PRELIMINARY

CASSINI

Imaging Science Subsystem (ISS)

Operations Document

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Introduction to the Imaging Science Subsystem

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 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 lossless 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 10242 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 ~10°C below its nominal operating temperature (-90°C), and then controlled to the operating temperature by a proportional control heater. To minimize radiator size and heater power the detector / radiator combination is thermally isolated from the rest of the Camera Head Assembly (CHA.)

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.

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.

General Operating Concepts

Launch and Cruise

ISS is in a non-operating state during the launch phase and for most of the cruise activities. The exception to this state is periodic maintenance during cruise and occasional checkout activities to monitor instrument health and functionality. Decontamination activities are also conducted during this phase. The ISS launch configuration for each camera has two non-overlapping filters crossed to protect against accidental incident sunlight. These filter combinations are the 656N (HAL) and 727N (MT2) filters for both the NAC and WAC. After the spacecraft has travelled beyond 2 AU, it is not necessary to cross the filters for boresight protection.

Off State

No power is drawn by the ISS main electronic assemblies (MEA) in either the Narrow Angle Camera (NAC) or Wide Angle Camera (WAC) in the Off power state. The spacecraft controlled replacement heaters and Level 1 decontamination heaters are required to be on. The replacement heaters keep the ISS within allowable flight non-operating temperature limits and the Level 1 decontamination heaters provide for CCD protection from the radiation environment. For replacement heater power , decontamination heater power and allowable flight temperatures in this state, see sections 2.5 and 2.6 respectively of this document.

Replacement heaters are controlled by the spacecraft and are normally activated when the cameras are OFF to maintain reasonable internal temperatures for the cameras. The heaters are located in the optical and sensor head assemblies on the science platform. Thermal control for the ISS Main Electronics Assembly (MEA) is provided within the spacecraft bus.

Maintenance

Maintenance activities are scheduled to take place four times per year during cruise. Each camera of the ISS will have power applied and will excercise the filter wheel and shutter mechanisms. This activity is programmed into read-only-memory (ROM) code in each camera. To activate maintenance, power is applied to the ISS MEAs and the spacecraft Command and Data Subsystem (CDS) turns the ISS Sleep discrete bit off. At the conclusion of the mechanism movement, the ROM code will loop until either a discrete is set telling the camera to "safe" (cross its filters and open the shutter for boresight protection from accidental incident sunlight), or power is turned off. [Program load can also take place but is not expected to be a cruise activity]. For a description of the ROM code, see section 2.2.1 of this document. During maintenance activities, the replacement heaters and the Level 1 decontamination heaters are on.

Decontamination

For a 30 days post launch, commencing within the first few days after launch, ISS will have its decontamination heater configured to level 2. After this initial 30 day period, level 2 decontamination activities are scheduled to take place at the same time as maintenance activities. In addition to the Level 1 heater, the spacecraft controlled Level 2 decontamination heater is turned on. It is not necessary to apply power to the MEAs in either the NAC or WAC during decontamination of the instrument. The power to the Level 2 decontamination heater needs to be on for greater than 8 hours for complete decontamination of the ISS to take place. For the upper allowable flight temperature during this activity, see section 0 of this document.

SOI - 2 Years and Orbit

Beginning at Saturn orbit insertion (SOI) 2 years, power is applied to the ISS for calibration and optical navigation activities. The ISS alternates between the Sleep, Idle, and Active states until these activities are completed. During the Saturn tour, 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. Activities at apoapse include long term atmospheric / ring monitoring imaging (movies) and calibrations.

Power On and ROM

When power is applied to the cameras, the Read-Only-Memory (ROM) code is executed. ISS is always brought up with the Sleep discrete bit on.

Sleep

The ISS Sleep state is a non-data taking power state in the cameras to be used when no activity will take place for an extended period of time. During this state, the MEA and sensor head electronics are drawing power, and the optics and CCD heaters are on to maintain operating temperature limits. The ISS will not accept commands in this state. Spacecraft controlled replacement heaters are off. The decontamination heaters may be used, if necessary.

Operating

The ISS Operating mode can be selected to acquire science data and to perform Calibration and Maintenance functions. In the Operating states, the replacement heaters and decomtamination heaters are off. The camera software has active control over performance heaters to set appropriate operating temperatures for the optics and CCD detector. The ISS will process and execute commands in this mode.

Idle

Idle is a program state first entered following program load into ISS RAM. Engineering data is monitored until the camera has reached thermal equilibrium and is ready to operate. When the camera is operating, Idle is a background state used for command processing. The camera always returns to Idle state after completing a command sequence.

Active

The active state is entered to collect science data as well as for calibration and maintenance activities. Command execution in the active state includes science data readout, filter wheel movement, shutter movement, activation of light flood and calibration lamps, and other high power consuming activities.

Decontamination

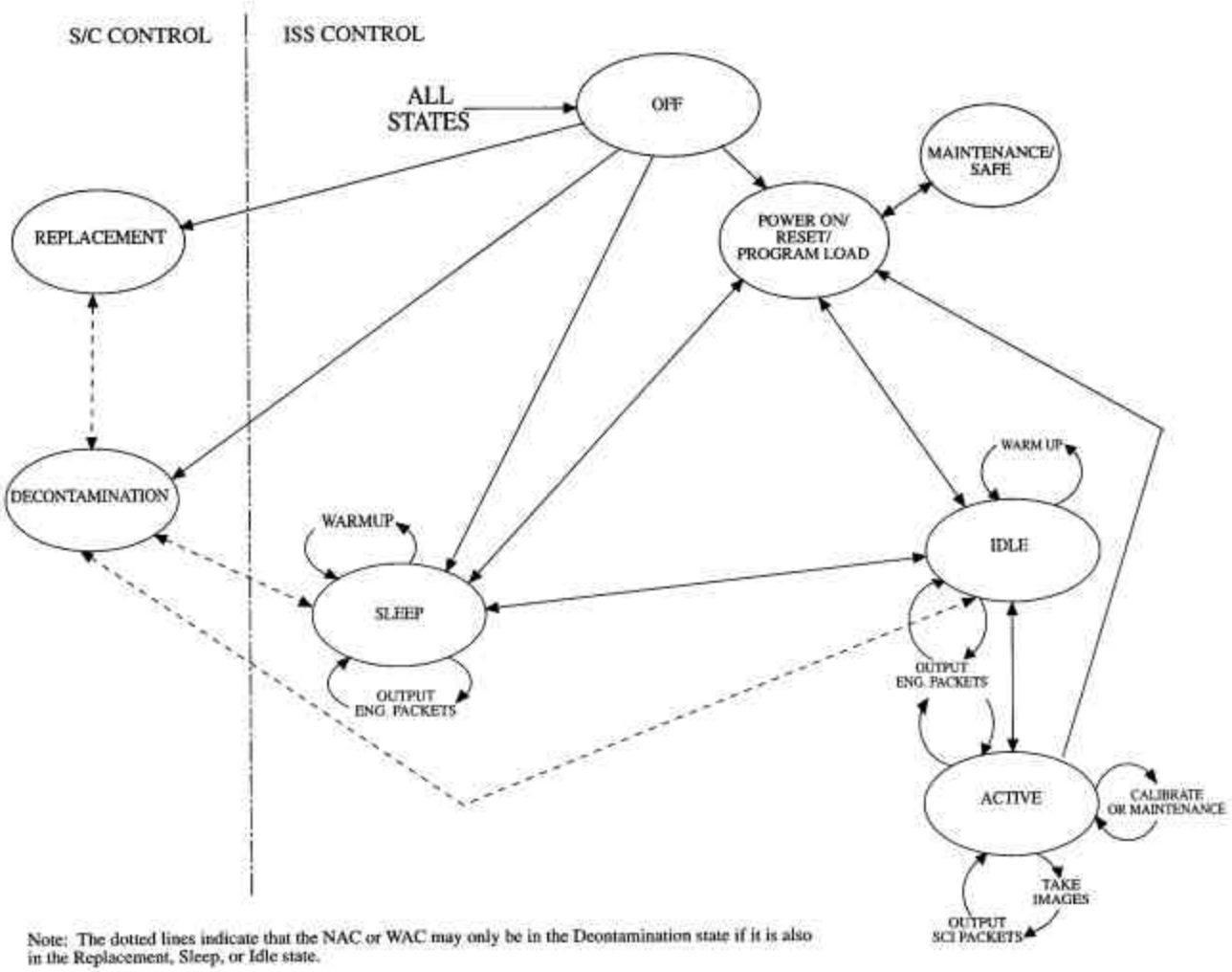
Heaters specifically for decontamination are activated to drive molecular contaminents from the ISS optics and detectors. The heaters are normally activated when the camera(s) are OFF. Both WAC and NAC can be in the decontamination mode concurrently. There are TWO decontamination states corresponding to two levels of decontamination heater power for each camera.

Detailed Camera Information

State Diagram

The ISS State Diagram is presented in Figure 0-1. For a description of each state, see section **Error! Reference source not found.** of this document.

Figure 0-1 ISS State Diagram



Note: The dotted lines indicate that the NAC or WAC may only be in the Decontamination state if it is also in the Replacement, Sleep, or Idle state.

Peak Power Table

ISS peak power estimates are presented in Table 0-1.

Table 0-1 ISS Peak Power

Camera State	Estimated Power for NAC (W)	Estimated Power for WAC (W)
Off (includes replacement heat)	8.4	4.5
Sleep	22.3	16.4
Idle	22.3	16.4
Active	26.2	19.4
Decon Level 1 (includes replacement heat)	25.7	21.4
Decon Level 2 (includes replacement heat)	35.0	30.7

ISS Temperature Control

Temperature Sensors

The temperature sensor and heater locations for controlling the temperatures of the cameras are given in Figure 0-2 and Figure 0-3. The default reference temperatures for the cameras are NAC = 5 ^{o}C, WACLO = 0 ^{o}C, and WACHI = 20 ^{o}C.

Allowable Flight Temperatures

Allowable flight temperatures are presented in Table 0-2.

Table 0-2 Flight Allowable Temperatures

Imaging Science Subsystem (ISS)	**Operating Min/Max (^{o}C)**	**Non-Operating Min/Max (^{o}C)**
Narrow Angle Camera Assembly	**-10/+25**	**-20/+35**
Detector (CCD)	-93 / -87	-120 / +50
Forward Optics	-10 / +25	-20 / +35
Rear Optics	-20 / +35	-40 / +50
Filter Wheel Housing	-10 / +40	-20 / +40
Sensor Head Housing	-10 / +40	-20 / +50
NAC Main Electronics Assembly	**+5/+50**	**+5/+50**
Wide Angle Camera Assembly	**-10/+25**	**-20/+35**
Detector (CCD)	-93 / -87	-120 / +50
Forward Optics	-10 / +25	-20 / +35
Rear Optics	-20 / +35	-40 / +50
Filter Wheel Housing	-10 / +40	-20 / +40
Sensor Head Housing	-10 / +40	-20 / +50
WAC Main Electronics Assembly	**+5/+50**	**+5/+50**

Figure 0-2 NAC Temperature Sensor and Heater Locations

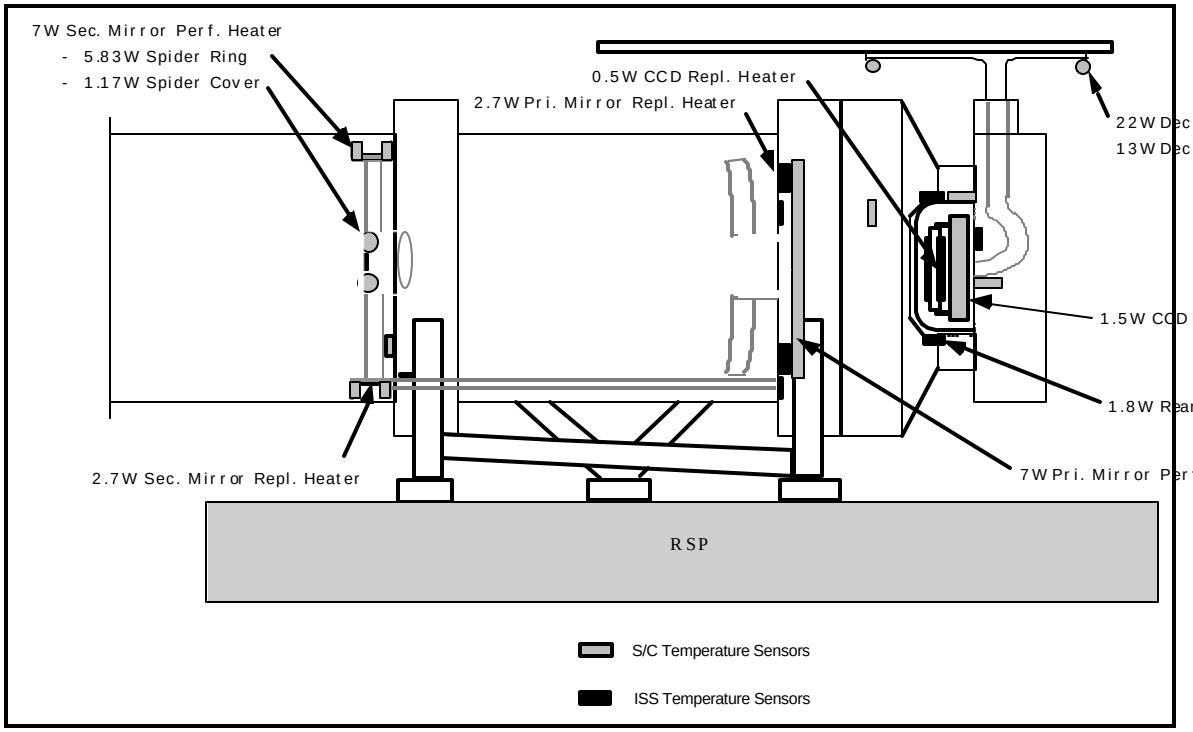
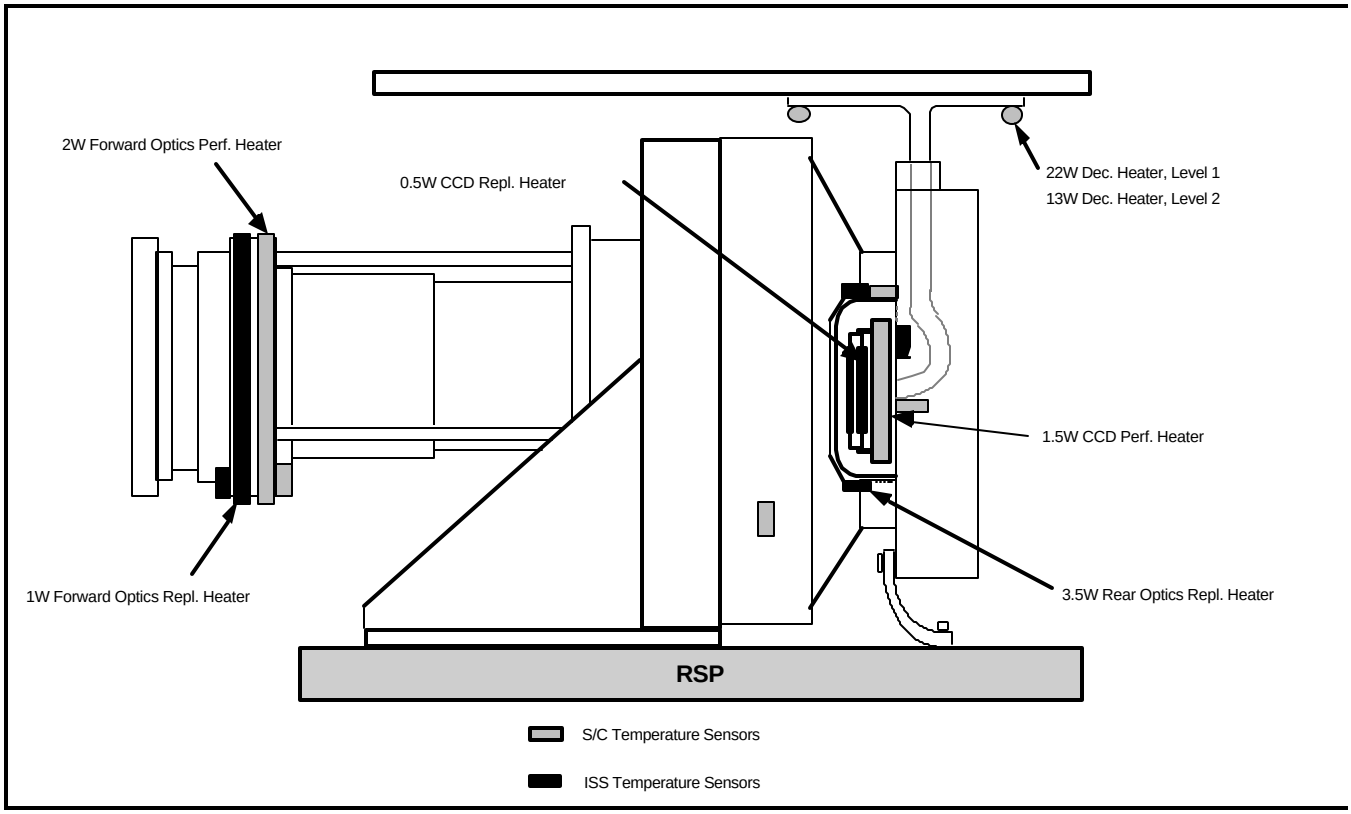


Figure 0-3 WAC Temperature Sensor and Heater Locations



Filter Wheel

The filter set and their positions are shown in Figure 0-4 and Figure 0-5. 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.

Figure 0-4 ISS Filter Positions for NAC

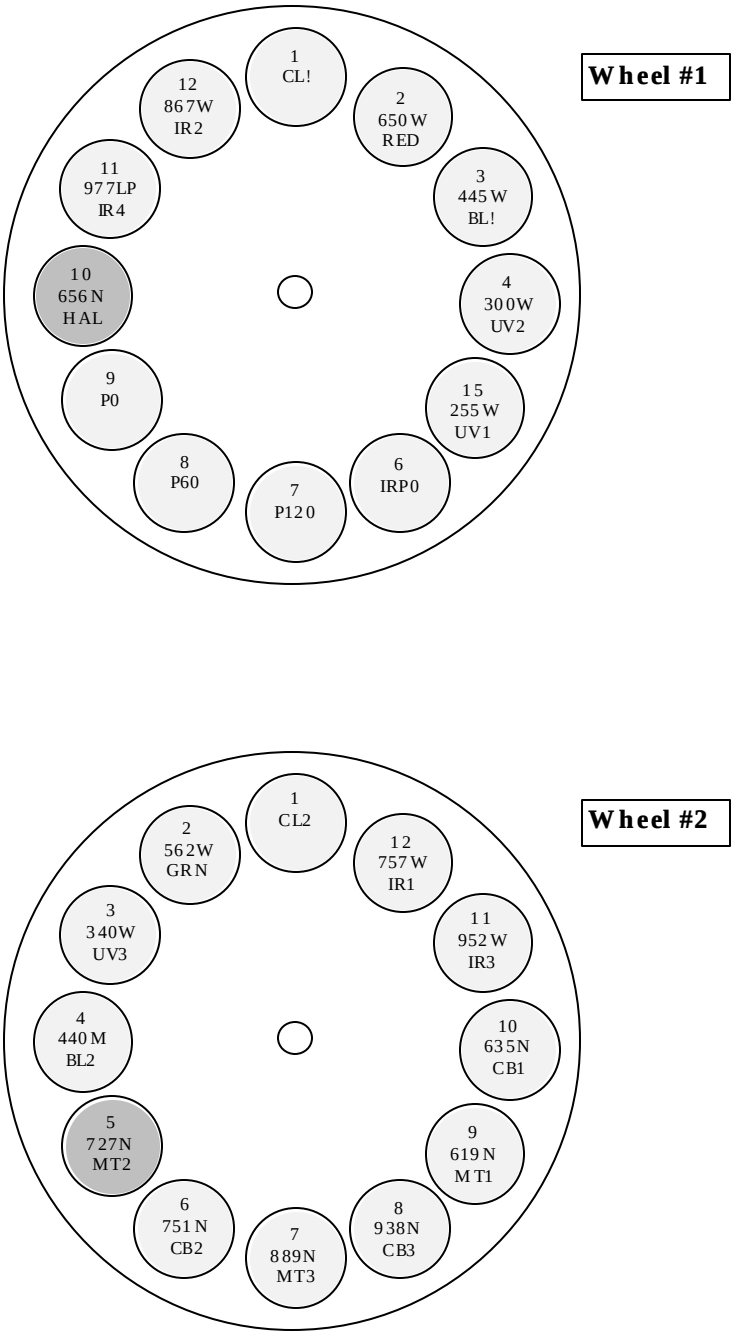
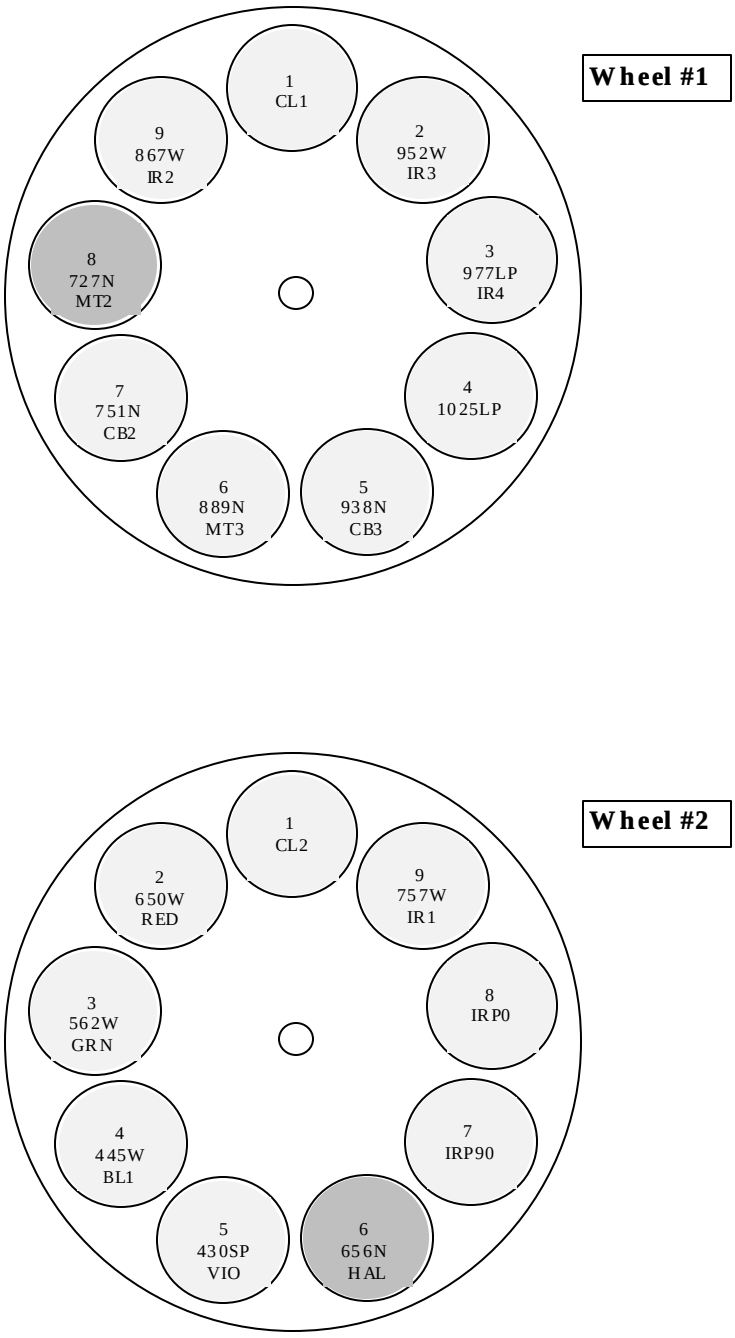


Figure 0-5 ISS Filter Positions for WAC



The ISS Command Set

ISS Commands from the Spacecraft CDS

There are several commands which control ISS functions that are sent from the spacecraft Command And Data Subsystem (CDS). A summary of these commands is given in Table 0-1. Detail of these commands can be found in Appendix 1 of this document or in CAS 3-291.

Table 0-1 ISS External Command Set

Cmd Stem	Cmd ID	Descriptive Summary
36NAC_ALF	32	NAC ALF Data Blk Receive
36NAC_ALF_END	35	NAC ALF End Blk Receive
36NAC_ALF_SKIP	37	NAC ALF Skip Blk Receive
36NAC_HALT	224	Puts the NAC into Sleep State
36NAC_INST_DATA	134	Pass instantaneous data to the NAC Instrument
36NAC_TRIGGER	128	Triggers the execution of an NAC internal command within NAC command memory
36NAC_UPLOAD	81	Transfers a block of upload data to NAC instrument upload memory.
36NAC_UPLOAD_END	240	Indicates the end of an Upload
36NAC_WAKEUP	16	Wakes up the NAC from Sleep State and causes it to enter IDLE / ACTIVE State
36PS_NAC	n / a	Turns ON or OFF the NAC Electronics
36PS_NAC_DECON1	n / a	Turns ON or OFF the NAC Radiation / Decontamination Heater 1
36PS_NAC_DECON2	n / a	Turns ON or OFF the NAC Decontamination Heater 2
36PS_NAC_HTR	n / a	Turns ON or OFF the NAC Replacement Heater
36PS_WAC	n / a	Turns ON or OFF the WAC Electronics
36PS_WAC_DECON1	n / a	Turns ON or OFF the WAC Radiation / Decontamination Heater 1
36PS_WAC_DECON2	n / a	Turns ON or OFF the WAC Decontamination Heater 2
36PS_WAC_HTR	n / a	Turns ON or OFF the WAC Replacement Heater
36RT_NAC_SAFE	n / a	An Interlock which tells the NAC to safe itself
36RT_NAC_SLEEP	n / a	An Interlock which holds NAC Software in Sleep Mode Operations or, if in RAM, releases it so that it can be commanded to another mode. If in ROM, releasing the interlock initiates maintenance.
36RT_WAC_SAFE	n / a	An Interlock which tells the WAC to safe itself
36RT_WAC_SLEEP	n / a	An Interlock which holds WAC Software in Sleep Mode Operations or, if in RAM, releases it so that it can be commanded to another mode. If in ROM, releasing the interlock initiates maintenance.

36RT_WDTERR_NAC	n / a	Enable / Disable the Watchdog Timer Expired Flag in the NAC BIU
36RT_WDTERR_WAC	n / a	Enable / Disable the Watchdog Timer Expired Flag in the WAC BIU
36RT_WPERR_NAC	n / a	Clear / Set the Write Protect Violation Flag in the NAC BIU
36RT_WPERR_WAC	n / a	Clear / Set the Write Protect Violation Flag in the WAC BIU
36RT_WPFNC_NAC	n / a	Enable / Disable the Write Protect Function in NAC BIU
36RT_WPFNC_WAC	n / a	Enable / Disable the Write Protect Function in WAC BIU
36WAC_ALF	32	WAC ALF Data Blk Receive
36WAC_ALF_END	35	WAC ALF End Blk Receive
36WAC_ALF_SKIP	37	WAC ALF Skip Blk Receive
36WAC_HALT	224	Puts the WAC into Sleep State
36WAC_INST_DATA	134	Pass instantaneous data to the WAC Instrument
36WAC_TRIGGER	128	Triggers the execution of an WAC internal command within WAC command memory
36WAC_UPLOAD	81	Transfers a block of upload data to WAC instrument upload memory.
36WAC_UPLOAD_END	240	Indicates the end of an Upload
36WAC_WAKEUP	16	Wakes up the WAC from Sleep State and causes it to enter IDLE / ACTIVE State

Since this section does not contain any ISS Instrument Internal Commands no ISS commands are wrapped and the WRAP function is not being implemented for ISS.

ISS Internal Commands

Commands from the ISS Flight Software

The commands that are available internal to the cameras are given in Table 0-2. Ther e are two major types of commands - Immediate and Triggerable. Immediate commands are interpreted with the flight software as soon as they are encountered. Triggerable commands are stored in the ISS memory until a TRIGGER command is received from the spacecraft. Each command in the table is identified as one of these types.

Command Syntax

The general syntax of a command is the command name followed by the command parameters. Command names and parameter names may be 1 or more words each. They are not case-sensitive. Parameter values follow their parameter names. Some parameter values are case-sensitive, for example comments and file names. They must be enclosed by double quotation marks. Command names, parameter names, and parameter values are separated by white space (blanks, tabs, newlines). There is no punctuation or other special character recognition.

In the following list of commands, the command name is uppercase bold. The parameters are listed below the command name, the parameter names on the left and the parameter values on the right. Multiple choice parameter values are separated by a **/** character. Numeric values are indicated by a **#** followed by the minimum and maximum values of the parameter. Hexadecimal values are indicated by a **X** followed by the minimum and maximum values in hex. String parameter values are indicated by a **$** followed by the maximum length of the string.

Housekeeping and science item numbers are specified by H and S respectively, followed by a range of numbers. Parentheses indicate that a list of item numbers is to be enclosed in parentheses in the command. Names of housekeeping and science items may be used in place of numbers. Omitting an item list is equivalent to a list of all items.

Table 0-2 ISS Internal Command Set

CMD Name	CMD Paramter	CMD Parameter values	Remarks
CAL LAMP			Set cal lamp.
(Immediate)	Operations	Off / On / / Interval	
	Seconds	# / 0 / 63	
FILTER			Set filter wheel.
(Immediate)	Wheel	1 / 2	1 or 2
	Position	# / 0 / 12	0 to 12
	Direction	Forward / Reverse	
	Flag	Absolute/Relative/Home	
FLOOD LIGHT			light to saturate ccd
(Immediate)	Operation	Off / On / / Interval	Remove residual dn
	Milliseconds	#	0 to 32767
HDE			Request HDE data.
(Immediate)	Flag	Normal / Select	Select= on
	Code	# / 0 / 31	channel# 0 to 31
	Rate	# 0 / 255 (sampling rate)	in units of 5secons
HEATER			Control heater
(Immediate)	Name	# / 0 / 15	0 = heater1

CMD Name	CMD Paramter	CMD Parameter values	Remarks
	Control	Off / On / Regulate / Interval	1= heater 2
	Interval	# / 0 / 31	of time in seconds.
IMAGE EVENT			
(Triggerable)	RO Index	# / 0 / 15	Readout cycle index
	Prepare Index	# / 0 / 15	Prepare cycle index
	Delay Time	#	time bet' image pos
	Position Count	#	#of images acquire
	Offset Time	#	trigger offset time
	Id	#	command id
	Order	# / 0 / 1	0=NAC Readout 1st
ITERATION			# of iterations
	Count	#	
	Filter1 Position	# / 0 / 11	
	Filter2 Position	# / 0 / 11	
	Exposure Index	# / 0 / 63	
	Gain State	# / 0 / 3	
	Summation	1x1 / 2x2 / 4x4	
	Lossy	Off / On	
	Blocks Per GOB	# / 1 / 255	Lossy group of bloc
	Compression Rate	# / 0 / 15	Lossy
	Malgo	Off / On	Lossy algorithm bit
	Tb	Off / On	Lossy Block Type
	Camera	Nac / Wac	
LOAD MACRO	Id	#13 / 32767	load temporary
END MACRO			To end macros
Load PMACRO	Id	# / 1 / 12	Must be 1..12. (T)
Load Memory			Load fsw memory
	Start address	X / 0 / FFFFF	starting at address
	File Name	$ 99	from a file
MonitorMemory			request 6 mem
(Immediate)	State	Off / On	
	addr count	# / 0 / 6	# of mem locations
	rate	# / 0 / 255 (sampling rate)	in units of 5ms
	Addr1	X / 0 / FFFFFF	
	Addr2	X / 0 / FFFFFF	
	Addr3	X / 0 / FFFFFF	
	Addr4	X / 0 / FFFFFF	
	Addr5	X / 0 / FFFFFF	
	Addr6	X / 0 / FFFFFF	
NOOP	Size	# / 0 / 117	Does nothing (I)
PORT			Write device port
(Immediate)	Page	X / 0 / FF	page #
	Addr	X / 0 / FFF	address
	Value	X / 0 / FFFF	value to write
	Mask	X / 0 / FFFF	
Read Memory			Read fsw memory
(Immediate)	Start ADdress	X / 0 / FFFFF	
	Stop Address	X / 0 / FFFFF	

CMD Name	CMD Paramter	CMD Parameter values	Remarks
SET CAMERA			Camera parameters
(Triggerable)	Summation Mode	1x1 / 2x2 / 4x4	
	Conversion Type	12-Bits / 8-Lsbs / 12-8	
	Compression Style	None / Lossless / Lossy	
	Blocks Per GOB	# / 1 / 255	
	Compreesion Rate	# / 0 /15	
	Malgo	Off / On	
	TB	Off / On	
	Id	# 0, 13 / 32767	0: use default id
	Reset	no / yes	n: reset camera state
SET COMP1			
(Triggerable)	Anti-blooming	Off / On	
	Erase	Off / On	
	State	Off / Sleep / Idle / Active	
SET COMP2	Pc Voltage	# / 0 / 15	Triggerable cmd
SET COMP3	Video Offset	X / 0 / FF	Triggerable cmd
SHUTTER			Set shutter
(Immediate)	Blade	A / B	
	Op	Reset / Activate / / Expose	
	Time	#	
TCE			Control temperature
(Immediate)	Flag	Off / On / Regulate / Interval	
	Seconds	# / 0 / 63	
WAIT			cause fsw to pause
(Immediate)	Seconds	# / 0 / 255	
	Milliseconds	# / 0 / 65535	
XSUB			Change fsw codes
	Id	# / 0 / 4	which xsub cmd.
	Value	# / 0 / 255	points to uploaded routine body