Mission Control Concepts for Robotic Operations

Existing Approaches and New Solutions

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Overview

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The MICCRO Project: Team & Funding

- MICCRO: Mission Control Concepts for Robotic Operations

- Project Team:
  - VCS AG, Bochum, Germany (Coordinator)
  - DLR Institute of Robotics and Mechatronics, Oberpfaffenhofen, Germany
  - DLR German Space Operations Center (GSOC), Oberpfaffenhofen, Germany

- The MICCRO project is funded by the Space Agency of the German Aerospace Centre (DLR) with federal funds from the Federal Ministry of Economics and Technology in accordance with the parliamentary resolution of the German Parliament (Grant ID 50 RA 1015 and Grant ID 50 RA 1016).
The MICCRO Project:
Objectives, Phasing & Schedule

- **Objective:**
  - Develop a generic mission operation concept for robotic space missions
  - Verify the concept in a prototype implementation for an example mission type

- **Project Duration:** 11/2010 – 10/2012

- **Split into two main phases:**
  - **Phase I: Concept Development**
  - **Phase II: Concept Verification**
    - 05/2011 – 10/2012
Autonomy Concept: Need for Autonomy

- Standard Satellites
- DS Probes
- Formation Flying
- Lander
- Rover
- OOS
- InSitu

Mission Complexity vs. Degree of Autonomy

Technology Innovation
### Autonomy Concept: Autonomy in Space Applications

<table>
<thead>
<tr>
<th><strong>DEGREE</strong></th>
<th><strong>TYPE</strong></th>
<th><strong>MEANS</strong></th>
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<tbody>
<tr>
<td><strong>LEVEL</strong></td>
<td><strong>APPLICATION DOMAIN</strong></td>
<td><strong>TECHNOLOGIES</strong></td>
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<tr>
<td>- ECSS levels E1-E4</td>
<td>- Managing</td>
<td>- Automation</td>
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<tr>
<td>- DAFA levels 0-6</td>
<td>- FDIR</td>
<td>- non- or conditional branching</td>
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<td>- ALFUS (environmental conditions)</td>
<td>- Intelligent Sensing</td>
<td>- time- or event-based</td>
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<td>- ...</td>
<td>- GNC</td>
<td>- Classical control engineering</td>
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<td></td>
<td>- Data Handling</td>
<td>- closed loops, PID,...</td>
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<td></td>
<td>- M&amp;C</td>
<td>- Machine learning</td>
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</tbody>
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- | | - neural networks, fuzzy logic, re-inforcement learning,... |
- | | - Planning, Scheduling |
| | | - STRIPS, MDP, CSP,... |
| | | - ... |
Autonomy Concept: Spinal vs. Cerebral

- Abstracted view on the 3T concept
- Autonomy may be located in
  - the control layer (e.g. smart motor controllers as a spinal function)
  - the deliberative layer (e.g. a re-planning facility as a cerebral function)
- Defines new DEGREE of autonomy
Autonomy Concept:
What makes a ground segment autonomous?
Organization, Roles and Responsibilities: Design Drivers

- How much time do you have to make decisions?
- How much information is needed to make these decisions?
- Does the robotic operation include a real time reaction via telepresence?
- What is the optimal way to cluster or fragment certain areas of responsibilities?
- Does this imply an integrated mission operations team in a single control room or a distributed team at spread locations?
Organization, Roles and Responsibilities: Standard Satellite Missions

- **Project Manager**
  - Space Segment

- **Satellite Team Lead (STL)**

- **MOD**

- **Flight Director**

Split into subsystems and interaction via voice loop is used for most satellite missions.
Organization, Roles and Responsibilities: Robotic Missions

- Project Manager, Space Segment
- Satellite Team Lead (STL)
- Flight Director
- MOD
- AOCS
- Data + Comm + TMTC
- PTS
- UPS
- CMD
- RCS

Strong interaction with other subsystems can be required incl. control!
Organization, Roles and Responsibilities: Control vs. Responsibilities

- Other than the control authority, the responsibilities should be never shifted:
  - Flight Director will always be responsible for the complete system
  - Subsystem operators will always have the responsibility for their subsystems

- This even implies that e.g. the AOCS subsystem engineer is responsible to keep the AOCS deactivated

- The responsibilities between Flight Director and Robotic Operator are similar to the roles of a Space Shuttle commander and pilot:
  - The robotic operator has the control authority on time scales of (milli)seconds
  - The Flight Director is responsible for the overview and general decisions on a time scale of seconds and minutes

- The procedure how to abort robotic operations depends on the situation and phase
  - Interaction with autonomy
Communication Concept: General Constraints

- Financial Constraints:
  - Ground segment with its ground station network
  - Compromise between a higher degree of onboard autonomy or robustness and the number of (costly) ground station contacts

- Political Constraints:
  - For many national security-related missions, the location of the ground segment with its control centre and ground stations is fixed within given countries

- Connectivity:
  - The bandwidth, jitter, latency, reliability of transmission, duration of radio contact, signal propagation time and the protocol influence the connectivity

- Availability:
  - Ground station network and antennas
  - Mission and ground station scheduling

- Security:
  - Encryption support
  - Modification to the ground station are limited to special ground stations run by national services

- Space Segment:
  - Mission specific capabilities
Communication Concept: Robotic Constraints

- Teleoperation or –presence induce needs
- Maximum latency of 500 msecs
- Standard infrastructures are not well suited
- Transfer of information in logical channels, comparable to the services identified by e.g. CCSDS, ECSS
Communication Concept: Visibility & Telepresence

- Using a chain of ground stations the visibility window can be increased for telepresence
- Seamless TM is available
- TC will be interrupted on handover between ground stations
- Powerful planning and scheduling tool need to provide support
User Concept

- For the robotic operation HMI should contain:
  - Virtual/augmented reality display
  - System overview HMI incl. timeline, etc.
  - Video Display
  - Haptic IO devices
  - Assistance system providing e.g. planning information
Concept Verification

- The concept verification prototype will implement an OOS scenario:
  - Spacecraft with integrated robotic arm
  - Challenging requirements in all areas discussed in the project
- For the demonstration all major components will be demonstrated
Conclusion and Outlook

- Future missions involving robotic components as key elements require to develop new common mission control concepts
  - Standards exist but terms are not uniquely defined and used
  - Robotic components need to be integrated with existing infrastructures, also in the future
  - Coupling of the robot with the satellite bus
  - Unique solution for the roles and responsibilities required
  - What is autonomy and what is its benefit?
  - Mission planning as of today is quite mission-specifically implemented

- Communication, user interfaces and autonomy as well as also the more organisational structures need to be adjusted

- Common guideline for the implementation of future robotic mission concepts will be provided within the MICCRO project:
  - Save costs
  - Reuse of the concepts and components across different missions
Questions?