IMPROVING MARS 2020 ROVER PLANNING

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MHCI+D Capstone 2019

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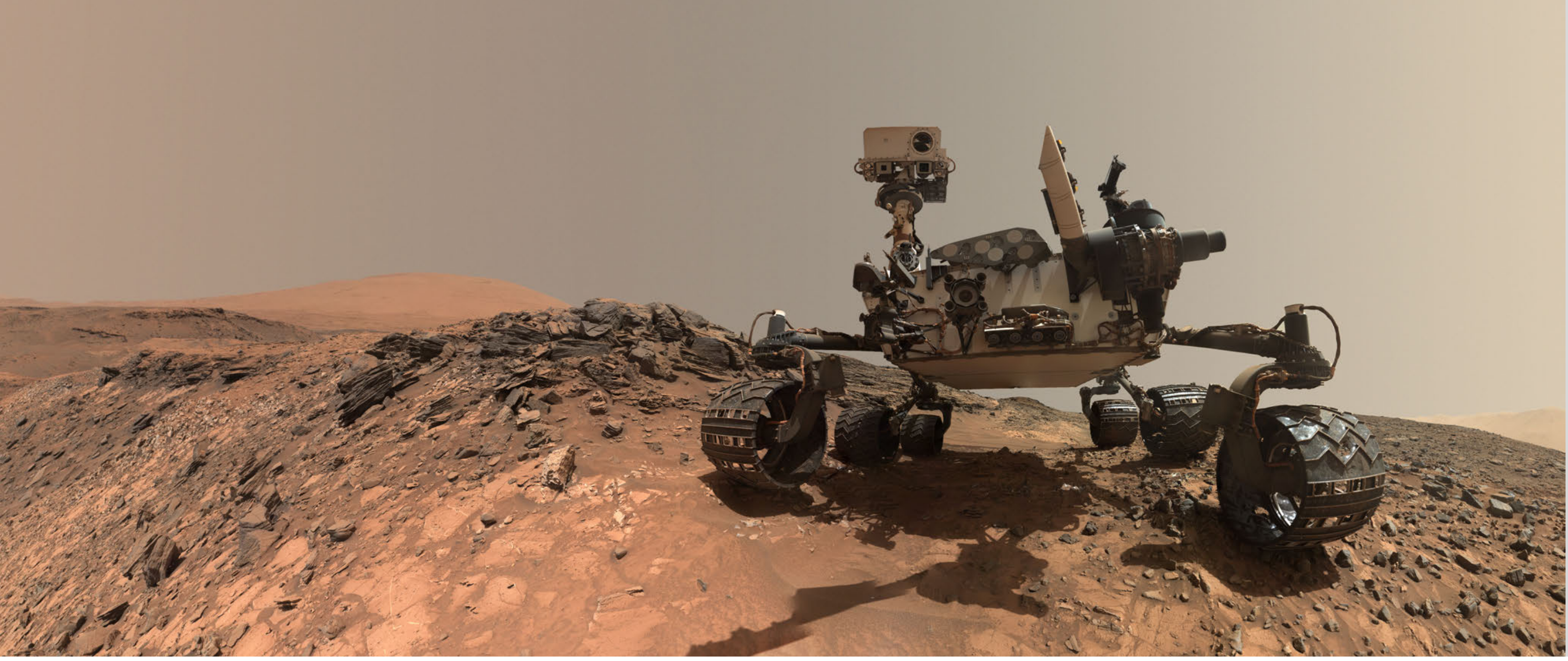
Last but not least, we want to embody NASA's culture of Heritage. We have included a detailed research plan, interview guide, and transcripts along with this report so that the team next year and learn and build upon our work.



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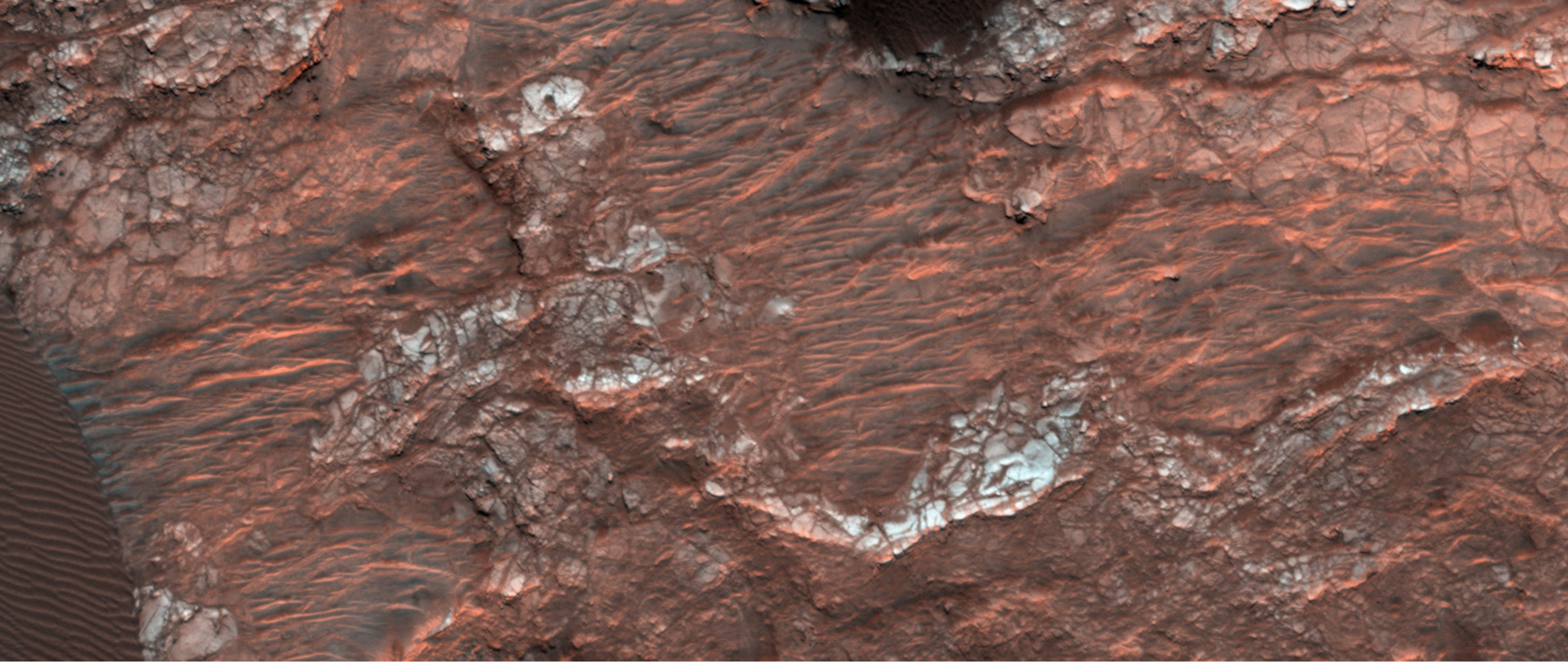


EXECUTIVE SUMMARY

In preparation for its upcoming launch, NASA Jet Propulsion Laboratory's Mars 2020 mission is working to reduce the amount of time spent planning rover operations in order to facilitate more time for scientific discovery. Rover planning at JPL is a complex decision-making problem, requiring consensus among various scientific and engineering domains competing for resources when choosing a course of action. This is complicated further by a fragmented tool ecosystem, geographical distribution of teams, and the fact that Mars' distance requires all activities occur asynchronously.

NASA Jet Propulsion Laboratory tasked us with finding some way of reducing deliberation time between these competing stakeholders in order to facilitate greater scientific discovery. We conducted an extensive literature review and 18 specialist interviews in order to gain a holistic understanding of Martian science and rover mission operations. We distilled this research into 8 insights to further our understanding of the problem space, direct us towards appropriate design opportunities, and inform our design requirements. With these insights in mind, we saw an opportunity to help scientists better understand and predict the impact of atmospheric opacity on rover instrumentation and data. We hope to increase data transparency and shift a traditionally tactical planning effort toward the campaign level. This will reduce the time needed for scientists to decide on a course of action and make more efficient use of the rover's limited resources.

INTRODUCTION

NASA Jet Propulsion Lab (JPL) is preparing for its upcoming mission, Mars 2020. This mission is the next stage in NASA's long-term effort of robotic exploration on Mars with multiple scientific goals, including searching for previous signs of life on Mars, characterizing the planet's climate and geology, and preparing for potential human exploration [1].

An accurate understanding of weather on Mars is critical to the success of the mission since there are several cases where conditions on Mars dictate where and how science experiments are conducted. For example, dust levels can dictate camera operability, temperature can affect rover power, the sun's position can affect the timing and feasibility of operations [2].

The Mars 2020 rover will run on nuclear power and as a result, it will have a longer operation time. NASA's internal policy dictates an equal amount of time planning and operating the Mars 2020 rover. This means that planning teams need to meet a daily 5-hour planning window, requiring quickly accessible data and an efficient decision-making process [3]. Seamless collaboration among the science, engineering, and instrument teams is crucial in order to meet this timeline.

Mission planning is dependant on geographically distributed teams comprised of individuals with varying skill sets and knowledge backgrounds. These teams rely on ad-hoc meetings, PowerPoints, and a company-wide wiki for communication. On previous NASA missions, breakdowns in communication have caused costly delays, wasted resources, and even irreparable damage to instrumentation [4]. Due to this lack of tool cohesion and improper documentation, the science intent often gets lost in the process further exacerbating collaboration efforts.

Over 10 weeks, our team conducted extensive secondary and primary research into various topics regarding the Mars 2020 operations. This includes Martian weather, scientific intent, team collaboration, and data visualization. Based on learnings from secondary research, we chose semi-structured interviews, directed storytelling, and iterative diagraming as 3 main methods for our research activity. We selected JPL scientists, engineers, and data visualization experts as the research population. A tailored guide was created for each interview participant based on their background, experience, and involvement with past and current Mars missions. We then used coding as a primary framework to synthesize insights and arrive at design requirements.

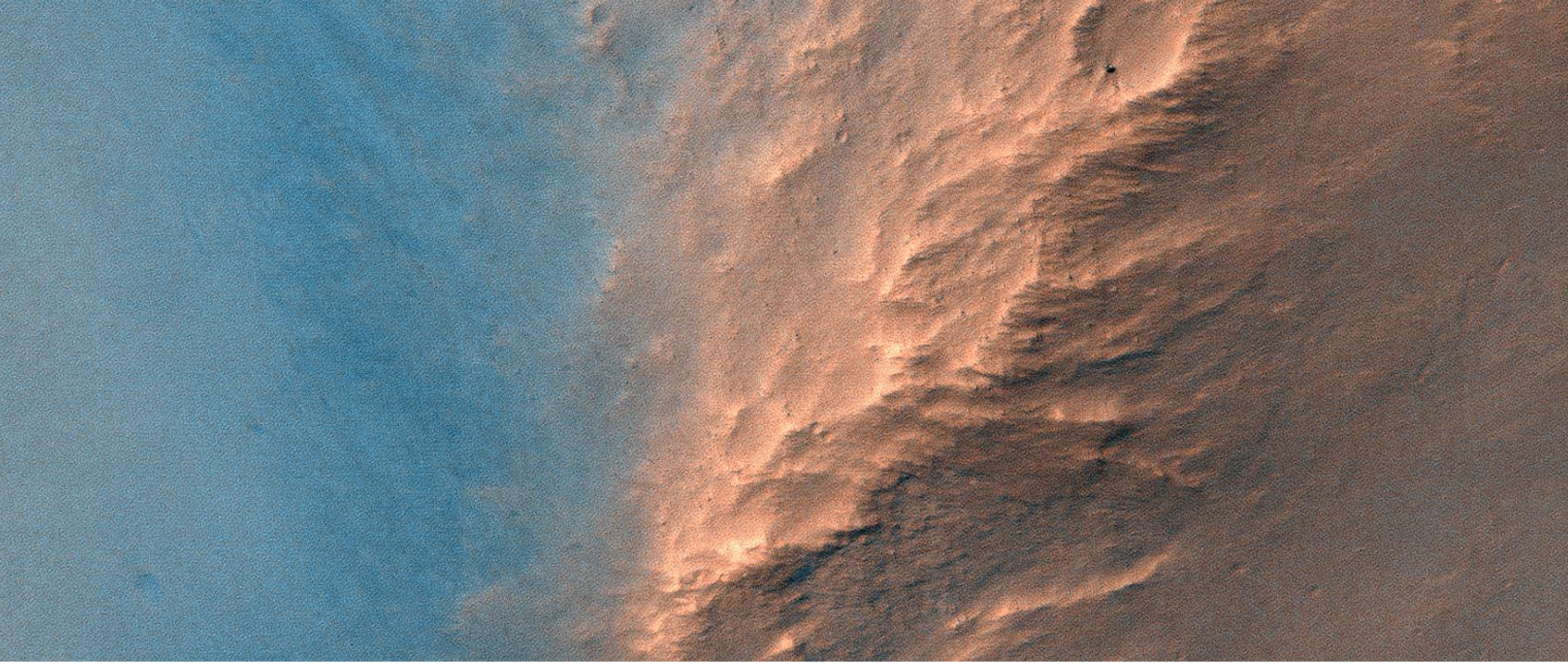
From our research, we identified 3 potential directions:
1. Helping scientists understand the effects of tau on instrumentation and data.
2. Preserving science intent to aid collaboration and decision making among operation teams.
3. Visualizing weather on Mars to provide scientists with data context with respect to the terrain.

We decided to move forward with direction #1 as it is well-scoped and aligned the most with our insights and design requirements.

There are 3 limitations to our research process: time, mission confidentiality, and location. Since NASA has a complex organizational structure, it is difficult to get a comprehensive picture of team collaboration and dynamics within 10 weeks. Second, the Mars 2020 mission is still evolving; information regarding operations and planning have not yet been finalized and can only be shared among internal employees. Third, our team conducted research remotely. This set a constraint in the type of method that could be used; ethnographic methods such as contextual inquiry or observational method which would have been a strong learning resource weren't a viable option.

CHALLENGE STATEMENT

How might we help scientists understand and predict the effects of tau on instrumentation and data?



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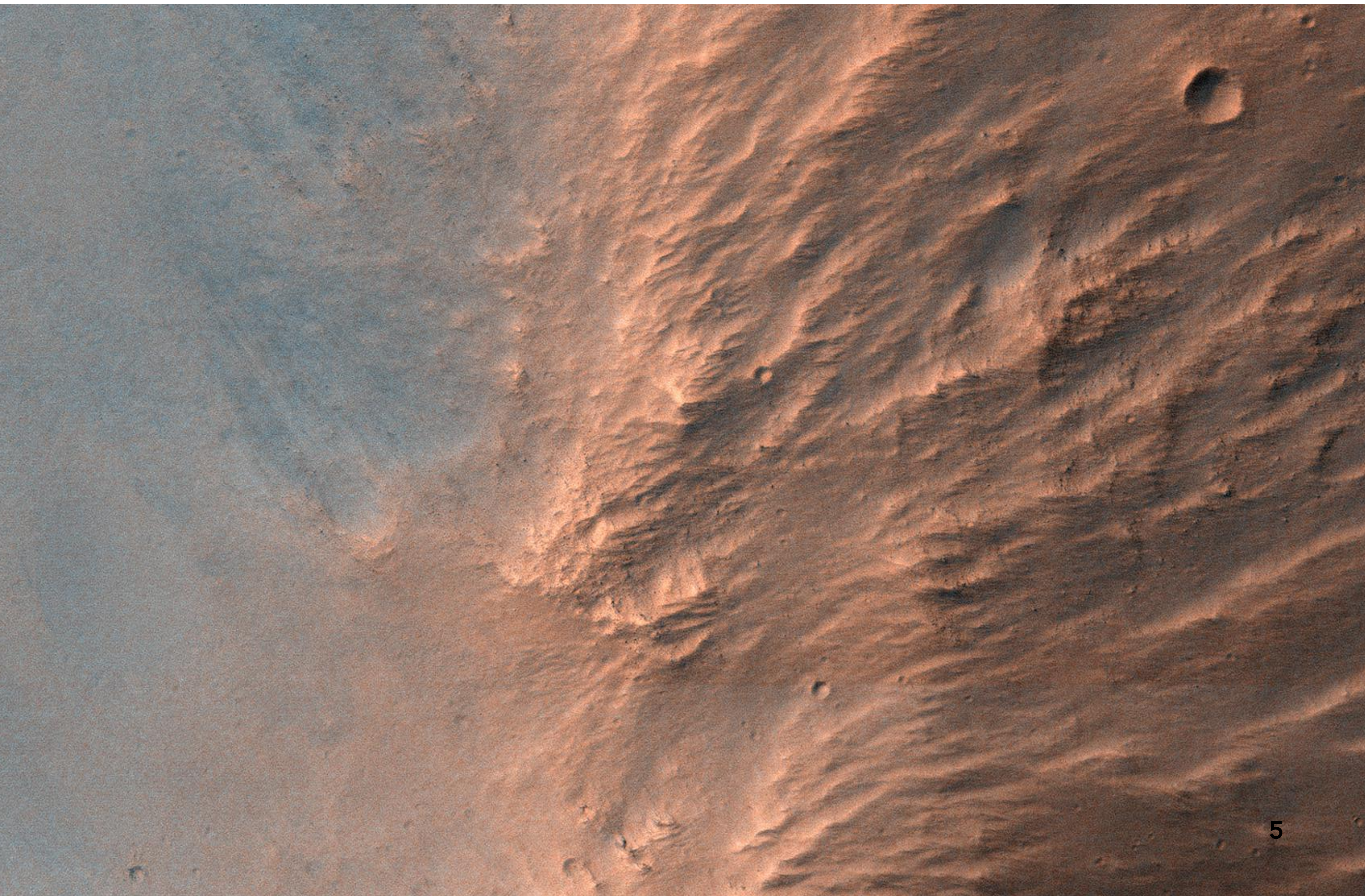
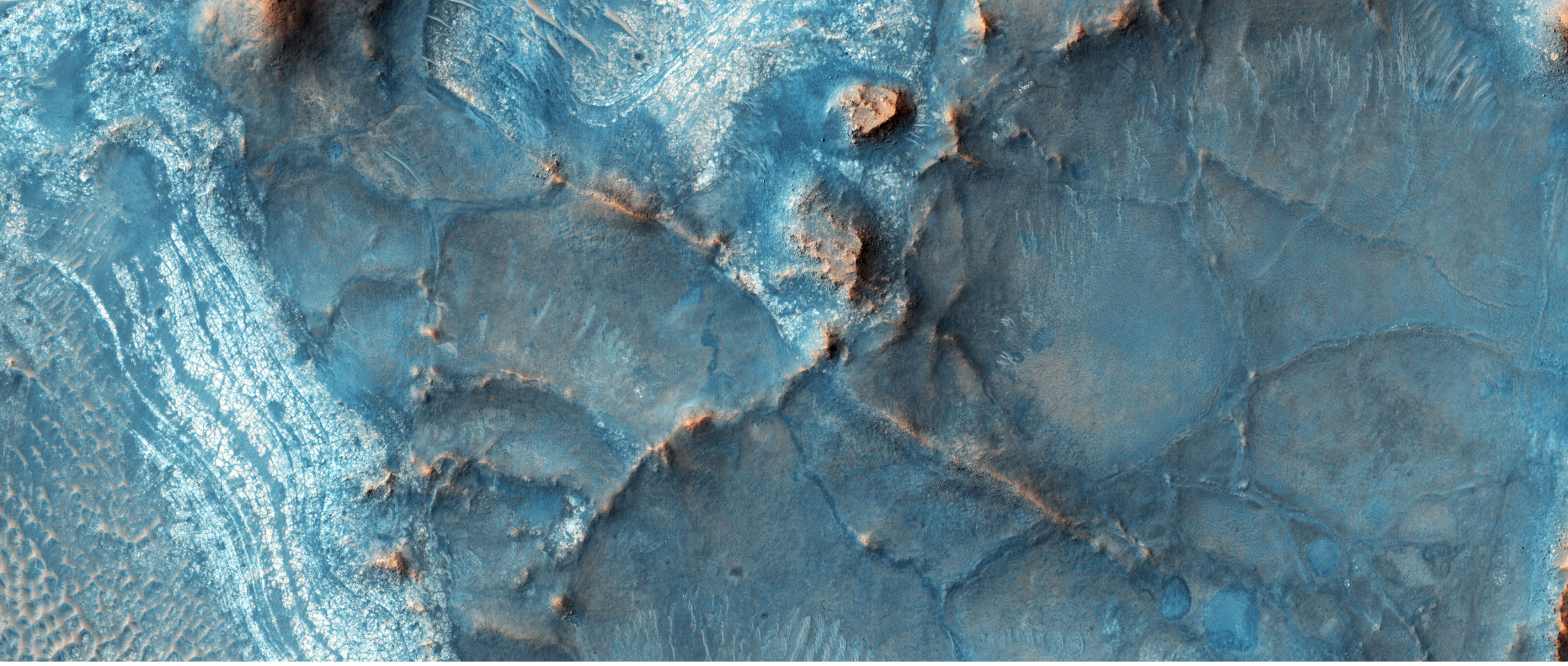
Background





LITERATURE REVIEW

Past Missions

NASA's Mars Exploration Program (MEP) was designed to study Mars as a planetary system using a variety of landers, rovers, and orbiters. Each mission builds upon previous research and innovations to continue to push to new discoveries. The goal of the program is to understand the geological and atmospheric processes on Mars, to study the planet's potential to sustain life, and to gather information that might help plan possible future human exploration on Mars. The original theme of Mars exploration was to "Follow the Water" as water is an indication of an environment that can support life. When past missions found evidence that water used to exist on the Martian surface, the Mars exploration theme evolved to "Explore Habitability," with the purpose of seeking additional chemical elements that were necessary for life [5]. Finally, with findings from the Curiosity rover, MEP marked a transition to the upcoming Mars 2020 mission, shifting the theme to "Seek Signs of Life".

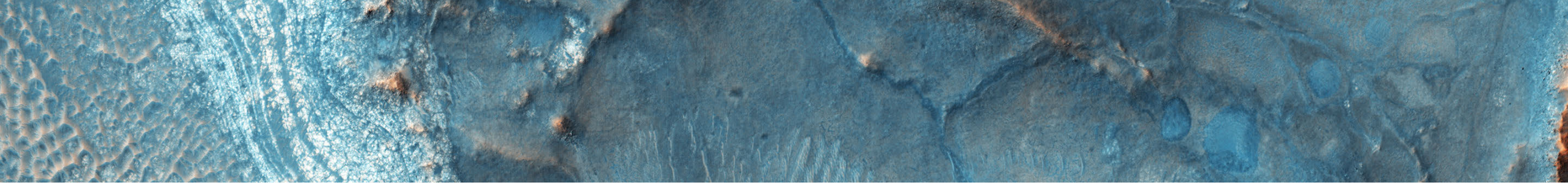
Mars 2020

With findings from Curiosity rover, MEP marked a transition to the upcoming Mars 2020 mission, shifting the theme to "Seek Signs of Life". The Mars 2020 program has 4 long-term science goals.

1 Determine whether life ever existed on Mars
The rover will conduct studies on the Martian surface and seek biosignatures from rock samples.

2 Characterize the climate of Mars
The rover will look for for evidence of ancient habitable environments where microbial life could have existed in the past.

3 Characterize the geology of Mars
Each layer of rock provides information about past Martian environmental conditions, revealing the history of how Mars' crust and surface evolved through time. The study could be further extrapolated to uncover the history of Earth itself. Current and future rovers will cache geological samples to be studied in the future.



4 Prepare for Human Exploration
The rover is demonstrating key technologies for using natural resources in the Martian environment for life support and fuel. It is also monitoring environmental conditions so mission planners get a better understanding of how to protect future human explorers.

Relevant instruments and spacecraft

The Mars Environmental Dynamic Analyzer (MEDA) is the instrument attached to the Mars 2020 rover that will help scientists gather information about weather on Mars. MEDA measures a wide range of variables such as temperature, wind speed and direction, humidity, and the size of dust particles in the Martian atmosphere [6].

Mars Reconnaissance Orbiter (MRO) is a spacecraft orbiting Mars since 2006 [7]. The mission goal is to study the Martian atmosphere and terrain, including the history of water flows on or near the planet's surface. It also serves as a key data relay station for other Mars missions. On May 15, 2019, it completed 60,000 orbits around Mars [7].

Mars Atmosphere and Volatile Evolution (MAVEN) is a satellite developed to study the Martian atmosphere and its composition. It has recently provided significant data around the loss of water and atmosphere on Mars and the role solar storms play [8].

Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) is a Mars lander that aims to study the "inner-space" of Mars: its crust, mantle, and core. It seeks to uncover how Mars was formed and evolve over time along with determining the tectonic activity on the red planet [9].

Weather variables and implications

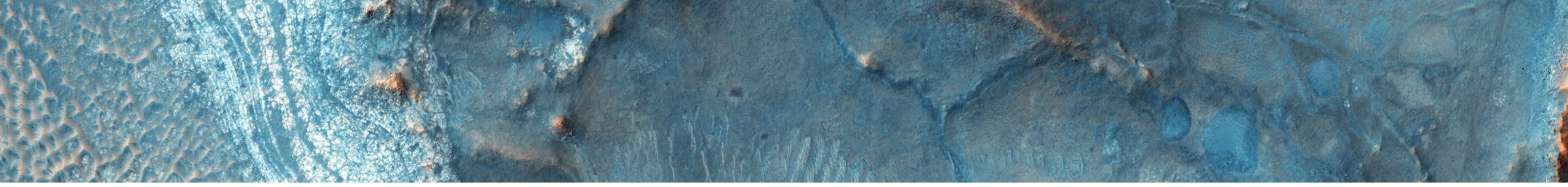
Atmospheric Opacity

Similar to the effect of water on Earth, dust dominates the surface of Mars and dictates most of its atmospheric conditions. Dust storms significantly reduce power on solar-dependent rovers, due to obscurement and settling of dust on the rover's arrays [10]. This obscurement risk has been somewhat mitigated in the Mars 2020 mission through the use of a nuclear power core, but meteorological data still holds significant mission planning repercussions. For example, the amount of dust particles in the atmosphere affects the optical opacity measurement (τ) which dictates camera operability, exposure times, and image quality [11]. Depending on the visibility, rover planners may also delay science activities that depend on external camera data [12]. Similarly, dust storms could damage delicate instruments and rover planners would need to know when to retract them in order to increase their longevity [13].

* (τ) - Tau, a measure of optical depth, or how much sunlight cannot penetrate the atmosphere. In the Martian context, it directly relates to how much dust present in the atmosphere

Temperature

Temperature is critical to rover operations, especially for Mars 2020 since the rover is running on nuclear power. Temperature profile includes near-surface air temperature and ground temperature. Near-surface air temperature affects rover powers as it influences how much heat is needed to warm up rover instruments. The rover also radiates heat which affects the surrounding soil temperature [14]. Understanding ground temperature, in this case, helps the operation team separate natural temperature effects from artificial ones to account for data error and uncertainty.



Wind

Wind can raise dust from the surface into the atmosphere, absorbing solar radiation and acting as an internal heat source. Near-surface wind speed and wind direction can have a direct influence on dust behavior and the formation of dust devils [15].

Atmospheric pressure

Atmospheric pressure and thermally driven tides are factors contributing to dust storm creation [16]. Understanding the effects of pressure and thermal tides can help scientists study and predict dust storm formation and behavior.

Relative humidity

Understanding water is critical for future human missions since it is a prerequisite for Earth-type life. Hence the study of relative humidity and its water vapor content is a paramount of scientific interests as it helps scientists identify the presence and behavior of water on Mars [17].

Radiation

Radiation from space and the sun can alter traces on Martian rocks which inhibits scientists from learning about the history of Mars. Measuring radiation will also help scientists measure habitable conditions and prepare for future human missions [18].

Seasonal and Interannual variability

All weather variable characteristics and patterns vary significantly depending on the time of the year. Studying how each variable behaves differently allows the operation teams to plan rover operations and scientific experiments at both short-term and long-term planning. For example, regional dust devils happen more frequently during the summer months [19]. Understanding this cycle helps the engineering team identify good windows for the rover's dust-cleaning schedule [20].

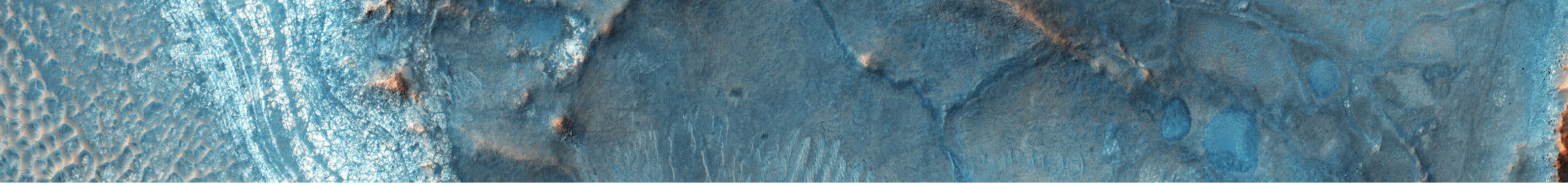
Remote Collaboration

Approximately 3 months from the date of the mission's launch, the team begins transitioning to operate via a distributed operations network, centralized at JPL. This enables the remote science teams to work remotely for the duration of the mission. The teams communicate with one another through telecommunication and video-conferencing software. This method of communication and collaborative work presents a set of complications may impact productivity. Research has found that videoconferenced discussions tend to be less social and more task-oriented than face-to-face discussions [21]. As a result, these meetings tend to be less efficient than face-to-face ones [22].

Remote collaboration is made more challenging when the collaboration occurs asynchronously. Research in the area of asynchronous collaboration has reported the success of view sharing, discussion, graphical annotation, and social navigation in addressing the challenges of asynchronous collaboration [23].

Decision-making process at high stake environment

In high-stakes domains, different roles and responsibilities must often work together to make decisions while geographically dispersed. While shared mental and situation awareness models are likely to be largely similar across an organization, some differences will persist as a result of distance, misaligned goals, and analytical methods. When these sense-making frameworks break, they present a risk to team cohesion and, ultimately, the project itself [4].



A mental model is defined as an internal representation of objects, actions, situations, or people [24]. They include knowledge of a system and of the relationships contained within them, supplying a "mechanism whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" [25]. Many studies have found that the greater the degree of overlap between the team members' mental models, the better that team performs [26], particularly if those shared mental models are accurate [27]. As such, an up-to-date and accurate mental model is imperative to effective decision-making processes in a high-stakes environment.

Team situation awareness is a shared understanding across the team of what is happening and what is going to happen due to well-defined campaign level goals. This allows a predictable process to occur in both nominal and abnormal events. When team situation awareness breaks down, predictability suffers, and communication becomes more difficult, if not impossible [4].

Closed-Loop communication is employed to prevent these breakdowns through stating the current action to reinforce trust between team members and providing a check on assumptions. This involves three steps: (1) A sender transmits, (2) A receiver accepts and acknowledges receipt, and (3) The original sender acknowledges the receipt message. This simple method is extremely effective by making what is usually implied overt - leaving no room for assumption [28].

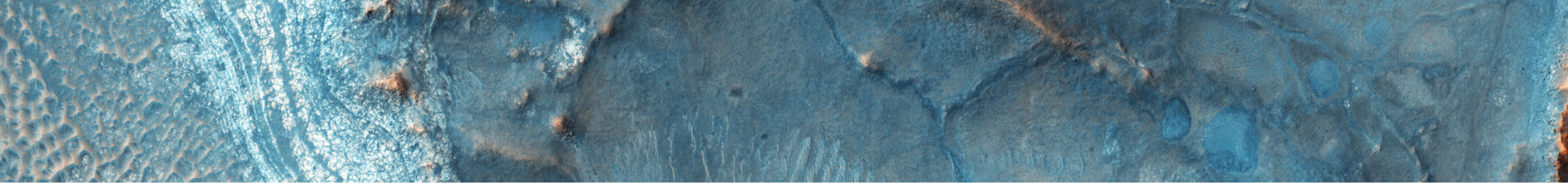
When breakdowns do occur, decision-makers employ recovery functions. These are ways of repairing a broken line of communication in the decision-making process [29]. One such method is the incident report which is used to assess breakdowns through open lines of communications and classification so that an organization may learn from and prevent future errors [30].

Despite safeguards and constructs meant to prevent breakdowns of decision-making capabilities, breakdowns will inevitably still occur in high-stakes distributed systems. Research suggests that informational (lack of information) and evaluative (a misunderstanding of information) disconnects lead to mental model and team situation awareness degradation, which in turn causes operational (difference in expected and actual actions) disconnects. Utilizing this model, they suggest that by focusing on the former, you can prevent the later from occurring [4]. These studies highlight the importance of ensuring all information is uniformly shared and understood in a decision-making process.

Visualizing Scientific Data

Web-based data visualization tools have become more accessible, sophisticated, and interactive due to the profusion of open source software and tool kits. While the commercial industry has adopted multiple applications of data visualization, the scientific domain still faces a wide range of challenges due to the inability to accommodate the specific nature of scientists' needs. There are many factors that contribute to this problem but two critical ones of note are: the method of data collection and the scale of scientific data [31].

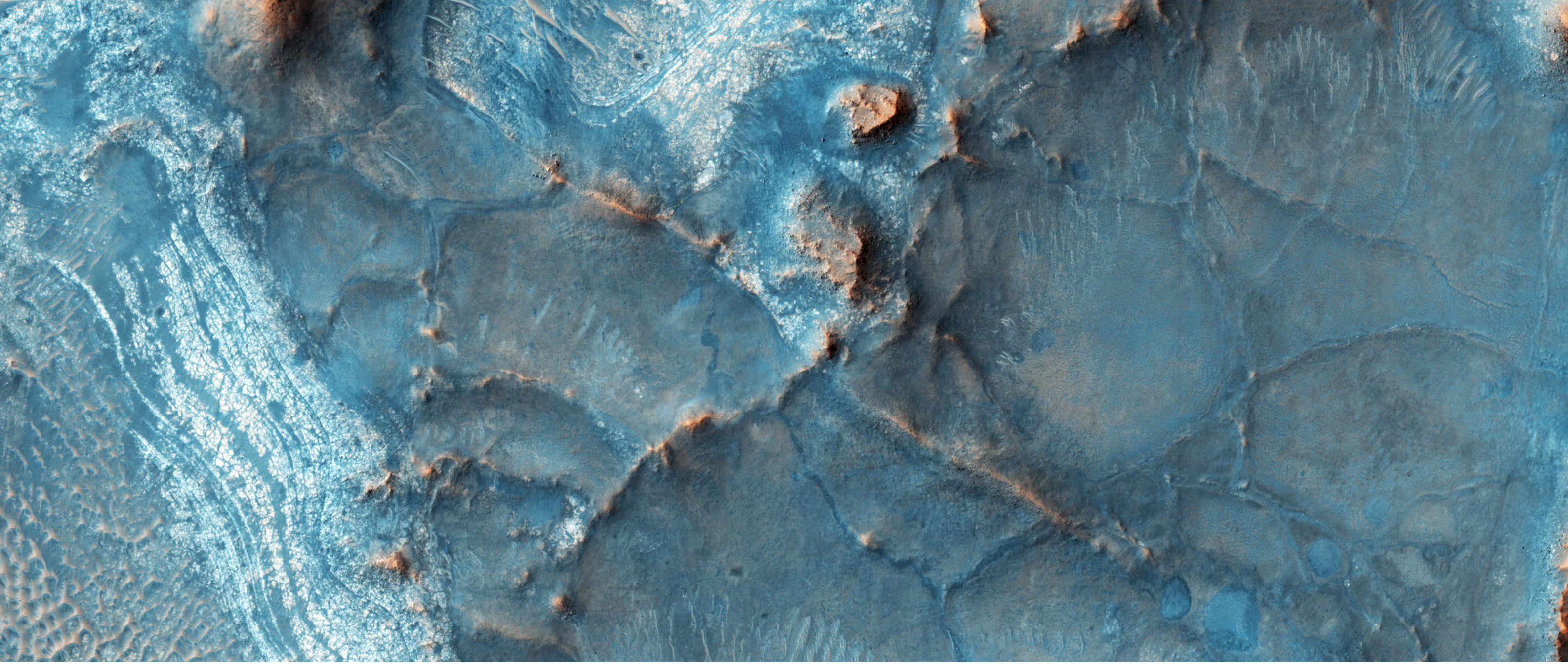
Collecting scientific data is difficult and instrument-specific. Depending on the source, each data variable comes in with a specific measurement, accuracy, or resolution [32]. Even though scientists have a good understanding of their own data and have means to make sense of raw data, getting the same intuitions from data across multiple instruments or from an unfamiliar research



area is difficult [31]. The second challenge is data scalability; scientific research requires a continuous influx of better data at a growing scale. Without live linking and quick data integration within internal tools, data visualization becomes its separate entity. As new data accumulates, the visualization quickly becomes outdated; it no longer reflects new findings and patterns [31].

Additionally, major scientific problems nowadays rely on the interdependence and integration of data from multiple sources and instruments. The role of visualization for complex data needs to evolve beyond aesthetic representation. It has to support scientists in forming hypothesis and exploring alternatives throughout the research life cycle [31].

Jim Gray described his vision of data-intensive science and called for a generic set of tools that could accommodate scientists through 3 main activities: data capture, curation, and analysis [33]. First, data needs to be holistically captured both at the mega-scale and a milli-scale [32]. Curation starts with identifying the right data structures to map into various stores. It must include the schema and the necessary metadata in order to integrate across instruments and make data interpretation become explicit [32]. Data analysis includes a set of activities such as workflow pipeline, the use of databases, analysis and modeling, and then visualization.



JPL STRUCTURE

Science Team Roles [34]

SOWG Chair: Leads the science team in tactical meetings and helps them reach a consensus for daily planning.

Science Uplink Representative (SUR): Represents science during the uplink process and documents any changes to the science plan.

SOWG Documentarian: Documents the science intent behind activities and any scientific breakthroughs.

Long Term Planner (LTP): Presents material that summarizes current rover activities and ensures the tactical plan is in line with the campaign goals.

Science Theme Lead (STL): Represents a specific science theme group (STG) during meetings and advocates for their desired observations.

Science Theme Group (STG) Member: Analyzes instrument data, develops and tests hypotheses.

Payload Downlink Lead (PDL) - Instrument Specific: Verifies and monitors the health and status of the received instrument data.

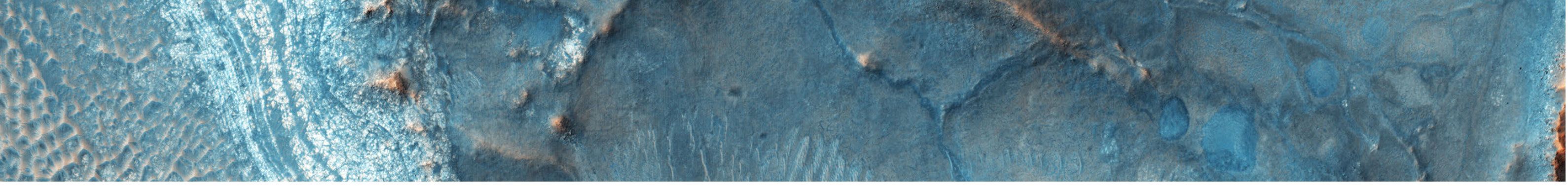
Payload Uplink Lead (PUL) - Instrument Specific: Creates instrument sequences and assess the compatibility of uplink commands with operational constraints.

Science Team Meetings (Tactical)

Science Kickoff Meeting: Scientists come together to review the data from the previous day and determine their highest priority science observations for the day.

Science & Engineering Tag-Up: Engineers and scientists meet so that engineers can inform scientists of any restrictions that they need to be aware of for that particular day.

Science Operations Working Group (SOWG) Meeting: This is the main tactical meeting where scientists and engineers have their discussions about the next day's targets.



Science Team Meetings (Campaign)

Principal Investigator (PI) Team Meeting: Instrument team meeting to discuss strategies for operations, scientific hypotheses, and findings.

Science Discussion Meeting: Science team members present science results, discuss working hypotheses, and campaign plans.

Project Science Group Meeting: Scientists discuss campaign issues, staffing and scheduling of roles.

MSL Science Team Meeting: Happens approximately once every 6 months to discuss status, results, and strategies of the mission.

Workflow/Meeting Challenges

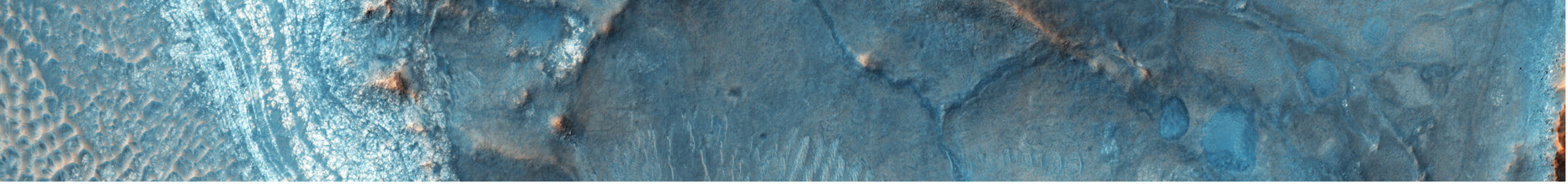
One of the challenges of the Mars Exploration Laboratory missions compared to other NASA missions, is the degree to which operations are impacted by the ever changing environmental variables. The operations teams can use previously captured orbital images to guide future activities, but these images don't capture all the information needed to decide what the rover's next target will be. As a result, planning happens daily based on the comprehensive data which is only available after the rover sends back the prior day's activities. Teams need to be reactive and responsive to this data in order to quickly develop the next day's plan which also aligns to the mission's long-term science goals [34].

NASA has introduced three categories of mission planning: tactical, supratactical and campaign. Tactical refers to the short-term, daily planning activities which include analyzing the most recent data, coming to a consensus about the next desired science observations, and generating new commands for the following day. Campaign planning refers to activities that focus on develop long-term plans spanning weeks or months to achieve the mission's high-level objectives. The supratactical stage provides a bridge between the long-term plan and the day-to-day processes [34].

A typical day's tactical meeting is 8 hours long and begins with a limited "uplink" window in which the team sends new commands to the rover. Throughout the day, there are periods of "downlink" where the teams receive data back from the rover; for example, this can include measurements from instruments or pictures that the rover has captured. Teams of scientists, rover planners, and engineers work together to make sense of this data and decide on the next course of action which will achieve scientific goals while still maintaining the rover's safety. Coming to a consensus about the next day's activities is a difficult process because various science teams must advocate for their plans. Additionally, scientists sometimes need to convince the engineering teams to implement specific plans that could put the rover at risk of lower power or instrument damage.

Science Intent

Science intent is the context around how a given activity fits into the larger picture of the mission. This context is used to determine a tactical list of goals, as well as prioritization of the overall task, given its relative importance [35]. Clear communication of scientific intent is a critical step in planning both scientific and engineering activities during planning meetings. Engineering needs this information in order to plan activities on a cadence so as not to inadvertently interfere with the scientific activities by calibrating instruments during a longitudinal study [36]. Historical knowledge of intent can be a useful tool in streamlining goal generation and prioritization. It prevents duplicative work



over time as previous discussions may be applicable to past debates [35].

Proper communication of scientific intent during rover operations is a subject of hot debate, but some common practices have emerged throughout the years. Generalists aggregate information and distill it to be understandable across the organization. This communication is largely done via annotated PowerPoint decks, which act as one of the few widely used tools across the organization [37].

This method works well in terms of communicating current intent, but breaks down when there is a need to access historical intent. The information is not easily searchable or accessible after its initial dissemination, so if a scientist needed to reference previous discussions around the scientific intent of an activity, she would have to sift through hundreds of PowerPoint decks [36].

Internal Tools

ASTTRO
The Advanced Science Targeting Tool for Robotic Operations (ASTTRO) is used by rover planners and scientists for selecting rover targets. The tool reconstructs the Martian terrain from images taken by the rover as scene visualization for situational awareness. The operation teams can tag target coordinates, scientist, and specific instrument, etc. as metadata. However, the tool currently only has limited information regarding the sun and doesn't include weather information.

PowerPoint
The science team uses Microsoft PowerPoint as the main tool to communicate scientific findings and proposals during meetings and planning discussions. While PowerPoint is a commonly acceptable tool with an easy learning curve, it doesn't provide all necessary capabilities to ensure effective communication. PowerPoint doesn't help preserve the context of the conversation. Science intent, critical discussions, detailed clarifications, and situational nuances tend to get lost in the process.

MSLICE
The Mars Science Laboratory InterfaCE (MSLICE) is a planning tool that helps scientists and engineers prepare for rover activities on a daily basis. It models the energy and time of all the instruments and intended activities on the rover's traverse in order to optimize scientific data and ensure rover safety.

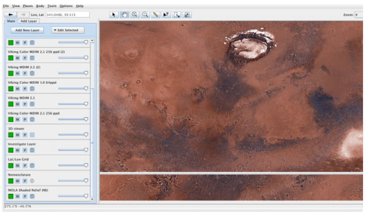
COMPETITIVE ANALYSIS

The competitive analysis helped our team explore existing tools in various domains, assess their pros and cons, and draw insights on how we might utilize existing features for our own design. We approached the competitive analysis with the intention to assess a variety of tools related to collaboration, communication, mapping, and data visualization. The analysis included translational products to better understand how other fields approach solving issues related to collaboration in time-pressing situations.

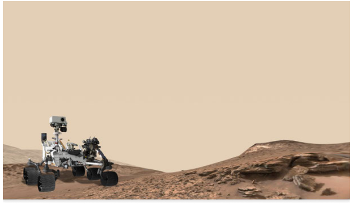
Based on our research, we identified five important criteria to measure the tools against: transparency, customization, shareability, comparability, and annotation. For each criteria, there was at least one tool that did a great job at mastering the interaction design. This could potentially serve as reference point for our team when we move into the ideation process.

A more detailed version of our competitive analysis can be found in the Appendices.

Mapping Tools



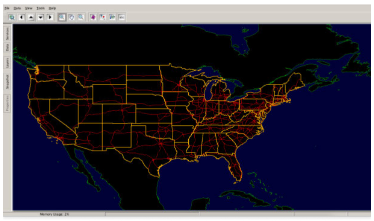
JMARS



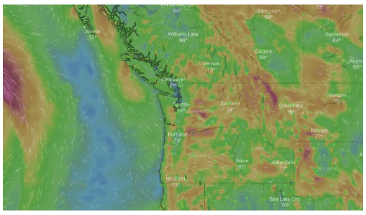
Access Mars

Google Earth Pro

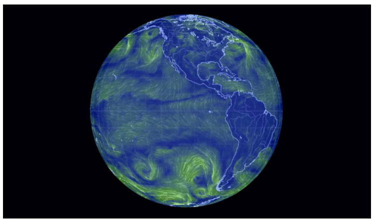
Weather Tools



NOAA Weather and Climate Toolkit (WCT)

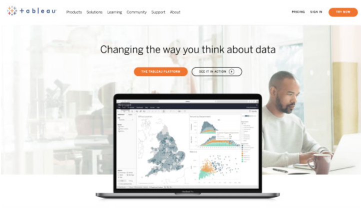


Windy



NullSchool

Data Visualization Tools



Tableau

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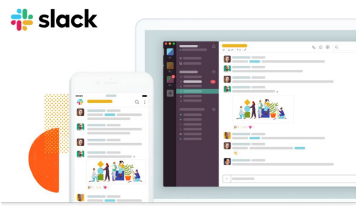
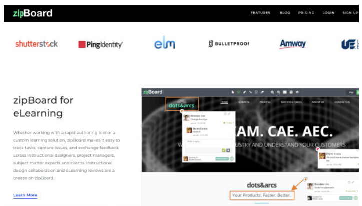
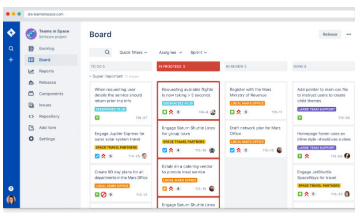
Collaboration Tools



Slack



zipBoard



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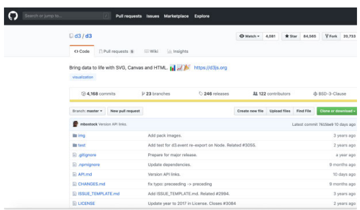
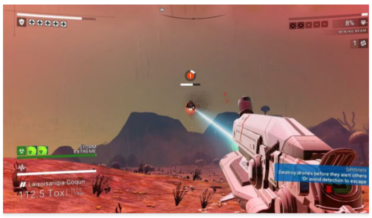


GitHub

Translational Tools

War Room



No Man's Sky

Bartending

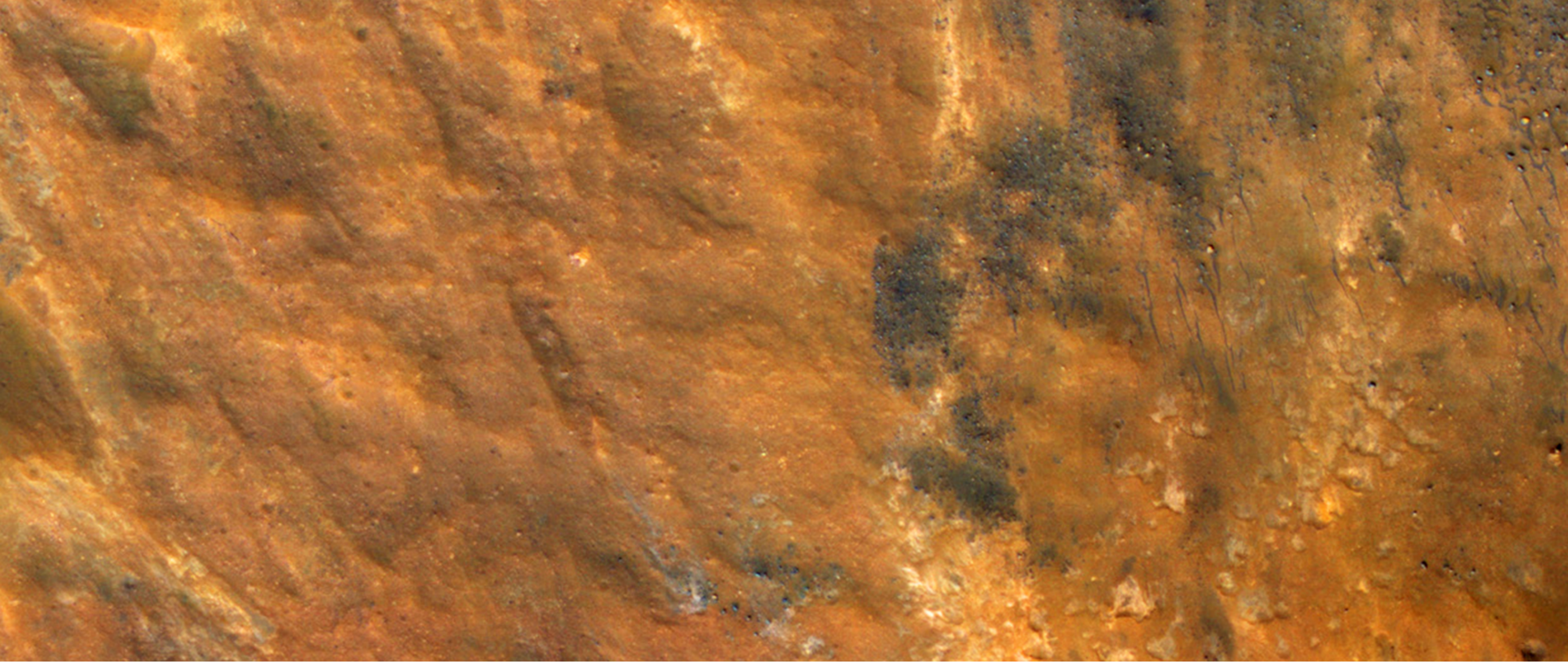
Key Findings

01 **Provide Collaborative Experiences:** Users should be able to have shared experiences when collaborating. A way to enhance collaboration is allowing users the ability to share their work with each other. Most JPL scientists use web-based tools when processing and analyzing weather data.

02 **Add context to data when possible:** Metadata plays an important role in providing additional contexts to data. A data point should have relevant metadata, tags, comments, and annotations so that users can interpret the dataset with a common ground. It could be enhanced if users can interact with the visualization, hovering over a data point to view more information.

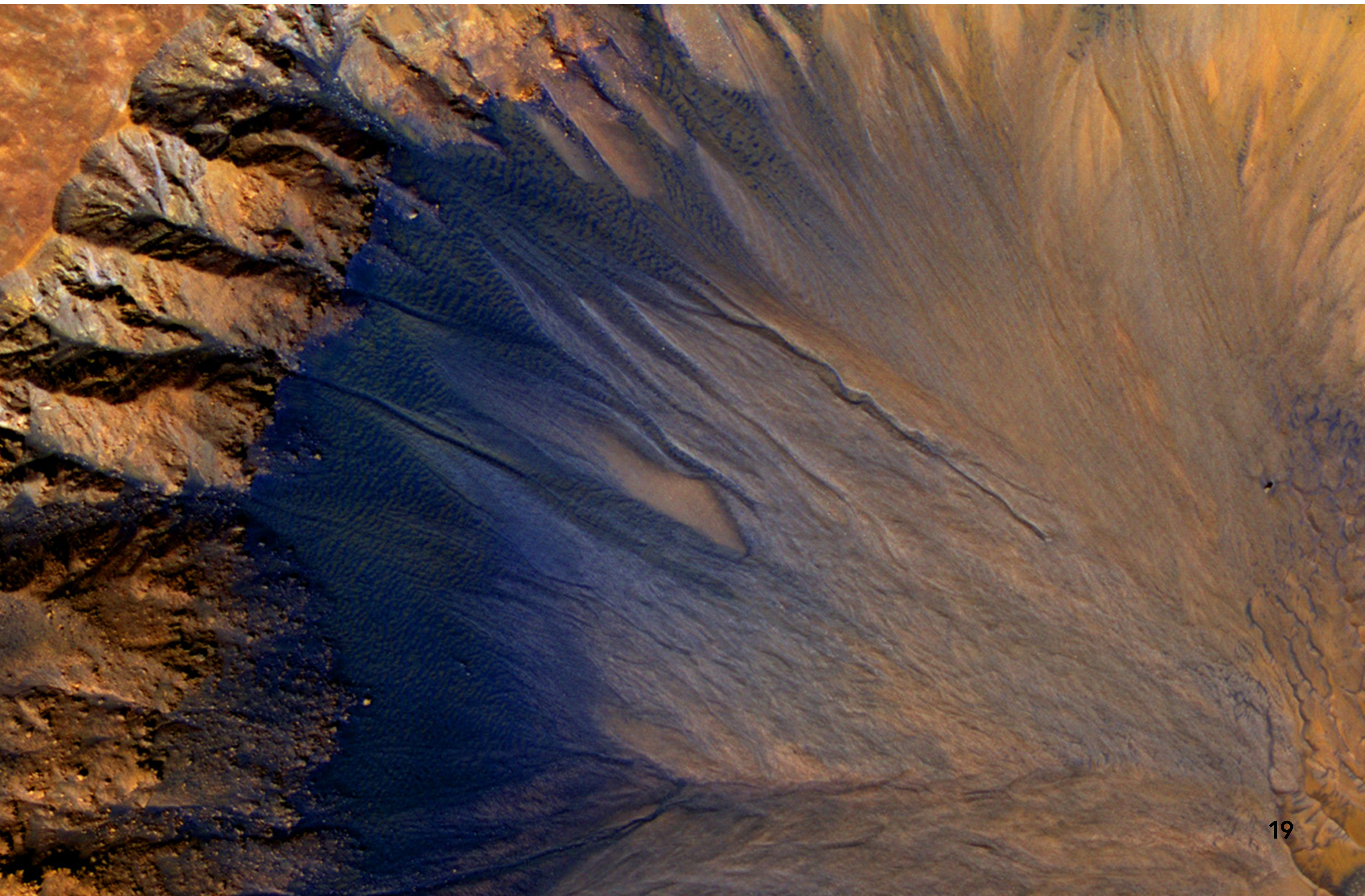
03 **Trace back to raw data:** When conducting data analysis or exploring a dataset, scientists prefer to have access to the raw data so that they can conduct a variety of analysis and manipulate different visual presentations.

04 **Enhance customization:** Customization can add significant values when analyzing data. Each user has a different need and a preferred method for exploring and manipulating dataset. This also extends to having the capability to adjust the tool bars, layout, customize the codes to accommodate personal needs.



02

Research



GUIDING QUESTIONS

What is the typical workflow for rover mission planning and what collaborative and operational challenges do they face?

Rover operations require collaboration between rover planners, scientists, engineers and other stakeholders. Understanding their typical workflow will help us uncover any flaws which could lead to a disconnect in their mental models regarding weather.

What tools and technology does the mission operation team currently use, or plan to use, to collaborate and assess weather information for mission planning?

Decomposing the tools that are currently being used for mission planning, with a focus on the ones that involve weather analysis, will help us uncover any limitations with the current technology which could act as opportunities during our design process.

What weather information does the mission operation team need to know and how do they use this information in making time-sensitive decisions?

There are a number of different weather variables that have varying levels of impact on short-term and long-term mission planning operations. We hope to understand what weather variables the mission operations team prioritizes, how often they examine them and how they interpret them to make decisions.

PARTICIPANTS

01 Weather Experts

We needed to interview Martian weather experts in order to better understand the domain and the needs of the field. We also were interested in the types of weather events they were interested in, and the tools they use to analyze and share data.

02 Rover Mission Personnel

We were interested in speaking to rover mission personnel such as engineers, drivers or planners to gain a full picture of the collaboration and workflow involved in a high stakes environment.

03 Data Visualization Experts

Data visualization experts provided us with information on best practices for communicating data to others.

METHODS

01 Semi-Structured Interviews

For each of our participants and experts, we created a list of questions that were tailored to each individual to guide our interviews. Their responses to the prepared questions led to new questions and dictated the direction of the conversation. This method opened up a window into our participants' mental models and decision making processes.

02 Directed Storytelling

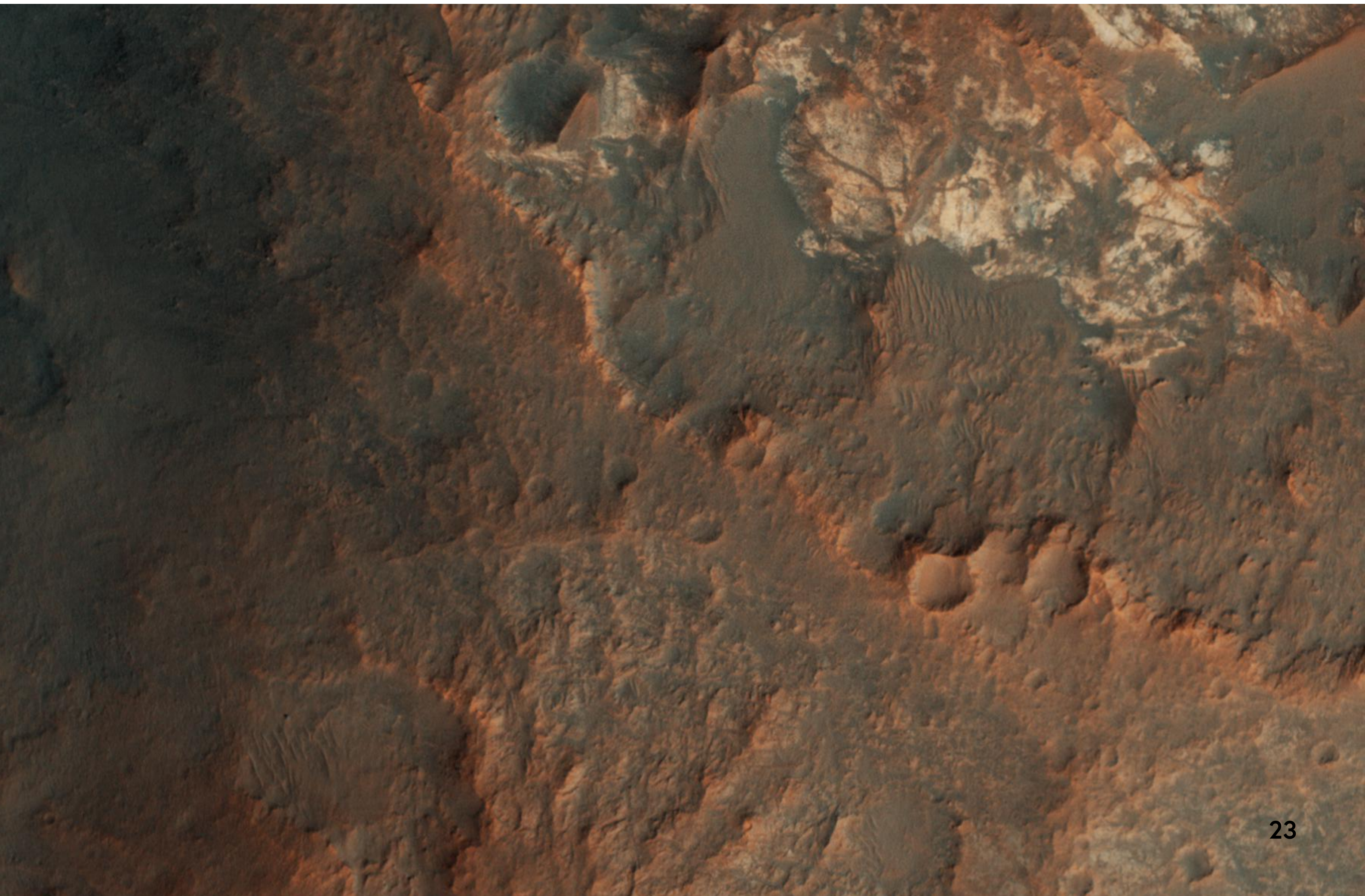
Participants were asked to talk about a past experience in detail. The questions were centered around events that sparked fear and/or required highly collaborative work. We aimed to understand our participant's perspectives during these experiences and better understand communication breakdowns, motivations, and actions taken.

03 Iterative Diagramming

In order to better understand the needs of scientists and engineers during the rover planning process, we needed to be able to conceptualize the structure of these planning meetings. We constructed a diagram based on information we gather from the literature. Participants were shown our sample diagram and were given time to offer changes or corrections.

03

Results



INSIGHTS

01
Meeting the proposed 5-hour operational timeline is unattainable unless rover teams shift focus to long-term goals.

02
Weather no longer poses a critical risk to rover safety, but still must be considered due to its impact on instruments and power constraints.

03
Weather on Mars is relatively predictable, however, there is no weather forecasting despite its potential applications to long-term planning purposes.

04
Unavailable atmospheric opacity (τ) measurements in internal tools negatively impacts operational efficiency.

05
Despite tactical disagreements and the varying cultures, rover safety takes precedence because without a rover, there is no scientific discovery.

06
In the conflict between mission groups, the only shared language is data. Even then, every specialty has its own dialect, leading to misunderstandings.

07
Data is more revealing when contextualized with other observations. Existing tools do not have this capability, hindering scientific discovery.

08
The use of numerous custom-built tools is "both a feature and a bug"; it makes output inconsistent, but leads to advancement through productive scientific discussions.

01 Meeting the proposed 5-hour operational timeline is unattainable unless rover teams shift focus to long-term goals.

The Mars 2020 mission duration is set to last 90 sols and during that time the rover planning structure will need to be at a campaign (long-term) level. After the initial 90 sols, the nominal mission comes to an end and for the remainder of the rover lifetime, planning meetings can continue at a tactical (short-term) level with mission planning process becoming more reactive. For the first 90 sols, JPL has suggested a 5-hour planning meeting limit. In past rover missions, early planning process often required 12-hour meetings to reach consensus. For this reason, many of the JPL personnel that we spoke to expressed concerns that the 5-hour timeline could result in sacrifices to tactical planning and opportunistic scientific exploration. The timeline leaves little room for discussions and proposals outside of the campaign level.

"In the very beginning, it took about 12 hours to just send one day's worth of uplink to Curiosity. I think it reduced down to an average of like seven to eight. On really great days, [...], they got really close to five. " - P8

"A lot of what we do is discovery-driven science. You drive to a new place, and you had a plan, and all of a sudden, someone says, wow, that's so cool. Let's go check that out. And, and that's a trade to be made. " P11

" My understanding is that the way they're kind of doing it is basically removing all decision making from the tactical process, it will all be planned in that strategic time window, which is going to take forever, because you're going to have the same kind of debates going on. " P3

02 Weather no longer poses a critical risk to rover safety, but still must be considered due to its impact on instruments and power constraints.

Unlink past missions, the Mars 2020 rover is nuclear-powered, which means that the weather won't pose that same critical risk. Weather still needs to be considered because of its impact on the rover's instruments. For example, dust storms still need to be closely monitored because the rover's cameras need to avoid dust on the lenses which would hinder the team's ability to take necessary images. Additionally, temperature affects the accuracy of certain instruments on the rover, so unless it was closely monitored data could be misconstrued.

On a tactical level, there's only a certain amount of power available for exploring and collecting scientific data. To optimize data collection, science teams need to be dynamic, flexible, and willing to shift priorities in response to weather events or new findings. This also means seizing the opportunity to collect as much data during unexpected situations.

"The Mars 2020 rover isn't going to be as critically in danger when it comes to storms because it's now nuclear powered [...] But dust storms [prevent us from taking] proper pictures." - P2

[Engineering] is going to get touchy about pointing the cameras very high up elevation wise when there is a lot of dust in the atmosphere. Atmospheric observations may be curtailed because you don't want to get your camera stuck pointing at the sky with a bunch of dust falling out of it. - P15

"It can get very very cold on Mars, that cold can be really bad for electronics. And so that means that when it gets too cold, you have to run heaters to do things to make sure there's no damage to electronics." - P13

03 Weather on Mars is relatively predictable, however, there is no weather forecasting despite its potential applications to long-term planning purposes.

Due to the lack of oceans, weather events on Mars can be predicted up to one Martian year (687 Earth days) in advance with variance of only a few weeks. This predictability is not surprising as Martian weather conditions are controlled by several factors that do not change much from year to year: seasonal heating from the sun, polar melting, and topographical features such as mountains. Despite this cadence, there is no tool to let mission teams know the weather forecast along the planned rover path. This presents an opportunity to aid the mission teams by surfacing expected weather conditions to facilitate proactive instrument and science activity planning, moving planning away from day-of tactical planning as is required by the Mars 2020 5-hour uplink goal.

"Scientists [predicted]...that Mars was going to get a really big dust storm and it did. That's why Opportunity no longer works, but they were able to predict it fairly well and that's because there's this pattern pretty frequently that occurs on Mars." - P2

We always know there's a dust season on Mars which is typically associated with the summer. There's typically a more cloudy season as the seasons change. [..] So at least on a seasonal cycle, things are fairly predictable. - P3

You actually plot the predictive temperature [...], it changes your access scale up to that much lower. I don't know what the temperature will be precisely, but here's the predicted range, add that to the chart, because that's the context in for the decision you're making. - P10

04 Unavailable atmospheric opacity (τ) measurements in internal tools negatively impacts operational efficiency.

The visibility measurement (tau) indicates how much dust is present in the atmosphere. This information affects 3 main stakeholders: science, engineering, and image processing teams. The engineering team ensures the safety of the rover and its instruments by taking into consideration how the rover's arm should move, the angle of the movement, and the topography of the terrain. However, current rover targeting tools (i.e., ASTTRO), without tau information, do not inform scientists of the engineering feasibility of their target requests. The lack of tau information also creates a communication setback between scientists and the image processing personnel. Both parties need to understand the amount of dust in the atmosphere to estimate image exposure and processing time in order to produce the highest image quality.

“

Before [scientist] go off and start harassing the folks that do the image processing to get it into the pipeline of what's wrong and why is this broken? It's a lot nicer to go, 'oh, okay, I'm dealing with the local dust storm, kick the tau up for a day or two.'- P15

I could see how [tau] might impact the way people think about things. And people generally keep it in mind, but I've never seen it in the planning tool. -P16

You're trying to take photos that have the same sort of lighting across a long traverse because you're comparing [rocks color and sizes]. If the lighting [of the image] changes halfway through your traverse, then it's a problem. - P7

05 Despite tactical disagreements and the varying cultures, rover safety takes precedence because without a rover, there is no scientific discovery.

During daily tactical meetings, engineers and scientists work together to decide on the next day's targets. This can sometimes lead to disagreements due to differing priorities and cultures. Scientists want to explore as much as possible to meet the mission's scientific goals, while engineers are concerned about the rover's safety and functionality. This leads to situations where scientists are more risk tolerant than engineers. These discussions tend to be difficult for both sides because engineers are trained to be quantitative and binary, while scientists are less apt to quantify the trade-off of risk and reward due to the uncertain and imperfect nature of science. At the end of the day, they will negotiate and find an acceptable level of risk to ensure rover safety is not compromised while still advancing science.

"It's very difficult for the science teams when you're doing [planning] trades, to be as quantitative and sure of ourselves as the engineering team [...] I wouldn't call it a conflict, but you know, just different culture expresses itself." - P14

"Engineers, of course, are extremely cautious..[..] we don't want to stand on the science, because, of course, that's how we get our next round of funding. [...] it's a balance, [...] in order to make sure that we're doing the best we can with the science collection, while also keeping the rover safe." - P11

"You kind of have to argue with them... 'Well, I'm the engineer, and I'm not going to do what you want, because I don't believe it will be safe for the rover.' And that typically is when they'll actually back off" - P3

06 In the conflict between mission groups, the only shared language is data. Even then, every specialty has its own dialect, leading to misunderstandings.

During daily planning activities, scientists must form a consensus on the rover's intended activities. Data drives these contentious discussions, but each scientific domain has it own unique practices, methodologies, and jargon to account for which makes it difficult for those from other domains to follow. Complicating matters, most scientists are admittedly bad at simplifying their data for specialists outside of their domain. Generalists, attempt to translate across domains, but they are in short supply and struggle with disparate toolsets. If scientific intent is not clearly understood by the planning committee, it will be difficult for a proposal to be granted resources and scientific opportunities may be missed. Planning may be hindered by unclear context around why a past decision was made. Further, planning around competing and complementary activities may not be able to take place at all if the intent is unclear.

“

For us to be able to communicate our ideas in a compelling way to the rest of the [scientists], the graphics need to be easy to understand for a non-specialist. If I tried to present something like this to geologists, they'd just say 'What is this noise? Take it away.' - P1

The geologist has his own kind of knowledge that comes from his expertise. The atmospheric scientists would have a different set of knowledge. Sometimes that's helpful, but also sometimes comes in the way of them seeing the data from the other person's perspective. So, how do you help them maybe step into each other's shoes? - P10

07 Data is more revealing when contextualized with other observations. Existing tools do not have this capability, hindering scientific discovery.

Context and integration of metadata can reveal unexpected findings, allowing scientists to arrive at new insights. For example, pairing temperature with rock colorization may lead to new hypotheses or present scientific opportunities that were not evident when analyzing rock colorization in isolation. Often times scientists create their own tools to analyze and visualize data in order to meet their scientific needs. These tools are not created with output integration in mind. As a result, this creates a fragmented tool ecosystem and a lack of ability to integrate datasets from multiple sources to provide context or comparative views. An example of this came to light during an interview when the participant expressed that the Mars Weather Service lacked the ability to view data over multiple days, which would allow scientists to observe weather patterns that occur temporally. These gaps in tool capabilities cause a need for workarounds that may not support efficient analyses.

"It would be nice if I could overlay one sol another. Like we expect that the meteorology is going to repeat kind of on a daily basis." - P1

"For meteorology, time of day is crucial. So if there were a nice way to be able to compare and contrast a couple of different days, that would be really helpful. Instead of looking at the left half of this plot and the right half. You'd have to visually try to compare this feature to that feature, and that would be awkward." - P1

"I then come up with a result... I believe my results but I believe it a lot more if I can compare it to something else." - P16

08 The use of numerous custom-built tools is "both a feature and a bug"; it makes output inconsistent, but leads to advancement through productive scientific discussions.

Every scientist has their own way of analyzing data, and they often end up building their own tools to meet their personal needs. At face value, this is problematic because the existence of multiple tools means a multitude of output forms. One scientist's output could be a visualization while another's is a data table. Additionally, although the input is the same, they may end up with completely different results through differing methodologies. The resulting output inconsistencies and the discussions around them are difficult because it takes time for different stakeholders to understand one another's output. However, these different ways of analyzing the same data helps advance science because it could lead to the detection of patterns which validates hypotheses, or to

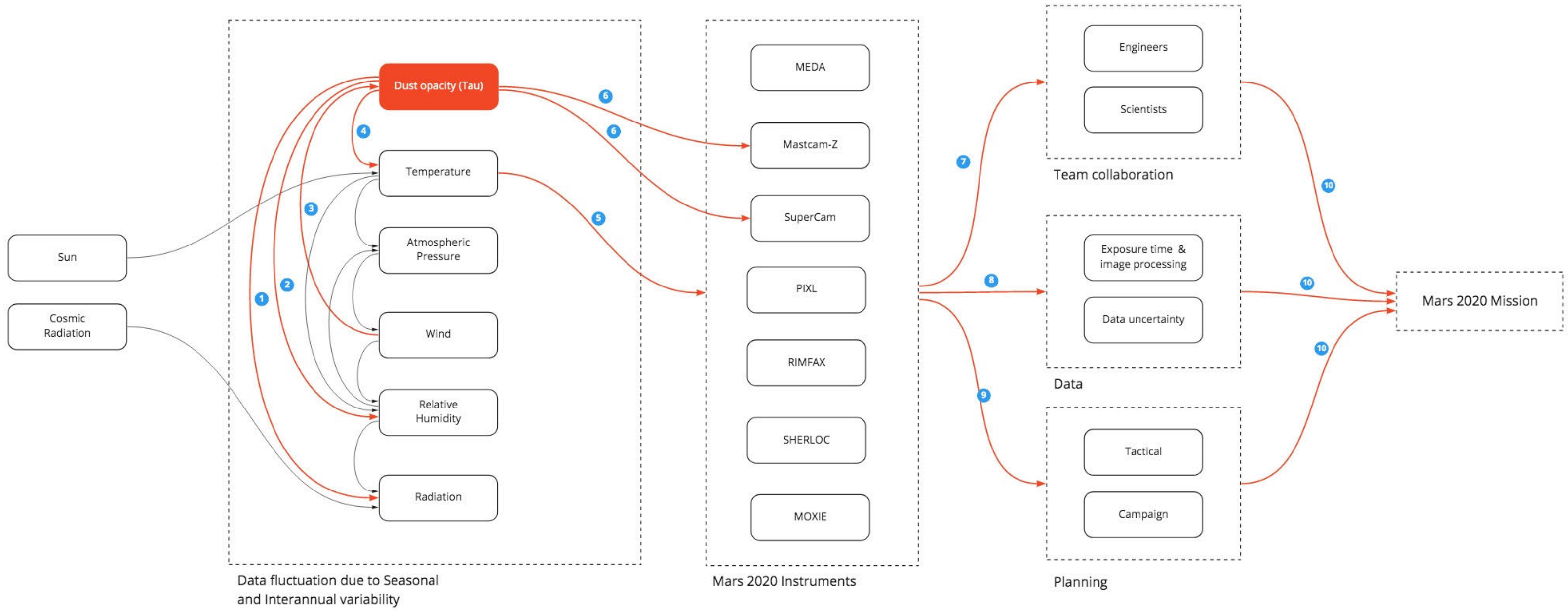
"Discrepancies aren't always bad, they just reflect that science is imperfect, we don't have all the tools, and they're not perfect. Our understanding of even how to build the tools to get the results is not perfect. So often, it's good to have healthy competition." - P14

"Sometimes, it's difficult to have the same collaborative tool because you don't use the same language. You don't have the same purpose with respect to the data, you don't have the same research code. So, you end up using your own tool because that's faster. And that's easier to customize." - P17

"For a given set of recorded data, there are definitely people giving different interpretations or different explanations, but I think that's how the science commands you in general." - P4

ARTIFACT

Atmospheric Opacity (Tau) and its impact on the Mars 2020 mission

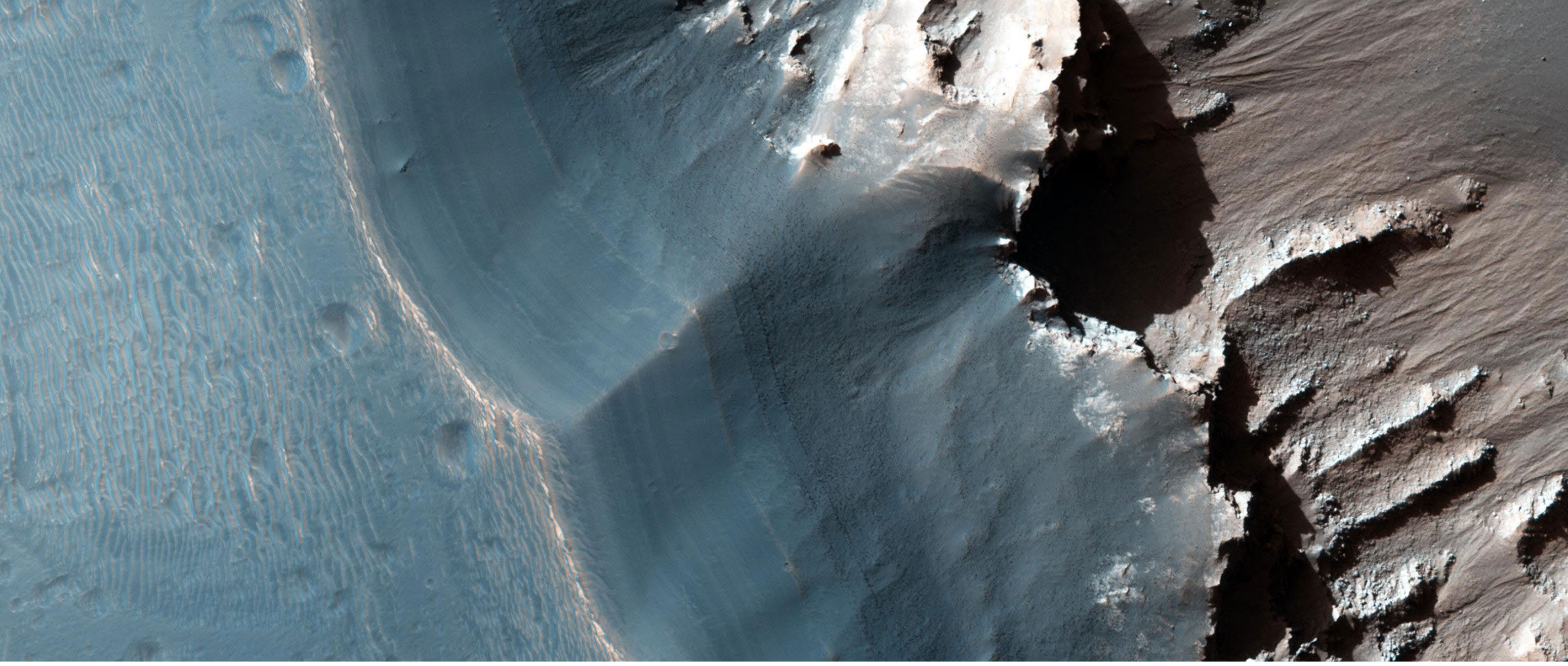


Color orange = Tau related

Arrow = Direct effect

1. Dust can absorb solar radiation which influence atmospheric temperature
2. Dust thrusts water into the upper atmosphere, interfering with Martian water cycle
3. Wind can lifts dust from the surface to the air, a critical factor in dust devil and dust storm formation
4. 5. Dust moderates atmospheric temperature which influences the amount of power rover uses to heat instruments.
6. Dust particles pose potential hazard for camera lens
7. Tau measurements create engineering constraints which affects team collaboration
8. Amount of dust in the atmosphere affects camera exposure time and image processing
9. Knowing the tau in advance can help the teams prioritize and plan strategically
10. All the components mentioned will affect the Mars 2020's overall mission.

04
Discussion



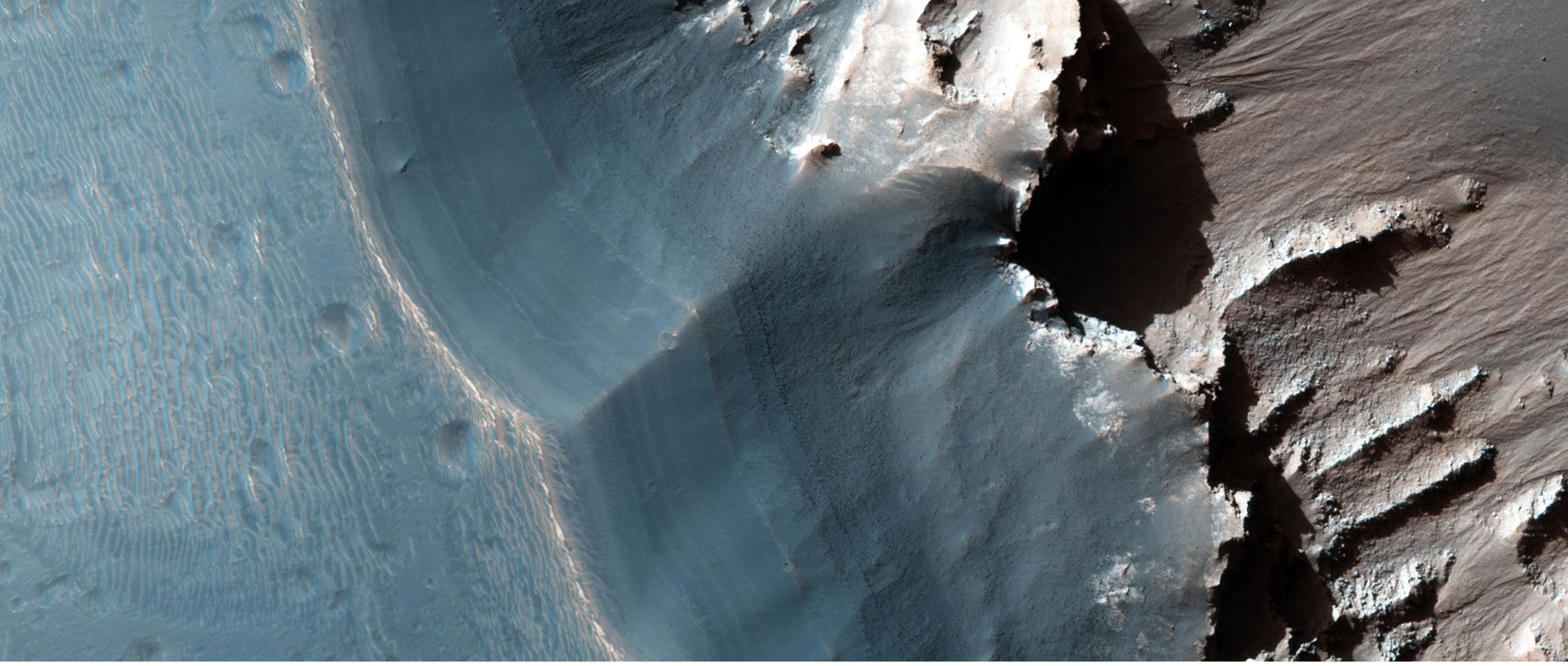
DESIGN OPPORTUNITIES

Express the impact of atmospheric opacity on instrumentation

Atmospheric opacity poses a threat to rover instruments, image exposure time, and data processing. We are interested in exploring ways to help scientists understand this impact on their work and how it pertains to the overall mission.

Use the predictability of Martian weather to help teams shift from short-term to long-term planning.

Knowing what to expect on upcoming sols makes it possible to plan instrument usage better. We want to explore how to help scientists optimize instrument selection.



DESIGN REQUIREMENTS

01 Facilitate debate

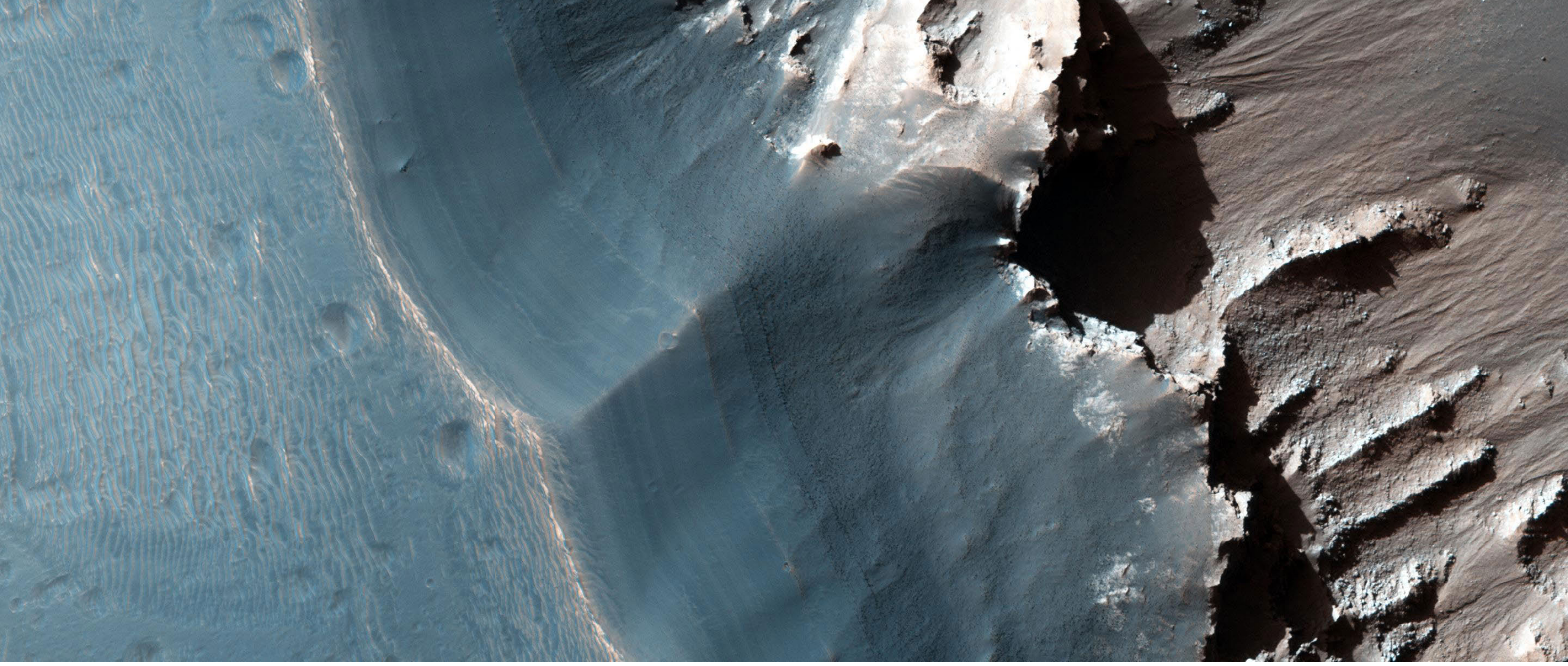
The advancement of scientific knowledge stands to benefit from disagreement as dissent breeds productive debate in order to reconcile conflicts. Our tool needs to facilitate healthy discussion between differing points of view in order to drive scientific advancement.
Insight 3, 8

02 Prioritize customization and flexibility

Scientific discoveries stem from finding novel ways to analyze and interpret data. To promote further exploration, the tool needs to provide scientists the ability to explore a dataset in various ways without disrupting existing work preferences.
Insight 6,7,8

03 See through the same lens

Scientists are using their own tools and this could lead to misunderstandings about the meaning of their output. As a result, enabling shared mental models is crucial in order to ground conversations
Insight 2, 3, 4, 5, 6



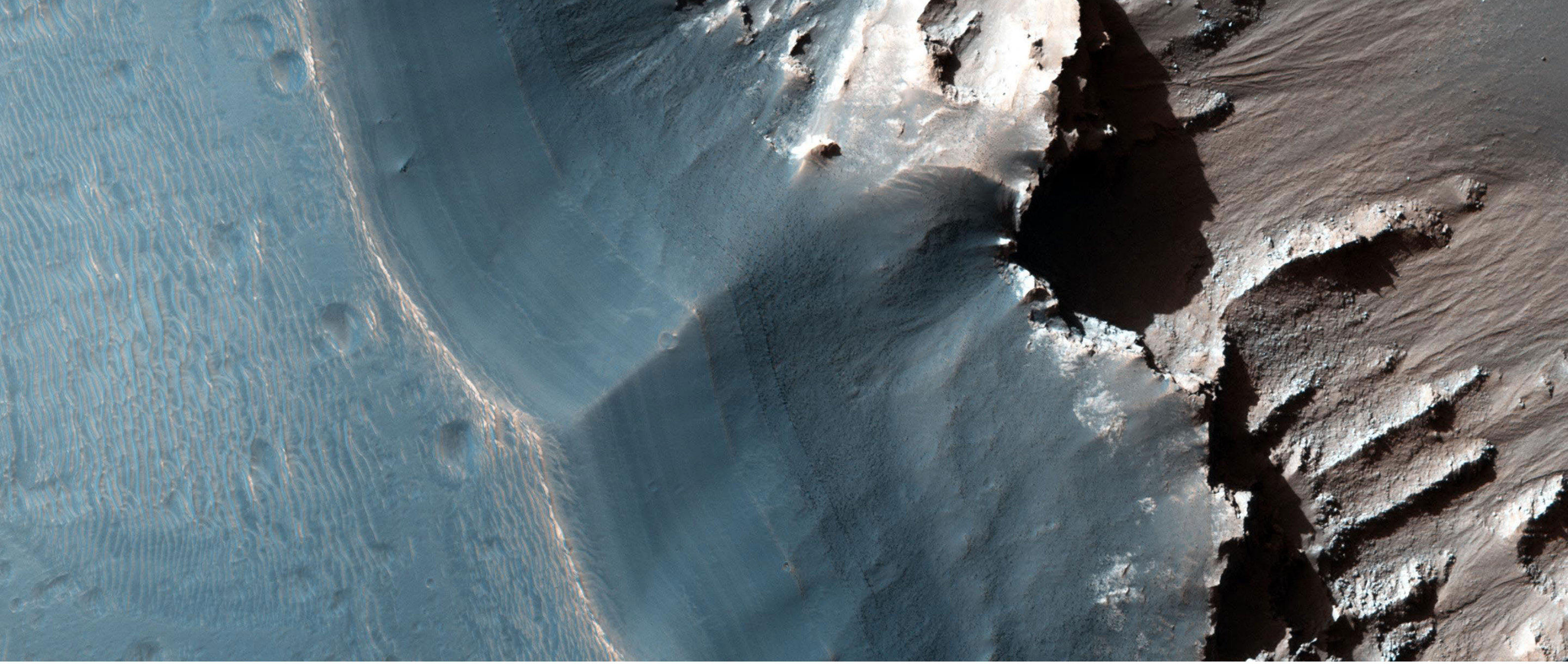
DESIGN REQUIREMENTS

04 Show how it fits in bigger picture

Scientists and engineers should understand how their work impacts each other and the overall mission. This can be done through contextualizing data to provide a comprehensive view of the situation.
Insight 1, 2, 3, 4, 5, 7

05 Stay transparent

Understanding the history of data is just as important as understanding what it means. To scientists, knowing the provenance of data facilitates trust, exposes caveats, and helps ground the conversations.
Insight 4, 6, 7



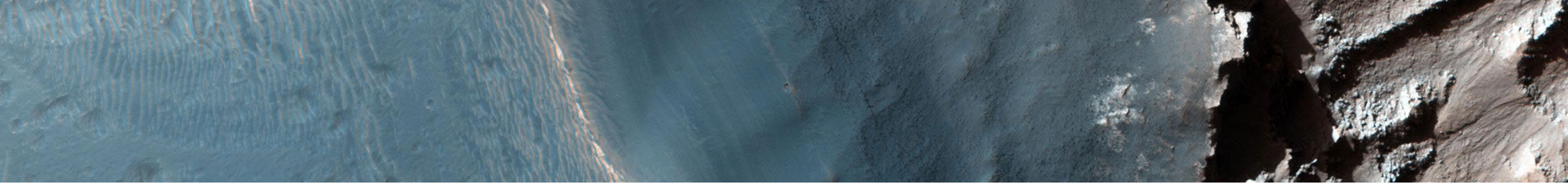
NEXT STEPS

01 Follow-up interviews with relevant experts how it fits in bigger picture

02 Conduct focused research on tau and its impact on instruments

03 Iterate design requirements as needed

04 Begin the ideation process



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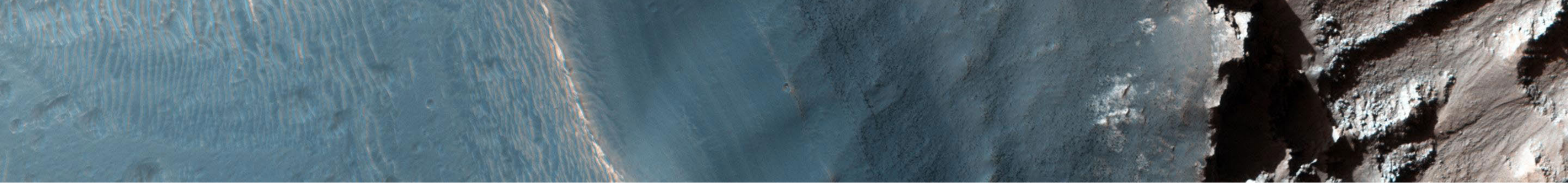

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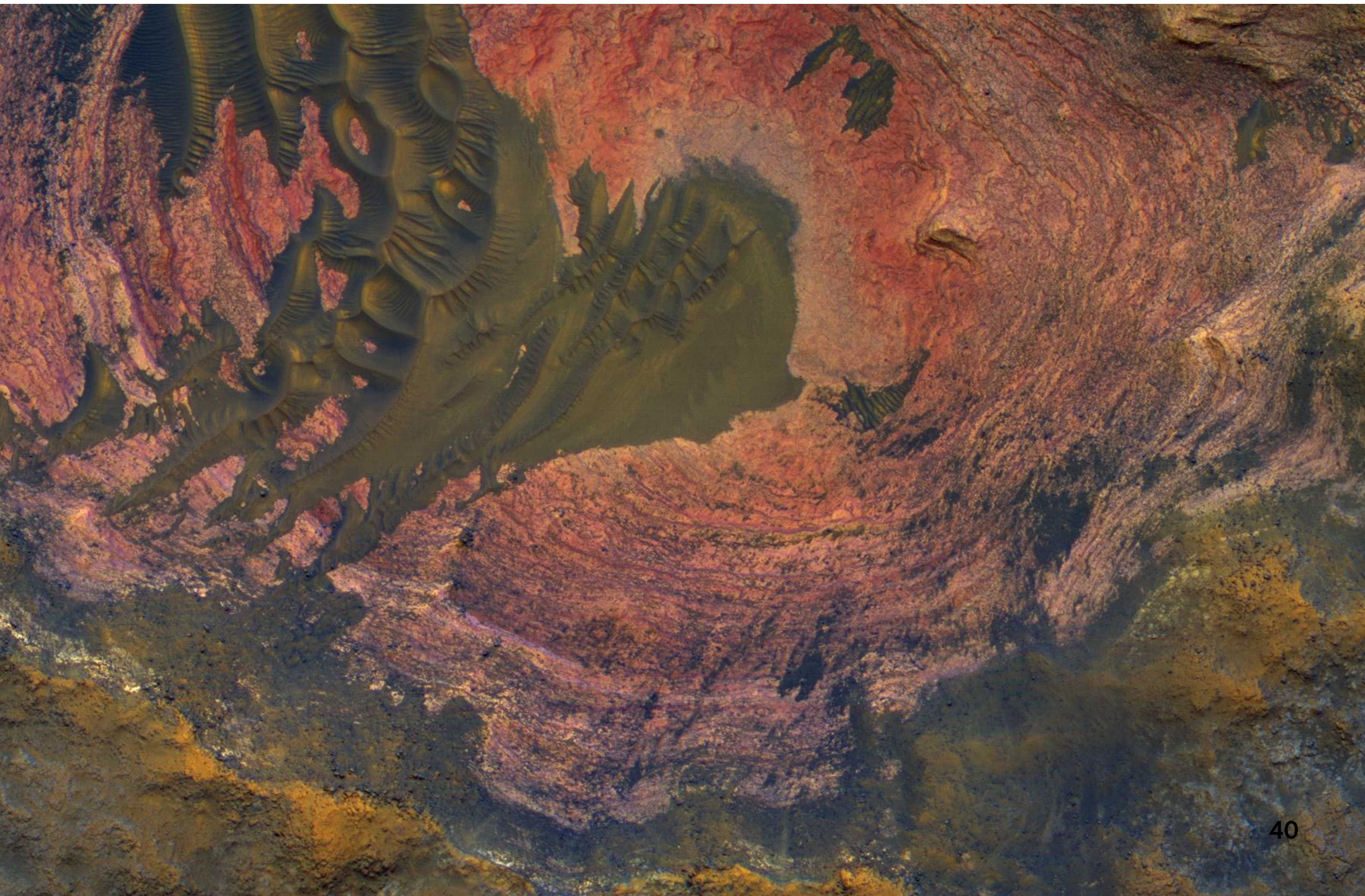
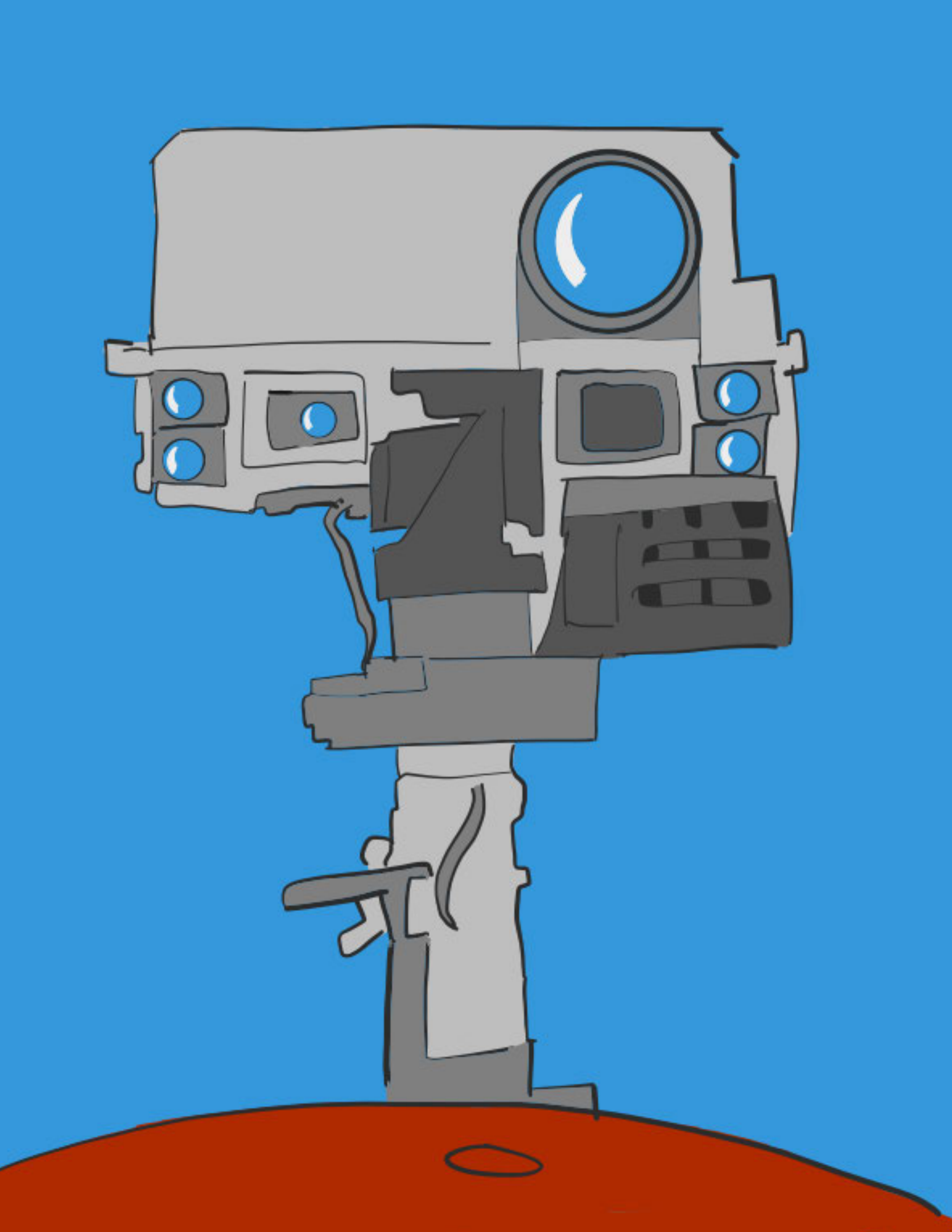
Appendix





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Introduction

NASA Jet Propulsion Lab (JPL) is preparing for its upcoming mission, Mars 2020. This mission is next in NASA's long-term effort of robotic exploration on Mars with multiple scientific goals, including searching for previous signs of life on Mars, characterizing the planet's climate and geology, and preparing for potential human exploration [1].

Accurate understanding of weather on Mars is critical to the success of the mission, since there are several cases where conditions on Mars dictate where and how science experiments are conducted. For example, dust levels can dictate camera operability, atmospheric conditions can affect daily rover target planning and the sun's position can affect the timing and feasibility of operations [2].

Previous mission rovers saw long periods of inactivity due to solar-powered battery limitations. As newer rovers have longer uptime as a result of their nuclear batteries, NASA's internal policy dictates an equal amount of time planning and operating the 2020 rover. This means that planning teams need to meet a daily 5-hour planning window, requiring that all data be quickly and efficiently available [3].

Additionally, mission planning is dependant on geographically distributed teams comprised of individuals with varying skill sets and background knowledge. These teams rely on ad-hoc meetings, powerpoints, and a company-wide wiki for communication. On previous NASA missions, breakdowns in communication have caused costly delays, wasted resources, and even irreparable damage to instrumentation [4,5].

Introduction

NASA's current rover planning tool (ASTTRO) only provides location and terrain data. Our challenge is to enable the rover planning teams to meet their deadline, by creating a tool that would communicate Mars' meteorological data between distributed teams, aiding scientists and engineers in planning and decision-making processes.

Through our research activities, we aim to better understand the typical collaborative challenges that rover planners, scientists, and engineers face with a focus on how martian weather impacts their goals. Additionally, we intend to learn more about current tools being used to assess and visualize meteorological conditions and how they are integrated into the mission workflow.

Background

Past Missions

NASA's Mars Exploration Program (MEP) has a long-term and systematic plan where each mission builds upon previous research, innovations, and discoveries. The early theme of Mars exploration was to "Follow the Water" as water is a critical indication of a habitable environment [6]. When past missions found evidence that water used to exist on the Martian surface, the Mars exploration theme evolved to "Explore Habitability", with a purpose to seek additional chemical elements that were necessary for life [7].

Mars 2020

With findings from Curiosity rover, MEP marked a transition to the upcoming Mars 2020 mission, shifting the theme to "Seek Signs of Life"[6]. The Mars 2020 program has 4 long-term science goals [8].

1. Determine whether life ever existed on Mars

The rover will conduct studies on the Martian surface and seek biosignatures from rock samples.

2. Characterize the climate of Mars

The rover will look for for evidence of ancient habitable environments where microbial life could have existed in the past.

3. Characterize the geology of Mars

Each layer of rock provides information about past Martian environmental conditions, revealing the history of how Mars' crust and surface evolved through time. The study could be further extrapolated to uncover the history of Earth itself. Current and future rovers will cache geological samples to be studied in the future.

4. Prepare for Human Exploration

The rover is demonstrating key technologies for using natural resources in the Martian environment for life support and fuel. It is also monitoring environmental conditions so mission planners get a better understanding of how to protect future human explorers.

Workflow Challenges

Mission planning operations involve teams of scientists, rover planners, and engineers who meet a daily 5-hour planning window. The typical workflow for mission planning involves reviewing downlink data, assessing shadows, monitoring engineering components, monitoring resources, and resolving conflict [17]. Although our knowledge regarding this topic is limited due to lack of publicly available information, we see an opportunity to design a tool that could assist in daily rover planning, reducing the amount of back and forth among team members. Accordingly, we will further study this area in our user interviews.

Weather Implications

Understanding atmospheric conditions on Mars is critical for successful rover planning. In mid-2007 a planet-wide dust storm posed a serious threat to the solar-powered Spirit and Opportunity rovers, reducing the amount of energy provided by the solar panels and necessitating the shut-down of non-essential systems while waiting for the storms to clear. Dust storms significantly reduce power on solar-dependent rovers, due to obscurement and settling of dust on the arrays [9]. This obscurement risk has been somewhat mitigated in Mars 2020 mission through the use of a nuclear power core, but meteorological data still holds significant mission planning repercussions [3].

Besides dust, there are several other weather conditions that could affect rovers' operations and long-term planning. For instance, the tau or an optical depth measurement can dictate camera operability and exposure times [10], the sun's position in the sky and its relative angle to the instrument can affect operation timelines.

Weather data is also used to determine which missions are feasible during a given period. For example, if visibility is limited due to dust particles, rover planners would delay science activities that depend on external camera data [11]. Similarly, dust storms could damage delicate instruments and rover planners would need to know when to retract them in order to increase their longevity [12].

Related Technology

The Advanced Science Targeting Tool for Robotic Operations (ASTTRO), is the tool used by rover planners for target planning. It currently provides information related to the 3D terrain and rover position, but it doesn't include information about weather and atmosphere, and only limited information regarding the sun [13].

The Mars Environmental Dynamic Analyzer (MEDA) is the instrument attached to the Mars 2020 rover that will help scientists gather information about weather on Mars. MEDA measures a wide-range of variables such as wind speed and direction, temperature, humidity, and the size of dust particles in the Martian atmosphere [14].

Mars Atmosphere and Volatile Evolution (MAVEN) is a satellite developed to study the Martian atmosphere and its composition. It has recently provided significant data around the loss of water and atmosphere on Mars and the role solar storms play [15].

Deep Space Network (DSN) is a network of antennas distributed globally which provide communication links between planetary exploration spacecraft and their mission teams on Earth. Their distribution allows for 24/7 data uplink to the multiple Mars missions, including Curiosity, MAVEN, and soon the 2020 rover [16].

Initial Insights

Data visualization tools for Mars mission planning need to help scientists, engineers, and rover planners embody the rover

In order to be fully prepared for my job I need to literally be that vehicle. That's what all the visualization software I use is about. For me, it's all about intuitively being able to make decisions, because you're gonna be getting questions on the fly and you're gonna have to answer them on the fly. You're not you, you're the rover...I think of myself as the Rover so I can call the shots. I need to know where I am as the rover. It's a huge, huge part of my job.

'Liz', MEP Team Member [17]

Images and instrument data from rovers act as a decisive element in team meetings and mission planning. All individuals in the Mars team harness their "rover" skills by developing the ability to interpret downlink images retrieved directly from the rovers and orbiters. This includes images with fisheye view and those processed in RGB colors. Interpreting these unprocessed images helps the team make sense of the rover's location, its surrounding environment, atmospheric conditions, and terrain challenges before doing target calculation [18].

The team also highlights the values of plurality in data visualization. Images and data when visualized in various forms provides different contexts and layers of information. This provides the team with unexpected knowledge and aligns multiple stakeholders' point of views [19]. Teams use multiple tools to enhance this data visualization, including enhanced reality displays and bodystorming techniques to better embody the rover and enhance the shared mental model among stakeholders.

Rover plays an important role in mission planning, collaboration, and defining team culture

"The techniques of being to see like a rover, being able to feel, and move, and be like a rover are all connected to the success of the team. I've argued that in order to operate robots on Mars, scientists and engineers must bring together this very complicated way not only visualizations and visual manipulations, but also this gestural and embodied relationship to the robots' experience on Mars. They do that in a particular social context, one that is oriented towards a very unique and particular model of teamwork that brings people around that robot"

Janet Veritsi, NASA Ethnographer [20]

In a flight mission, the main team is created by grouping different teams with various scientific objectives. These teams typically work separately, prioritizing individual goals and placing less emphasis on cross-functional team collaboration. Since the spacecraft has limited time, power, and memory, during the mission, these teams compete against each other for a scarce resource, creating a disjointed decision making process and a micro-political environment. This challenge was also highlighted by the past two MHCI+D projects in 2018 and 2017 [21].

In contrast, the Mars mission team has a flattened hierarchy and a single Principle Investigator. Work revolves around the rover as it’s capabilites play an important role in daily operations. It acts as a totem object that cultivates team dynamics and culture [22].

The Mars mission team embraces the unilateral consensus when making decisions. The team is somewhat more collaborative compared to the flight mission teams. The main challenge does not lie in competing for resources but rather, enhancing collaboration and ensuring team members are able to analyze data and produce a detailed mission plan in an efficient manner [22].

Mission planning relies on a combination of new and old techniques used to reinforce shared mental models and form concensus

When we're training new rover drivers, we can really tell that they get it when you start talking about moves with the [Robotic Arm] and they start moving their own arm to kind of show you what they mean, and they say you know we're going to swing this to the left and then move their elbow [moves his elbow to the left, wrist hanging down].

'Mark', MEP Rover Driver and Trainer [23]

Scientists and engineers often utilize bodystorming in order to help visualize the actions a rover is intended to take, going as far as creating props to imitate intended target rocks and obstacles to see if a course of action is feasible. Embodying the rover in 'the right way' is considered an acquired skill that is seen as the mark of an initiated team member [24].

Daily rover planning meetings require consensus building among scientists and engineers who often have competing points of view around rover activities. Scientists are primarily focused on gathering data, while engineers focus on the health and safety of the rover. Communication at planning meetings is primarily done through annotated images which are enhanced in multiple ways and data visualizations shared on slide-decks in virtual meetings. Only when a course of action has been agreed upon the Keeper of Plan (KOP) enters the instructions into rover planning software, which is then sent to Mars via the DSN uplink [25].

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RESEARCH PLAN

Research Questions

01 What is the typical workflow for rover mission planning and what collaborative and operational challenges do they face?

Rover operations require collaboration between rover planners, scientists, engineers and other stakeholders. Understanding their typical workflow will help us uncover any flaws which could lead to a disconnect in their mental models regarding weather.

02 What tools and technology does the mission operation team currently use, or plan to use, to collaborate and assess weather information for mission planning?

Decomposing the tools that are currently being used for mission planning, with a focus on the ones that involve weather analysis, will help us uncover any limitations with the current technology which could act as opportunities during our design process.

03 What weather information does the mission operation team need to know and how do they use this information in making time-sensitive decisions?

There are a number of different weather variables that have varying levels of impact on short-term and long-term mission planning operations. We hope to understand what weather variables the mission operations team prioritizes, how often they examine them and how they interpret them to make decisions.

Participant Profile

Primary

- Mars rover planners/drivers
- Mars rover engineers
- Mars atmospheric scientists
-Mars principle investigator
- Mars data visualization

The main objective of our research is to uncover the typical mission planning workflow. Ideally, the primary research audience are NASA employees who participate direcrly in Mars rover mission planning. This includes scientists, engineers, and rover planners on the Mars 2020 mission and those who previously worked on the Spirit, Opportunity, and Curiosity rovers.

Secondary

- Air traffic controllers
- NOAA scientists (weather, climate visualization)

Learning that previous MHCI+D teams faced problems with recruitment in the past, our team chose air traffic controllers and NOAA scientists as our secondary (or backup) research audience. Similar to the work of rover planners and engineers, their work heavily resolves around planning with lots of time pressure. We believe insights derived from this audience could be translatable to our research space.

Recruitment Methods

- Systematically go through the list of NASA Mars employees and filter out potential candidates based on their job descriptions, background, and mission involvement
- Leverage Lyle's network at NASA JPL
- Snowball recruitment

Budget

16 semi-structured interviews x $20 per participant = $320

1ST ROUND (8 PEOPLE) 04/15 - 05/03

Strategy

- Each interview will have a facilitator and a note-taker. The interview will be recorded and all 4 team members will attend/watch the interviews to ensure team alignment.

- The facilitator of the interview is responsible for performing research on participant's work and background to avoid asking unnecessary questions.

- After each session, the facilitator will transcribe the interview and the team will debrief and provide feedback prior to the next one.

Objective

- Pilot the primary research process.

- Learn about the mission planning workflow and the roles of scientists, engineers, and rover planners.

- Determine what kind of data and atmospheric variables are critical for planning rover mission.

- Identify the challenges that scientists and engineers when finding appropriate targets.

2ND ROUND (8 PEOPLE) 05/04 - 05/15

Objective

The objective of the second round interview is to reach 16 participants in total. Based on the insights from the first round, our team will strategize and restructure our questions accordingly.

Study Method

ITERATIVE DIAGRAMMING

FOR ALL INTERVIEWS WITH NASA EMPLOYEES 04/15 - 05/15

Overview

Understanding the workflow of the 5-hour rover planning meeting accurately is critical to the success of the project. This exercise will be used to decompose the meeting by having participants review the workflow diagram and give feedback/make adjustments. After every session, the research team will iterate on the diagram based on the insights collected.

Strategy

The iterative diagramming exercise will take place during the first half of the semi-structured interview when workflow details and challenges are the topics of discussion. Before each session, we will send the participant an image of the latest workflow process, *as we understand it to be*, and ask them to go through it and comment about different parts of the process. Following every session, the team will debrief and make any necessary updates to the workflow diagram.

Objective

The objective of this exercise is to ensure we have an accurate understanding of the team's workflow. Additionally, it's to help participants visualize the workflow so they can accurately answer questions about it.

Study Method

HYPOTHETICAL SCENARIO

FOR ALL INTERVIEWS WITH NASA EMPLOYEES 04/15 - 05/15

Overview

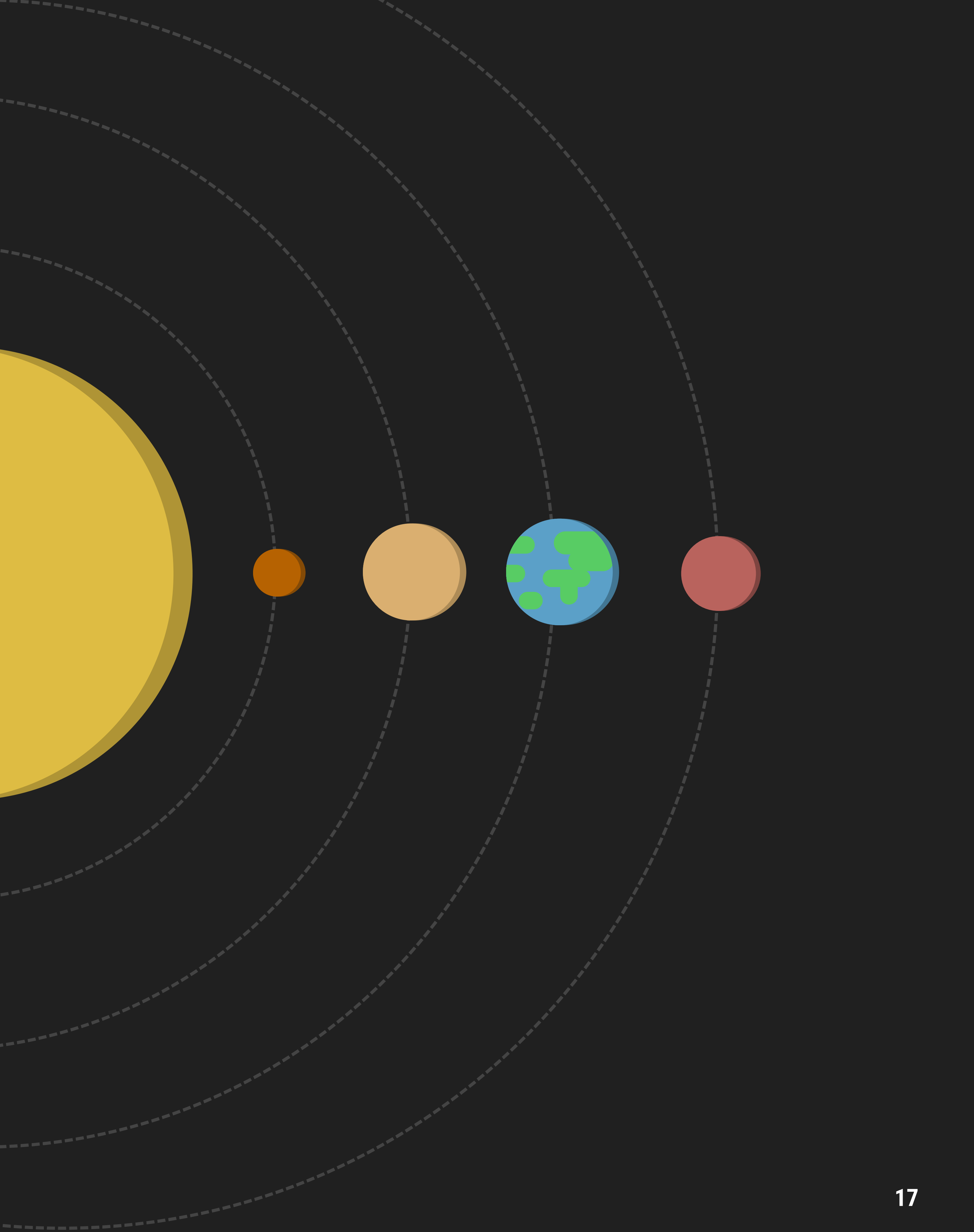
The hypothetical scenario is a form of directed storytelling meant to help draw upon past experiences of the participant in order to explain what they see as a typical or best response to a given challenge. It will also allow the researcher to compare responses across different teams within NASA to understand how those perceived best or typical responses differ. This study method isn't the primary method; it will only be conducted if time permits.

Strategy

The hypothetical scenario will be inserted in the middle of the semi-structured interview session. The activity is conducted after the facilitator learns about rover mission planning and collaboration tools from participants. After participants provide a step-by-step process or strategy to solve such problems, the facilitator will ask follow-up and weather-related questions.

Objective

Further decompose participants' mental models, team dynamics, and team dependency when it comes to solving weather-related issues.



Recruitment Kit

Introduction Email

My name is [insert name], a graduate student in the Master of Human-Computer Interaction + Design at the University of Washington.

I came across your profile at [insert text] and was fascinated by your work on [insert text]. I'd love to have a 1-hour chat with you to learn more about your work and to develop a better understanding of how weather could potentially affect rover mission planning.

For our capstone project, my team and I are working with NASA JPL to build a tool that helps scientists understand weather conditions on Mars for better rover control during the Mars 2020 mission. Besides learning more about how Martian weather affects operations, we are also interested in how scientists, rover planners, and engineers work together to plan and find valid targets. Information such as the typical workflow, decision-making process, collaboration efforts, and challenges is significantly valuable to our team.

I'm looking forward to hearing from you soon.

Thank you,
[insert name]

URL for Scheduling

https://calendly.com/tylerla129/60min

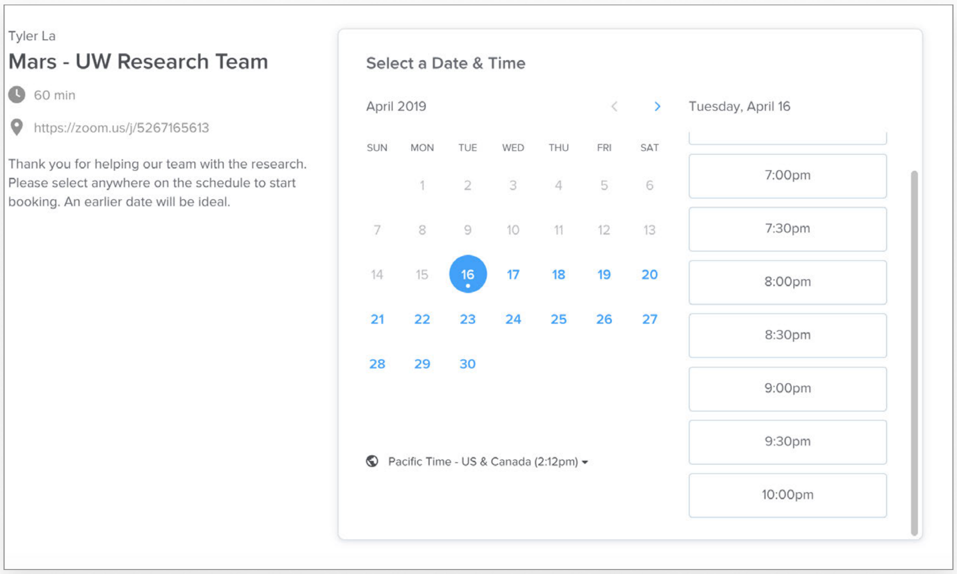
Consent & Gratuity Release Forms*

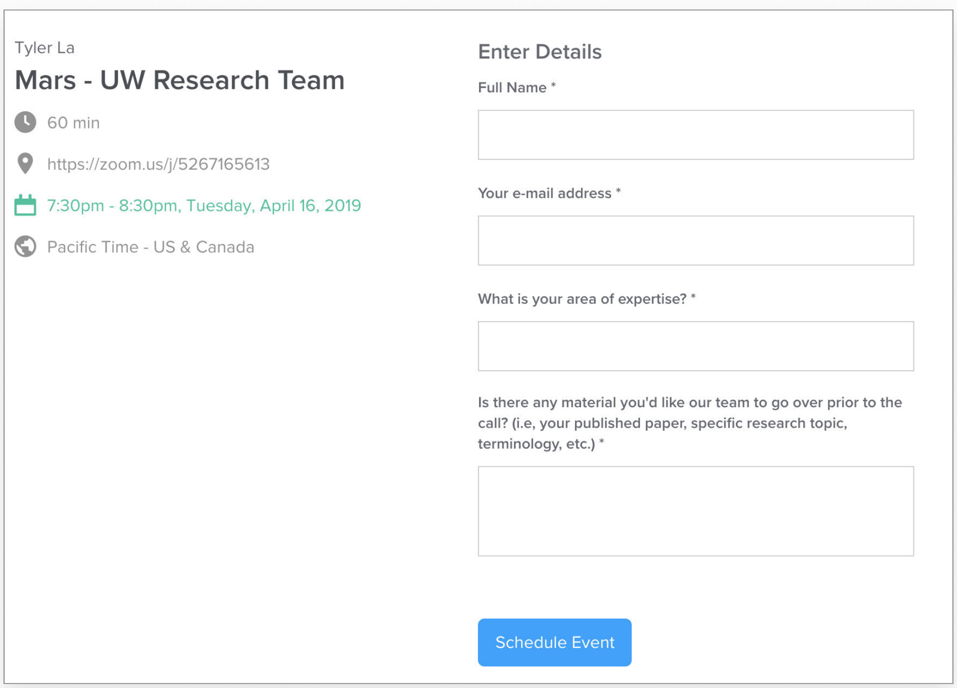
Hi [insert text],

As a part of our project, we are offering a $20 Amazon gift card as a thank you for helping our team with this research. I will send you the consent and the gratuity forms shortly. Please sign them when you have a chance. Looking forward to talking to you.

**This will be sent 12-24 hours prior to the interview date*

Calendar Booking & Pre-questions





Capstone Project

Master of Human-Computer Interaction + Design

Project Brief

Mars 2020 Overview

The Mars 2020 rover mission is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the red planet. The Mars 2020 mission addresses high-priority science goals for Mars exploration, including key questions about the potential for life on Mars. The mission takes the next step by not only seeking signs of habitable conditions on Mars in the ancient past, but also searching for signs of past microbial life itself. The Mars 2020 rover introduces a drill that can collect core samples of the most promising rocks and soils and set them aside in a "cache" on the surface of Mars. A future mission could potentially return these samples to Earth. That would help scientists study the samples in laboratories with special room-sized equipment that would be too large to take to Mars. The mission also provides opportunities to gather knowledge and demonstrate technologies that address the challenges of future human expeditions to Mars. These include testing a method for producing oxygen from the Martian atmosphere, identifying other resources (such as subsurface water), improving landing techniques, and characterizing weather, dust, and other potential environmental conditions that could affect future astronauts living and working on Mars.

Why Weather, Atmospheric and Sun Information Matter to Mars 2020

The Mars 2020 mission has a requirement to support 1:1 uplink operations —meaning that scientists and engineers may only use the same amount of time to develop instructions for the rover as it takes the rover to execute them. This differs from other Mars rovers which frequently sit idly while the ground teams plan their next move.

Scientists and rover planners must work closely together to find valid places to make targets in order to meet this timeline. There are several cases where conditions on Mars dictate where and how science experiments are conducted. To improve collaboration and enable operations teams to effectively meet the five hour timeline, you'll be conducting research and find a solution that helps scientists make valid targets with less back and forth between the rover planners. ASTTRO (The Advanced Science Targeting Tool for Robotic Operations) currently provides information related to the 3D terrain and rover position, but it doesn't currently include information about weather, atmosphere, and only includes limited information regarding the sun.

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Research Timeline

Timeline: April 7th - June 12th

Deliverable: Submit a research report on June 12th

Audience:
- Mars scientists, rover planners, engineers (NASA JPL)
- Data visualization experts
- Weather experts
- Translational experts (i.e, air traffic controller, etc.)

Research Methods

A - Literature Review

Our team will conduct literature reviews of Martian weather, atmospheric conditions, Mars 2020 mission, and rover operations to familiarize ourselves with the research space.

B - Semi-structured Interview

We will be interviewing 16 participants (~1 hour each). Ideally, we aim for JPL scientists, engineers, and rover planners. Prior to any interview, our team will review their published work to prepare for a productive conversation.

C - Comparative analysis

We will perform comparative analysis in parallel with conducting semi-structured interviews. The objective is to assess the pros and cons of existing tools before coming up with the design.

D - Data Synthesis

Our team will then synthesize all insights collected from A,B,C to produce appropriate design principles for the design and prototyping phase. The final deliverable is a research report.

Research Ethics & Guidelines

The consent and gratuity release forms must be signed prior to any interview. We will make sure the consent form outlines clearly participants' privacy protection and permission to be recorded. Participants must understand that they don't have to answer any question that they don't feel comfortable answering and that they can exit the interview at anytime.

Sample Interview Questions

Collaboration among scientists, rover planners, and engineers

- Can you tell me more about your role and any mission you've worked on?
- Can you tell me more about the 5-hour rover planning operation?
- Can you walk me through your team's typical decision making process?
- What is the role of data visualization in rover mission planning?
- Can you tell me more about the different tools you use during mission ops?
- What are the features and capabilities that you'd like to have in a mission planning tool?
- Can you walk us through a tool that you use for analyzing data or making decisions?

Understand weather conditions on Mars

- When analyzing weather on Mars, what variables are important for rover ops?
- What types of weather events strike fear into your team? What are just inconvenient?
- What weather information would help the rover operate more efficiently on Mars that we don't understand yet?
- What don't we know about Martian weather? Where are the glaring knowledge gaps?
- How do you visualize weather data?

Data visualization

- What data viz programs do you and your colleagues typically use the most? (ie. Python, R, MatLab)
    - How do these tools integrate with the daily and end of Sol meetings?
- When using a new data vizualization software, what do you find helps reduce the learning curve?
    - Is there anything you can think of that makes it harder?

Checklist

INTERVIEW PREPARATION

- [ ] Make sure the facilitator & note-taker roles are assigned
- [ ] Review participant pre-questions & review their published work (if applicable)
- [ ] Review 4 sets of interview questions and prioritize accordingly

TOOLS & TECHNOLOGY CHECKLIST

In-person Session

- [ ] Mobile phone for audio recording
- [ ] Video camera & tripod for video recording
- [ ] Additional mobile phone and camera in case of technical difficulties

Remote Session

- [ ] Email to participant with call instructions, consent and gratuity forms
- [ ] Laptop with video recording software
- [ ] Additional laptop in case of technical difficulties

Form & Data Collection

- [ ] Consent form
- [ ] Gratuity release form
- [ ] Semi-structured interview guide
- [ ] Stationary - Pen, paper, pencil, eraser

Study Method

INTRODUCTION AND CONSENT FORM — 5 MINUTES

Thank you for helping us with our research project. We are working with NASA JPL to design a tool that helps scientists understand weather conditions on Mars for better rover control during the Mars 2020 mission. Your background in _____ will help us understand _____ and provide us with insights on_____.

Before we begin, please have a look at the consent agreement we have sent you. It outlines that the interaction we will be having today will be kept anonymous, it specifies how the data collected will be used. During the interview, you do not have to answer any questions you do not feel comfortable answering and you are free to stop at any time if you don't want to continue.

Before we start, we wanted to know if it's okay for us to record audio and video of this interview.

[If YES] Thanks so much. We're starting the recording now.

[If NO] No problem, we can proceed without recording.

Do you have any question for us before we start?

SEMI-STRUCTURED INTERVIEW — 30 - 40 MINUTES

ITERATIVE DIAGRAMMING [IF APPLICABLE] — 10 MINUTES

HYPOTHETICAL SCENARIO [IF APPLICABLE] — 10 MINUTES

WRAP-UP — 5 MINUTES

Study Method

SEMI-STRUCTURED INTERVIEW

- We know that you are a [insert text] working on [insert text] but can you tell me more about your role and any mission you've worked on?

    - [If NASA] How does it fit into the Mars team structure? What other teams do you collaborate with?

SET 1: ROVER MISSION PLANNING

- Can you tell me about the main highlights of your day?
- Can you tell me more about the 5-hour rover planning operation?

    - What compromises (if any) do scientists make around decision making due to the time limitation?
    - How much time is spent on x,y,z?
    - Can you tell me more about your experience working with [scientists, engineer, rover planners]?
    - How often are you collaborating with each other?
    - How do you communicate with each other?
    - Are there any challenges you face in the process?

- Can you walk me through your team's typical decision-making process?
- What processes reinforce shared mental models across the organization? What do you find most helpful personally?
- What is the role of data visualization in rover mission planning?
- Can you tell me about the time when you or your team use both bodystorming and data viz tool to plan for rover ops?
- Can you tell me more about the different tools you use during mission ops?
- Can you walk us through a tool that you use for analyzing data or making decisions?
- What does an ideal mission planning tool look like to you?

    - What features do you want to include? Why?
    - What other capabilities do you want to see? Why?

SET 2: WEATHER

- When analyzing weather on Mars, what variables are important for rover operation?

    - What are the must-have variables? Why?
    - Is there any other weather variable that is important to look at? Why?
    - How often should weather be studied? (how often does Martian weather fluctuate?)
    - How much time do you need to spend looking at data to interpret and analyze daily weather patterns?

- What do you think are some implications of dust storms on rovers?

- What do you think are some implications of the sun on rovers?

- What types of weather events strike fear into your team? What are just inconvenient?

- What are the limitations with the current information available regarding weather on Mars?

- What weather information would help the rover operate more efficiently on Mars that we don't understand yet?

- If possivle, can you walk us through a tool that you use for analyzing data or making decisions?

- Is there any existing tool out there that does a good job at visualizing weather info that you'd recommend us looking into?

- When interpreting weather data, do you want to see all the variables being visualized or just a few selected ones? Why?

- What does an ideal weather visualization tool look like to you? Can you walk me through its capabilities and features?

Study Method

SEMI-STRUCTURED INTERVIEW

SET 3: DATA VISUALIZATION

- What do you think is the role of data visualization at NASA?
- How does this tool fit into the daily rover operation planning? (5-hour meeting)
- What data viz programs do you and your colleagues typically use the most? (ie. Python, R, MatLab)
- Can you walk us through how you use it to analyze data or to make decisions?
- How does this tool help you collaborate with other teams?
- How does it help you explain for defend for your scientific experiment?
- What are some pros and cons that you encounter when using this tool?

[IF SCIENTISTS]

- How did you learn to use this tool?
- What features do like about this tool? Why?
- What do you think could be improved?

[IF DEVELOPER]

- How do you see this tool helps scientists and other teams in terms of rover mission planning?
- What features/capabilities would you like to add?

- How is the data structured?
- How do you typically access the data for analysis?
- Do you specialize in a specific type of dataset or do you jump across domains as needed?

Study Method

SEMI-STRUCTURED INTERVIEW

SET 4: TRANSLATIONAL INSIGHT

- Can you walk me through a typical task that you encounter? What is process like?

- What tools do you use to communicate with colleagues in different physical locations?

- There are a lot of moving parts in ATC, how do you prevent breakdowns in communication?

- What kind of planning meetings do you have? What general topics are discussed there?

- How do you and your teams make decision?

- How does weather factor into your role?

  - What meteorological information do you find vital?
  - What tools do you use to analyze meteorological data?
  - Where does the data come from?

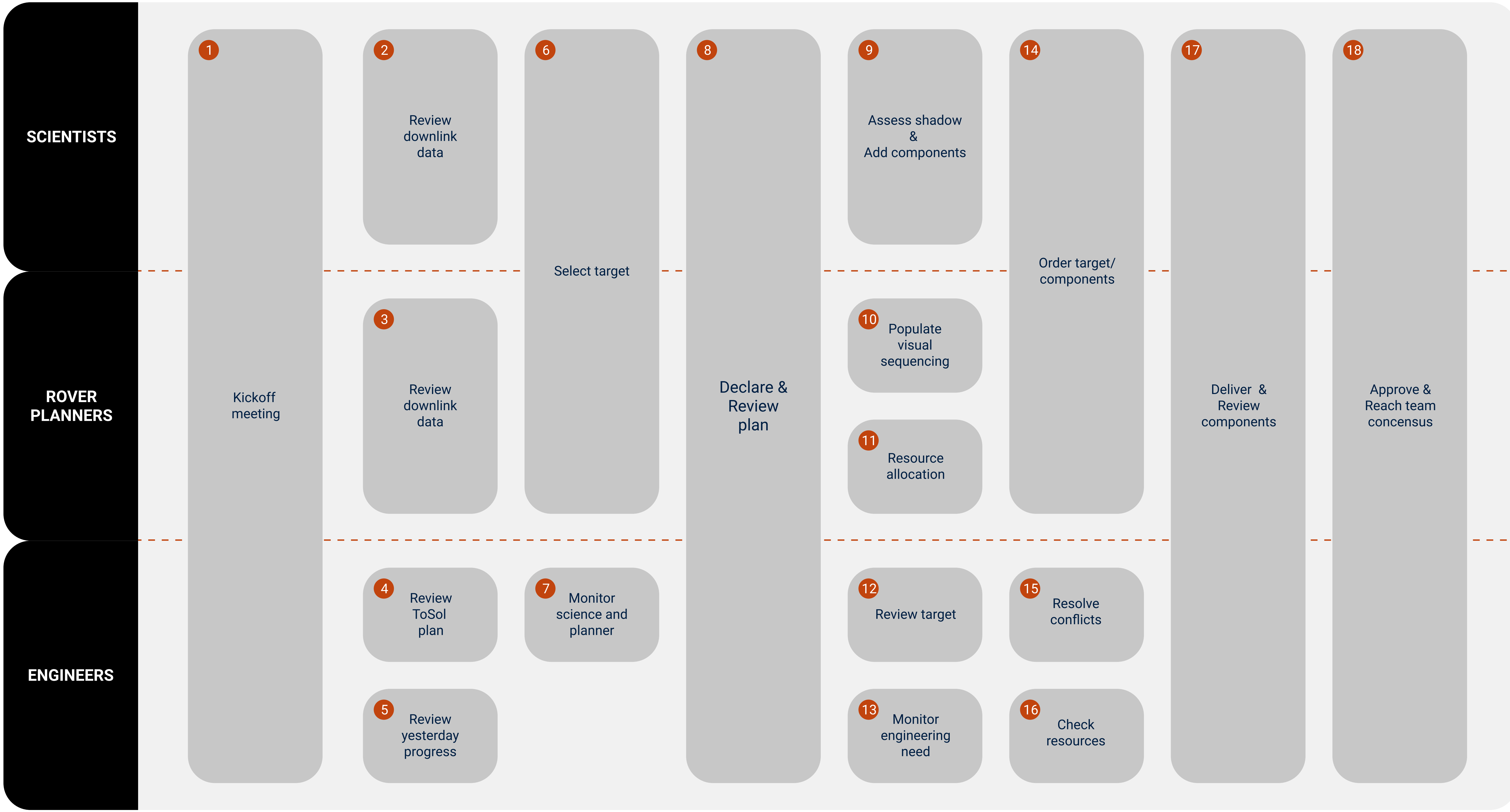
- What processes reinforce shared mental models across the organization?

- Do you have any stories about a breakdown in communication and how it was resolved?

- Alternatively, a story where you realized that a good line of communication was vital to solving an issue?

Study Method

ITERATIVE DIAGRAMMING



Study Method

HYPOTHETICAL SCENARIO

Scenario

You've just been informed there is a previously unpredicted dust storm approaching the location of the rover. What processes do you follow? What does the overall rover mission planning team reaction look like?

Probing Questions

- How do you confirm there really is a dust storm approaching?
- Where do you find this information?
- How do you interpret this weather information?
- How do different people on the team react to it?
- How does the team make decisions in that instance?
- How often do you look at weather and atmospheric information?
- What weather variables are important in rover ops?
- What types of martian weather strike fear into your team?
- How is this info being visualized currently?
- Can you tell me about a time when weather impacted rover operations?

WRAP-UP

Thank you so much for taking the time to talk to us. Your feedback is really valuable to us and will help us significantly with this project.

Do you have any additional information that you would recommend our team looking into?

Do you have any question for us?

How would you like to be credited for your contribution in our project?

Snowball Recruitment

We are still looking for more people to talk to for our project. If you know any [scientist/enginner/rover planner] that work on Mars missions, please let us know. That'd be really helpful!

[IF YES] - Do you think you could send an introduction email for us? We'd be happy to send you a blurb or an overview of our project if it helps.

Thank you once again!

Consent Form

I voluntarily participate in a research project at the University of Washington. I agree that the research will be conducted via a phone call or a face-to-face interview and the session will be approximately 60 minutes in length, during which I will be interviewed by researchers from the University of Washington. Notes will be written during the interview. Both audio and video recordings of the interview will be captured, and I give my consent to be recorded.

I understand that the researcher will not identify me by name in any reports using information obtained from this interview. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

There are no costs or risks to me for participating in this study, however, if I feel uncomfortable in any way during the interview session, I have the right to decline to answer any question or refuse to continue participation in this study.

I have read (or someone has read to me) this form, and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction.

Printed Name

____

Signature

____

Date

____

Gratuity Release Form

I acknowledge that I have received a gift card valued at $20 for my voluntary participation in this research study.

Printed Name

____

Signature

____

Date

____

Interview Guide

Don Banfield

About Dr. Banfield

Don Banfield is a principle atmospheric research scientist at Cornell Center for Astrophysics and Planetary science. He has previously worked on rover missions and has been the long term planning lead for Insight where he is a vital part of the decision making process for Insight. He has also designed the visualization software that his team currently uses to analyze data from Insight.

Dr. Banfield's experience with various past NASA missions, and his work as a long term planning lead for Insight will allow us to gain esssential insights about the decision making process involve in scientific planning. His experience designing their current visualization software can give us insights as to the essential functions that scientists need in a data visualization tool.

Key Takeaways

- Rover planning is based on rover constraints and prioritizing science goals.

- Decisions are always data driven

- Meteorological data is imporant to science but also to human exploration but the meteorlogical data that Mars 2020 is able to obtain will be limited due to instruments.

- Being able to compare multiple sols in a data visualization or analysis tool would be a very important and necessary addition

Session Goals

01. Gain a better understanding of how scientific goals are prioritized and how that leads into decision making.

02. Learn about the data visualization tools used by scientists and how this information is shared among scientists with different specializations.

03. Identify the essential weather variables

FACILITOR: ANGELA YUNG

Interview Questions

WEATHER

When analyzing weather on Mars, what variables are important for rover operation?

> What are the must-have variables? Why?
>
> Is there any other weather variable that is important to look at? Why?
>
> How often should weather be studied? (how often does Martian weather fluctuate?)
>
> How much time do you need to spend looking at data to interpret and analyze daily weather patterns?

What do you think are some implications of dust storms on rovers?

What steps were taken after the observation of the global dust storm?

What do you think are some implications of the sun on rovers? How do you avoid direct sun exposure?

What types of weather events strike fear into your team? What are just inconvenient?

What are the limitations with the current information available regarding weather on Mars?

What weather information would help the rover operate more efficiently on Mars that we don't understand yet?

If possivbe, can you walk us through a tool that you use for analyzing data or making decisions?

Is there any existing tool out there that does a good job at visualizing weather info that you'd recommend us looking into?

When interpreting weather data, do you want to see all the variables being visualized or just a few selected ones? Why?

What does an ideal weather visualization tool look like to you? Can you walk me through its capabilities and features?

What does a scientist present to other scientists during meeting?

> Are proposals (including data) usually easily understandable by everyone?
>
> Do scientists need to "translate" their data/data viz so it can be understood by other scientists?

Stephen Scheuerle

About Stephen Scheuerle

Stephen Scheuerle is a Doctoral Student in Astronautics at Purdue University. Stephen has a YouTube channel called “Martian Wolf”, where he makes videos about Mars exploration. He has a number of videos that address Martian weather specifically. Additionally, Stephen interned as an Engineering Designer at NASA Goddard, where he designed planning software.

Session Goals

01. Identify critical weather variables that could potentially rover operation and instruments.

02. Uncover how weather data is being visualized & how scientists approach to collecting and interpreting weather data.

03. Identify what visualization tools exist currently and ask for more references of resources (tools, papers, etc.) to further look into after the interview.

Keri Bean

About Ms. Bean

Keri Bean is a training lead for the Mars 2020 mission and a former Rover Planner on Curiosity along with roles on previous Mars missions including Phoenix and Dawn.

Her background is in atmospheric sciences and meteorology, but as a Rover Planner she's also had training on the engineering side of Rover Operations. She has firsthand experience running the daily Science Operations Working Group (SOWG) which handles rover planning and target selection activities, giving her in-depth knowledge on what information this team needs in order to operate effectively. She is also one of the most knowledgeable people on how procedures will change in the upcoming Mars 2020 mission.

Key Takeaways

- The 5 hour timeline for the Mars 2020 is very aggressive, it will require sticking to campaign and super-tactical planning rather than discussing daily targets.

- Geologists and atmospheric scientists don't cross-pollinate unless they have to due to planning requirements.

- Rover missions are operated differently than any other type of NASA mission, much more collaborative.

- Main concern around weather for Rover ops team is making sure the temperature doesn't get too low. Dust isn't an issue like it once was because Rovers are nuclear now.

Session Goals

01. Better understand a rover planner's duties and needs in relation to Martian weather

02. Gain insight into Martian weather's effect on Rover operations

03. Understand how a rover planner interfaces with other stakeholders in the process with special focus on scientists and engineers.

FACILITOR: JOHN SYKES

Interview Questions

High priority question

ASTTRO & Mission Planning

- So you are one of the developers of ASTTRO. Can you tell me more about the tool, who are the intended users and its capabilities?
    - How does ASTTRO fit into the daily rover operation planning? (5-hour meeting)
    - How do different stakeholders interact and collaborate with each other on ASTTRO?
- Can you elaborate more on weather-related features of ASTTRO?
    - [We haven't had the chance to take a look at the tool] What kind of weather variables are available in ASTTRO?
    - How do you see this tool helps scientists and other teams in terms of rover mission planning?
    - Do you know which variables do scientists find most valuable?
    - How do different stakeholders interact and collaborate with each other on ASTTRO?
- Have you received any feedback from scientists regarding the tool? (pros and cons)
- Is there any feature/capability that would you like to add, both weather- and non-weather related?

Data Visualization

[I recently watched a talk that you've given on Youtube back in 2017. I was really fasinated by your work at Ops Lab and all the tools that you built. It looks like you have experience visualizing data in both 2D and 3D, and tested them with scientists and astronaults]

- What do you think is the role of data visualization at NASA, specifically on the Mars 2020 mission?
- How can we structure and visualize data in a way that is meaningful for scientists?
- Do scientists prefer to interpret data in any specific way? (raw vs. processed data, how its being labeled, type of graphs and charts, or any specific unit measurement)
- What kind of comments/annotations do they use when using the tool? (we want to know more about what kind of language we should consider when designing this)
- Do you have any story or example of how scientists, rover planners, and engineers use weather-related data visualization to collaborate and make decision?

Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

GERMAN MARTINEZ

About Dr. Martinez

Dr. Martinez is the Co-Investigator of the Mars Environmental Dynamics Analyzer (MEDA) instrument on the Mars 2020 rover. He has involved with the Mars Science Laboratory (MSL) since 2013. He received 2 Group Achievement awards from NASA MSL in 2015 and 2017. In the past decade, he has produced 31 publications, most of which entail Martian atmospheric conditions. He is actively involved in the operation of Mars 2020 while teaching at the University of Michigan.

Dr. Martinez's work experience and his knowledge will provide our team with valuable insights regarding Martian weather and atmosphere.

ERIK FISCHER

About Dr. Fischer

Dr. Fischer received his Ph.D. in Climate and Space Sciences and Engineering at the University of Michigan in 2018. He is currently working with the MEDA team on the Mars 2020 mission and has insights on rover operations.

Dr. Fischer received 2 Group Achievement Awards from NASA MSL in 2015 and 2017. He has produced 7 publications and spoken at over 10 conferences since 2014.

Dr. Fischer will provide our team with a lens into how scientist, engineers, and rover planners collaborate with each other. These insights will further help us uncover the challenges and how a data visualization tool could act as a design opportunity to enhance the workflow.

Session Goals

01. Identify critical weather variables that could potentially rover operation and instruments.

02. Uncover how weather data is being visualized & how scientists approach to collecting and interpreting weather data.

03. Identify what visualization tools exist currently and ask for more references of resources (tools, papers, etc.) to further look into after the interview.

Interview Questions

High priority question

Weather-related

- Can you tell me more about your role and your research in the field?
- When analyzing weather on Mars, what variables are important for rover ops?
    - What are the must-have variables? Why?
    - Are there any other weather variables that are important to look at? Why?
    - How often should weather be studied? (how often does Martian weather fluctuate?)
    - How much time do you need to spend looking at data to interpret and analyze daily weather patterns?
    - What do you think are some implications of dust storms on rovers?
    - What do you think are some implications of the sun on rovers?
    - What types of weather events strike fear into your team? What are just inconvenient?
- What are the limitations with the current information available regarding weather on Mars?
- What weather information would help the rover operate more efficiently on Mars that we don't understand yet?
- What don't we know about Martian weather? Where are the glaring knowledge gaps?
    - How do you visualize weather data?
- What do you think are the challenges of visualizing weather data on Earth vs. data on Mars?
- Can you walk us through a tool that you use for analyzing data or making decisions?
- Is there any existing tool out there that does a good job at visualizing weather info that you'd recommend us looking into?

Rover Operations

- Can you walk me through your team's typical decision making process?
- What is the role of data visualization in rover mission planning?
- What are the features and capabilities that you'd like to have in a mission planning tool?
- Can you walk us through a tool that you use for analyzing data or making decisions?

Mark Powell

About Dr. Powell

Mark Powell is a Senior Member of the Technical Staff in the Mobility Systems Concept Development Section at NASA JPL. Currently, Dr, Powell workscience data visualization and science planning for telerobotics

Session Goals

01. Understand ASTTRO at a deeper level including its current capabilities/features and limitations.

02. Discover how scientists use the tool, their mental models, expectations and perceptions of data visualization.

03. Receive advice of how to design a tool for scientists at NASA: what elements we should pay close attention to, what are some tips, and resources that the team can further look into.

Interview Questions

High priority question

ASTTRO & Mission Planning

- So you are one of the developers of ASTTRO. Can you tell me more about the tool, who are the intended users and its capabilities?
    - How does ASTTRO fit into the daily rover operation planning? (5-hour meeting)
    - How do different stakeholders interact and collaborate with each other on ASTTRO?
- Can you elaborate more on weather-related features of ASTTRO?
    - [We haven't had the chance to take a look at the tool] What kind of weather variables are available in ASTTRO?
    - How do you see this tool helps scientists and other teams in terms of rover mission planning?
    - Do you know which variables do scientists find most valuable?
    - How do different stakeholders interact and collaborate with each other on ASTTRO?
- Have you received any feedback from scientists regarding the tool? (pros and cons)
- Is there any feature/capability that would you like to add, both weather- and non-weather related?

Data Visualization

[I recently watched a talk that you've given on Youtube back in 2017. I was really fasinated by your work at Ops Lab and all the tools that you built. It looks like you have experience visualizing data in both 2D and 3D, and tested them with scientists and astronaults]

- What do you think is the role of data visualization at NASA, specifically on the Mars 2020 mission?
- How can we structure and visualize data in a way that is meaningful for scientists?
- Do scientists prefer to interpret data in any specific way? (raw vs. processed data, how its being labeled, type of graphs and charts, or any specific unit measurement)
- What kind of comments/annotations do they use when using the tool? (we want to know more about what kind of language we should consider when designing this)
- Do you have any story or example of how scientists, rover planners, and engineers use weather-related data visualization to collaborate and make decision?

Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

NATHANIEL GUY

About Mr. Guy

Mr. Guy is a former Lead User Interface Developer at NASA JPL. He is the expert in spacecraft telemetry and data visualization. During his time at JPL, he worked at Ops Lab where he served as a lead developer, working on interfaces that assist mission planning and rover operations. His prominent works include the development of ProtoSpace, SideKick, OnSight, Destinated Mars, ASTTRO, and so on.

Since the ASTTRO team serves as a client for our project, Mr. Guy will provide our team with valuable insights regarding the tools and its current features/capabilities. He will be a valuable source to help us understand how the tool is being used by scientists, rover planners, and engineers during mission planning.

Mr. Guy also received his Master of Science in Aeronautics & Astronautics at the University of Washington in 2016. Over the past few years of his professional career, he has created 2 patents and has been invited to 10+ talks and poster sessions.

Session Goals

01. Understand ASTTRO at a deeper level including its current capabilities/features and limitations.

02. Discover how scientists use the tool, their mental models, expectations and perceptions of data visualization.

03. Receive advice of how to design a tool for scientists at NASA: what elements we should pay close attention to, what are some tips, and resources that the team can further look into.

FACILITATOR: TYLER LA

Interview Questions

High priority question

ASTTRO & Mission Planning

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- Do you have any story or example of how scientists, rover planners, and engineers use weather-related data visualization to collaborate and make decision?

Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

Erin Murphy

About Ms. Murphy

Erin Murphy is a UX practitioner who worked on many of JPL's internal tools including ASTTRO, the rover targeting tool that currently has the closest functionality to a weather planning tool for the rover team at NASA. She pioneered utilizing storyboards and low-fidelity prototyping techniques in order to perform rapid iterative design and understand how geologists perform their targeting activities.

Erin's experience in building the ASTTRO targeting tool is invaluable as we've utilized some of her sketches and early work to reconstruct her thought processes. In this interview, we intend t ask her more about her experience designing these tools and how she thinks they could be improved.

Key Takeaways

- A great way to sidestep complexities of NASA is to lean into low-fidelity testing techniques. She used storyboards, sketches, and paper prototypes to great effect.

- There is poor documentation around the reason decisions were made, but good documentation what the decision were.

- Science intent is extremely important, it's basically the reason the planning meeting uses to choose to go after a specific target. If you can communicate that well, you can get backing for your proposals.

- Annotation is a weak point at JPL. Many tools have it, but few or none do it well.

Session Goals

01. Learn about the design and development of ASTTRO and other NASA tools.

02. Get a designer's perspective on the NASA culture , meeting structure, toolset and any potential unmet needs.

03. Gather expert opinion on how to approach problems at NASA and any insider tips.

FACILITOR: JOHN SYKES

Interview Questions

High priority question

ASTTRO & Mission Planning

- So you are one of the developers of ASTTRO. Can you tell me more about the tool, who are the intended users and its capabilities?
    - How does ASTTRO fit into the daily rover operation planning? (5-hour meeting)
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- Have you received any feedback from scientists regarding the tool? (pros and cons)
- Is there any feature/capability that would you like to add, both weather- and non-weather related?

Data Visualization

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- Do you have any story or example of how scientists, rover planners, and engineers use weather-related data visualization to collaborate and make decision?

Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

Scott Guzewich

About Dr. Guzewich

Scott Guzewich is a research astrophysicist at NASA. He reiceived a PhD at Johns Hopkins University where his main research interests were in dust and tides in the martian atmosphere. His current research focuses on mars atmoshperic dynamics, atmospheric modeling, and atmospheric aerosols. Dr. Guzewich works with data from the Mars Science Liboratory in which he utilizes data from the Mast Camera and the Rover Environmental Monitoring System.

Dr. Guzewich's previous experience with NASA missions will provide us with useful insights on the decision making process surrounding science goals. He is also involved in the Mars 2020 rover mission and can be a window into the scientific planning process for the future mission.

Session Goals

01. Learn more about the decsion making process

02. Gain insights on the weather data that is most essential to an atmoshperic scientist

Interview Questions

High priority question

Weather & Atomosphere

- Can you tell me about your research and role at NASA
- When analyzing atmosphere on Mars, what variables are important for rover operation?
    - What are the must-have variables? Why?
    - Is there any other weather variable that is important to look at? Why?
    - How often should weather be studied? (how often does Martian weather fluctuate?)
    - How much time do you need to spend looking at data to interpret and analyze daily weather patterns?

- Is there any type of weather event that could negatively effect the data that you are looking for?
- What do you think are some implications of dust storms on rovers?
- What do you think are some implications of the sun on rovers?
- What are the limitations with the current information available regarding weather on Mars?
- What weather information would help the rover operate more efficiently on Mars that we don't understand yet?
- If possible, can you walk us through a tool that you use for analyzing data or making decisions?
- Is there any existing tool out there that does a good job at visualizing weather info that you'd recommend us looking into?
- When interpreting weather data, do you want to see all the variables being visualized or just a few selected ones? Why?
- What does an ideal weather visualization tool look like to you? Can you walk me through its capabilities and features?

JEFFERY HEER

About Dr. Heer

Jeffrey Heer is a Professor of Computer Science & Engineering at the University of Washington, where he directs the Interactive Data Lab and conducts research on data visualization, human-computer interaction and social computing.

Jeffrey is a relevant expert for us because we need to understand how to effectively visualize weather data in a way that promotes shared mental models and facilitates discussions, while still being open-ended enough to promote scientific exploration.

Session Goals

01. Learn more about best data viz strategy and practice.

02. Seek for advice of how to create a tool that could support collaboration among scientists and engineers.

FACILITOR: YOMNA HAWAS

Interview Questions

High priority question

We're working with NASA JPL to help mission operation teams - comprised of scientists and engineers - understand Martian weather conditions so they can make better short-term and long-term rover planning decisions for the Mars 2020 mission. We're still in the early phases of trying to understand the space, but we've already learned some interesting things from our interviews with engineers and scientists, that we're excited to talk to you about because of your knowledge about interactive data visualiation, reverse-engineering visualizations and collaborative interpretation of data.

1. Efficiency

Decisions based on weather information need to happen in a limited time window. Resultantly, scientists and engineers need to quickly understand it and come to a consensus about what the data means.

What are some ways to make visualizations more quickly understandable?

> Are there any common pitfalls that we should avoid?
>
> What are some examples of visualizations that you think do this really well?

2. Discussion Facilitation

Scientists and engineers speak different languages, and they like to visualize data in their own way, which can then lead to misinterpretation and miscommunication.

What are some ways to reduce data misinterpretation/cognitive bias when there's different stakeholders viewing the same dataset?

> What are some examples of visualizations that you think do this really well?

What are some ways to support asynchrous collaboration on a data visualization system?

> What are some examples of software that facilitates discussions about vizualisations on the platform?
>
> What makes it successful and what can be improved?

3. Promote Scientific Exploration

Data needs to be clear enough that different stakeholders can come to a quick consensus, but it still needs to promote scientific exploration.

How can data visualization be used to foster curiosity and further user exploration?

> What visualization libraries are most suitable for user vizualisation customization?
>
> What makes them successful and what can be improved?
>
> How can you make customized visualizations still understandable by others?

FACILITOR: YOMNA HAWAS

High priority question

4. Learnability

Scientists and engineers can understand complex systems but whatever we build needs to be easy for them to quickly learn and grasp, otherwise they will just fall back to their own custom tools.

When using a new data visualization tool, what do you find helps reduce the learning curve?

> How do you assess the ease of learnability of a data viz software?

5. Prototyping

Most of our research participants are remote and as we progress in the project, we will want to test what we have with them.

What tools/software do you find helpful in prototyping interactive data visualizations?

> How do you assess the ease of learnability of a data viz software?

6. Weather Visualization

I saw that you worked on an interactive data analysis project in 2014 called "Weathering the Data Storm"

What are some challenges specific to visualizing weather data?

What existing software is most suitable for visualizing weather?

> What makes it successful?
>
> What are some ways it can be improved?

What are some advantages/disadvantages of visualizing weather in common visualizations as opposed to animated 3D weather channel type visualizations?

7. General Tips

Would you recommend a particular library (d3, vega, trifacta, etc) over the others for our project? Why?

What are some steps we haven't touched on that we need to take to design a great data visualization experience?

Is there any additional person/literature/tool that you think would be helpful for us to learn more about?

BETINA PAVRI

About Betina Pavri

Ms. Pavri is a systems engineer at NASA JPL with a background in planetary geology. She currently works on Mars Curiosity Rover operations. Her work with downlink rover data can give us further insights on how the downlink data is used and how that data is processed and visualized. As a systems engineer on the Curiosity Rover, she played a role in ensuring MSL science instruments were healthy and safe. She has expertise in assessing instrumentation anomolies and may be able to shed light how these anomolies occur and what can be done to prevent them.

Session Goals

01. Gain a better understanding of the process of obtaining downlink data and how that data is used

02. Understand decision making and conflict resoultion

03. Gaining better understanding how how weather can negatively effect downlink data or instrumentation

FACILITOR: ANGELA YUNG

Interview Questions

- Can you tell me about your research and role at NASA

- What are the different tools you use regularly and what do you like/dislike about them?

- How do you visualize downlink data? how is it interpreted and presented to different stakeholders?

- Can you tell me about how different teams work together, specifically in rover ops meetings, (I've attached a diagram of how we understand the process to be)

- Any past experiences you've had/ you've witnessed where there's collaboration between people of varying expertise (scientists, rover planners ets), the nature of that communcation

- How decision-making and conflict resolution occurs

- How martian weather has impacted instrumentation/data in the past and how you think it can impact instrumentation in the future

- We know that the sun can have damaging effects on the rover instruments. What steps are taken to avoid direct sun exposure?

- Anything else you think is valuable for use to know about engineer/scientist collaboration and martian weather's impact on operations.

FRED CALEF

About Dr. Calef

Mr. Guy is a former Lead User Interface Developer at NASA JPL. He is the expert in spacecraft telemetry and data visualization. During his time at JPL, he worked at Ops Lab where he served as a lead developer, working on interfaces that assist mission planning and rover operations. His prominent works include the development of ProtoSpace, SideKick, OnSight, Destinated Mars, ASTTRO, and so on.

Since the ASTTRO team serves as a client for our project, Mr. Guy will provide our team with valuable insights regarding the tools and its current features/capabilities. He will be a valuable source to help us understand how the tool is being used by scientists, rover planners, and engineers during mission planning.

phd at U of Alaska 2010 studying Mars crater distribution and ejecta

post doc at jpl, join full time 2012

extensive xp in ESRI and GIS tool

currently the Geospatial nformation scientist for MSL (“Keeper of the Maps”) - maintain geographic info system containing msl cience data, provide geospatial reference for all data product related to “hard target” (rocks)

provide geospatial product, such as geologic maps , traverse path, and surface roughnessfor traverse planning to MSL r.p

Session Goals

01. Understand ASTTRO at a deeper level including its current capabilities/features and limitations.

02. Discover how scientists use the tool, their mental models, expectations and perceptions of data visualization.

03. Receive advice of how to design a tool for scientists at NASA: what elements we should pay close attention to, what are some tips, and resources that the team can further look into.

FACILITATOR: TYLER LA

Interview Questions

High priority question

1. Intro

We are graduates students at the University of Washington. For this project, we are working with NASA JPL to research and design a tool that helps scientists understand weather on Mars.

I'm sure you know this pretty well already, the Mars 2020 mission has a requirement to support 1-to-1 uplink operations, and scientists and rover planners must to work closely together to find valid places to make targets.

Currently, we are in the research process. We are trying to understand the implications of weather on rover operations, what kind of tools are being used, and how to design them properly so that they are useful for scientists.

And you have extensive experience working on mission planning and with scientists, you also know how to design and develop tools that support mission planning. Any insight that you can give us today will be really valuable and thank you again for taking the time to talk to us.

And I think I have a good understanding of the Mars missions but this is a new space for us, so I also want to apologize in advance if I ask any dumb questions.

I think maybe we can start this by learning more about your role at NASA? What is your involvement with Mars 2020, and what is it like to be the "Keeper of Maps"?

2. Geospatial & Weather Tools

- Who are the main users of the geospatial products or the tools that you created?
- How much weather information do you take into account when plotting and mapping the Martian surface?
- Does weather information change between short-term and long-term science planning?
- What weather variables are available on this tool?

Interview Questions

High priority question

3. Retrieving and Processing Data

We talked to a atmospheric and environmental scientists, we learned that to understand weather or atmospheric conditions, they need data from the rover, orbiter, and lander, and even data from specific instruments. I don't know if it is a fair assumption, and please correct me if I'm wrong, to say that a portion of your role is also similar since you need to take data from the MRO and process it.

Could you walk me through the process of how you collect and turn data into something meaningful?

- What are the challenges?
- How do you cope with them?
- What kind of format is the data?
- Is there a tool or a technique that you use for data integration?

3. Weather data visualization

- What are some challenges specific to visualizing weather data?
- How can we structure and visualize data in a way that is meaningful for scientists?
- Do scientists prefer to interpret data in any specific way? (raw vs. processed data or how the data is labelled)
- What kind of comments/annotations do they use when using the tool? (we want to know more about what kind of language we should consider when designing this)

5. Prototyping

Most of our research participants are remote and as we progress in the project, we will want to test what we have with them.

What tools/software do you find helpful in prototyping interactive data visualizations?

How do you assess the ease of learnability of a data viz software?

4. General Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

HEATHER JUSTICE

About Ms. Justice

Ms. Justice is a system engineer at NASA JPL, with an undergraduate degree in Computer Science from Harvey Mudd College and a Masters degree in Robotics from Carnegie Mellon University.

Ms. Justice was one of the lead rover drivers for Opportunity which was exposed to the global dust storm of 2018.

Resultantly, Ms, Justice can shed some light on the nature of decision making between engineers and scienticts when weather factors in,

Session Goals

01. Understand decision making and conflict resoultion

02. Gaining better understanding how how weather can negatively effect downlink data or instrumentation

03.

FACILITOR: YOMNA HAWAS

Interview Questions

High priority question

We are graduates students at the University of Washington. For this project, we are working with NASA JPL to research and design a tool that helps scientists and engineers understand weather on Mars so they can make quicker decisions during the Mars 2020 mission operations. We're still in the research process, and we're essentially trying to understand how engineers and scientists work together, the implications of weather on operations, and the different tools being during mission planning.

We're really excited to talk to you since you were one of the lead rover drivers for Opportunity. Thank you for making the time to talk to us, we'll do our best to make this short and sweet. We've talked to multiple people at NASA now but this is still a new space for us, so please let me know if any of my questions are irrelevant or stupid.

Interview Questions

High priority question

3. Weather

We've been looking into how weather can affect rover planning.

Can you recall a time when Martian weather impacted rover operations somehow?

What weather information is essential to understand for rover planning?

> How is this visualized?

What weather information do you find interesting to look at?

> How is this visualized?

What data do scientists look at and what data do rover planners look at?

4. Wrap up

We're just about ready to wrap up. We're still looking for more people to interview.

Are there any relevant people (scientists, data viz experts, engineers) at NASA that you would recommend?

Can we credit you?

ASHWIN VASAVADA

About Dr. Vasavada

Ms. Justice is a system engineer at NASA JPL, with an undergraduate degree in Computer Science from Harvey Mudd College and a Masters degree in Robotics from Carnegie Mellon University.

Ms. Justice was one of the lead rover drivers for Opportunity which was exposed to the global dust storm of 2018.

Resultantly, Ms, Justice can shed some light on the nature of decision making between engineers and scientícts when weather factors in,

Session Goals

01. Understand decision making and conflict resoultion

02. Gaining better understanding how how weather can negatively effect downlink data or instrumentation

Interview Questions

High priority question

We're graduate students at the University of Washington studying Human-Computer Interacrion & Design. For our project, we are working with the user experience team at NASA JPL to research and design a tool that can help scientists make quicker decisions during the Mars 2020 mission operations by possibly improving their shared understanding of eachother's science. We're still in the research process, and we're essentially trying to understand how scientists interact with data, how they work with eachother and how they work with engineers. We're also looking to specifically understand the implications of weather on operations because that's one area that we're considering focusing on.

We're really excited to talk to you because of your extensive experience as a scientist at JPL and your research in geology and atmospheric dynamics. Thank you for making the time to talk to us, we'll do our best to make this short and sweet. We've talked to multiple people at NASA now but this is still a new space for us, so I apologize in advance if any of my questions are irrelevant.

Can you tell me about your role at NASA?

Science Planning

I imagine you've been a part of countless science planning meetings for the Mars missions, I'd love to discuss the nature of those meetings.

General Science Planning Meeting

Can you walk me through the typical science planning process?

> How long do these meetings last on average?
>
> How many scientists are involved?
>
> What are the different types of scientists that take part in this?
>
> Are any external teams included in the planning process?

Are scientists usually working together in-person or remotely?

> What are some challenges that exist from working remotely?
>
> What are some ways to overcome these challenges?

What is the nature of the scientist's relationship with one another?

> Have they typically been working together for a long time? Does the time they've worked together have an impact on their working relationship?
>
> Do some scientists get along better with other scientists? Why?

Interview Questions

High priority question

Preparing Proposals

I'd like to take a step back and talk about the processes that scientists go through before the meeting.

What are some steps scientists will take when preparing their proposal?

> What's the most challenging part in the process?
>
> How long does this normally take?

What are the most common data variables that scientists look at when preparing their proposals?

> Do all scientists have access to the same data?
>
> Do scientists analyze data individually or together?
>
> How often is the data analysed? How long does the process take?
>
> How far back would they look at the data? Do they look at historical data?
>
> How is this data visualized?
>
> What are some challenges that they go through when analysing data?
>
> What are some factors that can cause data uncertainty? How do you overcome that?
>
> When reviewing data, what do you do when you run across an anomaly?

How important is context when reviewing data?

> Can you give me an example?
>
> How do scientists go about understanding the context when analysing data? How do they fill gaps?

Why do you think scientists build their own data analysis tools?

> What are the positive outcomes of custom tools?
>
> What are the negative implications of custom tools?

What are some factors other than data that can influence what the scientist proposes?

Presenting Proposals

What does a scientist present to other scientists during meeting?

> Are proposals (including data) usually easily understandable by everyone?
>
> Do scientists need to "translate" their data/data viz so it can be understood by other scientists?

Interview Questions

High priority question

Decision Making + Conflict

Have you observed conflict or been a part of conflict with other scientists before?

Can you recall a specific example and tell me more about it?

Was this a one-off situation or does conlict occur regularly? What type of conflict occurs regularly?

Why do you think this conflict occurs?

What are some ways this conflict can be resolved?

Have you experienced being the long term planning lead?

Can you briefly talk to me about your responsibilities as an LTP lead?

Can you break down the decision making process for me?

What do you enjoy about the experience?

What are some of the challenges?

How do you go about prioritizing when there's conflicting plans?

Wrap-up Science Planning

How has the process evolved over time?

What are the biggest opportunities for improvement?

How do you make sure you're still on track with long term goals while still allowing for spontaneous discovery?

Weather

Do you think there's value in helping all types of scientists understand Martian weather? Why?

From our other interviews we've been told there isn't much visibility in terms of martian meteorological data over time. Do you have thoughts around this? Is this important to have?

How much info do (or will we) have on Martian global air currents? Is that data being collected by the atmospheric satellites?

We learned that weather on Mars doesn't fluctuate much, how often is it being looked at?

We learned that there's some seasonal changes that have an effect on operations (e.g. temp, dust storms). How far ahead in advance are these planned for?

How early are global dust storms usually discovered? Why was 2018 dust storm discovered only 1 week in advance?

How do different atmospheric conditions impact science prioritization?

MIKE SEIBERT

About Mr. Seibert

Mr. Seibert was working on the MER team for over 10 years. During this time at JPL, he has taken on multiple roles such as engineer, rover driver, and flight director.

He was directly involved in the day-to-day operation of the Opportunity rover, especially through the global dust storm that Opportunity and Spirit faced in 2007.

His extensive experience and knowledge regarding collaboration and atmospheric atmosphere will help provide our team with meaningful insights for the project.

Paper:

Operations strategies for the Mars Exploration Rovers during the 2007 Martian global dust storm

Session Goals

01. Gain more understanding about atmospheric opacity and its effects on rover instruments and operations.

02. Discover how scientists and engineers collaborate during a global dust storm

03. Uncover the needs and desires of the engineering team in terms of tool and features in order to operate rover effectively during a global dust storm

FACILITATOR: TYLER LA

Interview Questions

High priority question

1. Intro

We're graduate students at the University of Washington studying Human-Computer Interacrion & Design. For our project, we are working with the user experience team at NASA JPL to research and design a tool that can help scientists make quicker decisions during the Mars 2020 mission operations by possibly improving their shared understanding of eachother's science. We're still in the research process, and we're essentially trying to understand how scientists interact with data, how they work with eachother and how they work with engineers. We're also looking to specifically understand the implications of weather on operations because that's one area that we're considering focusing on.

And you have extensive experience operating the rover, working with scientists, and you also wrote the paper on the global dust storm in 2007. Any insight regarding mission planning, Martian weather, and interactions with scientists that you can give us today will be really valuable.

And I think I have a good understanding of the Mars missions but this is a new space for us, so I also want to apologize in advance if any of the question is irrelevant.

I know you're not at JPL currently but I think we can start by learning more about your previous role at JPL? What was your involvement with the Mars missions?

2. Planning & Working with Scientists

We've talked to a few scientists and engineers, it seems like there are a lot of stakeholders in rover operation process.

Can you tell me more about your collaboration with scientists on both the strategic and tactical levels?

- What are some challenges?
- Can you break down for decision making process for me?
- Where do disagreements happen?
- How do engineers and scientists resolve any conflict or come to an agreement?

How do you support or work with different teams of scientists? (i.e, geology, atmospheric scientists)

2. Dust storm & Tau

This is a good segway into weather information. I'm really glad that the work that you did and the collaboration with with different teams helped Spirit and Opportunity survive the storm in 2007. It's also sad that we lost Opportunity to the storm last year. But thinking back to that experience, can you elaborate more on how different teams work together during the storm?

Interview Questions

High priority question

Even though M2020 will operate with nuclear the power, knowing the tau measurement is still critical for mission planning because it could affect the instruments on the rover. We've talked to a few people who use ASTTRO to select targets. Currently, information regarding the tau isn't integrated into the tool.

If we were to design a way to integrate or visualize the tau, what information is relevant for us to include?

Could you walk me through the process of how you collect and turn data into something meaningful?

> - What are the challenges?
> - How do you cope with them?
> - What kind of format is the data?
> - Is there a tool or a technique that you use for data integration?

3. Weather data visualization

- What are some challenges specific to visualizing weather data?
- How can we structure and visualize data in a way that is meaningful for scientists?
- Do scientists prefer to interpret data in any specific way? (raw vs. processed data or how the data is labelled)
- What kind of comments/annotations do they use when using the tool? (we want to know more about what kind of language we should consider when designing this)

5. Prototyping

Most of our research participants are remote and as we progress in the project, we will want to test what we have with them.

What tools/software do you find helpful in prototyping interactive data visualizations?

> How do you assess the ease of learnability of a data viz software?

4. General Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

MARK LEMMON

About Dr. Lemmon

Dr. Lemmon focuses on planetary atmosphersic science with a specific focus on aerosols and particulates on alien planets. His long-time focus has been Mars and monitoring atmospheric dust load, studies dust properties, measures dust lifting in dust devils, and moonlights in astronomical imaging. He is currently preparing for a similar role on Mars 2020. Previously, he was the imaging team lead for the Phoenix mission, as well as a participant in Spirit's mission and a member of the imaging teams for Mars Pathfinder and Mars Polar Lander. His work hasearned him the nickname “Keeper of the Tau” among the Martian teams at NASA JPL.

Key Takeaways

- Tau (optical opacity) is an atmospheric measurement that is very commonly used across specializations, but it isn’t something many scientists are aware they need to do their work.

- If two scientists are measuring the same thing in different ways, that can actually be a great thing because it allows for validation or discussion on why there are differences. Both cases are valuable to scientists.

- Instruments degrade over time and require recalibration. Re-calibration can be very weather dependent.

Session Goals

01. Better understand the role Tau plays in overall planning for rover missions.

02. Better understand how atmospheric data like tau can be used across all types of scientists.

03. Understand key needs from an atmospheric scientist perspective

FACILITATOR: JOHN SYKES

Interview Questions

High priority question

1. Intro

We're graduate students at the University of Washington studying Human-Computer Interacrion & Design. For our project, we are working with the user experience team at NASA JPL to research and design a tool that can help scientists make quicker decisions during the Mars 2020 mission operations by possibly improving their shared understanding of eachother's science. We're still in the research process, and we're essentially trying to understand how scientists interact with data, how they work with eachother and how they work with engineers. We're also looking to specifically understand the implications of weather on operations because that's one area that we're considering focusing on.

You have extensive experience with martian rover instrumentation, specifically around atmospheric data. Any insight you have around rover planning and scientific needs specifically related to Martian meterology would be very valuable ot us.

And I think I have a good understanding of the Mars missions but this is a new space for us, so I also want to apologize in advance if any of the question is irrelevant.

To start off with, would you mind briefly summarizing your contributions to JPL andthe missions you've participated in?

We've heard you called ' Keeper of the Tau' by some of our other interview participants referring to your expertise in Martian dust.

Can you tell us about what that entails?

Are there specific data sets you work with?

2. Planning & Working with Scientists

We've talked to a few scientists and engineers, it seems like there are a lot of stakeholders in rover operation process.

Can you tell me more about your collaboration with other scientists on both the strategic and tactical levels?

- What are some challenges?
- Can you break down for decision making process for me?
- Where do disagreements tend to happen?
- How do engineers and scientists resolve any conflict or come to an agreement?

How do you support or work with different teams of scientists?

Alternatively, how do other teams support your research?

Interview Questions

High priority question

Is there anything you wish all the non-atmospheric specialists on the mission knew about your field going in?

2. Dust storm & Tau

Even though M2020 will operate with nuclear the power, knowing the tau measurement is still critical for mission planning because it could affect the instruments on the rover. We've talked to a few people who use ASTTRO to select targets. Currently, information regarding the tau isn't integrated into the tool.

If we were to design a way to integrate or visualize the tau in a tool, what information is relevant for us to include?

Could you walk me through the process of how you collect and turn data into something meaningful?

- What are the challenges?
- How do you cope with them?
- What kind of format is the data?
- Is there a tool or a technique that you use for data integration?

3. Weather data visualization

- What are some challenges specific to visualizing weather data?
- We've been told that because the newer rovers are nuclear powered, weather isn't as worrisome as it used to be for rover health. However, We've been todl instruments are still affected by weather (temperature, tau, wind, sunlight have come up a lot) Are there other weather events that are less well-known on Mars we should look into?
- Do scientists prefer to interpret data in any specific way? (raw vs. processed data or how the data is labelled)
- What kind of comments/annotations do they use when using the tool?

(we want to know more about what kind of language we should consider when designing this)

From our other interviews we've been told there isn't much visibility in terms of martian meteorological data over time. Do you have thoughts around this?

- (theoretical) What are some interesting stories we could tell if we had better visibilty into longitudinal Martan atmsopheric data?

Interview Questions

High priority question

How much info do (or will we) have on Martian global air currents?

- Is that data being collected by the atmospheric satellites?

- Is there any existing tool out there that does a good job at visualizing weather info that you'd recommend us looking into?

5. Prototyping / Tools

What tools/software do you find helpful in prototyping interactive data visualizations?

How do you assess the ease of learnability of a data viz software?

4. General Tips & Advice

- Is there any other details that we should pay close attention to when designing a data visualization tool?
- Do you have a favorite tool or literature that you'd recommend us looking into?

Aymeric Spiga

About Dr. Spiga

Dr. Spiga currently serves on the faculty of Sorbonne Université in Paris, France. His research focuses on astrophysics and geophysical fluid dynamics and more specifically planetary atmospheres which he studies using data from orbiting space crafts and telescopes.

Dr. Spiga also develops software tools such as the online interface for the Mars Climate Database.

His experience in developing software tools and his expertise in martian atmospheres will provide us with many insights in our research space.

Session Goals

01. Learn more about the developing software tools

02. Gain further insights on using Martian atmospheric data

03. Receive advice of how to design a tool for scientists at NASA: what elements we should pay close attention to, what are some tips, and resources that the team can further look into.

Interview Questions

High priority question

1. Intro

We're graduate students at the University of Washington studying Human-Computer Interacrion & Design. For our project, we are working with the user experience team at NASA JPL to research and design a tool that can help scientists make quicker decisions during the Mars 2020 mission operations by possibly improving their shared understanding of eachother's science. We're still in the research process, and we're essentially trying to understand how scientists interact with data, how they work with eachother and how they work with engineers. We're also looking to specifically understand the implications of weather on operations because that's one area that we're considering focusing on.

You have expertise in both Martian atmospheres and developing software tools.

To start off with, would you mind briefly summarizing your work?

-Are there specific data sets you work with?

Can you describe the tools that you've developed? (Specifically the Mars Climate Database & planetoplot)

- What led you to develop these tools?
-What considerations did you have while developing these tools?
- What were the goals of creating these tools?
-Who was the intended audience/user?
- Was ease of collaboration of high importance when developing either of these tools?
- What is your process when developing a tool?

Do you collaborate with other scientists in your research?

- What are some challenges?
- Are there instances where you have to make collaborative decisions related to your work?
- Where do disagreements tend to happen?

Interview Questions

High priority question

What are the most common data variables that you look at when studying planetary atmospheres?

Do all scientists have access to the same data?

Do scientists analyze data individually or together?

How often is the data analysed? How long does the process take?

How far back would they look at the data? Do they look at historical data?

How is this data visualized?

What are some challenges that they go through when analysing data?

What are some factors that can cause data uncertainty? How do you overcome that?

When reviewing data, what do you do when you run across an anomaly?

How important is context when reviewing data?

Can you give me an example?

How do scientists go about understanding the context when analysing data? How do they fill gaps?

Do you often build your own analysis tools or is there a tool that works for you?

What are the positive outcomes of custom tools?

What are the negative implications of custom tools?

What is the best way for you to present your data or findings to others?

Are there certain tools that you use for sharing your findings?

Katie Stack

About Ms. Stack

Katie Stack is a research scientists at NASA JPL who focuses on Martian geology. Her research focuses on the Martian sedimentary rock record, using orbital and rover image data to understand the evolution of ancient surface processes on Mars. Katie has been a member of the Mars Science Laboratory (MSL) Science Team since 2012 and will continue her work on Mars 2020.

She has also acted as Campaign Lead on the Curiosity Mission which consists of gathering insights from multiple teams and distilling them into usable information for all organizations - this feeds directly into our investigation of how to translate information across science specialties.

Key Takeaways

- Atmospheric scientists are concerned with time, geologists are concerned with space and location. Geologists require more planning to get their measurements whereas atmospheric measurements can be taken en-route.

- Atmospheric science is generally considered secondary to geology because geology is more likely to produce the findings they are looking for. Specifically, around water and potential habitability.

- Tools for bridging the dialect gap: annotations, utilizing generalists, visual reference points.

Scientists are not skilled at translating findings down to be consumable by the general public. Generalists who are able to do this are hard to come by and very valuable.

Session Goals

01. Better understand the relationship between scientists, specifically geologist interacting with non-geologists.

02. Determine expected needs from a geologist perspective

03. Understand the process of collaboration between different scientists and how they bridge the ‘language barrier’

Interview Questions

High priority question

1. Intro

We're graduate students at the University of Washington studying Human-Computer Interacrion & Design. For our project, we are working with the user experience team at NASA JPL to research and design a tool that can help scientists make quicker decisions during the Mars 2020 mission operations by possibly improving their shared understanding of eachother's science. We're still in the research process, and we're essentially trying to understand how scientists interact with data, how they work with eachother and how they work with engineers. We're also looking to specifically understand the implications of weather on operations because that's one area that we're considering focusing on.

You have extensive experience with martian geology. Any insight you have around the how weather impaxcts your research, either directly or indirectly would be valuable.

And I think I have a good understanding of the Mars missions but this is a new space for us, so I also want to apologize in advance if any of the question is irrelevant.

To start off with, would you mind briefly summarizing your contributions to JPL andthe missions you've participated in?

I've noticed you seem to be the 'face' of AccessMars. How did that come about?

2. Planning & Working with Scientists

We've talked to a few scientists and engineers, it seems like there are a lot of stakeholders in rover operation process.

Can you tell me more about your collaboration with other scientists on both the strategic and tactical levels?

- What are some challenges?
- Can you break down for decision making process for me?
- Where do disagreements tend to happen?
- How do engineers and scientists resolve any conflict or come to an agreement?
- How do you support or work with different teams of scientists?
- Alternatively, how do other teams support your research?
- Is there anything about Martian meteorology you find difficult to get information on? or is certain data tedious to get or distributed through inefficient methods?
- How do scientists need to "translate" their data/data viz so it can be understood by other scientists?

Interview Questions

High priority question

What variables do you typically look at when analyzing data? To your knowledge, does weather factor in ?

Can you tell me a story about an interesting finding you came across? What led up to it? What was planning for it like? Did you expect something or was it kind of serendipity?

Have you been involved in any 'dress rehearsals' for 2020? How did they go? How do they compare to Curiosity planning meetings?

- Can you walk me through how you go about deciding on a target to analyze? What do you look for? How do weather conditions factor into the decision?

If we were to design a way to integrate or visualize the tau in a tool, what information is relevant for us to include?

- What kind of comments/annotations do they use when using the tool?

(we want to know more about what kind of language we should consider when designing this)

From our other interviews we've been told there isn't much visibility in terms of martian meteorological data over time. Do you have thoughts around this?

- (theoretical) What are some interesting stories we could tell if we had better visibilty into longitudinal Martan atmsopheric data?

- Is there any existing tool out there that does a good job at visualizing weather info that you'd recommend us looking into?