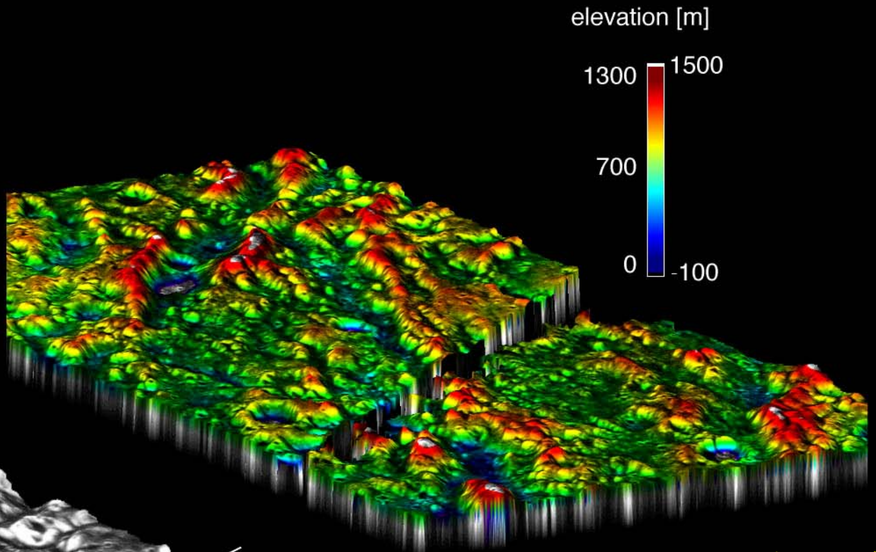
Study of the Wide Angle and Stereo Cameras for JGO

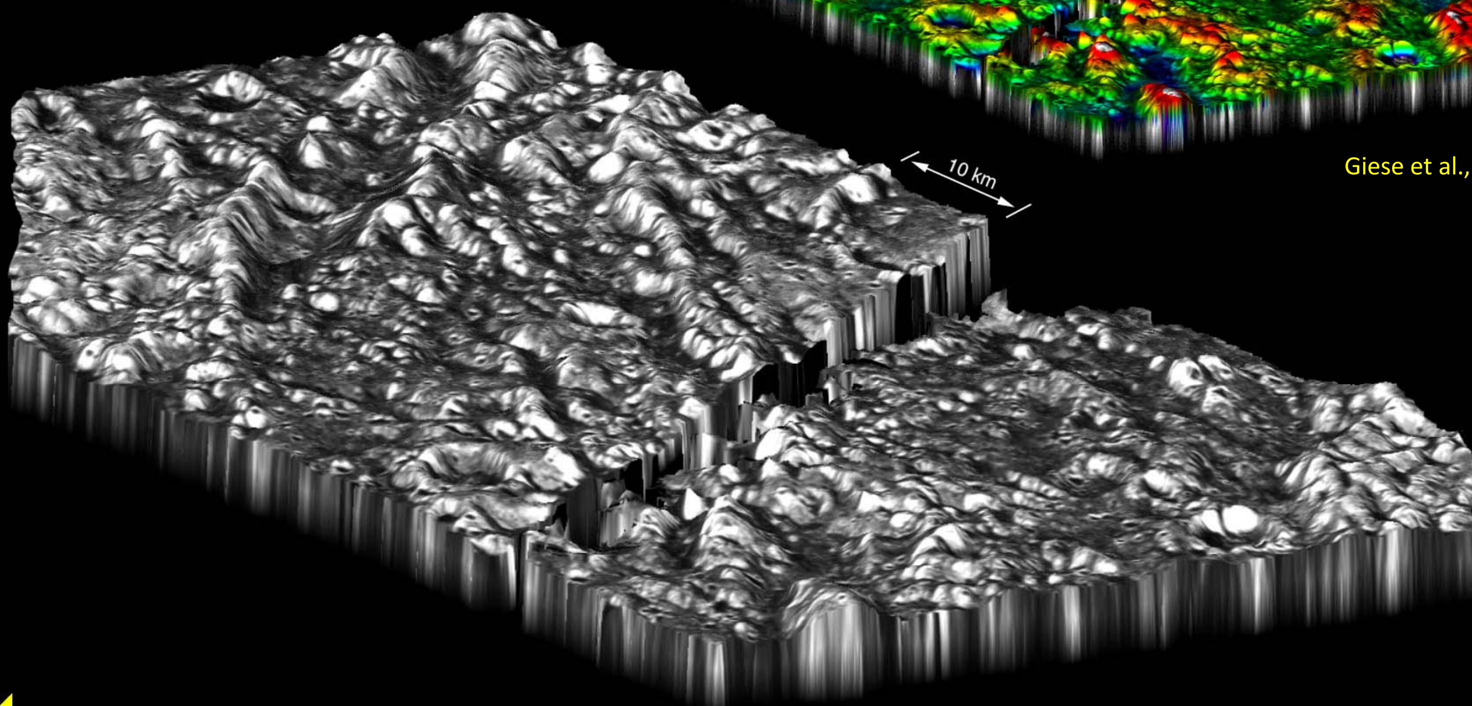
G.Cremonese, Y.Langevin, L.M.Lara , G.Neukum ,
M.T.Capria, S.Debei, J.M.Castro, P.Eng, S.vanGasselt,
and the JGO-WASC team

Ganymede

Galileo Regio



Giese et al., Icarus (1998)



DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. German Aerospace Center

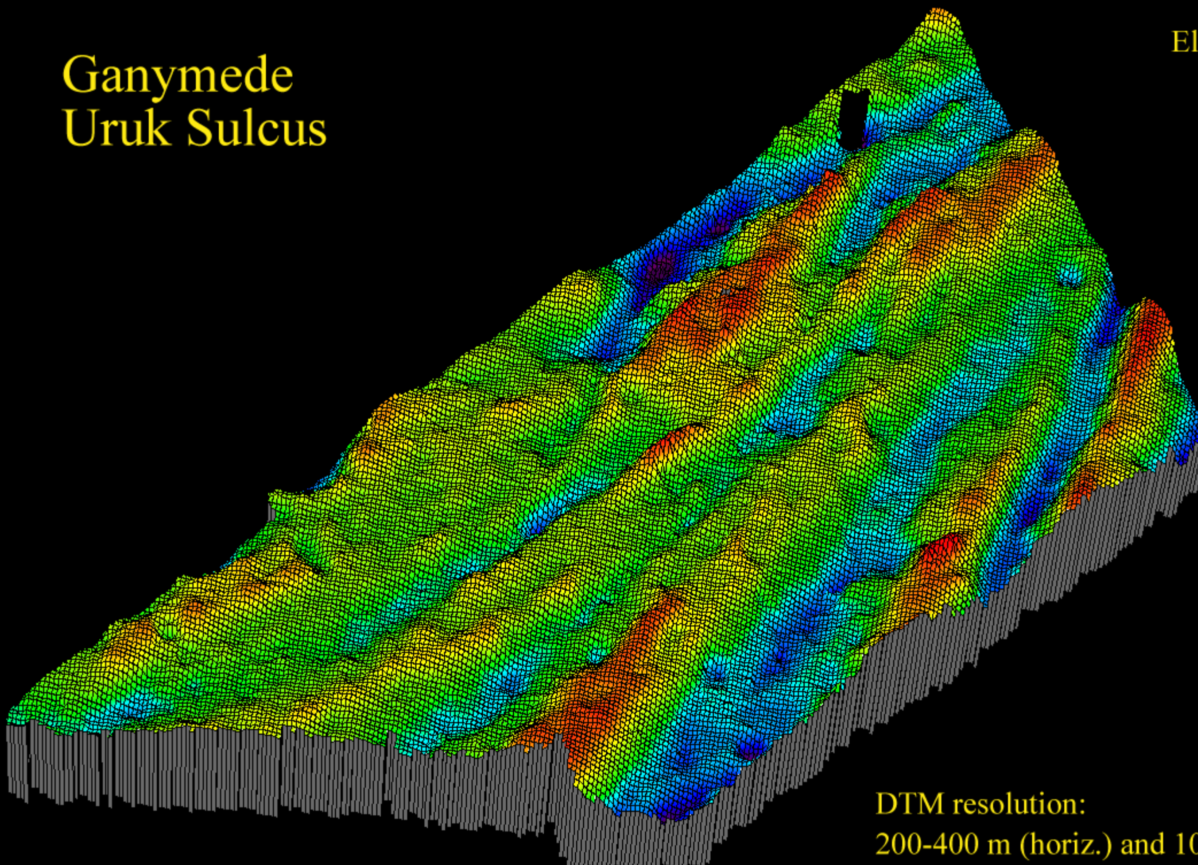
DTM resolution:
250-450 m (horiz.) and 15-30 m (vert.)

Ganymede
Uruk Sulcus

Elevation

1100 m

0



DTM resolution:
200-400 m (horiz.) and 10-20 m (vert.)

Giese et al., Icarus (1998)

Key points on the Digital Terrain Model

Up to now the accuracy of the Digital Terrain Model is of the order of more than 1 pixel vertically with the grid size of 3-5 pixels.

The stereo resolution should be at least a factor of ten better than the local relief. This requires resolutions better than 50 m/px from a 200 km orbit for an icy body as Ganymede

Stereo may be performed even using the overlapping images obtained by two cameras having different spatial resolutions, but the DTM has a lower accuracy.

New requirement

  - According to the GLL SSI Imaging results, the height differences on Ganymede are generally less than 1000m maximum, mostly on the order of a few hundred meters, even on the terrain with the roughest large-scale topography (Galileo Regio)
  - For the Sulcus areas, the spacing of the individual ridges is on the order of ~100m to ~1km and the topography ~100m to a few 100m, often less
- The scientific objectives and the known surface of Ganymede suggest a bettter spatial resolution for MRC.
- We assume in our study 15 m/px. Together to the new software we have developed the DTM grid size may be around 1 pixel providing very good scientific return.
- Higher spatial resolution means higher data rate and volume, we may get the DTM on selected regions and/or apply different strategy in the compression of the stereo pairs as we have already simulated within the project of the stereo camera for BepiColombo.
- **It is important that the ratio between the spatial resolution of the two cameras will be within a factor 10, as usually adopted in planetary missions (Mars Express, Rosetta, Messenger, BepiColombo).**
- It means that the WAC will have a spatial resolution of 150 m/px.

Performance requirements

MRC

Derive long color stereo imaging swaths at medium-high resolution (*15-20* m/pix @ 200 km)
- Derive *regional basemaps at 15-20 m/pix* in stereo
- Derive *topographic models of interesting areas* at an effective resolution of 15 – 20 m
- Derive global 4-color maps at 60 m/pix (using macropixel formation)
- Obtain 4-color coverage for selected large areas, up to *15-20* m/pix
- Multiphase coverage for measurements of surface physical properties
- Nighttime imaging (surface illuminated by Jupiter)
- High dynamic range
- High signal-to-noise
- Allow for geometric and radiometric calibration
- Lifetime: 2 years in Ganymede orbit

Observation of the laser spot

One requirement for the camera is to look at the spot of the laser altimeter.
At the moment the spot is visible at 1064 nm, that is not in the range of the detector considered for the WAC and the MRC.
Even if there is a detector, used for visible imagers, sensitive to this wavelength the EQ is very low being on the tail of the curve.

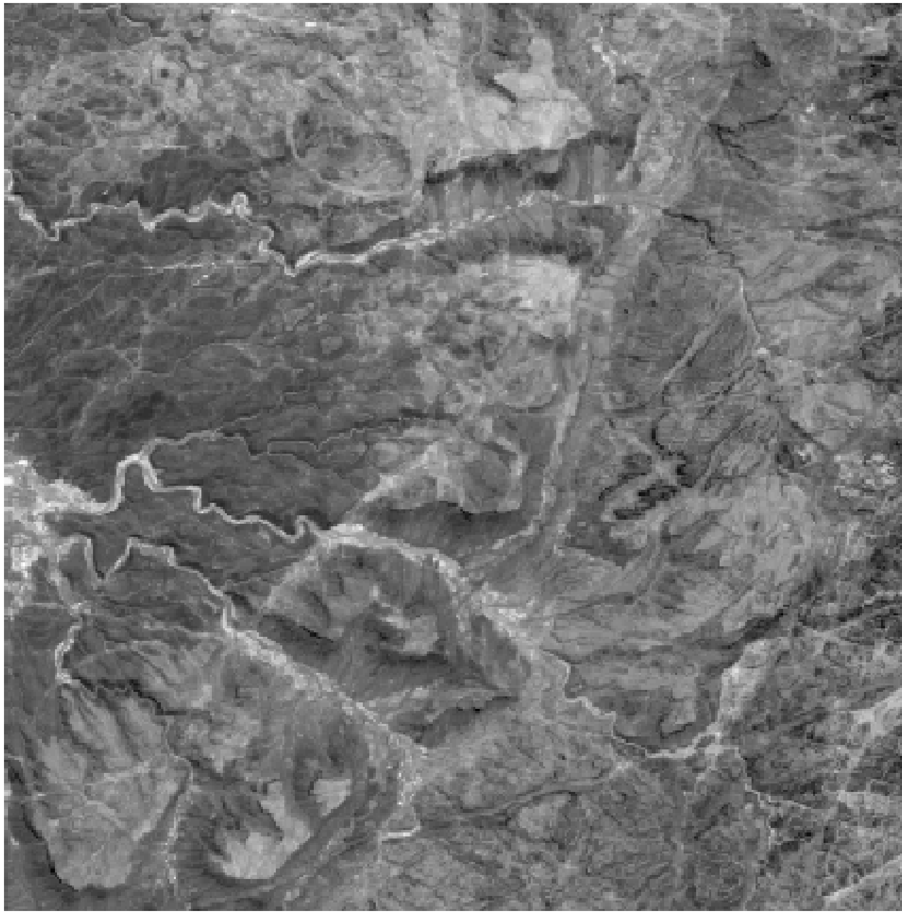
The camera has to be a push-frame.

The same requirement has been discussed within the BepiColombo mission without finding an accceptable solution.

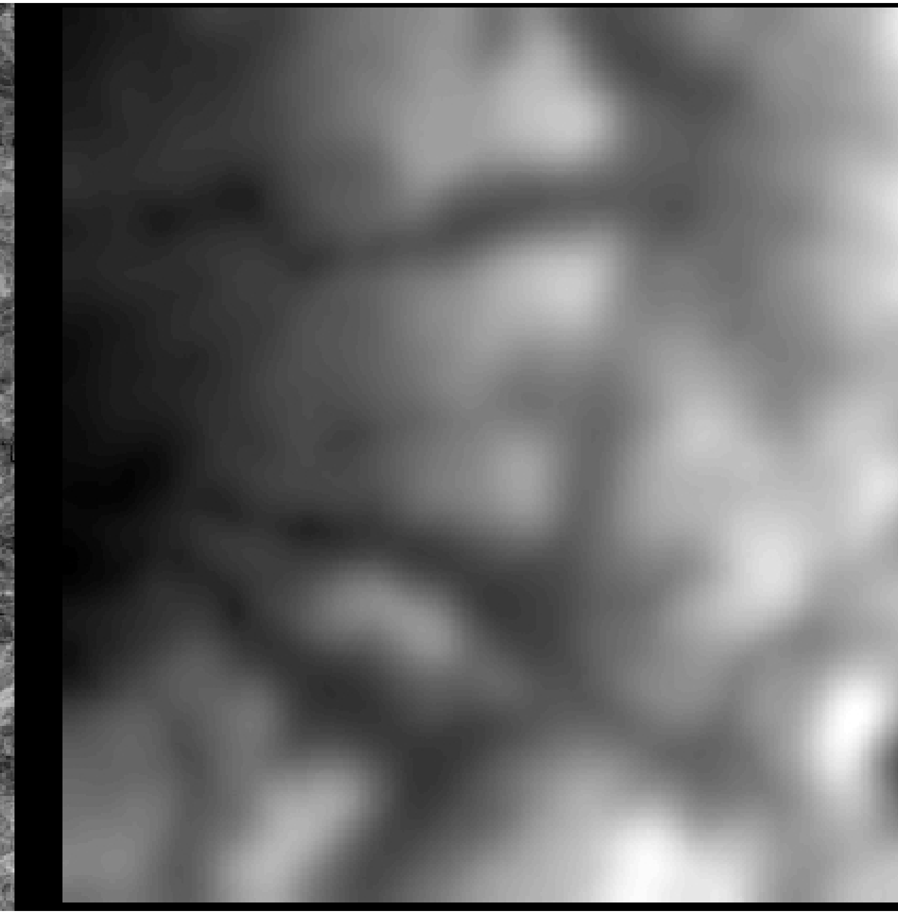
A New stereo reconstruction software for STC/SIMBIOSYS on BepiColombo

E. Simioni, G. Cremonese, G. Naletto
G .Forlani, V. da Deppo, M. Massironi

Application



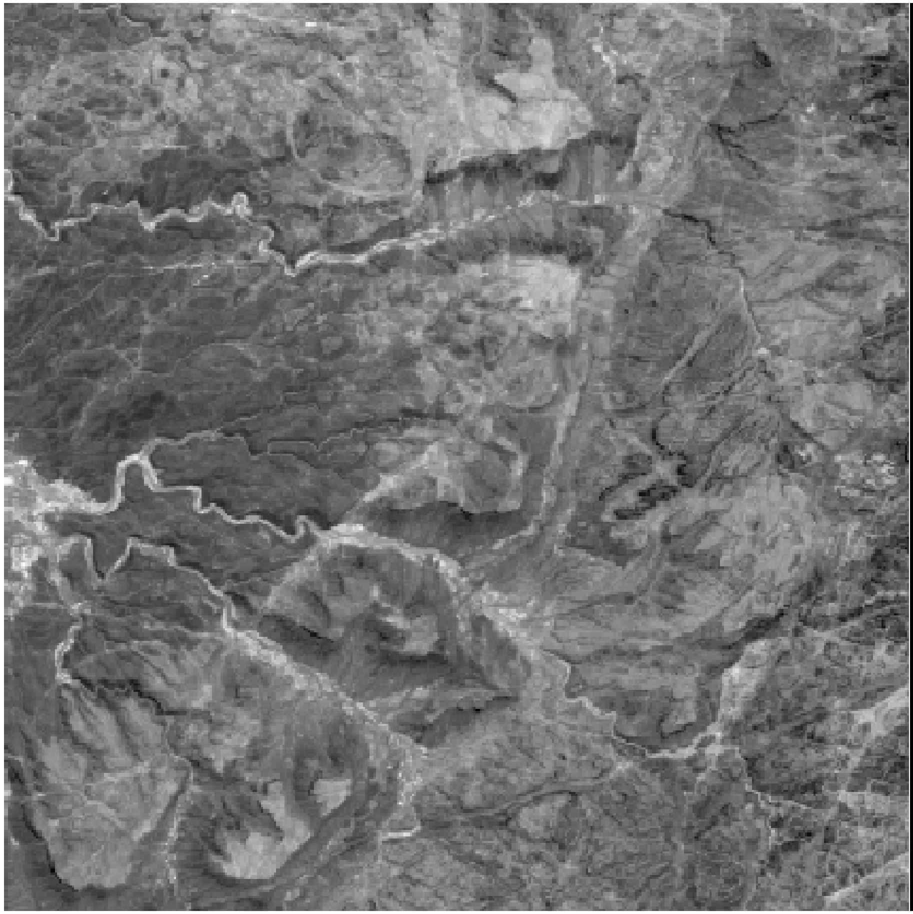
2D Image



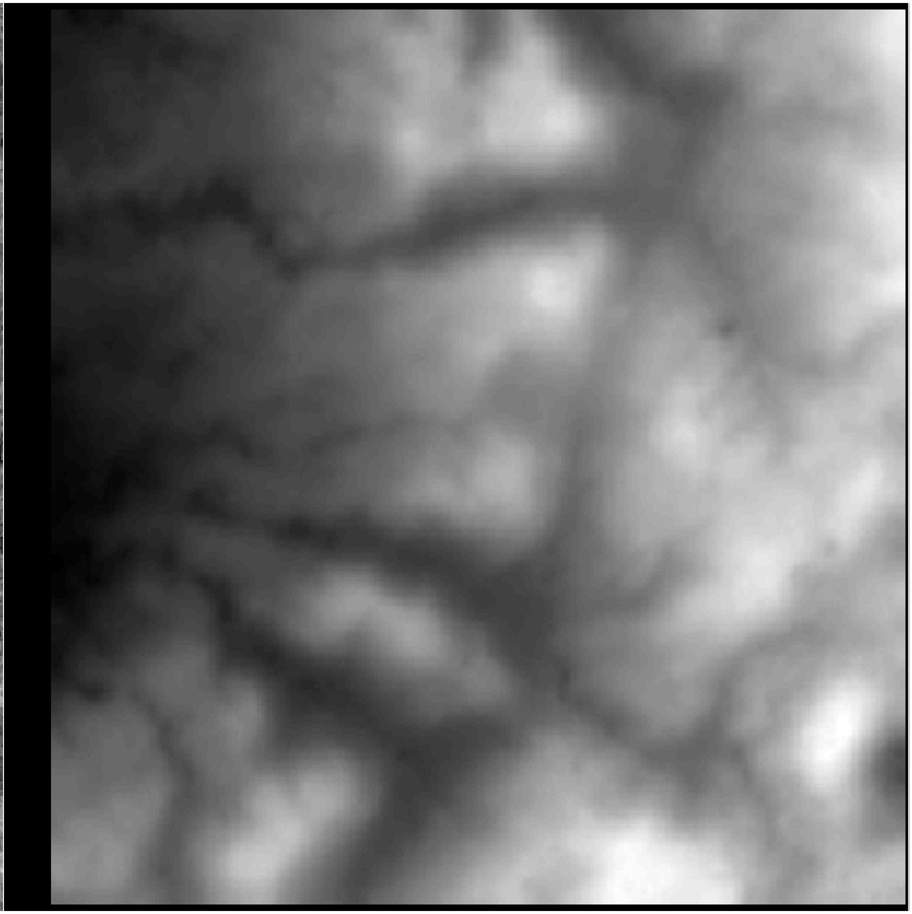
DTM

DLRmatch2 ASTER (ARIZONA) - matching window 5 pxl

Application



2D Image

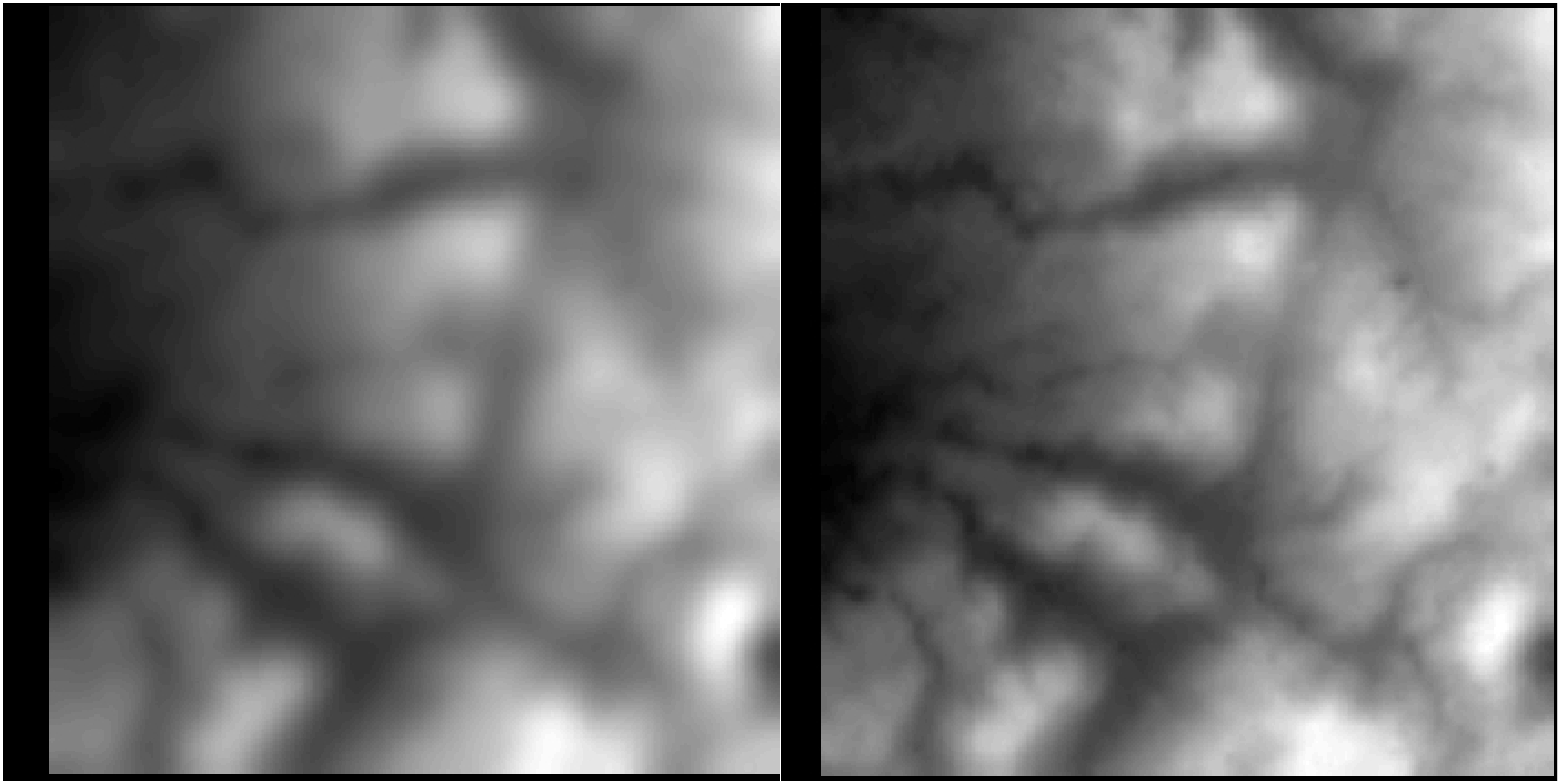


DTM

OUR ALGORITHM ASTER (ARIZONA) – matching window 3 pxl

The DTM has grid size of 1 pixel

Comparison between the two methods



Effects of the compression factor on disparity map

Standard deviation in pixel units between the disparity map obtained from compressed image pairs and that obtained from non-compressed image pairs as a function of the compression ratio applied to the left and right images respectively

compression ratio, left image

compression ratio, right

o	1	4	8	12	16	32
1	0.00	0.16	0.24	0.29	0.33	0.47
4	0.16	0.18	0.25	0.3	0.33	0.47
8	0.24	0.25	0.28	0.32	0.36	0.48
12	0.29	0.3	0.32	0.35	0.38	0.49
16	0.33	0.33	0.36	0.38	0.41	0.52
32	0.47	0.47	0.49	0.49	0.52	0.61

The compression noise on the DTM is < 0.5 pixel up to large compression ratios (16,16)
Applying different compression ratios for the two images can be considered in a trade-off between coverage (data volume) and performance

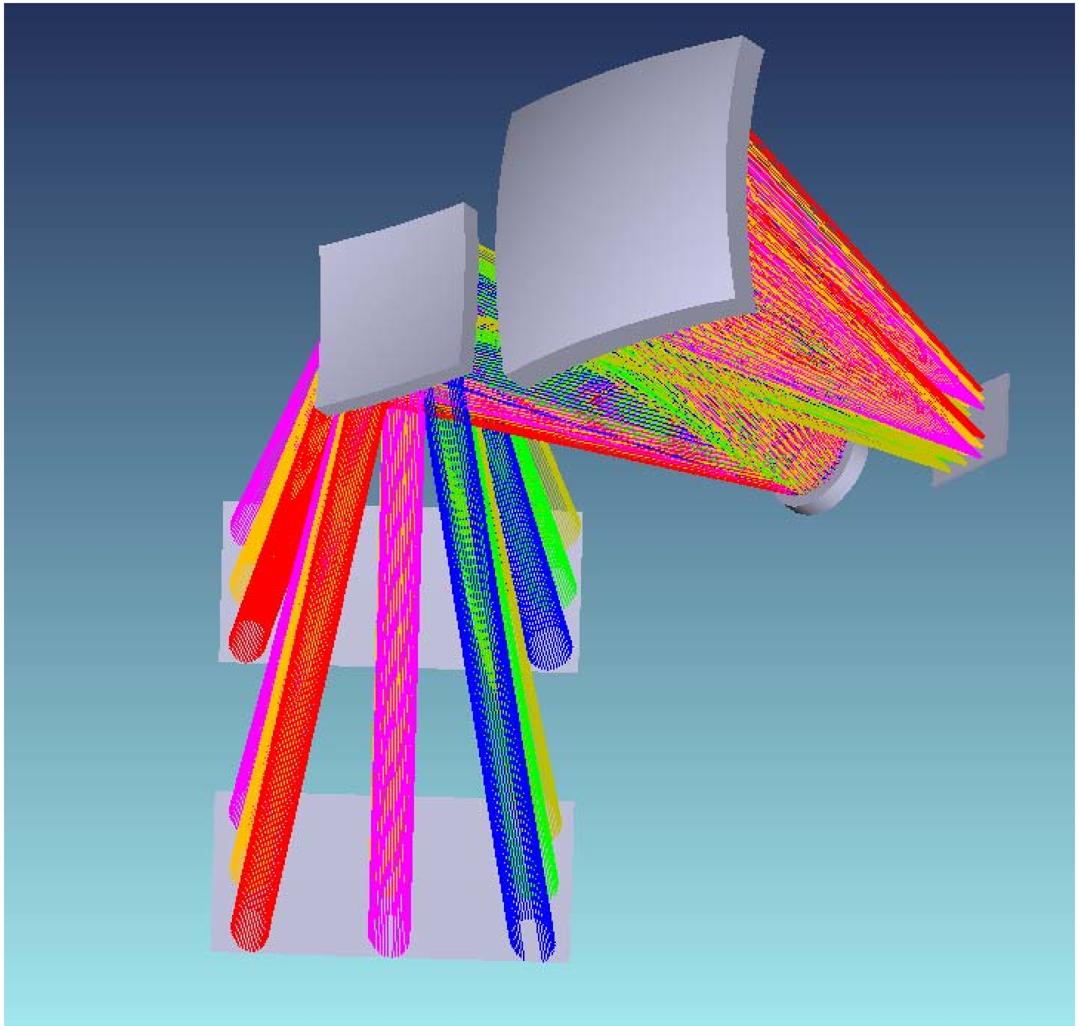
Wavelet compression algorithm: Langevin and Forni, SPIE 2000

Data Volume

According to our new baseline for the spatial resolution of **MRC 15 m/px** (providing a DTM with grid size and vertical accuracy of 1 pixel) and assuming two channels looking at the surface which images are compressed with the factors of 8 and 16 we can have the **stereo global mapping with 127 Gbyte.**

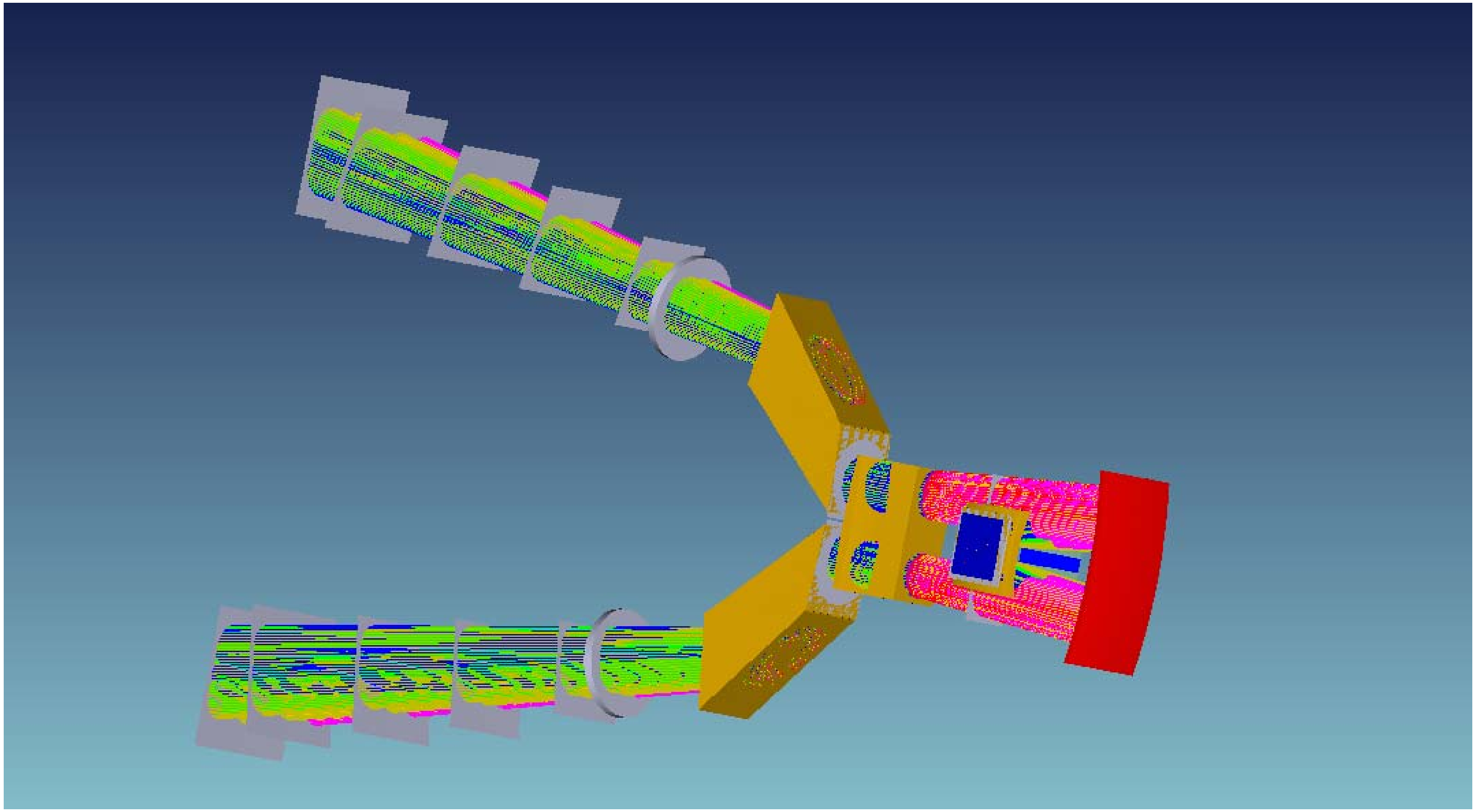
This is the same strategy adopted by CIVA, the camera on the Rosetta lander, for the stereo images.

MRC: Optical layout A



Three mirrors design; heritage from WAC/OSIRIS on Rosetta

MRC: Optical layout B



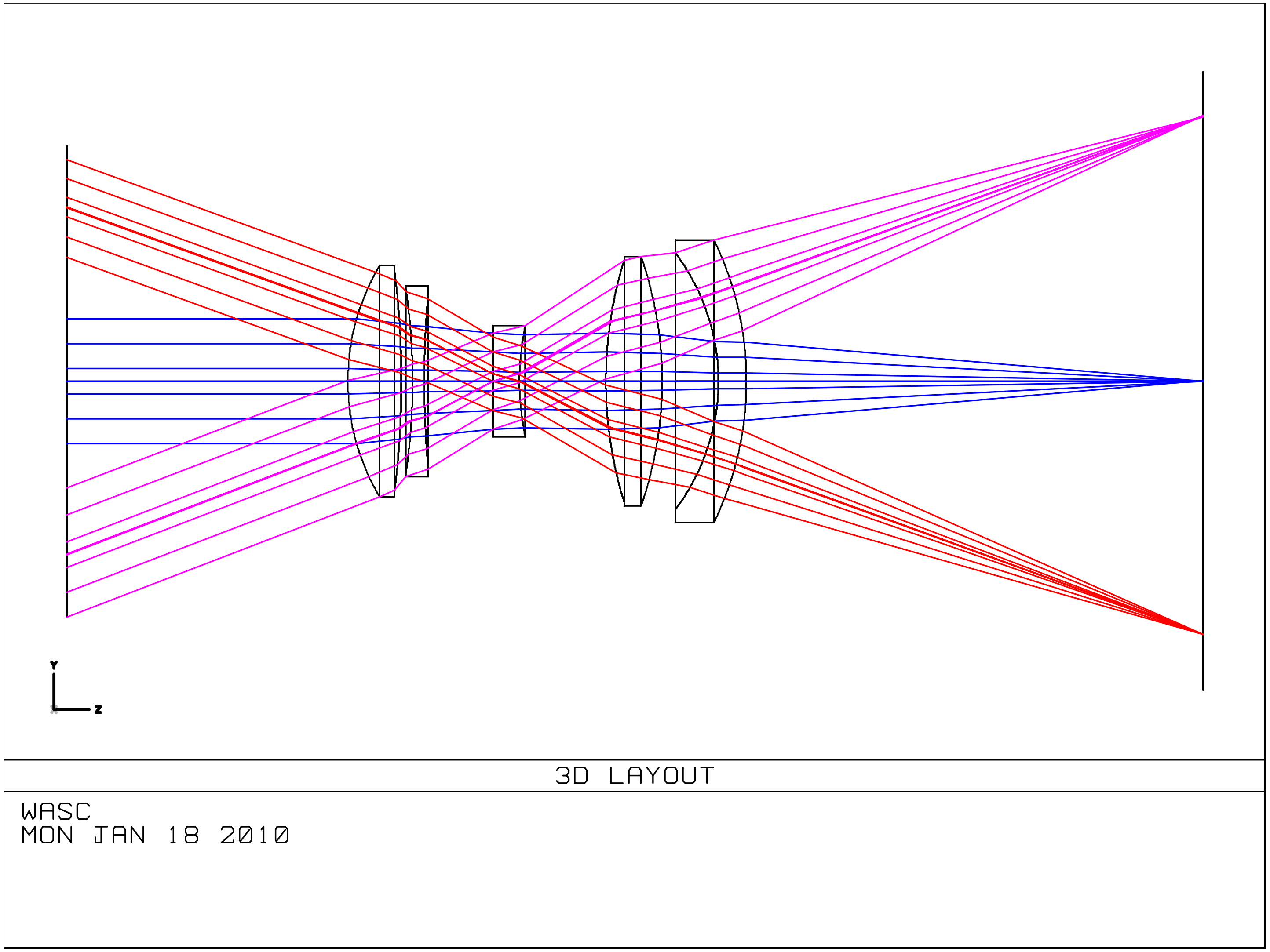
Catadioptric original design; heritage STC/SIMBIOSYS on BepiColombo

Push-broom or push-frame ?

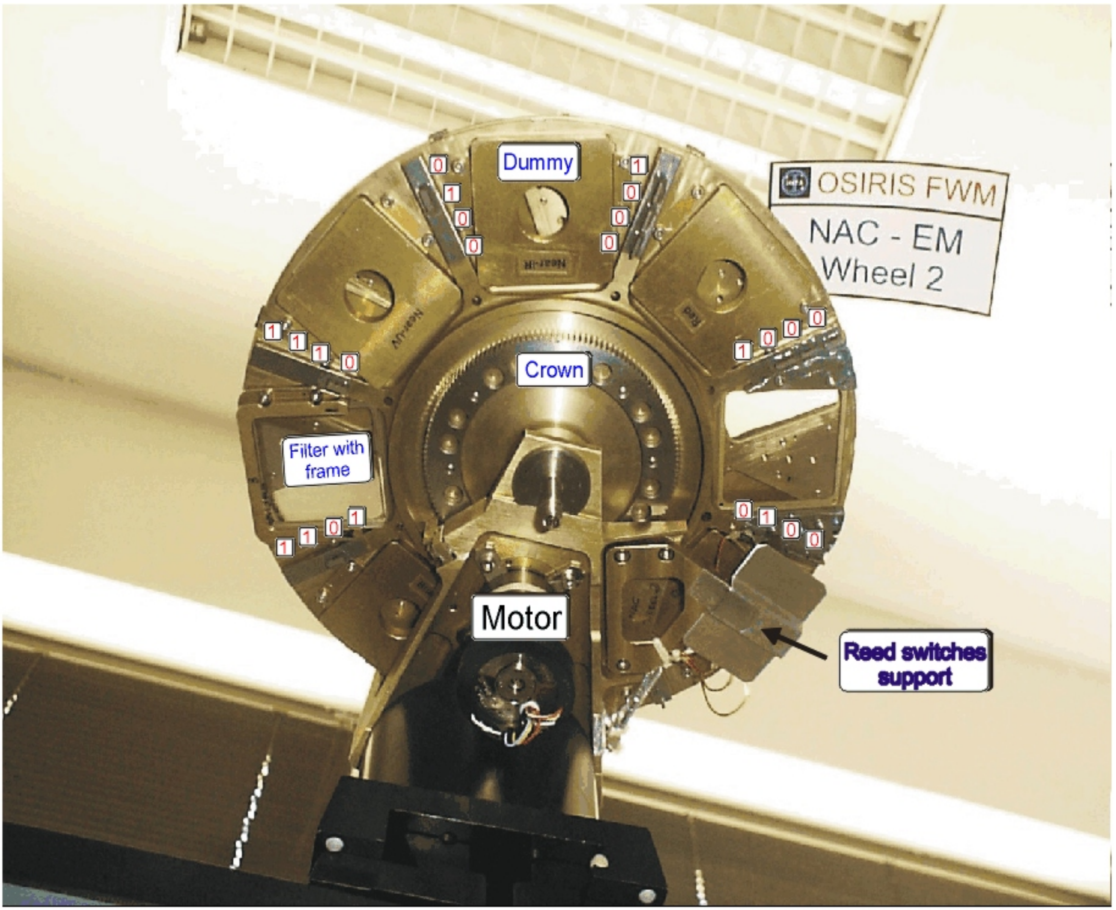
From "*Cartography for lunar exploration: 2008 status and mission plans*", Kirk et al., USGS Flagstaff, AZ

Robust and efficient methods for processing large numbers of scanner images from the various Mars and lunar missions do not yet exist. Line scanner cameras also have a substantial disadvantage over framing cameras in that the images are strongly affected geometrically by spacecraft "jitter," i.e., random to systematic motion while an image is being collected. It may be possible to resolve this problem to some extent with specially designed CCD arrays (e.g., the multi-segment array of the MRO HiRISE camera), but the necessary procedures and software to perform jitter correction for such cameras have yet to be developed and tested. Algorithms used for Earth based imaging are also often inadequate, as they assume that accurate ground point (surveyed) coordinates or GPS derived platform coordinates are available. Unfortunately, all the upcoming lunar missions are planned to have line scanner cameras, including Chang'E-1, Chandrayaan-1, SELENE, and LRO. In fact we find it surprising that such systems were approved, particularly for mapping purposes, given the problem of jitter and the lack of adequate software to photogrammetrically control the images on a production scale.

WAC: Optical layout



FILTER WHEEL FOR THE WAC



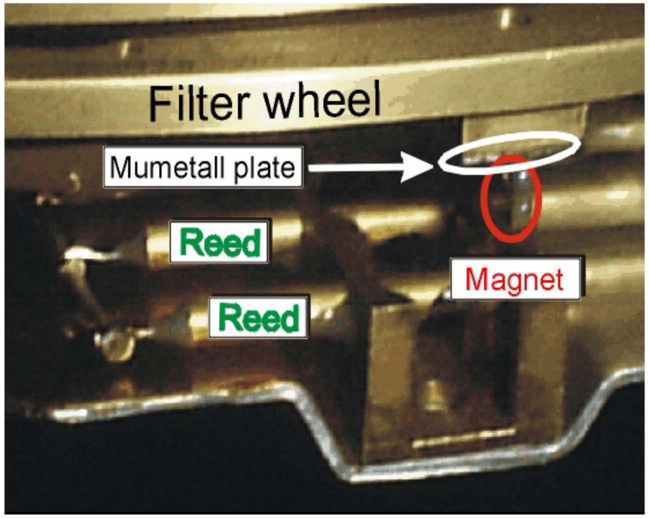
OSIRIS (ROSETTA) HERITAGE

The assembly is composed of:

• a support structure,
• a common shaft with two parallel filter wheels,
• two stepper motors with gears (crown and pinion),
• position encoders and mechanical locking devices,
•the FWM electronic controller called Mechanism Controller Board, MCB

• Each filter wheel is turned by a stepper motor to position a filter in front of the CCD in less than 1s (half wheel turn)

FILTER WHEEL



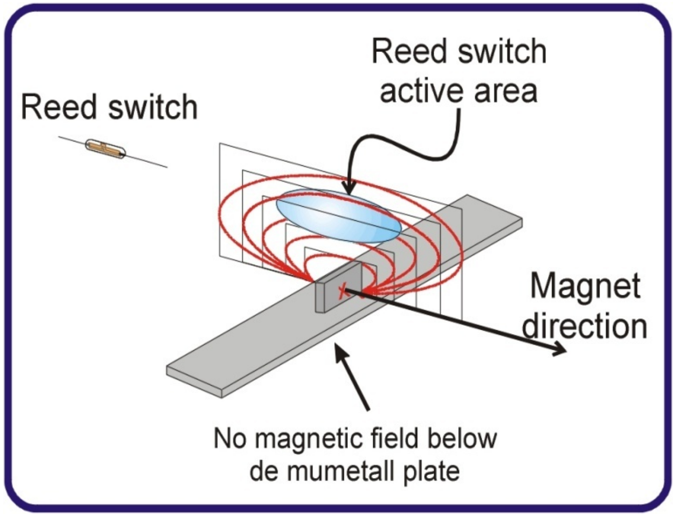
- Motor movement is achieved by sequential activation of the 4 motor phases

- Motors are variable reluctance type

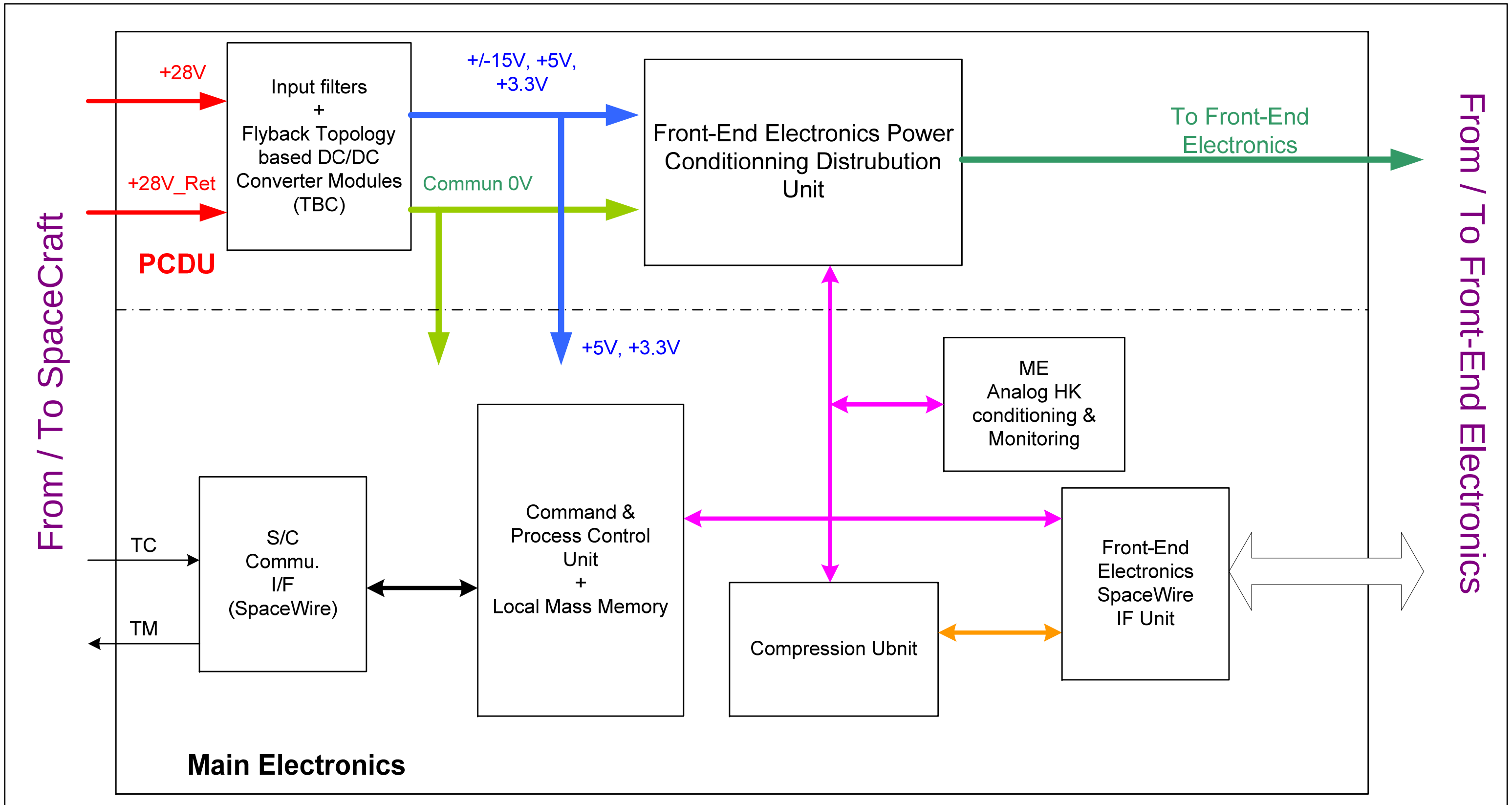
- A mechanical locking device is required to keep the filter wheels in place when a filter change is completed

- The filter selection is monitored by a binary system where the code is given by 1–4 SmCo encoder magnets beside each filter and a stationary set of 4 reed switches

- Smooth operation is obtained by a ramped step rate provided by the Mechanism Controller Board



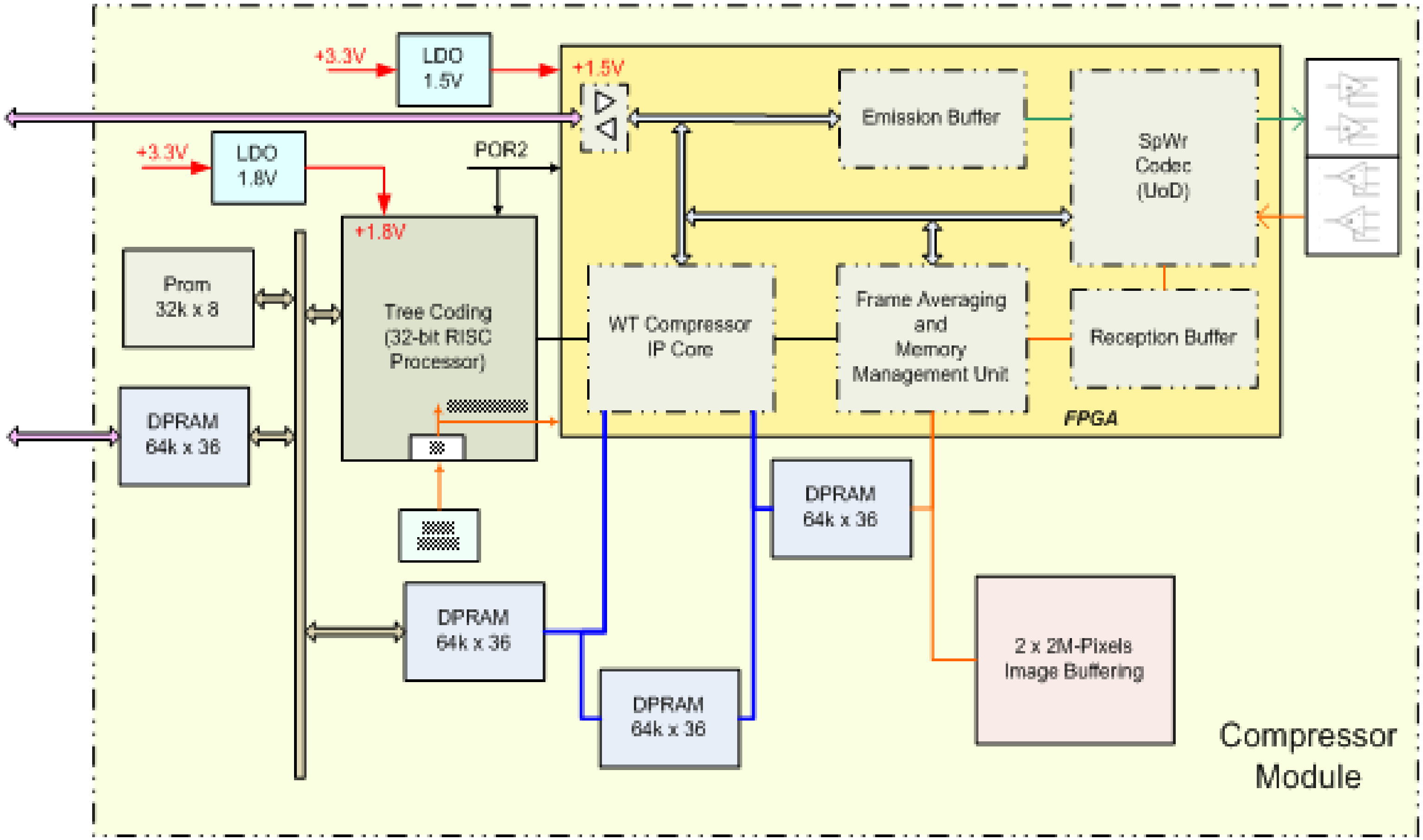
ME Architecture and Block Diagram – ME Block Diagram



Main Electronics Functional Block Diagram

2 PCBs: 1 ME/DPU & 1 DC/DC converters

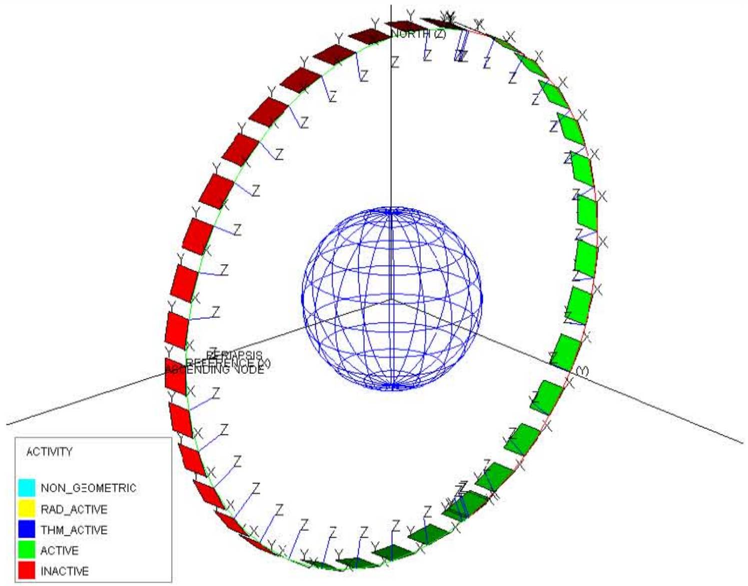
ME Architecture and Block Diagram – ME CU

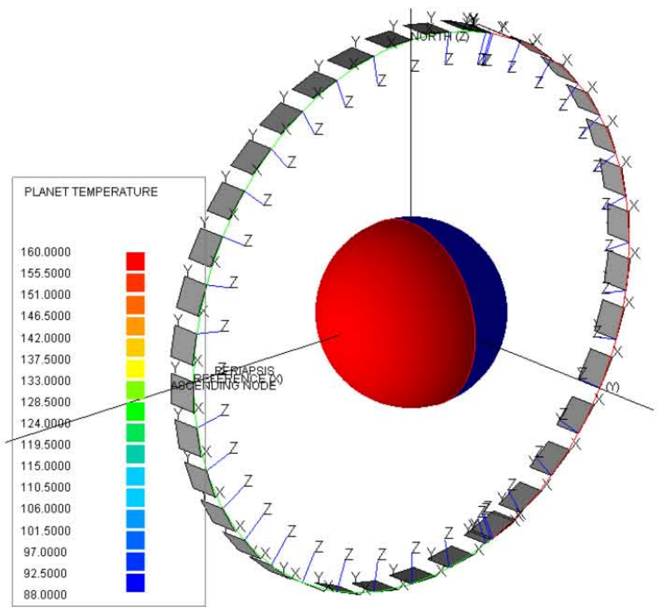


- SpW link from/to the Camera @ 100Mbit/s
- WT lossy Data Compression capability @ 2Mpx/s

JGO thermal environment

Orbit: circular Polar orbit
Altitude: 200 km





Environmental parameters

Planet hot side: 160 K
Planet cold side: 88 K