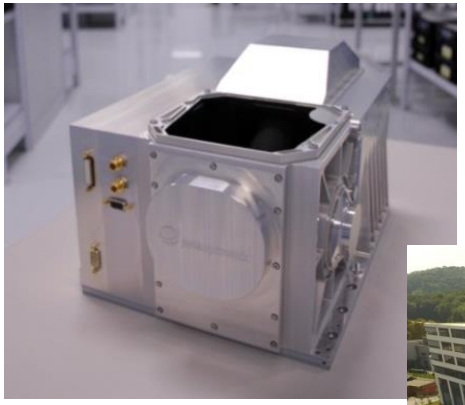
Space-Qualified Scanning LIDAR for Rendezvous and Docking Applications

EPIC Meeting on Photonics at the Final Frontier - September 2022

Thomas Kämpfe – Systems Engineer, ***Jena-Optronik GmbH,*** *LIDAR group*

jenaoptronik

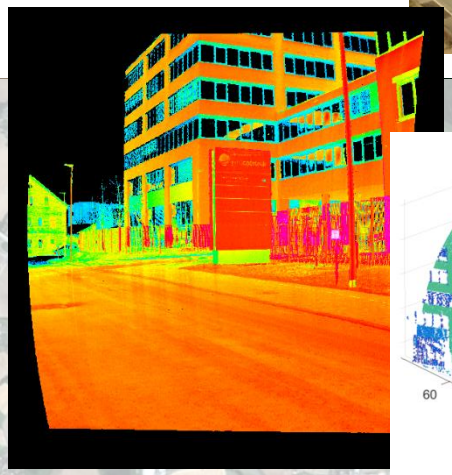


RVS3000-3D

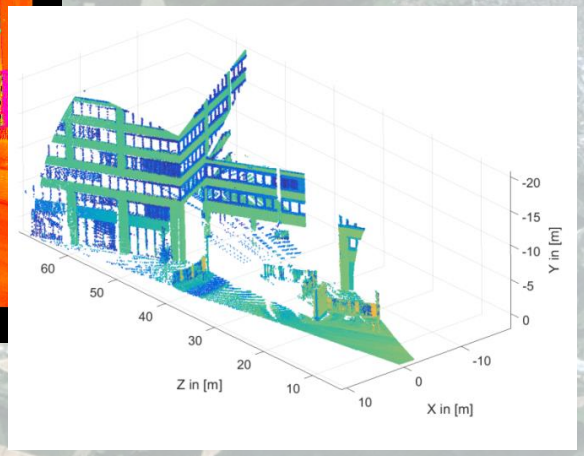
RVS3000(-3D) LIDAR

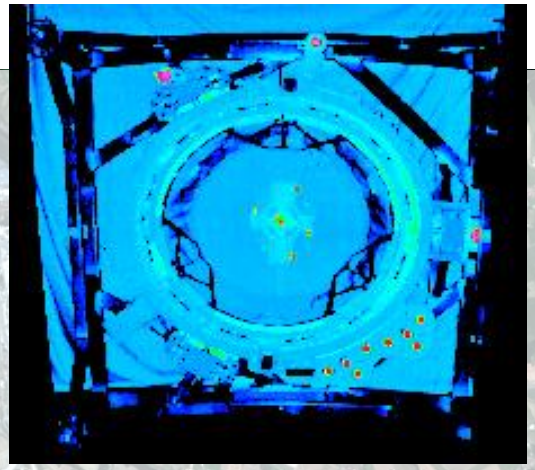
Product Family

- Smart & Versatile 3D Sensor for Space Applications



RVS3000-3D Scan





RVS3000-3D Scan of IDA3 FM

Berthing, Docking, Servicing, Sample Return, Landing

Outline

- Introduction of Jena-Optronik & Product overview
- Jena-Optronik LIDAR Heritage
- Rendezvous and Docking Sensor RVS3000
  - Concept & Technology
  - Applications
  - Development Roadmap
- RVS3000 Challenges for Photonic Subsystems

Jena-Optronik Company

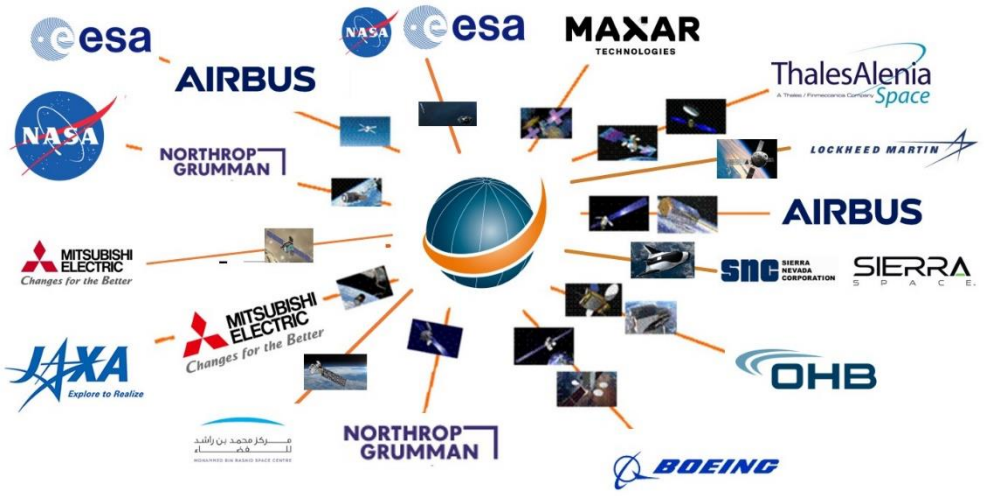
Exploring new horizons.
We are ready.

space for success

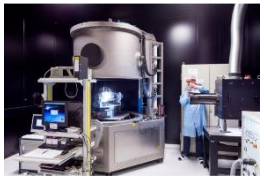
Jena Optronik at a glance

- **Sensors by Jena-Optronik** keep satellites stable and on track.
- Our **space optics & electronics** help to generate crucial Earth Observation data, helping to improve the quality of life.

- Jena-Optronik is DIN EN 9100:2018 certified
- Location **Jena, Germany**
- Management **Peter Kapell (CEO)**
- Employee **238** (as per December 2021)
- Revenue 2021 **55,0 Mio €**



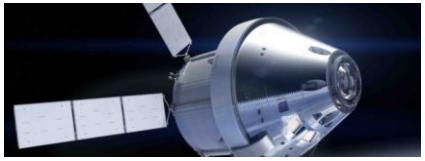
International Partner & Customer Network



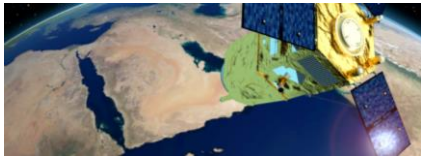
Jena-Optronik, Applications and Products

Areas of application

Space exploration

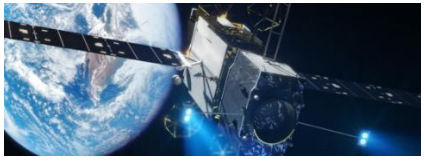


Human spaceflight

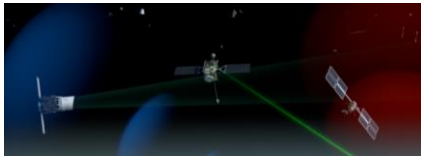


Earth observation

Telecommunication & Navigation

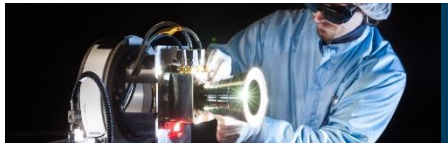


Space logistics & Debris removal

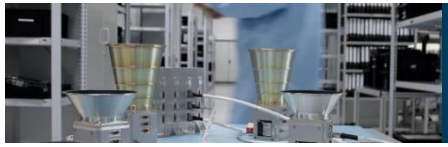


Space Situational Awareness (SSA)

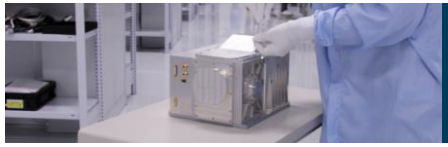
Jena-Optronik Products



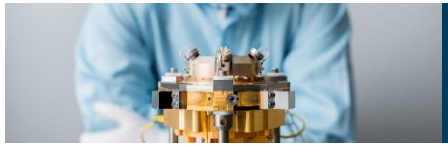
Star Sensors (APS, ACL)
ASTRO© product family



Cameras / Camera systems



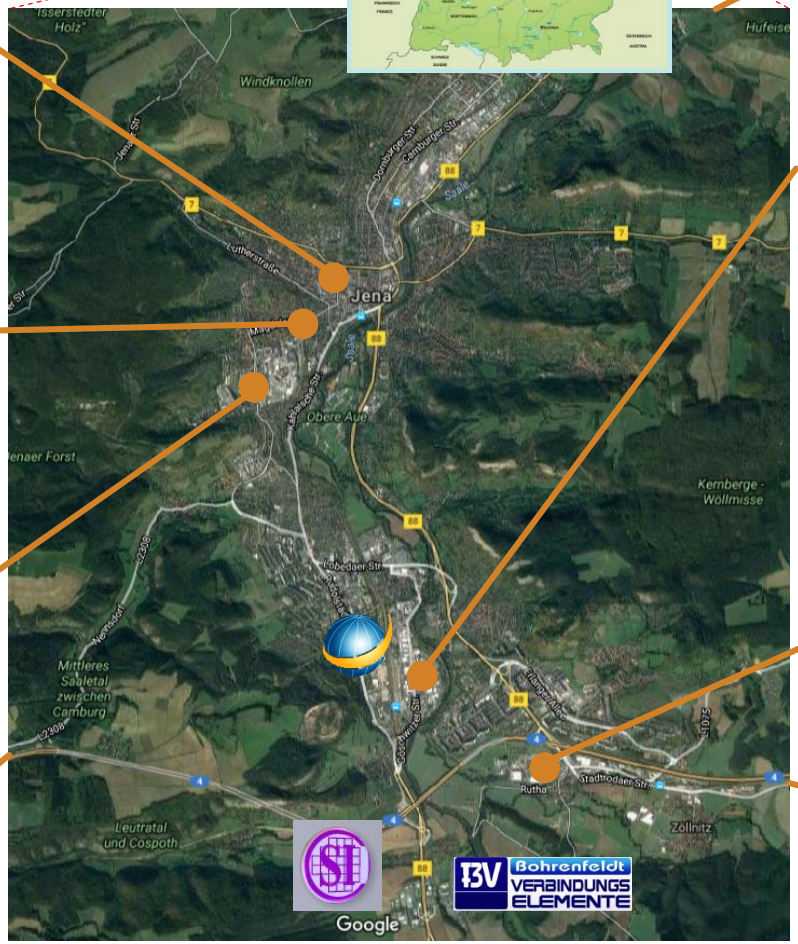
LiDAR
RVS© product family



Space optics & electronics

Services

Regional supply network



Jena-Optronik LIDAR Heritage

Exploring new horizons.
We are ready.

space for success

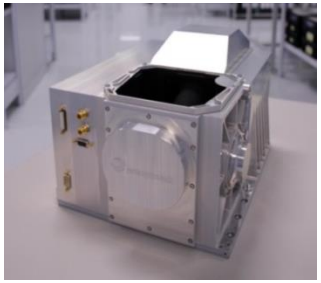
Jena-Optronik LIDAR development for Rendezvous and Docking




RVS-ARP

RVS for ATV / HTV / Cygnus
48 Flight Models delivered, 48 under contract, flawless flight heritage





LiQuaRD*

LIRIS-2 on ATV-5

RVS3000(-3D) mutliple FMs delivered & flown & contracted

* LIDAR Qualification for Rendezvous and Docking (DLR)

RVS3000-(3D) LIDAR System

Exploring new horizons.
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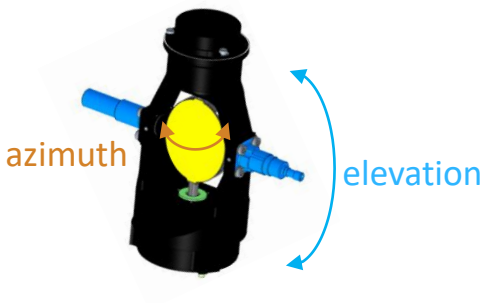
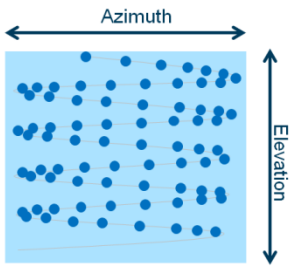
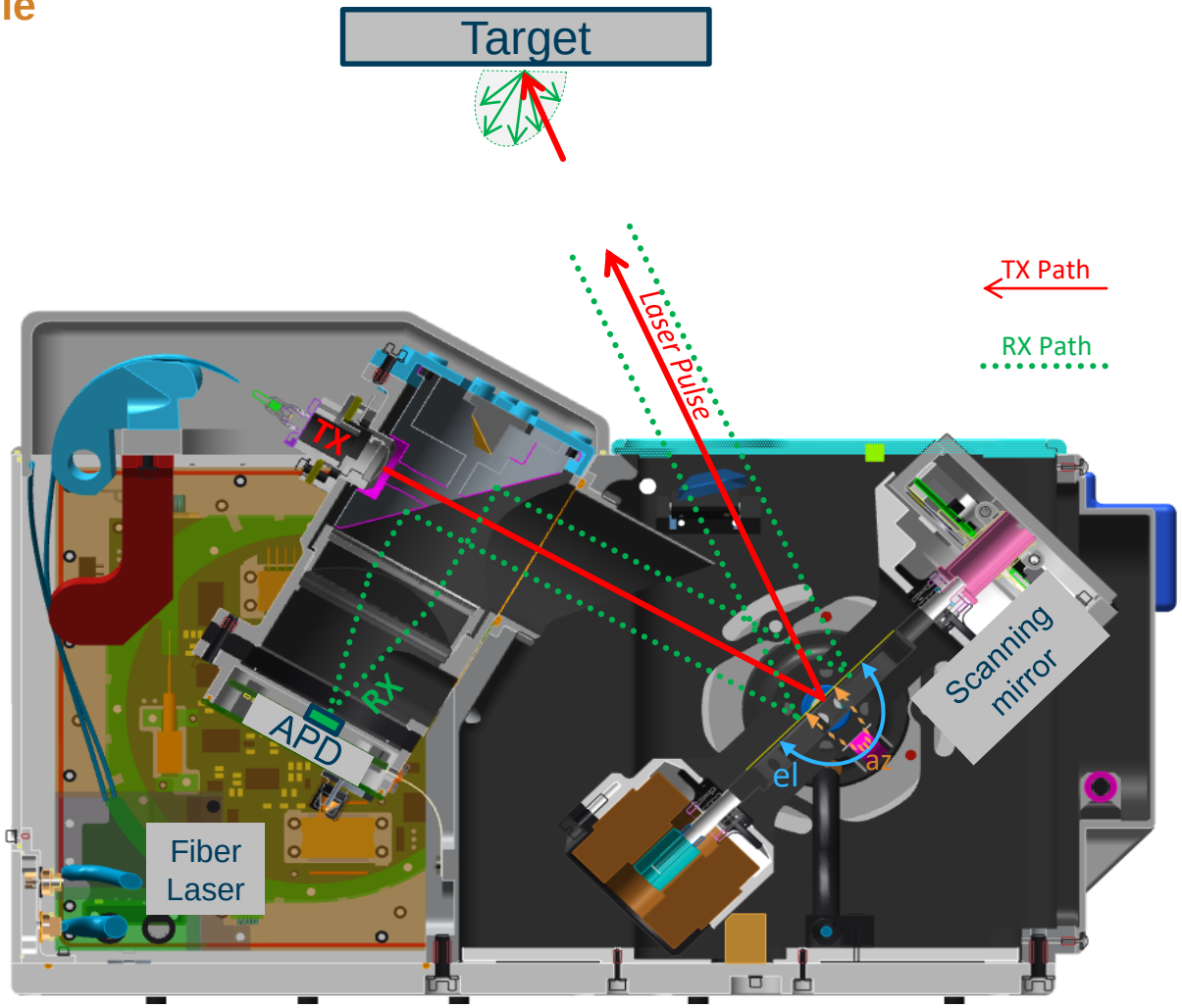
Scanning LIDAR principle

Scan head



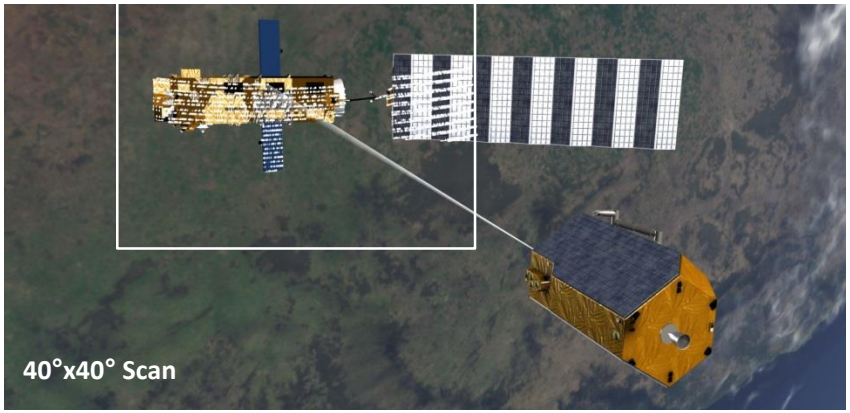


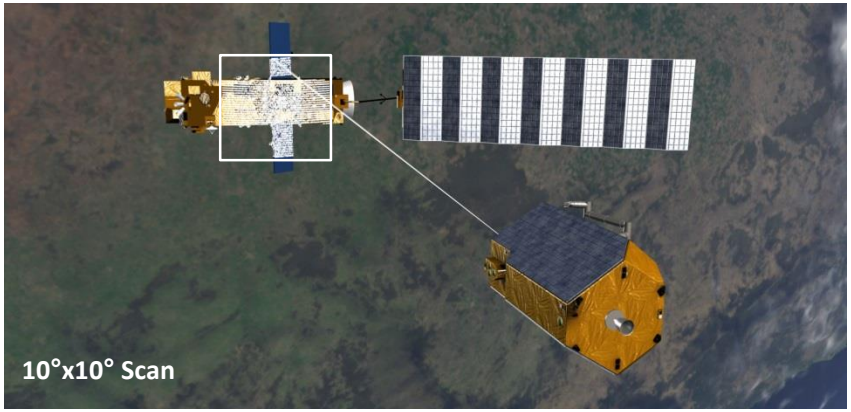
Scan pattern



Scanning LIDAR advantages

- Large degree of flexibility with respect to Field-of-View (<1x1…40x40 deg)
- High performance angular measurement (noise ~ 0.001 deg, bias < 0.05 deg)
- Range, azimuth, elevation and amplitude information
- Variable scan speed leading to adjustable point cloud resolution
  - Slow high-resolution scans with “megapixel” images
  - Fast scans for proximity operations with moving/rotating objects
- No “dead pixels”
- Single Shot Range 3σ Noise: < 1–2 cm; Single Shot Range Bias: < 1 cm (close range)

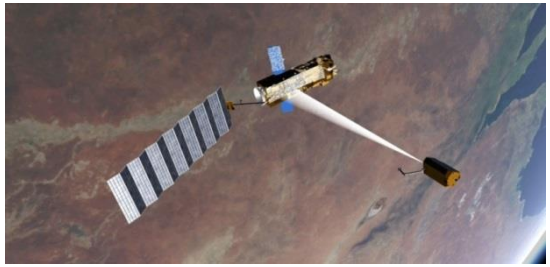


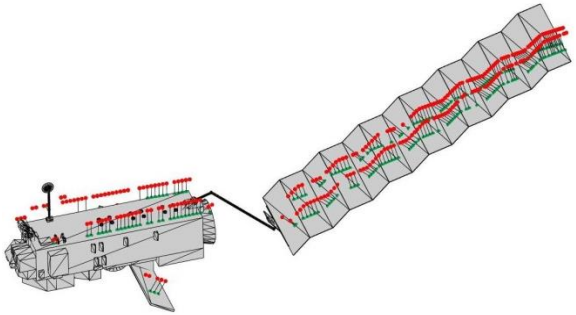


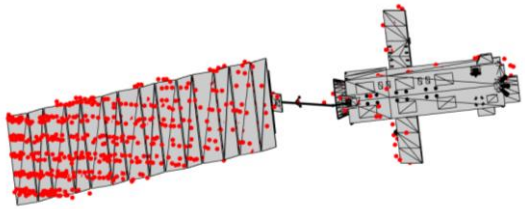
Scanning LIDAR in Debris Removal Scenario

RVS 3000-3D – Pose Estimation

- Pose calculated based on matching between RVS scan and target reference model
- Real-time algorithm application on dedicated image processing board
  - 2 Hz Pose Update Rate, 1s Latency
- Algorithm Flow:







1 — Acquisition of LIDAR Scan

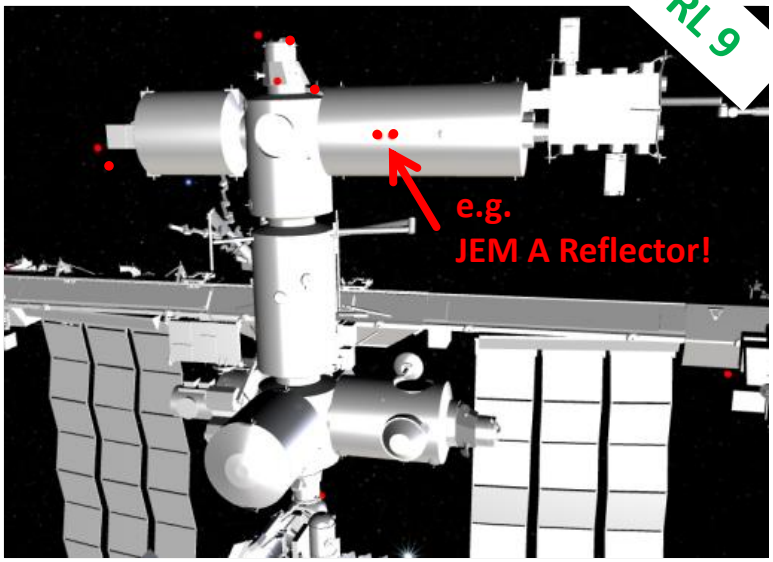
2 — Matching LIDAR Scan vs. Model

3 — Pose

RVS 3000 – Retro Reflector Tracking

- Identification & tracking of retro reflector objects
- JOP heritage retro identification algorithms
  - 2 Hz Update Rate
  - > 50 flights to ISS

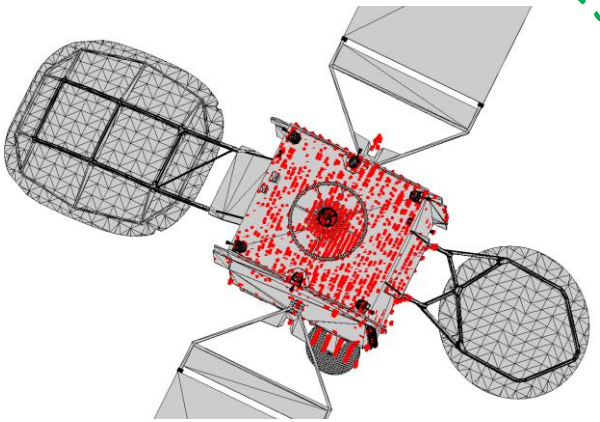
TRL 9



RVS 3000-3D Pose Estimation

- Pose calculated based on matching between RVS scan and target reference model
- **Dedicated image processing board**
- Succesful Docking in frame of NG‘s MEV 02/2020 & 04/2021

TRL 9



JOP RVS3000-3D - Scan & Pose of IS901 in Orbit

A Smart 3D Sensor for various Space Applications in a Single Box

3D Point Measurement
cooperative/
non-cooperative targets

- Scanning LIDAR
- Time-of-flight ranging

3D Point Cloud
low-level

- Calibration & Correction
- Filtering, ROI

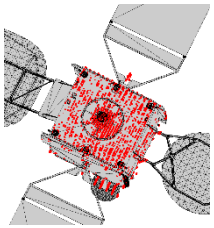
3D Point Cloud
high-level

- Retro Tracking
- 3D Pose Estimation
- Hazard Detection

High Level Analysis

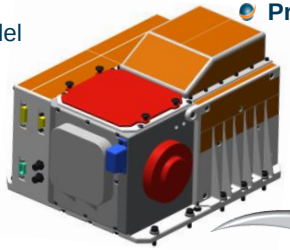
- Processed & Reduced Information
- CONOPS adapted communication to GNC

RVS3000 Family Evolution – Smart 3D Sensor Berthing, Docking, Servicing & Landing



RVS3000-3D ✓

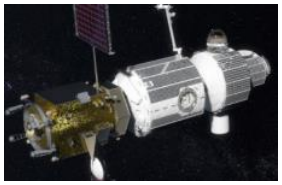
- Docking non-cooperative targets
  6D Pose Estimation
  point cloud matching to CAD model
- **TRL 9 production**



RVS3000-X

Development on going

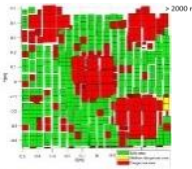
- non-cooperative & cooperative targets
  Retro Tracking & 6D Pose Estimation
- **Crew-handling Design**
- **Product line harmonization**

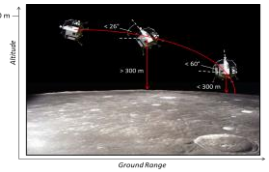


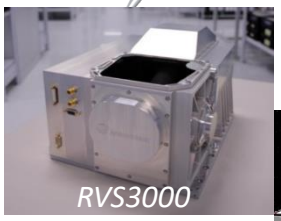
RVS3000-L

Development kicked-off

- non-cooperative & cooperative targets
  Landing Application
- **Motion Correction & Hazard Detection**

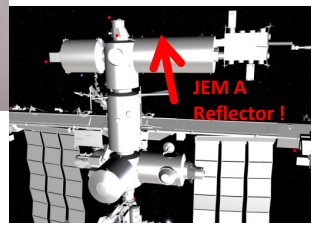






RVS3000 ✓

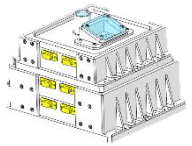
- ISS/cooperative targets
  Retro Tracking
- **TRL 9 production**



µRVS – the next step

Technology development

- Single-photon avalanche diode array technology
- Powerful pulsed diode laser (~905 nm)
- Miniaturized scan mirror
- Reduction of mass, power consumption



RVS3000-(3D) LIDAR System – Photonics

Challenges for Photonic Subsystems

Exploring new horizons.
We are ready.

Optical System

Components:

(1) TX output fiber laser, 1550 nm

(2) TX collimator lens

(3) Combiner mirror

(4) Scan mirror, (gimbal mount)

(5) RX spectral filter

(6) RX focusing lens

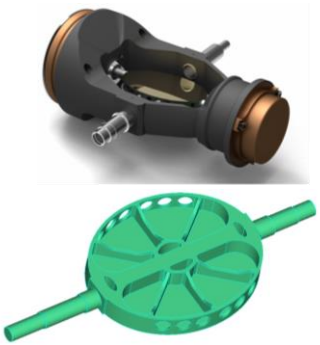
(7) APD detector

(8) TX monitor output fiber laser

(9) Monitor collimator lens

(10) deflection mirror

Scan Mirror



- Material: AlBeMet, Ni-plated
- Au coating
- Weight 18g

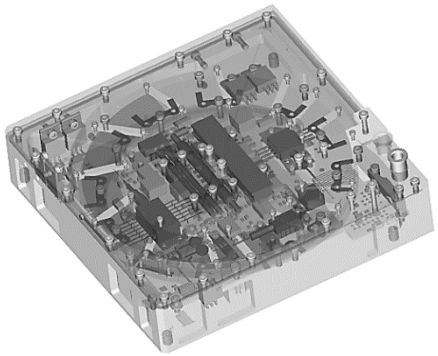
Needs/Interests/Ideas:

- *Coatings, glasses, lenses (optical systems)*
- *Scan mirrors/systems (electro-mechanical systems)*

RVS3000 Fiber Laser Sub assembly

Fiber Laser in master oscillator power amplifier design

- Distributed feedback laser diode seed
- 2 pass preamplifier pumped by single mode laser diode (SMLD)
- main amplifier pumped by another SMLD and a multi mode laser diode (MMLD)



Wavelength	1550 nm
Pulse length	3 … 8 ns
Pulse repetition rate	20 kHz … 120 kHz
Avg. power	< 350 mW
M^2	<1.2

Needs/Interests/Ideas:

- Laser diodes

- Fibers, Fiber couplers, Fiber optics

RVS3000 RX Detection

APD InGaAs detector

- biasing voltage in the range of 50 to 70 Volts at room temperature to have a nominal gain of 10
- APD voltage regulated & temperature stabilized

Amplitude Detection

- pulse amplitude detection enables compensation of time-walks due to nonlinearities and noise

Needs/Interests/Ideas:

- APDs, APDs arrays, LIDAR detectors

- Detectors with integrated readout electronics/circuits

Conclusion

- RVS3000 is a space qualified LIDAR capable of autonomously acquiring and tracking cooperative and non-cooperative targets, for rendezvous and docking applications
- RVS3000 3D with pose matching opens up new application areas (satellite servicing, HDA for planetary landing..)
- Main further development goals
  - Improvement of scan performance (point density, scan rate..)
  - Improvement of laser performance (divergence, max pulse power, max range)
  - Towards a smart sensor (object recognition, mode choosing, high level data analysis)
- **A major key is to improve components in the optical subassemblies**

Thank you for your attention