TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Electrical and Computer Engineering • Institute of Automation

Image Recognition and Processing for Navigation (IRPN) Presentation for Clean Space Industrial Days

Arne Sonnenburg

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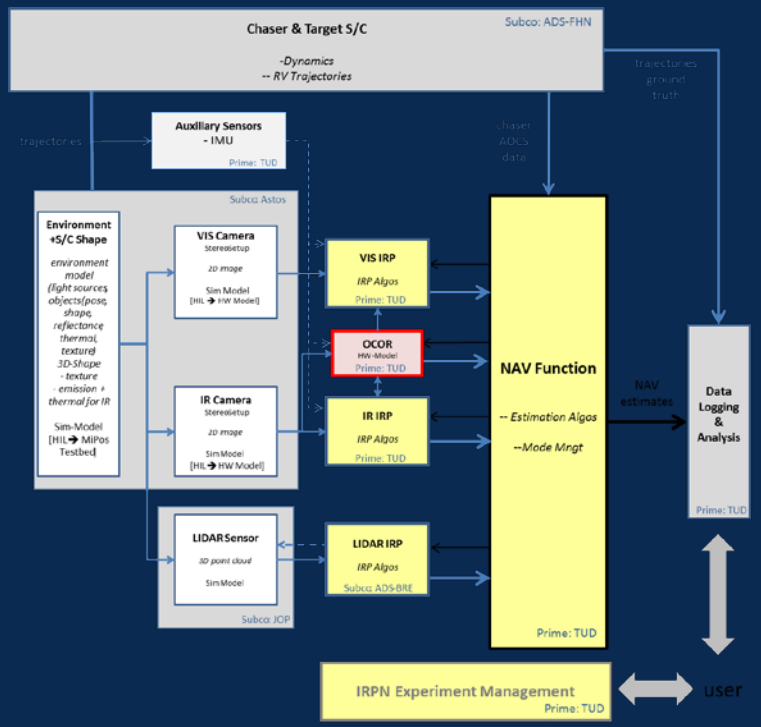
- Concept and Consortium
- Algorithms
- Verification Procedure & Results

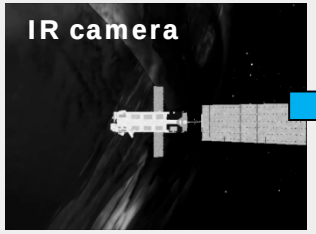


May 26, 2016

Goals of the Activity

Ref.: AO/1-7937/14/NL/MH, GSTP G61C-029EC

sensors



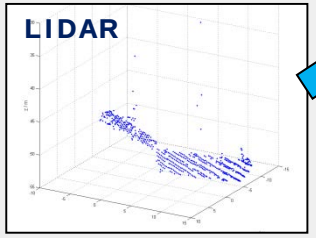


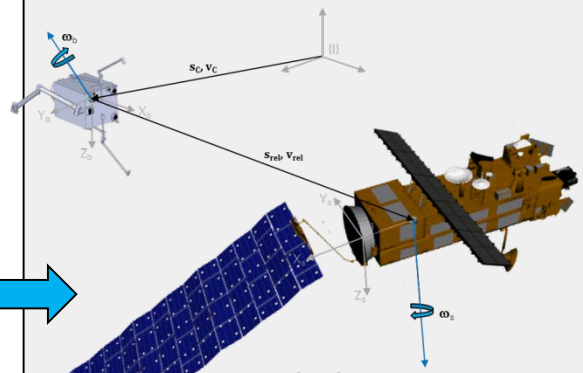
image recognition and processing (IRP) algorithms to be developed

- IRP algorithms for visual (VIS) camera
- IRP algorithms for infrared (IR) camera
- IRP algorithms for LIDAR

navigation function to be developed

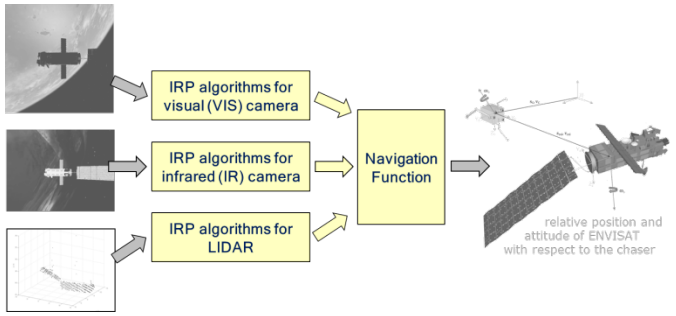
Navigation Function

objective



relative pose (position and attitude) of ENVISAT with respect to the chaser

→ define requirements to run algorithms on dedicated hardware



System Concept and Consortium

Ref.: AO/1-7937/14/NL/MH, GSTP G61C-029EC

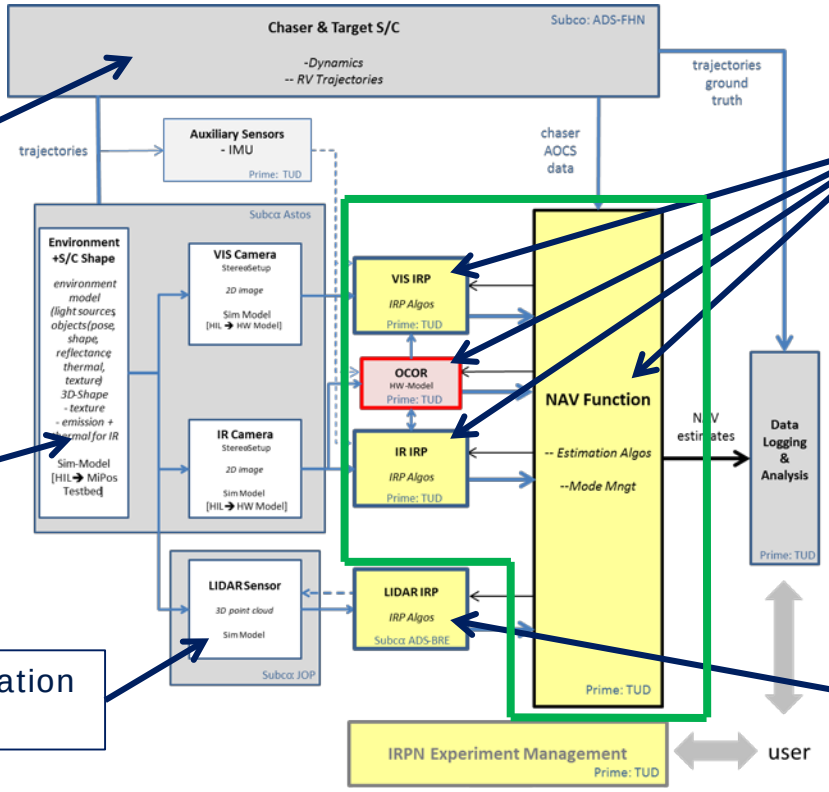
Dynamics Simulation and Trajectory Generation (*Airbus DS Friedrichshafen*)

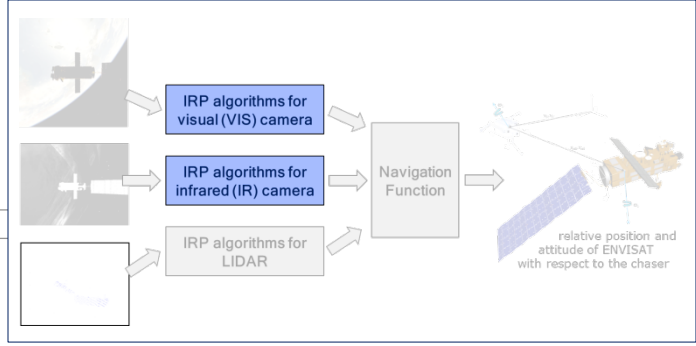
Camera Simulator for generation of image and LIDAR data (*Astos Solutions*)

LIDAR Sensor Simulation (*Jena-Optronik*)

VIS IRP & IR IRP Algorithms,
Optical Flow determination with Optical Correlator OCOR,
Navigation Function
(*TU Dresden*)

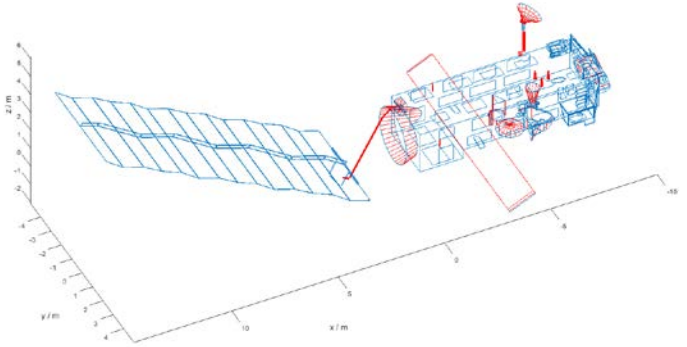
LIDAR IRP algorithms (*Airbus DS Bremen*)

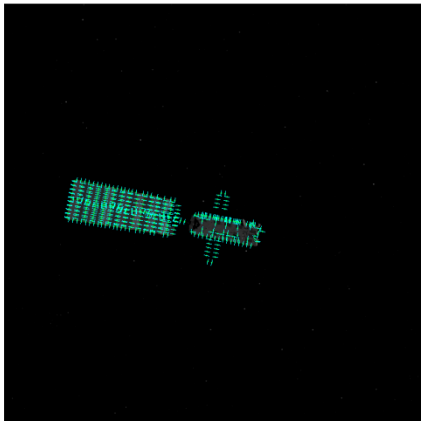


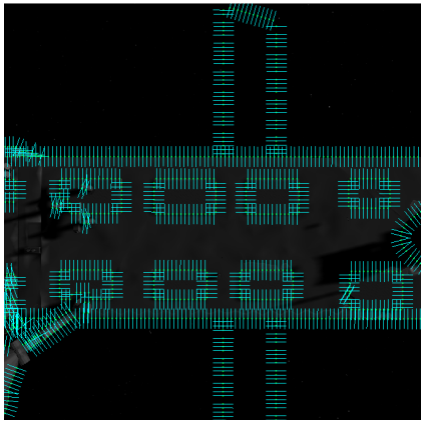


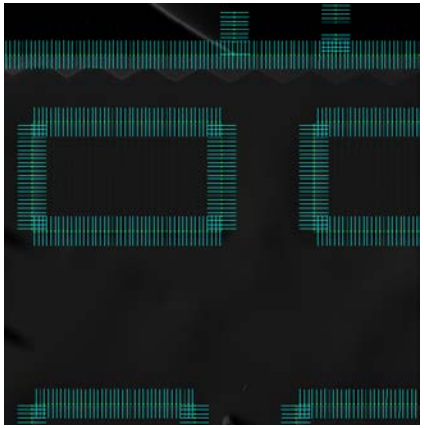
Camera IRP algorithms

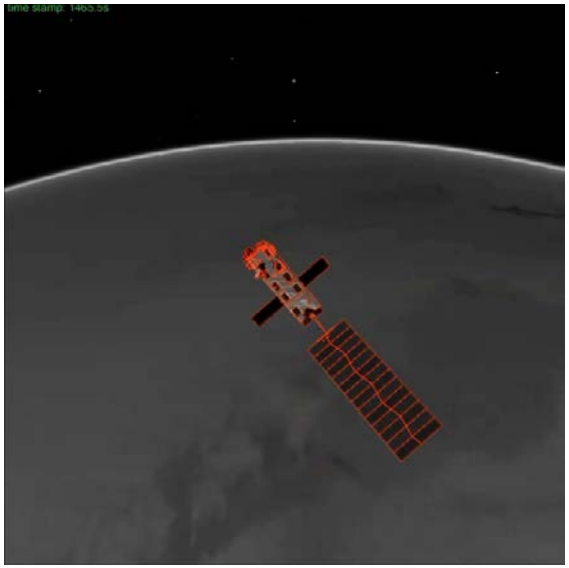
- Pose tracking for determination of relative pose and uncertainty
- Pose estimation using line tracking algorithms, i. e. model-based approach for known target
- Same algorithms used for VIS and IR images





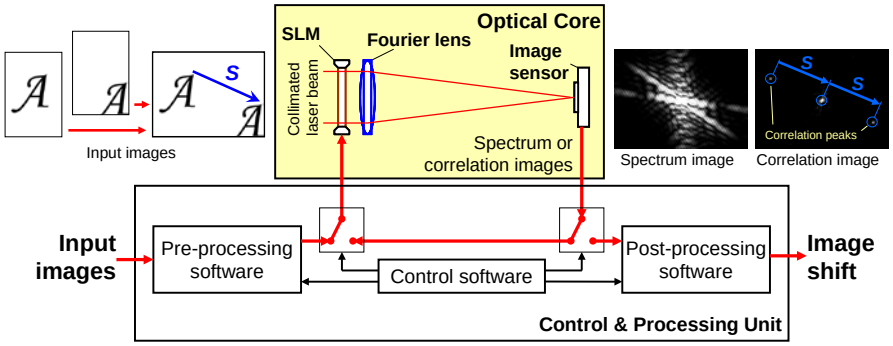


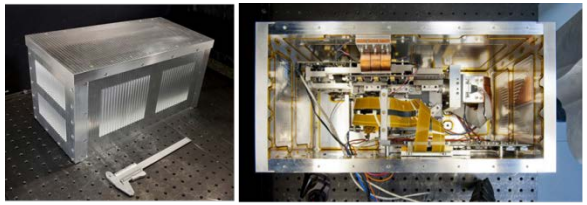


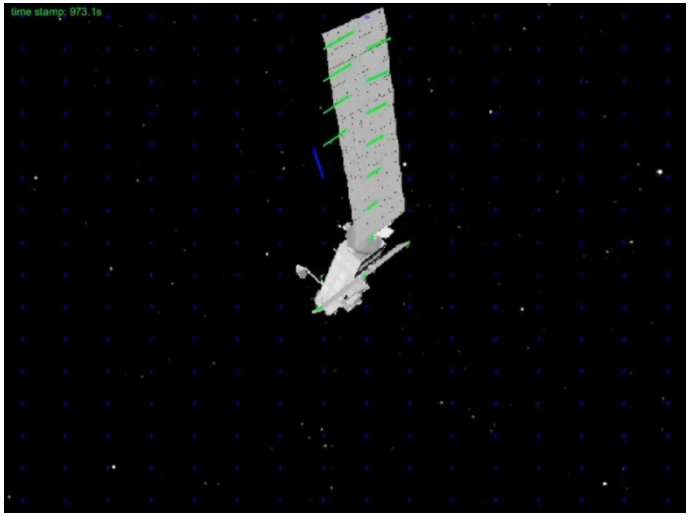


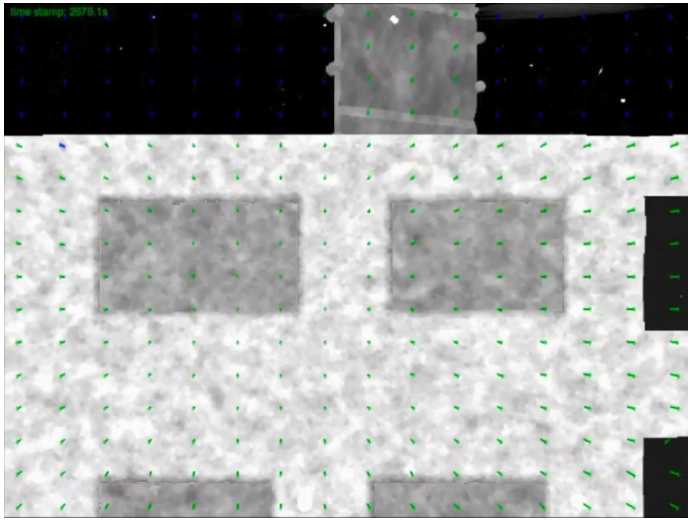
Optical Correlator - OCOR

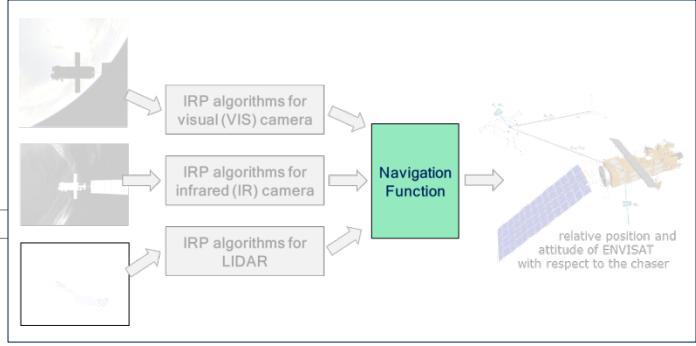
- Determination of Optical Flow fields with TUD's optical correlator hardware (OCOR): ultrafast computation of 2D area correlation patches from 2D image data
- Optical Flow vectors used for improving Camera IRP algorithms





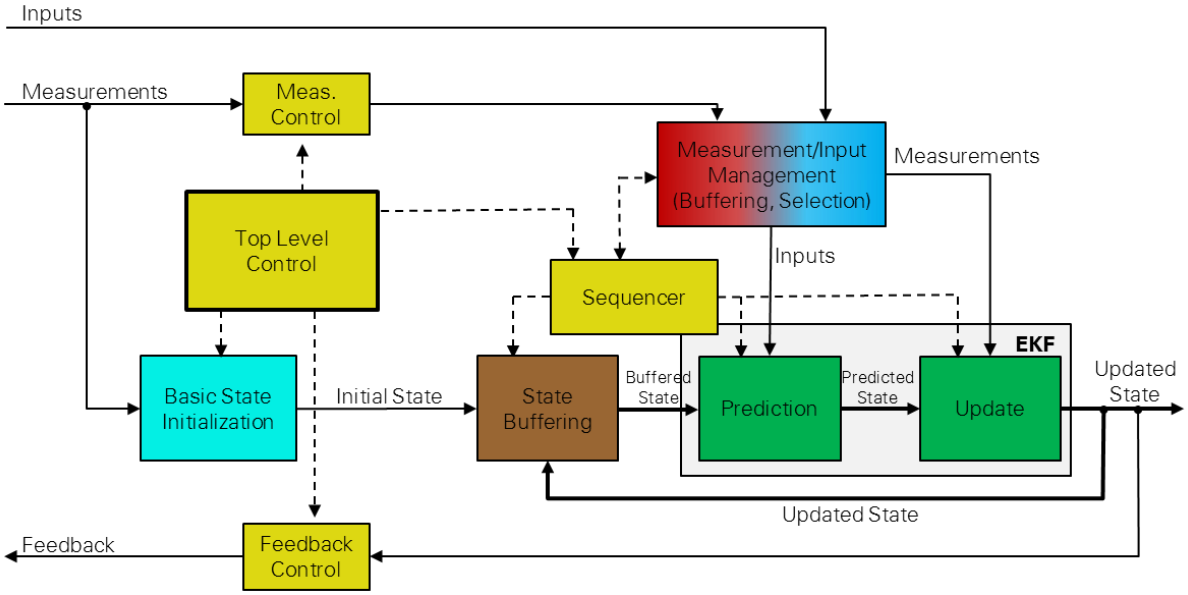




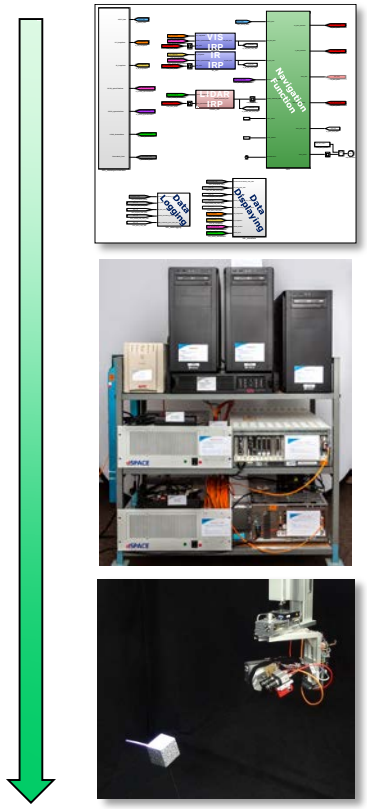


Navigation Function

- Estimation of ENVISAT's relative position, velocity, attitude and attitude rate
- Inputs/measurements from AOCS, VIS IRP, IR IRP and/or LIDAR IRP
- Different measurements rates (cameras 10 Hz, LIDAR 3 Hz) and delays (100 ms up to 500 ms) handled
- Feedback for IRPs



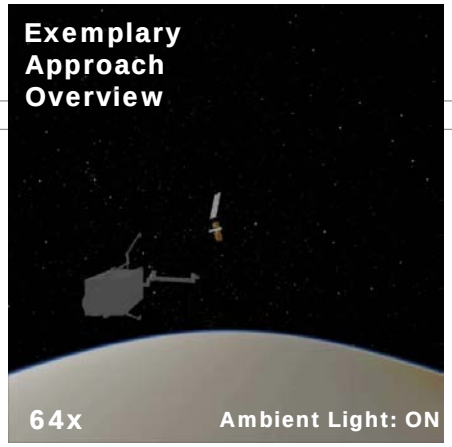
Verification Procedure

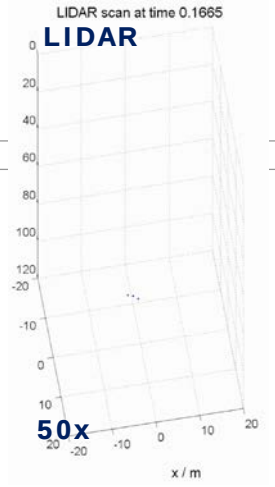


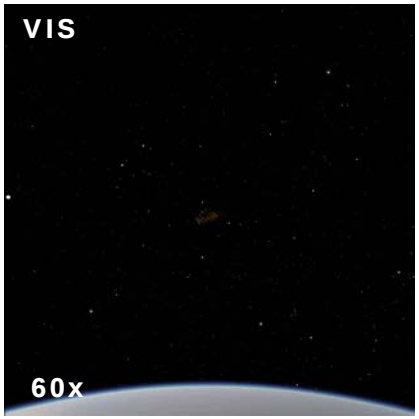
- Simulink simulation (Model in the Loop, **MIL**)
  - assess system design
  - evaluate algorithm performance
  - usage of synthetic sensor data
- Real-time hardware (dSPACE) tests (Processor on the Loop, **PIL**)
  - show real-time capability (timings, parallelization, …)
  - evaluate real-time performance
  - usage of synthetic sensor data
- Image generation by real camera hardware (Hardware in the Loop, **HIL**)
  - evaluate algorithm performance with real image data
  - image processing on PIL hardware

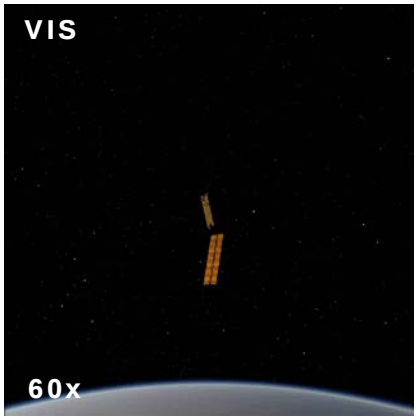
Input Image Data

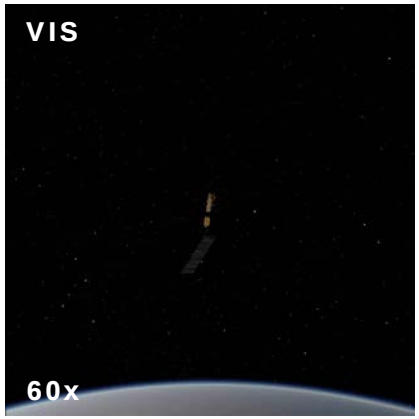
- offline generated synthetic image data (for MIL and PIL)
- different scenarios
- several Monte Carlo experiments for every scenario (slightly different trajectories, too)

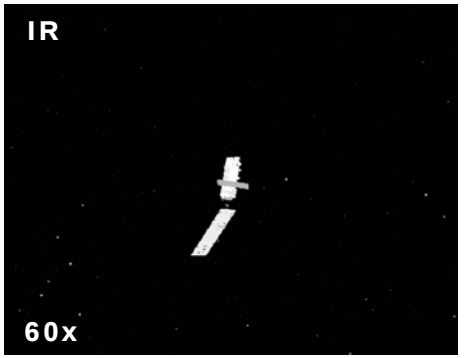


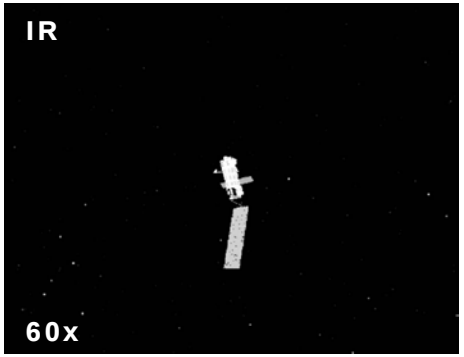


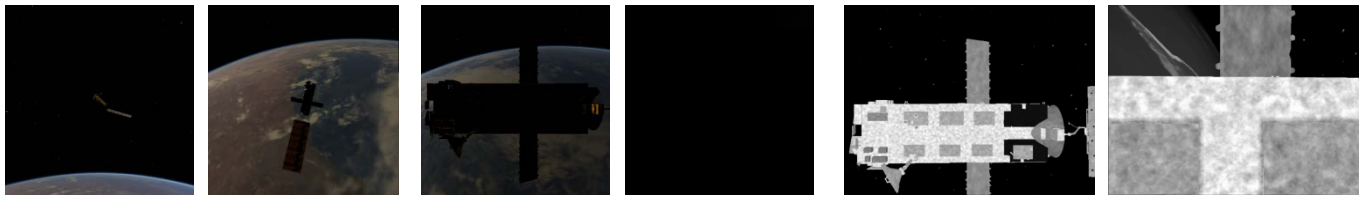










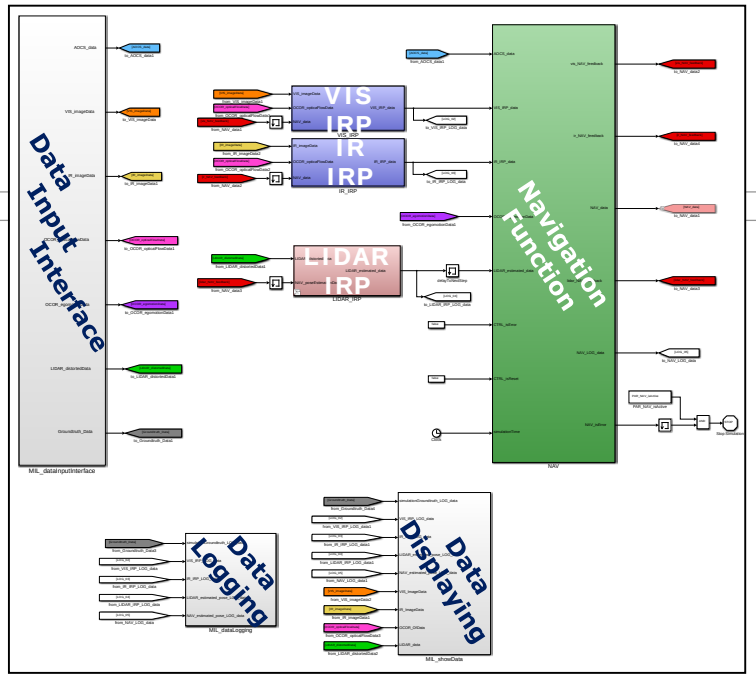


MIL Model and Test Results

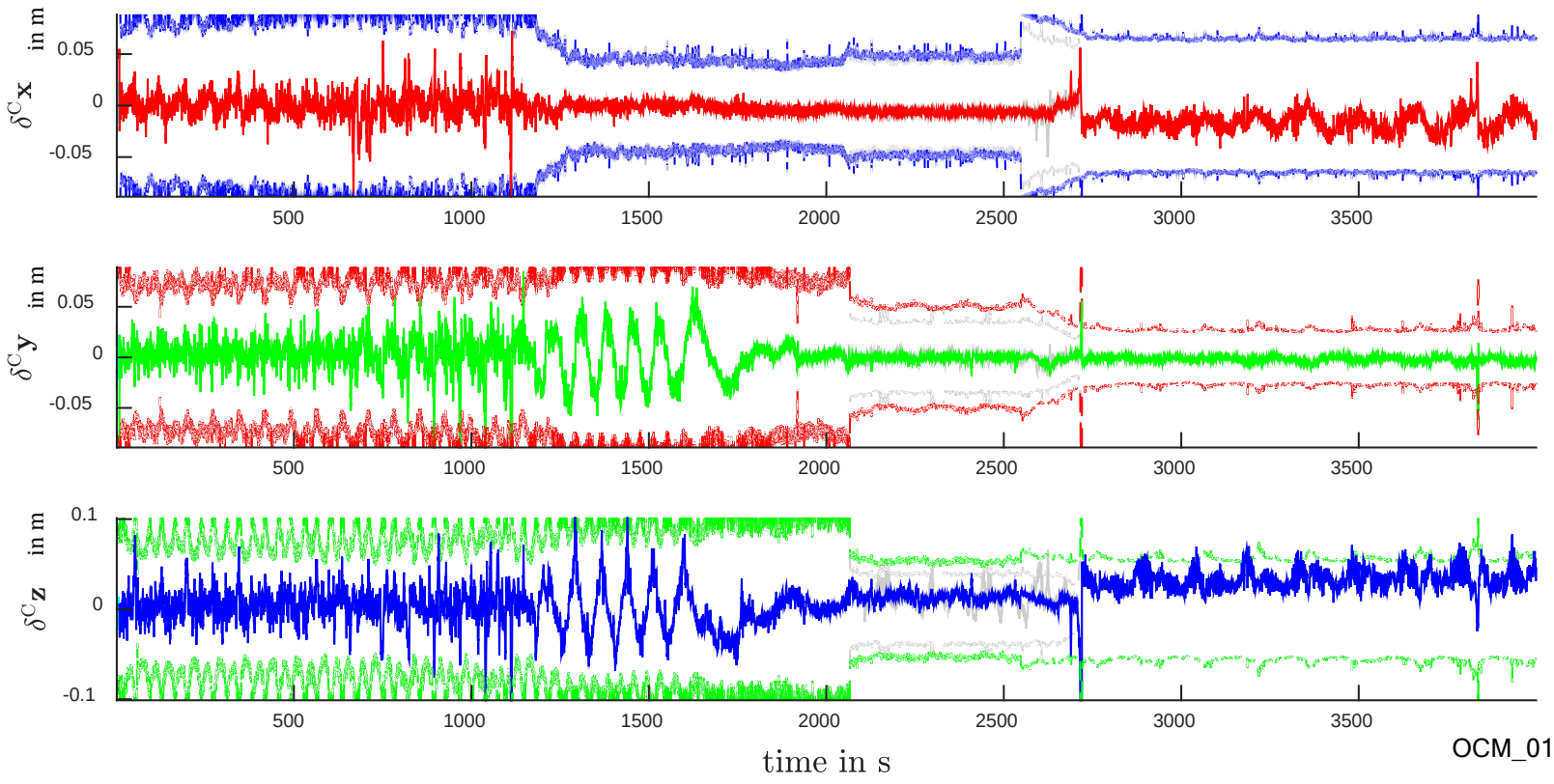
- A substantial MATLAB/Simulink MIL facility for experimental analysis of IRPs with and without NAV module has been developed

- Tests with different configurations:
  - single sensors only operational in limited conditions, robustness cannot always be guaranteed
  - configuration “all sensors + NAV” shows good results, IRP’s capabilities complement each other

- Combination “LIDAR + IR + NAV” seems to be best compromise with regard to robustness, accuracy and required computation performance

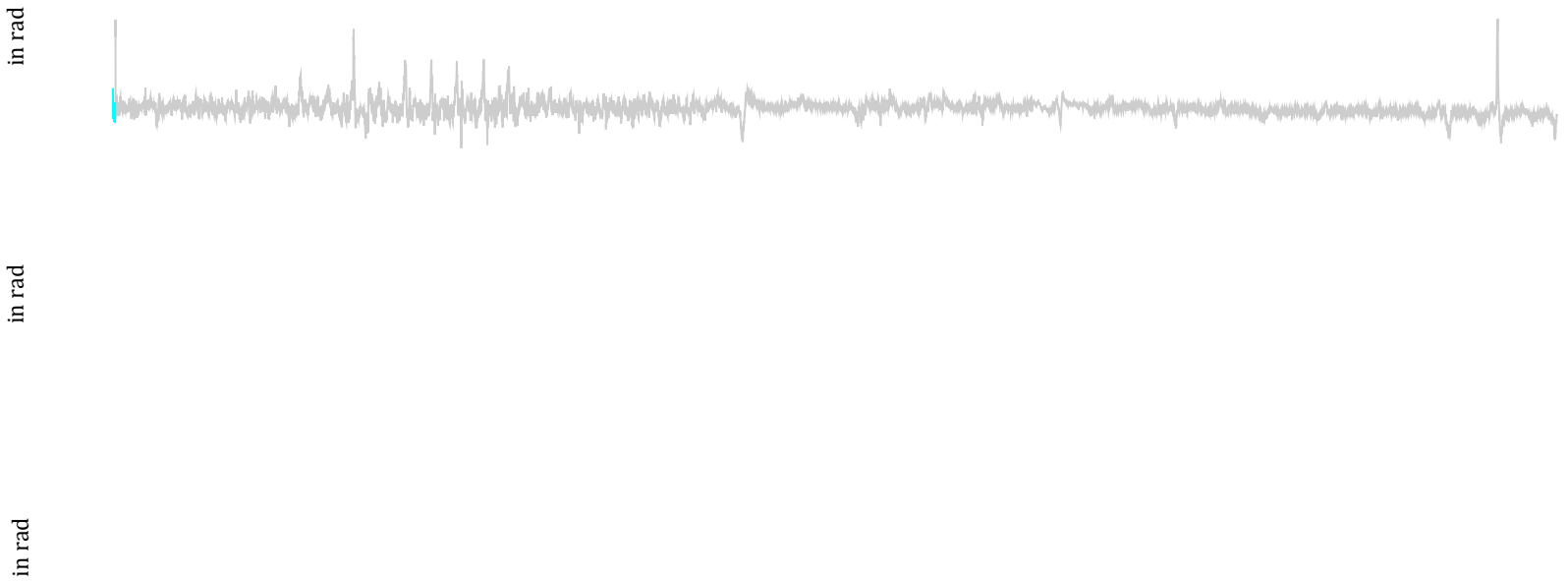


Navigation Results – IR + LI + NAV – Pos. Err.



OCM_014_001

Navigation Results – IR + LI + NAV – Att. Err.



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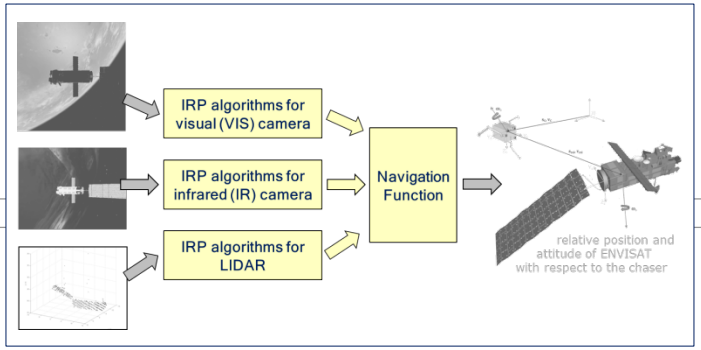
PIL Facility

4 parallel DS1006 processor boards represent multi-core processor HW for each IRP + NAV



Gateway PCs provide image data and LIDAR data to IRP algorithms

SIL workstation PC for code compilation, programming of the dSPACE boards and experiment control

Control PC

3x control & data, 3x log data

estimate data, control data

peripherals simulation

Gateway PC 1

VIS image data, OCOR data

Gateway PC 2

IR image data, OCOR data, AOCS data

Gateway PC 3

LIDAR data

dSPACE System

MultiLink Panel

Box 1

processor core

VIS Tracking

2x VIS image

misc. data

VIS Initialization

pose estimation, misc. data

Box 2

IR Tracking

AOCS pass-through data

2x IR image

misc. data

IR Initialization

pose estimation, misc. data, AOCS pass-through data

Box 3

NAV

3x trigger

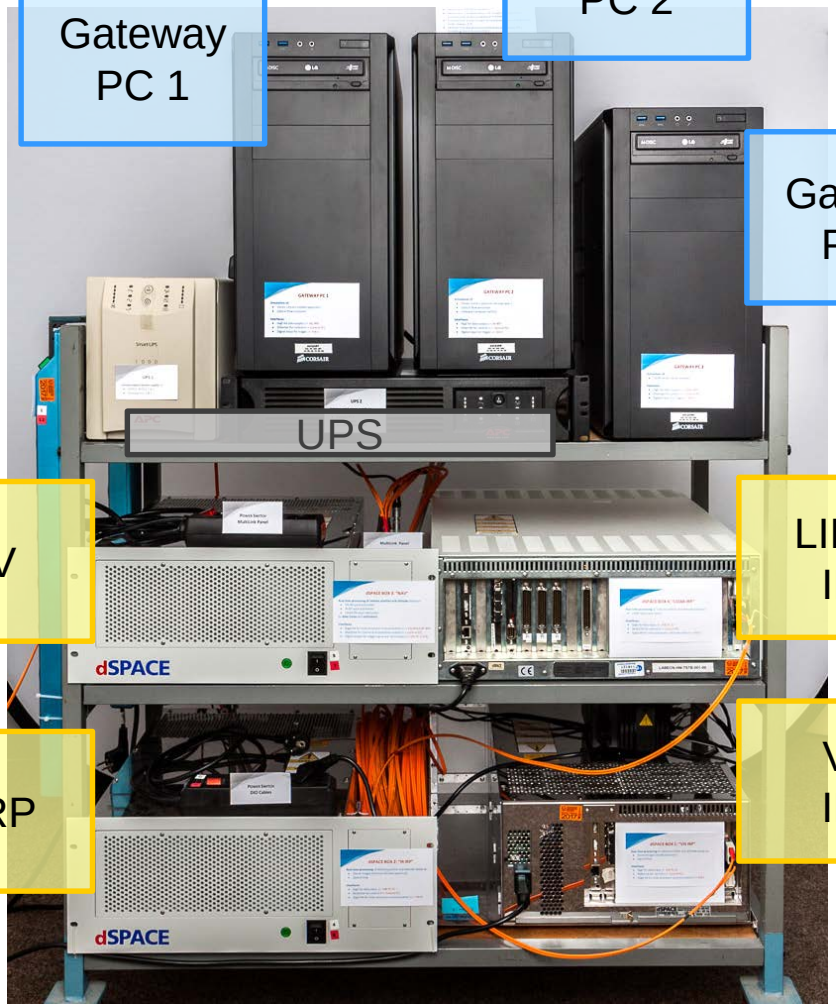
Box 4

LIDAR

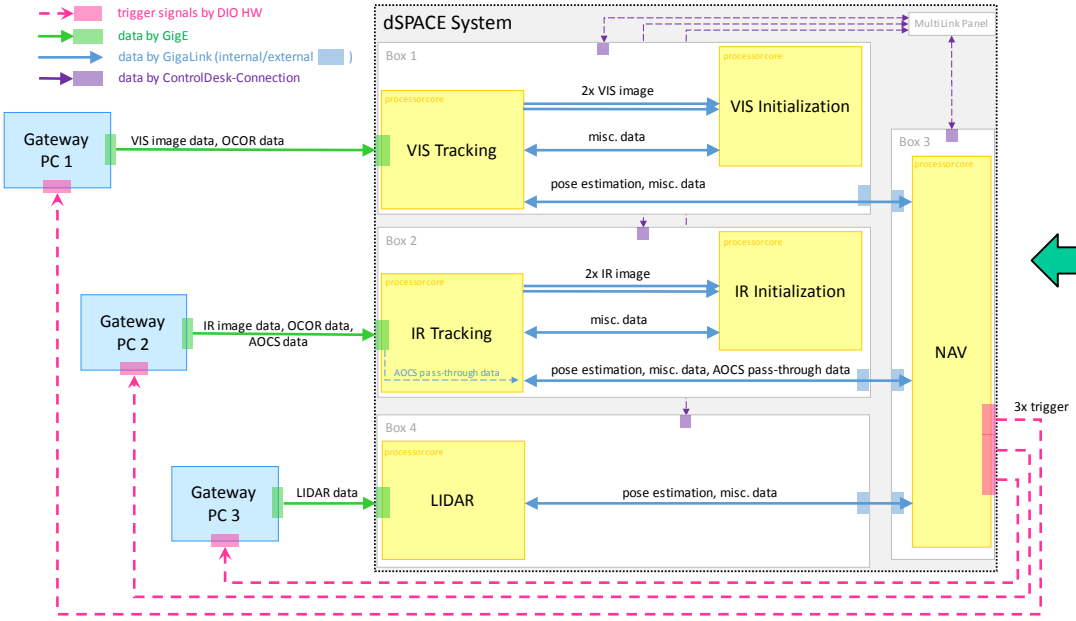
pose estimation, misc. data

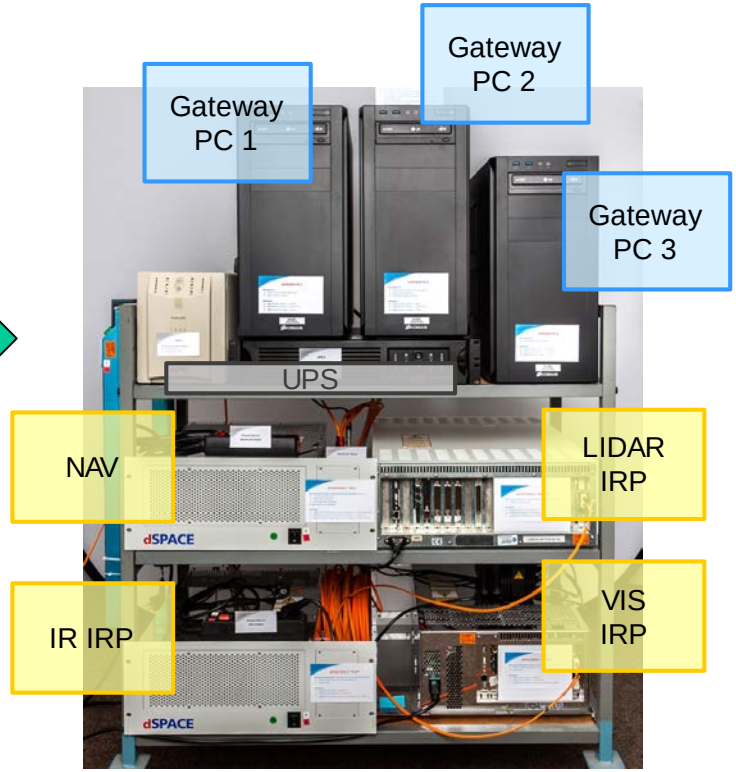
trigger signals by DIO HW
data by GigE
data by GigaLink (internal/external)
data by ControlDesk-Connection
data by Ethernet
mass storage

PIL Facility



PIL Facility

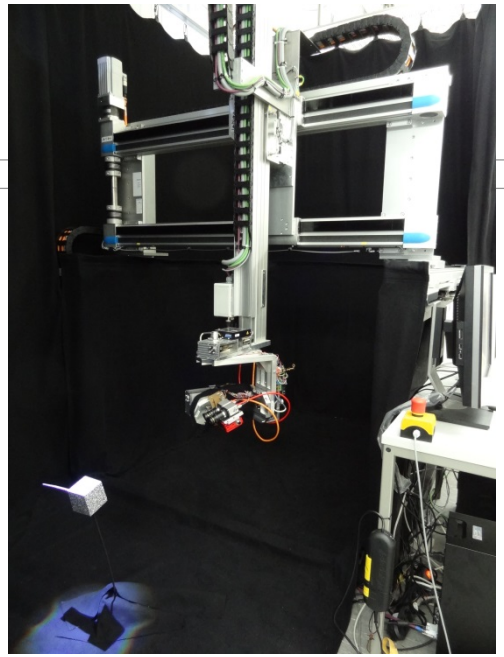


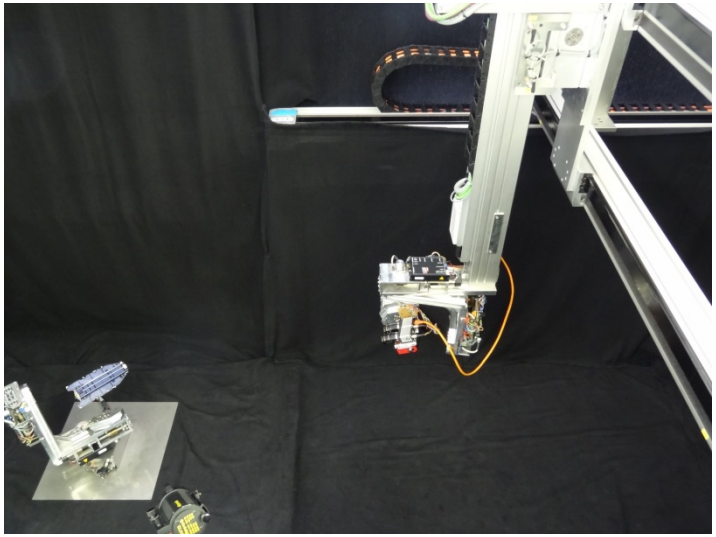


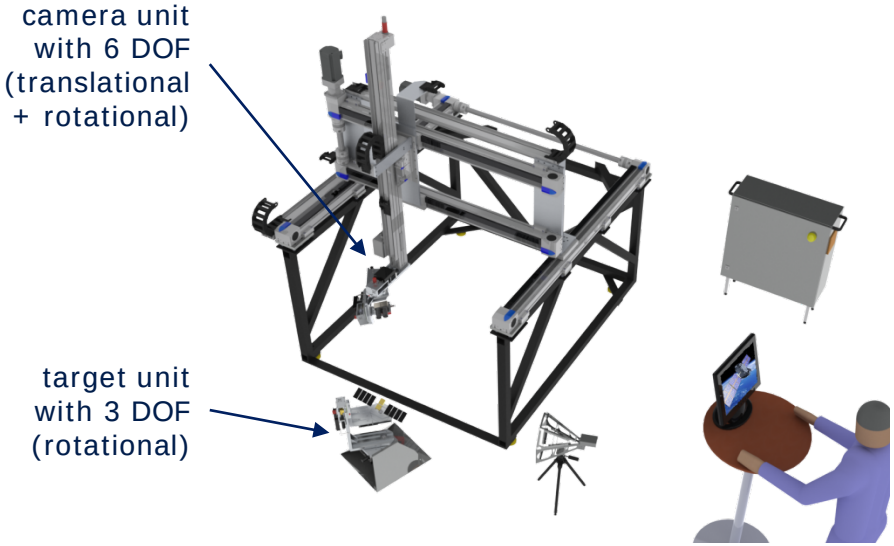
→ PIL Tests currently running (prelim. result: performance comparable to MIL tests)

HIL Facility

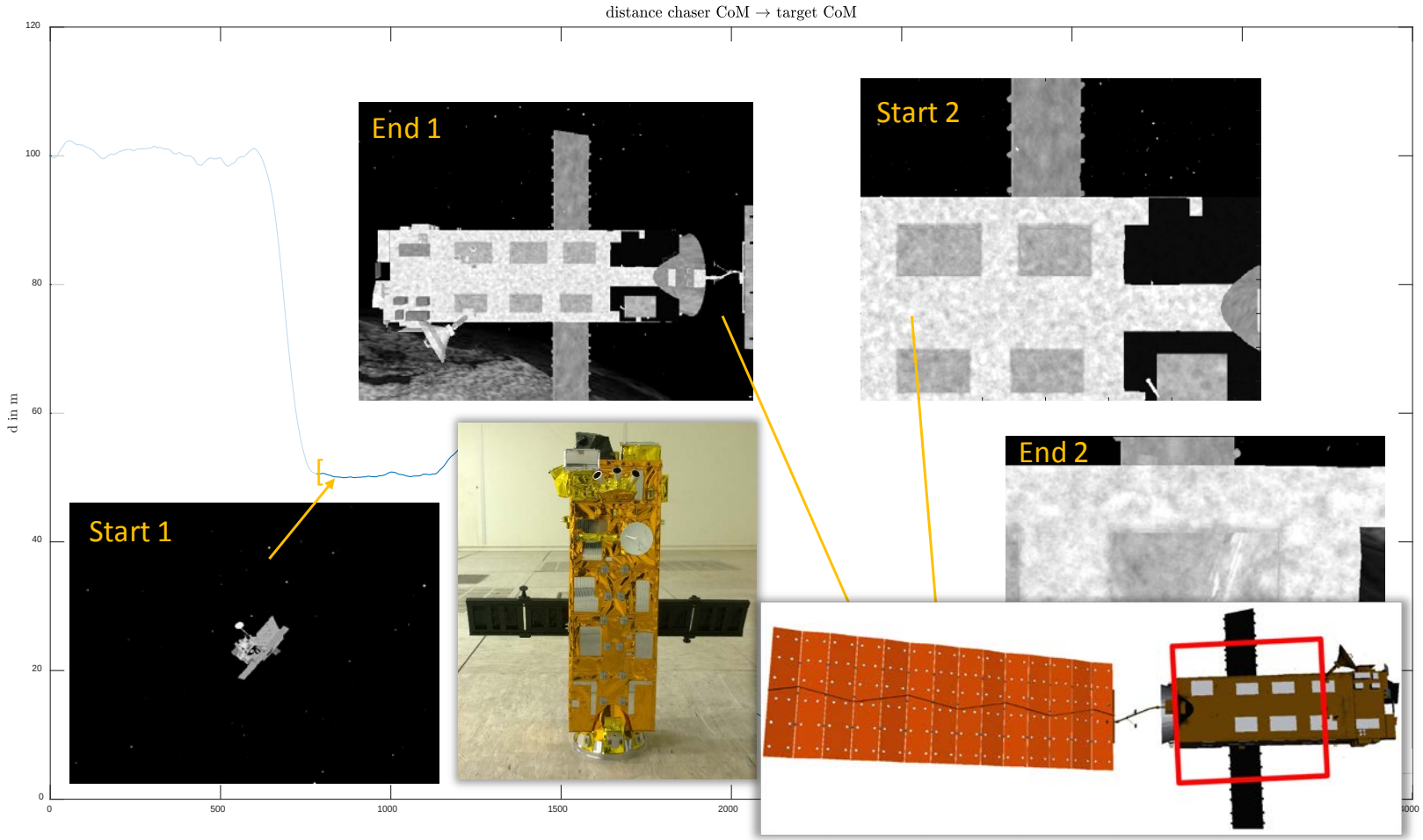
- Generation of real image data with TUD's Spacecraft Rendezvous Simulator *MiPOS*
- Processing of the image data with the dSPACE system
- HIL tests are currently in preparation







HIL ENVISAT Models (suitable for VIS & IR)



Thank you for your attention!

Mission Definition

Airbus DS Friedrichshafen