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Kayser-Threde GmbH

Space

Industrial Applications

On-Ground Verification of VIBANASS (Vision Based Navigation Sensor System): Capabilities and Results

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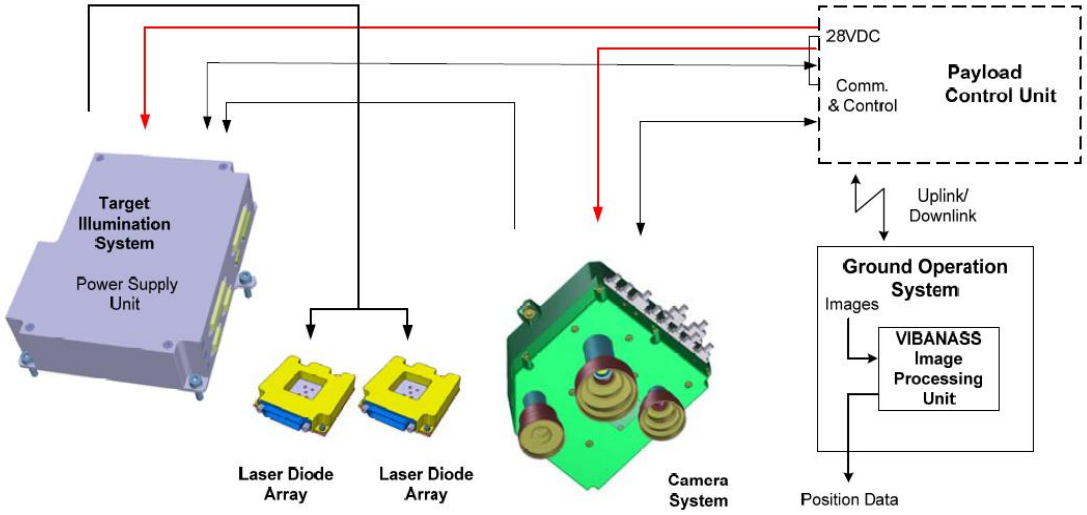
Q. Mühlbauer, P. Rank, C. Kaiser

An OHB Company

Introduction

- VIBANASS is an optical navigation sensor system designed for rendezvous and docking applications



VIBANASS comprises:

- Two Camera Systems (CS), each with
  - Far Range Camera (3km to 75m)
  - Mid Range Camera (500m to 4.5m)
  - Close Range Camera (5m to 0.7m)
- Laser-based Target Illumination (TIS) System to enhance the natural illumination in close range
- Ground Operation System (GOS) including image processing algorithm for target tracking
- The two Camera Systems can be used as a stereo camera system in close range
- Possible applications include the Orbital Live Extension Vehicle (OLEV)
- Successfully tested under realistic illumination conditions at the new European Proximity Operations Simulator (EPOS) at DLR/GSOC in Oberpfaffenhofen

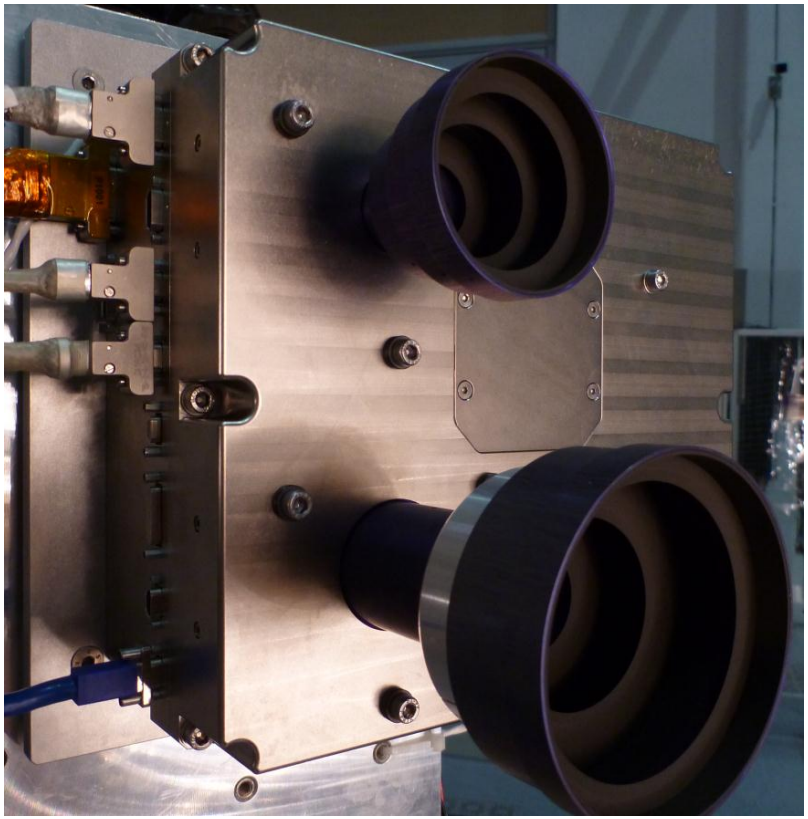
Agenda

- Description of VIBANASS
  - Camera System
  - Target Illumination System
  - Ground Operation System
- Test Setup
- Test Results
  - General Test Results
  - Evaluation of Image Quality
  - Evaluation of Tracking Algorithm
- Summary

VIBANASS Camera System

Core functions:

- Image size up to 1024x1024 pixel
- Image acquisition rate: max 10Hz
- Lossy and lossless JPEG compression
- Configurable image size
- Redundant SpaceWire interface Encoder/Decoder
- Individual control of each camera head
- Synchronization for stereo camera and with TIS
- Simultaneous operation of 2 camera heads
- Optional Image Processing Module (internal Add-on Module for image pre-processing functions)
- Power consumption: 28 V / 5 W
- 4.8 kg for GEO application and 3.7 kg for LEO
- Size of CS: 250.5mm x 236.5mm x 215.1mm



VIBANASS Target Illumination System

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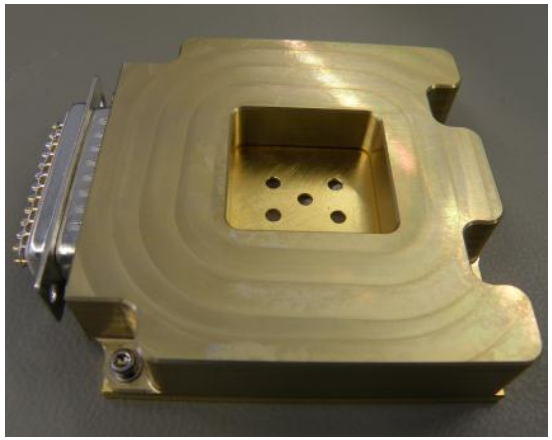
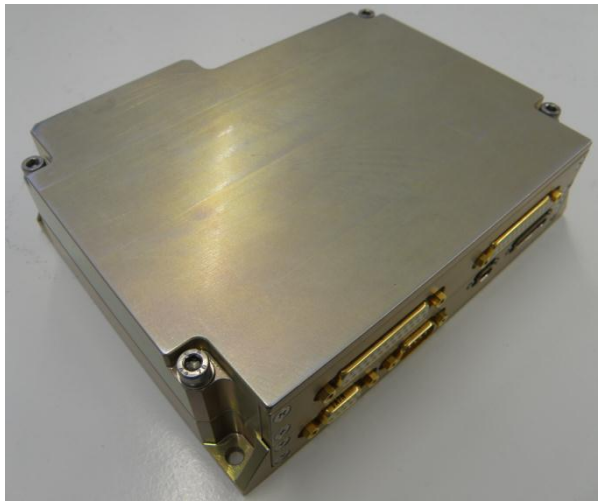
General requirements

- Illumination with at least 10% of the irradiance of natural sunlight within a bandwidth of 20nm
- For reference mission:
  - Field of view: 42°x42°
  - Distance: up to 5m
  - Required optical power: 32 Watt

Modular approach

- TIS Power Supply Unit and 2 TIS Laser Diode Arrays
- Size of TIS-PSU: 169 mm x 106 mm x 40 mm
- Size of TIS-LDA: 70mm x 76mm x 20mm
- Mass: 2.05 kg (incl. 2 LDAs) for GEO, 1.65 kg for LEO
- Power consumption: 28 V / 15 W @ 16W optical power and 10% duty cycle
- Successfully tested with a TID of 235 KRad(Si) and with 3.1E11 protons/cm2 @ 30MeV

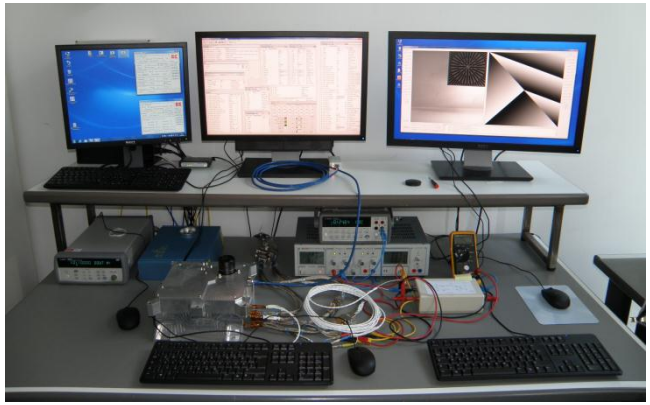


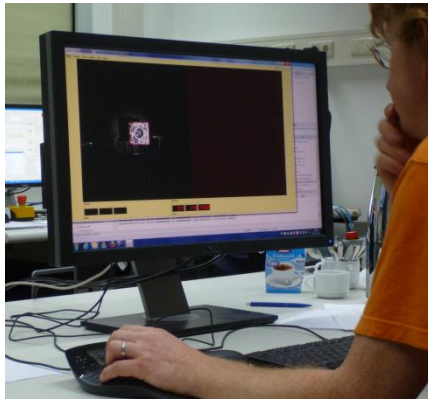


VIBANASS Ground Operation System

Features of VIBANASS GOS:

- The GOS connects to:
  - Two Camera Systems (CS)
  - One Target Illumination System (TIS)
- GOS emulates OBC/ICU Interfaces against CS and TIS
- GOS implements a GUI for:
  - Display of telemetry
  - Generation and transmission of telecommands
  - Recording of camera images including playback functionality
- GOS comprises power supply for CSs and TIS
- Distribution of system time via SpaceWire (Camera System) and local network (GOS)





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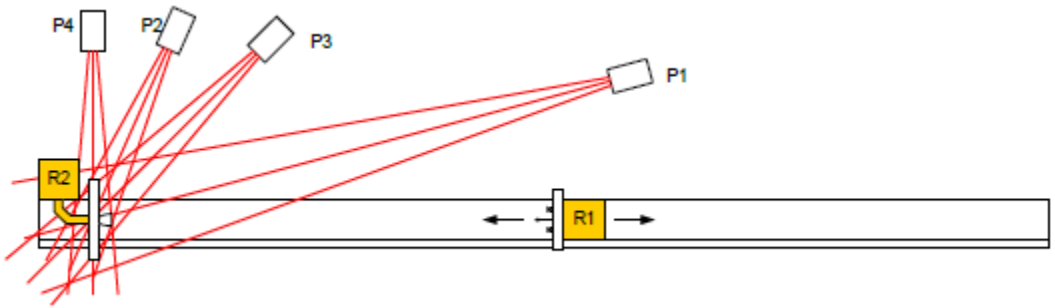
Test Setup

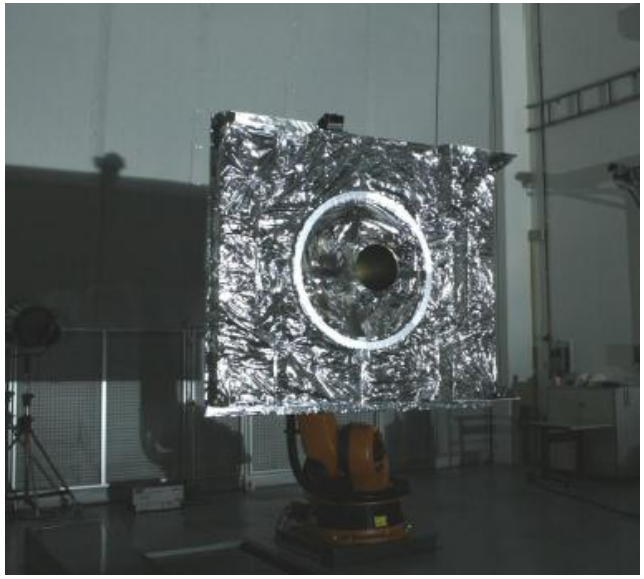
Test articles and test equipment

- Left Camera System: CAM-CR and CAM-M
- Right Camera System : CAM-CR
- Target Illumination System:
  - Power Supply Unit
  - 2x Laser Diode Array
- Ground Operation System
  - VIPU with image processing / tracking algorithm
- Mockup of target satellite

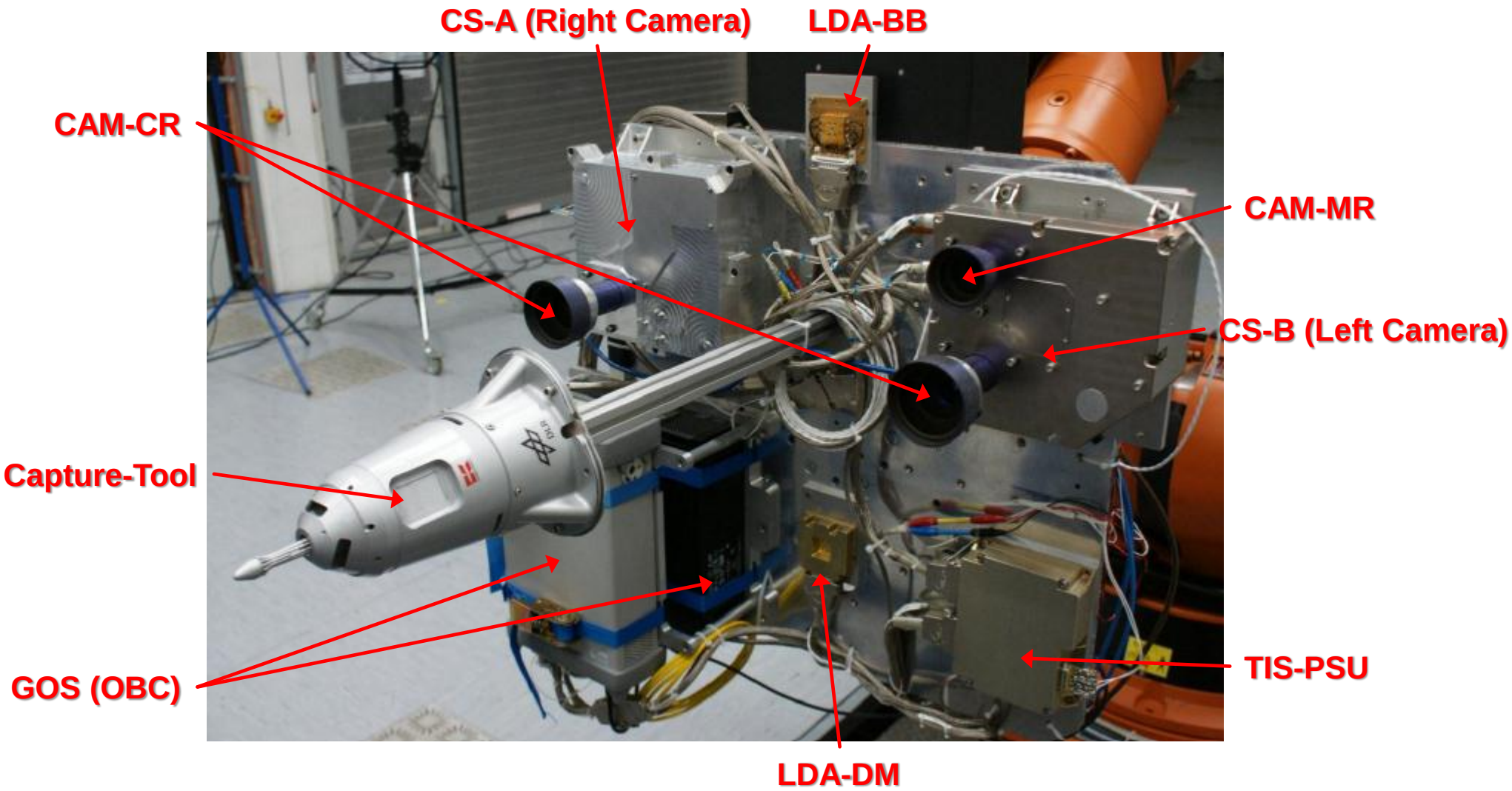


53 Test cases

- 4 different positions of the sun simulator
- 5 different trajectories (nominal and non-nominal)
- Different relations between the brightness of TIS and sun: TIS/Sun = 0%, 5%, 10%, 20%, no sun



Test Setup


CS-A (Right Camera)
LDA-BB
CAM-CR
CAM-MR
CS-B (Left Camera)
Capture-Tool
GOS (OBC)
TIS-PSU
LDA-DM

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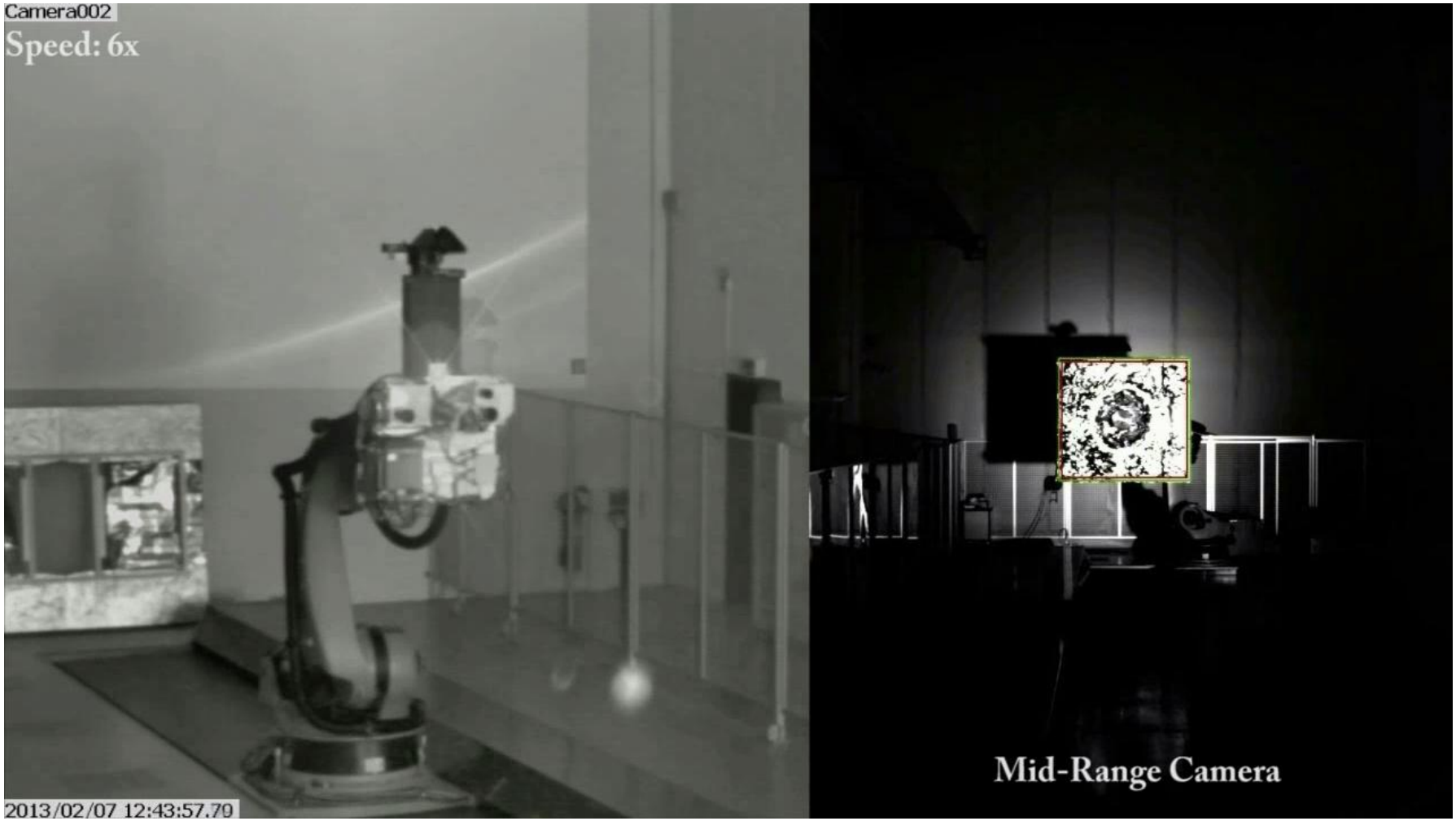
Test Results – Video



General Test Results

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Camera System

- Internal Power Supply, digital electronic, CAM-CR and CAM-MR were operated with different acquisition rates and different downlink rates
- Operating temperature within expected range
- Synchronization between CS-A and CS-B: accuracy < 1ms

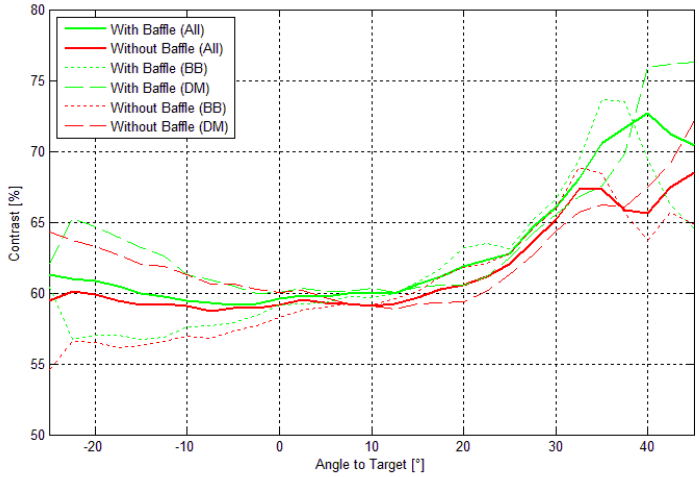
Target Illumination System

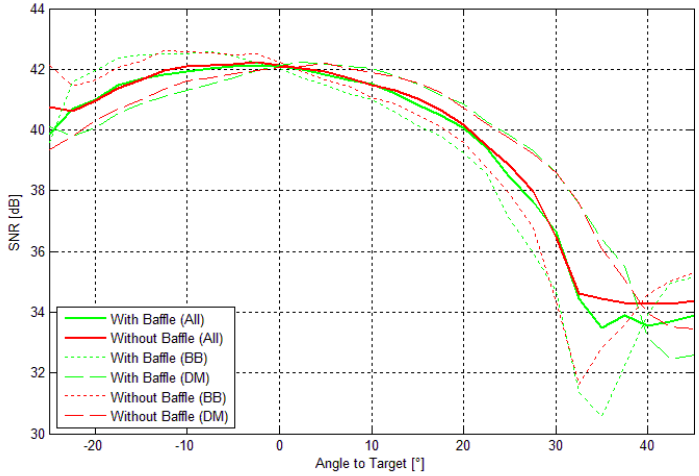
- TIS-PSU and 2 TIS-LDAs were operated in synchronization with the Camera System
- Power consumption and operating temperature within expected range
- Total measured optical power: 17.1W, Irrdiance @ 5m: 1.64 W/m²
- Homogeneity of illumination pattern > 95%

General Test Results

Optical tests

- Have been conducted due to uncertainties during the straylight analysis
- Impact of the baffles in the image quality has been investigated using an increasing amount of straylight
  - No impact on SNR
  - Increased contrast when using baffles at a high amount of straylight





General Test Results

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Delay

- Measured between image acquisition at the Camera System, transmission of the full image to the GOS and after Image processing
- Depending on image size and compression setting
- Synchronization with common GPS time

Image Compression	CS to VIPU	Image Processing	Sum
Lossless	350 ms	130 ms	480 ms
Low Compression	75 ms	130 ms	205 ms
Medium Compression	35 ms	130 ms	165 ms
High Compression	20 ms	130 ms	150 ms

Evaluation of Image Quality

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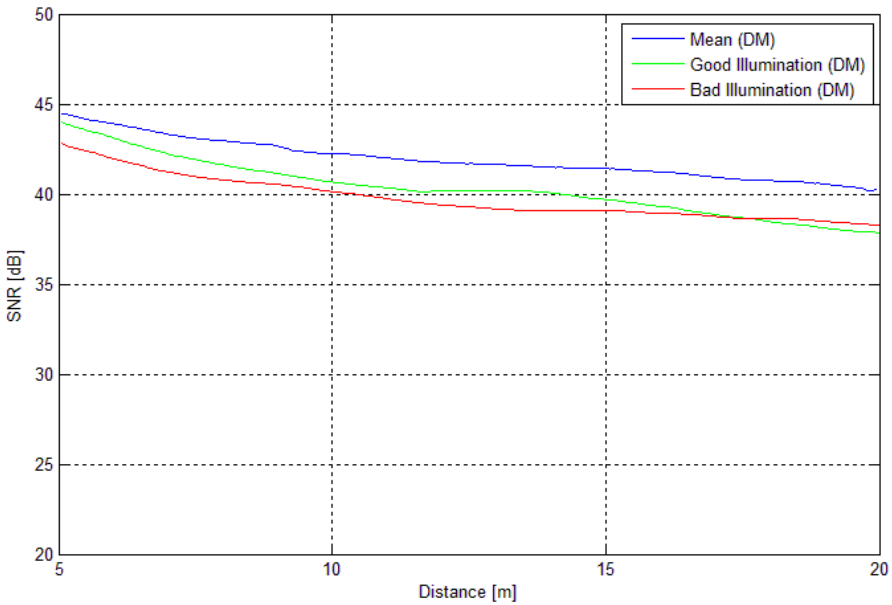
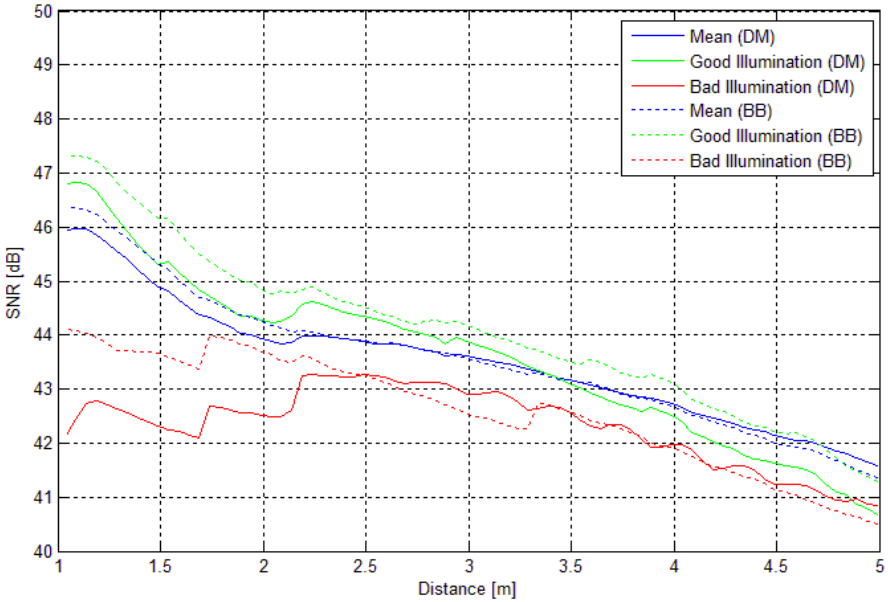
SNR

- CAM-CR: strong dependency on distance and illumination conditions
- CAM-MR: weak dependency on distance and illumination conditions
- Fall-off at 2m: Occlusions and shadows induced by the target satellite increase straylight





Evaluation of Image Quality

Blur

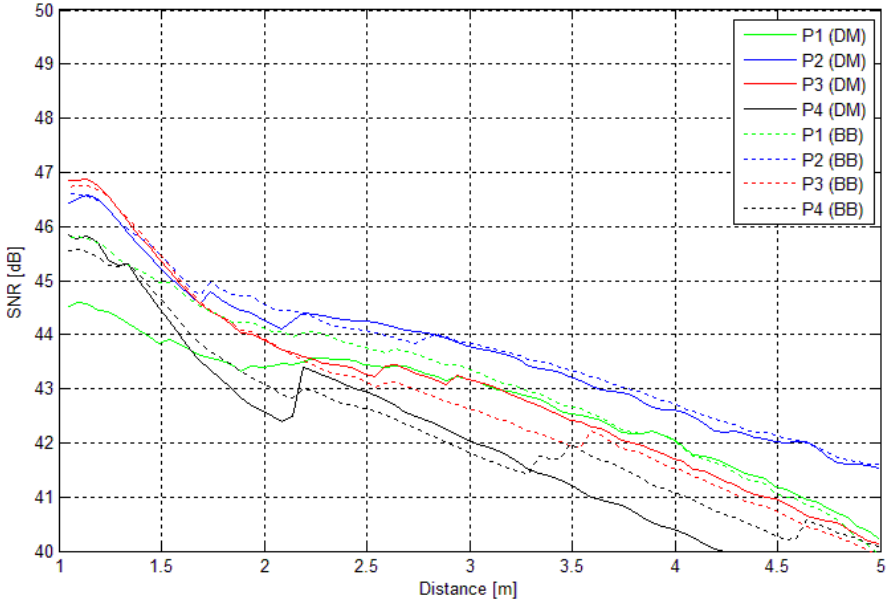
- Dependency on contrast, no dependency on illumination conditions

Contrast

- No dependency on contrast, weak dependency on illumination conditions
- Fall-off at 2m: Occlusions and shadows induced by the target satellite increase straylight

Dependency of illumination conditions on image quality

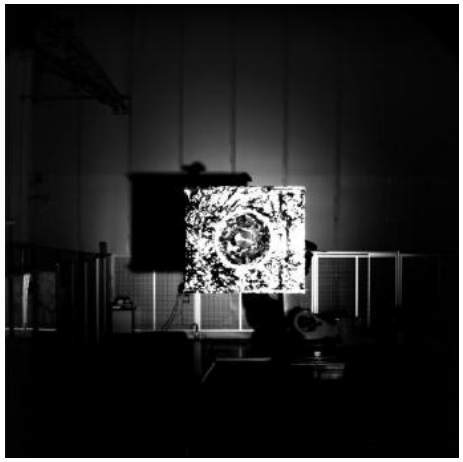
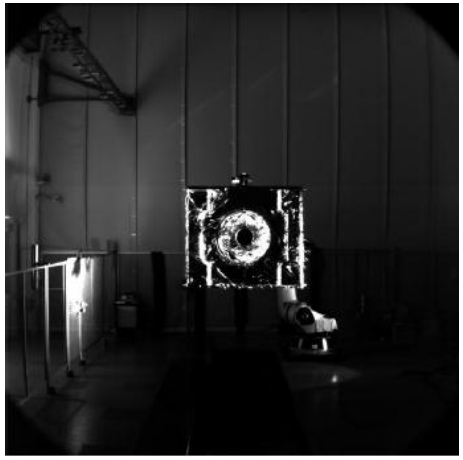
- CAM-MR: Weak dependency
- CAM-CR: Strong dependency
- Strongest fall-off at P4



Evaluation of Image Quality

Impact of position of sun simulator:

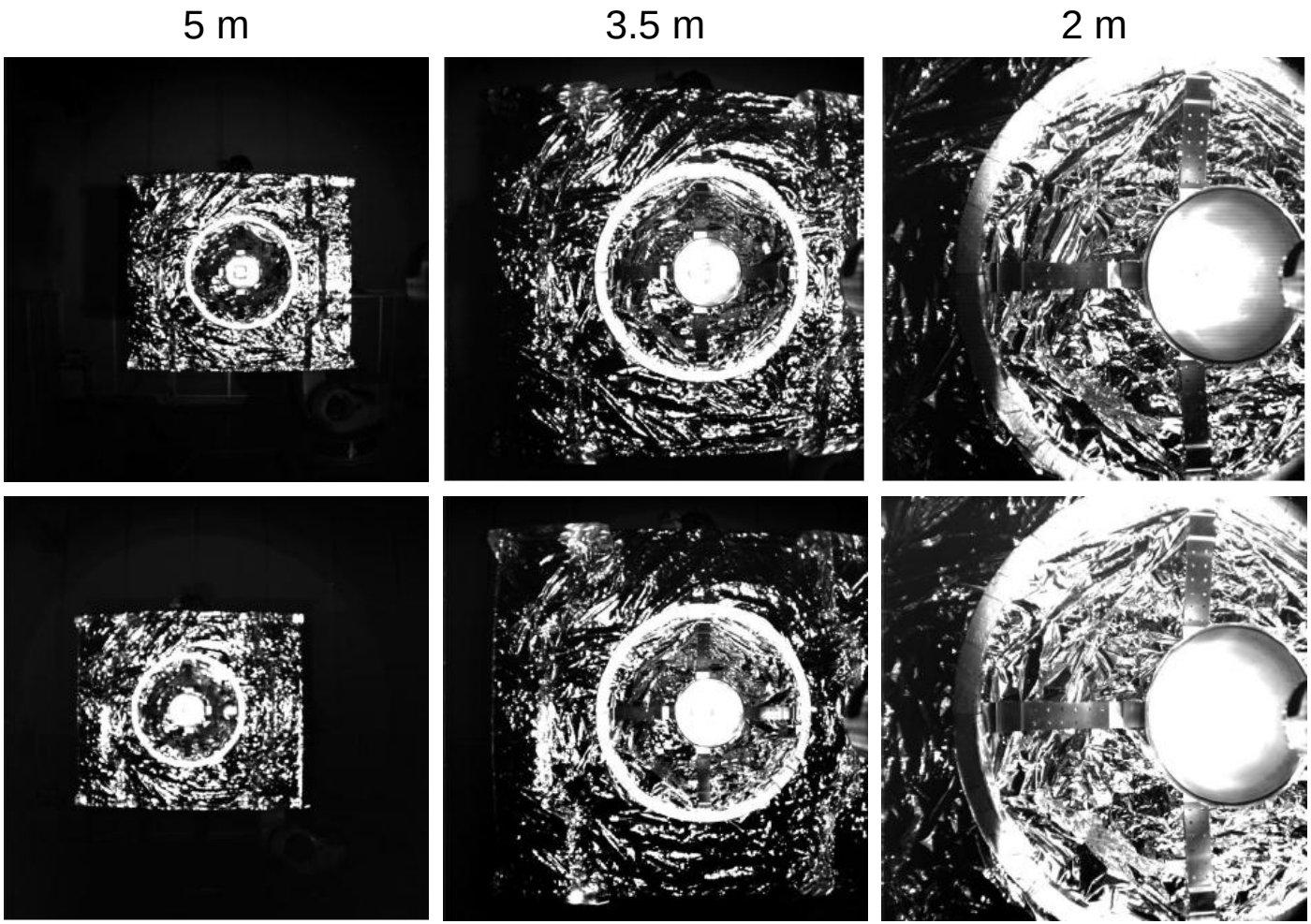
- CAM-MR
- without TIS

	20 m	12.5 m	5 m
P1			
P4			

Evaluation of Image Quality

Impact of position of sun simulator:

- CAM-CR
- with TIS (10%)



Evaluation of Image Quality

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Impact of image compression

- Compression levels (Stereo image pair, resolution of 1024x1024px, 8bit, 1 image per second)
  - Lossless
  - Low compression (4MBit channel), typical bandwidth for LEO application
  - Medium compression (2MBit channel)
  - High compression (0.4MBit channel), typical bandwidth for S-Band link in GEO application
- Better SNR for compressed images due to noise reduction during compression

Evaluation of Tracking Algorithm

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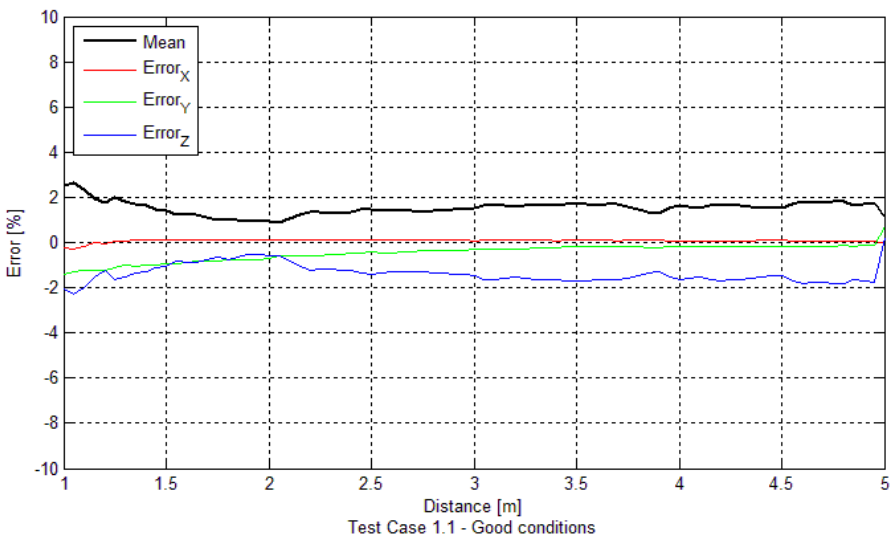
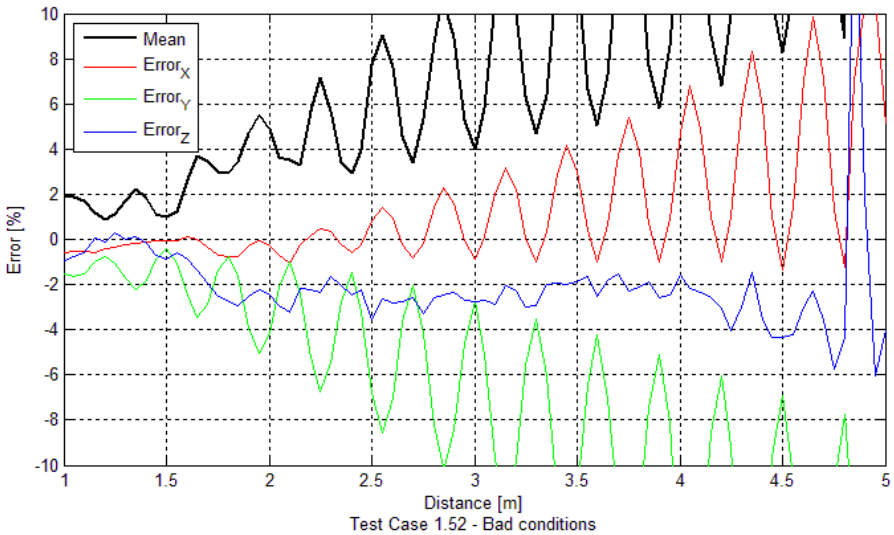
Goals and approach

- Identify and quantify the impact of illumination conditions on the accuracy of the tracking algorithm
- Measurement of the relative error in x-, y- and z- direction
- Orientation of the target is assumed to be known
- GPS-Signal for time-synchronization between VIBANASS und EPOS





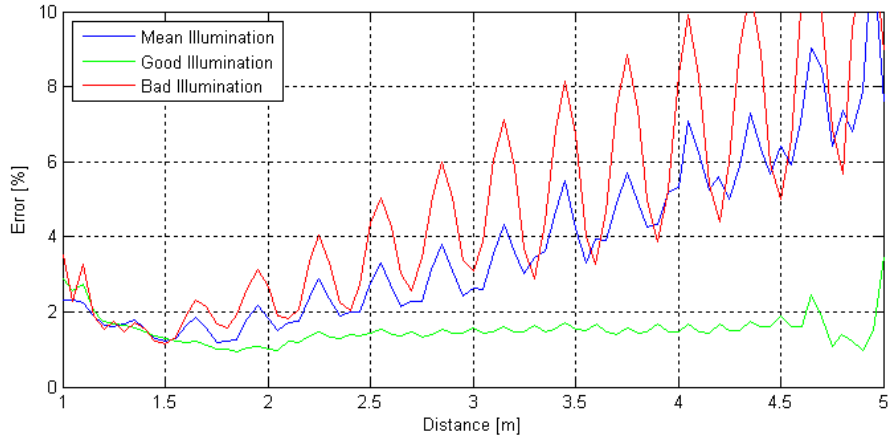
Evaluation of Tracking Algorithm

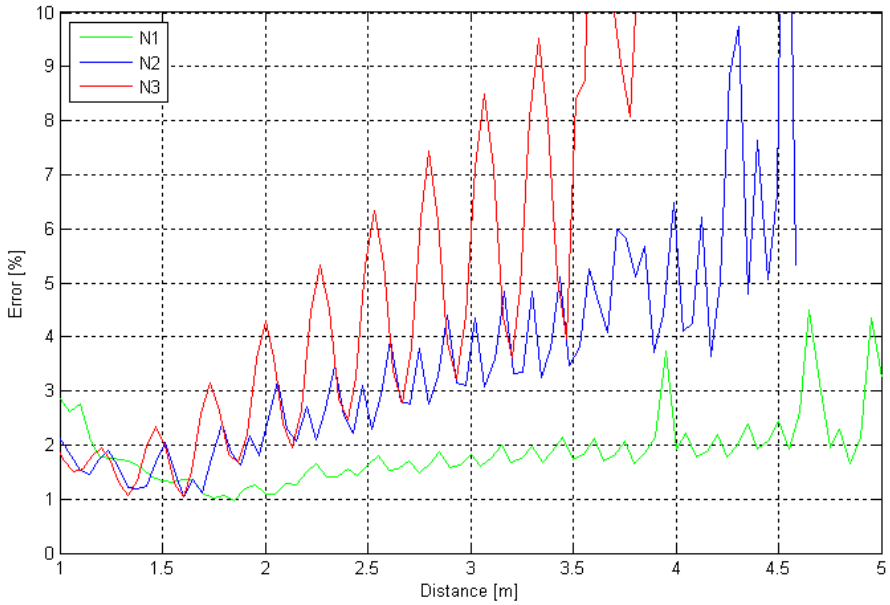
Stereo-Tracking (CAM-CR)

- Strong dependency on the used trajectory
  - Nominal approach: N1
  - Sinusoidal rotations at N2 and N3
  - Speed was increased by a factor of 5
- Strong dependency on the illumination conditions

Mono-Tracking (CAM-MR)

- No dependency on illumination conditions could be identified





Evaluation of Tracking Algorithm

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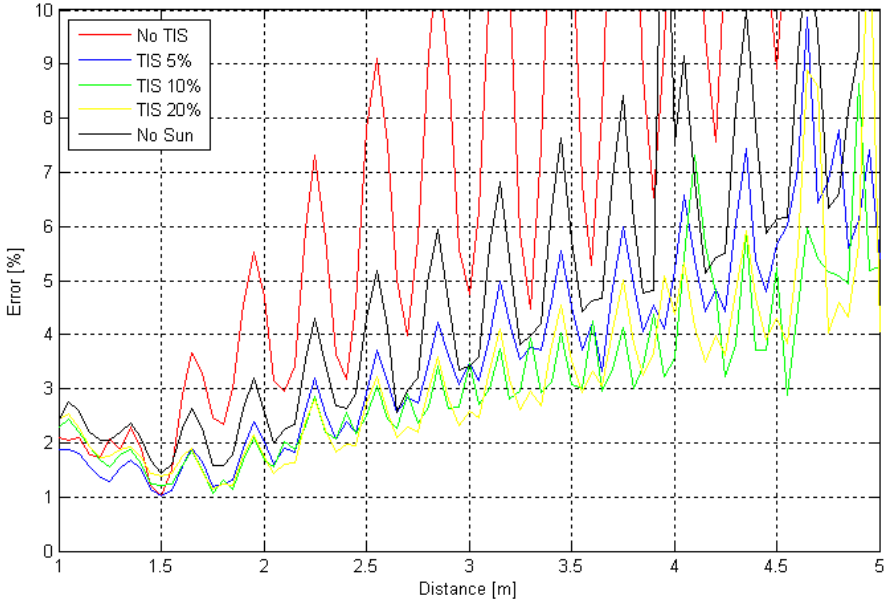
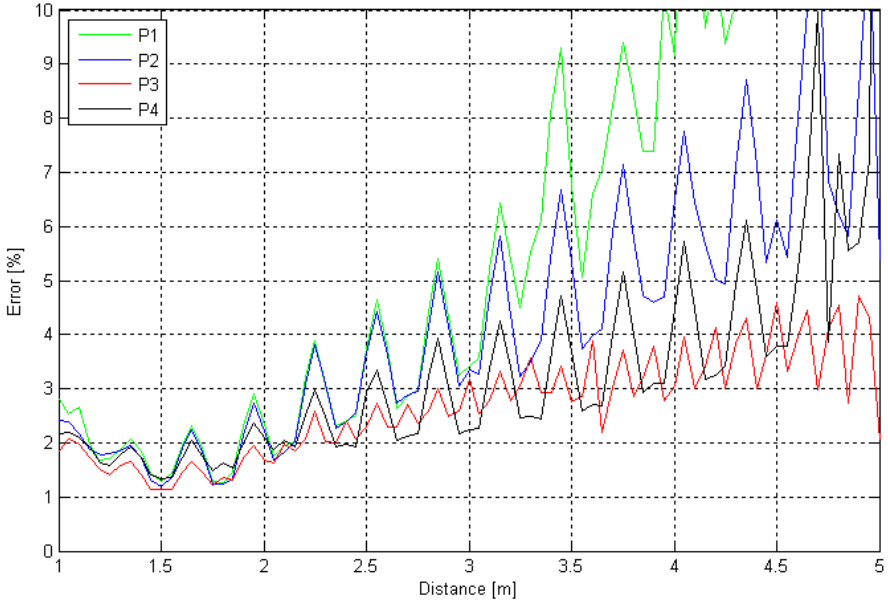
Dependency on the illumination conditions

- TIS significantly increases the accuracy
- Presence of TIS more important that brightness
- Position of sun simulator has a smaller impact than brightness of the TIS





Evaluation of Tracking Algorithm

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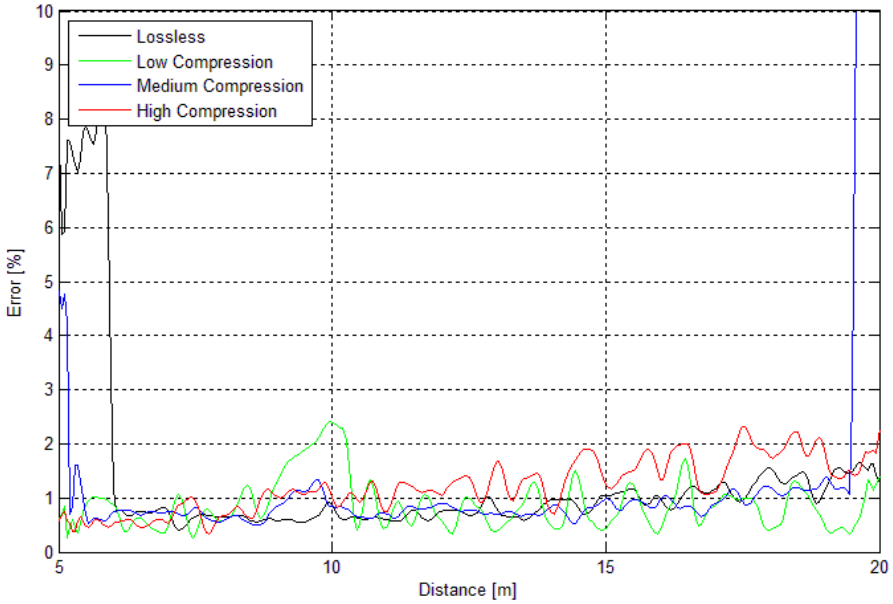
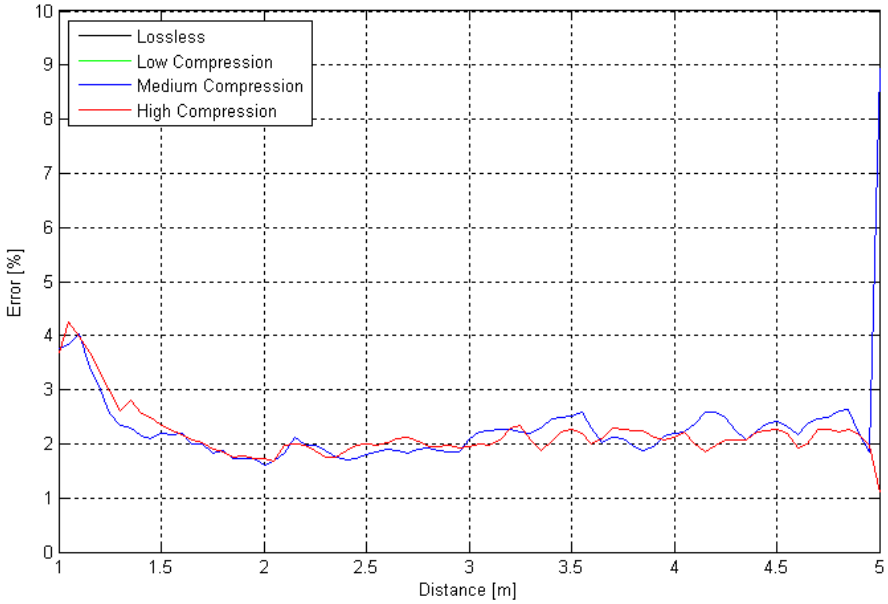
Impact of image compression

- Compression levels: lossless, low (4MBit channel), medium (2MBit channel) and high (0.4MBit channel)
- No impact of image compression could be measured, even for a low bandwidth of 0.4 MBit





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EPOS Tests – Summary

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General tests with the Camera System and the Target Illumination System

- Delay: 130ms for image processing, 20ms … 250ms for image acquisition and transmission
- Optical requirements (e.g. SNR or field of view) have been fulfilled

Evaluation of the VIBANASS EPOS-Tests

- The impact of illumination conditions on the image quality was investigated
- Image compression has an impact on SNR but no impact on the accuracy of the tracking algorithm could be measured
- Tracking fulfills the required accuracy under good conditions during a nominal approach
- A strong relation between the tracking algorithms and the illumination conditions and the selected trajectory could be found in close range
- The Target Illumination System significantly increases the accuracy of the tracking algorithm

VIBANASS is a Kayser-Threde development programme under co-funding by DLR (Förderkennzeichen 50RA1001), the German Space Agency and in cooperation with DLR-RM (DLR Institute for Mechatronics and Robotics) and DLR-RB (EPOS). vH&S (von Hörner und Sulger) is subcontractor.

KAYSER-THREDE

Kayser-Threde GmbH

Wolfratshauser Str. 48
81379 München
Tel.: (089) 72495-0
Fax: (089) 72495-291

Kayser-Threde GmbH

Perchtinger Str. 5
81379 München
Tel.: (089) 72495-500
Fax: (089) 72495-482

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