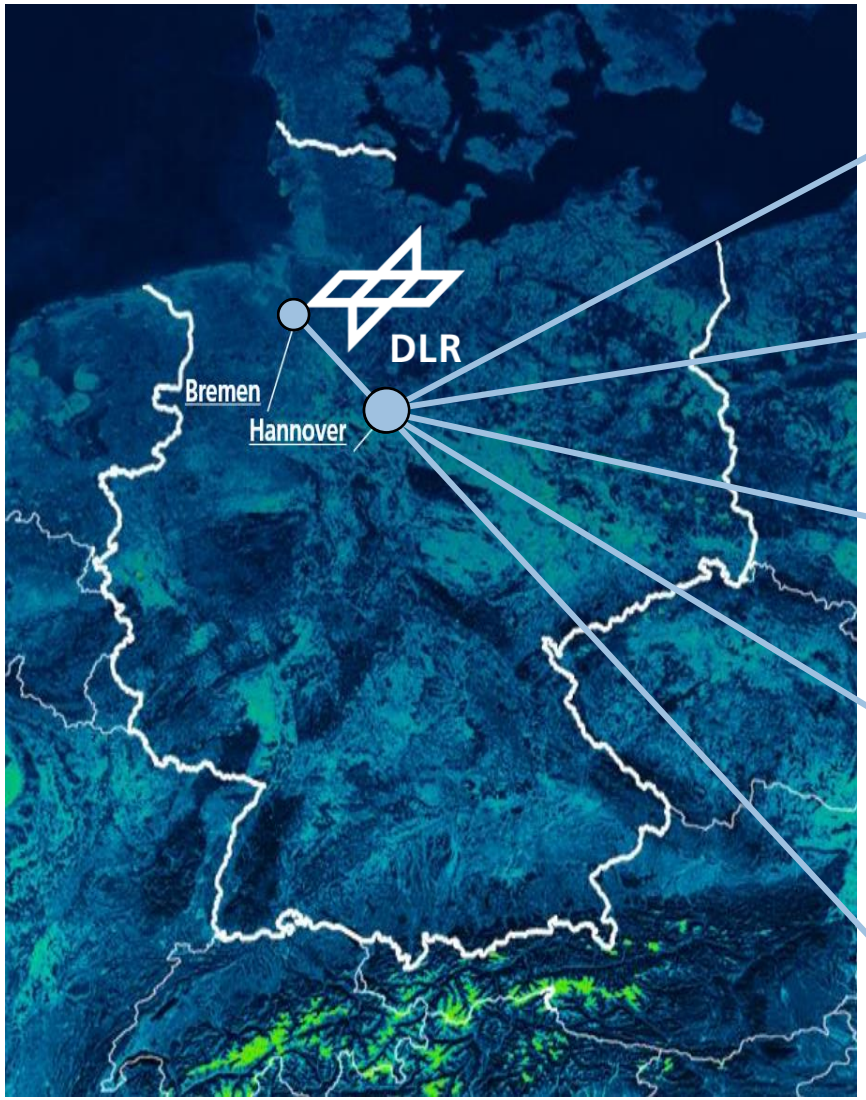
MINICAS

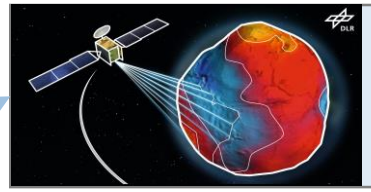
Miniaturized Constellation Acquisition System - A compact constellation acquisition system for intersatellite laser interferometers

LISA SYMPOSIUM 2024

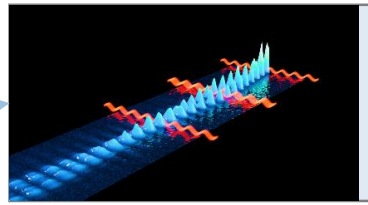
Julia van den Toren, Institute for Satellite Geodesy and Inertial Sensing,12.07.24

The DLR Institute for Satellite Geodesy and Inertial Sensing (SI)

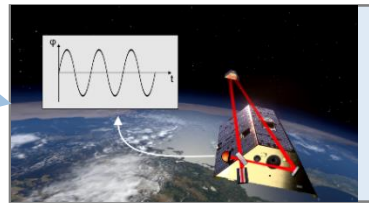




Satellite geodesy and geodetic modelling
Study and development of **novel mission concepts** and **Simulations** of **novel sensor types** and their effect on the retrieval of geodetic observables

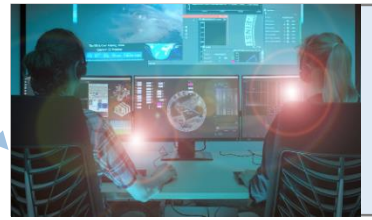


Quantum Sensing
Development of **novel quantum sensors** e.g. for applications in navigation, gravimetry / Earth observation

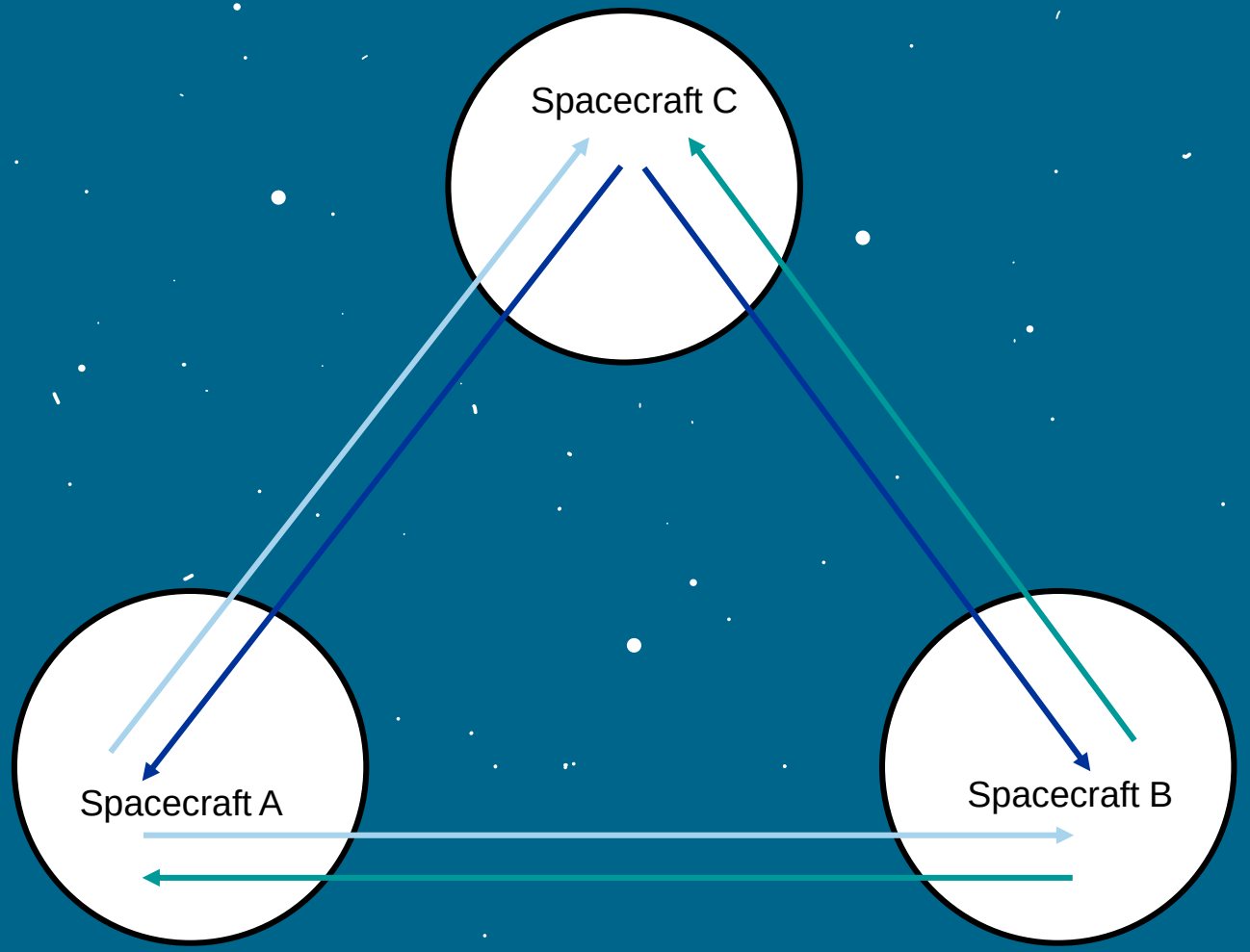


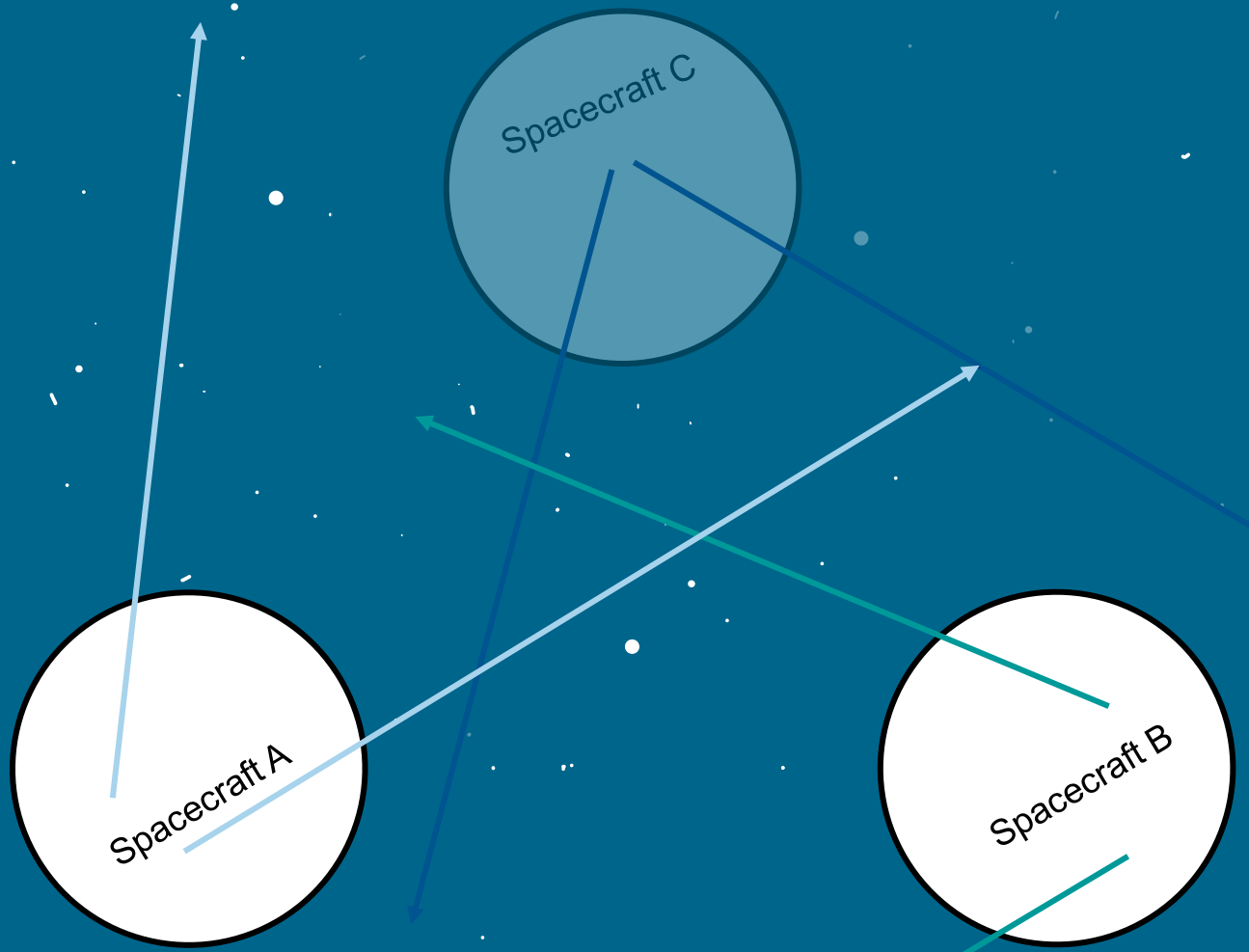
Quantum Optical Sensing
Development of (mostly) **laser interferometric sensor systems** and closely related technologies for application in high precision metrology, e.g. for Earth observsation

Optical Frequency Metrology
Development of **space-borne optical atomic clocks** for geodetic height reference systems, global time and frequency reference systems, fundamental physics tests



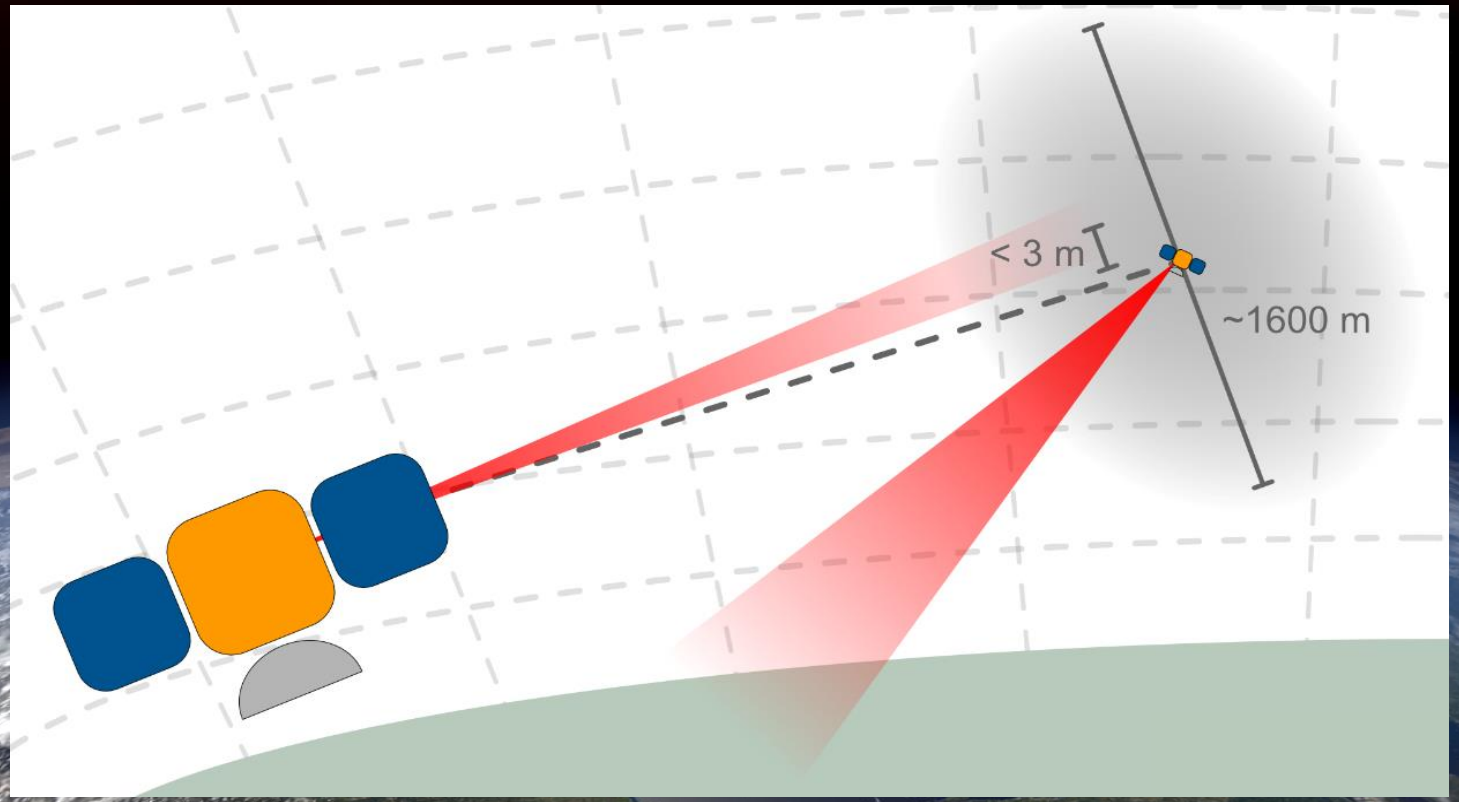
Relativistic Modelling
Development of **specialized software** to enable development of **innovative sensor concepts:**
Sensor simulation in spa ce | Model-based systems engineering tool | Mission control system


Spacecraft C
Spacecraft A
Spacecraft B

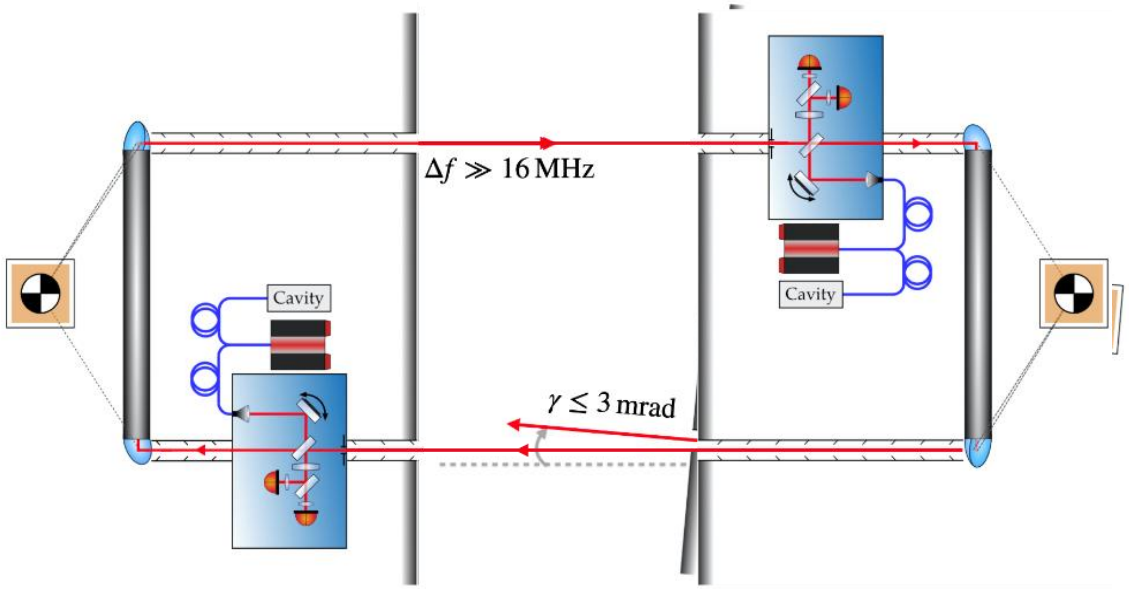

Spacecraft C
Spacecraft A
Spacecraft B

Constellation acquisition in an ideal world

Constellation acquisition in reality



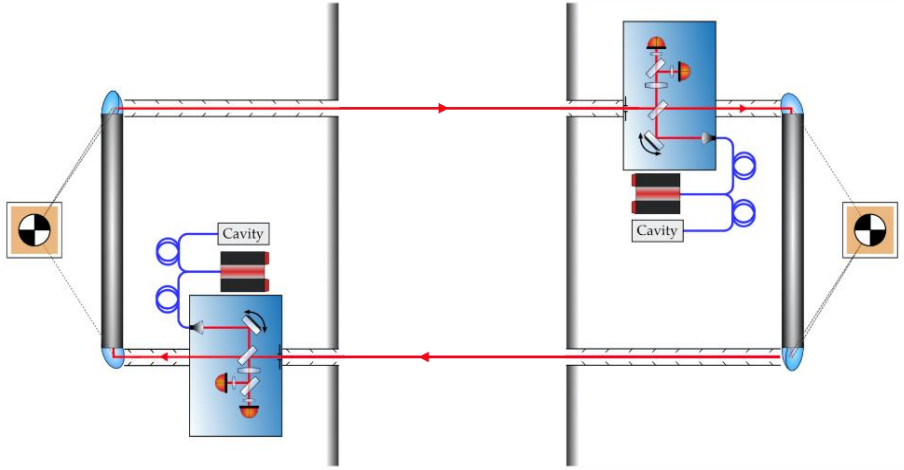
Commissioning of an Intersatellite Laser Interferometer – Laser Link Acquisition I

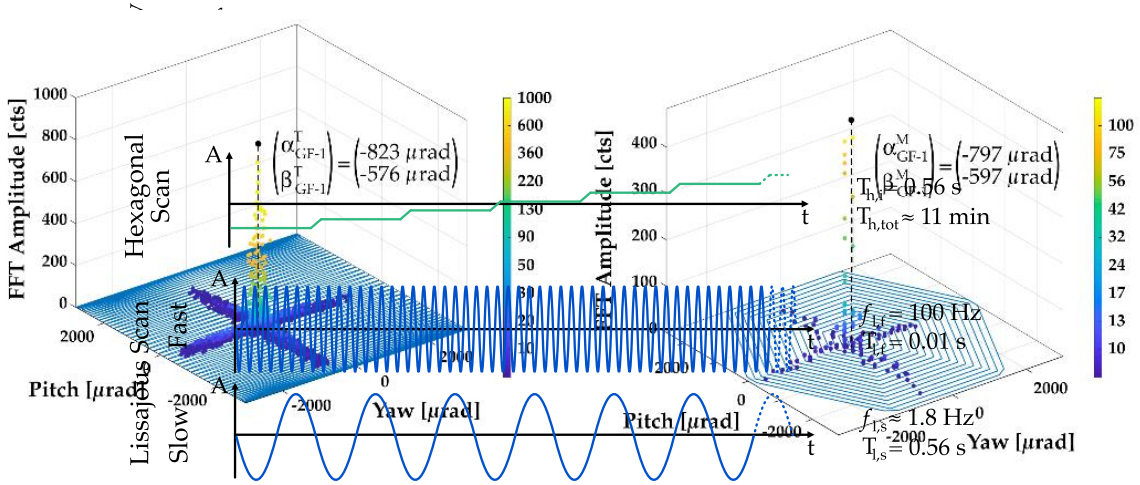


- Unknown errors in estimation of true line of sight
  - Manufacturing and integration tolerances
  - 1g – 0g effects
  - Vibrations and setting effects due to the rocket launch
- Frequency differences between the lasers on the two spacecraft
  - Temperature differences

A. Koch, Dissertation, Leibniz University Hannover, (2020)

Commissioning of an Intersatellite Laser Interferometer – Laser Link Acquisition II





- Simultaneous spatial scans of both laser beams:
  - FSM on Master S/C carries out hexagonal scan pattern
  - For each scan step Transponder carries out Lissajous scan

→ All 5 degrees of freedom have to match at least once at the same time

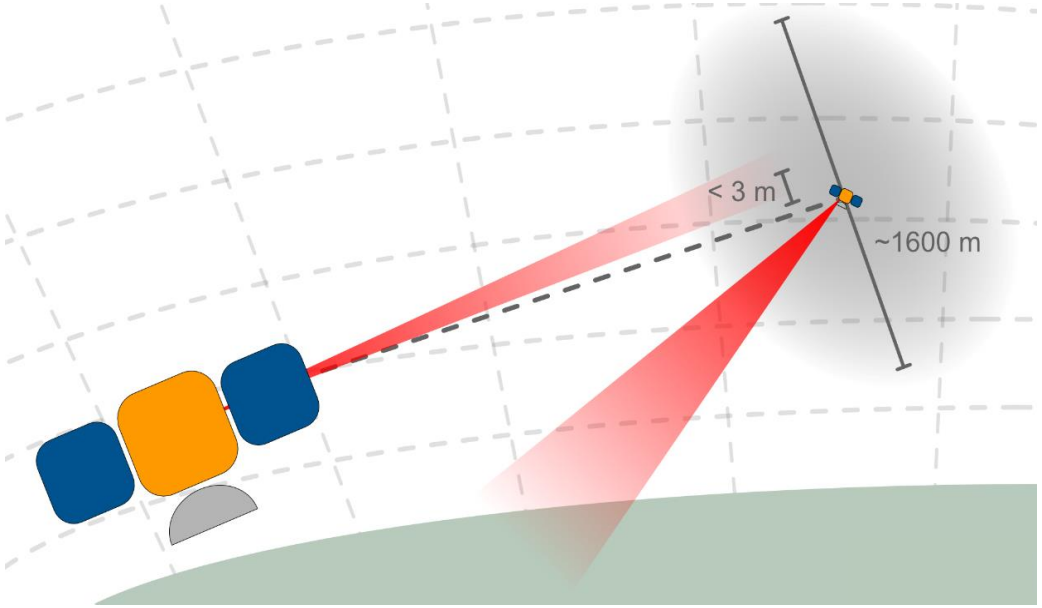
- Procedure ends after ~9hrs, data is downlinked, processed and pointing commands & frequency setpoints are uploaded

A. Koch, Dissertation, Leibniz University Hannover, (2020)
C. Mahrdt, Dissertation, Leibniz University Hannover, (2014)
A. Koch, et. al, Opt. Express 26, 25892, (2018)

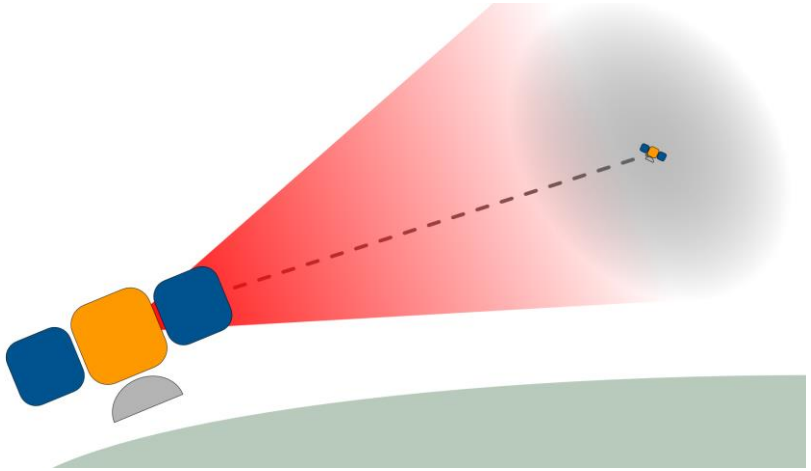
Dedicated Link Acquisition Systems

Benefits:

- Link acquisition process becomes more robust, is sped up, risk of failure is reduced
- Higher autonomy possible
- Mission concepts without fast steering mirrors require dedicated link acquisition hardware



MiniCAS – Miniaturized Constellation Acquisition System



- Modular system: Emitter + Receiver
- Emitter emits beacon beam

A. Koch, Dissertation, Leibniz University Hannover, (2020)

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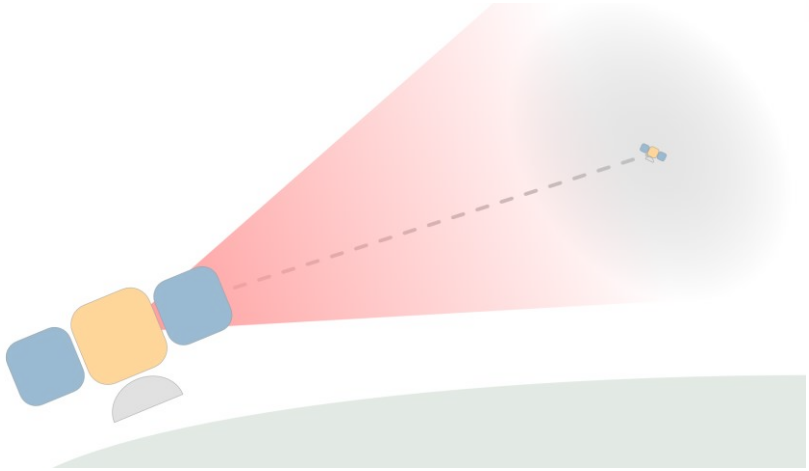

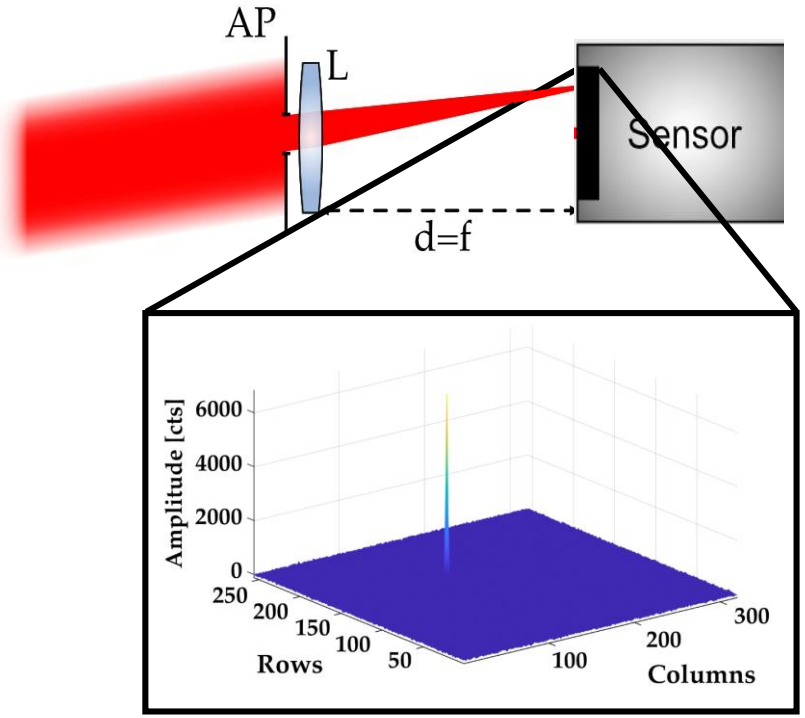

- Modular system: Emitter + Receiver
- Emitter emits beacon beam

- Beacon beam which is detected by the receiver sub-system on other S/C
- Receiver determines position of received beam

A. Koch, Dissertation, Leibniz University Hannover, (2020)

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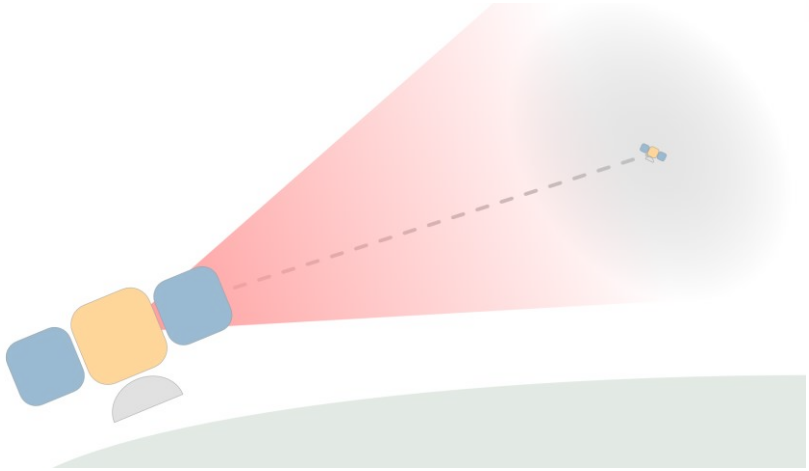
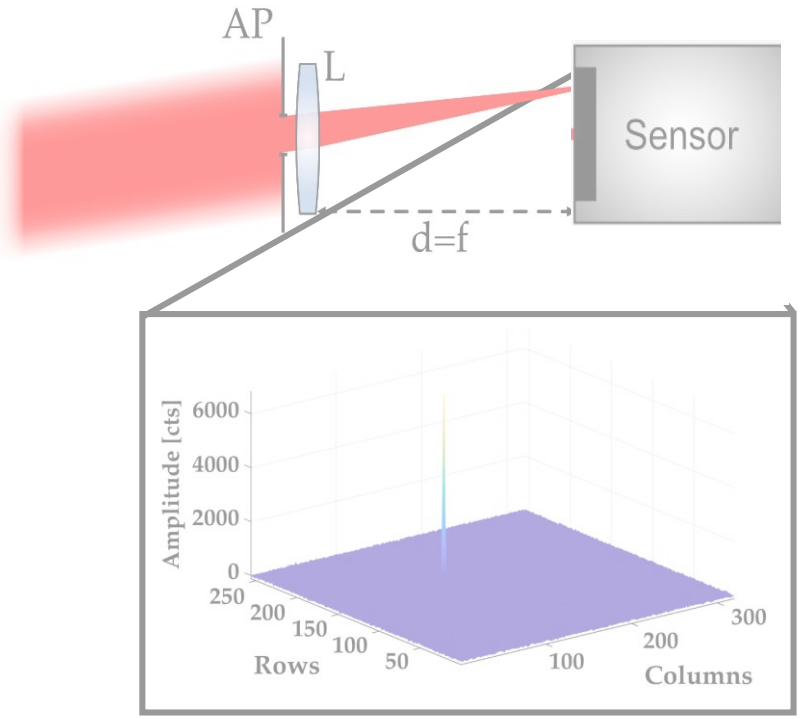
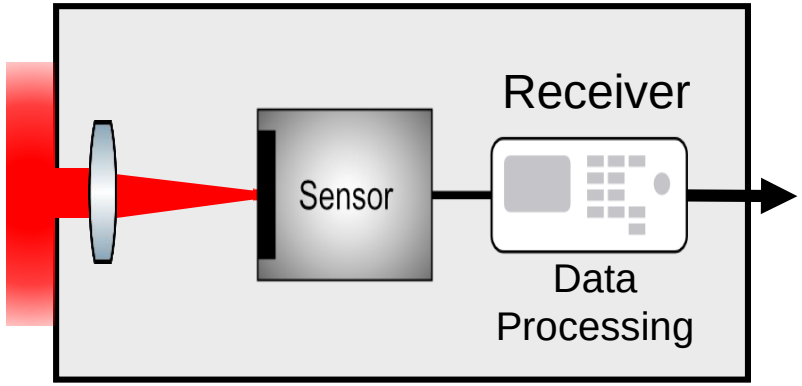






- Modular system: Emitter + Receiver
- Emitter emits beacon beam

- Beacon beam which is detected by the receiver sub-system on other S/C
- Receiver determines position of received beam

- Receiver determines tilt of local S/C with respect to the LOS

A. Koch, Dissertation, Leibniz University Hannover, (2020)

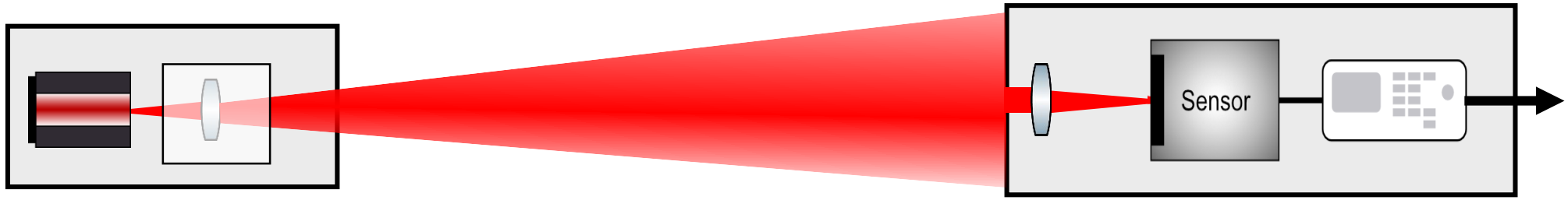
MiniCAS – Miniaturized Constellation Acquisition System

Emitter :

- Tailored to the needs of the receiver
- Beam divergence large enough to cover complete uncertainty cone without the need of spatial scanning

Receiver :

- Optical sensor, most likely InGaAs FPA
- Imaging optics
- Sensitive to 1064nm/1550nm
- Received power ~pW
- Determination of pointing error in 2D better than 10 µrad
- Field of View of a few mrad



A. Koch, Dissertation, Leibniz University Hannover, (2020)

MiniCAS – Miniaturized Constellation Acquisition System

	LISA	NGGM
Intersatellite Distance	2.5 mio.km	~ 220 km
Wavelength	1064 nm	1064 nm
Operating Temperature	20°C	~20°C
Transmitted Laser Power	~ 2 W	~ 25 mW
Received Laser Power (at CAS)	**1- 150 pW**	**<=1 nW**
FoV Requirement	**± 30.4 mrad**	**± ~ 3 mrad**
Pointing Error Estimation Accuracy	**~ 1 µrad**	**~ 10 µrad**

LISA Project Team, ESA-LISA-EST-CAS-RS-001, (2024)
W. Brzozowski, et. al. Proc. Spie 12180 7, (2022)
A. Koch, Dissertation, Leibniz University Hannover, (2020)
L. Massotti, et. al. SPIE Remote Sensing (RS103), (2022)

MiniCAS – Miniaturized Constellation Acquisition System

- ADMIRE Project with 13 participating DLR Institutes
- DLR participants on MiniCAS from Hannover, Cologne, Berlin, Hecklingen
- TRL 6 by 2026

→ Potential applications aside from intersatellite laser interferometers: Scenarios in which the **orientation of two objects** is of interest (satellites, planes, drones, monitoring of structures, …)

More here: https://www.dlr.de/en/si/

THANK YOU FOR THE ATTENTION!

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