ISS shall satisfy all performance and functional requirements specified herein over all combinations of specified DC input voltages, storage and operating lifetime, on/off cycles and environmental conditions, including radiation.

3.2 SCIENCE AND MISSION OBJECTIVES

3.2.1 CASSINI IMAGING SCIENCE OBJECTIVES

The primary goal of the imaging science experiment is to characterize the Saturnian system in detail, at a variety of resolutions and lighting angles, in wavelengths spanning the range from long uv through the visible and into the near IR (200 to 1100 nm). The imaging system will image a variety of targets in the complex Saturnian system: the atmosphere of Saturn, its rings (whose surface area is far greater than a body the size of Titan), Titan's atmosphere and possibly its surface, and Saturn's icy satellites. (Reference 699-050, Science Requirements Reference Document.)

Many Saturn atmosphere imaging science objectives are accomplished with time-lapse sequences, with narrow angle frames embedded in the wide angle field of view to provide context, pointing reconstruction, and additional spectral and polarimetric information. These objectives include: a) the 3-dimensional wind field as a function of time, b) divergence, vorticity, streamlines, and correlations between velocity components, c) transport of heat and momentum, and d) processes such as waves, eddies, and moist convection that are believed to maintain mean atmospheric circulation and give rise to major atmospheric storms. Other Saturn atmospheric objectives, which influence the selection of filters, particularly at methane absorption wavelengths, are to: study the composition, spatial distribution, and physical properties of the clouds and aerosols; investigate scattering, absorption, and solar heating in the atmosphere; determine the global heat balance for the planet; and constrain models of Saturn's interior. In addition, the imaging system will search for evidence of lightning, aurorae, and airglow, which require the ability to do long exposures with low noise, and search for planetary acoustic oscillation, which requires very stable instrument performance.

Ring science objectives which address a) satellite/ring dynamics; b) the rate and nature of the transfer of angular momentum and energy within the rings; c) improving the estimates of ring evolutionary timescales and lifetime; also require two scales of resolution. High resolution detail is necessary for identification of features such as bending waves, density waves, and eccentric rings, placed in the lower resolution context of the ring system as a whole. Understanding exogenic and endogenic ring modification processes; and determining the nature of the particle disk (ring thickness, the particle size distribution, composition, and physical nature of the particles) and detecting variation of these properties across the rings; requires full use of the ISS spectral range, polarizing filters, and a well-baffled system capable of looking relatively close to the sun. Very low noise is essential to detect diffuse rings and subtle features in diffuse rings, understand the properties of the diffuse Saturnian E and G rings and, in particular, examine the relationship between the E ring and the satellite Enceladus. Ring spoke kinematics and periodicities of appearance will be studied by observing their creation and evolution over short and long timescales in very rapid high resolution imaging sequences and in spoke movie sequences at moderate to low resolution.

Key Titan science objectives include: determining the dynamical state of Titan's atmosphere; determining the rates of conversion of atmospheric gases into aerosols and their subsequent deposition onto the surface; the composition, spatial distribution, and physical properties of Titan's clouds and aerosols; and the scattering, absorption, and solar heating in the atmosphere, through vertical atmospheric sounding at a variety of wavelengths; as well as searching for evidence of lightning, aurorae, and airglow. In addition it may be possible to detect Titan's surface at long (i.e., near-IR) wavelengths (depending on the scattering properties of Titan's atmosphere), and this exciting possibility drives the choices of filters at these wavelengths and the overall importance of system performance in the short IR.

The icy satellites exhibit a great variety of surface properties, and understanding their thermal, geological, and impact histories in detail is an important imaging science objective. A large dynamic range is necessary to image the bright and dark materials on Iapetus, whose albedos differ by a factor of twenty six. Subtle color differences and high resolution images may help distinguish endogenically and exogenically altered surfaces. The imaging system will be used to search for and monitor active geologic processes if they exist, characterize wispy terrain on Dione and Rhea, and study the leading/trailing hemispheric asymmetries on many satellites. Improving the understanding of the spectral and photometric behavior of each satellite's surface, determining the nature and origin of the dark material in the Saturnian system and understanding why there is so little of it relative to other outer planet satellite systems, will help constrain models of the proto-saturnian nebula and its evolution. Other objectives include constraining satellite interior models, and examining the rotational dynamics and polar motion of the satellites, especially those exhibiting chaotic motion, like Hyperion.

3.2.2 CASSINI OPTICAL NAVIGATION REQUIREMENTS

The ISS cameras will be employed to obtain navigation data for the mission. The narrow angle camera will be the primary camera for these observations. However, since close Titan flybys are dependent on the capability of ISS to provide imaging data, the wide angle camera is also required to provide an independent capability for imaging. The ISS shall meet the performance requirements of 699-565, Cassini Navigation Requirements, paragraph 4.1.1, Imaging Science Subsystem. The ISS is required to provide optical navigation imaging beginning at Saturn orbit insertion minus 90 days.

3.3 PERFORMANCE REQUIREMENTS

The ISS performance requirements are given in TABLE 4-2036:-01, "Cassini Imaging Science Subsystem (ISS) Performance Requirements" for spectral and spatial requirements of the optical system and for the sensor. Stability requirements are given in TABLE 4-2036:-02, "ISS Stability Requirements" and refer to internal camera parameters only. Additional performance requirements are given below. The ISS filters shall be as given in TABLE 4-2036:-03, "Cassini Filter Requirements".

TABLE 4-2036:-01 Cassini Imaging Science Subsystem (ISS) Performance Requirements (November 9, 1995)

Parameter	Data
Narrow Angle Optics	
Type	Ritchey Chretien
Focal length	2000 mm
Relative aperture	f/10.5
Spectral range	200 - 1100 nm
Number of filters	24
Pixel FOV	6.0 microradian/pixel
Field of view	0.35 x 0.35 deg
Wide Angle Optics	
Type	Refractor
Focal length	200 mm
Relative aperture	f/3.5
Spectral Range	380 - 1100 nm
Number of filters	18
Pixel FOV	60 microradian/pixel
Field of view	3.5 x 3.5 deg
Sensor	
Type	CCD
Format	1024 x 1024 pixels
Pixel size	12 x 12 um
Full well	$\geq$ 50,000 e^- (goal of 100,000 e^-)
On-chip processing	Pixel summation up to 800,000 e^-
Dark current	$\leq$ 0.3 e^-/pixel/sec at operating temperature
Charge transfer efficiency	0.99996 at operating temperature
System Read Noise	$\leq$ 60 e^- rms (goal of 20 e^- rms) at end of mission
Minimum Frame Time	9 sec
Data rate range	1 to 366 kbps
Data encoding	Two 12 to 8 bit encoding schemes, (1) a lookup table and (2) read 8 LSBs; 2:1 lossless data compression available; lossy compression (from CNES) available
Gain states	4
System MTF	$\geq$ 0.15 at 32 line pairs/mm
Exposure selection	Focal-plane shutter controlled by command
Exposure times	5 msec to 20 min, simultaneous WA/NA shuttering possible

TABLE 4-2036:-02 ISS Stability Requirements (June 16, 1994)

Sensitivity changes	≤ **1%/month (unbiased errors which cannot be calibrated)** ≤ **2% over 16 hours** ≤ **20% cumulative over the Saturn tour**
Shutter time offset changes	≤ **0.1 msec/year**
Filter bandpass shifts	≤ **0.6A/year**

TABLE 4-2036:-03 Cassini Filter Requirements (June 16, 1994)

Filter Name	Central λ or Cutoff	FWHM	Transmission	Blocking	Camera	Comments
255W	2550	425	0.30	10^{-2};1700-2100,3000-3500 10^{-4};3500-4500 10^{-5};4500-5400 10^{-6};5400-11000	NA	UV1
300W	3050	600	0.40	10^{-2};1700-2200,3500-4500 $10^{-5.5}$;4500-11000	NA	UV2
340W	3400	750	0.40	no requirement below 3000 10^{-5};4100-10000 5 X 10^{-4};10000-11000	NA	UV3
430SP	4300	sp	0.60	10^{-2};4400-5400 10^{-5};5400-11000	WA	VIO
440M	4400	300	0.60	10^{-2};3000-4100,4700-5400 10^{-5};5400-11000	NA	BL2
445W	4450	1000	0.70	10^{-2};3000-3800,5100-6000 10^{-4};6000-11000	NA/WA	BL1
562W	5625	1250	0.80	10^{-4};3000-4500,7500-11000 10^{-2};6750-7500	NA/WA	GRN
619N	6190	40	0.60	10^{-5};2000-6000,6380-11000	NA	MT1
635N	**see note 2**				NA	CB1
650W	6500	1500	0.80	10^{-4};3000-5500,8500-11000 10^{-2};8000-8500	NA/WA	RED
656N	6560	90	0.70	10^{-5};2000-6310,6810-11000	NA/WA	HAL
727N	7273	40	0.60	10^{-5};2000-7000,7550-11000	NA/WA	MT2
751N	7512	100	0.70	10^{-5};2000-7250,7770-11000	NA/WA	CB2
757W	7575	1650	0.80	10^{-4};9000-11000 10^{-5};2000-6250	NA/WA	IR1
867W	8675	1150	0.80	10^{-2};7600-7800,9750-11000	NA/WA	IR2

TABLE 4-2036:-03 Cassini Filter Requirements (June 16, 1994)

				10^{-4};2000-7600		
889N	8895	100	0.70	10^{-5};2000-8600,9200-11000	NA/WA	MT3

Filter Name	Central λ or Cutoff	FWHM	Transmission	Blocking	Camera	Comments
938N	9383	100	0.70	10^{-5};2000-9100,9700-11000	NA/WA	CB3
952W	9525	1450	0.80	10^{-2};11000 10^{-4};2000-8200	NA/WA	IR3
977LP	9775	lp	0.80	10^{-2};9300-9575 10^{-5};2000-9300	NA/WA	IR4
1025LP	10250	lp	0.70	10^{-2};9600-10000 10^{-5};3800-9600	WA	
CL1	6500	7000	0.90	no requirement	NA/WA	CL1
CL2	6500	7000	0.90	no requirement	NA/WA	CL2
P0	9000	See Figure 4-2036:-03		no requirement	NA	P0
P60	9000	See Figure 4-2036:-03		no requirement	NA	P60
P120	9000	See Figure 4-2036:-03		no requirement	NA	P120
IRP0	9550	**see note 3**			NA/WA	IRP0
IRP90	9550	**see note 3**			WA	IRP90

Notes:

1. All wave lengths in Angstroms. All filters have no requirements for lambda < 1700 or for lambda > 11000.

2. CB1: Double-lobe filter centered at 6190 ± 10, with transmission peaks at 6040 and 6340 ± 10. At these wavelengths transmission should be 40% or greater. Integrated transmission for the two lobes should differ by no more than 30%. Block the central 100 Angstroms where transmission is no greater than 2%. Full width half max for each lobe should be 100 ± 20 Angstroms. Blocking outside envelope should be < 10E-4.5.

3. Passband: 600 - 11000. From 7000 - 11000, major principal transmittance ≥ 0.85, minor principal transmittance ≤ 10-3.

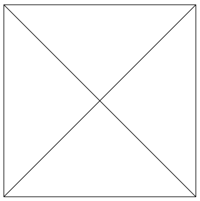

FIGURE 4-2036:-03 ISS Polarizing Filter Requirements (June 16, 1994)

3.3.1 SYSTEM MTF, THROUGHPUT AND OPTICS PERFORMANCE TEMPERATURE REQUIREMENTS

The system modulation transfer function given in TABLE 4-2036:-01, "Cassini Imaging Science Subsystem (ISS) Performance Requirements" is required to meet this performance level broadband. For the narrow angle camera, broadband is defined as 200 to 1100 nm and for the wide angle camera, broadband is defined as 380 - 800 nm. System throughput for both the cameras shall be as given in FIGURE 4-2036:-02, "ISS System Throughput". This requirement is defined over a wavelength range of 300 to 1100 nm for the narrow angle camera, and 380 to 800 nm for the wide angle camera assuming a nominal filter transmission of 0.6 and a nominal filter passband of 100 nm. System throughput for the wide angle camera from 800 - 1100 nm will be to accept the provided capability.

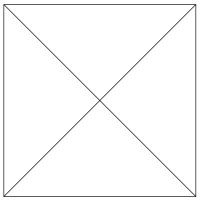

FIGURE 4-2036:-02 ISS System Throughput (July 31, 1992)

ISS Optics performance temperature requirements are listed in TABLE 4-2036:-13, "ISS Temperature Gradient Requirements". These requirements are under internal ISS control. The WAC temperature gradients are goals only.

TABLE 4-2036:-13 ISS Temperature Gradient Requirements (June 16, 1994)

Subassembly	**Requirement**
Optics, Narrow Angle	**± 1°C radially center-to edge for Primary and Secondary Mirrors** **± 2°C axially, Primary to Secondary including connecting structure**
Optics, Wide Angle	**± 5°C radially center-to-edge (goal)** **± 10°C axially along lens barrel (goal)**
CCD	**± 3°C range control** **± .2°C stability control**

3.3.2 RADIOMETRIC REQUIREMENTS

Requirements for the absolute radiometric accuracy of the ISS at delivery of the cameras to the spacecraft are given in TABLE 4-2036:-04, "ISS Radiometric Accuracy". These requirements are defined as a percentage against NBS standards. Ghost images due to ISS internal reflections shall not decrease the MTF of the system by more than 5% in the NAC and 15% in the WAC. Geometric distortion in the ISS camera shall be minimized with a goal for the distortion not to exceed 0.1 pixels anywhere in the frame.

TABLE 4-2036:-04 ISS Radiometric Accuracy (August 6, 1992)

Wavelength Range	**Requirement**
Less than 400 nm	**≤ 10%**
400 nm to 800 nm	**≤ 2% (goal of 1%)**
Greater than 800nm	**≤ 5% (goal of 1%)**

Scattered light within the ISS cameras will be controlled to minimize its effect. The following numbers are goals for the system:

(1) System MTF ≥ 90% at 0.05 cycles/sample
(2) Off-axis point-source attenuation factor of:
$\leq 10^{-4}$ for $\Theta = 6°$ and
$\leq 10^{-10}$ for $\Theta = 40°$

where the attenuation factor is defined as the ratio of light reaching the center pixel from a point source at an angle Θ = x deg off axis (defined above) to the light reaching that pixel when the source is exactly on axis.

NOTE: For in-flight radiometric calibration, natural sources shall generally be used. As a goal, however, the calibration lamps for the WAC (Voyager optics) shall be made available for use in flight.

3.3.3 DYNAMIC RANGE, GAIN, AND LINEARITY REQUIREMENTS

Pixel information from the ISS sensor shall be digitized to 12 binary bits; thus providing 2^{12}, or 4096 discrete levels. The digitizing system transfer characteristic shall be linear, with overall non-linearity (integral non-linearity) not to exceed .5DN, and have no missing codes. As a goal, the signal range encoded in each DN step shall vary by no more than 5%, the signal range encoded over any 10 DN band to vary by no more than 1% and the signal range encoded over any 100 DN band to vary by no more than 0.1%.

The ISS shall maintain the zero exposure DN level ("black level") at a fixed level between 2 and 30 DN in each gain state and summation mode, with variations at any particular level within that band to be stable to ≤ 0.5 DN over a complete frame readout period. In addition, the ISS shall provide at least two over-clock pixels, not to include the first overclock, per line for calibrating the zero-exposure DN level.

The ISS shall have four gain states. The gain states shall encode as follows: (1) a low gain state to provide encoding with its maximum DN value occurring between 90% and 100% of the average CCD full well capacity, (2) a high gain state to provide encoding of 12 e^-/DN, (3) a summation gain state to provide encoding with its maximum DN value occurring between 90% and 100% of the average 2 x 2 summed CCD full well capacity, and (4) a summation gain state to provide encoding with its maximum DN value occurring between 90% and 100% of the average 4 x 4 summed CCD full well capacity.

3.3.4 RESIDUAL IMAGE CONTROL REQUIREMENTS

Residual image effects with the ISS shall be controlled. The parameters used to define an acceptable effect are to have pixels containing measurable levels of charge ≤ 0.1 DN. The level of charge shall be measured within thirty seconds after an image containing ≤ 100% of the pixels reaching 50 times average full well capacity has been exposed. For images containing pixels reaching full well, no residual image effect shall be present.

3.3.5 DATA RATE REQUIREMENTS

The data rates that are required to perform the mission range from 1 to 366 kilobits per second with ≥ 5 specific rates available at any given time. The goal for ISS is to provide as much flexibility as possible to meet these rates. Negotiations for specific data rates which includes spacecraft constraints shall be accommodated. The ISS shall provide data rates which send science packets to the CDS at n packets per RTI where n is 1, 2, 3, 4, 5, and 6. For reference, TABLE 4-2036:-05, "ISS Data Rates and Granularities" gives the current packet size for science data collection and the rates resulting from that packet size and the collection of n packets per RTI to CDS.

TABLE 4-2036:-05 ISS Data Rates and Granularities (June 2, 1994)

Data Rate (kbps)	Packet Size (bits)	Packets/RTI
365.6	7616	6
304.6	7616	5
243.7	7616	4
182.8	7616	3
121.9	7616	2
60.9	7616	1

ISS shall also provide an implementation which allows the cameras to share the maximum data rate allocated by swapping BIU addresses between the NAC and WAC (ISS BIU Swapping.) This swapping shall be transparent to the Spacecraft CDS and Ground Data System. (When ISS BIU Swapping is in effect, the Spacecraft telemetry mode table will carry a non-zero entry for the NAC and a zero entry for the WAC.) This capability shall meet the single point failure requirements of CAS-3-100 (No ISS single point failure may cause the loss of both the WAC and NAC.)

3.3.6 RADIATION CONTROL REQUIREMENTS

The radiation effects on the optics shall be controlled by selecting radiation hardened optics. For the electronics, per CAS 3-100, the ISS shall withstand the predicted environment with a radiation design margin (RDM) of 2 at end of mission (RDM of 3 for shielded parts).

The ISS shall have a goal of limiting energetic particle interactions in the CCD detectors for both cameras. The parameters used to define this goal are:

a) radiation-induced charge shall not change the total signal by more than 50 times the average full well capacity of a pixel over a 100 x 100 pixel area in the NA camera or by more that 0.5 times the average full well capacity of a pixel over a 10 x 10 pixel area in the WA camera during a 30 second period.

b) radiation interactions with the CCD shall not exceed 100/frame in a 30 second period for star calibration images (5000 events/image can be accepted if double shuttered pairs of images are acquired).

c) radiation interactions with the CCD shall not affect more than 2800 pixels in a 30 second period.

d) radiation interactions with the CCD shall not affect more than 10% of the pixels over an integration time of 500 sec.

e) radiation interactions with the CCD shall not affect more than 1000 pixels over an integration time of 100 sec.

3.3.7 BLOOMING CONTROL REQUIREMENTS

The ISS shall incorporate a mode to control CCD blooming effects when high intensity scenes are anticipated. This mode shall prevent one CCD pixel from spilling into another pixel and shall be commandable ON or OFF in flight. The "anti-blooming" mode function shall be accomplished by clocking the CCD in and out of inversion during image integration. Full well performance of the CCD will degrade when this mode is activated.

3.3.8 LIFETIME REQUIREMENTS

As specified in CAS-3-100 "Orbiter System Requirements", the ISS shall meet the Cassini post-launch lifetime requirement of ≥ 12 years including four years of on time, 150 on/off cycles, and 2000 operate/sleep cycles. The ISS shall be capable of taking ≥ 500,000 images during the primary encounter with the Saturnian system. This capability is divided between the narrow and wide angle cameras where the narrow angle camera shall be capable of taking ≥ 300,000 images and the wide angle camera capable of taking ≥ 200,000 images in flight. Additional images for in-flight maintenance and calibration (every six months for the mission) and for pre-launch ground testing shall also be accommodated.

3.3.9 CONTAMINATION REQUIREMENT

The ISS performance shall not be degraded by more than 4% relative transmission in the 200 - 400 nm spectral wavelength band due to contamination sources.

3.3.10 EXPOSURE CONTROL REQUIREMENTS

The ISS shall have 64 commandable exposure durations at any given time. These exposure times shall be updatable in flight.

The minimum interval between exposures shall be given in TABLE 4-2036:-01, "Cassini Imaging Science Subsystem (ISS) Performance Requirements". The minimum calibrated exposure time shall be 5 msec with an accuracy of ± 1 msec. The minimum granularity of exposure times shall be 1 msec. Exposure times shall provide the same actual exposure duration for a given commanded exposure duration to within ± 0.1 msec. In addition, the fraction of light that reaches the ISS focal plane when not exposing the detector shall be $\leq 10^{-8}$ of the light that would reach the focal plane in the shortest exposure time.

3.3.11 FILTER POSITIONING REQUIREMENTS

The total number of filter positions in each ISS camera shall be evenly divided into two wheels to allow two filters with overlapping bandpasses to be spectrally crossed. The assignment of filters to specific positions shall be supplied by the ISS science team. The ISS shall be able to change filter positions at a rate of at least 2 positions per second and shall be able to get to any filter position in $\leq$ 3 seconds. Positioning of the ISS filters shall be commandable by both absolute position commands and by incremental stepping commands. Homing sensors which allow repositioning the filters to a known configuration shall be incorporated.

3.3.12 DATA PROCESSING REQUIREMENTS

3.3.12.1 TWELVE TO EIGHT BIT ENCODING

The ISS shall encode the 12 bit data (4096 dynamic range) to 8 bit data with the encoding values supplied by the science team. As stated in TABLE 4-2036:-01, "Cassini Imaging Science Subsystem (ISS) Performance Requirements", two types of 12 to 8 bit encoders shall be available: (1) a look up table in ROM and (2) reading the 8 least significant bits (LSBs.) Selection of the encoder shall be an in flight commandable parameter. Use of 12 to 8 bit encoding shall also be commandable ON or OFF in flight.

3.3.12.2 LOSSLESS DATA COMPRESSION

To enhance image data return, the ISS shall include a lossless data compressor. The compressor shall be capable of accepting 12 or 8 bit input, and on average, provide a data compression ratio of 2:1 or greater. The compressor shall operate at a rate of $\geq$ 600 kbps and shall not reduce the effective data rate of the camera. The lossless compressor shall be commandable ON or OFF in flight.

3.3.12.3 LOSSY DATA COMPRESSION

The ISS shall include on a best efforts basis, the French Centre Nationale d'Etude Spatiale (CNES) supplied lossy compressor board with the MATRA COFO (compressor formatter) chip set. The lossy compressor shall be commandable ON or OFF in flight. Expected characteristics of the lossy compressor are that it shall be (1) capable of accepting 8 bit data, (2) on average, provide compression ratios from 1:1 to at least 8:1 and (3) operate at a rate of $\geq$ 600 kbps.

3.3.12.4 DATA PATHS

The ISS shall have five data paths for pixel data as described in TABLE 4-2036:-06, "ISS Data Paths". Only one path per exposure may be chosen and none of the processing methods shall reduce the effective data rates.

TABLE 4-2036:-06 ISS Data Paths (September 2, 1993)

Data Path	Definition
12 Bit	The ISS shall convert each pixel to a 12 bit data value.
12 to 8 Bit	The ISS shall convert each pixel to a 12 bit data value and then apply 12 to 8 bit encoding.
Lossless Compression	The ISS shall convert each pixel to a 12 bit data value and then losslessly compress the data.
12 to 8 Bit plus Lossless Compression	The ISS shall convert each pixel to a 12 bit data value, apply 12 to 8 bit encoding, and then losslessly compress the data.
12 to 8 Bit plus Lossy Compression	The ISS shall convert each pixel to a 12 bit data value, apply 12 to 8 bit encoding, and then compress the data with a lossy DCT algorithm.

3.4 OPERATING REQUIREMENTS

The ISS shall accept memory uploads from CDS for program loads and science observation commands.

3.4.1 COMMAND REQUIREMENTS

3.4.1.1 COMMAND STORAGE AND EXPANSION

The ISS shall accept and act upon commands transferred from CDS that contain ISS imaging modes, parameters, and timing. Commands will be transferred as blocks of commands which shall be stored in ISS memory. The ISS shall be capable of accessing sufficient commands to allow acquisition of $\geq$ 5000 images in 168 hours (1 week) without the need for ground intervention. The minimum ISS command storage space shall be 10 kilowords.

Each block shall contain imaging commands which shall be expanded in the ISS which specify camera mode, timing and data taking parameters for several frames of ISS data. There shall be a maximum loss of no more than 2% of the planned images. As a minimum, commands which perform the functions defined in TABLE 4-2036:-07, "ISS Commands" shall be required. Additional commands to operate the cameras, defined internally, may be required.

TABLE 4-2036:-07 ISS Commands (June 16, 1994)

MODE AND TIMING COMMANDS

Function	States/Contents
Spacecraft Time	UTC Time specifying start of frame
Number of Images	≥ 1
Prepare Cycle Duration	Specified in seconds with 5 sec minimum
Readout Cycle	Specified in seconds

IMAGING PARAMETER COMMANDS

Function	States/Contents
Camera ID	NAC or WAC
Gain State	0- 3
Exposure Duration	Reference to table of 64 entries
Filter Wheel	1 or 2
Filter Position	1- 12 for NAC 1- 9 for WAC Step
Filter Wheel Direction	Minimum motion Forward Reverse
Summation Mode	None 2 x 2 4 x 4
12 to 8 Bit Encoding	On or Off Least 8 significant bits or look-up table
2:1 Compression	On or Off
Lossy Compression	On or Off Blocks per group Compression factor Compression constants

TABLE 4-2036:-07 ISS Commands (June 16, 1994)

MODE AND TIMING COMMANDS	
Abort	**Stop all camera functions, reset**

3.4.1.2 GENERAL COMMAND STRUCTURE

ISS science commanding shall be on a frame basis which has an associated frame time. The frame time is split into two major cycles, the prepare cycle and the readout cycle. The prepare cycle time shall be used to perform ISS mode changes, filter wheel stepping, light flooding, and any other defined functions to prepare for an exposure. The prepare cycle shall include the exposure time. The ISS shall also have the ability to take and transmit images with zero exposure time. The readout cycle shall be used to collect pixel data, encode and/or compress the data, collect engineering and status data, and packetize the data.

The ISS prepare cycle shall have a minimum duration of 5 seconds. Specific windows of time shall be allocated during the prepare cycle for performing functions. The window for filter positioning shall range from a minimum of 2 seconds to a maximum of 10 seconds. The window for exposure time shall be minimum of 1 second and a maximum of 20 minutes.

3.4.2 TELEMETRY REQUIREMENTS

3.4.2.1 TELEMETRY COLLECTION

The ISS shall collect pixel data, engineering data, and status data. These data shall be collected and packetized as science telemetry and housekeeping telemetry. Science telemetry shall consist of all three types of data packetized with CCSDS header information. This type of telemetry is used when the ISS is actively taking data. Housekeeping telemetry shall consist of engineering and status data only, also packetized with CDSDS header information. This type of telemetry is output by the ISS whenever it is on, and its memory has been loaded. The interval to collect data within ISS for housekeeping packets shall be programmable. As a minimum, the engineering and status telemetry defined in TABLE 4-2036:-08, "ISS Telemetry" shall be available.

TABLE 4-2036:-08 ISS Telemetry (June 2, 1994)

```
Pixel Data

Engineering Data

    Microprocessor State
    Data Rate
    Voltages (6)
    Currents (1)
    Temperatures (5)
    Look-up Tables (3)

Status Data

    Spacecraft Time
    Camera ID
    12 to 8 Bit Encoding State
    2:1 Compression State
    Lossy Compression State
    Summation Mode State
    Line Number
    Pixel Number Start
    Partial Line Flag State
    Line Error Detected State
    Exposure Start Time
    Exposure Duration
    Exposure Count
    Filter Position
    Shutter Position
    Gain
    Line Truncation
```

Note: Numbers in parentheses indicate the number of items within that category defined (i.e. Temperatures (5) means 5 temperature sensor measurements.)

When the ISS is on without its memory loaded, its only telemetry output is the BIU Discrete Status Bits. During cruise the instrument will regularly perform maintenance without loading memory. Status and errors will be returned on the BIU Discretes. Per CAS-3-310 telemetry from BIU Discrete Status Bits will be collected, downlinked, and made available to the instrument team.

3.4.2.2 PACKETIZATION

ISS data shall be packetized before transmission to CDS using CCSDS standards outlined in CAS-3-271. The ISS science packet shall be 7616 bits long. Within the packet, engineering and status data shall be placed before the image data in order to simplify decommutation. The ISS housekeeping packet shall be 1120 bits long. Three other packets; Memory Dump, Memory Monitor, & HDE Monitor have been defined for test and diagnostic purposes. The Memory Dump packet shall meet the size requirements of the science packet. The other 2 packets shall meet the size requirements of the housekeeping packet.

3.4.3 CAMERA OPERATION REQUIREMENTS

3.4.3.1 COMMAND TIMING

Several timing constraints are placed on the ISS in order to acquire science data at specific points in the spacecraft orbit, to acquire data in concert with other instruments on the spacecraft and to coordinate data taking between the NAC and WAC. To accomplish the first two items, ISS imaging commands shall begin to be issued within 5 milliseconds of the spacecraft time specified by the command. In addition, the shutter close time shall always occur at the same time within a prepare cycle. Shutter open time shall be determined by the commanded exposure time.

To accomplish the last item, the ISS shall be able to command simultaneous shuttering in the NAC and WAC. Simultaneous is defined as closing the shutter within 10 millisecond of each other. Also, in order to simplify ground operations, the ISS shall have the capability to limit camera readout to a single camera at a time (ie, 1024 by 1024 pixels maximum from one camera until completed).

3.4.3.2 POWER MANAGEMENT

The ISS shall limit the power drawn by the subsystem from the spacecraft at or below its given allocation (see section 6.2 of this document). Methods to accomplish are described in Section 4.1, IMAGING SCIENCE SUBSYSTEM OVERVIEW, of this document.

The maximum power state that the ISS NAC and maximum power state that the ISS WAC shall be in (reference to 3-350 power states) for all possible ISS WAC and NAC BIU Power Discrete values is given in TABLE 4-2036:-12, "ISS Valid Power States for Given BIUs Power Discrete States".

TABLE 4-2036:-12 ISS Valid Power States for Given BIUs Power Discrete States (June 2, 1994)

Max. Power State Allowed (refer to 3-350 for values)	BIUs Power Discrete State
Sleep	0
Operate	1

While operating in RAM, ISS internal logic shall not permit transitions to a higher power state than that specified by the current BIU Power discrete bits. If these discrete bits change, the ISS shall ensure its power consumption does not exceed that of the newly specified state by autonomously making any necessary state transitions per the requirements of CAS-3-310.

When operating in PROM, both the ISS WAC and NAC shall start up in the Sleep power state, and remain in that state until their BIU Power Discrete is set to "1". Once that occurs they shall perform maintenance in its entirety. When finished they will be within their Sleep power allocations.

3.4.4 POWER ON, INITIALIZATION, MAINTENANCE & SAFING

At power turn on the ISS Start-up ROM is in control of the instrument and shall perform 3 functions; maintenance, safing, and program load.

Maintenance shall be performed if the BIU Power Discrete Command bit is set to 1. After that bit goes to 1, maintenance will be performed in its entirety. Maintenance shall consist of movements of the NAC and WAC shutters and filter wheels to insure functionality, and will occur once every ~ 3 months throughout cruise.

Another of the BIU Discrete Command bits shall be used to tell the instrument to safe itself after maintenance is completed. Safing shall be performed only if the BIU Safe and Power Discrete Command bits are both set to 1, and maintenance is finished. For each camera, safing consists of crossing the filter wheels to maximize the blockage of light, and opening the shutter.

Program load may be done independent of the Power Discrete Command bit. After program load the ISS shall be put in Sleep mode if the Power Discrete Command bit is 0, or in an idle power state if not. If ISS goes to Sleep mode it shall inhibit filter positioning and shuttering, disable camera detector readout for both cameras, and turn off the WAC Sensor Head Electronics (SHE.) Otherwise it shall issue a shutter reset for both cameras, and turn on the WAC SHE. At this time the camera is ready to be set to any operational state desired by the ISS Team, and coordinated with mission operations personnel and the spacecraft.

3.4.5 OPERATIONAL CONSTRAINTS

The following constraints will be documented in PD-699-270 "Spacecraft Flight Rules and Constraints".

The ISS cameras shall launch in the safe configuration and remain there, except during maintenance, throughout early cruise. After 2 AU this configuration is no longer necessary.

Throughout the mission sun exposure on the ISS radiators will be limited to prevent the CCD temperature from exceeding its upper proto-flight test limit of 60°C. The CCD temperature will be one of the triggers for the Emergency Overtemperature Monitor and Response Algorithm in spacecraft system fault protection.

During tour the ISS boresights shall not be pointed closer than 2° to the limb of the sun during ISS data taking periods.

4.0 SYSTEM DESCRIPTION

4.1 IMAGING SCIENCE SUBSYSTEM OVERVIEW

The Cassini orbiter imaging experiments will encompass a wide variety of targets (Saturn, rings, satellites, star fields) and a wide range of observing distances. Therefore, the ISS will use two separate camera designs. The first is a Narrow Angle Camera (NAC) design which will obtain high resolution images of the target of interest. The second is a Wide Angle Camera (WAC) design which provides a different scale of image resolution and more complete coverage spatially. The spacecraft will carry one NAC and one WAC. The NAC is also used to obtain optical navigation images for the mission with the WAC acting as a functionally redundant backup unit.

Each camera is a framing charge coupled device (CCD) imager. They differ primarily in the design of the optics: the NAC has a focal length of 2000 mm and the WAC, which uses optics inherited from the Vogager mission, has a focal length of 200 mm. Both cameras have a focal plane shutter of the Voyager / Galileo type, and a two-wheel filter changing mechanism derived from the Hubble Space Telescope WF / PC. The filter set and their positions are shown in (TBD reference) and (TBD reference). The cross filter positions for each camera which protect the shutter and CCD from accidental exposure to sunlight down the boresight are shaded. The default (HOME) filter positions are wheel 1/ position 1, wheel 2/ position 1 in each camera. The detector is a charge coupled device (CCD), cooled to suppress dark current and shielded from ionizing radiation.

The electronics for each camera are identical and contain the signal chain and CCD drivers (located in the sensor head), the Cassini Engineering Flight Computer (EFC), command and control logic, a power supply, mechanism drivers, a digital data compressor, a lossy compressor and an interface to the Command and Data Subsystem (CDS). All ISS command and telemetry functions will be handled by the electronics including storage of science commands, expansion of commands, collection of science imaging data and telemetry, transmission of imaging data and telemetry to CDS and receipt of commands from CDS.

The CCD detector design is a square array of 1024^2 pixels, each pixel 12 micrometers on a side. The chip will use three phase, front side illuminated architecture, with a coating of lumogen phosphor to provide ultraviolet response. The detector is passively cooled by a radiator to its nominal operating temperature (-90°C), and then controlled to the operating temperature by a proportional control heater.

The entire NAC is thermally isolated from the Remote Sensing Pallet (RSP) in order to minimize the effects of RSP thermal transients on NAC image quality. The WAC, having an inherited design without having the same stringent imaging requirements, is not thermally isolated.

The ISS will provide a variety of effective data rates to match the input rates of the spacecraft solid state recorder and the real time downlink. There are also several options for data compaction, including on-chip summation, data encoding, lossless compression and lossy compression. A functional block diagram is shown in FIGURE 4-2036:-04, "ISS Functional Block Diagram". A state transition diagram is shown in FIGURE 4-2036:-05, "ISS State Transition Diagram".

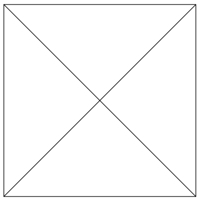

FIGURE 4-2036:-04 ISS Functional Block Diagram (August 13, 1993)

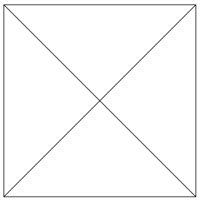

FIGURE 4-2036:-05 ISS State Transition Diagram (June 16, 1994)

ISS controls the amount of power drawn from the spacecraft during operations. To accomplish this, the profile of ISS command timing is structured to allow determination of the power required for a particular internal function (i.e., shutter movement, filter wheel movement) on the ground during sequence generation. During image frame times when the filter wheel is moving, the power from the optical heater (if present) in the active camera is turned off. When the movement is complete, the optical heater is turned on (if needed.) In addition, simultaneous filter positioning within a single camera, either the WAC or NAC, is not permitted.

4.2 OPERATING CONCEPT

During the cruise phase of the Cassini mission, the cameras will periodically be turned on for maintenance, calibration, and monitoring of instrument health and performance. Other than these specified times, the instrument will be off and replacement heaters will be on. Additionally, Decontamination/Radiation Heater 1 will be on throughout most of cruise.

Upon arrival at the Saturnian system, the cameras will be on most of the time. Spacecraft power limitations will be the controlling situation for turning the instrument off or into a low power state.

During the Saturn tour, high activity periods will be clustered around periapse. At this time, high resolution images of Saturn, rings, and moons through various camera filters will be acquired. Data will be stored in the spacecraft solid state recorder. During lower activity levels at apoapse, long term atmospheric and ring (spoke) monitoring and calibrations will be performed.

5.0 INTERFACE REQUIREMENTS

5.1 ELECTRICAL INTERFACES

5.1.1 GENERAL

Requirements for electrical interface circuits are contained in CAS-3-110, Cassini Electrical Interface Listings. All spacecraft non-flight circuits, including direct access circuits, are listed in CAS-3-1110, Support Equipment Functional Block Diagram and Interface Listing Requirements.

Requirements for electrical grounding are contained in CAS-3-260, Electrical Grounding and Interface Circuit Requirements. Specific system-level requirements for electrical interface circuits and grounding are contained in the applicable circuit data sheets.

5.1.2 POWER INTERFACES

The ISS shall meet requirements for the power interface contained in CAS-3-250, Power System Design and Functional Requirements.

5.1.2.1 PRIMARY POWER

The spacecraft Power/Pyro Subsystem (PPS) will provide commandable on-off regulated primary power per the requirements of TABLE 3-250:5.1-01, "Power Bus Regulation at User Input", to the ISS over a single, independent interface for each camera.

TABLE 3-250:5.1-01 Power Bus Regulation at User Input (July 17, 1996)

Condition (c)	Level (a)	Safety inhibit or polarity reversal relay between power switch and User?							
		No					Yes (b)		
		Load Current					Load Current		
		≤ 1A	≤ 2A	≤ 3A	≤ 4A	≤ 4.8A	≤ 1A	≤ 2A	≤ 3A
Used for analysis of power converter efficiency and thermal dissipation	A	30.25V	30.25V	30.25V	30.25V	30.25V	30.25V	30.25V	30.25V
	B	28.36V	27.86V	27.36V	27.86V	27.36V	28.24V	27.62V	27.00V
In-specification: Steady State - accommodates 100W load step.	C	31.50V	31.50V	31.50V	31.50V	31.50V	31.50V	31.50V	31.50V
	D	27.11V	26.62V	26.12V	26.62V	26.12V	26.99V	26.38V	25.76V
In-specification: Transient - ≤ 10 microseconds duration.	E	35.20V	35.20V	35.20V	35.20V	35.20V	35.20V	35.20V	35.20V
	F	23.38V	22.88V	22.39V	22.88V	22.39V	23.26V	22.64V	22.03V
Load Fault: Transient - ≤ 5 milliseconds duration.	G	35.20V	35.20V	35.20V	35.20V	35.20V	35.20V	35.20V	35.20V
	H	23.38V	22.88V	22.39V	22.88V	22.39V	23.26V	22.64V	22.03V

Notes:

(a) See Figure 3-250:5.1-02 "Power Bus Regulation Levels" for illustration of levels referred to

TABLE 3-250:5.1-01 Power Bus Regulation at User Input (July 17, 1996)

```
    in this table.
(b) See CAS-3-251 for users that are provided a polarity reversal function,
    see CAS-3-360 for users that are provided a safety inhibit.
(c) The resistance at ambient temperature is 120 mohm for BOTH the safety inhibit relay and the
    polarity reversal relay.
```

5.1.2.2 REPLACEMENT HEAT

Replacement heat for the ISS will be provided by two circuits from the spacecraft and is documented in CAS-3-110 "Flight Equip. Functional Block Diagram and I/F Listings".

5.1.2.3 DECONTAMINATION HEAT

Decontamination heat for the ISS will be provided by four (4) circuits from the spacecraft and is documented in CAS-3-110 "Flight Equip. Functional Block Diagram and I/F Listings", and CAS-3-251 "Power Switch and Pyro Allocations".

The WAC and NAC decontamination heaters each require 2 circuits and are identical. The first circuit, Radiation/Decontamination Heater 1, is designed to warm the instruments' CCDs to an ambient temperature between 0 and 25°C. It will be turned on shortly after launch, and is planned to be left on throughout the entire cruise period with the exception of Probe Checkouts, Gravity Wave Experiments, and Δ V's (~27 events total). Doing this limits the amount of contamination depositing on the CCD as well as the radiation damage it incurs from the RTGs and space.

In conjunction with Radiation/Decontamination Heater 1 the second circuit, Decontamination Heater 2, shall raise the temperature of the CCD to 50°C maximum in order to drive contamination off of the CCD. It will be used periodically during cruise, and in orbit as needed.

For instrument (both WAC and NAC) safety when decontaminating, it is necessary that either the instrument or its replacement heater be on at the same time as the decontamination heater(s).

5.1.3 COMMAND AND DATA INTERFACES

The ISS shall meet requirements for the command and data interfaces contained in CAS-3-310, S/C Information System Functional Requirements.

5.1.3.1 DATA BUS

The orbiter will provide each camera with connections to the redundant data buses via the BIU. The ISS shall receive commands and timing, and provide telemetry data via the spacecraft data bus. The ISS shall meet the requirements contained in CAS-3-271, S/C Data System Intercommunication Formats, CAS-3-281 S/C Telemetry Formats and Measurements, and CAS-3-291, Uplink Formats and Command Tables.

5.1.3.2 TEMPERATURE SENSORS

The ISS shall have four CDS supplied temperature sensors per camera which are connected directly to and monitored by the Spacecraft Command and Data Subsystem.

5.2 MECHANICAL INTERFACES

5.2.1 ISS MOUNTING

The ISS Camera Assemblies shall be mounted on the fixed remote sensing pallet as specified in CAS-3-180 "Mechanical Configuration Requirements". The ISS main electronics assemblies shall be mounted as specified in the same document. The subsystem shall be compatible with the mechanical interfaces, including optics nitrogen purge, as specified in JPL Interface Control Drawings 10135900 and 10135902 and Drawing 10144252 for the main electronics.

5.2.2 CAMERA ASSEMBLY CARTESIAN COORDINATES

The ISS camera assembly coordinates x_i, y_i, and z_i, are defined as a coordinate system having its origin centered on the CCD. The orientation of $+z_i$ is normal to the CCD surface and is defined by a line beginning from the intersection of the four central pixels of the CCD array towards the look direction of the camera. This is very nearly co-linear with the center of the optical elements of the telescope. x_i is parallel to the plane determined by the camera mounting surface. y_i is the direction normal to the ISS radiator. The CCD array shall be oriented so that scan lines across the image of an object shall be parallel to the ISS/remote sensing pallet mounting surface. The coordinate system and CCD array orientation are shown in FIGURE 4-2036:-06, "ISS Coordinate System and CCD Array Orientation".

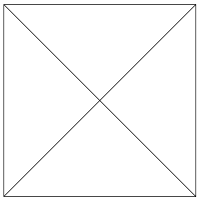

FIGURE 4-2036:-06 ISS Coordinate System and CCD Array Orientation (November 9, 1995)

5.2.3 ALIGNMENT REQUIREMENTS

The ISS shall be aligned in accordance with the requirements of CAS-3-170, Accuracy Requirements and System Capabilities. The NA camera boresight shall be aligned relative to its mounting surface to a control angle of ± 0.3 mrad with a knowledge of ± 0.05 mrad. The WA camera boresight shall be aligned relative to its mounting surface to a control of ± 1.0 mrad with a knowledge of ± 0.1 mrad. The boresight twist in both cameras shall be ≤ 1 degree.

The normal to the ISS radiator shall be perpendicular (in the y-axis direction) to the boresight of the instrument (FIGURE 4-2036:-01, "ISS Configuration").

6.0 PHYSICAL CHARACTERISTICS AND CONSTRAINTS

6.1 MASS

ISS total mass, excluding cabling, shall not exceed its allocated mass as specified in CAS-3-230, Mass Allocations. The ISS shall be compatible with CAS-3-200, Inertial Properties Requirements. For reference only, the allocated mass for ISS is 66.15 kilograms.

6.2 POWER

The power required by the ISS shall not exceed its allocation as specified in CAS-3-350, Power Allocations. For reference only, the allocated power for ISS is 70.8 Watts in the optical remote sensing operational mode, and 43.0 Watts in all other operational modes.

6.3 VOLUME

The ISS shall be compatible with the geometrics as specified in JPL ICDs 10135900 and 10135902 and the ISS volume shall be as specified in CAS-3-180. The volume for each main electronics shall be less than 600 cubic inches.

6.4 PACKAGING REQUIREMENTS

The ISS shall be packaged in accordance with CAS-3-220, Electronic Equipment Design Criteria Requirements.

6.5 ENVIRONMENTAL CONSTRAINTS

6.5.1 GENERAL

Environmental requirements which the ISS is required to meet are given in CAS-3-240, Environmental Design Requirements.

6.5.2 THERMAL LIMITS

6.5.2.1 ALLOWABLE FLIGHT TEMPERATURE LIMITS

The ISS allowable flight temperature limits shall be as given CAS-3-210 "Design Criteria for Temperature Control", and are listed in TABLE 4-2036:-10, "Allowable Flight Temperature Limits (°C)" for reference. The preferred operating temperature range for both the NAC and WAC CHAs is 0 to 10 °C. The temperature of the camera assemblies shall not change by greater than 2 °C per hour after ISS turn-on and stabilization.

TABLE 4-2036:-10 Allowable Flight Temperature Limits (°C) (June 16, 1994)

Assembly or Subassembly	Allowable Flight Temperatures		Assembly Level Flight Acceptance Test Temperatures		Assembly Level Qualification Test Temperatures	
	Operating	Nonoper.	Operating	Nonoper.	Operating	Nonoper.
NA Camera	-10/+25	-20/+35	-15/+30	-25/+40	-35/+50	-45/+55
WA Camera	-10/+25	-20/+35	-15/+30	-25/+40	-35/+50	-45/+55
CCD/Detector	-93/-87	-120/+50	na	na	na	na
Fwd Optics	-10/+25	-20/+35	na	na	na	na
Rear Optics	-20/+35	-40/+50	na	na	na	na
Filter Wheel Housing	-10/+40	-20/+40	na	na	na	na
Sensor Head Housing	-10/+40	-20/+50	na	na	na	na
Main Elec	+5/+50	+5/+50	0/+55	na	-20/+75	na

Note: na = not applicable

6.6 STRUCTURAL DESIGN REQUIREMENTS

The structural design of the ISS shall be in accordance with CAS-3-190 "Structural Design Criteria Requirements".

6.7 FAULT PROTECTION REQUIREMENTS

Fault protection requirements are contained in CAS-3-330 "Fault Protection Requirements".

6.8 OPERATIONAL REQUIREMENTS

The articulation of the movable masses within ISS shall be in accordance with CAS-3-160 "Maneuver and Pointing Requirements".

7.0 SAFETY CONSIDERATIONS

Safety requirements that the ISS is required to meet are given in CAS-3-360 "Safety Requirements". Of primary importance is the requirement that the ISS shall be designed so that if it fails (either through hardware or software failures), it shall not jeopardize the safety of the S/C or damage adjacent instruments.

7.1 OPERATIONAL SAFETY CONSTRAINTS

7.1.1 TEMPERATURE

During flight, subsystem or system-level testing, the ISS camera assembly flight equipment, with the exception of the detector, will not be exposed to temperatures greater than +35 °C or less than -25 °C. The rate of temperature change will not exceed a linear rate of 8 °C/hour.

7.1.2 GROUND TESTING

The optics will never view the solar simulator lights.

The ISS CCD/Radiator shall not exceed its allowable flight non-operating temperatures. These temperatures are given as the CCD/Detector temperatures in TABLE 4-2036:-10, "Allowable Flight Temperature Limits (°C)".

7.1.3 ANGLE CONSTRAINT TO SOLAR DISK

Under nominal conditions, the following will apply: (1) the angle between the ISS optical axis and the closest edge of the solar disc will never be less than 20 degrees when the spacecraft is less than 5 AU from the sun; (2) when the spacecraft is between 1.0 and 5.0 AU, the constraints given in TABLE 4-2036:-11, "Viewing Time vs Angle of Optical Axis to Solar Disc, 1 to 5 AU" will apply; and (3) from 70 to 180 degrees, there is no constraint. Between 5 AU and Saturn, the ISS optical axis will not intentionally be pointed closer than 5 degrees from the solar disc. At Saturn, very high phase angle (2 degrees from the sun) observations are desired by the science team. These observations will be allowed under limited conditions to be specified and agreed on among the remote sensing pallet instrument scientists.

TABLE 4-2036:-11 Viewing Time vs Angle of Optical Axis to Solar Disc, 1 to 5 AU (July 31, 1992)

Angle of Optical Axis to Solar Disc (degrees)	Viewing Time
20 to 30	ÅÚ9 minutes
30 to 53	ÅÚ3 minutes
53 to 70	ÅÚcos Θ hours

8.0 SPECIAL REQUIREMENTS

8.1 MECHANICAL

The spacecraft configuration will provide the ISS an ≥ ±45 degree conical field-of-view free of any part of the spacecraft and free of stray light.

8.2 POINTING CAPABILITY, CONTROL AND KNOWLEDGE

The orbiter system will provide the capability to point the ISS z_i-vector over the angle ranges specified in CAS-3-160. Pointing control and knowledge for the ISS z_i-vector will be provided as specified in CAS-3-170, Accuracy Requirements and System Capabilities.

8.3 SLEW RATES AND SETTLING TIME

The orbiter system will provide ISS z_i-vector slew rates and settling time as specified in CAS-3-160.

8.4 EXTERNAL CONTAMINATION CONSTRAINT

As specified in 699-004, paragraph 4.2.2.3, total molecular contamination from spacecraft sources at the aperture entrances of the Imaging Science Subsystem will not exceed the following during the mission lifetime:

Narrow Angle Camera	266 $\mu g/cm^2$
Wide Angle Camera	1375 $\mu g/cm^2$

8.5 GROUND HANDLING AND GAS PURGE

8.5.1 GROUND HANDLING

During ground operations, storage and transportation, the ISS will be controlled to a temperature range of -25 °C to +35 °C and will have a controlled humidity environment of 30% to 50% .

When directly handling the ISS cameras, the appropriate lifting fixture provided with the camera shall be used.

All personnel touching or handling the ISS cameras shall be grounded to prevent electrostatic damage. If the cameras are attached to the RSP, personnel handling the RSP shall be grounded.

ISS protective covers shall be over the ISS apertures at all times. Exceptions shall be coordinated and approved by the ISS System Engineer or designated ISS personnel. The covers shall be removed before launch.

8.5.2 GAS PURGE

The ISS will receive purge gas from the spacecraft science instrument purge equipment starting at spacecraft assembly and lasting until launch. In controlled cleanroom conditions, the ISS will not be without purge for a period greater than one (1) hour in any 24 hour period unless approved by the ISS systems engineer. Purge downtime during off nominal cleanroom conditions will be less than thirty (30) minutes and the ISS camera assembly cover must be in place.

The gas quality, flow rate, and other requirements are specified in CAS-3-240. The purge equipment will provide a sharp edge orifice sized appropriately such that the instrument flow rate stays within the limits specified CAS-3-240 when the purge gas input pressure is as specified in CAS-3-240. The purge equipment will provide a 50 micron or less filter upstream from the orifice in order to guard against inadvertent plugging. The mechanical details of the purge equipment/ISS interface connector will be specified by the ICDs. The ISS will provide the location and structural support of the interface connector. The ISS will also provide sufficient exhaust port area such that the pressure on the downstream side of the flow control orifice provided by the purge equipment does not exceed 0.1 PSI above local ambient pressure at 1 atmosphere and at vacuum at the maximum flow rate specified in CAS-3-240.

ACRONYM LIST

AU	astronomical unit
CCD	charge coupled device
CCSDS	Consultative Committee on Space and Data Standards
CDS	Command and Data Subsystem
CHA	Camera Head Assembly
CNES	Centre Nationale d'Etude Spatiale
cos	cosine
EFC	Engineering Flight Computer
DN	data number
°	degree(s)
C	Centrigrade
e^-	electrons(s)
FWHM	full width/half maximum
HDE	Housekeeping Data Electronics
ICD	interface control drawing
ID	identification
IFOV	instantaneous field-of-view
IR	infrared
ISS	Imaging Science Subsystem
JPL	Jet Propulsion Laboratory
kbps	kilobits per second
kg	kilograms
LSBs	Least Significant Bits
min	minutes
mm	millimeter
mrad	milliradians
msec	milliseconds
MTF	modulation transfer function
nm	nanometer
NA	Narrow Angle
NAC	Narrow Angle Camera
NBS	National Bureau of Standards
PPS	Power/Pyro Subsystem
RDM	radiation design margin
rms	root mean square
RSP	Remote Sensing Pallet

RTI	real time interrupt
S/C	Spacecraft
sec	seconds
SEU	single event upset
SHE	Sensor Head Electronics
TBD	to be determined
UTC	universal time, coordinated
um	micrometer
uv	ultraviolet
Vdc	volts dc
W	watts
WA	Wide Angle
WAC	Wide Angle Camera

REVISION LOG

Revision	Date	ECRs Incorporated	Comments
Original Issue	31 Jul 92		Cassini Redesign and Baseline Updates
Amendment 1	9 Mar 93	80065, 80082, 80089	
Amendment 2	2 Sep 93	80251	
Amendment 3	14 Sep 93	80232	
Revision A	2 Jun 94	80086, 80195, 80208 80243, 80326, 80333 80488	
Revision B	16 Jun 94	80505, 80507	
Amendment 1	10 Nov 95	80748, 80871	
Amendment 2	5 Sep 97	81011	
Revision C	9 Oct 97	82100	

These paragraph-sequence-discrepancies were found in: CAS-4-2036

8.5.2
(65682) Paragraph is out of sequence.