Informatics and Decision Support Technology Roadmap

IEEE SMC-IT/SCC 2025

NASA JSC/Geraldo Cisneros

Informatics & Decision Support Roadmap Purpose & Scope

Purpose

- Identify shortfalls/gaps, shortfall/gap closure strategies, and candidate investments to mature Informatics and Decision Support technologies in support of M2M Program risk mitigation activities, enable and enhance crew insight to system performance, decision making, and computer-human interaction.
- In this first publication, scope of the Informatics and Decision Support Roadmap is limited to Deep Space Crew Displays and Audio Systems. Future publications will expand scope to other capabilities.

Scope

- **Deep Space Crew Displays**
  - Develop high availability radiation-tolerant display systems capable of withstanding the harsh radiation environment of deep space and meeting the needs of various systems with differing use cases and requirements.
  - Implement a radiation-tolerant graphics processing architectures that feature radiation tolerant by design components and single event fault interrupt mitigation software and middleware
  - Evaluate and characterize the display and optics trade space to better understand and catalog their capabilities and benefits as they pertain to human spaceflight
  - NASA-STD-3001 Vol 2, Human Factors, Habitability, and Environmental Health, specifies visual display parameters for spacecraft displays: NASA-STD-3001 Vol 2
  - Avionics Radiation Hardness Assurance (RHA) Guidelines, specifies current state of NASA's RHA best practices: Avionics Radiation Hardness Assurance (RHA) Guidelines
- **Deep Space Audio Systems**
  - Develop robust audio processing hardware capable of withstanding high-radiation environments and ensuring consistent and reliable audio performance in space.
  - Implement advanced voice control systems and Speech-To-Text (STT) technology for seamless communication between crew members and ground control, enhancing operational efficiency and preserving communication records.
  - Design and deploy intuitive audio interface devices tailored for space environments, providing clear and effective communication tools for crew members during missions.

Priorities for Informatics & Decision Support

- **Develop, enable, and integrate advanced avionics & informatics technologies for deep space exploration**
  BENEFIT: Enhances the safety, efficiency, and success rate of deep space missions, ensuring precise information exchange and robust system operations in the challenging environment of deep space.

- **Identify and integrate radiation mitigation technologies and strategies for informatics systems**
  BENEFIT: Protects critical informatics systems from harmful space radiation, thereby ensuring the longevity and reliability of mission-critical data and communication systems, ultimately safeguarding mission integrity and crew health and safety.

- **Identify and enable informatics technologies that promote crew autonomy and self reliance**
  BENEFIT: Promotes reduced dependence on ground control, empowering astronauts to make informed decisions, manage unforeseen issues independently, and maintain mission continuity in real-time, which is vital for long-duration deep space missions.

- **Develop and integrate reliable spacesuit audio systems for crew safety and mission success**
  BENEFIT: Ensures reliable contact between the crew and mission control, facilitating timely updates, emergency responses, and seamless coordination, which are critical for maintaining crew safety and achieving mission objectives in deep space.

- **Determine more cost-effective verification methods for speech-intelligibility**
  BENEFIT: Ensures clear and accurate communication among crew members and between crew and mission control, enhancing operational efficiency, reducing misunderstandings, and preventing costly errors, thereby contributing to the overall success and safety of space missions.

Informatics & Decision Support Key Observations

Deep Space Crew Displays

- **No readily available radiation-tolerant solutions exist that meet Artemis performance and reliability requirements for safety critical crew**
  - High-Performance Space Computer (HPSC) is a promising radiation-tolerant solution, but is itself a technology development activity with flight-ready delivery in 18+ months
  - HPSC may not be a one-size-fits-all solution, each Program/Project will need to assess specific application and potentially determine alternatives to HPSC
- **Targeting Display panel gap closure in 2-3 years**
  - NASA screen/pixel radiation characterization and body of knowledge report completed in FY24.
  - Anticipate industry collaboration to prototype full display with multi-layer software mitigation
- **Feasibility for the development of an EVA Heads-Up Display (HUD) has increased**
  - An RFI conducted by the Joint AR project collected several feasible proposed solutions capable of developing a suit integrated heads-up display within a reasonable timeframe. This SBIR Phase 1 will further increase TRL for suit integrated heads-up displays
  - Implementation of optics solution with a helmet bubble form factor and radiation performance and characterization of projector systems are forward work

Deep Space Audio Systems

- **Pursue Industry engagement /collaboration for implementing a radiation-tolerant audio system compatible with spacecraft network interfaces**
- **For EVA audio, alternatives to current EVA communication design (”snoopy cap”) continue to have issues with echo**
  - Echo cancellation technology development needs attention and funding
- **Lack of Speech recognition testing standards makes future requirements development difficult**
  - Modern systems depend on Earth-based cloud computing, not feasible for spaceflight

Informatics and Decision Support Roadmap – STMD Shortfalls and ESDMD Gaps

STMD Shortfall ID	Shortfall Title
Avionics 1541	Intuitive and Efficient Human Robot Interaction for Safe Teaming and Remote Supervisory Control
Avionics 1550	Crew Audio/Visual Interfaces for Long Duration Missions Beyond LEO
Avionics 1551	Distributed Avionics to Enable Improved Performance and SWaP Efficiency
Avionics 1552	Extreme Environment Avionics
Avionics 1553	Foundational Technologies for Future Avionics Devices and Systems
Avionics 1554	High Performance Onboard Computing to Enable Increasingly Complex Operations
Avionics 1555	Next Generation Avionics Architectures

ESDMD Architecture-driven Gap ID	Gap Title
0201	Extreme Environment Computing
0202	High Performance Onboard Computing
1004	Trustworthy Autonomy for Planning and Decision-making

https://techport.nasa.gov/framework
Envisioned Futures Charts - Advanced Informatics - Human Interfaces
https://www.nasa.gov/moontomarsarchitecture/
Moon2Mars Architecture Definition Document
https://www.nasa.gov/spacetechpriorities/
Civil Space Shortfalls

Mid to High Level TRL NASA Informatics & Decision Support Investments

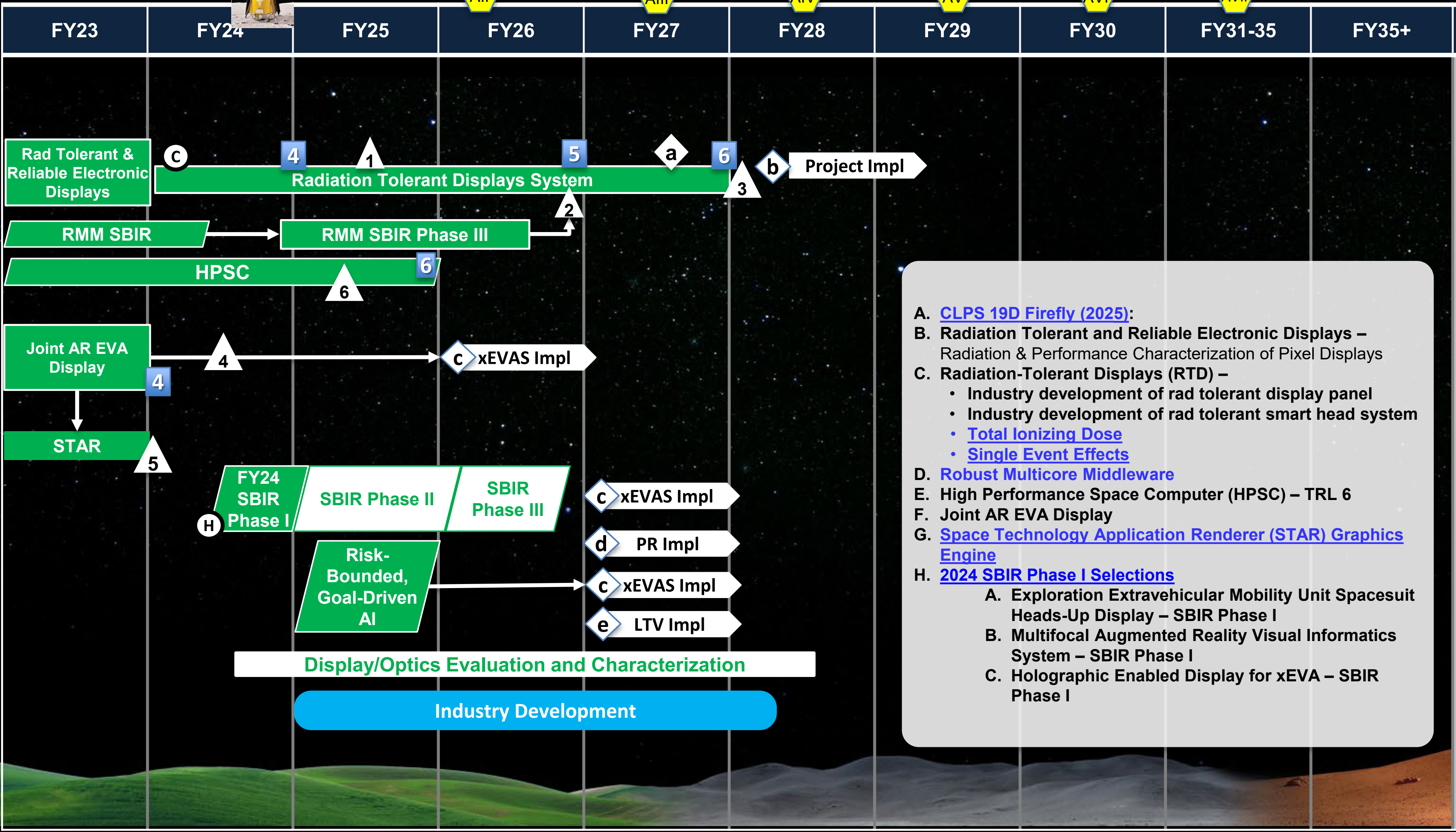
1. DEEP SPACE CREW DISPLAYS	TRL	FY	POTENTIAL INFUSION TARGET
– **High Performance Space Computing (HPSC)**	6	2022-25	GW, LTV, PR, HLS, Habitats
– **Joint AR EVA Display - STAR**	4	2020-23	xEVAS, LTV, HLS, Habitats
o *2024 – JETT5 Testing*		*Completed*	
– Radiation Tolerant & Reliable Electronic Displays	4	2021-23	GW, xEVAS, LTV, PR, HLS, Habitats
o *2022: Total Ionizing Dose Radiation Testing*		*Completed*	
o *2023: Single Event Effects Radiation Testing*		*Completed*	
– **Radiation Tolerant Displays**	6	2024-25	GW, xEVAS, LTV, PR, HLS, Habitats
o *2024: Display Prototype Development*			

2. DEEP SPACE AUDIO SYSTEMS	TRL	FY	POTENTIAL INFUSION TARGET
– Acoustic Echo Cancellation	7	2022-25	xEVAS, PR
– Audio Systems	7	2024	GW, xEVAS
– Bone Conduction Evaluation	6	2022-23	xEVAS, PR
– ASO, IRIS	4	2020-22	xEVAS
– Pratt Bone Conduction Headsets	4	2024-25	xEVAS, PR

DEEP SPACE CREW DISPLAYS

(Shortfalls: 1541, 1550, 1551, 1552, 1553, 1554, 1555)
(ESDMD Tech. Gaps: 0201, 0202)

POC: JSC EV/Geraldo Cisneros
Revised: Fall 2024



A. CLPS 19D Firefly (2025):
B. Radiation Tolerant and Reliable Electronic Displays – Radiation & Performance Characterization of Pixel Displays
C. Radiation-Tolerant Displays (RTD) –
   - Industry development of rad tolerant display panel
   - Industry development of rad tolerant smart head system
   - Total Ionizing Dose
   - Single Event Effects
D. Robust Multicore Middleware
E. High Performance Space Computer (HPSC) – TRL 6
F. Joint AR EVA Display
G. Space Technology Application Renderer (STAR) Graphics Engine
H. 2024 SBIR Phase I Selections
   A. Exploration Extravehicular Mobility Unit Spacesuit Heads-Up Display – SBIR Phase I
   B. Multifocal Augmented Reality Visual Informatics System – SBIR Phase I
   C. Holographic Enabled Display for xEVA – SBIR Phase I

Additional Information

Deliverables & Milestones

1. RTD architecture configs defined for various system use cases
2. System prototype dev complete with flight like components and vendor supplied display
3. Radiation Tolerant System Reference Design
4. Joint AR participation in JETT5 Analog Test
5. STAR Software Releases
   1. STAR Engine Released (Dec '23 – US Only Release)
6. HPSC Dev Kits Available (Q2 '25)

Decision Points a

a. Assess infusion potential to pursue maturation to TRL 6
b. Infuse into Programs/Projects (c-f below)
c. Infuse into xEVAS
d. Infuse into PR
e. Infuse into LTVS
f. Infuse into GW

Candidates Under Evaluation

- *Rad-Mat - Radiation hardened polymer material for displays*

Objectives (FOM/KPPs):

KPPs: Display Performance (see page 18)
FOM: Radiation Tolerance (see page 19)

Ground | Lunar surface | Notes | Funded | ESDMD | STMD | Industry
ISS / LEO | Decision point | Unfunded
Lunar orbit | Deliverable/Milestone | Artemis missions | Touchpoint | # TRL

See acronyms list. All mission information is notional and for planning purposes only

NASA Funded Deep Space Crew Displays Investments

Task Bar Name	Description & Status	Start	Finish
High Performance Space Computing (HPSC)	The objective of HPSC is to develop a next-generation flight computing system that addresses computational performance, energy management and fault tolerance needs of NASA missions through 2040 and beyond.	2022	2025
Joint AR EVA Display	The Joint AR project worked to develop a space suit augmented reality display and control system reference design to promote crew autonomy and help meet the demands of future EVA missions in deep space. This project also produced a custom, NASA built, graphics engine known as STAR.	2019	2023
Spacesuit Technology Application Renderer (STAR)	STAR is a low-power, high-performance, zero-dependency graphics engine developed by NASA for next-generation human exploration missions. STAR is light weight and feature's fault mitigation capabilities. STAR has been open sourced to US citizens.	2021	2023
Rad Tolerant & Reliable Electronic Displays (2REDPANDAS)	The Radiation Tolerant and Reliable Electronic Displays project was an early career initiative which took foundational steps towards the development of displays in deep space. This project characterized the performance and metrology of several pixel panel display technologies before and after their exposure to radiation. Complete, radiation characterization and test results collected and available for knowledge transfer	2021	2023
Radiation Tolerant Display System (RTD)	Radiation Tolerant Displays aims to partner with industry to develop a reference design for a display and computer system that can withstand and mitigate the effects of radiation in deep space. The project seeks to develop a system that is scalable to meet the needs of various lunar assets and their respective use case. Fully funded, working toward architecture down selection, display system prototyping, and vendor selection processes.	2024	2025

NASA Funded Deep Space Crew Displays Investments (Cont'd)

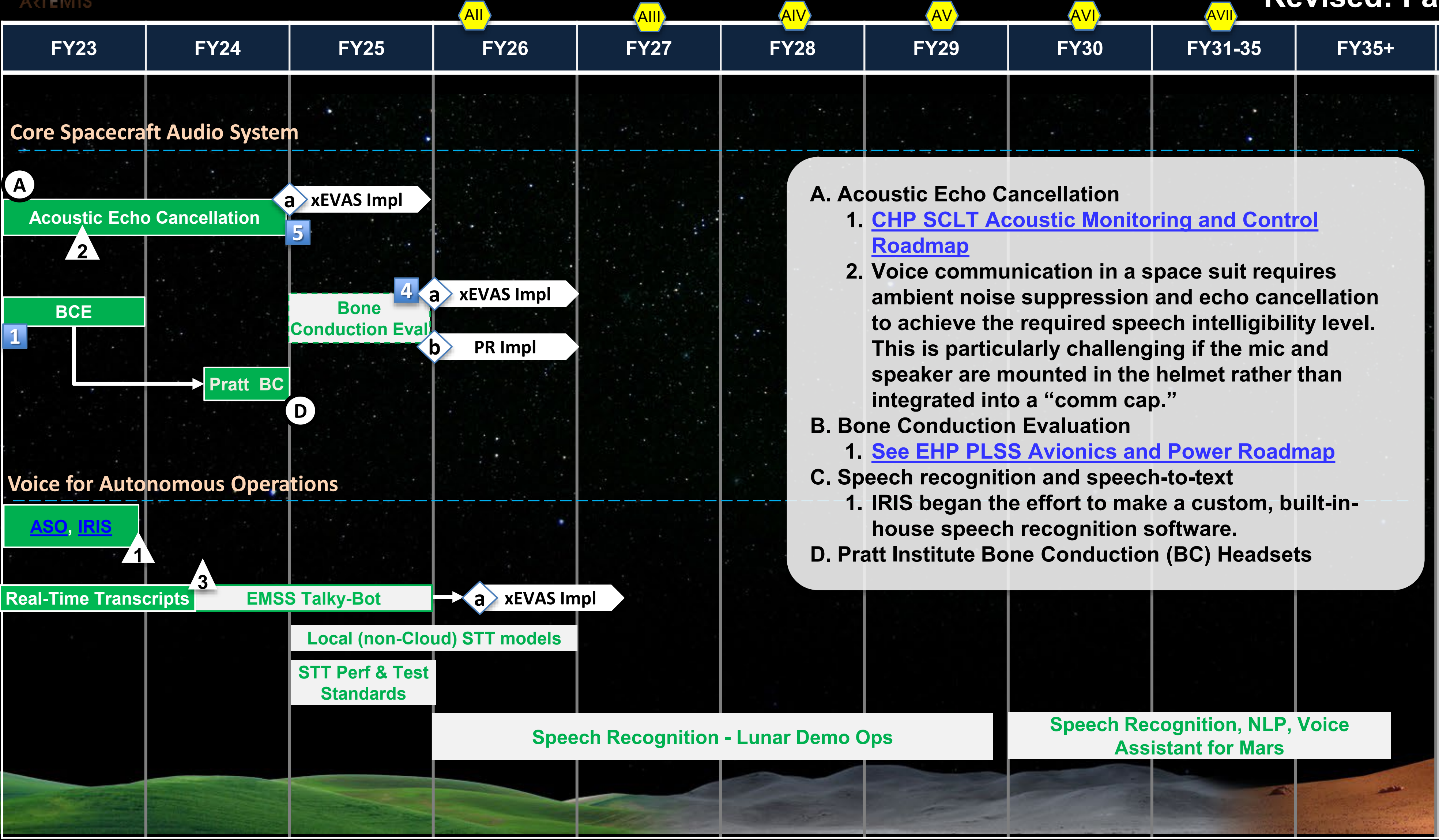
Task Bar Name	Description & Status	Start	Finish
Risk Mitigation Middleware (RMM)	The significance of this Risk Mitigation Middleware (RMM) innovation is that it is the only feasible technology that provides a path to enabling these types of missions by allowing high-performance COTS processors to operate with a high degree of fault tolerance without the need for rad-hard electronics, and thus simultaneously meets advanced mission criticality and performance requirements	2021	2023
Exploration Extravehicular Mobility Unit Spacesuit Heads-Up Display	To address NASA's need for an augmented reality (AR) display system for EVAs, This SBIR awardee proposes to develop a new Exploration Extravehicular Mobility Unit (xEMU) Spacesuit Heads-up Display (xHUD) based on innovative integration of laser projectors and wave guide pupil expander combiner (WPEC) optics. 2024 SBIR Phase I Awardee.	2024	2025
Multifocal Augmented Reality Visual Informatics System	This proposed technology, the Multifocal Augmented Reality Visual Informatics System (MARVIS), is a spacesuit-integrated, head-decoupled, solid-state, augmented reality (AR) system designed to provide astronauts with an immersive, informative visual interface that significantly enhances decision-making capabilities and situational awareness (SA) during EVAs. 2024 SBIR Phase I Awardee	2024	2025
Holographic Enabled Display for xEVA	This proposed technology aims to develop a Heads-In Display coupled to information systems and potentially Augmented Reality processors and sensors. The proposed solution can bridge the technology gap that exists with state-of-the-art AR displays that can't simultaneously provide the metrics of eye relief, field of view, brightness and resolution needed in a spacesuit helmet display. 2024 SBIR Phase I Awardee	2024	2025
Risk-Bounded, Goal-Driven AI for Human Planetary Exploration	When planning an EVA, flight operations identifies goals and decides traverse paths and timelines given the constraints and risks of a mission. This proposal will mature risk-bounded, goal-driven AI methods for generating mixed traverse and activity planning for crewed Lunar and Martian exploration.	2025	2025

Proposed Deep Space Crew Displays Investments

Task Bar Name	Description & Status	Start	Finish
Display/Optics evaluation and characterization	Create and expand body of knowledge and subject matter expertise pertaining to display mediums, form factors, and metrology and determine the best techniques for verifying and validating displays for human spaceflight.	2025	2028

Deep Space Audio Systems *(Shortfalls 1541 and 1550)*

POC: JSC EV/Geraldo Cisneros
Revised: Fall 2024



A. Acoustic Echo Cancellation
   1. [CHP SCLT Acoustic Monitoring and Control Roadmap]
   2. Voice communication in a space suit requires ambient noise suppression and echo cancellation to achieve the required speech intelligibility level. This is particularly challenging if the mic and speaker are mounted in the helmet rather than integrated into a "comm cap."

B. Bone Conduction Evaluation
   1. See EHP PLSS Avionics and Power Roadmap

C. Speech recognition and speech-to-text
   1. IRIS began the effort to make a custom, built-in-house speech recognition software.

D. Pratt Institute Bone Conduction (BC) Headsets

Additional Information

Deliverables & Milestones #

1. Callisto Payload flown on Artemis I, demonstrated voice control
2. Completed thermal vacuum testing
3. JETT 5 Analog Test
   1. Usefulness of real-time transcripts spawned EMSS product called Talky-Bot that is now used for ISS operations and will be part of the suite of tools provided by the EMSS team for Artemis

Decision Points a

a. Infuse into xEVAS
b. Infuse into PR

Candidates Under Evaluation:

Ground | Lunar surface | Notes | Funded | ESDMD | STMD | Industry
ISS / LEO | Decision point | Unfunded
Lunar orbit | Deliverable/Milestone | Artemis missions | Touchpoint | # TRL

Objectives (FOM/KPPs):

KPP: Speech Intelligibility (see page 20)
KPP: Speech Recognition Accuracy (see page 20)
FOM: Radiation Tolerance (see page 21)

See acronyms list. All mission information is notional and for planning purposes only

NASA Funded Deep Space Audio Systems Investments

Task Bar Name	Description & Status	Start	Finish
Acoustic Echo Cancellation	Development and evaluation of technology that identifies and eliminates echo in audio communication systems. This is crucial for ensuring clear and uninterrupted crew voice transmission in where signals may be reflected and captured again leading to disruptive feedback.	2022	2025
Bone Conduction Evaluation (BCE)	Investigation of bone conduction audio transducers to eliminate acoustic coupling of inbound/outbound audio in space suits. Includes custom design of bone conduction headsets optimized for long term wear comfort, fit and adjustability as well as optimization of transducer selection, placement and amplifier design.	2022	2023
Autonomous Systems and Operations(ASO), Intelligent Response and Interaction System (IRIS)	IRIS began the effort to create a custom speech recognition software by building upon existing speech recognition software. IRIS prototypes had the capability to understand wake words and translate speech to text when in an environment with very little noise pollution.	2020	2023
Pratt Institute Bone Conduction Headset	Pratt institute is investigating the potential of bone conduction earphones equipped with moisture-proof transducers. This innovative approach aims to resolve the audio coupling issues encountered in space suit communications.	2024	2024
EMSS Talky-Bot	The real-time transcripts, used during JETT 5 Analog testing, were so useful that they spawned a new EMSS product called Talky-Bot that is now used for ISS operations and will be part of the suite of tools provided by the EMSS team for Artemis.	2024	2025

Proposed Deep Space Audio Systems Investments

Task Bar Name	Description & Status	Start	Finish
STT Performance & Test Standards	Establishing benchmarks to assess the accuracy, speed, adaptability, and user experience of speech-to-text engines, with a specific focus on comparing cloud-based and local STT engines for their integration and compatibility across various platforms.	2025	2026
Local (non-cloud) STT models	Focuses on creating STT-models that operate locally, emphasizing the development of an efficient, accurate, and adaptable system capable of processing STT without cloud connectivity.	2025	2028
Bone Conduction Eval (Cont'd)	Investigation of bone conduction audio transducers to eliminate acoustic coupling of inbound/outbound audio in space suits. Includes custom design of bone conduction headsets optimized for long term wear comfort, fit, and adjustability; as well as optimization of transducer selection, placement, and amplifier design.	2025	2026
Speech Recognition for Lunar Demo Ops	Evaluation of control of non-critical systems using voice control. Also includes use of speech-to-text for communication via long latency communication channels.	2026	2029
Speech Recognition, NLP, Voice Assistant for Mars	Expanded application of system control via voice and continued assessment of speech-to-text application for communication over long haul comm links.	2030	2036+

Deep Space Crew Displays - KPPs Display Performance

- **NASA-STD-3001, Volume 2, RevisionD, Human Factors, Habitability, and Environmental Health, specifies visual display parameters for spacecraft displays (right).**
- **Display performance requirements vary by how the display is used. Table 10.4-2 represents performance goals for display technologies that may be considered for infusion.**
- **NASA display standards do not encompass unique display form factors such as augmented reality, virtual reality, and projector-based displays. NASA STD-3001, and M2M GUI Standards (50040) are two relevant documents for displays. There are international display standards that are widely accepted by all projector, TV, and display companies which may be more applicable for unique form factors.**

Metric	Minimum	Maximum	Context	Notes
Peak white luminance	>100 cd/m^2	--	Emissive displays	400 cd/m^2 or higher preferred
Ambient contrast ratio	100:1	--		1000:1 or higher preferred
Color gamut area	0.17	--	Color displays	Fraction of CIE 1976 u'v' chromaticity space
Viewing angle	-/+45 deg	as defined by task analysis		Four-point viewing angle (left, right, up, down), contrast and color gamut criteria met
Spatial resolution	32 pixels/deg	--	Image and video displays	64 pixels/deg or higher preferred
Frame rate	60 Hz	--	Video displays	60Hz is an absolute minimum to avoid flicker, but 90Hz should be the minimum for any display used for active control
Moving edge blur	--	15 ms		Using metric GET (preferable) or BET; use average of five equal lightness levels, including white and black
Number of colors	2^{24} (1,627,716)	--	Image and video displays	
	2^{12} (4,096)	--	Text and graphics displays	
Number of gray levels	2^8 (256)	--	B/W image and video displays	
Except where noted, metrics are as defined as in International Committee on Display Metrology (ICDM), Display Measurement Standard (DMS 1.0), or Video Electronics Standards Association (VESA) Flat Panel Display Measurements (FPDM 2.0). Further details on metrics may be found in chapter 10, Crew Interfaces, of the HIDH.				

Table 10.4-2 Visual Display Parameters
From NASA-STD-3001 Vol 2 Rev D

Deep Space Crew Displays - FOM Radiation Tolerance

- **Radiation tolerance is the driving FOM for this gap, with an overall goal to maximize display reliability**
  - Displays are composed of the pixel or projector technologies, driver circuitry, rendering pipeline, and computing/networking controllers
  - Reliability requirements vary by use case, function, and the overall spacecraft displays and controls architecture. Radiation tolerance requirements vary by mission environment and duration.
  - This gap targets displays used by crew to perform safety-critical tasks with short time-to-effect hazards in the Lunar vicinity or Lunar surface
- **RT Design Goal 1: Destructive Single Event Effects (SEEs) Immunity**
  - Up to Linear Energy Transfer (LET) of 60 MeV-cm2/mg
  - SEE characterization of performance, failure modes
- **RT Design Goal 2: Non-destructive SEE Immunity**
  - Minimize probability of down time
  - Minimize duration of down time
- **RT Design Goal 3: Total Ionizing Dose (TID) Tolerance**
  - 100Krads(Si), TNID and ELDRs considered
  - TID characterization of performance, failure modes

Notional Lunar Mission Description *Displays are operated only during crewed periods*	**Example Spacecraft**
30 days in Lunar orbit *Crewed for full mission*	Orion
15 years in Lunar orbit *Crewed for 30 days annually*	Gateway
10 years on Lunar surface *Crewed for 20 days annually*	Lunar Rover
10 years in Lunar orbit *Crewed for 20 days annually, transported to/from Lunar Surface*	Space Suit
3 months in Lunar orbit *Crewed for 20 days on Lunar surface*	Lunar Lander

Deep Space Audio Systems - KPP

Speech Intelligibility KPP

Speech intelligibility refers to the ability of a person to correctly identify speech in accordance with a standardized testing method

NASA-STD-3001 Vol 2 Human Factors, Habitability, and Environmental Health specifies speech intelligibility requirements for audio systems:

> 10.5.3.7 Speech Intelligibility: For critical communications, <u>the system shall ensure 90% English word recognition</u>, using ANSI/ASA S3.2-2009, Method for Measuring the Intelligibility of Speech over Communication Systems.

Speech Recognition KPP

Speech recognition accuracy refers to the performance of a hardware and software system in recognizing human spoken words. In Human Spaceflight this may be used for a variety of commanding or speech-to-text applications such as voice transcription when real-time voice is impractical.

Speech recognition solutions with a performance minimum of 90% accuracy may be considered for infusion in some spaceflight applications.

Significantly higher accuracy, >99%, would be required for speech recognition to be considered for critical commanding.

Notes

– There are no industry standard performance metrics or test methods for speech recognition systems. Word error rate may be used to assess speech to text performance but is not suitable for systems that directly execute commands from speech.

– Spacecraft speech recognition engines cannot rely on Earth-based servers due to communication delays. This necessitates a novel “offline” speech recognition architecture that deviates from modern commercial implementations.

– KPP: The above NASA-STD-3001 Speech Intelligibility requirement is an appropriate target, although specific use cases and operational design may ultimately determine a higher or lower accuracy requirement

Deep Space Audio Systems - FOM Radiation Tolerance

- **Radiation tolerance is the driving FOM for this gap, with an overall goal to maximize audio system reliability**
  - Voice communication and annunciation of caution and warning via spacecraft Audio systems are critical spacecraft functions
  - Radiation tolerance requirements vary by mission environment and duration

- **RT Design Goal 1: Destructive Single Event Effects (SEEs) Immunity**
  - Up to Linear Energy Transfer (LET) of 60 MeV-cm2/mg
  - SEE characterization of performance, failure modes

- **RT Design Goal 2: Non-destructive SEE Immunity**
  - Minimize probability of down time
  - Minimize duration of down time

- **RT Design Goal 3: Total Ionizing Dose (TID) Tolerance**
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10 years in Lunar orbit *Crewed for 20 days annually on Lunar Surface*	Space Suit
3 months in Lunar orbit *Crewed for 20 days on Lunar surface*	Lunar Lander

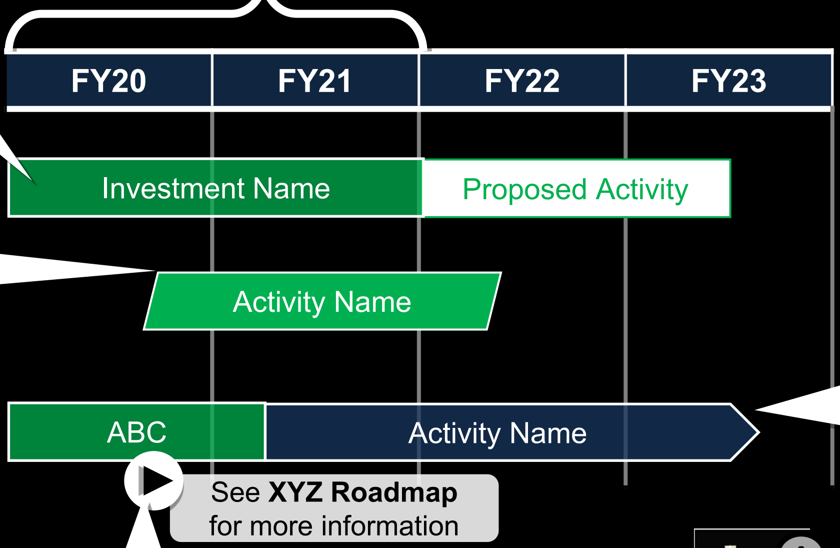
BACK-UP

Tips for Reading Roadmaps

1 Each box represents an activity or set of activities and the length of the box denotes the duration of the activity.

2 The color of each box represents the activity is planned/funded and the platform where the activity takes place (not the platform where the technology will be enabled). In this example the activity takes place on the ground although it may be the development of hardware for flight.

3 The shape of each box represents the source of funding. NASA ESDMD, NASA STMD, or Industry. See legend below for shapes.



9 White background indicate activities that are under evaluation but are not yet confirmed or fully funded.

8 Boxes that end in an arrow indicate activities without a defined end date or where the hardware will go into regular operation after a demo.

4 Color codes and icon keys are located in the bottom left corner of each slide.

5 Play button icons show "touchpoints" between roadmaps.

6 CLPS lander icon indicates manifested H/W related to activity.

7 Capability objectives, FOMs, or KPPs are located in the bottom right corner.

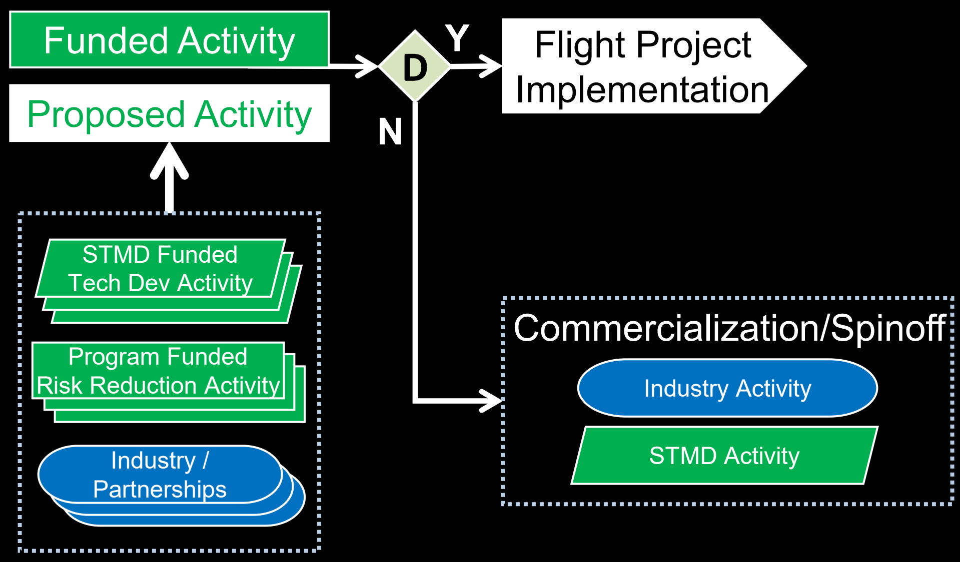
Ground
ISS / LEO
Lunar orbit
Lunar surface
Notes
Decision point
Deliverable/Milestone
Act Funded
Act Unfunded
Artemis missions
ESDMD
STMD
Industry
Risk
Touchpoint
TRL

Objectives (FOMs/KPPs):
Performance measures that define the required capability

Life Cycle of Technology Integration

(Iterative, but not necessarily a serial process)

Shortfall Title/#



1. **Review capability/technology challenges**
2. **Identify activities to mitigate risks and close shortfalls**
3. **Periodically assess project/activity status**
4. **Decide on Infusion** (D)
5. **Implement in Flight Program and/or Flight Project**
6. **Initiate Technology transfer to sponsor commercialization or spinoff**

Technology maturation and demonstration to enable Mars occurs in parallel and follows similar life cycle

Definitions & Acronyms

2D	2-dimensional	HSM	Human Surface Mobility
2REDPANDAS	Radiation tolerant and Reliable Electronic Displays: a Preliminary Assessment Necessary for Deep-spaceflight Applications	HUD	Heads Up Display
AR	Augmented Reality	Hz	Hertz
ASO	Autonomous Systems and Operations	ICDM	International Committee on Display Metrology
AV	Audio Visual	IRIS	Intelligent Response and Interaction System
BET	Blur Edge Time	IT	Information Technology
C&DH	Command & Data Handling	Joint AR	Joint Augmented Reality
CHP	Crew Health & Performance	JETT	Joint EVA and Human Surface Mobility Test Team (JETT)
CIE	International Commission on Illumination	KPP	Key Performance Parameters
COTS	Commercial Off the Shelf	LCD	Liquid Crystal Display
DMS	Display Measure Standard	LED	Light Emitting Diode
DSM	Deep Space Missions	LET	Linear Energy Transfer
EVA	Extravehicular Activity	NLP	Natural Language Processing
EHP	EVA & HSM Program	OLED	Organic Light Emitting Diode
ELDRs	Enhanced Low Dose Rate Sensitivity	PCD	Portable Computing Device
ESDMD	Exploration Systems Development Mission Directorate	PR	Pressurized Rover
FOM	Figure of Merit	RT	Radiation Tolerant
FPDM	Flat Panel Display Measurements	SCLT	System Capability Leadership Team
GCD	Game Changing Development	SEE	Single Event Effects
GET	Gaussian Edge Time	STMD	Space Technology Mission Directorate
GPC	Gateway Portable Computer	STT	Speech to Text
GSS	Gateway Support Server	TID	Total Ionizing Dose Tolerance
GW	Gateway Program	TNID	Total Non-Ionizing Dose
HIDH	Human Integration Design Handbook	TTS	Text to Speech
HLS	Human Lunar Systems Program	VESA	Video Electronics Standards Association
HPSC	High Performance Space Computer	xEVAS	Exploration EVA Services contract
HRP	Human Research Program		