The RVS3000 and RVS3000-3D LIDAR Sensors

ESA CleanSpace Industry Days, 27. May 2016
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>Foundation of Jena-Optronik</td>
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<tr>
<td>1980</td>
<td>MKF 6 ASTRO 1</td>
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<tr>
<td>1991</td>
<td>Start of space activities in Jena</td>
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<tr>
<td>1994</td>
<td>First European re-entry capsule MIRKA</td>
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<td>1996</td>
<td>First flight Precision Sun Sensor for Artemis</td>
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<td>1997</td>
<td>Qualification of R&amp;D Sensors by Space Shuttle flights</td>
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<tr>
<td>2000</td>
<td>Launch of CHAMP</td>
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<td>2002</td>
<td>Launch of INTEGRAL with ACS</td>
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<tr>
<td>2003</td>
<td>Jena-Optronik 100% subsidiary of JENOPTIK AG</td>
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<td>2005</td>
<td>Boeing Supplier of the Year</td>
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<td>2006</td>
<td>ASTRO 10 on SAR-Lupe and TerraSAR</td>
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<td>2007</td>
<td>First approach of ATV to the ISS with R&amp;D Sensors TGM &amp; VDM</td>
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<td>2008</td>
<td>Launch of RapidEye constellation with JSS56</td>
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<td>2009</td>
<td>Jena-Optronik 100% subsidiary of Astrium GmbH</td>
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<td>2010</td>
<td>METimage Phase B2 contract</td>
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<td>2011</td>
<td>ASTRO APS on AlphaSat</td>
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<td>2013</td>
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</table>
• 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
Outline

- **Introduction to LIDAR**
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- **Summary**
Time-of-Flight (Scanning) LIDAR Working Principle

Scan Pattern

LIDAR Sensor

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)

LIDAR scanning of Envisat

Range Image

2.9 m - 3.8 m

Astrium / JOP
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
42 Flight Models delivered, flawless flight heritage

LIRIS-2 on ATV-5

LiQuaRD*

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

Nominal performance of LIRIS-2 during rendezvous and docking

ISS at about 30m distance from docking port

ISS at about 10m distance from docking port
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### 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

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

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

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