This poster describes a training approach that applies empirically derived principles of training to reimagine the overall design of NASA's space flight training program. The poster is focused specifically on the design of astronaut training for NASA's future deep space, exploration missions to Mars. We briefly describe NASA's space flight training practices during the Apollo and Space Shuttle eras as well as NASA's current practices for training astronauts for their missions to the International Space Station. We provide an overview of NASA's current concepts for a mission to Mars to scope our training approach. We envision a new space flight training approach which we term "crew-centered, mission-oriented" training, inspired by the design approach offered in the context of airline pilot training by Barshi. We apply research-based training principles reviewed by Kole and his colleagues, as well as by other researchers in training science, into real-world, practical guidelines for the particular context of training astronauts for a mission to Mars.

**INTERNATIONAL SPACE STATION TRAINING**

While the International Space Station (ISS) crew training program produces highly skilled and effective crewmembers, the longer ISS missions, wider range of astronaut duties, and ongoing, continuous ISS operations preclude instructors from “hampering in” known mission timelines. NASA recognizes that there are issues with the crew retaining all of their pre-mission preparation and that real-time ground support is critical to the success of ISS missions. With this real-time support, this design of training is very effective for Earth-relatied operations.

**MISSIONS TO MARS**

For NASA future missions to Mars, astronauts will require training to operate at a level of autonomy that has never been needed before. Most critically, they will need training for technical expertise and decision-making skills necessary to respond to unanticipated, high-risk, time critical events without real-time ground support.

**REFERENCES**

We envision a new training approach which we term "crew-centered, mission-oriented training" (CCMOT). This approach incorporates empirically derived principles of training to imagine a redesign of NASA's astronaut training program to ensure that more effectively supports skill development. Examples of how research-based training principles reviewed by Kole et al. (in press), as well as others, might be incorporated in this design include:  

**Training Principle: Easy to Difficult Ordering.** Barshi (2015) suggests that easy to difficult ordering can motivate the design of the entire training flow. This can be seen in Figure 2 in the progression from a nominal Orion flight in which newly hired astronaut candidates (ASCANS) simply monitor vehicle data, to more demanding flights in which they execute procedures to configure vehicle systems; to later when they learn to pilot Orion.

**Training Principle: Use of Strategic Knowledge.** Kole et al. (in press) stress that, “When acquiring new information, learners should attempt to relate that information to prior knowledge.” They go on to explain that, “When genuinely new information to long-term memory, that information becomes associated with retrieval cues … By increasing the number of retrieval cues, the chance of successful retrieval in the future increases.” By starting cruise-to-Mars training (Figure 2) with the simplest of Saturday tasks for which ASCANS should already have some familiarity from their home lives (e.g., trash, garbage, and exercise), the ASCANS can begin to relate new information to preexisting knowledge and begin to build their knowledge of the vehicle, layout, and interfaces. As training expands into new areas, training would be designed to use this simpler vehicle knowledge to build retrieval cues for more challenging tasks (e.g., conducting research, piloting spacecraft, responding autonomously to unanticipated, high-risk events).

**Crew-Centered, Mission-Oriented Training**

Crew-centered, mission-oriented training is a design approach that incorporates research-based training principles to imagine an astronaut training program that supports the retrieval necessary for NASA's future autonomous missions to Mars.

**REFERENCES**

**Training Principle: Variability of Practice.** Variability of practice refers to a training design that provides varying conditions under which a task is practiced so that the task is not practiced in the same manner (Kole et al., in press). Although variability of practice slows the acquisition process, according to Kole et al. it is a “particularly powerful” training principle that it applies to both procedural and declarative memory tasks and supports both retention and transfer. Variable practice conditions include variations in the task itself, variations in the conditions under which the task is trained such as the sequencing of the task with other tasks, or even variations in similar but different tasks (Barshi, 2015; Kole et al., in press). For example, the ASCANS would be trained multiple times using different conditions (e.g., different payloads, different crewmembers) each time they practiced the task.

**Training Principle: Use of Strategic Knowledge.** Kole et al. (in press) stress that, “When acquiring new information, learners should attempt to relate that information to prior knowledge.” They go on to explain that, “When genuinely new information to long-term memory, that information becomes associated with retrieval cues … By increasing the number of retrieval cues, the chance of successful retrieval in the future increases.” By starting cruise-to-Mars training (Figure 2) with the simplest of Saturday tasks for which ASCANS should already have some familiarity from their home lives (e.g., trash, garbage, and exercise), the ASCANS can begin to relate new information to preexisting knowledge and begin to build their knowledge of the vehicle, layout, and interfaces. As training expands into new areas, training would be designed to use this simpler vehicle knowledge to build retrieval cues for more challenging tasks (e.g., conducting research, piloting spacecraft, responding autonomously to unanticipated, high-risk events).

**Earth Ascent Monitoring Orinon**

1. **APOLLO and SPACE SHUTTLE TRAINING**

Apollo-era astronauts learned the vehicle systems as they worked collaboratively with system engineers on the vehicle design. They were assigned unique roles with a well-defined set of duties or tasks and provided extensive practice of mission operations as an intact team training to a detailed flight plan, almost to the point of memorization. “Practice, practice, practice” was the unofficial motto of Apollo-era training (Weaver et al., 2015). During this time, NASA made tremendous engineering advancements in designing simulators that could mimic the various space flight environments the crew would encounter. In order to better simulate the vehicle layout, to include for extra-vehicular activities (EVAs, aka space walks), motion-based simulators for ascent/entry, and reduced gravity simulators for lunar surface operations (Weaver, et al., 2015; Woodling, et al., 1973) allowing the astronauts to practice for their missions.

For Space Shuttle training, NASA developed motion-based and flight simulators designed to provide pilots with training on the handling characteristics of the Space Shuttle (Null et al, 2019). The first crews of Space Shuttle astronauts learned the vehicle systems as the vehicle was being designed. As the Space Shuttle program progressed, space flight training was formalized into lessons, where sets of lessons were designed into system or discipline training flows (e.g., an electrical power training flow, an avionics training flow, a robotics training flow, and an EVA training flow), and training culminated in a series of full team simulations that provided realistic rehearsal (or “hammering in”) of their specific roles for well-planned and detailed mission timelines.

The tremendous successes of the Apollo-era and Space Shuttle programs proved that this design of training was very effective for short-duration, near-Earth missions.

**RESEARCH QUESTIONS**

The design of a training program “should be informed by the best information science has to offer” (Salas, Tannenbaum, Kragier, & Smith-Jentsch, 2012).

To provide our astronauts with the training they will require for their missions to Mars, we agree with Salas et al. (2012) that the design of a training program “should be informed by the best information science has to offer” (p. 74). While we know a lot about training science, human research is needed to inform gaps in our knowledge base.  

- What skills necessary for space missions are domain-specific?  
- What training design guidelines support both team and technical skills development?  
- What level of simulation fidelity is necessary for a given skill or task?  
- What is the suitability of available training measures to the projected needs of long-duration missions?  
- How do we train for expertise with automation?  
- How do we train for expertise with automation?

We propose that by incorporating future research results into our CCMOT flow, this new program of training will provide astronauts with the skills necessary to operate at the level of autonomy needed for NASA’s future missions to Mars, including the ability to respond to unanticipated, high-risk, time critical events without real-time ground support.

**REFERENCES**