AMIE

Asteroid Moon micro-Imager Experiment

AMIE detector orientation in s/c coordinate system

S1-AMIE-RSSD-TN-001/1d

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Document Change Record

Iss./Rev.	Date	Pages affected	Description
1	17 Sep 2003	All	First release
1/a	25 Sep 2003	10	Added s/c coordinate system in image of AMIE FoV
1/b	06 Nov 2003	10	Corrected s/c coordinate system orientation, taking into account the effect of the optics.
1/c	22 Jan 2004	None.	New pages added to reflect the first real observations.
1/d	30 Jan 2004	14	Updated AMIE-S/C alignement document

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1General items

1.1Scope

This document was created during the preparation of the first Scenario Parameter Lists describing operational scenarios. It is necessary to understand the orientation of the detector in the AMIE camera head and its orientation with respect to the spacecraft to understand *e.g.* about which axis the spacecraft has to rotate to achieve a certain movement in the field of view of AMIE.

1.2Introduction

We first collect the information available about the coordinate systems and the detector orientation. Then a precise correlation is done.

1.3Applicable Documents

no.	Document name	Document number, Iss./Rev.
AD 1	Smart-1 Experiment Interface Document – Part A (EID-A)	S1-EST-EID-3001/4.0, 17 Apr 2001, p. 49
AD 2	Calibration report AMIE PFM	S1-AMI-RSSD-RP-001/1a, 20 Feb 2003 (p. 3)
AD 3	AMIE Mechanical ICD	S1-AMI-ICD-3003/1.3, 16 Feb 2001
AD 4	AMIE-SIR Alignment Clarification	P-SMT-REP-5095-SE, 30 Jan 2004

1.4Reference Documents

no.	document name	document number, Iss./Rev.
RD 1	AMIE Test and Calibration Plan	S1-AMI-PL-3004/2.0, 21 Jun 2000

1.5Abbreviations

AMIE Advanced Moon Imaging Experiment
CCD Charge-Coupled Device
Co-I Co-Investigator
ESA European Space Agency
FoV Field of View
IDL Interactive Data Language
RSSD Research and Scientific Support Department

2Information relevant for the coordinate conversion

2.1Spacecraft coordinate system and the mounting of AMIE on the spacecraft

The EID-A (1.3) gives on page 49 an overview drawing of the spacecraft, defining the spacecraft coordinate system. For information, it is repeated in Figure 1. This coordinate system will hereafter be abbreviated with a subscript '_sc', *i.e.* x_sc, y_sc, z_sc.

Quoting from the EID-A:

"The SMART-1 spacecraft co-ordinate system is defined as follows:

- The Origin is located in the centre of the S/C to launcher I/F adapter.
- The Z-axis is perpendicular to the launcher interface plane, directed positively through the S/C body.
- The X-axis is perpendicular to the Z-axis and the solar array drive axis, directed positively through the side of the S/C containing the Medium Gain Antenna.
- The Y-axis completes the right hand system."

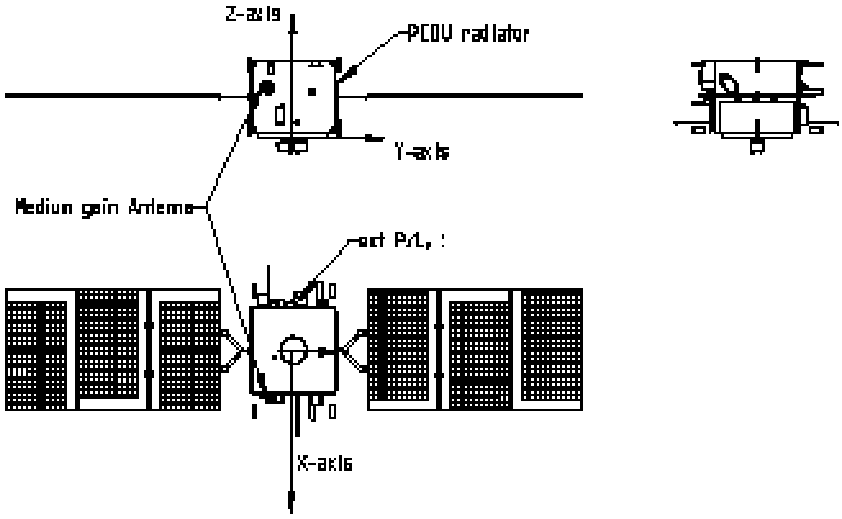

Figure 1: Spacecraft coordinate system (Figure 4.2.1-1 on p. 49 of the EID-A)

The mounting of the AMIE camera can be seen from Figure 2. The camera line-of-sight is pointing towards the +z_sc direction, the mounting plane is in the y_sc-z_sc plane.

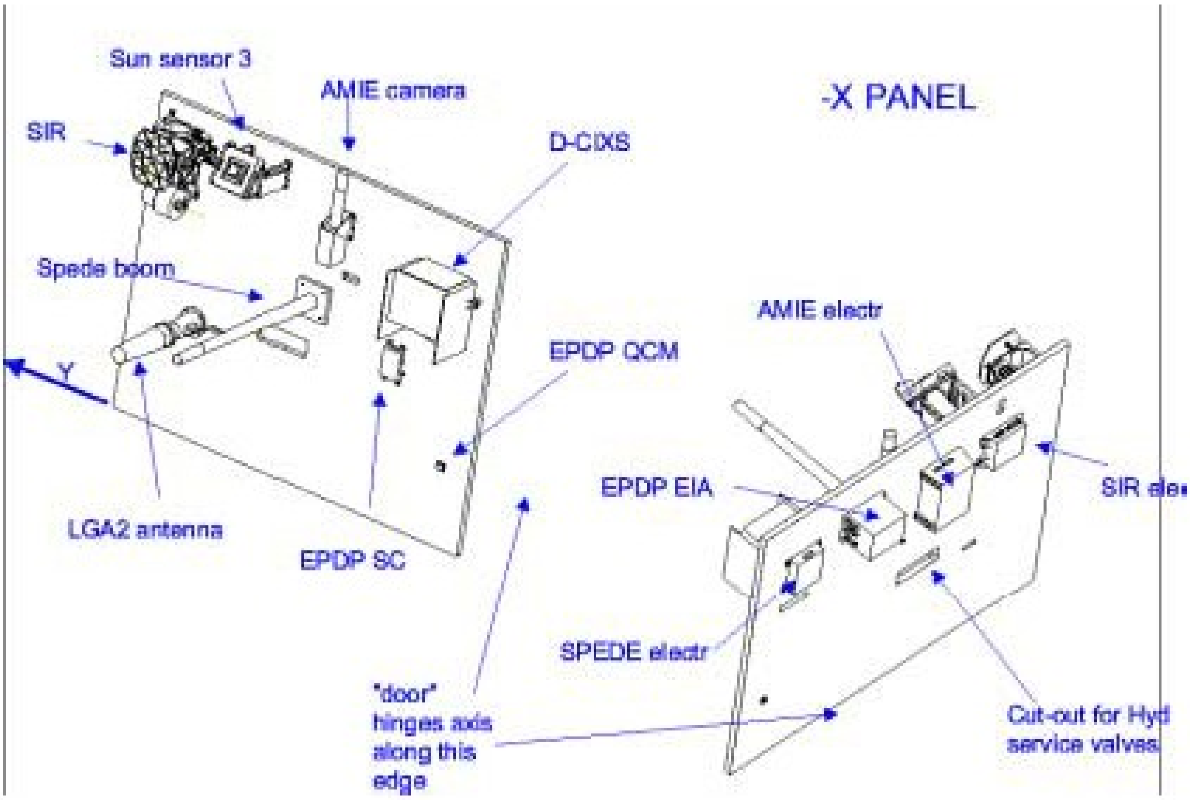

Figure 2: External and internal view of Smart-1 -X panel with experiment accommodation (Figure 4.3.2-1 from EID-A).

2.2Camera unit coordinate system

The camera unit coordinate system is defined in the Mechanical ICD (1.3). Figure 3 shows the relevant drawing. The coordinate system has its origin at the center of one of the mounting holes. The +z axis is parallel to boresight and points towards the object. The +x axis points downwards. This coordinate system is parallel to the s/c coordinate system.

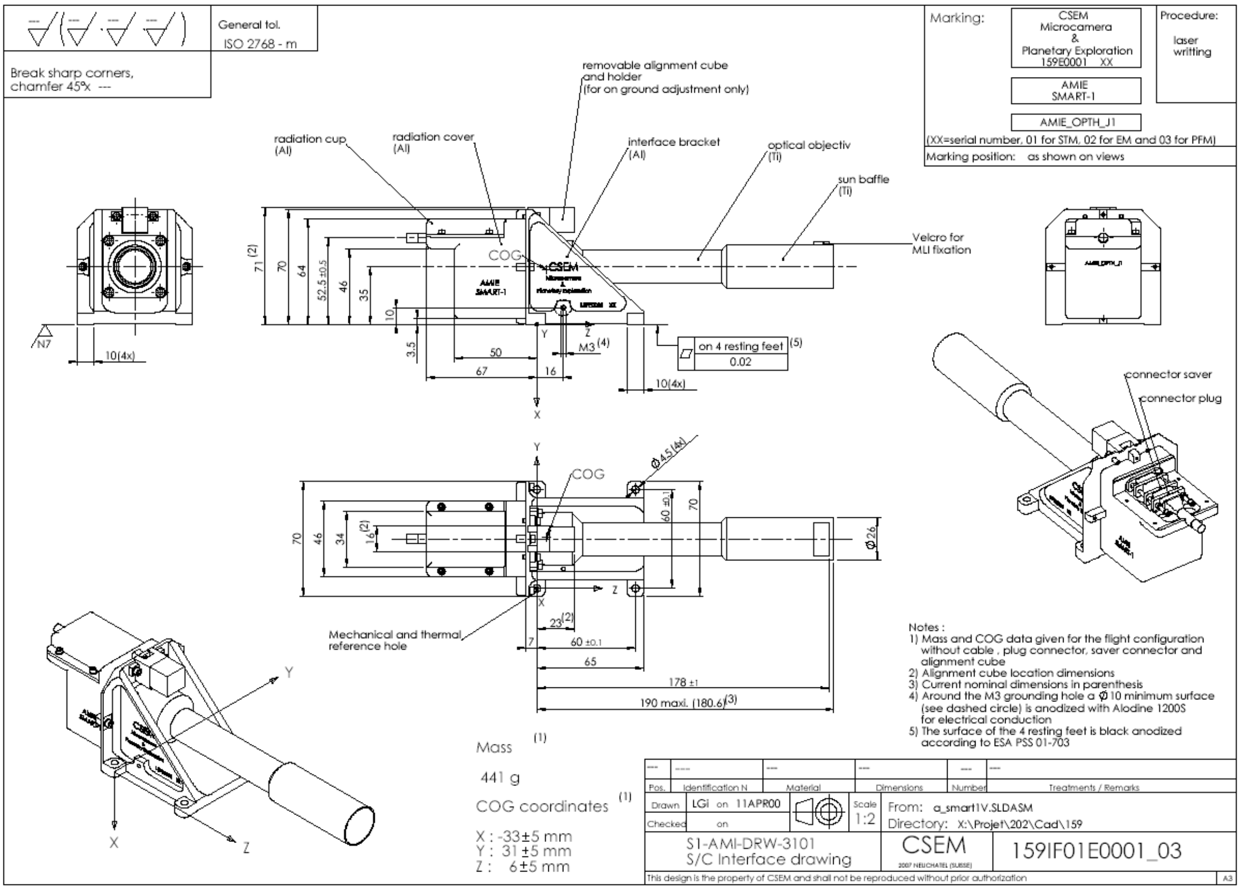

Figure 3: Mechanical ICD drawing of AMIE, defining the unit coordinate system.

2.3Coordinate system and naming conventions for CCD detector

The AMIE CCD detector is a frame-transfer device as shown in Figure 4. When the camera is seen standing 'upright', *i.e.* with its mounting holes on the bottom, the imaging area is on the top, the storage area at the lower part of the detector. When seen from the object, the detector has the horizontal register (= serial register) oriented below the detector and read out to the left. The imaging area consists of 1024 pixels x 1024 pixels.

The first pixel to be read out has the coordinates x = 0 and y = 0, the last one x = 1023, y = 1023. This follows the IDL convention (IDL = Interactive Data Language – the software language used in the AMIE calibration routines) where array subscripts start with a 0 (zero). Note that the center of the array lies between two pixels, namely at x = 511.5, y = 511.5.

The Figure shows the detector as seen from the object. This can also be seen in the photograph kindly provided by Stephane Beauvivre of the camera head without the optics installed, where the clear filter area is visible (Figure 5).

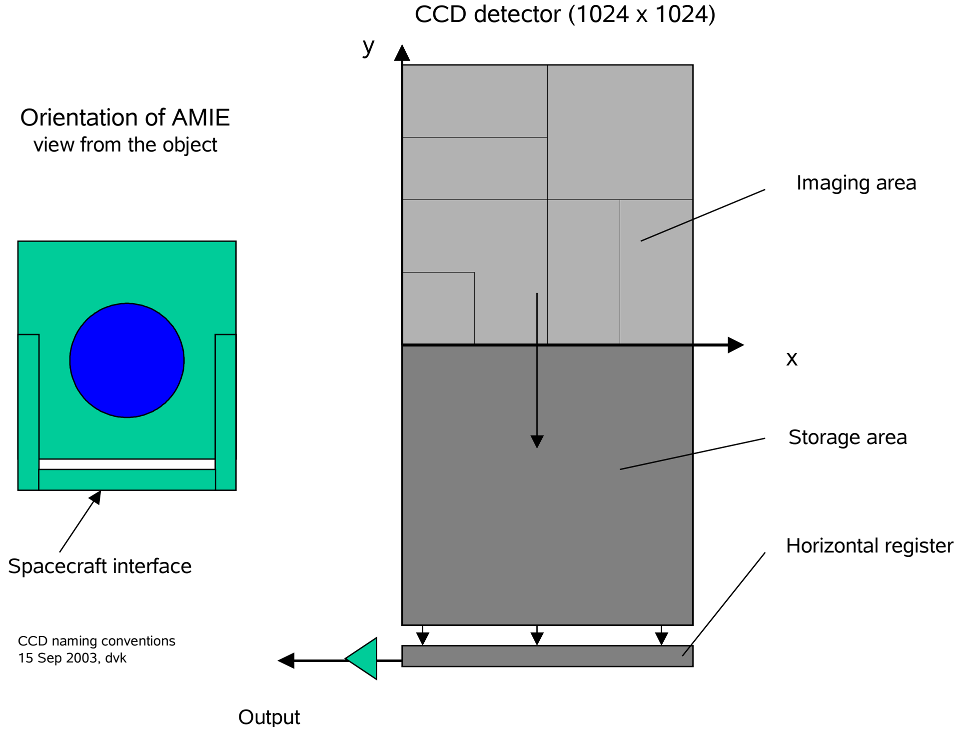

Figure 4: Naming conventions and coordinate system used in the AMIE calibration.

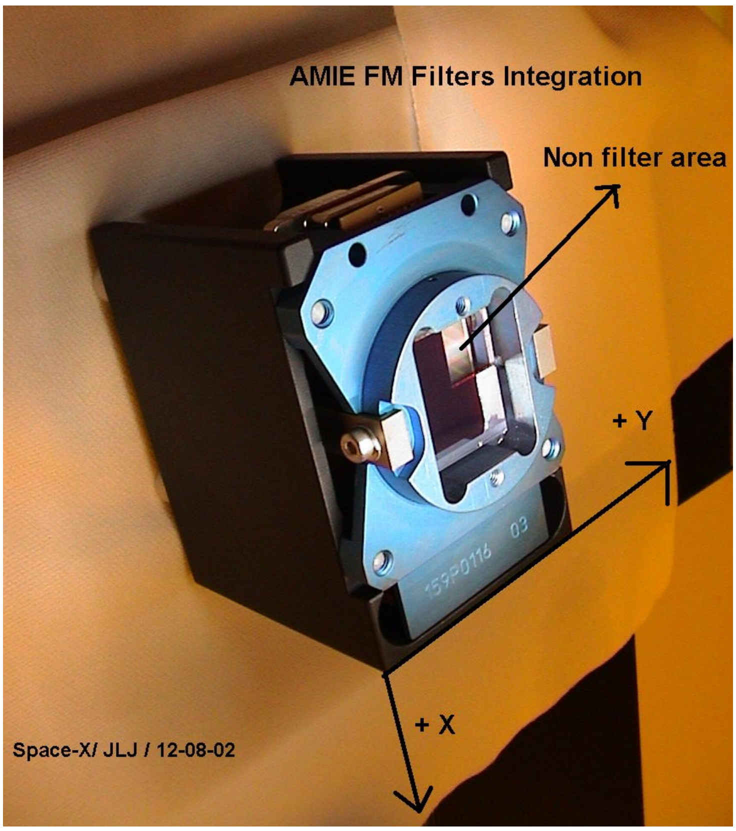

Figure 5: View of the detector without optics, showing the filter orientation.

3Combining the information

Combining all the information gives the following picture, Figure 6. It can be seen that the +x_ccd axis is parallel to the +y_sc axis, the +y_ccd axis is parallel to the –x_sc axis.

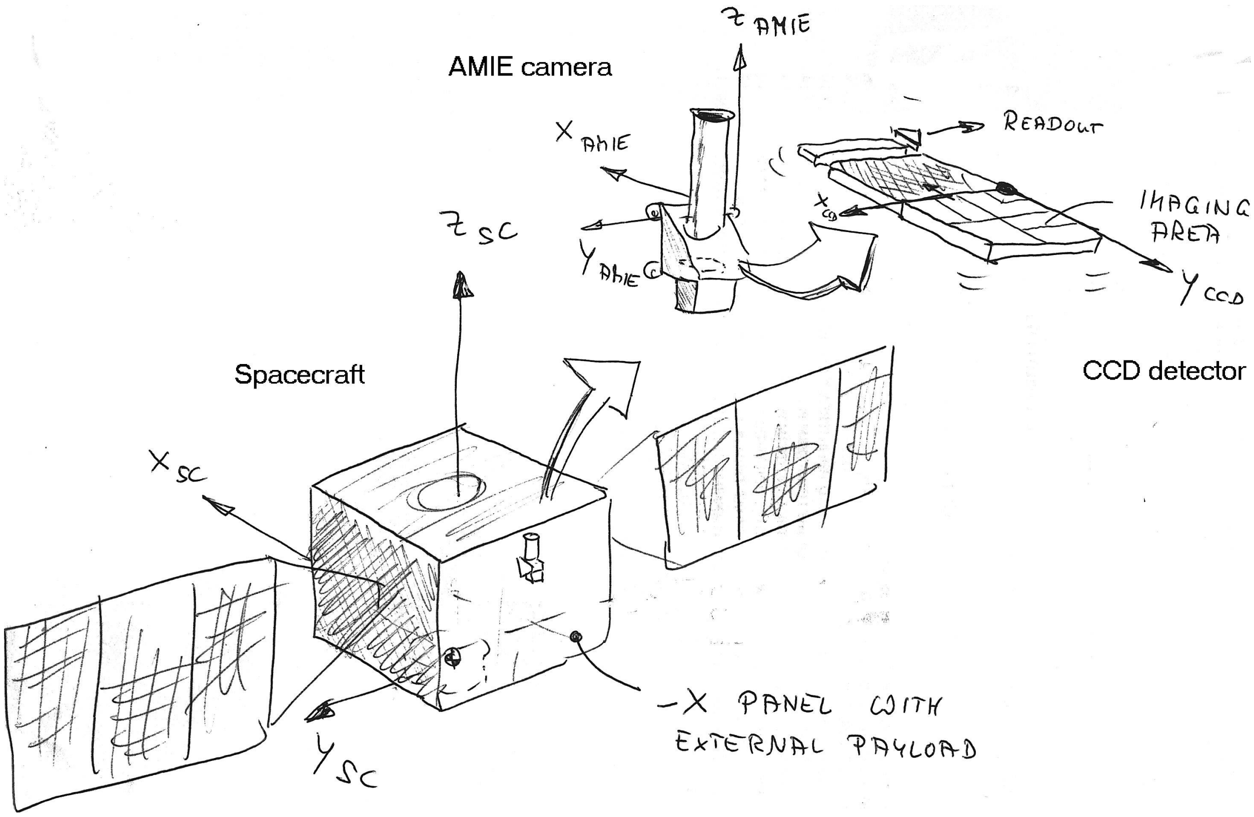

Figure 6: Coordinate systems of the spacecraft, AMIE, and the detector.

To find out which direction the spacecraft has to move for a given movement on the detector, consider Figure 7. A thick arrow shows a movement of the spacecraft in the direction of +x_sc and –y_sc. This will result in a movement of +y_ccd and +x_ccd. Or, the other way around: To achieve a movement in the positive x_ccd direction, the spacecraft has to move in the direction of –y_sc (negative y_sc); to move into the positive y_ccd direction, the spacecraft has to move in the direction of +x_sc.

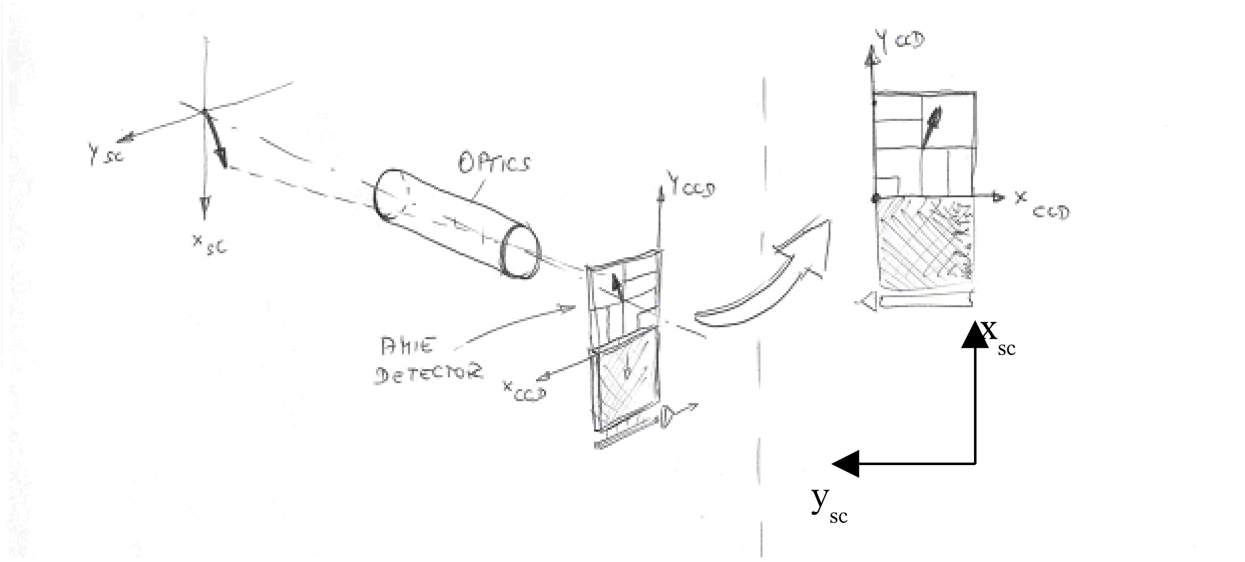

Figure 7: AMIE detector orientation and image projection.

The final image (Figure 8) shows a screen shot of a white flatfield done in the lab. It was read in using the IDL routine 'read_amie_pds' and displayed using 'iImage'. It can be seen from the location of the clear filter area in the upper right that the display on the screen is such that the x_ccd axis is horizontal, the y_ccd axis is vertical. The spacecraft coordinate system is shown in the proper orientation as derived from the previous Figure.

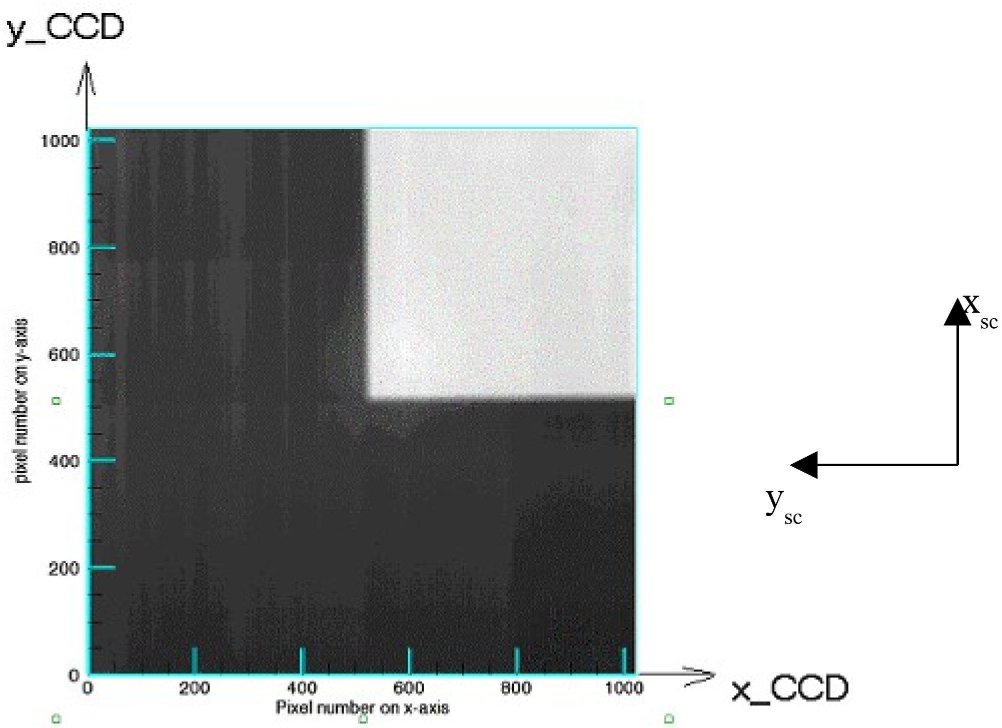

Figure 8: File '2001.12.06_16_AMIE_FM_Spectral_White_1094_100ms.pds' as displayed by the IDL routine 'read_amie_pds'

4Image orientation and the real world

In this chapter a common visualization problem is issued.

On Figure 8 the Z-axis of the CCD coordinates is pointing in the direction of the reader. Although this is the natural orientation considering the CCD coordinates, it doesn't represent the reality, as we know it when looking at the image created, but an inverted mirror image. As seen in Figure 9.

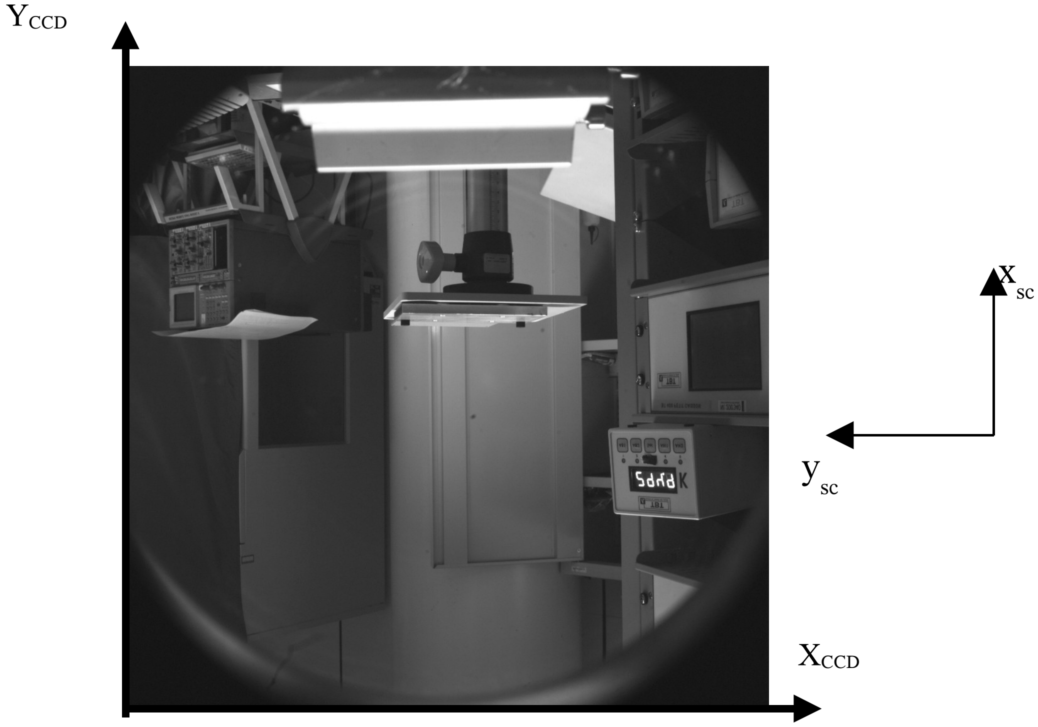

Figure 9 – AMIE Cryostat laboratory image.

By doing a horizontal **flip**, we get the image as in reality. As can be seen in Figure 10.

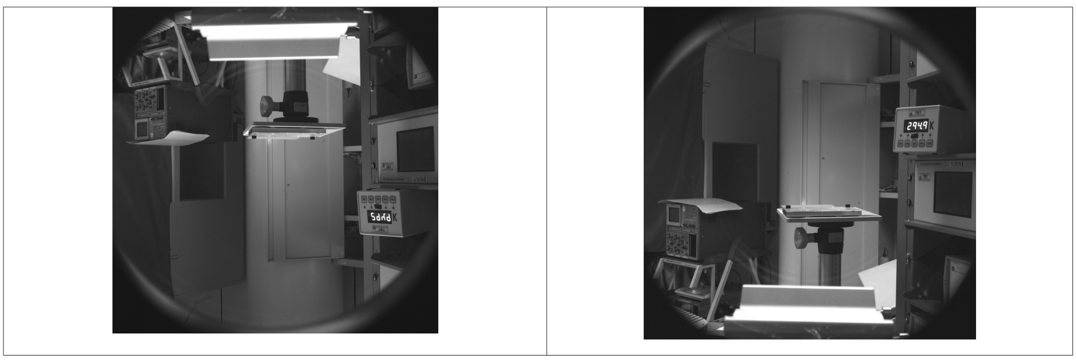

Figure 10 – AMIE Cryostat laboratory image flipped

When we flip it the Z-axis coordinate of the CCD is now pointing in the opposite direction of the reader. If we transpose that to the spacecraft coordinates that we can see in Figure 8, and use the same image. We have the final result in Figure 11.

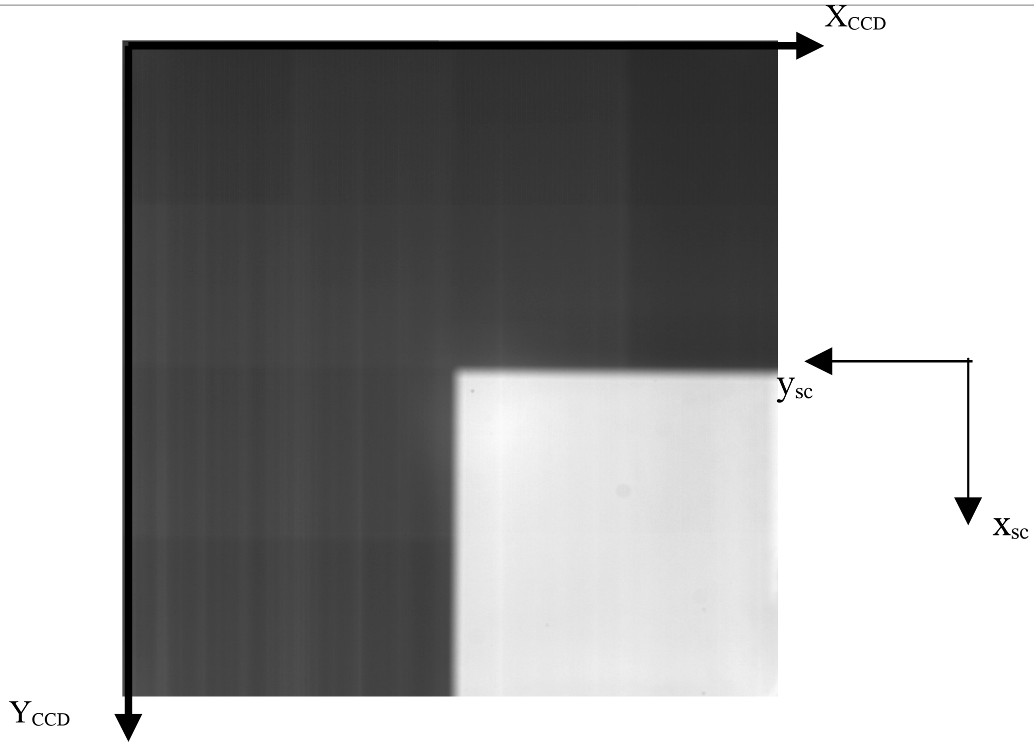

Figure 11 - '2001.12.06_16_AMIE_FM_Spectral_White_1094_100ms.pds' flipped over the Y-axis.

In Figure 11 the orientation is such that the real world as we know it would be represented.

5Testing the orientation in Space

Using the first images obtained by the AMIE camera in space, on January the 18th of 2004, it is possible to confirm the CCD orientation with respect to the spacecraft.

First is important to notice that there is a slight misalignment between the spacecraft Z-axis and the AMIE bore sight, these values can be found in AMIE-SIR alignment clarification (AD 4), and shown in Figure 12.

AMIE to SIR Alignment

	Before environments	After First vibration	After second vibration	Before shipment
AMIE	Euler (3-2-1) vs Structure Ψ 0.034 Â° φ -0.671 Â° ν -0.542 Â°	Euler (3-2-1) vs Structure Ψ 0.019 Â° φ -0.668 Â° ν -0.535 Â°	Euler (3-2-1) vs Structure Ψ 0.0202 Â° φ -0.6670 Â° ν -0.5307 Â°	Euler (3-2-1) vs Structur Ψ 0.0256 Â° φ -0.6652 Â° ν -0.5370 Â°
SIR	Rotation around Structure (3-2-1) Z 0.0000 Â° Y 0.0073 Â° X 0.1686 Â°	Rotation around Structure (3-2-1) Z 0.0000 Â° Y 0.0069 Â° X 0.1589 Â°	Rotation around Structure (3-2-1) Z 0.0000 Â° Y 0.0025 Â° X 0.1704 Â°	Rotation around Structu Z 0.0000 Â° Y 0.0063 Â° X 0.1684 Â°
AMIE to SIR	Around Y_{sc} 0.678 Â° Around X_{sc} 0.710 Â°	Around Y_{sc} 0.674 Â° Around X_{sc} 0.694 Â°	Around Y_{sc} 0.670 Â° Around X_{sc} 0.701 Â°	Around Y_{sc} 0.671 Â Around X_{sc} 0.705 Â
Wanted	Around Y_{sc} 0.662 Â° Around X_{sc} 0.662 Â°	Around Y_{sc} 0.662 Â° Around X_{sc} 0.662 Â°	Around Y_{sc} 0.662 Â° Around X_{sc} 0.662 Â°	Around Y_{sc} 0.662 Â Around X_{sc} 0.662 Â
Misalign	Around Y_{sc} -0.016 Â° Around X_{sc} -0.048 Â°	Around Y_{sc} -0.012 Â° Around X_{sc} -0.032 Â°	Around Y_{sc} -0.008 Â° Around X_{sc} -0.039 Â°	Around Y_{sc} -0.009 Â Around X_{sc} -0.043 Â
Half cone error Requirement	0.051 Â° 0.070 Â°	0.034 Â°	0.040 Â°	0.044 Â

Figure 12 – Part of the AMIE-SIR alignment clarification document (P-SMT-REP-5095-SE)

This document can be translated into the drawing in Figure 13. Here it is possible to see where the Z-axis of the spacecraft points in the AMIE Field of View.

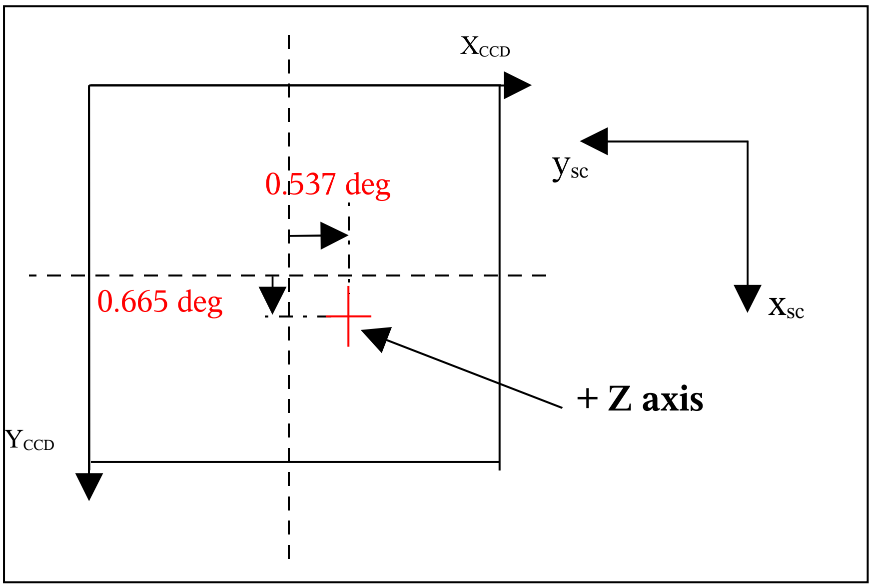

Figure 13 – Spacecraft pointing in the AMIE Field of View.

On the 18th of January, some Moon images were acquired while the spacecraft Z-axis was pointing to the Moon as confirmed by simulating the attitude file on the PTB.

In Figure 14 the AMIE Moon image is displayed according to Figure 4 orientation axis.

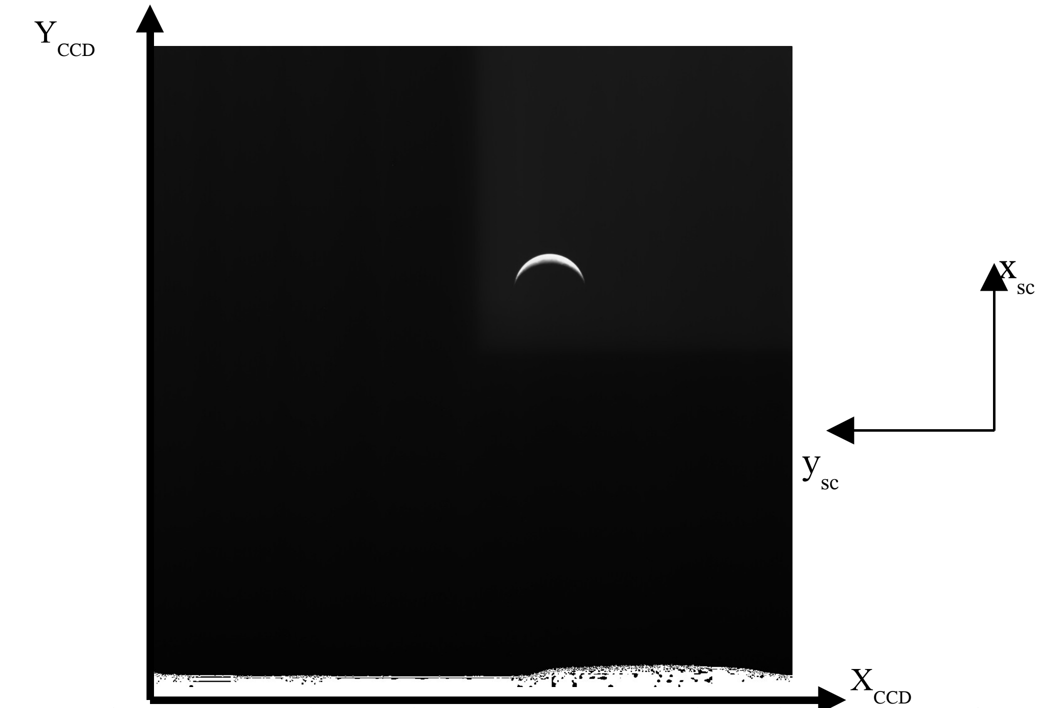

Figure 14 – First AMIE Moon image with the CCD (0,0) coordinates in the bottom left.

By flipping the image on Figure 14, the image in is obtained. There is possible to observe that the predicted pointing direction of the Z-axis of Figure 13 is matched by the position of the Moon that is also in the direction of this same axis.

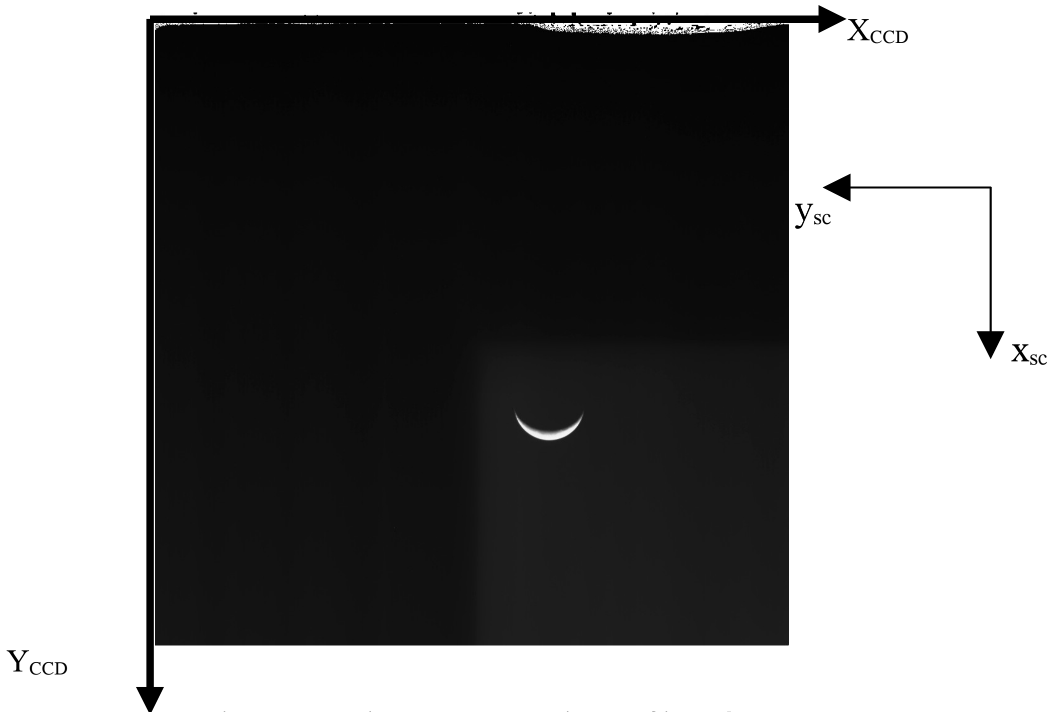

Figure 15 – First AMIE Moon image flipped.