Technical

Abstract

The Collaborative Lab for Advancing Work in Space (CLAWS) proposes the *Immersive Reality Interplanetary System* (IRIS). IRIS is an interactive augmented reality interface that supports astronauts in EVA operations on Mars by helping crewmates perform UIA egress, navigate to and from locations of interest, assess geological samples, direct a rover, perform airlock and ingress procedure, and manage equipment and diagnosis repair.

IRIS's design aims to be seamless, intuitive, visually lightweight, and as automated as possible. To support this, IRIS provides astronauts with AR screens and audio feedback to help astronauts complete each operation. Astronauts may interact with IRIS's interfaces using voice commands or tactile inputs for maximum flexibility and usability. Tasks each trigger a unique *mode*, in which the layout of screens will change to aid the astronaut in the specific operation they are performing. Each *mode* will show only the most relevant screens to the astronaut for their current task.

With IRIS, CLAWS' goal is to provide a fully functional and realistic simulation of an AR head-mounted display (HMD) in Mars EVA conditions as it interacts with the Local Mission Control Console, peripheral hardware systems, a rover, and other astronauts. IRIS supports and enables seamless, effective teamwork between all parties involved in an EVA. Features like the task list, map, and vitals monitoring have been designed to allow astronauts to monitor the status of other astronauts. Throughout the entirety of the EVA, there will be two-way communication between astronauts and the Local Mission Control Console (LMCC) controlled by the IVA operator. The geological sampling, rover commanding, and navigation procedures have also been designed realistically, incorporating NASA's expectations and concerns in their Mars EVA CONOPS.

The LMCC is a mission control center designed for local activities based on Mars, which allows for planned autonomy. In the case of unexpected situations like broken equipment, loss of communication (LOC), or an incapacitated crewmember (ICM), IRIS is proactive, helping astronauts to mitigate potential issues in advance and respond quickly to issues when they arise. LMCC is built to be powerful, enabling the IV to send astronauts informational messages, images, and drawings; generate navigational routes; highlight screens on the astronaut's UI; and take control of astronaut suit settings.

IRIS will allow CLAWS to comprehensively simulate astronaut operations and mission control operations on a Martian EVA. In this proposal, we will describe the system we plan to build and our motivations behind those choices.

Software and Hardware Design Description

Design Concept

IRIS's augmented reality information display will seamlessly adapt to astronauts' current needs. Through past anonymous astronaut interviews and research, CLAWS has determined astronauts prioritize having their hands free during EVAs (Anonymous Informant #1, personal communication, Oct. 20, 2022). Thus, the system will be primarily controlled through voice commands, and direct touch interaction will serve as a fallback input medium. The interface will be designed around a navigation bar containing key features and the ability to launch focused *modes* for specific tasks (Figure A). These *modes* will reduce visual overload by hiding less relevant information during tasks. IRIS's design will be

visually lightweight, with subtle animations and restrained color use. Feature-rich, simple, and consistent flows will put the astronaut in control, enabling true autonomy with ease. The system will automate as much as possible, automatically changing suit controls to remedy issues and classifying geological samples' shape and color. Multiplayer capabilities will be integrated throughout IRIS, allowing astronauts to communicate with and monitor one another. Information between AR and the LMCC will be directly synchronized, with the LMCC being able to control all aspects of an astronaut's HMD. These design choices have been derived from the NASA CONOPS document in consideration of Mars EVAs potential concerns and points of failure as well as design heuristics intended for effective use of AR technologies [1, 2].

Task List

The task list will allow the user to see all mission tasks and subtasks that have been assigned to the user, as well as the name and description of each subtask (Figure M). A progress bar will show the overall EVA status and, throughout the entire EVA, the user will be able to see their current task by looking down at a screen placed near their stomach. This screen will be placed outside the user's normal FOV, but will be easily accessible by looking down. In the case a user shares a task with their companion astronaut, the task list will show the names of each astronaut working on the task and whether they are ready to begin the shared task. The LMCC will show all tasks for all astronauts in the EVA. At any time during an EVA, the IVA operator can create a new task or edit an existing one. These changes will be relayed to each astronaut with the new or edited task via a pop-up message, and the astronaut's task list will update accordingly.

UIA Egress and Utility Air Lock

To support the astronaut during UIA Egress, IRIS will use a computer vision (CV) panel-tracking system to display a holographic arrow over the current UIA switch that the astronaut needs to toggle.When a switch is correctly toggled, the UI will update and a new arrow will appear over the next switch. In the case of CV failure, IRIS will send a pop-up with information on the name of the next switch and additional parameters that must be met (Figure C). IRIS will also provide warning messages to alert the astronaut if switches are moved incorrectly.

IRIS will also use CV to support astronauts during the Utility Air Lock procedure by displaying a holographic arrow over each air lock latch that the astronaut should pull. During this task, the IVA operator will select specific latches on the LMCC for the astronaut to pull while watching a live video feed of the HMD. IRIS will then show arrows over the corresponding latches and alert the user if they pull an incorrect switch.

Equipment Diagnosis and Repair

The LMCC enables robust equipment diagnosis and repair capabilities to assist astronauts during EVAs. The LMCC can guide the astronaut through repairs via voice instructions based on live video feed and conversation. To further aid in troubleshooting, the LMCC can send relevant information, such as cue cards, images, diagrams, and illustrations, directly to an astronaut's HMD (Figure M). For more precise guidance, the LMCC has the ability to visually highlight specific buttons on the astronaut's display. With this diverse set of assistive features, the LMCC allows for flexible, customized troubleshooting tailored to any form of equipment failure.

Geological Sampling

When an astronaut enters an area they would like to investigate for geological sampling, they will enter *Geological Sampling Mode*. In this mode, the user will scan many samples within a geological sampling zone. The user will first take notes and pictures of the geological sampling zone. Then, the user will begin taking individual samples. During this process, IRIS will use CV to determine important metadata tags like the shape and color of samples. Geological sampling screens will be spatially anchored to the location of the sample and will contain information such as XRF data, location, shape, and color. The user can interact with these screens to check relevant data, record speech-to-text observations, and take pictures of the sample (Figure D). The user may also "recall" the sample screens to them to interact with them within a HUD rather than in space allowing for easier access.

Additionally, LMCC will receive all scanned sample data, sample zone data, and can indicate samples of interest. The corresponding sample screens will then be highlighted within IRIS. LMCC will also give the IVA operator the ability to search the database of samples using the metadata tags attached to each sample. This gives LMCC quick access to samples that may otherwise be hard to find. The AR UI will also have a geological sample database, which can be accessed through geological sampling zones folders (Figure E).

Map

IRIS will contain a 3D map, which can be opened via a voice command or button within the menu. This will place a 3D render of the local Martian surface in front of the user in space. When the 3D map is open, the user will be able to rotate the map on the y-axis, zoom in and out, and place pins at any location using touch input. This 3D render will also showcase all features related to navigation such as pins, dangerous terrain, navigational paths, rover location, and companion astronaut location (Figure L).

IRIS will also include a 2D miniature elevation map of the rock yard that is fixed at the user's location. This will serve to show all important information related to location and navigation at a glance. The map will show the user's current path in addition to pins, stations, and the companion astronaut's navigational path.

Navigation

IRIS will enable dynamic route-planning to any landmark, point of interest, or astronaut using Unity NavMesh on a 3D terrain map. In *Route Planning Mode* a user can walk around a 3D map anchored to world space and can select multiple pinned locations to navigate to. The most optimal navigational path would then be rendered on the 3D map and additional screens will show route details, like the distance, estimated time, and estimated resource consumption. When a route is confirmed, *Navigation Mode* will begin (Figure L).

In *Navigation Mode*, the UI will shift to a more focused layout to support navigation; screens that are normally positioned near the user's stomach will either disappear or shift to the side to allow the user to look down and avoid rocky terrain as they walk (Figure B). A trail of breadcrumbs will show a path that avoids terrain hazardous to the user. As the user walks, they will see a screen that shows navigation metrics, like the destination, elapsed time, remaining distance, and traversed distance. Additionally, waypoints will show up in space at the locations they are defined at within the map. Upon reaching a destination or manually ending navigation, *Navigation Mode* will end.

LMCC can also play a vital role in navigation. The IVA operator can create a route plan for an EVA astronaut and send this to the astronaut anytime during the EVA. The user who receives this route may view it in *Route Planning Mode* and then begin navigation. During *Navigation Mode*, the LMCC operator will be able to see each astronaut's breadcrumb trail in the console's 2D map as well as each astronaut's navigation metrics. At the end of the mission, the user can start the ingress procedure by navigating back to the starting station (Figure H).

Rover Commanding

The LMCC provides robust capabilities for remotely commanding the rover and showcasing rover system state data. The rover adds an additional level of mobility to the team, providing storage and imaging capabilities, as well as acting as a safety resource [1]. The IVA operator can control the rover on the Martian surface by utilizing two live camera feeds on the vehicle alongside mouse and keyboard input. For navigation guidance, the LMCC displays a mapped path showcasing the optimal route the rover should take to a given destination. Once the rover arrives at a site, it can remotely pick up and drop geological samples under the LMCC's control. The rover logs location data for each sample collected, takes pictures, and allows the operator to append textual notes (Figure I).

Vitals and Suit Data

From astronaut interviews and test week feedback, CLAWS has learned that users typically only want to see vitals and suit data if the values are entering off-nominal ranges. Thus, IRIS shows only the EVA mission time persistently to the user. If more detailed vital and suit data is required, the user can expand a vitals screen, which will include biometric and suit data for both the user and their companion astronaut (Figure F). All this information will be forwarded to the LMCC, allowing the IVA operator to track the health and suit systems of the astronauts on the EVA.

In the event of EV suit or biometric data entering off-nominal ranges, IRIS's caution and warning response system will automatically engage. The application UI will alert the user of the issue. The user will have the capability to manually adjust suit controls (Figure G). IRIS can also automatically adjust the suit controls to fix certain issues with the EV suit. The user will be prompted to decide to either accept or reject these changes. In addition, IRIS will send a warning alert to LMCC and the companion astronaut. In the case of an ICM, the LMCC operator can directly take control of the endangered astronaut's suit controls.

VEGA

In previous testing, CLAWS has found that users greatly prefer voice commands over tactile or eye-gaze inputs, especially in the context of astronaut EVAs. IRIS is designed to be controlled primarily through verbal commands, with tactile inputs available as a fallback. Our Voiced Entity for Guiding Astronauts (VEGA), an AI voice assistant that classifies astronaut voice commands based on intent, will be expanded upon to increase flexibility and efficiency. Further development will improve VEGA's ability to break down multi-step commands into a sequence of actions. VEGA will act similarly to a human assistant, having the ability to quickly complete complex tasks after being prompted by an astronaut. These multi-step commands will more closely resemble natural speech, and are especially useful for making *geological sampling*, *navigation*, and *rover commanding* faster.

COR

Through research and previous experience with the NASA SUITS Challenge, CLAWS has found the HoloLens' field of vision to be a major obstacle in the usability of our application. The device's FOV is

limited to only 52 degrees [3]. Last year CLAWS implemented a software fix to partially address this issue. This year, the team is utilizing software in tandem with a hardware solution to expand the HUD space of IRIS. COR (Cardiac and Orientation Reporter) is an orientation unit with an inertial measurement sensor that sends heading data to the HoloLens. COR will use this information to effectively expand the FOV of the HUD by orienting screens to the astronaut's body rather than their head. The intended functionality of this sensor can be seen in Figure J and Figure K. When the astronaut looks to either side, screens in the HUD will stay body-locked, matching the rotation of the user's chest. This functionality will allow HUD screens to be placed above, below, and to either side of the astronaut, rather than always appearing head-locked.

SCOUT

IRIS will require a high-fidelity 3D render of the Martian surface to enable its navigation features. To enable this, CLAWS will develop SCOUT (Space Companion for Observing Uncharted Terrains), a fully featured rover focused on improving the navigational abilities of our application. Utilizing lidar and RGBD cameras, SCOUT will map the Martian surface autonomously. This data and the coordinates of any dangerous terrain will be sent to LMCC and the HoloLens. With this information, we can create navigational paths that avoid obstacles and keep the astronaut safe.

Technical Implementation

AR

The AR team will use the Unity game engine and Microsoft's MRTK 2 toolkit to create UI and interactive components. MRTK contains many built-in features and UI that the team will modify to fit the outlined goals for IRIS. Our software architecture relies on a publisher-subscriber event system to decouple dependencies between features, allowing for modular development of multiple features simultaneously. To enable rapid, iterative testing by the UX team, we have made a CI/CD pipeline. Developers will push new changes to GitHub often, which will trigger an automatic WebGL build through GitHub Actions. Members of the UX team can view this WebGL deployment online and quickly give feedback. To ensure the Web, AI, and Hardware teams' deliverables can integrate with the AR component, we have already defined a detailed API and data flow diagram that describes how data will be sent and received through JSON (Appendix D). The WebGL deployment will also allow these teams to rapidly test integration to AR without requiring Unity or a HoloLens.

Web

The web team will utilize a React frontend to provide the LMCC interface. This frontend will be supplemented by a ExpressJS RESTful API, which will provide several endpoints that allow the frontend to interact with system data stored within a MongoDB database. Websockets will be responsible for transferring a majority of data relating to astronaut vitals, locations, and task progress. These connections will have fault tolerance to detect connection failures. The web team will utilize a CI/CD pipeline to allow AR and UX teams to fully utilize LMCC features during the development process.

AI

In order to perform command classification IRIS will utilize a speech-to-text service to transcribe astronaut speech. VEGA will then utilize an intent classifier built using RASA to determine the intent of a given command, which can either lead to an action (such as retrieving vitals) or could be a compound command that can be parsed utilizing an LLM (LLAMA2). Which will break down complex commands

into a sequence of actions (chain-of-thought LLM prompt). To achieve the panel-tracking implementation for UIA Egress and Utility Airlock tasks, spherical markers will be affixed to items of interest, such that we can utilize a Haar Cascade Classifier to detect said markers within the astronaut's POV. AR ray-casting can determine depth, such that the orientation of the given panel can be determined in real time (Figure C). To perform AI sample detection, VEGA will utilize a YOLO5 object detection model, which will be trained to identify viable geological samples and estimate their makeup and type by their color and shape.

Hardware

The Hardware team will utilize resources from the university, Intel, and Nvidia to gather the materials and sensors needed to develop the heart rate sensor and SCOUT. The Hardware Team plans to use a Raspberry Pi programmed with Python to read information from a heart rate sensor and send it wirelessly to the HoloLens 2. Additionally, the team will use lidar and RGBD sensors aboard SCOUT to create a 3D map of the area SCOUT is in. SCOUT will use the Robot Operating System (ROS) running on a Nvidia Jetson board to process and send this data wirelessly to the HoloLens 2. The team will utilize 3D printing to design and develop the chassis of SCOUT. The Hardware team will also conduct in-depth research into the capabilities of each component and create a hardware and systems design for each.

UX

The User Experience Design team will craft a design system within Figma, utilizing standardized, reusable components. This foundation will enable rapid design iteration while preserving feature consistency. Design components will be flexible, allowing their implementation to be tailored to each feature's specific needs. The team will also use a comprehensive research process for deducing optimal design decisions, involving interviews with astronaut contacts and a design exploration procedure. Throughout all design stages, concepts will be subject to design reviews to review functionality and aesthetic considerations.

Research

Our design decisions are based on research into NASA's EVA procedures for Mars, Microsoft's design recommendations, astronaut interviews conducted by CLAWS, and user-testing feedback from our previous AR interfaces–HOSHI and NOVA. Last year, the team conducted research to examine the effects of varying luminescence and hand coverings on HoloLens functionality, published in the Journal of Human Factors and Ergonomics Society [4]. This year, our team plans to simulate the effects of background noises as heard in a real Mars EVA setting on the reliability of voice commands on the HoloLens 2, expanding on previous research that examines the effects of office background noises on the HoloLens 2 [5]. An alternate research topic is to simulate the red luminescence of the Martian environment and examine its effects on HoloLens 2 reliability. In addition to these experiments, the research team will facilitate HITL testing with test participants outside of CLAWS at the end of the year, and conduct outreach at events and conferences.

Concept of Operations (CONOPS)

IRIS is primarily controlled through voice commands, allowing the astronauts' hands to remain free during their EVA. A menu pane and mini-map persistently stay at the top of the HMD. As a backup to voice commands, IRIS also supports direct touch interaction. There will be constant two-way voice communication between LMCC and EVA astronauts. The following six scenarios showcase a detailed sequence of potential mission events, presenting IRIS's assistive capabilities in an EVA. The procedures

primarily follow Alex and Steve—two EVA astronauts exploring Mars—and the IVA operator Efe. The detailed scripts can be found in Appendix B.

Scenario 1: UIA Egress

The UIA Egress Script outlines how Alex completes the UIA Egress process using IRIS. A guiding hologram appears above the first switch that needs to be manipulated on the UIA egress panel. When Alex toggles the switch, a hologram appears over the next switch in the sequence. When Alex accidentally moves an incorrect switch, a warning message appears, which provides guidance on how to remedy the mistake. For the next switch, a timer pop-up appears informing Alex that she must wait until the water level reaches 95%. When complete, Alex asks Efe to review the UIA data on LMCC. Efe confirms that the settings are correct and that she can continue with the EVA.

Scenario 2: Navigation

Demonstrated in the Navigation Script, Alex plans a route and navigates on Mars. To begin, Alex says "Open Navigation." A 3D map of the nearby terrain displays a list of stations. Alex references the task list and uses a voice command to select a destination. Alex is shown a preview route on the 3D map and data for estimated travel time, distance, and resource consumption. She says, "Confirm" to begin navigation. The navigation screen closes and the HMD overlays a breadcrumb path onto the Martian terrain. IRIS enters *Navigation Mode*, adjusting the layout of screens to give the astronaut more visibility in navigation. A small window appears at the top of her field of view, showing the estimated travel time remaining and travel distance left. A mini-map provides the route path and an overhead view of the nearby terrain. Midway through her journey, Alex receives an alert from LMCC that Steve's oxygen levels are low and that Alex must reroute to assist. Alex says "Begin Navigation to Steve." The system re-routes and Alex confirms the change. When Alex reaches Steve, the navigation automatically ends.

Scenario 3: Rover

The Rover Script demonstrates how Efe pilots a rover through the Martian terrain using the LMCC's intuitive controls. She manages acceleration, turning, and sample collection using keyboard and mouse inputs. Efe first drives the rover to a point of interest with many potential geological samples nearby, using a path displayed on the LMCC's map for guidance. Efe then begins controlling the rover to pick up and log potential geological samples, referencing the vehicle's camera feeds and system state data. Once Efe finishes the process of surveying the Martian rocks, she reviews the location of the logged samples, all displayed on the LMCC map and in a sidebar list view.

Scenario 4: Equipment Diagnosis and Repair

By following the Equipment Diagnosis and Repair Script, Alex repairs a communications tower by clearing dust off solar panels. With the LMCC, Efe monitors Alex's camera feed and sends a holographic screen to the HMD, listing out common issues to look out for. At the communications tower, Alex informs Efe of dust build-up, which is obscuring a series of solar panels. Efe confirms the diagnosis by glancing at the connected video feed and quickly searching the LMCC's repair instructions database to find the guide for clearing dust from equipment. She sends the instructions document to Alex's HMD, where the information opens as a holographic screen. The directions are listed for Alex in clear steps and simple images. Finally, Efe observes on the LMCC dashboard that the communication tower is functioning properly and informs Alex that the repair was successful.

Scenario 5: Geological Samples

To begin the Geological Samples Script, Alex arrives at a chosen area of interest and says, “Enter Geo Sampling Mode” to create a geological sample zone. Within the zone, Alex is prompted to begin scanning samples with her spectrometer. After scanning each sample, a screen appears above the rock displaying XRF data and location tags. Efe views the LMCC geological sample database, which has been populated with new entries from Alex’s scans, and marks two samples that have unique chemical make-ups, requesting additional data. The two sample screens are highlighted in Alex’s HMD, and Alex uses voice input to enter additional data and take a photo of each sample. When finished, Alex says, “Leave Geo Sampling Mode” to return to the default HMD view. Finally, Alex uses voice input to launch the geological sample database and view the newly added geological samples, ensuring the information was stored correctly.

Human-in-the-loop (HITL) Testing

CLAWS will perform formative research in order to ensure the usability of our design. This will include regular user testing of our design and integration of academic studies on the HoloLens 2 for use in different environments.

During our iterative design and development cycle, UX team members embedded in cross-functional feature teams will conduct weekly user testing sessions. These weekly testing sessions will be held by the UX members assigned to a specific feature. During this testing, UX members will comment on the usability and consistency of IRIS. Then the evaluations will be sent back to technical developers who will iterate and improve on the implementation of the designs they have created. This iterative flow will continue until the feature is finished, at which point, more formal testing will be conducted. CLAWS intends to formally test our design in such a way as to simulate the conditions of a Mars EVA. This includes testing our design in different lighting conditions, terrain, and levels of background noise. Formal testing sessions will consist of a trained moderator (member of the UX team) conducting a structured protocol. Participants will be asked to complete a set of tasks, and the moderator will observe their efforts. Once the tasks are completed the moderator will interview the participant about their experience. Participants will be members of CLAWS as well as members of the greater University of Michigan community. IRIS will be tested by those who have familiarity with our augmented reality system and those who have limited familiarity with HMDs in general.

During both weekly testing sessions and formal testing, we will collect qualitative (ex. observation notes, quotes from users) and quantitative (ex. time it takes to perform certain tasks, number of errors, system usability scale test scores) data. We will ask participants to evaluate our design using the System Usability Scale (SUS).

In addition to testing our design with UM students, we will be recruiting subject matter experts (SMEs) to evaluate our design. This is a crucial part of our research process as we are designing for highly trained astronauts who have a very different knowledge set than the average UM community member. We aim to recruit astronauts, who will have intimate knowledge of the EVA process, as well as engineers with experience working in human factors in engineering. These SMEs will participate in interviews, usability tests, and heuristic evaluations. The NASA Modified SUS (NMSUS) was developed to be more targeted in surveying crew member's assessment of the usability of spacecraft technology and has been verified as a replacement for the SUS [6]. While the NMSUS, is not necessarily suitable for our usability tests with the general public, the NMSUS will be used in place of the SUS during usability tests with astronauts.

Project Management

To develop NOVA, CLAWS is divided into 7 subteams: the UX, AR, Web, AI, Hardware, Business, and Research teams which focus on functional tasks respective to their team. In tandem with our subteams, CLAWS is promoting cross-functional collaboration. The CLAWS project is partitioned into three well-defined phases, serving as key milestones throughout the year. Within each phase, team members from various areas of expertise will unite under specialized "Feature Teams." These collaborative units will harness the collective strengths of various subteams, channeling their efforts toward the development of a specific product. See Appendix C for a breakdown of the composition of these teams. Feature teams will be led by designated Product Leads, who will set deadlines, ensure features are delivered on time, and report to the project manager on progress. This organized framework will enhance project efficiency and maintain a professional standard. See Appendix C for a detailed outline of our Agile timeline.

CLAWS will also facilitate weekly meetings between the project manager, technical leads, and product leads. In these meetings, Product Leads will present a comprehensive update on each feature's progress in relation to the project timeline. If there are any concerns or delays, Product Leads will work with the Project Manager to discuss an effective solution to mitigate any delays and work through any obstacles. These meetings will be integral to our commitment to a task-oriented Agile development framework.

Technical References

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Outreach

At CLAWS, the goal of our outreach is to promote interest in space exploration and spread awareness of how new technologies and innovations contribute to astronaut EVAs. We want to show that space exploration is open to anybody, now more than ever. We also recognize that the future of space exploration will rest in the hands of the next generations, thus it is important to us to spark their curiosity in STEM and astronautics from a young age.

In order to accomplish our goals, we split our outreach efforts into two categories, public and K-12, spearheaded by a specialized outreach team. Our public outreach is focused on participating in conferences to share our innovations and research. This year we are planning to attend 3 conferences across the country to present our research on the HoloLens and our previous applications. Our outreach team aims to especially promote CLAWS' K-12 outreach this year. With our planned events, we aim to reach nearly 1,000 students in our local districts, promoting their curiosity in STEM and aerospace. What follows is a more detailed description of our planned events.

Public Outreach

vMed24 Conference - March 2024

vMed is a virtual medical conference where attendees, ranging from doctors and patients to hospital executives, share the implementation and outcomes of medical extended reality in clinical practices. CLAWS will aim to present research on our application at this conference with the approach of synergy between space and medicine. Members of CLAWS' research team and UX team will engage in a poster session, where we will present our research on HoloLens visibility in high-brightness environments, like operating rooms. Our goal is to establish open dialogue among XR developers to spark XR innovations in both medicine and space.

XR at Michigan Summit - April 2024

The XR at Michigan Summit is a two-day university research symposium in Ann Arbor where students present research and applications of XR to UM students, UM faculty, and industry professionals. Last year, CLAWS showcased our NOVA application through an EVA to illustrate how AR can be used in unique situations. This year, we plan to demonstrate our IRIS application. Attendees will have the opportunity to try IRIS on the HoloLens, talk to CLAWS members about the UX design and software development process, and learn about the unique design challenges of Mars EVAs. CLAWS members will also present a poster and first-person FOV video that highlight our application's use of multiple astronauts, mission control, rover commanding, geological sampling, and navigation. The objectives of this outreach event are to share how AR is being used for space exploration, inspire students about AR technology, strengthen our scientific communication skills, receive feedback, and gain future connections with XR developers in the industry. Thus, this is both an outreach event, and an opportunity for CLAWS members to learn and grow.

68th HFES International Annual Meeting - September 2024

This year, a representative from CLAWS went to the 67th HFES meeting during the week of October 23-27. We presented a poster titled *Illuminating the Augmented Reality Stage: Assessment of Lighting Conditions For Space Exploration.* This paper aims to evaluate the lighting compatibility for successful hand gestures using the HoloLens 2 as a potential way to provide critical information to astronauts

during extravehicular activities. Our research team will work with our faculty advisor to submit an abstract for the 68th Annual HFES Meeting.

UX@UM Conference - April 2024

UX@UM is a two-day conference where graduate students share their products, designs, and research in UX. Two years ago, CLAWS gave a presentation titled “Designing AR Experiences for NASA Astronauts on Lunar Missions”, in which our UX Team presented our HOSHI application, specifically highlighting the unique design challenges that come with designing AR applications for lunar environments. This year during UX@UM, CLAWS’ UX team will be participating to raise awareness of how UX designers can contribute to innovations in space exploration. We aim to foster interest in XR within the UX community and also give insight into how UX and XR development teams can work effectively together on large projects to enable rapid, iterative development.

K-12 Outreach

6-12 STEM Day - January 2024

6-12 STEM Day is an event where CLAWS members will visit local middle and high schools to present about STEM careers with a focus on computer science. During STEM Day, CLAWS will introduce students to new fields of study, specifically UX design, aerospace engineering, and computer science. Last year, CLAWS members gave an interactive presentation to students about UX design, where students got to envision and draw their own AR interfaces for Lunar EVAs. CLAWS members also hosted a panel on aerospace engineering and created bottle rockets with students from Huron High School. This year, we aim to bring 6-12 STEM Day to five schools in our district and estimate reaching approximately 300 students across all days. To successfully implement this initiative, CLAWS will be returning to Huron High School and expanding our network to Clague, Slauson, Ann Arbor Steam, and Forsythe schools by contacting school administrators. This year, CLAWS plans to continue to facilitate student-centered activities and support their interest in aerospace and technological innovations.

Elementary Hour of Code - December 2023

Elementary Hour of Code is an event where CLAWS will run an “Hour of Code”. We will spark the interest of students by demonstrating our 2022-2023 Application, NOVA, and teaching the applications of programming through an aerospace lens. This could involve building a basic vitals system that can keep track of the amount of oxygen an astronaut has. When administering the activity, CLAWS members will assist students who may be struggling, while also challenging the more experienced members of the group to create new applications for their code, such as adding additional vitals. We aim to visit ten local elementary schools and reach 600 students with this initiative.

Aerospace Day - April 2024

Aerospace Day is an event where CLAWS collaborates with other student organizations on campus to introduce K-12 Students to space-related technologies through hands-on activities. In order to promote curiosity in STEM and Aerospace, we will demonstrate our IRIS application and give a simplified overview of the build process behind it. We will begin with a beginner-friendly educational introduction to Mars and NASA missions, ensuring interactivity among the students. Next, we would engage the students in activities to expand their knowledge of artificial reality and its uses in space exploration. Students will then divide into their choice of short, Mars-themed, STEM activities to further explore

their interests. For example, students could be prompted to design paper prototypes of an AR interface to interact with Martian geological samples, build an EV suit using cardboard and aluminum foil, or create tools that can easily be stowed in a rover. We hope that Aerospace Day promotes young students' interest in science, technology, and space.

Social Media

CLAWS will be using platforms such as Instagram and LinkedIn to spread the word about our mission and the utility of AR in Aerospace innovation, as well as to encourage more scientific innovation through accessible education with social media, especially in topics related to the NASA SUITS challenge.

In addition to social media posts that involve each team's progress in the NASA SUITS Challenge, there will also be regular social event posts and weekly posts on the main page or story featuring educational content from our teams on complex scientific topics. We will post about each of our outreach events to Instagram and LinkedIn to bring our mission to a wider audience. There will also be weekly "Trivia Tuesday" story posts asking questions about space and innovations for astronauts. The goal of these posts is to express CLAWS's progress towards our mission, to make information about the broader context of space exploration more available, and to spark interest for possible new members or for anyone interested in space exploration.

	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
Week 1				Team Feature Instagram Post		Instagram Story Quiz	
Week 2	Member Spotlight Post		Social Event Story Post			Instagram Story Quiz	Social Event Post
Week 3				Team Feature Instagram Post		Instagram Story Quiz	
Week 4	Member Spotlight Post	K-12 Event Story Post	Linked-In Update Post			Instagram Story Quiz	K-12 Event Post

Table 1 - Social Media Monthly Schedule