Small Satellite Mission Program
of the Technische Universität Berlin

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5. Distributed Satellite Systems
6. Applications of Satellite Systems
Major Challenges on Today's Space Technology

OECD report: "Space 2030: Tackling Society's Challenges"
[CORDIS-News, 23.06.2005]

Space technology can be used in particular to tackle five major challenges, according to the report:

1. environmental problems, including natural disasters,
2. the use of natural resources,
3. the increasing mobility of goods and people,
4. growing security threats,
5. and the development of the information society.

It is recommended that governments do three broad things:
• implement a sustainable space infrastructure;
• encourage public use and
• encourage private sector participation.
# Some Operational Earth Observation Systems

<table>
<thead>
<tr>
<th>System</th>
<th>Repeat Time</th>
<th>GSD (VIS und NIR)</th>
<th>Spectral Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDSAT-7</td>
<td>17 days</td>
<td>30 m</td>
<td>VIS, NIR, TIR</td>
</tr>
<tr>
<td>SPOT-4</td>
<td>14 days</td>
<td>20 m</td>
<td>VIS, NIR</td>
</tr>
<tr>
<td>SPOT-5</td>
<td>14 days</td>
<td>5 m</td>
<td>VIS, NIR</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>17 days</td>
<td>30 m</td>
<td>VIS, IR, SAR, hyper-spectral</td>
</tr>
<tr>
<td>Ikonos</td>
<td>12 days</td>
<td>1 m</td>
<td>VIS, NIR</td>
</tr>
<tr>
<td>RADARSAT</td>
<td>10 days</td>
<td>1-5 m</td>
<td>SAR</td>
</tr>
<tr>
<td>Blackbridge (former Rapid Eye)</td>
<td>1 day</td>
<td>1-5 m</td>
<td>VIS, NIR multi-spectral</td>
</tr>
</tbody>
</table>

GSD - ground sampling distance  
VIS - visible  
NIR - near Infra-Red  
IR - Infra-Red  
SAR - Synthetic aperture radar
Status of Operational Earth Observation Service

Many different Space Sensor Systems
• Different Operators and Owners
• for tackling environmental problems including natural disasters:
  • Spectral characteristics and GSD partly suitable
  • Repeating Rate insufficient (mostly)

For tackling environmental problems by use of space technologies:
• The existing space infrastructure is only partly suitable
• increasing repetition rate and dedicated instrumentation are required
• dedicated nano and pico satellite missions can fill the gaps in time coverage and the user needs at affordable costs
Small satellites can be used in particular to tackle environmental problems, including natural disasters.

They can contribute to early warning and monitoring of:

- Floods,
- Vegetation fires,
- Volcanic eruptions,
- Cyclones and storms,
- El Nino,
- Earth quakes,
- Earth slits,
- Oil spills (vessels),
- Environmental pollution,
- Industry- and power plant disasters.

Principle of forest fire detection by the nano-satellite TUBIN of TU Berlin with an infrared bolometer sensor system (planned launch: 2017).
New Opportunities by Nano Satellites and CubeSats

- Inspection and repair of space infrastructure
- Dedicated environment and disaster monitoring missions
- Increase the time coverage or the area coverage of large single Earth remote sensing satellites by supplementation with nano or pico satellites in formation
- Environmental monitoring with high time coverage by satellite formations
- Low-cost missions in science niches
- In-orbit verification of new technologies
- Store and forward communication
New Prospective of Nano Satellite Networks: Swarms for Environmental Monitoring

- Advanced technologies lead to
  - Small and high performance sensors
  - High performance data processing and sensor fusion
- Space based flying sensors can give global information
- Formations and swarms of nano satellites could investigate with different instruments and with a high time coverage different phenomena and effects on Earth
- Nano- and pico-satellites will be capable to fulfil dedicated mission objectives for low cost efforts
Space Technology at TU Berlin in Research and Education

Curricula in space technology

Research: miniaturisation of space technologies

Practice

Education

Theory and “hands-on” education in space robotics

Theory and “hands-on” education in satellite technology

Theory and “hands-on” education in rocket technology
Small Satellite Activities of TU Berlin

The Chair of Space Technology has 4 main fields of expertise:

- Application of space systems
- Distributed space systems
- Small satellite missions
- Miniaturization on unit level: small satellite technologies on ground and for space
Small Satellites Mission Program in the Space Technology Research of TU Berlin

• The Chair of Space Technology at TU Berlin has 4 main fields of expertise (see figure)
• each of the 4 main fields of expertise are sub-structured into 4 to 6 research areas (see picture left. research areas = white areas within the colored main fields).
• The research activities within each research area are based on projects with external funding.
• The research funding sources are different: DLR, DFG, EC Tempus, EC FP7, research institutions, industry.
• They are supplemented by selected university funded research projects.

Space Technology

Miniaturized Space Systems
- Small Satellites
- Planetary Rover
- Sounding Rockets
- Satellite Ground Stations

Distributed Space Systems
- Satellite Constellations
- Satellite Formations and Networks
- Satellite Swarms
- Fractionated and Modular Satellites

Applications of Space Systems
- Data Fusion in Earth Observation
- Data Mining in Earth Observation
- Capacity Building for Earth Observation
- Space-based Early Warning Systems

Component Miniaturization for Small Satellites
- Attitude Control
- Space Sensor Technology
- Component Multifunctionality
- Automation of AIV and Operations
- Satellite Communication
- Satellite Navigation
Miniaturisation of Space Technologies for Small Satellites

Challenges to Nanosats and CubeSats:

- Very limited resources for payload
- Lack of mass, volume, and power for spacecraft components
- Lack of high performance components and sub-systems
- Small surface for solar panels
- Lack of thermal capacity
- Lack of high reliability

Way of TU Berlin for Solution:

- Further miniaturization of components of the satellite’s bus
- Find of innovative solutions with low budget requirements (low mass, low volume, low power consumption) for components
- Reduce the number of components and interfaces
- Find ways for higher degree of Integration of the components
- Integration of bus components in the outer panels as much as possible
Miniaturization on Unit Level: Small Satellite Technologies on Ground and for Space

The research field “miniaturization of space components” and related research areas

<table>
<thead>
<tr>
<th>Research area</th>
<th>Research projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude control</td>
<td>Micro wheel, fluid-dynamic actuator</td>
</tr>
<tr>
<td>Space Sensor Technology</td>
<td>Infrared sensor system for TUBIN mission</td>
</tr>
<tr>
<td>Component Multi-functionality</td>
<td>Multi-functional component integration</td>
</tr>
<tr>
<td>Automation of AIV and Operations</td>
<td>Software-defined TNC for nano-satellite missions</td>
</tr>
<tr>
<td>Satellite Communication</td>
<td>HISPICO, SCOM, S-Net</td>
</tr>
<tr>
<td>Satellite Navigation</td>
<td>PiNaSys</td>
</tr>
</tbody>
</table>
Ways to Reduce the Number of Components and Interfaces

To work on solution for integration several components into one unit like:

- Attitude control components (magnetic coils, other)
- Attitude sensors like sun sensors,
- magnetic field sensor,
- Antennas for communication,
- Components of power supply like solar cells, power regulation units, other

Solar array of BEESAT with integrated Sun sensor

Solar array of BEESAT with integrated Sun Sensor and integrated magnetic coil (3 components into 1 physical unit)
Miniaturisation on Unit Level:
Multi-functional Integration of Satellite Components

Multi-functional integrated side-board of TU Berlin for CubeSats
Small Satellite Missions of TU Berlin

Research areas and related research projects on “Miniaturized Space Systems”:

<table>
<thead>
<tr>
<th>Research area</th>
<th>Research projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Satellites</td>
<td>BEESAT-1 to 4, TUBIN, TECHNOSAT</td>
</tr>
<tr>
<td>Planetary Rover</td>
<td>TUBROB: lab model of a Moon Rover</td>
</tr>
<tr>
<td></td>
<td>SEAR: development model of an Mars rover</td>
</tr>
<tr>
<td>Sounding Rockets</td>
<td>DECAN – DEutsche CAN-Sat Träger-Rakete</td>
</tr>
<tr>
<td>Satellite Ground Stations</td>
<td>Unified UHF/VHF-Ground Station for universities</td>
</tr>
</tbody>
</table>

The research field “Miniaturized Space Systems” and related research areas
# Small Satellite Missions of TU Berlin

<table>
<thead>
<tr>
<th>Launch</th>
<th>Mission</th>
<th>Sat.mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>TUBSAT A</td>
<td>35 kg</td>
</tr>
<tr>
<td>1994</td>
<td>TUBSAT B</td>
<td>40 kg</td>
</tr>
<tr>
<td>1998</td>
<td>TUBSAT N</td>
<td>8 kg</td>
</tr>
<tr>
<td>1998</td>
<td>TUBSAT N1</td>
<td>3 kg</td>
</tr>
<tr>
<td>1999</td>
<td>DLR-TUBSAT</td>
<td>45 kg</td>
</tr>
<tr>
<td>2001</td>
<td>MAROC-TUBSAT</td>
<td>48 kg</td>
</tr>
<tr>
<td>2007</td>
<td>LAPAN-TUBSAT</td>
<td>45 kg</td>
</tr>
<tr>
<td>2009</td>
<td>BEESAT-1</td>
<td>1 kg</td>
</tr>
<tr>
<td>2013</td>
<td>BEESAT-2</td>
<td>1 kg</td>
</tr>
<tr>
<td>2013</td>
<td>BEESAT-3</td>
<td>1 kg</td>
</tr>
</tbody>
</table>

In preparation:

| 2015/16 | BEESAT-4 | 1 kg |
| 2016    | TECHNO SAT| 15 kg|
| 2016    | TUBIN     | 15 kg|
| 2016    | S-NET     | 4 x 8 kg |

Satellites of TU Berlin
BEESAT-4

(Berlin Educational and Experimental SATellite 4)

Mission Objectives
- On-orbit demonstration of a CubeSat precise position determination by GPS signal reception and processing
- Hands-on education of students in satellite design and operations

Launch: I/2016 (T.B.C.)
Orbit: LEO, T.B.C.
Mission duration: 1 year
Mission operations: TU Berlin
Special features: 3-axis stabilisation, single failure tolerant design, camera

Funding: Bundesministerium für Wirtschaft und Technologie

Flight model of BEESAT-4
The TechnoSat Mission

Mission Objectives

- On-orbit demonstration of new small satellite technologies:
  1. A novel fluid dynamic actuator [TU Berlin]
  2. A S-band transmitter [IQ wireless]
  3. Commercial laser retro-reflectors [TU Berlin, GFZ Potsdam, ÖAW, DLR]
  4. The Solar Generator Impact Detector (SOLID) [DLR]
  5. The star tracker STELLA [University of Würzburg]
  6. A new reaction wheel system [TU Berlin]
- Hands-on education of students in satellite design and operations

Launch: I/2016
Orbit: LEO
Mission duration: 1 year
Mission operations: TU Berlin
The TUBIN Mission

- Primary mission objectives are the development and testing of a Earth remote sensing thermal infrared (TIR) payload using a micro-bolometer array and the enhancement of the TUBiX20 nanosatellite bus of TU Berlin.

- Secondary mission objectives are the development and testing of a high performance attitude determination and control system and the analysis of payload data aboard the satellite.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunch Date</td>
<td>2017</td>
</tr>
<tr>
<td>Design Lifetime</td>
<td>1 year</td>
</tr>
<tr>
<td>Mass</td>
<td>15 kg</td>
</tr>
<tr>
<td>Volume</td>
<td>450 × 450 × 300 mm</td>
</tr>
<tr>
<td>Communication</td>
<td>UHF (Platform), S-Band (Payload)</td>
</tr>
<tr>
<td>Attitude Sensors</td>
<td>Two Star Trackers, Fibre-Optic Gyros, Sun Sensors, MEMS Magnetic Field Sensors, MEMS Gyros</td>
</tr>
<tr>
<td>Attitude Actuators</td>
<td>Magnetic Torquers, Reaction Wheels</td>
</tr>
</tbody>
</table>
Distributed Satellite Systems

Research areas and related research projects on “Distributed Space Systems”:

<table>
<thead>
<tr>
<th>Research area</th>
<th>Research projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite Constellations</td>
<td>MicroGEM, NanoGEM, FUSION (completed studies)</td>
</tr>
<tr>
<td>Satellite Formations and Networks</td>
<td>S-NET</td>
</tr>
<tr>
<td>Satellite Swarm</td>
<td>Flying sensors (completed research proposal)</td>
</tr>
<tr>
<td>Fractionated and Modular Satellites</td>
<td>iBOSS - Intelligent Building Blocks for On-Orbit Satellite Servicing</td>
</tr>
</tbody>
</table>

The research field “Distributed Space Systems” and related research areas
4 Options for Distributed Satellite Systems

Formation Flying Satellites
- S-Net

Constellation of Satellite Systems
- MikroGEM, NanoGEM, FUSION

Fractionated Satellite
- iBOSS

Satellite Swarm
- (Research proposal Flying Sensors)


wissenschaftliche Machbarkeitsuntersuchung gefördert durch die Technologiestiftung Berlin

Institute of Aeronautics and Astronautics| Prof. Dr.-Ing. K. Brieß | 10th IAA Symposium 2015
Seite 22
**iBOSS –**

*Intelligent Building Blocks for On-Orbit Satellite Servicing*

**Approach:** Fragmentation of classical, monolithic satellite bus into single, but standardized building blocks

**Challenges:**

1. Development of necessary interfaces for connection of blocks, for transfer of data, power and thermal heat
2. Concepts for implementation of robotic intelligence for modular satellite systems

Courtesy of EnMap.org
Intelligent Building Blocks for On-Orbit Satellite Servicing

Duration: 07/2010 – 08/2012
Partner: RWTH Aachen, FZI Karlsruhe
Funding: by German Space Agency DLR
Status: Successful completion of Phase A
- Development of laboratory models for interfaces
- Simulation of reconfiguration and detection capabilities of a modular satellite architecture
S-NET: S-Band Network for Distributed Nanosatellites
Motivation and Background

Increasing demand on distributed low-cost satellite systems

High performance intersatellite communication shortens response time and increases network performance of distributed systems

Small distributed satellite systems will complement classical monolithic satellite systems
## Mission Overview

<table>
<thead>
<tr>
<th>Mission Objective</th>
<th>On-orbit demonstration of S-band inter-satellite communication within a nano-satellite network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Satellites</td>
<td>4</td>
</tr>
<tr>
<td>Orbit height</td>
<td>&lt; 650 km circular</td>
</tr>
<tr>
<td>Launch Date</td>
<td>Q2 2016 (TBC)</td>
</tr>
<tr>
<td>Design lifetime</td>
<td>1 year</td>
</tr>
<tr>
<td>Mass</td>
<td>&lt; 8 kg (TBC)</td>
</tr>
<tr>
<td>Volume</td>
<td>250 x 250 x 250 mm$^3$</td>
</tr>
<tr>
<td>TM/TC</td>
<td>UHF (nominal): 10 kbps UL / DL</td>
</tr>
<tr>
<td></td>
<td>S-band (experiment): 1 Mbps ISL, DL</td>
</tr>
<tr>
<td>Attitude Control</td>
<td>Three axis stabilization using MEMS sensors and magnetic torquers (momentum wheel optional)</td>
</tr>
<tr>
<td>Payload</td>
<td>S-band transceiver (SLink) for ISL and up/downlink</td>
</tr>
<tr>
<td></td>
<td>Laser reflector for high precision position measurement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DL</th>
<th>Down-Link</th>
<th>TC</th>
<th>Telecommand</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISL</td>
<td>Inter Satellite Link</td>
<td>TM</td>
<td>Tementry</td>
</tr>
<tr>
<td>MEMS</td>
<td>Mieo Electro-Mechanical System</td>
<td>UL</td>
<td>Up-Link</td>
</tr>
<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Applications of Satellite Systems

Research areas and related research projects on “Application of Space Systems”:

<table>
<thead>
<tr>
<th>Research area</th>
<th>Research projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Fusion</td>
<td>MEDEO- Methods and Tools for dual access to the EO databases of the EU and Russia</td>
</tr>
<tr>
<td>Data Mining</td>
<td>POPDAT- Problem-oriented Processing and Database Creation for Ionosphere Exploration</td>
</tr>
<tr>
<td>Capacity Building</td>
<td>GeoNetCast (completed)</td>
</tr>
<tr>
<td>Space-based Early Warning</td>
<td>MicroGEM, NanoGEM (completed)</td>
</tr>
</tbody>
</table>

The research field “Application of Space Systems” and related research areas.
MEDEO- Methods and Tools for dual access to the EO databases of the EU and Russia

Project objectives:

- to improve significantly the joint use of Russian satellite capabilities (i.e. the Resurs DK and Resurs P satellites) and European satellites
- to take full advantage of the possibilities provided by the integration of several datasets in one single application
- to enhance the GMES EO coverage, particularly in areas related to agriculture, forestry, earthquake precursors and arctic regions
MEDEO- Methods and Tools for dual access to the EO databases of the EU and Russia

3 Main tools:

- Resurs converter: to convert "Resurs DK“ and “Resurs P” system images in GEOTIFF or IMG
- Resurs Data Handling Toolbox: to upload data from the MEDEO project website
  http://www.medeo-eu-ru.org/index.php/project-outputs/satellite-imagery-converter
- Resurs Data Collection Web Interface: to upload data products
Many thanks for your attention!