CHALLENGES OF POSE ESTIMATION FOR FUTURE OOS MISSIONS

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DLR

INTRODUCTION

On-Orbit Servicing Missions

On-orbit Servicing, Assembly, and Manufacturing 1

OSAM 1, Credit NASA

Clearing of the LEO Environment with Active Removal (CLEAR) mission

Clearspace 1, Credit Clearspace

Mission Extension Vehicle

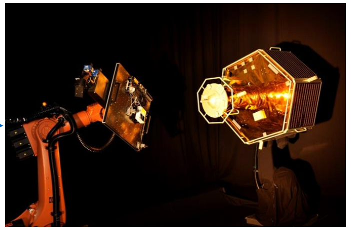
Credit: Northrop Grumman

OOS at DLR

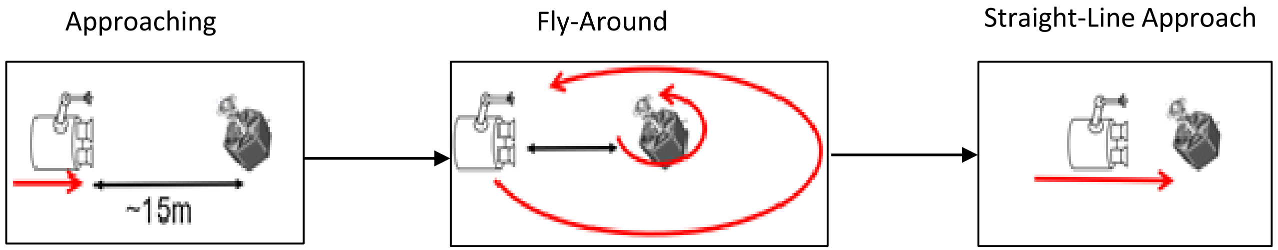
RICADOS Project - Rendezvous, Inspection, CApturing and Detumbling by Orbital Servicing

Control room at DLR

Ground Segment
- Communication Infrastructure
- Rendezvous Console
- Docking/Robotic Console
- Satellite Console

Space Segment
- EPOS Rendezvous Simulator → 
- OOS Sim Berthing Simulator → 
- Satellite Simulator

Close Rendezvous in OOS Mission



Visual Navigation with Lidars and Cameras

Star Tracker Credit: Jena Optronik

Lidar sensor Credit: Jena Optronik

European Proximity Operations Simulator (EPOS)

Hardware-in-the-Loop (HiL) simulator with two industrial robots for physical real-time simulations of RvD maneuvers

- 2 Robots with 6 degrees of freedom to simulate a servicer and a client
- Linear rail up to 25 m
- Rendezvous sensors
- Target mockup
- Sun simulator

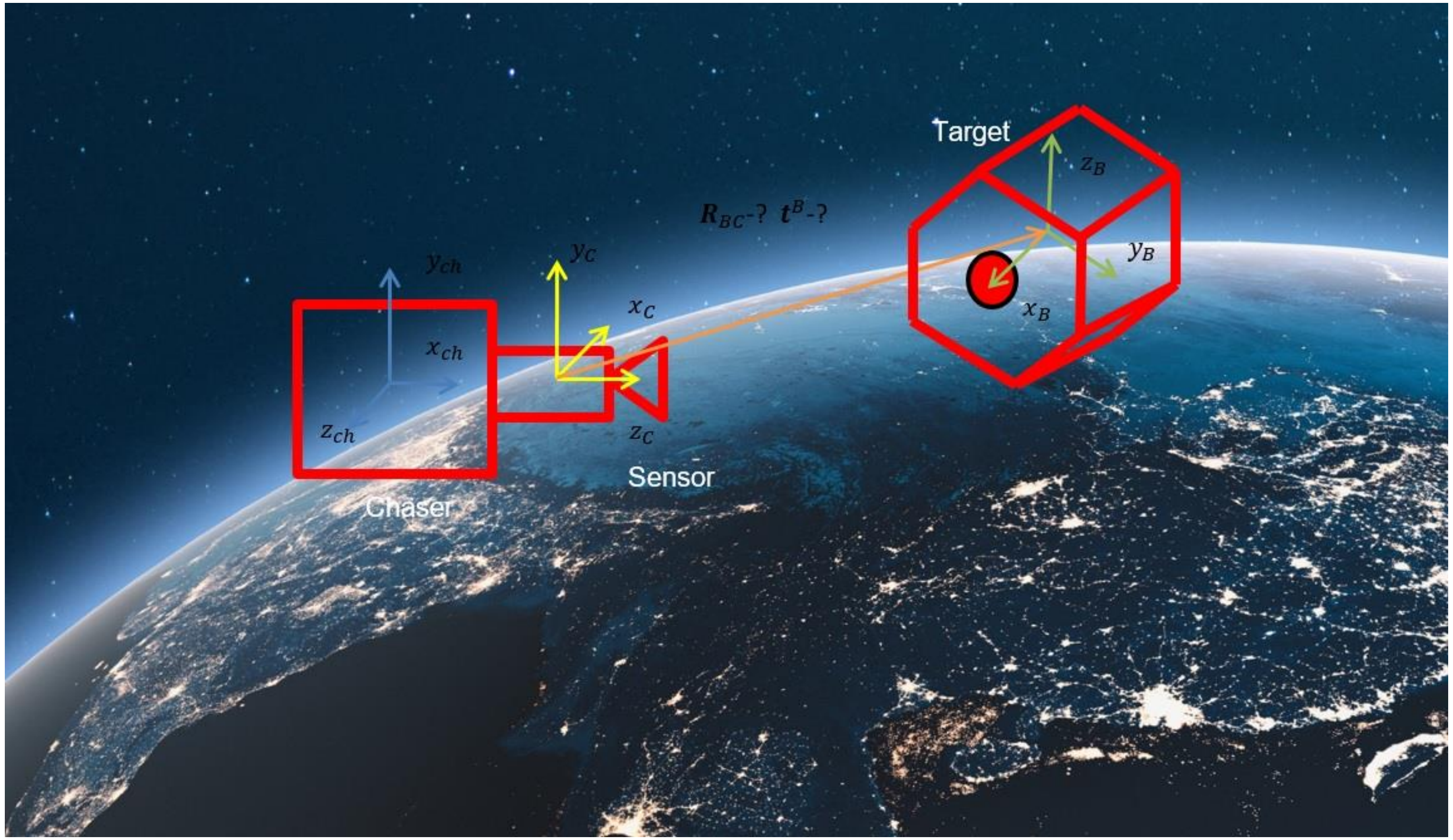
Visual Sensors for Close Rendezvous

Carbon plate with visual sensors at EPOS

Mid/close range cameras, Livox lidar and PMD camera

Development of Robust Pose Estimation

Goal: robust pose estimation of the target space object during close range approach
What means robust in this context?

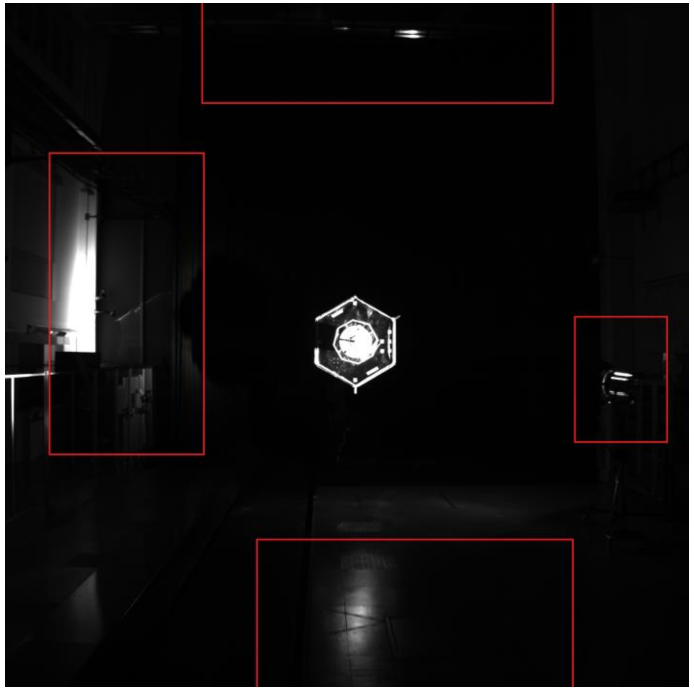


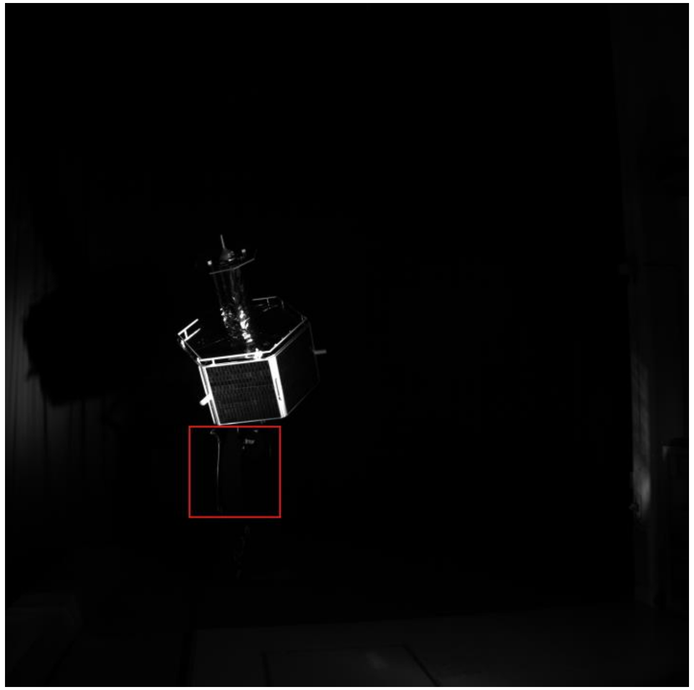
CHALLENGES

Simulation Scenarios and Illumination Conditions

Laboratory Environment ≠ Space Environment

- walls, floor, celling, lamps on the celling do reflections
- curtains position can be moved
- robots flange reflects on the image
- no space environment simulator (hard vacuum of space, thermal vacuum chamber for temperature simulation) -> EPOS inside a chamber!

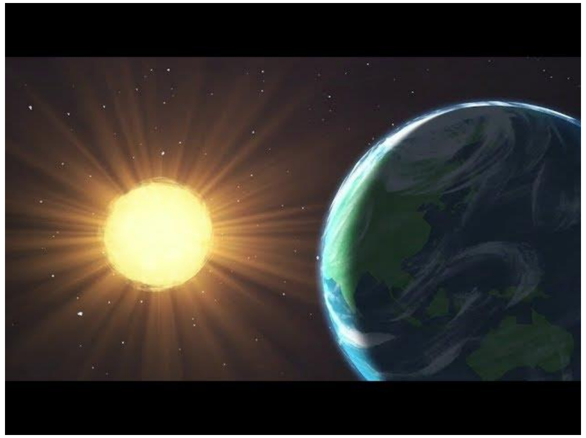




Simulation Scenarios and Illumination Conditions

Illumination conditions ≠ space illumination

- Simulation of sun position
- Simulation of sun irradiance
- Earth albedo radiation
- Earth background



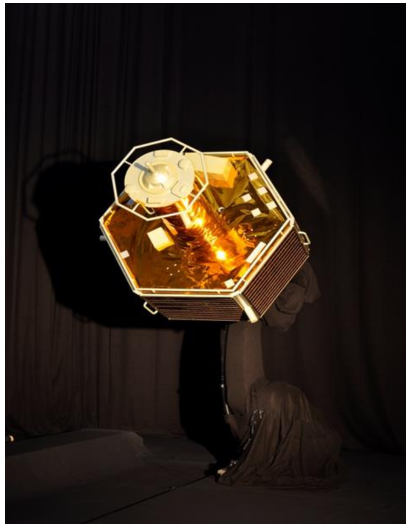
Credit: NASA

Uncounted possible trajectories to be simulated for an approach
(using collision avoidance constraints, nonlinear rotational dynamics, and fuel efficiency)
main goal: must be safe

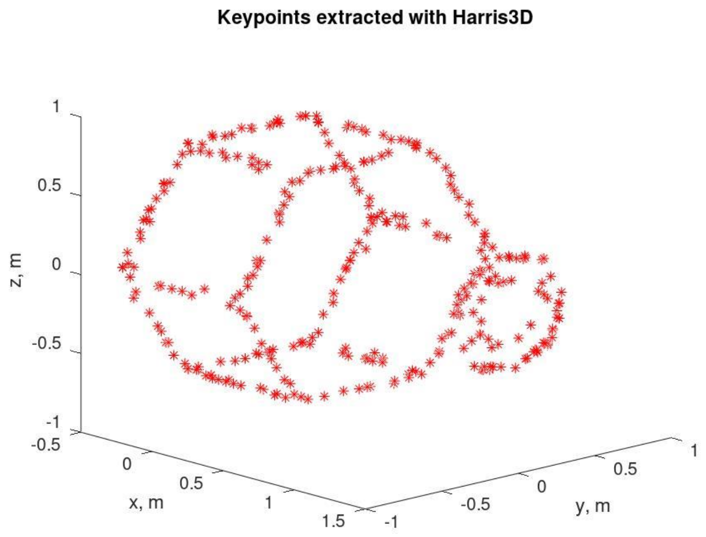
Target Model

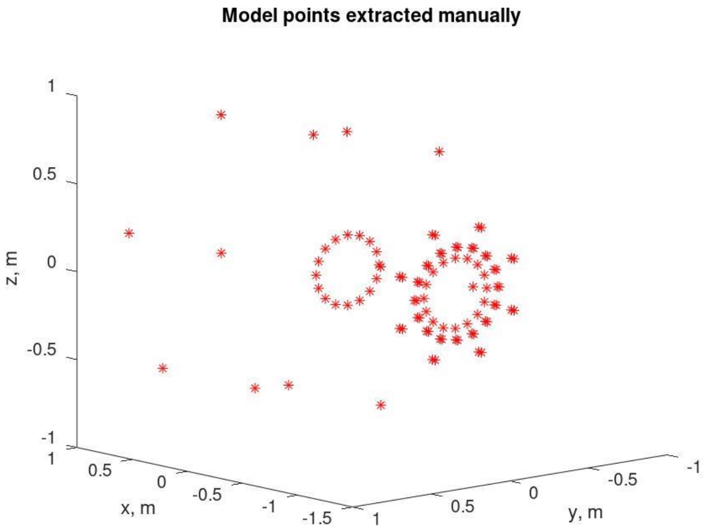
Target mockup = Real satellite ?
- geometry of the target
- surface materials (MLI, solar panels)

Mesh model for pose estimation
- precise model, many points -> high computational costs
- no defined consensus to select keypoints for pose estimation
- visual perception or automatic extraction?



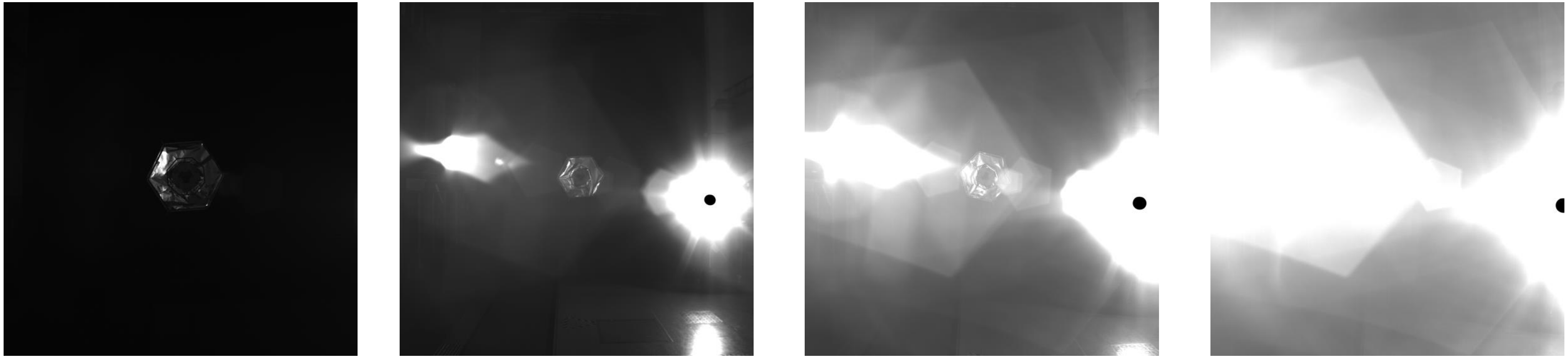
EPOS Mockup





Data Quality

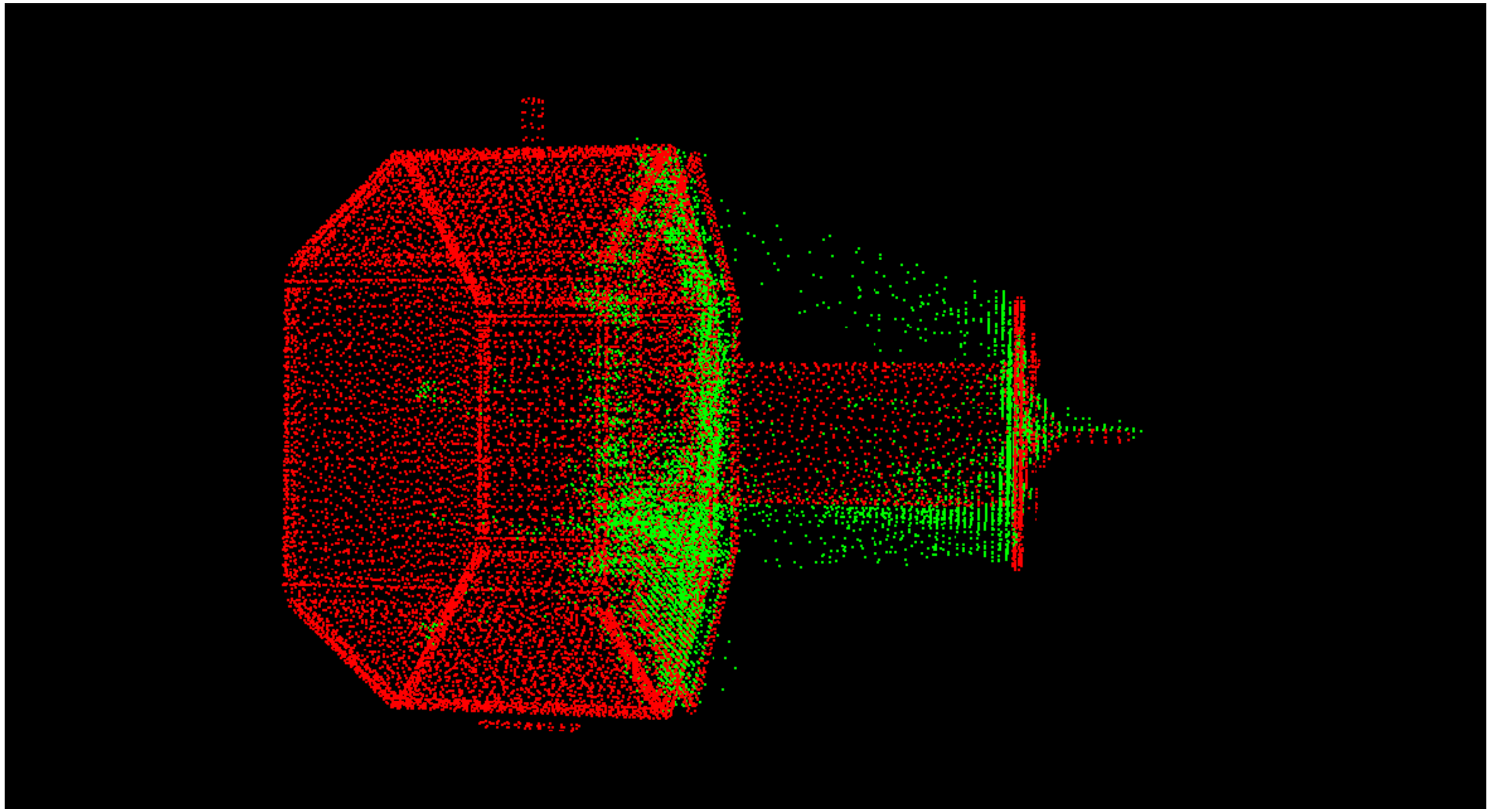
Camera images



- Nothing unexpected happens if image is overexposed/underexposed
- Automatically recognition of bad/non-suitable images

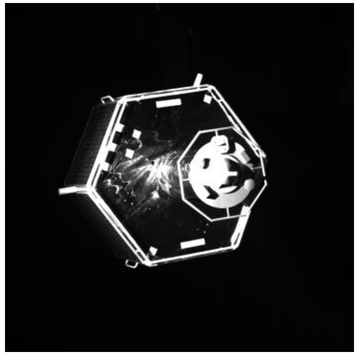
Data Quality

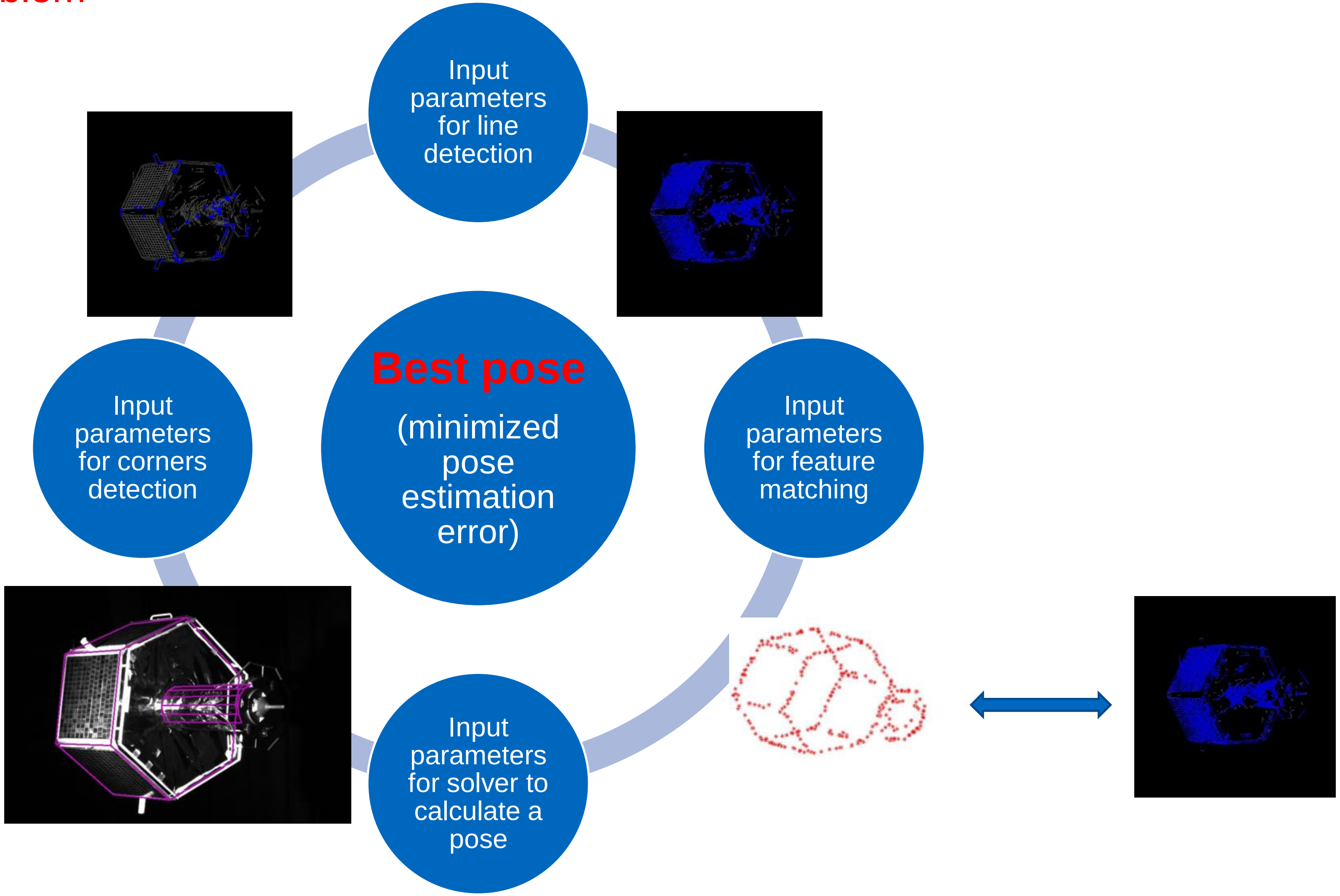
Lidar point cloud (green) and model point cloud (red)



Input Parameters for Pose Estimation Algorithm

Complex optimization problem





Input Parameters for Pose Estimation Algorithm

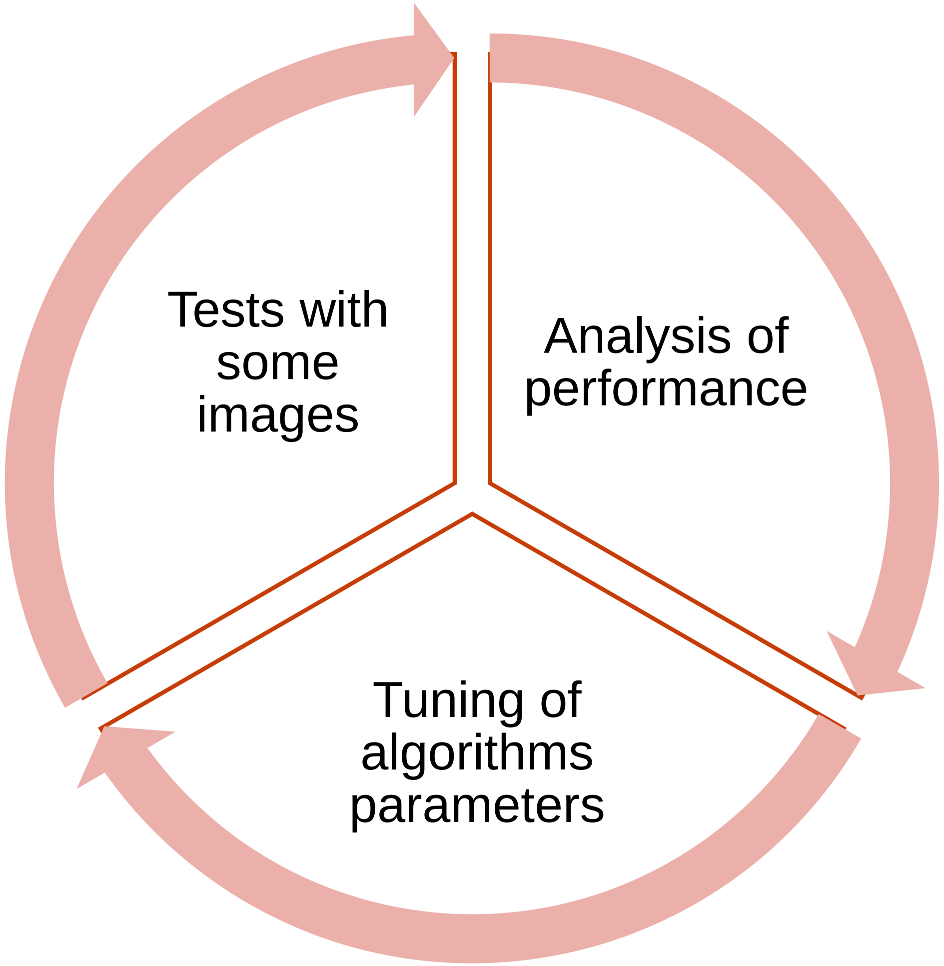
Solve complex optimization problem -> pose estimation algorithm performance is reliable for any simulated case

Controversial issue: not possible to simulate unlimited HiL scenarios

Manual tuning of the parameters -> maybe good performance only by limited simulation scenario

Input Parameters for Pose Estimation Algorithm

Offline testing cycle takes **plenty** of time (endless)



Example 1:
Rendezvous from 18 m to 15 m
Fly-around hold point 15 m

Example 2:
Rendezvous from 18 m to 10 m
Fly-around hold point 10 m

Pose Estimation Suitable for On-board Computer

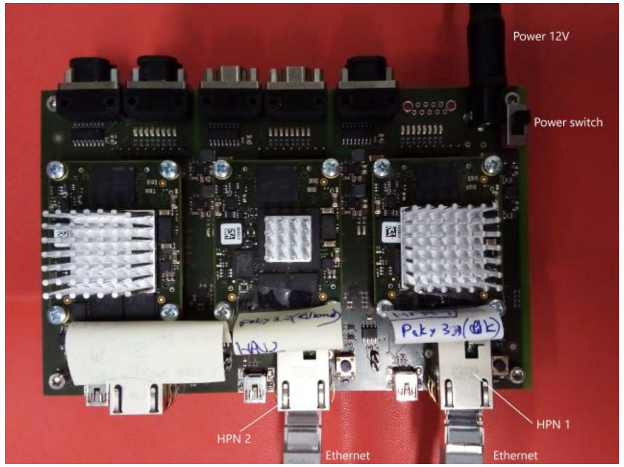
Computing performance with PC ≠ Computing performance with OBC

- OBC processor must be sufficient for image processing

- Reliable pose estimation (restricted support)

- Pose estimation must be prepared for on board failures

Keep control of the spacecraft, while handling the failures



Scosa OBC

- Pose estimation compatible with OBC platform

Differences can be in used Operating System (OS), supported computing language, supported build tools, availability of software libraries, interfacing to external hardware and system resources

How to Cope with Challenges

I. Automatization of the testing of pose estimation with

- Different sets of images different trajectories and illumination conditions
- Different 3D simplified models of the mockup
- Automatic report on the failures, accuracy

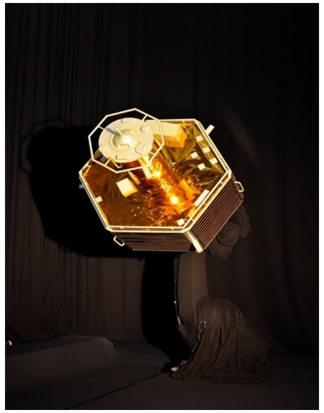
II. Definition of the constrains when the algorithm is working as intended

III. Estimate risks of the failures and be ready to react rapidly

Nice to have

Pose estimation technique is reusable :

- different shape of the object
    - automatic key point extraction of known 3D model
    - feature extraction/matching



EPOS Mockup

SmallGEO Credit: ESA

ISS Credit: NASA

Virginia Space Grant Consortium - Old Dominion University
Creator: Bradley Willett

NOTHING IS IMPOSSIBLE…