University of Michigan

AR/VR Final Presentation

May 21st, 2020

Presentation Goals

Review the problem posed in the RFP

Overview of the system design and project scope

Summarize major recommendations and findings

Demonstrate the current deliverable iteration

Outline a plan for continued future work

AR/VR Team is comprised of two main groups.

BLiSS

Amit Kothekar	UI/UX Chief Engineer
Alex Sena	AR/VR Chief Engineer
Annika Stoldt	Program Manager
Rosie Van Alsburg	Systems Engineer
Megan Lacerenza	Systems Engineer
Sarah Ting	Systems Engineer

CLAWS Leadership

Riley Schnee	Team Lead
Emily Rassel	Software Lead
Cesar Mu	CMCC Lead
Sahil Farishta	System Administrator
Rupal Nigam	Administrative Lead

Software Developers	UI/UX Team
Delenn Bauer	Jiaxi "Rosemary" Chen
Mariana Ramirez	Krista Dunger
Sharon Thomas	Matthew Garvin
Drew Vanderspool	Tianyang "Nigel" Lu
Kevin Zhao	Esther Tang

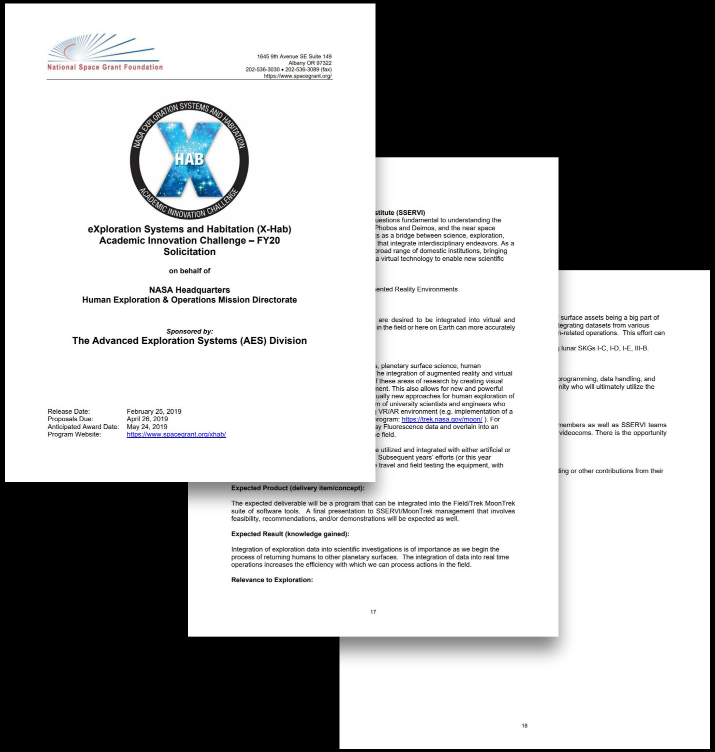
Problem Statement: RFP Retrospective

"SSERVI has a focus on the interaction of robotics, planetary surface science, human exploration, ConOps, and analog field science. The integration of augmented reality and virtual reality with surface datasets can enhance each of these areas of research by creating **visual linkages between datasets and the local environment**."

"Create a pipeline for data input in a working VR/AR environment"

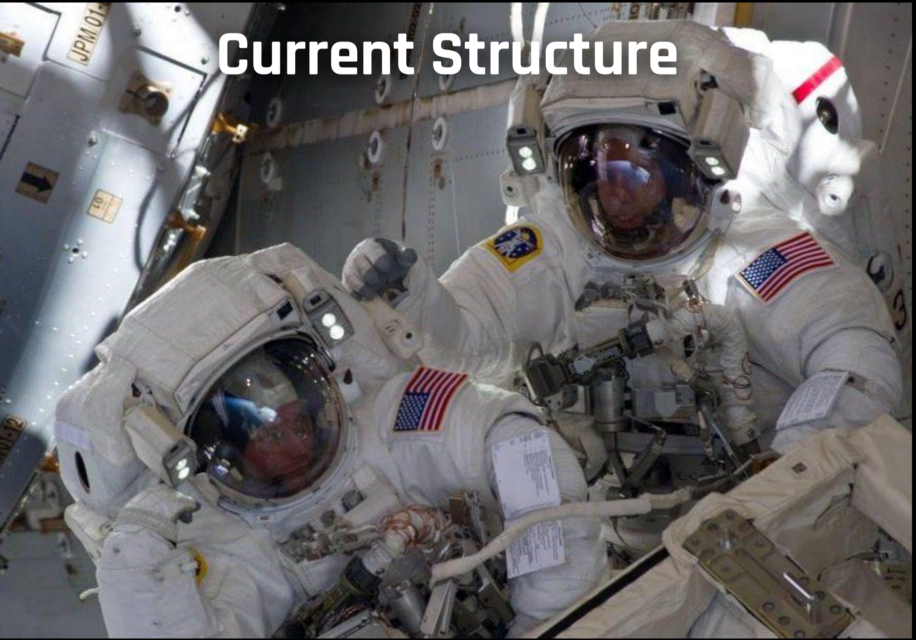
"Subsequent years' effort … can include field testing" of prototype

"… the integration of data into real time operations increases the efficiency with which we can process actions on the field"



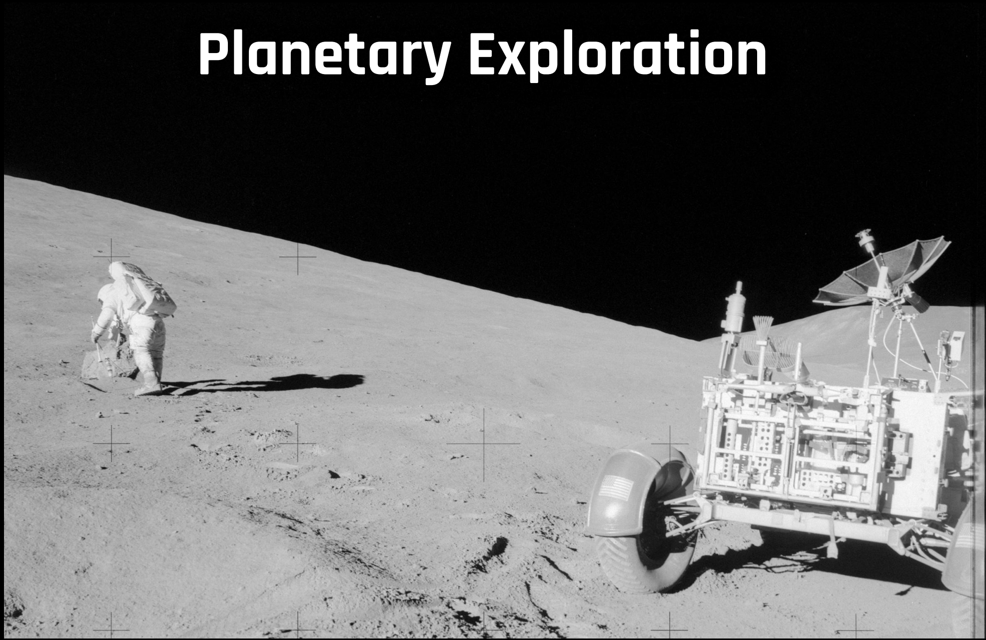
Changing EVA Needs

Current Structure



"... engineering-based EVA tasks are more readily translatable to detailed, sequential procedures with obvious success criteria."

Planetary Exploration



"...planetary EVA operations may need to cope with a **greater degree of flexibility** than what has been traditionally allowed."

Beaton et. al 2018

Narrowing our design philosophy

- We chose to pursue a flexible toolkit rather than an overall interface. Something that could make specific tasks easier rather than overhauling the whole trek experience.
- Emphasis placed on **non-intrusive tools** that could be **utilized for specific tasks** rather than being ever-present
- **A**R **T**oolkit for **L**unar **A**stronauts and **S**cientists

ATLAS
AR TOOLKIT

Top-level Requirements

1. The AR/VR system shall decrease the task load of a user during analog field treks
   Rationale: The final deliverable should make analog field work "easier" with NASA TLX acting as the system for measuring task load properties.

2. The system shall have distinct operational modes
   Rationale: A flexible toolkit requires different modes of operation to meet the specific needs of different tasks. Requiring different modes prevents an all-encompassing solution from becoming overbearing.

3. The AR/VR system shall be intuitive and easy to use.
   Rationale: NASA TLX surveys will again make "intuitive and easy" more quantitative and measurable. Minimizing distraction and visual intrusiveness is an explicit focus governing all system principles.

4. The system shall store all field data with spatial and temporal references.
   Rationale: Data synchronization is critical for easing the organization of collected information from the field back at ground stations. It also allows for mission-ops work to be easily transplanted in the field.

Unique Features of Augmented Reality (AR)

AR offers unique capabilities beyond being just a simple Heads-Up Display (HUD).

- **Virtualize your environment**
  - AR removes the need for screens to display or interact with information in your environment
  - Holograms can be placed anywhere in space
- **Shared 3D Views**
  - These holographic projections can be shared across multiple users wearing headsets
  - Information sharing no longer limited to 2D
- **Hands-free interaction**
  - Gaze and voice control allow for new interfaces
  - Users can physically move around a stationary hologram to explore different views

[Trimble Mining Data Example]

Feasibility Conclusions

Current usages in the space industry:

- Holo-SEXTANT - AR Planetary EVA Navigation Interface
- Joint Augmented Reality Visual Informatics System (JARVIS)
    - CLAWS participates in the SUITS challenge, which stems from this work
- AEXA - used during NEEMO 20
- Project Sidekick - HoloLens onboard ISS
- Destination: Mars - JPL visualizing Mars

Feasibility Conclusions

- HoloLens (1st Gen) limitations
  - Field of View
  - Battery Life: 2-3 hours per charge
  - No eye-tracking
  - 64GB Flash, 2GB RAM
  - 16:9 frame
  - Low resolution (720p at max)
  - Unable to simultaneously record audio and process voice commands without external mic
- FoV is the most restricting
  - JARVIS uses custom hardware to display directly on the xEMU helmet
  - Our designs are optimized for improved FoVs, over that of the 1st gen HoloLens

30°
HOLOLENS 1

52°
HOLOLENS 2

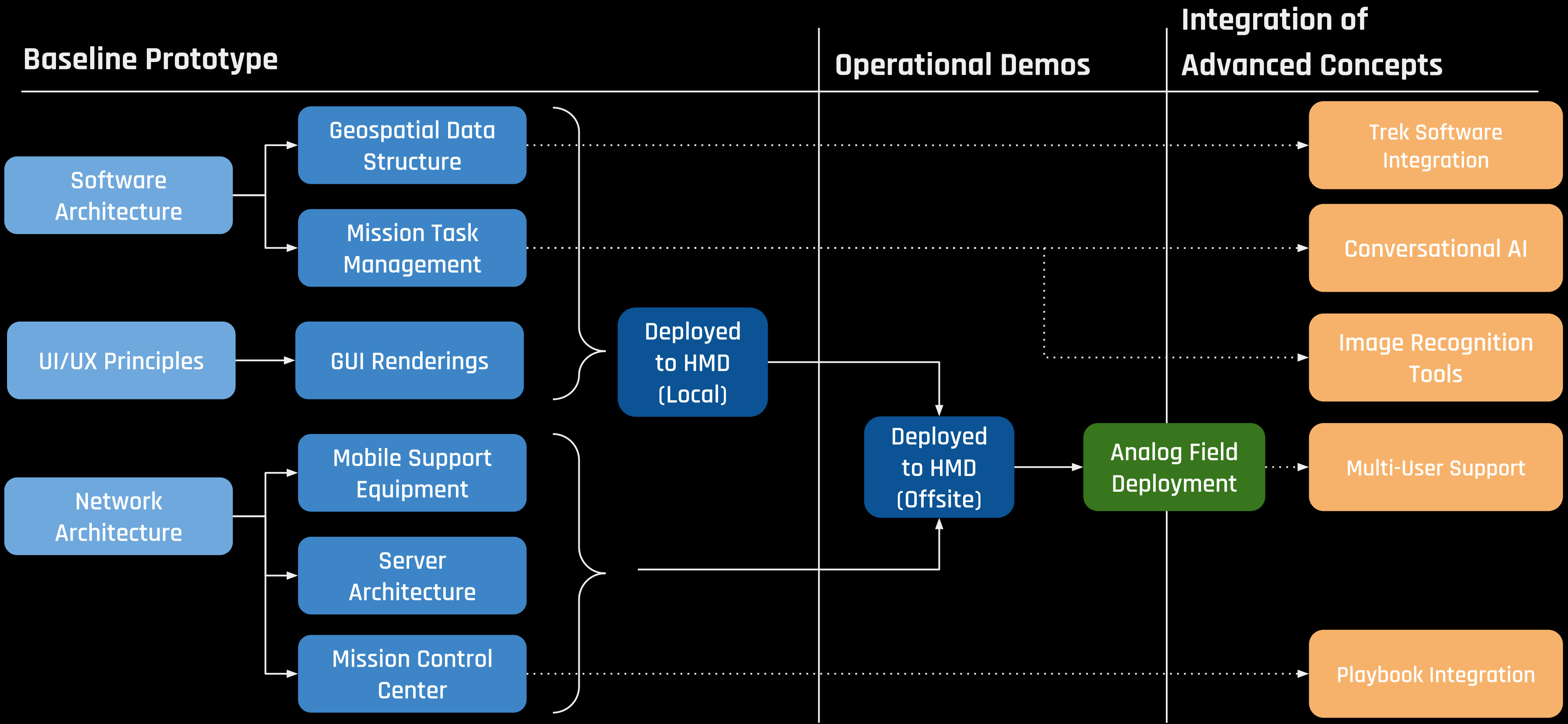
Best Use Case: Spatial Awareness

After assessing the needs of the Exploration Science community, AR seemed best equipped to add spatial awareness among EV crew

- BASALT mission used wrist-mounted displays and "situational-awareness" (S/A) cameras to provide users with the broader context of their EVA
- This hardware can be implemented into an AR system
  - Provide a mini-map with user position, heading, and waypoints of interest
  - Allow the user to place virtual waypoints within the space that can be processed at a ground station
  - **Can be used before, during, and after an EVA**

Scoping the Deliverable

What could be achieved from this by students in two semesters?

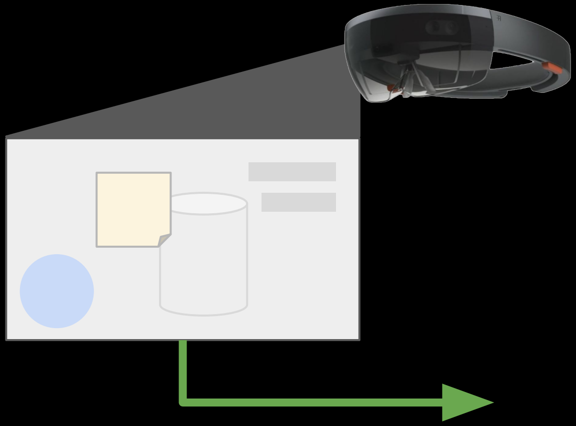


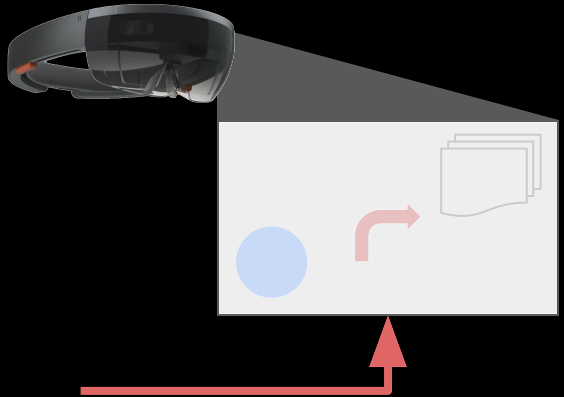
Deliverable Goal: Demo of 2 Functions

ATLAS
AR TOOLKIT

1. Tools created to ease the process of data collection and organization

2. Visualization of mission ops data out on the field



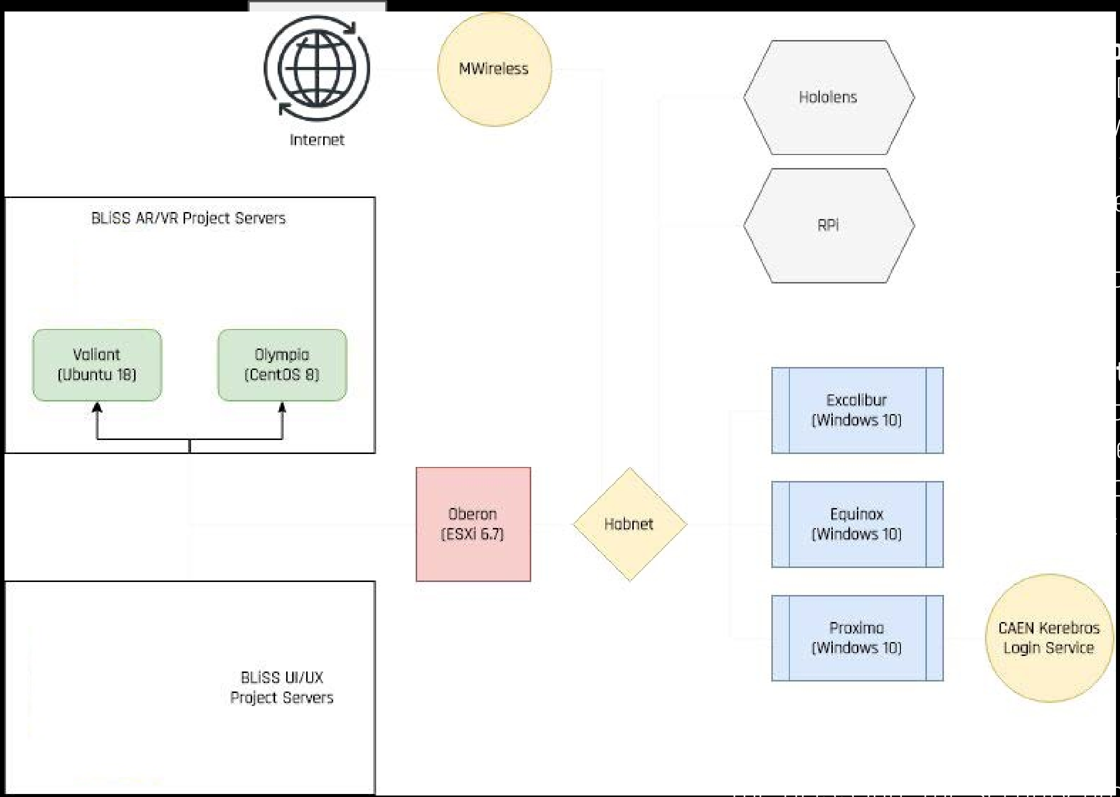


- Data collection and backup at mission control center
- Navigation aids
- Mission task aids

- Manipulate, visualize, and organize data gathered in the field
- Create data for field visualization

- Visualize ground-ops information projected on environment
- Convey updates or changes from CMCC

Network Diagram



Virtual Machines
"Valiant" and "Olympia" will do most of the server tasks for this team.

Virtual Machines-Extended
Our sister team working on the Gateway UI X-Hab project will need similar infrastructure. We are sharing our capabilities with them.

pport Equipment
D and MSE require
ork tether. It is
to Habnet for on-site
e objective is to support
internet at space
ations.

tory Computing
ain computers are
ed in the BLiSS lab with
bitat mockup, lovingly
the "Hab Lab".

into
the BLiSS lab. The security protocols
allow for devices to interconnect as well use internet features.

Mobile Support Equipment (MSE)

Ultimaxx Hardshell Backpack (Waterproof, 3.55lb)

AR Head Mounted Display (HMD)

AR Device

Microsoft Hololens

Secondary Cameras

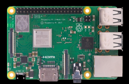
ELP 5MP USB Camera

Lighting

Non-specific/Custom

Onboard Sensors and Tools

Onboard Computer

 + 

RPi 4 (4GB RAM)

400GB Memory

Altimeter

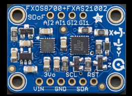
Adafruit BMP280 (0.25 m accuracy)

GPS & Compass

ublox

U-BLOX 7 (2.5m, 0.5°)

Misc. Orientation



Adafruit 9-DOF (Accel, Gyro, Mag)

Power Supply

Power Bank

Anker Portable Charger

2x 5V 3A USB

26800mAh (8.9 hrs) → Based on 15W power draw

Handheld Geology Tools

Field Notebooks

Sample Containers

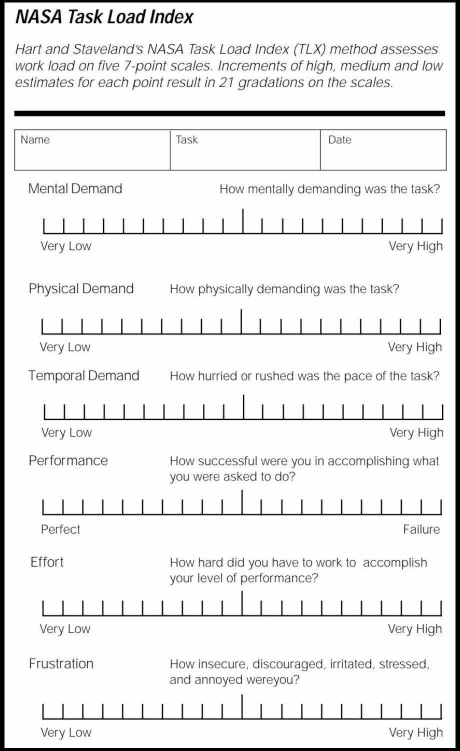
+

QR Tags

Verification and Validation

Three main categories:

- **Ergonomics:** impact on the user
  - Task Load Index
  - Physical comfort
- **Hardware:** physical components
  - Individual sensor calibration
  - Component level testing to performance specifications
- **Software:** codebase and data handling
  - End-to-end testing
  - Unit testing



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

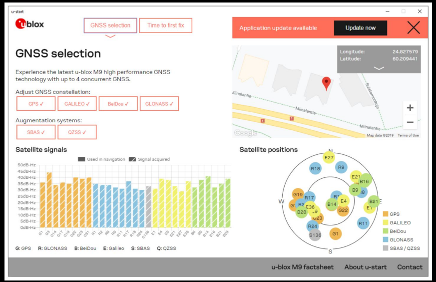
Perfect — Failure

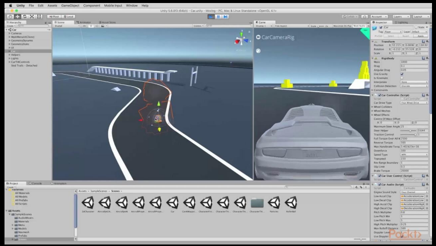
Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

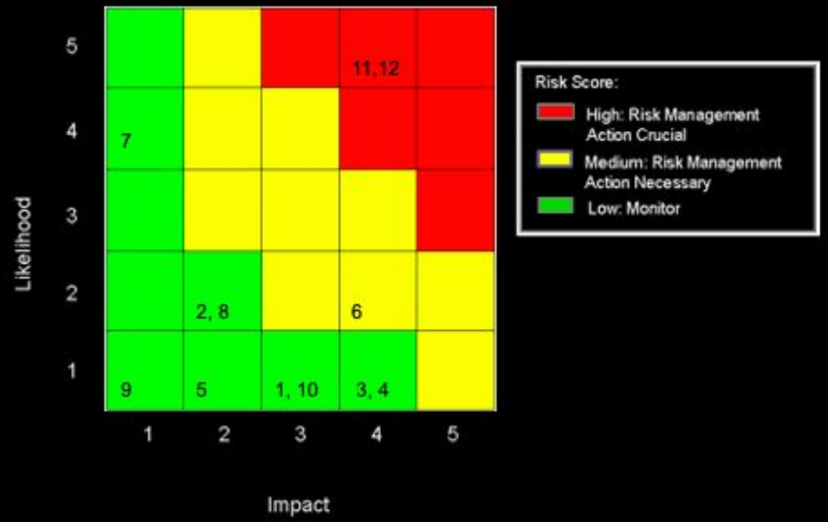




Field Testing Hardware

- The system is being designed to work out in the field, so major validation techniques will involve working outside with the full assembly
- Two main phases:
  - **Local:** use the "wave field" outside of the Aerospace building as an initial test-bed
  - **Analog:** travel to an actual site of geologic interest and collect data

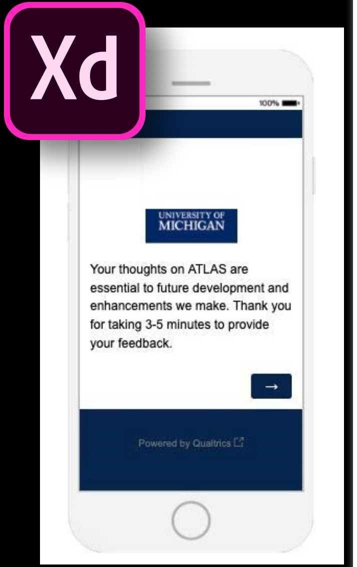
Risk Matrix

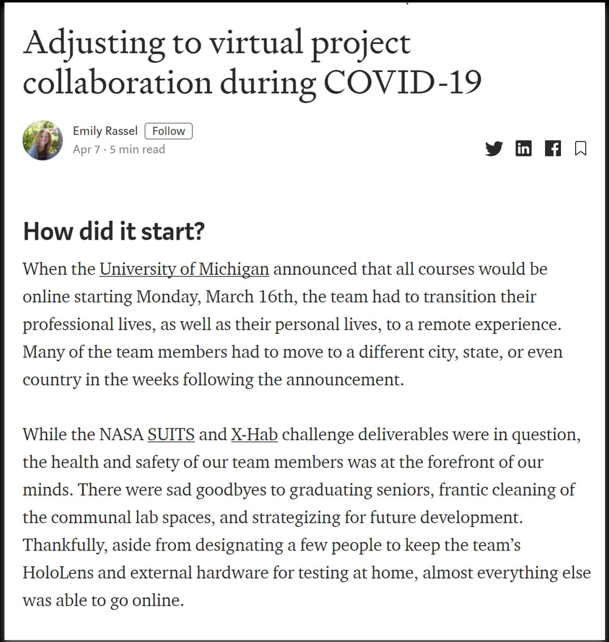


Risk #	Title	Impacted Areas
1	Network Libraries	Technical
2	Hololens 2 Hardware	Technical, Cost
3	Software Crashes mid-trek	Technical
4	Distracting GUI	Safety
5	Hardware Discomfort	Safety
6	Power box	Safety
7	Hololens 2 Cost	Cost
8	Student Engineers	Schedule
9	U of M IT protocols	Schedule
10	Cannot deploy to Hololens	Technical
11	Mobile Support Equipment	Technical
12	Testing limitations	Schedule, Technical

COVID Response: Virtual Work Adjustment

- Lost access to lab space
  - Unable to access CMCC server
    - Shifted to Heroku
  - Extremely limited access to HoloLens
  - Team scattered across the globe
- Deliverable became:
  - Back-end: Develop foundation & documentation
  - Front-end: Mockups





Adjusting to virtual project collaboration during COVID-19

Emily Rassel Follow
Apr 7 · 5 min read

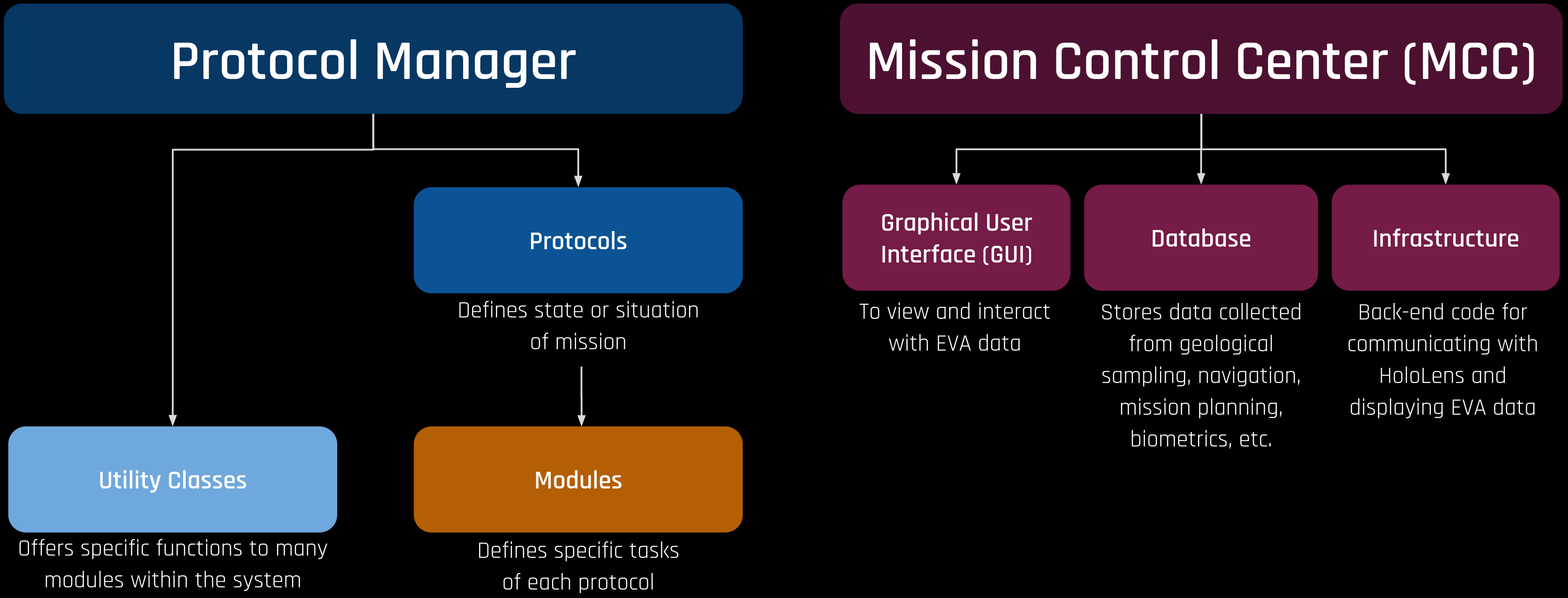
How did it start?

When the University of Michigan announced that all courses would be online starting Monday, March 16th, the team had to transition their professional lives, as well as their personal lives, to a remote experience. Many of the team members had to move to a different city, state, or even country in the weeks following the announcement.

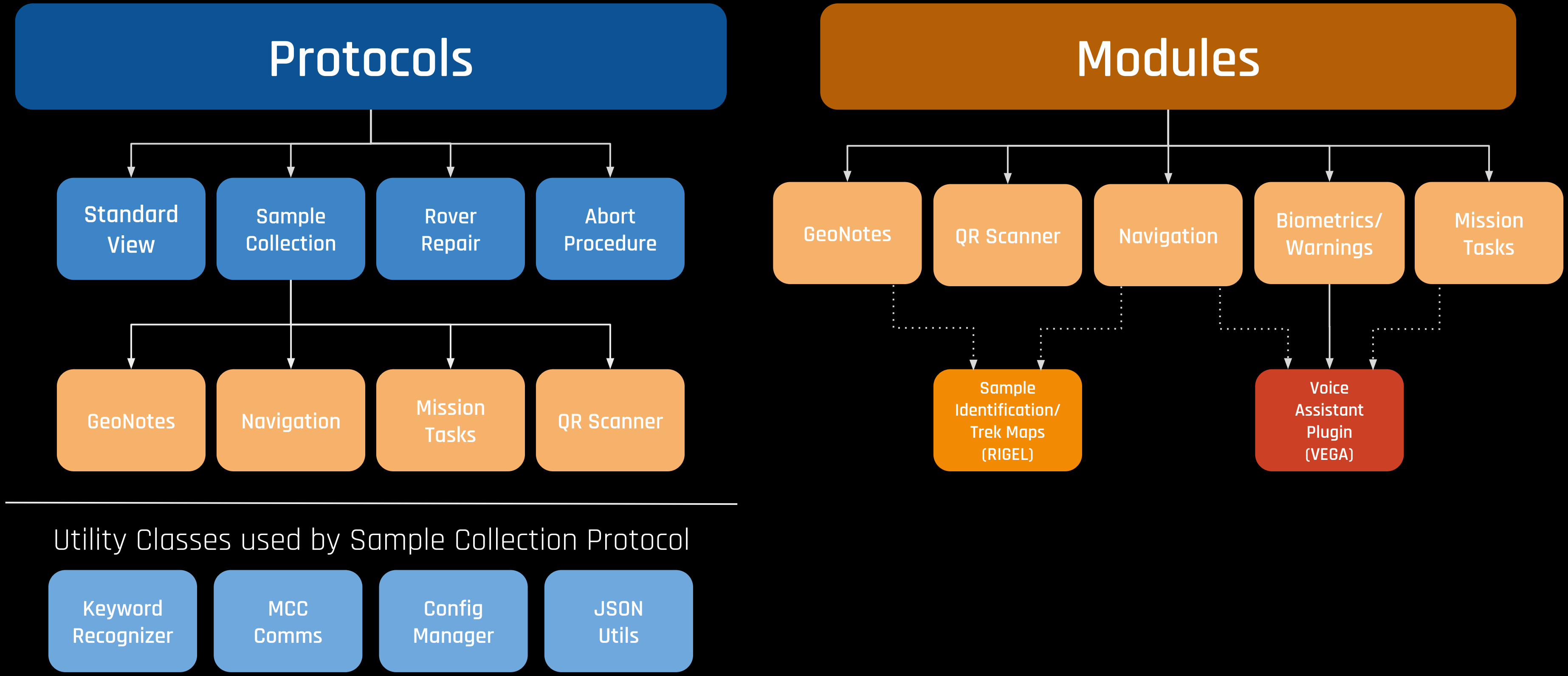
While the NASA SUITS and X-Hab challenge deliverables were in question, the health and safety of our team members was at the forefront of our minds. There were sad goodbyes to graduating seniors, frantic cleaning of the communal lab spaces, and strategizing for future development. Thankfully, aside from designating a few people to keep the team's HoloLens and external hardware for testing at home, almost everything else was able to go online.

Check out our Medium article!

Software Backend

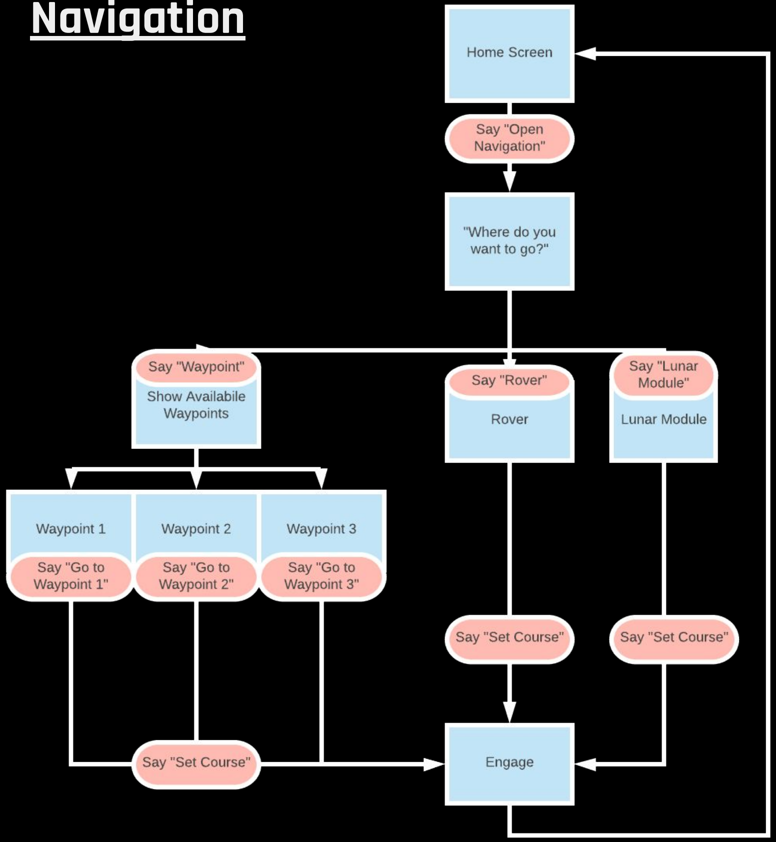


Software Backend

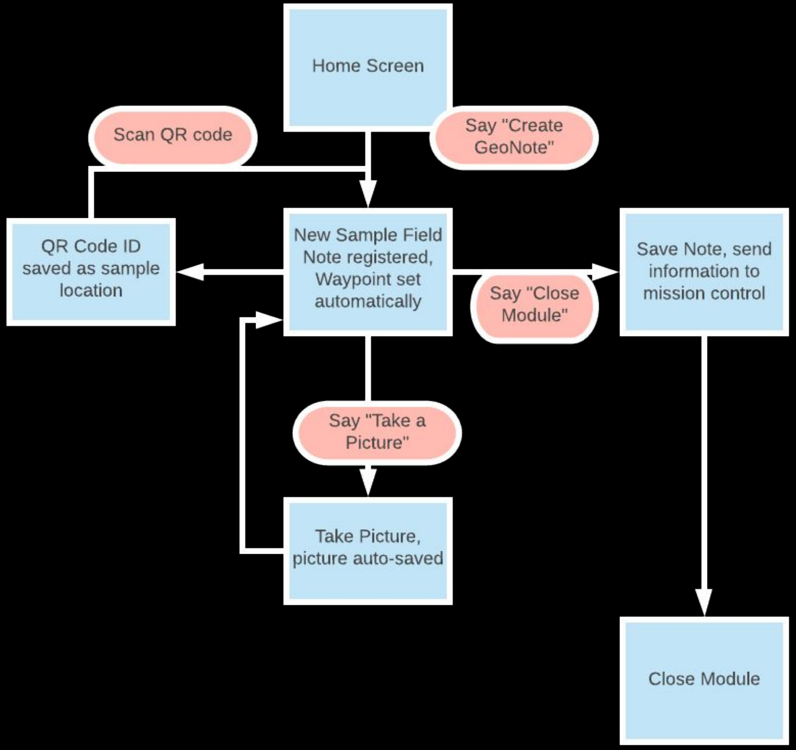


User Experience: Navigation and GeoNotes

Navigation



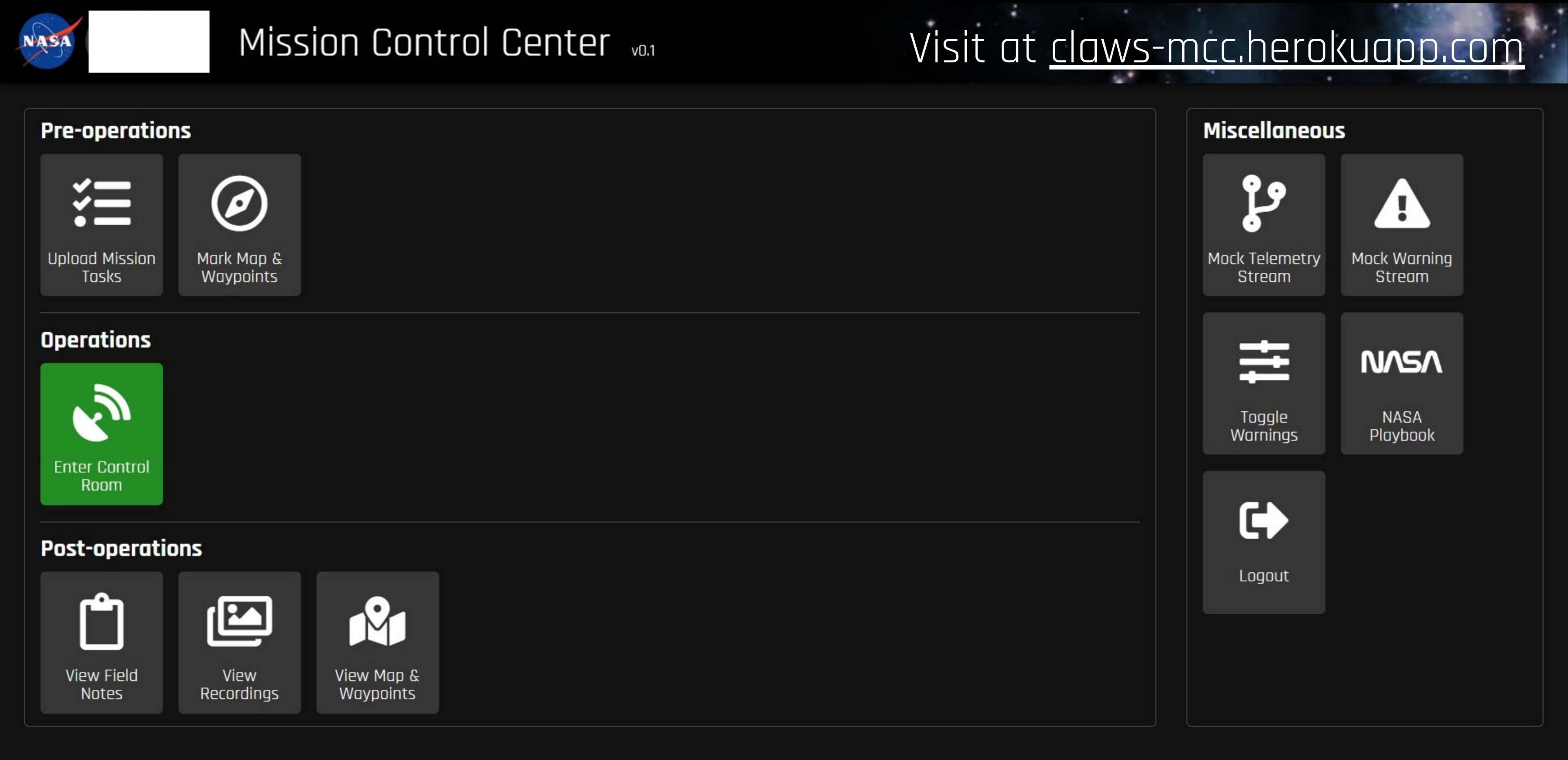
GeoNotes



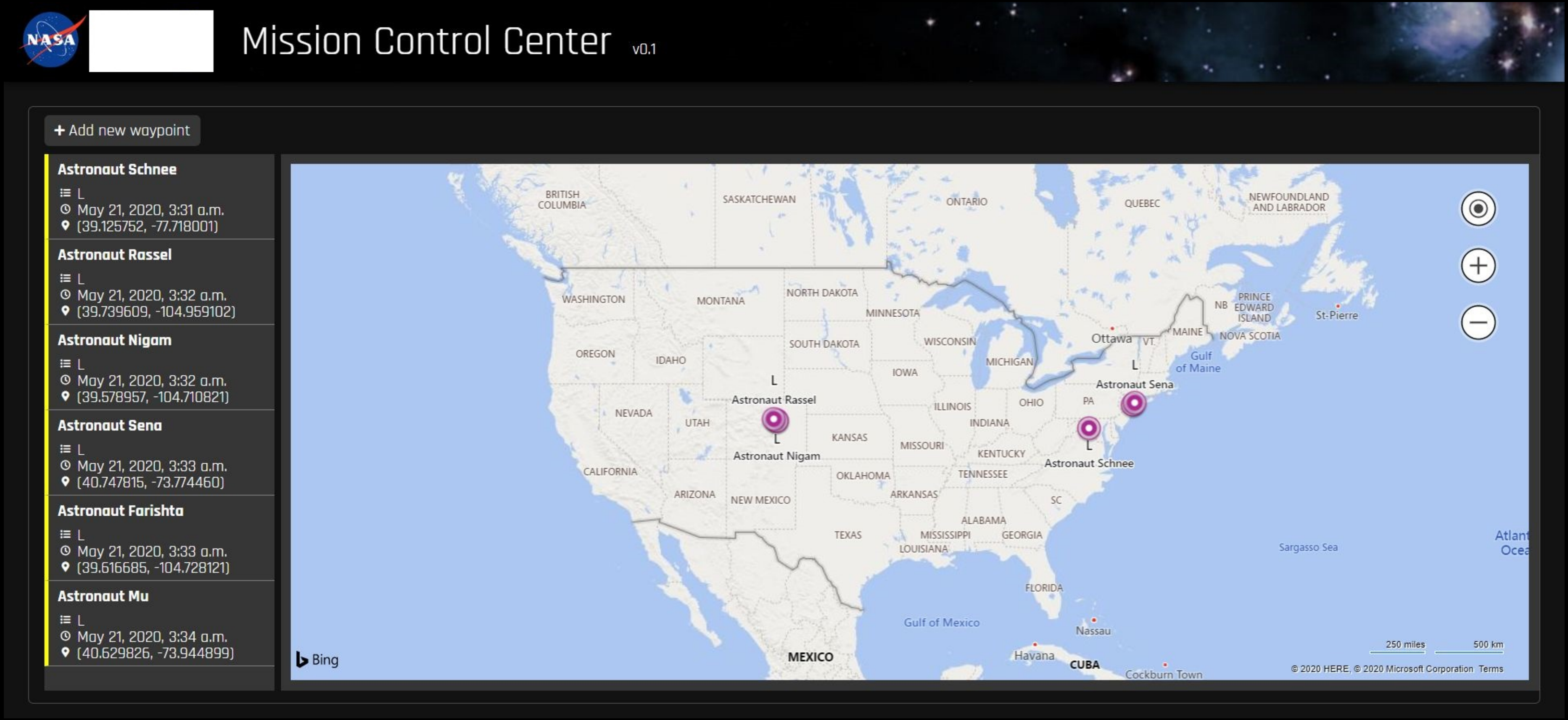
DEMO

Adobe XD Demo

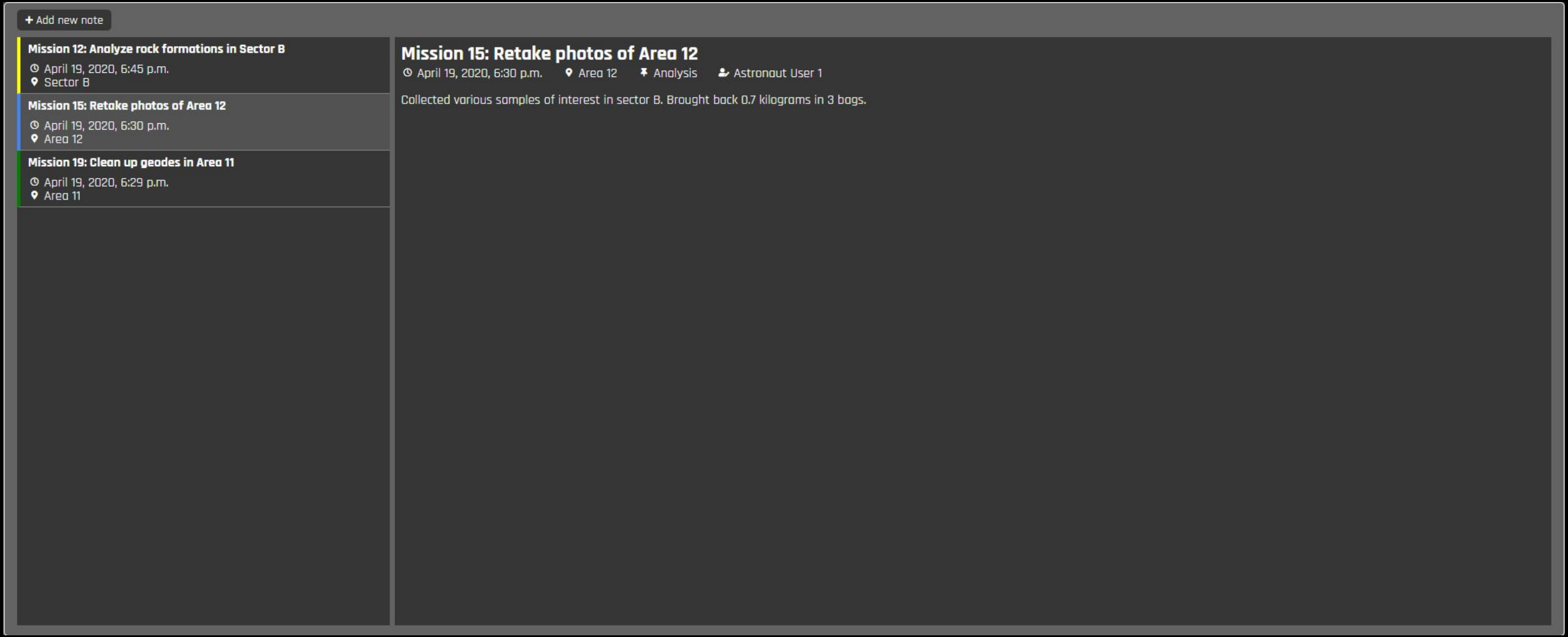
Mission Control Center (MCC)



Mission Control Center (MCC)



Mission Control Center (MCC)

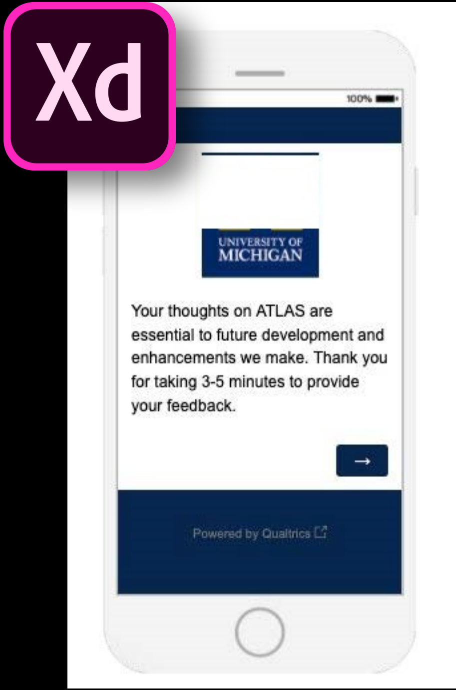


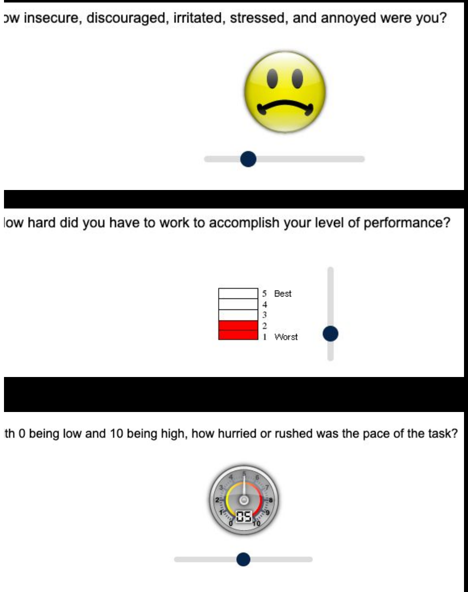
Mission Control Center (MCC)

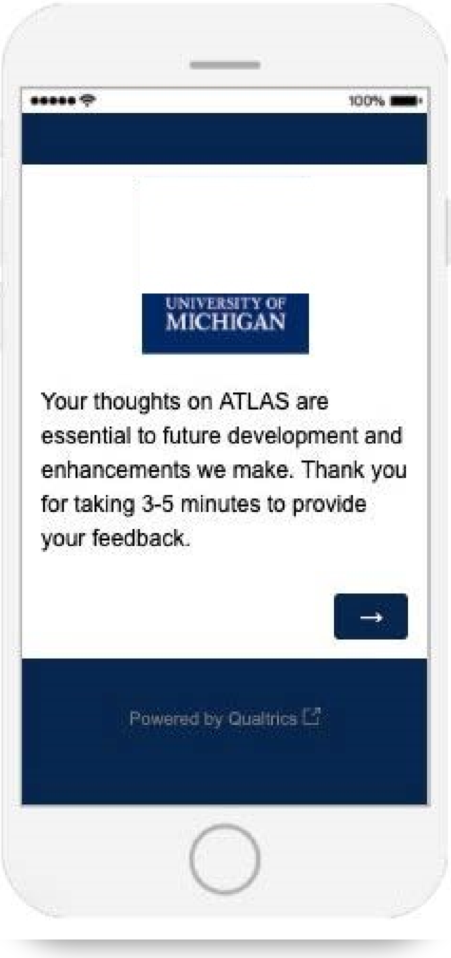
Future Work

Interim Testing in Adobe XD

- All of the validation and verification processes originally agreed upon have been made impossible by COVID-19
- An interim testing period based on virtual demos and user surveys can still collect data in the meantime
- In lieu of bringing in subjects, we can get virtual feedback on our layout concepts
- Survey Preview from Qualtrics







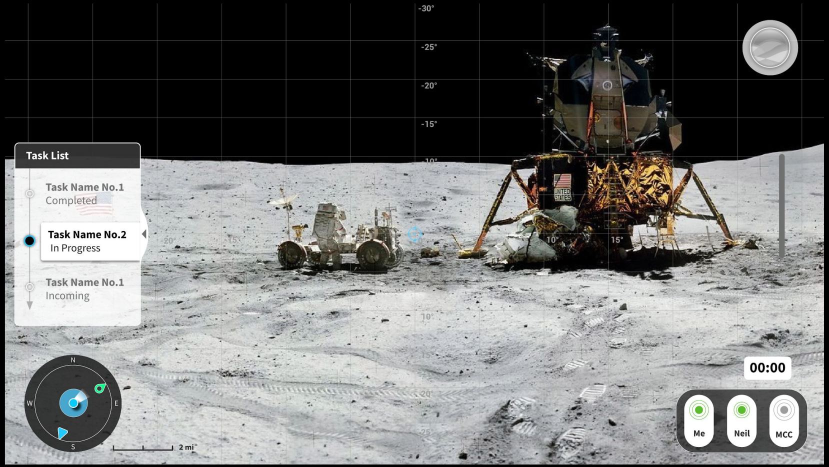
How insecure, discouraged, irritated, stressed, and annoyed were you?

How hard did you have to work to accomplish your level of performance?

With 0 being low and 10 being high, how hurried or rushed was the pace of the task?

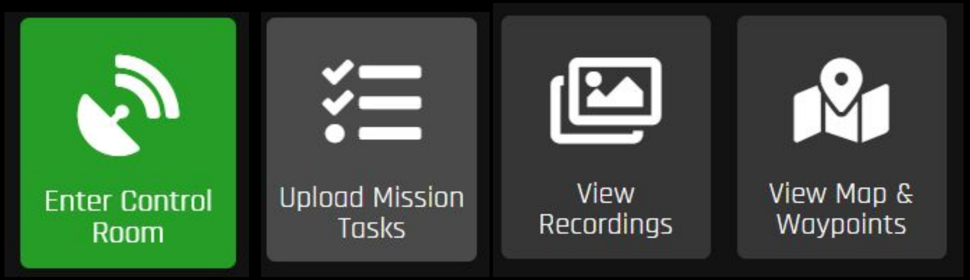
ATLAS Continuation

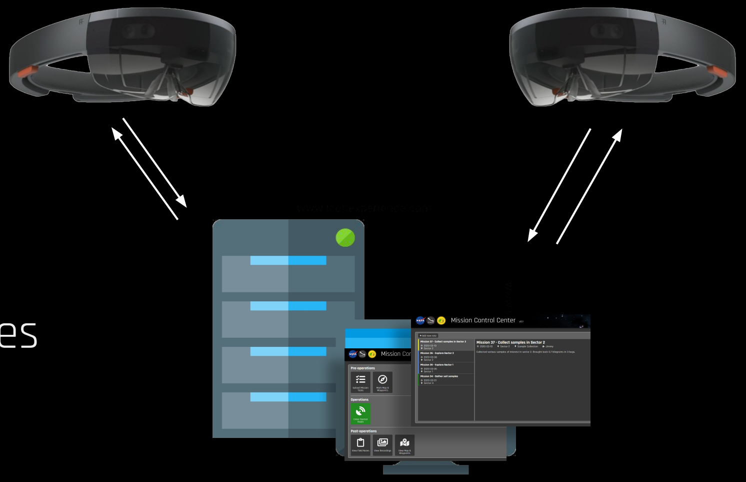
- Frontend Development
  - Migrate XD Demo to HoloLens prototype
  - Add code to support the UI elements
  - Continue to iterate on GUI
- Sensor Integration
  - Component unit tests
  - Field testing (potential analog destination)
- HITL testing
  - In-person tests with HoloLens
    - Qualtrics surveys as backup
  - Potentially adapt system to HoloLens 2
  - Provides feedback for future iterations



MCC Extensions

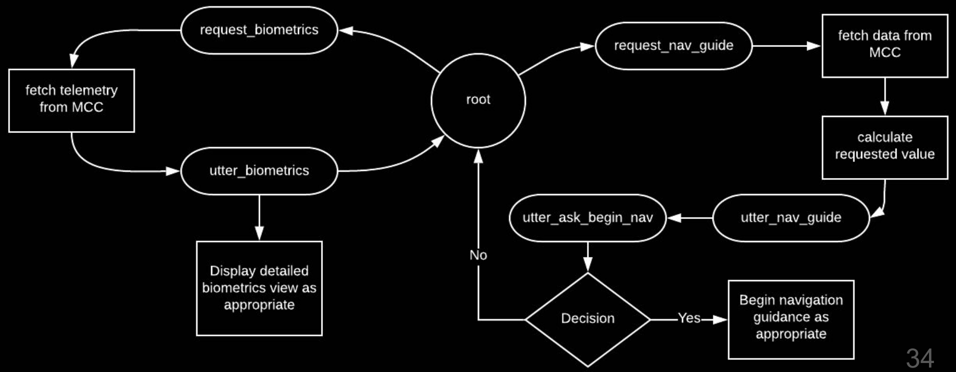
- Finishing ATLAS support
  - GeoNotes
  - Navigation
  - Mission Tasks
  - Communications
- Iterate on user interface
  - Can be designed and tested remotely
- Create Control Room tool
  - Monitoring EVAs in real time with biometric trend visualization
  - What flight controllers would see
- Secure communication with multiple HoloLenses
  - Model real EVAs better by supporting multiple astronauts
  - Increase robustness of system





VEGA: Voiced Entity for Guiding Astronauts

- Astronauts often work on tasks that can require the use of both hands
- Voice commands provide an easy way to obtain information and perform tasks
  - Naive solution: Keyword Recognizer
  - Proposed solution: Conversational AI
- Currently able to provide biometric data when requested
  - "What is my heart rate?"
- Plan to handle navigational requests and mission tasks
  - "Guide me to the rover"
  - "What do I do after the bolt is removed?"
- Will integrate into ATLAS



VEGA Sample Conversation

What is my heart rate?

Your heart rate is 60 bpm.

Any warnings?

No warnings detected.

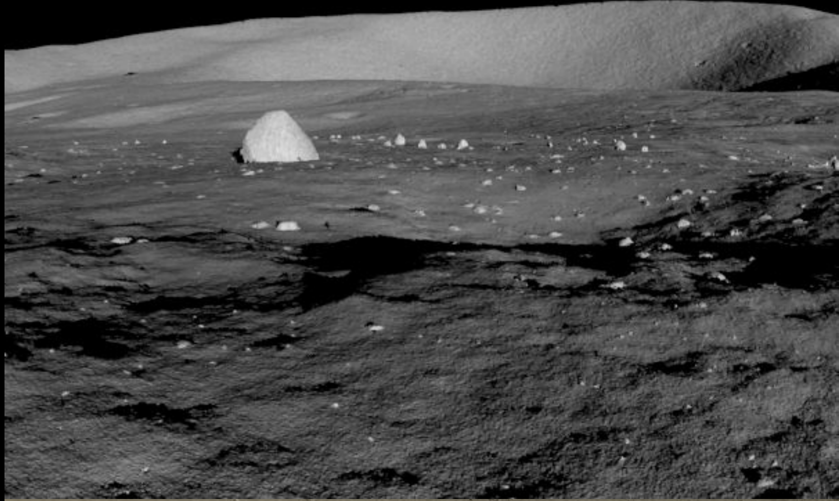
I want to explore that crater over there. The map says its 65 minutes away. How much water do I have left?

You have 3 hours and 24 minutes of water remaining.

...

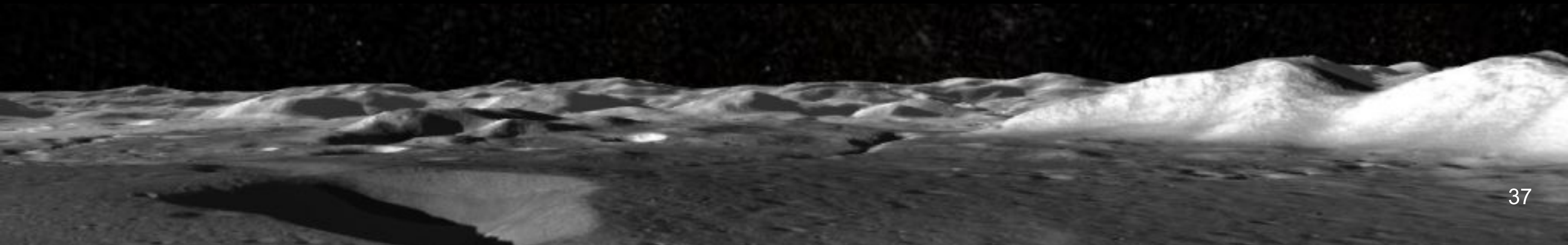
RIGEL: Rock Identification and Geological Evaluation

- Lunar environment can be difficult to work in due to lighting
  - Hard to identify features such as craters and hazards
  - Most famous example: Apollo 14 crew missed Cone Crater by 30 meters
  - Applies to both human eyes and cameras
- RIGEL provides a computer vision module that works in the lunar environment
  - Will use NASA POLAR dataset - pictures taken in replicated lunar environment
  - Will be able to identify potential samples along with hazards



RIGEL: Rock Identification and Geological Evaluation

- Trek Integration
  - Will collaborate with SSERVI's Trek team to develop an API
  - Use Trek data to augment information available to CMCC and astronauts
  - Potential to implement lunar geolocation
- Current RIGEL Progress
  - Identification of potential samples
- Will integrate into MCC

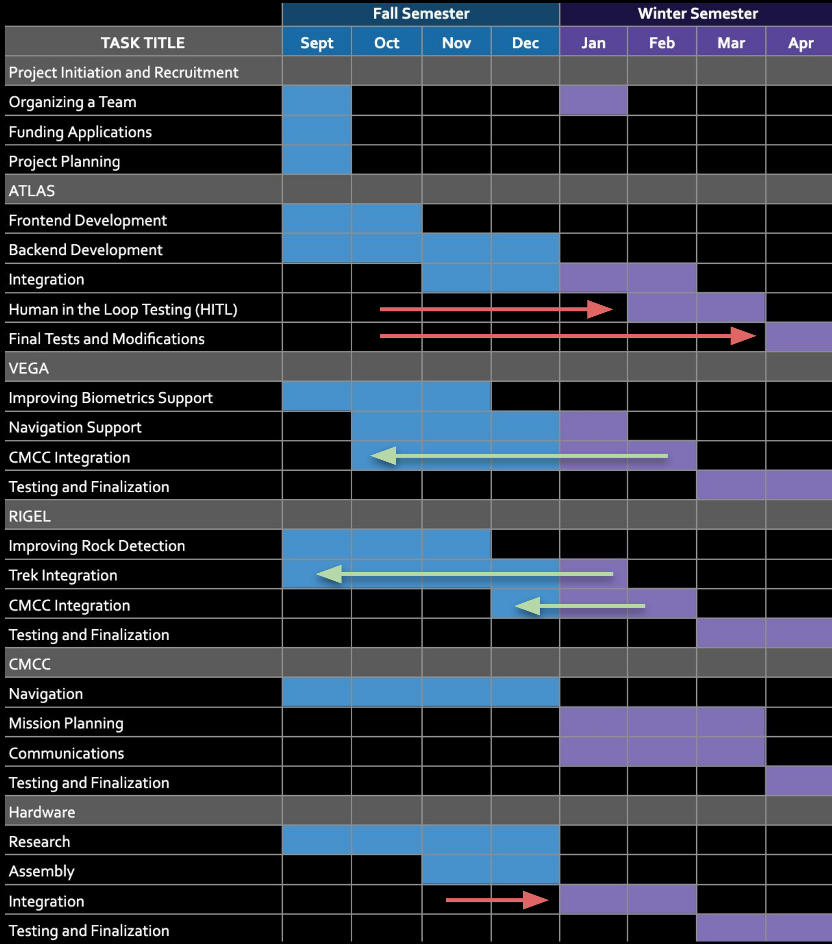


Ideal Timeline

- Goal is to complete ATLAS by Dec 2020
- Continue development of VEGA, RIGEL, CMCC, and hardware support into May of 2021

COVID-19 Impacted Timeline

- If current circumstances continue, focus will be shifted over to VEGA, RIGEL, and MCC development
  - Can be worked on and tested remotely



Conclusions

The project has been defined and given explicit goals from the original RFP

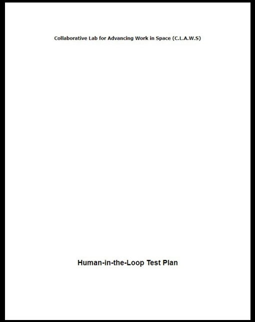
Design work has been completed for hardware, however testing was interrupted by COVID-19

Shifting to software focused work and extending the timeline in response to virtual work adjustment

BLiSS will be handing over final documentation of the project to CLAWS for further management

Concluding Documents: **05/22/20**

Transition Documents: **07/01/20**



Contact us with questions:

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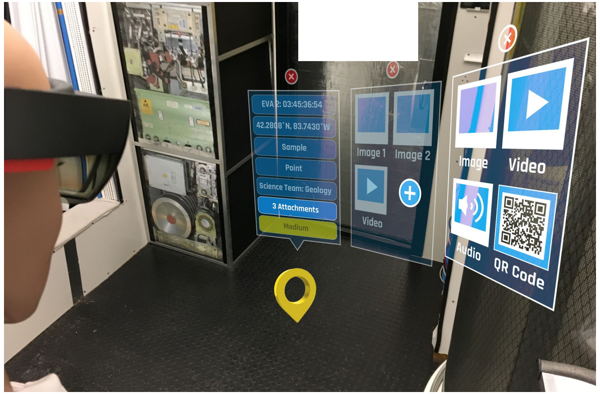
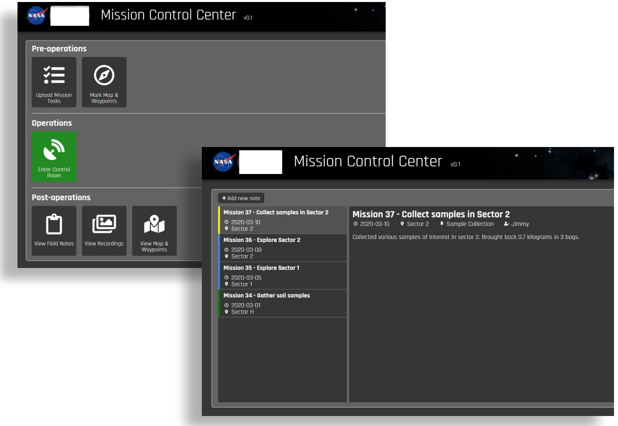
Thank you!





1: Pre-Mission Ops

- User can visualize hologram of terrain
- Multiple filters
- Place waypoints and multimedia throughout

2: EVA Waypoints and Field Notes

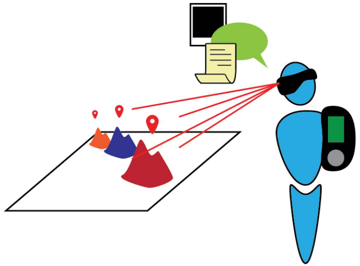
- Access the data placed pre-mission
- Place new waypoints and field notes
- Geospatial and temporal data synchronization

3: Post-Mission Debrief

- Compare planned EVA traverse to actual route
- Access to data from 2 previous operational modes
- Add data and plot second EVA, repeating 2-3 until returning home

SDR

Simple time-stamped and spatially annotated data to save time with post-mission synchronization.



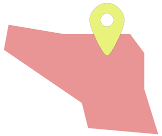
- Conducted a literature review
- Defined a scope for the project
- Created the notional timeline for the work ahead

PDR

Now serves as a data structure for storing and syncing all EVA activities. Given categories and area properties.

Categorized Waypoints

Recommended to allow for easier sorting, search, and selection of tasks

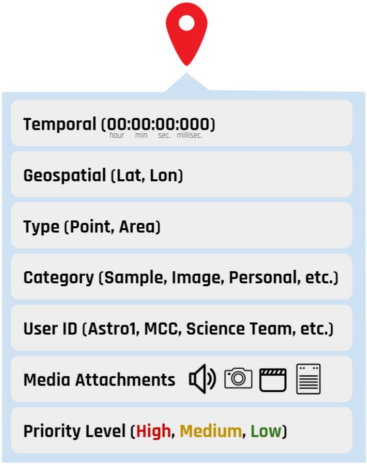


Area Waypoints

This was recommended based on problems experienced in Apollo 17. Often times EVA markers are not 1-D dimensional points in space but spatial.

CDR

Consolidated into a "waypoint" architecture with set parameters alterable by both IV and EV crew.

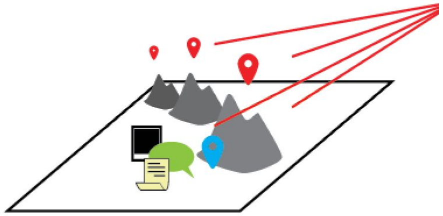


Waypoint Structure

The data flow and requirements of a waypoint are now more robust.

SDR

Visual aid only used for pre and post mission operations. Shows data location and points of interest.



- Very little was understood at this point about the type topographical data would be available
- Didn't want to rely on this feature too much in the design if it could become infeasible later

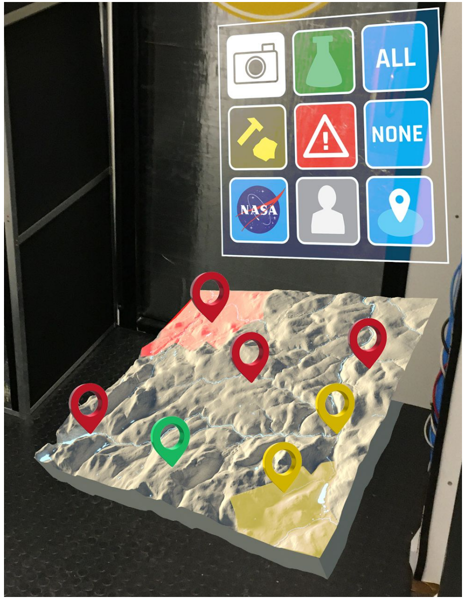
PDR

Becomes a menu for accessing waypoint data. Available in all phases of operation.

- Geologist assistance with topographical tools made this feature feasible
- Became a central way to interact with the system

CDR

Renderings completed based on PDR specs. Additional support menus added.

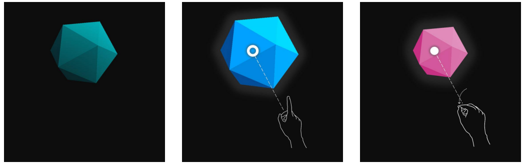


SDR

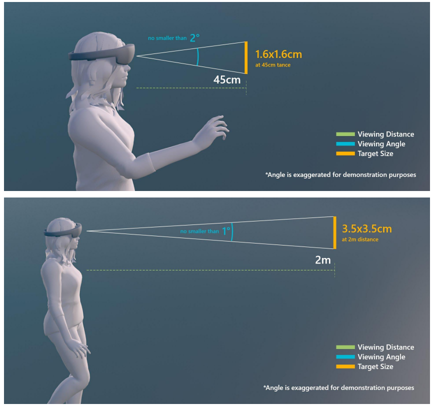
At this point there were no major guidelines in place. Minimized distraction was the only major requirement.

PDR

MCC GUI now included. Adopted AR graphic guidelines from Microsoft.

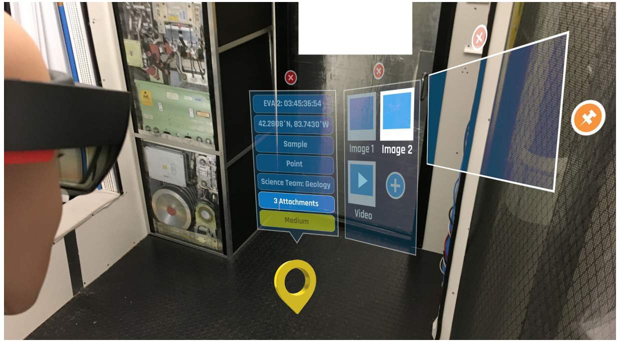


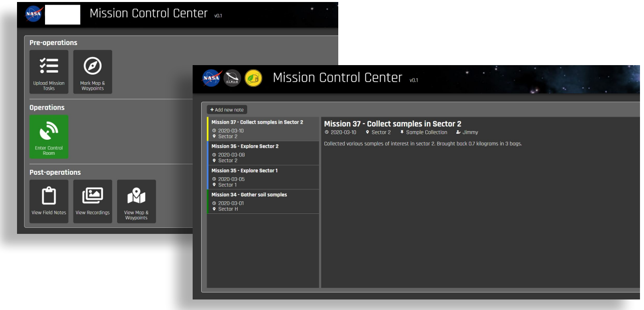
Natural Hover Selected



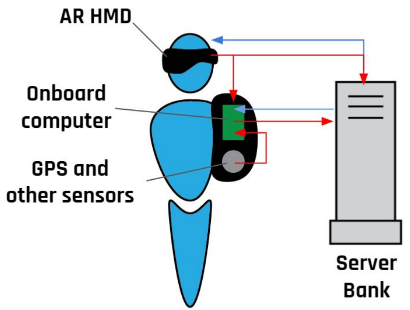
CDR

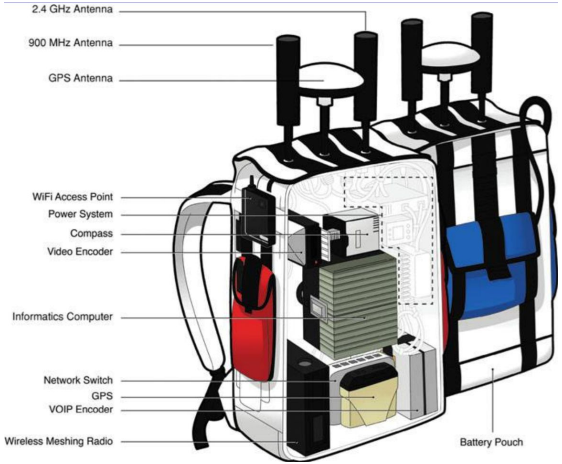
First GUI renderings completed.



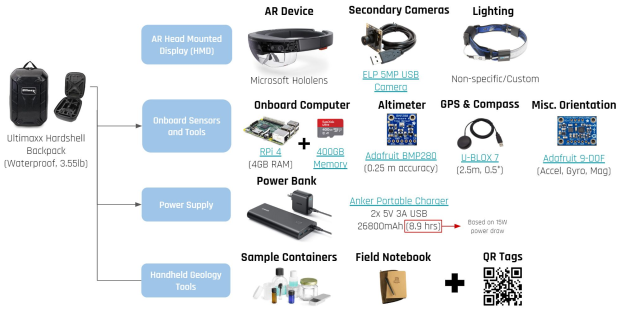


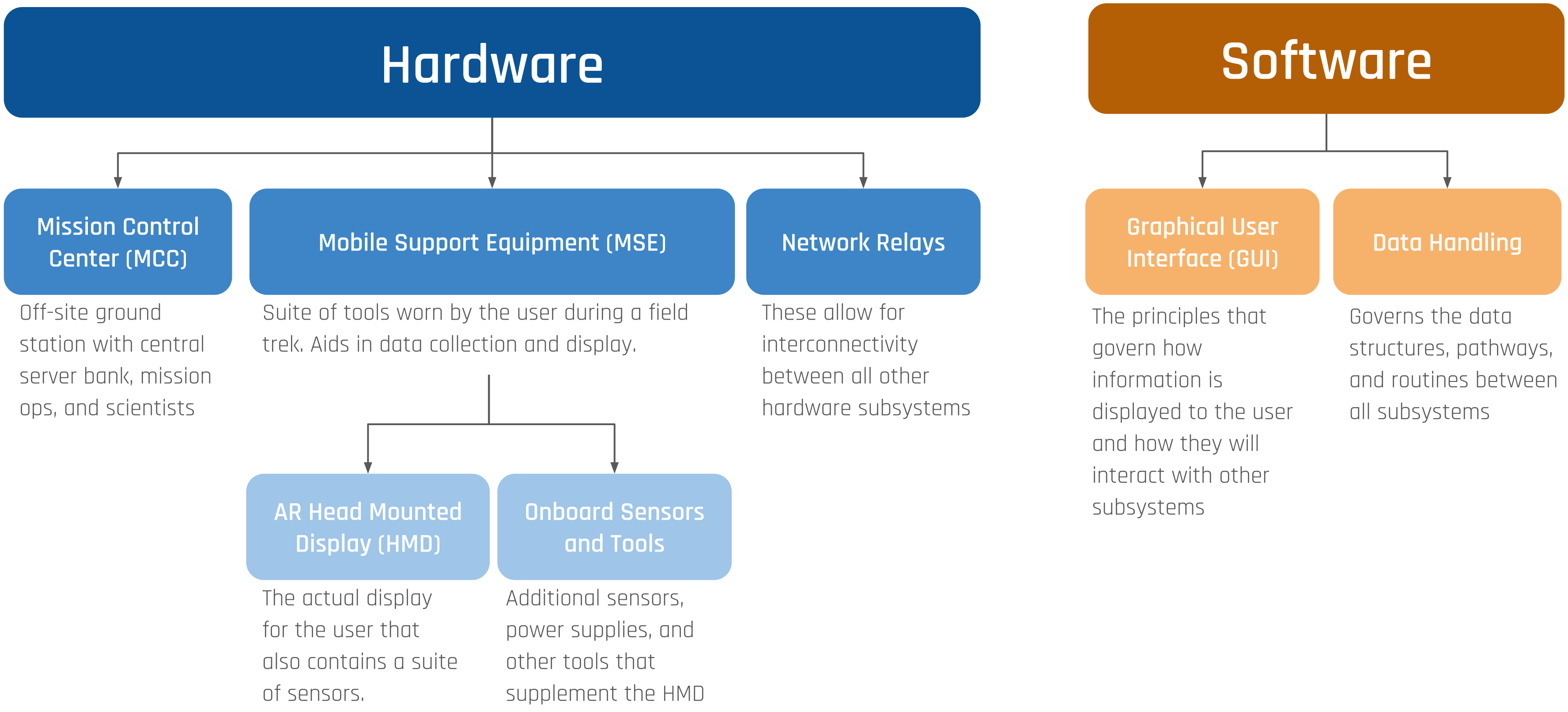
SDR	PDR	CDR
It was only understood at this point that there would need to be *some* equipment that travels with the user to support the AR HMD. No specific requirements had arrived yet.	The equipment used by the BASALT team met our high level requirements and was used as a model.	A full list of compliant components were selected. The entire MSE was due to be assembled in mid-March.





Miller, Michael J., et al. "A flexible telecommunication architecture for human planetary exploration based on the BASALT science-driven Mars analog." *Astrobiology* 19.3 (2019): 478-496.




Hardware
Mission Control Center (MCC)
Off-site ground station with central server bank, mission ops, and scientists
Mobile Support Equipment (MSE)
Suite of tools worn by the user during a field trek. Aids in data collection and display.
AR Head Mounted Display (HMD)
The actual display for the user that also contains a suite of sensors.
Onboard Sensors and Tools
Additional sensors, power supplies, and other tools that supplement the HMD
Network Relays
These allow for interconnectivity between all other hardware subsystems
Software
Graphical User Interface (GUI)
The principles that govern how information is displayed to the user and how they will interact with other subsystems
Data Handling
Governs the data structures, pathways, and routines between all subsystems