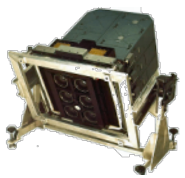
The RVS3000 and RVS3000-3D LIDAR Sensors

ESA CleanSpace Industry Days, 27. May 2016

jenaoptronik

Space developments from Jena.

1976 | 1980



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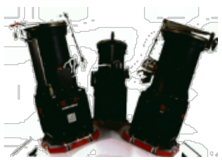


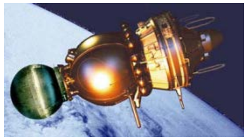
ASTRO 1

Start of space activities in Jena

1991

Foundation of Jena-Optronik

1994



First European re-entry capsule MIRKA

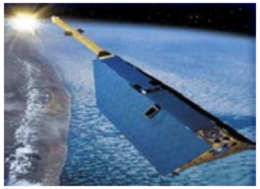
1996

First flight Precision Sun Sensor for Artemis

1997

Qualification of R&D Sensors by Space Shuttle flights

2000



Launch of CHAMP

2002

Launch of INTEGRAL with ACS

2003

First launch of ASTRO 15

2005

Jena-Optronik 100% subsidiary of JENOPTIK AG

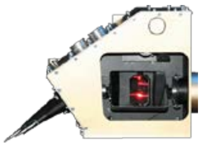
2006

Boeing Supplier of the Year

2007

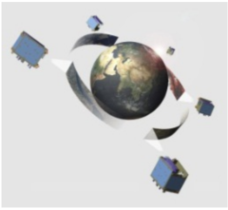
ASTRO 10 on SAR-Lupe and TerraSAR

2008



First approach of ATV to the ISS with R&D Sensors TGM & VDM

2009



Launch of RapidEye constellation with JSS56

2010

Jena-Optronik 100% subsidiary of Astrium GmbH

2011

METimage Phase B2 contract

2013

ASTRO APS on AlphaSat

Outline

- **Introduction to LIDAR**
- **LIDAR Developments at Jena-Optronik**
- **The LIRIS-2 3D Imaging LIDAR on ATV-5**
- **RVS3000 and RVS3000-3D**
  - Introduction
  - Features
  - Technology
  - GSE
  - Availability
- **Summary**

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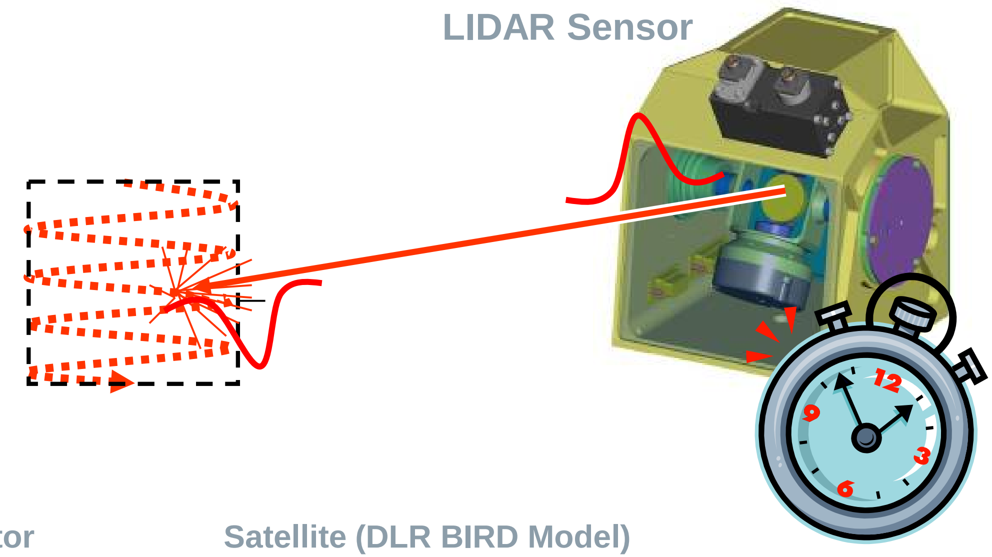
Time-of-Flight (Scanning) LIDAR Working Principle

LIDAR Sensor

Scan Pattern

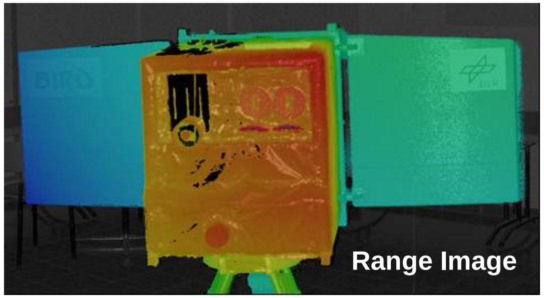


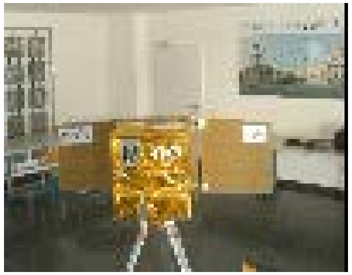
Scanning of a target object with a moving scan mirror

Range measurement with time-of-flight of a laser pulse

Retro Reflector

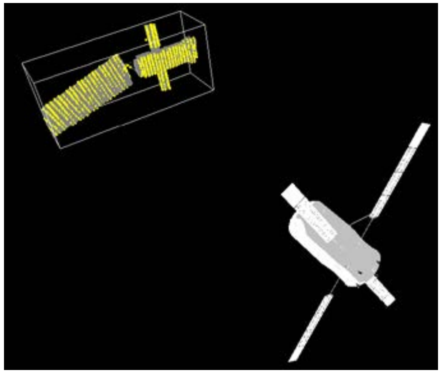
Satellite (DLR BIRD Model)





2.9 m 3.8 m

LIDAR scanning of Envisat



Astrium / JOP

Features of a Scanning LIDAR

Scanning LIDAR uses a movable mirror system to steer the laser beam

- Completely flexible FoV (1° x 1° … 40° x 40°) and scan parameters
(low speed – high resolution „megapixel image“ vs.
high speed – low resolution for pose estimation of fast-moving objects)
- High LOS resolution possible

Single detection channel

- High dynamic range – from non-cooperative targets at long distance to reflective elements at short distance
- High range resolution

Detection channel as standalone Laser Range Finder

- The detection channel can be used as a high-accuracy non-scanning Laser Range Finder for distance measurements („Laser Altimeter“)
- Options:
  - Compact Laser Altimeter using stand-alone detection channel
  - Scanning LIDAR system with Laser Altimeter mode for extended operating range

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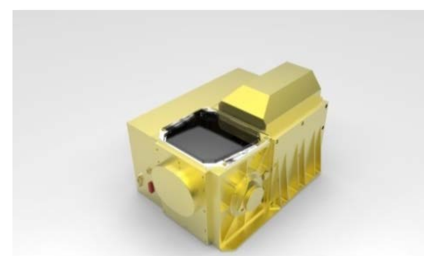
Jena-Optronik LIDAR Sensors for Rendezvous and Docking




RVS-ARP

RVS for ATV / HTV / Cygnus
42 Flight Models delivered, flawless flight heritage





LiQuaRD*

LIRIS-2 on ATV-5

RVS3000

* LIDAR Qualification for Rendezvous and Docking (DLR)

The RVS Rendezvous- and Docking Sensor

- **RVS – the most successful LIDAR sensor for Rendezvous and Docking**
  - Acquisition and tracking of ISS via retroreflector targets, up to 1500m distance
  - 42 flight models delivered (and counting…)
  - up to now, RVS was used on 16 missions:
    2x Space Shuttle – MIR Docking (RVS-ARP prototype)
    5x ATV Docking,
    5x HTV Berthing,
    5x Cygnus Berthing
  - no issues – flawless flight heritage
  - insensitive against sunlight and parasitic reflections
  - robust and reliable

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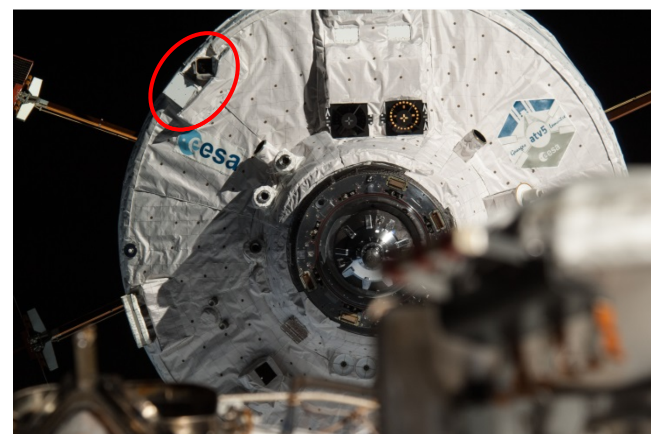
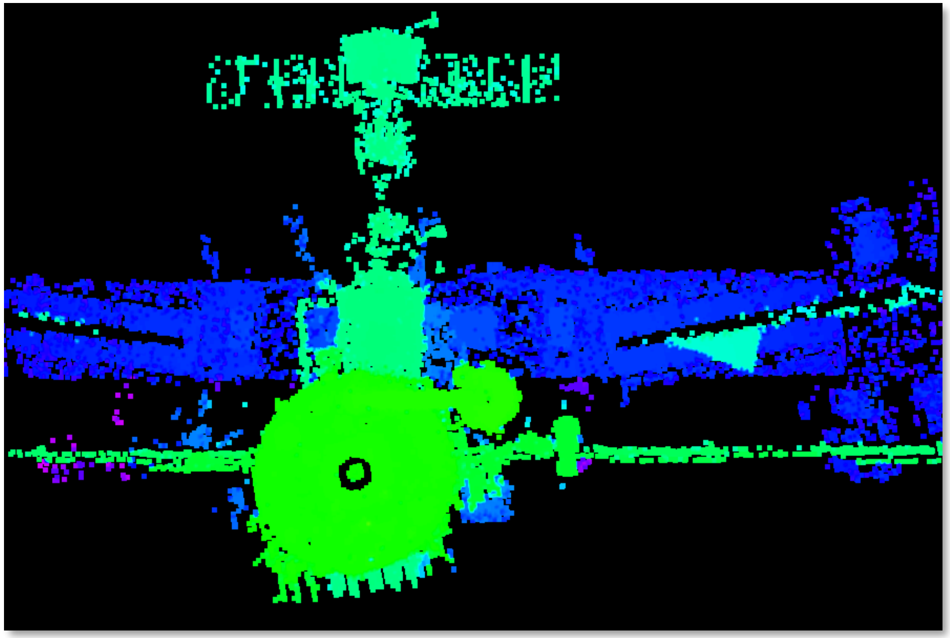
LIRIS-2: RVS3000 Flight Demonstration on ATV-5

- **LIRIS (Laser Infrared Imaging Sensor) Technology Demonstration on ATV-5 „Georges Lemaître“**
  - RVS3000 flight demonstration model designed, built and qualified for first space flight within about 1 year
  - Acquisition of 3D image data during ATV-5 approach to ISS
  - Switch-on at ca. 3500m to collect retroreflector data
  - 3D image data from ISS (operating range limited by laser eye-safety regulations for ISS)
  - 3D data from sensor is time-correlated with the approach data of the operational RVS (TGM) / VDM sensors on ATV-5
  - 1.3 GB of 3D data and housekeeping data collected
  - Additional switch-on after undocking – nominal performance after 6 months in orbit

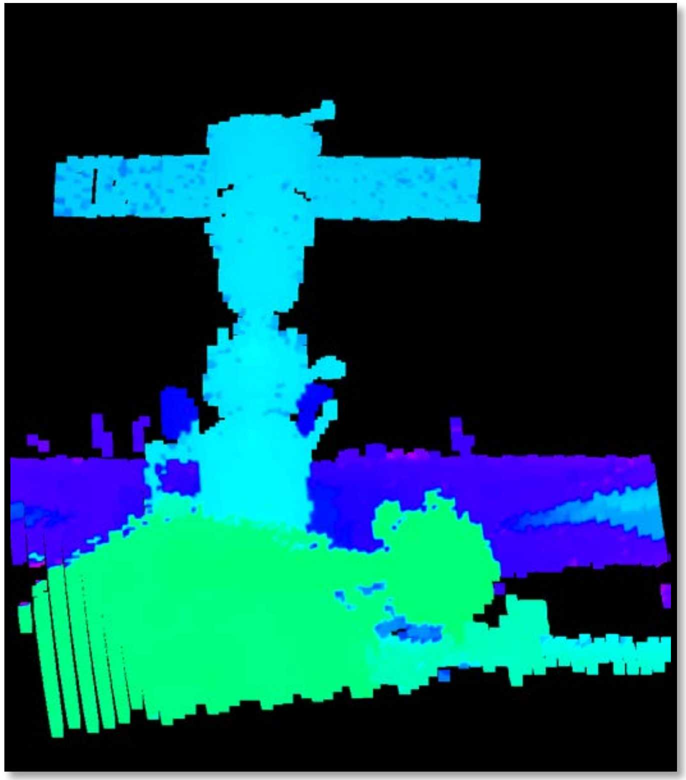


Recorded Image Data

ISS at about 30m distance from docking port



ISS at about 10m distance from docking port



Nominal performance of LIRIS-2 during rendezvous and docking

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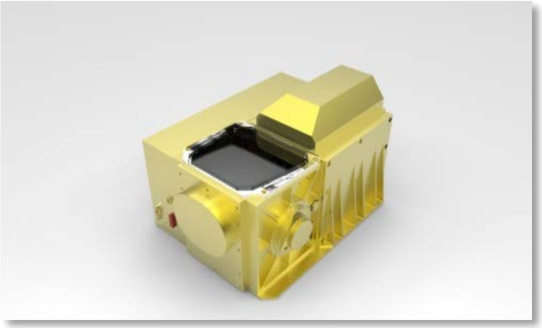

LIDAR Sensors RVS3000 and RVS3000-3D

RVS3000
cooperative targets

3D-LIDAR in One-Box-Design

- intended for cooperative targets (retroreflectors), e.g. ISS supply
  → short-duration LEO missions
- internal data processing for retroreflector targets
- reduced laser power for eye safety
- One-box-design for simplified test, handling and installation

RVS3000-3D
non-cooperative targets

3D Imaging LIDAR in One-Box-Design

- intended for non-cooperative targets, e.g. space robotics, on-orbit-servicing
  → long-duration LEO/GEO missions
- more powerful internal processing than RVS3000
- high laser power for large operating range against non-cooperative targets
- One-box-design for simplified test, handling and installation
- Additional Laser Altimeter Mode or detection channel as stand-alone Laser Altimeter

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Performance Comparison

Parameter	RVS	LIRIS-2 on ATV-5	RVS3000	RVS3000-3D
Mirror system	2 separate scan mirrors	1 gimbal-mounted scan mirror		
Field-of-View	1° x 1° … 40° x 40°	40° x 40° fixed	1° x 1° … 40° x 40°	
Min. operating range			<1m	
Max. operating range (retroreflectors)	1300 m	2500 m	Up to 3000 m (customer-specific)	
Max. operating range non-cooperative targets	n/a	ca. 250 m	(ca. 250m)	ca. 1400 m for reflectivity = 0.17
Max. frame rate	(1 Hz)	3 Hz	2 Hz (scan rate can be higher, e.g. 4 Hz)	
Size	E-Box (270 x 278 x 196) mm Optical Head (315 x 224 x 176) mm	E-Box (250 x 265 x 131) mm Optical Head (293 x 235 x 196) mm	Integrated Box (286 x 310 x 195) mm	
Mass	14.7 kg	13.3 kg	<10 kg (tbc)	
Interface	MIL1553B	Proprietary	MIL1553B	SpaceWire

Acquisition and Tracking, Manual

- Initial acquisition of target: scan of full field-of-view
- Tracking: step-wise reduction of scan window size depending on target size and distance
- Manual mode: user-defined scan parameters, e.g. for high-resolution inspection image at a hold point

Data Output

- RVS3000: identified and assigned retroreflector data (like RVS)
- RVS3000-3D: 3D point clouds, average range & LOS, bounding box, 6DOF pose (with appropriate co-processing board and software)

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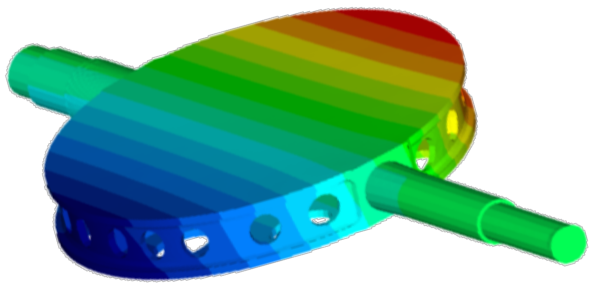
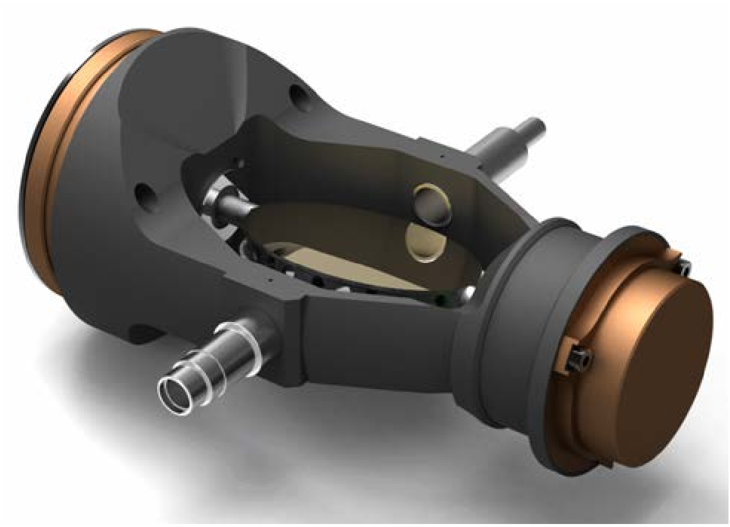
Design Solutions for High Performance Optical Head



Highly optimized scan mirror made from Beryllium alloy

- Minimal weight (14 g) & moment of inertia
- High stiffness at scan frequencies up to 100 Hz

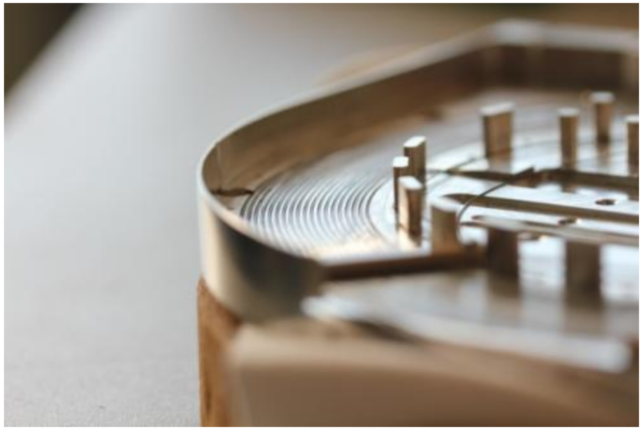


Optimized scan motors

- High torque at low weight and low power consumption

Optics design

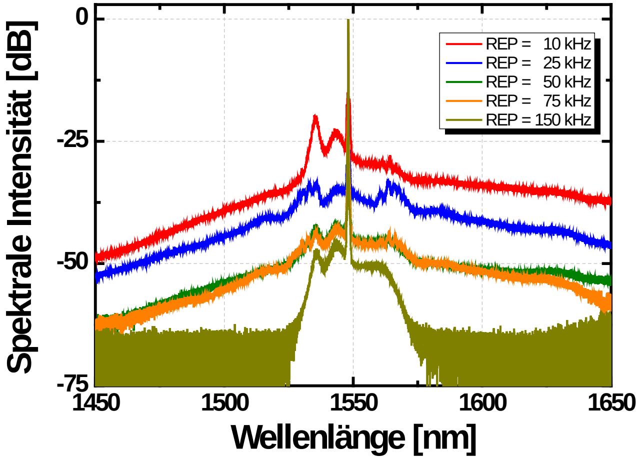
- Coaxial optical frontend for measuring range against retroreflectors and satellite materials

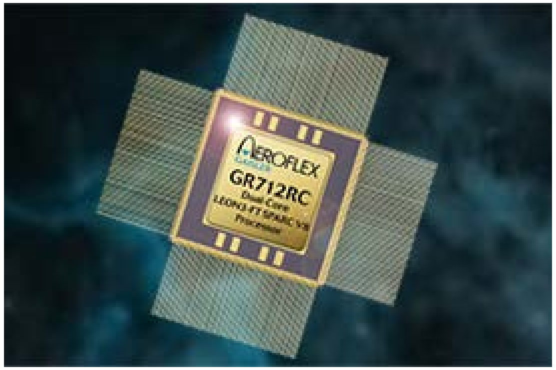


Development of a qualified fiber laser for space applications together with Fraunhofer IOF, Jena

- Wavelength: 1550 nm (Erbium-doped fiber)
- Pulse duration: 3…10 ns (LIRIS-2: 10 ns)
- Pulse peak power: >4 kW (LIRIS-2: 7,5 W)
- Rep. rate: 20…150 kHz (LIRIS-2: 35…40 kHz)

Switchable power levels – same beam characteristics





Internal Processor / Interface Board

- LEON3FT dual-core processor
- redundant MIL1553B bus or SpaceWire
- … controls sensor functions and implements interface to spacecraft

Available internal space for additional co-processing board, e.g.

- specialized co-processing board for 3D data processing
- solid state data recorder
- …

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GSE: Stimulation Unit

Not all aspects of a mission can be tested on ground…

… some means of verifying sensor performance with respect to data processing is necessary

GSE: Stimulation Unit

Not all aspects of a mission can be tested on ground…

… some means of verifying sensor performance with respect to data processing is necessary

Solution:

- feeding „artificial“ measurement data to the sensor via dedicated GSE interface (like „FEE“ for RVS on ATV)
- the LIDAR processes the data as if it were real measurement data
- allows to verify approach trajectories and simulate (new) scenarios

Technical basis:

- VeroSIM simulation software produces artificial LIDAR 3D data
- Interface box between simulation PC and LIDAR sensor

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Summary

RVS3000 is based on

- RVS experience on ATV, HTV and Cygnus and
- DLR LiQuaRD & ESA LIRIS-2 3D Imaging LIDAR technology elements

RVS3000 in two versions

- RVS3000 for cooperative targets (like RVS)
- RVS3000-3D for non-cooperative targets, internal 3D data processing possible

RVS3000 EM available in Q3/2016

Thank you very much!

Questions?