Journées du GDR Robotique

10th November 2010, CNRS-Paris

Overview of Space Robotics at ESA

Luc Joudrier,

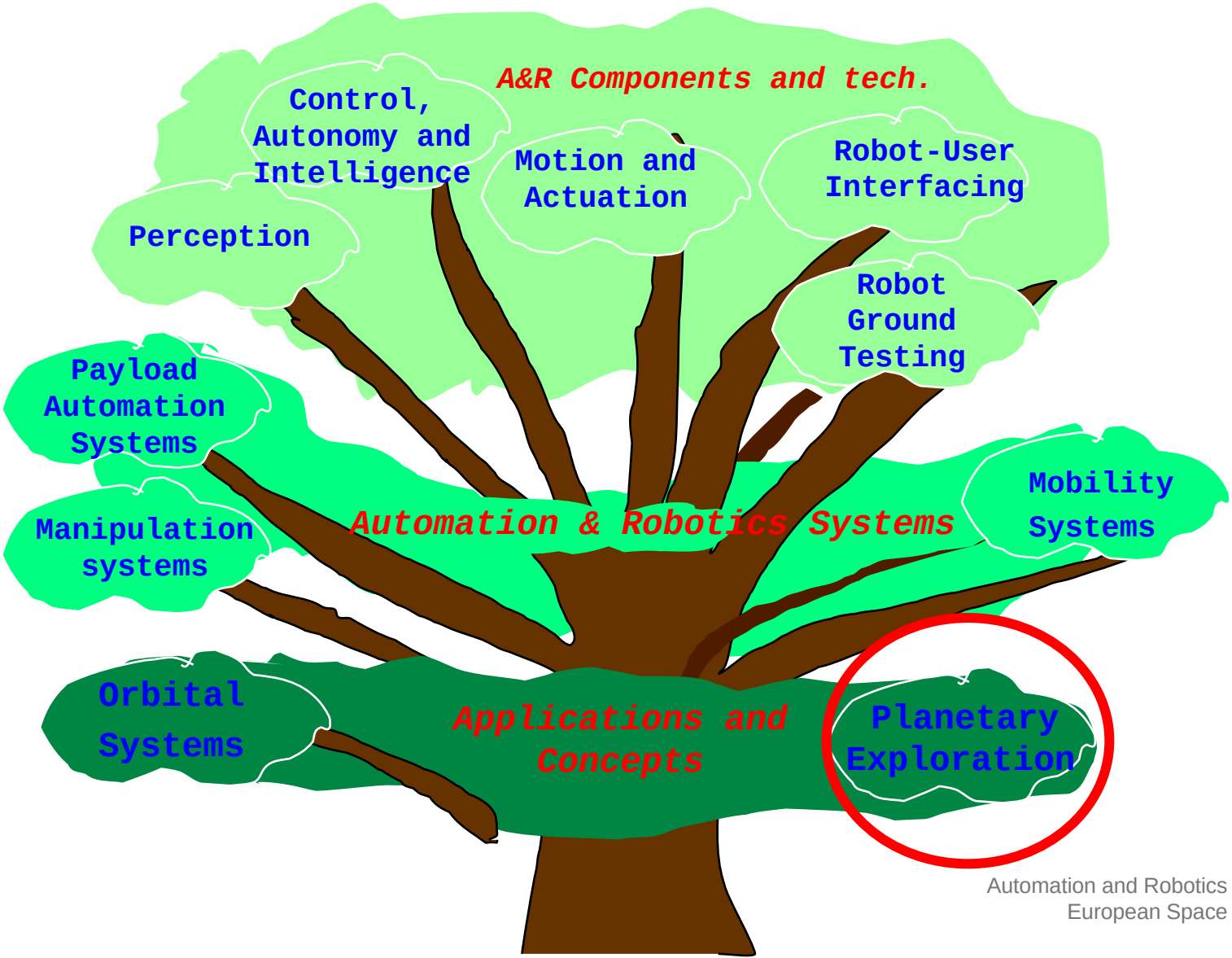
Automation and Robotics Section

ESA/ESTEC

Outline

After an introduction of Robotics section R&D activities at ESTEC, the presentation aims at showing through examples, how the R&D activities are reused into space robotic projects with specific focus on Planetary Exploration Missions like ExoMars.

Research and Development
Automation & Robotics Technology Tree

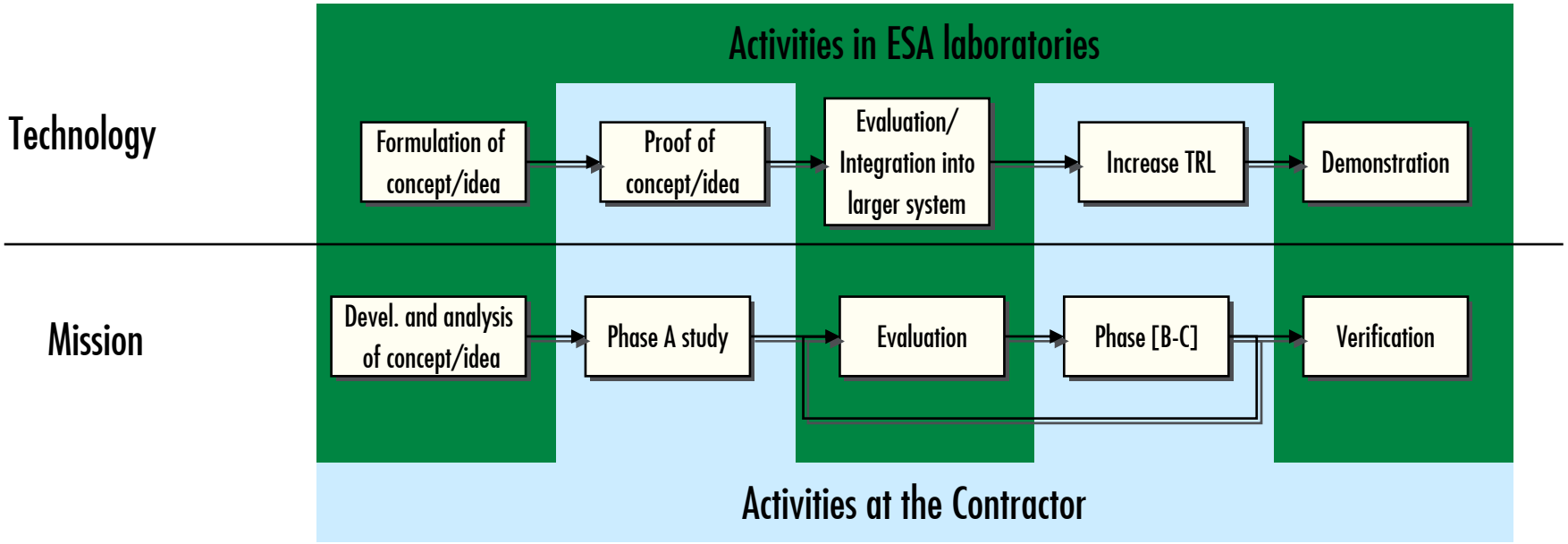


Role of ESA and Robotics Section

ESA is a procurement agency with the mission to support the development of European space activities.

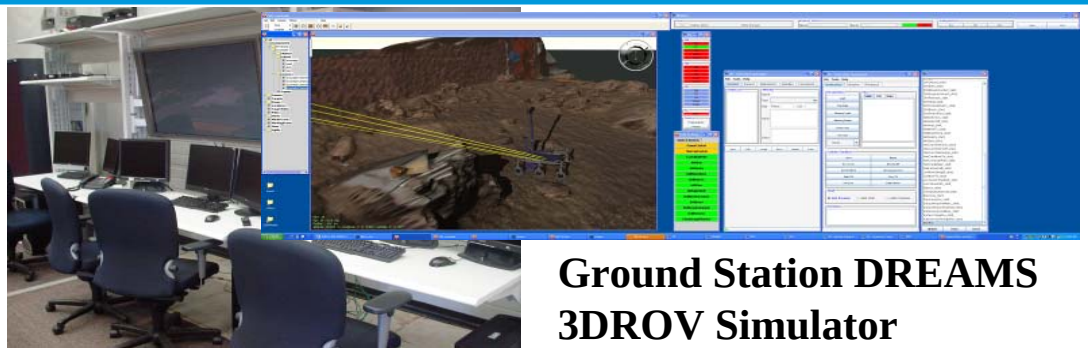
Robotics section terms of reference:

- Increasing the Technology Readiness Levels (TRL >= 5) of technologies necessary for future missions.
- Provide independent technical assessments
- Support to projects from the concept definition phase



ESTEC A&R Lab
for Planetary Exploration

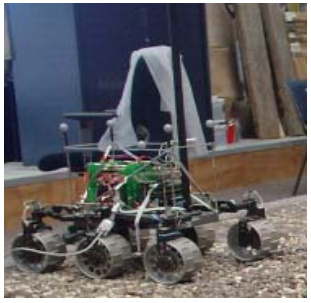
RIEGL scanner



Ground Station DREAMS 3DROV Simulator

Terrain 9*9m

VICON Motion Tracking



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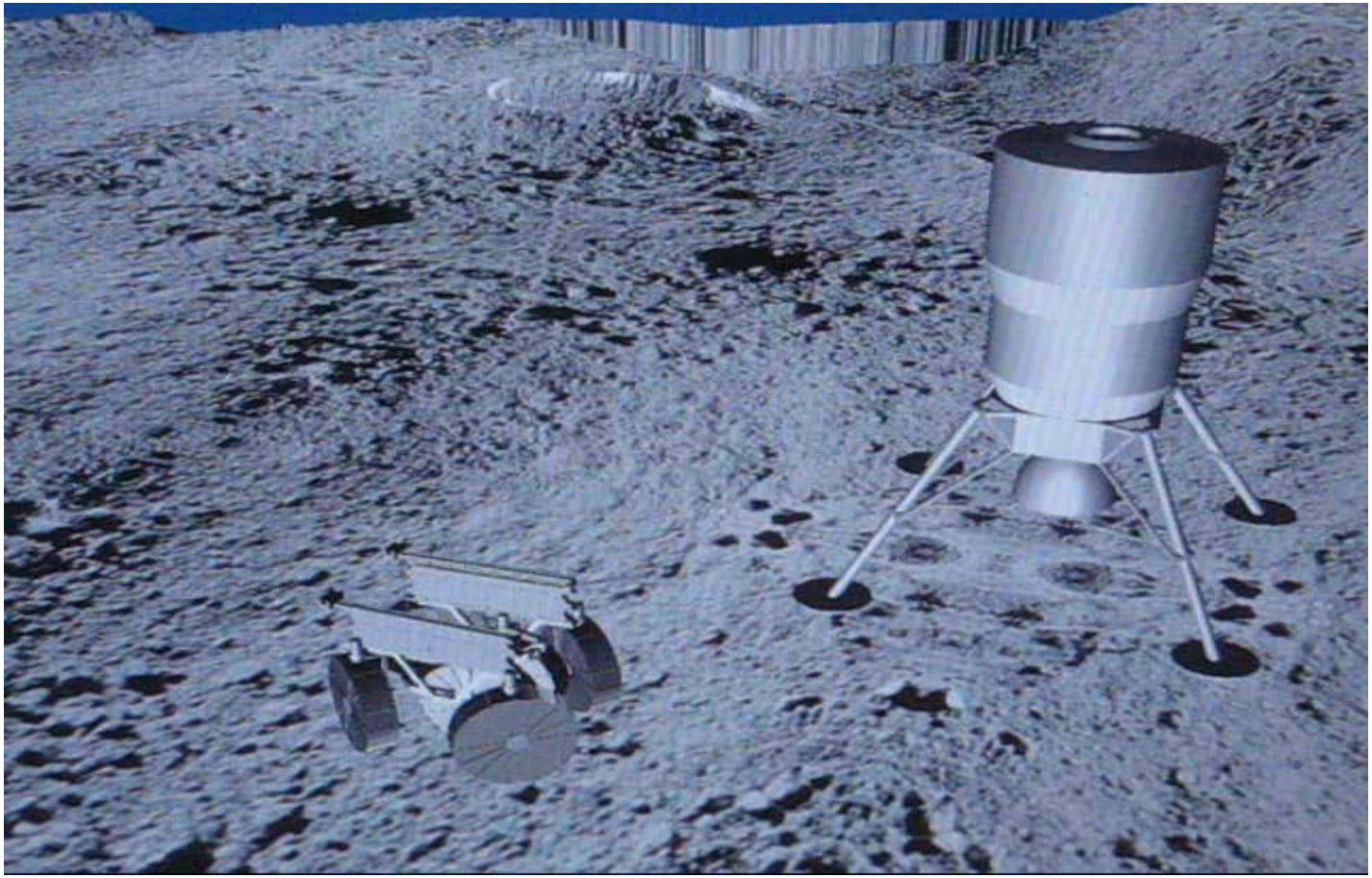
Examples of Robotic Section Internal Activities

- Heavy duty lunar rover concept design
- Autonomous navigation demonstration
- Locomotion subsystem concept design
- Operations testing
- Robotized-AIV concept study

Study of system concepts & scenarios



Autonomous Navigation from CNES -> concept will be reused for ExoMars

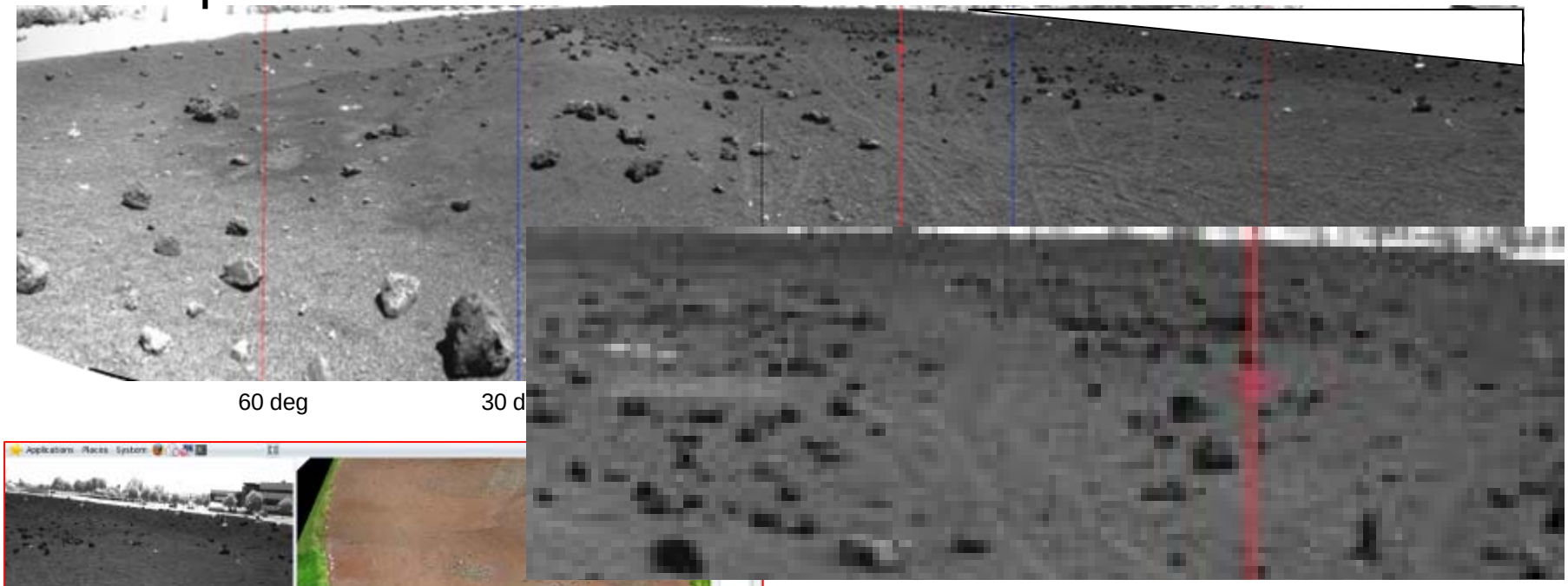
Obstacle climbing

Sandy slope climbing

Deployment

Egress

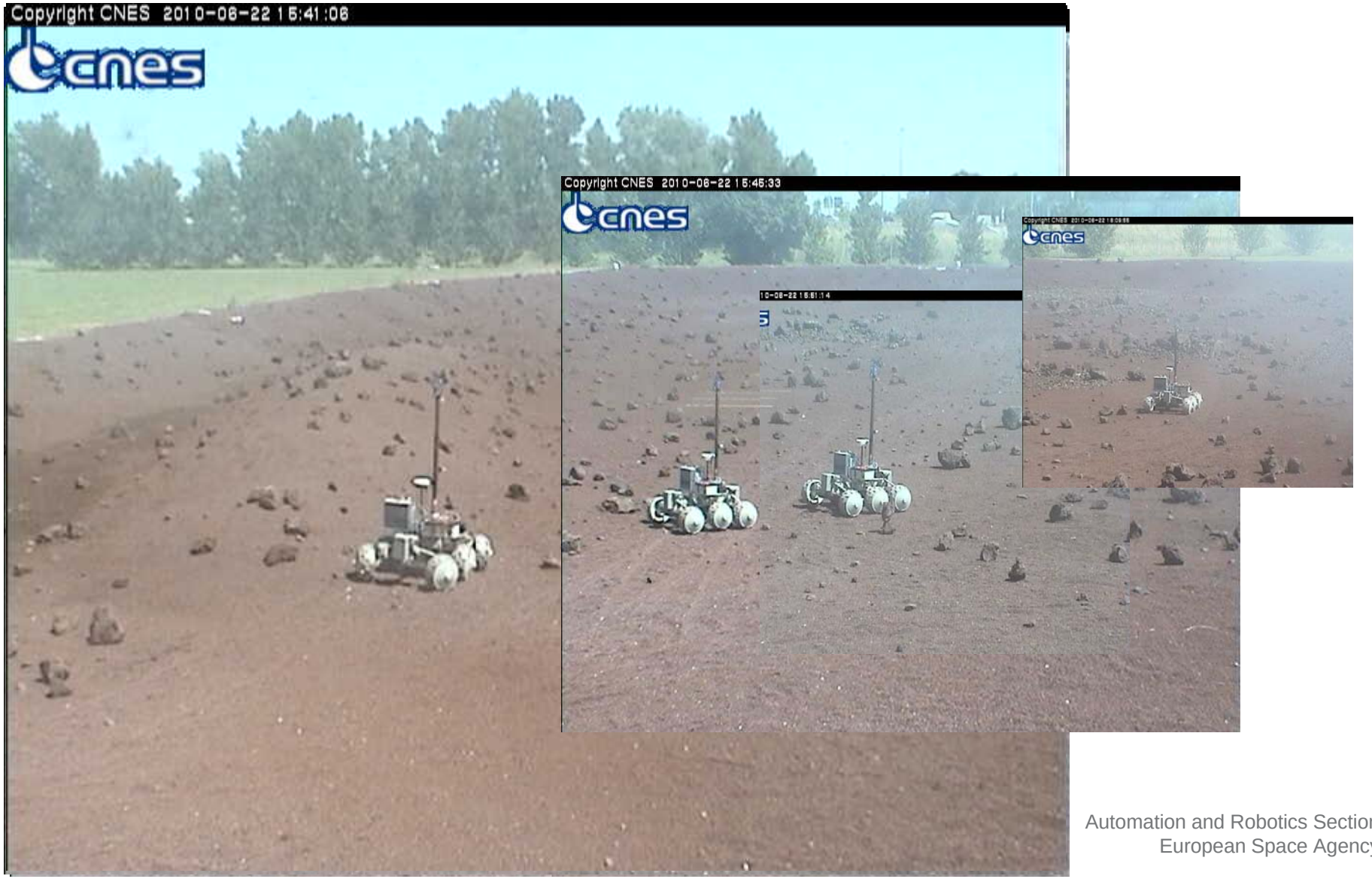
Remote Experiment between ESTEC and CNES



60 deg 30 d

Target is ~28m away

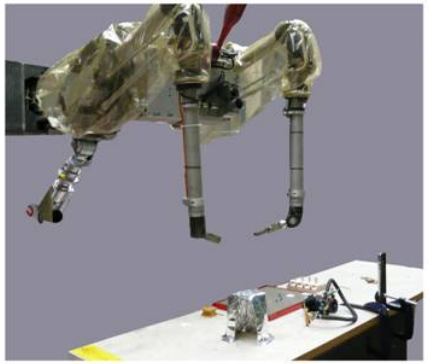
Remote Experiment #1
Actual motion to first target



ESA Robotic R&D

Robotized-AIV as solution of Planetary Protection issues

Study to assess suitability of robotic means to limit the contamination of spacecraft during Assembly and Testing.




Major outcomes:

- Demonstration to AIT people that robots can do useful job
- Discovery of Fraunhoffer IPA knowledge about cleanroom design, cleaning techniques and robot certification for cleanrooms.
- F-IPA is now a major subcontractor of TAS-I in the frame of ExoMars project

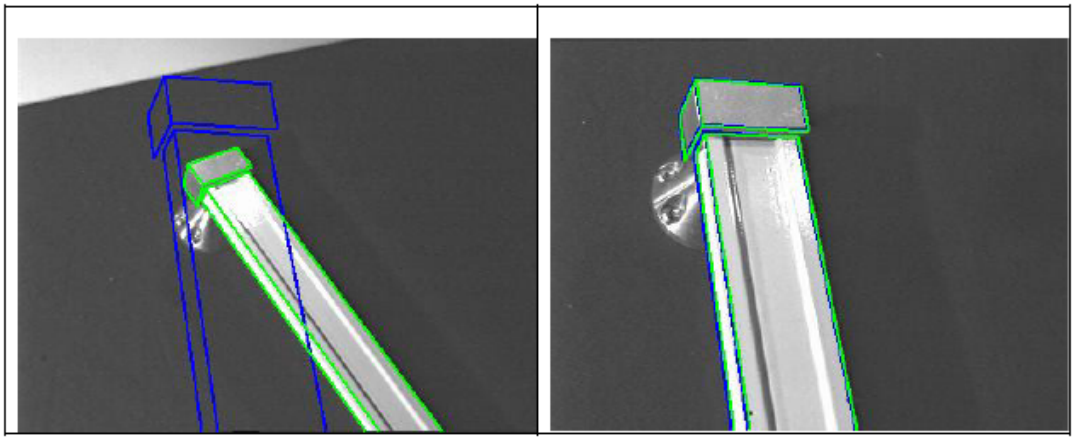
Activity performed by ASTRIUM UK with kind participation of HAPTION and CEA-LIST

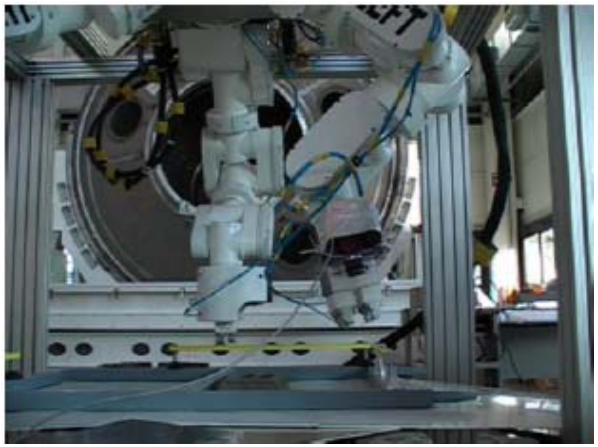
Examples of Robotic Section R&D Activities

- Vision-based Manipulation of Non-cooperative Robots
- Formal Specification and Verification Tools
- Rover Chassis Evaluation Tools
- 3DROV rover system design and simulation Tool
- Motion Control Chip
- Goal Oriented Autonomous Controller

ESA Robotic R&D
Vision Based Manipulation of Non Cooperative Objects

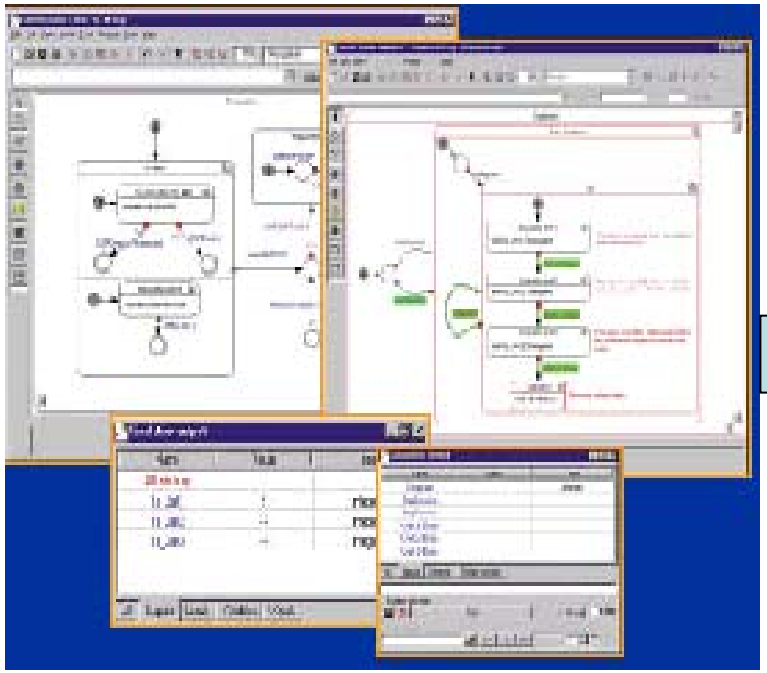
VIMANCO R&D activity performed by TRASYS Space, INRIA LAGADIC, KUL, Galileo Avionica.





- Tested as part of back-up solution for Eurobot WET model in 2007

ESA Robotic R&D
Formal Specification and Verification of Robotic Activities (Task & Actions)



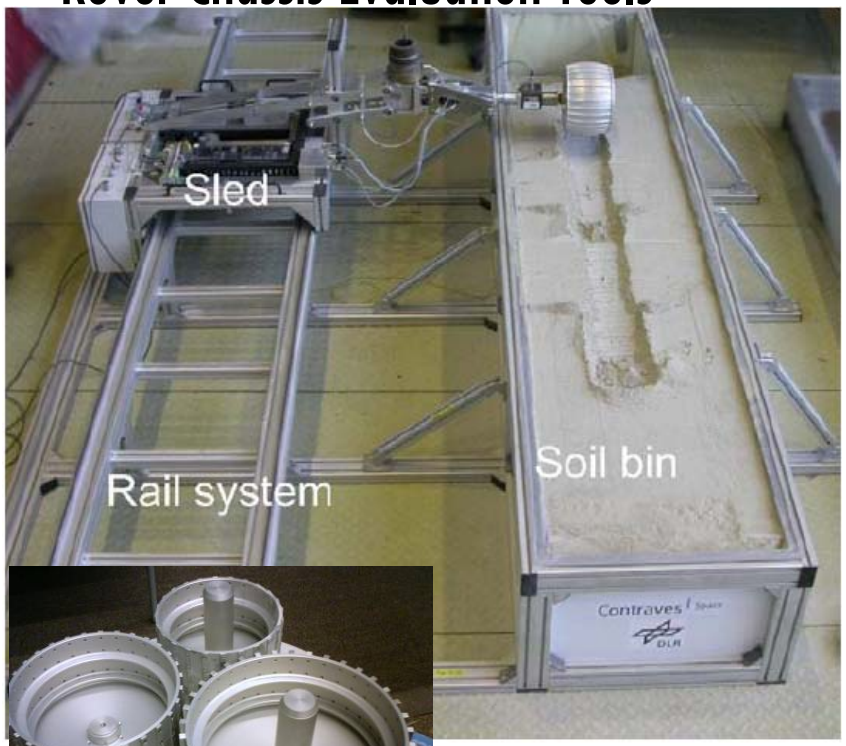
```
/* EXTERN DECLARATIONS */
extern void
MODULE_O_OUT();

/* OUTPUT ACTIONS */
#define __MODULE_A2 \
MODULE_O_OUT()

/* EQUATIONS */
E[1] =
E[0]&&(__MODULE_A1);
...
```

- Event based control of a reactive system based on Task & Actions has been retained for ExoMars rover.

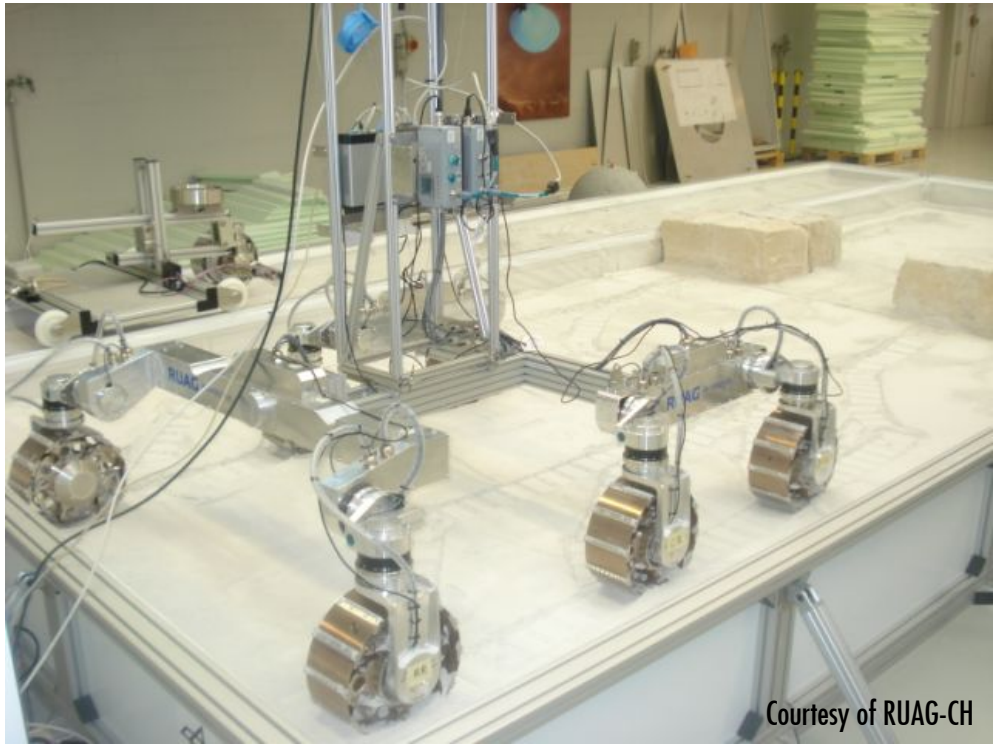
- Fairly new type of control in the space domain.

ESA Robotic R&D
RCET use in ExoMars Locomotion Subsystem developments by RUAG-Zurich

Rover Chassis Evaluation Tools



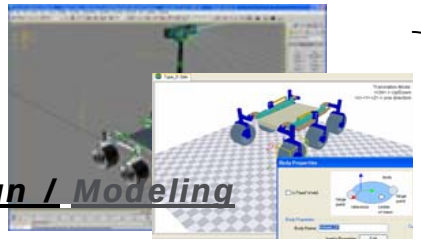
Single Wheel Testbed & Modulal Wheels



System Testbed

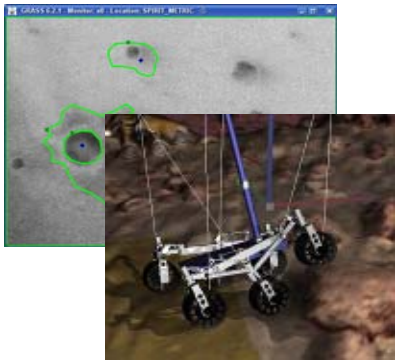
ESA Robotic R&D
3DROV reuse in ExoMars Operation Simulation

- ***Rover***
- Mechanical
- Thermal
- Power

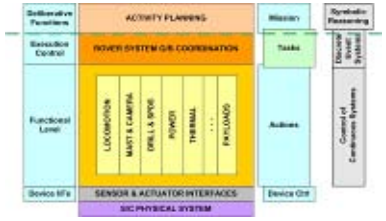


Design / Modeling

- ***Environment***
- Atmosphere
- Orbiter & Timekeeping
- Terrain



- ***Generic Controller***
- Actions
- Tasks
- Real-time impl.

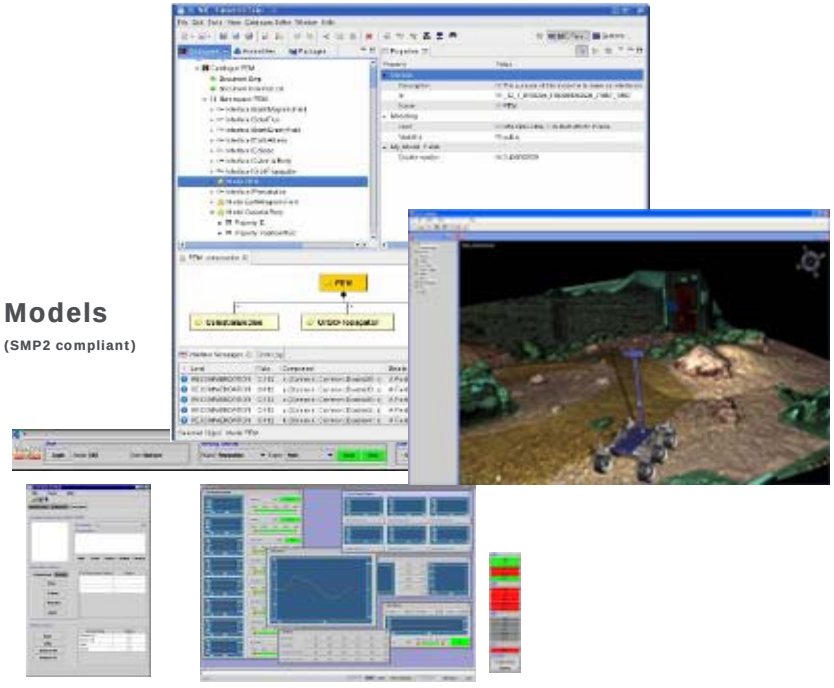


- ***Control station***

- ***Simulation***
- **(SIMSAT)**

- **Models**

(SMP2 compliant)



- ***Control station***

ESA Robotic R&D
Motion Control Chip (MCC)

MCC provides for the digital low level control
(commutation/torque/speed/position) of 3-brushed/1-brushless DC drives with RTU command/telemetry capability via CAN bus

MCC uses special wide-thermal-range macro-chip integration technology that allow the system to work at very cold temperatures

On-going activity interesting for ExoMars

- potential mass gain to control all the actuators
- limited warm-up needs (Mars night is <-100degC)

ESA Robotic R&D
Goal Oriented Autonomous Controller (GOAC)

Running activity which has the objective of implementing a template of a general-purpose autonomous controller for Autonomy Level E4 (goal-oriented mission re-planning), as well as the lower levels E3, E2 and E1, for Space Robotics Systems, including

- ISS Robotic Crew Assistants,
- Orbital Robot Explorers, Lunar Robotic Agents, Lunar Robotic Explorers, Lunar Robotic Assistants.

	Description	Functions
E1	Mission execution under ground control; limited onboard capability for safety issues	Real-time control from ground for nominal operations Execution of time-tagged commands for safety issues
E2	Execution of pre-planned, ground-defined, mission operations on-board	Capability to store time-based commands in an on-board scheduler
E3	Execution of adaptive mission operations on-board	Event-based autonomous operations Execution of on-board operations control procedures
E4	Execution of goal-oriented mission operations on-board	Goal-oriented mission re-planning

Example of supported robotic projects

- ExoMars Rover mission
- Mars Sample Return concept definition

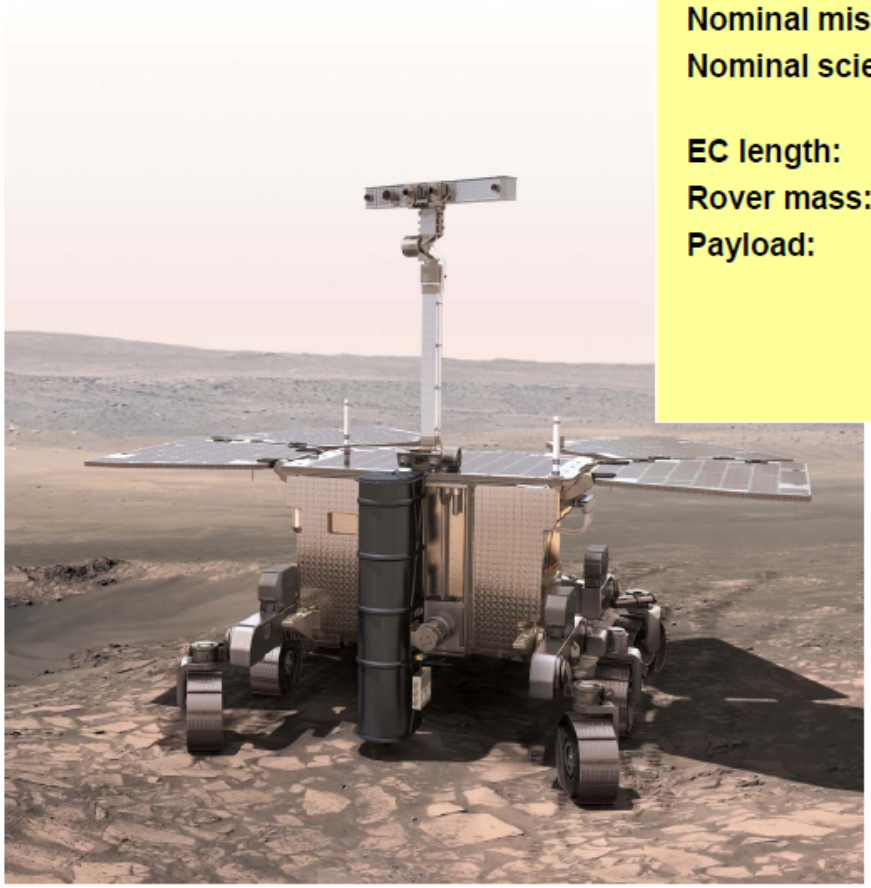
ExoMars Program

- Recent evolution with cooperation with NASA in the frame of Mars exploration agreements.
- One programme and two missions
  - 2016 mission ESA lead : Trace Gas Orbiter carrying NASA scientific payloads and an ESA Entry, Descent and Landing demonstrator
  - 2018 mission NASA lead: use of MSL sky-crane to deposit a platform with two rovers of about 300kg each on Mars surface
    - NASA Sample Caching Rover
    - ESA ExoMars Rover

2018 mission: Launch in April 2018 and surface operations early 2019

ExoMars Rover in brief

ExoMars Rover



Nominal mission:	218 sols
Nominal science:	6 Experiment Cycles + 2 Vertical Surveys
EC length:	17–22 sols
Rover mass:	300 kg
Payload:	9 Instruments; 18.7 kg - Panoramic camera - Ground Penetrating Radar - ExoBiology Laboratory

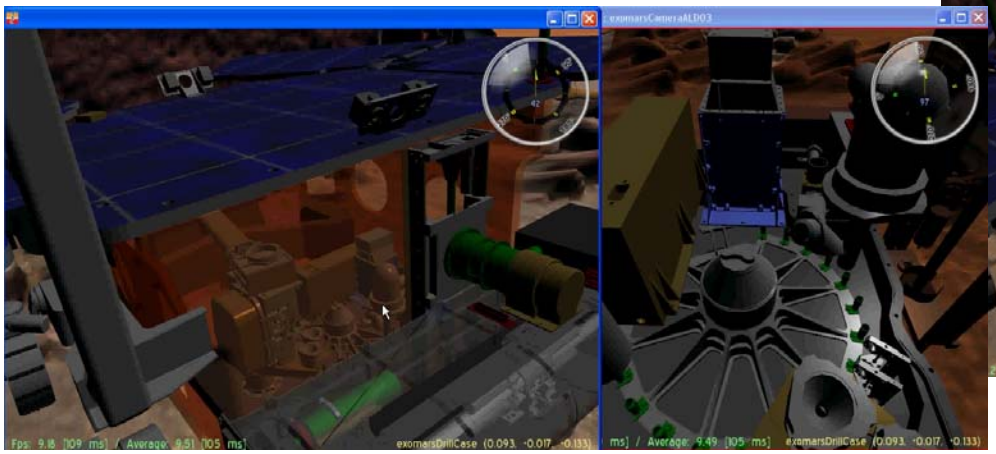
ExoMars Rover Experiment Cycle
Summary in pictures

Drive to site

Scan the site

Drill

Analyse the sample



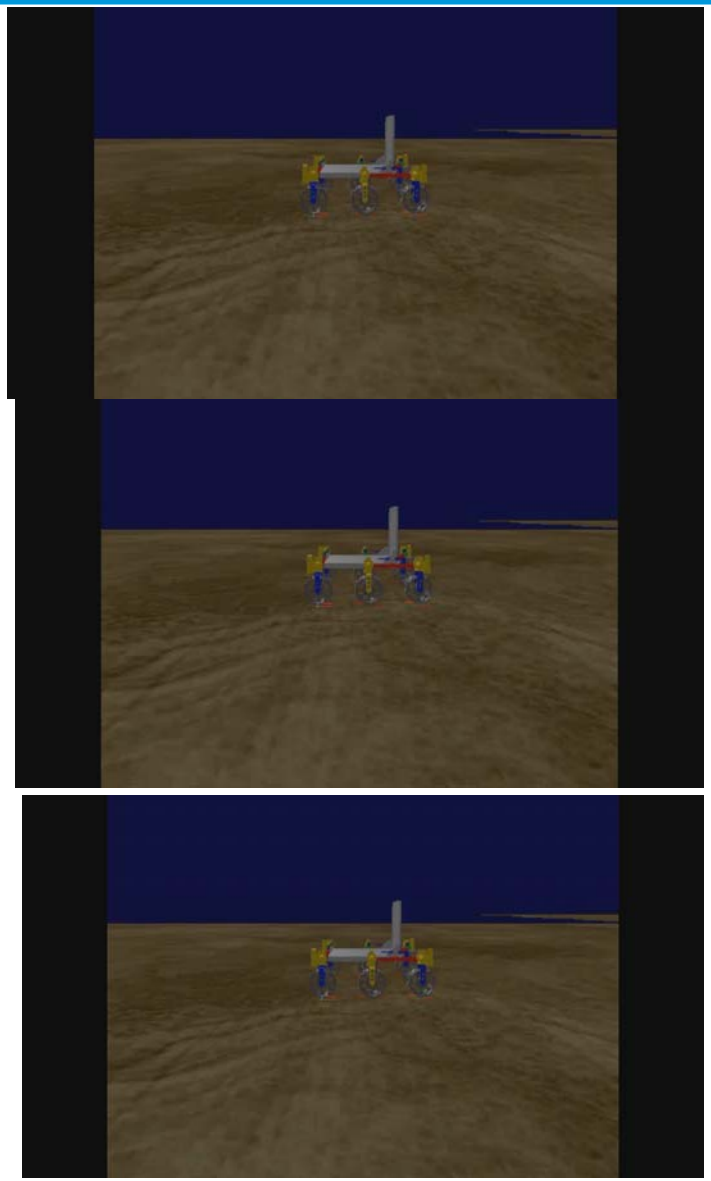
Get the sample

Automation and Robotics Section
European Space Agency

ExoMars Rover Main Robotic Aspects

- Locomotion subsystem: 6x6x6 +6W
  - Self deployment
  - All wheel steering
  - Wheel-walking capabilities
- Rover Mobility
  - Autonomous navigation (70m per sol)
  - Slippage estimation based on visual odometry
  - Placement of ground penetrating radar & Drill
- Autonomy
  - Event driven control (ECSS E3) based on Task & Action paradigm
  - On-board Fault Detection
  - Execution of predefined alternative activities in case of resources availability
- Operations
  - Two communications per sol via the data relay orbiter
  - Preparation and upload of 2-sols activity plan

Wheel-walking simulations



- Increased mobility capabilities
- Various gaits possible

Future of Robotic Exploration
Mars Sample Return

Mars Sample Return in cooperation with NASA is being designed at concept level and early definition phase.

Possible main challenges in addition to ExoMars capabilities are:

- Mars Sample Fetching Rover
- Rendez-vous between landing site and ascent vehicle after several kilometers traverse
- Sample canister delivery to ascent vehicle
- Sample curation on Earth.

R&D with ESA ?
ESA websites

Student Trainees

Young Graduate Trainees

PostDoctoral research Fellowship

Intentions to Tender on EMITS for R&D activities

Networking / Partnering Initiative

ASTRA'11 Workshop at ESTEC

The best way to know the actors and be known by the space robotics community.

- Next ASTRA is from 12th to 15th April 2011
- No registration fee
- Abstract submission deadline: 15th December 2010