BLiSS

Voice User Interface (VUI)

NASA X-HAB Moon to Mars Academic Innovation Challenge

College of Engineering
Winter 2021: Final Report

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Acronyms

BLiSS	Bioastronautics and Life Support Systems
HALO	Habitation and Logistics Outpost
RFP	Request for Proposal
VUI	Voice User Interface
IOT	Internet of Things
NPAS	NASA’s Platform for Autonomous Systems
LEO	Low Earth Orbit
ASL	Autonomous Systems Laboratory
DHAS	Distributed Hierarchical Autonomous System
VSM	Vehicle System Manager
PPE	Power and Propulsion Element
VV	Visiting Vehicle
NLP	Natural Language Processing
NLPU	Natural Language Processing Unit
UI	User Interface
UX	User Experience
PPU	Power Processing Unit
PPE	Power and Propulsion Element

EVA	Extravehicular Activity
MCC	Mission Control Center
CG	Center of Gravity
EDR	Electric Orbit Raising
ISRU	In-Situ Resource Utilization
WBS	Work Breakdown Structure
API	Application Programming Interface

1 Acknowledgements

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2 Introduction

The BLiSS team at the University of Michigan responded to the 2020/2021 X-HAB request for proposal (RFP) solicited by the NASA Stennis team. NASA Stennis tasked BLiSS to design a modern, efficient, and intuitive voice user interface (VUI) for crew interactions on the Lunar Gateway. The goal of this project is to advance the knowledge and technology needed to successfully design voice interfaces. This includes developing Gateway querying actions, such as 'by crew' and 'to crew', and what command structures are needed. The main driver is to understand how a Gateway crew member can communicate with the Lunar Gateway's Autonomous Vehicle System Manager through voice, so that information can be efficiently and intuitively distributed to the crew. This requires that the VUI provide accessibility for all the system state data points and provide effective awareness methods for the user. The intention is to build on the research that BLiSS conducted as part of the 2020 X-HAB challenge where the team developed an intuitive User Interface/User Experience for the Lunar Gateway that built on the technology of the Internet of Things (IOT) and the VUI will leverage NASA's Platform for Autonomous Systems (NPAS) software.

2.1 Background

NASA is actively preparing to advance human presence beyond Low Earth Orbit (LEO). By doing so, astronauts will be able to further scientific knowledge through their work and life in space. This will require expansion on current infrastructure that will not only benefit scientific exploration, but also to ensure safety of the crew and mission. The stakeholders for expanding human presence around the Moon include those that are directly and indirectly involved with this mission. Notably the stakeholders are NASA, The University of Michigan BLiSS and SPACE 582/590 teams, the scientific community, U.S. taxpayers and U.S. Congress. These entities have individually and collectively made contributions to the success of this mission.

The Lunar Gateway, officially known as Lunar Orbital Platform - Gateway, is a NASA-led lunar-orbit space station that will serve as a multi-functional outpost for missions. Northrop Grumman is contributing the HALO module which will be the first module in a space station around the moon. Functions of this station will include serving as a scientific laboratory, short term habitation module, a communications hub, and docking station for rovers/robots. This shall provide a means to fulfill scientific research in the realms of astrophysics, astrobiology, planetary sciences, as well as human health. Just recently, NASA defined the scientific priorities for the first crewed mission to the moon, the Lunar Gateway will support these scientific goals and more. As of the time of writing this, Gateway is no longer on the critical path for the Artemis program. Although this is the case, Gateway will be integral to the success of conducting sustainable missions on the moon and the decision also enables additional time to burn down the risks associated with novel space architecture and technology.

The current state of the art software for NASA missions is NPAS. This platform was developed by NASA Stennis and is under continual advancement by the Autonomous Systems Laboratory (ASL). Such expansions provide critical autonomy capabilities that are necessary for success, safety, and survival of the crew. NPAS sufficiently addresses the needs of NASA's missions, however, the team at NASA Stennis is seeking to build upon this infrastructure to provide a robust, user-friendly interface for the Distributed Hierarchical Autonomous System (DHAS) that will control Gateway. The BLiSS team at the University of Michigan responded to a solicitation of 2021 Moon to Mars eXploration Systems and Habitation Academic Innovation Challenge and was selected to design and develop user interfaces for the Lunar Gateway and other autonomous spacecraft. NPAS is built within the G2 coding language and Ignite, the company that created this software has provided licenses to the BLiSS team and the University of Michigan to support our work. BLiSS may be building the next step in VUI for space application but there have already been voice assistants used in space and the research and development of these systems were investigated to provide an understanding of these systems.

One of the first voice assistants controlled the Space Shuttle’s CCTV footage to gimbal the camera and to change where it was pointing. This was done in 1990 and was used to study microgravity’s effect on speech production and recognition. The next voice system adopted by NASA for use on the ISS was Clarissa, this was developed in partnership between NASA and Xerox. This system actively listened for questions and commands that is was capable of carrying out. The most recent voice systems were Cimon I and II which were developed by a German company and are a “floating head” shaped robot that was designed to analyze human emotion. Cimon is shown in the figure below. BLiSS intends to build on these systems and lay the groundwork for the next VUI adapted by NASA, while shying away from the floating head design.

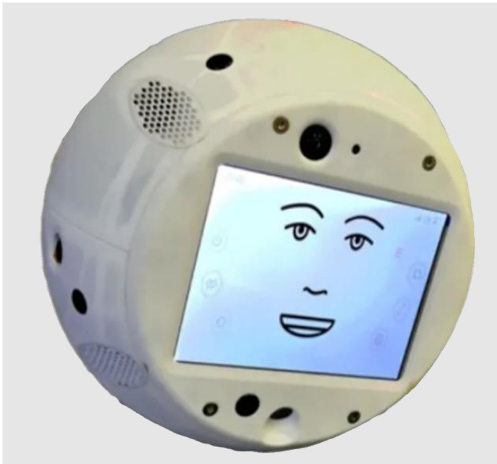

Figure 1: CIMON German developed AI robot currently onboard the ISS

2.2 Goals and Objectives

The goal of the VUI project is to design a user friendly, intuitive, efficient system to support crew operation on the Lunar Gateway. The system objectives for the VUI developed through this project are derived below.

1) Provide accessibility to all system state data points

2) Provide efficient awareness methods for system state

3) Implement intuitive and user friendly VUI

4) Apply modern VUI design principles

5) Demonstrate the functionality of the system in a habitat mockup

The system goals and objectives were resolved though preliminary discussions with the stakeholders at the kickoff meeting with NASA's X-HAB team and through the solicitation.

2.3 Requirements

The Level 1, Level 2, and Level 3 system requirements were derived from the system objectives and flowed down from the X-HAB solicitation. Tables 1, 2, and 3 show the breakdown of the requirements of the project.

2.3.1 Level 1 Requirements

The Level 1 requirements are shown below.

System Requirements (Level 1)				
Code	**No.**	**Requirement**	**Type**	**Reference**
SR	L1-01	The VUI for crew operations shall be included.	Operational	X-HAB Solicitation
SR	L1-02	The VUI shall be intuitive and easy to use.	Functional	Kickoff Meeting
SR	L1-03	The VUI shall provide complete system awareness in an efficient manner.	Functional	X-HAB Solicitation
SR	L1-04	The VUI design shall be limited to existing and emerging technologies.	Constraint	Kickoff Meeting

Table 1: System Requirements Level 1

2.3.2 Level 2 Requirements

The Level 2 requirements are shown below.

System Requirements (Level 2)				
Code	**No.**	**Requirement**	**Type**	**Reference**
SR	L2-01	The VUI shall provide system warnings based on the current hierarchy used by NASA for the ISS.	Functional	L1-01
SR	L2-02	The VUI shall use natural language processing.	Functional	L1-02
SR	L2-03	The VUI shall implement Google's Conversation Design Language	Functional	L1-02
SR	L2-04	The VUI shall provide multiple access methods for the same gateway dataset.	Functional	L1-02
SR	L2-05	Decisions made by the vehicle systems manager shall be accessible within the VUI.	Functional	L1-03
SR	L2-06	The VUI shall implement noise mitigation and filtering techniques so that the signal to noise ratio >20dB.	Constraint	L1-04

Table 2: System Requirements Level 2

2.3.3 Level 3 Requirements

The Level 3 requirements are shown below.

System Requirements (Level 2)				
Code	**No.**	**Requirement**	**Type**	**Reference**
SR	L3-01	The VUI shall first be developed for crew interactions with the lowest hierarchy of events.	Functional	L2-01
SR	L3-02	The technology selected to implement the VUI shall have embedded language processing.	Functional	L2-02
SR	L3-03	The user personas developed shall be based on astronauts from the Artemis Generation.	Functional	L2-03
SR	L3-04	Access methods to be implemented shall be defined in user stories.	Functional	L2-04
SR	L3-05	Desired information from the vehicle systems manager shall be defined in user stories.	Functional	L2-05

Table 3: System Requirements Level 3

2.4 Traceability Matrix

The Traceability Matrix shown below links all requirements to the goal of the VUI and to the end user, which in this instance is NASA.

Traceability Matrix				
User	**Goal**	**Level 1 Requirements**	**Level 2 Requirements**	**Level 3 Requirements**
NASA	Develop a VUI for interactions with crew on Gateway /Lunar Habitat	The VUI for crew operations shall be included.	The VUI shall provide system warnings based on the current hierarchy used by NASA for the ISS.	The VUI shall first be developed for crew interactions with the lowest hierarchy of events.
		The VUI shall be intuitive and easy to use.	The VUI shall use natural language processing.	The technology selected to implement the VUI shall have embedded language processing.
			The VUI shall implement Google's Conversation Design Language	The user personas developed shall be based on astronauts from the Artemis Generation.
			The VUI shall provide multiple access methods for the same gateway dataset.	Access methods to be implemented shall be defined in user stories.
		The VUI shall provide complete system awareness in an efficient manner.	Decisions made by the vehicle systems manager shall be accessible within the VUI.	Desired information from the vehicle systems manager shall be defined in user stories.
		The VUI design shall be limited to existing and emerging technologies.	The VUI shall implement noise mitigation and filtering techniques so that the signal to noise ratio is >20dB.	N/A

Table 4: Traceability Matrix

2.5 System Definition

The system concept that is being used is one of a DHAS, with an assumption that the Lunar Gateway or a Lunar Habitat will operate with a central vehicle systems manager (VSM) (1). The VSM controls and interfaces between module managers from each module of the Lunar Gateway. For the system, we investigated the Habitation Element, the Power and Propulsion Element (PPE), the Visiting Vehicle Element (VV), and the aspects related to EVAs and In-Situ Resource Utilization. The VSM will facilitate the transfer of data from each module and the passing of the data to the crew when the crew queries the VUI. The accessibility and control of the VUI shall be reflected in the capabilities of the VSM. Additionally, the differences in systems that can be controlled through the VUI versus those that can only be queried through the VUI shall be managed by the VSM. The figure on the following page defines the system and data flow within part of the system.

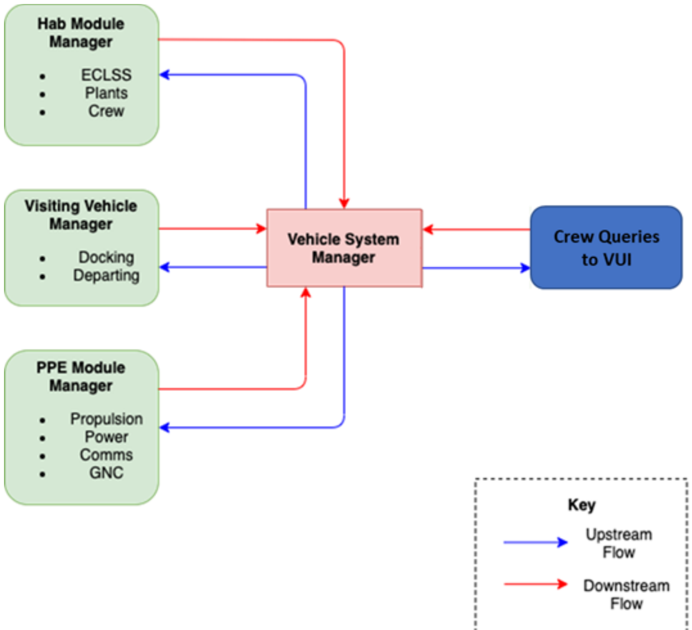

Figure 2: System definition and flow

The above figure only highlights some of the data that the VSM may query from three modules on the Lunar Gateway. However, VUI is being built to be agnostic to implementation on a Lunar Gateway or a Lunar Habitat.

2.6 Concept of Operations

The concept of operations for the VUI can be seen in the figure below.

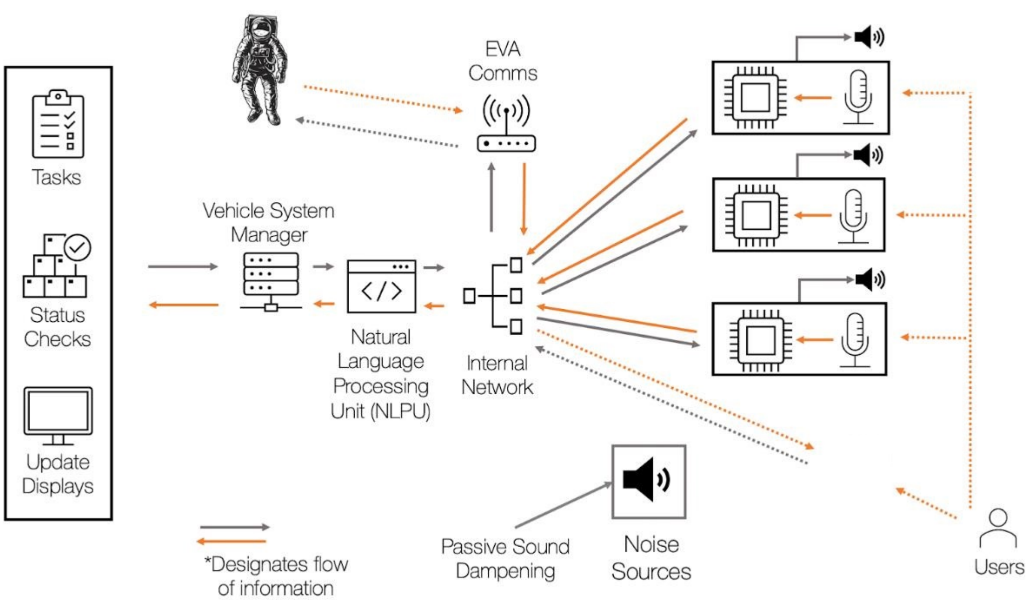

Figure 3: Concept of Operations

The VUI operations have been broken down into the simple components that are involved in the interactions between the crew and the system. The crew can speak to the VUI either through microphones that are placed throughout the system or through wearable technology that passes the queries to the internal network. Around parts of the system that are generating noise there will be a level of passive noise dampening that will be determined by NASA and its contractors. BLiSS is investigating passive noise dampening solutions to allow a better understanding of the effect of them on microphones or other audio pickup systems that are intended to record and transmit the queries to the internal network. The audio that is received can also be passed through sound processing software to attempt to isolate the spoken query versus the ambient noise. The internal network will pass the information to the Natural Language Processing Unit (NLPU) which may be a piece of software that parses the query and identifies the key words that the VSM needs to search for or identify and passes these to the VSM so that it can update displays, execute tasks, or determine the status of systems. The information the VSM pulls or the tasks it executes are relayed through the NLPU to generate a human response which is then passed to the wearable technology or to the speakers in the system to then inform the crew member who queried the system. The speakers in the system in combination with the microphones may also be used to actively cancel noise sources and this is another area of research that BLiSS is pursing to obtain a detailed understanding for the application of active noise cancellation in a space environment.

2.7 Work Plan

The work plan for the VUI is shown in the figure below.

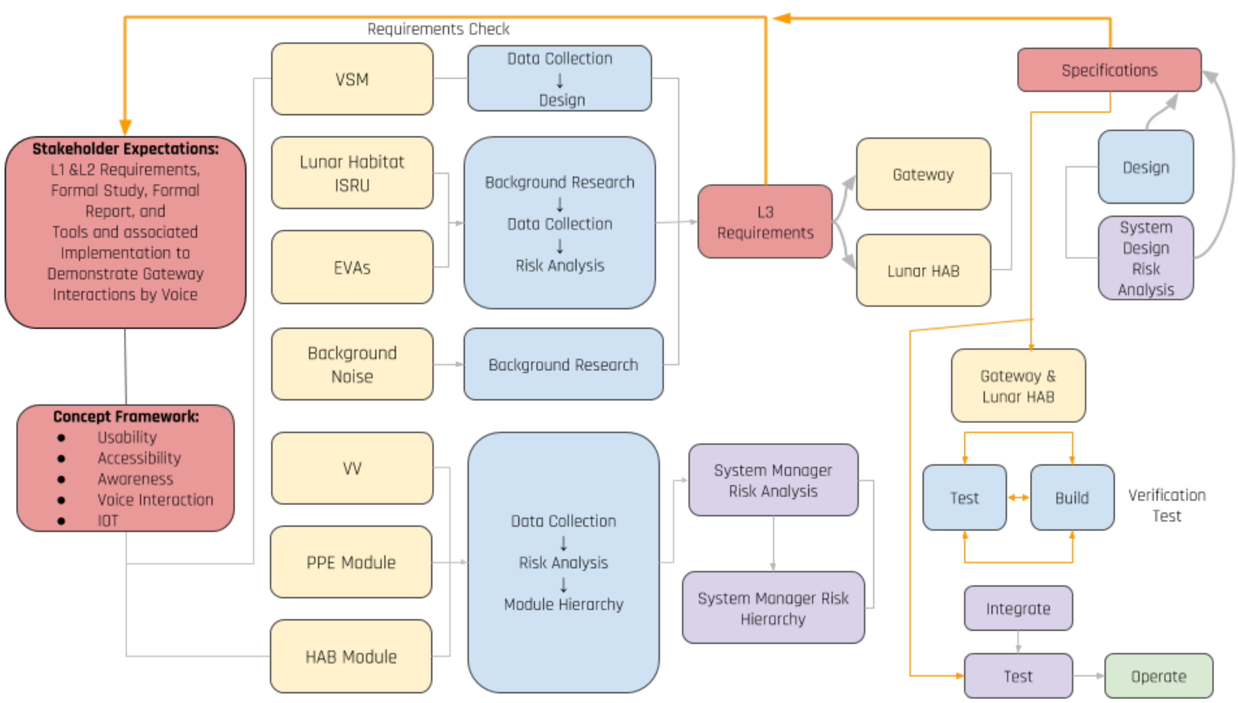

Figure 4: Work Plan

The design of the VUI was broken down into specific steps to ensure the process was manageable. The first aspect that needed to be understood was the stakeholder expectations. With BLiSS's development in the last X-HAB challenge being interrupted by COVID-19, BLiSS wanted to ensure that NASA was clear about expectations and deliverables to ensure that the team could delivered the best product possible while managing a remote work environment. After nailing down expectations, the next step was to develop a concept framework for the VUI both in what is can do and how it goes about doing it. This was the primary driver for the development of Level 1 and Level 2 requirements previously discussed in this paper.

Leveraging past research that BLiSS has conducted and expanding upon it, the concept of a VUI for a Lunar Gateway or a Lunar Habitat was investigated from a systems perspective. To do this we identified the high-level systems or components associated with these two space habitats and then identified the subsystems, the components, and what a crew member could in theory control or monitor using a VUI. Not all the systems identified were deemed appropriate to control with a VUI, it was determined to mitigate risk that some systems should only be monitored and not given commands or controlled. The other approach that was done was a design approach using conversation design and starting from a VUI from scratch and identifying how the interactions between the crew and the system should look and feel. This allows the design to be agnostic to the implementation because the conversation design start with the look and feel of the VUI and not what the VUI should or should not control.

The above processes allowed us to decompose the Level 2 requirements into Level 3 requirements and to begin planning the implementation, verification and validations steps that we completed in the Winter semester.

3 Project Management

3.1 Work Breakdown Structure

To maximize efficiency throughout the project, the main components of the project have been broken down into smaller, more individualized projects and are documented in a Work Breakdown Structure (WBS). The figure below shows the WBS for the BliSS VUI project which includes a breakdown of top-level elements: Analysis, VUI Development, Hardware Development, and Deliverables.

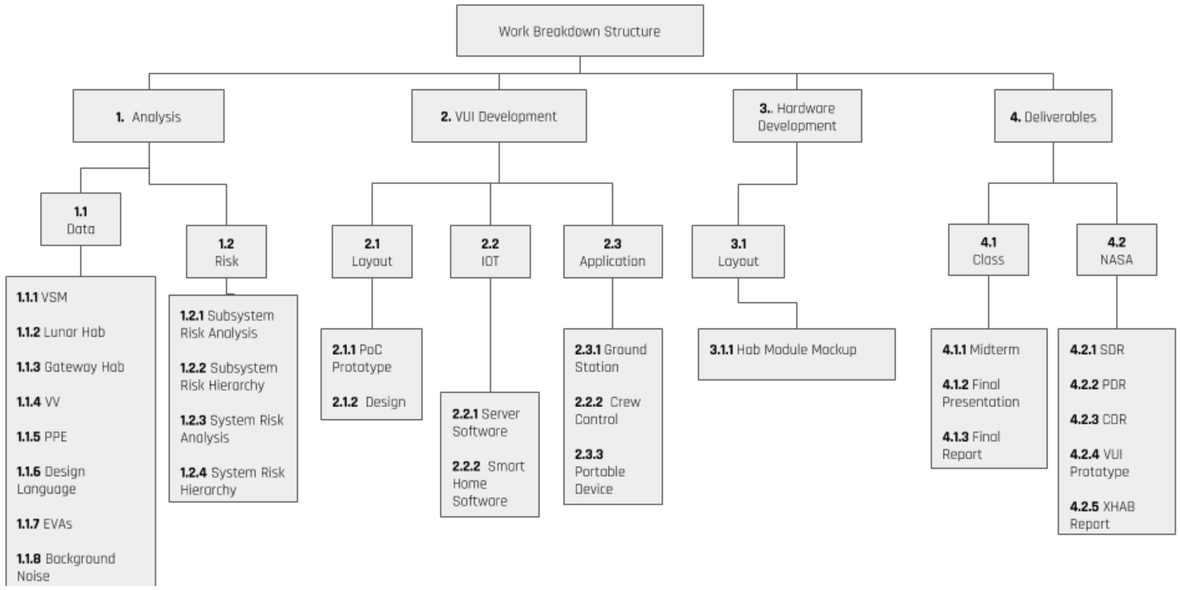

Figure 5: WBS of BLiSS VUI

3.2 Programmatic Risk

For the risk assessment we analyzed 8 different failure modes and determined their effects and risk scores and ways to control these potential hazards. Out of these 8 possible failure modes, we created a risk hierarchy using 5 different failure modes representing a range of different overall risk scores.

The failure modes shown in Figure 6 and Figure 7 are the end of the semester failure modes and mitigation strategies. Of the 8 major risks assessed, the high risk was eliminated, there are 6 medium failure modes, and 2 low risk failure modes. Compared to the failure modes seen at the time of the SDR where the 8 major risks assessed, there was one high, 6 medium, and one low. A comparison of these risks can be seen in the figure below.

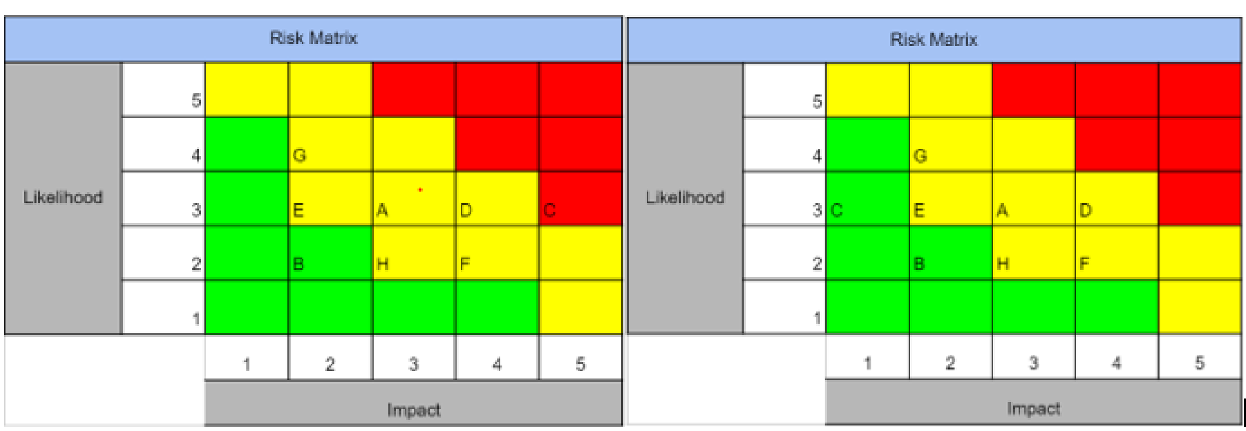

Figure 6: Risk Matrix at SDR (left) updated at end of year (right)

Letter	Title	Description	Date Reviewed	Due Date	Impact Areas	Owner	Likelihood	Impact	Mitigation Strategy	Risk Score
A	Team	Ineffective communication between team members	10/21/20	12/15/20	Schedule	M	3	3	Regular team meetings x 2/wk Work sessions of sub teams X 1/wk Ensure accessibility via Slack/Zoom	9
B	Team	Reduced time team members are unavailable due to time constraints or class constraints appearing unexpectedly	11/23/20	12/15/20	Schedule	SE	2	2	Projected value of completion time is based on bi-weekly worksessions and "take-home" work is actively limited.	4
C	Voice Control	Increased complexity with creating voice control from scratch.	11/30/20	12/1/20	Deliverable, Schedule	SW	1	3	Leverage G2 for analyzing voice or use third party Alexa application on Apple Watch and use Alexa hardware.	3
D	Voice Control	Large amount of simulated data collected and transferred between server and application.	1/1/21	3/1/21	Deliverable, Schedule	SW	3	4	Use manual evaluation of the spoken language from user to direct VUI decision making.	12

Figure 7: End of semester Risk and Mitigation Strategies (A – D)

Letter	Title	Description	Date Reviewed	Due Date	Impact Areas	Owner	Likelihood	Impact	Mitigation Strategy	Risk Score
E	Validation	VUI validation as part of the server architecture results in increased complexity.	1/1/20	N/A	Schedule, Cost	SE	3	2	Integrate hardware with no connection to server to have validation recorded via observed action of user and manually selected response.	6
F	Software Compatibility	Prototype deployment is unsuccessful due to compatibility issues.	1/1/20	2/1/20	Schedule	SE	2	4	Create strict version control and interface documentation before implementation process begins.	8
G	Recruitment	Required skill sets for polished development and implementation are not within the team.	9/4/19	1/1/20	Schedule	M	4	2	Recruitment of specialized team members.	8
H	VUI Stories	Too many use cases to integrate and develop.	12/13/19	4/1/20	Deliverable, Schedule	M	2	3	Implement VUI with only high level stories for majority of use cases and developed stories for selected use cases.	6

Figure 8: End of semester Risk and Mitigation Strategies (E – H)

3.3 Schedule

All tasks were broken down by subsystem and scheduled from September 15, 2020 to May 6, 2021. This schedule allowed sufficient time for analysis, development, and varying reviews of the system to take place. All tasks for the Fall 2020 and Winter 2021 have been completed as seen in the figures below.

Figure 9: Fall 2020 Schedule

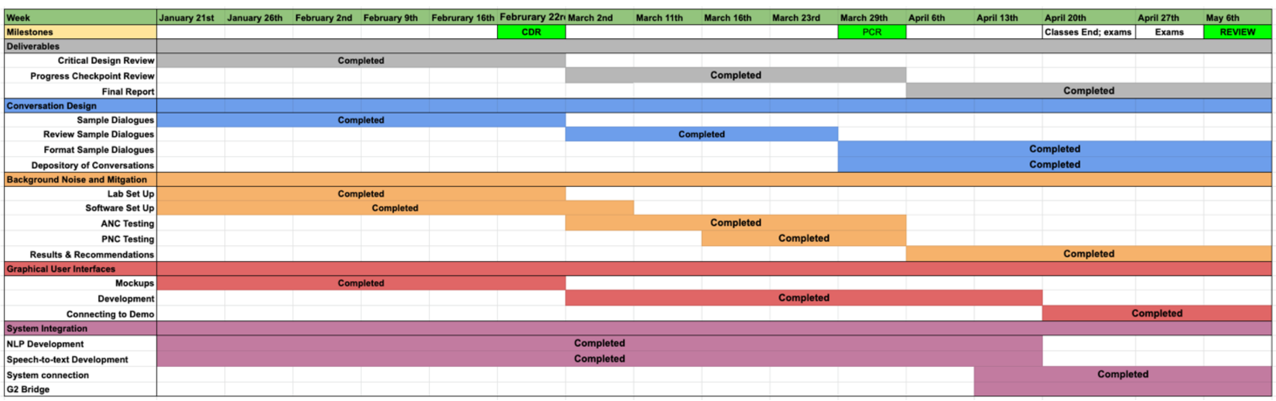

Figure 10: Winter 2021 Schedule

3.3 Milestones

As part of designing the work breakdown structure, schedule, and budget, certain key milestones were recognized and shown in the table below.

Milestone	Date	Output Product
Kickoff	15-September-2020	Assignments
SDR	14-October-2020	Presentation
PDR	23-November-2020	Presentation
CDR	22-Feburary-2021	Presentation
PCR	29-March-2021	Presentation
Final Review	6-May-2021	Presentation & Report

Table 5: Fall 2020 & Winter 2021 Milestones

These milestones were critical to the development of the overall system architecture and management of each subsystems progress.

3.4 Budget

BLiSS was awarded $ USD in funds for this project over the duration of the 2020-2021 academic school year. Approximately $ USD has been spent to date by the BLiSS VUI team. The table below shows a breakdown of the funding distribution.

Performance Period: June 2, 2020 through May 31, 2021		
	Funds Requested from Sponsor	Proposed Cost Sharing (if any)
1. Direct Labor		
2. Other Direct Costs		
a. Subcontracts		
b. Consultants		
c. Equipment		
d. Supplies		
e. Travel		
f. Other (Recruitment)		
3. Indirect Costs		
4. Other Applicable Costs		
5. Total		
6. Total Estimated Costs		

Table 6: VUI 2020-2021 Budget

4 Concept

There were two approaches used to develop the VUI one was a system approach where the systems within a Lunar Gateway and a Lunar Habitat were analyzed and broken down into their subsystems. Once the decomposition of these systems was done, each was evaluated for the risk to control a system remotely though a voice interface to determine if specific systems should allow for this control or merely monitoring through a VUI. This process is associated with the Level 1 requirement L1-03 and its associated lower-level requirements.

The other approach to develop a VUI was through implementation of a design language. Google's conversation design language was selected to be the VUI design language as it is one of the most thoroughly researched and detailed processes available. This was reflected in the Level 2 requirement L2-03 and its associated lower-level requirements.

4.1 Systems Approach to VUI Design

In this approach the Lunar Gateway and a Lunar Habitat were analyzed and broken down into their respective subsystems. These two systems will share functionalities between many of the core subsystems and elements including: habitation element (e.g., experimentation), power element, visiting vehicles (either docked onto station or landing vehicles), and EVA's (either in space outside the station or on the surface of the moon). In comparison, the Lunar Gateway will additionally require a propulsion element and it will only need communication within the modules of the station. The Lunar Habitat in addition will leverage In-Situ Resource Utilization and will need to also communicate with vehicles and other exploration/research equipment on the lunar surface outside of the Lunar Habitat. Each subsystem was evaluated for the use of voice control and is further discussed in the sections below.

4.1.1 Habitation Element

For both the Lunar Gateway and the Lunar Habitat, there are key system features of the Voice Management System for the habitation module. The Voice Management System will need to be accessible within each module with multiple microphones and a single speaker in each module. The system will also need to be accessed through tablets and computers in case of emergencies or for ease of access where voice command is not feasible. The figures below show the configuration of the habitation module for the Lunar Gateway and an example concept design of a Lunar Habitat (58,20, 19).

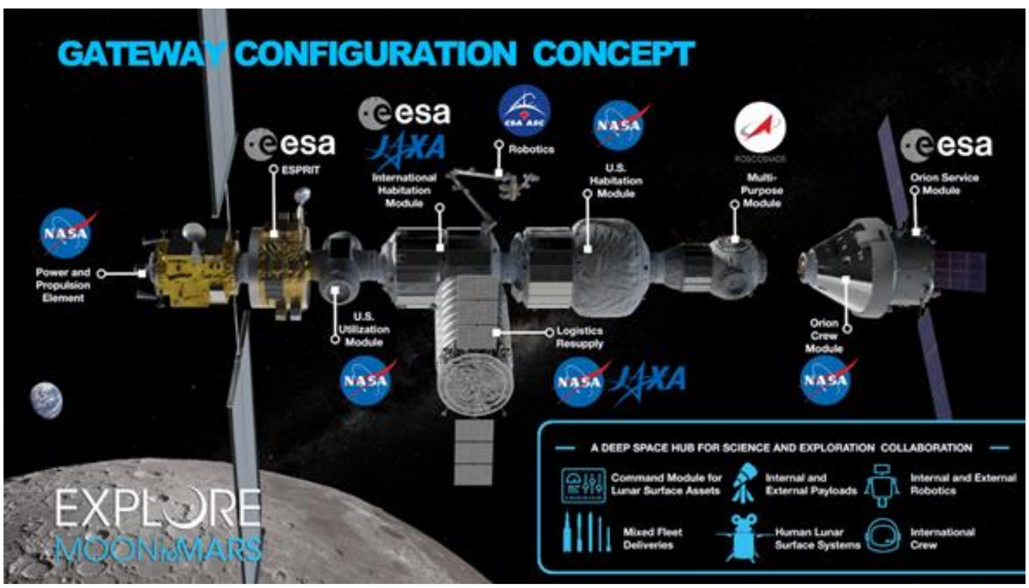

Figure 11: Lunar Gateway configuration concept

Figure 12: Conceptual Design of a Lunar Base from Bigelow Aerospace

For the habitation module there are key system interactions the Voice Management System should be able to execute for three categories: life support, environmental monitoring, and physical and mental health. Within life support is atmosphere management, water management and waste management, where the system should be able to at any time tell the composition of the atmosphere and remaining oxygen levels, check into remaining water levels and quality, and identify progress on waste recycling. Within environmental monitoring there is radiation monitoring, fire detection and suppression, and acoustic monitoring. For this interaction, the system should be able to monitor past and current radiation levels and potentially expect future levels, monitor potential issues that might lead to fires and provide suppression if needed and lastly, the system's microphones should monitor the acoustic levels of the module and ensure that they are at a safe level for the astronauts. For the last category, physical and mental health, there is food storage, exercise, and mental health management. The system should be able to track and verify the current food amounts and indicate how many days are left with the current supply, notify astronauts of daily exercise, and keep record of the time they have exercised, and provide mental health support for the astronauts including access to messages from home and news or jokes to lift spirits.

For the habitat element the implementation opportunities were accessed. Some possible applications include using the VUI as a task manager for the crew, to alert the crew when conditions are dangerous or systems malfunction, to support astronauts' physical and mental health, and to monitor acoustic conditions (notify when noise is dangerous or possible system degradation). Additionally, it is important to consider the experiments that will most likely be done in the future on the Gateway and Lunar Habitat. There are two experiments that have already been selected to go on the Gateway, a suite of instruments to monitor space weather conditions and measure radiation conditions. Apart from these two, there will be experiments to analyze lunar material samples, experiments to evaluate behavioral health, neurocognitive functions, radiation and microgravity effects, and the possible use of robotics to support visiting crews and maintain operations when the Gateway or Lunar Habitat is not crewed. It is important that the VUI system can support these experiments; some possible actions the VUI system can help astronauts with while they conduct these experiments include setting timers, checking data, taking notes, reviewing instructions, and connecting with scientists on Earth.

4.1.2 Power Element

The power systems for both the Gateway and the Lunar Habitat will have three of the same core elements including solar panels, batteries, and a power distribution system. The Lunar Habitat will have a unique fourth element, a Kilopower Nuclear Generator that has been developed by NASA but has not yet been flown.

Figure 13: Power Element for the Lunar Gateway (left) and Kilopower Nuclear Generator for a Lunar Base (right)

From these studies we looked at what needs to be monitored for the subsystems within the power element to identify use cases for the VUI. For solar arrays, the positioning (angle) can be potentially monitored. The core temperature control rad position, and heat pipe temperature can be monitored for the Kilopower system. For the PPU (Power Processing Unit), we can monitor the delivered, stored, and disposed power and we can monitor the available power like confirming the power available to perform various tasks and identifying times at which power is being wasted. Below is a sample diagram of a power subsystem that could be used for a Lunar Base or for the Lunar Gateway if the Kilopower is removed (3).

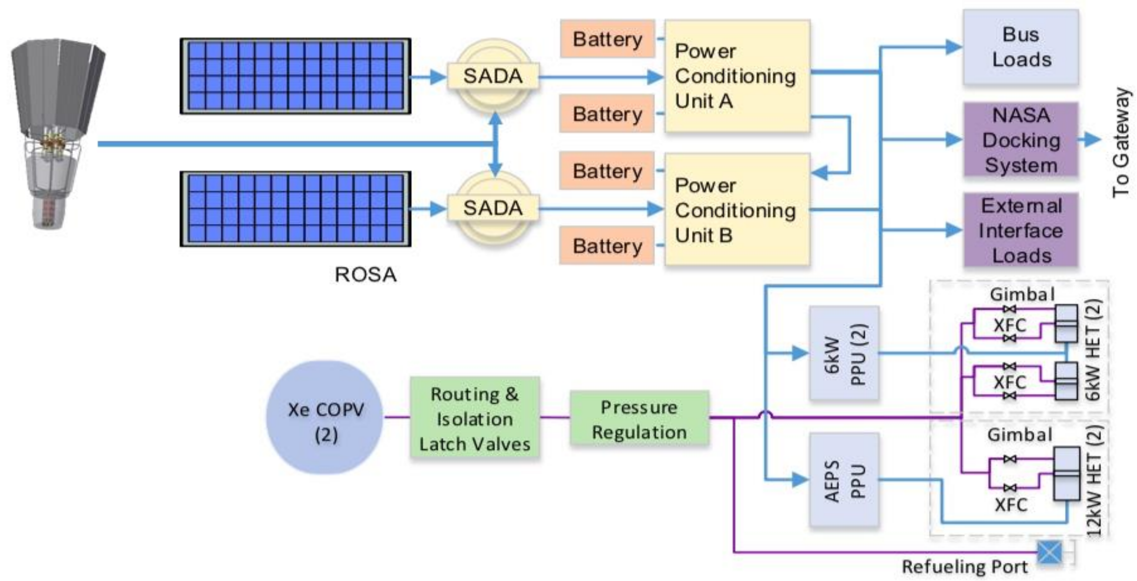

Figure 14: Modified PPE SEPP system to include Kilopower Nuclear Reactor for a Lunar Base

Primarily, what we discovered is the VUI should not control the power elements in any way but should merely report their status to the crew. Some implementation ideas include providing verbal crew notifications for major events (e.g., *core temperature too high – adjust control rad*), status updates on system and their subsystems and components, and enabling secondary systems with a voice override. For further analysis we can continue to determine safe applications of voice control for these systems, determine what components of system's health are relevant to the crew and develop concept of operations for these interactions.

4.1.3 Visiting Vehicles

For this subsystem we determined what key information the VUI should provide for the crew. The VUI should provide spatial and timing awareness of vehicle and end point, the status of connection, status of vehicle including the systems plus cargo and fuel and consumable levels and finally, be able to manifest information of the location of items in the cargo (63,64).

Figure 15: Blue Origin Lunar Lander (left) and Orion Lunar Gateway concept (right)

For safety reasons the VUI should not control the vehicle in any manner during the docking process. The VUI however could be used to monitor the process and notify the crew as well as help the crew during the unpacking cargo stage by helping them locate necessary supplies quickly and efficiently. This could be very beneficial, saving the astronauts a lot of time.

4.1.4 EVAs

There are a lot of potential implementations of voice control during EVAs. We have gathered a list of potential use cases:

1) Task management: check available tasks, check time spent on a specific task, check time left in EVA, adjust priority of tasks, update schedule

2) Task assistance: query instructions on how to complete common and uncommon tasks (replace battery, resolve technical issue, etc.), allow astronauts to control robotics via voice command

3) Check suit vitals: query their vitals directly, potentially adjust levels (will need to do risk analysis research)

4) Request communication: allow astronauts to open communication line with specific party (MCC, another astronaut, etc.)

5) Base connection: access all information on Gateway/Lunar Base as if they were inside the habitats

EVAs on the surface of the moon would require same commands as used for experiments to log information found during exploration including collection of samples or other experiments done on the surface.

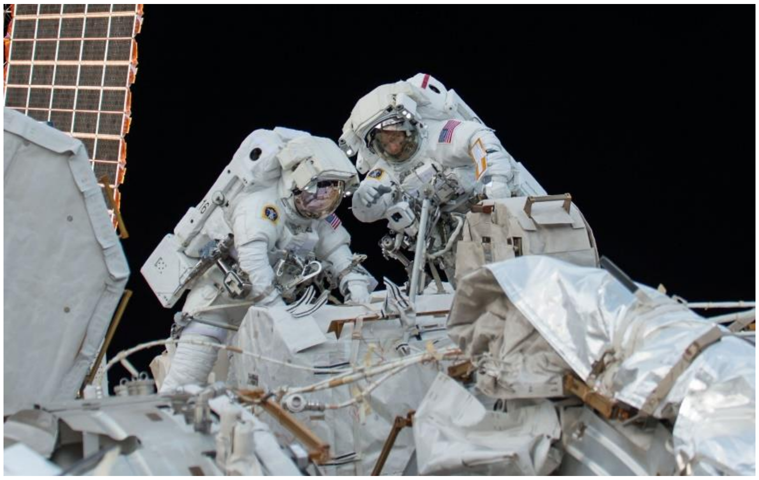

Figure 16: Two astronauts our on an EVA

4.1.5 Lunar Gateway Propulsion Element

The propulsion element for the Lunar Gateway has three core components, the propulsion systems, telemetry, and momentum control (30).

Figure 17: Propulsion Element on the Lunar Gateway using 50 kW solar electric propulsion

For the propulsion system, the VUI can check the overall system health including voltage, current and gas flow. The VUI system can monitor the thruster positioning (autonomously change positions to fire through CG) and monitor fuel consumption in terms of percentage of available fuel. With respect to orbit control, the VUI can monitor station keeping and orbit corrections, electric orbit raising (EDR), which is an entirely autonomous process that takes 21 days to get up to initial orbit, and display SEP trajectory, current location on trajectory, fuel consumption and time left in EDR. The VUI should not control the propulsion element at any given time, it should only provide status to the crew as discussed above.

4.1.6 Lunar Habitat ISRU

In-Situ Resource Utilization (ISRU) technology studies were conducted for this subsystem of the Lunar Habitat. Resources on the Moon consist of solar energy, volatiles (e.g., Hydrogen and Oxygen), and regolith. The technologies used for ISRU include drilling, mining, construction and manufacturing. The image below demonstrates the concept of construction on the moon using robotics and other equipment.

Figure 18: ISRU concept using robotic construction

For this system, the VUI can be implemented to help communicate with excavators/extractors to share important data and status updates on construction (e.g., *How much H_2 has been extracted today?).* ISRU consists of microwave extraction of water from Lunar regolith, where fleets of rovers equipped with microwave extractors could be used to collect water. The fleets can also be used to extract volatiles from the lunar surface. These rovers could automatically perform extraction operations when required since extraction technology is efficient and not difficult to manufacture. Collected water can be used to produce drinkable water or as propellant. This extraction process will be very important for future lunar missions so it is important we think about how VUI can help in this aspect. Forms of implementation for extraction include, relaying important information about the fleets' status and notifying users about machine failures and unexpected behaviors. Some example commands and notifications are as follows:

- *How filled are the water tanks in Rover A10?*
- *What is the battery charge percentage of Rover B12?*
- *VUI: Attention, connection was lost with Rover A32 and A36.*
- *VUI: Warning, Rover B30 is exhibiting malfunction error 312.*

4.2 Design Language Approach to VUI Design

The design language approach for developing a VUI is a "new process". The concept of a design language, human centered design, and conversation design are all things that people "know" are important in a design. However, they are also things that have not been well defined until more recently with the development of software standards and voice standards that have been in part led by Google, Apple, and IBM. For the VUI we follow Google's design principles.

4.2.1 Human-Centered Design

To begin the process of designing a VUI we started with the concept of a human-centered design. According to ISO Standards, “Human-centered design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety, and performance” (ISO 8241-210:2019). This process is marked by three primary phases of activities:

1) Understanding the user and their domain

2) Visualizing the design

3) Evaluating the design.

The figure below visualizes the human centered design process that we adapted. This takes the three phases identified above and puts them into an iterative cycle to develop, improve and re-develop a concept until it is refined. IDEO, one of the world’s leading human-centered design firms speaks of HCD as a philosophy, saying, “Embracing human-centered design means believing that all problems, even the seemingly intractable ones like poverty, gender equality, and clean water, are solvable. Moreover, it means believing that the people who face those problems every day are the ones who hold the key to their answer” (62). This process was not something that BLiSS had used prior to the development of the VUI. However, as BLiSS is always looking to improve its engineering by taking radical approaches and implementing new methods. The diagram was developed by NASA to identify the proper method to develop a proper human computer interaction for any system.

Figure 19: Human Centered Design Process

Using a human-centered design for a VUI is also a relatively novel concept especially when it comes to developing a VUI for space applications. According to Salazar, although speech recognition technology has improved considerably over previous attempts to implement it for the purposes of supporting crewed spaceflight, there are still many challenges such as how to handle various recognition errors. He recommends utilizing an iterative, human-centered design process, with adequate usability evaluations, to develop a reliable system that appropriately provides feedback and handles errors (Salazar, 2018). From the interactions between BLiSS and NASA through our SDR and PDR, NASA has been thrilled at the process we have been implementing.

4.2.2 Design Thinking

Design Thinking is the best process for thinking outside the box, to develop innovative, human-centered solutions to wicked problems. These are problems that are ill-defined and essentially unique. The key to Design Thinking is iteration, which allows for incremental improvements validated with user data (47). The Hasso Plattner Institute of Design at Stanford defines Design Thinking in terms of a five-stage process, but it is important to stress the non-linearity of Design Thinking. Teams will often run these various stages in parallel, in any order, and repeat them as necessary through each iteration cycle.

Figure 20: Design Thinking Process

For BLiSS to properly take advantage of design thinking in conjunction with human centered design process we re-structured the sub teams after the SDR to focus in on design thinking.

4.2.3 Human Information Processing Model

When designing information systems, it is important to consider the human information processing model. When a user is interacting with an information system, they are using it to achieve a goal. The design team must understand the context which includes the other environmental stimuli that the user must process in addition to interactions with the system. Thus, the goal of good information systems design is to mitigate sensory stimuli and feedback to effectively extend the user’s capabilities by making design invisible (57). What we strive to do in the design of information systems then is to free up attentional resources that would otherwise be spent on perceptual encoding so that the user can devote more of those resources to central processing and responding, e.g., thinking and acting. There are two primary aspects to the human information processing model. The first is cognitive overload, this is in essence a person’s working memory. The other aspect is the gulf of execution and evaluation, in essence this is the difference between what is desired, what happens and how a person interprets what happened.

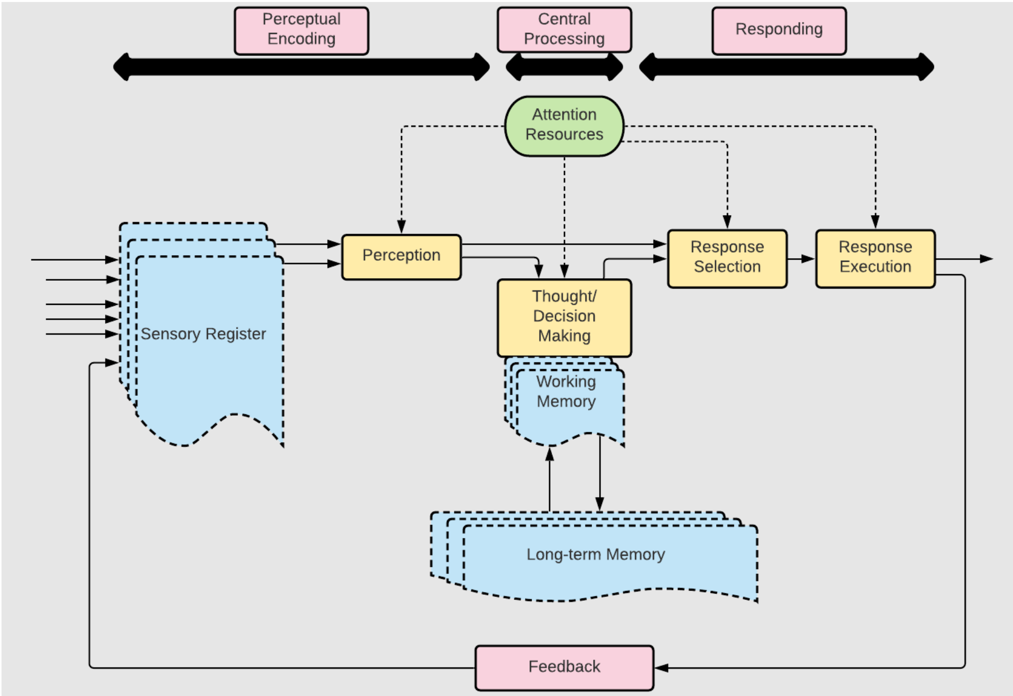

Figure 21: Wickens Human Information Processing Model

Cognitive Overload

There are various models to describe channel capacity in terms of working memory. The most referenced model is Miller's, which suggests that humans can store 7+/-2 pieces of information at any given time. For the design of information systems, Broadbent's model of 4+/-1 is more applicable because it is a better method to account for information chunking and the relationship between meaningful physical and cognitive chunking (57). For example, which of the following is easier to remember: FB ICIAU SA, or FBI CIA USA? This can be better shown in the figure below.

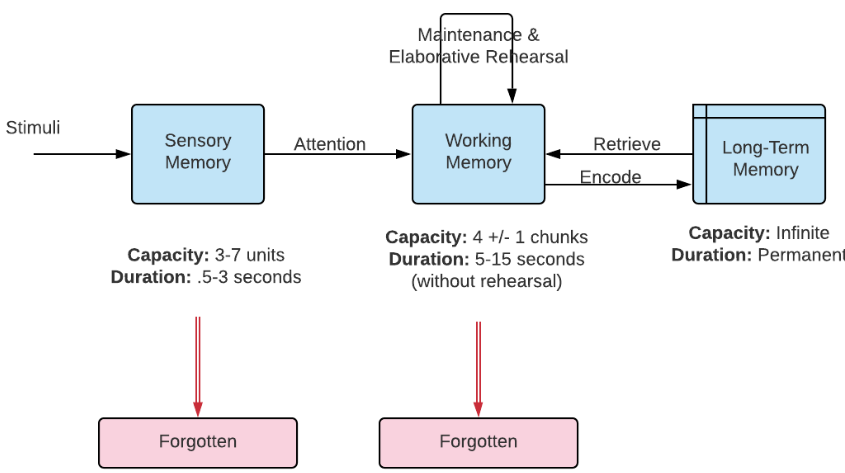

Figure 22: Cognitive Overload

With space applications and with NASA's astronaut training program, there is an alphabet soup of abbreviations that can be leveraged to ensure that the crew can be informed of things via the VUI or request things from the VUI. These abbreviations although many can ensure the crew is able to retain a much larger amount of information. For example, having the VUI say PPE versus Power and Propulsion element reduces the cognitive load that the VUI will end up placing on the crew.

Gulf of Execution and Evaluation

In Don Norman's classic, "The Design of Everyday Things," he refers to the Gulf of Execution, where a user tries to figure out how a system works, and the Gulf of Evaluation, where a user tries to figure out what happened (51,52). Our job as designers, is to bridge these two gulfs. Typically, with GUI, we have about 200 milliseconds to 1 second to present a state change to not disrupt the user's flow. This is similar to the length of time in conversation before people start to feel awkward. Our challenge is to effectively bridge this gulf when the system needs more time and there is not a visual display to support the user by showing system status, like a progress bar or spinner. Tied to this response is the ability of the system to interpret what the user is trying to accomplish.

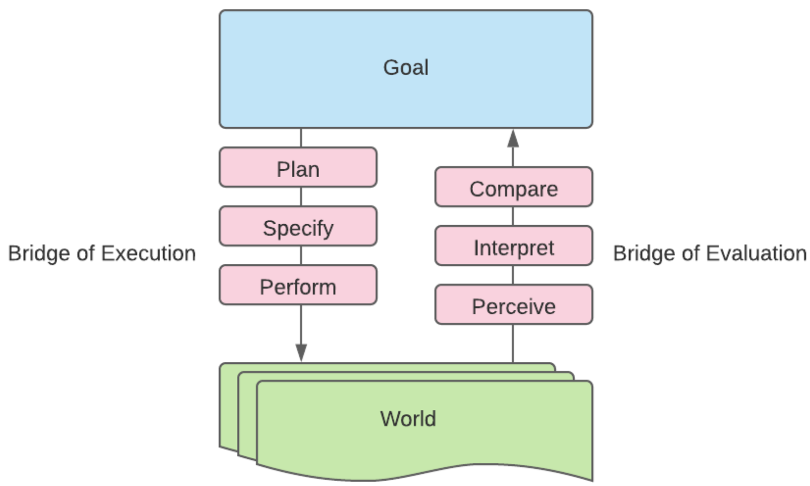

Figure 23: Gulf of Execution and Evaluation

A user for example may say "when is the next sample return mission scheduled" a user on a lunar base may be looking for when it is scheduled to takeoff from the Moon while a user on the Lunar Gateway may be looking for when it is expected to dock. The system will need to interpret the user's location and intent in their questions and then identify the answer to provide. Any "disagreement" between the request and the answer that is considered the gulf of execution. To determine the gulf of evaluation, the system provides the user an answer and the gulf discussed is the difference in the user's interpretation versus what the system meant.

5 Conversation Design

The Conversation Design team was formed in response to top level requirements, identified before the project began work. All project requirements can be found within section 3. Requirements related specifically to the work of the Conversation Design team are as follows SR-L1-02 “The VUI shall be intuitive and easy to use” , SR-L2-03 the “VUI shall implement a design language”, SR-L3-04 “The user personas developed shall be based on Artemis generation astronauts” and finally, SR-L3-05.

5.1 Trade Studies

The work of the conversation team started out by researching the structure of a conversation, the nature of a user interface, and how to make the interaction of the two, seem *natural.* We started with the idea of a human centered design process.

Figure 24: Human Centered Design Process (HCD)

The HCD process was developed by NASA to identify the proper method to develop a proper human computer interaction for a system. The process was referred to often for this project, paying special attention to evaluating and redefining our design.

5.2 System Design

Once the team understood what it meant to create a conversation between user and system, we began the design of the conversations.

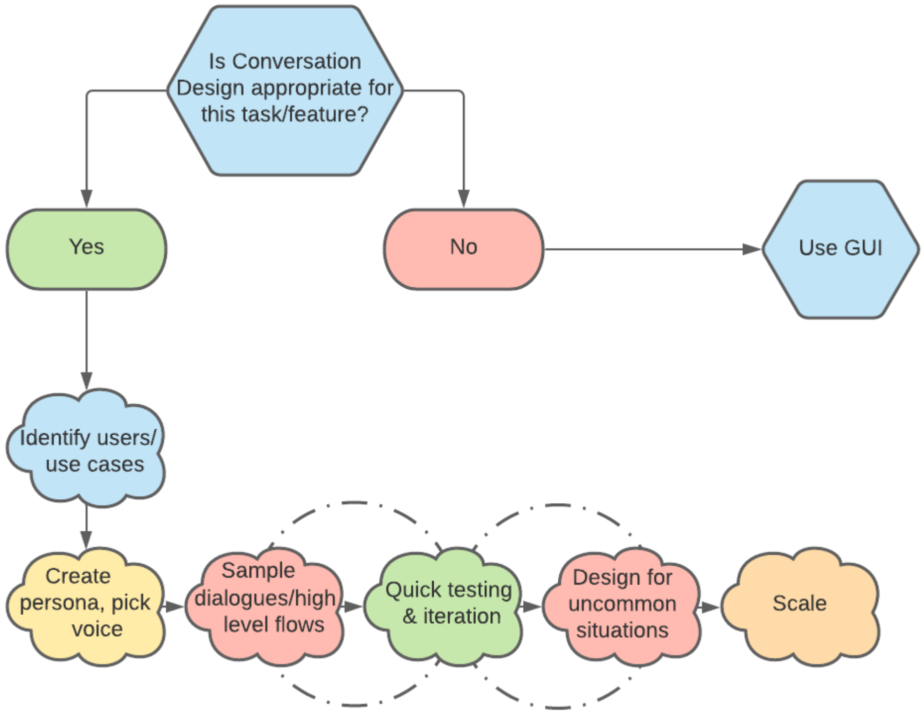

Figure 25: Conversion Design Process

In the figure above, from the paper by Dasgupta, R. "Voice User Interface Design" [45] we got a sense of the process that would need to take place to complete the work driven by requirements. Users and cases have been identified, Artemis generation astronauts and the following use cases:

- **Scheduling** - asking about specific tasks, adding reminders for tasks.
- **Communication** - making a call, sending a text, sending a voice message.
- **Station Vitals** - query of a vital - what is it, what is it in a specific location.
- **Tasks** - pull up instructions, read out step by step, how long should it take / how much is left.

Which were derived from a survey we sent out to those Artemis generation folks, such as faculty members and fellow students. Once the use cases and users were identified, the next step was to design the persona. Another survey was sent out for this, shown in the image below.

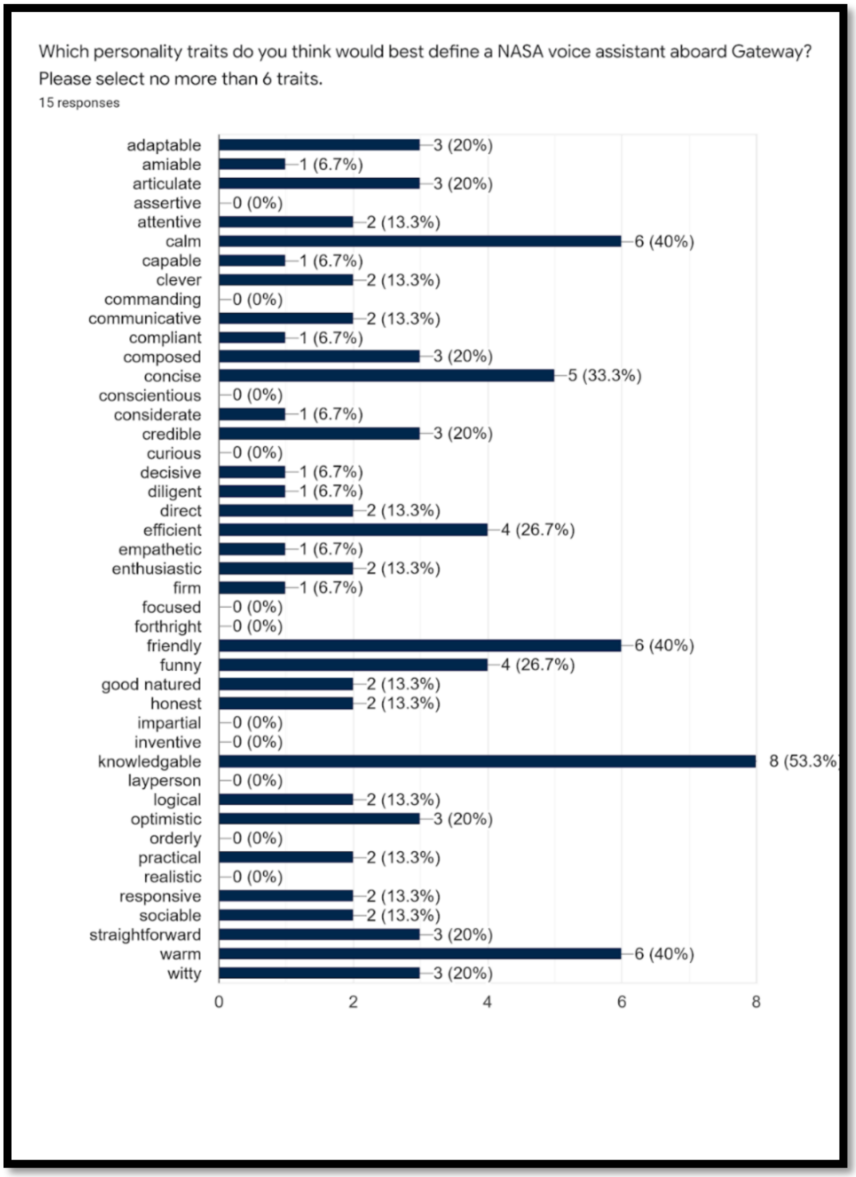

Figure 26: results of survey on desired personality traits of the system

The Conversation Design team began by identifying the personality traits of the system we would want to interact with us. In this scenario we placed ourselves in the shoes of astronauts and brainstormed a long list of personality traits. We came up with a list of 45 traits to deploy a survey to the rest of the team to vote on traits and converge on 4-6 ideal traits. Subjects were instructed to select no more than 6 traits. Responses were collected (n=15), and the following traits were identified: knowledgeable, friendly, warm, calm, concise, funny. A few of the Design Team members designed a personality accompanied by a face and a background story they thought fit the desired traits and thus Diego was born.

Name: Diego Sanchez

Age: 38

Occupation: Directorate Chief Scientist

Hometown: Santander, Spain

Current residence: Long Beach, CA

Education: BS - Physics, MS-Applied Physics, MS-Systems Engineering, PhD-Planetary Science

Hobbies: Skiing, surfing, astronomy, volunteering

Short description: Diego is from the bustling city of Santander, which is right on Spain's north coast. Here he grew up to love the water, and developed a strong passion for astronomy during his star gazings nights with the family. Diego's family owned farms and a specialty coffee shop where he learned how to interact well with customers, and the value of hard work. After highschool, he attended the University of Bordeaux in France, where he met a few colleagues planning to work with NASA post graduation and offered to set him up with one of the hiring managers. After graduating with his second MS degree, Diego returned home for a year to help with the family business and then set out to Pasadena, CA where he accepted his first position as a Research Space Scientist. Since then, he has worked hard to achieve his current position of Directorate Chief Scientist for NASA JPL. In Diego's free time, he enjoys vacations with his family, teaching his youngest daughter French, and surfing on the LA coast.

Voice: Slight accent, warm and kind and easy to follow/respect.

Figure 27: System Personality

5.3 Conversation Design

Now that the persona and functionalities of the system had been developed, it was time to write the full conversations out, the interactions between user and system. Also known as the "happy paths" These are scenarios in which the user has the best experience possible interacting with the system to achieve their goals. Again, Communications, Tasks, Schedule and Station Vitals were the functionalities focused on. An example of one of the conversational components can be seen below.

1. **Pull up instructions**
   a. Hey Diego
      i. Hello, how can I help you today?
   b. Can you pull up instructions for "_____"? / Pull up instructions for "_____" / Could you pull up instructions for "____" (e.g. toilet repair, microgravity experiment, etc.)
      i. Pulling up instructions for "_____" (repeat input) / Yes, pulling up now / Here are the instructions for "____"
   c. Thank you. Can you go to section "__"? / Turn to page "__" / Diego, go to section "___" / Skip to section "___"
      i. Here's section "__" / Turning to page "___"

2. **Read out instructions step by step**
   a. Diego, can you read instructions for "__"? / Read out instructions for "___" / Diego read step by step instructions for "__"
      i. Ok, Instructions for "___" Step 1 … / Ok, I will begin reading instructions for "___"
   b. Diego, slow down / Read slower / Read at 0.5X speed
   c. Diego read faster / Read at double speed / Can you read at 1.5X speed?
      i. Ok, I will read at 0.5X speed. Is this speed ok?
      ii. Ok, I will read faster now, is double speed ok? / Ok, what speed would you like me to read?
   d. Yes / Yes, that's fine / No, read at "___" speed
      i. Ok, I will read at "__" speed (when speed is corrected)
   e. Can you repeat step "__" / Repeat step "___"
      i. Ok [repeat]

Figure 28: Example of the "Task Function" conversational component of the system

Each conversation begins the same, the user starts the system with “Hey Diego” along with a few other acceptable phrases, the system responds with a few different phrases as well (as not to become dull and redundant), and then the user follows the system's response with their query. In this case above, the user is looking for the VUI to pull up task instructions, as discussed more in the software integration section (section 4.4) and their chosen natural language processing software RASA, the VUI can understand a few ways that the user asks a question, as long as it picks up the key words such as “instructions”. There is always a verification following the user request, to ensure that the system has heard correctly, and then the execution. All of the conversational components and directions on how to navigate them are found within the VUI User Manual can be found in appendix C.

The intention with the conversation design was that the user feel as though they are talking with another human, maybe even eventually, a friend. It is known that astronauts can often feel lonely while spending months at a time on an isolating platform such as the ISS and their interaction with our VUI ideally would serve to mitigate some of that. To do so, we are designing to diego to have a human like voice, that shows emotion. We are also working on including jokes within the systems, and questions that the user can ask such as “Diego, where are you from”. In return, Diego should be able to pick up on cues from the user that something is off, and be able to respond with either a joke, or questions as well such as “Hey Izar, have you read your messages from home lately?”. This is hopefully just the beginning of a human, system interface where the two can relate, and feel happy in each other's company.

6 Graphical User Interfaces

The Graphical User Interface (GUI) Team was created in response to a few of the top-level requirements. All requirements and their discussion can be found in section 2. Those that relate most closely to GUI are SR-L1-04 “The VUI shall be limited to existing and emerging technologies” and SR-L2-04 “The VUI shall provide multiple access methods for the same gateway dataset”.

6.1 GUI Design

Once the trade studies were completed, and Adobe XD was chosen for the User Interface, the next step was to figure out which functionalities the system should have and what the design would look like. The GUI team worked alongside the Conversation Design team, who were deciding what capabilities the system was going to have. The following were decided upon:

- **Scheduling** - asking about specific tasks, adding reminders for tasks.
- **Communication** - making a call, sending a text, sending a voice message.
- **Station Vitals** - query of a vital - what is it, what is it in a specific location.
- **Tasks** - pull up instructions, read out step by step, how long should it take / how much is left.

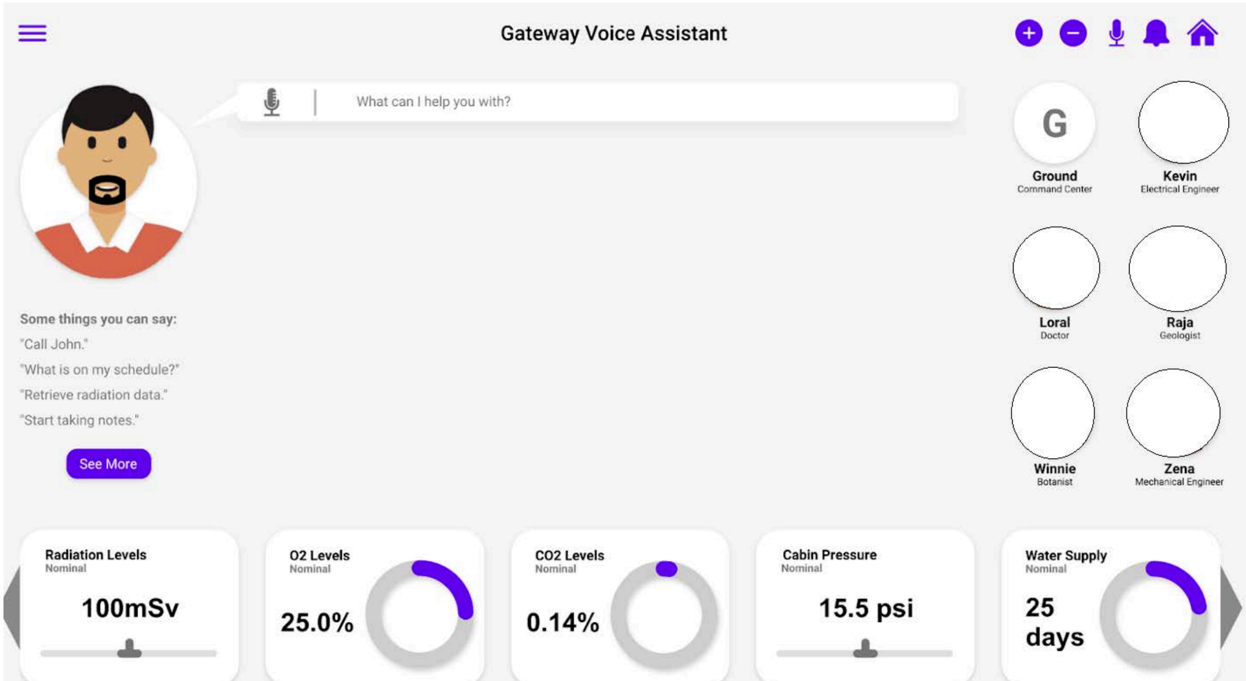

Figure 29: GUI Design in Adobe XD

The figure above is the outcome of the trade studies and the understanding of the requirements of the system. The image shown is the main screen, where astronauts have easy access to other system users, for communication, vitals on the bottom with real time data and a search bar at the top, that users can write in, or speak in, to pull up any of the VUI's additional capabilities. This user interface was designed with the two driving requirements in mind: existing technology and multiple access methods. Additional images of the system are in appendix B and all mockups can be found at Reference [65].

7 Background Noise and Mitigation

In this section we discuss the background noise environment expected on future spacecraft, and mitigation strategies that can be implemented to ensure the VUI can accurately distinguish the human voice from other noise.

7.1 Spacecraft Noise Environment

To begin our study of background noise, we first need to establish an expected environment with which to work. Although the Lunar Gateway does not yet have public acoustic data, we can model our noise environment based on a popular human-rated spacecraft, the International Space Station. There are papers written by NASA Johnson Space Center and other organizations quantifying the noise environment on the ISS. *International Space Station Acoustics - A Status Report* was particularly useful for quantifying the acoustic environment. The figure below illustrates how JSC tracks noise levels to ensure compliance with US government regulations for continuous noise levels.

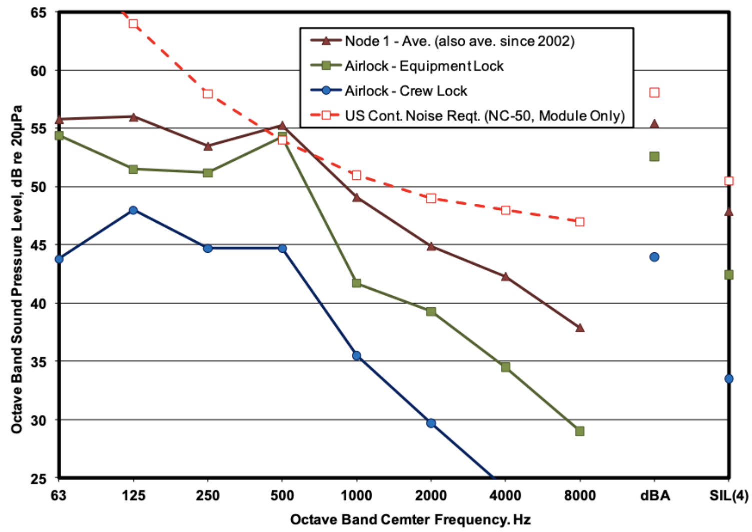

Figure 30: ISS Noise Tracking at Johnson Space Center

As seen in Figure 23 the JSC team records sound pressure in dB according to a baseline reference level, and also tracks noise based on frequency in Hz. The NC-50 line seen in red stands for Noise Criterion 50. NC plots are agreed upon noise level limits that are used by the government and industry. For the ISS, the goal is to not exceed the NC-50 curve in the US portions of the station. The figure below shows that Node 1 violated that curve at the 500 Hz octave, which required a special approval to override (22, 33).

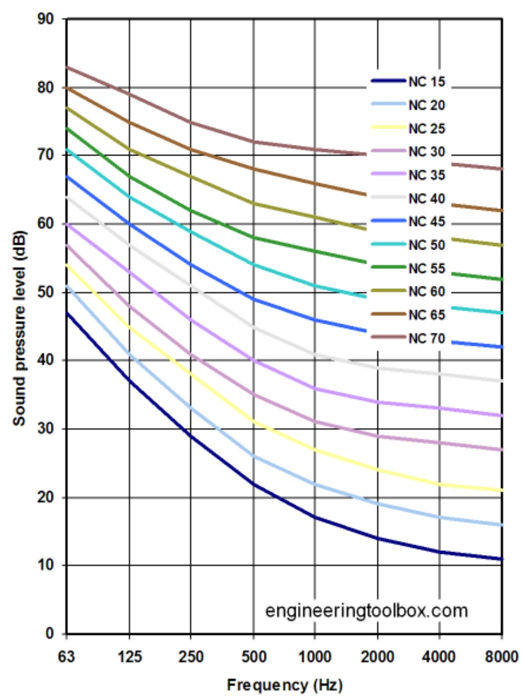

Figure 31: Standard Noise Criterion Curves

We believe that future spacecraft will adhere to the NC protocols, although it is unclear which NC curve will be approved for specific spacecraft. Since NASA astronauts are US Government workers, they typically must adhere to OSHA guidelines for noise as well. This includes "daily noise limits" and different max exposure times to different noise levels.

Reducing the noise environment in spacecraft is beneficial to the astronauts themselves and NASA, who must schedule work based on noise environments if levels are exceeding requirements. In the subsequent section we will also explain the importance of low background noise for Voice User Interface (VUI) applications.

Based on the ISS acoustic papers, we will treat the work environment noise level as 70dB. This slightly violates the NC-50 curve as seen in the ISS. We will also assume that the ambient noise in crew areas (for eating and sleeping) should be 60dB in accordance with OSHA guidelines. These two values will be our maximum noise level constraints for the spacecraft and thus the initial values for background noise levels.

7.2 Acceptable Noise Environment for VUI

Now that we have a baseline noise environment, we can determine what an acceptable noise environment looks like for effective VUI usage. Research papers on the subject indicate that a signal to noise ratio of at least 20dB is needed for VUI to distinguish human voices from background noise. Below are general speech levels for average human voices.

Speech Level	Noise Level (dB)
Whisper	~30
Normal Speech	~60
Yelling	90-95

Table 7: Typical Speech Noise Level

From this table, we gather that there are a few options for obtaining 20dB of SNR for our 70dB. The first is to accept the ambient noise levels and have the astronauts speak at ~90dB when accessing the VUI (21,19). This option is not sustainable or healthy for the astronauts as they would be forced to yell whenever using the VUI. The second option is to reduce the ambient noise to 40dB so astronauts can speak at 60 dB. This option is ideal but quite difficult. Spacecraft have several actuators for the life support systems and science instruments including pumps. These devices produce noise that is necessary for the success of the mission. Reducing this noise to 40dB (average library ambient noise) is a daunting task. A compromise is to reduce the noise to a level such as 50dB where astronauts need to speak at slightly above conversational levels, but not so much as to strain muscles. Using this rationale, we will aim to reduce the noise environment in work areas from 70dB to 50dB and in crew areas from 60dB to 50dB.

7.3 Methods for Reducing Background Noise

Now that we have a mandate to reduce background (ambient used interchangeably) noise, a review of noise mitigation strategies is in order. There are two basic types of noise mitigation. The first is passive noise cancellation (PNC) which uses materials to absorb sound and dampen the total amplitude. PNC is common in buildings and vehicles we use every day. Apartment building install foam sheets between units to lower noise levels for tenants. Your car uses rubber seals to limit road noise inside the vehicle. Recording studios and auditoriums utilize foam paneling to dampen echo and provide less reverb.

The second type of noise mitigation is active noise cancellation (ANC). ANC uses digital computing to analyze noise and produce additional noise which destructively interferes with the original noise. This principle is visualized below in Figure 25. ANC is common in high-end audio equipment such as noise cancelling headphones and even some vehicles. An ANC system is more complex because it needs a microphone, a speaker and a computer for analysis and generation of destructive waves. As an example, the Apple Airpod Pros utilize a series of speakers which sample at 200 Hz and generate their own waves which counteract outside noise.

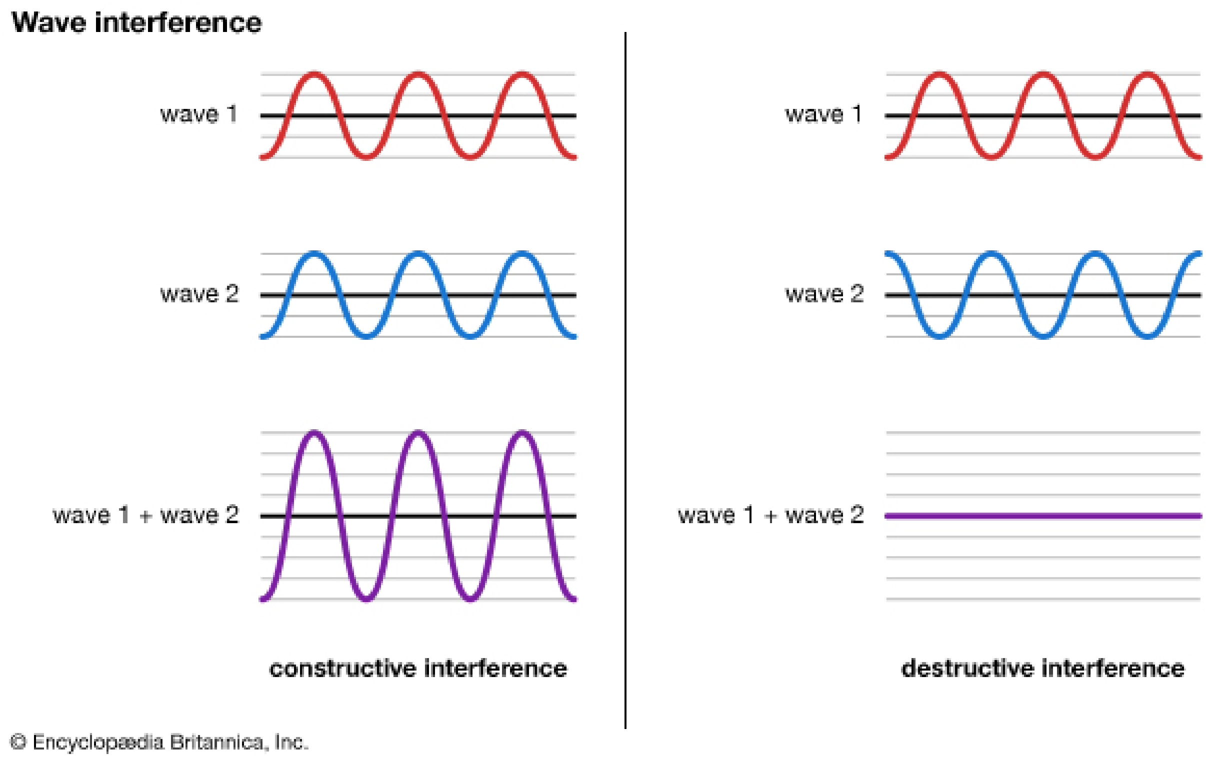

Figure 32: Construction and Destruction Interference

PNC and ANC are often used concurrently due to their synergistic effects. PNC is more effective at high frequencies (typically above 300Hz). The damping factor for PNC materials depends on shape, density, thickness and a number of other factors. ANC tends to be more useful for damping low frequency noise. The effective ANC range depends on the sampling rate (recall Nyquist Theorem principles) and the delays built into the system. By pairing the two systems, one can typically mitigate noise at a large range of frequencies. Our team will be exploring both noise mitigation strategies and testing a variety of techniques to lower ambient noise levels for more effective VUI usage.

7.3.1 Passive Noise Cancellation

Passive Noise Cancellation (PNC) utilized sound absorbent materials to dampen noise in a given environment. As previously mentioned, PNC is more effective for high frequency noise. 300 Hz is the typical minimum frequency where PNC is effective. Lower frequencies are less susceptible to physical objects interfering with their signal. A useful analogy is 2.4 GHz vs. 5.5 GHz Wi-Fi. If you have dual frequency Wi-Fi at home or work, you will notice that the 2.4 GHz signal has better range, especially when there are walls between you and the router. Although the data rate is lower at this frequency, the signal itself experiences less interference so it has greater range. The dual frequency routers are often installed so that you can have high data rates near the router, but also get solid range throughout your home/office (35,36).

When deciding on passive noise cancellation two the main factors to consider are the Noise Reduction Coefficient (NRC) of the material and the placement of the material. The NRC is a standard measurement of how much sound a material absorbs on a scale of 0.0 to 1.0. This value is calculated by producing noise at specific frequencies (250, 500, 1,000 and 2,000 Hz) and measuring how much noise is reflected off the materials. A NRC of 0.0 indicates that all noise is reflected, whereas a NRC of 1 means the material is absorbing 100% of the noise proportional to its 2D surface area facing the noise source. It is possible to have an NRC over 1 using geometry where the surface area is not proportional to the 2D projected surface area. One example of this usage is an anechoic chamber (pictured below) where the objective is to reduce noise as much as possible. Such walls are excellent at reducing noise levels, but they require a large amount of volume and surface area.

Figure 33: Anechoic Chamber with PNC Dampening

The NRC is affected by more than just surface area. The thickness of the material also affects how much noise is reflected. Having greater thicknesses allows the material to more gradually absorb the pressure waves which reduces reflection.

Such walls are excellent at reducing noise levels, but they require a large amount of volume and surface area. With spacecraft we want to minimize our PNC mass and volume, while also leaving enough surface area in modules to other equipment. There are several types of noise reduction materials, but we are exploring foams because of their low mass properties. After researching different PNC solutions & applications, we have determined through a trade study that the following 2-part strategy will have the best specific noise reduction (dB reduction per unit mass) while remaining inert to astronaut activities.

1. Surround large noise contributors with PNC at their source

2. Design module interior and add PNC with the remained of the surface area

Part 1 of this strategy helps limit the total mass, volume and surface area of foam needed to reduce noise. Large contributors such as pumps can have PNC installed around them so less of the noise reaches larger areas. Part 2 of this strategy will further diminish noise in the crew quarters, including reverberation/echo from astronauts without interfering with their activities. The main principle is to install all required equipment and then fit PNC around remaining areas. This foam provides both a safe environment for astronaut movement and can further diminish background noise (36).

Selecting foam properties requires testing of different samples due to the relative lack of data on thickness, density and shape effects on NRC. BLiSS has purchased a variety of foams from commercial suppliers and has built a testing mechanism to examine dampening effectiveness. Since there is documentation on the effect of material thickness, we have decided to fix our thickness to 2 inches and vary the density and shape. We can then extrapolate data for different thicknesses and determine what dampening we can achieve for a given mass/volume requirement.

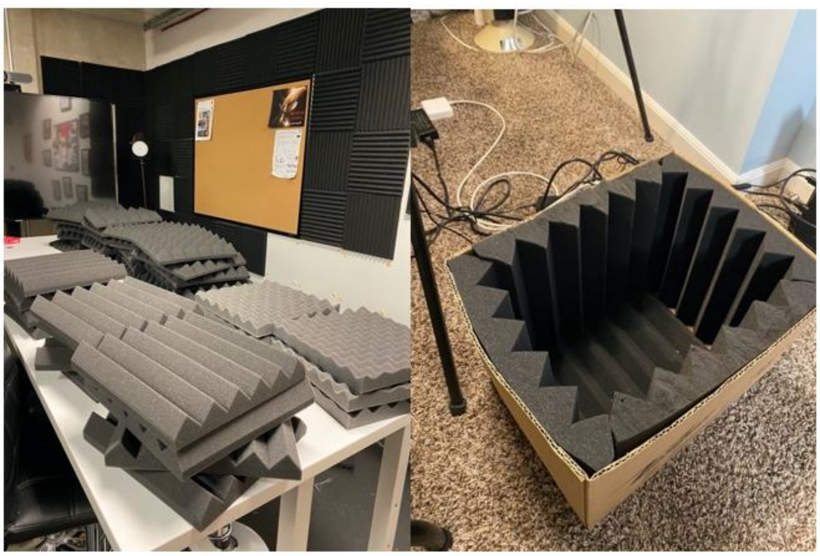

Figure 34: BLiSS 2" Foam Samples (left) and Mounting Box Prototype (right)

This testing process will commence in the BLiSS lab in February of 2021 once the labs have reopened. Figure 26 illustrates the PNC testing setup that has been designed & constructed by the Noise Research team. The test system will generate a noise inside the mounting box and capture noise data inside and outside the box. The test will be run for each foam sample we purchased and compared to determine the optimal shape and thickness for use in future missions. These results will be shared with NASA at the X-Hab final presentation in the Spring of 2021.

7.3.2 Passive Noise Testing

The objective of the work done in the passive noise space is to test the ability of a given foam sample to mitigate the sound produced from a uniform source at a known frequency. To do so, four foam samples were selected to undergo testing. Each sample was fitted to the inside of cardboard boxes to create a noise reduction box for a given sample to be used in the testing setup described later in this section. The four samples are shown below and can be described as the following:

Sample A - 2” vertical cuts
Sample B - 2” diamond cuts
Sample C - 2” Wave cuts (egg crate)
Sample D - 1” Vertical Cuts

Figure 35: Foam Box Samples

To measure the noises tested, the noise testing required two microphones, a reference to measure the instantaneous noise (in decibels), and a DAQ microphone that is reading data to the computer in the form of voltage responses. The reference microphone selected is the FLIR Extech Digital Sound Level Meter 407730, and the DAQ microphone is the Adafruit Electret Microphone

Amplifier Max 4466. The testing setup for the foam sample testing is shown below, featuring the two microphones mentioned, a Raspberry Pi 4B running a code to produce a noise of a known frequency, and the corresponding speaker system to output the noise. Lastly, a computer running a LabVIEW program that reads in the DAQ microphone data and writes it to file.

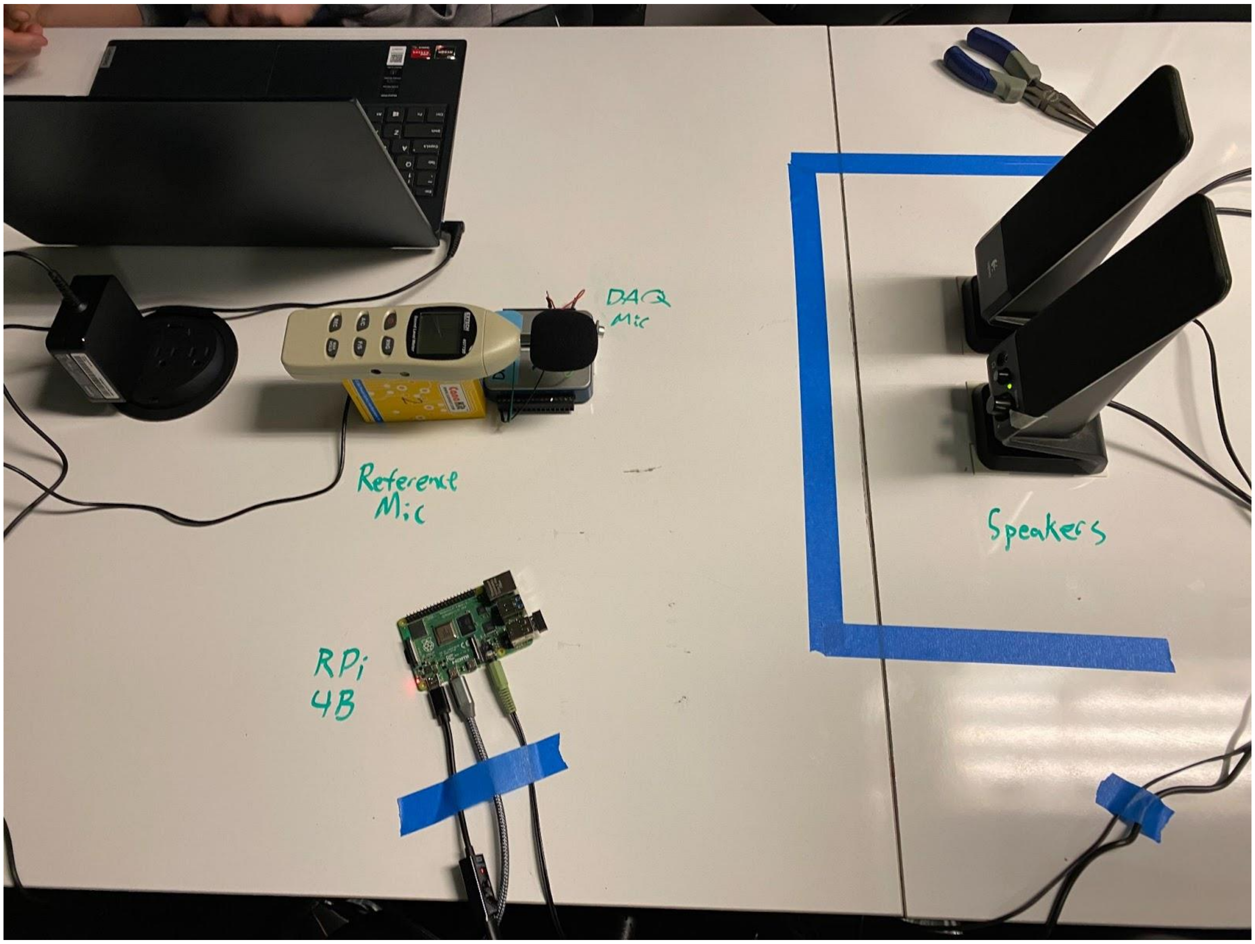

Figure 36: Passive Noise Test Setup

During testing there were two main phases, first the baseline noise output needed to be characterized. To do so, the ambient sound was recorded, then at multiplying intervals (doubled) from 100-6400 hertz, a sound was produced, and recorded on both microphones. The second phase is the actual foam testing in which, for each sample the box was placed over the speakers and the same noise output progression was recorded. This produced data relating to the ability for each sample to reduce the standardized disruption noise. The data products for these tests are shown below, where we can visualize the reduction in noise due to a given foam sample at a given frequency.

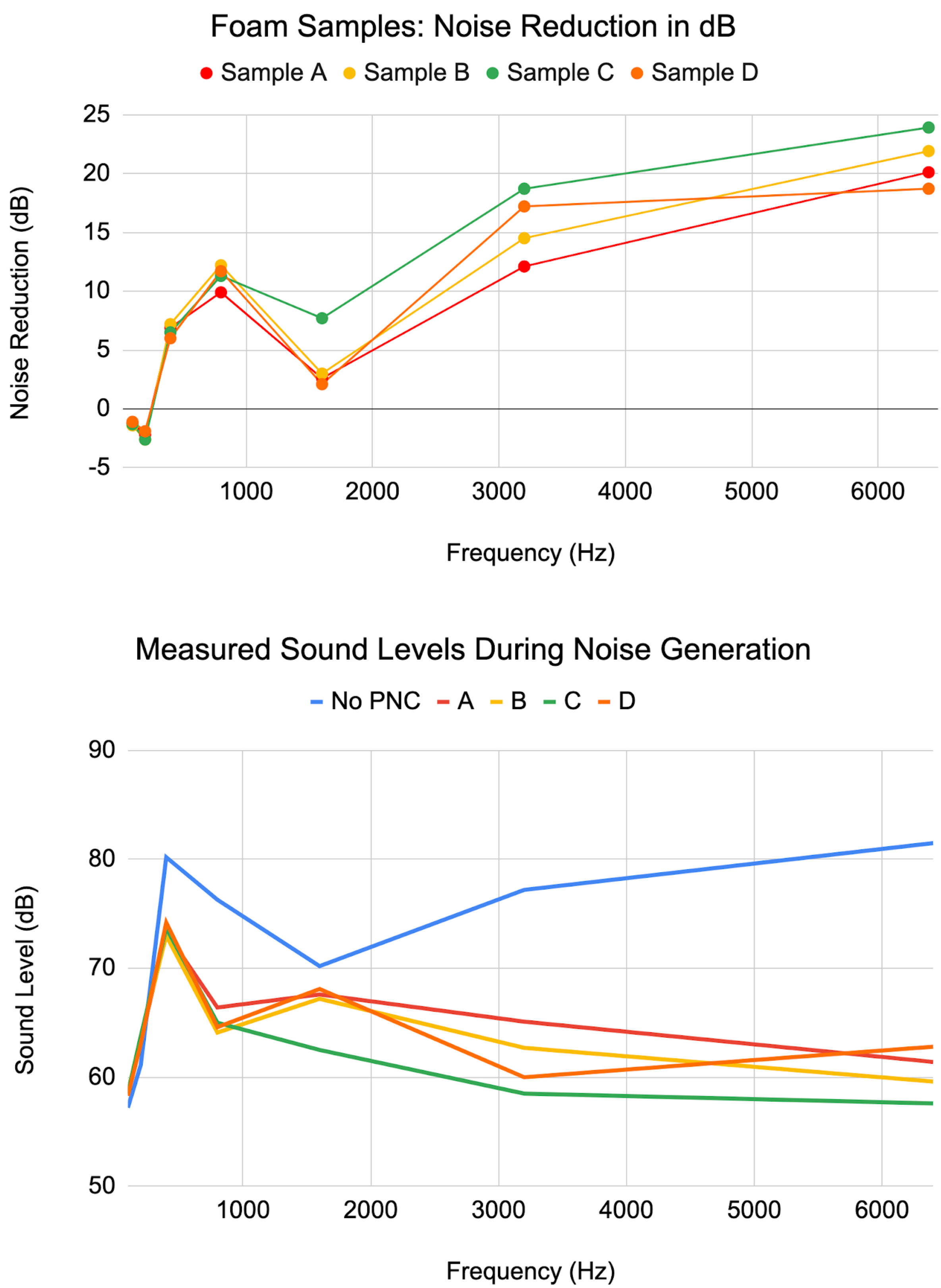

Figure 37: Foam Sample Data Results

To reiterate the main objective of this subsystem, the background noise and mitigation system aims to achieve a signal to noise ratio greater than 20dB. Tied to this effort the deliverable implementation of the signal to noise ratio aims to reduce a 70dB sound to 50dB, such that any voice commands spoken at 70dB or above can be registered by the VUI.

What can be noticed from the foam sample testing is the variation of noise reduction based on the disruption frequency. For frequencies under 800 Hz there is very minimal noise reduction, however for higher frequencies the data demonstrates that passive noise cancellation is near suitable to achieve a 20dB signal to noise ratio standalone. This conclusion is fairly consistent across all of the foam samples, as we see a signal to noise ratio greater than 15dB for frequencies above about 4000 Hz, even for the poorest performing foam sample. It is commonly known that low frequencies can prove to be difficult to mitigate due to the long wavelengths, but with increased foam thickness we can achieve increased sound reduction.

Of the four selected foam samples, the 2” waveform cuts provided best noise reduction for most all of the tested disruptive frequencies. As expected, the 1” and 2” vertical cut samples perform very similarly, with the diamond cuts slightly outperforming those as well. The waveform, most commonly referred to as an “egg crate” design provided the best performance, likely due to the rounded edges of the foam which allows for more multi-directional sound dampening.

7.3.3 Active Noise Cancellation

Active Noise Cancellation (ANC) utilizes the power of digital computing to analyze noise and create “anti-noise” which causes destructive interference. This principle is more complicated than PNC but still reasonable to implement in spacecraft. There are several components that are needed to run a successful ANC setup

1. Microphones
2. Digital computing module
3. Speaker(s)

There are two types of microphones used in ANC setups. The reference microphone is used to measure the original noise signal that needs to be attenuated. The error microphone measures the resulting noise level once ANC has been implemented to ensure that the system is working at optimal levels. These microphones can be 1 single mic, but more often there is an array of reference microphones and at least 1 separate error microphone. The digital computing module receives the microphone data and analyzes the data to identify patterns. ANC works best on noises with fixed frequencies such as fans and pumps running at steady state (34). Once the module has identified the dominant noise frequencies, it drives the speakers to generate noise at the same amplitude, but at opposite frequency. This so-called “anti-noise” results in destructive interference outlined in Figure 25 which reduces the overall background noise.

There are a few key tradeoffs between ANC and PNC. ANC can be effective at low frequencies (on the order of 100Hz) where PNC does not provide much attenuation. The drawback of ANC is the complexity and implementation of the systems. ANC systems need to correctly identify the frequencies and phase of the original noise to successfully deploy “anti-noise”. Failure to do so can actually result in constructive interference which *increases* the noise environment. To determine the feasibility of implementing this system on spacecraft, the BLiSS Noise Research team is attempting to build their own ANC system and test open-source ANC algorithms. These different algorithms will be tested for a variety of input frequencies to see which algorithms most effectively reduce the potential noise spectrum on spacecraft.

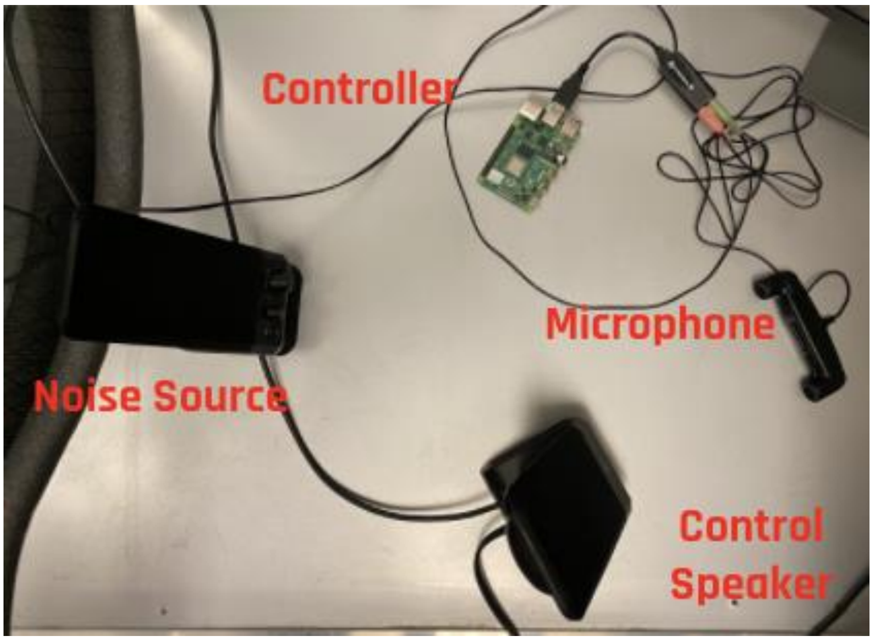

Figure 38: BLiSS ANC System

7.4 Combination of Noise Cancellation Methods

As stated at the beginning of this section, our goal is to reduce the noise environment so that astronauts can speak at a reasonable level when interacting with the VUI. To obtain the best noise reduction, a combination of PNC and ANC needs to be used to cover the range of noise frequencies experienced on spacecraft (34,23).

As of now, our plan is to independently test our PNC and ANC setups to determine the optimal setups for each system. We will then combine the two systems by running the PNC test with the addition of an ANC algorithm. Our hope is that the combined system will be able to reduce 70dB of noise across a broad range of frequencies down to ~50dB. We will also create trade diagrams illustrating how adjusting factors such as PNC foam thickness and ANC algorithm sophistication can improve noise reduction. Our VUI testing will most likely occur remotely for the remainder of this project, so we will not be able to implement the noise reduction system into the VUI environment. The final deliverables for this portion of the project will be to present our data and recommendations for a theoretical background noise mitigation system for spacecraft that want to implement VUI systems.

7.5 Noise Mitigation Recommendations

Based on our active and passive noise cancellation studies, we recommend the following strategy for reducing noise in the spacecraft environment:

1. Passive noise cancellation foam should be placed around noise sources such as fans and pumps. The shape and thickness of this foam should be determined based on the dominant frequencies and amplitude as measured on the ground
2. A quality active noise control system should be implemented within the VUI microphone system to filter background noise without adding system mass.

Our first recommendation is the direct result of our PNC testing in the lab. Foam samples had varying dampening properties depending on the frequency of the noise, so going with a case-by-case basis should result in the best dampening properties for each noise source. One alternative idea was to cover all surfaces in crew areas with PNC, but this would add additional mass compared to surrounding the sources themselves with the foam.

Our second recommendation is the result of testing open source and industry ANC systems. We experienced an array of issues with the open-source codes, and even when they were operational the results were too inconsistent to conclusively quantify their effects. In contrast, NVIDIA's RTX Voice has a proven track record of being able to cancel our constant and discrete noises thanks to its AI-based infrastructure. This option will likely be expensive and require a partnership with NVIDIA, but it would result in superior ANC and allow astronauts to speak rather quietly even where machinery is present.

We believe that combining our PNC and ANC can result in a >30dB reduction for a noise environment with dominant frequencies above 3,000 Hz and >20dB reduction for noise environments with a dominant frequency above 800 Hz.

8 System Integration

To create a human-centered, intuitive, and interactive experience with the Gateway Lunar Station, we aim to deliver an out-of-the-box solution that comprises two modules: *Speech-to-text (STT)* and *Natural Language Processing (NLP)*. It shall provide an accurate and responsive command relay for daily routines on Gateway through a robust voice-based interface.

The *STT* module handles the following tasks:

1. **Monitor** its surroundings and **Invoke** speech-to-text transcription service when "Hey Diego" is heard.
2. **Listen** and **Transcribe** audio into text until the current session has finished.
3. **Package** and **Deliver** transcribed text to NLP for user intent extraction.
4. **Provide** real-time voice user feedback.

The *NLP* module handles the following tasks:

1. **Extract** user intents and categorize them on a set of pre-defined criteria.
2. **Generate** G2-compatible executable command sets.

To reiterate, the goal of these components is to emulate a personalized voice assistant that takes in audio inputs, parses for executable intents, and provides real-time feedback to the current user to inform status or completion rate on demand. It bridges the G2 interface (provided by NASA) and astronauts onboard. The complete system architecture is shown below in Figure 39.

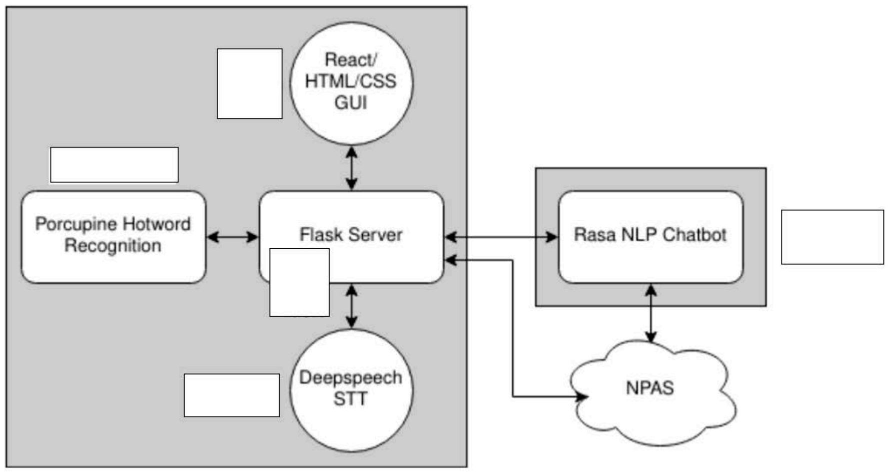

Figure 39: System Architecture

It is worth noting that all requests and hand-offs are routed through the Flask server shown in Figure X (above). It coordinates the activation sequence of modules, providing a synchronous and coherent user experience and allowing for centralized error-handling and fail-state implementation.

The complete package shall run on a *POSIX*-compliant operating system and is currently under development in Ubuntu 20.04 LTS prior to migrating to two Raspberry Pi's running CentOS 7 for integration testing and workflow validation.

8.1 Speech-to-Text (STT)

The STT module has been sourced to optimize for ease-of-use, modularity, and compatibility. It is required to be functional without an internet connection. This requires localized machine-learning and advanced neural networks that provide intuitive feedback as well as an acceptable level of transcription accuracy.

In the preliminary study phase, we determined that modularity is at the core of an integrable and easy-to-use solution. Thus, we proposed to proceed with *three* independent subcomponents that would accomplish the task at hand:

8.1.1 Porcupine by Picovoice (Hot Word Recognition)

A hot word (as known as “wake word”) is a custom key phrase that triggers a sequence of pre-programmed events when heard. It serves as only interactive entryway to a complete sequence run to its intended users. We have selected “Hey Diego” as the hot word for our implementation.

Porcupine (by Picovoice) has been selected out of the three potential candidates (*Porcupine, PocketSphinx, and Precise)* due to its detailed documentation and ability to train models on their distributed server at no cost. Shown below in Figure 40 is a summary of the three candidates.

Libraries	Porcupine	PocketSphinx	Precise
License	Apache-2.0	Carnegie Mellon University	Apache-2.0
Size	64 Mb	202 Mb	0.448 Mb
Accurate	Yes	No	Yes

Table 8: Hot word trade study

Porcupine runs silently in the background as soon as the physical hardware on which it is being host powers on. Anything other than Hey Diego does not trigger the event sequence. We have thoroughly tested it with the following phrases and **none of them** were misinterpreted to trigger an event run.

1. “Hey water bottle”
2. “Hi computer”
3. “Hey computer”
4. “Hello world”
5. “Hi”
6. “Hey” <Pause for five seconds> “Diego”

Furthermore, we have simulated a power outage by terminating the Flask server during a workflow run. Triggering the event run in such state did not result in core dump or segmentation fault. Our implementation allowed Porcupine to run separately and would notify the user of its current state despite the status of said Flask server. This attests to its being modular and intuitive to both end users and the developer team.

8.1.2 DeepSpeech by Mozilla (Transcription)

DeepSpeech is an open-source speech-to-text transcriber based on Baidu’s years of research (arXiv:1412.5567v2) on relevant topics. It uses Google’s TensorFlow to make the implementation easier. DeepSpeech is simple: it lets the user speak and uses a pre-trained model on a chosen language to generate text. Its accuracy can be vastly improved by complementing the transcription process with a scorer. This was chosen not only because of the promising and exciting results that relevant research has shown, but more because of the ever-growing community of developers centered around Mozilla's core values: open-source and privacy.

Figure 40: Mozilla DeepSpeech

We have conducted extensive testing on a set of commands produced by the conversation design team that are reflective of real use cases. The results are very promising: over 90% of the words we said were accurately transcribed verbatim. A higher accuracy could be theoretically if we trained our model. However, due to time constraints and insufficient background knowledge of machine learning, we have chosen to use the pre-trained English model as well as its complementary scorer from the latest stable release (v. 0.9.3).

8.1.3 Coqui by Coqui.ai

Coqui is an advanced, embedded, and offline Text-to-Speech generator under a copyleft license. It leverages the latest research and offers a wide selection of pre-trained models for developers' convenience. It takes a text input and articulates it back to you in a natural, human voice. This functionality is used throughout our implementation to generate real-time voice feedback for the current user. Coqui is supported on all major platforms (Linux, MacOS, Windows) and system architectures (Intel x86 and ARM). Furthermore, it has APIs for numerous languages (Python, C/C++, Java, JavaScript, .NET, etc.). This affords us quantifiable compatibility as well as modularity.

Figure 41: Coqui.ai TTS conversion layers

8.2 Natural Language Processing (NLP)

The NLP module is required to understand the requests made by the user by extracting intents and entities. Intents are the intentions behind the user's queries. Entities are important pieces of data within the queries that may be used as input data for the underlying task performed in response to the query. This module takes text requests from the STT module and interprets them to perform the action requested by the user.

The NLP module was sourced to optimize ease-of-implementation and workflow fit. It is required to be functional without an internet connection. This requires machine learning and advanced neural networks to pre-train a language recognition model for intent recognition and entity extraction.

Through the preliminary study phase, we determined that ease-of-implementation with a good conversation design workflow fit would be optimal for implementing a solution efficiently from existing conversation data. Thus, we proposed a chatbot-building framework to accomplish the task:

8.2.1 Rasa Open Source by Rasa (NLP and Chatbot Framework)

Rasa Open Source is an open-source framework for building complex chatbots using NLP technology. It leverages various underlying technologies including machine learning framework Tensorflow for training, NLP framework spaCy for tokenization and language recognition, and Duckling for entity extraction. Rasa provides an all-in-one package which simplifies chatbot creation by reducing training to a simple task of entering structured conversational data.

Rasa was chosen for a few reasons, the biggest being its all-in-one packaging, including all elements needed to create a functional chatbot. Because of this, very little setup was necessary to get started with implementation. Rasa also provides a built-in REST endpoint to receive input from an external program or source, thus allowing simple integration with the STT module. The structure of Rasa's training data fit closely to the work of the conversation design team, allowing an efficient transition between conversation design and chatbot training. While simplifying the chatbot creation process, Rasa still allows complex configuration and training through language processing pipeline modification and a built-in action server which runs Python code.

9 Usability Testing

To ensure our VUI is working efficiently it is important to conduct Usability Testing. Due to time constraints the team was not able to conduct this testing but below we detail the methodology of such tests. Within usability testing we consider the user interface (UI), the user experience and usability. User interface is the point of contact to facilitate human-computer interaction. User experience (UX) is the practical, meaningful, and valuable aspects of interactions with the system. Usability is a measure of how well the user can use a design. An example of these categories uses ketchup bottles as seen below (61).

Figure 42: UI vs. UX vs Usability by challenged users

The glass bottle on the left-hand side represents the UI because it is "workable". It is a solution that works and meets the user's requirements. The bottle in the middle represents the UX as an improved design experience that makes it easier for the user to get the ketchup out of the bottle. However, this design did not account for usability. That ketchup skin that builds up around the lid diminishes the experience (as shown in the far-right bottle image). A lot of users reported that ketchup explodes out of the bottle when the cap is opened, resulting in stained shirts and other messes. Usability testing identifies these weak points.

Figure 43: Usability testing process

Usability testing identifies weak points in a design by creating the opportunity to gather and triangulate performance, self-reported, and observational data. We will be testing across three industry-standard usability metrics. These metrics are discussed below.

9.1 Metrics

These tests are valuable because they allow us to triangulate performance, self-reported, and observational data to derive insights into how to improve the overall system from a UI, UX, and Usability standpoint (32). We test across 3 industry standard usability metrics, success (performance), ease of use (self-reported), and usability (self-reported).

Figure 44: Usability metrics combine performance and self-reported data with observations

Success

The first task is to measure success. For success criteria scoring and differential, each usability test is made up of several tasks, and each of these tasks are broken down into the specific steps required to complete the task. All these steps are put into a spreadsheet, and each participant's performance is scored on each step. Scores range from –1 (Fail/needed help), 0 (Pass/struggled but succeeded), 1 (Success/no problems). Calculating the differential (SUM - COUNT) provides human performance data and yields insights into where the users struggled the most. Success rate is calculated using the following formula: Success + (Pass*0.5)/Attempts

There are certain aspects we want to test for in our VUI. We will consider these features as we move forward. We are going to look for:

- Natural conversation – do users sound conversational? Or does it seem like they are constrained to short phrases? Do they feel comfortable with the persona?

- User confusion – Are they confused? Why?

- Unexpected utterances – Did they say something we didn't expect?

- Frustration or impatience – We probably have to revise to be more concise if the user is experiencing this.

- Who's in control of the conversation, the user or the system? – If users aren't in control of the conversation, we should probably change it.

Ease of use

Ease of use is self-reported data through responding to the single ease questions. At the end of each task, test subjects will be asked how difficult or easy the task was to complete on a 7-point Likert scale. Then we calculate the average and compare it to the historical average of 5.5 (55). Below is an example of a chart plotting the results from the single ease question. This is the self-reported data of how easy or difficult the test subject felt the interface was. Often, this chart will sync up with what's revealed in the previous chart, but sometimes a subject may not have any issues with the interface, but reports the task as being difficult, and that is of particular interest to us.

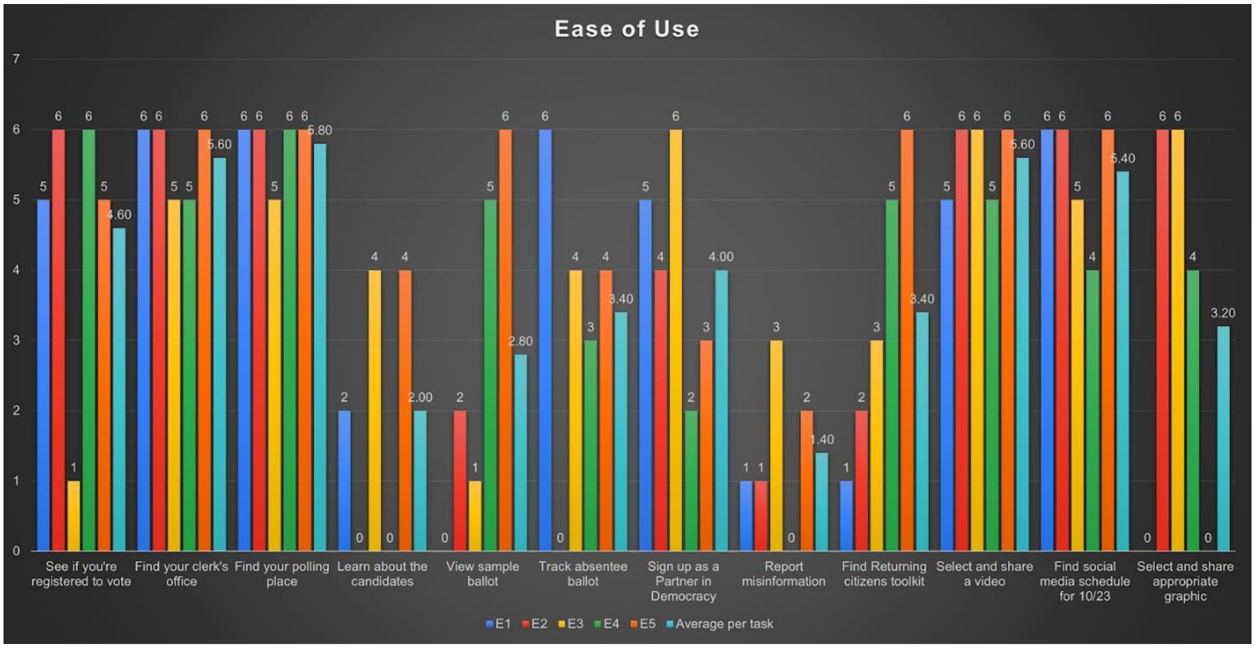

Figure 45: Ease of use results from single ease of use questions

Usability

To measure usability, we use a system usability score. We will use this System Usability Scale (SUS) because it is the industry standard. This is a 10-questions survey administered after all tasks are completed and the responses are then aggregated into a SUS score. The average SUS score from years of historical data is 68 (55). What usability engineers have found is that a 10-question survey is a little long and diminishes the value of the subject's feedback following an hour to hour and a half long test session (e.g., people are more likely to tell you what you want to hear so they can get out of there).

Another aspect to consider is the usability metric for user experience (UMUX). Seeking to improve the quality and reliability of the feedback from a post-test questionnaire, in 2010, Intel researcher Kraig Finstad developed the usability metric for user experience, or UMUX. UMUX cuts the questions down to 4, with 2 positive and 2 negatively framed questions. Yet, they still found this questionnaire too long, so they developed and validated UMUX-lite. Researchers at IBM went even further, scrutinizing the efficacy of using both positive and negative questions. According to their research, they found they can acquire a similar quality of feedback from simply asking participants the 2 positively framed questions. This metric is referred to as UMUX-lite (50). UMUX-lite asks test subjects to rate their level of agreement to the following statements on a 7-point Likert scale: 1) This system’s capabilities meet my requirements; 2) This system is easy to use. In order to standardize and communicate UMUX-lite scores to other stakeholders and usability professionals, the researchers at IBM developed a regression formula to convert UMUX-lite scores to the more widely recognized System Usability Score. This formula is as follows: UMUX-L = ((a. / 7) + (b. / 7))/2 * 100

Below is a chart showing the results of the UMUX-lite, whether the system's capabilities met the user's requirements and if the system is easy to use.

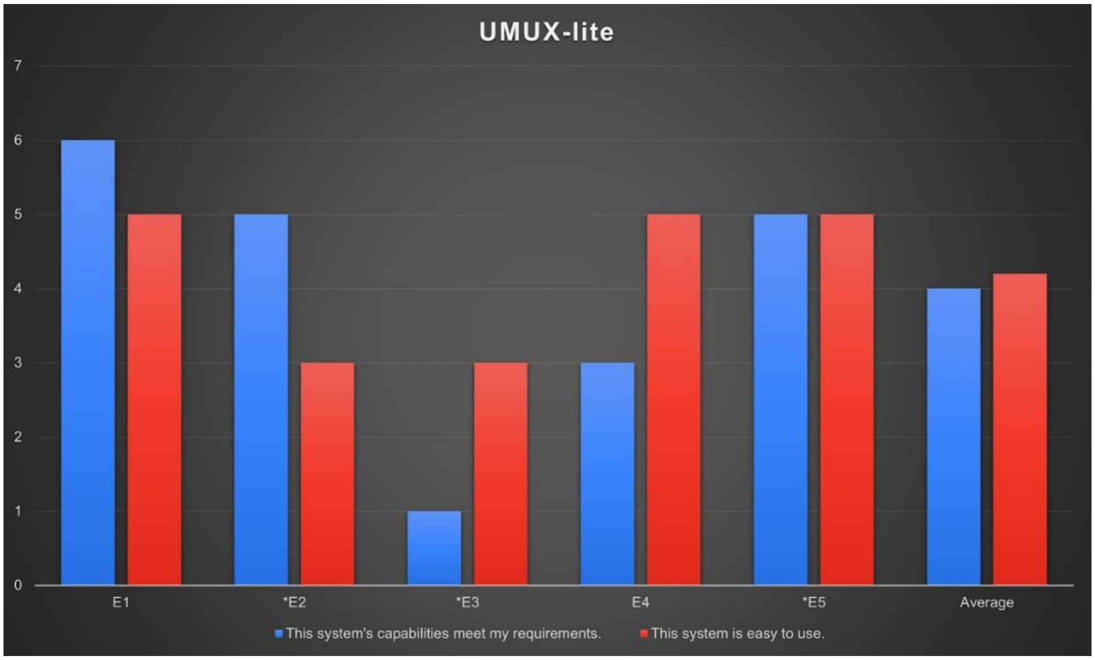

Figure 46: UMUX - Lite user analysis

Below is an example of a chart that was made by one of our team members from the success criteria scoring from a round of usability testing on a project for the Michigan Department of State. When analyzing this chart, we care the most about the bottom line, we want to be able to quickly identify the steps in test where the users had the least success. Those points in the interface are going to be prioritized in the recommendations for how to improve. We will create something similar for the VUI we are working on now.

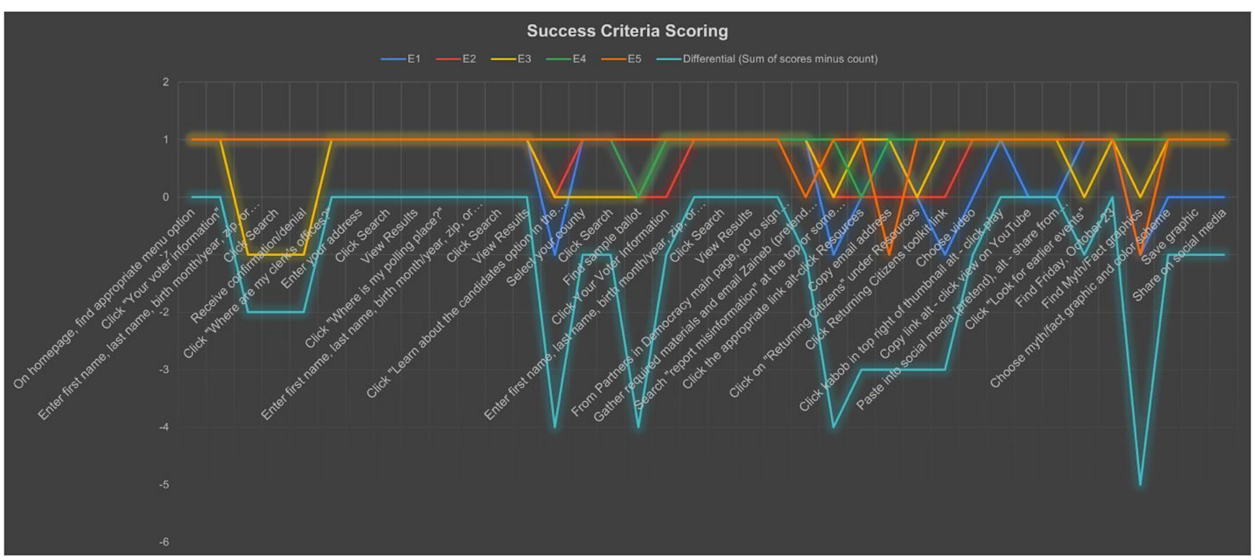

Figure 47: Success criteria scoring chart

9.2 Testing: Wizard of Oz

Wizard of Oz testing is another one of these quick and dirty usability tests that we can perform to uncover design issues before committing it to code. Wizard of Oz experimentation is so called because of the movie. In essence, we can test the prototype dialog without developing any software, because instead of a system we have a person behind the curtains pretending to be the system. This is how you maximize return on investment. We will begin internal Wizard of Oz testing when we reconvene and iterate over the design until we think we're ready for testing with external participants. In both cases, one of our team members will be playing the role of the system. This is quick and dirty usability testing to evaluate functionality, support user needs and improve the experience for maximum return on investment.

Figure 48: Ideal Wizard of Oz test setup. BLiSS would have implemented differently

10. Conclusion

BLiSS has done a lot of work on the NASA X-HAB challenge this year. The possibility of visiting NASA centers to facilitate the robustness of design and presenting our work at conferences external to NASA is currently not possible due to COVID-19 but we hope we have provided a sufficient alternative presentation to those interested in our work.

We have laid the groundwork for developing the VUI with a G2 bridge, designed a user persona, created a user manual for our voice assistant system, made mockups of supporting graphical interfaces, and conducted experiments to find the best methods for mitigating background noise. All these contributions have helped shape our final product and will serve to guide others in their development of voice user interfaces. Despite COVID-19 obstacles, we believe our final product to accurately displays the hard work the entire BLiSS team has devoted to this project.

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Note: Not all references are directly linked to content in this paper. A lot of the references helped guide our thinking and were useful for understanding systems thinking, the Lunar gateway, and UI/UX and VUI interactions with users.

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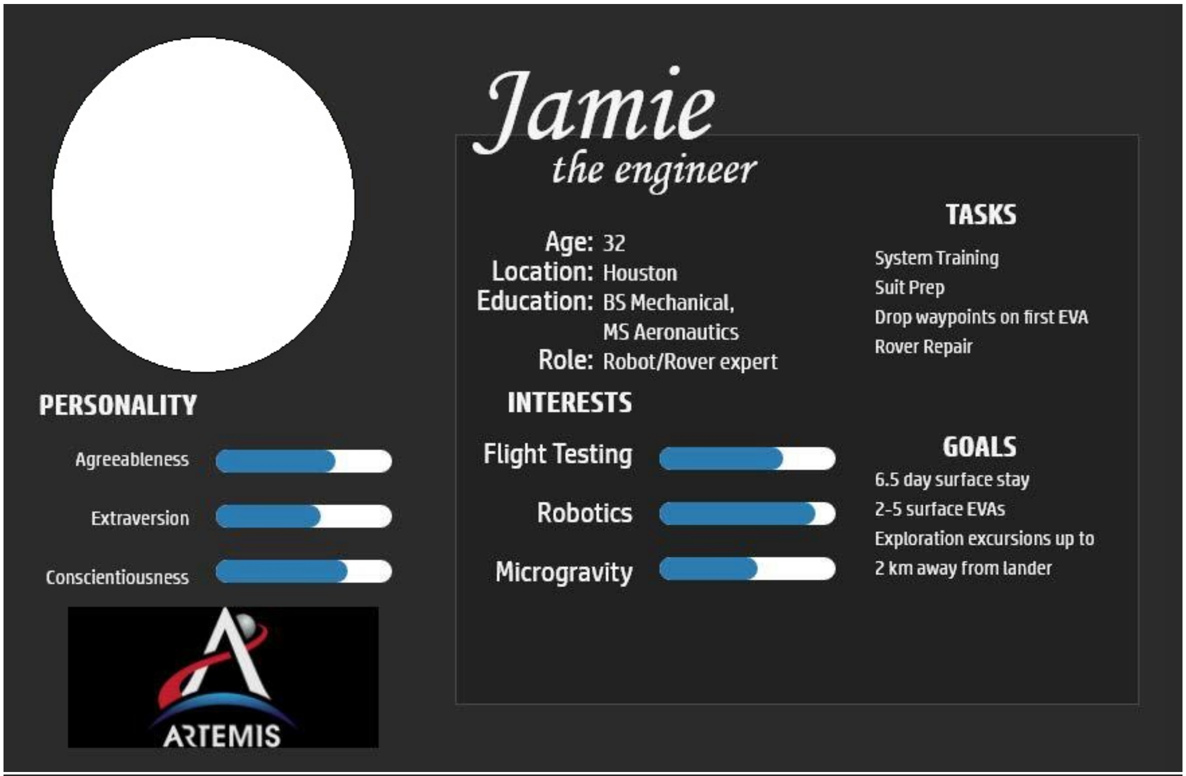
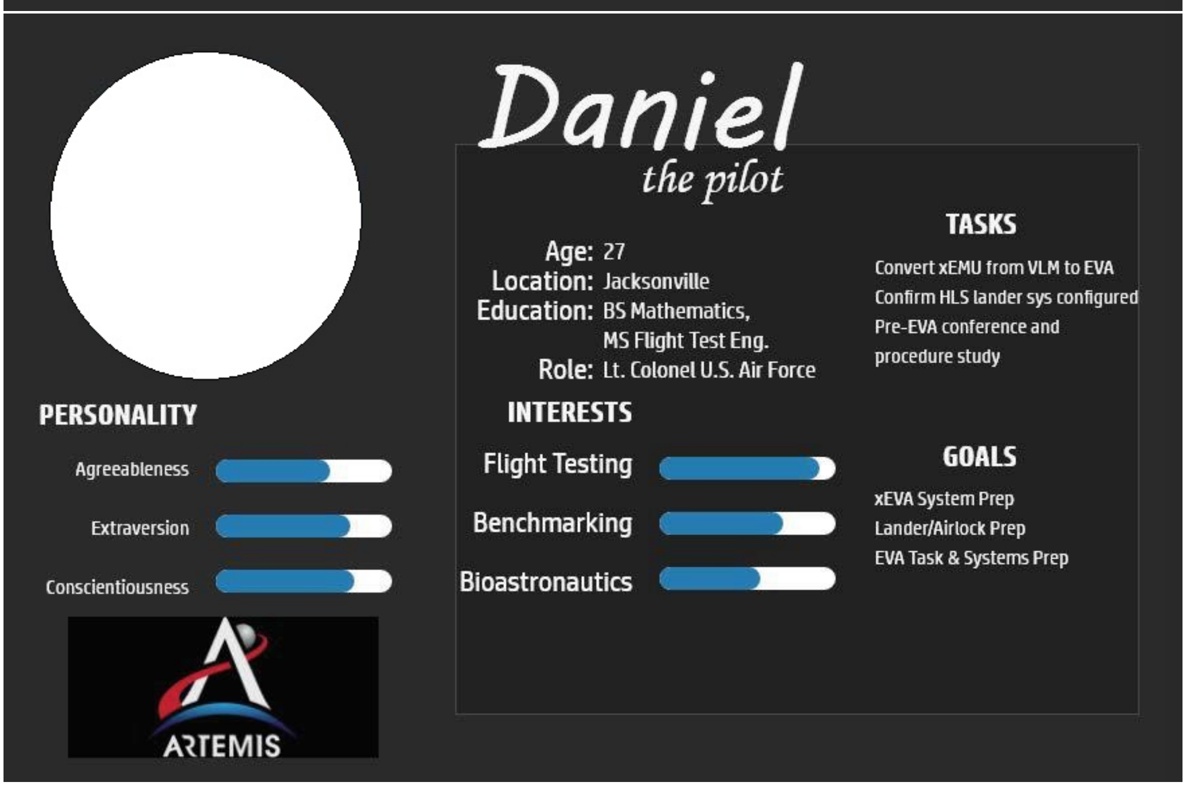
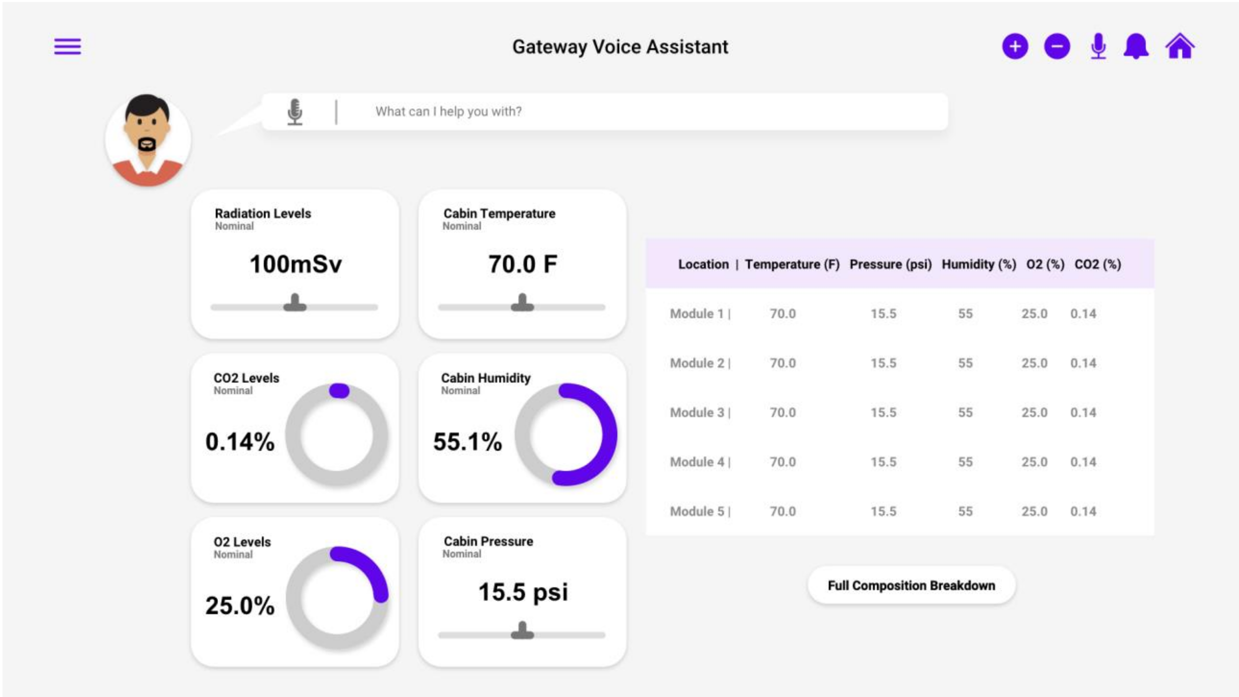
Appendix

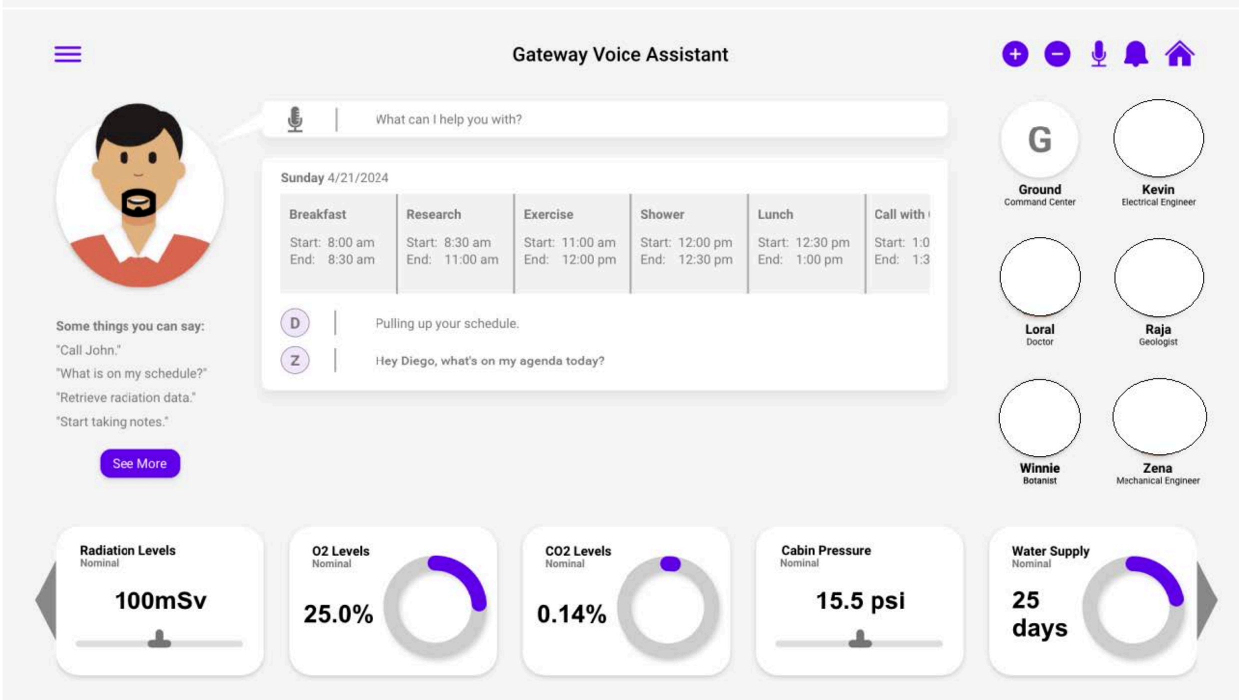
A: User Personas

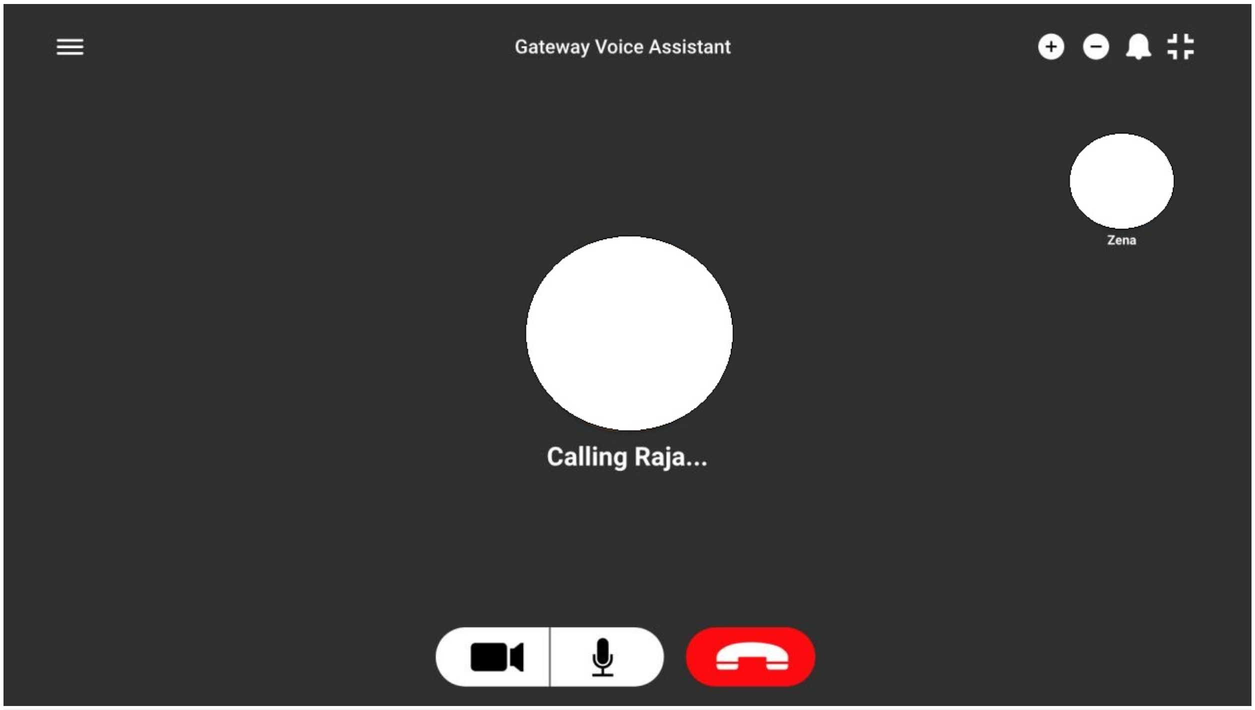


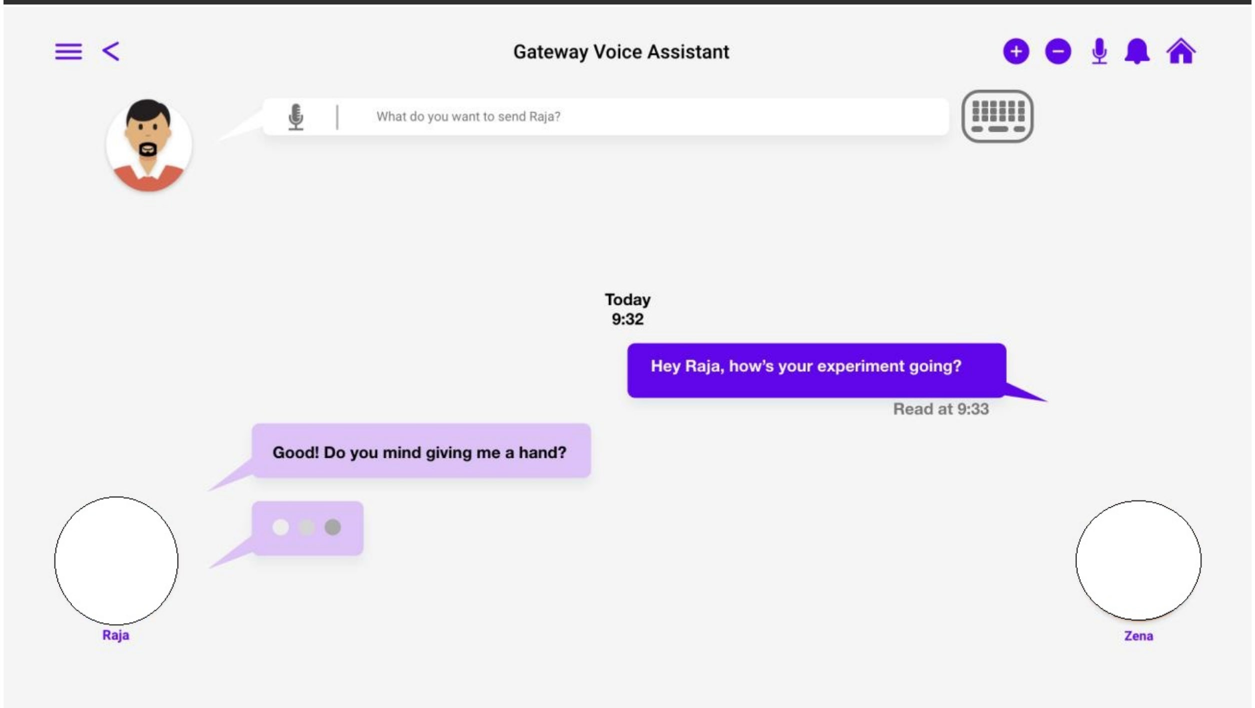


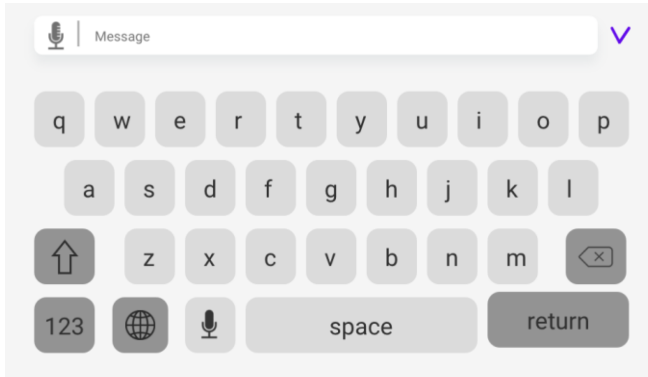
B: GUI Mockups

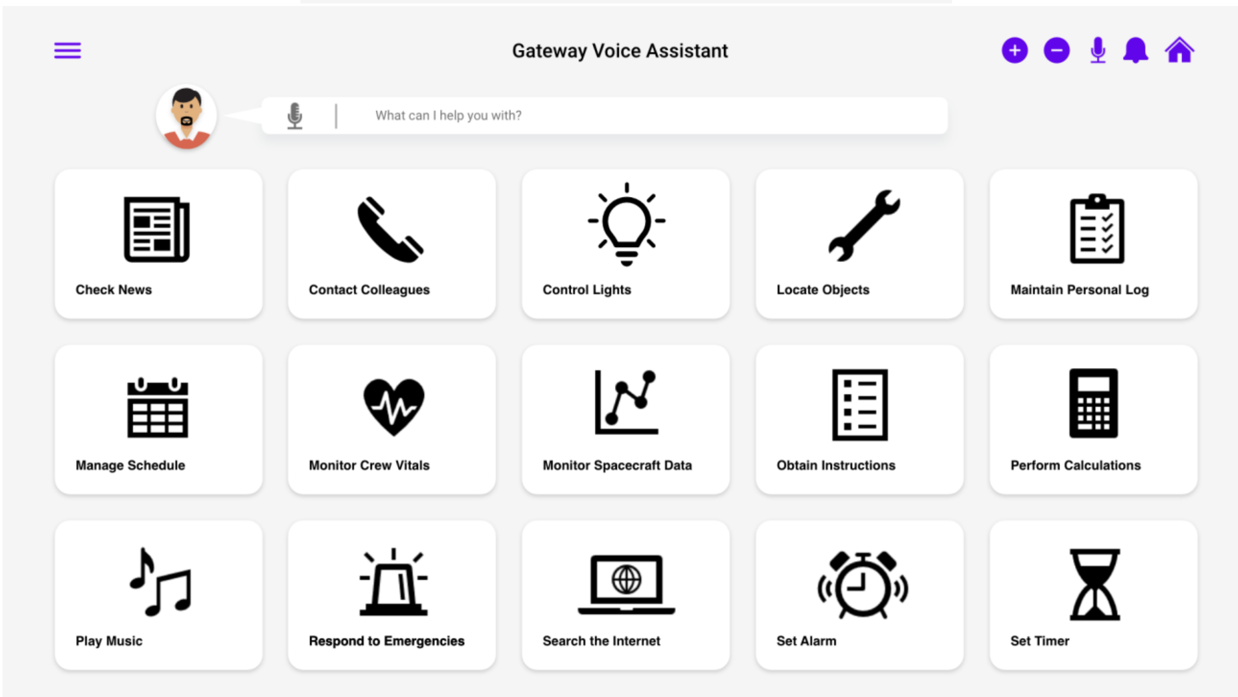





Gateway Voice Assistant
Zena
Calling Raja...


Gateway Voice Assistant
What do you want to send Raja?
Today
9:32
Hey Raja, how's your experiment going?
Read at 9:33
Good! Do you mind giving me a hand?
Raja
Zena


Message
q w e r t y u i o p
a s d f g h j k l
z x c v b n m
123
space
return


Gateway Voice Assistant
What can I help you with?
Check News
Contact Colleagues
Control Lights
Locate Objects
Maintain Personal Log
Manage Schedule
Monitor Crew Vitals
Monitor Spacecraft Data
Obtain Instructions
Perform Calculations
Play Music
Respond to Emergencies
Search the Internet
Set Alarm
Set Timer

C: User Manual

USER'S MANUAL

Voice User Interface - VUI

Bioastronautics and Life Support Systems - University of Michigan, Ann Arbor

May 6, 2021

Rev. 1

Revision Sheet

Release No.	Date	Revision Description
Rev. 1	05/06/2021	Original First Edition

User’s Manual
Authorization Memorandum

I have carefully assessed the User’s Manual for the Voice User Interface

MANAGEMENT CERTIFICATION - Please check the appropriate statement.

______ The document is accepted.

______ The document is accepted pending the changes noted.

______ The document is not accepted.

We fully accept the changes as needed improvements and authorize initiation of work to proceed. Based on our authority and judgment, the continued operation of this system is authorized.

______________________________ ____________________
NAME – Chad Cerutti DATE
Project Co-Leader

______________________________ ____________________
NAME – Catalina Garza DATE
Operations Division Director

______________________________ ____________________
NAME – Lauren Underwood DATE
NASA Representative

______________________________ ____________________
NAME – Fernando Figueroa DATE
NASA Representative

USER'S MANUAL

TABLE OF CONTENTS

Page #

1.0 GENERAL INFORMATION

1.0 GENERAL INFORMATION

1.1 System Overview

The Voice User Interface (VUI) is a voice assistant designed by the Bioastronautics and Life Support Systems (BLiSS) project team at the University of Michigan. It's built to serve astronaut needs aboard the Gateway Space Station with the potential for application to other space structures. Its primary objectives are to:

- Manage crew schedules
- Help conduct tasks by relaying instructions
- Facilitate communication between crew and ground
- Gather information on Station Vitals

The BLiSS team designed a personality for the system: Diego, and his personality should be obvious during interaction. He is readily available to answer specific questions, which are further outlined in section 4.0. For the purpose of this first revision, only Station Vitals will be expressed, but note that the system does have capabilities to access the other 3 objectives.

The system uses Natural Language Processing (NLP) powered by Rasa to make the conversation between user and system more natural, and remove the need for specifically structured queries. As the user, you should be able to access specific commands by using the most common words included, this is explained further in section 4.0. For any issues communicating with the system, please refer to section 4.1. Background noise during communication between user and system has been considered as well, noise on a space station is understood and should not be an issue for communicating with the system.

The VUI is designed to work cohesively with a Graphical User Interface (GUI). This User Interface can be found on tablets and laptops. Any image of the interface can be found below. The GUI currently includes the following key features:

- Messaging text boxes
- Note-taking
- Schedule carousel
- Task instructions visual access to documents
- Station vitals graphics
- Notification and menu pop-ups
- VUI command assistance home screen

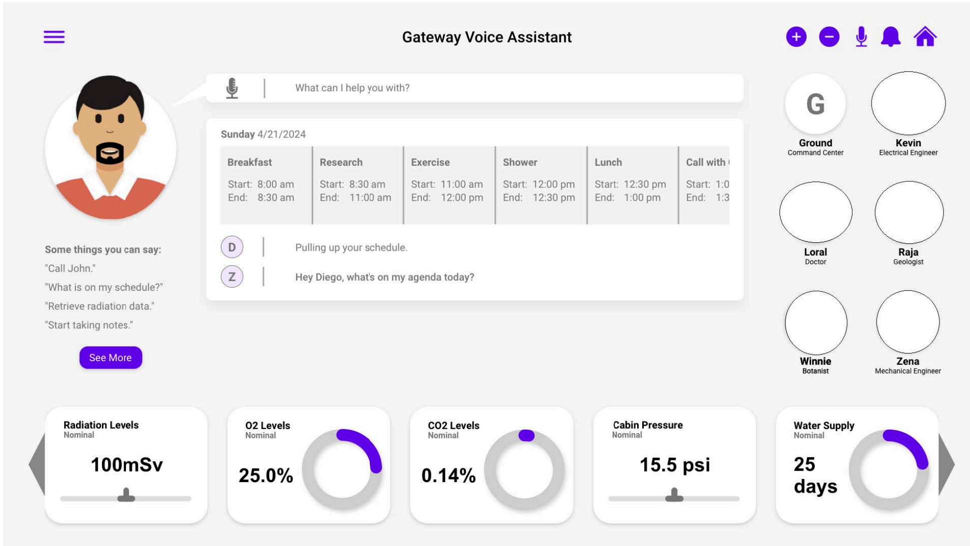


Figure 1 Graphical User Interface example of home screen, users are shown on the right, system vital graphics shown at the bottom and schedule carousel in the center

1.2 Project References

Please reference the paper "BLiSS Voice User Interface (VUI) NASA X-HAB Moon to Mars Academic Innovation Challenge Final Report" for further information regarding the unit.

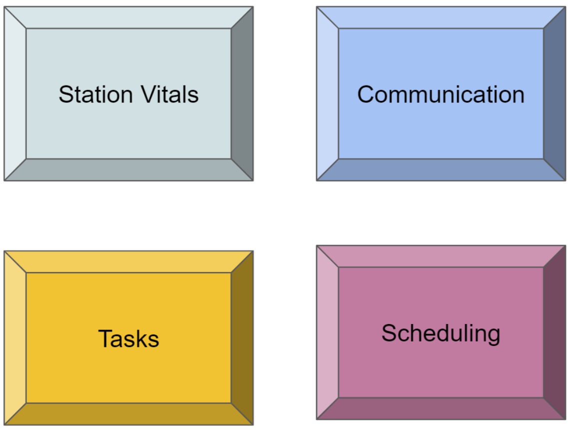
1.3 Points of Contact

1.3.1 Information

Chad Cerutti - Team Leader - ccerutti@umich.edu
Catalina Garza - Team Leader - cafeg@umich.edu
Ariana Bueno – Team Member – aribueno@umich.edu
Tara Vega – Team Member – taravega@umich.edu
Achintya Kattemalavadi– Team Member – akattema@umich.edu

1.3.2 Coordination

Please send an email to any points of contact above with any questions regarding operation of the VUI/GUI.



2.0 SYSTEM SUMMARY

2.0 SYSTEM SUMMARY

The VUI is intended to support astronauts aboard Space Stations, in 4 specific categories: Scheduling, Communications, Vitals Checks and Task Completion. As expressed in section 1.0 *General Information,* only Station Vitals will be fully described in this manual. The conversation between user and system should be intuitive, specific words and commands are explained further in section 4.0 *Using the System.*

The system can be accessed by voice command, or GUI on a tablet or computer. Commands can be entered with the same structure, and responses will be spoken or written depending on chosen start path.

Diego will always be on, listening for the required start phrase which includes the word "Diego" and upon hearing this, the system will respond, and the conversation can begin.

2.1 System Configuration

The system consists of two parts: the NLP server and the speech-to-text server. To set up the NLP server, Python 3 must be installed on the system. After creating a virtual environment, install the dependencies in the requirements.txt file. Docker must also be set up on the system in order to run the Duckling server to handle date and time recognition. Duckling, the Rasa action server, and Rasa NLU must be running for the NLP server to function properly.

The speech-to-text server requires Python 3 to be installed on the system, along with PulseAudio. Once these dependencies are set up, python dependencies can be installed with pip using the requirements.txt file. The Flask server as well as the hotword recognition program must be running for the speech-to-text server to function properly.

3.0 GETTING STARTED

3.0 GETTING STARTED

This section provides a general walkthrough of the system from initiation through exit.

3.1 Turning On

To start the system, use an initial greeting such as:

- Hey Diego
- Diego, can you help me?
- Hey Diego, I need your assistance

An initial greeting should contain the name Diego and may contain a request following it. The request can be general, like the examples above, or more specific to a task (i.e. "Hey Diego, what's on my agenda today?").

The system will give a confirmation that it is listening after an accepted initialization, such as "Hi, how can I help?" Once this confirmation is said, the system is on and ready for use.

3.2 System Menu

The system is accessible by voice or through GUI on laptops and computers. Station Vitals is highlighted as this is the main function of the system, for the first revision of this manual. In general, the system can assist with the 4 following categories.

- Station vitals
- Task instructions
- Communication
- Scheduling

Figure 1 in the system overview shows the User Interface found on tablets and computers. On this main screen, you can access all 4 of the categories listed above. These categories were chosen to ease the lives of astronauts by giving them quick access to pertinent information as well as a hands-free way to communicate with each other and ground.

3.3 Exit System

At the end of a request, Diego may ask if there is anything else you need help with. You can respond in a number of ways including the following.

- That'll be all
- I'm all set
- That's it, thank you
- No
- End

A chime will sound, indicating the system has turned off.

4.0 USING THE SYSTEM

4.0 USING THE SYSTEM

A quick note, the Diego VUI has the capability to assist with the 4 categories discussed in the System Summary, however, for the purpose of this Manual, and the work completed by the BLiSS team over the 2020/2021 school year, only Station Vitals will be covered. Future editions of this Manual may include the remaining command categories - Communications, Task Completion and Scheduling.

The process for asking Diego to gather Station Vital data, should always start and end as described in the "Getting Started" section. Below are the options for accessing the Station Vitals capability. 3 options are outlined which are asking what a specific vital is, with options to ask about specific locations of the space station, and in specific units.

Station Vitals:
The commands can be categorized into three actions:

1. What is the [vital]?
2. What is the [vital] in [location]?
3. What is the [vital] in [units]?

Example commands are as follows:

- What is the temperature?
- What is the atmospheric composition?
- Can you tell me the atmospheric composition?
- How much oxygen is in the atmosphere?
- What is the carbon dioxide in the atmosphere?
- Can you tell me the atmospheric pressure in [location]?
- What is the humidity level in [location]?

An example interaction between a user and Diego is as follows.

User: Hey Diego
Diego: Hey there, how can I help?
User: I would like to know the temperature in module 6, in celsius please.
Diego: To verify, you would like to know the temperature of module 6, in celsius?
*note - the system will always ask a verifying question, to minimize errors
User: Yes that's right
Diego: The current temperature in module 6 is 15.5 degrees celsius.
User: Great thank you.

The system uses natural language processing, so it is not necessary to state a request in only 1 specific way. You may alter the structure of the sentence, for example " What is the temperature in module 6" or " i need to know what the temperature is in module 6". The system will pick up the keywords temperature, module 6, and celsius and be able to respond accordingly.

4.1 Special Instructions for Error Correction

In the case that PulseAudio or ALSA give issues, reinstall PulseAudio and your audio drivers. Sometimes, other programs which use the microphone or speakers may interfere with the hotword recognition and speech-to-text servers.

If there are issues with ports already being used by other programs, reconfigure the ports being used and queried by the hotword, speech-to-text, and Rasa servers.

4.2 Additional Features for Diego/VUI

Moving forward as the team continues to test and finalize the prototype there are additional features that we would like to incorporate into the system. Diego was developed with a specific personality in mind so we will incorporate these characteristics into the responses of Diego. This will include incorporating jokes and alternating between different responses to keep the conversation more human-like.

D: Sample Dialogues

Task Instructions

Edit 1 - Ariana

List of commands we would like Diego to execute

1. **Pull up instructions**
   a. **Go to a specific page or section**
2. **Read out instructions step by step**
   a. **Change reading speed**
   b. **Ask to repeat**
3. **Ask for help (interconnecting with communication dialogue)**
4. **Ask how long task should take or how much time they have left (interconnecting with scheduling dialogue)**

Sample Dialogues:

1. **Pull up instructions**
   a. Hey Diego
      i. Hello, how can I help you today?
   b. Can you pull up instructions for "_____"? / Pull up instructions for "_____" / Could you pull up instructions for "____" (e.g. toilet repair, microgravity experiment, etc.)
      i. Pulling up instructions for "_____" (repeat input) / Yes, pulling up now / Here are the instructions for "____"
   c. Thank you. Can you go to section "__"? / Turn to page "__" / Diego, go to section "___" / Skip to section "___"
      i. Here's section "__" / Turning to page "___"

2. **Read out instructions step by step**
   a. Diego, can you read instructions for "__"? / Read out instructions for "___" / Diego read step by step instructions for "__"
      i. Ok, Instructions for "___" Step 1 … / Ok, I will begin reading instructions for "___"
   b. Diego, slow down / Read slower / Read at 0.5X speed
   c. Diego read faster / Read at double speed / Can you read at 1.5X speed?
      i. Ok, I will read at 0.5X speed. Is this speed ok?
      ii. Ok, I will read faster now, is double speed ok? / Ok, what speed would you like me to read?
   d. Yes / Yes, that's fine / No, read at "___" speed
      i. Ok, I will read at "__" speed (when speed is corrected)
   e. Can you repeat step "__" / Repeat step "___"
      i. Ok [repeat]

3. **Ask for help (interconnecting with communication dialogue)**
   a. Diego I need help, can you connect me with HQ?

4. **Ask how long task should take or how much time they have left (interconnecting with scheduling dialogue)**
    a. Diego, can you tell me how long “___” task should take? / Diego, what is the expected time for completing “____” task / Diego, how much time do I have left to complete this task? (see if we can reference “this task”)
        i. I can get that for you! “___” (task) should take approximately(time) / “___” (task) usually takes about (time) / You have (time) left to complete this task

Station Vitals

REAL Edit 1: Catalina and Chad

Main functions of ECLSS

- Provides oxygen for breathing
- Removes carbon dioxide from the cabin air
- Recovers and recycles oxygen from carbon dioxide to resupply the crew
- Filters particulates and microorganisms from the cabin air and maintains cabin pressure, temperature and humidity levels
- Removes volatile organic trace gases, such as ethanol, that are colorless, odorless and can build up over time
- Distributes cabin air between each room, or module, of the station;
- Provides potable water for consumption, food preparation and
- hygiene
- Purified recycled water from multiple sources back to potable water

System Vitals Monitored

1. Temperature
2. Atmospheric Condition
    a. Composition
        i. Oxygen
        ii. Carbon Dioxide
    b. Pressure
    c. Humidity levels
3. Water/Food Supply

Actions

1. **What is the [vital]?**
2. What is the [vital] in [location]?
3. What is the [vital] in [units]?

Optional Actions

4. How much [vital] do we have?

Options for Each Vital

1. **Temperature**
    a. Options to start conversation
    b. Options for system acknowledgement
    c. Options for Actions
        i. What is the [vital]?
            1. What is the temperature?
            2. Can you tell me the temperature?
        ii. What is the [vital] in [location]?
            1. What is the temperature in [location]?
            2. Can you tell me the temperature in [location]?
        iii. What is the [vital] in [units]?
            1. What is the temperature in Celsius?
            2. Can you tell me the temperature in Celsius?
            3. What is the temperature in [location] in Celsius?
            4. Can you tell me the temperature in [location] in Celsius?
            5. What is the temperature in Kelvin?
            6. Can you tell me the temperature in Kelvin?
            7. What is the temperature in [location] in Kelvin?
            8. Can you tell me the temperature in [location] in Kelvin?
        iv. Tell me [vital] at [time interval]
            1. Tell me temperature at [time interval]
            2. Can you tell me the temperature at [time interval]
            3. Please tell me the temperature at [time interval]
    d. Options for response
        i. Response to Action 1
            1. The temperature is [value] degrees fahrenheit. This is nominal.
            2. The temperature is [value] degrees fahrenheit. This is below nominal.
            3. The temperature is [value] degrees fahrenheit. This is above nominal.
        ii. Response to Action 2
            1. The temperature is [value] degrees fahrenheit in [location]. This is nominal.
            2. The temperature is [value] degrees fahrenheit in [location]. This is below nominal.
            3. The temperature is [value] degrees fahrenheit in [location]. This is above nominal.
            4. The [location] temperature is [value] degrees fahrenheit. This is nominal.
            5. The [location] temperature is [value] degrees fahrenheit. This is below nominal.

6. The [location] temperature is [value] degrees fahrenheit. This is above nominal.

iii. Response to Action 3

1. The temperature is [value] degrees Celsius. This is nominal.
2. The temperature is [value] degrees Celsius. This is below nominal.
3. The temperature is [value] degrees Celsius. This is above nominal.
4. The temperature is [value] degrees Celsius in [location]. This is nominal.
5. The temperature is [value] degrees Celsius in [location]. This is below nominal.
6. The temperature is [value] degrees Celsius in [location]. This is above nominal.
7. The [location] temperature is [value] degrees Celsius. This is nominal.
8. The [location] temperature is [value] degrees Celsius. This is below nominal.
9. The [location] temperature is [value] degrees Celsius. This is above nominal.
10. The temperature is [value] Kelvin. This is nominal.
11. The temperature is [value] Kelvin. This is below nominal.
12. The temperature is [value] Kelvin. This is above nominal.
13. The temperature is [value] Kelvin in [location]. This is nominal.
14. The temperature is [value] Kelvin in [location]. This is below nominal.
15. The temperature is [value] Kelvin in [location]. This is above nominal.
16. The [location] temperature is [value] Kelvin. This is nominal.
17. The [location] temperature is [value] Kelvin. This is below nominal.
18. The [location] temperature is [value] Kelvin. This is above nominal.

2. Atmospheric conditions

a. Options to start conversation

b. Options for system acknowledgement

c. Options for Actions

i. What is the [vital]?

1. What is the atmospheric composition?
2. Can you tell me the atmospheric composition?
3. What is the oxygen in the atmosphere?
4. How much oxygen is in the atmosphere?
5. What is the carbon dioxide in the atmosphere?
6. How much carbon dioxide is in the atmosphere?
7. What is the atmospheric pressure?
8. Can you tell me the atmospheric pressure?
9. What is the humidity level?

        10. Can you tell me the humidity level?
    ii. What is the [vital] in [location]?
        1. What is the atmospheric composition in [location]?
        2. Can you tell me the atmospheric composition in [location]?
        3. What is the oxygen in the atmosphere of [location]?
        4. How much oxygen is in the atmosphere of [location]?
        5. What is the carbon dioxide in the atmosphere of [location]?
        6. How much carbon dioxide is in the atmosphere of [location]?
        7. What is the atmospheric pressure in [location]?
        8. Can you tell me the atmospheric pressure in [location]?
        9. What is the humidity level in [location]?
        10. Can you tell me the humidity level in [location]?
    iii. What is the [vital] in [units]?
        1. What is the atmospheric composition in [units]?
        2. Can you tell me the atmospheric composition in [units]?
        3. What is the oxygen in the atmosphere in [units]?
        4. How much oxygen is in the atmosphere in [units]?
        5. What is the carbon dioxide in the atmosphere in [units]?
        6. How much carbon dioxide is in the atmosphere in [units]?
        7. What is the atmospheric pressure in [units]?
        8. Can you tell me the atmospheric pressure in [units]?
        9. What is the humidity level in [units]?
        10. Can you tell me the humidity level in [units]?
        11. What is the atmospheric composition in [location] in [units]?
        12. Can you tell me the atmospheric composition in [location] in [units]?
        13. What is the oxygen in the atmosphere of [location] in [units]?
        14. How much oxygen is in the atmosphere of [location] in [units]?
        15. What is the carbon dioxide in the atmosphere of [location] in [units]?
        16. How much carbon dioxide is in the atmosphere of [location] in [units]?
        17. What is the atmospheric pressure in [location] in [units]?
        18. Can you tell me the atmospheric pressure in [location] in [units]?
        19. What is the humidity level in [location] in [units]?
        20. Can you tell me the humidity level in [location] in [units]?
d. Options for response
    i. Response to Action 1
        1. The atmospheric composition is [value]% oxygen and [value]% carbon dioxide. This is nominal.
        2. The atmospheric composition is [value]% oxygen and [value]% carbon dioxide. This is abnormal.
        3. There is [value]% oxygen and [value]% carbon dioxide. This is nominal.

4. There is [value]% oxygen and [value]% carbon dioxide. This is not abnormal.
5. The atmospheric pressure is [value] pascal(s).
6. Gateway's atmospheric pressure is [value] pascal(s).
7. The humidity level is [value]%.
8. Gateway's humidity level is [value]%.

ii. Response to Action 2
1. Oxygen accounts [value]% of the atmosphere in the Hab. This is nominal.
2. Oxygen accounts [value]% of the atmosphere in the Hab. This is below nominal.
3. Oxygen accounts [value]% of the atmosphere in the Hab. This is above nominal.
4. Carbon dioxide accounts [value]% of the atmosphere in the Hab. This is nominal.
5. Carbon dioxide accounts [value]% of the atmosphere in the Hab. This is below nominal.
6. Carbon dioxide accounts [value]% of the atmosphere in the Hab. This is above nominal.
7. The atmospheric pressure in the Hab is [value] pascal(s).
8. The Hab's atmospheric pressure is [value] pascal(s).
9. The humidity level in the Hab is [value]%.
10. The Hab's humidity level is [value]%.

iii. Response to Action 3
1. The atmospheric composition is [value]ppm oxygen and [value]ppm carbon dioxide. This is nominal.
2. The atmospheric composition is [value]ppm oxygen and [value]ppm carbon dioxide. This is abnormal.
3. There is [value]ppm oxygen and [value]ppm carbon dioxide. This is nominal.
4. There is [value]ppm oxygen and [value]ppm carbon dioxide. This is not abnormal.
5. Atmospheric pressure is [value]psi.
6. The hab's atmospheric pressure is [value]psi.
7. Pressure in the hab is [value]psi.
8. Atmospheric pressure is [value]kPa.
9. The hab's atmospheric pressure is [value]kPa.
10. Pressure in the hab is [value]kPa.
11. Humidity is [value]g/cm^3.
12. Humidity in the Hab is [value]g/cm^3.
13. Hab humidity is [value]g/cm^3.
14. Humidity is [value]g/kg.
15. Humidity in the Hab is [value]g/kg.
16. Hab humidity is [value]g/kg.

3. Water/Food Supply
    a. Options to start conversation
    b. Options for system acknowledgement
    c. Options for Actions
        i. What is the [vital]?
            1. How much water is left?
            2. How much drinking water do we have?
            3. What’s our water supply level?
            4. How much food is left?
            5. How much food do we have?
            6. What’s our food supply?
            7. How many rations do we have?
        ii. What is the [vital] in [location]?
            1. n/a, for whole ship
        iii. What is the [vital] in [units]?
            1. How many days of drinking water do we have left?
            2. How many gallons of water are left?
            3. How many liters of water are left?
            4. How many weeks of water do we have?
            5. How many days of food do we have left?
            6. How many pounds of food are left?
            7. How many kilos of food are left?
            8. How many kilograms of food are left?
            9. How many weeks of food do we have?
        iv. How much [vital] do we have?
            1. How many meals do we have left?
            2. How many desserts do we have left?
            3. How many power bars do we have left?
            4. How many snacks do we have left?
    d. Options for response
        i. Response to Action 1
            1. There are 5 days of water left.
            2. We have 5 days worth of drinking water.
            3. There is enough water left for 5 days.
            4. The station has enough water for 5 days.
            5. The station has 5 days worth of water left.
            6. We have enough water for 5 days.
            7. There are 12 days of food left.
            8. We have 12 days worth of food.
            9. There is enough food for 12 days.
            10. The station has enough food for 12 days.
            11. The station has 12 days worth of food left.
            12. We have enough rations for 12 days.

ii. Response to Action 3
1. There is enough water for 5 days.
2. We have enough water for 5 days.
3. There are 2000 gallons of drinking water left.
4. We have about 2000 gallons of drinking water left.
5. There's about 2000 gallons of drinking water on the station.
6. We have enough water for just under a week.
7. There are 7500 liters of drinking water left.
8. We have about 7500 liters of drinking water left.
9. There's about 7500 liters of drinking water on the station.
10. There is enough food for 12 days.
11. We have enough food for 12 days.
12. There are 3500 pounds of food left.
13. We have about 3500 pounds of food left.
14. There's about 3500 pounds of food on the station.
15. There are 1500 kilograms of food left.
16. We have about 1500 kilograms of food left.
17. There's about 1500 kilograms of food on the station.
18. We have enough food for a little under 2 weeks.

iii. Response to Action 4
1. We have 17 desserts left on station.
2. Enough for you to have dessert tonight :)
3. We have 102 power bars left.
4. Enough for you to take one :)

Scheduling

Edit 1 - Tara

1. Asking what the full schedule for the day is
    a. Meetings, work, workout, eating, shower, tasks,
2. What is the next task on the schedule
3. Add to the schedule
4. Ask about specific tasks for the day - when do i need to work out today, when do i need to perform x task today
5. Adding reminders for meetings, tasks etc
    a. Ask to have these pop up on computer only, not out loud
6. When does my day end
7. How many specific things today e.g., how many meetings do i have today
8. Option to manage schedule on computer, and have "buttons" to simplify common requests such as adding reminders, adding to schedule etc - GUI

1. Asking about the full day's schedule
    a. Options to start conversation :

Hey Diego
Diego are you there
Diego i need your help
Diego can/would/will you help me
Diego, I have a request
Diego, read my full schedule - leads right to step d

b. Options for response(these should be randomized?)
   Hi, yes how can i help you
   I am here, how can i help you
   Yes I can help, what do you need?
   Yes, what can I help you with?
c. Options to ask about the full days schedule
   Can you read to me my full schedule today
   I would like to know my full schedule today
   What is on my schedule for today
d. Options for diegos initial response
   Just to make sure, you want to hear your full day's schedule?
   Okay, you would like to hear the full days schedule?
e. Follow up to verification
   Yes
   Yep
   Yes please
   Uh huh?
   That's right
   No - (Diego responds) okay, what did you need help with instead

Diego will need full access to the scheduling system, ability to read, add, remove, adjust, etc

f. Options for diego to read the full schedule
   -Alright you got it! Your schedule starts at 0900 with 1, at 1000 2, at 1200 3, at 1300 4 at 1500 5,
   -Sure thing, here it goes - 0900 x, 0930 y, 1000 z, 1200, 1230 a, 1300 b etc
   -Yes! You have x things on your schedule today, the first is x at 0800, second is y at 0900 etc

Issues - if the user cuts off diego
Diego stop command
Diego stop
Ok diego - to start a new request

2. **What is the next task on the schedule**
   a. Options to start convo, same as above
      Add - hey diego, what's my next scheduled task
      Hey diego, what's next on my schedule
      Hey diego.. Etc
   b. Options to respond - same as above

c. Options to ask for next task
   Please tell me my next task
   What is next on my schedule
   What do i have to do next
   What is my next activity
   I would like to know what's next on my schedule for today
   Could you tell me what is next on my schedule
   Could you tell me my next activity/task
   Will you
d. Options for responses to request
   Sure thing! Your next task is…
   You got it! Next on your schedule is …
   Coming right up! Your next activity is..
   Sure thing, next on your schedule is…
e. Follow up with…?
   Would you like to hear the rest of your schedule?
f. User answers either yes (please) or no (thank you)
g. If yes, then
   Here is the rest of your schedule, at 1100 xxx, at 1230 xxx, at 1500 xxx

3. Add to schedule

a. Options to start, same as above but add
   Hey diego, i would like to add to my schedule
   Hey diego, can you add something to my schedule

b. Options to respond
   Yes, what would you like added to your schedule
   Yes, what would you like to add to your schedule
c. Expected responses from user
   I would like you to add X meeting at 1500
   Can you remind me to call X at 1300 tomorrow
   Can you add x to my schedule at 1400 today
   I would like to add a X to my schedule
d. If no specific time is given.. Such as: can you add a CO_2 check to my schedule..
   I can add that to your schedule, what time will that be at?
e. User adds time
f. End convo options
   Alright, i have added X to your schedule at 1300 today/tomorrow

4. Inquire about specific scheduled tasks - (maybe we could get a list of general tasks)

a. Options to start convo
   Hey diego
   Hey diego i have a question about my schedule
   Hey diego when am i scheduled to XX today
   Hey diego, when is my meeting with XX today
   Hey diego, what time do i have XX today

b. Options to respond
Hey yourself! Your meeting with XX is at XX(time) today
Hi! Your scheduled workout is at XX(time) today
Well hello! Your meeting with XX is scheduled for XX(time) today

5. **Adding reminders**
    a. Options to start convo
    Hey diego
    Hey diego can you set a reminder for me
    Hey deigo can you set a reminder for my meeting at XX(time) today
    Hey diego can you remind me 10 minutes before my meeting with XX(person) today
    Hey diego, i need you to set a reminder for me
    b. Options to respond
    Sure thing! What do you need a reminder for (if the first request was not specific)
    Sure thing, how long bedore XX(thing) would you like to be reminded? (if the request was sort of specific but without a time)
    Sure thing, i can remind you about XX(meeting etc) X(time) minutes/hours before it starts(if the request is specific)

6. When does my day end
    a. Options to start convo
    Hey diego
    Hey diego, whens my last scheduled task for the day
    Hey diego, when is my day over
    Hey deigo, what time is my last scheduled meeting
    Hey diego, what time is my last scheduled item for the day
    Hey diego, when does my day end today
    Hey diego, what time am i done with work today
    b. Options for diego to respond
    Hi there! You are almost done, your day ends in 2 hours at 2100
    Well hey! Your last scheduled meeting/activity is for Xx(time) today
    I can help with that, your day ends in 2 hours at 2100
    Hi! You have 2 hours left of scheduled activities for the day

7. How many specific things
    a. Options to start convo
    General greetings
    Hey diego, how many meetings do i have today
    Hey diego, how many break times do i get today
    Hey diego, how many meals do i have scheduled today
    Hey diego, how many meetings do i have scheduled today
    Hey diego, what is my scheduled number of tasks today
    Hey diego, how many activities are on my schedule today
    Hey diego, how many meetings do i have on my schedule today
    Hey diego, how many items are on the schedule today
    b. Options for response from diego

Hi! I can answer that, you have XX(amount) of (tasks/meetings etc) today
Hi! Sure, let me get that for you, you have XX(number) xx(tasks) on your schedule today
c. If the user says thank you, diego should respond with something…
8.

Communications

Edit 1 - Giuliana
Communication Uses for VUI
Note: Bolded points are fleshed out below, regular are incorporated in the dialogue for the bolded ones

1. **Make a call**
    - Ground
    - Other astronaut(s)
    - Make a group call
2. **Send a text message**
    - Send a group message
3. **Send a voice memo**
4. **What notifications do I have**
    - Do I have any missed calls/messages
5. Read my message from X
    - Read all my unread messages
6. **Play a voice memo/voicemail**
    - Save or delete the memo/voicemail
7. **Ignore incoming call**
    - Send incoming call to voicemail
    - Voice memos from others could be stored the same way as voicemail if you miss a call?
8. **Mute my mic for a bit**
9. **Raise/lower the volume**
10. Call vs video call
    - How do we want to handle this? Always default to voice call and give option to turn on video?
        - Turn on/off my video
        - Key words: call vs. video call/facetime/skype
            - Do we incorporate slang like ‘facetime’ or ‘zoom’?
11. End call/hang up the phone
12. Close/leave my messages
13. Show me all my messages
14. Can I see my call history

Dialogues

1. **Make a call**
    a. Start Convo:
    Hey Diego
    Hey Diego, can you do something for me?
    Hey Diego, can you help me?
    Diego, can you help?

    Skip to (d)
    Diego, can you make a call for me?
    Hey Diego, call [NAME]
    b. Initial Responses:
    Hello, would you like some assistance?
    Yes, what can I help with?
    What would you like me to do?
    Gladly, what can I do?
    c. Make Request:
    Can you call [NAME] for me?
    Can you video call/FaceTime/Skype [NAME]?
    - do we want slang terms like FaceTime to be recognized?
    Can you set up a call with [NAME 1] and [NAME 2]?
    Call [NAME] (or [NAME 1] and [NAME 2]
    d. Action from Diego:
    Ok, calling [NAME]
    Gladly. Calling [NAME 1] and [NAME 2]
    Ok, I'm making a group call with [NAME 1] and [NAME 2]
    Ok, would you like to call them now or add a call to your schedules for later?
        - Scheduling
    Follow-Up Questions
    Would you like your video on or off?
        - GUI note: add screen for minimized video call so you can view other things simultaneously?
    e. Response to Follow-Up:
    On/off, please
    On/off
    f. End Call:
    Diego, hang up
    Hang up
    End call
    Diego responding to words in call - not sure if we want this
    Bye
    Talk to you later
    g. End Call Confirmation:

The call has ended. Can I help with anything else?
I've hung up for you.

2. **Send a text message**
    a. Start convo:
    See 1. Make a call
    Skip to (d)
    Hey Diego, send [NAME] a text/message
    Diego, text [NAME 1] and [NAME 2]
    b. Initial Responses:
    See 1. Make a call
    c. Make a Request:
    Can you text [NAME]?
    Send a message to [NAME]
    Can you send a message for me?
    d. Action from Diego:
    Ok, what would you like the message to say?
    Ok, what do you want to text them?
    Ok, what should the text say?
    Who would you like to message/text?
    e. Response Follow-Up
    [message]
    Send them [message]
    Ask them if [message]
        - Should know to send message worded as a question
    f. Confirmation:
    I've sent the message.
    I sent the text. Can I help with anything else?
    Message sent. Would you like to be notified when it's read?
    Message sent. Would you like to be notified when [NAME] responds?
    g. Final Follow-Up
    Nope, I'm good, thanks.
    Yes/yup/sure/yeah/ok
    No/nah/nope/um, it's ok

3. **Send a voice memo**
    a. Start Convo:
    See 1. Make a call
    Skip to (d)
    Deigo, send a voice message/note to [NAME]
        - Might need to add clarifying question about text vs. voice if the user only says 'send a message'
    b. Initial Response:
    Who would you like to send a voice message to?

Would you like to send a voice or text message?

c. Make a Request:
   A voice message
   A text message
   [NAME]
   [NAME 1] and [NAME 2]
d. Action from Diego:
   Ok, I'm listening…
e. User recites message
f. Confirmation:
   I've sent the message. Can I help with anything else?

4. Notifications

a. Make Request
   What are my notifications?
   Do I have any notifications? (or missed calls/messages,etc)
b. Action from Diego
   Yes, you have X notifications. You have X missed calls from [NAME], X messages from [NAME] and [NAME], and X reminders.
c. End Confirmation

5. Hear voice memo/voicemail

d. Make Request
   Play my voicemail/voice memos
e. Action from Diego
   [plays message]
   Would you like to reply?

5. Ignore call

f. Make Request
   Send it to voicemail
   No, I don't want to talk now
   It's not a good time
g. Confirmation from Diego

6. Mute mic & raise/lower volume

a. Make Request:
   Hey Diego, turn off my mic for a bit
   Turn it up/down
   Can you raise/lower it/the volume?