

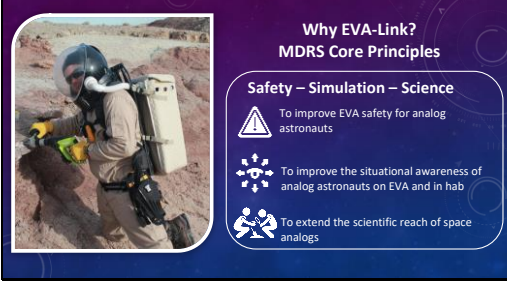







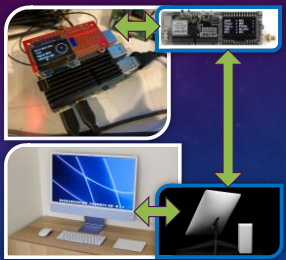
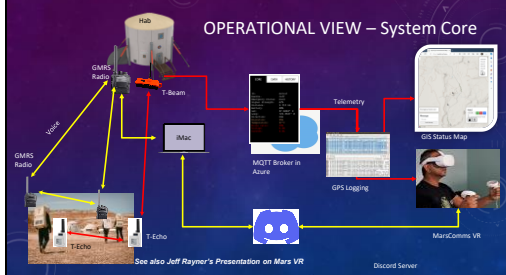
 <p>EVA-Link – Long Range Tracking and Communication at MDRS</p> <p>Presented by Kent Nebergall Developed by Mars Society Chicago Chapter/ Archipelago Space Research Mars Society Conference – August 2024, Seattle.</p>	<p>Hi everyone. Eric and Jason have done this talk in past years, and this year it's my turn.</p>
<p>Abstract</p> <ul style="list-style-type: none"> In 2022, the Chicago Mars Society chapter proposed a system for "Digital EVA Tracking at MDRS." We are pleased to announce the core system functions will be available for testing by crews during the next MDRS field season. Crews will be able to monitor the locations of EVA teams from several kilometers away and send text messages with cell phones/tablets connected to these devices via Meshastic peer-to-peer networking. Near real time maps of the EVA crews appear on the main computer at MDRS. The EVA-Link network has been extended with several solar-powered relay stations placed on hilltops around the facility during the field season. These are also monitored for battery performance, temperature, and other diagnostic data. Logs of the EVA will be recorded along with any text messages sent to and from crews, along with the GPS coordinates when the messages are sent. This can simplify tracking sample locations or other interesting items found during exploration. The core principles of MDRS are "Safety, Simulation, Science". EVA-Link contributes to all three by allowing the crews to keep in touch with the Hab and each other over great distances using a system that would have an equivalent on future human Mars missions. EVA-Link experiments tying the system into Mars VR have been done as well, allowing the crew locations to be seen. These experiments can use voice radio communication over short distances for cooperative EVA experiments. This talk will discuss both the progress made and give a background for future MDRS crews on how to apply the system to their research. It will also discuss new directions and opportunities for additional talent on the EVA-Link development team. 	
<p>Overview</p> <ul style="list-style-type: none"> What is EVA-Link? How Does it Help Analog Crews? 2023/4 Prototype Field Tests Lessons Applied to Baseline System Plans for the Next Field Season Volunteers Needed 	<p>First, I'll introduce EVA-Link and the connected systems. This past year, we tested it at MDRS with prototypes and made improvements. This coming field season, we are installing EVA-Link at MDRS as standard equipment. Lastly, I'll get into planned improvements and how you can join our efforts.</p>

 <p>Mars Desert Research Station</p> <p>The slide features three images: a wide shot of the station's white domes in a desert landscape, a close-up of a rover, and a map of the station area with a green circle indicating a specific location and an orange circle indicating a larger range.</p>	<p>A key problem with MDRS has always been that once you get outside the range of the handheld radios, you are basically cut off from rescue or communications. On the map, if you go as far as the orange circle and your radio only goes as far as the green one, you may have a problem if you break something and can't call for help.</p> <p>All geotagging of samples had to be done with a hand-held GPS. You can use smart phones to geotag pictures and therefore sample sites, but that restricts the data to personal devices.</p>
 <p>EVA-Link Features</p> <ul style="list-style-type: none"> GPS Tracking Texting Location Tags Voice Links VR Integration <p>The slide includes an image of an astronaut in a desert environment and a list of features for the EVA-Link system.</p>	<p>Outdoor Analogs need a system that gives basic text and GPS tracking information over very long ranges. You want crews to report locations for both help and science reporting.</p>
 <p>Why EVA-Link? MDRS Core Principles</p> <p>Safety – Simulation – Science</p> <ul style="list-style-type: none">  To improve EVA safety for analog astronauts  To improve the situational awareness of analog astronauts on EVA and in hab  To extend the scientific reach of space analogs <p>The slide features an image of an astronaut and three bullet points explaining the core principles of the EVA-Link system.</p>	<p>The core principles of MDRS are Safety, Simulation, and Science, in that order. We wanted a system that could add to all three elements at once. A live tracking system can make EVAs safer by showing where people are if they are overdue and allowing them to send an SOS.</p> <p>Live tracking also makes the experience more immersive for both field crews and those at the Hab keeping track of them.</p> <p>Finally, science is simplified by allowing crews to log and retrace their steps in the field.</p>

<p>Who Participates?</p> <p>EVA Crew</p> <p>VR Participants</p> <p>Hab Crew</p> <p>Mission Support</p> <p>©2022-2024 EVA Link Project</p>	<p>The overall system extends beyond the hab and desert to include mission support around the world. We can also use a custom version of Mars VR to see the beacons and EVA crew locations. This is an invite-only network so we maintain the security and privacy of crews on and off site. It also means we can link simulations so that an EVA participant in Hawaii could text another in Utah, or either crew can get help from anywhere.</p>
<p>Definitions: LoRa – (Long Range)</p> <p>High</p> <p>Low</p> <p>Bandwidth</p> <p>Short</p> <p>Range</p> <p>Long</p> <p>Wi-Fi BLE Video/Voice Consumer IoT</p> <p>Cellular Mission critical Outdoor use case Higher Power</p> <p>LoRa Sensors, Actuators and Tags Lowest Power and Lowest Cost</p> <p>https://www.lora-alliance.org/technology/lorawan</p>	<p>Before we get started, I need to define a few words. Our hardware uses a digital radio system called LORA, which stands for Long Range. It can send very slow data signals over many kilometers with very little power, so it's commonly used with things like weather balloons, CubeSats, and weather stations.</p>
<p>Definitions: Mesh Network</p> <p>Wireless Mesh Routers</p> <p>Gateway Routers</p> <p>INTERNET</p> <p>Mesh Clients</p>	<p>A mesh network is like wi-fi, but every device in the system sends signals that any other networked device can hear. Those devices then resend that information and so on for a limited number of bounces, called “Hops”. You can send from device to device without a central hub. You may have seen a similar system proposed for exploring caves on the moon and mars with robots. Each would leave a bread crumb trail of mesh network relays as they went. This is the same principle.</p>

<p>Definitions: Meshtastic</p> 	<p>The most popular open-source LORA mesh network protocol is called Meshtastic. This software package can run on smart phones, browsers or dedicated pocket devices to exchange data. Connect a small Meshtastic device with a Lora radio and Bluetooth to the phones you want to use, and then let the devices send the messages or other data to the mesh network. This also works with PCs connected to these devices. Meshtastic can be linked to the internet backbone so that messages can be sent globally. It also allows encryption and private channels.</p>
	<p>Let's go over the hardware and then dig into what the system does.</p>
<p>Suit Module</p> <ul style="list-style-type: none">• Currently a LILYGO Meshtastic Device.• Comes with Bluetooth, LORA communications, and GPS receiver.• Can communicate with Meshtastic software on a cell phone or tablet to communicate and show maps in the field. 	<p>First, we put a small, affordable Meshtastic device inside each suit, or on it with a clip. By itself, this system can send GPS data back to the network for each crew member every minute. When used with a tablet or smart phone, it can also send text messages and display maps with every beacon on it in near-real time. Since the text messages and tracking data are together, you can geo-code what you say to identify sample locations or send an SOS with your coordinates.</p>

<p>Hilltop Relays</p> <ul style="list-style-type: none"> Positioned on hilltops around MDRS to cover any areas without line of sight on the Hab. Solar powered and self-monitoring for temperature, battery health. Installed last field season, ready for re-deploy each season from now on. 	<p>We installed relays on various hills halfway through the last field season. These are solar powered and check in with their battery and temperature data periodically, along with their position. This set were made by Peter Dekluyver, and so got nicknamed the Peter Repeaters.</p>
<p>Hab Base Station</p> <ul style="list-style-type: none"> Links the outside long range network with wi-fi in the hab and the internet/cloud. Real time maps on the Mac for every tag. Tablets/phones on network can send and receive messages in or outside of hab. Database of tracks for each EVA and crew being built up, along with text messages sent, battery data, etc. 	<p>At the Hab, we have a special T-Beam that can route all the data to a server in the cloud via Starlink. Our cloud system also hosts a map for tracking the astronauts in their suits outside and any other data sources. This can be viewed on the iMac, but also by anyone with a valid account. We also have a Raspberry-Pi based system that communicates with the T-Echo devices back in the hab to keep the software updated.</p>
<p>OPERATIONAL VIEW – System Core</p> 	<p>We still use the hand-held radios for voice communication when close to the hab. We use Discord to share voice between the computer network, VR, and the radios. We can send the GPS log data and tracking data to the VR model of terrain. So for short range experiments within a kilometer of the hab, it will be possible to see and talk with crews in VR while they work outside.</p>

Technology Stacks: Hybrid to Simplified

Capability	As Tested	2024/5 Season	Planned
GPS Tracking	EVA LINK	EVA LINK	EVA LINK
Texting	Meshtastic Phone App	Hub: EVA-Link Field - Phone App	EVA LINK
Location Tags	Meshtastic App plus Data Logs	Use Location Data with other systems	EVA LINK
Voice Links	Discord MDRS to VR Only	Discord MDRS to VR Only	Discord Logged and Bidirectional
VR Integration	JSON Data File, Quest 2 Headset	JSON Data File, Quest 2/3 Headset	EVA LINK + Mars VR + Discord

As of now, the whole MDRS ecosystem can do texting, GPS tracking, location tags, voice, and show crew locations in VR. However, we're using other systems in parallel like Meshtastic and Discord for most of that functionality. Keeping them separate for now lets us ensure each is working in the MDRS environment before certifying them. As we merge them into a single, simplified system, I want to be able to explain the whole system in five minutes and have a new crew know 90 percent of the functionality.


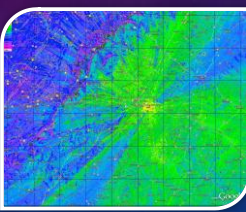



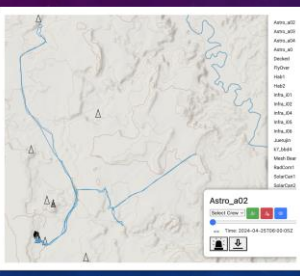
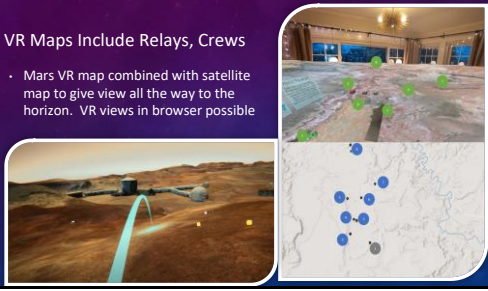
So... from PowerPoint to MDRS in three short years...

Timeline

2022-3	Team build/Design
	<ul style="list-style-type: none"> • Workbench Prototypes • Virtual Office Setup for Dev Team (Discord, etc.)
2023-4	Prototype Field Tests
	<ul style="list-style-type: none"> • Secondary Systems to Boost Feature Set • Gap Analysis and Fixes • Relay Field Tests
2024-5	Live System Launch
	<ul style="list-style-type: none"> • User interface Features • Cell Phone Text Relay

During the last season, we got prototypes in the field with James Burk's Crew. We have just assembled the package for permanent use at MDRS for the new field season. Any crew at MDRS going forward will have basic tracking capability.

<p>Crew 261 - Lessons Learned Subset of Prototype hardware/software</p>  <p><small>See also James Burk's Presentation on Crew 261, 2023 Mars Society Conf.</small></p>	<p>Thanks to James Burk's Crew 261, we got some live data from our homebuilt prototypes, shown here. We found lots of signal blocking and other problems on site that didn't appear in our neighborhood experiments.</p>																
<p>Crew 261 – Findings and Solutions</p> <table border="1"> <thead> <tr> <th>Prototype System Tested</th> <th>Issue Found</th> <th>Solution Found</th> <th>Result or Plan</th> </tr> </thead> <tbody> <tr> <td> <ul style="list-style-type: none"> Basic T-Beams used as Repeaters Manually placed on Hilltops </td> <td> <ul style="list-style-type: none"> Shadows where no signal in field </td> <td> <ul style="list-style-type: none"> Used software to simulate tower placement and optimized locations. Better electronics and antennas </td> <td> <ul style="list-style-type: none"> Field testing with Sergei shows issue resolved. </td> </tr> <tr> <td> <ul style="list-style-type: none"> T-Beam Basic used in field Positions verified with Garmin backup system </td> <td> <ul style="list-style-type: none"> "Jumpy" GPS reporting with spikes in unexpected directions </td> <td> <ul style="list-style-type: none"> Software rejects noise. Radios standardized. Much better radios for relays, Hab. </td> <td> <ul style="list-style-type: none"> Initial field tests (Sergei joggling) are clean and reliable. </td> </tr> <tr> <td> <ul style="list-style-type: none"> Minimal "Breadboard" systems with "alpha" software, draft procedures </td> <td> <ul style="list-style-type: none"> Processes too complex for setup. Documentation poor. Field support limited </td> <td> <ul style="list-style-type: none"> Software improved User Interfaces simplified Documentation. Versions standardized </td> <td> <ul style="list-style-type: none"> In development Summer 2024. Promising results so far. Better documentation will help a lot with support. </td> </tr> </tbody> </table>	Prototype System Tested	Issue Found	Solution Found	Result or Plan	<ul style="list-style-type: none"> Basic T-Beams used as Repeaters Manually placed on Hilltops 	<ul style="list-style-type: none"> Shadows where no signal in field 	<ul style="list-style-type: none"> Used software to simulate tower placement and optimized locations. Better electronics and antennas 	<ul style="list-style-type: none"> Field testing with Sergei shows issue resolved. 	<ul style="list-style-type: none"> T-Beam Basic used in field Positions verified with Garmin backup system 	<ul style="list-style-type: none"> "Jumpy" GPS reporting with spikes in unexpected directions 	<ul style="list-style-type: none"> Software rejects noise. Radios standardized. Much better radios for relays, Hab. 	<ul style="list-style-type: none"> Initial field tests (Sergei joggling) are clean and reliable. 	<ul style="list-style-type: none"> Minimal "Breadboard" systems with "alpha" software, draft procedures 	<ul style="list-style-type: none"> Processes too complex for setup. Documentation poor. Field support limited 	<ul style="list-style-type: none"> Software improved User Interfaces simplified Documentation. Versions standardized 	<ul style="list-style-type: none"> In development Summer 2024. Promising results so far. Better documentation will help a lot with support. 	<p>We found jumpy signals where bad data made crew members spontaneously teleport for a minute or two. Filtering the noise out of the data cleaned up these stray readings. Improving the beacons also helped de-Heisenberg our teleporting crew members with more data points.</p> <p>We also found documentation gaps to fill for crew members going forward.</p>
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<p>Radio Shadow Study Tools</p> <ul style="list-style-type: none"> Used an online Radio Propagation Simulation to find the best hilltops for the relays Able to use Mars VR and the extended map to plan routes up and down the hills to put the equipment in place. 	<p>We found some online tools for modeling radio shadows. This allowed us to overlap our relay stations to knock out the shadow zones.</p>																

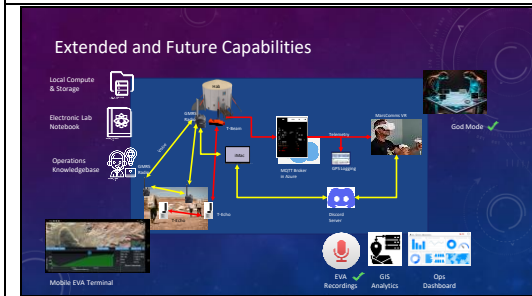
<p>Relay Upgrades</p> <ul style="list-style-type: none"> • Better Electronics • Better Batteries • Solar powered • Insulated <ul style="list-style-type: none"> - Warm batteries at night - Cool electronics in daylight 	<p>We also built much better repeaters for live use this next year. We field tested them for a few months before putting them away until the next season. For testing, Sergei wore a beacon out jogging a few times and we track his position from home over our network. No teleportation detected.</p> <p>The repeaters are solar powered and check in with their battery and temperature data periodically, along with their position. This set were built by Peter Dekluyver, and so got nicknamed the Peter Repeaters.</p>
<p>Dashboard Map Advances</p> <ul style="list-style-type: none"> • Added Messaging Window • Can assign a crew/name to a beacon so map shows names, not numbers • Can click on a beacon to see status. • Ground Track Records Visible 	<p>On our map view at the Hab, we've made a lot of improvements. In the short term, we want to label crew members by name rather than suit number using a list of crew suit assignments. We eventually want to add the text message feature here as well. This is a work in progress.</p> <p>Clicking the download button will send all the logged position and message data to a local drive. This is also the data log we are integrating with Mars VR to show crew positions.</p>
<p>VR Maps Include Relays, Crews</p> <ul style="list-style-type: none"> • Mars VR map combined with satellite map to give view all the way to the horizon. VR views in browser possible 	<p>Speaking of Maps, the Mars VR custom version for EVA-Link has been expanded with satellite data so you can see all the landmarks to the horizon, not just the few square kilometers where we have drone maps. Some of our beacons are in places like Phobos Peak which were off the original map. Putting on the headset can show crew in real time as tiny icons on a room-sized map, and teleporting down into VR shows them as suits.</p> <p>So with EVA Link and Mars VR – you can view the map on the screen, and in VR from either from the surface or from the air.</p>



And as I've mentioned, we are finally live with a production system this season! These are the suit terminals being shipped out after having improvements to the hardware and software configured. We can also remotely update them to a degree.



So, what next?



VR Surface Integration

- Data Streams from Crew and Relays can be overlaid on the crew member as an information box.




We are also working to add the live suit data to the icons in VR. For now, this is just the battery and temperature of the sensor in the backpack. Doing live health data is difficult because of medical privacy and experimentation laws. That said, there's nothing preventing a crew member from monitoring themselves privately with a Smart Watch and lining up the data later by time stamps. I would like a temperature sensor in the helmet, though.

In Development/Must Haves

Current Work	Important Next Work	Operational Improvements	Nice to Have Items
Map Improvements <ul style="list-style-type: none"> Astronauts named Logs kept by Crew, EVA and labeled Ability to display past EVA tracks. 	Lab Notebook <ul style="list-style-type: none"> Settle on an open-source software package Incorporate EVA logs into "paper trail" 	<ul style="list-style-type: none"> Pre-set protocols for sample collection tags. Operational knowledgebase of EVA-Link and all station hardware/software, expanded over time 	<ul style="list-style-type: none"> Meshtastic Weather station that can be prompted for data Heads-up display in helmet Unified software with simplified user experience.
Documentation <ul style="list-style-type: none"> Standard install guides Troubleshooting guides Operation guides 	Field Comms <ul style="list-style-type: none"> New crew devices with two-way text onboard 	<ul style="list-style-type: none"> ESP32 Suit devices with display in helmet or on wrist Mobile EVA Terminal 	<ul style="list-style-type: none"> Long range digital voice radio with synchronized logging of speech. Text to Speech in suit for messages sent.
VR Improvements <ul style="list-style-type: none"> Crew data overlap 	GIS analytics <ul style="list-style-type: none"> See where on map past crews found rock types 	<ul style="list-style-type: none"> Wall terminals (tablets) around base for local point-to-point use Echo/ equivalent in hab 	<ul style="list-style-type: none"> Open Platform for crew-specific equipment

So as noted, we are wrapping up our baseline system in the coming months before the field season. We want a lab notebook system for the Science Dome that works with the EVA logs. Ultimately, this would give scientist a paper trail from the field to the lab and publication. We want to make the suit systems smarter for two-way texting, so you can log samples or ask what's for lunch. In the long run, we found a compatible and affordable weather station and a heads-up display. Our gadget junkies are salivating.

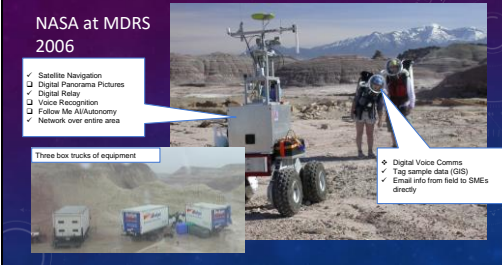
EVA Link Team







CORE TEAM:
 Brad Midgley
 Patrick Selby
 Kent Nebergall
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 Lily MacFaydian
 Mark Midgley
 Jeff Rayner + MXTreality
 Peter Dekluyver
 James Burke
 Eric Kristoff
 Ashton Zeth
 Taylor Anhalt

SPECIAL THANKS TO:
 Sergii Iakymov
 Mike Stoltz
 Louis Dekluyver
 Jason Simpson

I want to acknowledge our team. This started out as me with a PowerPoint presentation three years ago. And now it's going live thanks to all these awesome people who actually know how to build stuff.

<p>YOU CAN HELP TOO !</p> <p>To the right are just a few of skills that could make a big impact.</p> <p>How?</p> <ul style="list-style-type: none"> • eric.kristoff@gmail.com • Sign up at https://forms.gle/YAupeWVhw4CPTg3v6 <p>Or find Kent, Peter or Aston around Convention</p> <p>GitHub Repo https://github.com/marsociety/EVALink</p> <ul style="list-style-type: none"> Technical writing Web Development MDRS crews Blogging Video editing Graphic design Information management Science advisory (geology, biology, etc.) Python coding Mobile/Android development Rich Web App Client Database, Edge computing, Hardware Integration. 	<p>Do you build stuff and code stuff? Or document stuff? Please talk to me or scan this QR code at the end of the talk.</p>
<p>One more thing...</p>	
<p>NASA at MDRS 2006</p> <ul style="list-style-type: none"> ✓ Satellite Navigation ✓ Digital Panorama Pictures ✓ Digital Relay ✓ Voice Recognition □ Follow Me AI/Autonomy ✓ Network over entire area <p>Three box trucks of equipment</p>  <ul style="list-style-type: none"> ◆ Digital Voice Comms <ul style="list-style-type: none"> ✓ Tag sample data (GIS) ✓ Email info from field to SMEs directly 	<p>In 2006, NASA sent several crews out to Mars Desert Research station to experiment with long range digital communications and rovers that interacted with crews via voice commands.</p> <p>They brought out three moving trucks of equipment and could cover the entire zone with wi-fi bandwidth linked to a satellite ground station. They could track astronauts in the field and send geotagged messages on samples.</p> <p>So, in the nearly two decades since then, we no longer need three moving trucks to track astronauts in the field...</p>

<p>EVA-Link – Compact tracking/Data Links</p> 	<p>Thanks to 20 years of technology advancements, we get roughly fifty percent of the benefits of the NASA system for less than they spent for gas money for one of those trucks. You could basically pack all the gear for EVA-Link in a carry-on suitcase.</p>
<p>NASA at EAA Airventure 2024...</p>  <ul style="list-style-type: none">• For Wildfires, an ATC for the field to track and guide in drones• Off the shelf, mesh network	<p>A couple weeks ago, I saw this at EAA Airventure in Oshkosh. This is a NASA Advanced Air Mobility project to make an Air Traffic Control system for drones using off the shelf parts and a mesh network. It's for use in wildfires when they fly drones at night to monitor hot spots and weather conditions. On the right is a drone with weather instrumentation on top for checking conditions around a fire zone. So at least one NASA project is much more like EVA-Link than the NASA project that inspired it in the first place.</p>
<p>Thank you! Questions?</p> <ul style="list-style-type: none">• archresearch.net• MacroInvent.com  	<p>Thanks everyone. Any questions? The QR code is for a volunteer form. If you are on an MDRS crew in the coming field season, please also contact us to learn more about how to use the system before you arrive.</p>