"Automation & Robotics (A&R) within the German Space Program"

On-Orbit Servicing of Satellites (OOS) as a major application field – The TECSAS mission

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IAC 2003, Bremen, Germany
Automation & Robotics (A&R) for Space Applications

Vision

- Sun probes
- Orbital infrastructures, Base in the Langrange point
- Manned Base on the back side of the moon for astronomy
- Unmanned exploration of the “cold” planets, interplanetary bodies and matter
- Unmanned exploration of the “hot” planets
- Manned and unmanned exploration of the Jupiter and its moons
- Mars station

Unmanned exploration of the "hot" planets

Unmanned exploration of the "cold" planets, interplanetary bodies and matter
Automation & Robotics (A&R) for Space Applications

Current and future application areas

A&R for Space Applications in Germany

- Satellite infrastructure
- Inspection
- Maintenance
- Repair

- Exploration of the Solar system
- Operation of interplanetary infrastructure
- Operation of space systems
- Experiment & Crew Support
- O/B autonomy
- Virtual reality
Automation & Robotics (A&R) for Space Applications

Capabilities & Technologies

The necessary capabilities:

- Interplanetary and planetary navigation
- Rendezvous, Capturing, Docking, Berthing
- Material processing, regeneration, handling and storage
- Fast and reliable high data rate communication
- Environment monitoring and control

A&R technologies to provide:

- Advanced man machine interfaces (virtual presence, tele presence)
- Integrated real time system control
- Actuators, manipulators
- Flexible attitude detection and control
- Sensor systems, sensor data processing and sensor data fusion
- Intelligent assessment of the environment
- Integrated database system
Automation & Robotics (A&R) for Space Applications

A changing world - from purely scientific exploration to markets

- The first artificial satellite
- Scientific space probes perambulate the solar system
- Planetary landing missions
- MIR, Skylab, Spacelab, ...
- Disposable satellite infrastructure
- Disposable launchers etc.

- ISS design & build up & beginning utilization
- The first space tourist
- Shuttle & Soyuz missions
- Disposable satellite infrastructure
- “New generation systems” studies
- “Back to the Solar System” studies
- Market & business potential studies etc.

- ISS utilization
- Unmanned maintainable GEO-stations
- On-orbit services infrastructure
- New generation space transportation system & reusable launchers
- Exploration & Exploitation of the Solar System
- Established commercial space markets etc.

past  present  future

Exclusively public funded
Science, technology and prestige driven
Basic research
Business or market considerations negligible
Commercialization only in selected areas and outsourcing

Public + private investments
Science, technology and market driven
Basic + applied research
First PPP’s
Slowly emerging commercial enterprises

Public + private investments
Science, technology and market driven
Basic + applied research
PPP’s dominate purely publicly financed activities
Profitable commercial enterprises provide a variety of services
It still remains a wide area which needs continuing public financing!

Agency up-front investments for:
- Scientific space probes
- Manned space exploration
- New technologies
- “Precursor and pathfinder” measures to facilitate commercialization

Programmatic emphasis

Space activities are more and more evolving from publicly financed to commercial undertakings.
Automation & Robotics (A&R) for Space Applications

From program to projects

- MISSISS Interim Phase
- NEX Study
- VITAL III
- MARCO II
- Beagle Drill
- Artificial hand
- Ultra light weight arm
- De-orbiting study
- Market analysis servicing
- Requirements analysis for extra terrestrial missions

Past activities

- Training/control system for on-board facilities
- A&R Components Qualification
- COF P/L operation preparation, VR
- ISS applications

Present activities

- Unmanned servicing
- Astronaut assistant/associate/surrogate
- Ground control and support
- Servicing

Goals

- E-t-e system engineering & demo-missions
- Market potential analyses and PPP-ventures
- Subsystem & components development
- Studies & support actions

"Reusable" orbital infrastructure
Advanced Ground Control
Missions to the Solar System!
Automation & Robotics (A&R) for Space Applications

Market potential for on-orbit servicing (OOS)

Study to investigate the potential markets for servicing, maintenance, repair etc. of orbital infrastructure elements.

Study statement:

- Description of potential servicing tasks deduced from public interest/responsibilities (e.g. de-orbiting)
- Description of potential servicing tasks deduced from private/industrial interest (re-orbiting, salvage, maintenance, repair, retro-fit, inspection, etc.)
- Assessment of the market potential based on non-cooperative as well as on cooperative satellite design
- Description of international activities in the field of orbital servicing
- Derivation of top level requirements for future satellite design taking into account marketing and business considerations
- Identification of drivers
- Recommendations to public and private actors
- Outline of an global OOS roadmap
Activities wrt On-Orbit Servicing (OOS)

Potential “OOS” Market (2001:High-Level Study I)

JOER G KREISEL
International Consultant

+ UK- and US-Partners

Implementation of Study Recommendations:

• Creation of OOS Community
  Discussion platform, Logo & Website
  (www.on-orbit-servicing.com)
• Focused Follow-On Activities, e.g.
  - SpaceTech: CCP 2003 on OOS
  Delft/DopTech
  - High-Level Study II: “Roadmap & commercial implications”
• International Workshop on OOS (Nov 2002) organized by DLR and CSA
• Next OOS-Workshop in 2004 at CSA, Montreal, Canada
OOS Challenge: System & Business Engineering Solution?

Services Types:
Emergency vs Scheduled
Orbits: GEO, MEO, LEO, SSO...
Satellite Types: T; N; EO; SC...
Customers: Public, Private/Commercial
Boundary Conditions:
Policy, Legal, Regulatory ...

Mission Architecture

Mission Design
Servicing Concepts
Orbital Infrastructure
Servicer
Logistics => Servicer Costs

A&R & Maneuvers

Target Sat

Servicing A&R Servicer
Co-Op Design Target Logistics => Target

Satellite Failures
Servicing Needs
Customer Benefits
Stakeholders
Market Drivers

G/S

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Model: Servicing Baseline

New Sats Launched: 100%

Launch Failure Rate: 5% → Total Loss: 5%

Injection Failure Rate: 5%

On-Orbit: 95%

Early Orbit Failure Rate: 5%

De-Orbiting (E)
Salvage (E)
Repair (E)
Retrofit (E)
Docked Inspection (E)

Remote Inspection (E)

Total Loss or Reduced Performance or Service

End-of-Life Failure Rate: 50%

End-of Life

De-Orbiting (S)
Salvage (S)
Maintenance (S)
Retrofit (S)

Remote Inspection (S)
On-Orbit
Docked Inspection (S)

Extended Life
Upgrade/Performance

On-Orbit: 90%

Total Loss

Recovery

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E: Emergency
S: Scheduled
Questions

Target

Sat Failures

Technical

Probability & Timing

Impact on Sat Mission

Impact on Operator

Value of Service

Service Need?

Servicer & Supply

Service Need

Time, A&R, Design, Orbit, Target ...

Mission Design

Cost

Servicing Concept

Feasibility?

• How to Match these two Major Streams?
• Co-Operative Satellite Design?
• High-Value Public vs ComSat Servicing?
• Servicing Concept?
Overall Potential OOS Market

Summary Servicing Market

OOS is playing in the Infoterra & Galileo Class!

Potential Market of app. 100 Service Events & 0.5-1 bill EUR p.a.
TECSAS TEChnology SAellite for demonstration and verification of a Servicing system

Mission statement:

TECSAS shall demonstrate the availability and advanced maturity of the technologies necessary for:

• Approach and rendezvous
• Inspection fly around
• Formation flight
• Capture
• Stabilization/calibration of the coupled satellite pair
• Flight maneuvers with the coupled satellite pair
• Manipulation of the target satellite
• Active ground control via tele-presence
• Passive ground control during autonomous operations
• Thrust control for disposal or de-orbiting
• De-coupling of the compound
MULTI-PURPOSE ORBITAL BOOST PLATFORM
SPACECRAFT COMPOSITION
**SPACECRAFT ARRANGEMENT ON LAUNCH VEHICLE**

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Mass, kg</th>
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<tbody>
<tr>
<td>Satellite</td>
<td>156</td>
</tr>
<tr>
<td>Boost Propulsion System:</td>
<td>93.00</td>
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<tr>
<td>Boost Propulsion System (dry)</td>
<td>29.00</td>
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<tr>
<td>Propellant</td>
<td>60.00</td>
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<tr>
<td>Separation System</td>
<td>4.00</td>
</tr>
<tr>
<td>Protective Cover</td>
<td>21.00</td>
</tr>
<tr>
<td><strong>UC Total Mass</strong></td>
<td><strong>270.00</strong></td>
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Potential Partners in TECSAS

Agencies:
- Deutsches Zentrum für Luft-und Raumfahrt
- Russian Aviation & Space Agency
- Canadian Space Agency
- Agence spatiale canadienne

Industries:
- European Aeronautic Defense and Space Company
- Babakin Science and Research Space Center
- MD Robotics
- EADS SPACE TRANSPORTATION
- MDRobotics the world’s leading space robotics company
Status:

• Autonomous and automated systems are used in a broad spectrum of applications in production, manufacturing and fabrication.
• In spite of some spectacular successes the utilization of “intelligent” systems in space missions is still in an initial state.
• Commercial oriented missions are in their very beginnings.

Perspective:

The combination of new information technologies, highly integrated “mechatronics”, e.g. advanced actuators or joints, and sensors together with powerful simulation tools will open up a large array of space applications in the future.
Areas of special interest within DLR Space Management

DLR Space Management pursues development of space systems in the application areas:

- Tasks inside and outside of the International Space Station (ISS)
- On-orbit servicing of satellites (OOS)
- Ground operations of space systems
- Exploration of the solar system and other celestial bodies

DLR Space Management puts major emphasis on the enhancement of space system autonomy and the level of automation on the basis of requirements created by the public and the commercial domain for future space utilization!