SpaceCHI 2.0: Advancing Human-Computer Interaction Systems for Space Exploration

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ABSTRACT

We are now entering the new space age! In 2021, for the first time in history that there is civilian crew in space, demonstrating the next frontier of human space exploration that will not be restricted to highly trained astronauts but will be open to a more general public. However, keeping a human healthy, happy and productive in space is one of the most challenging aspects of current space programs [11]. Thus, there is an emerging opportunity for researchers in HCI to design and research new types of interactive systems and computer interfaces that can support humans living and working in space and elsewhere in the solar system.

Last year, SpaceCHI workshop (https://spacechi.media.mit.edu/) at CHI 2021 welcomed over 130 participants from 20 countries around the world to present new ideas and discuss future possibilities for human-computer interaction for space exploration. The SpaceCHI 1.0, for the first time, brought together crossdisciplinary researchers from HCI, aerospace engineering, robotics, biological science, design, art, architecture to envision the future of human space exploration leading the workshop participants and organizers to form a new global community focused on HCI research for space applications. With success from the previous SpaceCHI, we are exploring the exciting opportunity for researchers in HCI to contribute to the great endeavor of space exploration by participating in our workshop.

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CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Interactive systems and tools**; **HCI design and evaluation methods**.

KEYWORDS

Space Exploration, Interplanetary Research, Aerospace, Astronaut

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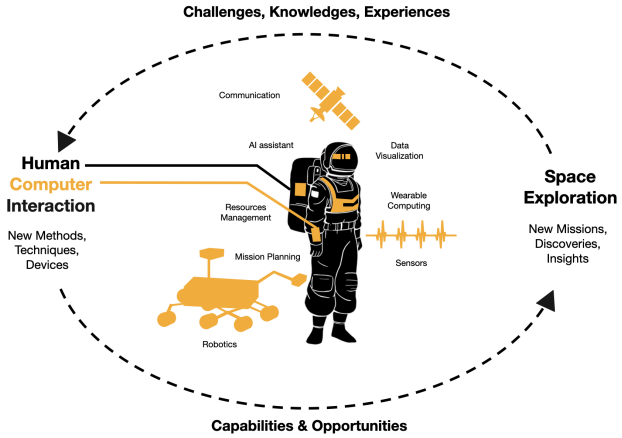

Figure 1: Areas of Human-Computer Interaction for Space Exploration

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1 BACKGROUND

We are now entering the new space age! In 2021, for the first time in history, both Space X and Blue Origin flew civilian crew in space[1, 7], demonstrating the next frontier of human space exploration that will not be restricted to highly trained astronauts but will be open to a more general public [12]. Even though the cost for commercial spaceflight today is still relatively high to become mainstream, in the grand history of human spaceflight, space transportation is slowly becoming more common as well as economical, enabling space exploration become more democratized and accessible to a new population of civilian crew members. Thus, there is an emerging opportunity for researchers in HCI to design and research new types of interactive systems and computer interfaces that can support humans living and working in space and elsewhere in the solar system [6, 10, 13].

Looking into the past, we can see how HCI and space exploration have influenced one another. For instance, influential ideas in HCI such as human-machine symbiosis or that of the "cyborg" by Clynes & Kline [2] that led to the creation of "Ubiquitous Computing and Wearable Computing" was developed in the context of space exploration as a framework for a computer to offload human tasks and support astronauts in space. Today spacesuit design applies this knowledge to improve human performance and health in Extra-Vehicular Activity [3].

Another example is virtual reality (VR) technologies, originally pioneered by HCI researchers at NASA for astronaut training program [4, 8], that are now commercialized for entertainment, education, and social gathering. Today new space missions at NASA are benefiting from the commercialized version of the VR technology that they pioneered [9].

Finally, we can also examine the groundbreaking work of Margaret Hamilton and her team in 1969 on algorithms and interfaces for Apollo 11. The system was designed with robustness and human-centered quality. Thus it allowed the astronauts to trust and collaborate with the computer, recognize error messages and ignore low-priority tasks for the computer to do, leading to a successful mission to the Moon and back [5].

These examples demonstrate the interplay between HCI and space exploration, which lead to new space missions, new scientific discoveries, and also new technologies benefiting people on Earth and in space. Therefore, advancing human-computer interaction in space would also impact people on Earth and vice versa.

Last year, the SpaceCHI workshop [11] (https://spacechi.media.mit.edu/) at CHI 2021 welcomed over 130 participants from 20 countries around the world to present new ideas and discuss future possibilities for human-computer interaction for space exploration. These projects addressed the challenges of keeping a human healthy, happy and productive in space. During SpaceCHI 1.0, the workshop explored four main research areas: Human-Machine Collaboration, Space Health, Humanizing Space, and Mission Operations.

SpaceCHI 1.0 participants investigated: the need to augment human capabilities in space and build trust in human-robots collaboration; the use of AI to support remote construction autonomy; the possibility of generating new self-help tools for social and mental health through exploiting virtual spaces; the demand of privacy and ownership about one's own body/data sharing for a common framework across astronauts and cultures; the challenge of designing multi-sensory experiences in a sensory deprived extreme environment, and collaborative concepts of operations for planning human and robotic deep space missions. For each of the topics, participants identified the possibilities, unsolved gaps, and challenges for future research.

SpaceCHI 1.0, for the first time, brought together cross-disciplinary researchers from HCI, aerospace engineering, robotics, biological science, design, art, and architecture to envision the future of human space exploration and inspiring the workshop participants and organizers to form a new global community focused on HCI research for space applications. Continuing the success and momentum from SpaceCHI 1.0, we are exploring the exciting opportunity for researchers in HCI to contribute to the great endeavor of space exploration. To inform and inspire participants in thinking about the opportunities for SpaceCHI 2.0, the goals of our workshop are as follows:

(1) Identifying new stakeholders for the new space age (space tourists, civilian space crew, analog astronauts, designers, artists, researchers etc).
(2) Exploring new possibilities, gaps, and challenges for HCI researchers in designing technology for space exploration through consideration of the current and future possibilities.
(3) Developing inspiring and meaningful scenarios, lessons, use cases, and applications for Space HCI research.
(4) Brainstorming strategies for deploying HCI research in space and envisioning its potential terrestrial application.

2 ORGANIZERS

2.1 Pat Pataranutaporn

Pat Pataranutaporn is an anti-disciplinary technologist/scientist/artist at the Massachusetts Institute of Technology (MIT). He is part of the Fluid Interfaces research group at MIT Media Lab, which specializes in designing on-body technology for human enhancement. Pat's research is at the intersection of human-computer interaction, biotechnology and wearable computing, specifically at the interface between biological and digital systems. Pat has worked with NASA The Translational Research Institute for Space Health (TRISH) and MIT Space Exploration Initiative to design wearable devices for realtime monitoring and supporting astronaut health. His interdisciplinary research ranges from: investigating human-AI interactions; developing wearable labs on the body with programmable bio-digital organs for space exploration; developing machine learning models to detect linguistic markers related to mental health issues; developing and designing mind-controlled 3D printers.

Pat's research has been published in IEEE, ACM SIGCHI, ACM SIGGRAPH, ACM ISWC, ACM Augmented Humans, Royal Society of Chemistry, etc. He also serves as a reviewer and editor for IEEE and ACM publications. Pat's artistic projects have been exhibited at the National Museum of Singapore (Singapore), Essex Peabody Museum (USA), London Design Festival (UK), Transmediale Festival (Germany), National Taiwan Science Education Center (Taiwan), IDEA Museum (Arizona), Mesa Arts Center (Arizona), Autodesk Gallery (California), and more.

2.2 Valentina Sumini

Valentina Sumini, PhD, is Space Architect and Research Affiliate at the MIT Media Lab in the Responsive Environments research group and the Space Exploration Initiative. Valentina is also Visiting Professor at Politecnico di Milano, where she teaches the course "Architecture for Human Space Exploration" at the School of Architecture, Urban Planning, and Construction Engineering. She develops design solutions and architectures to sustain human life in extreme environments on Earth, and to enable human space exploration in Low Earth Orbit, on the Moon and Mars. Her passion in advancing human performance during deep space exploration missions dates back to 2009 when she designed a hotel on the lunar surface for democratizing the access of space for tourists. Over the years she developed more in-depth studies at MIT and MIT Media Lab, which she applied to different scenarios and award winning competition projects, mainly organized by international space agencies, such as: a Space Hotel orbiting in Low Earth Orbit around Earth (NASA RASC-AL Competition 2017); a city on Mars and its generative design model (Mars City Design Competition 2017); a greenhouse on Mars (NASA Big Idea Challenge 2019); an ice extraction system for Mars (NASA RASC-AL Competition 2018); a Moon Village (European Space Agency); a soft robotic exoskeleton for enhancing astronaut movements and performance in microgravity and a pavilion; the Tidmarsh Living Observatory Portal (NASA TRISH), used to reconnect astronauts with nature during long duration missions.

Valentina's work has been featured among others in MIT News, Harvard Design Magazine, the Wall Street Journal, Forbes, WIRED, Structure Magazine, IAC, IASS, CHI and AIAA proceedings, and TEDx Talks. She is Vice Chair of the ASCE Earth and Space Technical Committee (American Society of Civil Engineers), a member of the Space Generation Advisory Council, and a reviewer for the American Society of Civil Engineers of Practice Periodical on Structural Design and Construction.

2.3 Melodie Yashar

Melodie is a design architect, technologist, and researcher. She is the co-founder of Space Exploration Architecture (SEArch+), a Senior Research Associate with San Jose State University Research Foundation at NASA Ames, and an Associate Researcher within the UC Davis Center for Human/Robotics/Vehicle Integration and Performance (HRVIP). Her research at NASA is with the Human Computer Interaction Lab within the Human Systems Integration Division at NASA Ames. As an associate within Space Exploration Architecture, SEArch+ won top prize in both of NASA's design solicitations for a Mars habitat (in 2015 and 2019, respectively) within the 3D-Printed Habitat Challenge. The success of the team's work in NASA's Centennial Challenge led to consultancy roles and collaborations with UTAS/Collins Aerospace, NASA Langley, and most recently with ICON, NASA Marshall, and NASA's Moon-to-Mars Planetary Autonomous Construction Technologies (MMPACT) initiative. Melodie is a professor at Art Center College of Design, where she teaches the topic studio "Life on the Moon." Having come from an interdisciplinary background, she appreciates those who see research and design as a confluence of different fields—allowing problem solving to become a more thoroughly collaborative exercise.

2.4 Susanna Testa

Susanna Testa, PhD in Design, is Assistant Professor at the Design Department of Politecnico di Milano. Her research focuses on interaction and technological innovation within the field of fashion, as well as bench-marking state-of-the art initiatives, technologies, and products related to the fashion ecosystem. Being at the forefront of pushing European academic initiatives, Susanna is involved in administrating academic collaborations for the development of Fashion-Tech with European multilateral projects like Edu4FashionTech and FTalliance. Among academic activities, Susanna lectures at the Bachelors level courses in: Jewellery and Accessory Design, working primarily with emerging manufacturing technologies; Fashion Illustration; Portfolio & Digital Branding (Politecnico di Milano). She is also didactic coordinator of the Masters in Accessory Design and of the Masters in Fashion-Tech (POLI.design). Susanna is part of the faculty for the Masters in Fashion Direction: Brand & Product Management at Milano Fashion Institute (consortium of Bocconi, Politecnico di Milano and Cattolica universities). Along with academic activities, she is active as freelancer illustrator and consultant designer with a focus on fashion and accessories. Among her publications: "FashionTech. Body Equipment, Digital Technologies and Interaction" (Universitas Studiorum, 2019), "Jewellery Between Product and Experience: Luxury in the Twenty-First Century" in "Sustainable Luxury and Craftsmanship" (Springer, 2020) and "Fashion Tech Today" and "Future Scenarios" in "Education for Fashion Tech. Design and Technologies for Future Fashion Creatives" (Nielsen Book, 2020).

2.5 Marianna Obrist

Marianna Obrist is Professor of Multisensory Interfaces at UCL, Department of Computer Science, and Deputy Director (Digital Health) for the UCL Institute of Healthcare Engineering. Before joining UCL, she was head of the Sussex Computer Human Interaction (SCHI/'sky') Lab at the School of Engineering and Informatics at the University of Sussex. Her research ambition is to establish touch, taste, and smell as modalities for human-computer interaction (HCI). As part of her research, she is studying multisensory experiences and perception, prototypes new gustatory and olfactory interfaces, and most noteable has developed a novel digital scent-delivery technology that was exhibited at the World Economic Forum (WEF) 2019 and 2020 in Davos. Supported by an ERC proof-of-concept, this technology is now commercialised through OWidgets Ltd, a university spin-out she co-founded in 2019. Marianna was selected as Young Scientist 2017 and 2018 to attend the WEF in China, and became an inaugural member of the ACM Future of Computing Academy (ACM-FCA) in 2017. She is also a Visiting Professor at the Material Futures Research Group at the Royal College of Art (RCA) and spent the summer of 2019 as a Visiting Professor at the HCI Engineering Group at MIT CSAIL, where she finished her recently published book "Multisensory Experiences: Where the senses meet technology".

2.6 Scott Davidoff

Scott Davidoff is a Research Scientist, Technical Group and Program Manager at the Jet Propulsion Laboratory, California Institute of Technology. He leads the teams that design and develop the command systems that fly JPL's spacecraft of today, and that envision the systems of tomorrow. His work explores how people understand complex data, from explainable Artificial Intelligence and Machine Learning, to the robotic exploration of Earth, Mars, and the outer solar system.

Today he leads the design of the tools that help Perseverance Rover look for evidence of past life on Mars. He also co-founded Virtualitics, the world's first immersive explainable artificial intelligence product. He has invented lightweight prototyping methods that are now practiced at the world's leading companies and taught at it's leading universities. Dr. Davidoff has served on program committees for the US National Science Foundation (NSF), the US Office of Naval Research (ONR), and ACM's Computer Human-Interaction (CHI) and Designing Interactive Systems (DIS) Conferences, and the Virginia Tech Institute for Creativity, the Arts, and Technology Board of Advisors. His work has won multiple Best Paper and NASA awards.

Dr. Davidoff has a PhD and MS in Human-Computer Interaction from Carnegie Mellon University.

2.7 Amber M. Paul

Amber M. Paul, Ph.D., is the Embry-Riddle Wessel Fellow. Dr. Paul received her BSc in Immunology from the University of Alberta, Canada and Ph.D. in Molecular Biology from the University of Southern Mississippi. She completed postdoctoral training at NASA Ames Research Center as a Universities Space Research Association fellow and is a visiting Blue Marble Space Institute of Science visiting scholar. Dr. Paul's research focuses on immunity and neuroendocrine crosstalk in extreme environmental conditions. She is interested in how physiological stress in both acute and chronic settings impacts immunity and nervous system function. Her goal is to identify signaling pathways involved and develop countermeasures that can circumvent these impacts. Dr. Paul's research is currently supported by NASA's Human Research Program. She is currently co-leading the The Omics Lab for Health and Human Performance.

2.8 Dorit Donoviel

As director for the Translational Research Institute for Space Health (TRISH), Dorit Donoviel, Ph.D., leads a $246M NASA-funded innovation R&D program which sources, funds, and fosters disruptive human health and performance solutions for astronauts traveling in deep space. In her previous role as Deputy Chief Scientist of the National Space Biomedical Research Institute (NSBRI), Dr. Donoviel led both domestic and international research programs that bridged academic, industry, and government resources to deliver fast and cost-effective tangible results. She is the recipient of multiple honors including recognition from NASA and the NSBRI Pioneer Award. A published research scientist and a frequently invited speaker, Dr. Donoviel is Associate Professor in the Department of Pharmacology and Chemical Biology and the Center for Space Medicine at Baylor College of Medicine (BCM). She lectures to and mentors graduate and medical students and advocates for science education for all ages. Before joining BCM, she led a metabolism drug discovery program at Lexicon Pharmaceuticals for 8 years. She serves as a mentor and judge for healthcare-related startup companies at pitch competitions with organizations and conferences such as SXSW-Interactive, American Heart Association, Ignite Health, and AARP. Dr. Donoviel is a die-hard Star Trek fan.

2.9 Jimmy Wu

Jimmy Wu serves Baylor College of Medicine Center for Space Medicine (CSM) as associate director of the Exploration Medicine Laboratory with the focus of using engineering solutions to provide medical care in space. With CSM, Jimmy develops, evaluates, and integrates technologies that will reduce human system risk during exploration space flight missions. Jimmy also a member of the Translational Research Institute for Space Health (TRISH) serving as their Senior Biomedical Engineer. Jimmy's role is to facilitate delivery of project deliverables to TRISH and NASA.

Previously, Jimmy worked at NASA Johnson Space Center for fourteen years providing engineering, integration, operations, research and development, information technology, and project management support to projects addressing human health and performance during space flight missions.

2.10 Sands Fish

Sands Fish is an artist and researcher at the MIT Media Lab's Civic Media group. His work falls between activism, computer science, ethnography, and design. Sands is interested in the unconsidered yet consequential assumptions embedded in objects — design for babies, for exorcisms, and for the police. His current work uses speculative design to help communities imagine and advocate for

more desirable futures. Previously, he was a data visualization fellow at Harvard's Berkman Center for Internet & Society and at MIT's HyperStudio. He also co-organizes Tech Poetics, a new media art community in Boston.

2.11 Ariel Ekblaw

Ariel Ekblaw is the founder and Director of the MIT Space Exploration Initiative, a team of over 50 graduate students, staff, and faculty actively prototyping artifacts for our Sci-Fi space future. Founded in 2016, the Initiative now includes a portfolio of 40+ research projects focused on life in space (from astro-biology to space habitats), and supports an accelerator-like R&D program that enables a broad range of payload development. For the Initiative, Ariel drives space-related research across science, engineering, art, and design. The Initiative charters an annually recurring cadence of parabolic flights, sub-orbital, and orbital launch opportunities. Ariel forges collaborations on this work with other MIT departments and space industry partners, all while mentoring Initiative research projects and providing technical advice for all mission deployments.

Ariel brings a humanist approach to her research at MIT with undergraduate degrees in Physics, Mathematics, and Philosophy from Yale University, as well as a Master's in Distributed Systems from the MIT Media Lab. Ariel's prior work experience includes: supersymmetry research and big data programming at the CERN Particle Physics Laboratory; user-centered design and product development at Microsoft Azure; microgravity research with NASA; and Mars2020 rover hardware systems engineering at NASA's Jet Propulsion Laboratory. Ariel's work has been featured in WIRED (March 2020 cover story), MIT Technology Review, Harvard Business Review, the Wall Street Journal, the BBC, CNN, NPR, IEEE and AIAA proceedings, and more. Humanity stands on the cusp of interplanetary civilization and space is our next, grand frontier. This opportunity to design our interplanetary lives beckons to us, and Ariel strives to bring our space exploration future to life.

2.12 Joseph Paradiso

Joseph Paradiso is the Alexander W. Dreyfoos (1954) Professor in Media Arts and Sciences, where he serves as the Associate Academic Head and directs the Media Lab's Responsive Environments group, which explores how sensor networks augment and mediate human experience, interaction, and perception. Paradiso worked as a Tufts undergrad on precision inertial guidance systems at Draper Lab, then completed his PhD in physics at MIT in 1981, while working with Prof. S.C.C. Ting's group at CERN in Geneva. After two years developing precision drift chambers at the Lab for High Energy Physics at ETH in Zurich, he joined the NASA-affiliated group at Draper Laboratory, where his research encompassed spacecraft control systems, image processing algorithms, underwater sonar, and precision alignment sensors for large high-energy physics detectors. He joined the Media Lab in 1994, where his current research interests include wireless sensing systems, wearable and body sensor networks, energy harvesting and power management for embedded sensors, ubiquitous/pervasive computing and the Internet of Things, human-computer interfaces, space-based systems, and interactive music/media. He has written over 350 publications and frequently lectures in these areas. In his spare time, he enjoys designing/building electronic music synthesizers, composing electronic soundscapes, and seeking out edgy and unusual music while traveling the world.

2.13 Albrecht Schmidt

Albrecht Schmidt is a computer scientist best known for his work in ubiquitous computing, pervasive computing, and the tangible user interface. He is a professor at Ludwig Maximilian University of Munich where he joined the faculty in 2017. Albrecht Schmidt received an M.Sc. in computing from Manchester Metropolitan University (UK) in 1996. Schmidt directed the 'Human-Computer Interaction' research group at the Institut für Visualisierung und Interaktive Systeme at University of Stuttgart. Since October 2017, he has been the head professor of the research group 'Human Centered Ubiquitous Media Group' at the Department of Computer Science at the Ludwig Maximilian University of Munich.

2.14 Pattie Maes

Pattie Maes is a Professor with MIT's Media Arts and Sciences Program, which until recently, she served for as the Academic Head. Additionally, Pattie runs the Media Lab's Fluid Interfaces research group, which aims to radically reinvent the human-machine experience. Coming from a background in artificial intelligence and human-computer interaction, she is particularly interested in the topic of cognitive enhancement; How immersive and wearable systems can actively assist people with memory, attention, learning, decision making, communication, and well-being. Pattie is the editor of three books, as well as serving as an editorial board member and reviewer for numerous professional journals and conferences. She has received several awards: Fast Company named her one of 50 most influential designers (2011); Newsweek picked her as one of the "100 Americans to watch for" in the year 2000; TIME Digital selected her as a member of the "Cyber Elite," the top 50 technological pioneers of the high-tech world; the World Economic Forum honored her with the title "Global Leader for Tomorrow"; Ars Electronica awarded her the 1995 World Wide Web category prize; and in 2000 she was recognized with the "Lifetime Achievement Award" by the Massachusetts Interactive Media Council. She has also received an honorary doctorate from the Vrije Universiteit Brussel in Belgium, and her 2009 TED talk on "The 6th Sense Device" is among the most-watched TED talks ever.

3 PRE-WORKSHOP PLANS

Our website is hosted at: http://spacechi.media.mit.edu/

We will distribute the workshop call through email, social media, and our website. Examples include: ACM SIGCHI mailing lists, NASA mailing lists, MIT mailing lists and social media outlets, and Facebook pages and Twitter. We will also reach out to researchers in the area of aerospace engineering who may not have a background in HCI but are creating computing interfacing technologies to support human life in space. Though this workshop focuses on designing technology for space exploration, we will encourage authors who may not have a background in, or experience working on, space exploration to present their most futuristic ideas (e.g. papers that show a vision about an interaction currently not implemented).

Table 1: Proposed Workshop Schedule

Time	Schedule Item
15 min	Introduction
45 min	Keynote Presentation
15 min	Short Break
45 min	Research Presentation
90 min	Brainstorming
45 min	Lunch Break
45 min	Research Presentation
90 min	Brainstorming
15 min	Short Break
90 min	Next Step and Ethical Discussion
15 min	Closing

The submission portal will be accessed through our website. We are planning the paper review timeline as follows: call out on December 15th, 2021; submission deadline on February 15th, 2022; notification of acceptance by February 22th, 2021; and final submissions due on March 1st, 2022. We will host accepted papers on the workshop website for participants and others to review.

4 WORKSHOP STRUCTURE

Our one-day workshop will consist of a keynote lecture, research presentations, lively discussion, and group brainstorming. We anticipate 60-120 participants. The workshop will be held online via Zoom or in-person (depending on the COVID situation). Our website would contain recording of the entire workshop session to support asynchronous viewing of participants that are unable to access in-person or synchronous virtual space. Accepted papers up to 4 pages long- will be hosted on our website prior to the workshop for participants and conference attendees to access.

During the workshop, accepted authors will present their papers. Following research presentations, small focus groups will be assigned to breakout sessions where they will design short user scenarios related to an HCI technology intervention or countermeasure. The topics could address the potential of an emerging technology solution in a spaceflight context, a particular form factor, or could be used as an opportunity to highlight a human-centered problem requiring further research. Groups will design a "day in the life" narrative showing a scenario of use for the technology, intervention, or countermeasure. Groups will be encouraged to storyboard interactions visually, or to act out the scenarios in a "skit" format. Successes, failures, and future potential of the narrative scenarios will be deliberated in the discussion.

Participants will also engage in an activity to work collaboratively and create a visual research map of CHI for space exploration in an online collaborative platform (Miro). During the group digital brainstorming, participants will use post-it notes to identify opportunities and produce road maps for how these trends may change the future. We will conclude with a reflective discussion on the future of space CHI and identifying directions for further collaboration.

The day's structure is in table 1.

5 POST-WORKSHOP PLANS

We plan to post photos and videos of the workshop on our website and social media during and after the workshop. We will encourage participants who have met through the workshop to submit articles together and to discuss other participants' articles on the web interface. Our intention is that workshop participants will become co-authors to foster community and collaboration.

6 CALL FOR PARTICIPATION

We are now entering the new space age! In 2021, for the first time in history that there is civilian crew in space, demonstrating the next frontier of human space exploration that will not be restricted to highly trained astronauts but will be open to more general public. Thus, there is an exciting opportunity for researchers in HCI to contribute to the great endeavor of space exploration by designing new types of interactive systems and computer interfaces that can support humans living and working in space and elsewhere in the solar system.

Last year, SpaceCHI workshop [11] (https://spacechi.media.mit.edu/) at CHI 2021 welcomed over 130 participants from 20 countries around the world to present new ideas and discuss future possibilities for human-computer interaction for space exploration. These projects addressed the challenges of keeping a human healthy, happy and productive in space. During the SpaceCHI 1.0, the workshop explored four main research areas: Human-Machine. Collaboration, Space Health, Humanizing Space, and Mission Operation. For each of the topics, participants identified the possibilities, unsolved gaps, and challenges for future research. The SpaceCHI 1.0, for the first time, merged together crossdisciplinary researchers from HCI, aerospace engineering, robotics, biological science, design, art, architecture to envision the future of human space exploration leading the workshop participants and organizers to form a new global community focused on HCI research for space applications.

With success from the previous SpaceCHI, We invite researchers from both academia and industry to submit a short position paper on the theme discussed above. We will evaluate submissions on fit, ability to stimulate discussion, and contribution to the future of HCI. Our website includes examples of past work in this area to help inspire and inform position papers. Papers should be maximum of 4 pages, and should be submitted in the CHI Extended Abstracts format. The submission deadline is February 15th, 2022.

At least one author of each accepted position paper must attend the workshop and all participants must register for at least one day of the conference. We will host accepted papers on the workshop website for participants and others to review. Submission can be accessed through our website: http://spacechi.media.mit.edu/.

Suggested topics / areas:

- On-body/Wearable Technology for Space Health
- Human-Robot Interaction for Deep Space Mission
- Interfaces for Human Expression in Space
- Trust within Autonomous and Intelligent Systems
- Cognitive load and Human Performance Issues
- Computer-supported Cooperative Work
- Augmented Reality/Mixed Reality

- Smart Vehicle and Habitat
- Digital Fabrication for Space Mission

REFERENCES

[1] Denise Chow. 2021. SpaceX makes history with first all-civilian spaceflight. https://www.nbcnews.com/science/space/spacex-makes-history-first-civilian-spaceflight-rcna2027

[2] Manfred E Clynes and Nathan S Kline. 1995. Cyborgs and space. *The cyborg handbook* (1995), 29–34.

[3] Nicholas De Monchaux. 2011. *Spacesuit: Fashioning Apollo*. MIT press.

[4] Michael A Gigante. 1993. Virtual reality: definitions, history and applications. In *Virtual reality systems*. Elsevier, 3–14.

[5] Margaret H Hamilton. 2018. What the Errors Tell Us. *IEEE Software* 35, 5 (2018), 32–37.

[6] Kaj Helin, Timo Kuula, Carlo Vizzi, Jaakko Karjalainen, and Alla Vovk. 2018. User experience of augmented reality system for astronaut's manual work support. *Frontiers in Robotics and AI* 5 (2018), 106.

[7] Eric M. Johnson. 2021. Bezos' Blue Origin to make history with unpiloted civilian space flight. https://www.reuters.com/business/aerospace-defense/bezos-blue-origin-make-history-with-unpiloted-civilian-space-flight-2021-07-14/

[8] Michael W McGreevy. 1993. Virtual reality and planetary exploration. In *Virtual Reality*. Elsevier, 163–197.

[9] Jeff Norris and Scott Davidoff. 2014. Nasa telexploration project demo. In *2014 IEEE Virtual Reality (VR)*. IEEE, 183–184.

[10] Marianna Obrist, Yunwen Tu, Lining Yao, and Carlos Velasco. 2019. Space food experiences: designing passenger's eating experiences for future space travel scenarios. *Frontiers in Computer Science* 1 (2019), 3.

[11] Pat Pataranutaporn, Valentina Sumini, Ariel Ekblaw, Melodie Yashar, Sandra Häuplik-Meusburger, Susanna Testa, Marianna Obrist, Dorit Donoviel, Joseph Paradiso, and Pattie Maes. 2021. SpaceCHI: Designing Human-Computer Interaction Systems for Space Exploration. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–6.

[12] Erik Seedhouse. 2013. *SpaceX: making commercial spaceflight a reality*. Springer Science & Business Media.

[13] Valentina Sumini, Manuel Muccillo, Jamie Milliken, Ariel Ekblaw, and Joseph Paradiso. 2020. SpaceHuman: A Soft Robotic Prosthetic for Space Exploration. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–8.