SMEI Instrument Commanding Protocol

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Issue 5

15 November 2004

Table Of Contents

Index of Tables

1. Introduction

The purpose of this document is to provide an overview of the commanding strategy and available commands for the SMEI data handling unit (DHU). Detailed command formats are given in the 'SMEI Instrument Commanding Specification' (SMEI/BU/SPE/002).

This document does not cover mechanisms for transmission of SMEI commands to the spacecraft, nor reception of SMEI telemetry.

2. Commanding Overview

The SMEI instrument has a number of discrete modes of operation. In each mode, only a subset of the available commands are permitted. This provides a measure of protection from software and commanding errors by requiring a multiple command sequence to be sent for some operations. It also permits the overall complexity of the control software to be reduced by minimising the number of interactions between data processing and instrument state change tasks.

Mode Name	MNEMONIC	Description
COLD START / BOOT	CS	Used during the boot sequence before applying software patches to the system software. This mode is used to recover from a corrupted data upload.
SAFE	SAFE	Used during emergencies. Entering this mode attempts to close the shutters and reduce SMEI power requirements to a minimum.
CONFIGURE / STANDBY	CONF	Used to select observing and instrument configurations. Thermal control settings can also be modified in this mode.
OBSERVING	OBS	Data acquisition mode. Camera images are only taken in this mode. Instrument configuration changes are not permitted.
PATCHING	PATCH	Non-volatile storage update mode. Permits the use of commands to modify data in the E^2PROM.
BOOT-PATCH	BOOTPATCH	This mode is available only from cold-start mode, and is used for recovery of a corrupted data upload.

Table 1 - Primary Instrument Modes

Commands to the SMEI DHU are supplied over a redundant MILSPEC-1553 bus. All the command blocks are structured with the same two word header, containing the command number, a sequence number, and the command checksum (CRC). The command blocks are all thirty two 16-bit words in length, and spare words are filled with zeros. This document does not consider the 1553 command words.

SMEI has three sub-addresses for different types of commands from the spacecraft. Sub-address 4 is used for standard commands. These are routine commands to change the instrument configuration, start observations and so forth.

Sub-address 5 is used during spacecraft emergencies to shutdown SMEI rapidly. Only the emergency safe command is accepted on this sub-address.

Sub-address 6 is used for supplying SMEI with time and attitude information.

Commands received by SMEI are returned as part of the telemetry stream. The command and instrument status return housekeeping block contains the command identifiers, checksums and processing status of the last 8 commands received, along with accepted and rejected command counts.

3. Command Summary

The table here summarises the available standard commands (sent via S/A 4), and shows which modes each command is available in. A brief description of each command is also given. The DHU ignores commands not permitted in the current operating mode. Boot-patch mode is very similar to standard patch mode, so where the command validity table is different to patch mode, the boot-patch setting is shown in brackets.

COMMAND	AVAILABLE MODES					Description
	CS	SAFE	CONF	OBS	PATCH	
SM_ENBL_SAFE	Y		Y	Y	Y (N)	Enable safe mode
SM_GOTO_SAFE	Y		Y	Y	Y (N)	Enter safe mode
SM_ENBL_PTCH	Y		Y			Enable patch mode
SM_GOTO_PTCH	Y[1]		Y			Enter patch mode
SM_GOTO_CONF		Y		Y	Y (N)	Enter configuration mode
SM_GOTO_OBS			Y			Enter observing mode
SM_DHU_COLD	Y					Continue boot sequence
SM_ENBL_SCNF	Y		Y			Enable system configuration
SM_SYS_CONF	Y		Y			System configuration control
SM_PATCH_UPL					Y	Upload patch data
SM_PATCH_BIN					Y	Upload compressed patch data
SM_PATCH_CMT					Y	Write patch data to E^{2}PROM
SM_PATCH_DEA					Y	Deactivate a code patch
SM_PATCH_ACT					Y	Activate a code patch
SM_THERM_CTRL			Y			Set-up camera thermal control
SM_1_PWR_ON			Y			Switch on camera power relay
SM_1_ICE_OFF			Y			Switch off de-ice heater
SM_1_ICE_ON			Y			Switch on de-ice heater
SM_1_HOP_EN			Y			Enable HOP activation command
SM_1_HOP_TEST			Y			Run a HOP continuity test
SM_1_HOP_ACT			Y			Active the HOP
SM_1_CONF			Y			Load a predefined configuration
SM_1_DYN_CONF			Y			Load a dynamic configuration
SM_1_MOTOR			Y			Change the shutter position
SM_2_PWR_ON			Y			Switch on camera power relay
SM_2_ICE_OFF			Y			Switch off de-ice heater
SM_2_ICE_ON			Y			Switch on de-ice heater
SM_2_HOP_EN			Y			Enable HOP activation command
SM_2_HOP_TEST			Y			Run a HOP continuity test
SM_2_HOP_ACT			Y			Active the HOP
SM_2_CONF			Y			Load a predefined configuration
SM_2_DYN_CONF			Y			Load a dynamic configuration
SM_2_MOTOR			Y			Change the shutter position
SM_3_PWR_ON			Y			Switch on camera power relay
SM_3_ICE_OFF			Y			Switch off de-ice heater
SM_3_ICE_ON			Y			Switch on de-ice heater
SM_3_HOP_EN			Y			Enable HOP activation command
SM_3_HOP_TEST			Y			Run a HOP continuity test
SM_3_HOP_ACT			Y			Active the HOP
SM_3_CONF			Y			Load a predefined configuration
SM_3_DYN_CONF			Y			Load a dynamic configuration
SM_3_MOTOR			Y			Change the shutter position

Table 2 - Standard Command Summary

In addition to the standard commands, SMEI recognises a spacecraft emergency command (sent via S/A 5), and attempts to make safe the SMEI instrument, and to reduce power consumption to a minimum. This command does not require an enable.

COMMAND	AVAILABLE MODES					Description
	CS	SAFE	CONF	OBS	PATCH	
SM_EMERG_SAFE	Y	Y	Y	Y	Y	Emergency safe mode

Table 3 - Emergency Safe Mode

The final 'command' recognised by SMEI contains time and attitude data sent via S/A 6.

COMMAND	AVAILABLE MODES					Description
	CS	SAFE	CONF	OBS	PATCH	
SM_SC_ATT	Y	Y	Y	Y	Y	Provide time and attitude data

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[1] From CS mode, this command enters BOOT-PATCH mode.

Table 4 - Time and Attitude Data

4. Detailed Command Descriptions

This section provides details of the parameters taken by each command. A number of the commands are per camera. To reduce the duplication in this section, we replace '1', '2' and '3' with the generic identifier '*x*'.

4.1 SM_ENBL_SAFE

This command is used to enable the SM_GOTO_SAFE command. It acts as protection from accidentally shutting down the instrument.

4.2 SM_GOTO_SAFE

This command puts SMEI into safe mode, in preparation for being switched off by the spacecraft. It is only performed if the preceding command is SM_ENBL_SAFE, and they are issued within 60 seconds.

4.3 SM_ENBL_PTCH

This command is used to enable the SM_GOTO_PTCH command. It acts as protection from accidentally entering the E^{2}PROM update mode.

4.4 SM_GOTO_PTCH

This command puts SMEI into patch mode, or boot-patch mode. It is only performed if the preceding command is SM_ENBL_PTCH, and they are issued within 60 seconds. Boot-patch mode is entered if the current SMEI mode is cold-start, and is used for recovery from corrupted data uploads.

4.5 SM_GOTO_CONF

This command puts SMEI into configuration mode. This mode is used to change observing parameters, thermal control settings and to change the system configuration word.

4.6 SM_GOTO_OBS

This command puts SMEI into observation mode. The camera configurations set in configuration mode are used to configure the CCD electronics, and images acquisition is started.

4.7 SM_DHU_COLD

This command finishes the SMEI boot process and enters configuration mode. The boot process pauses in cold start mode before the system software checks the uploaded software image area of the E^{2}PROM. This allows recovery from a corrupted E^{2}PROM image by directly entering patch mode and either disabling or re-uploading a fresh software image.

4.8 SM_ENBL_SCNF

This command is used to enable the SM_SYS_CONF command. It acts as protection from accidentally changing the global configuration register.

4.9 SM_SYS_CONF

This command provides access to the SMEI instrument global configuration register. This command is used to enable data test modes for interface tests, and tweak internal behaviour for problem diagnosis. The command contains a logical-and mask, and a logical-xor mask. Appropriate use permits individual bits of the SMEI global configuration register to be set, cleared or toggled. It is only performed if the preceding command is SM_ENBL_SCNF, and they are issued within 60 seconds. The most significant bit of the global

configuration is defined as a command test bit. It can be set and cleared without changing the behaviour of the instrument.

4.10 SM_PATCH_UPL

This command supplies 29 words of binary patch data to SMEI. The 29 words are written into an 5 kiloword buffer at the commanded offset. Issuing this command repeatedly permits a complete patch to be uploaded to the buffer before it is committed to the E^{2}PROM using the SM_PATCH_CMT command.

4.11 SM_PATCH_BIN

This command supplies 29 words of compressed binary patch data to SMEI. The 29 words are arranged as a set of 3-bit symbols, with each symbol being expanded to one or two pre-defined pixel values. Issuing this command repeatedly permits a complete patch to be uploaded to the buffer before it is committed to the E^{2}PROM using the SM_PATCH_CMT command.

Symbol	Word 1	Word 2
000	0xFFFF	
001	0x7FFF	
010	0x5331	
011	0x3FFF	
100	0x0000	
101	0x3FFF	0x3FFF
110	0x5331	0x5331
111	0x5331	0x0000

Table 5 - Symbol Expansion Table

Symbols are tightly packed and can stradle two consecutive command words. The first symbol is in the least significant bits.

There are 154 symbols per command, and these expand to between 154 and 308 16-bit values. Care must be taken to ensure that the command does not overflow the patch buffer space.

4.12 SM_PATCH_CMT

This command copies the commanded portion of the patch buffer to the given location in the E^{2}PROM. It is used after a patch has been uploaded by SM_PATCH_UPL to commit the change to the non-volatile store. The SMEI DHU can take longer than 200ms to commit a large patch. This command therefore requires a delay of 5 seconds to be inserted after a commit command before another command is transmitted.

This command can also be used to update all eight copies of the flight software stored in the Boot E^{2}Prom. The test connector must be present, and the Boot E^{2}Prom write enable switches set, and the special loader software image installed, as per the SMEI Instrument Onboard Data and Software Update Procedure (SMEI/BU/PRO/006).

Pages	Function
0x40	Command Processing Tables
0x41	Camera ASIC Setup Tables
0x42	Software Upload Storage Area
0x43	Camera Mode Configuration Tables
0x44	Temporary Software Patch Store (Ground-based updates only)
0x45	Spare
0x46	1553 Interface Configuration Table
0x47	Spare
0x48 - 0x4f	Camera 1 Flat Field Tables
0x50 - 0x57	Camera 2 Flat Field Tables
0x58 - 0x5f	Camera 3 Flat Field Tables
0x80	Boot E^{2}Prom (Requires Test Connector Enable)

Table 6 - Onboard E^{2}Prom Page Usage

4.13 SM_PATCH_DEA

This command deactivates an uploaded software patch. Software images are committed to a special region in the E^{2}PROM which is reserved for this purpose. This patch sets the checksums used to verify the presence and validity of an uploaded software image to an invalid pattern. This prevents the uploaded software image from being used.

4.14 SM_PATCH_ACT

This command activates an uploaded software patch by writing the commanded software image CRC value to the E^{2}PROM. Software patches are are only loaded if the CRC value is correct. This CRC is calculated using the 16-bit SDLC CRC algorithm.

4.15 SM_THERM_CTRL

This command sets the control temperatures for the three camera cold fingers. It also sets the maximum number of heaters that are permitted to be active at any given point in time. This allows active control of the cold finger temperature to prevent thermal cycling of the cold finger to CCD bonding material.

4.16 SM_*x*_PWR_ON

This command switches on the power relay for a camera. This enables power to the secondary switching facilities in the DHU, and does not switch on the cameras directly. There is no corresponding off command to avoid a single point failure.

4.17 SM_*x*_ICE_OFF

This command switches off a de-icing heater override. Note that the active temperature control settings configured using SM_THERM_CTRL have precedence over this command.

4.18 SM_*x*_ICE_ON

This command enables a de-icing heater for the specified amount of time. The target temperature for the cold finger is also specified, and if the temperature is below that specified, the heater is switched on. Note that this command overrides the global thermal control specified in SM_THERM_CTRL.

This command was extended to provide a fixed-duty cycle option. The target temperature word was split into two 8-bit fields. IF the most significant byte is zero, then the command retains the original function, with the least significant byte indicating the target temperature.

If the most significant byte, N, is non zero, it indicates a duty cycle of N/16 * 100%. The least significant byte must be zero.

4.19 SM_*x*_HOP_EN

This command enables the SM_*x*_HOP_ACT command. This serves as protection against accidental activation of the HOP. Note that the camera relay must also be in the ON position for the HOP to be fired.

4.20 SM_*x*_HOP_TEST

This command is used to test the continuity of the HOP firing circuitry. It switches on the HOP briefly, and allows the instrument power monitor to register the increase in current while the HOP is powered. This command requires that the camera power relay is in the ON position. It does not require SM_x_HOP_EN to have been sent, as a single erroneous transmission of this command will not cause the hop to fire.

4.21 SM_*x*_HOP_ACT

This command activates the HOP for the specified duration. It is only performed if the SM_*x*_HOP_EN command was the previous command, and that both are issued within 60 seconds. Note that the camera power relay must be in the ON position for power to be supplied to the HOP.

4.22 SM_*x*_CONF

This command selects a predefined observation configuration for the specified camera. It copies the relevant table from the E²PROM. The currently configured observation parrameters are returned in the telemetry stream.

N	Camera Mode Description	CCD Binning	Rice Comp	ROI Filter	Flat-Field	Shutter Position	FF LED
0	Off	-	-	-	-	Flat Field	Off
1	Standby	-	-	-	-	Flat Field	Off
2	Eng (Default)	1 x 1	On	On	Off	Open	Off
3	Hi-Res (Default)	2 x 2	On	On	On	Open	Off
4	Normal (Default)	4 x 4	On	On	On	Open	Off
5	Normal (Low FF Cal)	4 x 4	On	Off	Off	Open	On
6	Normal (Med FF Cal)	4 x 4	On	Off	Off	Closed	On
7	Normal (High FF Cal)	4 x 4	On	Off	Off	Flat Field	On
8	Eng (Low FF Cal)	1 x 1	On	Off	Off	Open	On
9	Eng (Med FF Cal)	1 x 1	On	Off	Off	Closed	On
10	Eng (High FF Cal)	1 x 1	On	Off	Off	Flat Field	On
11	Eng (Low FF Cal)	1 x 1	On	On	Off	Open	On
12	Eng (Med FF Cal)	1 x 1	On	On	Off	Closed	On
13	Eng (High FF Cal)	1 x 1	On	On	Off	Flat Field	On
14	Eng (No ROI)	1 x 1	On	Off	Off	Open	Off
15	Eng (ROI LED FF)	1 x 1	On	On	On	Flat Field	On

Table 7 - Predefined Camera Configurations

Notes: 'Off' mode switches off the camera electronics at the next GOTO_OBS command.
'Standby' mode leaves the electronics on but inhibits camera readout.

Mapping of shutter positions against motor coil phases (parameter N in the 'SM_X_MOTOR N,T' command) is given in the following table.

Shutter Position	Motor Phase		Shutter Monitor
	DHU A	DHU B	
Open	1	3	Open = 1
Closed	2	2	Open = 0
Flat Field	0	0	Open = 0

Table 8 - Shutter Position To Motor Phase Relationship

Note: Different motor phases are required for 'Open' position for the two DHUs in order get valid feedback from the shutter position monitor.

Other camera configurations can be set using the 'SM_X_DYN_CONF command where the thirty words of configuration data D_{00} to D_{29} must be supplied.

4.23 SM_*x*_DYN_CONF

This command sets the observation configuration for the camera to the uploaded data supplied. This allows test or infrequently used configurations to be configured 'on the fly', without requiring changes to the E^{2}PROM.

4.24 SM_*x*_MOTOR

This command can be used to manually test the filter wheel stepper motor. The supplied parameters indicate which of the four coils to energise, and the duration. Note that the camera power relay must be in the ON position for power to be switched.

Bits	Function
0-7	Phase to energise (1 / 2 / 4 / 8)
8-15	Camera identifier (1 / 2 / 3)
16-23	Time to energize phase (seconds)
23-31	Settle time after energizing (seconds)

Table 9 - Shutter Control Command Fields

4.25 SM_EMERG_SAFE

This command is issued during emergency conditions. On receipt, SMEI immediately switches off the three cameras, and attempts to sequentially close the shutters, starting with camera 3. Note that SMEI does not protect this command. It's format is defined in Section C of the Interface Control Document. It is ignored unless it is received on sub-address 5.

4.26 SM_SC_ATT

This command provides the time and attitude solution data to SMEI. The format is defined in Section C of the Interface Control Document. The time provided is used to timestamp the SMEI science data stream. Post-processing of the SMEI science data uses the attitude solution for star substraction. It must be received on sub-address 6.

5. References

SMEI Instrument Command Specification   SMEI/BU/SPE/002

SMEI Instrument Telemetry Specification   SMEI/BU/SPE/004

SMEI Instrument Onboard Data and Software Update Procedure   SMEI/BU/PRO/006

Coriolis Interface Control Document   CDRL NO. 004