Clean Space Industrial Days

Rendezvous sensors and navigation

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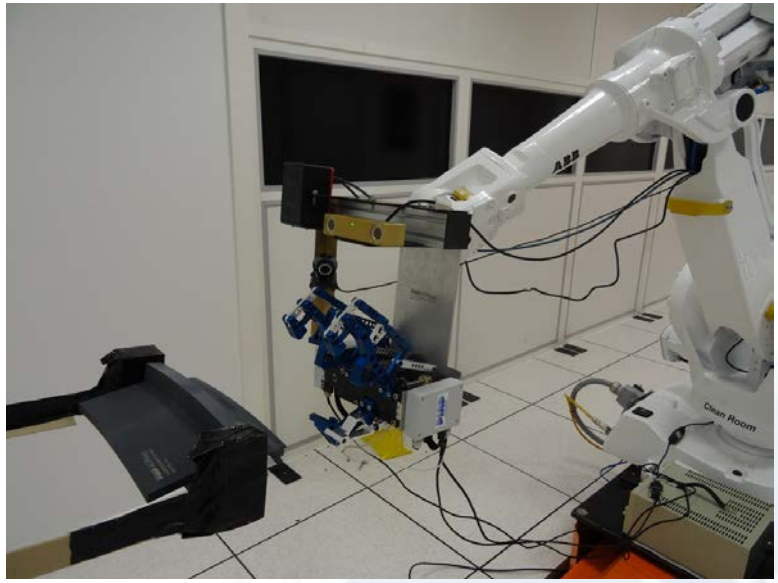
Agenda

- Collection of R&T studies enabling vision based rendez-vous
  - Sensors & processing
    - 3D Time-Of-Flight Camera Breadboard Demonstration (ESA study)
    - Multispectral sensor for rendezvous (ESA study)
    - Image processing algorithm development (Internal)
  - Simulation tool & Demonstrator
    - TAS-F SPICAM image generation (Internal)
    - TAS-F Rendezvous test bench (Internal)



TAS-F Rendez-vous test bench

3D TOF Camera Breadboard Demonstration

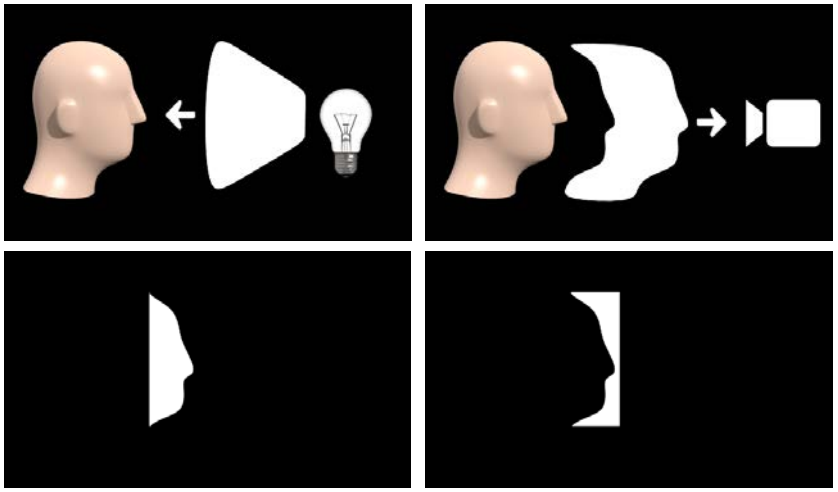
- ESA study

- Objectives
  - Identify the requirements for a 3D Time-Of-Flight camera to meet the needs of spatial missions
  - Trade-off the technologies complying with these applications
  - Elaborate a preliminary design
  - Manufacture and test a breadboard of such a camera
  - Reach TRL 4

- Industrial team
  - TAS-F: Prime + RdV & docking missions requirements + tests
  - TAS-I: Landing & rover missions requirements + tests
  - SINTEF: Technology trade-off + tests
  - TERMA: Camera design, breadboard manufacturing, development plan

3D TOF Camera Breadboard Demonstration

- Pulse-based GATE technology has been selected
  - Area sensor (Flash-LIDAR)
  - Short pulses (20-300 ns) and similar short exposure times
  - On-chip precise gating is used to convert differences in per pixel integrated light (gates 1&2) into distance
  - Several images are accumulated to improve SNR

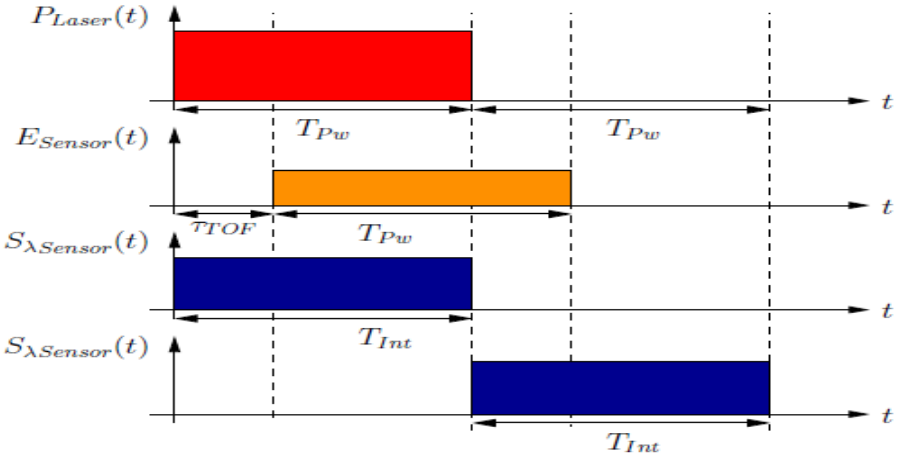


TOF camera based on integration time

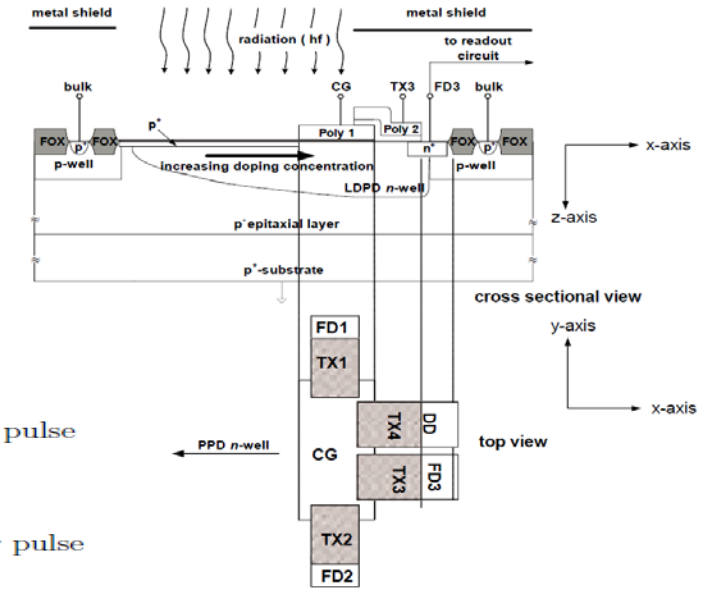
- Advantages wrt to phased-based technology
  - Inherent Suppression of Background Illumination (SBI), particularly important for long range imaging or with bright body behind the target (better SNR)
  - Longer ranges are expected than PHASE, then larger mission coverage
  - Less prone to multi-reflections
  - No ambiguity issues

3D TOF Camera Breadboard Demonstration

- Gate Sensor
  - TriDiCam ToF sensor control sequence
    - Pulse width: 15-100+ ns with current TriDiCam driving electronics
    - Possibility to integrate 1024 subframes to increase SNR
  - Two consecutive shutter times of same duration as the pulse (MDSI3 algorithm baseline)
    - A third integration is done with background light only and is subtracted to both signals



Sensor shutter principles



TriDiCam sensor

- Range computation (simplified)

$$d = \frac{c}{2} \cdot \left(T_{SD} + \frac{s_2}{s_1 + s_2} T_{Pw} \right)$$

T_{SD} = shutter delay wrt pulse emission (here $T_{SD} = 0$)

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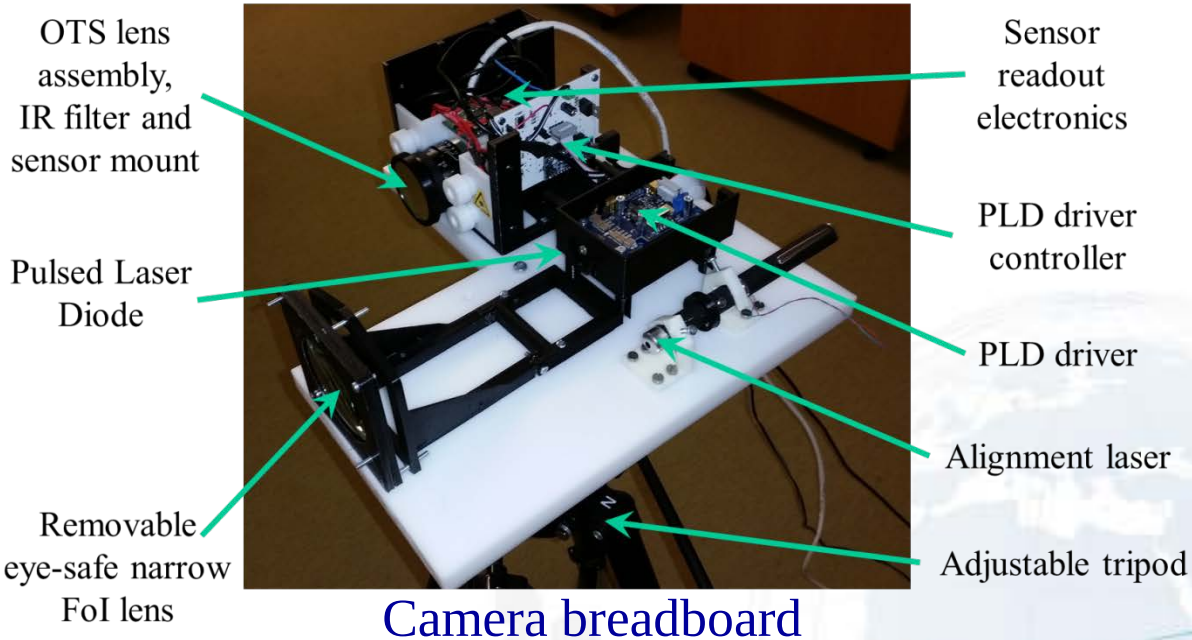
3D TOF Camera Breadboard Demonstration

- Preliminary design (TERMA)
  - Camera module
  - Light source module

Preliminary design of the TOF camera

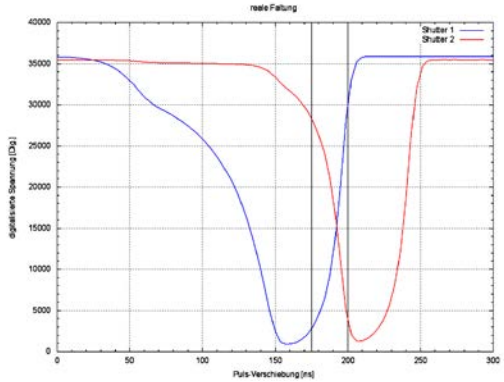
- Breadboard mock-up (TERMA)



Camera breadboard

3D TOF Camera Breadboard Demonstration

- Breadboard test plan
  - Preliminary tests by TERMA
  - Calibration tests by SINTEF
    - Best per-pixel range estimate wrt the signals of both triggers: *d = d(s1, s2)*
  - Tests on TAS-F rendezvous test bench
    - Performance test for MSR rendezvous
  - Tests on TAS-I rover test bench
    - Rover navigation solution



Gate offset and duration tuning

TAS-F and TAS-I test benches

Multispectral Sensing for Relative Navigation

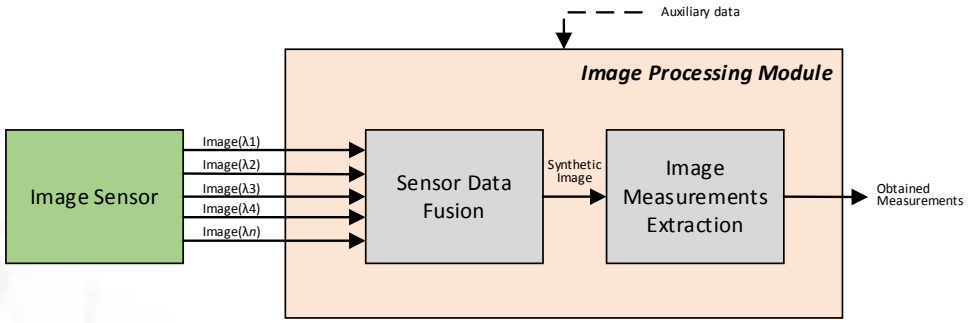
- ESA study

- Objectives
  - Evaluate the benefits of a multispectral sensing device (MSD) compared to the usual visible sensing
  - Make a preliminary design of a generic MSD to cover the following scenarios
    - Cooperative rendezvous in LEO or Earth-Moon L2 orbit
    - Non-cooperative rendezvous (debris detection and removal)
    - Descent and Landing on an asteroid
    - Navigation for planetary flybys
  - Reach TRL 3

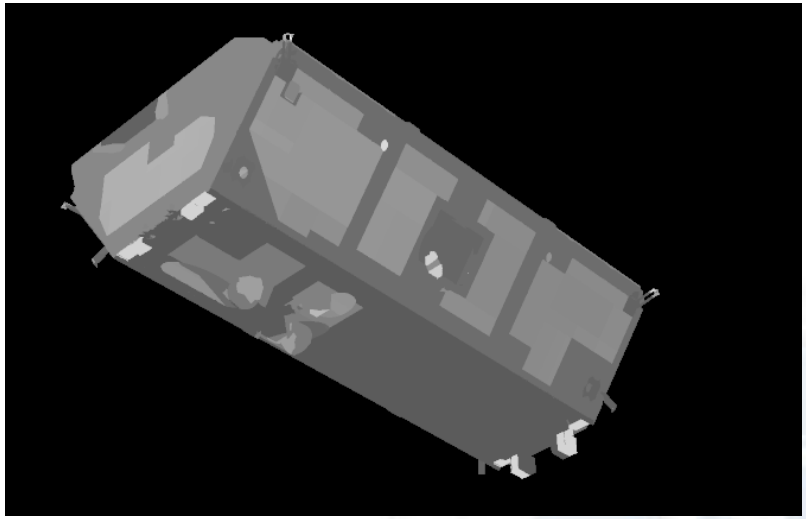
Multispectral Sensing for Relative Navigation

- Industrial Team
  - TAS-F: Prime, scenarios and requirements, simulator integration
  - IMEC: Technology trade-off
  - RUAG: MSD design and model
  - Deimos: Navigation and data fusion algorithms
  - Observatoire de la Côte d'Azur: consultancy on targets signature

- Data fusion of several wavelengths (visible, NIR, UV, thermal IR)



Multispectral sensor architecture

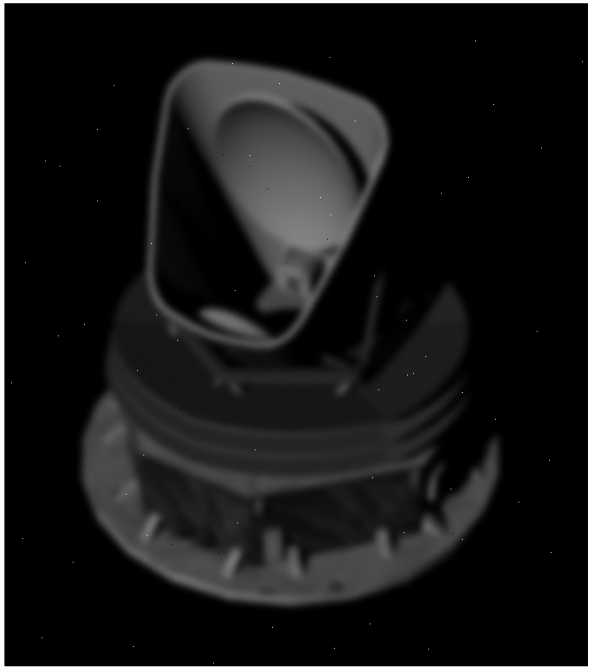


IR image of the Iridium Platform

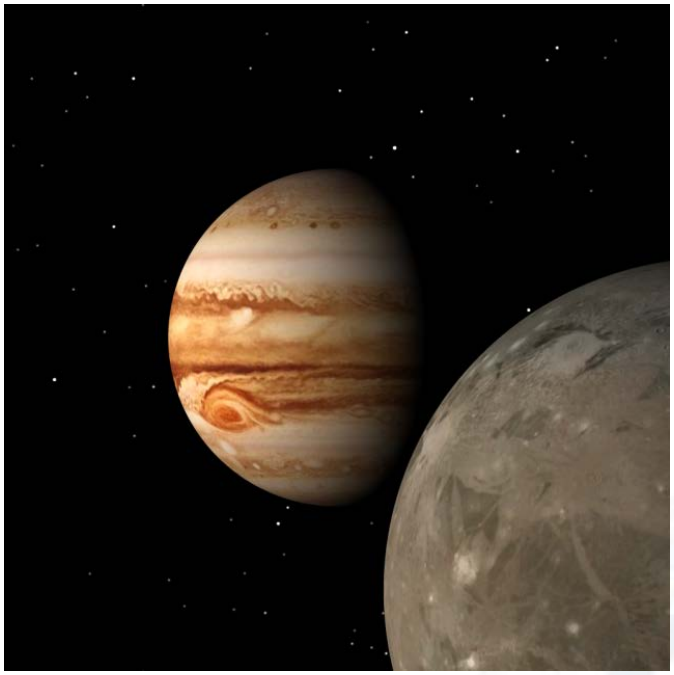
TAS-F SPICAM image generation

- Spacecraft and Planetary Imaging by Camera Modelling
  - Aims at modelling a camera and generating representative images for interplanetary and rendezvous missions

SpiCam



Planck CAD model displayed by SpiCam



Ganymede and Jupiter displayed by SpiCam

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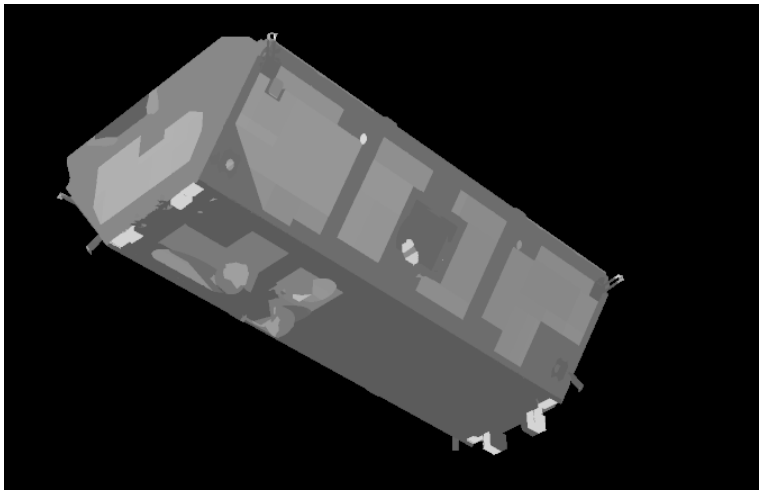
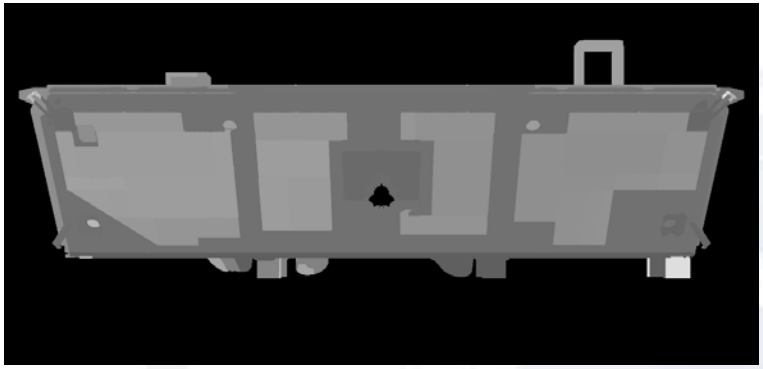
TAS-F SPICAM image generation

- Update of SpiCam tool for generating multispectral / thermal images
  - Radiance based on models from thermal analyses
    - Temperature
    - Gray-Body Emissivity
    - Reflectivity
    - IR Sources in environment
  - Geometry from detailed CAD model



IR image of the Iridium Platform



IR image of the Iridium Platform (from side)

SpiCam

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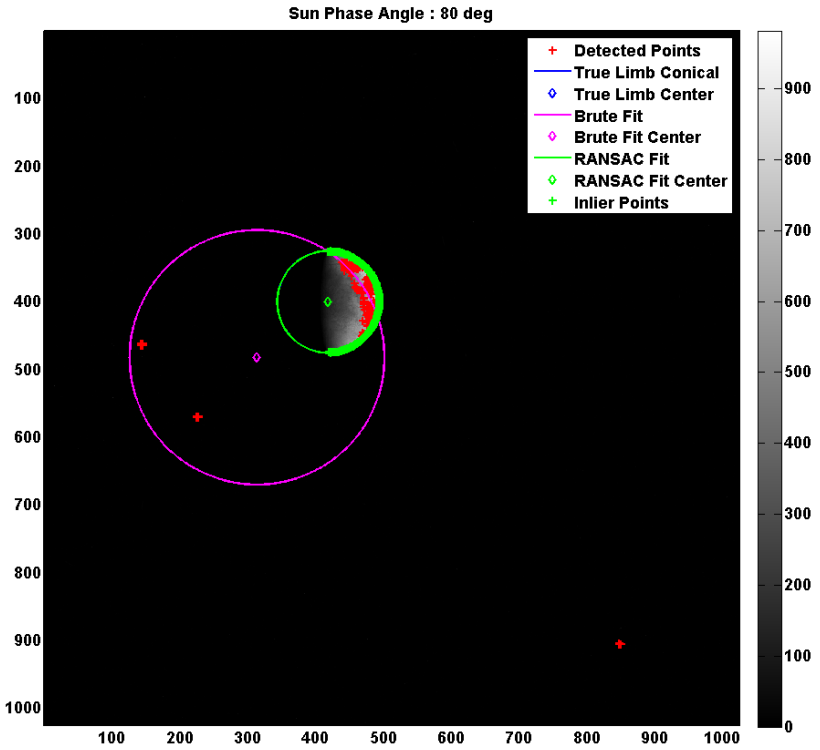
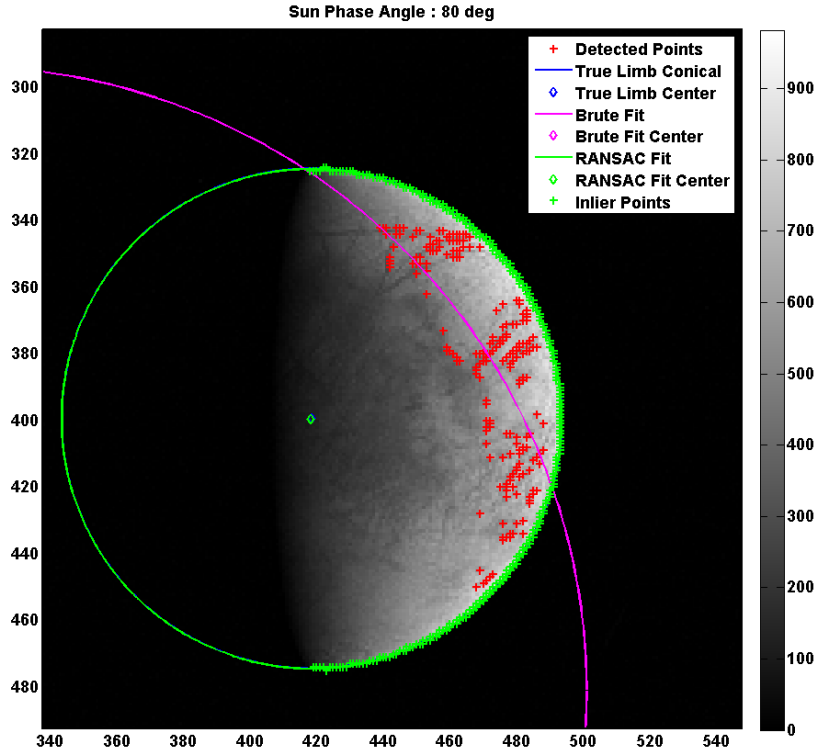
Image processing algorithms development

- Robust Limb Fitting
  - Image processing used for:
    - SEU/Straylight elimination
    - Noise Reduction
    - Edge Detection
  - Robust fit ensured by outliers rejection
  - Accurate fit ensured by non-linear solution
  - Cross-correlation for small target sizes

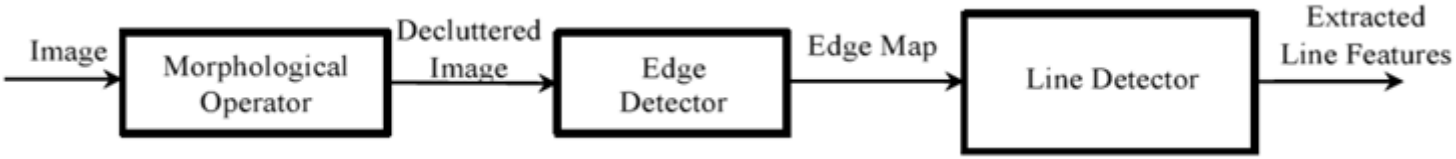


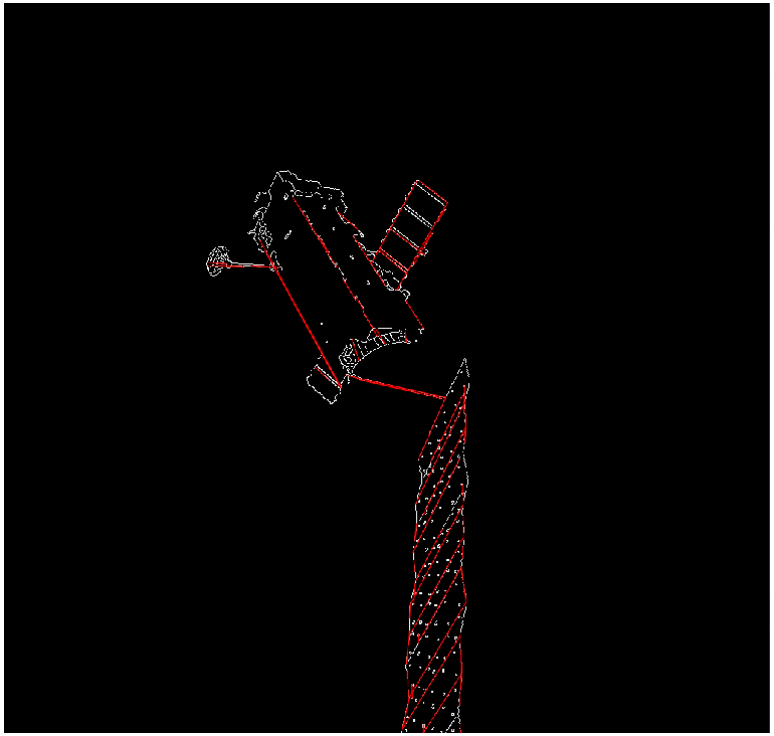


Robust limb fitting with outliers rejection

Image processing algorithms development

- Pose Estimation for rendezvous (1/2)
  - Pre-processing and edge detection

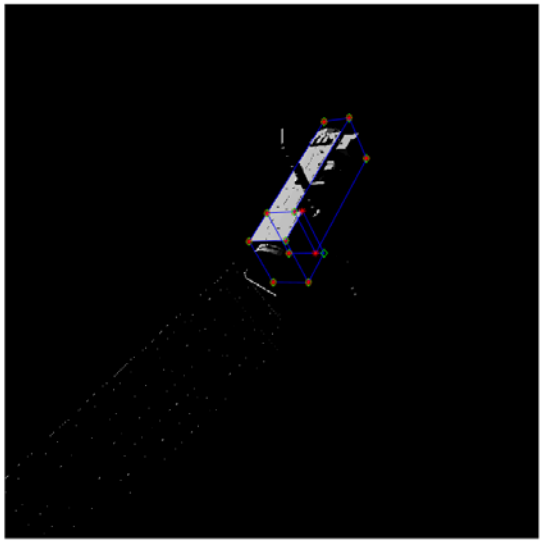




Lines extraction on Envisat

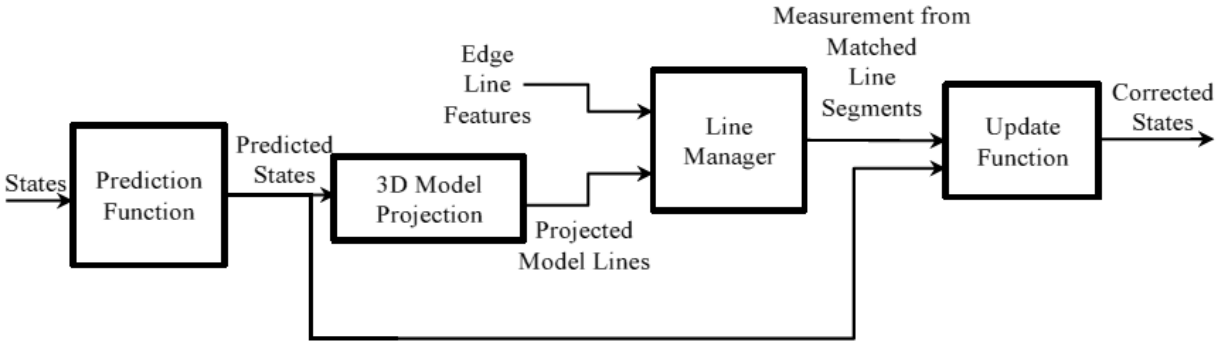
Image processing algorithms development

- Pose Estimation for rendezvous (2/2)
  - Model-based matching



Model based matching

  - Pose Estimator

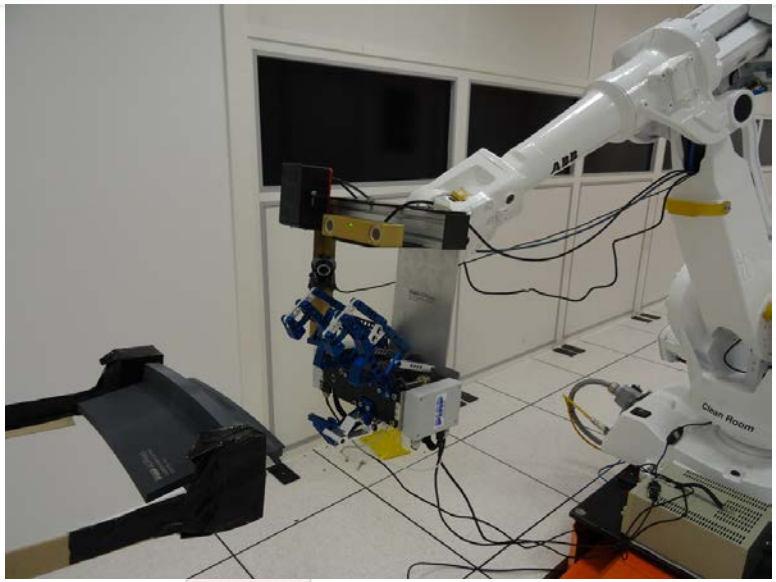


Pose estimator architecture

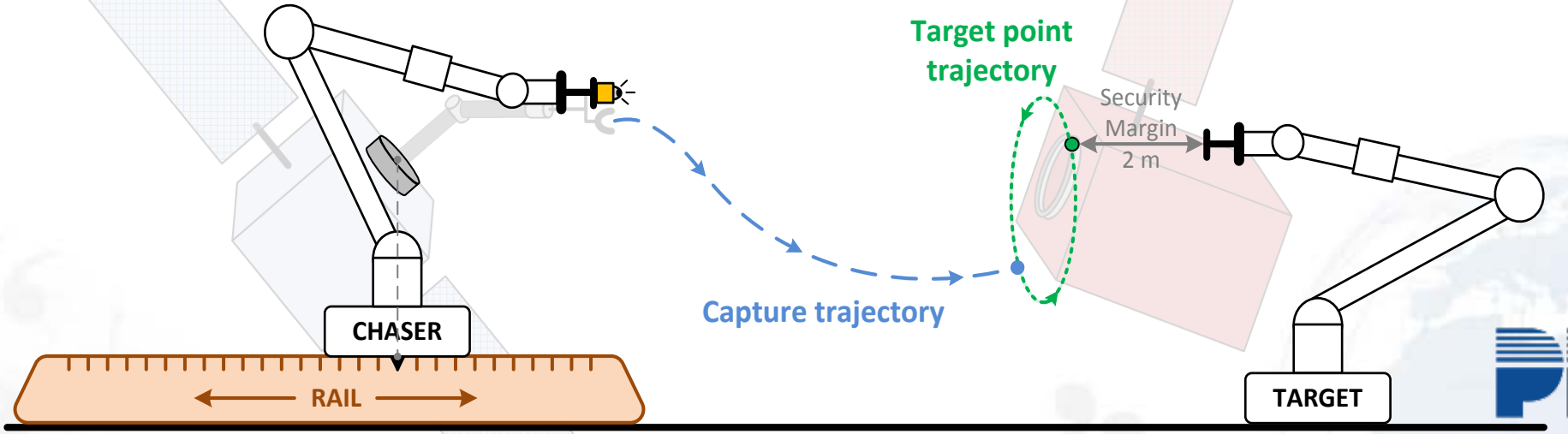
- Being implemented for real time use on the rendezvous testbench

TAS-F Rendezvous test bench

- Closed-loop demo of a debris capture
  - Gripper made by PIAP (ADRexp study)
  - Simulation of last meters approach
  - Hardware and images in the loop
  - GNC closed loop
  - Target movement in position & attitude

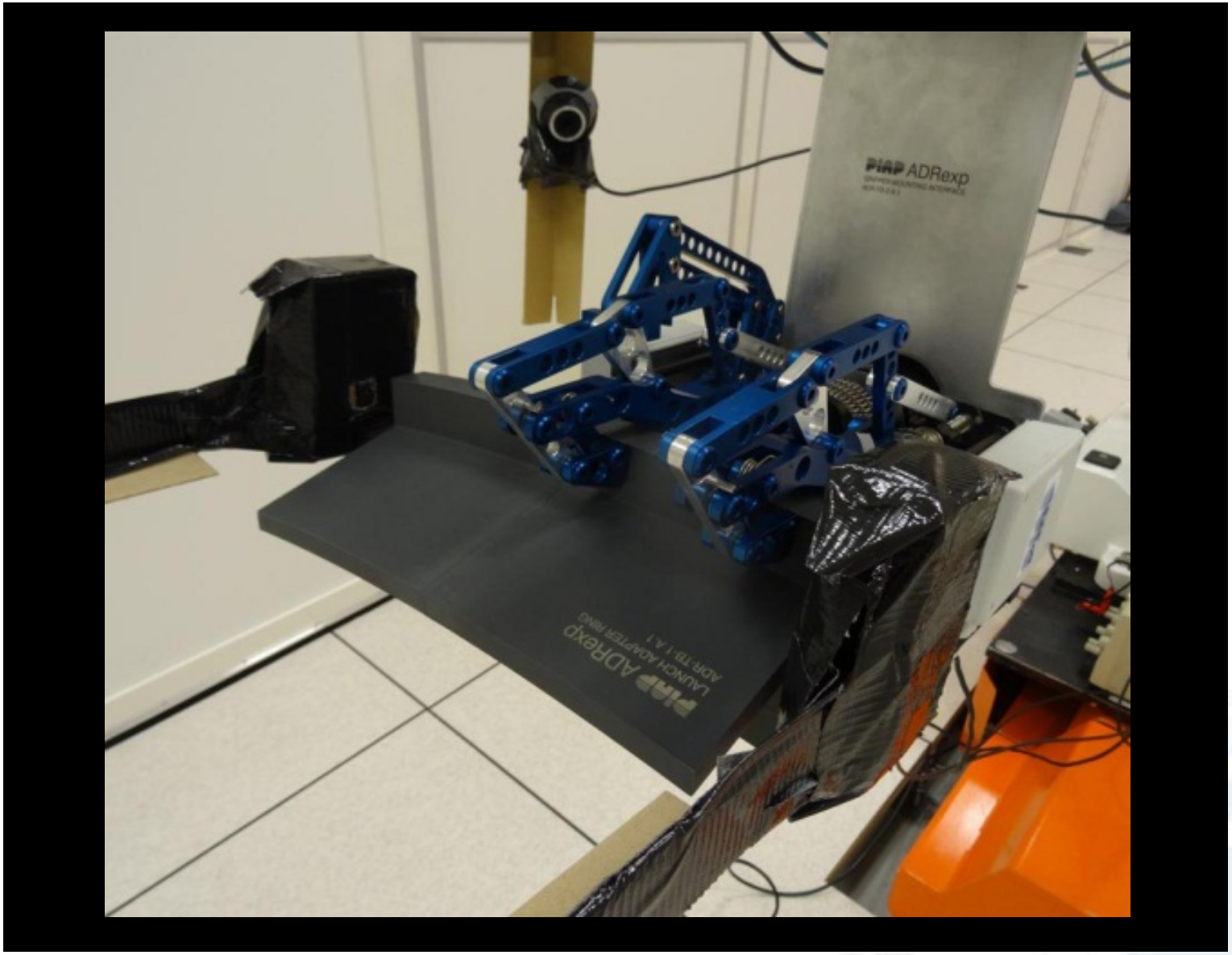


TAS-F rendezvous test bench



Rendezvous test bench for robotic arm capture demonstration

TAS-F Rendezvous test bench



Thank you for your attention

Questions ?