



## ***Enhancing Team Performance for Long-Duration Space Missions***

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## ***Exploration Missions: Unforgiving Isolated and Confined Environments, Stressors***





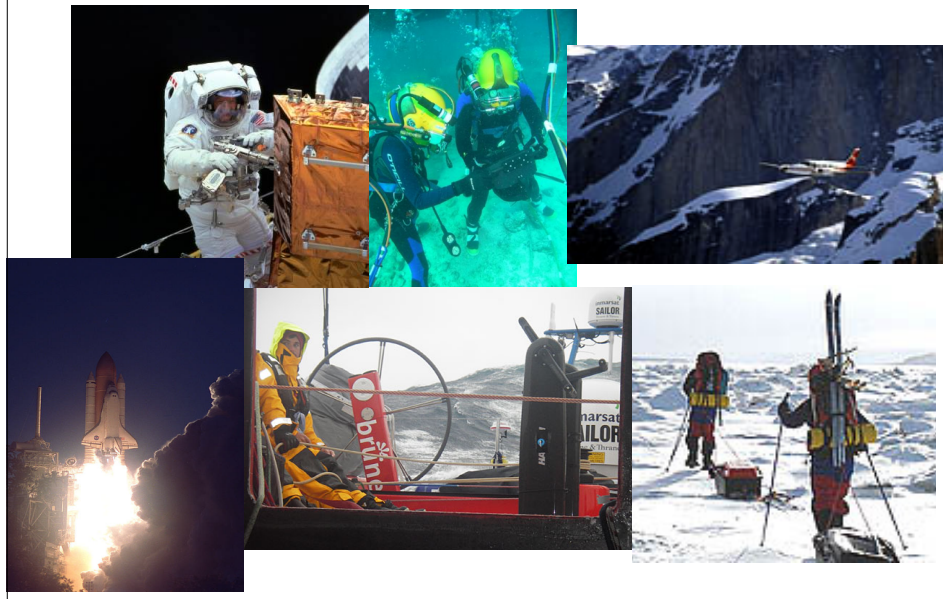
## NASA BHP Team Risk



- **Risk of team performance decrements due to inadequate**
  - Cooperation
  - Coordination
  - Communication
  - Psychosocial Adaptation
- **Potential issues in space**
  - System failures in habitat
  - EVA gear
  - Health of crew: illness, injuries
  - Space threats
  - Psychosocial conflicts/tensions

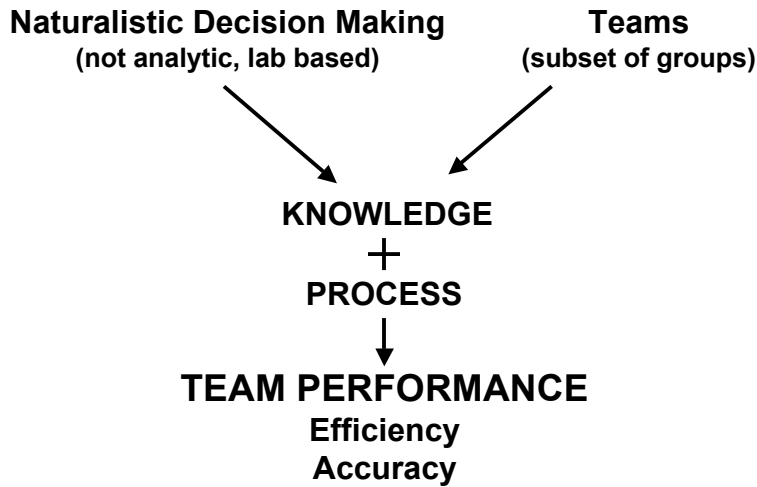


## High-Risk Environments





## Preface - Historical Research Shifts



## Overview



### ***I. Features of Effective Team Cognition***

- Shared Mental Models
- Collaborative Decision Making
  - NDM
  - Risk Assessment
  - Metacognitive Strategies
  - Communication
- Teamwork
  - Social processes
  - Cohesion

### ***II. Challenges to Effective Team Cognition***

- Limits of expertise
- Individual stress effects
- Sleep deprivation
- Interpersonal stresses
- Diversity factors

### ***III. Supporting Effective Team Cognition***

- Training
- Support tools



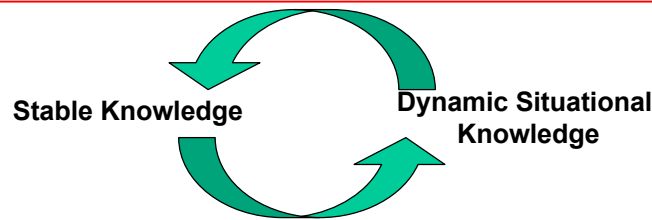
## Some definitions



- **Teams:** *Two or more individuals with specified roles interacting adaptively, interdependently, and dynamically toward a common and valued goal. (Dyer, 1984; Salas, et al., 1992)*
- **Coordination**
  - Tasks are largely procedural, with specific subtasks assigned to different members of the team. Often scripted contributions
- **Collaboration**
  - Tasks are non-procedural. Contributions to joint problem solving, decision making or task completion involve unscripted contributions
- **Cooperation**
  - Team orientation, motivation to work together as a team



## Shared Mental Models



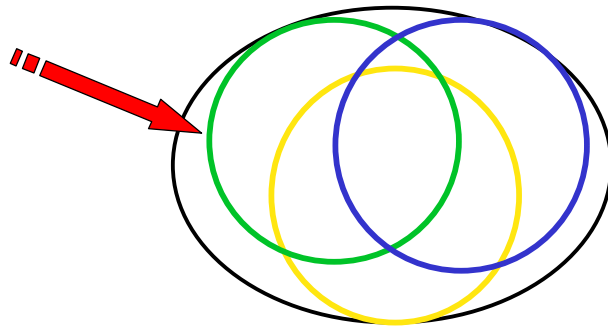
- **Mental Models**
  - Understand, explain, predict
  - Models for
    - System
    - Tasks
    - Procedures - including roles & responsibilities
    - Teamwork - interaction and coordination processes
    - Individual team members



I. *Features of Effective Team Cognition*  
**Shared Mental Models**



- *How much overlap? Original view*



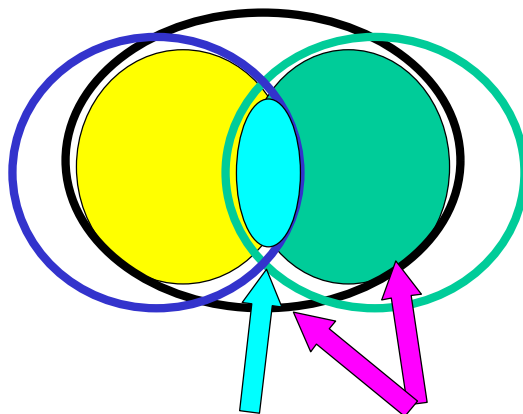
**Goal = Maximize overlap**



*Features of Effective Team Cognition*  
**Shared Mental Models**



***New View of "Shared" Knowledge***



**+ Shared  
GOALS**

**Shared = Common + Complementary**



## Collaborative Decision Making



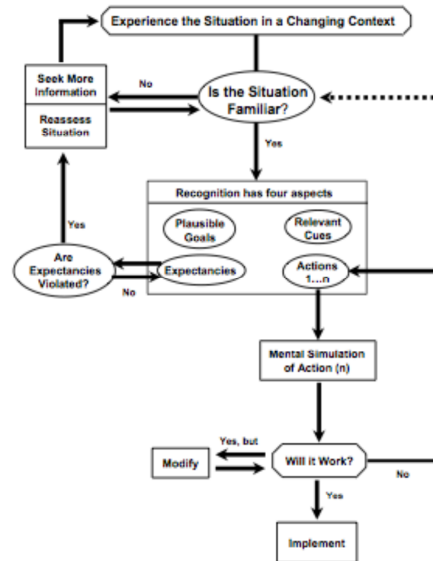
- **Needed to cope with unexpected events**
  - E.g., UA 232, Apollo-13
- **Difficult events**
  - Ambiguous cues
  - Dynamic conditions --> shifting goals
  - Uncertain outcomes
  - High workload
  - Time pressure

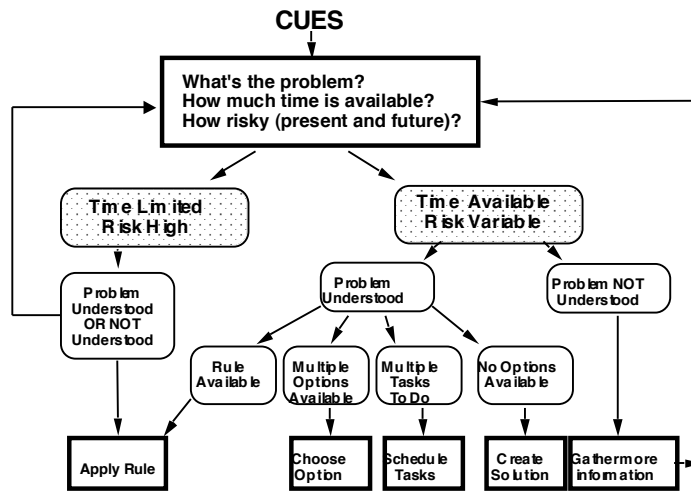


## Collaborative Decision Making - NDM



- **Two major components**
  - Assess the situation
  - Choose a course of action
- **Recognition-Primed Decisions (RPD)**
  - Knowledge-based
  - Good under time pressure
  - Serial vs. concurrent comparison of options
  - (Klein, 1989, 1993)





## • Risk Assessment

- Implicit process - but evident in data
  - Monitoring - challenging study
  - MIT-LL study: pilots diverting around thunderstorms
- Make explicit: low-fidelity sim study

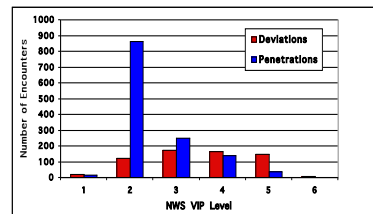


Captain: "Smell the rain. Smell it?"

First officer: "Yup. Got lightning in it too."

"Managers pursue risky actions because they fail to *perceive* accurately the risks involved."

(March & Shapira, 1987, p. 33)



(Rhoda & Pawlak, 1999)



## Risk perception drives action

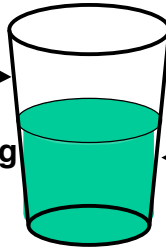


**Half Empty** →

Focus = negative:  
Weather approaching  
Windshear likely

**Avoid risk ->  
CHANGE plan**

**Action: Delay  
departure until  
weather improves**



← **Half Full**

Focus = positive:  
Windshear diminishing

**Accept mitigated risk->  
CONTINUE with plan**

**Action: Review takeoff  
windshear procedures,  
Adjust T/O configuration**



## How Do Pilots Manage Risks?



**All decisions aimed at PREVENTING LOSS  
while achieving GOALS**

- **AVOID safety risk**
  - Delay takeoff or divert
- **MITIGATE safety risk**
  - Request priority handling to avoid fuel critical situation
- **Prepare for worst case**
  - Take precautions (e.g., review windshear procedures)

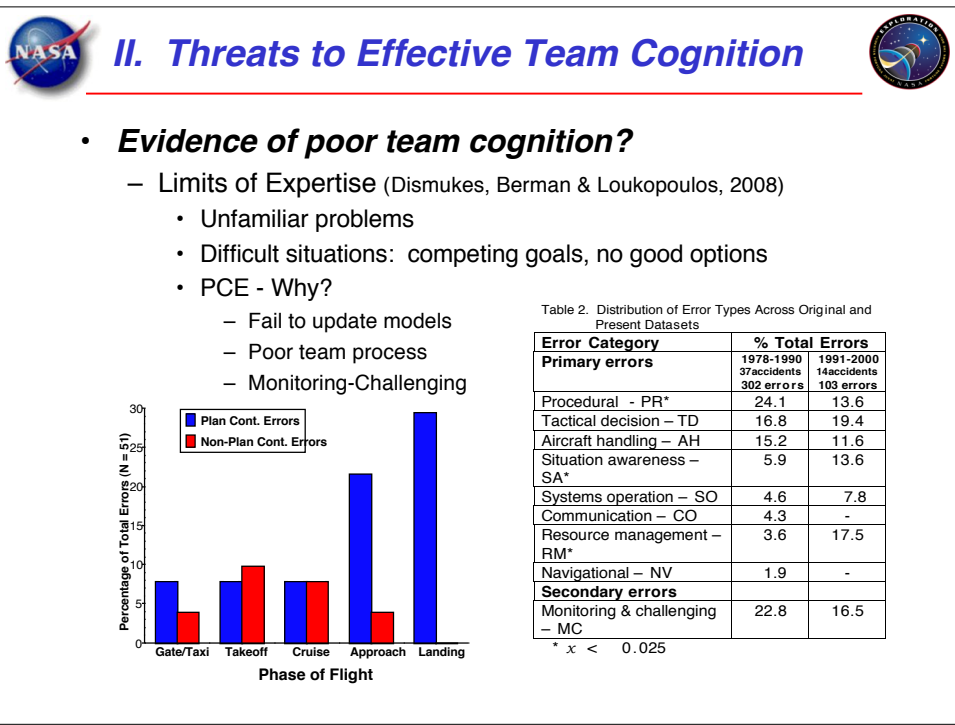
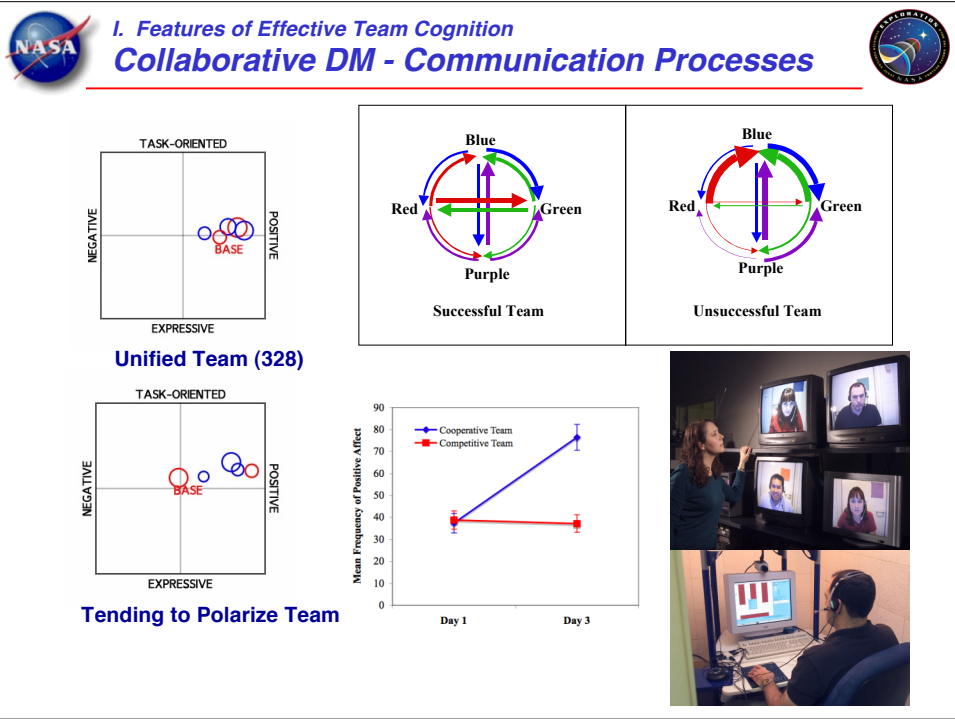




- **Awareness of demands of situation + crew resources available to meet them**
- **Core of ADAPTIVE processes**
  - Critical to
    - High workload situations
    - Unfamiliar situations
    - Ambiguous cues/incomplete information
    - Uncertain outcomes
- **C.f. Cohen, Freeman & Wolf (1996)**
  - Recognitional/Metacognitive training - Mil C2



- **Taskwork**
  - Share information - explicit (build shared sit model)
  - Closed loop
  - Efficient: Grice's maxims
- **Teamwork**
  - Briefings
    - CDR's intent, strategies, plans, contingencies
    - Involve all crewmembers
  - Error correction (Monitoring/challenging)
    - Maintain positive crew climate - fix problem
  - Relational communication
    - Important to cohesion
  - INDIRECT techniques to assess
    - C.f. EXEMSI (Cazes, Rosnet, Bachelard, Le Scanff, Rivolier (1996))



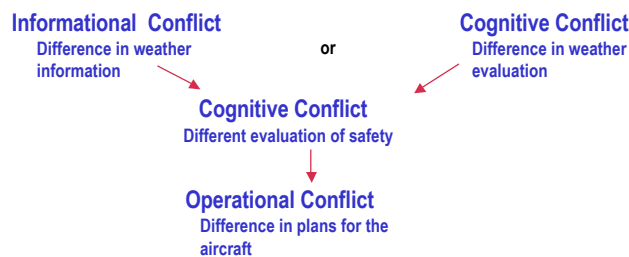


## II. Threats to Effective Team Cognition



- **Inherent in Distributed Teams**

- Alternative perspectives
  - Differences in goals, risk perception, expertise
  - Pilots - ATC
    - Risk perception and action
    - Breakdowns (Bearman et al., 2005; in press)
      - » Informational, Operational, Cognitive



## II. Threats to Effective Team Cognition Individual stressors



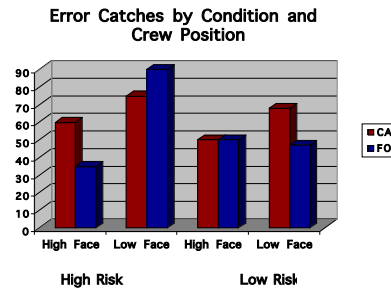
- **Individual stressors**
  - Loss of cognitive resource
  - Focus shifts to own highest priority - Lose team orientation
    - Driskell & Salas
- **Sleep deprivation**
  - Indirect cognitive effects rel to DM
    - Information updating failures
    - Underweight new information
    - Rigidity - loss of cognitive flexibility
    - Degrades mood
  - Affects communication
    - Less task-relevant information transferred
    - Less discussion of strategies
    - Comprehension degrades
    - Simplified vocabulary - pronominalization
      - “How’s IT coming along up there?”



## II. Threats to Effective Team Cognition



- **Interpersonal stress - conflict**
  - Failures to monitor each other, back up, correct errors
  - Reduced information sharing
  - Withdraw social / emotional support
  - Lose team orientation
- **Social pressures**
  - Status, face
    - B-747 study
    - USS Greenville sinks Ehe
- **Diversity pressures**
  - SFINCSS
  - Mt. Everest



## III. Supporting Effective Team Collaboration



- **Training**
  - Turn a TEAM of EXPERTS into an EXPERT TEAM
    - Self-managing, adaptive, flexible
  - Integrate TEAMWORK training w/ TECHNICAL
  - TEM = Threat and Error Management
    - Updated CRM
  - Validated Approaches
    - TACT (Team Adaptation and Coordination Training)
    - TDT (Team Dimensional Training)
    - Cross-Training
    - Interpersonal Training
    - Team Development (cohesion)
    - Multicultural
  - Meta-analysis of training approaches: Salas, DiazGranados, Klein, Burke, Stagl, Goodwin, & Halpin (2008)
    - Pos effects on team cognition, affect, process and performance



### III. Supporting Effective Team Collaboration **TACT, TDT**



- **TACT** (*Serfaty, Entin, & Johnson, 1998*)
  - Adjust coordination and communication strategies to maintain successful task performance under high WL and time pressure
  - Grounded in
    - Shared situation models
    - Team metacognition
    - Mutual team models of interacting team members' tasks and abilities, including stress and WL
  - Generate shared expectations for how situation will evolve
  - Reduce communication overhead
    - Implicit coordination
    - Anticipation ratio of information sharing/requested info



### III. Supporting Effective Team Collaboration **TACT, TDT**



- **TDT** (*Smith-Jentsch, Zeisig, Acton & McPherson, 1998*)
- **Similar to TACT but --**
- **Team self-diagnosis, correction and debriefing skills**
- **Four dimensions**
  - Information exchange
  - Communication
  - Backup (supporting behaviors)
  - Initiative/leadership
- **Validation study**
  - More accurate teamwork MM
  - More effective outcomes



### III. *Supporting Effective Team Collaboration Cross-Training*



- **Important for LD space missions**
  - Limited number of crew
  - Cover if one member is disabled
- **Rotate positions in training**
  - Taskwork vs. teamwork training
- **Most critical when**
  - High team WL
  - Tasks must be reallocated
  - Contributes to implicit coordination  
(Cannon-Bowers, Salas, Blickensderfer & Bowers, 1998)
- **Measuring Team Knowledge**
  - Teamwork training develops best in context of Taskwork training
  - Full cross-training better than conceptual cross-training  
(Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003)



### III. *Supporting Effective Team Collaboration Interpersonal Skills, Team Building*



- **Fosters cohesion**
  - Working with others
  - Leadership
  - Positive communication
  - Conflict management
- **Evaluation - business environments**
  - Meta-analysis: IST had greatest benefits to productivity, cohesion, morale, job satisfaction
- **BUT other meta-analysis**
  - Team development/affect = most difficult to impact
  - Compared IST w/other training approaches: TACT etc.
  - Do NOT have good understanding of how to develop cohesion
    - Hint: Transformational Leadership is key



## Team Effectiveness Framework

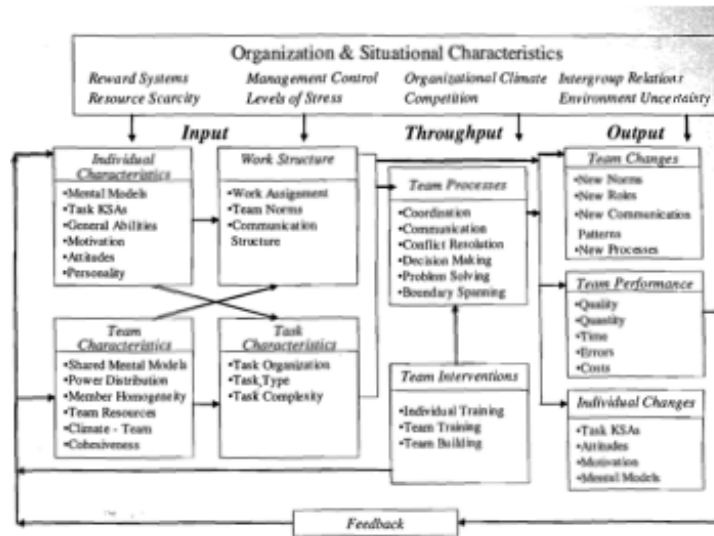


Figure 7.1 Team effectiveness framework adapted from (Tannenbaum, Beard and Salas, 1992)



### III. Supporting Effective Team Collaboration Technology Supports



- **Distributed teams**
  - Locally distributed (within space crews)
  - Crew - ground (no time lag)
  - Crew - ground (time lag)
- **Face-to-face vs. Video vs. Audio**
  - Maintain team SA and collaboration
  - Face to Face (F2F)
    - Understand others' actions, intentions
    - Computer-mediated = F2F for idea-generation
    - Lack of F2F
      - Difficulty in establishing conventions
      - Neg impact on performance on complex tasks / judgments
  - Video
    - Facilitates problem solving vs. email
    - Contributes to cohesion among distributed team members
  - Audio, Email
    - OK when no time restrictions
    - OK when onboard info is adequate



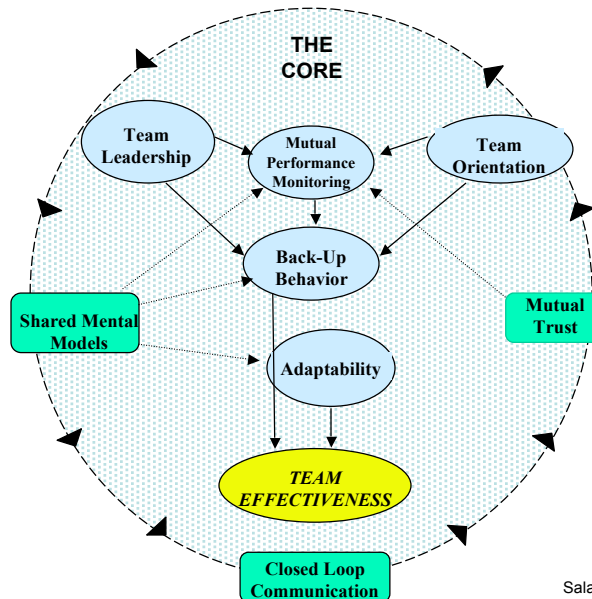
### III. Supporting Effective Team Collaboration Technology Supports



- **Asynchronous collaboration**  
(Krauss & Bricker, 1966; Kraut, Fussell, Brennan & Siegel, 2002)
  - Time lags in Mars communication
  - Even small delays affect establishment of common ground
  - Requires more explicit message formulation
  - Reduces efficiency, especially w/complex problem
- **Autonomous crew performance**
  - Requires onboard information systems
    - Easily searchable data architectures
    - Access to relevant systems data
    - Simplified procedures
    - Support medical care
  - On-board countermeasures
    - Psychosocial support
    - Conflict management



Graphical representation of high-level relationship between the 'Big Five' and coordination mechanisms



Salas, Sims, & Burke, 2006

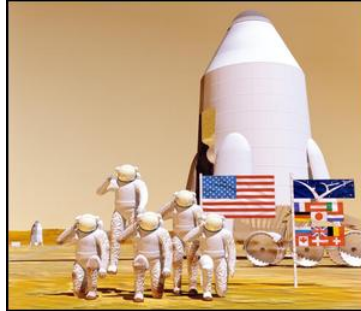




## Questions?



- *I look forward to your input*
- *Judith.Orasanu@nasa.gov*



***We all THANK YOU!***



## Happy campers





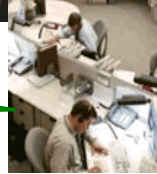
## Distributed Problem Solving in Aviation



*Flight crews*



*ATC*



*Airline Ops Centers*

- Naturalistic DM
- Shared mental models
- Error detection & correction
- Risk perception/DM
- Conflict resolution