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Policy-Based Design of Human-Machine Collaboration in Manned Space Missions

SMC-IT09, Pasadena, 19-23 July 2009 (paper ID9)

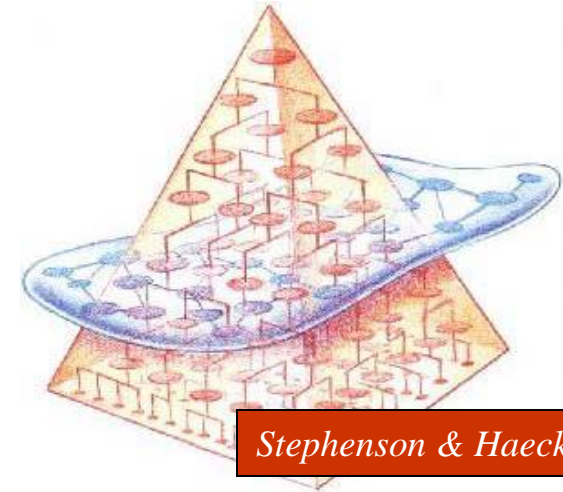
Jurriaan van Diggelen, Jeffrey M. Bradshaw, **Tim Grant, Matthew
Johnson, Mark Neerincx**

- **Goal:**
 - To present methodology for developing astronaut-rover team support, illustrated using MECA scenario
- **Outline:**
 - Motivation
 - MECA project
 - KAoS framework, ontologies, & policies
 - Illustration: simulating hypothermic astronaut scenario
 - Further work

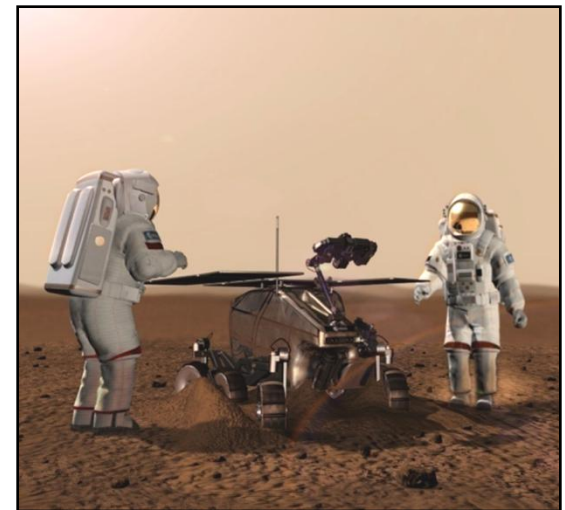
- Manned spaceflight experience:
 - Largely LEO; as far as Moon:
 - Communication delay (Earth-Moon) max 1.35 secs
 - Rescue difficult but feasible
 - CONOPS: Earth-centric, hierarchical mission control
- Future manned planetary missions:
 - Much greater distance:
 - Communication delay (Mars-Earth) max 22 mins
 - Rescue impossible
 - Will existing CONOPS still work?

- Mission control trends:
 - Ubiquitous computing
 - Network centricity
 - Autonomy (empowerment)

- Manned missions:
 - From astronaut teams
 - To astronaut-rover teams



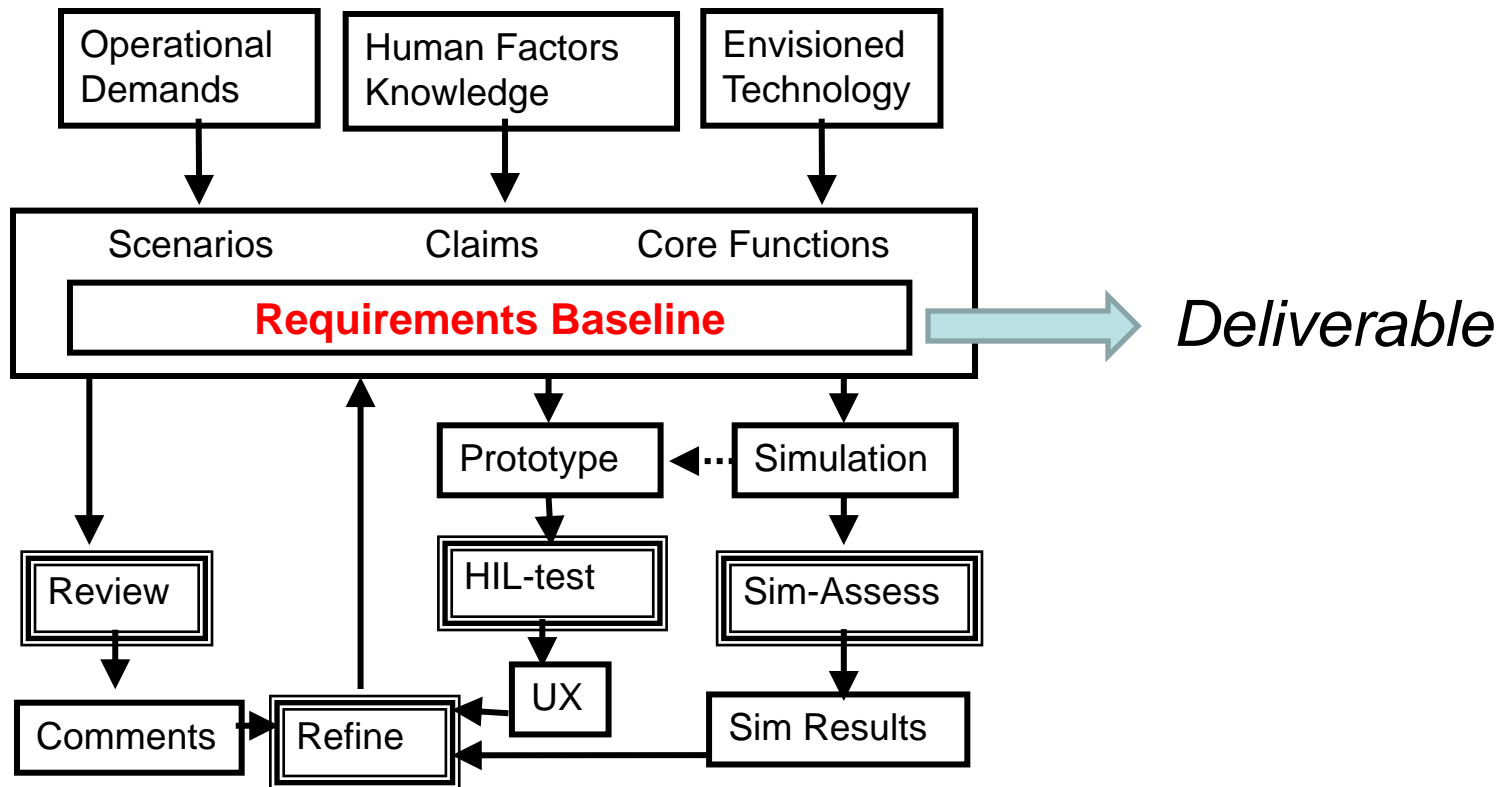
Stephenson & Haeckel, 2006



- Project objective:
 - To empower cognitive capacities of human-machine teams during planetary exploration missions to cope autonomously with unexpected, complex, & potentially hazardous situations

- MECA approach:
 - Personal *ePartners*





- Phases:

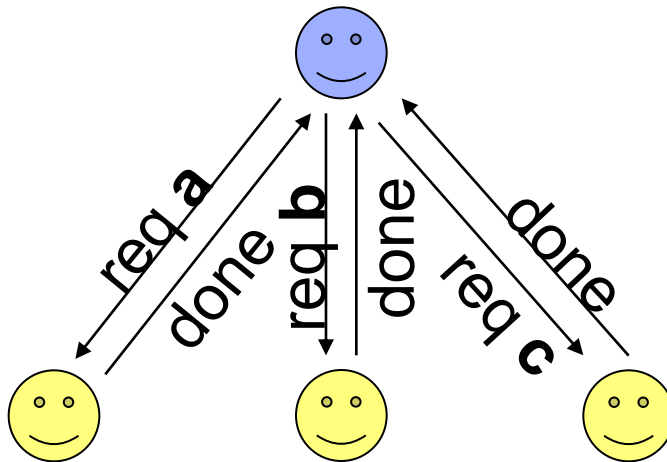
- Phase 1: Initial requirements (TRL 2)
- Phase 2: Prototype *ePartner* in lab (TRL 3/4)
 - Task model + human-machine collaboration:
 - Cognitive task load + emotion Neerincx et al, 2006
- Phase 3: Simulated environment (TRL 5)
 - MECA-T & MECA-I (common MECA-Framework)
 - This paper looks ahead to TRL 6:
 - Adds *ePartner*-mediated human-human collaboration
 - Issue: How do we organize astronaut-rover teams?
 - » Methodology: simulate organizations

- Work team:
 - Group whose effort results in performance greater than sum of individual members' inputs
 - Members accept policy constraints on behaviour:
 - Positive & negative *authorizations* (permit / forbid)
 - Positive & negative *obligations* (require / not require)
 - Highly contextual (i.e., situation- & role-specific)
 - Members strive to maintain “common ground”
- Policy constraints implemented as:
 - OWL ontologies in KAoS *Breebart et al, 2009 (SMC-IT09, paper 14)*
 - Leveraging KAoS policy services *Bradshaw et al, 2004*

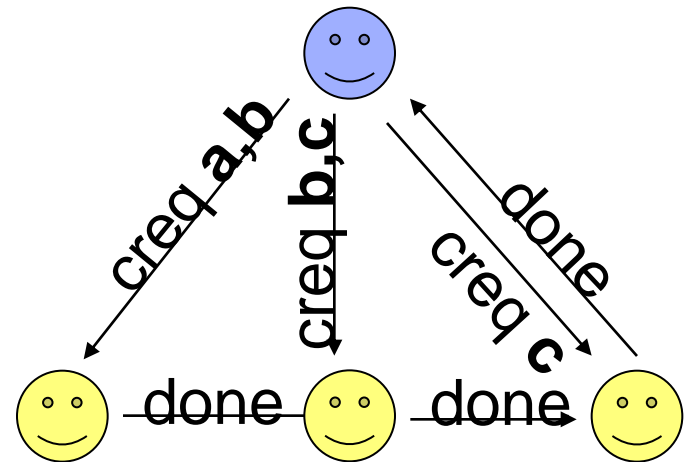
- Leader policy set (Definition 1 in paper):
 - Leader accepts collective obligations (CO) of team
 - Members notify leader when situation triggers CO
 - Leader authorized to:
 - Generate plans (action-sequences)
 - Request member(s) to perform action(s)
- Coordination policy set (Definition 2 in paper):
 - On action completion, inform actor who performs next action in plan, if known
 - Else inform requester



Centralized

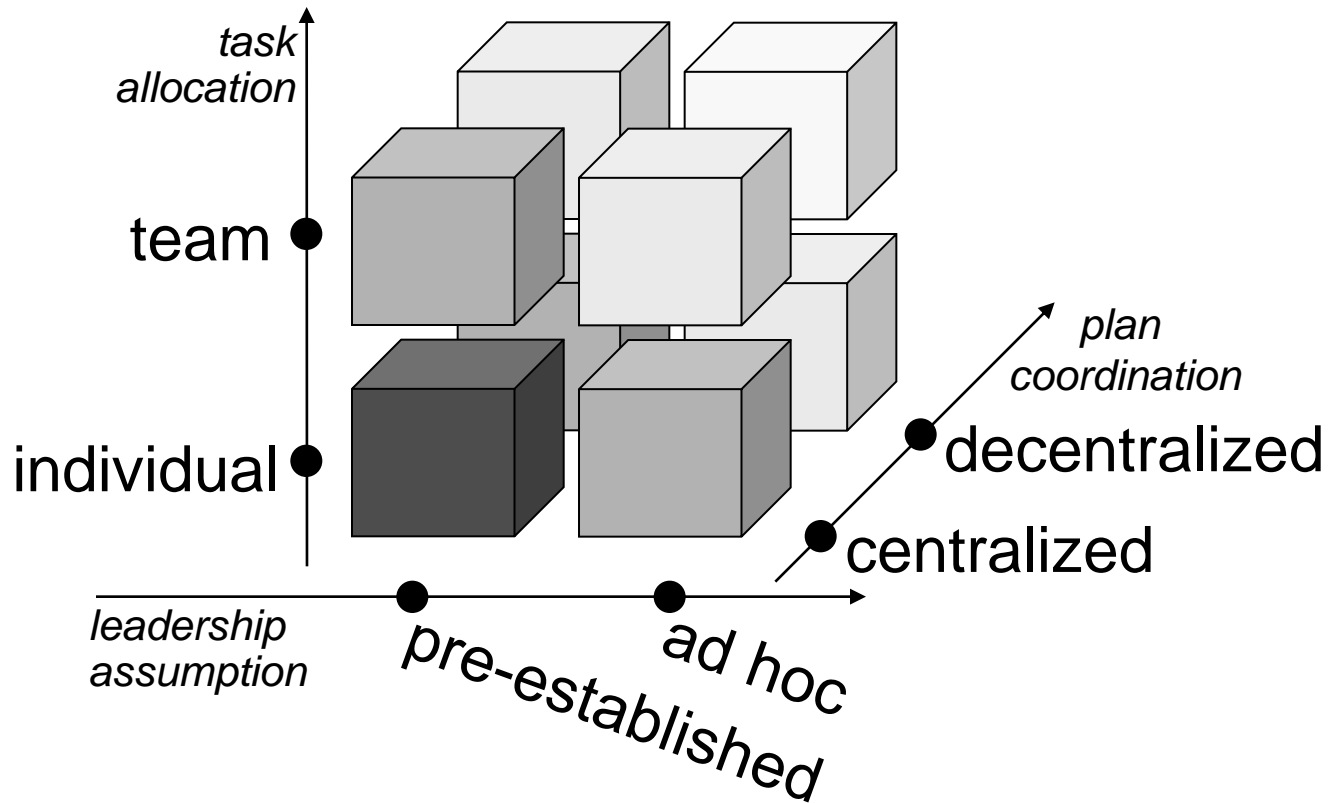


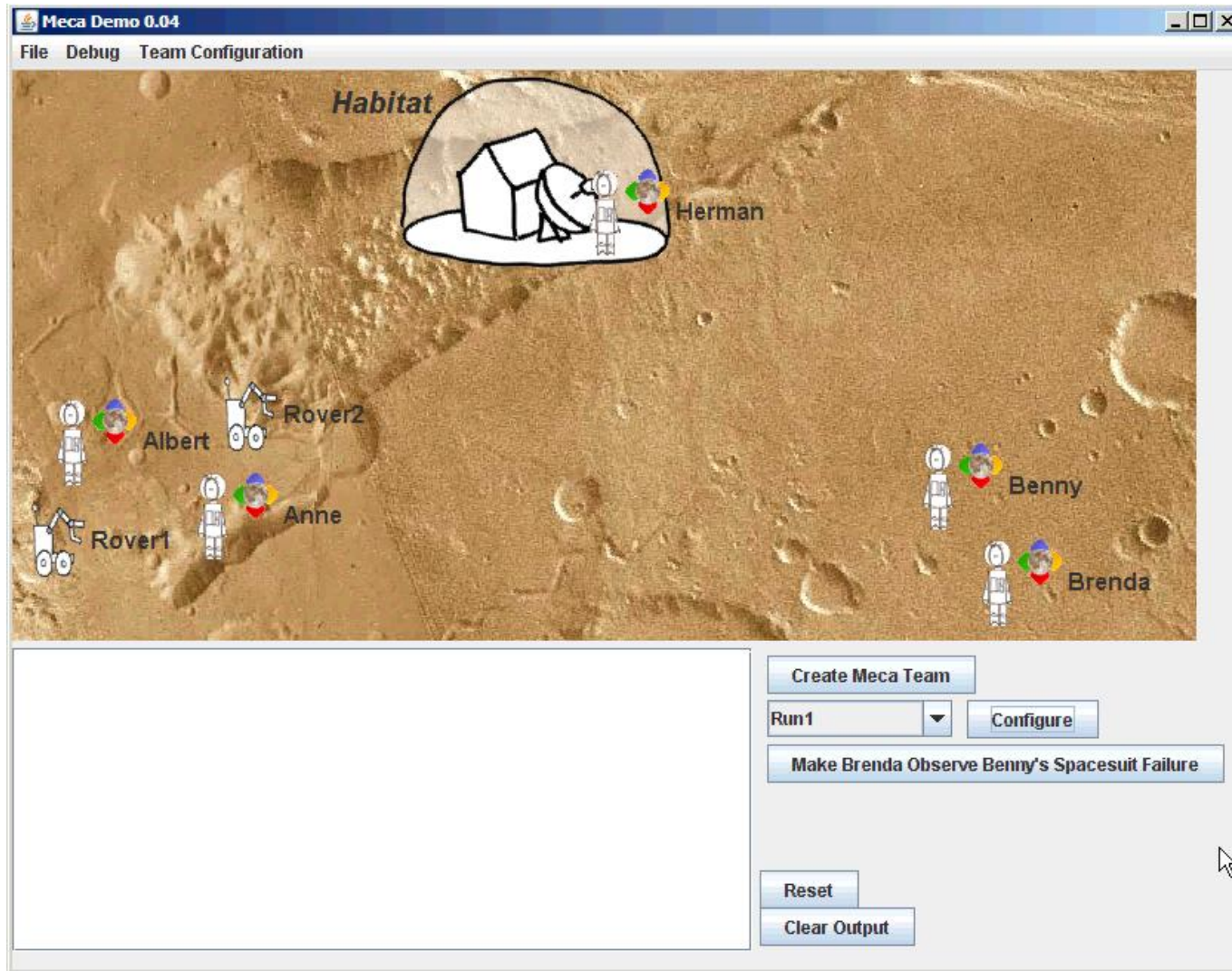
Decentralized





Eight possible organizations:





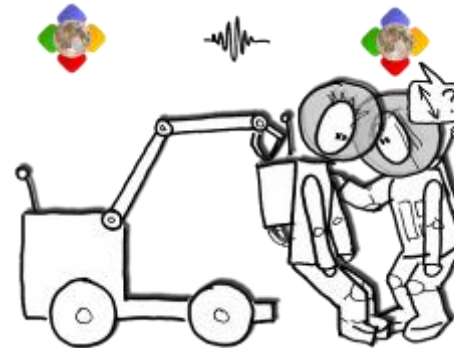
Benny and Brenda are on a rock collecting procedure.



Suddenly, Benny's spacesuit fails



A Rover from another team comes to pick up Benny



Benny is brought to the habitat for recovery



JOHAN VAN BALKEN

- **Event trace (fully centralized team):**

Brenda performs ObserveSpaceSuitFails

Brenda is obliged to perform SendNotificationOfTrigger

Brenda to Herman: SendNotificationOfTrigger

Herman is obliged to perform EnsureSafety

Herman is authorized to perform CreatePlan

Herman performs CreatePlan

Herman is not authorized to perform RequestCoordinatedAction

Herman is authorized to perform RequestAction

Herman to Rover1: request BringToHabitat

Rover1 performs BringToHabitat

Rover1 is obliged to perform SendNotificationOfRequestedActionFinished

Rover1 to Herman: SendNotificationOfRequestedActionFinished

Herman to Albert: request PerformSurgery

Albert performs PerformSurgery

Albert is obliged to perform SendNotificationOfRequestedActionFinished

Albert to Herman: SendNotificationOfRequestedActionFinished

Herman to Anne: request Nurse

Anne performs Nurse

Anne is obliged to perform SendNotificationOfRequestedActionFinished

Anne to Herman: SendNotificationOfRequestedActionFinished

- Simulation results & limitations:
 - All eight organizations simulated with:
 - Perfect communications
 - Same organization (set of policies) for both teams
 - Scenario successfully resolved in all eight runs
- Conclusions:
 - Methodology feasible
 - More simulation runs needed:
 - Esp. with communication delays & interruptions

- **Work done since paper written:**
 - *ePartner* monitors policy compliance
 - Astronaut can relax policy if vital for safety
 - Implementation technology:
 - K AoS linked to Brahms agent environment
 - Output displayed on *ePartner* prototype
- **Possible further research lines:**
 - Imperfect communications & limited time
 - Teams with diverse organizations / cultures
 - Investigate how humans react to policies



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Any questions?



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