Emerging Autonomy Solutions for Human and Robotic Deep Space Exploration

Motivation

- Autonomy and human-robot interaction (HRI) is coming to space exploration!
- Astronauts, remote operators, and robotic assets must operate as a team.
- Trust and shared awareness are key to successful collaboration.

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CASE STUDIES

Real-Time, Co-located: Mars

- Multiple astronauts + varied robotic assets
- Flexible mission design + agent interaction
- Collaborative tasks such as carrying heavy/awkward equipment

Challenges

- Dynamic task allocation
- Cost function changes based on situation
- Safety of humans and equipment

Shared Challenges

- Bi-directional intent recognition
- Shared mental models
- Use of autonomy requires increased trust and transparency

Deep Space, Remote: Europa

- Mobile robot deployed on surface
- Flexible fault-tolerant autonomy with minimal human intervention

Challenges

- Intense radiation environment precludes human exploration + limits robot lifespan
- Extreme distance leads to lower comms bandwidth + high round trip delay

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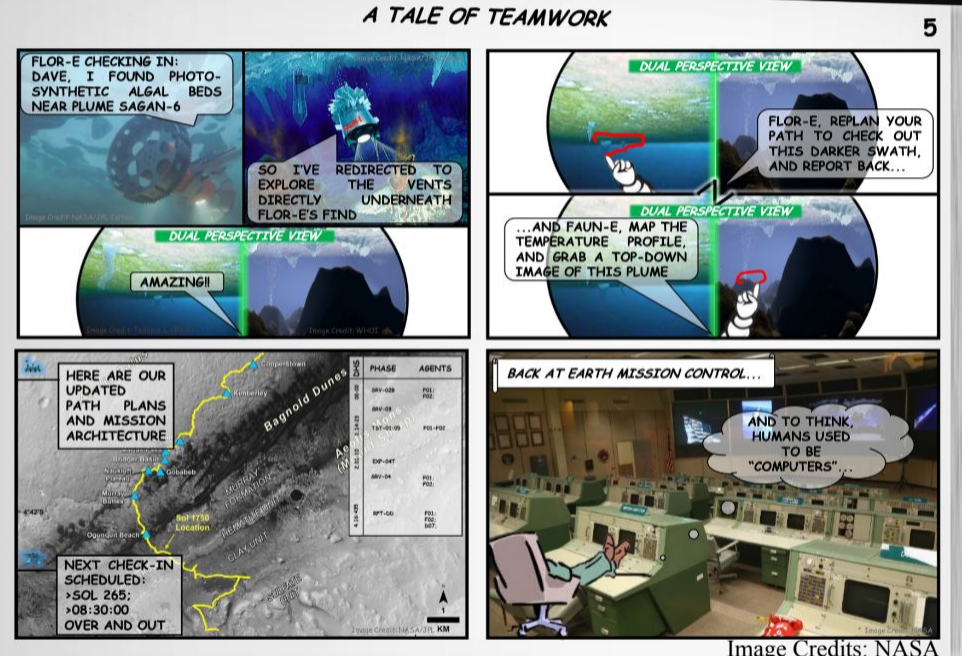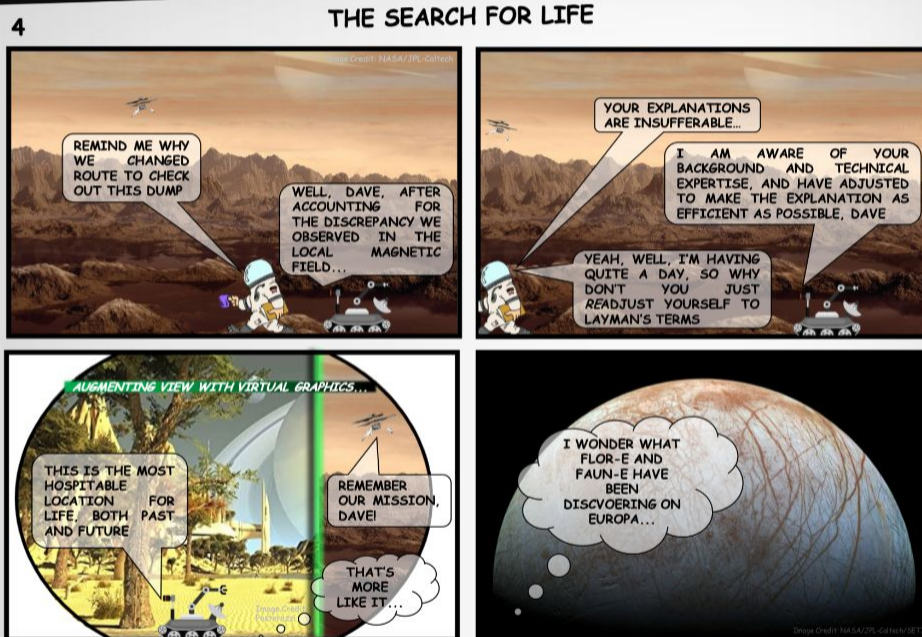
EMERGING TECHNOLOGIES FOR FUTURE SPACE AUTONOMY

Explainable AI

- Facilitates human interpretability of complex models and machine learning algorithms.
- Provides assurances and increases trust.
- Allows for quick reference of a system's capabilities and decision-making rationale.

Potential Applications

- Increased fluency and teamwork
- Model validation and debugging
- Failure identification + recovery
- Synchronization of expectations

Virtual, Augmented, and Mixed Reality

- Provides supplemental information and visual aids.
- Increases situational awareness.
- Allows for additional modes of communication among teammates.

Potential Applications

- Navigation cues for humans
- Object recognition and display
- Path planning for robotic assets
- Communication between human(s) and robot(s)

Adaptive & Adaptable Automation

- Adaptive control adjusts parameters as a function of specific measurement(s).
- Adaptable control is changed manually by the human operator.
- Balance adaptive robotic teammates and human agency through adaptable capabilities.

Potential Applications

- Dynamic task allocation
- Human-machine teaming
- Safety and efficiency measures
- Optimal crew resource utilization

See the full paper here: http://www.cairo-lab.com/papers/spacechi21.pdf