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Perspective Paper

IDS 6147: Perspectives in Modeling and Simulation

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Introduction

The recent privatization and commercialization of spaceflight and exploration has sparked a renewed interest in extraplanetary endeavors. Companies like Space X and Blue Origin have proposed establishing long-term colonies on Mars, the Moon, and creating commercial spaceflight for civilians who want to experience the stars firsthand. Current astronaut training sees space agencies employing a mixture of simulation and virtual reality. Immersive virtual reality simulations allow astronauts to practice operating spacecraft and performing extravehicular duties. The Neutral Buoyancy Laboratory is an extremely large pool that similarly allows astronauts to experience the sluggishness of micro gravity or weightlessness and conducting activities in their space suits.

Although current training methods have been effective for past missions, they are often mission-specific and past missions have been short-term. Long-duration missions like those to the Moon and Mars will involve performing significantly more tasks to ensure survival. For example, astronauts may have to perform activities like extensive monitoring of resource utilization, expeditions into the field, establishing and upkeeping habitats, and maintaining communications with space agencies here on Earth. These activities are unprecedented, resulting in higher risks and requiring more comprehensive, in-depth training with less specificity and more versatility, to be useful for novel situations or crises.

It would thus be useful to craft a comprehensive training database that fills this need by compiling all known training methods and scoring them based on versatility, mission-specific effectiveness, and cost, both financial and temporal. Training instructors would be able to quickly discern which technique is best for a specific mission by accessing the database and viewing the working histories, taking note of the scoring guides, and improvising based on the two if necessary. The database would be constructed by compiling current research by either comparing multiple training methods or analyzing the effectiveness of one.

The database would contribute to current and future astronaut endeavors by providing an empirical view of effective training, supplying a metadata analysis of the use and effectiveness of each training method, and being amendable, allowing for allowing for new training methods or technology to be directly compared to past methods. Most importantly, it will allow space agencies to make proper choices to offer a more thorough and inclusive training procedure, reducing the possibility for risk and thus better ensuring the safety of future astronauts and colonists.

The remainder of this paper will first take a look at current literature on various training methods, to both identify any lapses in research and begin creation of the meta data analysis that will be used to shape the database. The following section will then be to perform the meta data analysis, explain how it can be used to create our database, and then to create the database that will describe different types of astronaut training and ultimately score them on the aforementioned criteria.

Literature Review

The objective of the database is to compile current literature about a specific technique in astronaut training and score its efficacy on the following guidelines: versatility, financial and temporal cost, and retention rates. It is thus imperative to synthesize past publications that describe training methods for extravehicular activities and detail their usefulness as per described by researchers in the studies.

There is very limited research on how effective one training method is compared to another. One such example is an evaluation of the various EVA training methods NASA has employed in the past and in the present to determine which ones should be used in future astronaut training (Moore & Gast, 2010). Researchers focused on the methods used in the Apollo missions of the late 1960s and early 1970s, the Skylab program – NASA's first space station in the 1970s, and the space shuttle missions that have been occuring since the 1980s (Moore & Gast, 2010). It also analyzed the use of the netural buoyancy lab, virtual reality technologies, computer based training and imaging software, and flight specific training in extravehicular activity training and synthesized how each can be used in future training (Moore & Gast, 2010). The results of this inquiry indicate that training to perform tasks in microgravity by emulating the feeling of weightlessness and increasing crew autonomy during training yield more efficient astronauts (Moore & Gast, 2010). As far as training itself is concerned, increasing crew autonomy, utilizing multiple modalities, and performing all training in a multi-faceted facility that can effectively simulate all of the conditions astronauts will face during a specific mission is the best course of action (Moore & Gast, 2010). It specifically underscores that effective training is performed when accounting for both the expected and unexpected (Moore & Gast, 2010). Instructors can do this by overcompensating for the unforeseen and providing astronauts with a more versatile skillset to tackle any task (Moore & Gast, 2010).

VR simulation systems have been observed as a potential medium for training astronauts to perform extravehicular activities (Liu et al., 2010). The simulation system in this case study is focused on teaching trainees how to perform various extravehicular activities such as spacewalk training and load retrieve training (Liu et al., 2010). The former saw participants using a head-mounted display and gloves with haptic sensors to simulate maneuvering a handrail in space (Liu et al., 2010). The haptic sensors provided participants with force feedback to deetermine how much force is being used to grasp the handrail (Liu et al., 2010). Load retrieve training was a two-persons simulation where one participant had to once again move along the handrail but also identify and obtain cargo, and pass it along to another participant in the spacecraft (Liu et al., 2010). The participant inside the spacecraft was tasked with catching the cargo and place it inside the spacecraft (Liu et al., 2010). The information in this simulation allowed researchers to also identify force feedback for grasping the handrail, grabbing the load, catching it, and placing it within (Liu et al., 2010). This study yielded findings that suggest motion tracking, assembly of immersive virtual space environments, and human-computer interaction with force feedback can be useful in astronaut training and preparation for missions in space (Liu et al., 2010).

A similar discovery on the effectiveness of VR simulation systems was found in an experiment that utilized an underwater VR system to train astronauts to perform spacewalks using jetpack locomotion. Participants wore a modified SCUBA mask that doubled as a head-mounted display and housed a smartphone that displayed the virtual reality environment (Sinnot et al., 2019).. They used a wired Xbox 360 controller in a waterproof latex breathing bag to control input in the virtual world (Sinnot et al., 2019). Participants were fully immersed in the water and the simulated environment and were required to spacewalk through a series of checkpoints to determine the efficacy of the system and its effects on VR sickness compared to its use on land (Sinnot et al., 2019). Findings of this study suggest that the virtual reality system was significant in training participants to perform jetpack locomotion during spacewalks when underwater compared to the above water control group (Sinnot et al., 2019). Participants in the underwater group required less time to complete the same tasks, at the cost of a higher risk of developing VR sickness when compared to the group who used the same system on land (Sinnot et al., 2019). These results are pertinent to the development of the database because using water has been shown as an effective means to simulate weightlessness, and placing astronauts in a virtual environment while below the surface may result in a complete immersion in a controlled setting.

An examination was conducted to determine how an electronic fieldbook (EFB) – a deployable information system capable of storing a range of information from fieldwork – can be used during planetary exploration (Turchi et al., 2021). Researchers used teams on Earth to judge the usefulness of the EFB in collecting and storing data from different sources (Turchi et al., 2021). Findings suggest that the EFB is valuable in providing a universal device that integrates a variety of sciences and gives astronauts a platform to review and dissect earlier fieldwork (Turchi et al., 2021). Future astronaut training for planetary exploration and data collection can see the use of this device given its capabilities. It's inclusion into the database is important because identifying technologies that have not been used or tested is a crucial aspect of its creation. Being able to amend the database with new, novel information is useful for researchers.

Another study examined the use of a wearable situational awareness terminal (WearSAT) for extravehicular activity training (Carr et al., 2002). A WearSAT is defined as a device capable of displaying information on a near-eye monitor through the form of text, graphics, or video (Carr et al., 2002). The WearSAT is connected to a wireless network, allowing for transferrence and storage of data between astronauts and onto the network itself (Carr et al., 2002).. The study only mentioned how an experiment can be performed with participants using the near-eye display to complete EVA tasks and having researchers test for compability of the device (Carr et al., 2002).. The applications of a tool like this are limitless, ranging from recording and transmitting data about a mission, astronaut vitals, spacecraft operations, etc. Further research on this tool and its compability with space suits and other technology like the EFB for example are necessary to fully determine its usefulness.

Based on the literature review, the synthesized studies have identified a slew of potential training methods that have proven effective or novel for EVA astronaut training. The vast majority of the studies performed on EVA astronaut training fail to specify which method is best for a certain scenario, instead mentioning new technology that may make the training easier. It is crucial for future long-term missions where uncertainty in the amount of scenarios an astronaut may face that researchers and training instructors understand which is the best technique and medium to apply a certain type of training. The proposed database would be created by collecting studies like the ones reviewed and scoring their proposed method on their versatility, mission-specific effectiveness, and temporal and financial cost. It will fill the void of contrast and provide an easy means of obtaining information about comparing efficacy.

Proposed Plan

In order to create my proposed database, I plan to conduct a more thorough literature meta-analysis to identify further relevant material.. Online research databases such as but not limited to IEEE Xplore, Web of Science, ScienceDirect, etc. will be used to perform the metadata analysis. Articles will then be divided into one of three categories based on their content – articles that evaluate effectiveness, articles that suggest new technologies for use during training, and articles that provide older metadata analyses on similar topics. Extravehicular activity astronaut training methods will then be categorized based on the information derived from the articles I've discovered. From there, I can create my scoring guide, and begin to score the training methods on their versatility, financial cost, training time duration, and retention rate as they pertain to a specific activity like spacewalking training. I can create a model that describes the different types of extravehicular activity astronaut training and their relative usefulness based on my scoring criteria. I will then be able to generate my database on my crafted model, and input all the known types of astronaut training methods for extravehicular activities in space. Users of my database will be able to input a specific activity that might be performed by an astronaut during a mission, and the database will respond by supplying the user with training methods suitable for the activity and their respective scores.

Future Directions

Future directions based on my proposed analysis will likely see further experimentation using my database. For instance, researchers can access my database and test its effectiveness by inputting a specific activity and then directly comparing opposing training methods to validate the validity of their associated scores. Future addendums will also be likely added to the database as more research is conducted on the effectiveness of EVA training methods, as well as new technologies are implemented into the field. These additions will also be scored, and past scores may be altered if proven invalid. Scoring criteria may also amended if need be. Future research must also be conducted into the future of astronaut training as future embarkments to the Moon and Mars are likely to be long-term and in the case of Mars, possibly even lifelong. Astronauts may receive training off planet and the database should also be amended with those methods in mind.

References

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