Development and Validation of an Autonomous Operations Task List

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Motivation and Objectives

- Future deep space missions present new challenges for crew
  - Stress
  - Fatigue
  - Radiation
  - Isolation
- Astronauts will have to be more independent, and operate autonomously from MCC due to distance from the Earth
  - Time delays
  - Communications blackouts
- In order to adequately prepare for future Exploration missions, we must:
  - understand the **types of tasks** that astronauts may have to perform autonomously on deep space missions
  - identify the **intelligent systems and tools needed** to ensure crew success when perform autonomous operations

Prior Work

- A draft list of tasks that astronauts may need to perform autonomously on a mission to Mars was derived from information gathered from the following FY19 projects:
  - **HCAAM Standards and Guidelines effort** – identified gaps in requirements needed to make autonomous crew successful (Holden, et al., 2019)
  - **Contextual Inquiry** interviews and observations - conducted to understand the role that NASA flight controllers currently play during space missions, including the tasks, tools, and methods they use to support the crew (Vera et al., 2019)
  - **Autonomous Operations Technical Interchange Meeting** - identified and confirmed a number of gap areas and autonomy challenges for future spaceflight (Wu & Vera, 2019)
  - **Task analysis for Exploration Missions** - provided a task list for a mission to Mars (Stuster, Adolf, Byrne, & Greene, 2018)

Expert Focus Group

- Participants (experts with more than 20 years experience)
  - Variety of domains/perspectives:
    - ❑ Crew
    - ❑ Flight/mission control
    - ❑ Mission planning
    - ❑ Medicine
    - ❑ Behavioral health
    - ❑ Crew training

- Focus group tasks
  - **Top concerns**: Discuss top 3 most concerning tasks or functions when thinking about autonomous crew operations
  - **Validation:** Validate the draft list of tasks
  - **Discuss detailed task challenges** of future autonomous crews and what needs to be developed to support them
  - **Discuss scenarios** that best illustrate the challenges

Method: Top Concerns

- Participants were asked:

What are the top 3 tasks or functions that might "keep you up at night" when thinking of future autonomous operations?

- Each participant generated their answers and then discussed them as a group.

Results: Top Concerns

- **Inability to autonomously perform medical diagnoses and interventions**
- **Isolation-related medical and behavioral problems**
- Detection of problematic health or teamwork
- Lack of preparation for scientific missions
- Unknown anomalies
- Catastrophic events on Earth
- Problems with complex information processing during anomalies
- **Need for enhanced decision making capabilities**
- Lack of clarity in data handling processes
- System failures and dynamic events
- Inadequate human interaction with smart vehicles/systems
- **Insufficient intelligent (smart) systems development**
- Human-Robot Integration risk
- Lack of long-term training retention
- Lack of preflight training

Results: Top Concern Details

- Inability to autonomously perform medical diagnoses and interventions
  - Uncommon events, such as those necessitating use of an ultrasound, could cause uncertainty for crew as to what should be done.
- Isolation-related medical and behavioral problems
  - Increased isolation during long-duration missions leads to inward turning; team cohesion could be negatively influenced
- Need for enhanced decision making capabilities
  - Because autonomous crew will not have consistent, timely access to MCC, autonomous decision making capabilities need to be considered and enhanced.
  - Crew are not currently geared towards problem solving issues that were not considered during training.
- Insufficient intelligent (smart) systems development
  - It is a mistake to assume 1) that fault detection capabilities will be built, and 2) they will work. Good requirements and procedures are driven by a long lead-time and crew need a lot of simulation time -- something that is currently not happening.

Results: Overall Trends

- Experts agreed that **we are inadequately prepared** for crew to operate autonomously, as the majority of unexpected situations and problems are, and have been, handled through communication with experts at MCC. This relates **especially to crew abilities to respond to anomalies** that are unexpected or for which they are underprepared.

- It was also widely felt that, although **smart systems** will be able to address certain concerns with autonomous mission functions, **crew interactions with such systems need to be significantly tested/vetted before they are flown**. Smart systems can lead to higher difficulty when solving problems if not designed correctly.

- There was also a concern about **inadequate training approaches for long-duration missions**, and how exactly just-in-time training should be implemented.

Method: Validation of Draft Tasks

- Participants were asked to review each task in the draft task list with examples, and consider/discuss:

1. Is this a likely task for crew on a Mars mission?
2. Do the crew have the onboard capabilities and training to perform this autonomously today?
3. What would crew need to be able to do this autonomously?

Draft Task List

GOAL: Maintain crew health		
	Tasks	
	1	**Respond to medical/behavioral health events**
	2	**Maintain physical and psychological crew health and fitness**
GOAL: Maintain vehicle/habitat		
	Tasks	
	3	**Respond to unanticipated major vehicle/habitat malfunctions**
	4	**Perform installation/activation/inspection of vehicle/habitat systems**
	5	**Manufacture hardware, software, and fuel**
	6	**Modify, maintain, repair, and replace hardware, software, and procedures**
	7	**Perform nominal system commanding**
GOAL: Perform mission-related tasks		
	Tasks	
	8	**Perform piloting/navigation task**
	9	**Perform space or planetary EVAs**
	10	**Perform planetary rover vehicle ops**
	11	**Perform robotics activities**
	12	**Perform science activities**
	13	**Perform scheduling, planning, and task allocation**
	14	**Perform in-mission training**
	15	**Perform inventory and consumables management**
Cross-cutting tasks (Task enablers)		
	A	**Coordination, leadership, and team work**
	B	**Communication**
	C	**Problem solving/decision making**

Results: Validation of Draft Tasks

Task: **Respond to medical/behavioral health events**

- Examples:
  - Respond to sudden cardiac arrest: Limited to BVM, chest compressions, AED, IO and epinephrine; treatment lasting < 45 mins.
  - Use medical software along with vitals/test results to help diagnoseis condition of unconscious injured/ill crewmember.1.
  - Respond to behavioral emergency: Treatment period is short (0-3 days) and well defined (acute, organic event).
  - Respond to unexpected traumatic injury in the context of an interplanetary mission.

Results: Validation of Draft Tasks (cont.)

Task: **Respond to medical/behavioral health events**

Q1. Is this a likely task for crew on a Mars mission?

A. **Yes**

Q2. Does the crew have the onboard capabilities and training to perform this autonomously today?

A. **None** of the listed tasks are able to be treated autonomously today, unless there is a physician onboard.

A. These are **high-consequence** tasks. Crew will need to have the capabilities to treat potential medical emergencies.

Results: Validation of Draft Tasks (cont.)

Task: **Respond to medical/behavioral health events**

Q3. What would crew need to be able to do this autonomously?

A. A **smart autonomous system** would be needed for autonomous medical capabilities.

- need **access to large amounts of crew data**,
- ability to observe and **communicate trends over time**
- **Ability to advise** on prevention and treatment.

A. Need **additional training** with scenarios requiring **immediate responses**. Crew currently operates under the assumption that they will receive any necessary input on what procedures should be performed and how.

The high level task list was agreed to with minor revisions in phrasing or examples.

Method: Scenario Development

- Descriptive scenarios were developed to illustrate challenges of autonomous operations, and/or describe how intelligent systems can mitigate risk.
- **Example**: Scenario for Loss of Mars Surface Habitat Power Channel
  - **Context**
    - Safing the habitat after unplanned power failure in the Mars surface habitat.
  - **Highlighted Functionality**
    - The system can annunciate warnings, diagnose root cause, display information….
  - **Assumptions**
    - There is an astronaut trained as a power specialist…
  - **Narrative**
    - The onboard computer system detects the failure of multiple power controllers and annunciates a warning alarm to alert the crew.…The system presents the EPS specialist with recommendations of hardware to be powered off via crew interface, including operational impacts for doing so……..

Results: Scenario Development

- Scenario for Loss of Mars Surface Habitat Power Channel
  - *Drafted by the focus group*
- Scenario for Loss of Mars Transit Vehicle External Cooling
  - *Developed by the HCAAM project team*
- Scenario for Mars Surface Science Platform Loss of Data/Power
  - *Developed by the HCAAM project team*
- Scenario for Urinary Tract Infection
  - *Developed by the Exploration Medical Capabilities (ExMC) research element in HRP*

Conclusions

- With respect to Exploration missions, experts agree there is currently:
  - Lack of preparation and experience for autonomous crew operations
  - Insufficient intelligent system development/testing
  - Inadequate training approaches for long-duration missions
- HFBP is addressing these challenges
  - Human Capabilities Assessment for Autonomous Missions (HCAAM) research in the HERA autonomy mission (Aug, 2020)
    - ❑ Performance support
    - ❑ Augmented reality procedures
    - ❑ Self-scheduling
    - ❑ Virtual assistants
    - ❑ Anomaly detection/resolution
    - ❑ Human performance measurement (workload, trust, situation awareness)
    - ❑ Human-automation interaction

Thank you!

References

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