Human-machine cooperation in space environments

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Human in outer space: a twofold perspective

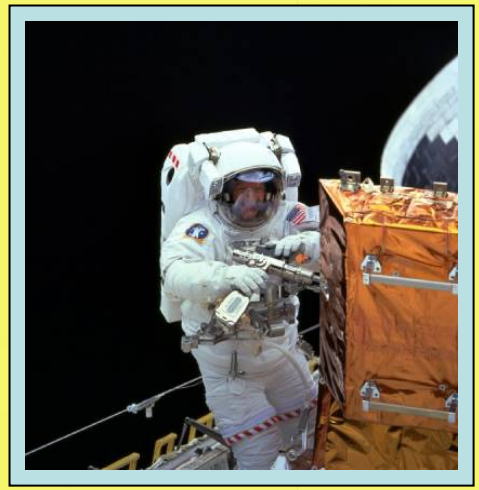
- ***Humans live*** in a new environment
  - Things float
  - Medical problems
  - Living together in small environments
  - ...

Psychology, Environmental psychology, Anthropology, Sociology, etc...

Astronaut Umberto Guidoni, STS-100 mission specialist representing the European Space Agency (ESA), exercises on a bicycle ergometer on the mid deck of the Space Shuttle Endeavour. (Photo: NASA)

- ***Humans work*** in a new environment
  - Hard and risky to work
  - Special tools
  - New complex technology
  - ...

Cognitive Psychology, Human Computer Interaction, Artificial Intelligence, etc...



Astronaut Claude Nicollier, mission specialist from the European Space Agency (ESA) uses one of the Hubble power tools in a storage enclosure during the second of three STS-103 extravehicular activities. Photo: Credits: NASA

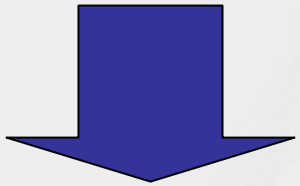
Humans at work in space

Humans working in space environments

In space working environments humans interact with advanced automated technology

Relevant aspects are:

- the ***degree of interaction*** between humans and machines/robots.
- the ***role of the humans*** with respect to their collaboration with "potentially overwhelming" technology.



Human Machine Cooperation

Learning from our experience and collaboration

2000 – 2004

- **ASI** (Italian Space Agency) - basic research
  - *DOVES*: Enabling On-board Autonomy: a platform for the Development Of VErified Software
  - *ARISCOM*: Constraint-Based Continuous Planning
  - *SACSO*: SAfety Critical Software

2000 – 2007

- **ESA** (European Space Agency)
  - *MEXAR*: Interactive Support for Mission Planning in MARS EXPRESS
  - MEXAR2: a software tool for continuous support to data dumping activities for MARS EXPRESS (http://mexar.istc.cnr.it/)
  - *RAXEM*: a software tool for continuous support to uploading activities for MARS EXPRESS (http://mexar.istc.cnr.it/)
  - *APSI* (Advanced Planning and Scheduling Initiative): a general *AI-based* software framework for developing advanced mission planning systems. Consortium: VEGA (prime), PST, ONERA, and Politecnico di Milano.

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SACSO: *SAfety Critical SOftware for planning in space robotics*

2004

2005

2006

2007

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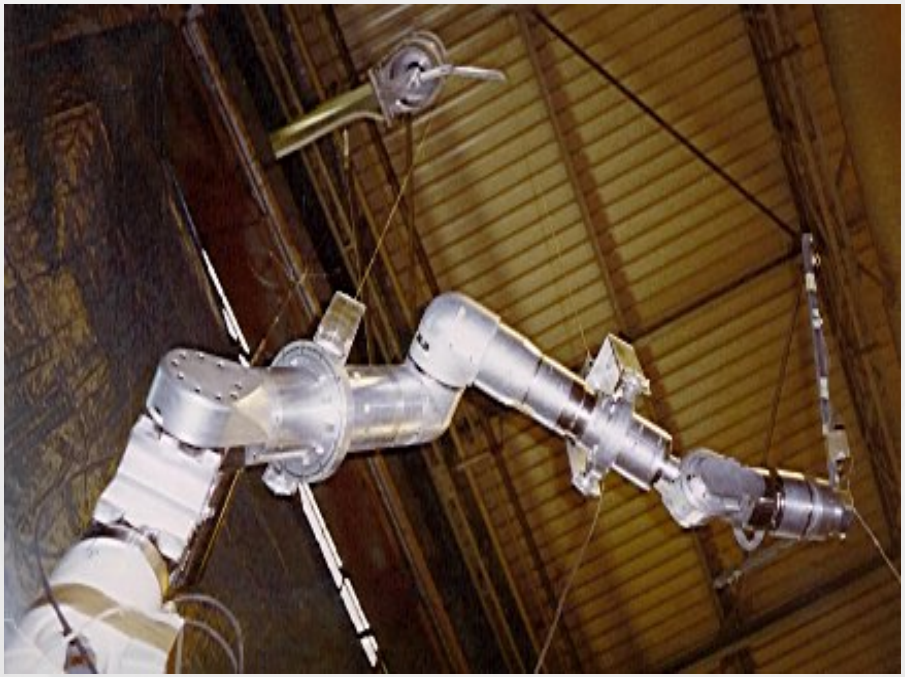
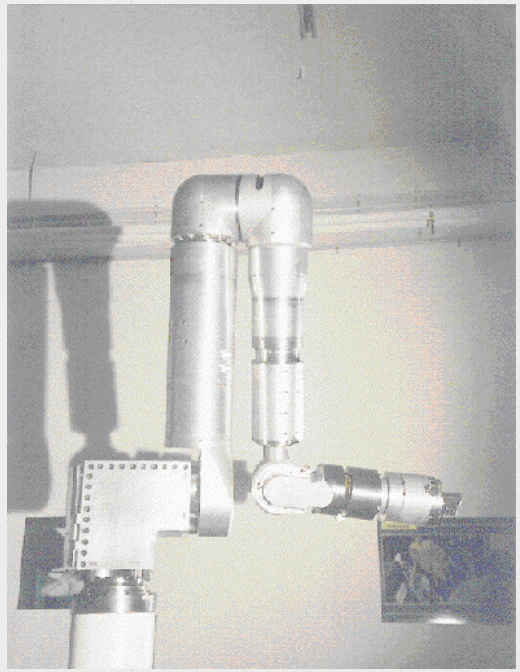
SACSO: *SAfety Critical SOftware for planning in space robotics*

The SACSO project explored the synthesis of a **facility** in which

expert users
(e.g., scientists responsible for the scientific experiments) and
technicians
(e.g., robot operators, computer programmers)

cooperate to specify goals and constraints for a robotic arm by means of a high-level specification language and the facility synthesize the actual robot program

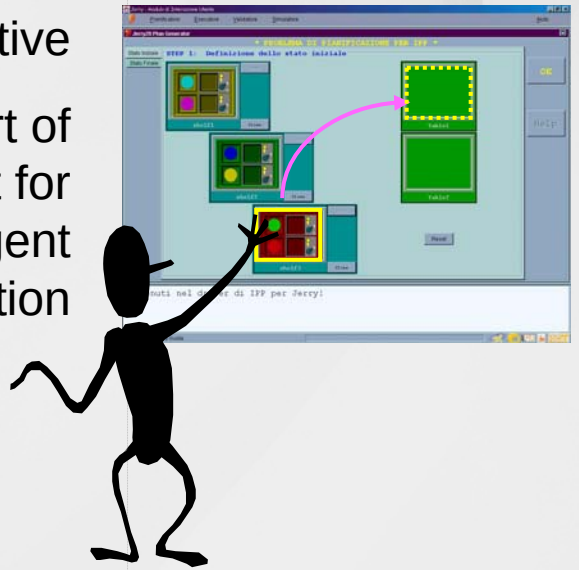


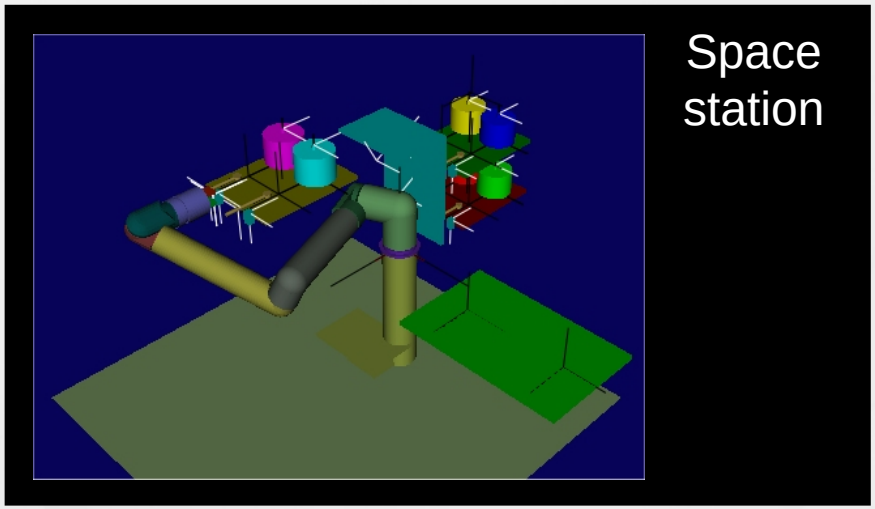


Jerry a demonstrator for SACSO

Scientist defines the high level objective

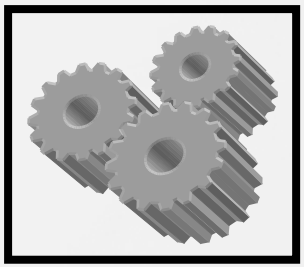
With the support of an environment for intelligent interaction





Space station

Plan Synthesis with Jerry



AI Algorithm
(planner)

Scientist defines the high level objective

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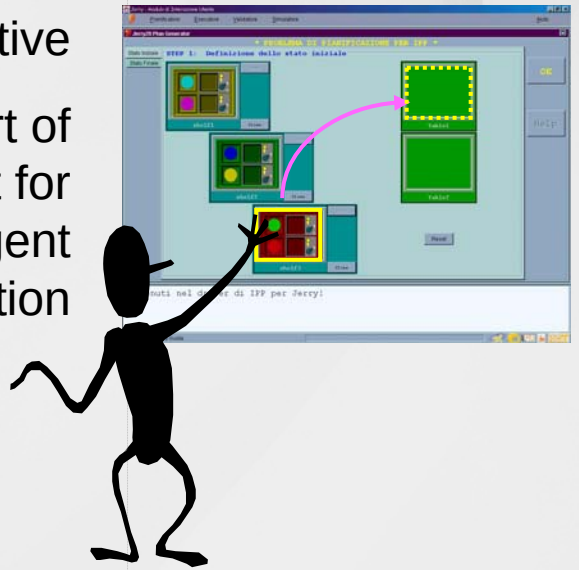

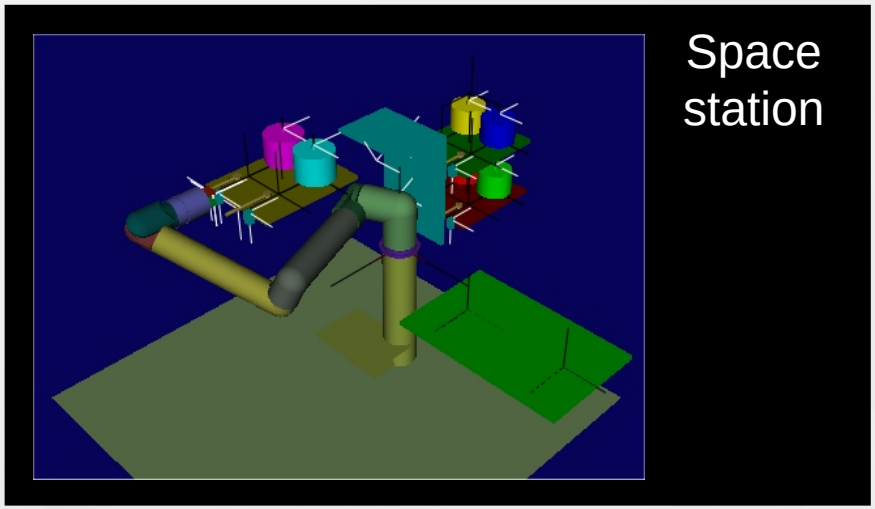

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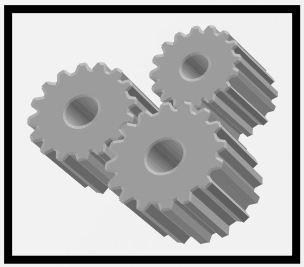

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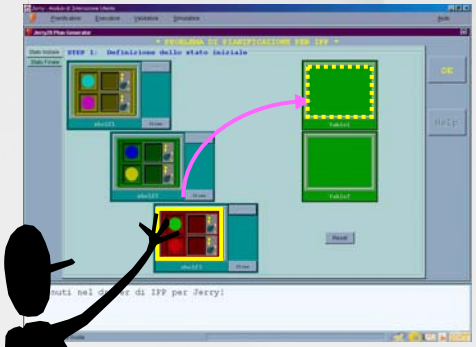
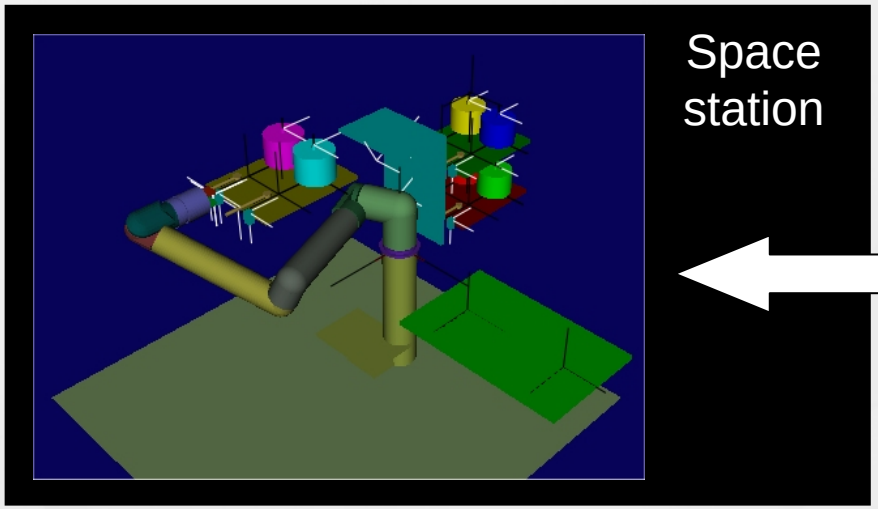




Space station

Instructions sequences (plans)

```
…
CLOSE HAND;
MOVE LINEAR AWAY 1200;
MOVE LINEAR TO POS (800, -400, 430, -180, 90, 0);
MOVE LINEAR TO POS (800, 400, 430, -180, 90, 0);
…
```

Some remarks from this experience

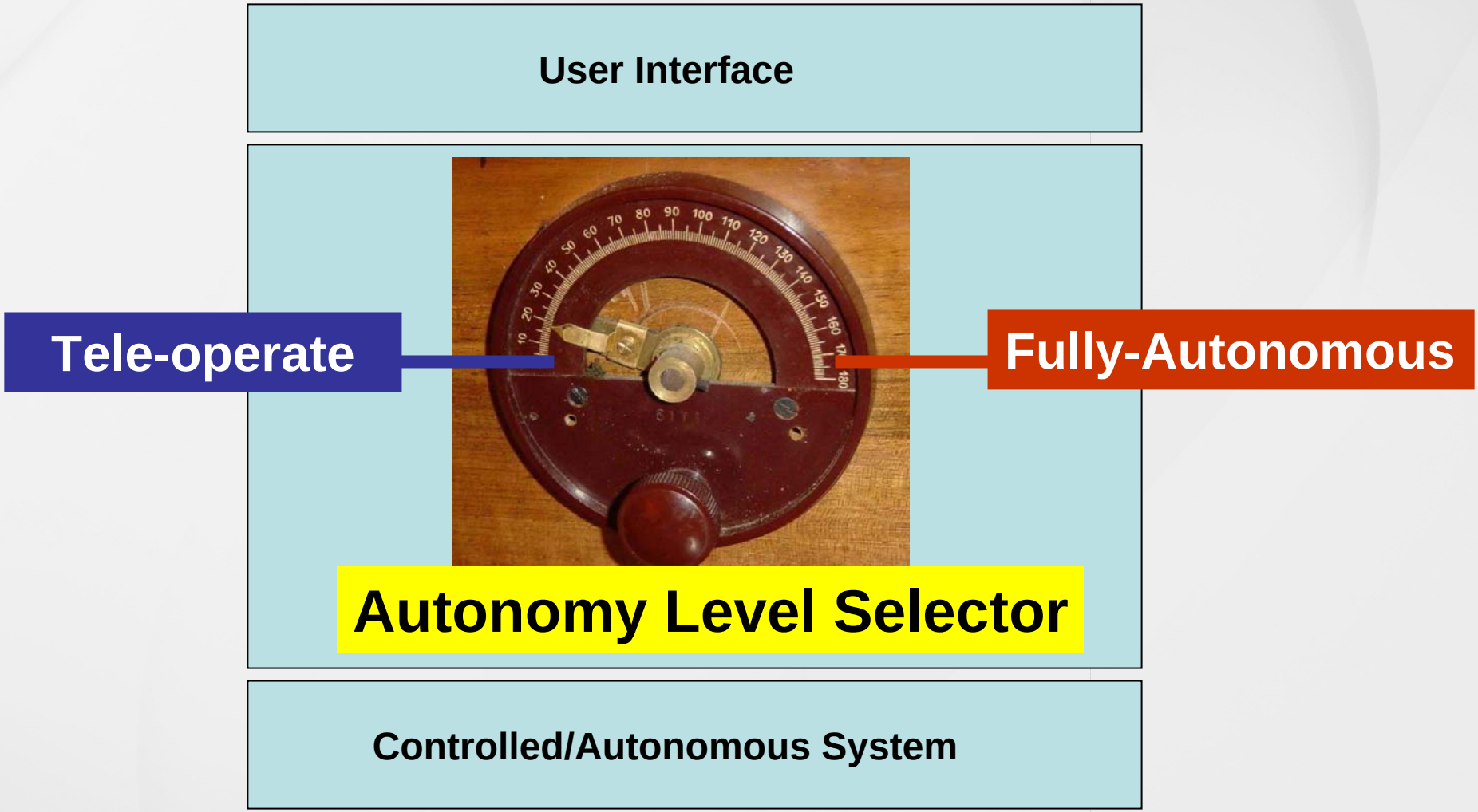
- Scientists should not necessarily be technology experts
  - They need to be able to access technology without delegating the technicians

INTERACTION

- Which is the right degree of autonomy of such interactive intelligent systems?
- Which is the optimal subdivision of labor between humans and machines?
- What's the role of humans?

Manned missions may have the additional problem of having humans interacting with robots …

Designing a Human-Centered Autonomous system

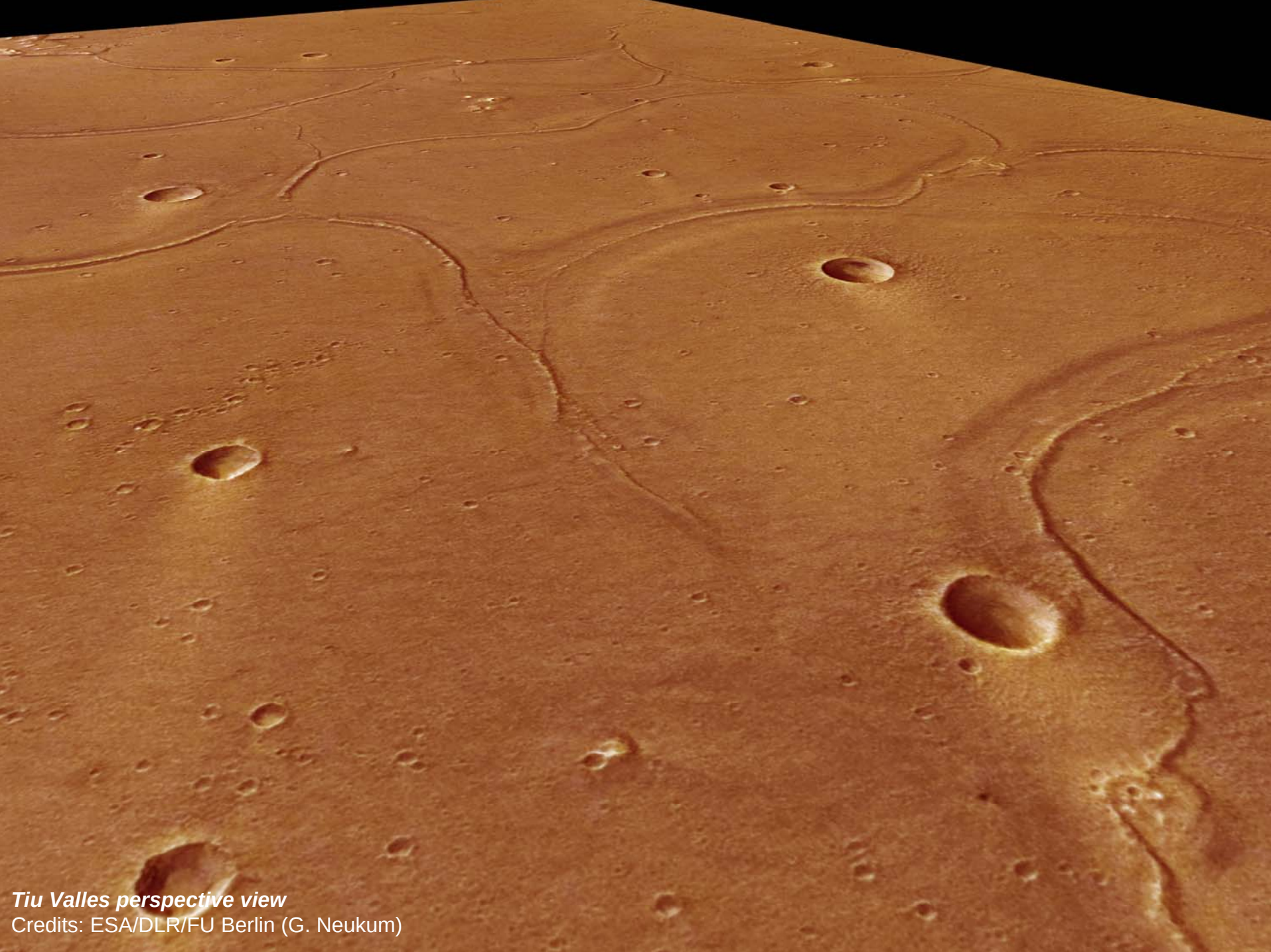


Adjustable Autonomy

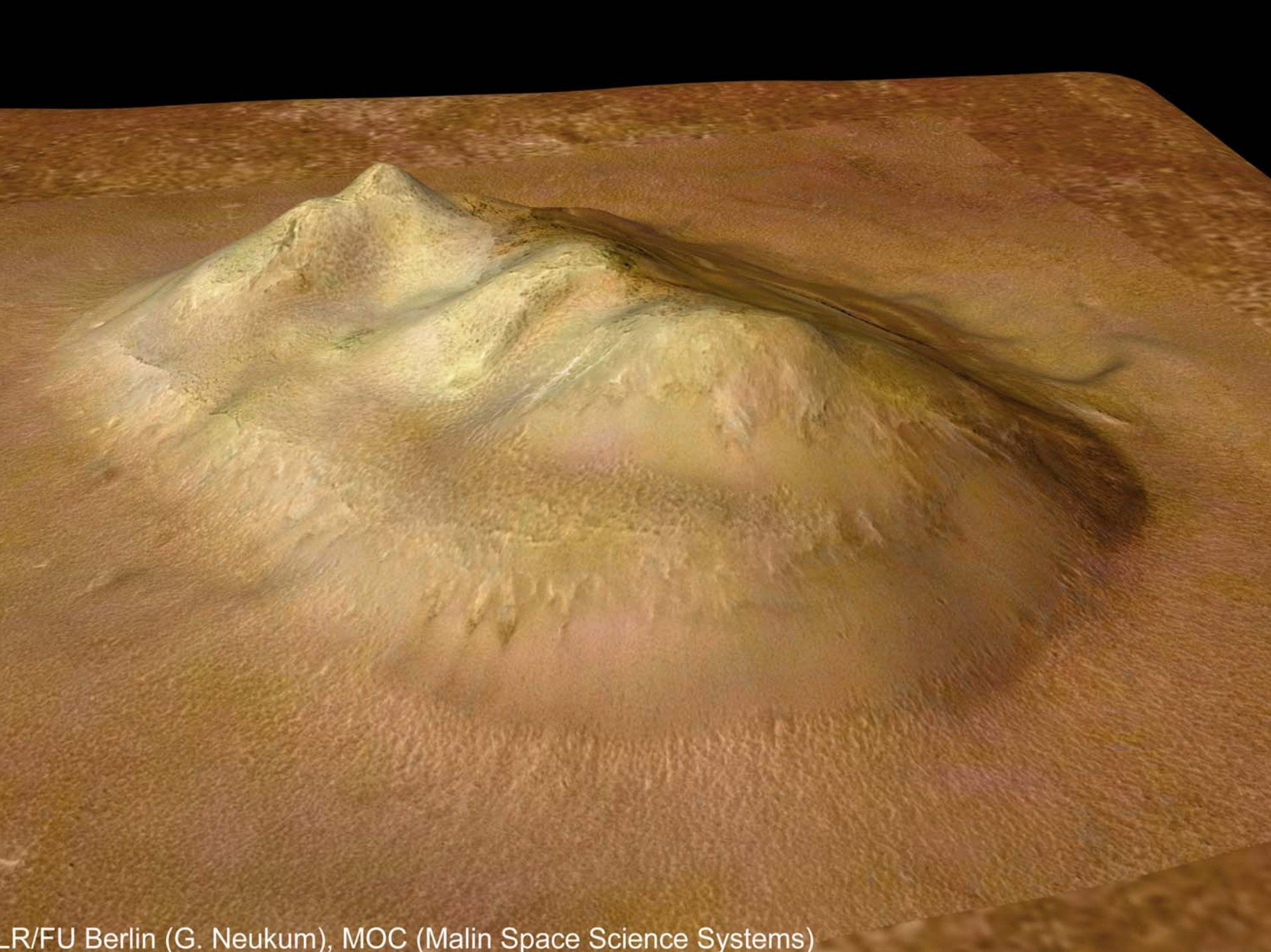
[See research at NASA Ames and NASA Johnson Space Center]

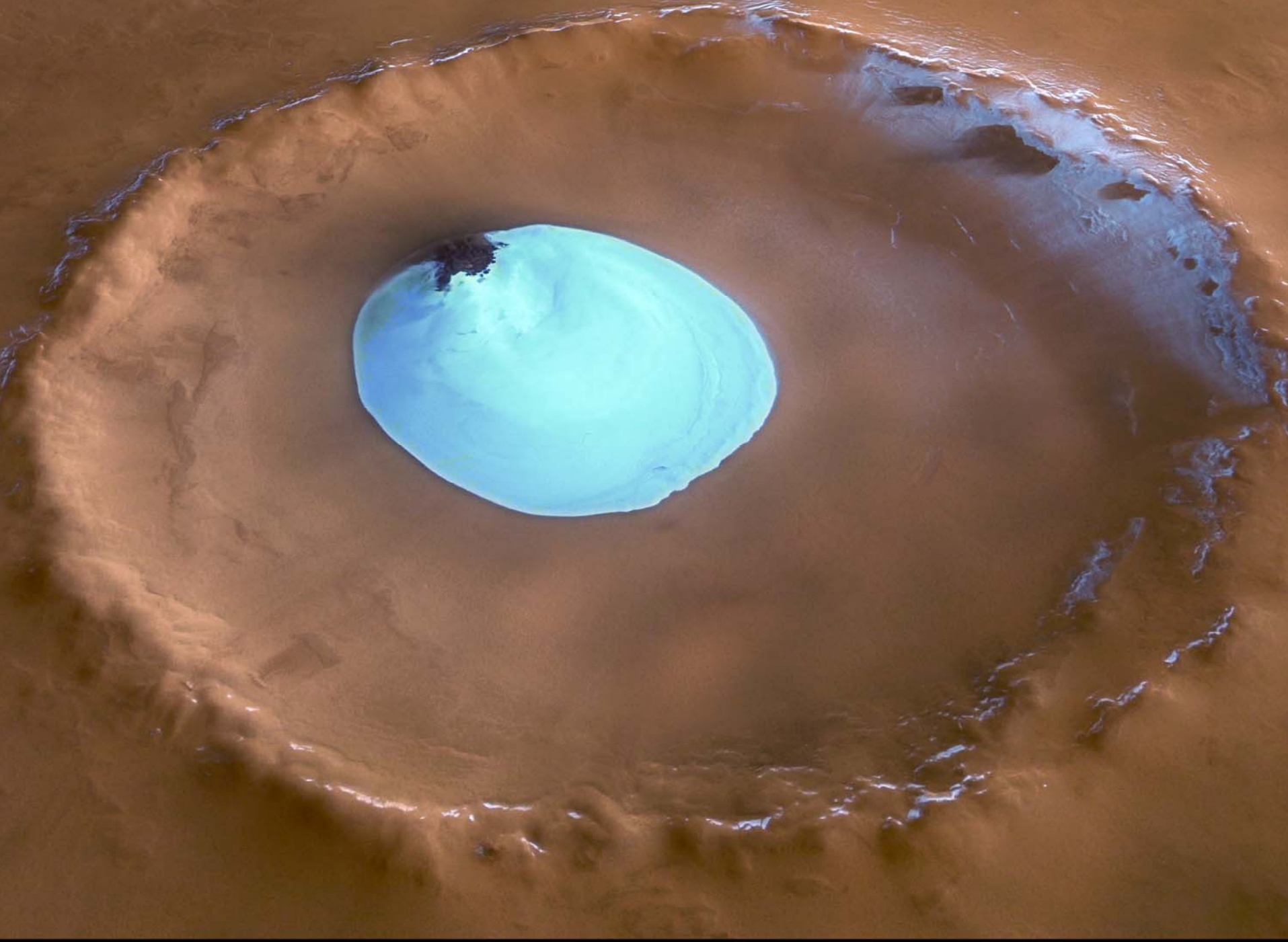
The MEXAR2 Experience

Mars Express ESA mission



Tiu Valles perspective view
Credits: ESA/DLR/FU Berlin (G. Neukum)


LR/FU Berlin (G. Neukum), MOC (Malin Space Science Systems)



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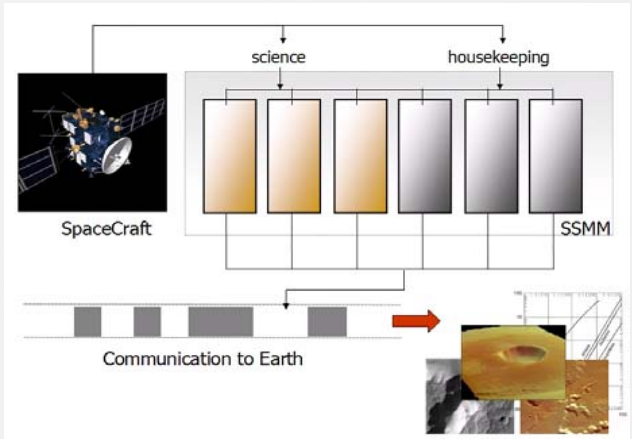
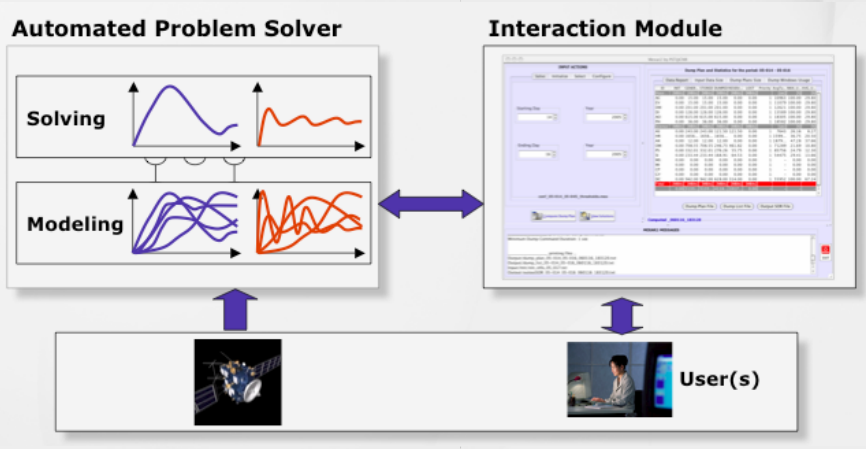
Mexar2: Supporting mission planning at ESA

The Data Downlink Problem

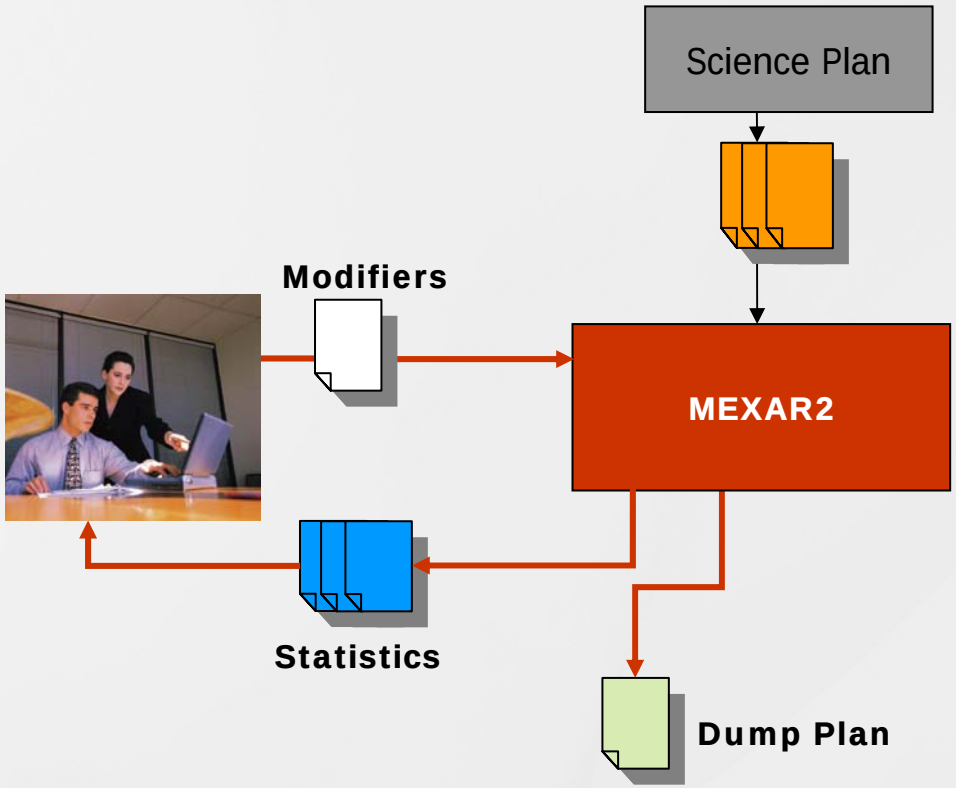


The MEXAR2 Solution



- MEXAR2 is **operational in ESA Mars Express mission** since February 2005
- Based on the idea of empowering human operators in their **daily work**
- Time needed to generate dump plans reduced by **50%**
- It produces **plans of higher quality** reducing significantly data loss
- It allows to spot in advance resource bottlenecks allowing **increased science return**

MEXAR2 as a software companion



Human-machine cooperation

Remarks from the MEXAR2 experience

- Previous practice at ESA was to **manually** decide the spacecraft downlink commands (decision task **extremely repetitive and demanding**)

- MEXAR2 **enhances human capabilities** dealing with the low level details and enabling **mission planners** to perform more strategic work**.**

- Mission planners have been **empowered with additional capabilities** through the creation of a cooperative work environment (**mixed-initiative approach**).

Human-machine cooperation has been instrumental to obtain users' **trust** and **acceptance**

Human-machine interaction in space environments

- Manned mission in outer space will be characterized by users working in very specialized environment with advanced technology

- The man-machine interaction is indeed a crucial aspect to define. What kind of interaction do we want?
  - Master-slave
  - Machine supervision and autonomy
  - Mixed-initiative (Collaborative)

Human Machine Cooperation seems a valid approach to use in space environments

Human-missions around the Earth

What effect does it have?

1. Humans need to trust technology for their work

2. Humans cognitive abilities are enhanced (not overwhelmed) by technology

3. Are we ready for a man-machine collaborative approach to space missions?