SPICAM LIGHT

Flight User / Operations MANUAL

A-1. Approval Page:

Written by: E. Dimarellis Service d'Aéronomie du CNRS

Approved by :

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ESA

Authorised for Mars Express Project:

……

Authorised for the Principal Investigator:

……
J.L. Bertaux, Principal Investigator

A-2. List of contents:

A-3. Documentation change record:

Issue	Rev.	Sec.	Page	Date	Changes
000	0	All	All	99 08 22	First Draft Issue
001		All	All	00 02 01	Updates after IPRD
002			several add para 7.2	00 09 05	Power, mass... TM/TC packet structures updates
003		All	add Section 6 add annexes	01 11 09 01 11 27	Reformat, updates from database Update FM1 power
004		All		02 04 17	Update after FM1 DRB

A-4. Distribution list:

Recipient	Institute	No. of Copies

A-5. List of Acronyms:

A/D	Analog to Digital
AOTF	Acousto-optic tunable filter
BE	Bloc electronique
BIRA	Belgisch Instituut voor Ruimte-Aëronomie
CCD	Charge Coupled Device
DPU	Dedicated Processor Unit
EGSE	Electrical Ground support Equipment
FM	Flight Model
GSE	Ground support Equipment
IASB	Institut d'Aeronomie Spatiale de Belgique
I/F	Interface
I/O	Input/Output
IR	Infrared
MOC	Mission Operation Center
MTF	Modulation Transfer Function
NA	Not Applicable
NIR	Near Infrared
PI	Principal Investigator
PM	Project Manager
PRNU	Photo-Response Non-Uniformity
QM	Qualification Model
SA	Service d'Aeronomie du CNRS
S/C	Spacecraft
SEU	Single Event Upset
SPICAM	SPectroscopy for the Investigation of Characteristics of the Atmosphere of Mars
SIR	Spicam Sensor IR
SUV	Spicam Sensor UV
SU	Spicam Sensor Unit
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TM	Telemetry
UV	Ultra Violet

PURPOSE

This document contains all the information needed to correctly operate in-flight Spicam Light in both nominal and emergency conditions.

CONTENT

This document describes the specific operational rules (and constraints) to operate the instrument during the spacecraft non-ground lifetime.

1. General Description:

1.1. Overview:

This document presents the Flight User Manual (FUM) for the Mars Express payload instrument SPICAM LIGHT. It defines the mission objectives, physical and functional configuration and operations modes of the instrument and also describes how the instrument can be controlled, utilised and monitored by ground operations.

The following documents are referenced in this Flight User Manual, and may be referred to if more information is required.

Reference Number	Title	Issue Number	Date
MEX-MMT-SP-0007	PID-A	2	Jun 7, 1999
SP-DES-011	PID-B	2	Aou 23,2000
SP-DES-012	EICD	3	Jun 9, 2000
ME-ESC-IF-5001	SGICD	2	Dec 20, 1999
-	Spicam BE soft reference et user manual	22	Jun 18, 2001
MEX-MMT-MA-xxx	Medoc reference guide Index 96 - Spicam	draft1	Jan 5 2001

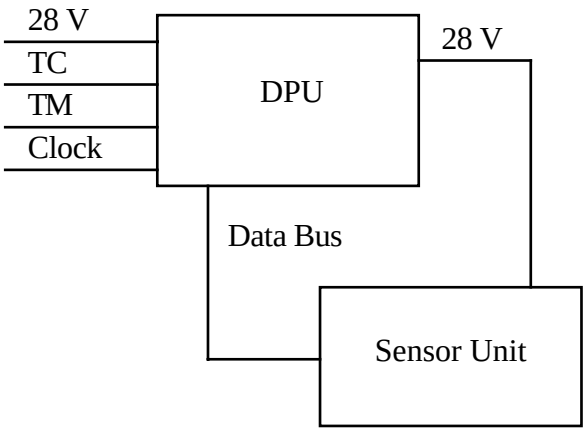
This FUM consists of 9 major Sections and the contents of these are summarised here and details are presented in the different individual sections.

Section 1 ‘General Description’
presents the scope of this document and a summary of scientific objectives
Section 2 ‘Instrument Configuration’
presents electrical and software configuration and gives all budgets
Section 3 ‘Detailed Description’ presents instrument description
Section 4 ‘Instrument Operations’ presents the nominal operations plan
Section 5 ‘Modes Description’ describes the various modes of operations of the instrument
Section 6 ‘Interfaces’ describes the interfaces with S/C
Section 7 ‘Nominal and Contingency Operations Procedures’ describes all procedures
Section 8 ‘Summary of Telemetry and Telecommand Data’ describes all telemetry packets
Section 9 ‘Data Operations Handbook'

1.2. Instrument summary:

SPICAM Light is a collaboration of Service d'Aéronomie, Verrieres le Buisson, France; IASB, Bruxelles, Belgique and IKI, Moscou, Russia.

The Spicam Light instrument is made of 2 boxes as depicted below. The first box called DPU acts as the main electronic interface with the Spacecraft. The other is the sensor box or unit. This sensor unit has one channel in the ultraviolet wavelength range - 118-320 nm - (named SUV), and another one (named SIR) in the near infrared wavelength range - 1.1-1.7 μm.



Mars Express / Spicam Light , General Concept

mar 22, 1999

SPICAM Light: DPU electronic block, Data processing Unit
SU Sensor Unit, with one UV channel and one IR channel

Table 1.1. SPICAM Light Main characteristics summary Table

Spectral bands	118 - 320 nm (UV) 1.1 - 1.7 μm (IR)
Spectral sampling	UV: 0.55 nm/pix IR: 0.8 nm/pix at 1.5 μm
Mass	DPU 0.71 kg SU 4.14 kg Total 4.85 kg
Power	DPU+SU 17 W to 26 W
Volume	DPU: 1.65 x 1.14 x 0.65 dm^3 SU: 4 x 2.4 x 1.15 dm^3
Data rate	9 and 34 kbit/s (*)
Data Volume	100 - 300 Mbits / day
Observations	One Board Time TC, One Spicam TC Duration: 5 to 30 mn
Pointing (orientation)	Inertial Star Inertial Sun Nadir

(*) averaged over several seconds

SPICAM LIGHT is a collaboration between Service d'Aéronomie in Verrieres Le Buisson, IASB in Bruxelles, and IKI Moscow.

1.3. Scientific objectives:

The Sensor UV is looking through the atmosphere of Mars either at :

a star :	vertical profiles by stellar occultation technique (CO_2, Temperature, ...)
the Nadir:	integrated profiles (O_3, ...)
the Limb :	vertical profiles of high atmosphere emissions
the Sun :	UV vertical profiles by solar occultation technique

The Sensor IR SIR is only used in the Nadir looking mode (column abondances, H_2O,CO_2..)

The suite of measurements of SPICAM Light in the various operation modes are addressing key questions of the atmosphere of Mars, present state, climate and evolution.

Chemistry: Simultaneous measurements of O_3 and H_2O will allow to validate and/or modify chemistry models, from which will be derived an assessment of the oxidation environment (effect of solar UV, O_3, H_2O_2, O, on minerals and oxidation molecules).

Structure/Dynamics/Meteorology: Vertical profiles of density / temperature (20-160 km) will provide unique information about the global structure and dynamics of the atmosphere, in particular in the altitude region crucial for aerocapture and aerobraking, and a better understanding of meteorological systems.

Clouds/dust/ aerosols: Occultation measurements will allow to detect, measure and characterise the physical nature of aerosols, and dust particles, and their vertical distribution.

Ionosphere/escape rate: Vertical profiling of daylight aeronomic emissions (H, C, O, CO, CO_2^+) will allow to adjust a comprehensive model of the ionosphere, from which an estimate of escape processes may be derived (evolution of the atmosphere), and to study the interaction with the solar wind.

In order to fulfill the previous scientific objectives, there are four configurations summarized below:

	Mode	Expected results
UV	Stellar occultation	Concentration vertical profile
UV	Solar occultation	Concentration vertical profile
UV+IR	Nadir	Total column abondance
UV	Limb emissions	Vertical profiling of aeronomic emissions

SUMMARY OF SPICAM Light SCIENTIFIC OBJECTIVES

Species	**Measurements**			**Accuracy**	**Altitude range**
	Scientific objective	**Mode (occultation, nadir, limb)**	**Spectral range**		
O_3	Concentration vertical profile	Stellar / Solar occultation	220 –300 nm	2 – 10 %	10 – 50 km
O_3	Total abundance	Nadir	220 –300 nm	5 % (>0.15 µ–atm)	N.A.
CO_2	Atmospheric density and temperature vertical profile	Solar / Stellar occultation	180 nm	2 – 10 % 5 K	20 – 160 km
Aerosols	Vertical profile of characteristics	Solar / stellar occultation	UV	10^{-3}(=photo-metric)	5 – 60 km
O_2	Concentration vertical profile	Stellar occultation	200 nm	20 %	35 – 90 km (never done before)
H, C, O, CO_2^+,CO	Vertical profiling of aeronomic emissions	Limb emission	118– 320 nm	20 %	80 – 400 km
H_2O_2	Total abundance	Nadir	210 nm	20 %	Never done before
SO_2	Total abundance	Nadir	220 nm		Tentative

CO_2	Surface pressure	Nadir	200 nm 1.43 µm	0.2 mbar 0.05 mbar	N.A.
H_2O	Total abundance	Nadir	1.38 µm	0.2. pr. µ m (detectable)	5 x 5 km ground
Aerosols	Mapping of properties	Spectro polarimetry in nadir	1.2 to 1.7 µm	10^{-3} (=photometric)	Exploratory
Soil	surface studies	Spectro polarimetry in nadir	1.2 to 1.7 µm	10^{-3} (=photometric)	5 x 5 km ground

1.4. Design Description:

The Sensor Unit is made of:
- the servitudes channel
- the UV channel
- the IR channel

The Sensor Unit has two openings for Nadir viewing, one for UV channel, the other for IR channel located on the Nadir face of S/C. In addition, there is an opening for Solar viewing. This Solar aperture is not on the S/C Nadir face.

The Sensor Unit has two mechanisms, one which move On and Off a slit in the UV channel, the other which moves a shutter on the Solar aperture.Spicam mechanisms are fully autonomous and no separate commands are needed for mechanism operations. Each mechanism has two statuses, ON and OFF for slit, OPEN and CLOSED for shutter.

The UV channel is a spectrometer with an optical baffle, an off axis parabolic mirror, a slit with two positions, a grating and a detector which an intensified CCD. On the CCD, the rows which are parallel to the unit baseplate, are the spectral dimension.

The IR channel is made of an entrance lens, an AOTF and two single pixels detectors (for each polarisation). As the AOTF acts as a filter, the IR spectrum is obtained by electrically scanning the AOTF frequency.

All the channels have their own digital electronics which performs all operations at detector level and digitizes the data, then waiting for transmission to the DPU through a RS422 link at 937 kbits/s.

The DPU main functions are:
- electrical interfaces with S/C
- send commands and get data from the subunits
- formatting data before transmission to S/C

In this document, flight software means software of the DPU.

There is no redundancy in the instrument, unless the Data and power connectors.

1.5. Operating principles.

There are four kinds of observations for SPICAM Light:
- Nadir observations, for Sensor Unit (UV and IR detectors):
- Star Occultation mode (UV channel):
- SUN Occultation mode (UV and IR channels):
- Bright limb observations (UV and IR (tentative) channels):

The observation is executed totally automatically, under SC control, in a schedule defined on ground, loaded well before execution.

The operating principle for one observation is:

- Put Spacecraft in good attitude for one kind of observation
- Switch On by S/C
- Send Spicam observation TC by S/C
- Record TM by S/C
- Switch Off by S/C at the end of observation.
- Put Spacecraft in nominal attitude

1.6. Operational profile

Summary of operation modes:

The operation modes of Spicam are test mode (ground use), Star mode, Sun mode, Limb mode and Nadir mode. The operation modes are derived from the scientific objectives and correlated Spacecraft attitudes.

Nadir: during the mission phase "Nadir", both UV and IR channel are operated.

Star, Sun, Limb: these modes need dedicated attitude from Spacecraft, only UV channel is used for Star mode.

For more details see section 5.

1.7. Performance

Spectral resolution and SNR performances:

The following table shows for each observation mode, data product and estimated performances of UV Channel (resolution and SNR). SNR is calculated with summation of pixels along the slit.

Observation Mode	product	Resolution (nm) [1]	estimated SNR (at 250 nm)	Comments
Star	density, T vertical profile	1	50	1 sec integration visual magnitude = 0.04
SUN	density, T vertical profile	2	> SNR star	
Nadir	Integrated density (O_3, H_2O,)	2	280/600	1 sec integration 100 pixels summ narrow/ 40 pixels summ large
Limb	Emission vertical profile	2	45	4 sec integration 50 pixels summ narrow

(1): along the narrow slit for extended sources.
with large slit, resolution is 11 nm, SNR is increased accordingly.

The following table shows data product and estimated performances of IR Channel in Nadir mode for two wavelengths.

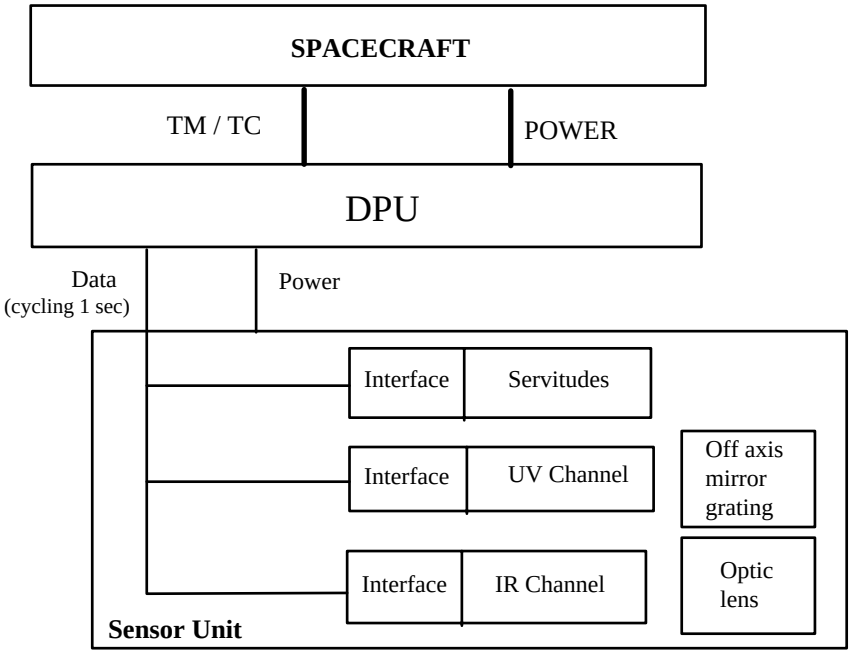
wavelength (micron)	Signal at The detector, nW	Resolution (nm)	estimated SNR	Comments
1.3	1.4	~ 0.7	100	
1.7	1.41	1.12	150	

The end-to end performances are summarized in the Scientific objectives table (section 1.3).

2. Instrument configuration:

2.1 Hierarchical configuration:

The relationship between the subsystems are shown in the the synoptic below (see also section 1.2).



SPICAM Light synoptique 99 12 02

The DPU has the general control of the instrument. It sends commands to the sub units and retrieves data. Then it formats and produces telemetry packets.

Servitudes refers to non-detector elements of Sensor Unit.

The polling of the sub units is done done by the DPU, at a rate defined in the Telecommand.

Depending on the operationg mode, The IR channel is switched On or not.

2.2 Physical configuration:

The Sensor Unit has two main directions of sight, one is Nadir (s/c +Z), the other is "behind" Solar panel, -Y side.

The Sensor Unit has two openings for Nadir viewing, one for UV channel, the other for IR channel located on the Nadir face of S/C.The instrument's optical axis is parallel to the baseplate and perpendicular to the Nadir face of the spacecraft.

In addition, there is an opening for Solar viewing. This Solar aperture is not on the S/C Nadir face. The Solar viewing opening opening is built in the base plate of the Sensor Unit. This opening will have to be oriented towards the Sun prior to each solar occultation observation. This opening can be closed by a mechanical shutter.

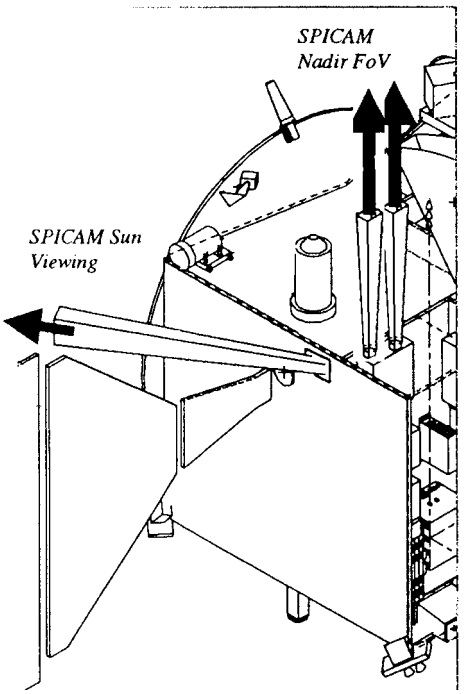
The Sensor Unit is located in the payload compartment of the S/C, near the -Y wall. A hole in the instrument mouting wall and in the -Y wall will be used for Solar occultation.

See section 3 for apertures axis definition

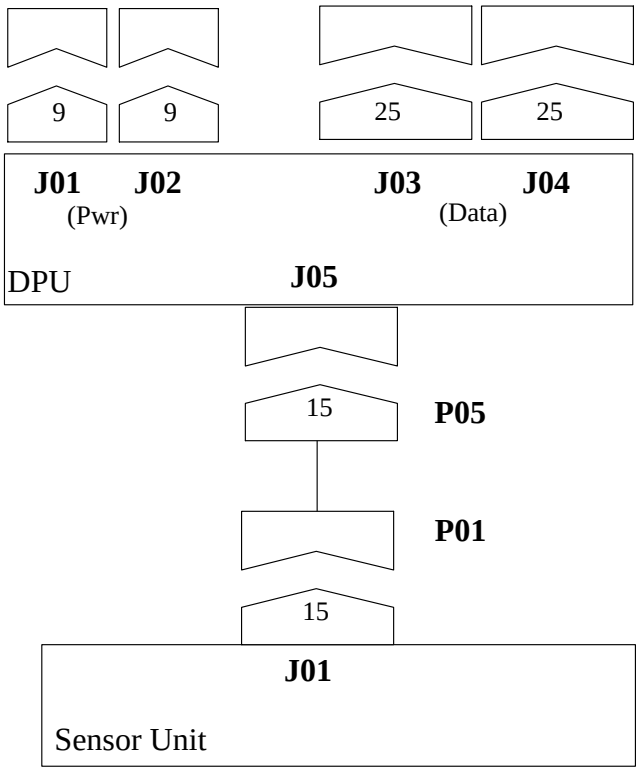
Below is the accomodation of Spicam on Mars Express.

The dedicated hole for Sun viewing has its field of view compatible with the spacecraft layout, bypassing between rotating solar array enveloppe and high gain antenna protuding reflector.

extracted and updated from EID-A page 2-12



The interconnections between S/C, Dpu and Sensor Unit are depicted below:



SPICAM 99 10 22
General Harness

2.3 Electrical configuration:

(This is copy of para 6.2 of PID-B)

Spacecraft interfaces:

Four connectors: two for TM/TC (nominal and redundant); two for Power (nominal and redundant)

Latch current limiter power: LCL class C

Power interfaces:

Spacecraft provides 28 V. The Spacecraft power line will feed DC/DC Interpoint modules in the two boxes of SPICAM Light through power lines filters. The instrument sensor unit has two mechanisms, one for slit motion and one for SUN aperture shutter. They are activated by two motors connected to 28V.

Others lines:

All other interfaces (data and clock) are directed to DPU only.

There are 3 main interfaces lines identified:

Clock line (on board time) is needed inside the instrument in order to time tag the science data. Time is needed on a basis of one information per second (external clock). It is supposed that the on board time reference can be correlated to Earth time with 0.1 s accuracy (or better 0.01 s TBC).

TC lines: On the DPU side, the TC buffer will be a FIFO.

TM lines: On the DPU side, the TM buffer will be a FIFO.

List of required signals:

		Nominal	Redon	Remarks
HPC	High Power Command	0	0	No internal relays (1)
MLC	Memory Load	1	1	131 Kbps (TC)
TSY	Time Synchro	1	1	
ANC	Thermistor Acquisitions	0	0	
ANS	Analog Acquisitions	0	0	
ANP	Platinum Sensors	0	0	
SDT	Serial Digital (16 bits) telemetry	1	1	131 Kps, same clock as MLC
RSS	Relay Switch Status	0	0	
BLD	Bi-level Digital	0	0	
HFC	High Frequency Clock	1	1	
CK	Clock Signals	1	1	for TM and TC

(1) Experiment is switched On when S/C put power on power lines.

Names of signals used in TM/TC:

MLC	memory load command	
	MLS	sampling line
	MLD	data line
	SDTC or SDC	clock line
SDT	serial digital telemetry	
	SDS	sampling line
	SDD	data line
	SDTC or SDC	clock line (same as for MLC)
HFC	high frequency clock	
TSY	timer synchronization pulse	

TM/TC redundancy selection:
TC selection (nominal or redundant) is done by:
detection of rising edge of SDS (nom or red)
then latch of corresponding SDS, MLS, MLD, SDC
This selection is done after interface circuits (in Interface board) by a FPGA Actel

2.4. Software:

2.4.1. Software operations overview:

The Spicam DPU flight software has in charge all TM/TC interfaces with the S/C.
The software general concept is the following:

```
switch on experiment (by S/C) induces start of flight software
wait for time update and start time synchronization
wait for TC defining operating modes
configure instrument following TC parameters
loop
        starts polling of Spicam subsystems
        format TM
end loop
        switch off (by S/C) is needed to terminate
```

The current Spicam implemented rules are:

```
use FIFO as telemetry buffer (contains telemetry blocks),
do not change telemetry blocks generation. (FIFO is able to store 16 sec of Spicam TM blocks)
Spicam observation duration is between 5 mn to 30 mn.
Components are latch free.
Spicam is switched ON and OFF for each observation. This allows hard reset at each switch ON.
        -software is stored in PROM
        -at switch ON, software is transferred in RAM
        -instrument parameters are set either :
                by selection of predefined values stored in tables (in PROM and so in RAM)
                or by TC which allows to update all instrument parameters in RAM
TC are only used to update instrument parameters
```

2.4.2. Autonomy concept:

The following characteristics are used in Spicam:

```
TC is needed to initiate observation and to get sensors data.
Software (and hence observation) is terminated by switch off.
```

Preliminary telecommand description:
Spicam uses packet telecommand structure
For Spicam we consider only one type of TC.
Main assumptions:
To operate Spicam (nominal mode) only one TC packet is needed.
Length of application data of TC packet is variable
In Spicam it is planned to use TC for
Operational mode selection (nadir,...)
Spicam DPU parameters (repetition rate of TM...)
Sensor Unit parameters (Star mode, exposure time, gain...)

All telemetry data are Science data. TM data are formatted in packets. At the beginning of observation, two (2) housekeeping packets are generated and sent to TM. We do not use event packets.

Power switch off is the nominal way to terminate an observation. So, an observation is totally defined by Time start and Time end defined on ground. (The duration of observation is also defined in telecommand allowing to stop sending of sub units science packets, in order to save telemetry allocation.)

For any reason, switch off can occur at any time, without need of instrument reconfiguration (done automatically at next switch on). There is no TC for what we call reconfiguration. In fact, at switch On, there is a reset of everything; shutter and slit are put in default position (shutter closed and slit On).

2.4.3. Software maintenance:

There is no in flight maintenance. The whole instrument configuration is defined by TC.
The software is totally frozen.
There is no capability to patch flight software.

With this approach,
software rely on PROM only
any event occurring during an observation has no impact on next switch ON (next observation)

2.4.4. Data delivery concept:

Only one Process ID = 96 is used by Spicam.

Process ID	Packet Category	Packet Type	Usage
96	12	TC	For ALL Telecommands packets
	12	time	Time update
	12	TM	Science data
	4	TM	Housekeeping

For each observation, there is only two HK packets:
one after the Board Time is received
the other at the beginning of Sensor Unit sampling data
i.e. after the Telecommand is received

Spicam packets:

Depending on Spicam observation phase we may have:

DPU	144 octets
DPU + SU or	3248 octets
DPU + SU + IR	4298 octets

Two or more packets are assembled to form a TM block and them put in the the telemetry buffer, ready for transmission to S/C.

see Section 2.5 and Secttion 3 for details on Command and Data handling.

The telemetry flow is the following:

at switch on, DPU packets are sent
when Board Time is received, HK packet is sent
when Spicam TC is received, HK packet is sent
until the end of observation,
either DPU+SU or DPU+SU+IR packets are sent

2.4.5. Timing requirements:

Spicam DPU uses the High frequency clock, Time Update and Pulse synchronization to maintain time accuracy.

High frequency clock is used to fill a counter. The ticks of this counter gives an internal reference. The Time Update and the Time Synchronization Pulse gives an absolute time reference which is then put in TM data.

The following concept is used: when DPU gets data from sensor, these data are time tagged and then packetized. So the time associated to each data is the time of the end of exposure duration.

2.5 Budgets:

(This is copy of para 2 of PID-B)

Definitions: (valid for this paragraph)

Basic weight: (identified weight) raw weight data from measurement, calculation, estimate
Specified weight: the maximum possible weight or agreed-to maximum
Current weight: current prediction of the final weight = basic +contingency

Spicam configurations of operations:

For all budgets the following definitions are used:
duration is typical for all computations.
Exact duration has to be computed on ground before observations
a same hardware configuration is used in several scientific objectives
resources are the same
only target is different

Configuration	Scientific objective	Duration	Subsystem	Comment
OFF				Instrument OFF
STAR	Star occultation Sun occultation Limb observation	5 mn	DPU+SUV (+ IR)	from 2 to 8 mn
NADIR	Nadir observation	30 mn	DPU+SUV+SIR	altitude < 800 km

Mass budget: (from Flight Model 1)

			Specified	Current	MASS budget	Remarks
DPU	total		900	711		
SU	total		3800	4138		
SPI	total		4700	4849		

Note: Alignment mirror = 121 g
Harness SU-DPU = 51 g

Power budget:

	POWER Budget	W	
DPU		2	
SUV		15	
SIR		8	
		Total	25

Energy budget:

Summary for one orbit: Assume: 1 Star configuration
1 Nadir configuration

Configuration	Power (W)	Duration (h)	Energy (Wh)	Remarks
STAR	16.2	0.1	1.6	1 observations
NADIR	25	0.5	12.5	
Total / orbit			13.1	

This energy budget is for Spicam **only**, without Spacecraft effects due to dedicated attitude.

Spicam TM/TC budget:

(copy of excel sheet TMstat20.x4)

Below is the various science packet lengthes: (for a typical observation)

Packet Length Computation Total = length of packet in octets		**octets**			Data compressed	
Source	Raw data	Data header	Spicam header	Source data	Packet header	Total
PBE	118	0	10	128	16	144
PUV1	3060	24	4	3088	16	3104
PUV2	2754	24	4	2782	16	2798
PIR	1024	0	10	1034	16	1050

TM budgets:

For a Star Mode duration of 5 mn, and a Nadir mode duration of 30 mn, the TM volume are:

Volume Donnes

T1 = start time (sec), T2 = end time (sec)
Data period = number of seconds between TM blocks ready (2 measurements)
Average duration of Star mode is 5 mn, Data frequency = one measurement / second
Average duration of Nadir mode is 30 mn, Data frequency = one measurement every 4 seconds
TM rate is AVERAGE (weighted with period) over several seconds

Mode **STAR** T1	T2	Period	TMBE octets	TMUV octets	TMIR octets	TMblock octets	TM rate b/s		Volume octets	
0	60	2	288	0	0	288	1152		8640	
60	300	2	288	6208	0	6496	25984		779520	
								Total =	788160	octets
									6305	kbits

Mode **NADIR** T1	T2	Period	TMBE octets	TMUV octets	TMIR octets	TMblock octets	TM rate b/s		Volume octets	
0	60	2	288	0	0	288	1152		8640	
60	1800	8	288	6208	2100	8596	8596		1869630	
								Total =	1878270	octets
									15026	kbits

Expected size of TC for each observation (TBC)

Modes	Length (16 bits word)	Remarks
Nominal operations Star, Sun, Nadir, Limb	2 to 40 (*)	instrument parameter

(*) for ground use, TC is fixed length, hence maximum length is kept with 0 padding

Summary for one orbit: Assume:
1 Star configuration
1 Nadir configuration

Configuration	TM (Kbits)	TC (16-word)	Remarks
STAR	6305x4 = 25220	40	1 observation
NADIR	15026	40	

Software budget:

Item		Remark
Software	26 Ko	no patch capability
Data	43 Ko	
TC	2	One Board Time TC
		One SPICAM TC
TM	2 types	Science packets (variable length)
		2 HK packets
		TM starts at Switch ON (without TC)
TM bitrate	variable	Can be selected by TC
		(between 8596 to 34384 bits/sec) (1)
Initialisation		At Switch ON only
Test Mode	Yes (2)	NO external constraints

(1) see section 3.3 and 5.1 for details
(2)Test mode is a mode which can be run without any attitude constraints.

Synchronization and datation budget:

Datation objective	Computation of geometrical parameters with orbit elements (ground post processing)
Datation reference	High Frequency clock Time Update and Pulse synchronization, at the beginning of each observation
Datation elements	individual spectra are dated (telemetry)
Datation tolerance	10 ms for each spectra

Alignment budget:

Subsystem	Type of alignment	Measurement tolerance	Reference system
SU	CAT 5 measured (3 axes TBC)	better than 5 arcmin	Spacecraft axis and/or Star sensor
DPU	NA		

Pointing budget:

The following table gives the summary about "pointing".
The columns 1 and 2 are copy of PID-A section 2.7.
The summary of Spicam Req are the maximum requirements of Spicam including Star and Sun occultations.

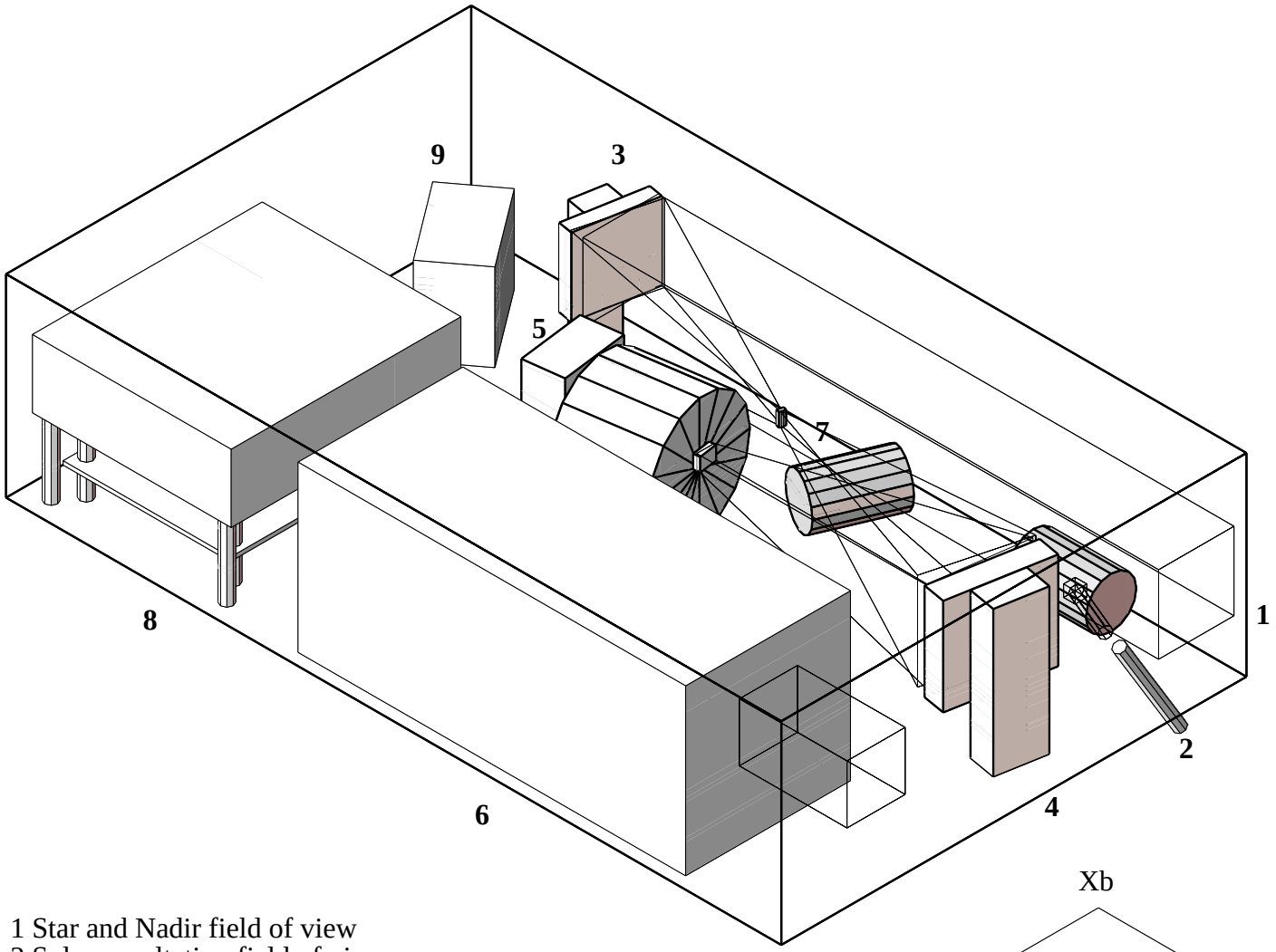
AOCS performances	PID-A specification	Summary of Spicam Req.	Spicam compliance
Attitude knowledge w.r.t.a stellar direction	0.05°	0.05°	Full
Pointing accuracy w.r.t.a stellar direction	0.06°	max 0.1°	Full
Attitude knowledge w.r.t.the Nadir direction	0.12°	0.5°	Full
Pointing accuracy w.r.t.the Nadir direction	0.15°	1°	Full
Rate stability	0.003°/s	0.04°	Full
Rate stability over 10 s	0.005°	0.1°	Full
Pointing stability over 60 s	0.009°	0.1°	Full
On board orbit knowledge	6 km	not used	N/A
On ground orbit knowledge	< 6 km	6 km	N/A

The Spicam requirements are totally fullfilled with the AOCS performances.

3. Detailed description:

3.1 Sensor Unit:

The following drawing gives the optical layout of the Sensor Unit.



1 Star and Nadir field of view
2 Solar occultation field of view
3 Off axis parabolic mirror
4 Grating
5 UV detector
6 IR channel
7 Slit mechanism
8 Electronics
9 HVPS

SPICAM Light Sensor Unit Overview
oct 22 1999

The instrument has two openings for Nadir viewing, one for UV channel, the other for IR channel. In addition, the UV and IR channel have an opening for Solar viewing.

Apertures definition:

apertures Nadir face (perpendicular to Zb)	42 x 45 mm^2 diameter 32 mm
aperture in (-Yb,-Xb) at 60 deg from -Yb (UV and IR Sun occultation)	diameter 2 mm (TBC)

Axis reference are in respect with Spacecraft Reference Frame (Spacecraft MICD).

Optical:

The Sensor Unit has three apertures:
- Main UV aperture on Nadir face.
- IR aperture on Nadir face.
- Secondary UV and IR aperture for Sun viewing
  internal mirrors and fiber bent the Solar light in the instrument main optical axis

n°	Operational Mode	Target	Subsystem Aperture
1	Test Mode	NA	NA
2	Sun Mode	Sun	Sun Secondary UV+IR aperture
3	Star Mode	Star	UV aperture on Nadir face
4	Nadir Mode	Nadir	UV+IR apertures on Nadir face
5	Limb Mode	Limb	UV aperture on Nadir face

Pointing, general assumptions:

Assume pointing is done by Spacecraft
Assume rotation of 90°, duration is around 11 mn (0.14 deg/s TBC).
It seems that Spicam is quite demanding concerning S/C manoeuvers and resources availibility. We examine resources needed by Spicam:

- manoeuver duration: is dependant on orbit parameters, actual Spacecraft attitude and desired inertial direction (selected objective) and will computed. It may be that total manoeuver duration during one orbit may be in conflict with Earth attitude needed for data transmission. However we note that there are 2 orbits (of 3) per day without transmission to earth.
- Other resources as wheel usage and power: Wheel usage is a resource to be shared between instruments. Nadir pointing is more wheel consuming than fixed inertial attitude. Power is not a concern for Sun occultation (it drops to 0 anyway). For Star occultation, the angle around +Z axis is a free parameter and therefore can be adjusted for maximum power collection if necessary.

In the Inertial mode, pointing direction is any inertial (relative to stars) direction. This direction must be kept fixed during observation duration of 2 to 8 mn. It is defined as any star direction which may be occulted by Mars in dark side of Planet. (see operational modes for details)
In nadir mode, nominal nadir pointing (as other instruments) in bright side of Planet.

The following table gives the Experiment viewing requirements for each objective.

Objective	FOV (*) (UV)	FOV avoidance	Pointing Direction	Duration (typical)
Star (UV)	1° x 3°	15° x 15° (Sun)	Inertial STAR	2 to 8 mn
Sun (UV+IR)	slit	NA	Inertial SUN	2 to 8 mn
Nadir (UV+IR)	slit	NA	Marsocentric (Nadir)	30 mn
Limb (UV)	slit	15° x 15° (Sun)	Inertial	2 to 8 mn

There is no illumination constraints for OFF mode of Spicam for sensor point of view (energy is spread by grating).

For information, following present orbit, 30 mn at Nadir around pericenter is the duration on orbit where S/C altitude is < 800km.

(*) Spicam fields of view:

UV channel

STAR mode	no slit	1 deg x 3 deg
Nadir, Limb	slit	1.3 arc min x 3 deg
Sun	pinhole	2 arc min

IR channel

Nadir		1 deg circular
Sun	pinhole	2 arc min

Subsystems:

List of elements of Sensor Unit:

UV channel parabolic off axis mirror, focal length = 120 mm
slit with two positions
grating
intensified CCD with electronics box

IR AOTF channel

see Annex4 for detailed diagrams

--->Servitudes Unit:

This block is made of two boards:

power board, which provides individual power for UV and IR
UV needs +5, +15, -15 V
IR needs +5, +/-12, +/-15V
Peltier cooler (UV and IR) 3.3 V
The input 28V is coming from DPU where it is filtered.

microprocessor board, this board controls:
the two mechanisms,
the IR switch on,
the high voltage level (for UV channel)
and retrieves 8 temperatures.

--->UV detector Unit:

The UV detector is made of 3 parts:

a CCD camera with the head and two electronic boards (follow on of Mars96)
an intensifier (Hamamatsu) with a 12 mm window which is coupled to the CCD by fiber optics
a programmable high voltage (Hamamatsu) for the intensifier

In the head, the CCD (TH 7863) is mounted on a one stage Peltier cooler for a delta T around 15 °C.
The two electronic boards of the CCD camera are mechanically mounted on the servitudes boards.

The CCD detector head is mounted in such a way that the columns are perpendicular to the baseplate of the Sensor Unit. The rows direction is the spectral dimension.

The UV detector records a window of 5 rows allowing to have at the same time, in Star mode, the Star spectrum surrounded by the background spectra. The rows can be elementary pixels or binned pixels (binned columns) The nominal binning is between 4 and 8. The position of the rows is programmable.

--->IR Channel Unit:

The IR channel is made of an entrance lens, an AOTF crystal which acts as a negative filter, two (Hamamatsu) single pixels detectors (two polarisations) with their own Peltier cooler, and an electronic board. When the AOTF is powered (at a certain frequency), it selects a wavelength which goes up to the detectors. A full spectrum is then obtained by scanning the frequencies. The measurement is obtained by the difference between the AOTF on and off.

3.2 DPU and flight software:

The DPU is made of 3 boards:

the power board which has 28V Interpoint filter modules for the whole instrument and provides 5V for the DPU itself (Interpoint module)

the microprocessor board, based on a 80C32 chip, with Ram, Prom, Fifos as buffer for telemetry, and counters for time maintenance.

the interface board which has an Actel FPGA RH1020 for telecommand/telemetry logic and interfaces circuits to S/C lignes.

The DPU has two connectors for data lignes (one nominal and one redundant), two connectors for power lines, and one connector towards the Sensor Unit.

Hardware characteristics:

microprocessor	80C32	30 MHz
Eprom	32 Ko	
Ram	128 Ko for 2 pages	
Fifo TC	32 x 8 Kbits	
Fifo TM	3 x 32 x 8 Kbits	(able to store 16 sec of telemetry data)

Software characteristics:

Software code	26 Ko
External data	43 Ko
CPU load	< 50 %

At Switch on, software code is transferred from Prom to Ram, then it is started.

Sequencing is done at a 1 second basis (minimal period). In each second, detectors are polled at fixed times. There are 256 interrupts coming from internal timer (see further) with the following steps:

tic	1	UV data reading
tic	90	IR data reading
tic	128	Servitudes and TC processing
tic	180	TM processing

Date and Time logic software:

```
wait for receipt of Board Time TC
set interrupt TSY      (TSY = pulse every 8 sec)
wait for TSY
        If interrupt
                save Board time
                start internal timer
                disable TSY          ( will never be used again)
Interrupt from timer gives 1/256 sec sequencing tic
Date and time values are built from timer+ Board Time
```

Telecommand logic software:

```
If TC fifo not empty
    wait 3 sec      (completion of TC, spec page E-IDS 7.2, t=2,2 sec)
    If TC Spicam already received
            clear fifo
    Otherwise
            read fifo
            verify length and copy in TM buffer
            read APID
                    If Spicam
                            read Type and Subtype
                                    If 9, 1                 ( OK for Spicam Board Time)
                                            Board Time processing
                                            Board Time received
                                    Otherwise
                                            set error flag in TM
                                    If 226, 1               ( OK for Spicam TC)
                                            If Board Time Received
                                                    TC Spicam processing
                                            Otherwise
                                                    Do nothing
                                    Otherwise
                                            set error flag in TM
                    Otherwise
                            clear Fifo
                            ignore TC received
                            set error flag in TM
Otherwise
    Do nothing
```

Global Software limitations:

All packets services NOT implemented.
The first TC MUST be Board Time. Only one Board Time TC is expected.
After TC Time correctly received, the TC Spicam is expected (others ignored)
After TC Spicam received, all others TC ignored

Accordingly:
- If no TC Board Time ---> no sampling of detectors
- If no TC Spicam ---> no sampling of detectors
- Each TC is related to one observation
- To start another observation, Switch Off is needed for reinitialisation

3.3 Command and Data Handling:

Telemetry sampling:
Preliminary comment:
It is stated (page E-IDS-71) that:
- each Packet Terminal shall not be polled more than once per sec
- each PT shall be able to buffer its TM for a period of 16 sec

Summary of TM requirements and Packet description:

Below is the various science packet lengthes: (for a typical observation)

Packet Length Computation **octets** Total = length of packet in octets					Data compressed	
Source	Raw data	Data header	Spicam header	. Source data	Packet header	Total
PBE	118	0	10	128	16	144
PUV1	3060	24	4	3088	16	3104
PUV2	2754	24	4	2782	16	2798
PIR	1024	0	10	1034	16	1050

TM packet header is 16 octets
Spicam has four types of Science packet. The packet length is (Packet data + header)

Depending on Spicam observation phase we may have the combinations:

DPU	144 octets
DPU + SU or	3248 octets
DPU + SU + IR	4298 octets

Spicam data production rate:

Spicam data are made of successive spectra. The rate of spectra recording is 1 sec .Assuming the worst case, data production rate is

(144+3104+1050) = 4298 octets per second

-----> Spicam maximum AVERAGE bit rate is 34384 bps

Spicam has two nominal modes which are NADIR and STAR mode:

NADIR mode: DPU+SU+IR. In this mode, the typical data sampling frequency is once per 4 sec. The average bit rate is 8596 bps. This bit rate is less than 10 kbps and so we are in case A), there no constraints.
STAR mode: DPU+SU. In this mode, the typical data sampling frequency is one per 1 sec. The average bit rate is (144+3104)*8 = 25984 bps. We are in case B), there are constraints on the actual active instruments.
---> All instruments cannot work together with Spicam at their maximum data rate without data loss. The good point is that in this STAR mode, there is a dedicated attitude (which is not Nadir) and so it is not foreseen that there are many other instruments active at this time.

Buffer size:
The Spicam TM buffer size depends only on the data production. For 16 sec, the minimum buffer size is (worst case) 34384*16 = 550144 bits. The TM buffer is made of FIFO whose size will be 768 kbits .

Spicam TM block:

In all operating modes, Spicam will provide a TM block corresponding to data produced in two measurements.

Maximum TM block length (words of 16 bits)

Star	3248	(or 6496 octets)
Nadir	4298	(or 8596 octets)

It will occur quite often that our TM block length word will be 0 when presented at polling sequence.

TM block building:

In flight software, the following actions are implemented: construct a TM block with two measurements.

```
count = 0
Every Timestep loop
                        (Timestep is one for STAR and 4 for Nadir)
    increment count
    get, compress, generate and store UV packet (PUV1 or PUV2)
    get, compress, generate and store IR packet (PIR1 or PIR2)
    get, generate and store servitudes and DPU packet (PPU1 or PPU2)
    If count = 2 Then
        count = 0
        If FIFO TM full then
                ( very abnormal situation )
                ( try to recover even with loss of data )
                empty FIFO TM
        generate TM block = PUV1+PIR1+PPU1 + PUV2+PIR2+PPU2
        put length + TM block in FIFO TM
    endif
end loop
```

Conclusion:
Our TM system delivers TM blocks of two measurements. Therefore, our FIFO can be emptied by polling sequence (if combination of experiment data rates allows it) faster than it is fed by the instrument.

3.4 Summary of bitrates:

For each operating mode, we have the capability to change the averaged bitrate by adjustment of the sampling period of the sub units, for example from 1 to 4 seconds (at the cost of reduced spatial resolution). This capability can be defined as sub mode or "mode BE". It is useful for Nadir observations, but it can be used in other modes.

The sampling period is defined in the Spicam TC, the first 4 bits of the Spicam TC, between 0 and 15 and named as "mode BE", with corresponding labels

The following table gives the bitrates according to the sampling period of the Spicam sub units:

(copy of excel sheet TMstat20.x4)

	p=period			**Bitrate** (averaged over 2 sec) (data are transmitted every 2 sec)				
mode	pBE	pUV	pIR	Bitrate	Attitude	duration mn		Power
test	1	0	0	1152	N/A	2	be	16,7
preop	1	0	0	1152	N/A	1	be	16,7
maxi	1	1	1	34384	S,L,Su	4	uv+ir	25,9
medi	1	1	2	30184	S,L,Su	4	uv+ir	25,9
	1	1	4	28084	S,L,Su	4	uv+ir	25,9
	1	1	0	25984	S,L,Su	4	uv+ir	25,9
	2	2	2	17192	NAD	30	uv+ir	25,9
mini	4	4	4	8596	NAD	30	uv+ir	25,9

NAD Nadir
S, L, Su Star, Limb, Sun

preop is the duration before science data are produced by sub units. This is useful for "precise" TM volume computation.

see paragraph 5.1 for details bitrates

4. Instrument Operations:

4.1. Overview of Operating principles

The following paragraph describes the operating principle for SPICAM Light observation:
- Put Spacecraft in good attitude for one kind of observation
- Switch On by S/C
- Send observation TC by S/C
- Record TM by S/C
- Switch Off by S/C at the end of observation.
- Put Spacecraft in nominal attitude

Summary of thermal constraints:

Spicam is collectively controlled with S/C.
Preferred Thermal Range for Spicam operations: -20°, +40°C.
Off mode limits: -80°, +100°C.
There is no other thermal constraints for Spicam switch ON

Summary of operational constraints:

There is no default observation scenario for SPICAM (TC Spicam is always needed).

		Duration (typical)	Number /orbit	Conditions	Comments
1	Stellar occultation	5 mn	<=4	Star set Dark side of Mars Spacecraft oriented towards star	11 12 13
2	Solar occultation	5 mn	1	Sunset and Sunrise Spacecraft oriented towards Sun	21 22
3	Nadir	30 mn	1	Bright side of Mars Spacecraft oriented towards Nadir	31
4	Limb emissions	5 mn	<=1	Mars bright Limb Spacecraft oriented towards Limb	 41

Comments:

11. Occultation time must be computed prior to observation
Duration of occultation is computed prior to observation
(depending on the geometry of occultation versus local horizon, vertical or not)
Observation starts 60 sec before the occultation (target at 200 km of altitude)
Observation stops 30 sec after the end of occultation (disparition of target behind Mars).
Service d'Aéronomie will provide Star catalog (about 40 stars) see Annex6
Star catalog is fixed and defined well in advance.
No update is foreseen, at the present time, during the mission.
Targets are defined by α, β, (J2000), format to be agreed.
Latitude and longitude coverage is provided by selection of star
12. A few occultations on bright side of Mars are possible
13. Only Spacecraft attitude is required
Spacecraft position along the orbit is indifferent
Line of sight is defined by Spacecraft position (NOT attitude) and star direction
Vertical resolution depends only on sampling of detectors
Measurements (spectra) are done every second. During one second, the effective exposure time depends on the brightness of the star occulted and can be adjusted by TC.

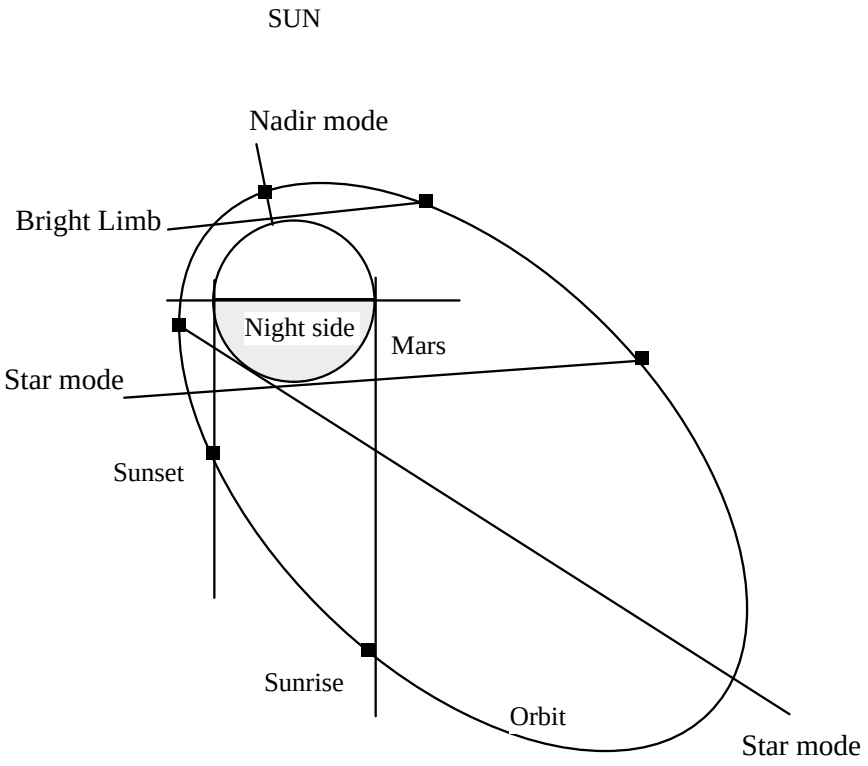
21. We suppose that Sun occultation exists
    (occultation through a special aperture, not on Nadir face)
    Sun occultations are described in the Orbit Analysis document (M. Hechler))
    All occultations are potentially good for science investigation (latitude coverage)
    Sunset and sunrise are independant
    Experiment is off during eclipse
    Latitude and longitude depends on geometry of Sun occultation
22. Vertical resolution of concentration profile depends on the altitude of the Spacecraft
    Lower altitude gives better vertical resolution

31. Same attitude as all others Nadir experiments
    Latitude and longitude coverage is done by satellite track

41. Lower altitude of the Spacecraft gives better vertical resolution

4.2. Nominal Operations Plan

The following diagram shows a possible orbit with SPICAM Light operational capability. (the only purpose of this diagram is explanation).



Spicam Light: operations modes
(not a true orbit, for explanation only)

Squares are Mars Express positions.

The following table shows an orbit operation profile. This is only an example and must be adjusted with actual orbit.

Orbit event	Spacecraft orientation	Remarks
apoastre	Earth	
	Star1	5 mn
	Bright limb	5 mn
Enter Mars day side		
	Nadir	30 mn
Exit Mars day side		
	Star2	5 mn
Sunset	Sun	5 mn
Sunrise	Sun	5 mn
	Earth	

The number of observations during one orbit depends only on the resources available at the time of observation. Most of time, during occultations, no other instrument is working (except Aspera which would benefit of this type of observation).

Present (february 2002) recommendation is to have one Nadir and only one inertial attitude for each orbit.

For one observation, the following table shows the distribution of functions for nominal flight operations:

Source	Action	Destination
On Ground	Operations preparation	
spacecraft	Switch On	DPU
spacecraft	Send TC	DPU
Sensor Unit	Science data	DPU
DPU	Send TM	spacecraft
spacecraft	Switch Off	DPU
On Ground	TM processing	

4.2.1. Ground operations plan:

The following paragraphs describe all the actions which are needed for operations of Spicam Light:

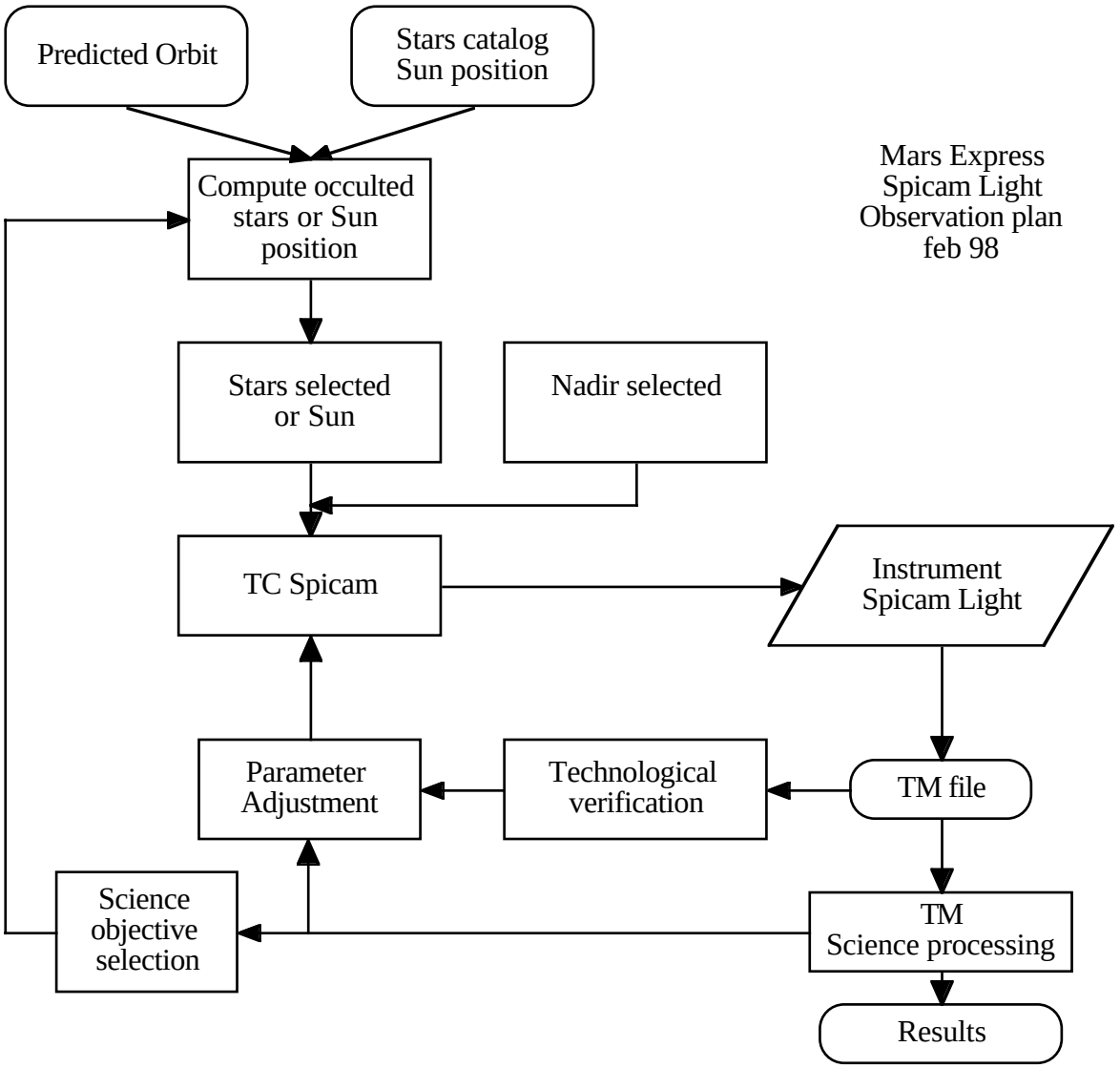
SA = Service d'Aéronomie

see annex9 for Spicam activities, every week

We propose the following phases:

Data Needed	Actions	Actioner	Remarks
Pre-mission			
Targets	Star catalog	SA	
Mission, every month			
Orbit data	Compute predicts	ESOC	
Occulted targets	Compute attitude	ESOC	In parallel at SA
Selected Stars	Choice by Science team	SA	
Attitude parameters	Elaboration	ESOC	verification by SA
TC Spicam	Elaboration	SA	

Spicam Light Observations: Operations functional diagram



This diagram reflects the Spicam operations. Interfaces during commissioning and routine phases will be described later.

Our minimal requirements are:
- operations first month (Near earth verification)
- operations last month before Mars approach (Pre-MOI)

Our desirable requirements:
- If possible one more operation every month

4.2.2. Near earth phase (NE or EV early verification):

Objectives: SPICAM Switch ON and health check

Constraints:

SPICAM First Switch ON in EV phase has to be in the later part of EV phase activities to allow instrument degassing.

No required attitude

SPICAM EV Phase requirements are as under:

One Star observation cycle with star in FOV provided EV phase spacecraft pointing permits such observations. SPICAM team will check whether such an opportunity is available based on the SPICAM star catalogue, star occultation data from ESOC and spacecraft orientation in this phase of the mission.

One Star observation cycle without star in FOV

Total duration of observation in EV phase may be an hour.

4.2.3. Interplanetary Cruise phase (IC):

In order to avoid any possible failure due to no motion of mechanisms during the long cruise phase of the mission, SPICAM team requested activation of SPICAM and execution of Test Mode once every month. In this mode, the two mechanisms are activated three times each.

In the same time, we require to run StarAlign mode and Nadir mode.

General conditions:

no attitude required
duration is 5 mn each Total 15 mn
support by PI if required by ESOC

End of IC phase: (pre-Mars Orbit Insertion)

The payload instrument checks at the end of Interplanetary Cruise (IC) phase is limited to instrument Switch ON and minimal health checks only. Test Mode will be used.

4.2.2. Mars Commissioning phase (MC):

Objectives:

In flight, there is no specific mode for calibration and the baseline operational modes are used. Observation can be done even if there is no occultation of star or Sun. The main purpose of observation during commissioning is to verify and adjust a few instrument parameters as exposure time, gain...

The following actions will be done in flight:

verification of main performances characteristics
adjustment of parameters as exposure time
verification of alignment

Constraints:

Dedicated Spacecraft attitude is needed.

Total time: around 1 hour (TBC) (with maneuvers) for each observation

All sequences are purely repetitive, off-line and remotely executed (as nominal ops).

The SPICAM requirements for the Mars Commissioning phase are as under:

Nadir Observation: 2 orbits of observation.

Limb Observation: Bright and Dark limb with 2 orbits of observation for each.

Star Observation:

a. Optics Alignment check: 1 orbit of observation
b. Star Occultation: 2 orbits of observation

Sun Occultation: 2 orbits of observation

In all the cases requiring two orbits of observation there should be enough spacing between the two orbits to enable performance evaluation and consequent fine adjustment of instrument parameters (if any).

Note: It is envisaged that from the spacecraft operations point of view the minimum gap will be 1 to 2 days between such commissioning phase test observations. The actual gap will depend upon the time required by the SPICAM team to analyze the data and to plan next step in SPICAM commissioning activity.

4.2.3. Flight operations plan by mission phase

TBD
Will be completed when Mission Planning will be issued.

For Spicam, the following strategy rules are applied in order to maximize the Sicence return:
use of Instrument bitrate flexibility
for Nadir mode with low bitrate (8.6 kb/s), Spicam can always be operated.
use of target opportunity
for Star mode, selection of target out of Pericenter/Nadir phase

4.3. Failure Detection and Recovery Strategy:

Instrument is switched On and Off (and so totally resetted) for each observation.
Failure detection is done through telemetry.
As observation time for occultation is short (a few minutes), there is no in flight recovery procedure and in case of SW or HW problem, ground analysis of problem is required.

In case of failure, the following rules will be applied (following TM analysis):

--> TM present but degraded performances — PI analysis of problem

--> No TM
- use Spicam TC "TestN" — NO constraints
  - If OK — continue nominal operations plan
  - If No TM
    - Switch to Power redundant lines
    - use Spicam TC
      - If OK — continue nominal operations plan
      - If No TM
        - Switch to Data redundant lines
        - use Spicam TC
        - If OK — continue nominal operations plan
        - If No TM — main failure

Slit and Shutter Failure Scenario:

The two possible failure scenarios of the mechanisms are the openings either permanently closed or open.

(a) If the openings are permanently closed no observation is possible in that particular viewing mode.
(b) If openings are permanently in Open state observation is feasible. The Sun occultation experiment can be switched on at any time and there is no constraint in activating the Sun occultation observation mode.

4.4. Routine operations:

As Spicam bitrates are mode dependant (see paragraph 3.4), the POR (payload operations request) will include data rate and data profile requirements, in addition to other informations as TC Spicam...

5. Modes description:

5.1. Summary of nominal modes:

Mode definitions:

Definitions of mode:
a mode is defined if one of the following conditions occurs:
change in demand on S/C resources (power...)
specific S/C operational status (pointing)
functionnaly distinct operating mode of instrument

Experiment Mode	Power Usage (W)	Data rate (Kbits/s) (*)	Functional use
Test	16.2	26	ground use
Sun	16.2	30.2	Science, occultation
Star	16.2	26	Science, occultation
Limb	16.2	26	Science, Bright limb
Nadir	25.0	8.6	Science, Nadir

(*) Data rate is not constant , this value is averaged see section 3.4

For Spicam, observations modes are a combination of
Experiment mode (which subsystem)
Spacecraft attitude (which target)
Spacecraft position (Mars viewing)

There are 5 operational modes defined for Spicam Light (all modes use DPU).

nº	Operational Mode	Target	Subsystem	Spacecraft attitude	Duration
1	Test Mode	NA	-	NA	2 to 8 mn
2	Sun Mode	Sun	SU (UV+IR)	Inertial Sun	2 to 8 mn
3	Star Mode	Star	SU (UV)	Inertial Star	2 to 8 mn
4	Nadir Mode	Nadir	SU (UV+IR)	Nadir attitude	30 to 60 mn
5	Limb Mode	Limb	SU (UV)	Inertial	2 to 8 mn

The sequencing of all modes are identical see section 2.4.1

In addition of the mode previously defined, Spicam has several bitrates selectable by TC. So, a same mode can be used with several bitrates. The following table gives the identification between the Spicam TC and the corresponding bitrate.

Identification Bitrates / Modes **TMbitrate00.x4**
See also TMstat20

02 04 17 BE modes identification and bitrates

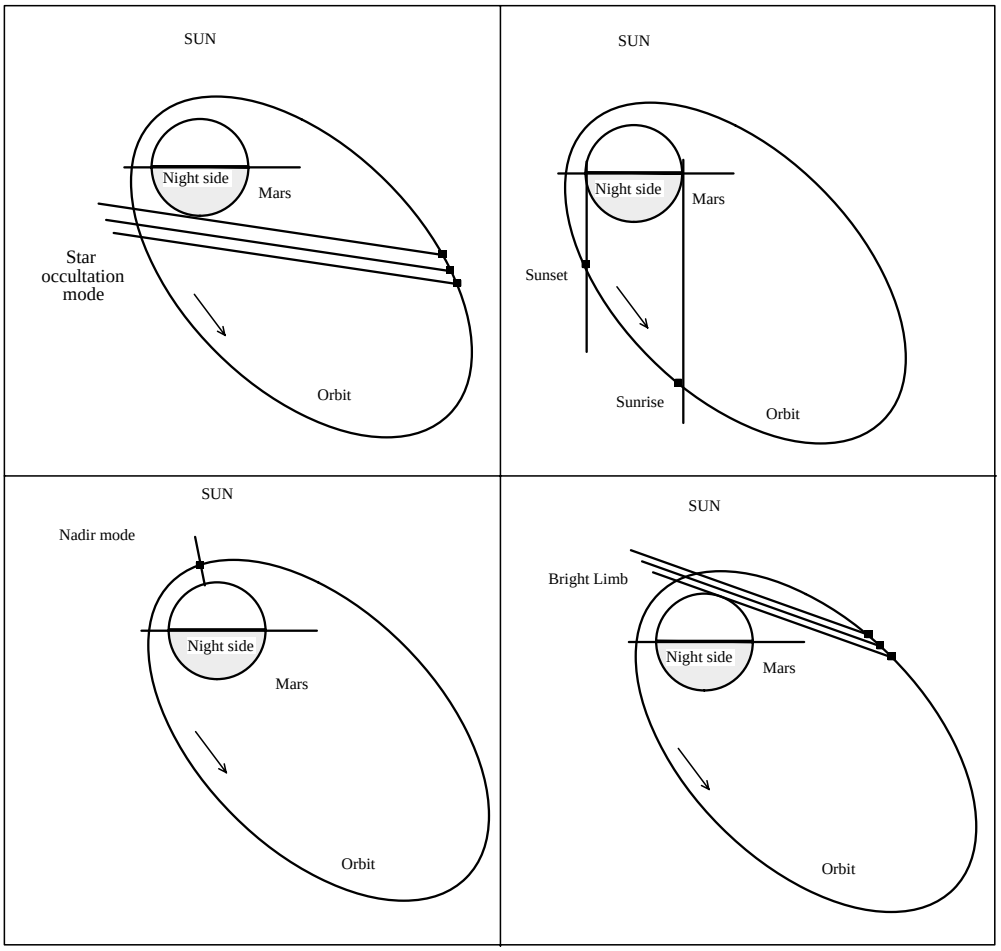
Spicam modes Identification and Bitrates:

Labels

TC Spicam	Hex configuration of TC
Database name	case sensitive, see Database in annex
pIR	sampling period of UV channel
pUV	sampling period of IR channel

	TC Spicam (Hex)	Database Name	Spicam name	pUV (sec)	pIR (sec)	Power (W)	Bitrate (kbps)
0	0xxxxxxx	Dummy TC	mini	0	0	16.2	1.1
1	1xxxxxxx	TestN	NadirMini	4	4	25.0	8.6
2	2xxxxxxx	TestS	StarMedi	1	2	25.0	30.2
3	3xxxxxxx	Cmde directe	mini	0	0	16.2	1.1
4	4xxxxxxx	Limb	LimbMini	2	2	25.0	17.2
5	5xxxxxxx	StarLimb1	StarLowi	1	0	16.2	26.0
6	6xxxxxxx	StarLimb2	StarMaxi	1	1	25.0	34.4
7	7xxxxxxx	StarLimb3	StarMedi	1	2	25.0	30.2
8	8xxxxxxx	Nadir1	NadirMaxi	1	1	25.0	34.4
9	9xxxxxxx	Nadir2	NadirMedi	2	2	25.0	17.2
10	Axxxxxxx	Nadir3	NadirMini	4	4	25.0	8.6
11	Bxxxxxxx	Align	StarLowi	1	0	16.2	26.0
12	Cxxxxxxx	TIprog	StarLowi	1	0	16.2	26.0
13	Dxxxxxxx	Sun1	SunMaxi	1	1	25.0	34.4
14	Exxxxxxx	Sun2	SunMedi	1	2	25.0	30.2
15	Fxxxxxxx	Sun3	SunLowi	1	0	16.2	26.0

Exemples of Spicam operations modes:



Spicam Light: operation modes

(not a true orbit, for explanation purpose only)

For star occultation, the distance to the Mars surface is not a relevant parameter. The star is a ponctual source, and the line of sight is only defined by Star and S/C positions.

For Limb observation (secondary objective), attitude is inertial, and the distance to Mars is a relevant parameter. Strategy is flexible and may accomodate other S/C constraints.

The distance to Mars impact is also valid for Sun mode.

The following table gives preliminary values concerning preferred distances in order to get maximum spatial resolution.

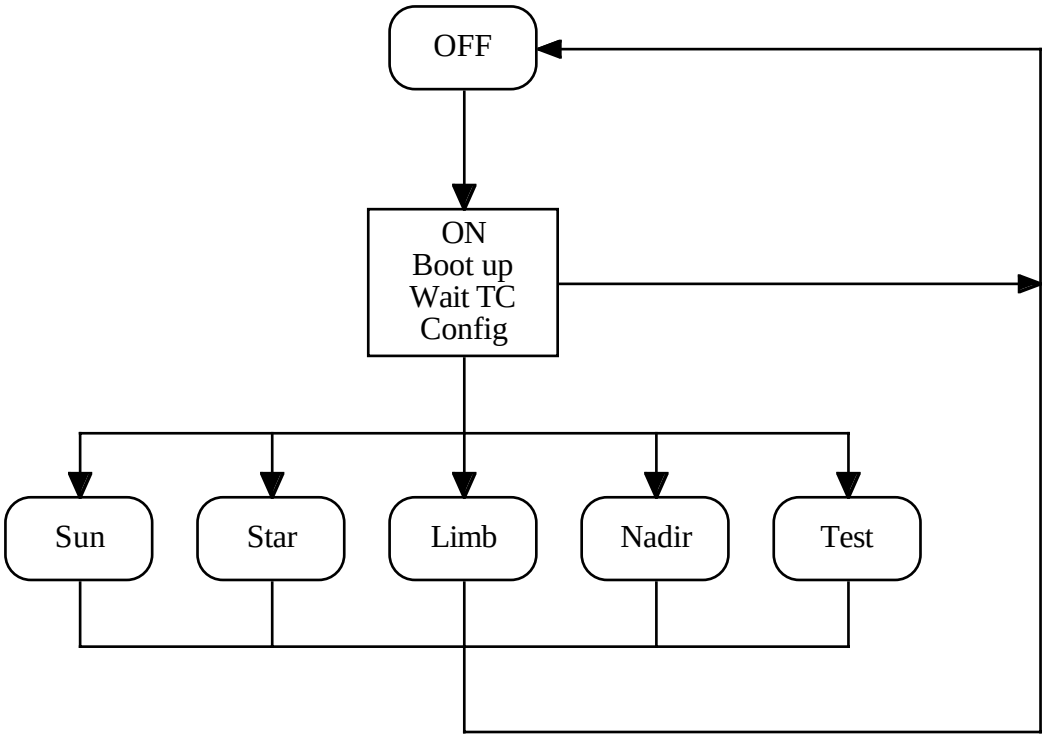
Mode	Min distance	Max distance	Remark
Star	NA	NA	
Limb	200	3000	km
Sun	200	3000	km

During flight, and for occultations, there is no specific calibration mode.

1. Experiment does not need any specific calibration because measurement is "absolute", i.e. comparison between spectra inside and outside atmosphere is instrument independent.

2. To verify experiment performances, the previous nominal operational modes will be used. The only difference is that during these specific observations, there is no occultation foreseen.

5.2. Mode transition diagram:



5.3. Detailed modes description:

5.3.1. Test mode:

In this mode, there is no sampling of detectors, and Science data are simulated. TM/TC functional performance is totally nominal.
There is no attitude constraints to run this mode.

5.3.2. Star occultation mode:

Star Occultation mode (UV channel):
In order to operate Spicam Light with sensor UV in occultation mode, the following assumptions hold:
- no on board ephemeris, i.e. operations are planned on Earth ground
- several potential targets (about 50 to 70 stars) see paragraphe 4.1
- star occultation computation (ESOC, SA)
- dedicated spacecraft attitude for Star occultation

5.3.3. Sun occultation mode:

SUN (UV and IR channels):
Three things are needed:
- Solar occultation time, computed from orbit characteristics (ESOC, SA)
- Spacecraft dedicated attitude
- Internal configuration of the instrument (exposure time...)

5.3.4. Limb mode:

Bright limb observations (UV channel):
Computation of direction and S/C attitude is done on ground (as for STAR mode).
The spacecraft Nadir face is oriented (inertial) towards bright limb of Mars (as a virtual star).
Scan altitude is provided by orbital motion.

5.3.5. Nadir mode:

Nadir observations Sensor Unit (UV and IR detectors):
There are no special constraints.
The instrument is operated (ON, OFF) during Spacecraft Nadir Mode (day side).
Bitrate can be selected (low, medium or high).

6. Interfaces:

Summary of Spicam interfaces:

Power demand is mode dependant (from 17 to 25 W).
Instrument is thermally collectively controlled. There is no constraints at switch On.
Alignment can be verified in flight.
There is no on board control or monitoring of instrument parameters

(This is copy of para 6.2 of PID-B)

TM/TC:
TM and TC interface with the spacecraft only concern the DPU of Spicam Light.
One TM channel and one TC channel are required.
All telemetry informations (science and associated housekeeping) are sent through the TM channel. Telemetry data will be time tagged and formatted by the DPU into packets according to standards defined for the mission. Inside packets, data can be sorted by means of identification (sensor UV, sensor IR).
Once the DPU is switched on, while waiting for a TC it will send back a few telemetry packets. After TC reception, the DPU will select the mode of operations and hence sensor UV or IR, and will return telemetry to the spacecraft. This process continues until the DPU is switched off.
The TC received by DPU has two fields:

mode selection	mandatory
instrument parameters	optional

Science Data:
As already explained all telemetry information is considered as science data.
In the DPU, upon TC selection, several parameters can be used in order to adjust the total volume of telemetry (mainly for Nadir observations). As an example the following features are be implemented:
-change of the rate of science data sampling from sensor: minimum time between science measurements is 1 sec, it can be increased until 15 sec.
-the DPU has the capability to just add successive spectra before sending them to telemetry.

7. Nominal and Contingency Operations procedures:

7.1. On-board control procedures:

None

7.2. Flight control procedures:

Preliminary list of Nominal Procedure/TC Sequence List Applicable to SPICAM

1	Spicam Nominal Switch ON	SP-FCP-001		
	Spicam Switch ON Spicam LCL Power ON Enable TC Link to instrument Enable TM Polling from instrument Start Spicam Time Update		ASPF001A	
2	Spicam Initialisation	SP-FCP-002		
	Spicam Initialisation Enable Spicam HK TBD TM Generation NA Stop Spicam Time Update Spicam Activities NA		ASPF002A	
3	Spicam Pre-observation	SP-FCP-003		
	Spicam Pre-observation Spicam Reset SMCS NA Spicam Start HS Link NA Enable Spicam Science Report Generation NA Spicam Activity NA		ASPF003A	
4	Spicam Start Write Operation to SSMM	NA		
5	Spicam Stop Write Operation to SSMM	NA		
6	Spicam Nominal Switch OFF	SP-FCP-006		
	Spicam Switch OFF Disable Spicam Science Report Generation NA Disable Spicam HK TBD TM Generation NA Spicam Power OFF NA Disable TC Link to instrument Disable TM Polling from instrument Spicam LCL Power OFF		ASPF006A	
7	Spicam Heater Activation	NA		
8	Spicam Heater Deactivation	NA		
9	Spicam Update Parameter Table	NA		
10	Spicam Bring to Post-observation State	NA		
11	Spicam Reset SMCS and Start HS Link	NA		
12	Run Spicam TBD Observation	SP-FCP-101		
13	Spicam Selection of Nominal TM/TC Branch	SP-FCP-201		
	Select Instrument Nominal TM/TC Branch		ASPF201A	
14	Spicam Time Update	SP-FCP-202		
	Instrument Time Update Start Spicam Time Update Stop Spicam Time Update		ASPF202A	
15	Spicam Get Status for Write Operation	NA		
16	Spicam Request Connection Test	NA		
17	Spicam Upload Memory	NA		
18	Spicam Dump Memory	NA		

Switch ON experiment	through S/C LCL (no relay in Spicam) hard reset, expected duration = 1 to 2 sec
TM polling (from S/C)	for nominal or redundant channel selection every one second
Send TM	about 8 sec after Switch On then every second
Time update (from S/C)	about 20 sec after Switch ON (absolute time reference)
Time sync pulse	(within 8 sec)
Spicam TC	About 20 sec after Time update

Start of science observation following Spicam TC received

End of observation is done by switch OFF experiment (by S/C)

7.3. Operational constraints:

Summary of operational constraints: (see section 4.1).

--SPICAM has no constraint on altitude for Nadir observation.
--When SPICAM is ON the detectors should not be exposed to the Sun directly within the instrument FOV (15 x 15 deg) on the Nadir face since the detectors could get damaged.
--Spicam is collectively controlled with S/C.
Preferred Thermal Range for Spicam operations: -20°, +40°C.
Off mode limits: -80°, +100°C.
There is no other thermal constraints for Spicam switch ON
--There is no default observation scenario for SPICAM (TC Spicam is always needed).

Additional note: (see also paragraph 4.3)
In case of any onboard SPICAM problem or other problem where SPICAM can be suspected, FCT will wait for fault diagnosis and recovery instructions from SPICAM team. Till the receipt of feedback from SPICAM team, on-board SPICAM operations will be under 'HOLD' de-scheduled and further SPICAM observations will be cancelled.

7.4. Contingency recovery pocedures:

TBD

8. Summary of Telemetry and Telecommand data:

8.1. List of dangerous commands:

None.

8.2. Summary of Telemetry and Telecommand packets:

In this paragraph we describe the general rules of telemetry / telecommand utilisation. The detailed description on TM/TC packets is done in Annex 2.

Packet service compliance:

Sub-type	Service Requests (TC)	Sub-type	Service Reports (TM)	C*
	Service 1: TC Acknowledge			
		1	Acceptance success	
		2	Acceptance failure	
	Service 3: Housekeeping Reporting			
5	Enable HK			
6	Disable HK			
		25	Housekeeping packets	X
	Service 5: Event Reporting			
		1	Normal progress report	
		2	Anomaly report - no action	
	Service 9: Time Synchronization			
1	Accept Time Update			X
	Service 17: Connection Test			
1	Request connection test response			
		2	Connection test report	
	Service 20: Science Data Transfer			
1	Enable Science Packet			
2	Disable Science Packet			
		3	Science report	X
	Service 192: Private services payload			
1	Telecommand for Spicam			X

(*) Services used by Spicam, the others services are NOT useful and we do not use them, for software simplification reasons (waiver issued).

Rationale for Implementation of separate HK packets:

Spicam has two main modes of observations which are STAR and NADIR.

Spicam is switched on and off for each observation.

The STAR duration is typically 5 mn and The NADIR one is about 30 mn.

Concerning the flight software, the STAR mode is the most stringent mode. NADIR mode will follow the STAR mode constraints, the only parameter change is duration. (the duration is fixed by the switch OFF experiment). The constraints on STAR mode are the following:

Data are recorded every second and no loss of data is allowed. The time of observation is very well defined (by computation on ground) and no shift can occur otherwise, occultation is missed.

So from Spicam point of view, we do not need to generate any HK packets because:

-there is no in flight action

-we do not need any parameter monitoring,

-we want to design a simple and sequential (fully testable) flight software.

Current Spicam implementation of HK packet:

There is a strong requirement from ESOC/MMS to produce HK packets. To our understanding, the reason for that is not linked to Science requirements. The implementation of HK packets introduces some complication in software, because we have to take care of HK services coming at any time (?) from DMS.

The present flight software requirements are fulfilled:

The flight software is separated in two main phases:

-init phase: in this phase, which duration is about 1 mn, the following actions are taken:

hardware and software resets
start of detector cooling
waiting for Time Update
waiting for Spicam TC mode
waiting elapsed 1 mn
At the end of this phase, it is not foreseen to receive anything else from DMS.

-observation phase: in this phase, spectra are recorded:

data are compressed, formatted and timetagged
this phase is not interruptible (unless by OFF experiment)

The only thing we can do is that during the "init phase" we produce 2 HK packets at the beginning (after Time update received by Spicam) and after Spicam TC received.

Telemetry, general Description:

General assumptions: (*from PID/URD ANNEX p 68*)

Spicam uses "Packet Telemetry", Spicam is seen as a Packet Terminal.

Polling capability:

at least once per 8 sec
not more than once per 1 sec

--->Spicam requires polling at once per 1 sec

Acquisition rate is 131 KHz

Telemetry	Meaning	Source	Comment
SPINHK	Instrument housekeeping	Spicam DPU	nominal channel
SPIRHK	Instrument housekeeping	Spicam DPU	redundant channel
SPINSCI	Instrument telemetry	Spicam DPU	nominal channel
SPRSCI	Instrument telemetry	Spicam DPU	redundant channel

Telecommand, general Description:

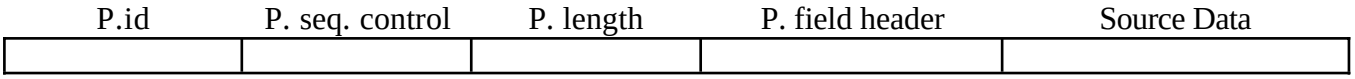
In order to operate Spicam, we need telecommands channel:

Telecommand	Meaning	Destination	Comment
SPINTC	Instrument parameters	Spicam DPU	nominal channel
SPIRTC	Instrument parameters	Spicam DPU	redundant channel

Spicam Telecommand:
Preliminary telecommand description:
Spicam uses packet telecommand structure
For Spicam we consider only one type of SPTC.
Main assumptions:
To operate Spicam (nominal mode) only one TC packet is needed.
Length of application data of TC packet is variable
In Spicam it is expected to use TC for
Operational mode selection (nadir,...)
Spicam DPU parameters (repetition rate of TM...)
Sensor Unit parameters (Star mode, exposure time, gain...)

Summary of TM packet structure:

(P. is for packet)



16 bits 16 16 80 variable

Spicam scientific data (without Packet headers) is called "Source Data".

Spicam Source data:
Source data as defined in Packet Telemetry is Spicam Science Data.
All telemetry of Spicam is considered as Science Data:

Preliminary source data type contents:
spectra
repetition rate from 1sec to 15 sec
pixel number is variable
source data length between 1 and 4096 octets
associated parameters (dark current, temp, status mode, exposure time...)
repetition rate from 1sec to 8 sec
source data length is fixed = 128 octets

Telemetry packet definition:

Science:

Telemetry Packet	Information		
Packet Name Packet Function Generation rules	SPINSCI Science every 1 sec	Instrument	SPICAM
Header Information			
Process ID	96	Packet category	12 'PRIVATE'
Service Type	20	Service subtype	3
Structure ID		Packet length	variable, max = 8596
Data Field Information			
Data Field	Field structure	Remarks Science data	
Notes:			

Housekeeping:

Telemetry Packet	Information		
Packet Name Packet Function Generation rules	SPINHK Housekeepig after Time board received after Spicam TC received	Instrument	SPICAM
Header Information			
Process ID	96	Packet category	4
Service Type	3	Service subtype	25
Structure ID		Packet length (octets) source data	4
Data Field Information			
Data Field	Field structure	Remarks HK data, 2 temperatures	
Notes:			

Telecommand function definition:

Telecommand Packet	Information		
Packet Name	SPITC	Instrument	SPICAM
Packet Function	Instrument configuration		
Verification rules	copy in Science TM		
Header Information			
Process ID	96	Packet category	12 'PRIVATE'
Service Type	226	Service subtype	1
Structure ID	N/A	Packet length (octets) (application data)	variable, max = 232 Spicam : 80
Data Field Information			
Data Field	Field structure	Remarks Science instrument configuration	
Notes:			

see Annex 2 for packets structure details 'TM/TC description'

8.3. Summary of Telemetry and Telecommand parameters:

Housekeeping Telemetry data:

Two temperatures (8 bits), allowable values 0-255.
Temperature of Servitudes board
Temperature of base plate near High Voltage power supply
No operational constraints on these values.
No on board monitoring

8.4. Summary of Software parameters:

In the telecommand, there are 2 sets of parameters:

Field2 arguments	ZSI01001 SCOE:="TMTCSC",ACKBITS:="NONE", FSID0022:="TestN", FSID0021:0BV:=0xE000000,FSIG0011:0BV:=0xABCD
The fisrt set	FSID002 and FSID0021 defines experiment modes (and bitrates)
The second set	FSIG0010 to FSIG0041 defines instrumental parameters default values are 00 (Hex)

As TC is fixed length, all default parameters are filled with 00 (hex) and sent to the instrument.

9. Data Operations Handbook:

Following data are extracted from
Medoc reference guide Index 96 - Spicam MEX-MMT-MA-xxx draft1, Jan 5 2001

Telecommand Function definitions:

Item	Meaning	Medoc Name
Command Description	**Accept Time update**	**SPINTIME**
TC Identification Number (TC ID)		ZSI02001
Instrument Name	Spicam	
Instrument subsystem (affected by TC)	DPU	
Instrument Assembly (affected by TC)	none	
Type of TC	9	
TC Address Parameters		
TC Function	Board Time to Spicam	
Constraints	1 st TC to Spicam	
Verification (TM parameter to be monitored for confirmation of TC execution)	Time in HK packet	
Corrective Action	none	
Alternative TC (if any)	redundant lines	SPIRTIME, ZSI02011
Complementary TC (If any)	none	
Remarks		

Item	Meaning	Medoc Name
Command Description	**Spicam TC**	**SPINTC**
TC Identification Number (TC ID)		ZSI01001
Instrument Name	Spicam	
Instrument subsystem (affected by TC)	DPU	
Instrument Assembly (affected by TC)	none	
Type of TC	9	
TC Address Parameters		FSID0022, FSID0021 FSIG0010 to FSIG0040
TC Function	Instrument configuration	
Constraints	After TC Board Time	
Verification (TM parameter to be monitored for confirmation of TC execution)	Science TM Packets	
Corrective Action	none	
Alternative TC (if any)	redundant lines	SPIRTC, ZSI01011
Complementary TC (If any)	none	
Remarks		

For the use of TC parameters, see Section 7.1

Telemetry Packet Definitions (minimum details to be required):

Item	Meaning	Medoc Name
Description	**Spicam Science**	**SPINSCIDPU**
TM Identification Number (TM ID)		YSI01001
Instrument Name	Spicam	
Instrument subsystem	DPU	
Instrument Assembly	none	
TM Address Parameters (if possible and firm address)		NSIA0101
Calibration Data (if possible and final data) (e.g. 0 = Enabled, 1= Inhibited)		
Function	Science data DPU	
Validity		
Surveillance (i.e. TC which has impact on this TM)	None	
Corrective Action	None	
Alternative TM	Redundant lines	SPIRSCIDPU, YSI01011
Remarks		

Item	Meaning	Medoc Name
Description	**Spicam Science**	**SPINSCIUV1**
TM Identification Number (TM ID)		YSI01002
Instrument Name	Spicam	
Instrument subsystem	UV channel	
Instrument Assembly	none	
TM Address Parameters (if possible and firm address)		NSIA0102
Calibration Data (if possible and final data) (e.g. 0 = Enabled, 1= Inhibited)	none	
Function	Science Data UV1	
Validity		
Surveillance (i.e. TC which has impact on this TM)	None	
Corrective Action	None	
Alternative TM	Redundant lines	SPIRSCIUV1, YSI01012
Remarks		

Item	Meaning	Medoc Name
Description	**Spicam Science**	**SPINSCIUV2**
TM Identification Number (TM ID)		YSI01003
Instrument Name	Spicam	
Instrument subsystem	UV channel	
Instrument Assembly	none	
TM Address Parameters (if possible and firm address)		NSIA0103
Calibration Data (if possible and final data) (e.g. 0 = Enabled, 1= Inhibited)	none	
Function	Science Data UV2	
Validity		
Surveillance (i.e. TC which has impact on this TM)	None	
Corrective Action	None	
Alternative TM	Redundant lines	SPIRSCIUV2, YSI01013
Remarks		

Item	Meaning	Medoc Name
Description	**Spicam Science**	**SPINSCIIR**
TM Identification Number (TM ID)		YSI01004
Instrument Name	Spicam	
Instrument subsystem	IR channel	
Instrument Assembly	none	
TM Address Parameters (if possible and firm address)		NSIA0104
Calibration Data (if possible and final data) (e.g. 0 = Enabled, 1= Inhibited)	none	
Function	Science Data IR	
Validity		
Surveillance (i.e. TC which has impact on this TM)	None	
Corrective Action	None	
Alternative TM	Redundant lines	SPIRSCIIR, YSI01014
Remarks		

Event Packet Definitions	None
Anomaly Report Definitions	None
Context File Definition	None
Data and Dump File Definitions	None

Annex:

Annex1: Spicam Contact point:

Name	Telephone	Fax	Email	Address
BERTAUX Jean Loup	33 (0) 1 64 47 42 51	(2)	bertaux@aerov.jussieu.fr	(1)
DIMARELLIS Emmanuel	33 (0) 1 64 47 42 87	(2)	dimarellis@aerov.jussieu.fr	(1)
DUBOIS Jean Pierre	33 (0) 1 64 47 43 31	(2)	dubois@aerov.jussieu.fr	(1)
VAN RANSBEECK Emiel	32 23 73 04 54	(4)	Emiel.Vanransbeeck@bira-iasb.oma.be	(3)

(1) Address

Service d'Aeronomie du CNRS
BP 3
91371 Verrieres le Buisson
France

(2) Fax number is 33 (0) 1 69 20 29 99

(3) Address

BIRA - IASB
3, Avenue Circulaire
B-1180 BRUXELLES
Belgique

(4) Fax 32 23 74 84 23

Annex2: TM/TC description:

A2.1. Conventions and Definitions:

Bit numbering (from PSS-04-107)

Bit 0	Bit N-1
Bit0 = first bit transmitted = MSB	

Functions of the DPU concerning Telemetry:

receives data from Sensor Unit (detectors)
timetag detector data
formats all scientific and technology data in packets and update headers
put packets in Fifo (TM ready)

Format of data ready for acquisition: TM blocks: (from PID/URD ANNEX p 68)

elementary unit is 16 bits word
first word is the length of following TM words

	16 bits word	Name	Contents
		TM Block Length	number of following 16 bits TM words
1		TM Block Data	Spicam Packets
....		=	
n		=	

TM Block Data may contain:
at least one Spicam packet
--->several Spicam packets

A2.2. TM/TC Packet structure:

TM Packet structure:

	Packet Header (48 bits)							Packet Data Field		
	Packet ID				Packet sequence control		Packet length	Packet Field header	Source Data	Packet error control
bits	16 bits				16 bits		16 bits	80	variable	0
	Version number	Type	Data field Header Flag	APID = pid+pcat	Segmen-tation Flag	Source Seq Count				NOT USED
bits	3	1	1	7+4=11	2	14				

BIN	000	0	1	xxx(a)	11	n (b)	(c)	(d)	(e)
Hex				0E0C		Cxxx			

(a) APID is concatenation de pid+pcat
pid is 96 (decimal) or 60 (Hex)
pcat is 12 (for science telemetry = 1100 bin
APID is 110 0000 1100 bin = 60C Hex = 1548 dec
Packet ID is 0000 1110 0000 1100 Bin = 0E0C Hex = 3596 dec

(b) number associated with APID, start at 0 at power on

(c) number of octets -1 of Packet Data Field
min 9 (10 + no source data)
max 4106 (10 + 4096 source data)

(e) experiment data variable
min 0 octets
max 4096 octets

(d) Packet Field Header Structure

	Time	PUS version	Check-sum Flag	Spare	Packet Type	Packet Subtype	Pad
bits	48	3	1	4	8	8	8
BIN	TBD	000	0	0000	00010100	00000011	0
					(a)	(b)	
Hex	x---x		0	0	14	03	00

(a) packet type is 20 (packet category is 12)
(b) subtype is 3

HK_Packet_structure:
c'est en fait un packet TM avec des parametres particuliers

	Packet Header (48 bits)							Packet Data Field		
	Packet ID				Packet sequence control		Packet length	Packet Field header	Source Data	Packet error control
bits	16 bits				16 bits		16 bits	80	variable	0
	Version number	Type	Data field Header Flag	APID = pid+pcat	Segmen-tation Flag	Source Seq Count			4 octets	NOT USED
bits	3	1	1	11	2	14				

BIN	000	0	1	xxx(a)	11	n (b)	(c)	(d)	(e)
Hex				0E04		Cxxx	000D		

(a) APID is concatenation de pid+pcat
pid is 96 (decimal) or 60 (Hex)
pcat is 4 (for housekeeping = 0100 bin
APID is 110 0000 0100 bin = 1540 dec
Packet ID is 0000 1110 0000 0100 Bin = 0E04 Hex = 3588 dec
(b) number associated with APID, start at 0 at power on
(c) number of octets -1 of Packet Data Field
min 9 (10 + no source data)
max 4106 (10 + 4096 source data)

(e) experiment data for HK = 4 octets = 00 01 xx yy Hex **so (c) = 13 octets**
xx = recopie octet 6 du message servitude
yy = recopie octet 10 du message servitude

(d) Packet Field Header Structure

	Time	PUS version	Check-sum Flag	Spare	Packet Type	Packet Subtype	Pad
bits	48	3	1	4	8	8	8
BIN	TBD	000	0	0000	00000011	00011001	0
					(a)	(b)	
Hex	x---x		0	0	03	19	00

(a) packet type is 3, packet category is 4 (for housekeeping)
(b) subtype is 25

TC Packet structure:

	Packet Header (48 bits)							Packet Data Field		
	Packet ID				Packet sequence control		Packet length	Data Field header	Application Data	Packet error control
bits	16 bits				16 bits		16 bits	32	variable	16
	Version number	Type	Data field Header Flag	APID (pid + pcat)	Sequence Flag	Source Seq Count			68 max	
bits	3	1	1	7+4	2	14				

BIN	000	1	1	(a)	11	(b)	(c)	(d)	(e)	(f)
Hex				1E0C		Cxxx	0049			
Dec							73			

(a) APID is concatenation de pid+pcat
pid is 96 (decimal) or 60 (Hex), = 110 0000 bin
pcat is 12 (decimal) 1100 bin
APID is 110 0000 1100 Bin = 60C Hex = 1548 dec,
Packet ID is 0001 1110 0000 1100 bin = 1E0C Hex = 7592 dec
(b) number associated with APID, start at 0 at power on
(c) number of octets -1 of Packet Data Field c = 73 total length is 80 octets
min 5 (6 + no source data)
max 241 (6 + 236 source data)
(e) max is 236 octets
(f) CRC checksum

(d) Packet Field Header Structure

	PUS version	Check-sum Flag	Ack	Packet Type	Packet Subtype	Pad
bits	3	1	4	8	8	8
BIN	xxx	1	0000	11100010	00000001	0…0
	(a)		(b)	(c)	(d)	
Hex		1	0	E2	01	00

(a) direct TM responses to this TC processed by Ground
(b) no acknowledge report required
(c) packet type is 226, (packet category is 12)
(d) packet subtype is 1

Board Time Packet structure: (en reception)
C'est un packet TC avec des paramètres particuliers:

	Packet Header (48 bits)							Packet Data Field		
	Packet ID				Packet sequence control		Packet length	Data Field header	Application Data	Packet error control
bits	16 bits				16 bits		16 bits	32	variable	16
	Version number	Type	Data field Header Flag	APID (pid + pcat)	Sequence Flag	Source Seq Count			6 octets	
bits	3	1	1	7+4	2	14				

BIN	000	1	1	(a)	11	(b)	(c)	(d)	(e)	(f)
Hex				1E0C		Cxxx	000B			

(a) APID is concatenation de pid+pcat
pid is 96 (decimal) or 60 (Hex), = 110 0000 bin
pcat is 12 (decimal) 1100 bin
APID is 110 0000 1100 Bin ,
Packet ID is 0001 1110 0000 1100 bin = 1E0C Hex
(b) number associated with APID, start at 0 at power on
(c) number of octets -1 of Packet Data Field total length is 18 octets
min 5 (6 + no source data)
max 241 (6 + 236 source data)
(e) for board Time = 6 octets **so (c) = 11 octets**
(f) CRC checksum

(d) Packet Field Header Structure

	PUS version	Check-sum Flag	Ack	Packet Type	Packet Subtype	Pad
bits	3	1	4	8	8	8
BIN	010	1	0000	00001001	00000001	0…0
	(a)		(b)	(c)	(d)	
Hex		5	0	09	01	00

(a) direct TM responses to this TC processed by Ground
(b) no acknowledge report required
(c) packet type is 9, (packet category is 12)
(d) packet subtype is 1

Annex3: Medoc Database:

Copy of Medoc Database sheets: Version Medoc = MAS_5.0/MAM_4.974

Questions: no description of redundant channels (TC and TM?)

Table MEDOC: S_GENPACK

NAME	SERVICE	SUBSERVICE	LNAME	TM_OR_TC	SDFPRESENT	SDFOFFSET	SDFLENGTH	
ETC22601	226	1	SPICAM TC	TC	N			

Signature Payload Team:

Date de Signature: 05/03/02
Date d'extraction: 05/03/02
Version Médoc: MAS_5.0/ MAM_4.974
Responsable extraction: R. CASPAR

Table MEDOC: C_TCPACK

NAME	LNAME	PKGE_NAME	PID	PCKCATEG	SCOPE	AUTHORISATION	PRECONDITION	ACKTYPE
ZSI01001	SPICAM Private TC Packet	ETC22601	96	12	SPACE	N	TRUE	NONE
ZSI02001	SPICAM-Accept Time Update	ETC00901TSAC	96	12	SPACE	N	TRUE	NONE

Table MEDOC: C_TCPCK_ELT

TCPK_NAME	TCPE_ORDER	ELTTYPE	TCPE_SIZE	FIXEDVALUE	REPEAT	PKBL_NAME	TCPA_NAME	TCPK_NAME_INNER	EXCP_CODE	DESCRIPTION	NGRPSIZE
ZSI01001	0	PARAM	32		1		FSIG0002				
ZSI01001	1	PARAM	16		1		FSIG0010				
ZSI01001	2	PARAM	16		1		FSIG0011				
ZSI01001	3	PARAM	16		1		FSIG0012				
ZSI01001	4	PARAM	16		1		FSIG0013				
ZSI01001	5	PARAM	16		1		FSIG0014				
ZSI01001	6	PARAM	16		1		FSIG0015				
ZSI01001	7	PARAM	16		1		FSIG0016				
ZSI01001	8	PARAM	16		1		FSIG0017				
ZSI01001	9	PARAM	16		1		FSIG0018				
	10	PARAM	16		1		FSIG0019				
ZSI01001	11	PARAM	16		1		FSIG0020				
ZSI01001	12	PARAM	16		1		FSIG0021				
ZSI01001	13	PARAM	16		1		FSIG0022				
ZSI01001	14	PARAM	16		1		FSIG0023				
ZSI01001	15	PARAM	16		1		FSIG0024				
ZSI01001	16	PARAM	16		1		FSIG0025				
ZSI01001	17	PARAM	16		1		FSIG0026				
ZSI01001	18	PARAM	16		1		FSIG0027				
ZSI01001	19	PARAM	16		1		FSIG0028				
ZSI01001	20	PARAM	16		1		FSIG0029				
ZSI01001	21	PARAM	16		1		FSIG0030				
ZSI01001	22	PARAM	16		1		FSIG0031				
ZSI01001	23	PARAM	16		1		FSIG0032				
ZSI01001	24	PARAM	16		1		FSIG0033				
ZSI01001	25	PARAM	16		1		FSIG0034				
ZSI01001	26	PARAM	16		1		FSIG0035				
ZSI01001	27	PARAM	16		1		FSIG0036				
ZSI01001	28	PARAM	16		1		FSIG0037				
ZSI01001	29	PARAM	16		1		FSIG0038				
ZSI01001	30	PARAM	16		1		FSIG0039				
ZSI01001	31	PARAM	16		1		FSIG0040				
ZSI01001	32	PARAM	16		1		FSIG0041				
ZSI02001	0	PARAM	48		1		FSIG0004				

Table MEDOC: C_TCPARAM

NAME	CATEGORY	LNAME	PTC	PFC	TCPA_SIZE	CALIB_TYPE	CALC_NAME_1	ENGLABEL	DEF_VALUE	TCDP_TCGP_NAME	TCDP_START_BIT
FSID0021	TCDP	BE Configuration Bit Field	0	28	28	NONE				FSIG0002	4
FSID0022	TCDP	BE Modes	3	0	4	DIG	CSIV0001	NA		FSIG0002	0
FSID0041	TCDP	On-Board Time at Next TBP (Coarse)	3	14	32	NONE				FSIG0004	0
FSID0042	TCDP	On-Board Time at Next TBP (Fine)	3	12	16	NONE				FSIG0004	32
FSIG0002	TCGP	BE Configuration Global Param	0	32	32	NONE		NA	0		
FSIG0004	TCGP	On-Board Time at Next TBP	0	48	48	NONE					
FSIG0010	TCGP	SPICAM Command Parameter #1	3	12	16	NONE		NA	0		
FSIG0011	TCGP	SPICAM Command Parameter #2	3	12	16	NONE		NA	0		
FSIG0012	TCGP	SPICAM Command Parameter #3	3	12	16	NONE		NA	0		
FSIG0013	TCGP	SPICAM Command Parameter #4	3	12	16	NONE		NA	0		
	TCGP	SPICAM Command Parameter #5	3	12	16	NONE		NA	0		
FSIG0015	TCGP	SPICAM Command Parameter #6	3	12	16	NONE		NA	0		
FSIG0016	TCGP	SPICAM Command Parameter #7	3	12	16	NONE		NA	0		
FSIG0017	TCGP	SPICAM Command Parameter #8	3	12	16	NONE		NA	0		
FSIG0018	TCGP	SPICAM Command Parameter #9	3	12	16	NONE		NA	0		
FSIG0019	TCGP	SPICAM Command Parameter #10	3	12	16	NONE		NA	0		
FSIG0020	TCGP	SPICAM Command Parameter #11	3	12	16	NONE		NA	0		
FSIG0021	TCGP	SPICAM Command Parameter #12	3	12	16	NONE		NA	0		
FSIG0022	TCGP	SPICAM Command Parameter #13	3	12	16	NONE		NA	0		
FSIG0023	TCGP	SPICAM Command Parameter #14	3	12	16	NONE		NA	0		
FSIG0024	TCGP	SPICAM Command Parameter #15	3	12	16	NONE		NA	0		
FSIG0025	TCGP	SPICAM Command Parameter #16	3	12	16	NONE		NA	0		
FSIG0026	TCGP	SPICAM Command Parameter #17	3	12	16	NONE		NA	0		
FSIG0027	TCGP	SPICAM Command Parameter #18	3	12	16	NONE		NA	0		
FSIG0028	TCGP	SPICAM Command Parameter #19	3	12	16	NONE		NA	0		
FSIG0029	TCGP	SPICAM Command Parameter #20	3	12	16	NONE		NA	0		
FSIG0030	TCGP	SPICAM Command Parameter #21	3	12	16	NONE		NA	0		
FSIG0031	TCGP	SPICAM Command Parameter #22	3	12	16	NONE		NA	0		
FSIG0032	TCGP	SPICAM Command Parameter #23	3	12	16	NONE		NA	0		
FSIG0033	TCGP	SPICAM Command Parameter #24	3	12	16	NONE		NA	0		
FSIG0034	TCGP	SPICAM Command Parameter #25	3	12	16	NONE		NA	0		
FSIG0035	TCGP	SPICAM Command Parameter #26	3	12	16	NONE		NA	0		
FSIG0036	TCGP	SPICAM Command Parameter #27	3	12	16	NONE		NA	0		
FSIG0037	TCGP	SPICAM Command Parameter #28	3	12	16	NONE		NA	0		
FSIG0038	TCGP	SPICAM Command Parameter #29	3	12	16	NONE		NA	0		
FSIG0039	TCGP	SPICAM Command Parameter #30	3	12	16	NONE		NA	0		
FSIG0040	TCGP	SPICAM Command Parameter #31	3	12	16	NONE		NA	0		
FSIG0041	TCGP	SPICAM Command Parameter #32	3	12	16	NONE		NA	0		

Table MEDOC: C_TMPCK

NAME	LNAME	PKGE_NAME	PID	PCKCATEG	SDFVALUE			
YSI01001	SPICAM-Science Report via RTU Link	ETM02003SDRP	96	12				
YSI02001	SPICAM: Housekeeping Packet	ETM00325HKPK	96	4	1			

Table MEDOC: C_TM_PCK_ELT

TMPK_NAME	TMPE_ORDER	ELTTYPE	ITEMOFFSET	TMPE_SIZE	FIXEDVALUE	REPEAT	PKBL_NAME	PKBL_CATEGORY	TMPA_NAME	EXCP_CODE	NGRPSIZE
YSI01001	0	PARAM	0	16		1			NSIA0101	VR_NOC	
YSI02001	0	FIXED	0	8	0	1					
YSI02001	1	FIXED	8	8	1	1					
YSI02001	2	PARAM	16	8		1			NSIA0001		
YSI02001	3	PARAM	24	8		1			NSIA0002		

Table MEDOC: C_TMPARAM

NAME	CATEGORY	LNAME	PTC	PFC	TMPA_SIZE	SGRP_NAME	CALIB_TYPE	CALC_NAME_1	CALC_NAME_2	ENGLABEL
NSIA0001	TMGS	Temp_BT2	3	4	8	SSISPICA	ANA	CSIY0001		NA
NSIA0002	TMGS	Temp_Struct	3	4	8	SSISPICA	ANA	CSIY0001		NA
NSIA0101	TMGS	Raw Science Data Word	3	12	16	SSISPICA	NONE			NA
NSIA0102	TMGS	Science Data UV-1	3	12	16	SSISPICA	NONE			NA
NSIA0103	TMGS	Science Data UV-2	3	12	16	SSISPICA	NONE			NA
NSIA0104	TMGS	Science Data IR	0	16	16	SSISPICA	ANA	CSIY0001		NA

Table MEDOC: P_CALIBRATION

NAME	LNAME	CALTYPE	REVERSIBLE	PTIT_NAME				
CSIV0001	SPICAM- BE Modes naming	SVAL	Y	ISISPICA				
CSIY0001	SPICAM- TC parameters string	CPOL	Y	ISISPICA				

Table MEDOC: P_CALVAR

CALC_NAME	MODL_MODEL	LNAME	COEFF0	COEFF1	DEFAULTTEXT	CALC_CALTYPE		
CSIV0001	DEFAULT	BE modes naming			ERROR	SVAL		
CSIY0001	DEFAULT	TC parameters string	0	1		CPOL		

Table MEDOC: P_CALVAR_ELT

CALV_CALC_NAME	CALV_MODL_MODEL	XVALUE	XVALUE_HIGH	YVALUE	YDIGTEXT	CALC_CALTYPE		
CSIV0001	DEFAULT	0	15		Dummy	SVAL		
CSIV0001	DEFAULT	1	15		TestN	SVAL		
CSIV0001	DEFAULT	2	15		TestS	SVAL		
CSIV0001	DEFAULT	3	15		Cmde directe	SVAL		
CSIV0001	DEFAULT	4	15		Limb	SVAL		
CSIV0001	DEFAULT	5	15		StarLimb1	SVAL		
CSIV0001	DEFAULT	6	15		StarLimb2	SVAL		
CSIV0001	DEFAULT	7	15		StarLimb3	SVAL		
CSIV0001	DEFAULT	8	15		Nadir1	SVAL		
CSIV0001	DEFAULT	9	15		Nadir2	SVAL		
CSIV0001	DEFAULT	10	15		Nadir3	SVAL		
CSIV0001	DEFAULT	11	15		Align	SVAL		
CSIV0001	DEFAULT	12	15		Tiprog	SVAL		
CSIV0001	DEFAULT	13	15		Sun1	SVAL		
CSIV0001	DEFAULT	14	15		Sun2	SVAL		
CSIV0001	DEFAULT	15	15		Sun3	SVAL		

The following is extracted from Acid 1.0.

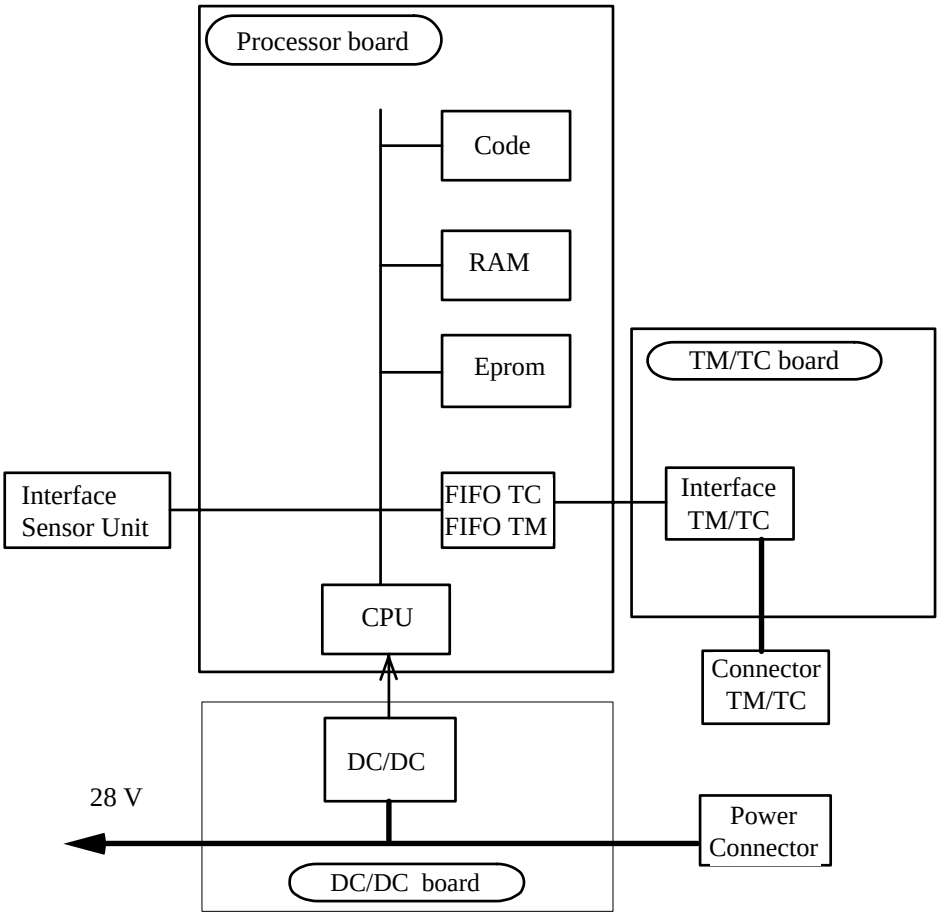
(kept for LCL command reference)

```
-- File:   ROSTC_Command (ROSTC_Command_data.acx)              #
-- Title:  Description of TC Packets                           #
-- Date:   09-JAN-2001 13:23          By user: SISMESAI        #
-- ############################################################
-- Source: MEDOC - MARS EXPRESS DATABASE, version V3.2.5       #
--         SIS - SIS Kernel, version V2.8                      #
-- Site:   SISMESAI - RSDB site "SAI"                          #
-- Data:   WORKING dataspace (SISMESAI), site version 0.0      #
-- ############################################################
-- ############################################################
acid [1.0] {

2001 11 15, search for spi then fsi, merged and sorted dima


line 149523: { -- begin record ZPWM2173 (SPICAM A ( LCL_11A  ON )) -----------------
line 149525:     { ["SPICAM A ( LCL_11A  ON )"] }
line 161925: { -- begin record ZPWM2212 (SPICAM B ( LCL_11B ON )) ------------------
line 161927:     { ["SPICAM B ( LCL_11B ON )"] }
line 174327: { -- begin record ZPWM2251 (SPICAM A ( LCL_11A  OFF )) ----------------
line 174329:     { ["SPICAM A ( LCL_11A  OFF )"] }
line 186570: { -- begin record ZPWM2290 (SPICAM B ( LCL_11B OFF )) -----------------
line 186572:     { ["SPICAM B ( LCL_11B OFF )"] }
line 199608: { -- begin record ZPWM2331 (SPICAM A ( LCL_11A  Sel Profile )) --------
line 199610:     { ["SPICAM A ( LCL_11A  Sel Profile )"] }
line 208989: { -- begin record ZPWM2373 (SPICAM B ( LCL_11B Sel Profile )) ---------
line 208991:     { ["SPICAM B ( LCL_11B Sel Profile )"] }
```

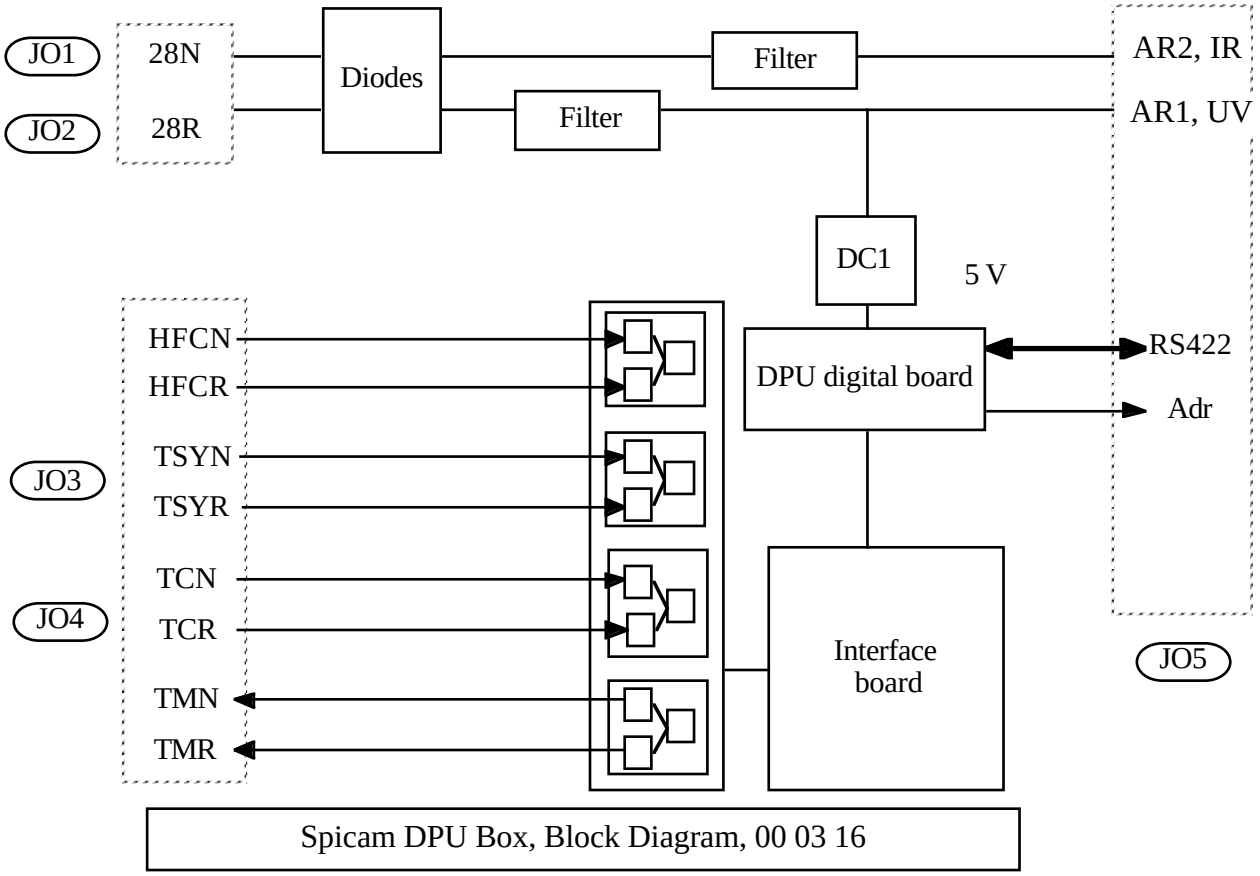
Annex4: Spicam Diagrams:

copy of PID-B1 and B2

DPU synoptic

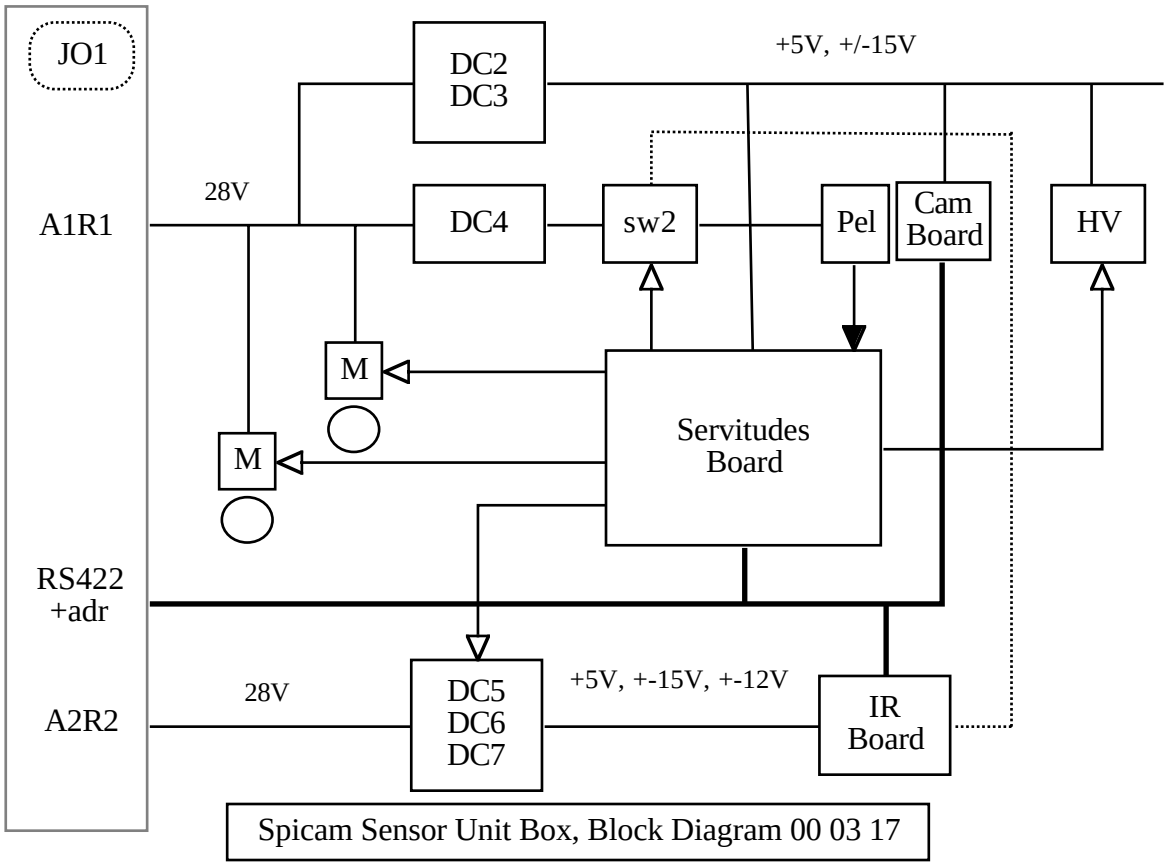


Functional Block Diagram DPU:



Spicam DPU Box, Block Diagram, 00 03 16

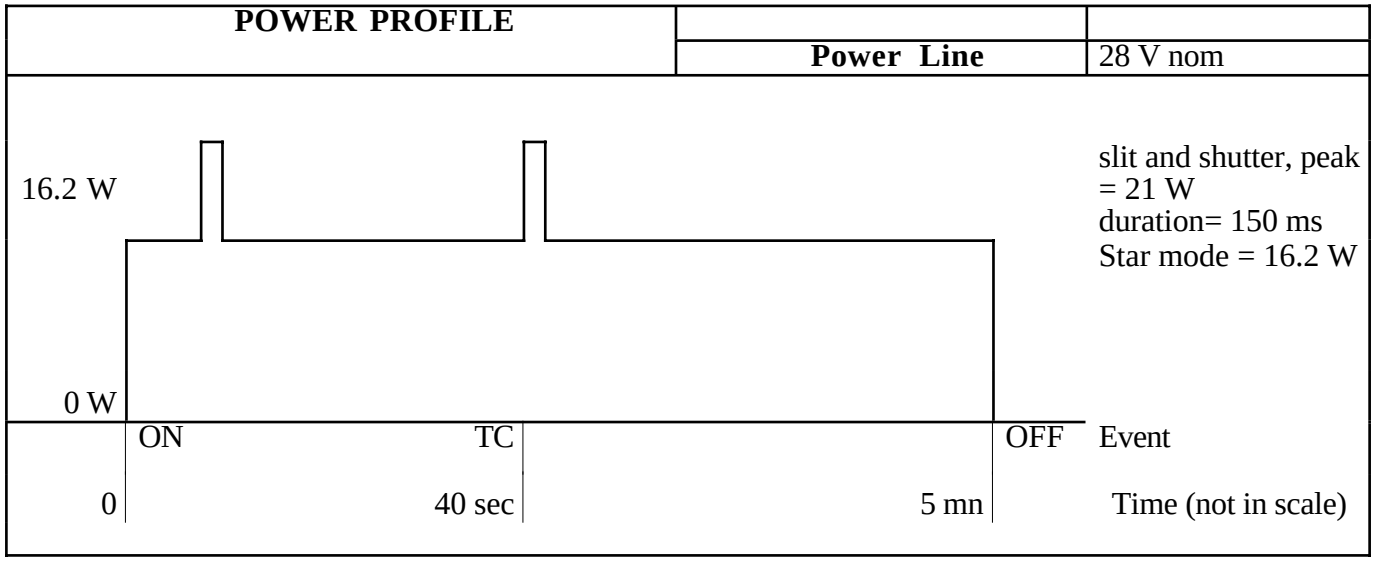
Functional Block Diagram SU (sensor unit):



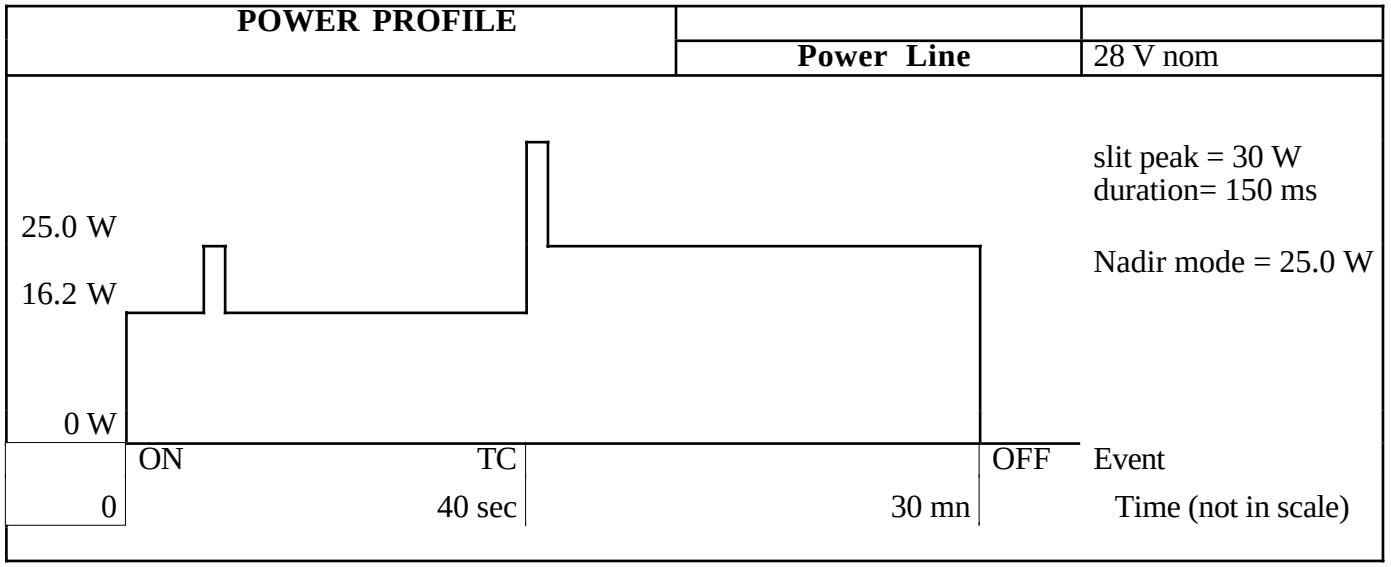
Power Demand:

Power Lines Description	Average Power BOL [W]				Long Peak Power		Short Peak Power	
	Modes				Peak [W]	Duration [s]	Peak [W]	Duration [s]
	Standby		Star	Nadir				
28 V main supply nom	0		16.2	25.0	30	0,15	0	
28 V main supply red	0		16.2	25.0	30	0,15	0	

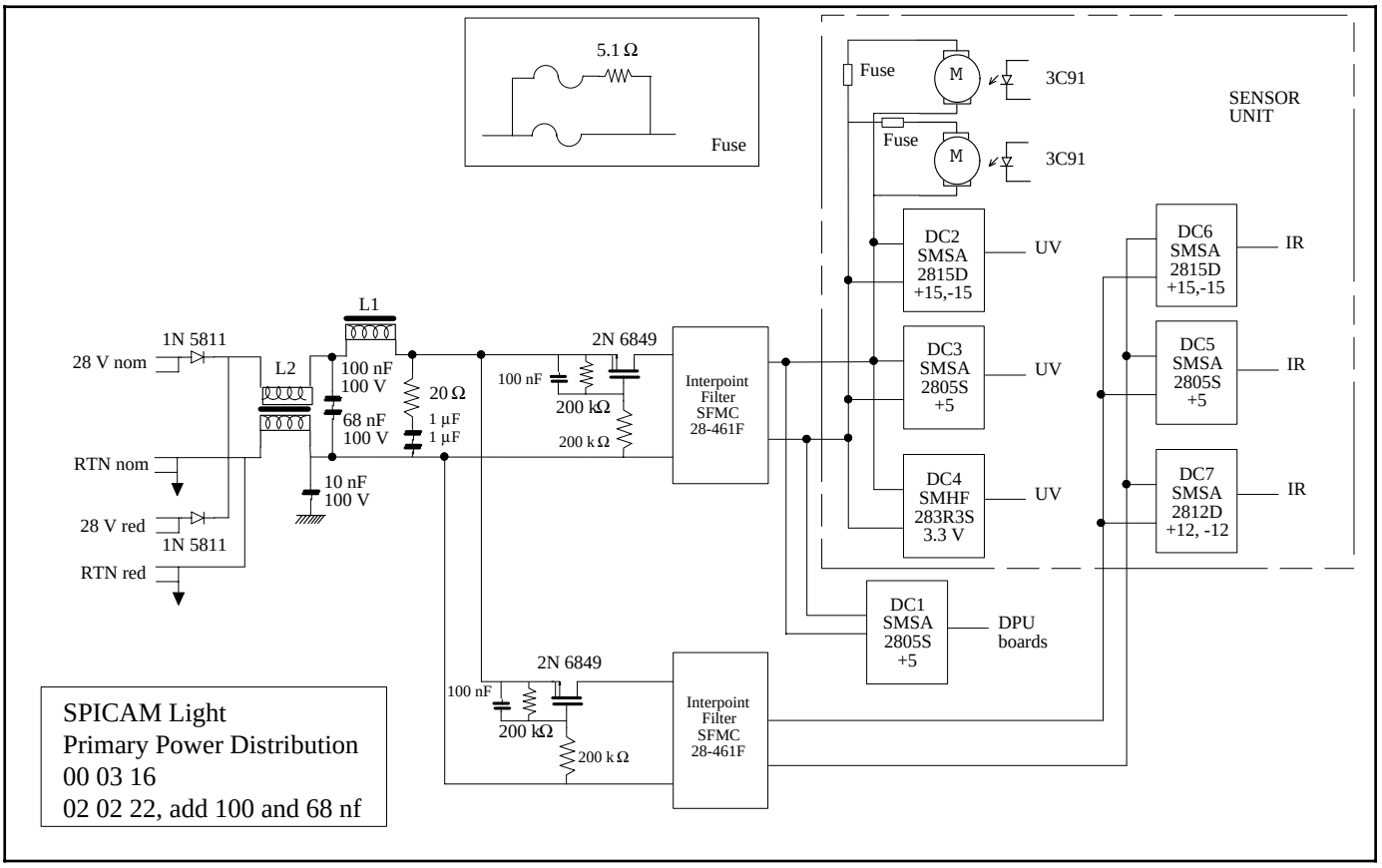
Power Profile Star Mode:



Power Profile Nadir Mode:



DPU Power Distribution and Interfaces circuits:



Conclusions of FMECA:

The results of the analyses at functional and component level show one type of failure propagation to the S/C.

It concerns failure mode leading to the short circuit on the power bus. However this failure can be accepted at the MEX S/C system level considering the S/C power line protection design.

Indeed, the LCL power protection implemented on the PDU provides the limitation of maximum current and the automatic disconnection of the SPICAM instrument in case of overload.

Annex5: Auxilliary data:

MEX auxilliary data:

Accuracy will be determined by Flight Dynamics, following numbers are given for information.

ORBIT AND ATTITUDE DATA CONSOLIDATED REQUIREMENTS

Data required	**Timing**	**Data source**	**Resp.**	**Delivery Method**	**Freq.**	**Sam-pling**	**Accuracy (Required)**
Major S/C events (Orbit Manoeuvres, Eclipse etc)	Planned and Predicted	Ground	ESOC	DDS (Aux Data)	Monthly	TBD	TBD
Long range Orbit Prediction	Predict	Ground	ESOC	DDS (Aux Data)	Monthly	1 / min	< 25 km
Near Term Orbit Prediction	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	1 / min	5 km
Quick look Orbit Estimation	Post-obs	Tracking Data	ESOC	DDS (Aux Data)	Once in 2 days	1 / sec	2 km
Precision Orbit Estimation	Post-obs	Tracking Data	ESOC	DDS (Aux Data)	Once in 2 weeks	1 / sec	0.5 km
Predicted Attitude	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	1 / min	0.1 deg
Reconstituted Attitude (Attitude and Rates)	Post-obs.	S/C Data + Ground	ESOC	DDS (Aux Data)	Weekly	1 / sec	0.05 deg

Data required	**Timing**	**Data source**	**Resp.**	**Delivery Method**	**Freq.**	**Sam-pling**	**Accuracy (Required)**
Rotation Angle of SA **(with respect to S/C frame of reference)**	Post–obs.	S/C Data	ESOC	DDS (Aux Data)	Weekly		
Pericentre 'TICK'	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	Every Orbit	1 sec
Orbit Time Period	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	Every Orbit	1 sec
Thruster Firing Times (Start Time & Duration)	Prediction & Post-obs.	Ground	ESOC	DDS (Aux Data)	Event related	Every Manoeuvre	1 sec
Sun Zenith Angle (Over Pericentre)	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	one sample / 10 sec	0.5 deg
Times of Occultation (Star/Sun) (Refer to SPICAM Star Catalogue)	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	NA	< 5 sec
Spacecraft Position (PSO)	Post Ops (2)	Ground	ESOC	DDS (Aux Data)	Weekly	1 sec	0.5 km
Longitude & Latitude of occulted Mars point	Post Ops (2)	Ground	ESOC	DDS (Aux Data)	Weekly	NA	0.1 deg
Solar Zenith Angle (of occulted Mars Point)	Post Ops (2)	Ground	ESOC	DDS (Aux Data)	Weekly	NA	0.1 deg
Duration of Occultation (between 200 Km and 0 Km)	Prediction	Ground	ESOC	DDS (Aux Data)	Weekly	NA	< 5 sec

Comments:

(2) these data are for Post processing, our requirements for Prediction are defined in the associated table "Instrument Data Requirements (4)", see next sheet

For these data, sampling and accuracy are not the same if they are 'Prediction ' or 'Post Obs.'

SPICAM auxilliary data:

Instruments Data Requirements (4)

SPICAM						
Data required	**Timing**	**Data source**	**Responsibility**	**Delivery Method**	**Frequency**	**Accuracy**
Star/Sun Occultation Observations: - Star occulted by Mars.	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	
- Time of occultation.	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	< 5 sec
- Spacecraft Position (PSO).	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	6 km ?
- Duration of occultation (between 200 and 0 Km).	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	< 5 sec
- S/C attitude (for Sun Occultation).	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	0.1 deg
- Latitude and Longitude of occulted Mars point.	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	0.5 deg
- Solar Zenith Angle of occulted Mars point.	Prediction	Ground	ESOC	DDS (ESOC)	Once/ month	0.5 deg

Annex6: Star Catalog:

```
25 03 2002 Etoiles Spicam (flux > 800 at 164 nm), 39 stars,  Dimarellis
 1  Spicam number
 2  BSC number
 3  Name
 4  Spectral Type
 5  Visual magnitude
 6  Right ascension (deg) J2000
 7  Declinaison (deg) J2000

   2  264 Gam Cas B0IVe  2.47  14.18  60.72
   5  472 Alp Eri B3Vpe  0.46  24.43 -57.24
   8 1203 Zet Per B1Ib   2.85  58.53  31.88
   9 1220 Eps Per B0.5V  2.89  59.46  40.01
  12 1713 Bet Ori B8Ia:  0.12  78.63  -8.20
  14 1790 Gam Ori B2III  1.64  81.28   6.35
  16 1852 Del Ori O9.5I  2.23  83.00  -0.30
  17 1879 Lam Ori O8III  3.54  83.78   9.93
  18 1899 Iot Ori O9III  2.77  83.86  -5.91
  19 1903 Eps Ori B0Ia   1.70  84.05  -1.20
  20 1948 Zet Ori O9.7I  2.05  85.19  -1.94
  21 2004 Kap Ori B0.5I  2.06  86.94  -9.67
  25 2294 Bet CMa B1II-  1.98  95.68 -17.96
  28 2491 Alp CMa A1Vm  -1.46 101.29 -16.72
  29 2618 Eps CMa B2II   1.50 104.66 -28.97
  36 3165 Zet Pup O5f    2.25 120.90 -40.00
  41 3734 Kap Vel B2IV-  2.50 140.53 -55.01
  44 4199 The Car B0Vp   2.76 160.74 -64.39
  46 4621 Del Cen B2IVn  2.60 182.09 -50.72
  48 4730 Alp1Cru B0.5I  1.33 186.65 -63.10
  49 4731 Alp2Cru B1V    1.73 186.65 -63.10
  53 4853 Bet Cru B0.5I  1.25 191.93 -59.69
  55 5056 Alp Vir B1III  0.98 201.30 -11.16
  56 5132 Eps Cen B1III  2.30 204.97 -53.47
  57 5191 Eta UMa B3V    1.86 206.88  49.31
  59 5231 Zet Cen B2.5I  2.55 208.88 -47.29
  60 5267 Bet Cen B1III  0.61 210.96 -60.37
  62 5440 Eta Cen B1.5V  2.31 218.88 -42.16
  65 5469 Alp Lup B1.5I  2.30 220.48 -47.39
  70 5944 Pi  Sco B1V+B  2.89 239.71 -26.11
  71 5953 Del Sco B0.3I  2.32 240.08 -22.62
  73 5984 Bet1Sco B1V    2.62 241.36 -19.81
  74 6084 Sig Sco B1III  2.89 245.30 -25.59
  76 6165 Tau Sco B0V    2.82 248.97 -28.22
  77 6175 Zet Oph O9.5V  2.56 249.29 -10.57
  84 6527 Lam Sco B2IV+  1.63 263.40 -37.10
  86 6580 Kap Sco B1.5I  2.41 265.62 -39.03
  89 7121 Sig Sgr B2.5V  2.02 283.82 -26.30
  91 7790 Alp Pav B2IV   1.94 306.41 -56.74
```

Annex7: Polling mechanism from PID-A:

- sequential polling of all (or a subset) experiments, numbered from 1 to 8,
- max TM block length delivered by one experiment during polling is
  6144 words (16 bits) or 98 kb
- min TM block length delivered by one experiment during polling is 0

Therefore one experiment may deliver a TM of variable length at each polling within the limits fixed above (0 - 98 kb)

- reading of TM block at 131 kbps
- max data polling during one second between 80 and 114 kb (depending on Packet-TC traffic)
- polling sequence starts always on 1 second synchro pulse
- polling sequence length depends on the lengths of individual TM blocks
- guaranteed total data rate for all instruments around 80 kbps

Conclusions:

If all 8 experiments are delivering the maximum authorized TM block (98 kb), then the polling sequence will last 8 seconds maximum. This is called worst case in the following. It still guarantees an average data rate of 12288 bps, averaged over 8 sec for each instrument.

There is a Spacecraft Requirement that the instrument should cope with the possible missing of one polling sequence. In the case of the "worst case", this means that the instrument must store about 16 sec of data.

If one instrument is "ON", and in the polling sequence, then it has a minimum guaranteed data rate of about 10 to 12 kbps (averaged over 8 sec). If several instruments are "ON", polled in sequence, the total average data rate (averaged over 8 sec) cannot exceed 80 to 114 kbps. If they try to deliver more, they will lose some data. It is a reasonable assumption that, during operations, the timeline will take care of such a constraint, and that Mission Operations Center will not operate a set of instruments which requires a total of (averaged) data rate > 100 kbps.

So we have to consider two cases:

A-- Spicam delivers data with average bit rate less than 10 kbps:
there is no constraints on Spicam whatever is the combination of other instruments.

B-- Spicam delivers data with average bit rate more than 10 kbps:
in this case, there is a constraint on the number of instruments which are active simultanously and this constraint is on the sum of their average bit rates: the sum of Spicam + all other shall not exceed about 100 kbps.

Annex8: Ground test sequence:

We define 2 functional tests which can be used during integration and ground testing:

FPT full performance test
this test consists of 3 independant Spicam modes

STAR,	5 mn,	26 kb/s
SUN,	5 mn	30 kb/s
NADIR	30 mn	8.6 kb/s

LPT limited performance test, same test for GO-NO-GO test
this test consists of one Spicam mode

NADIR	10 mn	8.6 kb/s

SCOE TC syntax:

From Database Medoc 3.0

telecommand name	ZSI01001	
parameters	FSID0022	experiment mode
	FSID0021	experiment config
	FSIG00xx	others parameters (default = 0)

Syntax of the RPRO message send to CCS: Telecommand

Type	TC-R
Field1	SYM-TC
Field2	ZSI01001
arguments	SCOE:="TMTCSC",ACKBITS:="NONE", FSID0022:="TestN", FSID0021:0BV:=0xE000000,FSIG0011:0BV:=0xABCD

Notes:
- ackbits = "NONE", "EXEC", "ACCP", "BOTH"
- all FSIG00xx are optional
- :OBV means "on board value"
- Hexadecimal values are preceded by "0x"
- For FSID0022, the value of the calibration curve must be set
  (Dummy, TestN, TestS, Cmde directe, Limb, StarLimb1, StarLimb2, StarLimb3, Nadir1, Nadir2, Nadir3, Align, Tiprog, Sun1, Sun2, Sun3)
  --->case sensitive

Summary of Spicam functional tests:

Seq name	Duration (mn)	Spicam conf	Kbits/s	Power (W)	TC (hex)
TESTM	10	UV+IR	8.6	16.7	1 E000000
STARLIM1	5	UV	26	16.7	5 00A4000
SUN2	5	UV+IR	30.2	25.9	E 20F4020
NADIR30	30	UV+IR	8.6	25.9	A 7084020

Annex9: Detailed Ground operations plan:

The following paragraphs describe all the actions which are needed for operations of Spicam Light:
SA = Service d'Aéronomie

We propose the following phases:

Data Needed	Actions	Actioner	Remarks
Pre-mission			
Targets	Star catalog	SA	
Mission, every month			
Orbit data	Compute predicts	ESOC	
Occulted targets	Compute attitude (1) (2)	ESOC	In parallel at SA
Selected Stars	Choice by Science team	SA	
Attitude parameters	Elaboration	ESOC	verification by SA
TC Spicam	Elaboration	SA	
Mission, every week			
Spicam master schedule uplink		ESOC	
Spicam health and status monitoring		ESOC	
TM	Retrieval	SA	SA Ground Segment
	Verification	SA	
	Processing	SA	

(1) For STAR mode, the following is a preliminary list of what has to be computed:
with predicted orbit and star catalog compute:
stars possible to be occulted by Mars
time and S/C position on the orbit
duration of occultation between 200 and 0 km
S/C attitude of the +Z axis (other axis are free)
coordinates of occulted point on Mars and SZA (Solar Zenith Angle) angle
Then resources availibility reduces the possibilities
if several targets are possible, selection by PI
Then calculations of orientation timeline by ESOC to put S/C in good attitude at proper time
Preparation of TC for Spicam (by experiment team)
Uplink to S/C

(2) For LIMB mode, the direction of observation is defined by alpha, delta, as a "virtual" star.
The S/C attitude is defined by the orientation of the slit of the spectrometer.
Computation to be done by Experiment team (TBC).
Computation is TBD.

Calibration and error budget:

On ground, calibration tests will be done at equipment level and instrument level (under ambient conditions and in thermal vacuum).

Main performances tests are following:

- detection chain measurements:
  - DC maps
  - Dark Noise
  - Detection chain gain (elctrons per DN, and electrons per photoevent)
  - Readout Noise
- opto mechanical verification
- straylight
- specific tests
  - spectral bands, wavelength assignment
  - spectro radiometric sensitivity
  - spectro Signal to Noise ratio
  - Linearity
  - Uniformity

They will be done on QM and FM and they will be included in a calibration data base.