ROBOTIC PROGRAMMES AND APPLICATIONS AT ESA: PRESENT AND PERSPECTIVES

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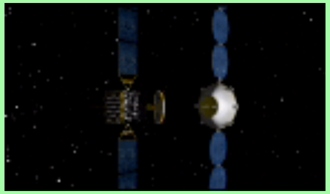
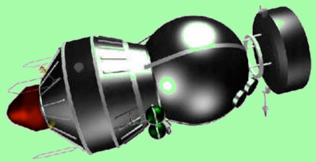
Overview

- **Missions: Orbital Robotics**

EUROBOT



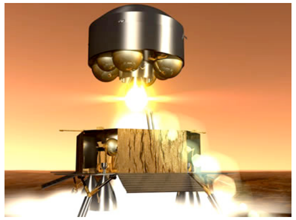
ConeXpress OLEV



Foton M2 & M3

- **Missions: Planetary Robotics**

EXOMARS (Phase B2)



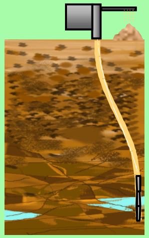
Mars Sample Return

- **Technology: R&D**

Aerobots

Innovative Mobility

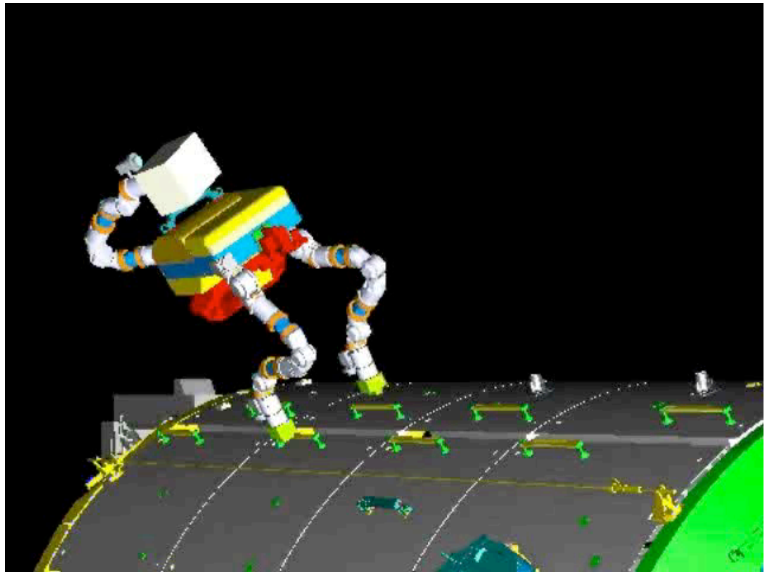
Microrover for Mercury



Underground Mobility

EUROBOT (1)

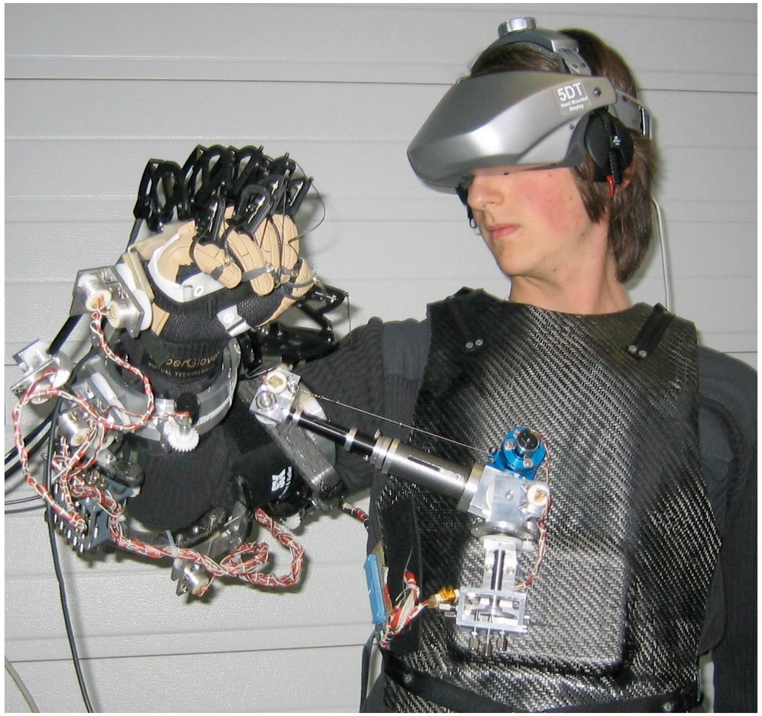
- **EUROBOT goal:**
  - ⇨ Reduce amount of crew time required for ISS external maintenance
  - ⇨ Reduce EVA duration and number of sortie
- **HOW?:**
  - ⇨ EVA Worksite preparation and clear-out
  - ⇨ Cooperation with EVA (1 EVA less)
  - ⇨ EVA replacement for
    - ✧ ORU exchange
    - ✧ Inspection / Servicing / Maintenance



Animation of EUROBOT transporting and installing an ORU on ESA's COLUMBUS

EUROBOT (2)

- EUROBOT Modes:
  - ⇨ AUTONOMOUS: for routine/structured tasks as:
    - ✧ Deployment, transfer and transport
    - ✧ Worksite preparation
    - ✧ ORU exchange
  - ⇨ MANUAL:
    - ✧ Unstructured tasks
    - ✧ Contingency
    - ✧ EVA support

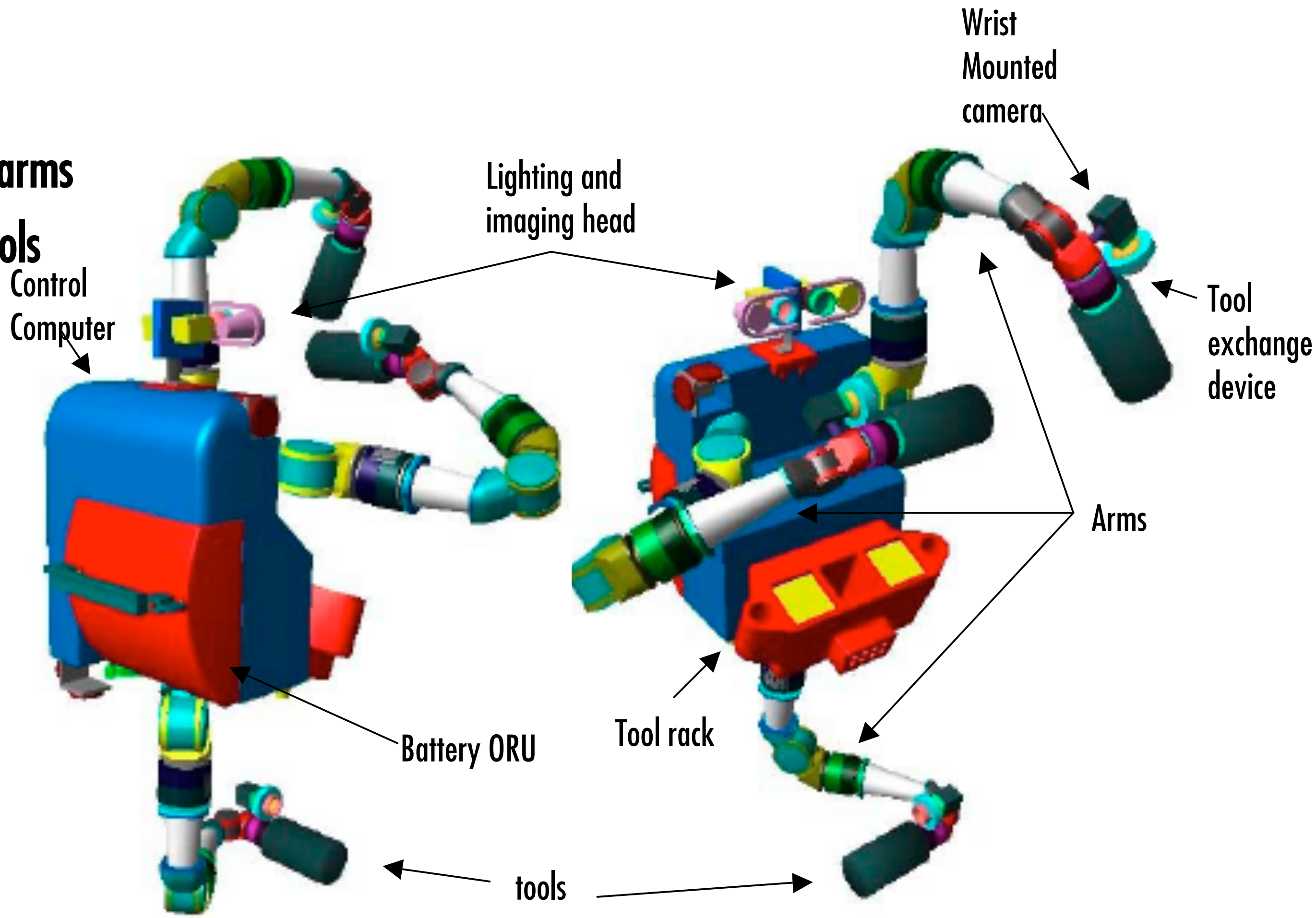


Teleoperation vest to command EUROBOT in manual mode

EUROBOT (3)

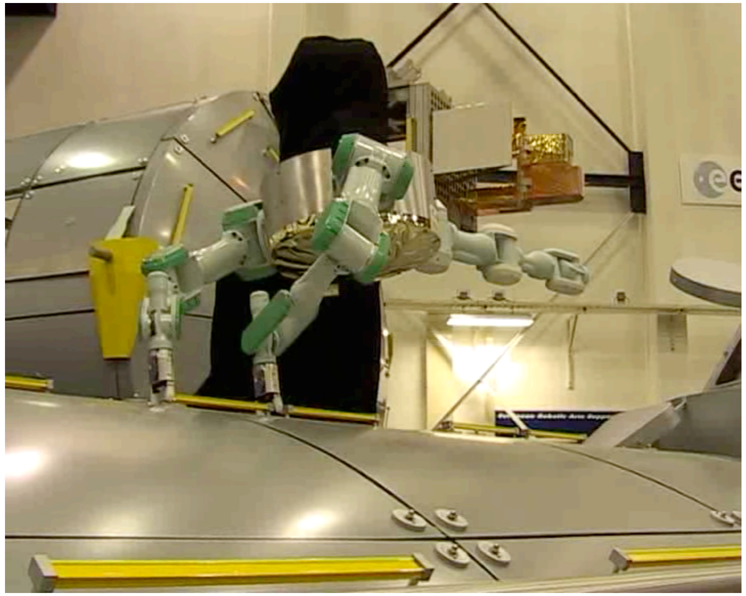
EUROBOT Structure

- ☐ 3 identical 7dof arms
- ☐ Exchangeable tools
- ☐ Tool rack
- ☐ Battery ORU

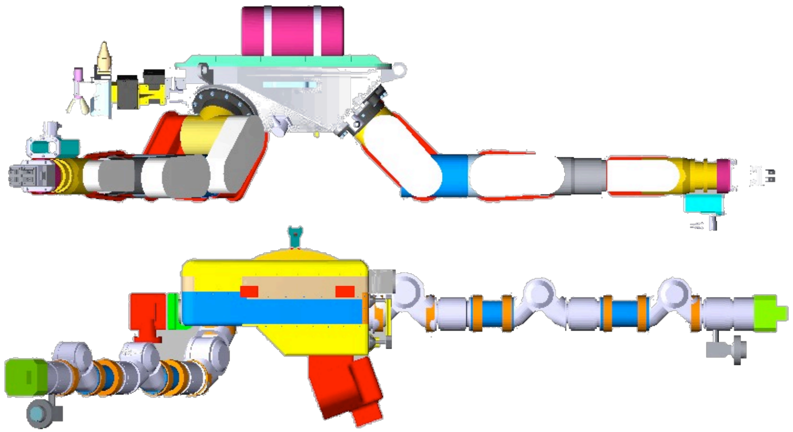


EUROBOT (4)

- The EUROBOT project before entering phase-B will now concentrate on technology and demonstration of operational aspects
- A functional WET model is being procured to be operated at ESA's neutral buoyancy facility at the Astronaut Training Centre in Cologne
- A functional demonstrator is operational at ESA's A&R Laboratories



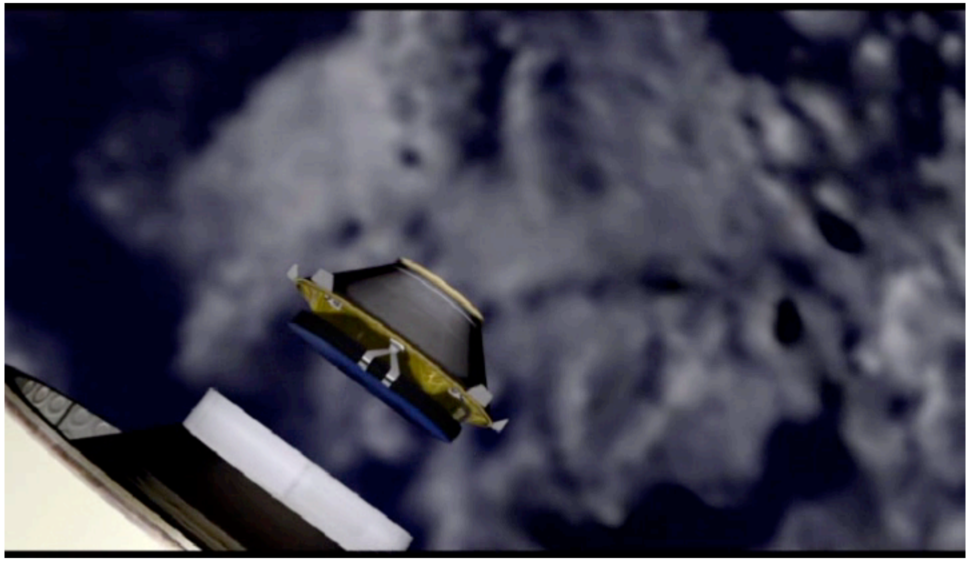
EUROBOT demonstrator at ESA's A&R labs



CAD drawings of EUROBOT (bottom), as studied by ALENIA and its WET model (top) currently in development

CNX-OLEV (1)

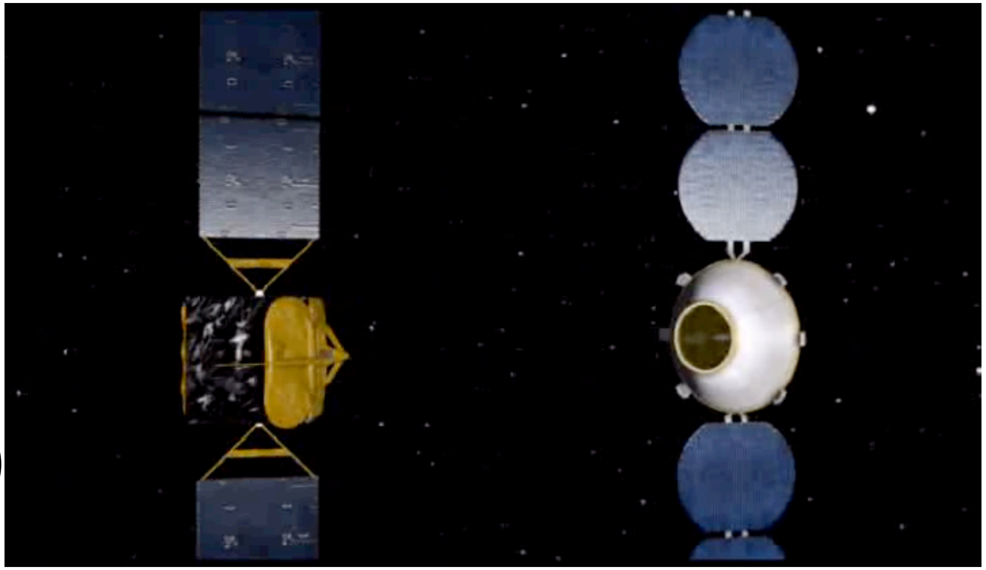
- ConeXpress (CNX) Orbital Life Extension Vehicle (OLEV): to provide a fuel-depleted GEO telecom satellite with 5+ more years of operational life.
- Commercially operated by Orbital Recovery Ltd. Developed by Dutchspace on ESA contract
- CNX can launch with EVERY Ariane 5 using its excess lift capacity as it replaces the payload adapter cone
- CNX-OLEV uses ion propulsion (SMART-1 derivative) to reach GEO (<200 days)
- CNX-OLEV carries a docking payload (DLR provided) to attach itself to the customer satellite



Animation of the deployment of CNX (credits Dutchspace)

CNX-OLEV (2)

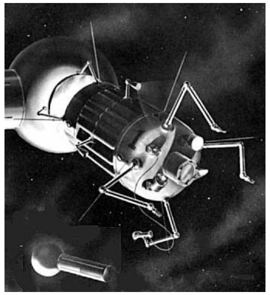
- CNX-OLEV (PDR baseline) uses GPS to drift along GEO and to enter target's orbital slot
- Medium range camera is then used to approach the target satellite
- A close-up stereo camera pair is used to drive the DLR satellite capture tool (SCT) into the AKM nozzle
- Once into the AKM, further insertion is controlled via laser distance sensor in the DLR-SCT



Animation of CNX-OLEV docking to a customer satellite (credits Dutchspace)

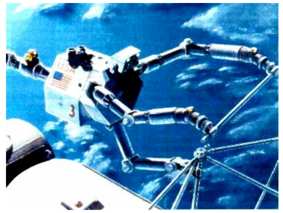
CNX-OLEV (3)

- After many years of proposed On-Orbit Servicing concepts, finally one endorsed by non-robotics space entities
- What made the difference:
  - ⇨ Real application with fairly solid business case
  - ⇨ No tech-frills: CX-OLEV is designed to do just one operation with the technology ready available for that.
  - ⇨ Clever platform allows to cut launch costs (2nd largest element) to acceptable levels

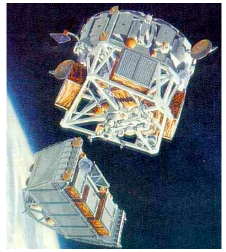


Lockheed space tug (1963), credits Lockheed

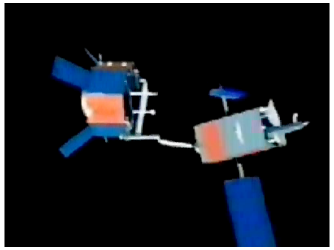
NASA's OMV (1984), c. NASA



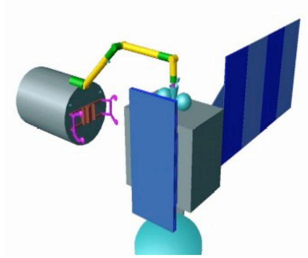
NASA's FTS (1987), c. NASA



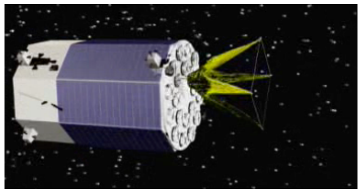
NASA's Robotic Satellite Servicer (1990) c. NASA



ESA's GSV (1992)



DLR's ESS (1994),c. DLR

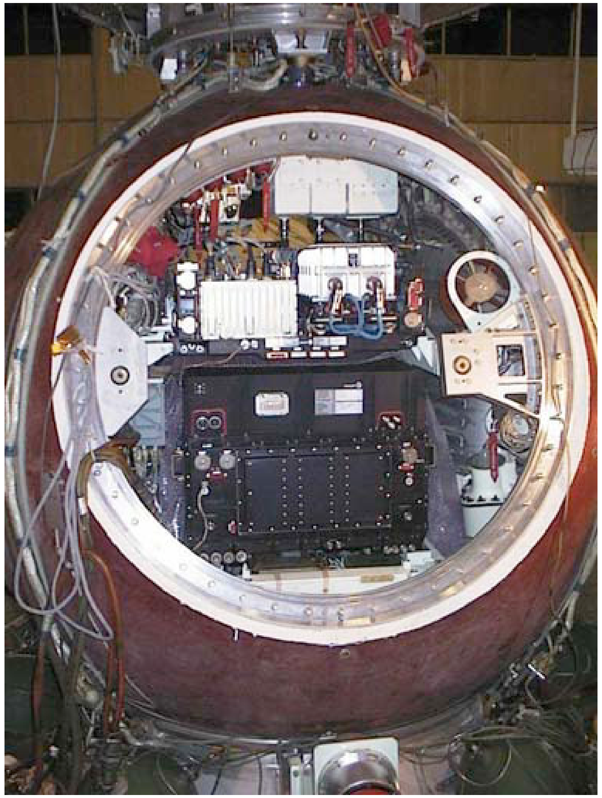


ESA's ROGER (2002)

CRL's OMS (2002), c. CRL

FOTON M2 & M3 (1)

- A&R in low-Earth orbit serves primarily microgravity investigation
- FOTON is an unmanned spacecraft for microgravity investigation
- The Telescience Support Unit (TSU) allows:
  - ⇨ autonomous control of experiments (including RT closed-loop control with video processing)
  - ⇨ Video/data compression and storage



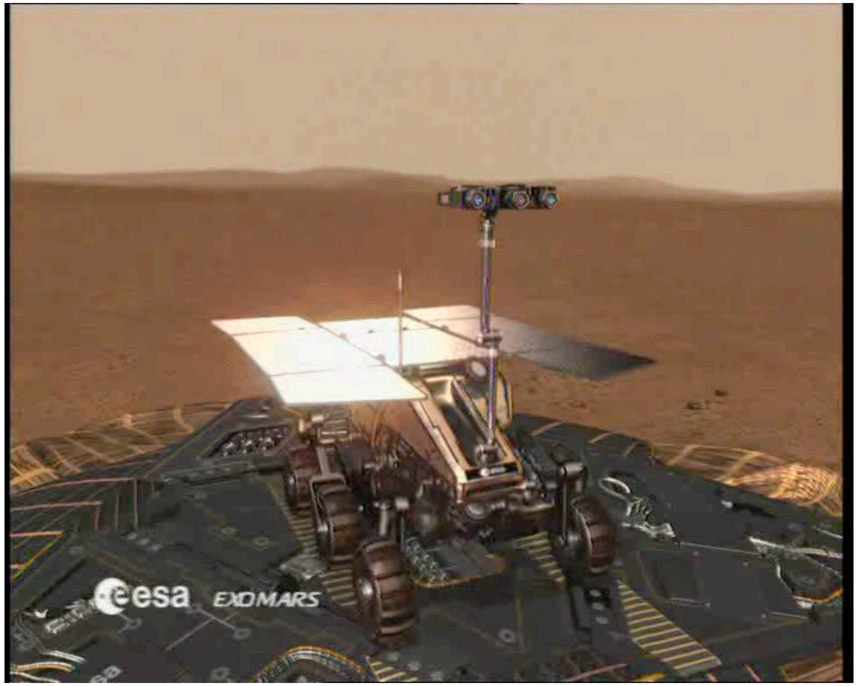
FOTON spacecraft during integration. The "ball" hosts microgravity experiments and the Telescience Support Unit (silver box in the top part)

FOTON M2 & M3 (2)

- M2 mission flew successfully on 31 May 2005, housing a payload complement of 39 experiments in physical sciences, biology, fluid physics, exobiology, materials science and technology
- The Foton M3 Mission is currently scheduled for launch in October 2006

ExoMars (1)

- To be launched in 2011
- features
  - ⇨ a descent module
  - ⇨ a large (~120 kg), high-mobility 6-wheels rover
  - ⇨ A rover-mounted Exobiology / Geochemistry payload
  - ⇨ A deep drill (2m)
- Starting Phase B1 now
- Paper in session 2A



Animation of the ExoMars rover deployment

ExoMars (2)

- Phase B1 will breadboard several critical elements of ExoMars
- Most notably the locomotion and navigation systems
- A preliminary breadboarding activity has produced a Demonstrator of the sought chassis capabilities
- The Demonstrator integrates the CNES navigation software

The ExoMars Demonstration Rover at ESA's robotics labs

Mars Sample Return (1)

An International Mars Sample Return Mission has been tabled at recent International Meetings on Mars Exploration

Our assumptions on the mission (needed to start working while the concept still in the making):

- ☐ Mobility is highly desirable but not essential to acquire samples
- ☐ International cooperation implies that:
  - ⇨ Mission leader requires to have complete control of all the elements that guarantee mission success
  - ⇨ Mission partners provide added value to the mission without compromising mission success (in case of failure or withdrawal)

Mars Sample Return (2)

- The ExoMars rover development constitutes an important investment for ESA which is a step in the development of exploration capabilities
- Re-using skills and hardware developed by the ExoMars project is part of a stepped approach. MSR is the best fit for such re-use
- Hence ESA aims at providing a so called Sample Fetching Rover (SFR) for MSR which will collect and carry “far samples” to a NASA MAV/lander (also assumed to have independent sample collection ability)

Mars Sample Return (3)

- SFR will be an evolution of the ExoMars rover
- SFR, will require a longer range in combination with shorter duration of surface operations (hence higher average speed, hence higher locomotion speed and/or higher level of navigation autonomy)
- Compared to the ExoMars Rover, which will transmit results of scientific analysis to Earth, an unrecoverable loss of mobility for SRF means loss of the collected samples on-board and inability to complete the (ESA) mission. Hence higher locomotion performance will be needed

Technology R&D

Besides the technology being readied to support approved projects, we are trying to prepare for future missions which:

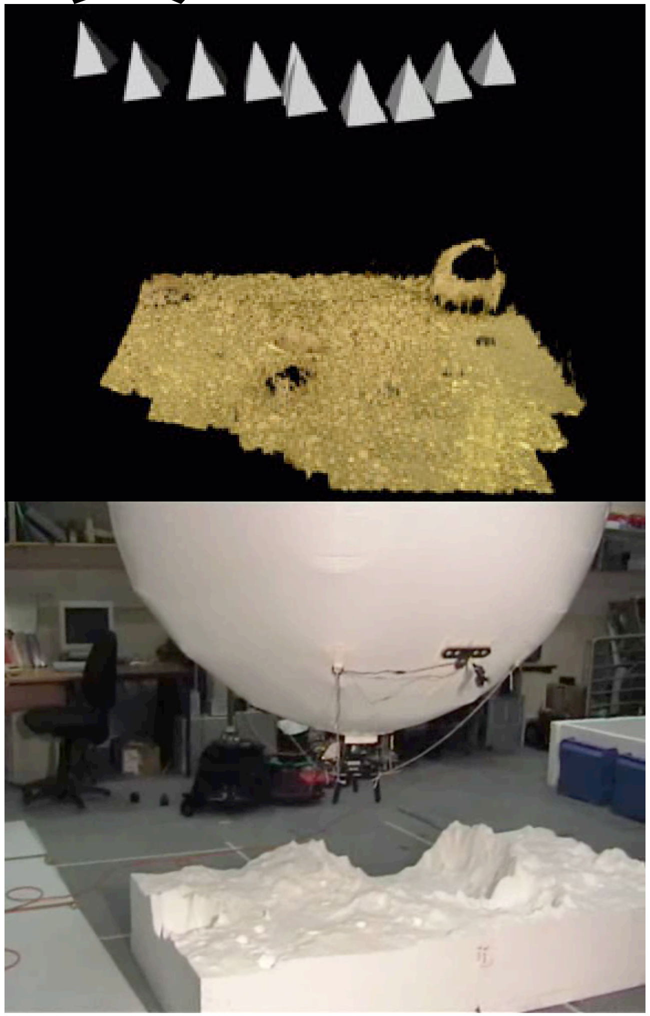
- ☐ Will make use of intelligent aerial platforms (Aerobots)
- ☐ Will try to access the really difficult but very interesting places on the surface of Mars (Advanced Mobility)
- ☐ Will work on very harsh environments with very small resources
- ☐ Will go deeper than ever below the Martian surface to reach secluded bodies of water/ice

Aerobots (1)

- The proposed mission Venus Entry Probe aims in-situ exploration of the atmosphere of Venus. It features a long duration balloon free drifting in the middle/top cloud layers of Venus.
- The balloon will release a swarm of about 15 microprobes (120 g each) which will relay atmospheric data back to the balloon during their plunge.
- Reliable localization and data transfer from the microprobes to the aerobot is the subject of an ESA R&D activity (see section 10b)

Aerobots (2)

- Several long range balloon /montgolfiere missions have been proposed for Mars
- Accurate, continuous localisation is one of their problems
- ESA has been developing an Imaging and Localisation Package (ILP) to manage the acquisition /storage of pictures and to provide localisation based on pictures
- Presentations (2) in session 10b



Aerobots (3)

ESA is developing technology for the realisation of continuous powered flight on Mars

The project named SkySailor aims at the development of a small solar powered motor-glider.

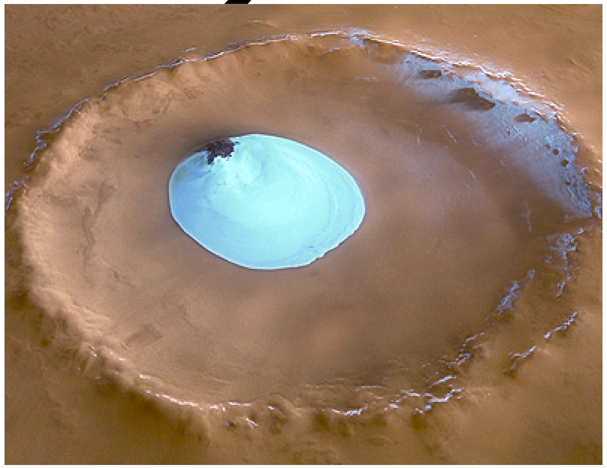
The project, run by EPFL (CH), has produced an ultra lightweight prototype (3.2 m wingspan, ~3 kg) that integrates:

- RWE-32 cells in the wings
- Lithium-ion batteries (1.145 Kg, 7.5 Ah)
- Integrated avionics and sensor (140 g, < 4 W)
- Propulsion motor and servos

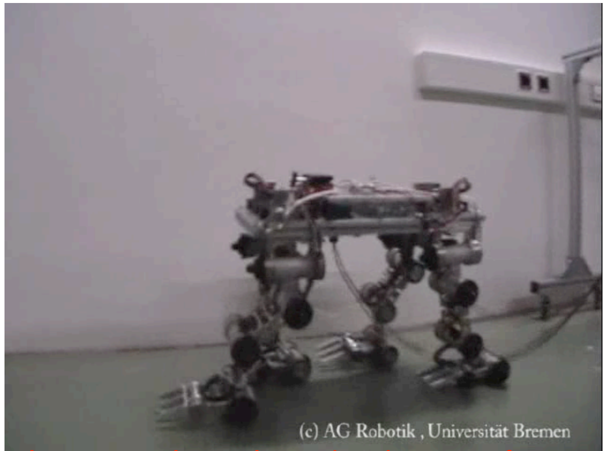
The SKYSAILOR Aerobot (credits ESA/Ecole Polytechnique Fédérale de Lausanne)

Alternative Mobility

- Orbital imaging of the Martian surface show that water resources and water-rich material are concentrated near cliff bases, bottom of craters
- Conventional wheeled mobility does not allow to access these places
- ESA with DLR are investigating alternative locomotion principles inspired by nature
- See presentation in session 6a



HRSC on ESA's Mars Express, Credits ESA/DLR/FU Berlin (G. Neukum)

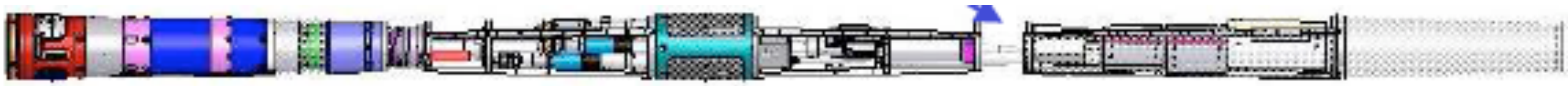


The ARAMIES robot (credits ESA/DLR/University of Bremen)

Underground Access

- Multi stem drills (as for ExoMars, see session 2a) work for shallow depths, however for reaching deeper they present problems that are too difficult to solve within the constraint of space missions.
- Drills of this type require a cumulated length of drill pipes as long as the depth reached,which translates into a large mass allocated to drill pipes.
- Alternatively Subsurface Explorers or Moles can be used as deep drills. These systems eliminate the rigid connection between the surface and the drilling head by allowing the latter to move independently.
- See presentation in session 4a

Assembly drawing of the Guided Mole Demonstrator (credits ESA/Tecnomare/CISAS)



Micro Robots for Harsh Environment

- Since many years ESA has pursued the development of a robotised Geochemistry Instrument Package Facility for small landers in harsh environment
- The package, based on the Nanokhod micro rover, has now reached the final stage of maturity
- A paper in session 2a illustrates the latest developments

The Nanokhod microrobot performing a turn by shunting

Conclusions

- EUROBOT, despite its usefulness and proven technical feasibility will have to wait better budget conditions
- The European Robot Arm (ERA) will be launched in 2007 on-board the Russian MLM
- ConeXpress-OLEV is a truly groundbreaking mission which hopefully will fly in 2008
- ExoMars is becoming a reality. We look forward to a positive decision on its budget to be made in December
- We also look forward to a inter-Agency negotiations to start up an International Mars Sample Return mission
- Technology R&D continues, however missions presently planned do not intend to make use of the most innovative technology at least until 2016