SPICAM LIGHT

Alignments

A-1. Approval Page:

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Authorised for the Principal Investigator:

…………………………………
J.L. Bertaux, Principal Investigator

14 01 03 update, dima
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A-4. List of Acronyms:

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
LOS	Line of sight = Optical axis
MOC	Mission Operation Center
NA	Not Applicable
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

1. Introduction:

1.1. Purpose:

The purpose of this document is:
- to summarize all informations about alignment
- to compute the vector components of the lines of sight (Nadir and Sun) of Spicam

Reference documents:

RD1:	Log book of Spicam SU2	Jul 2002
RD2:	Spacecraftexp_alignt1.xls, Excel sheet from Astrium	Dec 2002
RD3:	Flight User manual, Spicam	
RD4:	SU1 Alignment report	Jul 2002

1.2. Overview of operations:

For Spicam, what must be pointed towards target is the optical axes. Orientation of optical axis is done by orientation of S/C axes. So, the alignment data are needed in order to define the optical axis versus Spacecraft axes. This exercise has to be done for the two apertures, Nadir and Solar aperture. When these optical axes are defined, these data are used in the 'operational request' (send to POS and then to ESOC), and these values are used to orient S/C.

So, a difference with theorical value has no impact (assuming that the measurements are correct), because the measured value are used for pointing, and not the theorical ones.

2. Definitions:

2.1. Instrument General Presentation:

. . .
The Sensor Unit has two main directions of sight, one is Nadir (s/c +Zb), 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 -Yb wall. A hole in the instrument mouting wall and in the -Yb wall will be used for Solar occultation.

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

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

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

2.2. Spicam Optical axis:

Optical axis is also called Line of sight (LOS)

UV Nadir:

The Optical axis is defined as the direction such that, at 253.7 nm (Hg line), the image through all optical elements is on the CCD at line 144, column 124.

Ajustement procedure:
1. by autocollimation, define miror M3 direction
2. by parallel transport, put this direction in UV channel
3. adjust parabolic miror by autocollimation on slit
4. adjust detector by thickness of Hg line through grating
5. adjust position of line on CCD by shims under grating
6. adjust fine position of parabolic miror with artificial star

IR Nadir:

As the field of view is 1 degree, we rely on mechanical mouting and Optical axis is same as UV.

IR and UV Sun:

The Optical axis is defined as the direction going through Sun aperture such that the image is focused on the Light trap or the IR sensor (AOTF off).

By mechanical ajustement, the UV Optical axis is the same as IR Sun.

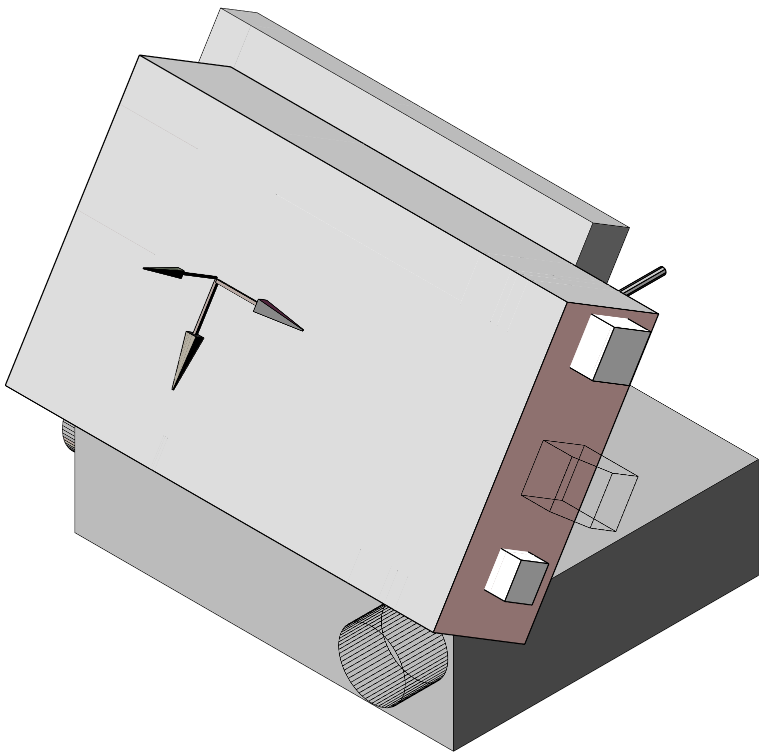
Ajustement procedure:

1. Sensor unit is mounted on a 3 axis table
2. Table is adjusted such that laser light goes to IR Light trap
3. by parallel transport, put this direction in UV Sun aperture
4. adjust UV folding mirror such that laser light goes through slit at line 100 (middle of narrow slit)

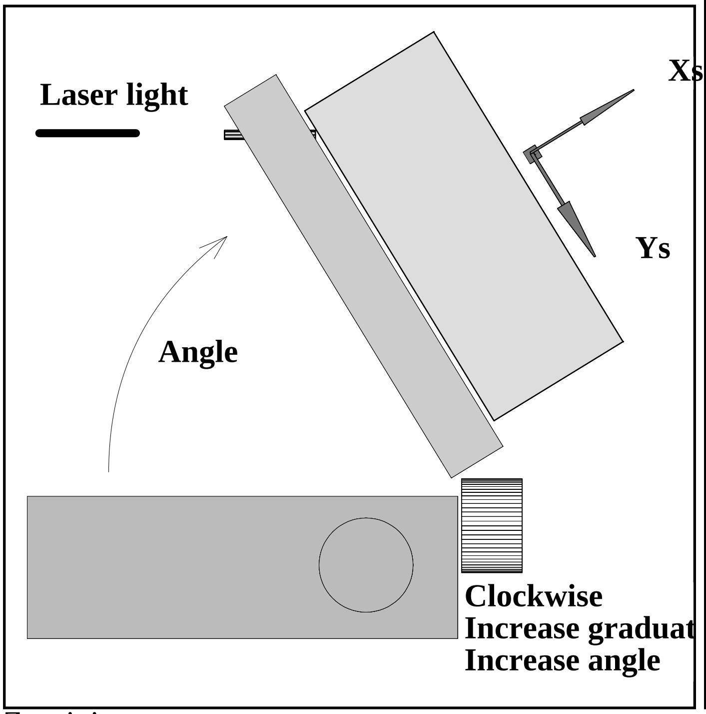
Measurement procedure:

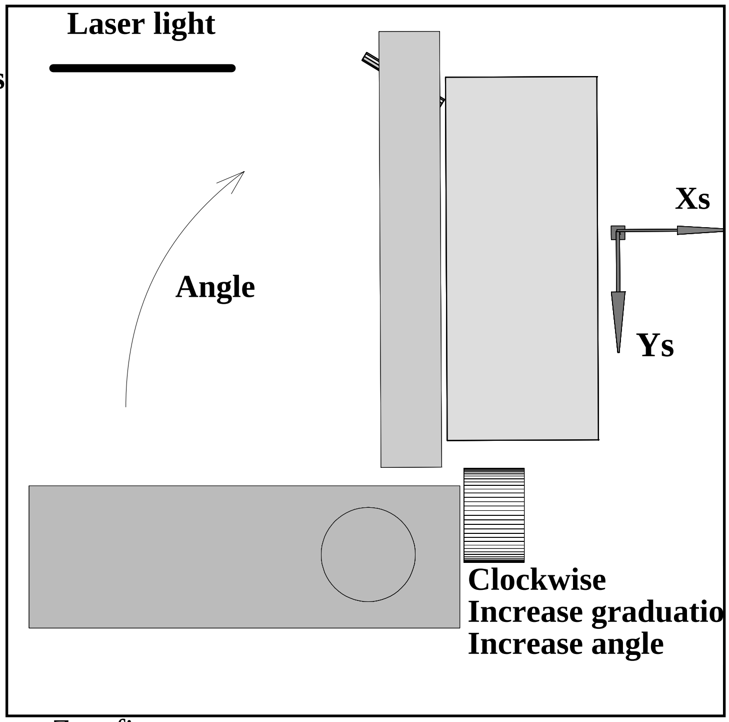
1. Plane mirror is glued on back face of baseplate
2. Turn table (2 axes) such that mirror is perpendicular to laser Light
3. Read and report angles

Below is a drawing of the 3D table used for alignment.



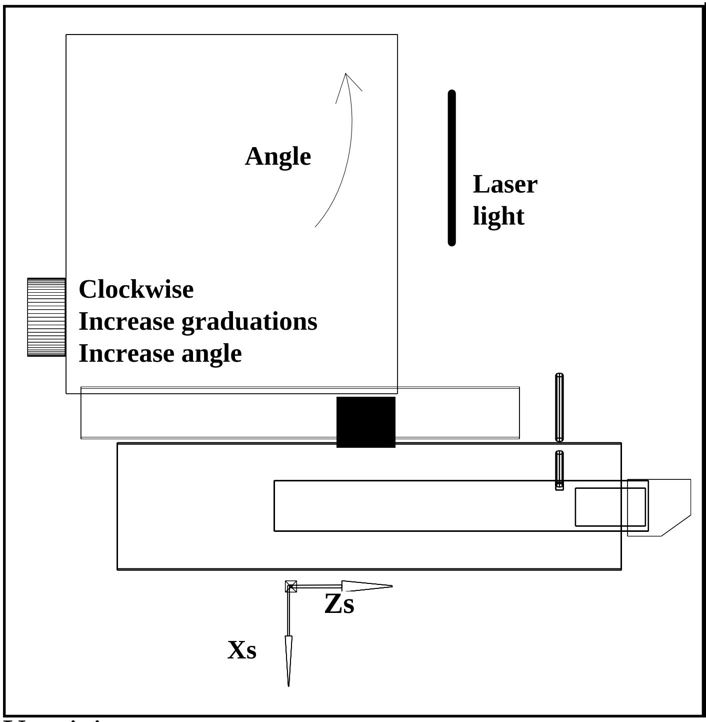
Rotation around Zs:

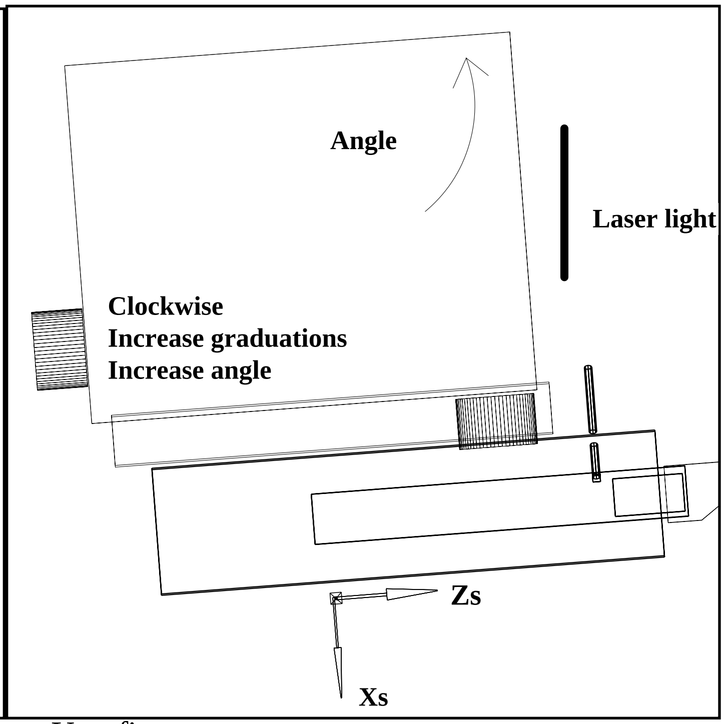




Zsuninit | Zsunfin
Angle = 59 deg 50 min | 90 deg 06 min

Rotation around Ys:





Ysuninit | Ysunfin
Angle = 48 min 25 | 1 deg 05 min

2.3. Frames:

Reference documents:

MEX-MMT-MA-1091, issue2, 31 May 02
Mars Express CReMA issue2, august 2000

As we are working with directions only, we do not specify origin.

Summary of frames:

Fb	S/C Structure Reference Frame
Fa	S/C Attitude Reference Frame
Fc	Spicam Cube Frame
Fs	Spicam Structure Frame

S/C Structure Reference Frame Fb used only for mechanical drawing

is frame Fa rotated +180 around +Z

Xb = -Xa
Yb = -Ya

S/C Attitude Reference Frame Fa used for Operations

+Xa HGA
+Za Lander
+Ya is defined so that (Xa,Ya,Za) is right-handed

Spicam Structure Frame Fs used for internal Sun and LOS alignment

Fs = Fb

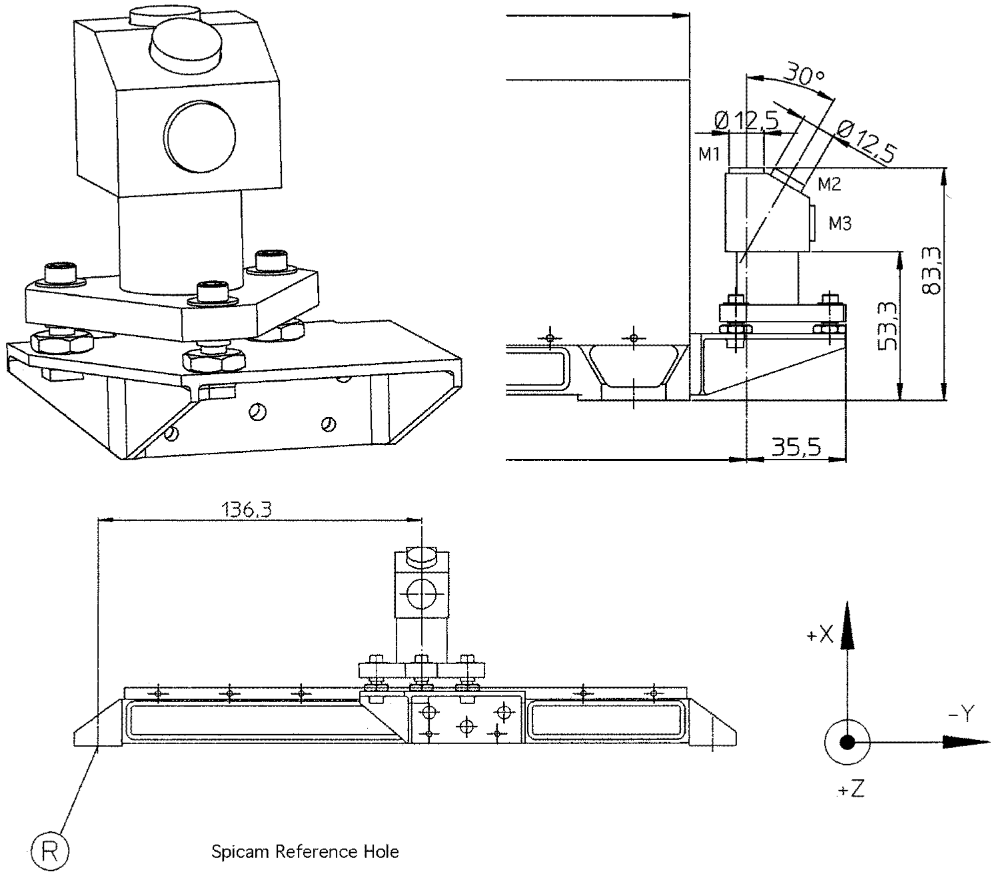
Spicam Cube Frame Fc used for internal alignment
alignment versus S/C

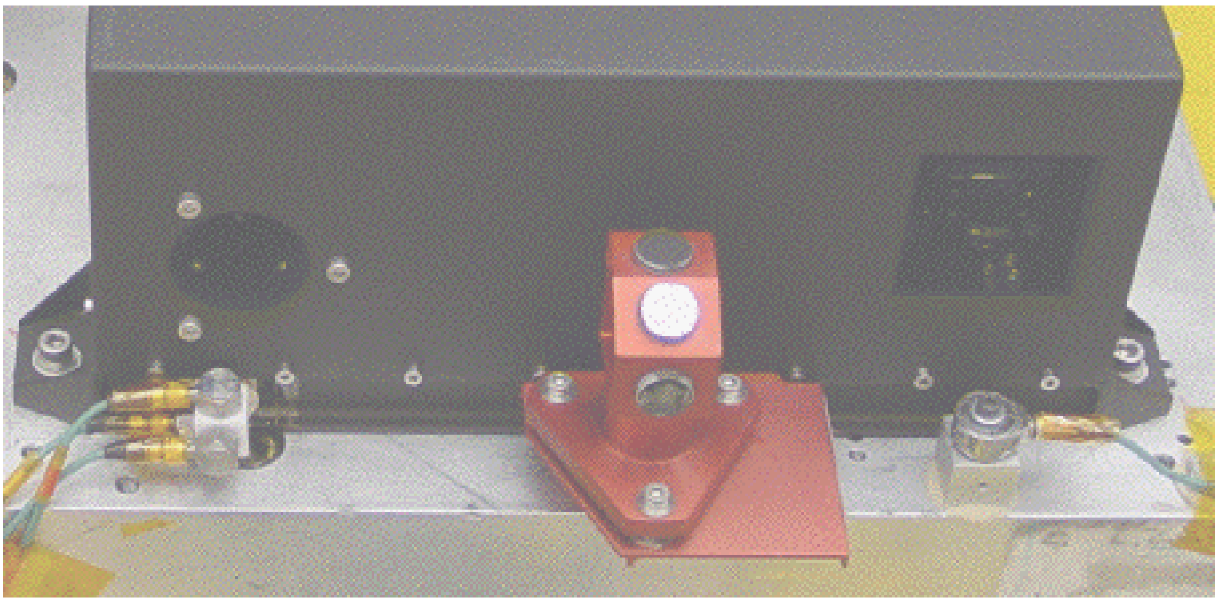
Note: the frame of the drawing is Fb
M1 and M2 are used for alignments versus S/C. M3 is used for internal alignment

The frame associated with cube is:

+Xc M1, outside cube
+Zc cross product of (M2, outside cube) and Xc
+Yc is defined so that (Xc,Yc,Zc) is right-handed

Below are drawing and pictures showing cube mirors and cube location on Sensor Unit





2.4. Frame to frame:

All directions are unitary vectors.
A vector in a frame can be described either by alf, del or by its 3 components.
To get the components of a vector in another frame, we use

$$\begin{array}{c} \text{Composantes de } \mathbf{x}_1 \text{ dans (2)} \\ \downarrow \end{array}$$

$$V(2) = \begin{pmatrix} R11 & R12 & R13 \\ R21 & R22 & R23 \\ R31 & R32 & R33 \end{pmatrix} \quad V(1)$$

$$V_2 = M_{21} * V_1$$

Following the definitions of our LOS, we have to compute the following matrix:

Let Vs be the vector LOS in Fs frame
Then Vc = Mcs Vs
and Va = Mac Vc

Mcs = matrix to express Vector from Fs to Fc
Mbc = matrix to express Vector from Fc to Fb
Mab = matrix to express Vector from Fb to Fa

3. Measurements:

3.1. Cube in Spicam structure frame:

Alignment of mirror cubes was done. see annex2

---> As all measurement angles are around 1 arcmin, we neglect them
---> Fc is same as Fs and Mcs is unitary

$$Mcs \quad \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

3.2. Nadir LOS in cube frame:

By adjustment we have Nc = { 0, 0, 1 } Nadir is towards Z axis

3.3. Sun LOS in Spicam structure frame:

By measurements we have Ss = (alf, dec)

alf = 180 deg +30 deg 16 min = 210 deg 16 min
dec = = 0 deg 17 mn

Ss = { cos(del) sin(alf), cos(del) cos(alf), sin(del) }

As Fc = Fs Sc = Ss

3.4. Cube in S/C attitude frame:

The S/C is equipped with 2 cubes located on the lower panel (motor side). These 2 cubes have their faces a 45 deg of refrence axes. These cubes where referenced versus the structure itself at Structural model level.

The S/C is mounted with Zb axis vertical, on a rotating table. A theodolite is fixed and mounted on a vertical column. The Spicam cube are measured in this configuration. To get rid of biases, 2 measurements are done with theodolite at 180 degres. Then an average of the 2 values is taken.

Following the Excel sheet of Astrium (Annex3), it stated that:

M1 and M2 were measured versus Xb axis

Spicam 2 (359,9377= 287,04 + 60,97(tableAz to Xb) - 11,91 (Average)

Elevation of Spicam2 is 59,76: it MUST be co-elevation (from Zb) **TBC**

M1alf = 359.974 ; from Astrium Excel file
M1dec = 90. - 89.760
M2alf = 359.938
M2dec = 90. - 59.762 ; above XY plane!

Cube frame axes in Fb:

CXb = M1b
CYb = M2b x M1b
CZb = CXb x CYb

$$
\begin{array}{cccc}
 & CXb & CYb & CZ \\
 & ! & ! & ! \\
 & (x & x & x) \\
Mbc & (y & y & y) \\
 & (z & z & z)
\end{array}
$$

Fb frame in Fa frame

$$
Mbc \quad \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix}
$$

Mac = Mab * Mbc

4. Results:

We have to compute :

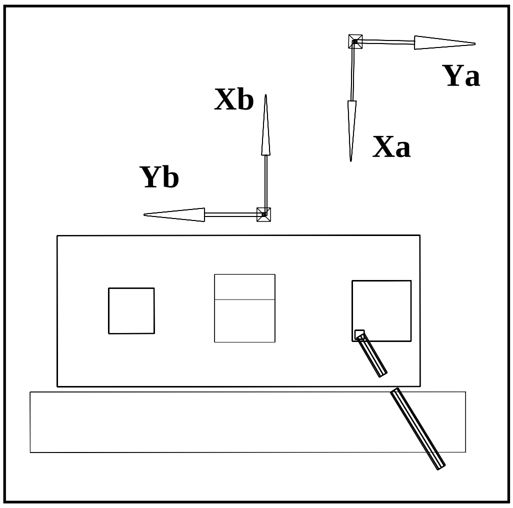
Nadir LOS in S/C attitude frame:

Sun LOS in S/C attitude frame:

```
IDL> Spialign

Spicam Light Mars Express, Alignments
Tue Jan 14 08:12:17 2003

See doc Spialign...
Fa (Xa,Ya,Za) is S/C attitude frame
Fb (Xb,Yb,Zb) is S/C structure frame
Fc (Xc,Yc,Zc) is Spicam cube frame
Fs (Xs,Ys,Zs) is Spicam structure frame = Fc

N is Nadir Line of sight
S is Sun Line of sight
V (alf, dec) is Polar coordinates, dec above XY plane
V {x,y,z} is rectangular coordinates
```

```
Matrix Mac, from cube to S/C attitude
  -1.000  -0.000   0.004
   0.000  -1.000   0.001
   0.004   0.001   1.000
```

```
Nadir in S/C Attitude, (alf, dec degres)
   0.004   0.001   1.000
      1.00000      14.5092      89.7521

Sun in S/C Attitude, (alf, dec degres)
   0.864   0.504   0.001
      1.00000      30.2406    0.0446930
```

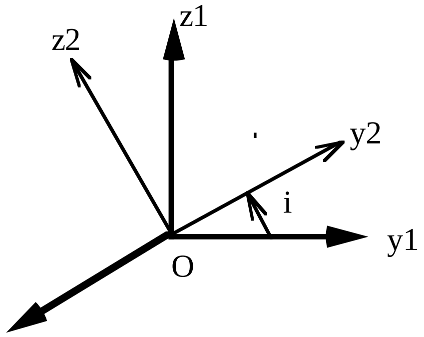


Annex1: Align software:

```
Pro Spialign
;----------10 01 03  dima
;---compute Nadir and Sun LOS in S/C frame Xa

Headeralign
;...Input data, degrees, see doc Spialign
Nc    = [ 0., 0., 1.]
Salf  = 210. + 16./60.    ; from Spicam log book
Sdec  = 17./60.
M1alf = 359.974           ; from Astrium Excel file
M1dec =  90. - 89.760
M2alf = 359.938
M2dec =  90. - 59.762     ; above XY plane!
r     = 1.
fmt = '(3F8.3)'

;...compute vectors and matrix, Polrec2D, r, az, ax, x, y, z,
Mcs = IDENTITY (3,/DOUBLE)
Polrec3D, r, 90.-M1dec, M1alf, M1bx, M1by, M1bz, /degrees   ;M1 rectangular
Polrec3D, r, 90.-M2dec, M2alf, M2bx, M2by, M2bz, /degrees   ;M2 rectangular
M1b = [ M1bx, M1by, M1bz]
M2b = [ M2bx, M2by, M2bz]
CXb = M1b
V   = CROSSP( M2b, M1b)
```

```
CYb = V / NORM(V)
V   = CROSSP( CXb, CYb)
CZb = V / NORM(V)
Mbc = [ [ CXb[0], CYb[0], CZb[0] ], $
        [ CXb[1], CYb[1], CZb[1] ], $
        [ CXb[2], CYb[2], CZb[2] ] ]
Mab = [ [ -1.,  0.,  0. ], $
        [  0., -1.,  0. ], $
        [  0.,  0., +1. ] ]
Mac = Mab ## Mbc
Print, 'Matrix Mac, from cube to S/C attitude'
Print, Mac, format = fmt

;...compute Nadir Los in S/C Fa
Na  = Mac ## Nc
x   = Na[0]
y   = Na[1]
z   = Na[2]
Recpol3D, x, y, z, rn, dec, Nalf, /degrees   ;N polar
Ndec = 90. - dec
Print, ' '
Print, 'Nadir in S/C Attitude, (alf, dec degres)'
Print, Na, format = fmt
Print, rn, Nalf, Ndec

;...compute Sun Los in S/C Fa
Polrec3D, r, 90.-Sdec, Salf, Scx, Scy, Scz, /degrees   ;Sun rectangular
Sc  = [ Scx, Scy, Scz]
Sa  = Mac ## Sc
x   = Sa[0]
y   = Sa[1]
z   = Sa[2]
Recpol3D, x, y, z, rn, dec, Sunalf, /degrees   ;N polar
Sundec = 90. - dec
Print, ' '
Print, 'Sun in S/C Attitude, (alf, dec degres)'
Print, Sa, format = fmt
Print, rn, Sunalf, Sundec

end; { Spialign }
```

Annex2: Rotations formulas



(1) repère de départ
(2) repère d'arrivée (après rotation i, angle de 2 par rapport à 1)

Composantes de **x**1 dans (2)

↓

$$V(2)=\begin{pmatrix}\mathrm{R11} & \mathrm{R12} & \mathrm{R13}\\ \mathrm{R21} & \mathrm{R22} & \mathrm{R23}\\ \mathrm{R31} & \mathrm{R32} & \mathrm{R33}\end{pmatrix} \quad V(1)$$

$$Rx(i)=\begin{pmatrix}1 & 0 & 0\\ 0 & \cos i & \sin i\\ 0 & -\sin i & \cos i\end{pmatrix}$$

rotation par rapport à X
i angle de (2 / 1)

$$Rz(i)=\begin{pmatrix}\cos i & \sin i & 0\\ -\sin i & \cos i & 0\\ 0 & 0 & 1\end{pmatrix}$$

$$Ry(i)=\begin{pmatrix}\cos i & 0 & -\sin i\\ 0 & 1 & 0\\ \sin i & 0 & \cos i\end{pmatrix}$$

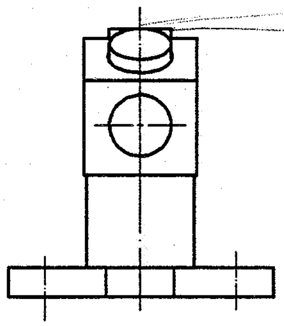
$$R(-i)=R^{-1}(i)=R^{T}(i)$$

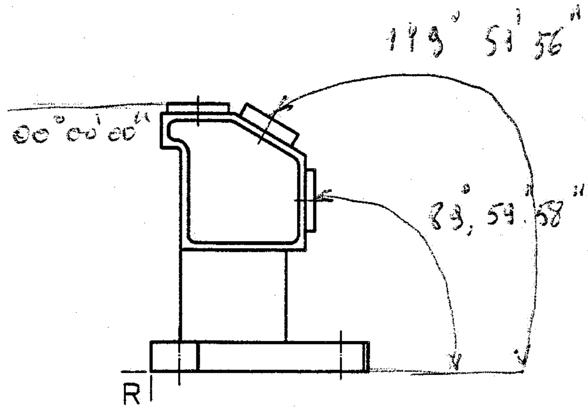
Annex3: Cube measurements in Spicam structure frame:

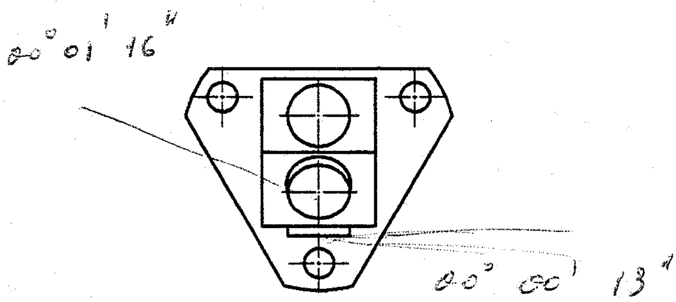
SPICAM-L-SU-01

Date: 19/04/02

Metrology alignment mirror







VERIFIED BY
VAN RANSBEECK

esa estec
Testing division
Metrology - YTE

Annex4: Cube measurements in S/C frames (RD2)

POST ENVIRONMENT		Str Target	RCT Bkt	SPICAM 1	SPICAM 2		
DECIMAL	**Table Az**	163,6964	164,0497	287,0415	287,0415		
Measurement	**Theo Az**	0	0	348,0475	348,0841		
@ 0°	**Theo El**	90	90	90,2402	120,2385		
Measurement	**Theo Az**	180	180	168,0473	168,0832		
@ 180°	**Theo El**	270	270	269,7603	239,7617		
		0	0	-11,9525	-11,9159		
NORMALISATION		90	90	90,2402	120,2385		
		0	0	-11,9527	-11,9168		
		90	90	90,2397	120,2383		
AVERAGE	**Theo Az**	0	0	-11,9526	-11,91635		
	Theo El	90	90	90,23995	120,2384		
CHECK		*0*	*0*	*0,0001*	*0,00045*		
		0	*0*	*0,00025*	*1E-04*		
PROCESSED		Str Target	RCT Bkt	SPICAM 1	SPICAM 2		
Table Az to Xb	**Azimuth**	224,6762	225,0296	359,97396	359,93771		
60,97985644	**Elevation**	0	90	89,76005	59,7616		
Str Target to Xb	**Per Face**				**SPICAM**		***Check :***
-135,323781	**Face 1**			359,97396	89,76005		
arget Positionin	**Face 2**			359,93771	59,7616		
Xb				0,999991127	-0,000454542	0,004187905	*1,00000000*
-818,6				0,863936970	-0,000939297	0,503599076	*1,00000000*
Yb				-0,000449967	0,999999301	-0,001093236	*1,00000000*
-809,4	**Boresight Direction wrt BRF Planes**			Local Z Angles	in (Xb,Zb) -0,2399216	in (Yb,Zb) -0,0625299	
		0			in (Xa,Za) 0,2399216	in (Ya,Za) 0,0625299	
PROCESSED wrt MRC1	**Azimuth**	0	0	315,14115	315,1049		
	Elevation	-90	180	89,76005	59,7616		
	Face 1		Face 1	360,14115	89,76005	315,14115	89,76005
	Face 2		Face 2	360,1049	59,7616	315,1049	59,7616
				0,999988196	0,002463508	0,004187905	*1,00000000*
				0,863936033	0,001581739	0,503599076	*1,00000000*
				0,002468107	0,999996357	-0,001093236	*1,00000000*
	Boresight Direction wrt MRC1 Planes			Local Z Angles	in MRC11 -0,2501406	in MRC12 -0,4289775	
Third Direction Determination for Non Othogonal Cube Faces	**wrt BRF**			-0,000225	0,4999765	-0,0005466	0,49997687
				-0,0041874	-0,0010913	0,9999902	0,99999959
					-0,0099967	-0,0026054	
							0,49997657
	wrt MRC1			-0,0043657	-0,007487	0,9999785	
				0,001234	0,499975	-0,0005466	0,49997687
				-0,0041906	-0,0011036	0,9999785	0,99998786
					-0,0104225	-0,0178741	