Ames Research Center

Human Factors in Aerospace Systems

supporting human decision-making in complex systems

December 11, 2002

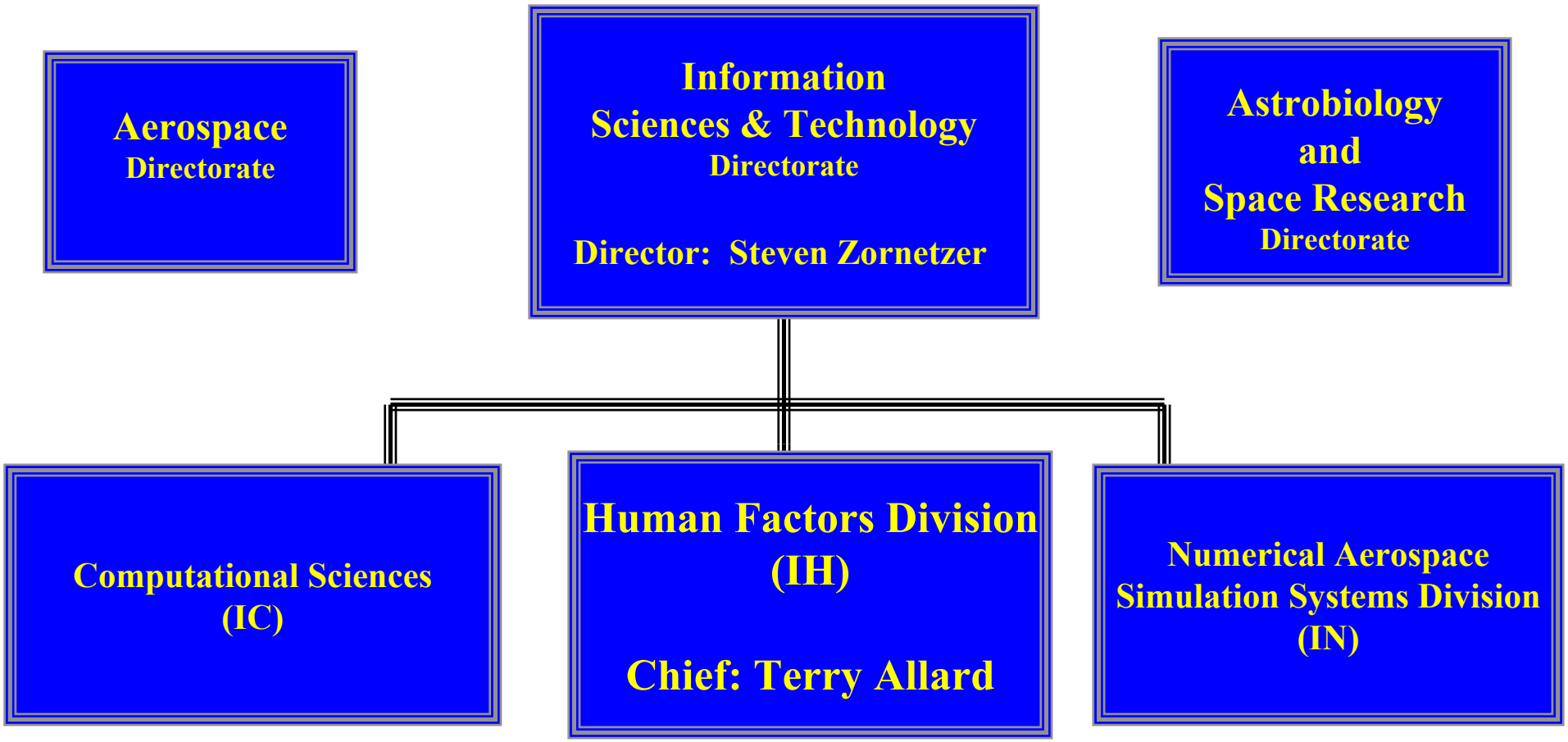
Human Factors
research and technology

Information Sciences and Technology Directorate
NASA Ames Research Center

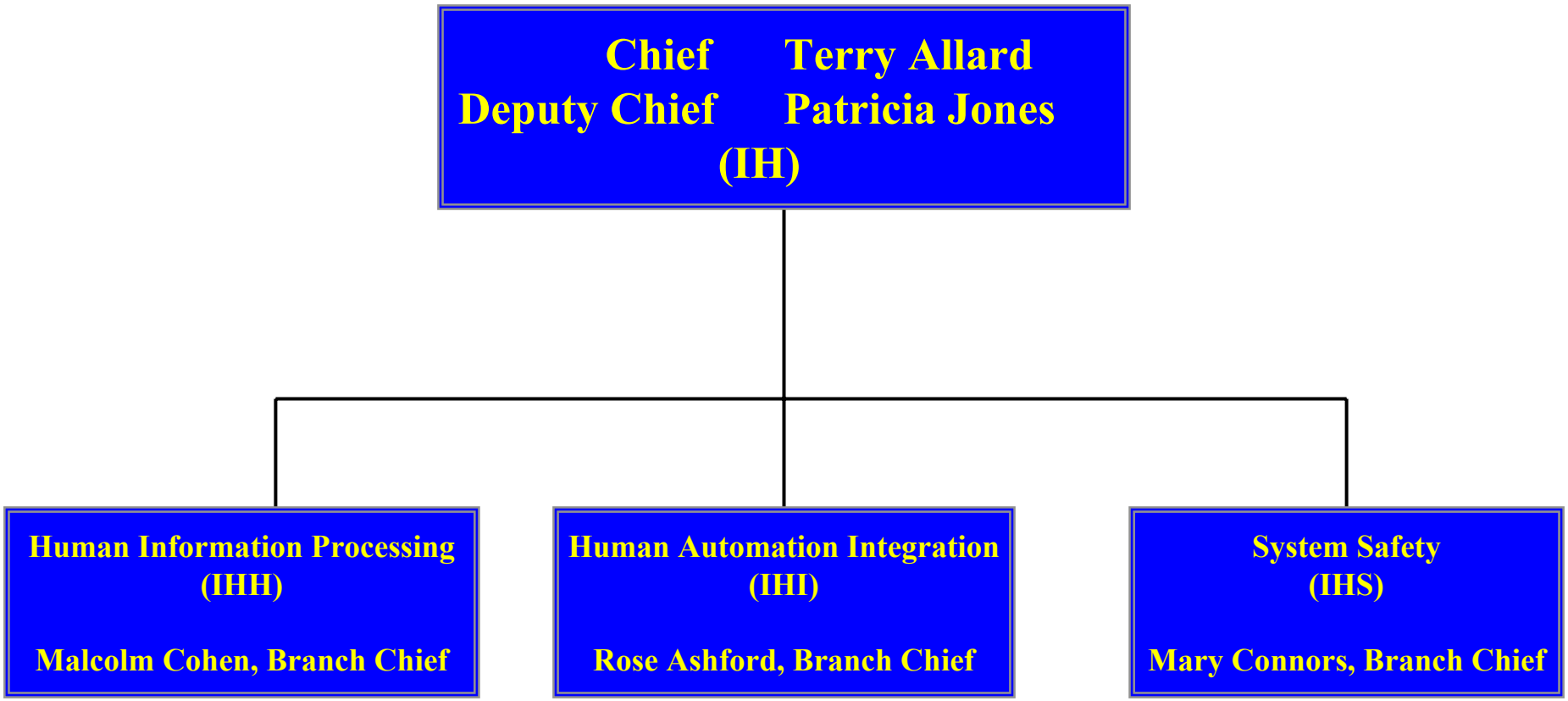
Ames Research Center Organization

Information Sciences and Technology Directorate (I)

One of 3 S&T Directorates at Ames



IH Division Organization



59 Government Employees:
Scientists, Engineers, Pilots, Controllers
~150 Support Contractors

NASA missions

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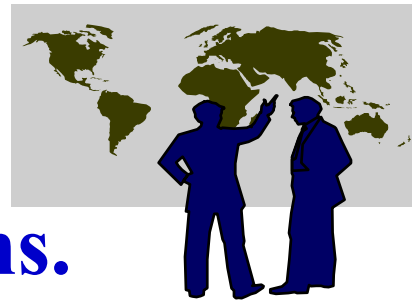

Understanding and supporting human performance in complex systems.

Technology Readiness Levels 1-6

- **Delivering today -- Anticipating the future**

NASA Missions:

Aviation

Safety, Efficiency, Security

- Cockpit / Flight Crew
- Ground Op's / Maintenance
- Air-Ground
- System Monitoring / Modeling

Space

- Bioastronautics
- Shuttle / RLVs
- Mars Rover
- Mission design
- Launch/Ground Op's

Research Areas

strong history of Aviation Human Factors leadership

1970's - 80's Division Roots

- Crew Resource Management
- Fatigue
- Workload
- Cockpit Displays
- Vision / Audition
- Incident Analyses

Current Work

- Team Decision-Making
- Training
- Distributed Air-Ground collaboration
- Fatigue Measurement & Countermeasures
- Maintenance Resource Management
- System Monitoring, Data Mining and Visualization
- Datalink
- Human-System Performance Models
- Cockpit Display of Traffic Information
- Distributed Human-in-the-loop Simulation
- Human-Automation Allocation
- Virtual Reality / Multi-sensory displays

ARC Expertise

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ARC Expertise X TRL	1-3	4-6	7-9
Automation/ Supervisory Control	√	√	√
Cockpit Displays	√	√	√
Cognition	√	√	
Crew Resource Management/ Team Performance	√	√	√
Communication	√	√	
Decision-Making/ Decision Support Tools	√	√	√
Human Error / Human Performance Modeling	√	√	√
Motor Control / Oculometrics	√	√	
Perception	√	√	√
Psychophysiology	√	√	√
Training	√	√	√
Virtual Environments/ Multi-modal Displays	√	√	
Workload	√	√	√

Methods

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Field Tests (Flight tests)

Accident & Incident Analysis

ASRS

Aviation Research

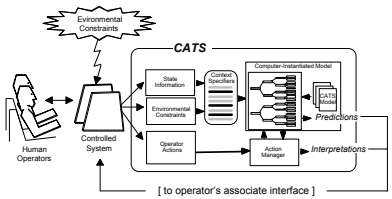
Literature Reviews

- Consult with subject matter experts
- Scientists are pilots

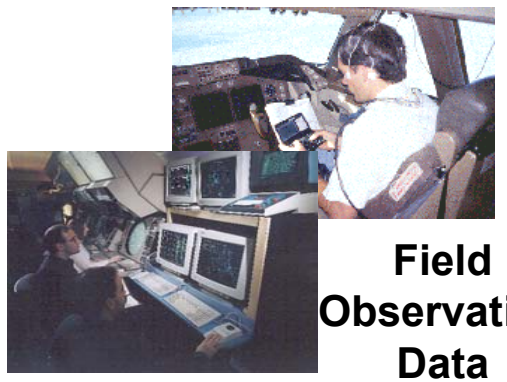
Part-task & Full Mission Simulations

Lab Studies

Computational Modeling



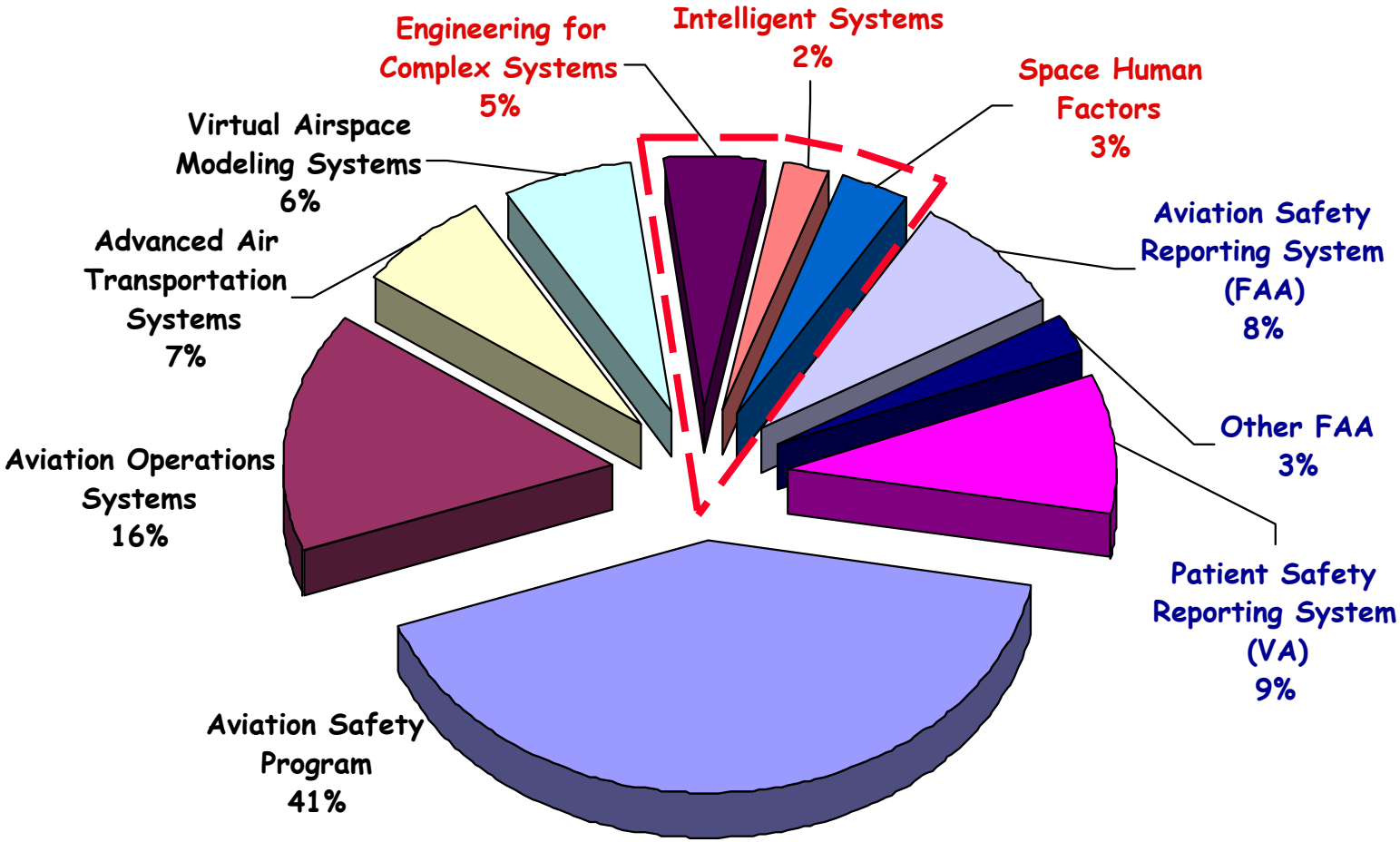
Field Observation Data



Critical Research Areas

- 1. Predictive Models of Humans and Human-System Interaction
  - Multiple levels of analysis: eg, perceptual/motor/cognitive, individual, team, organization
  - For design, decision support, operational monitoring, training
  - Scalability and usability are key challenges
- 2. Advanced Human-Computer Interaction / Interfaces
  - Virtual and Augmented Reality, Oculometrics, Multi-modal Systems
- 3. Individual and Team Decision-making in Operational Contexts
  - Human error, fatigue, communications, collaboration, risk perception
  - Automation-assisted decision-making, automation design, training, procedures
  - Distributed human-in-the-loop simulation, air-ground collaboration.
- 4. IT Tools for Proactive Management of System Risk
  - Safe, secure and efficient operation of aerospace systems
  - Transform large amounts of data into useful information
  - Organizational design and evaluation

Wide Range of Programs



Key Customers

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Technology Readiness Level	1-3	4-6	7-9
Academia / Science Community	√	•	
Airlines	•	√	√
Avionics Suppliers	√	√	
FAA - Air Traffic Services		√	√
FAA - Safety		√	√
FAA - Certification	•	•	
National Transportation Safety Board	•	•	•
Pilots, Astronauts, Controllers		√	√
NASA Mission Control		•	
NASA Ground Processing / Launch Control		√	
NASA Mission Design		√	
NASA Mars Exploration Rover		√	?
Dept of Veteran's Affairs		•	√
Dept of Defense	√	√	

Ames Full Mission Simulation Facilities

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- Vertical Motion Simulator
  - Space Shuttle Orbiter

- Future Flight Central
  - 360˚
  - ATC
  - Mars

- CVSRF
  - B747
  - ATC
  - ACFS

Ames Life Science Facilities

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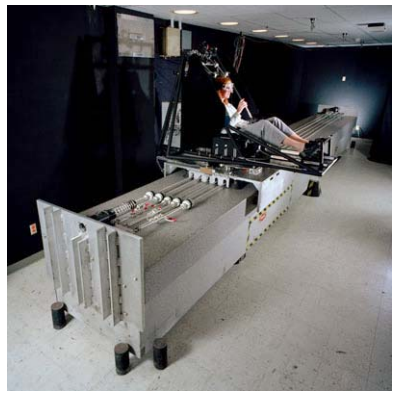
- 20-G Centrifuge
  - Variable gravity gradients
  - Angular acceleration

- Vestibular Research Facility
  - 30-foot Linear Sled
  - Ground-based multi-axis centrifuge



- Human Powered Centrifuge

Human Factors
research and technology

Human Factors Facilities

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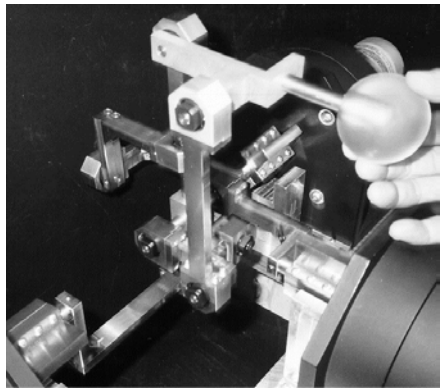
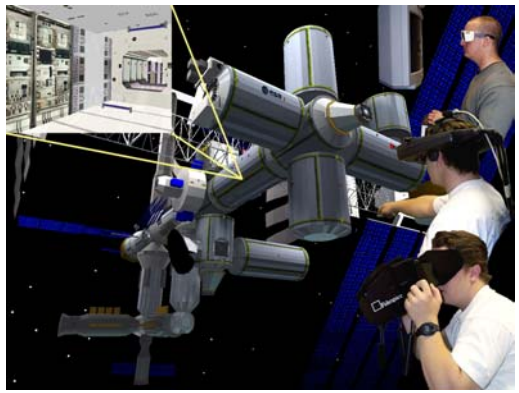
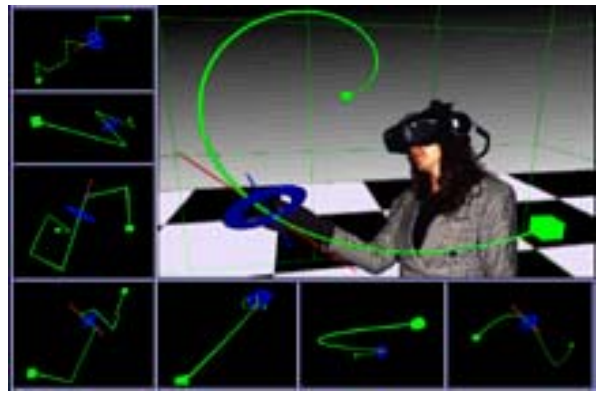
- Virtual Environments
  - Multimodal







- Aviation
  - HUDs
  - ATM
  - Small Jet Simulator

Human Factors Facilities

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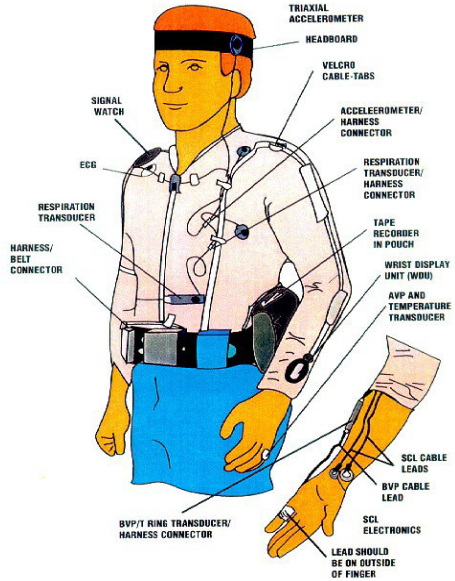
- Psychophysiological Research Facility



- Eye Movement Technology

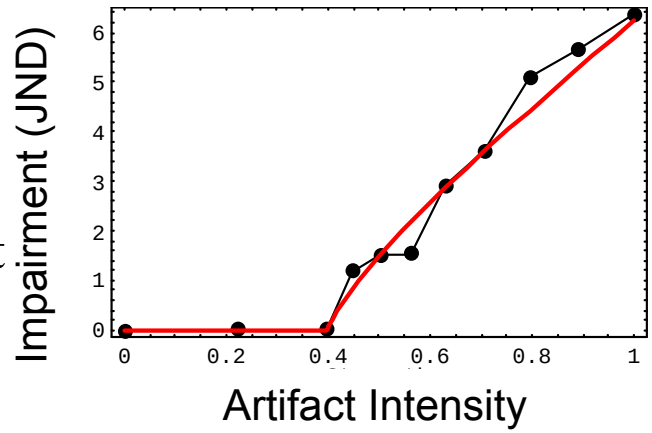
- Intelligent Spacecraft Interface Systems

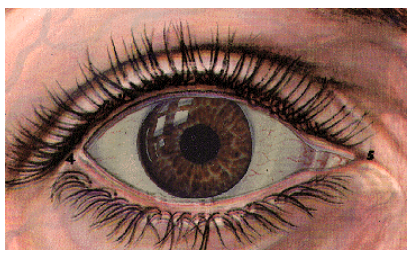
Visual Quality

Measurement Technology and Optimization Tools

Visual quality is a primary goal in displays, interfaces, and visual communication systems. We are building the scientific and engineering infrastructure to enable optimal design of systems that depend upon visual quality.

- Research
  - JND measurements of video quality
- Technologies
  - Subjective measurement methods (EASE)
  - Objective measurement tools (DCTune, DVQ, SSO)





Oculometrics

Non-Intrusive Performance Monitoring for Aerospace Applications

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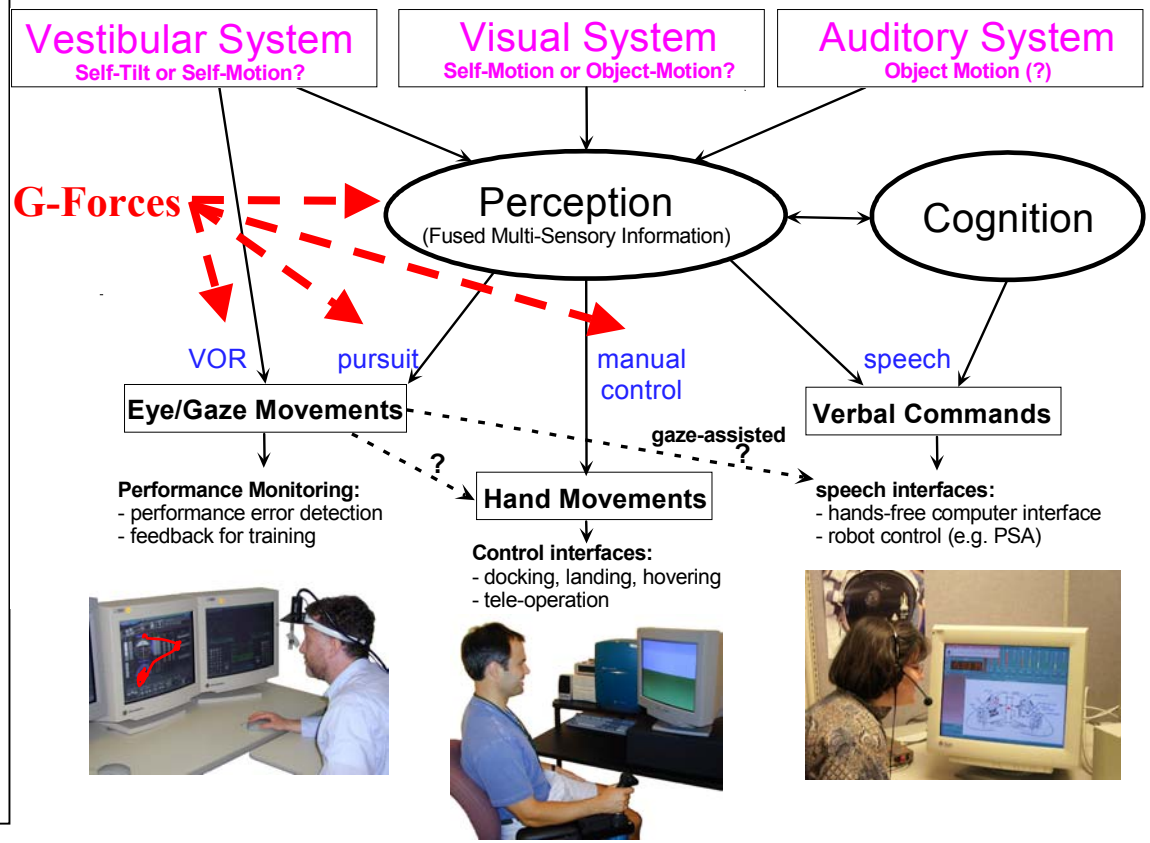
Vision and eye movements play a central role in any man-machine interface. Significant adverse perceptual and oculomotor effects of microgravity have been experienced during spaceflight and upon re-entry that jeopardize astronaut safety and mission success.

- **Research**
  - Vision and visuomotor control
  - Modeling microgravity effects
- **Technology Impact**
  - Countermeasures
  - Human performance evaluation
  - Display/Interface assessment
  - Enhanced training tools



Virtual Environments for Training and Design

New counter-measures for three major deficiencies in user interfaces to VE simulations have been developed and are being evaluated.

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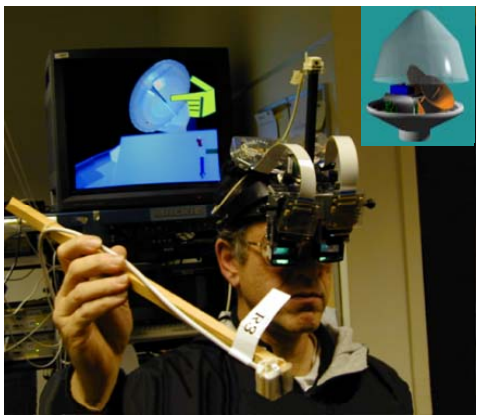
System Lag

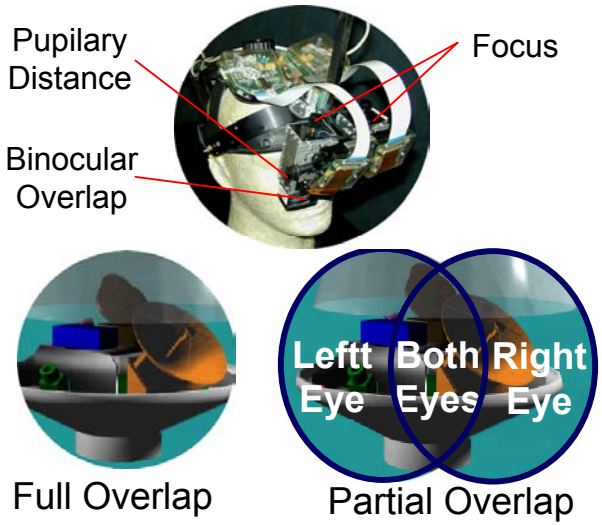
Perceptual artifacts of predictive filtering have been determined. Spacecraft virtual assembly testbed is implemented for predictor studies



Perceptually tuned predictors minimizing artifact detectability: Design and user validation studies have been conducted

Limited Field of View

Reconfigurable, stereoscopic see-through HMD testbed has been developed to extend field of view by partial binocular overlap.



User visual fatigue, stereoscopic accuracy, and tolerance for optical distortion will be studied in part task simulation.

Haptic Feedback

High fidelity arm- & finger- scale haptic interfaces completed with performance surpassing COTS technology.

High fidelity haptic-visual virtual assembly testbed is being developed for human performance evaluation

Development of an Index of Habitability Using Converging Indicators

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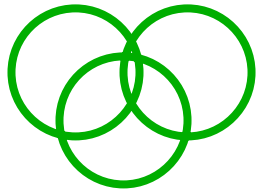
Performance
(cognitive, perceptual, neuro-motor)



Subjective States
(mood, symptoms)

Physiology (ANS, CNS)

- Objectives

  -Assess spaceflight effects on crew health, safety and performance.

  -Evaluate effectiveness of countermeasures.

  -Determine individual differences in adaptational capacity.

- Approach

  -Database analyses and archival.
  -Develop signal processing software.
  -Conduct operational research studies.

Astronaut Scheduling Assistant

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A biomathematical model of the neurobehavioral performance capability of space shuttle crews

- Research
  - Biomathematical model to predict human performance during short and long duration space flight
- Technology
  - Software that will aid in planning astronaut work/rest schedules by:
    - predicting times at which performance may be sub-optimal
    - determining times most suitable for restful on-board sleep
    - estimating the overall impact of new schedules on crew performance

Model-Based Support for Crew Activity Planning and Tracking

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- **Goal**

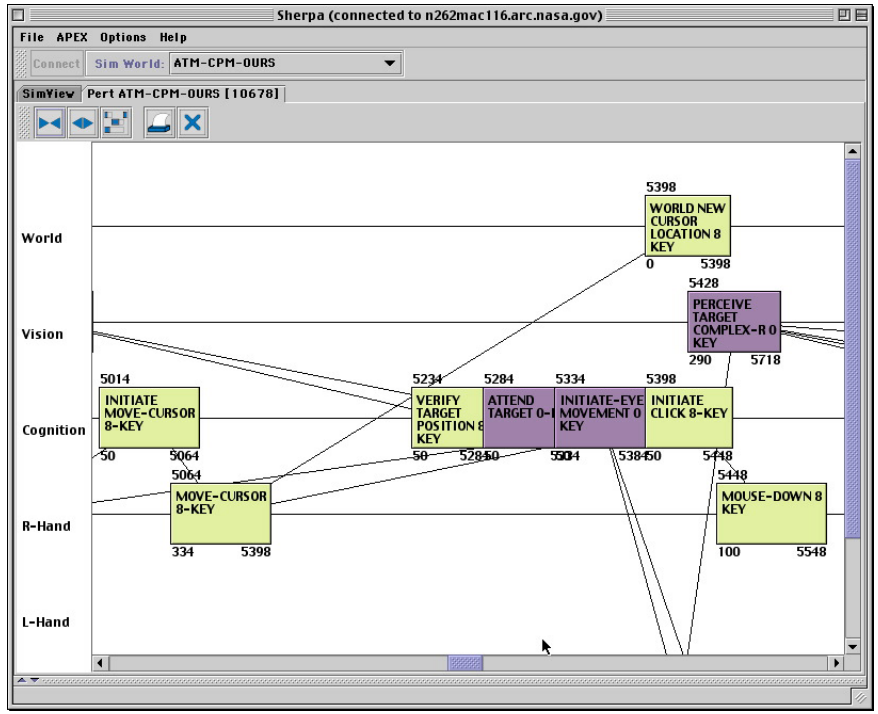
  Improve mission planners' ability to schedule astronaut time

- **Current problem** with accurate scheduling probably stems from some combination of:
  - Multitasking effects (interruptions, clobbers,…)
  - Inaccurate duration predictions

- **Our approach**

  Create simulation-based tool that models diverse sources of duration variability including multitasking overhead.

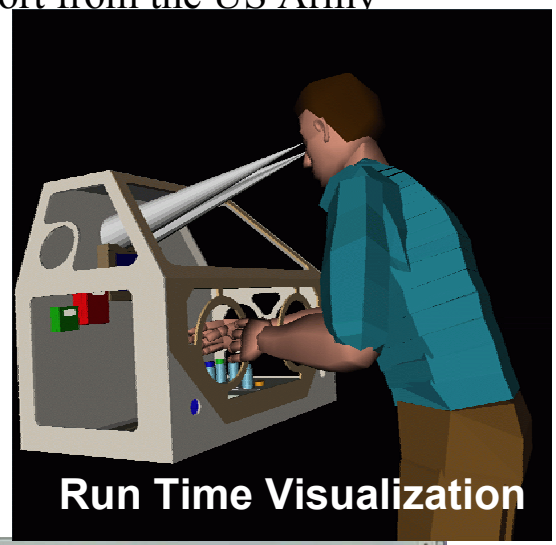
  The Apex agent architecture will be used to simulate astronaut behavior.

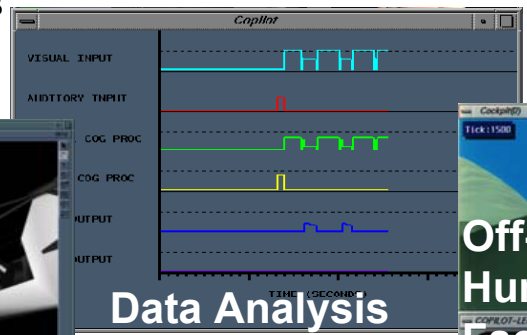


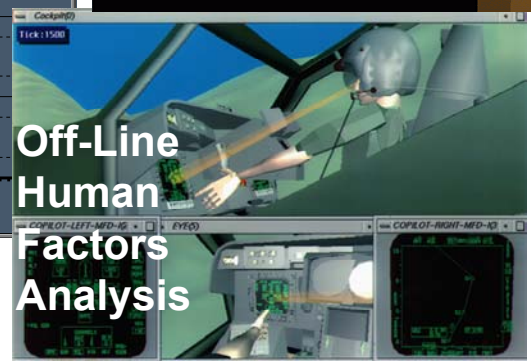
Apex-generated Pert chart for CPM-GOMS analysis

MIDAS

- The Man-Machine Integration Design and Analysis Simulation (MIDAS) has been under development at Ames for nearly two decades with primary support from the US Army Aeroflightdynamics Directorate.
- MIDAS offers an integrated human performance modeling environment to simulate, evaluate and visualize notional designs & procedures in a virtual operational environment.
- Goal: Model life sciences glove box to predict challenges of use in micro-gravity, to develop more efficient science procedures and more effective training.







Shuttle Upgrade

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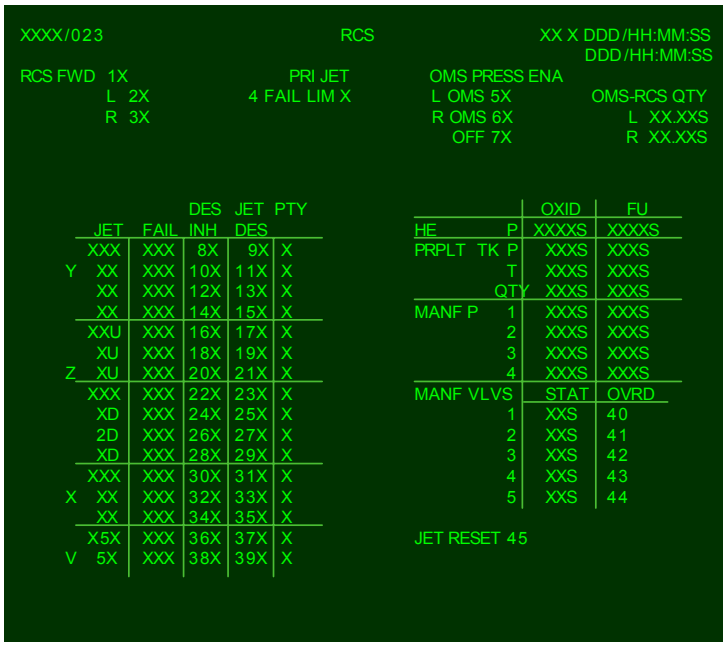
Redesigning shuttle cockpit displays to enhance crew situation awareness and improve flight safety

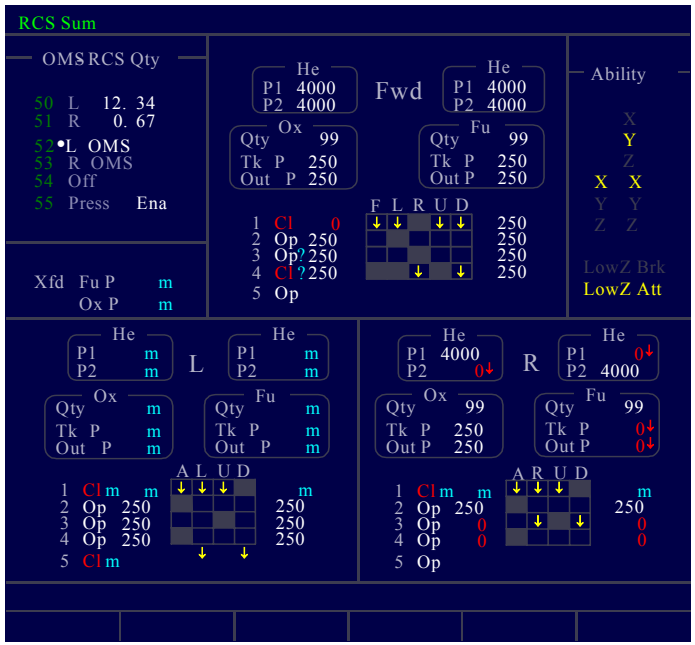
Current RCS Display



Suboptimal display characteristics:

- Only one RCS pod can be shown at a time.
- Color and graphics are not available.
- All information is capitalized, making readability difficult.

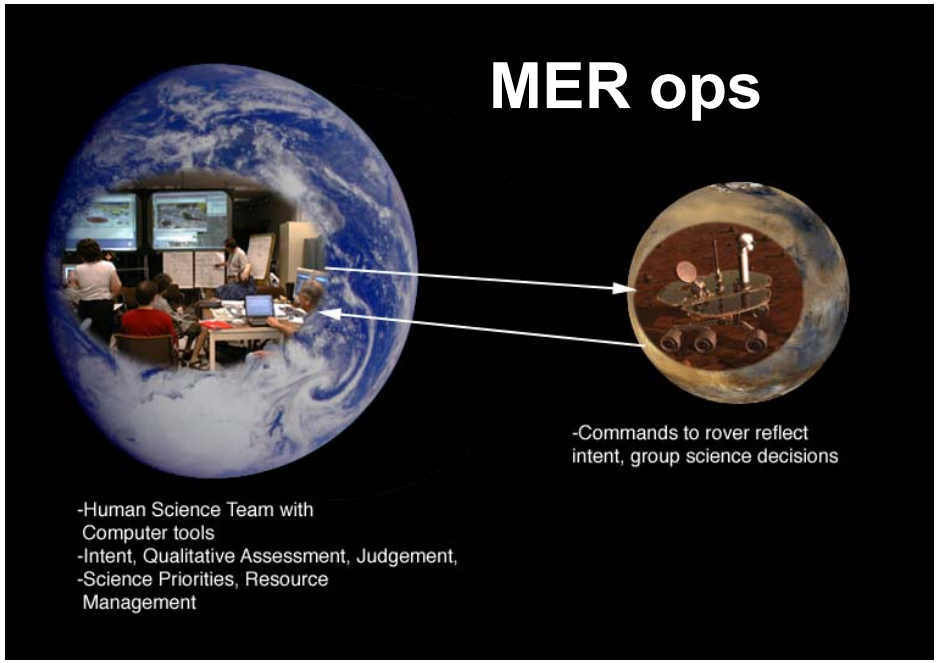
Proposed RCS Display Redesign



Design improvements:

- RCS pods (forward, aft left, aft right) are clearly demarcated and arranged in an intuitive spatial layout
- Propellant flow within each pod is arranged logically (top to bottom).
- Color coding identifies missing data (cyan), cautionary items (yellow) and warnings (red).

MERBoard



- 4 core applications, API for extensibility
  1. Browser / data display tools
  2. Virtual network computer for real-time sharing/control
  3. Digital whiteboard with drawing tools (with specific Long Term Planning tools)
  4. Pervasive and ubiquitous data storage and retrieval
- meta-tools for data capture and distribution

- IC/IH effort to develop a tool to support co-located and distributed collaborative activities of engineering and science teams in mission contexts

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Human Factors Incident Analysis: Perilog

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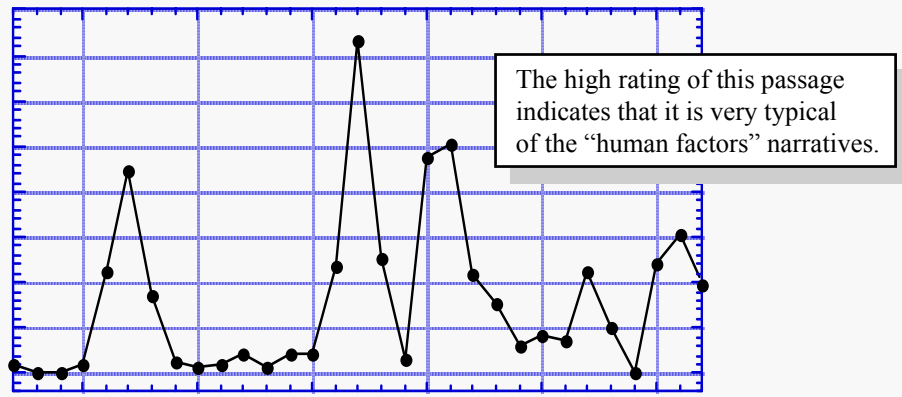
- Research
  - KSC Shuttle Event Database (1996-99)
  - Network model of the narrative text in the "Human Factor Contributing Causes" fields used to rank the typicality of passages
  - A set of questions manually developed, based on review of the typical passages and their contexts within the incident narratives.

- **Technologies**
  - Adaptation of text analysis tool for modeling and relevance-ranking incident narratives
  - Serves as an aid for incident analysts to
    - characterize specific communication or task scenarios, based on actual incidents
    - identify significant commonalities among communication or task scenarios.

Example of a typical passage from the "Human Factor Contributing Causes" narratives

"...SLING LEGS AND ORBITER. THE LEFT SIDE OMD FAILED TO OMMUNICATE TO THE RIGHT SIDE OMD THAT THE SLING...".



Team Approach to Procedure Improvements

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Operational procedures provide a first line of defense against human error. They are key to streamlining work processes, standardizing work practices, and providing invaluable reminders and cautions during high risk, complex operations.

- Research
  - Collaborate with KSC Shuttle Processing Work Instruction Task Team (WITT)
  - Address known, systemic procedural problems
  - Integrate results with existing enterprise planning initiatives

- Technologies
  - Tools for collecting input from technicians during real time execution of work instructions
    - Portable, hands-free, minimal intrusion to work
    - Transfer of voice to digital database
  - Process for analyzing and incorporating technician input into procedure design
    - Policies for protecting confidentiality
    - Risk-based criteria for selecting tasks
    - Methods for coding and analyzing verbal protocols
    - Incorporation of results into engineering process

Distributed Team Decision Making *(NSBRI)*

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Successful space exploration missions will depend on the flight crews' ability to solve problems and make decisions under highly stressful conditions.

- Research
  - Gender and cultural factors
  - Communication medium w/ground
  - Stress and team decision making

- Technologies
  - Monitor physiological arousal levels
  - Monitor task performance and team interaction patterns
  - Develop team problem solving and decision strategies
  - Predict team breakdown and develop countermeasures

Organizational Risk Perception and Management

- Goals
  - Understand how teams and organizations perceive and manage risk
  - Develop decision support technologies for risk-based decision making
- Approach
  - Observation, interviews, surveys
  - Laboratory studies and iterative prototyping of technologies
- Application Contexts
  - International Space Station Mission Control Center
  - International Space Station Vehicle Integrated Performance and Resources (VIPeR) Team
- Technologies
  - Computational models of organizations
  - Integration of social and technical risk assessment and management technologies

Other Space Related Interests

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- Perceived spatial orientation
  - Cues, training, virtual environments
- Concurrent task management in space operations
  - Interruptions, distractions, procedures, safeguards against errors
- Embedded (or unobtrusive) measures of readiness to perform or operational performance
- Metrics/models of human/system performance in autonomous space ops
- Visual-motor assessment technologies and objective assessment of countermeasure effects on visual-motor performance
- Models of human performance in micro-g
  - Perception, attention, problem solving, etc
- Diagnostic cognitive test battery
- Human-system design requirements for space flight automation
- Design of procedures to enhance science productivity
- Scientific intuition and remote science
- Determination of the balance and methods of skill-based and task-based training required for autonomous operations
- In-situ training/aiding methods and technologies