ESA Automation and Robotics 
R&D Overview 

Gianfranco Visentin 
Head, Automation & Robotics Section (TEC-MMA) 
ESA/ESTEC, P.O. Box 299, 2200 AG Noordwijk, The Netherlands 
Tel: +31-71-565-4835, Fax: +31-71-565-5545, 
e-mail: Gianfranco.Visentin@esa.int 
http://robotics.estec.esa.int
Outline:

1. The past
   1. Mission needs
   2. The ESA R&D Philosophy
   3. R&D activities and results
   4. Lessons learned

2. The present
   1. Mission needs
   2. What is being developed

3. The future
   1. Which missions? The trend.
   2. The technology Tree
   3. The vision
   4. How to make it happen

4. Conclusions
1.1 The Past: Missions Needs

ESA missions which (might have) required A&R:

♦ A&R for external or internal applications on Space Stations

♦ S/C servicing applications

♦ Planetary exploration

November 28th 2006
1.2 The Past: ESA R&D philosophy

Goal:
• Break the deadly loop

Recipe:
• Use the little funding available to prepare multi-use “building-blocks”
• Harmonise R&D across European partners (i.e. try to avoid duplication: ESA avoided development of robot arm, dexterous gripper, autonomous rover navigation, robot teleoperation)
1.3 The Past: R&D activities and results (1)

Space Station Applications

- Calibration Platform (RODYM)
- 1st generation Robot Control SW (SPARCO)
- Flexible Ground Control Station (FAMOUS)
- Servo and Power S/S Flight HW (SPEAR)
- 1st generation Robot Control SW and Flight HW (CESAR)
- Ground Station validated in flight (VIABLE)
- Complete demonstrator of microrover application

Planetary Applications

- Microover Ground Control Station
- Microover Hardware
- Microover end-to-end control system
- Imaging System for Rover Control

- MTFF was cancelled
- ERA made use of RODYM
- Robotic EuTEF faded away (no arm)
- MFC do not use common controller
- Marsnet/Intermarsnet did not materialise
- BepiColombo MSR descoped due to budget
1.3 The Past: R&D activities and results (2)

- **ROSETTA Application**
  - Large Corer with care capture mechanism
  - Experimental knowledge in low-temperature drilling
  - Rosetta re-sized (small lander Philae)
  - Experience passed in Philae DS

- **GSV Application**
  - Computer Vision system for GSV
  - Simulator tool for Maneuvering a Servicing Inspection Vehicle
  - Full understanding of GSV RVD
  - GSV did not materialise
  - RVD experience and MIV used in ConeXpress OLEV
1.4 Lesson Learned

Observations:

1. Availability of proven (even flight-ready) technology is no guarantee for use in mission. Project planners will use “exotic” technology only if nothing else works

2. Even already developed technology needed by missions, might be re-developed due to geographical /industrial constraints

3. Harmonisation not always works
   - Harmonised items come with too many strings
   - ExoMars will use CNES navigation
   - No-robot, no-robotised EuTEF

Conclusions for planning R&D:

- Do not follow too much project needs as it does not pay. Follow the general application.
- Do not go for the full qualification, unless it is for a multi-application product
- Foster technology across boundaries to decrease the geographical risk
- Secure non-ESA harmonised items with firm agreement
2.1 The present: Missions needs

Current ESA missions which use A&R are:

🔹 A&R for external or internal applications
  - MFC Facilities
  - Foton M2 & M3
  - ERA
  - EUROBOT

🔹 S/C servicing applications
  - ConeXpress OLEV (Phase B)

🔹 Planetary exploration
  - EXOMARS (Phase A/B)
  - ROSETTA
2.2 The present: What is being developed (1)

- Testbed for ISS External Robot System (Session 1.1)
  - CESAR control s/w
  - Interactive autonomy ground control
- Lightweight Dextrous Arm (Session 2.2.2)
  - Compact autom. tool exch. device (Session 2.2.2)
  - Compact low-power imaging head
  - Coord. control of mult. arms
  - Vision-based manipul (Session 2.2.2)
  - COTS-based o/b controller h/w (Session 2.2.2)
  - Extens. of stand. o/b contr. s/w (Session 2.2.2)
- ISS Ext. Robot System (Eurobot)
  - Robust tactile sensors
  - Local r/t image processing
  - Bi-arm telemanipulation
  - Control of Multi-finger hands
  - Bi-arm telemanipulation
  - Robust tactile sensors
- Vision-based manipul (Session 2.2.2)
  - COTS-based o/b controller h/w (Session 2.2.2)
- Telemanipul. from ground (Session 3.1.2)
2.2 The present: What is being developed (2)

- Mars geochem. micro rover “Nanokhed”
- E2E control system for Nanokhed
- Mobile drill package prototype
- Integr. of Mercury micro rover system (Session 2.3.2)
- Mercury Micro Rover (BepiColombo)
- Mars geochemistry Micro Rover (Aurora)
- Mars exobiology missions (e.g. Aurora)
- Highly integr. mobile drill station
- Micro rover for mob. drill station
- 13.1 Field tests of micro rover operations (600 k)
- Nanokhed adapt. for Mercury

Time
2.2 The present: What is being developed (3)

- 6.2 O/B controller h/w design for extreme temp., radiation toler.
- 6.3 Extreme mass + power reduction for o/b controller h/w
- 4.3 Compact low-power imaging heads
- 4.2 Local real-time image processing

- Semi-autonomous rover control s/w for regional Mars rover
- Regional Mars rover for scouting and sample collection
- Simulator + Testbed for Regional Rover (Exhibit Session)
- Mars exploration mission (Aurora)
3.1 The Future: Which Missions?

- Difficult to say. In general we can say that future space missions will use:
  - **Robot Assistants**: helping Astronauts to perform their task quicker, safer, with higher quality and more economically.
  - **Robot Agents**: working into hostile and dangerous areas and acting in place of humans to perform assembly, maintenance and production tasks in tele-operated or semi-autonomous way
  - **Robot Explorers**: venturing in the hostile and remote environments for exploration and science. Coping with and taking advantage of the peculiar environmental conditions to achieve long duration and extensive range missions.
3.2 The Future: The Technology Tree

A Applications and Concepts

A&I Planetary Exploration

B Automation & Robotics Systems

Manipulation Systems

Orbital Systems

C A&R Components and tech.

Control, Autonomy and Intelligence

Motion and Actuation

Robot-User Interfacing

Robot Ground Testing

III Payload Automation Systems

II Mobility Systems

I Perception

II Control, Autonomy and Intelligence

IIII Motion and Actuation

IV Robot-User Interfacing
### 3.3 The Future: ESA Vision (1)

#### Robot Assistants:

<table>
<thead>
<tr>
<th>Planetary Applications: Moon crew support</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-I</td>
</tr>
<tr>
<td>B-I</td>
</tr>
<tr>
<td>B-II</td>
</tr>
<tr>
<td>C-I</td>
</tr>
<tr>
<td>C-II</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orbital Applications: crew support Eurobot-like on Space Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-II</td>
</tr>
<tr>
<td>B-I</td>
</tr>
<tr>
<td>C-I</td>
</tr>
<tr>
<td>C-II</td>
</tr>
</tbody>
</table>

A-I | 2 arm manipulator with crane torso |
B-I | 6 wheels heavy-duty articulated chassis (ExoMars derived) or 6 legs chassis |

B-II | 6 wheels heavy-duty articulated chassis (ExoMars derived) or 6 legs chassis |

C-I | Need for detection and tracking of humans |
C-II | Semi-autonomous control with teach-in capacity |
C-III | Need for high-efficiency powerful locomotion drives |
C-IV | Language based interfacing |
C-V | Need large size testing facility |

C-I | Need for detection and tracking of humans |
C-II | Semi-autonomous control with teach-in capacity |
C-III | No extra development w.r.t Eurobot |
C-IV | Language based interfacing |
C-V | No extra development w.r.t Eurobot |
### 3.3 The Future: ESA Vision (2)

**Robot Agents:**

<table>
<thead>
<tr>
<th>A-I</th>
<th>Planetary Applications: Exploration of Moon pole craters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B-I sampling arm</td>
</tr>
<tr>
<td></td>
<td>B-II climbing/rappelling capable chassis / robot crew (ARAMIES based?)</td>
</tr>
</tbody>
</table>

| C-I | Need for low energy perception in the dark |
| C-II| Need for supervisory teleoperation with LOS autonomy |
| C-III| Need for high-efficiency/low-temp. drives |
| C-IV| Need for predictive dynamic simulator |
| C-V | Need large size testing facility |

<table>
<thead>
<tr>
<th>A-II</th>
<th>Orbital Applications: Eurobot-like servicer on GEO satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B-I 2 arm manipulator mounted on large arm or 3 arm manipulator with scaffold</td>
</tr>
</tbody>
</table>

| C-I | No special needs |
| C-II| Need for coordinated AOCS-satellite control |
| C-III| Need for highly dexterous end-effectors |
| C-IV| Need for haptic (exoskeleton) manipulation with predictive dynamics |
| C-V | No special development w.r.t Eurobot |
3.3 The Future: ESA Vision (3)

**Robot Explorers:**

**A-I** Planetary Applications: Sample Return from Mars

- **B-I** sampling arm
- **B-II** 6 wheels long range articulated chassis (ExoMars derived)

**C-I** Need for low energy perception in the dark
**C-II** Need for more autonomous control than ExoMars
**C-III** No new technology w.r.t ExoMars
**C-IV** No new technology w.r.t ExoMars
**C-V** Need of large size testing facility

**A-II** Orbital Applications: Autonomous Opportunistic Science Probes

- **B-III** Automation system for on-board processing of science data (similar to ESA Aerobot project)

**C-I** Possibly need for specialised event triggering detectors
**C-II** Need for autonomous science processing
**C-III** Not applicable
**C-IV** Not applicable
**C-V** Not applicable
3.3 The Future: ESA Vision (4)

Robot Explorers:

A-I Planetary Applications: Aerobot Mission Study
   B-II Balloon/ Motorglider/ Microprobes/ Rotary Decelerators

C-I Not applicable
C-II Need for autonomous navigation and resource management
C-III Not Applicable
C-IV Not Applicable
C-V Not Applicable

A-I Planetary Applications: Deep Underground Explorers
   B-II Mole/Subsurface Explorer

C-I Not applicable
C-II Not applicable
C-III Full implementation of chip removal system and tether
C-IV Not applicable
C-V Not applicable
3.4 How to make it happen (1)

FUNDING SOURCES for A&R R&D:

- ESA
  - GSP, TRP, GSTP, CTP, ASTE, ARTES
  - Project specific developments
- National Agencies
  (ASI,CNES,DLR,PPARC,BSNC)
- The EU
  - indirectly through FP until FP6
  - Directly with FP7 through the priorities identified by the technology platforms:
    - ESTP
    - EUROP

PROBLEMS in ESA R&D:

- “Space only” A&R
- Breadth: not all R&D fields needed by space can be pursued (lack of funds)
- Depth: subjects that require upfront research have to be discarded (rigid funding scheme)
- Time span: no long term research and no product development from lab proven technology
3.4 How to make it happen (2)

The SOLUTION

ESA sees the different Space related platforms as ideal complement of ESA’s activities to:

- Enlarge the breadth of R&D in Space A&R (EUROP)
- Provide upfront R&D (EUROP)
- Allow R&D to turn into products (ESTP) for strategic independence

The ESA Harmonisation process is again proposed as a means to achieve:

- Co-ordination with National Agencies (institutional)
- Co-ordination with EUROP for possible co-funded EU-ESA activities
- Steer ESTP towards funding of robotics components
4. Conclusions

Lots of technology being prepared at the moment, however this could still improve as not much is done

A Harmonisation Exercise will take place on February 14-15, 2007.

ESA will propose the development of technology supporting our vision:

• In agreement with National Agencies and Industry
• promoting co-funding with EUROP
• Using the possibilities offered by ESTP
THANK YOU