Characterizing Work-Life for Information Work on Mars: A Design Fiction for the New Future of Work on Earth

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We present a design fiction, which is set in the near future as significant Mars habitation begins. Our goal in creating this fiction is to address current work-life issues on Earth and Mars in the future. With shelter-in-place measures, established norms of productivity and relaxation have been shaken. The fiction creates an opportunity to explore boundaries between work and life, which are changing with shelter-in-place and will continue to change. Our work includes two primary artifacts: (1) a propaganda recruitment poster and (2) a fictional narrative account. The former paints the work-life on Mars as heroic, fulfilling, and fun. The latter provides a contrast that depicts the lived experience of early Mars inhabitants. Our statement draws from our design fiction in order to reflect on the structure of work, stress identification and management, family and work-family communication, and the role of automation.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; *Computer supported cooperative work*; *Ubiquitous and mobile computing theory, concepts and paradigms.*

Additional Key Words and Phrases: Space; Mars; work; life; remote work; COVID-19; the future of work; design fiction.

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1 INTRODUCTION

Humanity is determined to inhabit Mars [142]. Society's fascination with becoming a multi-planetary species has been regurgitated by many for decades, citing Mars' unquestionable suitability as a second home for humanity [111, 143]. Recent successes in space aeronautic technologies (e.g., SpaceX, Blue Origin) have contributed to the public's excitement about the possibilities of space travel [140]. Beyond understanding the needs of advances in habitation, the Martian context has motivated new research in various areas: perception [133], medicine [32], and sustainability [92] – all of which seek to understand and support human life not only in space, but also on Earth.

One particular aspect of human-computer interaction that has yet to be examined from the lens of Mars is the *information workplace*. From small start-ups to large technology corporations, modern information workplaces on Earth involve teams of people, often acting as experts of a particular information domain (e.g., writing, programming, data science), who cooperate toward an information-oriented end-goal through computers [52]. Today, information work is riddled by a myriad of challenges, such as task management [14], interrupted work [94], and burnout [31]. Modern research mitigates these challenges with various artificial intelligence techniques [50, 74, 137]. However, the complexity of these challenges has risen significantly in light of the on-going COVID-19 pandemic [127], that has forced the majority of our planet's information workforce to operate in a significantly more distributed and isolated fashion. These recent developments motivate new questions about the needs of post-pandemic work practices.

This paper seeks to answer the question: *How can we use the context of information work on Mars to better understand the needs of an increasingly distributed future of information work on Earth?* We present a design fiction that depicts a habitation mission to Mars in order to provoke and structure discussion of the promises and potential shortcomings of information work on Earth. Our inquiry is inspired by the global shift to remote work forced by the on-going COVID-19 pandemic and its associated shelter-in-place mandates that caused information organizations across the world to unexpectedly adapt to a telework practice [127]. Through our design fiction, we examine the similarities between working from home and working on Mars and describe their shared challenges and opportunities. Thus, our design fiction serves as a creative needfinding exercise that considers the needs of future information workers as work itself continues to become more complex, more distributed, and more AI-mediated.

Our design fiction is grounded in the ability to study and learn from analogies that exist between the Earth and Mars contexts. Prior research developed analogs to space missions with durations from two weeks to one year and 4 to 1,000 people [82]. Kitmanyen et al. developed close-quarters environments to simulate non-Earth crew deployment [78]. Stuster compares the long confined conditions of spacecraft to sailing ships marooned by polar ice caps, characterizing stress-inducing social situations [122]. The Mars 500 project simulated the isolation and tasks of a Mars trip and mission with 6 crew members to better understand how the Martian environment shapes human behavior [24]. Similarly, the NEEMO project trained astronauts in an undersea research habitat to study human physiology in long-duration space flight [129]. While these studies were conducted on Earth, the experiences of crews approximate aspects of extraterrestrial travel and habitation.

1.1 Approach and Structure

Our approach is inspired by prior design fictions that have utilized fictional artifacts, such as advertisements [23], API specifications [119], and creative writing [12]. These artifacts provide a rich social and technological context where researchers can distil new challenges and opportunities. We see the Design Fiction method as one that is closely related to scenarios [20] and personas [25], both of which are conventional tools for understanding the needs of interaction and system design in HCI research [97, 107].

Our inspiration for this paper began as a desire to apply work-life research to a new context. Reflexively, the "we" [115] in this paper is a mix of students and seasoned researchers in the HCI community. We were and are impacted by the COVID-19 pandemic and have continued to adjust our work-life in response. During the writing of this paper, some authors were blocked from seeing family across national border, took on more parenting responsibility, and generally managed more roles than before. As we thought more about our own experiences and those of other workers during shelter-in-place, we realized how similar the experiences could be to workers living on Mars.

Thus, we organized group meetings where we developed ideas for the design fiction. We outlined constraints for a narrative that would focus on the work-life challenges of information workers on Mars and during shelter-in-place. As the text fiction was nearing a rough draft and we discussed recruitment, we had the idea for creating a propaganda poster (Figure 1) as a foil for the "lived experience" of workers on Mars. The author statement was simultaneously developed as the poster and text narrative neared completion. This approach is similar to the approach of Baumer et al.'s design fiction [12] at GROUP 2018.

In this paper, we contribute a design fiction and an authors' statement. In Section 2, we present and describe a design artifact – a recruitment flyer for a corporate space endeavor aimed at establishing a small information workforce on Mars. In Section 3, we present our design fiction which is a curated narrative of the work and life of the information workforce's members on Mars. The recruitment flyer paints the work-life on Mars as heroic, fulfilling, and fun. The narrative provides a contrast that depicts the lived experience of early Martian inhabitants. Our goal in creating this fiction is to identify issues that intersect both work and life that affect the nature of information work not only on Mars, but also inevitably on Earth as well. In Section 4, we provide commentary on the fictional narrative interleaved with considerations for information work on Mars. In 5, we conclude with a reflection on our statement and its broader connection to the new future of work on Earth.

2 DESIGN ARTIFACT: THE APOLLO INITIATIVE RECRUITMENT FLYER

In our design fiction, the recruitment flyer advertises the *Apollo Initiative*, an experimental exploration of long-term, multi-planetary habitation. Facilitated by an artificially intelligent habitat ecosystem named EVE, the initiative seeks to establish a "prosperous work and life" beyond Earth. The flyer was designed around principles of propaganda to promote both individual and communal feelings of patriotism, prosperity, and technological futurism [49]. The initiative is managed, supported, and funded by *Apollo Corp*, an American aerospace manufacturer that engineers habitat and transportation services designed for extraterrestrial contexts in space [139]. The initiative is also federally-funded by the National Aeronautics and Space Administration's (NASA) *"Beyond Work and Life"* program, which served as the successor to the National Science Foundation's renowned and widely successful *"Future of Work and Life at the Human-Technology Frontier"* (FWL-HTF) program that funded convergent computing research aimed at simultaneously improving the prosperity of terrestrial work and life at societal scale. Through this program, our design fiction

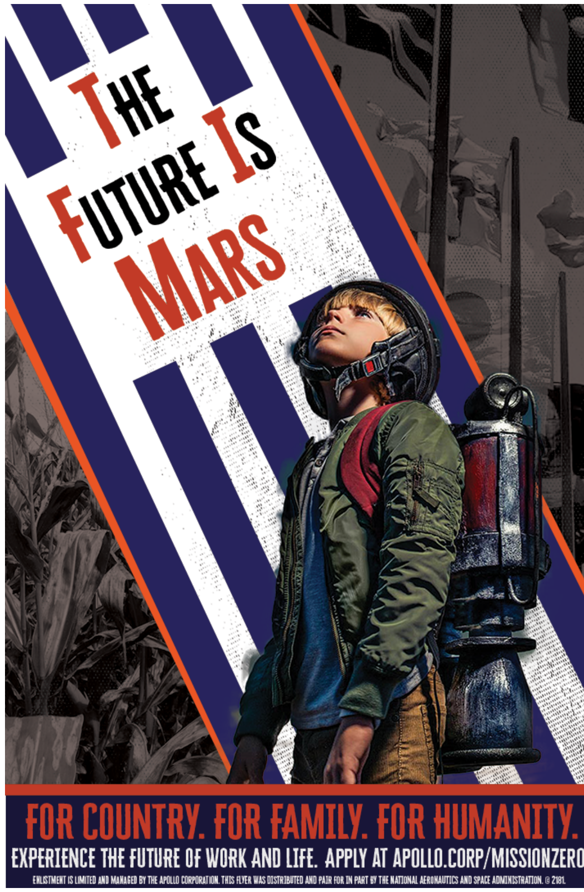

Fig. 1. The recruitment flyer for the Apollo Initiative's *Mission Zero* ©Alex C. Williams.

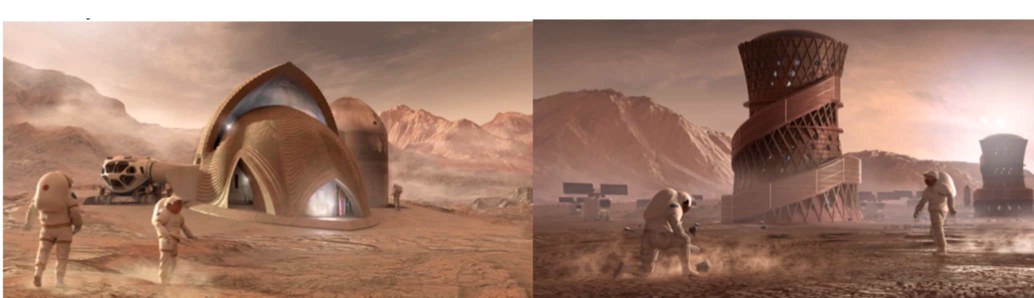

Fig. 2. Early-century habitat designs that inspired the EVE habitat system from Yashar et al. [139]

details the Apollo Initiative's first longitudinal endeavor in space, made possible by a wealth of advancements in science.

2.1 Study Design: Mission Zero - An AI-Assisted Mission to Mars

Mission Zero is the alias given to the Apollo Initiative's first deployment of human participants to the Martian surface. Here, we describe the mission's goals, timeline, and recruitment methodology used to select participants who could thrive in the demanding Martian environment.

2.1.1 Mission Goal: Understanding AI-Assisted Productivity and Well-being with EVE. The primary goal of Mission Zero is to "improve society's definition and understanding of the future of productivity and well-being beyond Earth". In support of this goal, the Apollo Initiative developed EVE, an AI-infused habitat architecture that mirrored the designs of early-century habitat design for the Martian environment (See Figure 2). As a habitat architecture, EVE is structurally embedded with a web of interconnected sensors and microprocessors that both archive and aggregate data. EVE's primary source of data is the ME-EG sensor, a sensor surgically implanted on the cranial skull of each crew member. EVE's secondary sensors include lifelogging tools, weather-resistant intelligent cameras, space suit sensors, and various on-skin interfaces that collectively support collaborative decision-making.

Through the lens of EVE, a secondary goal of Mission Zero is to understand the challenges and opportunities that exist in supporting information organizations that are subjected to a severely isolated and cognitively taxing environments. In Section 3.1, we describe a man-machine methodology to lifelogging that allowed the Apollo Corp to assess this goal through computer-assisted writing and curation, based on the collection of data in a fully-surveilled environment. Architecturally, EVE follows a data storage pattern that emphasizes locality. Due to bandwidth constraints between Earth and Mars, the system stores and processes the majority locally. The system allows Apollo Corp researchers (i.e., on Earth) to remotely request a summary of sensing information, but does not export raw data. Methodologically, the EVE system's architecture facilitated the collection of participant data in such a way that would not only be unethical on Earth, but also illegal.

2.1.2 Mission Timeline: 52 Earth Months. Following the successes of year-long space expeditions to the surface of the Earth's Moon, the longevity of the mission was scheduled to last a total of 52 months. The mission's length was jointly motivated by the optimal course of trajectory between Mars and Earth that arises momentarily every 26 months [101] alongside the estimated travel time between Earth and Mars amounting to approximately seven months [66]. Given the unknown consequences of being subjected to the Martian environment for an extended period of time, participation in the mission was therefore internationally regarded as a patriotic service to one's country and humanity. Before the mission, Apollo Corp recruited for 6 months. Candidates were trained for one year for extended space travel and close-quarter living at the Johnson Space Center in Houston, Texas. The mission departed for Mars on July 1, 2081, and approximately seven months later, arrived on the Martian surface on February 3, 2082. 38 months later, the Mission Zero crew departed from Mars on April 2, 2085 and returned to Earth on November 7, 2085.

2.1.3 Recruitment Methodology. The mission's recruitment procedure ran across a 6-month period and was facilitated with a digital flyer that was distributed via ADiot, a web service that routes personal advertisements to individuals using personal data collected via ME-EG sensors. More than 19 million individuals engaged with the flyer for more than 10 seconds with 56% of this engagement having been facilitated by mixed-reality hardware (e.g., contact lenses) while other devices (e.g., in-ear assistants) accounted for substantially less engagement.

Eligibility for participation required that individuals be 18 years or older, a mix of skills and specializations, familiarity with computing or mechatronics, and be capable of passing an extended version of the NASA long-duration flight astronaut physical [112]. The two exceptions to these requirements were the necessity of U.S. citizenship, which was waived in support of ensuring

Table 1. Demographic information of Mission Zero's twelve participants.

Person	Gen	Age	Education	Nationality	Partner	Kids	Expertise
Diwa	F	24	Mech. Eng, BS	USA	N	0	Mechatronics engineer, specializing in drone fleets.
Paulo	M	46	Biology, PhD	Brazil	Y	2	Plant geneticist, specializing in agriculture.
Aleksandra	F	33	Physics, PhD	Russia	Y	0	Physicist, specializing in data science and sensing.
Jens	M	28	Psych., PhD	Germany	N	1	Psychologist, specializing in mental health counseling
Genevieve	F	49	MD	Canada	N	0	General Physician, specializing in family medicine
Bryan	M	29	Comp. Sci, MS	UK	N	0	Software developer, specializing in low-level systems.
Iman	M	40	Trade School	Iran	Y	2	Construction practitioner, specializing in welding.
James	M	30	Trade School	USA	N	0	Electrician, specializing in fabricated electronics.
Bjørg	F	19	High School	Norway	Y	0	No specialization; Dustwalker
Muhammad	M	21	High School	Malaysia	N	0	Repairman, specializing in automation repair
Valentina	F	29	LPN/RN	Argentina	N	0	Apprentice Physician, specializing in nursing
Ryo	M	37	Info. Sci, PhD	Japan	N	0	Information Scientist, specializing in library science

international representation, and the necessity of piloting experience, which was unnecessary in a highly-automated context. Eligibility was automatically assessed based on information collected via ME-EG sensors. Participants who were assessed to be ineligible were not engaged for recruitment.

A total of 96,129 individuals from more than 37 nations across the world applied to participate in the Mission Zero program. ME-EG sensor data automatically reduced this to 3,500 individuals suitable for the Martian environment. Crew needed to be able to thrive in isolation, work with each other on Mars, and cooperate effectively with EVE. Permutations of all participant combinations were explored to maximize the likelihood that teams would cooperate and coordinate with other crew and EVE. Pool reduction continued until an optimal team composition emerged.

2.1.4 Study Population. A total of twelve participants (6M/6F) were selected based on the limited capacity of the Apollo Corp's transporting spaceship, which was also transporting the EVE habitat architecture. Participant ages ranged from 19 to 49 (μ=32.0; σ=9.0). Three participants identified themselves as having a romantic partner or companion, for a period of greater than three years at the time of recruitment. Three participants also reported having at least one child. Seven participants held at least a Bachelor's degree in a field of study related to science and technology. The preference for specializing in technology and science was waived for two participants, after the reduction procedure repeatedly identified the significance of having team members who were not only significantly younger in age, but also more comfortable in assisting experts in their task domains.

3 DESIGN FICTION

This section presents a narrative that describes the general setting of life on Mars that the Apollo Initiative has established and crew experienced 24 months into their 52-month-long mission. Through the lens of this setting, we introduce Apollo Initiative participants through third-person narratives that articulate their day-to-day life. In our story, the narrative itself was generated by EVE from a variety of input data from conversations, trace data, lifelogging, and sensor data (e.g., via ME-EG) summarized and organized by EVE – the AI agent built into the habitat ecosystem.

3.1 EVE and Ryo: The Generator and The Curator

The crew was implanted with a multitude of sensors to monitor aspects of their mental and physical health. EVE used all of this to generate reports and narratives that were to be sent back to Earth and available for team awareness. To avoid leaking sensitive industry information reported by EVE, the crew included a curator: Ryo. The curator manually reviewed the reports and tuned the EVE system. To do this, Ryo rated the quality of generated text summaries and picked the best versions.

3.2 The Landscape of Martian Life

Dust blew over the silvery spider web of pods, whizzing into any cove that it could find, desperately trying to claw its way into the havens that humanity had created and return them back to the normal, uninhabitable state of nature that surrounded them. The landscape of the Red Planet had taken on a new, modern look in the last couple of years. Going from the classical barren desert that everyone knew into a mess of construction and metallic facilities that dotted all around the jagged features of Mars.

For years humanity had been chasing the grand cosmic trophy that was Mars. Its dusty, red atmosphere and unique geography made it a holy grail for most aspiring scientists. To look up into the stars and say, "we claimed a piece of the heavens"was dream that inspired a brilliant effort. It was a once in a lifetime merging of fields where scientists and engineers met under the same lamp light, enchanted by equations and simulations, watching test rockets fly and crash, rolling plastic robots across mock terrains and delighting in the process of progress. After decades of work from both industry and academia, humanity had not only set foot on Mars, but firmly planted their feet.

The new construction took years of careful logistical planning and precision engineering with the result being an undeniably impressive achievement. The bases were never meant to be pretty, as Mars' thin atmosphere and great distance from Earth forced them to be creatures of necessity. They never stuck to a general theme. Their layouts varied from compound to compound and molded themselves into whatever shape the sprawling planet demanded. Some bases were tight and barrack-like, stacking people one over the other and squishing buildings into close quarters. Other bases appeared to be intricate spider webs of metal, spread out and connected by long tube-like appendages.

All of this combined to create the weird, mechanical beast that was humanity living in a place that it didn't belong. People attempted to live normal lives in an abnormal place, attempted to have dinner in a cramped mess hall only inches away from an inhospitable atmosphere. Crew tried to relax while hearing machines of survival whirl like helicopter blades. The engineering side of colonizing Mars was brilliant and impressive, but the human side was much more complicated. Apollo Corp had no time to think about leisure or comfort when designing the bases and planning the missions; Mars left no room for such pleasantries. Instead, crew were expected to adapt in the hope that one day their struggle would be paid for in progress.

3.3 Diwa, Robot Maintainer and Construction Manager

Sitting in one of these alien installations, idling and biting her nails to pass the incessant time, was Diwa. She was the construction manager for a project that was set to add two new buildings to her compound, and keep pushing into the Martian wilderness. Diwa was "managing" a team of robots and drones that operated independently outside of the compound. They rolled and buzzed all around outside the compound, unhindered and perfectly at home in the thin atmosphere. Diwa watched them from a thin, metal tower positioned high above the site. Its interior was packed with screens, dashboards, and lights that were constantly blinking and beeping about the current state of this or that robot, along with large projections of the current weather on the red planet.

Getting up into this structure was a dangerous and delicate process, seeing it was only a temporary structure the normal safety measures were never added. So, instead of suiting up and going through the multi hour process of transit each and every day, Diwa decided to just live on site and wait until phase one of construction was over, which was scheduled for three and a half weeks. Everyday she woke up and spent her morning leisure hour in the cramped pod, then stepped six inches over back into her chair and began watching the drama of construction robots unfold all over again.

This process took its toll on her psyche, as human interaction was limited and the day-to-day was quite unchanging. Not being present with other people doing similar work could leave her feeling unmotivated to focus on doing the same monotonous tasks. The only real tasks she had to accomplish in between watching the drones was formulating high-level reports on the general status of the construction, something the EVE system wasn't yet capable of. The scientists back on Earth were quite precise, and wanted to know the location of every individual screw and piece of scrap metal to plan for future endeavors. The reporting process was simple enough, Diwa put on a headset, thought aloud in her head, and watched her words appear on a screen before her. Even with this automatic typing, it was still mentally taxing. So, Diwa combated this draining work routine by having breakfast "with" some of her colleagues every morning.

3.3.1 A Brief Breakfast. "Hello again, everyone." Diwa said to the screen before her.

"Morning D," said one of the familiar faces on the bright panel. "The tower still treating you well?"

"Oh lovely," Diwa said sarcastically in between bites of rations. "You should really see the view this morning. Drones look just like morning doves back on Earth, and they are just as annoying." That brought out a chuckle from everyone on the call.

They all continued to banter and joke around, trying to temporarily forget about their crazy work-life and pretend that they were having a normal coffee meetup before work like they would back on Earth. Some on the call talked about workplace drama, others about how their current station was not nearly as good as the last. Though, after only about twenty minutes, all of them understood that they had work to do, and that Mars didn't leave much time for such interactions. So, with brief goodbyes and promises to do the same thing again tomorrow, the screens went black and Diwa remembered she was alone again.

It was moments like this that seemed to make Diwa reflect on everything, made her think about how she got here and what it all used to mean to her. Mars was a 52 month commitment, it was an endeavor that demanded one-hundred percent of your immediate future and took over all of your current life. Diwa could remember coming out of college idealistic and being excited about what might lay in her future. She was a drone fleet engineer, a coveted specialization and a hard skill to master. She was proud of what she was doing. Now look at her. She sits behind some computer screen and watches robots buzz around like a fancy puppet show. Was this what she was meant to do? Was this a part of the visionary things she had always dreamed about doing? She knew that if she spent any longer thinking about it she would become upset.

The day started out as it normally would. The drones automatically developed simple daily logs and forwarded them to EVE, the compound's AI system. EVE summarized drone activity into a macro document for Diwa to read at the beginning of the day. Diwa tried to focus on reading this paper, but she was distracted by her coming deadlines. During her last meeting with the compound manager Genevieve, she was informed that the board back on Earth had dropped the expected finish date for phase A by two weeks. In order to do this, they laid out a detailed plan of all the changes that would have to be made. Reading it was also on Diwa's to-do list for the day. Another big problem was that the recent storm had wrecked parts of the construction site. Diwa had not yet found the time to fully screen and quantify the extent of the damage it caused.

"Oh man," Diwa said to herself while shaking her head at the thought of everything that was going on, "I swear this job is-" before she could finish her sentence, the small device located on her wrist vibrated violently and its screen lit up with a message.

3.3.2 A Meeting with the Counselor. "Christ!" She said in shock as she looked down at it. *HRV indicates increased stress. Start guided breathing?* was displayed on the small, digital screen along with an option for her to self report her mood. Diwa let out a laugh and attempted to swipe the message away. *It is not recommended you ignore this message, job description shows that you have long periods of isolation. Would you like to request a break?* "Ha! A break, yeah sure buddy, that would be great." She said jokingly after dismissing that message as well.

Diwa hated the automated warnings and preferred to monitor herself. She tried to shake off her frustration and continue her work, but the wrist watch vibrated again. "Are you kidding me?", she said as she looked down at the screen. *Incoming call from resident health counselor. Accept?*

Diwa shook her head as she reluctantly accepted the call. One of the screens on her desk closed out of its drone monitoring systems and opened up a clear panel for the video call, "Good morning Diwa!" The exuberant face of Jens said with a heavy German accent. "Lovely to see you again."

"Hello Jens, how was your breakfast?" Diwa said with a smirk.

"Brutal, I miss Germany." She said with her usual on-point sarcasm. "Anyways Diwa, I imagine you know exactly why I called. Those work-stay missions that you go on can be dreadful for your mental health sometimes, you shouldn't skip the self report like that." She hated the way Jens' eyes could pierce right through even a digital screen.

Diwa thought about what she'd even say to the self report, *Hey sorry, I'm just a little upset that my job is just watching robots buzz around all day and sitting in a glorified prison cell. Maybe some better food would help?* It was the type of thing that she didn't really like to talk about, she'd power through it, she knew she could. So to her there was no reason to report anything, "Oh come on Jens, I'm okay, and even if I wasn't what would you would do? Recommend more sunlight?"

Diwa could see Jens' face turn when she said that, maybe she shouldn't have been that harsh about it? Before she could try and backtrack Jens straightened up and raised her finger in excitement, "I have an idea! You have your headset lying around, don't you?"

"Yeah of course. I use it to do a flyover with the drones sometimes." Diwa said with confusion.

"Great! Once you're done for the day put it on and come to room five. I'll see you there!" Before Diwa could protest the screen went black. She sighed and shook her head. It all felt like too much, but she didn't want to just leave Jens waiting in the room alone. So, after a long arduous day of creating reports and watching drones buzz, she put on her headset that tracked her brain signals and signed into room five.

"What in the world are we doing?" She said while watching the room around them digitally build into a fantastic medieval scene.

"I know you're not one for prescriptions and recommendations. So, I thought you and I could enjoy a game together. Just relax for a bit and play one of the new ones sent over from the latest transmission."

Diwa couldn't hide her smile, she'd usually try and shy away from these sorts of things, say she had work to do or that she was tired. But for once it felt okay. An audible alarm would go off if the robots needed her.So, she pulled a blanket over from her bed and got comfy in her chair. She hadn't played a good game in a while, it felt right to just let go for a moment and enjoy the good company.

3.4 Limited and Dangerous Outside Time - Dust Walk

Iman looked down at the laminated picture before him, trying to stare at it long enough so that the fire that it started in his chest wouldn't immediately go out after he put it back. With the great distance of Mars and the need to send vital data first, direct interaction with family members was a rarity. Usually the team was able to communicate with them at least once a week. With the recent major revisions the construction team was planning, family time was not on the transmission schedule yet.

"Iman," said a voice from across the room, jolting him out of his trance. "Come on, it's time to eat breakfast and get the day started. Look at the EVE docket, Muhammad is on kitchen duty this morning, so that means you're with me for this mornings maintenance briefings."

Iman glanced over at one of the various screens positioned on the walls. Everyday EVE would gather up all of the various tasks that it detected needed to be done throughout the day and assign them to the crew members. Iman's docket was filled with various status checks and structural integrity modifications, but at the beginning, like Bjørg had said, was the maintenance briefing.

Iman nodded his head and got up from his bench, moving over towards the table that was now starting to fill up with the other members of crew B. The room they were in was cramped and stuffy, like all rooms in the compound.Already at the table was Bjørg, who had just talked to him, and Bryan. Since it was Muhammad's day to cook he was at the kitchen station, choosing to eat his food while cleaning up.

"Picture change since last time you saw it?" Bryan asked Iman with food in his mouth and a half-smirk peaking through.

"Bout as much as your humor did, Bryan." Iman replied quickly before silently reciting his dua.

Bryan smiled and nodded his head in acknowledgment, "I'm just messing with you Iman, I understand the feeling. Home can feel far away sometimes."

"Don't forget why we do this though, for humanity!" Bjørg said with a large dose of sarcasm. *For Humanity* was the motto used by the Apollo Initiative to recruit people back on Earth, and the team often used it as the back end of jokes.

After the brief exchange they all sat silently and ate their food, listening to the subtle hum of Muhammad singing to himself as he was loading the dishes into a machine. "You know," Bryan said breaking the silence. "I like to watch Footloose at night whenever I miss home. There's just something about it, you know?"

"Footloose?" Iman asked. "That's the one movie that reminds you most of home? Isn't that thing like eighty years old?"

"And aren't you from New York?" Bjørg said following him up.

"No, no, no." Bryan said with his hands up defensively. "I mean, yes I am from New York, and yes it's like eighty, but that's not what I meant. There's something about watching everyone dancing together in that wide open space, just having a good time. That's what I think of when I think of home, when I think of Earth, and I'm a sucker for the old time cinema experience."

"I'll do without seeing you dance." Muhammad quipped from the kitchen area.

"I second that." Bjørg said, resulting in everyone enjoying a small moment of laughter as they finished up their meals.

3.4.1 A Task Update. As everyone was getting up and beginning to get ready for the day, the intercom positioned above the room buzzed awake, "Crew B, can you hear me?"

"Oh great." Iman said while moving over to the screen that was by one of the doorways. "Yes, we're here. Just finishing breakfast."

The mood around the room was the same, no one liked when crew A called them. It almost always meant they had to do what felt like useless work. "Great!" The voice said, "EVE reported some structure damage out by the east wall from yesterday's storm. I need you all to go check it out for us."

Iman drew a heavy breath before replying, "Could a drone not see it? What's Diwa doing?"

"Diwa flew a drone over right when it got reported, but said she couldn't see anything for certain. She need boots on the ground to be sure."

"Of course she does." Bjørg muttered from the corner of the room.

"Alright," Iman said grimly, "We'll go check it out."

"Great!" The voice said, "EVE should be able to provide all the details you need about it. If you have any problems, just call Diwa. Also, call Valentina before you go out. I know she was wanting some more deep soil samples from the next dust walk."

"Would love to." Iman said as he glanced over to the EVE docket and saw everyone's schedules unanimously change to the dreaded words of *Dust walk*. He wanted to protest or suggest some different course of action, but he knew that would be irresponsible. All he could do was watch the mid-day rest and relaxation period disappear from EVE's digital face and imagine how far behind he'd be by the time the day was over. That is, if he made it out of the dust walk at all.

Dust walks were a dangerous and intense event on the Martian planet, the methodology surrounding them was to avoid them at all cost, and when you where forced into one, make sure you got the most out of it so you wouldn't have to come back soon. It's not hard to imagine why they were so dangerous, any outside exposure to the atmosphere could result in fatal accidents, and the lack of truly accurate weather modeling made the event even more precarious.

The team was quick to finish up their suit checks, they just had a couple of more security checks before opening up the airlocks. "Lovely." Bjørg said with a dry smile, "EVE predicts a seven percent chance of a storm today." Bjørg confirmed with Crew A on the task at hand and informed them of their timetable. Muhammad made sure he had all the tools necessary to perform whatever job might be required at the site. Bryan made sure that he had all the wiring and electronics that he might need in case a vital system was broken, and Iman checked in with Valentina to make sure he could get what she needed while outside of the compound.

Once that all was done, the only thing that was left to do was open the airlock and step onto the red planet's dusty surface. It was a tense moment for the team, one none of them cared much for. They knew that they were all on their own out there, no emergency team could come help them and no robot had the power to rescue them. If things went wrong it was up to them and them alone. They means that they could not solely focus on the mission, but had to also monitor incoming alerts from the EVE system in case they had to respond to any imminent danger, such as adverse weather predictions. Iman had his hand resting on the lever that opened the door and took a deep breath before swinging it down, "How are we feeling?"

"Open the dang door Iman," Bjørg said with a slight bite in her voice, "I hate the waiting."

Iman shook his head and had to bite his tongue. The last thing he wanted was another conflict with Bjørg on the space walk. She was a highly capable team member but Iman could do without her dry attitude towards things, it'd caused a problem between them more than once.

3.4.2 The Dust Walk. Iman pulled on the lever and the air was sucked from the small room that they were in. Dust flew in all corners of the opening and seemed to swirl all around them. The sun angled toward the entrance and glared off of the tinted spheres of their helmets. It was an alien experience perfectly fitting the red planet. The team immediately went into autopilot and began executing the training that they all knew so well. One member took the lead and followed the path laid out by EVE to the supposed compromised area, another kept a vigilant eye on the weather predictions and constantly updated the team. "Eight percent over the next hour", "six percent over the next hour" was the resounding song that accompanied them on their journey.

When they arrived at the site, the process was swift and efficient. Muhammad came right up to the hole in the Eastern facing wall and began scanning it for all of its damage. "Seems A team was right for once, this is a real problem."

"What's it looking like?" Iman said while preparing to gather the deep soil sample from about fifty yards away.

"Seems the recent storm catapulted a small rock deep into the metal wall, another hit like that and we have a depressurization catastrophe."

"That is indeed a problem," Iman said while booting up the little machine to dig into the surface. "ETA on the fix?"

Muhammad was silent for a second while he analyzed the hole, “Bryan, you can weld. Come over here and help me patch this thing up.”

Bryan hurried over: “Great. Looks like if you and I both attack this thing we can get it patched in about thirty minutes.”

“Brilliant,” Iman said as he monitored the machine before him. With that said they all got to work: Iman on the soil sample, Bryan and Muhammad on patching the hole and Bjørg on weather duty. It was a tense effort that could be observed through the heavy breathing and perspiring sweat of the team. Meanwhile in the background drones could be seen flying over the base like some sort of alien bird migration, moving with intent and decorating the light-pink sky with black specks.

3.4.3 The Storm. “Gentlemen we have a problem,” Bjørg said after some time, “we’re at twenty percent and rising quickly.”

The team immediately went silent, the thought of a flash storm shook them all to their core. Everyone began gazing at the horizon to see a wall of dust quickly beginning to spin up and materialize. “We don’t have much time.” Iman said with a desperate voice, “We’re going to have to leave right now.”

“No!” Muhammad said in stout defiance, “No we can’t! If that storm hits hard and another rock finds its way into this hole then we have a real problem. Bryan, quick tell me what systems this room stores.”

Bryan immediately went to work on the screen attached to his wrist, “It houses some of the vital drone systems as well as back-up power for the facility. If it gets damaged we not only could risk losing the drones, but also are at risk of having all of our power taken out.”

“We can’t leave it!” Muhammad said in a loud voice, “Bjørg, get over here and help us patch this! Iman, start packing the gear so we can get out of here as soon as this is done!”

Iman looked up at the sky and saw the swirling wall of dust approaching them, the fear he felt was intangible. He thought about his family, and how he hadn’t been able to talk to them in months. Is caused him to freeze for a second.

“Iman!” Muhammad yelled.

Without thinking Iman scooped up the digging machine and quickly dashed over to the others. When he arrived, he started rolling up the wires and gathering the scattered metals. Anything that was left out was at risk of being used by the storm as a battering ram.

“There’s not a third welder!” Bjørg said while desperately digging through the equipment bag.

“That’s alright, just hold the metals in place for me and Bryan.” Muhammad said while welding at speeds he’d never dream of doing on a regular day.

As they all scurried about their tasks, they could feel the wind picking up. Eventually small rocks were being scooped up and thrown by the storm. The EVE system was yelling at all of them from their wrists, *Head inside immediately, potentially fatal weather conditions.* Crew A was pipping in from their coms system, “Crew B why are you still out there? Get back in here right now!” All of this berated them as they methodically and swiftly tried to patch the wall.

Finally, after twelve minutes of welding they had sufficiently patched the hole. Its surface was rough and unclean, but strong enough to take another storm. “Go now!” Muhammad shouted as soon at it was done, and just like that they all took off, welders still in hand, running for the airlock. The mechanical birds that previously decorated the pink sky were now gone, and the horizon had a dark-brown that foretold of its coming destruction.

They skid into the room’s protection and immediately threw down the large lever, shutting the door and re-pressuring the room. Unanimously they all slumped on the floor and hung their heads, taking a moment to regather themselves and process what had just happened. It was the closest call they had had yet, and its sting was sharp and real. As they all sat there, pooling in their left over adrenaline, Bjørg raised her head and with a dry, sarcastic smile said "My smartwatch says I have two missed notifications. I wonder why, EVE."

"And I swear, if that docket tells me to do squats for exercise tomorrow, I'm punching a screen." Bryan said while whipping the small rocks from his suit. Iman raised to his feet and replied with a smile, "Don't forget, for humanity!"

4 AUTHORS' STATEMENT: IMPLICATIONS FOR MARS AND EARTH

Our design fiction argues that modern organizations, teams, and individuals are collectively unprepared to support the challenges that stem from distributed information work whether it be today on Earth or within the next century on Mars. In March 2020, the vast majority of information organizations were subjected to a near-global work-from-home mandate that required employed individuals to telecommute to work [127]. The shift to remote work introduced a number of significant changes: blurred boundaries between work and home, a reliance on video-conferencing communication systems, and an overwhelming feeling of isolation despite being more "connected" to work than ever before [26, 48, 108]. We now provide a statement on the needfinding our narrative provokes within for a new future of work on Earth.

4.1 The Adaptive Nature of Martian Work and Life

Mars introduces challenges that demand *adaptability*. Like the terrestrial world of Earth, the Martian environment requires that its inhabitants, whether they be human or machine, to consistently make decisions under uncertainty [60]. Cognitive theories and frameworks have continued to use the lens of biases and heuristics as guiding principles for explaining human behaviors in decision-making [27, 29, 67]. Humans often make decisions through a process of "satisficing", where they iteratively and subconscious search for solutions until they find that meet an acceptable threshold [118].

4.1.1 Managing Interrupted Work: Implications for Structure, Attention, and Health. Working on Mars frees workers from many interruptions normally experienced on Earth, such as phone calls and colleagues. Modern research repeatedly highlights that being capable of minimizing or – better yet – avoiding these distractions will facilitate concentrated and focused work [95]. However, having increased autonomy over work also means responsibility shifts to the individual on how to carry out work, and not everyone may be as equipped to do so [40]. For example, it requires more self-motivation to stay on task if people are not collocated with others and human interaction is limited [57]. Further, there may be instances in which such distractions may be welcomed as they facilitate an enjoyable distraction from the monotonous repetition of every-day work—whether it be repeatedly doing HITs on Amazon Mechanical Turk [138] or supervising a drone fleet on Mars.

A key characteristic of our narrative's work environment on Mars is that it *demands* a model of structured interruption. For the vast majority of adults on Earth, modern life can be separated into two spheres: work and non-work. Occupational health psychology has repeatedly convey the importance of psychologically detaching from one's work environment and the consequences that stem from failing to do so [120]. As one such consequence, burnout can be described as the "prolonged response to chronic emotional and interpersonal stressors on the job" [98], negatively impacting well-being and limiting long-term productivity. However, so-called "workaholics" may not be aware of how chronic overwork will lead to burnout and lack of sleep [7]. HCI has experimented with supporting work detachment from work with chat bots [137] and simulated commutes [127] for shelter-in-place employees. For a docket optimizing system, planned activities should change based on empirical data about health and historical data and to account for well-being.

Our narrative identifies an opportunity to create interactive systems that optimize for well-being by helping manage work and life activities through structured interruption. EVE creates dockets that lists tasks for each individual to perform. The system also prompts Diwa to take a break, based on real-time HRV data, finally escalating the issue and engaging Jens for human intervention and guidance [28]. NASA claims psychological health is crucially important for long-duration space campaigns, such as missions to Mars [11]. Management research has found boredom [93] and burnout [98] to be detrimental to psychological well-being and job productivity. Self-directed Mars workers may benefit from guidance on how to best structure their work, in order to stay focused on work when needed, and take necessary breaks as appropriate. Text reminders, for example, may be helpful for reminding people to take a break or focus on work, whereas human support may be particularly useful for addressing a lack of motivation to focus [22].

4.1.2 Supporting Adaptive Expertise. Our narrative highlights that, in an information organization of limited capacity, domain expertise is not a panacea. Mission Zero recruited individuals specializing in science and technology. In our scenario, an expected issues requiring welding experience arose for Bjørg, who lacked welding experience. Such unexpected events require the rapid acquisition of new skills and for workers to be "jack of all trades". For example, a computer engineer may also be expected to assist in medical surgeries, prepare food, fix plumbing issues, and lead physical fitness routines for the team.

A job description for a Research Scientist position in Antarctica requires a broad spectrum skills beyond the academic [2]. These include physical fitness, emergency response team experience, and IT experience. They are tasked with assisting meteorologists with weather observations and should expect "other duties". The uniquely extreme environment of Mars [60] further exacerbates the unpredictable need for workers to learn skills beyond those of their profession.

We expect "just-in-time" training methodologies will be a critical part of Martian work-life. Similarly, NASA has identified a need for new systems that better enable constant training and learning processes [1]. They highlight the importance of maintaining relevant expertise during long-term space exploration and Mars missions. Promising new systems, such as the one proposed by Karasinski et al. [73], address the need with augmented reality and the internet-of-things for just-in-time training of astronauts. Karasinsk et al.'s evaluation showed that an augmented reality and internet-of-things prototype was useful in not only helping participants find necessary tools to complete a task, but also in completing tasks [73]. This presents the opportunity for new systems that incorporate augmented reality and intelligent agents, such as EVE in our fiction, to support just-in-time training on Earth and Mars.

4.1.3 Supporting Dynamic Teamwork. Teamwork is critical for deep space exploration as crews are exposed to living and working conditions shaped by atypical contextual factors[82]. In our narrative, members of Crew B have to go out onto the Martian surface to conduct repairs on a "dust walk". In such dangerous environments, transactive memory can mean the difference between success or failure of the mission[87]. In the teamwork literature, transactive memory systems (TMS) are defined as emergent states where team members work towards developing a shared understanding of each other's expertise and roles and manage information in dedicated knowledge repositories [135].

In our narrative, we show how a developed TMS can help to improve a team's problem-solving and decision-making skills[80]. Amid an impending dust storm, Crew B leverages their TMS to complete an emergency welding task and later create a record of their solution for future use.

This is only one example of the unique conditions which crews will have to face on Mars. Past research has shown groups with a TMS perform better [70, 86, 106], are more creative [55], and learn more than groups without a TMS [88]. On Mars, this could be the difference between life and death.

However, this same research has been primarily conducted under routine circumstances and (mostly) in controlled lab-environments. Even studies related to non-routine, extreme circumstances such as overwintering in an Arctic research station (or widespread quarantine during the COVID-19 pandemic) have only spanned months instead of years. Our narrative suggests that the myriad of unique physical, emotional, and psychological stressors present on Mars makes this past research not representative of how TMS development and maintenance may occur there. This highlights the need for new understanding of cognition and cohesion necessary to create TMS systems that can effectively facilitate group dynamics under extreme conditions.

4.2 Team and Family Communication

Like experiences with COVID-19, our narrative shows crew getting together virtually, where physical togetherness is impractical. Extreme asynchronous communication and shifting timezones make collaboration and socialization across great distances an important problem to solve.

4.2.1 Communication Types. Mars-to-Mars communication will have similar constraints to terrestrial internet. For crew on Mars, being together in person may be rare, which is why our narrative a virtual video game-playing experience between Diwa and Jens. While our narrative describes an initial project and installation on Mars, we expect the distant future will across Mars. This would facilitate video chat and mixed-reality experiences across the scattered teams on the Martian surface. Meeting virtually avoids danger from "dust walks" and novel viruses.

While Mars-to-Mars latency enables video chat other live experiences, the lag in Mars-to-Earth communication denies the possibility of real-time communication. Looking at asynchronous communication with long delays, the Mars 500 project simulated latency between crew and mission control [24]. Increasing the distance and duration of communication for the Mars 500 crew provoked distrust, which suggests great difficulty for both work and non-work relationships.

Asynchronous communication that can provide interactions that build trust for COVID-19 and Mars habitation contexts are crucial. Potential technological solutions for maintaining social ties across include asynchronous video messages and slow technology. Beal et al. report on how sending messages over Marco Polo – short asynchronous videos in a "snapchat for old people" app helped grow team social ties during COVID-19 shelter in place [13]. Unlike other apps, Marco Polo has neither likes nor content forwarding, but removes after it is viewed. Odem et al. argue for *Slow Technology* that contrast realtime and fleeting interactions and embrace peripheral and abstract interactions that build meaning over weeks and months [102]. Examples of these are Odem et al.'s Photobox [102] that prints photos from collections throughout a week and Shakeri Neustaedter's Painting Portals [117] that slowly transforms webcam feeds into abstract shared paintings. This abstract approach is an alternative to realistic [121] and immersive synchronous experiences.

4.2.2 Connecting Across Shifting Timezones. In addition to the challenges introduced by long latency in communication sent between Mars and Earth is their difference in length of solar days. While Earth's solar day is nearly exactly 24 hours, Mars' solar day is 24 hours 39 minutes seconds long [125]. This 2.7% difference in solar days quickly compounds. After a single week, the offset in Mars solar time increases to nearly 5.5 hours. Every three days, the solar day difference would be equivalent to heading west by two time zones on Earth.

CSCW and software development research has extensively studied best practices for managing and optimizing the performance of globally distributed teams [18**? ?**]. Research suggest the best performance requires coordinative technologies and team-wide familiarity with these technologies, especially as companies become large and globally distributed. In anticipation of collaboration with workforces on Mars, researchers should design collaborative tools that coordinate communication between Martian and Earth-based team. These tracking tools need to consider (1) the time-zones and locations of available Earth-based team contacts, (2) the current time lag between Earth and Mars in terms of the solar day, and (3) the physical latency time for messages to arrive. This will help optimize contact points for communication at any given Martian time.

4.3 The Nature of AI-Mediated Collaboration for Work and Life

Through the life-logged reflection of our narrative, we introduced *EVE*, an artificial agent embedded into the fabric of the Martian ecosystem that supports our fictional characters in their every-day work and life on Mars. Here, we describe how the Martian context introduces a new world-view of challenges in collaboration between human and AI systems, using EVE as a contextual lens.

4.3.1 Supporting Decision-Making between Human and AI. Collaborative decision-making is generally regarded as a promising approach for managing tasks, but has challenges. For example, *collaboration fluency* in human-AI teams [62], as well as *human trust and adaptability* in the context of automation [84] are fundamentally challenging. Principles of mixed-initiative interaction [63] have served as a guiding force behind the development of these systems. Previous principles of mixed-initiative interaction may need to be revised, inasmuch as the the Martian context [126] impacts system and cognitive functions. Revisions to these principles have been made, for example, to accommodate the user experience of interactive and intelligent systems deployed in commercial contexts [6].

"Head inside immediately, potentially fatal weather conditions." - EVE

Beyond the interaction design of these systems, a multi-planetary context introduces significant challenges to AI system design. Across the last decade, human crowds that generate data and provide on-demand human steering have been crucial to the deployment of AI systems [3, 44, 83]. Communication latency, the lack of an on-demand Martian workforce (e.g., a Martian Amazon Mechanical Turk), and a general lack of reliable infrastructure prevent architectures with a similar scale from being utilized across planets. These observations highlight the necessity for advancements in AI methods that facilitate autonomous systems with amplified interpretability [30] and human-in-the-loop systems that rely on guidance from an extremely small number of qualified people [35]. More broadly, collaborative decision-making will require integrated approaches for managing knowledge and computation that fit human mental models, which continues to remain an open problem for terrestrial contexts as well [9, 10, 136].

4.3.2 AIs That Summarize Brain Interfaces. In our fiction, EVE aggregated brain and trace data signals to facilitate lifelogging used to generate a summary of work. COVID-19 has scattered information workplaces on earth, making awareness and summaries of work difficult. Advances in automatic text summaries [76], description generation from video [100], and story writing [59] indicate that EVE-like work summaries will be developed soon. Our narrative portrays a near saturation trace data from sensors, interpreted thoughts, and cameras. *Trace data* is incidentally created information that did not require additional intentional user input [54]. We think of brain data as a kind of trace data.

An NIH paper authored by Fiani et al. reviews recent advancements in brain-computer interaction efforts, such as Neuralink [51], show strong potential for thought-based interaction. The Neuralink device embeds an array of electrodes in brains and transmits the raw signals to computers. With moderate success in animals, the technology will soon run in human trials for patients with limited mobility. Processing neural signals requires machine learning techniques. According to Liu et al. machine learning is widely used in hybrid EEG-NIRS systems that detect muscle intentions to produce categorizations that assist in providing motion control, emotional states, and visual attention [91]. As the feasibility of meaningful signal increases, the desire to provide team awareness of signals may also grow.

Data and AI summaries alone, however, are not meaningful without human interpretation and guidance. This is why various HCI qualitative methods [107], such as Interaction Analysis [65] and Grounded Theory [17], are useful methods of inquiry. In principle, qualitative methods work because "human instruments" are the best sensor for understanding personal experiences [89]. While AI systems are beginning to imitate rough drafts of human writing, we see humans as eternally in the role of curating and making sense of human experiences. The human act of choice in curation [75] is a creative act that provides the value that drives algorithmic success. This highlights a need for HCI research to develop new theory about how AI can enhance qualitative inquiry, the basis of summarizing human activity, though AI-collaboration.

4.4 Identifying and Managing Stress

Workplace stress plays an important role in managing burnout on Earth [98]. On Mars, the general hostile environment [60] and impossibility of immediate escape makes stress identification and management crucial. Technology can be the both the source and solution to these problems, placing the onus HCI research for stress mitigation. In the context of isolation caused by Mars habitation and COVID-19 shelter-in-place, solutions for stress mitigation in highly-distributed contexts are important.

4.4.1 HCI-related Stressors. Our design fiction highlights the HCI-related stressors in a workplace that is heavily reliant on computer systems, from screens and wearable devices to sensors and AI that generates instructions in dockets. Studies of information workers on Earth found that the average information worker spends approximately 4.5 hours actively working on the work computer during business hours [96]. We expect the Martian workforce to spend more time at their information workplace, given that in-person activities on Earth (e.g. meetings, conferences) would also be completed remotely. In our design fiction, Diwa eats her breakfast with her colleagues remotely before switching to her work. She managed multiple connected systems, multitasking between monitoring drones and writing reports. Besides prolonged screen time, multitasking with many connected systems that require attention and action can be associated with increased stress, diminished productivity, and more errors [5, 39, 94, 104]. Diwa frequently received notifications about the status of the drones and notifications from her wearable device, which could lead to alert fatigue and potentially ignoring important messages.

4.4.2 Workplace Stress Measurement. Stress can be tracked with self-reports and physiological sensors, which could measure different aspects of the stress experience and each has its unique challenges [4]. Self-reports of stress are widely used by psychologists, although concerns have been raised about collecting self-reports for continuous stress tracking at the workplace. Notifications for filling out self-reports (e.g. through Ecological Momentary Assessments on wearable devices [61] or an AI therapist that conducts frequent and personalized assessments [38]) require the full cognitive attention of the user and can be disruptive when a person is busy. Our narrative showed examples of biases in self-reports [58, 114]. In our narrative, workers on Mars missed or dismissed self-report notifications when they were busy or highly stressed. Diwa also had difficulty articulating how she felt. Physiological sensors and brain implants, on the other hand, are unobtrusive. They can be embedded on individuals on Mars or Earth for overall health monitoring and communication with colleagues.

4.4.3 Technology-supported Stress Management. Martian systems will have to deal with the issue of information overload and alert fatigue when combining work systems with personal health tracking systems, as each of these system may utilize notifications that compete for a user's attention [37]. When high stress is detected, either through wearables or self-reports, users might receive a notification with stress management tips. Examples of just-in-time micro-interventions for stress reduction that are suitable for the workplace include peripheral breathing guides [124], short video games [45] and taking breaks [53]. Other activities outside of the work context can also encourage relaxation, such as taking a break to watch a movie or short walks [53]. Adaptive and intelligent interventions can find opportune moments to suggest a personalized relaxation exercise depending on the user's stress level and context [37] to avoid overburdening the user with notifications and suggested actions. An AI therapist offers the advantage of being always available and gathering frequent information about a person's behavior, context and preferences to optimize communication [38, 77].

4.4.4 Identifying Interpersonal Stress Factors. Space analog experiments on Earth show interpersonal issues can cause problems in long-duration space travel. Understanding how well teams will work together, while avoiding interpersonal stress, depends on various number of complex factors [68, 69]. For example, the crews' general heterogeneity in terms of expertise, career motivation, gender, culture, race, and personality can impact overall cohesion. Additionally, environmental and task factors, such as lack of privacy and high complexity of missions, contribute towards potential anger frustration. Cosmonaut Sevastyanov commented that [68] "We had disagreements in flight…The disagreement did not reach a scandal, in as much as there was no 'platform', it was simply fatigue, and frequently simple inattention which would cause the argument." In some cases team conflicts have affected mission goals in space [21]. In 1999, [8] the Baldwin et al. conducted a large, national, multi-specialty serious conflict survey consists of 6,106 residents in the US.

Interpersonal issues are also a problem on Earth. In a 2018 cross-sectional study among 200 health care professionals, over 20 percent of residents reported conflict with other staff [113]. Doctors, nurses, and administrative officers all reported interpersonal conflict. A longitudinal study of 260 undergraduates in 53 teams evaluated relationships and conflict [128] . The study found teams with more conflict reported poorer performance, satisfaction, and outlook on viability. In our design fiction, Crew B members felt their tasks were often useless compared to Crew A. Iman and Bjørg were annoyed with Diwa when they were asked to check some structural damage in the construction site. COVID-19 may have removed some of the conflict from work, but potentially introduces more interpersonal conflict at home.

5 DISCUSSION

We sought to answer: *How can we use the context of information work on Mars to better understand the needs of an increasingly distributed future of information work on Earth?* Our design fiction and statement discussed how Mars amplifies problems with information workspaces and how research can better prepare us to address them. For adaptive contexts of work and life, researchers should develop new systems that manage attention, breaks, work and life activities, and that support task resumption. As communication becomes more distributed, so does the need for new AI mediated synchronization and media that supports synchronous and asynchronous socialization. Advancements in AI bring new potential solutions for collaboration and well-being. However, creating technological solutions often risks generating new problems.

Our research draws inspiration from the COVID-19 pandemic and its global influence on information organizations. In March 2020, the majority of information workers across the planet brought work into their homes — blurring former borders between work and non-work [127]. In contrast, our Mars narrative conveys a story in which information workers bring their home life and non-work to Mars. In both cases, the former boundaries between work and non-work diminish, and we see how information workers experience an amplified need to take on additional roles. Understanding pathways for mitigating the effect of the new environment on individuals' productivity and well-being remains an open frontier for exploratory research, specifically in the era of artificial intelligence. We now reflect on these connections more broadly to better plan for the new future of work on Earth in relation to these issues.

5.1 Work and Life: Definitions, Characterizations, and Boundaries

Watson defines "work" as "*the carrying out of tasks which enable people to make a living within the social and economic context in which they are located*" [134]. By definition, what people perform that helps them carry out tasks, whether in their homes during shelter-in-place or to inhabit Mars, is a kind of work. Our characterization of work-life on Mars introduces a philosophical question for future research: *How can we aptly define "work" in the new future of work?* Throughout the on-going COVID-19 pandemic [127], the context of remote work has demanded that we more robustly define what it means to be "at work" and "at home".

The challenge that comes with defining "work" in these contexts highlights our ability to determine our psychological attachment to our workplace, whether it be at home or elsewhere. In our design fiction, escaping work is difficult to impossible. Scholars, such as Kanter, highlight the "myth of separate worlds" [72]. The "myth" is that modern industrial society can be separated into two worlds: "work life" and "family life". In this idealized image, neither world relates or acts on the other. From a sociological perspective, the recognizing this perspective is a myth acknowledges complexity of work-life. Transgression of these boundaries take the form of "work-to-family" and "family-to-work" conflict [99].

Individuals have invented strategies for managing work-life boundaries, avoiding these transgressions, by placing distance and friction between work and non-work. For example, Kreiner et al. interviewed parish priests to elicit several strategies [81]. Clerics would place physical distance between home and work, set specific days of the week where they were not to be bothered, and block out time for deep work and personal time. However, these strategies were developed without consideration of shelter-in-place practices. In many homes, COVID-19 has brought more duties to families in terms of childcare and care-taking [141]. Women take on the brunt of the additional care-taking, even in dual-income families [141]. Recent work suggests strategies to maintain work-life balance during the COVID-19 pandemic [109], such as dedicating a separate workspace and relaxation space. However, small apartments and early Mars living quarters may lack sufficient room for separate spaces. Our story shows Diwa using VR to create a boundary from her productive work task.

Our statement describe the opportunity that AI-mediated systems can play in helping us experience *structured interruptions* for mitigating technology induced stress. Previous HCI research has explored a similar concept through the lens of tools that assist people in detaching from work and later reattaching to work [137]. In boundary theory, there are several actors that negotiate for time and resources: workers, management at various levels, family, friends, and non-work social obligations. Adding an AI that manages tasks and dockets in real time may help or hurt the general wellness of individuals. The amount of power that we give AI systems to make our choices for us greatly impacts society [103], which renegotiates how boundaries are shaped between work and non-work activities.

5.2 Information Workplace Structures and Socialization

Studies have shown that modifying office floor plans impact how people collaborate [16]. Documentation on data structures, the quality of information, and institutional knowledge remain complex enterprise data science [71]. Generally, people are expected to learn about different aspects of work. As Suchman reflected, representing work practices is important and social habits change how work is accomplished [123]. Without analogous shared spaces, it is unlikely these ties will become widespread. “Watercooler” talk, the informal office socialization that takes place between work, is an important for team morale that COVID-19 has made difficult [110, 127].

The void of socialization caused by COVID-19 has inspired work groups to use various technology. For synchronous discussion, systems for Virtual Reality with avatars and audio chat provide an immersive, albeit chaotic, feeling of immersion and presence [110]. Another technology for strengthening asynchronous social ties is Marco Polo, which Beal et al. for work an watercooler socialization in an academic work group [13]. However, these systems (VR Chat and Marco Polo) were not specifically built to support information workplaces or general awareness. Telepresence research [47] predates consumer video chat tools. The Portholes paper states “*Awareness may lead to informal interactions, spontaneous connections, and the development of shared cultures”*. The modern ubiquity and ease of real-time video chat technology, such as Zoom, provides visibility into what people are doing at their workstations and on their screens. However, it does not support the kind of awareness envisioned by Portholes. COVID-19 has shown excessive video chat increases fatigue [127]. To support socialization in the future information workplace, researchers should borrow ideas from platforms that support informal awareness, such as VR Chat and Marco Polo, can be utilized for work.

5.3 The Promise and Ethics of Data Collection and Surveillance

One of the promises of AI systems, such as EVE, is that they will be enable better decision making and increase both productivity and well-being. Sharing personal tracking data with third parties, whether employers in a shelter-in-place context or Mars habitation, could benefit employees who need to take breaks. In modern times, AI systems help experts recognize cancer more effectively [79], increase the effectiveness of our entertainment [56], guide our purchasing decisions, and are essential in organizing a range of labor and activities [85]. HCI research has argued that giving managers more data, such as general affect, can give companies insight into how to set policy and intervene [41]. Partly in response to a lack of personal contact from COVID-19, companies such as Hubstaff, Veriato, and Teramind have created dashboards for displaying and analyzing remote data [19]. With the right interpretations and context, personal sensors that can measure stress and other responsesmay create valuable insight [131].

However, the Faustian bargain for a better outcome also manifests ethical concerns: misdiagnoses, privacy violations, oppressive surveillance, and autonomy-removing Taylorism. Making these ethical interventions worse, powerful organizations in our fiction and modern society have more power compared to the individuals with the most risk of exposure. As technology upsets and reconfigures practice and experience, HCI researchers should be concerned about politics [46] and uneven power relations [64] across organizational and domestic hierarchies. The Apollo Corp skirted laws otherwise applicable in various nations and IRB oversight. COVID-19 has given little control to individuals in terms of consenting to new policies and more surveillance at home, where schooling, employment, and non-work is expected to take place simultaneously. Citizens, students, and employees have less autonomy than policy makers, teachers, and employers. However, the later can dictate policies while the former faces the brunt of negative outcomes.

Even with tremendous data, AI often misdiagnoses or lacks sufficient context for decision making. For example, increasing data and models size does not guarantee better outcomes and introduces unnecessary risk [15]. In education, dashboards meant to maintain academic integrity can fail to provide the necessary context to administrative staff to draw appropriate conclusions from system-made observations [19]. Likewise, Voida et al. [131] explain that the primary weakness of using sensors for high-level inferences about observed phenomena in HCI research is their poor ability to answer questions of *why*. If used inappropriately, sensors can misdiagnose the *what*, especially for higher level extrapolations. For example, an increase in HRV may indicate stress from work or an exciting video game. Higher level interpretations (e.g. triggers, intentions, goals) from log and sensor data need additional investigations.

Amid the COVID-19 pandemic, people who work or learn from home have been introduced to camera-monitoring systems and keystroke loggers that run during work hours or during exam periods [116]. Companies such as Hubstaff, Veriato, and Teramind, use electronic surveillance to create dashboards for managers [19]. Systems that track people and collect data have the potential to violate privacy. Raij et al. conducted a user study to explore privacy concerns associated with the disclosure of wearable sensor data in the everyday life [105]. In their study, participants found the idea of exposing their stress levels to be highly concerning. On-demand gig economy companies, such as Uber and Lyft, have more data than ever, but have been criticized for poorly supporting workers and avoiding their classification as employees [42]. Amazon's workers have arduous experiences in warehouses that track and optimize their movements [43]. In highly-tracked work, such in Amazon fulfillment centers, is that the job tracks an employee's every move.

Another ethical challenge in data collection is agency. People should have agency over their data, making informed decisions on what to track and share [33, 34, 36, 131]. Tracking every movement reduces autonomy because the optimization of movement limits acceptable behavior and personal decision making [43]. The monotony and constant pressure makes the work-life of factory fulfilment workers arduous. While increasing a worker's ability to control the complexity and design of their work improves job satisfaction [130], removing their autonomy likely does the opposite. Removing choices and dictating each action of a worker is a form of Taylorism, which seeks to optimize production by regularizing jobs [90].

New research should address these ethical issues. Voida et al. suggest several steps to help users make informed privacy decision for systems collecting sensor data streams [131]. To ensure user agency, Voida et al. suggest informing participants details about collection and its storage, and also to allow users to revoke participation and delete their data. Raij et al. found that restricting or abstracting collected data had a significant effect on reducing privacy concerns about data exposure [105]. Perceived privacy risks always deter users from disclosing their data, while sharing data due to perceived benefits depend on data sensitivity [132]. We suggest that if employees are expected to share personal data, the benefit should outweigh the risks and be consented to.

6 CONCLUSION

We have presented a design fiction with a propaganda poster and fiction narrative about a Martian information workforce. Following the tradition of design fiction and scenarios in HCI, we discussed the issues that both COVID-19 and a Martian habitation amplify. Our narrative highlights challenges in alien information workplaces. Both COVID-19 and Mars create a stress context with a more distributed workplace, cramped living areas, and the need to take on multiple roles. New strategies that integrate AI and work and non-work boundaries can better maintain productivity and well-being for the present and in the future.

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