AUGMENTED REALITY INFORMATIONAL SYSTEM FOR ASTRONAUTS (*ARIS*)

FINAL PRODUCT REPORT

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CM/TM: Dr. Tomas Materdey

University of Massachusetts Boston | *2023 – 2024*

Augmented Reality Informational System (May 2024)

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***Abstract*—The Augmented Reality Informational System is an interconnected system that transmits data and signals wirelessly via a TCP Socket Protocol within the Python programming language. Biomedical data - such as heart rate, blood pressure, and body temperature – are measured by two Sensor Hubs via sensors connected to two separate Raspberry Pi's, each of which contain GPS Breakouts and XBee Modules. A separate Sensor Node contains the sensors on a PCB and transmits data wirelessly via an Arduino Nano. This data is collected and analyzed via machine learning algorithms to determine health safety ranges of the users. A caution and warning system is intended to alert the user on their Head-Mounted Display (HMD). This HMD is a HoloLens, an Augmented Reality goggle-interface that allows for hand and eye tracking to access and display information. The Rover is a land-based machine with remote access and a USB camera which utilizes a Raspberry Pi. A Local Mission Control Console (LMCC) is intended to centralize all these components and allow for real-time display and communication between the HMD users, their Sensor Hubs, and the Rover. The ARIS is motivated by NASA SUITS and intended to develop technology for the future of space exploration.**

***Index Terms*—Augmented Reality (AR), HoloLens/Head-Mounted Display (HMD), Rover, Local Mission Control Console (LMCC), Sensor Hub, Graphic User Interface (GUI), XBee Modules, GPS Breakout, Raspberry Pi, Sunfounder, Python, Unity, C#, HTML/CSS, KiCad, Machine Learning, TCP Socket Protocol, Arduino Nano, RealSense D435i**

I. Problem definition

THIS document contains the final product report of ARIS: an Augmented Reality Informational System for Astronauts. This project is intended to research and design an augmented reality system for astronauts in the hope of advancing the future of space flight and exploration. A wireless and interconnected system with four major components are assembled and coded: the Head-Mounted Display (HMD), Sensor Hubs, Local Mission Control Console (LMCC), and Rover.

A. Motivations

The motivation behind the project is to enhance an astronaut's experience and improve their efficiency during space missions by utilizing augmented reality technology. This technology can provide real-time information, virtual guidance, and interactive visualizations, offering a more intuitive and immersive environment for astronauts to work in. The prompt and specifications are provided by the NASA SUITS (Spacesuit User Interface Technologies) documentation **[1]** which include detailed necessities and requirements for ARIS.

B. Customer Requirements

There are engineering demands for safe and efficient modes of space exploration on the surfaces of the Moon and Mars. These customer requirements are outlined in the NASA SUITS mission description document **[2]**. Important aspects are egress, navigation, utility airlock, equipment diagnosis/repair, geological sampling, rover, and ingress. All must be implemented on a coherent system containing a Local Mission Control Console (LMCC) and Head-Mounted Display (HMD) for seamless communication and processing of telemetry data.

C. Engineering Requirements

An embedded, communicable, and multi-layered system is required. The capture and processing of telemetry data must be implemented and displayed for multiple users in order to maintain the safety of both astronauts and equipment. Software and hardware must be integrated. The HMD must be programmed and transmit data seamlessly to the LMCC, Sensor Hubs, and Rover. The Rover and Sensor Hubs must be wired and functioning with the ability to capture and send important data to and from client servers. The AR interface on the HMD must be easily navigated and also ensure the safety of the user. All of these engineering requirements maintain the primary mission: develop space-walk technologies and methodologies.

D. Unique Features

This specific ARIS design is unique in that it contains two Sensor Hubs in the pursuit of creating a multi-network of HMD-users. The Sensor Hubs contain GPS Breakouts so that global positional data can be transferred to the LMCC and HMD. In addition, the HMD is Unity-coded on a HoloLens 2 **[11]** and contains interesting components such as a 2D map, compass, task log, and biometric data display. In addition, a RealSense D435i Depth-Sensing Camera is used to calculate 2D distances **[7]**.

II. Project Specific Success Criteria (PSSCs)

This project focuses on five Project Specific Success Criteria. These are intended to centralize the design and allow for the constant maintenance/upkeep of tasks and progress. In addition, the completion of the PSSCs would ensure and confirm the overall success of our efforts.

*A. **Data Communication***

Establishing data communication between all components, i.e. the LMCC, HMD, and Rover. The LMCC is the central unit and receives/sends all data. The sensor nodes on the ARIS user sends biomedical, acceleration, and GPS information to the LMCC, and the HMD displays that data via its GUI. Since the Project Readiness Presentation (PRP), the Rover can be wireless commanded, the LMCC has a working template interface, and the HMD displays sample data. Verification and validation tests were performed by testing each component to ensure they are functioning. The ethical considerations are making certain that the health and safety of the user comes first: making sure the sensors are working properly, the caution/warning is accurate, and that the HMD is not cluttered so that the user can travel safely.

IEEE: Standard for Biometric Open Protocol 2010-2015: Identity assertion, role gathering, multilevel access control, assurance, and auditing.

ISO: 20922:2016 Information Technology - Message Queuing Telemetry Transport (MQTT): Client Server publish/subscribe messaging transport protocol.

B. *2D Map*

A 2D map must be displayed on the HMD with points of interest, i.e. pins, that the user must follow. Utilizes GPS to provide accurate location. LMCC can also see and access this data. Updates since the PRP: the HoloLens has a map configuration, an AR compass is designed, and the RealSense D435i can calculate distances. Verification and validation tests were initiated by using Journey logistics to test the GPS coordinates on the Sensor Hubs. Ethical considerations are focused on ensuring accurate data to the ARIS user and considering navigational hazards.

IEEE: P1952 - STANDARD FOR RESILIENT POSITIONING, NAVIGATION AND TIMING (PNT) USER EQUIPMENT: Critical infrastructures rely on PNT data.

ISO: 24245:2023 - Space systems Global navigation satellite system (GNSS) receiver class codes: Class codes for transmitting GNSS data.

C. *Caution/Warning*

The HMD must be alerted when their biomedical data is abnormal, such as a high heart rate or unsafe oxygen levels. This is performed with the help of machine learning algorithms to determine user-specific health thresholds. Updates since the PRP involve the testing and sensing of abnormal biomedical data. The verification and validation tests involve the actual display of the caution and warning signal on the HMD. Ethical considerations are to first-and-foremost ensure the safety of the user, provide real-time biomedical status updates, and also ensure a clear line-of-sight whilst the warning is displaying.

IEEE: 11073-10201-2004 - International Standard for Health Informatics: Point-of-care medical devices.

ISO: 11073-10407:2022 - Health informatics Device interoperability: Blood pressure monitoring standards.

D. *Rover Commanding*

The LMCC can make the Rover move, as well as making the camera's move and access their feeds. The intention is for the HMD to also possess this capability, and for the user to see the camera feed and incorporate the insights into their space exploration. Updates since the PRP include the ability for the Rover to travel wirelessly via a TCP socket server **[13]**. The verification and validation tests involve the confirmation that the Rover is indeed receiving command signals and moving accordingly. Ethical considerations include the safety involved in operating the vehicle and ensuring no user comes into harm's way whilst controlling it.

IEEE: 1609.3-2020 - Standard for Wireless Access in Vehicular Environments (WAVE)

ISO: 29341-8-10:2008 (E)
Remote control, monitoring and configuration of a Dynamic Host Configuration Protocol (DHCP) and DNS server

E. *Fully Developed GUI*

All components of the HMD and LMCC must be fully operational and communicable. Real-time data is displayed and usable. The AR coded GUI must be easily navigated and still allow for a clear line-of-sight by the ARIS user. Updates since the PRP include the HoloLens code, which is structured and initiated, and a LMCC task-log template is designed. Verification and validation tests focus on the speed of information transfer, noting the time to access and view the data on the HMD. Ethical considerations again consider the user's experience and ensures that they avoid any obstacles while utilizing the HMD's AR interface.

IEEE: 1471-2000 - Recommended Practice for Architectural Description for Software-Intensive Systems

ISO: TS 20071-15:2017: Provides guidance on various aspects of the user interface of applications that scan visual information that are used directly by humans.

III. SYSTEM DIAGRAM

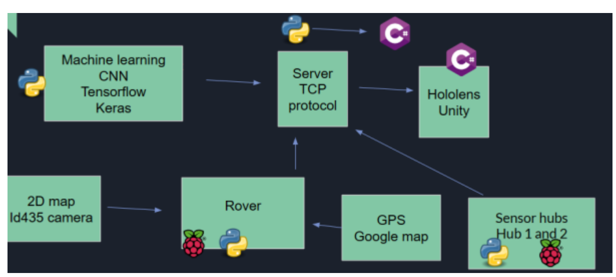


Fig. 1: Overall system diagram of ARIS.

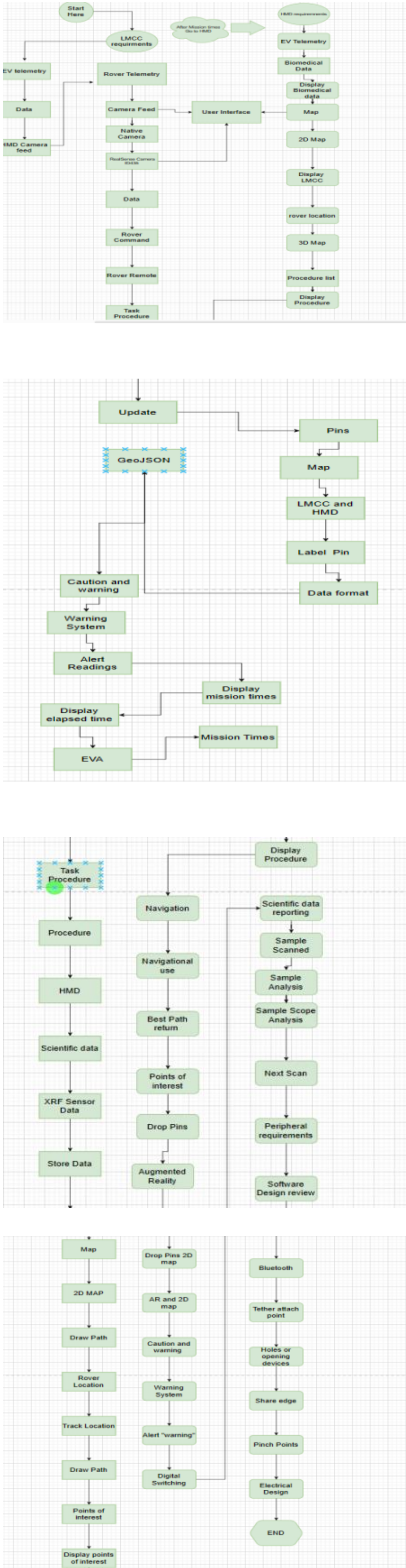


Figure 2: A detailed system diagram.

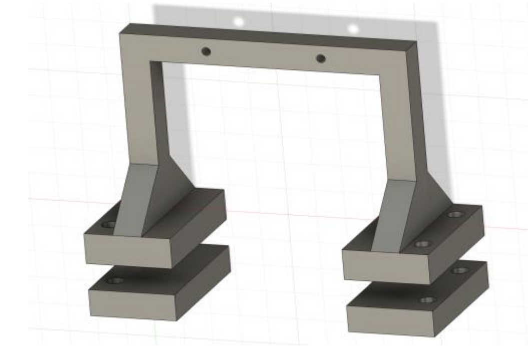


Figure 3: A proposed CAD design of a mount for the RealSense D435i on top of the Rover.

IV. PROJECT MANAGEMENT

A. Team Roles

- **Salvador Baez** (CE), Co-Lead: Machine Learning and HoloLens
- **Fisseha Tegegne** (EE), Co-Lead: Sensor Hubs and Battery Management
- **John Scovell** (EE), Co-Lead/Junior Member: Rover Commanding and PCB Design

B. MS Project Gantt Chart

Milestone 1	**21 days**	**Wed 9/20/23**	**Sun 10/15/23**				**100%**
PSSC 1: Data Comm	**21 days**	**Wed 9/20/23**	**Sun 10/15/23**		**Venkata, Sal, Fisl**		**100%**
Design	21 days	Wed 9/20/23	Sun 10/15/23				100%
Alternative Tasks	21 days	Wed 9/20/23	Sun 10/15/23				100%
PSSC 2: Map	**21 days**	**Wed 9/20/23**	**Sun 10/15/23**		**Karthik**		**100%**
Design	21 days	Wed 9/20/23	Sun 10/15/23				100%
Alternative Tasks	21 days	Wed 9/20/23	Sun 10/15/23				100%
PSSC 3: Caution	**21 days**	**Wed 9/20/23**	**Sun 10/15/23**		**Parth**		**100%**
Design	21 days	Wed 9/20/23	Sun 10/15/23				100%
Alternative Tasks	21 days	Wed 9/20/23	Sun 10/15/23				100%
PSSC 4: Rover	**21 days**	**Wed 9/20/23**	**Sun 10/15/23**		**Sal, Fish, John**		**100%**
Design	21 days	Wed 9/20/23	Sun 10/15/23				100%
Alternative Tasks	21 days	Wed 9/20/23	Sun 10/15/23				100%
PSSC 5: GUI	**21 days**	**Wed 9/20/23**	**Sun 10/15/23**		**Parth**		**100%**
Design	21 days	Wed 9/20/23	Sun 10/15/23				100%
Alternative Tasks	21 days	Wed 9/20/23	Sun 10/15/23				100%
Report: Problem Definition	**7 days**	**Sun 10/1/23**	**Mon 10/9/23**		**Sal, Fish, John**		**100%**
Draft	3 days	Sun 10/1/23	Tue 10/3/23				100%
Final	5 days	Tue 10/3/23	Mon 10/9/23				100%
Presentation	**7 days**	**Sun 10/1/23**	**Mon 10/9/23**		**Sal, Fish, John**		**100%**
Draft	3 days	Sun 10/1/23	Tue 10/3/23				100%
Final	5 days	Tue 10/3/23	Mon 10/9/23				100%

Milestone 2	**50 days?**	**Mon 10/16/23**	**Fri 12/22/23**				**100%**
PSSC 1: Data Comm	**42 days?**	**Mon 10/16/23**	**Tue 12/12/23**				**100%**
Design	**42 days**	**Mon 10/16/23**	**Tue 12/12/23**				**100%**
Understand previous team's progress	12 days	Mon 10/16/23	Tue 10/31/23		Fish,John, Karthik, Parth,Sal,Venkat		100%
Deciding add-ons	12 days	Mon 10/16/23	Tue 10/31/23		Fish,John,Sal		100%
Order camera	16 days	Mon 10/16/23	Mon 11/6/23		John		100%
Block Diagrams	24 days	Mon 10/16/23	Thu 11/16/23		Sal		100%
Camera feed	10 days	Fri 11/10/23	Thu 11/23/23		Fish,John,Sal,Ve		100%
~~Design PCB~~	~~8 days~~	~~Fri 11/10/23~~	~~Tue 11/21/23~~		~~Fish,John,Sal~~		0%
~~Order PCB~~	~~3 days~~	~~Wed 11/22/23~~	~~Fri 11/24/23~~	37	~~Fish,John,Sal~~		0%
Building	**42 days**	**Mon 10/16/23**	**Tue 12/12/23**				**100%**
Connect sensor hubs	6 days	Tue 10/31/23	Tue 11/7/23		Fish,Sal,John		100%
~~Connect RealSense Camera~~	~~6 days~~	~~Fri 12/1/23~~	~~Fri 12/8/23~~				0%
Connect Native Camera	4 days	Thu 11/16/23	Tue 11/21/23		Fish,John,Sal		100%
~~Mount PCB~~	~~2 days~~	~~Mon 11/27/23~~	~~Tue 11/28/23~~	38	~~Fish,John,Sal~~		0%
LMCC Development	10 days	Fri 11/10/23	Thu 11/23/23		Venkata		100%

Validation Test	42 days	Mon 10/16/23	Tue 12/12/23			100%
Confirm sensor hubs are working properly	8 days	Wed 11/8/23	Fri 11/17/23	40	Karthik	100%
~~Confirm sensor node data and machine learning~~	~~12 days~~	~~Wed 11/8/23~~	~~Thu 11/23/23~~		~~Karthik~~	~~0%~~
~~Confirm server is working~~	~~12 days~~	~~Thu 11/16/23~~	~~Fri 12/1/23~~		~~Venkata~~	~~0%~~
~~Confirm native camera feed~~	~~12 days~~	~~Thu 11/16/23~~	~~Fri 12/1/23~~		~~John,Karthik~~	~~0%~~
~~Confirm RealSense feed~~					~~Venkata~~	~~0%~~
~~PSSC 2: Map~~	~~35 days?~~	~~Mon 10/16/23~~	~~Fri 12/1/23~~	~~30~~		~~0%~~
~~Design~~	~~1 day?~~	~~Mon 10/16/23~~	~~Mon 10/16/23~~			~~0%~~
~~Building~~	~~1 day?~~	~~Mon 10/16/23~~	~~Mon 10/16/23~~			~~0%~~
~~Validation Test~~	~~1 day?~~	~~Mon 10/16/23~~	~~Mon 10/16/23~~			~~0%~~
~~PSSC 3: Caution~~	~~35 days?~~	~~Mon 10/16/23~~	~~Fri 12/1/23~~	~~30~~		~~0%~~
~~Design~~	~~1 day?~~	~~Mon 10/16/23~~	~~Mon 10/16/23~~			~~0%~~
~~Building~~	~~1 day?~~	~~Mon 10/16/23~~	~~Mon 10/16/23~~			~~0%~~
~~Validation Test~~	~~1 day?~~	~~Mon 10/16/23~~	~~Mon 10/16/23~~			~~0%~~

PSSC 4: Rover	42 days?	Mon 10/16/23	Tue 12/12/23			100%
Design	42 days	Mon 10/16/23	Tue 12/12/23			100%
Choose and order rover	16 days	Mon 10/16/23	Mon 11/6/23		John	100%
Utilizing Rasperry Pi to send/receive commands	11 days	Tue 11/14/23	Tue 11/28/23		John	100%
CAD model to mount RealSense on Rover	11 days	Tue 11/28/23	Tue 12/12/23		John	100%
Building	19 days	Thu 11/16/23	Tue 12/12/23			100%
Build Rover	9 days	Thu 11/16/23	Tue 11/28/23		John	100%
~~Print and attach CAD to Rover/RealSense~~	~~8 days~~	~~Fri 12/1/23~~	~~Tue 12/12/23~~		~~Sal,Fish,John~~	~~0%~~
Validation Test	11 days?	Tue 11/28/23	Tue 12/12/23			100%
~~Confirm both native camera and RealSense camera feed~~	~~11 days~~	~~Tue 11/28/23~~	~~Tue 12/12/23~~		~~Karthik,Venkata~~	~~0%~~
Send commands to move Rover	1 day	Tue 11/28/23	Tue 11/28/23		John	100%

PSSC 5: GUI	42 days?	Mon 10/16/23	Tue 12/12/23			100%
Design	23 days	Mon 10/16/23	Wed 11/15/23			100%
Design display for HMD	23 days	Mon 10/16/23	Wed 11/15/23		Parth	100%
Building	20 days	Wed 11/15/23	Tue 12/12/23			100%
Complete display on HMD	13 days	Wed 11/15/23	Fri 12/1/23		Parth	100%
Build interactive system to communicate with HMD	8 days	Fri 12/1/23	Tue 12/12/23		Parth	100%
~~Validation Test~~	~~8 days?~~	~~Fri 12/1/23~~	~~Tue 12/12/23~~			~~0%~~
~~Display real-time data~~	~~8 days~~	~~Fri 12/1/23~~	~~Tue 12/12/23~~		~~Karthik,Parth~~	~~0%~~
~~Interact with data and communicate with LMCC/Rover~~	~~8 days~~	~~Fri 12/1/23~~	~~Tue 12/12/23~~		~~Karthik,Parth, Venkata~~	~~0%~~
Report	10 days	Fri 12/1/23	Thu 12/14/23		Sal,Fish,John	100%
Draft	7 days	Fri 12/1/23	Mon 12/11/23			100%
Final	4 days	Mon 12/11/23	Thu 12/14/23			100%
Presentation	10 days?	Mon 11/20/23	Fri 12/1/23		Sal,Fish,John	100%
Draft	7 days	Mon 11/20/23	Tue 11/28/23			100%
Final	3 days	Wed 11/29/23	Fri 12/1/23			100%

Milestone 3	35 days?	Mon 1/29/24	Fri 3/15/24			92%
Action: LMCC to Rover Communication	11 days?	Mon 1/29/24	Mon 2/12/24		John	99%
Create server and establish connection	4 days	Mon 1/29/24	Thu 2/1/24			100%
Control rover from LMCC	1 day	Mon 1/29/24	Mon 1/29/24			100%
~~Send Video to LMCC~~		~~Mon 1/29/24~~				~~0%~~
Build LMCC GUI	1 day	Mon 1/29/24	Mon 1/29/24			100%
Data validation Test	1 day	Mon 1/29/24	Mon 1/29/24			100%
~~Connect/Send RealSense feed to LMCC~~						~~0%~~
Action: HoloLens to LMCC Communication	11 days?	Mon 1/29/24	Mon 2/12/24		Sal	68%
Install Unity	1 day	Mon 1/29/24	Mon 1/29/24			100%
Follow Parth's HoloLens Instructions	1 day	Mon 1/29/24	Mon 1/29/24			100%
Make HoloLens work		Mon 1/29/24				50%
Display sensor hub csv data on HoloLens		Mon 1/29/24				20%

Action: Sensor Data	35 days?	Mon 1/29/24	Fri 3/15/24		Fish,John	95%
Rebuild sensor hubs	23 days	Mon 1/29/24	Wed 2/28/24			100%
Debug code and fix errors	9 days	Wed 2/28/24	Sun 3/10/24			100%
Order new PCB	1 day	Mon 1/29/24	Mon 1/29/24			100%
Test sensors and replace bad ones		Mon 1/29/24				20%
Send csv data to HoloLens Unity project						0%
Action: Build team webpage	31 days?	Mon 1/29/24	Sun 3/10/24		Sal,Fish,John	99%
Email TA for password	1 day	Fri 2/2/24	Fri 2/2/24			100%
Watch/follow tutorial	1 day	Wed 2/7/24	Wed 2/7/24			100%
Upload first webpage requirements	1 day	Wed 2/7/24	Wed 2/7/24			100%
Upload second webpage requirements	1 day	Wed 3/6/24	Wed 3/6/24			100%
Action: Develop LMCC GUI	10 days?	Tue 2/13/24	Mon 2/26/24			57%
Choose interface	1 day	Tue 2/13/24	Tue 2/13/24			100%
Display all communications on GUI		Tue 2/13/24				60%
Validate all connections		Tue 2/13/24				10%
Design Validation Report	11 days	Fri 3/1/24	Fri 3/15/24			100%
Draft	1 day	Fri 3/1/24	Fri 3/1/24			100%
Final	1 day	Fri 3/1/24	Fri 3/1/24			100%
Design Validation Presentation	11 days	Fri 3/1/24	Fri 3/15/24			100%
Draft	1 day	Fri 3/1/24	Fri 3/1/24			100%
Final	1 day	Fri 3/1/24	Fri 3/1/24			100%

Milestone 4	38 days?	Sat 3/16/24	Tue 5/7/24			50%
PSSC 1: Data Comm	38 days?	Sat 3/16/24	Tue 5/7/24			25%
Design		Sat 3/16/24				75%
Building						0%
Validation Test						0%
PSSC 2: Map	38 days?	Sat 3/16/24	Tue 5/7/24			65%
Design		Sat 3/16/24				65%
Building		Sat 3/16/24				65%
Validation Test		Sat 3/16/24				65%
PSSC 3: Caution	38 days?	Sat 3/16/24	Tue 5/7/24			65%
Design		Sat 3/16/24				65%
Building		Sat 3/16/24				65%
Validation Test		Sat 3/16/24				65%
PSSC 4: Rover	38 days?	Sat 3/16/24	Tue 5/7/24			33%
Design	1 day	Sat 3/16/24	Sat 3/16/24			100%
Building						0%
Validation Test						0%
PSSC 5: GUI	38 days?	Sat 3/16/24	Tue 5/7/24			33%
Design	1 day	Sat 3/16/24	Sat 3/16/24			100%
Building						0%
Validation Test						0%

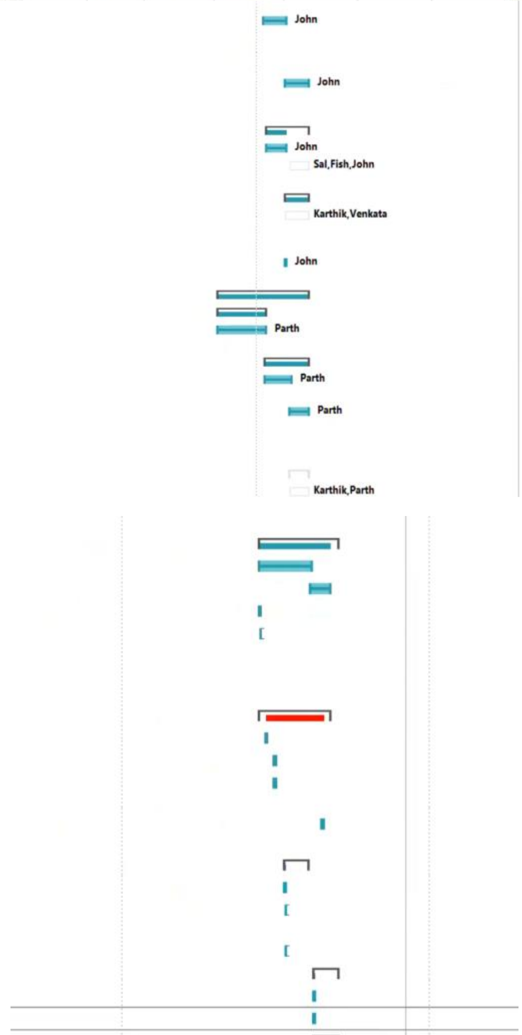


Figure 4: MS Gantt Charts for ARIS.

C. Critical Tasks

The progress made on the HoloLens AR GUI development was substantial, as well as building the Rover and implementing/debugging its wireless commands. The Sensor Hubs were rebuilt and tested, and the machine learning protocols were run and tested as well. The battery packs were recharged. The LMCC was coded to display a task log, astronaut information, and a GPS-populated map. In addition, all required presentations and reports were completed on time.

D. Weekly Reports

Each week, a different team member wrote and submitted a weekly report which all members signed via DocuSign. These reports are all uploaded and organized on the shared Microsoft Teams drive.

E. Document Sharing

All documents were shared and collaborated either via MS Teams or Google Drive. Reports and presentations were written and edited on Google Docs and Google Slides. Our CM/TM and the TA all had access to these documents as well.

V. Components

A. Items Purchased/Final Budget

Item	Manufacturer/Item No.	Distributor/Item No.	Distributor's Price	Total
RealSense D435i	Intel (00735858403931)	Intel (00735858403931)	$354.88	$354.88
Smart Video Car Kit	SunFounder (SF-PICARVS)	Amazon (B06XWSVLL8)	$99.99	$454.87
Raspberry Pi 4 Model B	Raspberry Pi (RAS-4-4G)	Amazon (B07TC2BK1X)	$61.69 x 2	$578.25
Smart Video Car Kit	Merconnet (new version)	Walmart	$178.28	$756.53
18650 Battery Charger	WDJD (WANGDAJIEDIAN)	Amazon (B0BFCP2GVV)	$9.99	$766.52
PCB	OSH Park	OSH Park	$25	**$791.52**

Figure 5: SunFounder Pi-Car.

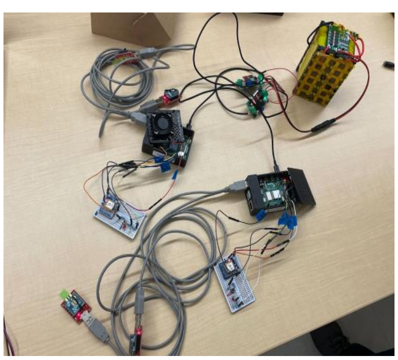


Figure 6: Sensor Hubs, Raspberry Pi's, Battery Packs.

Figure 6: RealSense D435i camera.

Figure 7: HoloLens 2.

Figure 8: Raspberry Pi 4b.

Figure 9: 18650 Battery Charger.

B. Items Designed and Printed

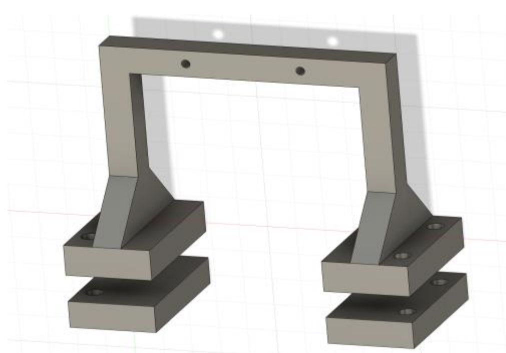


Figure 10: A proposed CAD design of a mount for the RealSense D435i on top of the Rover.

C. *Resources*

NASA SUITS mission description, HoloLens documentation, Python libraries, 2022-2023 Team 4 Final Product Report/Video, CM/TM Meetings, Supply Chain Manager

D. *Tools*

KiCad, Fusion 360, LTspice, Unity, Visual Studio Code, DC Power Supply, Multi-Meter

E. *Skills*

Python coding, server development, data communication, GUI design, C# HoloLens Development, Raspberry Pi usage, HTML/CSS, CAD design

VI. PCB

A. *Reasoning*

The current state of the Sensor Hub modules is messy and disorganized. It is easy for wires to come loose and for the system to come apart. Therefore, we decided that it would be useful to create a compact PCB to replace the current Sensor Hub.

B. *Functionality and Performance*

The PCB design ended up being faulty and unusable. The components were mixed up, such as the resistors and pins. The alignment was off, and the spatial dimensions were off scale. Therefore, the final functionality and performance did not meet expectations.

C. *Schematics, KiCad Design, Photos*

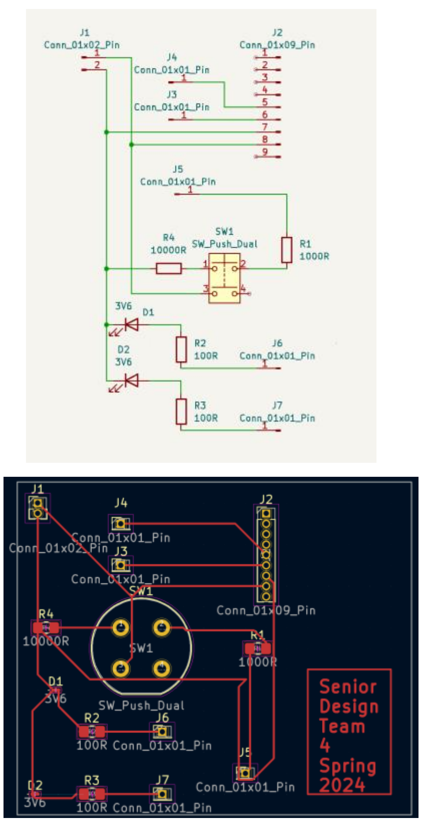


Figure 11: KiCad Schematic and Design.

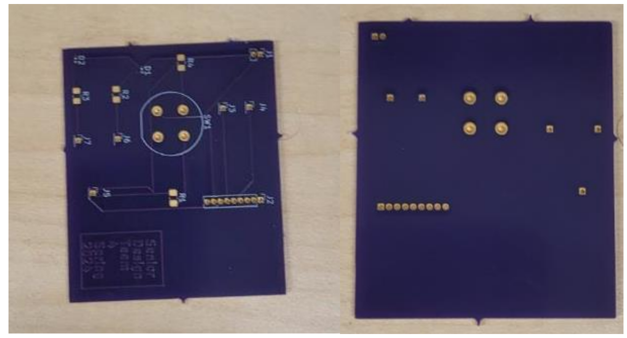


Figure 12: Printed PCB from OSH Park.

D. *Verification/Validation Data*

We did not initiate verification and validation data for our PCB since the design and production was wrong.

VII. Verification And Validation Data

A. *Results for PSSC:*

1. <u>Data Communication</u>: Sensor hubs are processing data and there is an established server-based communication between components.
2. <u>2D Map</u>: HoloLens map configuration, AR Compass, RealSense Distance Calculations.
3. <u>Caution/Warning System</u>: Sensor Hubs sensing abnormal data.
4. <u>Rover Commanding</u>: Rover is working and moving via server-based communication.
5. <u>Fully Developed GUI</u>: HoloLens Structured and Coded, LMCC Template for Task Log.

B. *Three Quantitative V&V Tests:*

1. PSSC 1: Data Communication

a. Testing the latency within our system. Sending data from Sensor Hub 1 to Sensor Hub 2 to the HoloLens and displaying said data. Comparing the rate of change with differing distances between components. It was found that the expected latency was quite similar to the actual latency.

Hub1 to Hub2 to HoloLens (seconds)	Distance between Hub1 and HoloLens (in)	Expected Latency
30	5	7.7685
32	10	15.537
35	15	23.3055
38	20	31.074
41	25	38.8425
44	30	46.611
48	35	54.3795
51	40	62.148
54	45	69.9165
59	50	77.685

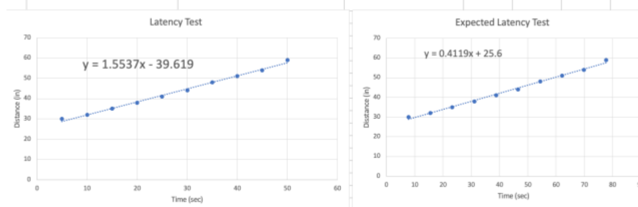


Figure 13: V&V for PSSC 1: Data Communication.

2. **PSSC 3: Caution/Warning System**
   a. Measuring the speed of the machine learning warning versus the pulse of the user.

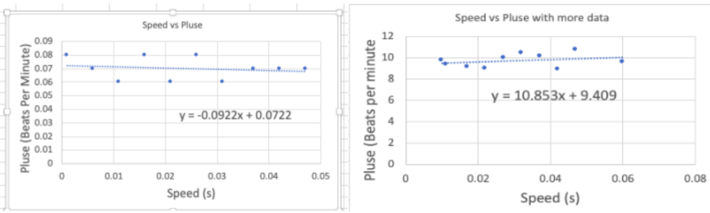
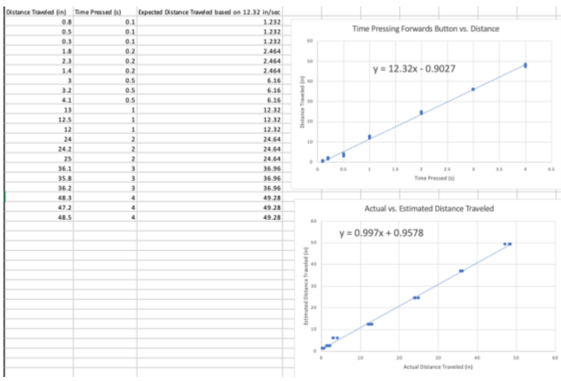


Figure 14: V&V for PSSC 3: Caution/Warning System.

3. **PSSC 4: Rover Commanding**
   a. Testing the time between pressing the controls on the server-based controller and the distance it travels. The results were found to be linear with the Rover moving at 12.32 inches per second.



Distance Traveled (in)	Time Pressed (s)	Expected Distance Traveled based on 12.32 in/sec
0.8	0.1	1.232
0.5	0.1	1.232
0.3	0.1	1.232
1.8	0.2	2.464
2.3	0.2	2.464
1.4	0.2	2.464
3	0.5	6.16
3.2	0.5	6.16
4.1	0.5	6.16
13	1	12.32
12.5	1	12.32
12	1	12.32
24	2	24.64
24.2	2	24.64
25	2	24.64
36.1	3	36.96
35.8	3	36.96
36.2	3	36.96
48.3	4	49.28
47.2	4	49.28
48.5	4	49.28

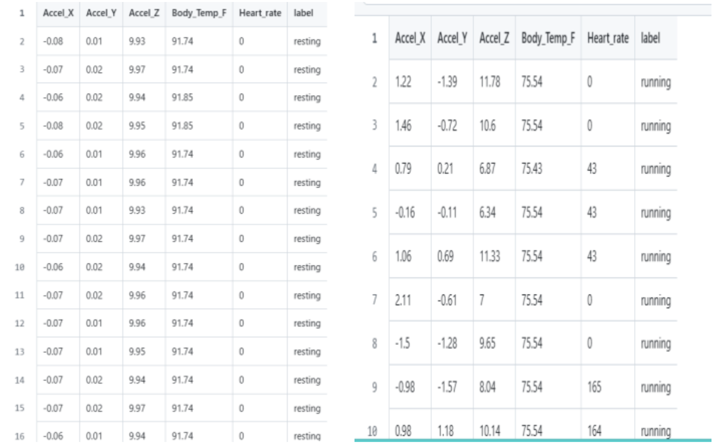
Figure 15: V&V for PSSC 4: Rover Commanding.

VIII. Machine Learning

The problem is making a caution & warning system to detect abnormal or normal readings when an astronaut is doing an activity. These activities include resting, walking, and running. An example of a resting and running data set are shown in *Figure 16*. Python was utilized to create a machine learning algorithm via the Keras and Tensorflow libraries.

The model.fit() command initiated 100 iterations of the machine learning to calculate an accurate prediction. This would allow for the ARIS user to see a proper caution/warning signal on their HMD when their vitals reached an abnormal range. The data was organized into CSV files which allowed for the machine learning model to randomize and fit the regression models.

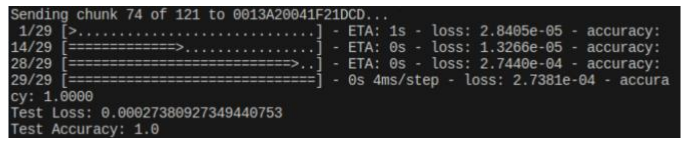
The loss was minimal and the accuracy was high after running our iterations and total of 100 epochs. This is shown in *Figure 17*.



1	Accel_X	Accel_Y	Accel_Z	Body_Temp_F	Heart_rate	label
2	-0.08	0.01	9.93	91.74	0	resting
3	-0.07	0.02	9.97	91.74	0	resting
4	-0.06	0.02	9.94	91.85	0	resting
5	-0.08	0.02	9.95	91.85	0	resting
6	-0.06	0.01	9.96	91.74	0	resting
7	-0.07	0.01	9.96	91.74	0	resting
8	-0.07	0.01	9.93	91.74	0	resting
9	-0.07	0.02	9.97	91.74	0	resting
10	-0.06	0.02	9.94	91.74	0	resting
11	-0.07	0.02	9.96	91.74	0	resting
12	-0.07	0.01	9.96	91.74	0	resting
13	-0.07	0.01	9.95	91.74	0	resting
14	-0.07	0.02	9.94	91.74	0	resting
15	-0.07	0.02	9.97	91.74	0	resting
16	-0.06	0.01	9.94	91.74	0	resting

1	Accel_X	Accel_Y	Accel_Z	Body_Temp_F	Heart_rate	label
2	1.22	-1.39	11.78	75.54	0	running
3	1.46	-0.72	10.6	75.54	0	running
4	0.79	0.21	6.87	75.43	43	running
5	-0.16	-0.11	6.34	75.54	43	running
6	1.06	0.69	11.33	75.54	43	running
7	2.11	-0.61	7	75.54	0	running
8	-1.5	-1.28	9.65	75.54	0	running
9	-0.98	-1.57	8.04	75.54	165	running
10	0.98	1.18	10.14	75.54	164	running

Figure 16: Resting and running data for machine learning.



```
Sending chunk 74 of 121 to 0013A20041F21DCD...
 1/29 [>.............................] - ETA: 1s - loss: 2.8405e-05 - accuracy:
14/29 [=============>................] - ETA: 0s - loss: 1.3266e-05 - accuracy:
28/29 [===========================>..] - ETA: 0s - loss: 2.7440e-04 - accuracy:
29/29 [==============================] - 0s 4ms/step - loss: 2.7381e-04 - accura
cy: 1.0000
Test Loss: 0.00027380927349440753
Test Accuracy: 1.0
```

Figure 17: Accuracy and loss of machine learning.

IX. Deliverables

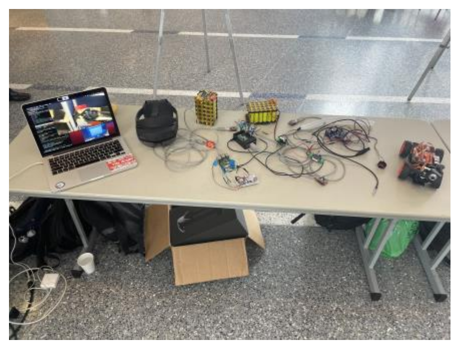


Figure 18: Full system presented together.

Figure 19: HoloLens GUI display.

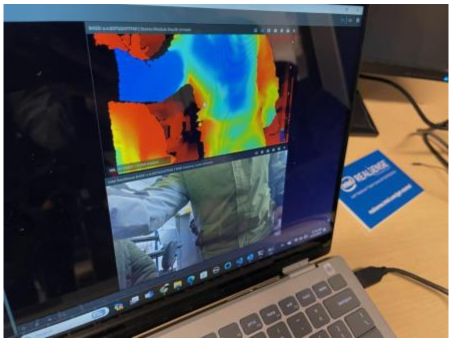


Figure 20: RealSense depth sensing camera.

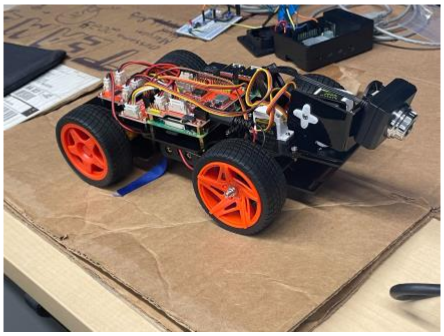


Figure 21: Rover next to Sensor Hub.

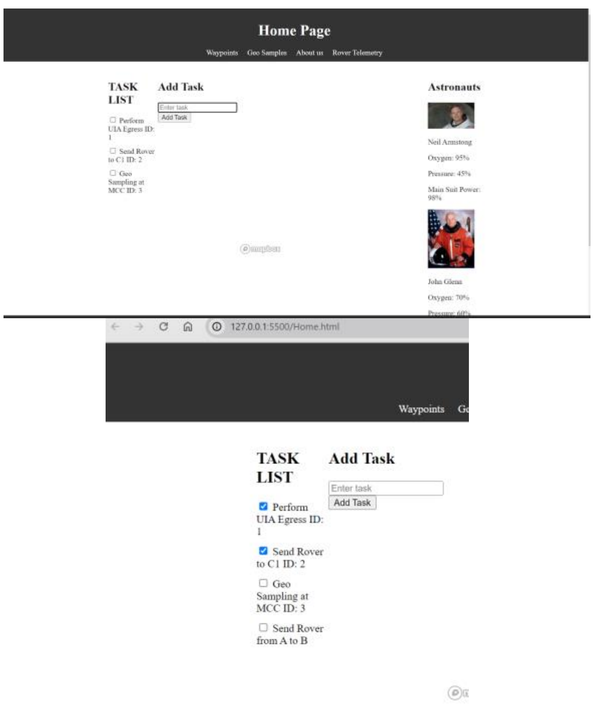


Figure 22: LMCC home page and task list.

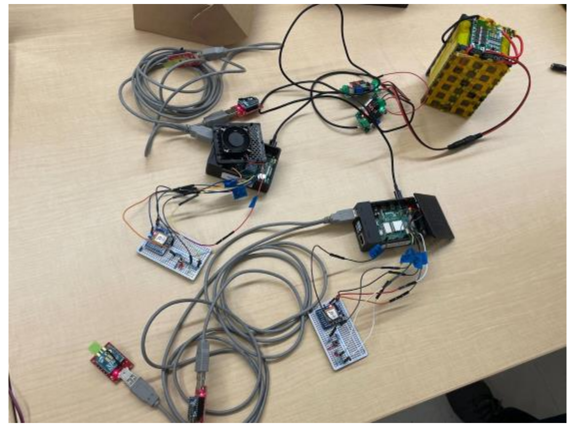


Figure 23: Close-up of Sensor Hubs and Battery Pack.

A. *Final Evaluation of PSSCs*

1. <u>Data Communication</u>: There is data communication within the Sensor Hubs, as well as the Rover. The HoloLens is almost capable of data communication and requires integration of Python TCP with Unity C# coding language.
2. <u>2D Map</u>: A 2D map template is created on the HoloLens, as well as GPS components integrated into the LMCC.
3. <u>Caution/Warning</u>: The machine learning algorithms can detect abnormal biomedical data but needs to be able to display on the HoloLens.
4. <u>Rover Commanding</u>: The Rover can be wirelessly commanded via a TCP Server Protocol.
5. <u>Fully Developed GUI</u>: The GUI for both the HoloLens and LMCC are developed and in a great position to be taken to the next step.

B. *Final Video: https://youtu.be/8anOoq1N8Tc*

X. Future Work

The Sensor Hubs, LMCC, HoloLens, and Rover all need to seamlessly communicate together. There is currently only one sensor node and one HMD, but two Sensor Hubs. A second sensor node and HMD are needed to allow for two astronauts to communicate together. The Sensor Hubs need to be redesigned so that it can be carried on the ARIS user's person, and so that the wires and circuitry are compact and stable. The HoloLens needs to receive the data directly from the LMCC, and the LMCC needs to receive the data directly from the Sensor Hubs. Or possibly the Sensor Hubs need to communicate directly to the HoloLens.

The Rover camera needs to be debugged, and there is a newly ordered Rover that should be built to replace the existing one. Hopefully, this updated model is better fit for testing and integration into the system. The machine learning needs to be updated and utilized to display the caution/warning on the HMD. Finally, the LMCC needs to be developed in order to be a central point anchoring all components to the Augmented Reality Informational System.

XI. Acknowledgment

Thank you to: Tomas Materdey for his role as CM/TM and professor of design; Andrew Davis for his role as technical director and supply chain manager; Venkata Vutukuru, Parth Akre, and Karthik Mukka for their roles as computer science mentors and their help in developing the LMCC and HMD interfaces.

XII. References

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XIII. Operation Manual

A. GitHub Link: https://github.com/johnscovell/ARIS/

B. Google Drive Link:
https://drive.google.com/drive/folders/1TDeO9jrBaVlAoOB7IxtzkSROdyFAsIbH?usp=sharing

C. MS Teams Link:
https://liveumb.sharepoint.com/:f:/r/sites/SD-F23-Team4/Shared%20Documents/General?csf=1&web=1&e=E5Cq8Z

D. Troubleshooting

Component	**Manual**	**Troubleshooting**
HoloLens	Utilize the Unity files provided to code and program the HMD in C#. You will need to connect to the WIFI, and also the IP address of your Unity-based device.	Make sure to restart and charge. Connecting to your Unity project and transferring the data files is necessary. You can simulate the HoloLens within Unity itself.
Rover	The Rover is based in the Raspberry Pi. It is connected to the school WIFI, and there is documentation in the References to help connect to WIFI **[4]**. The remote-control folder contains the code to control the Rover.	The SunFounder documentation is very important **[3]**. There were many issues with the initial code, and the video streaming library was unable to transmit video. However, the USB camera works as a standalone.
LMCC	An HTML/CSS coded project that can be opened in a web browser. Uses Google GPS functionalities.	Run the code and see how it works.

Sensor Hubs	Each Sensor Hub is connected to a battery pack. You will need to connect a monitor and mouse to the Raspberry Pi to access its code. In addition, RealVNC can be used to remotely access both Sensor Hubs at the same time. You will need to create a RealVNC account and reset the current connections in order to access the mainframe. Importantly, start Hub1.sh and Hub2.sh at the same time via RealVNC or a similar remote server. Each needs to communicate with the other.	The Sensor Hubs need to be calibrated and tested with the sensors. Check the machine learning code and ensure everything is working correctly.
Battery Packs	Each battery pack can be charged with a DC power supply. There is a converter attached that allows for this. The display on the converter shows the voltage currently in the battery.	The batteries need to be charged when it gets too low. Use a DC power supply.
Sensor Node	The sensor node is a PCB with an Arduino Nano. It has the capability of transmitting sensor data wirelessly. There is Arduino code within each Sensor Hub.	The sensor nodes need to be fixed. The Arduino Nano might need to be replaced.