Human Capabilities Assessments for Autonomous Missions: A Multi-Team Research Effort to Reduce Risk in the Human-System Integration Architecture for Future Deep-Space Missions

Stephen K. Robinson (UC Davis)
Brian F. Gore (NASA Ames Research Center)
Alexandra M. Whitmire (NASA Johnson Spaceflight Center)

Virtual Nasa Specialized Center Of Research "Human Capabilities Assessments For Autonomous Missions" (HCAAM)

- In future exploration missions beyond low earth-orbit, crew will have to execute complex operations and respond to off-nominal events, without real-time support from Mission Control on Earth.

- This crew autonomy could result in increased risk of adverse outcome due to inadequate Human Systems Integration Architecture (HSIA)

- In response, the Human Factors and Behavioral Performance Element (HFBP) in the NASA Human Research Program has initiated a multi-pronged study to reduce HSIA risks to crewmembers aboard long-duration space-exploration missions.

Virtual Nasa Specialized Center Of Research "Human Capabilities Assessments For Autonomous Missions" (HCAAM)

- Launched in 2018, HCAAM is a major NASA research effort that has assembled a multidisciplinary team from seven institutions to work closely with design and engineering efforts on research towards developing and refining human performance standards, guidelines and automation tools.

- The scientific focus is on quantitative assessment of human capabilities relevant to future deep-space missions during which earth/spacecraft communication is so delayed and intermittent that the crew must be able to function autonomously.

HCAAM Science Vectors (7 Research Teams)

assess/measure
augment/extend/improve
countermeasures

- Task performance (accuracy, efficiency) (crew + automation)
- Crew performance (accuracy, efficiency)
- Crew Situation Awareness (SA)
- Procedure design and multi-modal enhancement
- Concurrent tasking (mixed manual + some level of autonomy)
- Task handover
- Self-planning/timelining
- Task-design
- Trust in automation, real-time calibration
- Human multi-sensory feedback and guidance
- Virtual assistants

NASA JSC Human Exploration Research Analog (HERA)

The HCAAM Principle Investigators

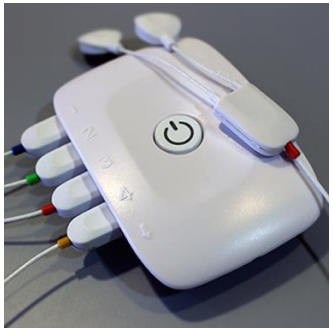
- Dr. Christine Fanchiang - Space Research Co
- Dr. Debbie Schreckenghost – TRACLabs
- Dr. John Lee - University of Wisconsin, Madison
- Dr. Leia Stirling – University of Michigan
- Dr. Daniel Selva – Texas A&M
- Dr. Jessica Marquez – NASA Ames
- Dr. Steve Robinson – UC Davis

Using a Human Capabilities Framework to Quantify Crew Task Performance in Human-Robotic Systems

(Fanchiang, et al)

- Use non-invasive physiological sensors (i.e. wearables) while performing specific tasks in a controlled environment
- Determine whether the sensors can be used as a proxy for measuring the crewmember's operational state

Empatica E4: EDA



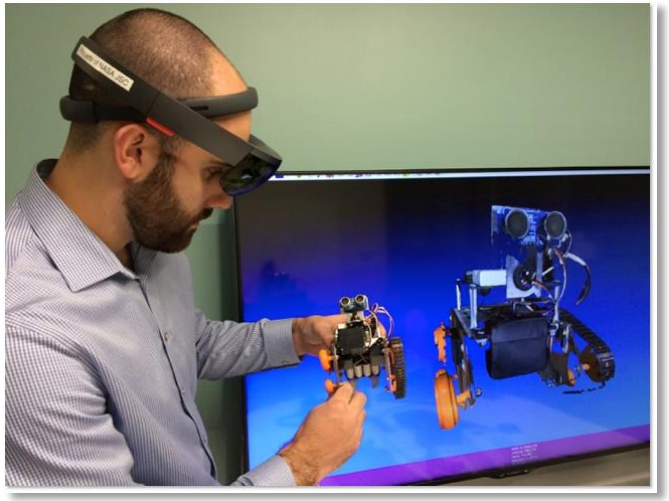
Biosignalsplux: fNIRS and ECG

Polar H10: Heart Rate

Enhancing Situation Awareness of Automated Procedures using Adaptive Multimodal Augmented Reality Displays

(Schreckenghost, et al)

- Objective: evaluate effect of VITA on human performance when preparing for and perform manual maintenance and assembly tasks (Project Aim 1)
- Participant Task: Preparing for and performing assembly of a small rover in one of four configurations
- 1X3 factorial design consisting of within-subject variables
- Three types of assistance
  - Procedure tasks from VITA via HoloLens
  - Procedure tasks displayed on tablet
  - Procedure tasks prompted by another crewmember



- Data Collected: Situation awareness, Workload, Usability, Completion time, Task accuracy, Subjective ratings & comments
- HERA Milestones
  - HERA Science Requirements Document for VITA signed (Mar 2020)
  - VITA hardware delivery to HERA (Mar 2020)
  - VITA functional testing in HERA complete (Sep 2020)
- HERA Pilot study in progress

traclabs

NASA

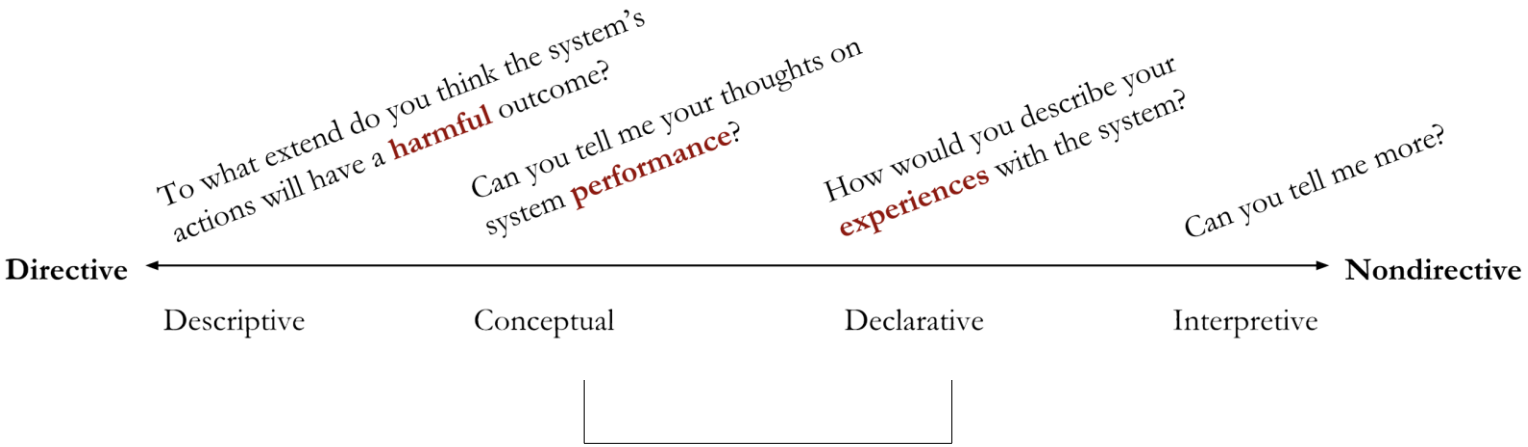
Conversational Analysis to Measure and Manage Trust in Virtual Assistants

(Lee, et al)

Measure Trust using Nondirective Prompts in a Conversation

Nondirective: Lexical choices and sentence structures.

- Descriptive: a direct mapping of the statement with specific attributes of the system.
- Conceptual: core concepts related to trust.
- Declarative: opening questions.
- Interpretive: following up probing questions.

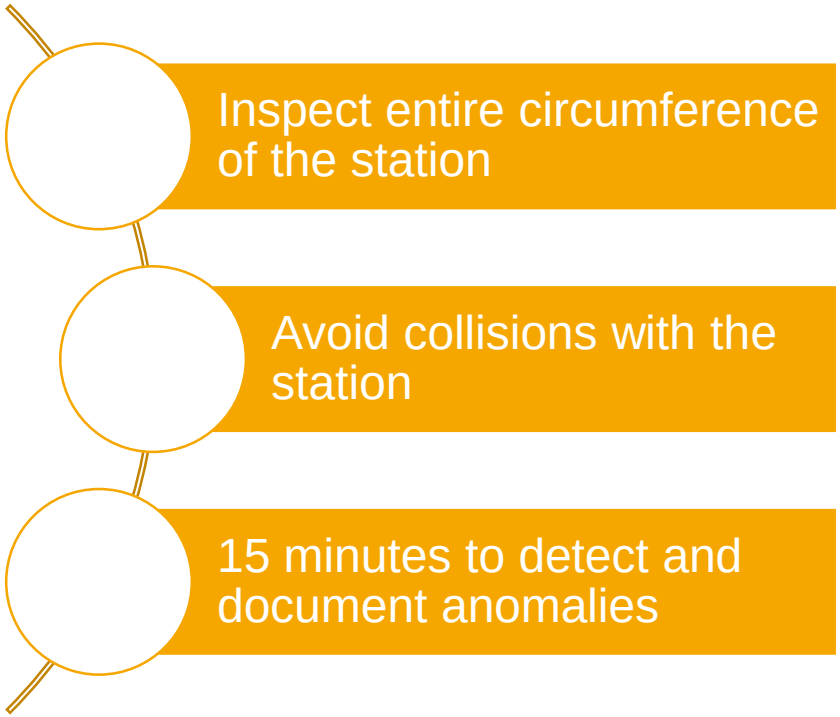


Comparison of Display Modality for Telerobotic On-orbit Inspection of Spacecraft

(Stirling, et al)

Research Questions | Task Goals

- How is the operator utilizing each interface to detect anomalies?
- How effective is this utilization in the completion of task goals?



Virtual Assistant For Anomaly Resolution In Long Duration Exploration Missions *(Selva, et al)*

AEROSPACE ENGINEERING
TEXAS A&M UNIVERSITY

GOALS

- Measure impact of AI virtual assistants on astronaut performance, workload, and situational awareness
- Develop **standards** and **guidelines** for development of future virtual assistants

PLAN

- 3 Lab experiments
  - Baseline & effect of **explanations** and **mixed-initiative** on measures above + trust
- HERA C6 campaign

Anomaly resolution

Detection → Diagnosis → Response

ISS ECLSS

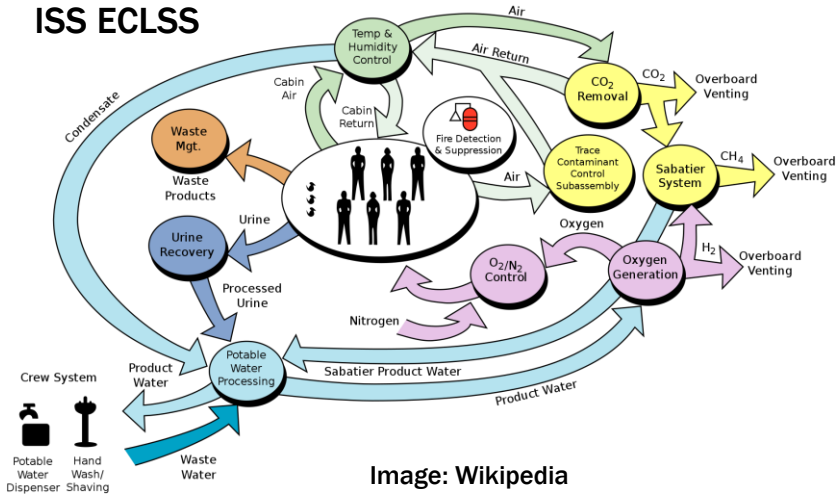


Image: Wikipedia

Crew Autonomy through Self-Scheduling: Guidelines for Crew Scheduling Performance Envelope and Mitigation Strategies

(Marquez, et al)

Research Objective

Characterize the human performance envelope for the task of planning and scheduling (crew self-scheduling), develop countermeasures to mitigate adverse performance effects due to plan complexity, and inform performance standards and guidelines based on research results.

ENABLING AUTONOMOUS CREW TASK PERFORMANCE WITH MULTIMODAL ELECTRONIC PROCEDURE COUNTERMEASURES

(Robinson, et al)

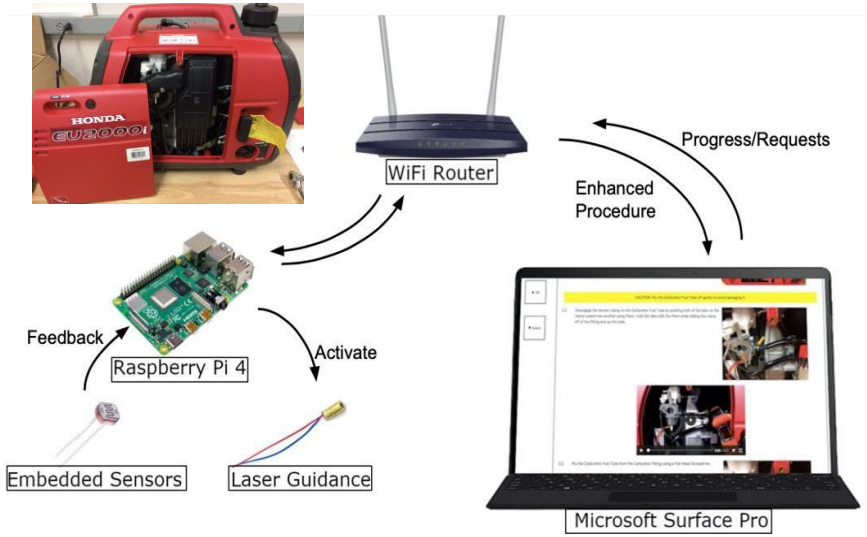
Background

Current Practice: PDF Procedures with assistance from personnel at Mission Control Center (MCC)

Issue: Long Duration Exploration Missions will have delayed communication with MCC so crewmembers need increased autonomy

Solution: Store more information on board so it may be accessed in a timely and context appropriate manner during routine and emergency procedures

Implementation: Development of interactive instructions that provide real time feedback using “Internet of Things” (IoT) and multimodal interactions such as augmented reality (AR) visual displays, spatial audio, and tactile feedback



Current system architecture for serving, displaying, and interacting with the enhanced procedure viewer. Raspberry Pi and sensors are built into the Honda generator to monitor the state of the system.

Next Steps: HCAAM Research Timeline

- Dec 2018 – NASA HCAAM grants awarded to the 7 research teams
- Feb 2020 – June 2021: pandemic shutdowns and delays
- Sept 2021 – launch HERA campaign 6 mission 1 – 45 days of crew experiments