Microwaves and Radar Institute

Research and Projects

Alberto Moreira

German Aerospace Center – DLR

Oberpfaffenhofen, Germany
Microwaves and Radar Institute

- 30+ years of experience in SAR systems and applications
- Participation in 4 Shuttle Imaging Radar Missions
  - MRSE (1983)
  - SIR-C/X-SAR (April and October 1994)
  - SRTM (2000)
- Contribution to satellite missions and projects
  - TerraSAR-X, TanDEM-X, Tandem-L, HRWS
  - ERS-1/2, ENVISAT, Sentinel-1, BIOMASS, CoReH2O
  - ALOS/PalSAR, MAPSAR, PAZ, SIGNAL
  - SAR-Lupe, SARah
- Airborne SAR systems
  - P-L-S-C-X-band
  - polarimetric and interferometric modes
Organization and Research
Microwaves and Radar Institute

Research profile: passive and active microwave systems
- Sensor concept, specification, design and simulation
- Technology demonstration
- Methods and techniques
- Sensor-specific applications and information extraction

Application fields
- Earth observation
- Reconnaissance and security
- Traffic monitoring

Organization
- 4 departments with 135 staff members
- Contributions to DLR’s Space, Aeronautics and Transportation Program Directorates
- DLR’s Center of Excellence on SAR (HR, IMF, DFD)
## Institute’s Projects and Research Programs

<table>
<thead>
<tr>
<th>DLR’s programmatic area</th>
<th>Main research theme at the Institute</th>
<th>Resources Allocation</th>
<th>Projects (internal &amp; external)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space</td>
<td>Earth Observation</td>
<td>63%</td>
<td>TerraSAR-X, TanDEM-X, Tandem-L, Sentinel-1, PAZ, TerraSAR-X2</td>
</tr>
<tr>
<td></td>
<td>Reconnaissance and Security</td>
<td>27%</td>
<td>Space-based reconnaissance and security (RSE)</td>
</tr>
<tr>
<td>Aeronautics</td>
<td>Reconnaissance and Security</td>
<td>5%</td>
<td>FaUSST, FFT-2</td>
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<tr>
<td>Transportation</td>
<td>Traffic Monitoring with Radar</td>
<td>5%</td>
<td>VABENE</td>
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Main Project Activities

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</thead>
<tbody>
<tr>
<td>TerraSAR-X</td>
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<td></td>
<td>2009</td>
<td>2010</td>
<td></td>
<td>2011</td>
<td>2012</td>
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<tr>
<td>TanDEM-X</td>
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<tr>
<td>TerraSAR-X2</td>
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<td>2013</td>
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<tr>
<td>Tandem-L</td>
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<tr>
<td>RSE (SAR-Lupe)</td>
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<tr>
<td>Sentinel-1a/b</td>
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<tr>
<td>BIOMASS/CoReH2O</td>
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<tr>
<td>PAZ</td>
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<tr>
<td>Airborne F-SAR</td>
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<tr>
<td>VABENE</td>
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- **Most important current projects:**
  - TerraSAR-X, TanDEM-X, SAR-Lupe and airborne DBF-SAR

- **Most important future projects (depending on approval):**
  - TerraSAR-X2, Tandem-L, SAR-Lupe follow-on
## Scientific Benchmarks

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Value per year</th>
<th>Increase</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average A 2000 – 2005</td>
<td>Average B 2006 – 2010</td>
<td>( \frac{\text{Average B} - \text{Average A}}{\text{Average A}} \times 100 )</td>
</tr>
<tr>
<td>Journal papers</td>
<td>11.8</td>
<td>16.4</td>
<td>39%</td>
</tr>
<tr>
<td>Conference contributions</td>
<td>51</td>
<td>105</td>
<td>107%</td>
</tr>
<tr>
<td>Patents</td>
<td>5.2</td>
<td>6</td>
<td>15%</td>
</tr>
<tr>
<td>Lectures at universities</td>
<td>3</td>
<td>5</td>
<td>58%</td>
</tr>
<tr>
<td>Doctoral thesis</td>
<td>1.7</td>
<td>2.8</td>
<td>65%</td>
</tr>
<tr>
<td>Diploma thesis</td>
<td>7.5</td>
<td>15.2</td>
<td>103%</td>
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</tbody>
</table>
Large Scale Facilities
Large Scale Facilities

F-SAR

TechLab

Compact Test Range

CALIF

Bistatic Signatures

Material Properties

Mechanical Lab
Facilities are available since March 2010

Compact Test Range Facility
TechLab: Compact Test Range
F-SAR: DLR’s Airborne SAR

- E-SAR has been operated by DLR-HR from 1983 until 2009
- The F-SAR was partly operational between 2008 and 2011
- F-SAR has fully replaced the E-SAR beginning of 2012
- F-SAR is operated onboard DLR’s DO228 D-CFFU
### F-SAR technical characteristics

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>C</th>
<th>S</th>
<th>L</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF [GHz]</td>
<td>9.6</td>
<td>5.3</td>
<td>3.2</td>
<td>1.3</td>
<td>0.35</td>
</tr>
<tr>
<td>BW [MHz]</td>
<td>800</td>
<td>400</td>
<td>300</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>PRF [kHz]</td>
<td>up to 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rg res. [m]</td>
<td>0.2</td>
<td>0.4</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Az res. [m]</td>
<td>0.2</td>
<td>0.3</td>
<td>0.35</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>PolSAR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Rg cov [km]</td>
<td>12.5 (at max.bandwith)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sampling</td>
<td>8 Bit real; 1000MHz; 4 channels.</td>
<td></td>
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</tbody>
</table>

### Main Goals:
- Defining the „state-of-the-art“ in SAR sensor technology
- Staying 5-10 years ahead of current spaceborne systems
- New approaches by multispectral & high-resolution PolSAR imaging
Kaufbeuren (Germany)
TerraSAR-X, X-band VV, HRS mode
1.0m x 2.0m resolution

Kaufbeuren (Germany)
F-SAR, X-band quadpol (HH, VV, HV)
0.25m x 0.25m resolution

Simulation of Future Spaceborne Products
Overview of Research and Projects
SAR Evolution in German Space Program

<table>
<thead>
<tr>
<th>Year</th>
<th>NASA Missions</th>
<th>German Satellite Missions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>MRSE</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>SIR-C/X-SAR</td>
<td></td>
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<tr>
<td>1995</td>
<td>SRTM</td>
<td></td>
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<tr>
<td>2000</td>
<td></td>
<td>TerraSAR-X</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>TerraSAR-X2</td>
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<tr>
<td>2010</td>
<td></td>
<td>TanDEM-X</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td>HRWS</td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td>SAR-Lupe</td>
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<tr>
<td></td>
<td></td>
<td>Next Generation</td>
</tr>
</tbody>
</table>

**NASA Missions**
- MRSE
- SIR-C/X-SAR
- SRTM

**German Satellite Missions**
- TerraSAR-X
- TerraSAR-X2
- TanDEM-X
- HRWS
- SAR-Lupe
- Next Generation

**SAR Evolution**
- **SIR-C/X-SAR** (1994) Color Radar
- **SRTM** (2000) Stereo Radar
- **TerraSAR-X** (2007) Radar Zoom
- **TanDEM-X** (2010) Global DEM
Overview of Projects and Research

- **SRTM (NASA/JPL, DLR, ASI)**
  - X-SAR sensor: 40% of the Earth topography (DTED-2)
  - Project leadership, system engineering, mission operations, calibration, scientific coordination

- **TerraSAR-X (DLR, EADS Astrium, Infoterra, GFZ)**
  - First German SAR satellite (X-Band)
  - System engineering, instrument operation, calibration, mission manager, science experiments, TOPSAR demonstr.
  - Start of the operational phase in January 2008

- **TanDEM-X (DLR, EADS Astrium, Infoterra, GFZ)**
  - Global Digital Elevation Model with 2 m height accuracy
  - Mission proposal submitted by the Institute
  - Project leadership for the ground segment
  - Launch on June 21, 2010
  - Start of the operational phase in December 2010
Overview of Projects and Research

- **Sentinel-1**
  - Work package for calibration concept and algorithm development as a sub-contractor of Thales Alenia
  - Member of ESA’s Science Advisory Group
  - Several airborne campaigns for data product simulation

- **ALOS/PALSAR (JAXA)**
  - Member of Carbon and Kyoto Science Team (PI)
  - Participation in the commissioning phase
  - Calibration and measurement of antenna pattern
  - Pol-InSAR product development

- **Tandem-L**
  - Innovative L-band SAR mission for monitoring Earth system dynamics (bio-, geo-, hydro- and cryosphere)
  - Pre-phase A concluded in October 2010
  - Helmholtz Alliance “Remote Sensing and Earth System Dynamics” started in 2012
Overview of Projects and Research

Traffic Monitoring with Radar

- Airborne SAR for traffic monitoring
- TerraSAR-X traffic monitoring and VABENE projects
- Airborne campaigns to provide traffic information in realtime

Airborne SAR – F-SAR

- Multi-Frequency, polarimetric airborne SAR
- Demonstration of tomography and Pol-InSAR campaigns in India (ISRO), Indonesia (ESA), Tunisia (ESA), Sweden (ESA) and Svalbard (ESA), England and TERENO (HGF)

Digital Beamforming

- Antenna beamforming is performed digitally
- Development of new concepts for high-resolution and wide-swath SAR
- Several advantages for future SAR systems
Military Use of Space

Investigation of long term military applications
DLR internal study covering the following topics:
reconnaissance (optical, infrared, hyperspectral, SAR),
communication, navigation, laser, telemedicine,
early warning, SIGINT, SSA, threats, protection

SAR-Lupe and follow-on system

Constellation of SAR satellites for reconnaissance
Scientific and technical consultancy for BMVg/BWB
Development of a reconnaissance mission simulator
for system design, analysis and evaluation

Calibration

TerraSAR-X & TanDEM-X calibration
TerraSAR-X: radiometric stability < 0.5 dB, image
localization accuracy < 0.3 m
TanDEM-X: ca. 30% of DEM data achieve target
performance after first year global acquisition
Overview of Projects and Research

- **Signatures**
  - 2D - Radar Cross Section of Aircraft F10
  - Monostatic and bistatic signatures of targets and clutter in both civil and military scenarios
  - Determination of dielectric properties of materials

- **Radiometry**
  - Line-scanner and aperture synthesis radiometer
  - Sensor and algorithm development for anti-personnel mine detection, personnel screening, through-the-wall imaging, soil moisture

- **HF-TechLab**
  - Microwave Technology Laboratory
  - Compact Test Range Facility, 3 microwave laboratories (radar, radiometry, calibration), 2 measurement chambers (bi-static signatures and material constant measurements)
Summary

- The Institute has a well-established know-how and expertise in passive and active microwave systems.

- Main task: Development of new microwave sensors and spaceborne missions, techniques and sensor-related applications.

- The Institute works closely with the German Space Administration, German industries, responsible ministries and ESA.

- Radar remote sensing from space is a key element of Germany’s space program.

- The Institute is the driving force of the SAR Center of Excellence at DLR.