Design of an AR Visor Display System for Extravehicular Activity Operations

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Abstract—**An Extra-Vehicular Activity (EVA) is one of the most challenging operations during spaceflight. The current technology utilized during a spacewalk by an astronaut crewmember includes real-time voice loops and physical cuff checklists with procedures for the EVA. Recent advancements in electronics allow for miniaturized optical displays that can fit within a helmet and provide an alternative method for a crewmember to access mission data. Additionally, cameras attached to helmets provide EV astronauts' several Point of Views (POVs) to Mission Control Center (MCC) and Intra-Vehicular (IV) astronauts. These technologies allow for greater awareness to protect astronauts in space.**

This paper outlines the design and development of a custom augmented reality (AR) visor display to assist with human spaceflight operations, particularly with EVAs. This system can render floating text checklists, real-time voice transcripts, and waypoint information within the astronaut's Field of View (FOV). These visual components aim to reduce the limitations of how tasks are communicated currently. In addition, voice commands allow the crewmember to control the location of the augmented display, or modify how the information is presented. The team used the Microsoft HoloLens 1 Head Mounted Display (HMD) to create an Augmented Reality Environment (ARE) that receives and displays information for the EVA personnel. The ARE displays the human vitals, spacesuit telemetry, and procedures of the astronaut. The MCC and other astronauts can collaborate with the EVA crewmember through the use of a 3D telepresence whiteboard, which enables 2-way visual communication. This capability allows interaction with the environment of the EV astronaut without actually having to be outside the spacecraft or even onboard. Specifically, mission personnel in a Virtual Reality (VR) Oculus Rift head mounted display could draw shapes in the EV members' view to guide them towards a particular objective. To test the system, volunteers were asked to proceed through a mission scenario and evaluate the user interface. This occurred both in a laboratory setting and in an analog mockup at the National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC), using both the Microsoft Hololens and Oculus Rift in coordination with the NASA Spacesuit User Interface Technologies for Students (SUITS) Competition. The major goal of testing the User Interface (UI) was determining features contributing to a minimized cognitive workload and improving efficiency of task completion.

AR technology has the potential of dramatically improving EVA performance for future manned missions. With the HoloLens, the team implemented an efficient and elegant design that can be individualized by the user. The system provides as much functionality as possible while remaining simple to promote user-friendliness.

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1. INTRODUCTION

The current technology for astronauts to complete EVAs is not conducive to the most productivity of the overall missions. Astronauts depend on real-time voice loops from their Intra-Vehicular counterparts and the MCC. Minimal task instructions are pinned on physical cuff checklists to the astronauts' wrist outside the suit. However, the perspective of the spherical helmet distorts the viewing and when using hands for operational tasks, it's not always suitable to reference the tasks pinned to the suit. These complications must be addressed before long-term missions occur, including the planned missions to the south pole of the Moon (targeted for the Artemis missions). Additionally, satellite capability prevents the MCC from being able to reach vehicles going to the Moon at all times and, more significantly, onto Mars [1]. A viable solution lies in implementing AR into a Heads-In Display (HID) to constantly provide what the MCC will not be able to provide at all points in the mission. In support for this obstacle, NASA is working on creating new spacesuits to incorporate a HID within the helmet of the future planetary spacesuit. Notably, the 2024 Exploration Extra-Vehicular Mobility Unit (xEMU) just passed its Preliminary Design Review (PDR) in August 2019, which will include a HID. In efforts to meet deadlines with unique and innovative solutions, the xEMU team partnered with an education division at NASA to create the SUITS competition for collegiate teams. Teams are asked to generate practical HUDs that could be used in human exploratory missions. While these are not enclosed in a helmet, competition moderators focus on the design aspects rather than the logistics of the hardware placement. The HUD capabilities must include task lists, telemetry streams, navigation features, and other specifics to directly correlate with the problems faced currently in missions. Through the SUITS challenge, teams across the United States genuinely contribute to these NASA objectives.

In the fall of 2018, a Texas A&M University team was created to participate in the SUITS competition. The team named their design the Space Communications, Operations, and User Telepresence (SCOUT) Assistant. SCOUT was designed to creatively display task lists, biometrics, and navigation features in an AR environment using the Microsoft Hololens. The team also explored the concept of having AR and VR devices communicate between each other. This capability would allow the IV astronaut to utilize a VR device while their EV partner uses an AR device. Concepts such as the one described are critical to integrating technology for user friendliness and promoting maximum efficiency. This paper describes the tools developed during the SUITS competition by our team, as well as the testing experience at JSC.

2. Background

Modern AR technology began its development in the public domain as a new means for interactive gaming and as assisting individuals with disabilities. Though these applications will become more prominent for the average individual, AR is quickly transforming into an asset for navigation purposes within advanced pilot training, military operations, and automobiles [2].

The actual term Augmented Reality was first coined by Boeing research scientist Tom Caudell in the early 1900's. Ironic to the most popular uses of AR today, he was given the task to come up with an alternative for factory workers in navigating the factory floor. His solution led to each factory worker wearing a helmet that guided them through the factory. Another early 1900's use, Sir Howard Grubb created a display that overlayed a target reticle on a distant target. His technology would be used to create gun sights for military planes. In the 1950's, the same technology was advanced and used to create a HUD for military aircraft. By the early 1970's, the first HMD was incorporated into military aircraft. The growing amount of sensors, switches, and buttons needed to properly convey information to pilots resulted in more time being spent looking inside the cockpit instead of outside the aircraft. HUDs were created to solve this problem, moving information previously displayed in the cockpit, often in alpha-numeric form, to a transparent display mounted in front of the pilot in symbolic form. This reduced the amount of information processing a pilot had to do, as well as maximizing the time spent looking towards the airplane's direction of flight.

The development of a HUD was a drastic improvement from the previous system of display boards inside the cockpit, but new problems arose. Information being projected on a fixed display in front of the pilot does not move if the pilot shifts their gaze elsewhere. For military applications this presented a major problem: when attempting to shoot heat-guided missiles, the pilot had to point their aircraft directly at the target for it to appear in the display. This led to the development of the HMD, which moved the information being projected to an overlay on the inside of the pilot's helmet. This allowed the pilots to view pertinent information with free range of motion of their head. This adaptation parallels most modern day AR systems overlaying material directly onto the user's FOV. For this reason, HMDs can be considered the first widely deployed augmented reality systems [3].

The military has the tendency to integrate emerging technologies into their area of competence in order to stay ahead of outside threats. The advancements in tactical weapons and machinery have grown exponentially with the integration of technology, but the military wants to extend its use of technology into every soldier. For this reason, the integration of Tactical Augmented Reality (TAR) has brought with it the era of contemporary warfare. The TAR HMD allows soldiers to minimize reaction time while maximizing real-time situational awareness. The TAR utilizes exact locations of soldiers in relation to the position of their allies and enemies. The TAR also shows soldiers their trajectory information and allows the soldier to see around a corner without risk when using a split display. Other uses of AR include Enhanced Night Vision Goggles - Binocular (ENVG-B), Synthetic Training Environment (STE), and Augmented Reality Sandtable (ARES). With these technologies, the military and its soldiers experience safer training environments, real-time targeting aid, enhanced spatial awareness, engaging mission planning, and less costly combat training [2].

AR devices still need work in addressing bulkiness and, most notably, a small FOV. Bulkiness limits mobility and user endurance, which can counteract the benefits of the device for varying tasks. Most devices take up most of the space around the head making it difficult to maneuver in tight areas, such as a cockpit or around a spacecraft. In addition to the heaviness of the device, the user might experience extreme tiredness and/or motion sickness. Mitigating this issue is vital to extending mixed reality devices to unique applications. Solutions ostensibly come from manufacturers, but interface developers might discover mechanisms to relieve users from the physical bulkiness of devices. The FOV can be defined as the total angular size of a virtual image visible to both eyes. This is conspicuously limited for most AR devices in use currently. A human's normal FOV on the horizontal level is usually 120°, whereas a typical AR FOV is usually about 30°-40°. Most AR applications require a user to position themselves in a particular manner to view the AR overlay, but this usually results in constant repositioning throughout use. Relating back to bulkiness, the AR device possesses the ability to strain a user's neck as they make use of the FOV. Better orientation of devices in how displays are presented might be a solution. Alternatively, utilizing different coordinate systems, perhaps spherical or cylindrical might widen the FOV.

NASA utilizes AR in a wide-variety of applications. One specific use is through assisting in training astronauts through Project Sidekick. Project Sidekick aims to use the augmented display capabilities of the Microsoft HoloLens to provide crucial information and support when and where necessary during the performance of tasks required during missions. These mixed reality applications allow astronauts to view the real world around them with an integrated interface designed to maximize productivity and minimize the delay in information retrieval. NASA has also used the HoloLens to aid their spacecraft technicians at Lockheed Martin in the construction of Orion. The AR application is used as a replacement to the bulky manuals that are traditionally used, allowing the workers to see holograms of the final spacecraft, as well as its individual parts. They can also receive information, such as torquing instructions relevant to the person wearing the headset. Using the HoloLens resulted in faster construction times, prompting further exploration of AR applications for potential use in space.

Minor issues indicative of most technology are battery life, tracking systems, and price points. The battery life for most AR devices is relatively average. The HoloLens has a battery life of 2.5 - 5.5 hours, which is pretty good for the amount of information a UI can display, but can pose a threat to longer duration uses. In the United States, most employees work 7-9 hours, meaning the HoloLens would run out of battery before the day is over. For the purpose of this investigation, the HoloLens would not be able to keep up with the 6 to 8-hour EVAs performed by astronauts on the International Space Station (ISS). Tracking systems vary in complexity and structure between devices, but many struggle with environment interaction. The HoloLens readjusts and builds on the spatial mapping feature, but initially struggles with dimensionalizing objects in a workspace. The composure, such as lighting, of an environment can also dramatically decrease performance in the tracking systems. Lastly, AR devices are extremely expensive, usually having a price tag of at least $1000. Widespread implementation is halted as common people and small businesses can't afford to incorporate AR devices into everyday practices. Additionally, developers such as student teams with motivation, time, and expertise can't contribute to their fullest abilities without AR devices at arms reach.

The aerospace industry provides more improvements to daily lives than people realize. From medical devices to food to overall technology advancements, missions beyond the atmosphere allow scientists to discover an incalculable amount. EVAs are an integral part of exploring deep space environments (further than automated technology is able to) and maintaining crafts and ensuring safety for future missions. However, the reliance on voice loops handicaps these endeavors, with most EVAs taking more than 8 hours. An appropriate UI would immensely increase the ability of astronauts to complete EVAs. Time efficiency is essential in missions to Lower Earth Orbit (LEO) and even more so beyond. A HID would allow astronauts inside the spacecraft to interact with the environment of astronauts outside the vehicle and this capability can be pivotal in high-stakes operations. Astronauts would have the ability to prioritize and individualize their display for optimal comfort, ultimately leading to more productivity. Navigating around the vehicle would also be easier as the AR overlays the most feasible route. A UI to improve efficiency for astronauts can transform the new exploration era of today. As NASA ventures to the Moon and onto Mars and missions need to become more independent from ground control, operations with AR devices can be a substantial catalyst towards that objective.

3. Design Methodology

The primary purpose of the SCOUT AR Assistant is to enhance the information available to astronauts during an EVA. SCOUT capabilities include additional auditory, visual, and spatial cues furthering productivity of tasks. The design consists of semi-transparent windows that follow the users gaze and can be controlled through voice commands, as shown in Fig. 1.

Figure 1. Display the astronaut sees in FOV when enabling the SCOUT AR Assistant on the Microsoft HoloLens.

Design requirements were established using guidelines from the NASA JSC SUITS technical team from the Human Integrated Vehicles and Environments (HIVE) lab. Nine system level requirements were given, as defined in Fig. 2.

Design of the SCOUT AR Assistant started with a VR prototype within the Unity 3D software. This design decision to make a VR prototype first was based on the fact that it is difficult to replicate the space environment within a laboratory setting. VR enables rapid prototyping and evaluation of concepts for the final AR design. The first iteration of the design included three windows to address the requirements defined by NASA. The windows could be moved around with the users gaze and users interacted with them via voice commands to suit their preferences. Aside from the windows, the design included waypoint highlighting and outlining objects, as shown in Fig. 3. The concept of highlighting and outlining familiarize the astronaut with current mission tasks, they also provide waypoints for navigation during a spacewalk [4].

The characteristics of the three windows are as follows: the first window includes the health status of the astronaut and his/her spacesuit system. The health status of the astronaut includes measurements such as their heart rate, EKG, and body temperature. Parameters for the status of the suit system may include: the oxygen supply/concentration inside the suit, nitrogen supply/concentration inside the suit, the battery life of the suit, temperature, CO2 concentration, and the suit pressure. In case any of these parameters are out of tolerance a bright red overlay appears in the 3D view of the astronaut describing the issue. Minor anomalies allow the astronaut to dismiss warnings. But in extreme cases, the astronaut would be directed through off-nominal procedures including, but not limited to, an EVA abort.

The second window consits of an EVA task checklist. On the window, the procedure steps appear in a simple and concise format. The astronaut can open a specific mission task for more detailed instructions; in the expanded form, instructions appeared in a checklist form for the astronaut to confirm completion by clicking (a gesture on the HoloLens) or utilizing voice command [5].

The third window includes a voice transcript of the audio loop from mission control, the IVA astronaut, and other significant personnel. All of the audio through the voice loop is transcribed into text for the astronaut to read. This solution mitigates the confusion occasionally resulting from issues with the sounds and strong accents of international partners. In addition to, astronauts have the ability to mute personnel in case of distraction or lack of relation to their mission.

Due to processing power requirements and camera limitations, it is difficult for the SCOUT assistant to outline and highlight objects automatically. Therefore, a new concept called the VR Telepresence Whiteboard was been developed. This feature allows for either the MCC or an IVA crewmember to virtually draw a line in 3D space that the EVA crewmembers could see in front of them, as shown in Fig. 4. This yields to other secondary personnel assisting and collaborating with the EVA crewmember in real-time [6]. This integration would also benefit in saving time confirming task completion instead of delaying for the primary EVA astronaut to do so.

The astronaut can make any window or whiteboard object appear, hide, or change transparency either through voice commands or through hand gestures. If the astronaut decides to change the transparency, a window appears with an adjustable bar that would be used to change the settings. The MCC would see everything the astronaut would, and they also obtain the ability to draw virtual sketches in the astronaut's FOV. This allows for swift clarity on a task and it also supplements communication if the communication link is impaired. The UI is tailored to work in a VR space environment using the HTC VIVE and Oculus Rift head mounted displays. This permits the astronaut crewmembers, developers, and fellow students on the ground to experience a virtual EVA scenario anywhere on the ISS. Personnel connected could run through a set of procedures and comment on which of the systems features are the most helpful and identify areas for improvement. The AR/VR Visor software was designed in such a way that it could be used in future scenarios for IVA crewmembers on the ISS [7], surface operations on the Moon/Mars, general space vehicle mockup training, as well as education and space outreach.

SCOUT Assistant Design Requirements	
#	**Description**
1	EVA task instructions shall be displayed
2	The astronaut shall be able to communicate with the IVA astronaut or ground control
3	Design shall be capable of assisting with navigation between waypoints
4	All gestures and external tools must be operable with EVA gloved hands
5	UI shall not be obtrusive nor a danger to the mission
6	The system shall interface with mission telemetry
7	Astronaut must be able to access spacesuit status at any time
8	Caution/Warning system must be implemented to inform astronaut of anomalies
9	In case of an interruption, astronaut must continue task on hand immediately

Figure 2. AR System Design Requirements as defined by the NASA SUITS coordinators in the the competition guidelines.

Additionally, the backend software architecture was appropriately modified for use with NASAs telemetry. Software routines for Telemetry & Data Handling, a User Interface Loop, and Communications/Voice Recognition were defined as shown in Fig. 6 and as follows:

Telemetry & Data Handling. This mechanism begins with the acquisition and processing of the telemetry stream. The navigation waypoint parameters, voice loop instructions, and other pertinent information are stored in a data cache. From the data cache, the instruction data were processed and transcribed into virtual checklists that are accessible within the AR UI. In case of a future loss of signal, instructions will be played from the offline data cache until a connection is re-established.

User Interface Loop. As a key feature, a flight controller from the MCC or another crewmember will have the ability to remotely direct the astronaut tasks. Due to the difficulty of recognizing gestures in a spacesuit, it is imperative for the human-computer interface to have multiple possible modes of control [8]. Thus, remote personnel will not only have voice loop, but also they will have the option to draw instructions on an EVA astronauts screen.

Communications and Voice Recognition. Real time transcripts will be provided, this allows the EVA crewmember to digest the information how they prefer. This also assists in mitigating confusion with unfamiliar accents as exploring space is an international effort. Further iterations of the design should aim to have translating capabilities. The voice hierarchy broken down in Fig. 5 was a complex organization

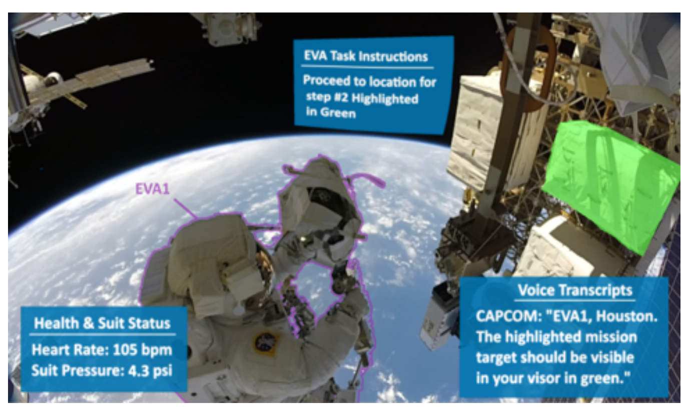

Figure 3. Display the astronaut sees through the HoloLens when all three windows are in their FOV on an EVA (along with their EVA partner).

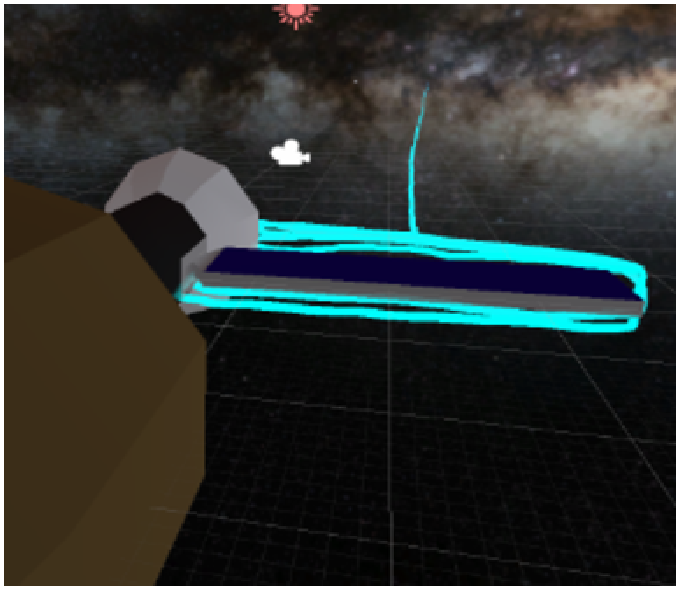

Figure 4. FOV of the astronaut when mission personnel utilize the VR Telepresence Whiteboard to indicate an object.

for the UI to include essential sections supporting astronauts.

The following voice commands are available as part of the software for menu navigation and interface control:

"*Hey SCOUT*"
—Opens SCOUT Assistant home window

"*Show Window [Status, Help, Checklist, Voice]*"
—Opens either the Status, Help, Checklist, or Voice-
—Transcript window.

"*Hide Window [Status, Help, Checklist, Voice, All]*"
—Hides the specified window.

"*Task [Alpha, Bravo, Charlie, Delta]*"
—Allows user to jump to a specific checklist task.

"*Next Task, Previous Task, Go Home*"
—Progress through groups of tasks, or return-
—to home window.

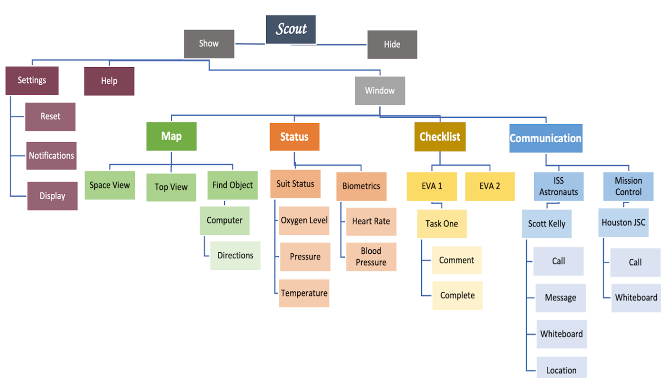

Figure 5. Voice command hierarchy that the user utilizes to interact with the user interface.

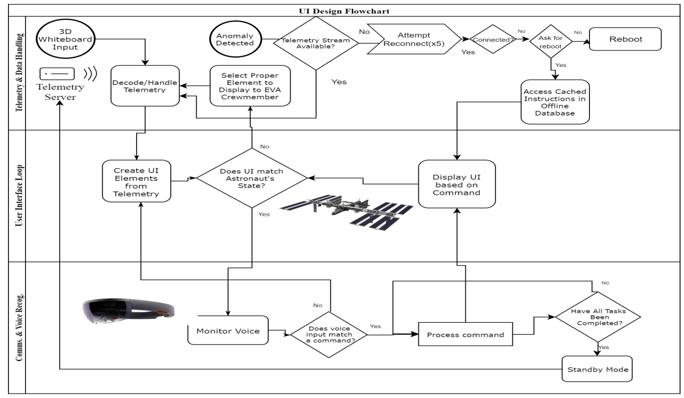

Figure 6. Diagram of the architecture of how the software reacts and organizes inputs.

Fig. 6 outlines the software architecture for the SCOUT Assistant. It begins with a telemetry input consisting of a JSON data stream of tasks and waypoints received from the MCC. Once the telemetry is decoded and processed, it appears on the UI which is constantly updating with changes while monitoring tolerance parameters. The UI also anticipates for triggered voice commands from the astronaut. This process continues until all tasks are finished. Once the tasks are completed, the software loop will go into standby mode waiting for additional data from the telemetry server. When data falls out of the correct average of that set of data, the program will confirm connection to the telemetry stream. If there is no connection found, the system will reboot and re-access stored data. Alternatively, if a connection is verified, a warning will overlay the UI for the astronaut to acknowledge. Figure 7 also describes the implemented UI architecture to constantly monitor the current state of the mission and alerts when failures are detected.

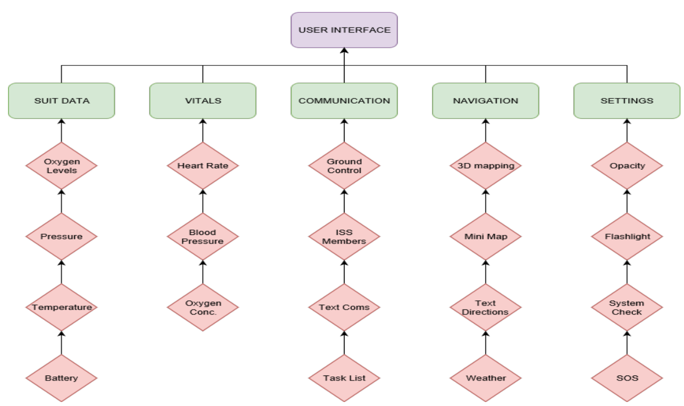

Figure 7. Inputs that feed different aspects of the UI and manipulate the display to the user.

4. Experimental Setup

Before attending the test week, the team researched on the user friendliness of the UI. Participants were asked to interact with the UI and provide feedback related to comfort and the overall experience using the SCOUT assistant. Upon arrival to JSC, NASA provided multiple tasks to be implemented into the UI, simulating a real EVA to be conducted in the Space Vehicle Mock-up Facility (SVMF). The coordinators set-up an area with an interactive piece of equipment representing a mechanism that would connect to a spacesuit in real life. The first task entailed of getting the spacesuit EVA ready by turning on the right switches on the Umbilical Interface Assembly (UIA), as shown in Fig. 8. The second task consisted of navigating from the UIA to the Display and Control Unit (DCU) through scanning QR codes on the HoloLens which would output directions. The final task was completing different actions with the DCU consisting of removing flaps and screwing in parts.

During test week, two different subjects evaluated the effectiveness of the UI. Participants were briefed on the background of the UI and what the user would be seeing. This was important to train participants so that they were not struggling with utilizing the UI. Then, the team assisted in adjusting the hardware and external attachments for testing. Once the setup was completed, the user was guided to the starting point in front of the UIA for the first task. Fig. 9 shows our first testing participant completing this task. The team opted to stay near subjects in the case of technical difficulties with the hardware or confusion on wording of the tasks the user was seeing for the first time. This parallels how an astronaut would be able to directly contact EVA flight controllers, so this was not a variable the team thought would negatively impact the results of the testing. The second participant was able to complete all of the tasks with minimal interactions between the team and competition moderators. The few questions he had entailed of misunderstanding the procedures, not how to utilize the UI.

Following test week, more extensive tests were completed in a laboratory setting at Texas A&M University. A total of 17 participants (12 male, 5 female) participated in the study. Subjects had some experience with HUDs or at least knew of them and their potential use to improve astronaut EVAs with them. Upon arrival to the lab, participants filled out a pre-test about the state of the subject and their knowledge of AR technology. Following this, participants received two flashcards describing how to build two different cube satellite

Figure 8. The equipment test subjects worked with as prompted by the UI.

Figure 9. Subject in the SVMF completing the first task during the NASA SUITS test week at JSC.

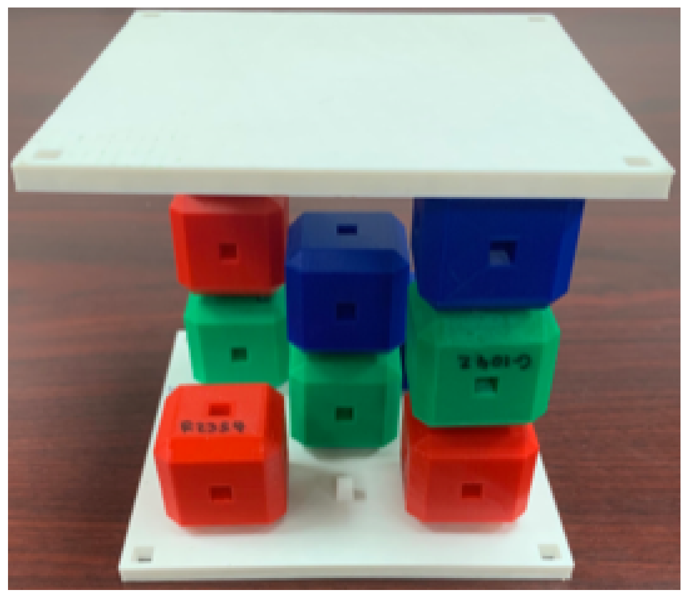

Figure 10. Assembly "A" participants would create through the study at Texas A&M University.

configuration assemblies from 10 small cubes, as shown in Fig. 10. The cubes were red, green, and blue with specific numbers associated with each cube.

Participants would build four different satellite configurations, two with the HoloLens and two with flashcards. The instructions were written in the exact same manner in both conditions: flashcards (without AR) and in the UI using the HoloLens. The HUD also had pictures of the steps and was manipulated via voice commands in comparison to just reading/flipping flashcards. The results of this study showed that some subjects preferred to work with the UI whereas others preferred the index cards. Researchers believe this indicates that subjective comfort levels were not generally met to accommodate the subjects. Future research will target specific variables to improve the human factors aspect of the

UI. Experimenting with different formats of writing instructions is also important to utilizing trigger words that subjects understand more clearly. Lastly, better paralleling actual astronauts in the sense of having a checklist on the wrist of the user instead of handheld flashcards, researchers believe would favor the HUD efficiency. Overall, a more controlled environment and improving the replication of an astronauts actual experience would be the next steps in proving a HUDs capability to maximize productivity in a task-based work environment.

5. Analysis & Lessons Learned

The data collected from the experimental trials proved to be worthwhile in development of future iterations of the SCOUT Assistant. Steps were taken to ensure that all data collected were anonymous in order to protect the volunteers willing to test out the AR system. Results show that for three out of four configuration assembly types, AR allows for a better assembly time. On average, the assembly time was 9.19 seconds faster using AR instructions versus the non-AR case (see Fig. 11).

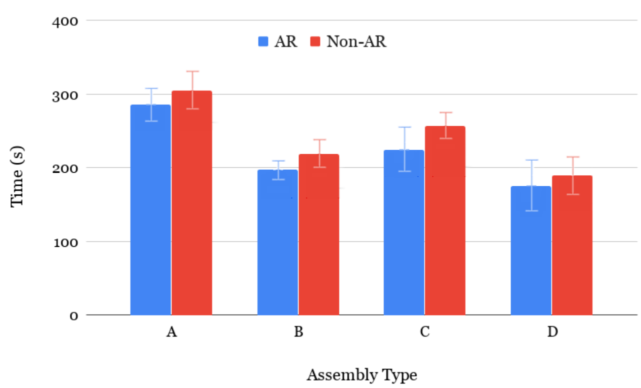

Figure 11. AR vs. Non-AR Guided Assembly Times as measured by research facilitators at Texas A&M.

Subjective feedback was also gained during post-experiment surveys, along with permission to share the comments. A major portion of the feedback included fitting the needs of the user. Not every task needs the same explanation and not every astronaut will need the same guidance. Displaying a video of each checklist item task is not necessary, and there was noticeable latency due to the HoloLens trying to process the video on each window. For a simple task, only showing the checklist item with an option to bring up the video would be ideal. Additionally, a 3D hologram of a complex task could have helped with understanding of the exact steps to take more than the videos. The real-time 3D scan of the test scenario utilizing the Zed Mini camera, as shown in Fig. 12 and Fig. 13, respectively, could help with on-orbit operations by providing IVA crewmembers and MCC an updated virtual view of the scenario. This is very useful for helping provide information about what UI to display to the EVA crewmember. It was suggested that if technology similar to this were attached to the back of the EMU helmet, it would provide astronauts with a 180 degree rear camera view that would add much to current capabilities.

All the competition facilitators were really intrigued with the idea of a way to overlay directions onto the EVA astronauts display. The ability to annotate features within the EVA crewmembers view is a novel idea (Fig. 14), and if it were used by MCC in such a way to help outline a certain module or identify a specific wire, it could drastically reduce the time needed to perform a certain task. The subjects that completed testing also agreed that this might have helped them when stuck on a task or forgotten which part was being referenced.

In testing with the teams UI and learning about the other competitors designs, the team realized how far simplicity can go. Astronauts dont need fancy displays for completing their tasks so keeping the UI as a supplement is important [10]. The team received feedback to implement minimizing what the user sees at a given moment on the HUD. It was suggested to have a reference image on the left and a list of only up to four procedures on the right made the tasks easy to understand and follow. Additionally, conforming the format of the text display to left justified also allows the astronaut to read more easily. Something the team hadnt thought about was how pivotal knowing exactly how long a task would take from the start. If an astronaut wanted to skip around based on the length of tasks they could easily do so.

Overall, the team got extremely lucky in having an EVA trainer that works directly with astronauts as a test subject. He offered a whole new insight to take the UI design to the next level. He thoroughly enjoyed the design windows being elegant and transparent so not obtrusive to the work at hand. Mainly, after completing the tasks he wished it had been more individualized to his personal needs. The team seeks to take that into account via training the user before the testing on how to personalize the UI settings to promote the utmost efficiency. Additionally, providing mechanisms for more mobility between tasks is important to fit the needs of the user. Some astronauts may distinctly remember procedures from their training and be able to complete tasks before they even read all the way through them, while others may need additional guidance. The latter would be benefited with flight controllers being able to directly interact with the displays of EV or IV astronauts.

The SUITS competition was created to engage students with NASA ideas and personnel. After receiving an invitation to test week, the team constantly interfaced with technical leads and other competition coordinators. In addition to acquiring real engineering design experience, the competition also serves to merge participants into the community of NASA JSC. The team had the privilege to connect with full-time employees professionally, even receiving specialized opportunities specific to the A&M team. The team set-up a tour of the Neutral Buoyancy Lab (NBL) whilst an EVA training was occurring, only emphasizing the need for supplementary forms of communication such as a UI with a HID. Direct communication with the competition leaders only maximized the finish product of the designs attempting to meet the guidance of the UI. Through these NASA-led competitions, other opportunities to work with NASA personnel and projects are encouraged. Test week consisted of

Figure 12. Zed Mini Stereo Camera [9] which was placed on the VR Oculus Rift device during NASA JSC test week.

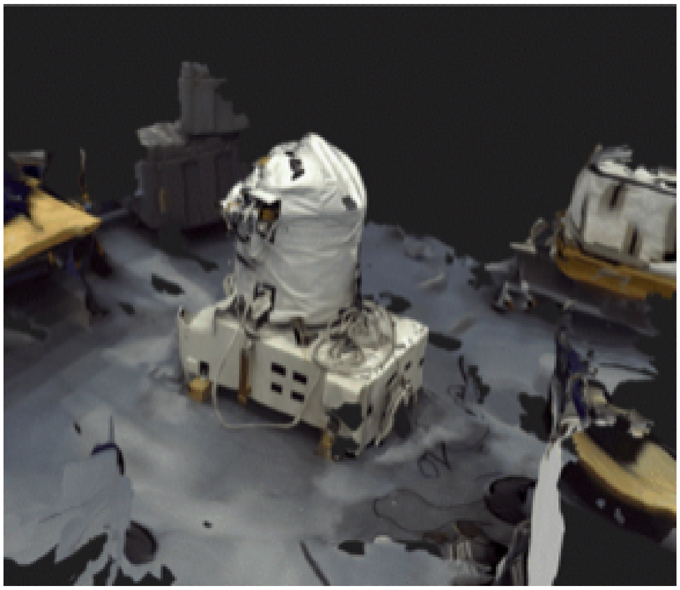

Figure 13. 3D Scan completed by the VR Oculus Rift During Test week at NASA.

testing, tours, and lectures by various leaders at JSC. The lectures showed teams the Micro-G Next, the community college NASA program, and participants got to talk directly with the NASA intern program manager. NASA leaders emphasized that the collaboration doesnt have to stop with a collegiate design competition, but that the lessons and experiences gained from the NASA SUITS competition ought to be applied to an actual career. NASA reiterated that the SUITS competition lends to real solutions and aims to have past participants serve as ambassadors for future cycles.

6. Outreach

In a similar fashion to NASA, the team remains committed to engaging the general public through outreach events. A considerable portion of the SUITS competition is the impact each team makes on their community. Through the 2019 competition cycle, the team completed two significant outreach events in collaboration with the Texas A&M Engineering Outreach. The first working with elementary students and the other with educators. Facilitating activities wherein participants would broaden their engineering knowledge, the team learned a lot about how to effectively engage audiences. Additionally, the team accomplished adapting lesson plans to meet the needs of varying audiences.

Figure 14. VR Telepresence Outline which would be utilized by mission personnel to indicate actions for the EVA astronuat on their AR device.

Figure 15. STEM4Innovation Conference outreach event where team members taught educators in collaboration with the Texas A&M Engineering Outreach team.

For the 2020 Competition cycle, the team is working with Microsoft stores around Houston on top of programs with the Texas A&M Engineering Outreach again. In coordination with Microsoft, the A&M SUITS team is helping launch the Microsoft EPIC program at Houston Microsoft stores. The team is mentoring middle and high school student design teams in the competition. The goal of this program is to challenge students to ideate solutions to real-world issues utilizing Artificial Intelligence (AI). For the A&M Outreach, the team plans to participate in two programs in influencing kids to explore STEM-related fields. In total, the team has impacted over 60 people and through the events already planned for the current cycle over 250 students will be impacted.

7. Conclusion

The SCOUT Assistant AR visor software proves to enhance the time necessary to complete a task on an EVA compared to traditional methods. Instead of depending only on the voice loop from MCC, the real-time display of information directly within the astronauts FOV allows for a concise visual display of the suit vitals, telemetry, waypoints, checklist items that are relevant to the mission.

Future studies hope to include alternative methods for controlling the UI with customized hardware buttons mounted on the EVA crewmembers arm, gaze/eye based selection of UI elements, and an automatically updating heads up display based on the elapsed mission time and physical surroundings. Additional design features that were experimented with but need more testing before being incorporated into the AR visor. The first of which is a spline path 3D augmented waypoint display to show a virtual pathway. This would come with guided navigation using audio cues to help the astronaut, such as traverse 3 meters further along the truss and then grab the handhold on your top right, as the EVA crewmember reaches certain checkpoints along the pathway. Also, a data cache in software with pre-loaded conditional instructions from mission control in case there is a loss of communication to ground or vice versa. This would include notes from previous missions by astronauts and other expert personnel. Lastly, a VR wrist-mounted top-down 3D map view of the environment could help expand astronauts perspective of the surrounding situation.

Many of the lessons learned from the UI consist of individualizing based on the user. This idea promotes the maximum user friendliness and therefore lends to higher productivity. The subject in our testing at NASA JSC emphasized that not all astronauts will need the exact same direction. Some EVAs can be fairly simple from reiterating numerous times in training [11], but others warrant more direction. Designing a UI to accommodate the astronaut would greatly decrease the time spent repeating next task to get to the needed display. Another pivotal lesson consisted of how interested the NASA SUITS team was in the designs. Before attending test week, the team didnt fully comprehend the impact of the actual competition. The designs collegiate teams brought to test week do lend to the xEMU suit creation for the 2024 Artemis mission. Furthermore, specific to the Texas A&M team, NASA expressed an extreme interest in finding how to make AR and VR devices compatible with each other in communicating and displaying different objects. This is the focus to master of the team in the 2020 NASA SUITS competition cycle. In deploying projects, the team faced many technological difficulties which go deeper than just the UI. The team seeks to purchase a HoloLens 2 upon availability in the market to solve some of the issues regarding integrating alternative AR/VR devices. Overall, the team continues to interface with the NASA SUITS personnel each week. The SUITS competition engages collegiate students with the current objectives of NASA in a very unique and beneficial way.

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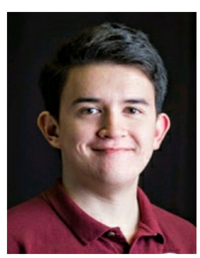
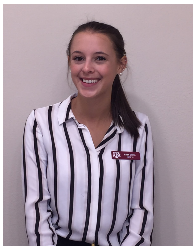
BIOGRAPHY

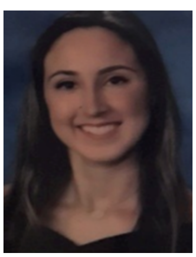


Neil McHenry *is currently a graduate student researcher at Texas A&M University and an active member of the Students for the Exploration and Development of Space (SEDS-USA). His research focuses on developing a virtual reality space sandbox called "Space-CRAFT" that aims to help shape the future of humanity in space. He hails from Dallas, TX and is currently is a PhD Candidate in the Aerospace Engineering Department at Texas A&M University, with a focus in spacecraft dynamics and control. He obtained his Bachelor's degree in Electrical Engineering and Master of Engineering degree in Aerospace Engineering from Texas A&M University in 2015 and 2016, respectively. During his undergraduate degree, he interned at the NASA Johnson Space Center for two summers, where he helped develop electrical hardware systems to train astronauts as part of the International Space Station program. At SpaceX, he helped develop flight software and hardware for the autonomous propulsive landing systems that are currently used on the Falcon 9 launch system. He is an Eagle Scout and enjoys volunteering around the community with the American Red Cross, and performing music on xylophone & viola with the "Chyao Pra Ya" Dallas Thai orchestra. His main passions are to become an astronaut and to ensure that humanity's future in space is bright.*



Leah Brooke Davis *is currently an aerospace engineering student at Texas A&M University in the class of 2021 and the Engineering Honors Program. She grew up in Dallas, Texas and attended Booker T. Washington High School for the Performing and Visual Arts for theatre. Leah helped found the Texas A&M SUITS team in her second semester and has enjoyed helping lead the team the past two years. Through the SUITS competition, Leah had the opportunity to intern at NASA JSC over summer 2019 working on the Artemis Mission Analysis and Design team. She will be returning to JSC in Spring 2020 for another internship with the team assisting in creating user interfaces for the Boeing Starliner missions. She hopes to end up working full time at NASA and continue tackling challenging work. In her free time she enjoys writing, music, and spending time with friends and family.*

Israel Gomez III *is an undergraduate mechatronics engineering junior a Texas A&M University. Born and raised in Houston, Texas, he is a Hispanic second generation student on his mother's side. Having a strong attraction to the robotics and aerospace field since a child, he came to A&M with the hope to expand his knowledge in the robotics field; however, when he heard about the NASA SUITS challenge, he did not hesitate to become involved. Now the Deputy Lead of the NASA SUITS team, he hopes to one day become a pioneer in both AR technology and the aerospace field. His hobbies include rock climbing and game development.*



Natalie Giselle Roehrs *is currently an undergraduate aerospace engineering junior minoring in computer science and mathematics at Texas A&M University. She is from McKinney, TX, and is the first on her mother's side of her family to attend a university. Upon entering the engineering program, she became involved in multiple organizations on campus that focus on leadership, community, and supporting women in STEM. After graduation, she aspires to focus on jet propulsion and gas dynamics as a Professional Engineer for the SLS as the United States makes its trek to Mars. Her passion for aerospace and flight derive from having flight experience with her father at a young age. She is currently seeking an internship as an aerospace engineer for summer 2020.*

Noemi Giselle Coute *is currently an undergraduate student at Texas A&M University in the Department of Visualization. She was born and raised in Clear Lake, Texas only 5 minutes away from the Johnson Space Center, which founded her interest in space exploration. Her passions include music, art, and game development, and her goal is to become a director in game development. She is a co-founder and mentor of 2VD, an organization that provides an outlet for students to pursue concept development and illustration. She is involved in multiple virtual reality research teams and has a strong interest in game development.*

Celest Villagran *is currently an undergraduate student majoring in Aerospace Engineering with a minor in math studying at Texas A&M University. She was born and raised in Houston, Texas, and has a strong identity with being a Hispanic first generation student. She has been recognized as a Hispanic Scholar by the Hispanic Scholarship Fund, and recently attended their STEM Summit held in San Diego, California. During her time as an undergraduate student at A&M she has found several ways to give back to her community, having been employed by the College of Engineering as a Peer Teacher for introductory Engineering courses for the past two years, and has been a mentor for freshmen engineering students for both the Society of Women Engineers and the Engineering Mentor Council. She currently serves as the Vice President of Out in Science, Technology, Engineering, and Math, or STEM, and hopes to work in the space industry after she graduates.*

Dr. Gregory Chamitoff *served as a NASA Astronaut for 15 years, including Shuttle Missions STS-124,126,134 and Space Station long duration missions Expedition 17 and 18. He has lived and worked in Space for almost 200 days as a Flight Engineer, Science Officer, and Mission Specialist. His last mission was on the final flight of Space Shuttle Endeavour, during which he performed two spacewalks, including the last one of the Shuttle era, which also completed the assembly of the International Space Station. Chamitoff earned his B.S. in Electrical Engineering from Cal Poly, M.S. in Aeronautics from Caltech, and Ph.D. in Aeronautics and Astronautics from MIT. He also holds a Minor and a Masters in Planetary Science. He is currently a Professor of Practice in Aerospace Engineering, and Director of the AeroSpace Technology Research & Operations (ASTRO) Laboratory at Texas A&M University. He is co-author and co-editor of Human Spaceflight Operations, a textbook on the lessons learned from the past 60 years of spaceflight. His research includes space robotics, autonomous systems, and the development of collaborative VR simulation environments for space system engineering and mission design.*

Dr. Ana Diaz Artiles *is an assistant professor in the Department of Aerospace Engineering at Texas A&M University. Her interests focus on the engineering, biomedical, and human factors aspects of space exploration, including artificial gravity, sensorimotor adaptation, space physiology, and human health countermeasures. At Texas A&M she directs the Bioastronautics and Human Performance research lab. She received her Ph.D. from the Massachusetts Institute of Technology in 2015, where she studied artificial gravity combined with exercise as a countermeasure for spaceflight-related physiological deconditioning. Prior to MIT, Ana worked for five years in Kourou (French Guiana) as a member of the Ariane 5 launch team. Dr. Diaz Artiles has a background in aeronautical engineering from Universidad Politcnica de Madrid (Spain), and SUPAERO in Toulouse*

(France). She is a 2011 Fulbright fellow and a 2014 Amelia Earhart Fellowship recipient.