MECA
Mission Execution
Crew Assistant
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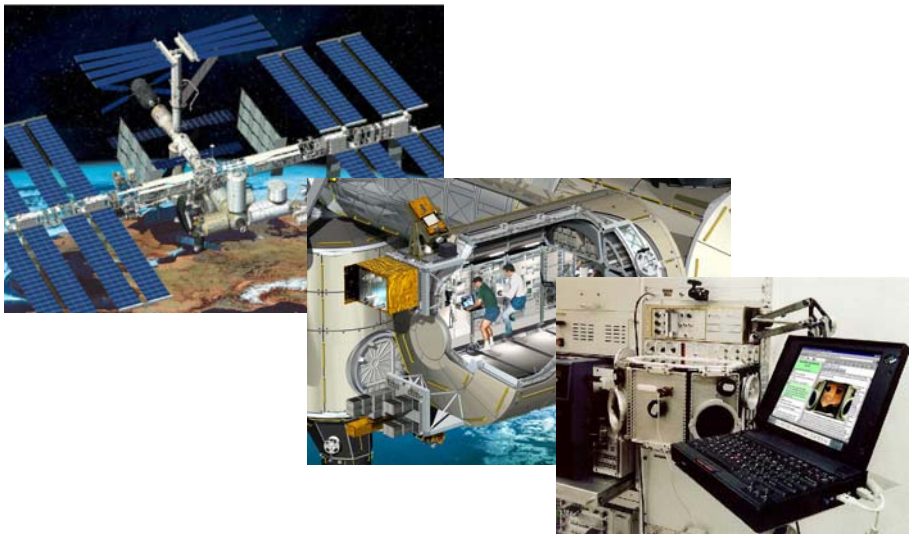
Cognitive Engineering for Long Duration Missions: Human Machine Cooperation on Moon or Mars

Mark Neerincx, Jasper Lindenberg, Nanja Smets, Tim Grant, André Bos, Antonio Olmedo Soler, Uwe Brauer, Mikael Wolff

Background



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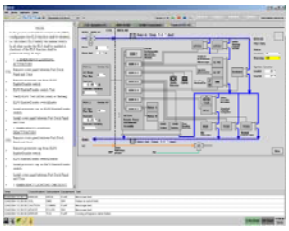
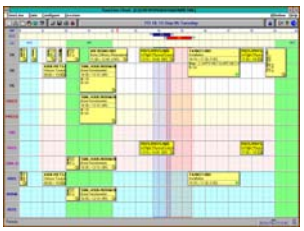
State of the Art

Our legacy….



LAPAP

SCOPE



CAOS

But MECA should extend this….

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Objective & Vision

Objective: support mission goals (without injury or loss of life) by

- empowering the cognitive capacities of human-machine teams during planetary exploration missions
- in order to cope autonomously with unexpected, complex and potentially hazardous situations.

Vision: crew support that

- acts in a ubiquitous computing environment
- as “electronic partner”, helping the crew
  - to assess the situation,
  - to determine a suitable course of actions to solve a problem,
  - to safeguard the astronaut from failures.

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Cognitive Engineering +

Background
- Operability-based design
- Anticipate for new Intelligent Interfaces
- Anticipate for new HFE standard

10 -- 25 yrs

Approach
- Human-Operation centered
- Enabling Technology focus
- Iterative process (specify-test-refine cycles)
- From abstract to detailed specifications
- Sound theoretical and empirical foundation

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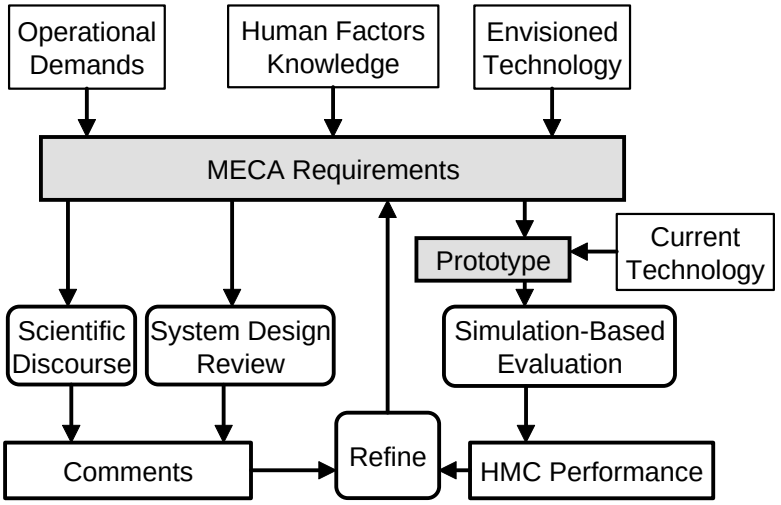
Iterative Requirements Analysis



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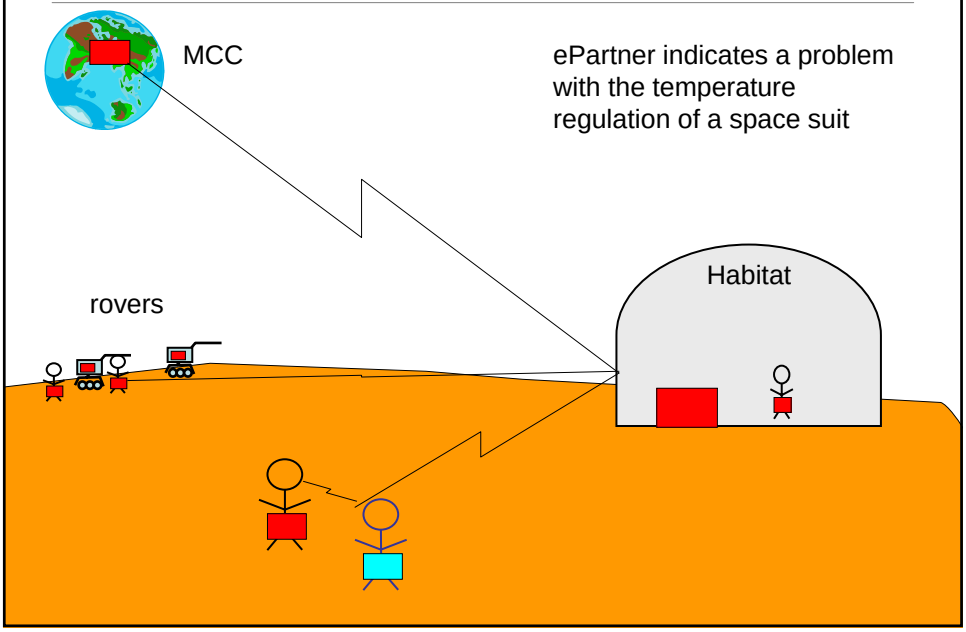
Scenario Analysis and Role Allocation



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Operational Demands

MECA shall take account of:

- the high-level operation goals
  - e.g., safe return to earth
- the environment
  - e.g., radiation and social monotony
- task performance
  - e.g., people will get seriously ill

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Human Factors Demands (1)

- Cognitive Task Load
  - Load scheduling based on time occupied, task switches and complexity
- Situation Awareness and Sense Making:
  - collect and interpret relevant data
  - generate and test hypotheses
- Diversity of Cognitive Capacities
  - tailoring the communication to the momentary capabilities, levels of attention and availability of modalities
- Trust and Emotion
  - explanatory user interface
  - attuning the support to the emotional state

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Human Factors Demands (2)

- Collaboration
  - coordinate for mutual human-machine benefits and joint results
  - generate and maintain shared mental model
  - show actor's goals, intentions, behavior and needs
- Crew Resource Management
  - manage crew skills
  - plan and support training
- Decision Making
  - rational: (exhaustive) option analysis
  - naturalistic: pattern analysis and assumption testing

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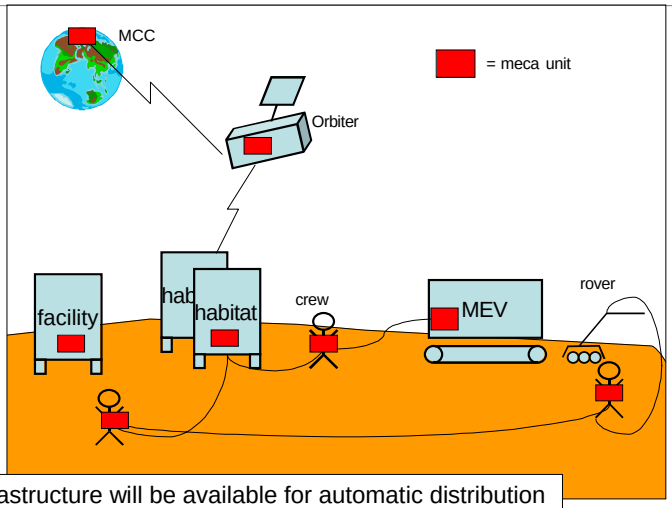
Envisioned Technology (1)



An infrastructure will be available for automatic distribution of data, software and reference documents.

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Envisioned Technology (2)

- MECA shall make use of this infrastructure and can cope with possible failures
- Continuous analysis and extrapolation of emerging technologies, e.g.
  - multi-agent systems
  - automatic planning and scheduling
  - model-based health management
- Technical requirements, such as
  - maturity
  - graceful degradation
  - maintainability
  - fault tolerance

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Current Requirements

- Different types of requirements:
  - task level,
  - functional,
  - user interface,
  - technical interface,
  - operational and
  - technical requirements.
- All requirements are linked to use cases.

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Use Case Template

ID	78
Title	Hypothermic astronaut
Level	Level 0
Goal	Treat hypothermic astronaut that is on EVA…
Actor	Personal MECA, MECA habitat, astronaut in habitat, rover..
Pre-condition	Astronaut on EVA is hypothermic
Post-condition	Hypothermic astronaut is in medical facility being treated
Frequency	Not frequent
Main success scenario	• Personal MECA detects hypothermia and • communicates to hypothermic astronaut …
Alternative scenario	• .. , Doctor is not in habitat, MECA will ask astronaut_1 to prepare…
Comment	Derived from RefDoc3 …

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Outline of Functional Requirements

Process	MECA function
Information Gathering	detect needs for operations and training
Goal Setting	select and prioritize goals for operations and training
Plan Generation or Selection	generate plans, or select pre-generated plans and procedures, for operations and training
Plan Evaluation	evaluate operational and training plans
Prepare for Execution	prepare the resources for executing operational and training plans
Execution	execute operational and training plans
Processing Evaluation of Results	evaluate execution results for operational and/or training purposes

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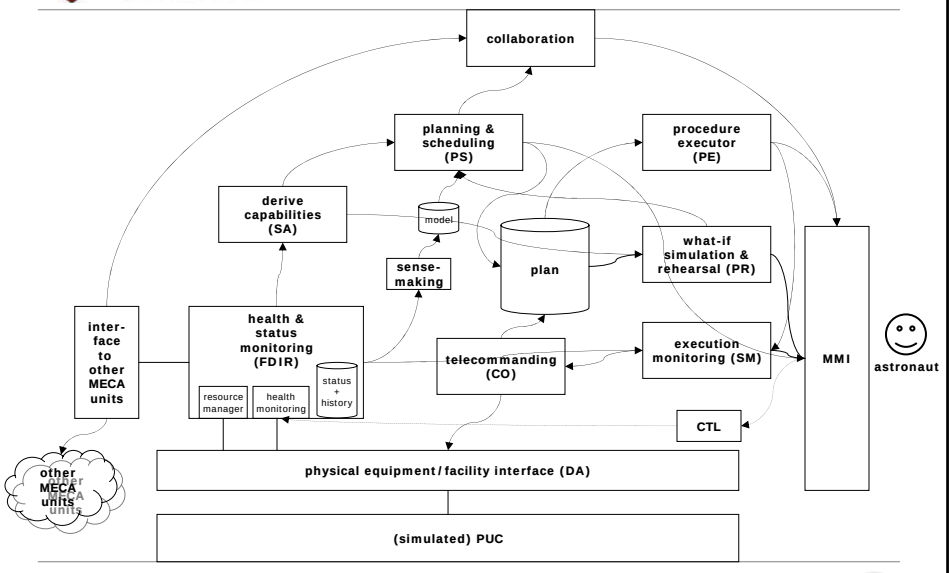
Architecture



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Incremental and Iterative Prototyping

- Both MECA and the humans will show mutual adaptive behaviour, which effects should be well tested with realistic scenarios.
- Prototyping, simulation and testing is therefore essential to establish a sound and coherent set of requirements.
- A game-based simulation environment can provide an effective platform for testing the human-machine collaboration (e.g. the Unreal Tournament game-engine) in combination with other simulators.

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Evaluation Criteria

- Long-term human in the loop effects
- Standard usability measures
  - effectiveness
  - efficiency
  - satisfaction
  - learnability
- Human experience measures, such as
  - situation awareness (perception, comprehension and projection)
  - trust (persistence and behavioural competence, servitude, and the understanding of the machine)
  - emotion (arousal and valence)

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Conclusion

Status:

- a theoretical, “task-analytical” and experience founded set of requirements

Next year:

- An empirical founded prototype that refines and validates the requirements

Other contributions SMC-IT 2006

- Grant et al. Space Autonomy as Migration of Functionality: The Mars case.
- Bos et al. Supporting Complex Astronaut Tasks: The Right Advice at the Right Time.

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Questions?

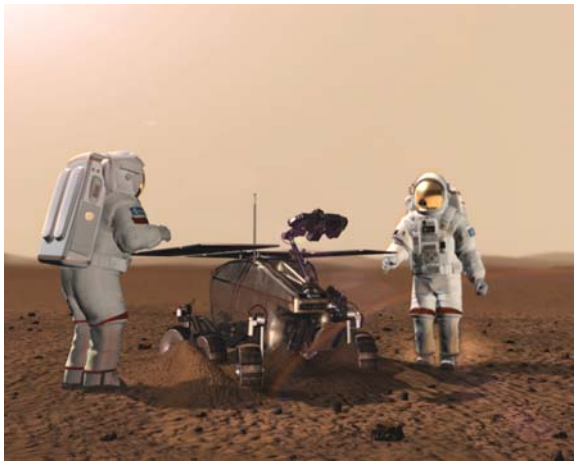

Photo: ESA/Aurora

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