NASA Extravehicular Activity Technology Roadmaps for Exploration 2025 Status

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Overview

- Introduction
- Historical Strategy
- Extravehicular Activity Roadmaps
  - Environment
  - Pressure Garment System Roadmap
  - Portable Life Support System Roadmap
- Conclusion
- Acknowledgements

Introduction

- Purpose
  - To share NASA's progress and plans of Extravehicular Activity (EVA) spacesuit development for exploration
  - To disseminate the EVA Technology Roadmaps for future exploration
- Updates to the maturation and development of the spacesuit technology roadmaps for the Moon to Mars (M2M) Program
- Roadmaps are in alignment with both NASA's Exploration Architecture and Civil Space Shortfalls

Historical Strategy

- Since 1965 (1st Spacewalk) - Spacesuit development has captured system changes, adapted to destination environments, improved safety, and conformed to operations with new vehicles
- Last 15 years - Exploration EMU Government Reference Design
  - xEMU Project was executed as a Government Furnished Equipment (GFE)
  - Designed, developed, and tested in-house
- 2021 New strategy for Commercial Extravehicular Activity Services
- 2022 NASA warded the Exploration EVA Services (xEVAS) to two vendors
  - Axiom Space
  - Collins Aerospace

EVA Roadmaps

- Goals
  - Enable EVA operations on Mars, using lunar surface opportunities for demonstration as appropriate
  - To facilitate risk mitigation for “sustained lunar” mission phase
  - To increase life robustness for long-duration lunar missions
- EVA Spacesuit
  - Integrated 1-person spacecraft
  - Consists of a Pressure Garment System (PGS), a Portable Life Support System (PLSS), and informatics system
- Environment (Mars)
  - Surface EVA exploration
  - Protect CM from various environments encountered
  - Martian gravity is higher than on the Moon – results in increased spacesuit weight
  - Predominance of carbon dioxide in the atmosphere will require changes in the PLSS

EVA Spacesuit Technology Roadmap Assumptions

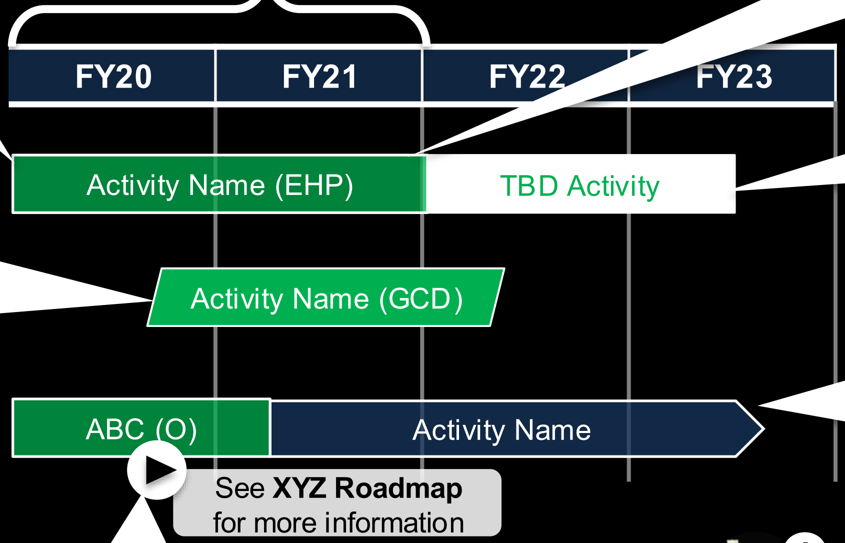
- Martian atmosphere 95% CO_2 at ~0.15 psia
- Martian gravity is 0.38g compared to Lunar gravity of 0.16g
- Long travel & mission duration
- Conditions of dust is a major hazard
- Martian radiation environment is a major hazard
- Unique seasonal environment
- Planetary protection may drive reduced suit leakage and/or compatibility with system-level bio-cleaning procedures.
- Suitport and commonality with vehicle systems is not considered

Tips for Reading Roadmaps

1 The color of each box represents the activity that 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

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

3 Throughout the roadmaps, funding source is indicated by the letters in parentheses after each activity name. Not all funded activities will necessarily be labeled. See key on previous page.



4 White background indicate activities that are under evaluation, but are not yet confirmed or fully funded

5 The shape of each box represents the source of funding. NASA ESDMD (typically this will be specific Program, such as EHP, GW, HLS, ISS), STMD (typically this will be a solicitation such as Game changing development, SBIR, etc) , or Industry. See legend below for shapes

6 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.

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

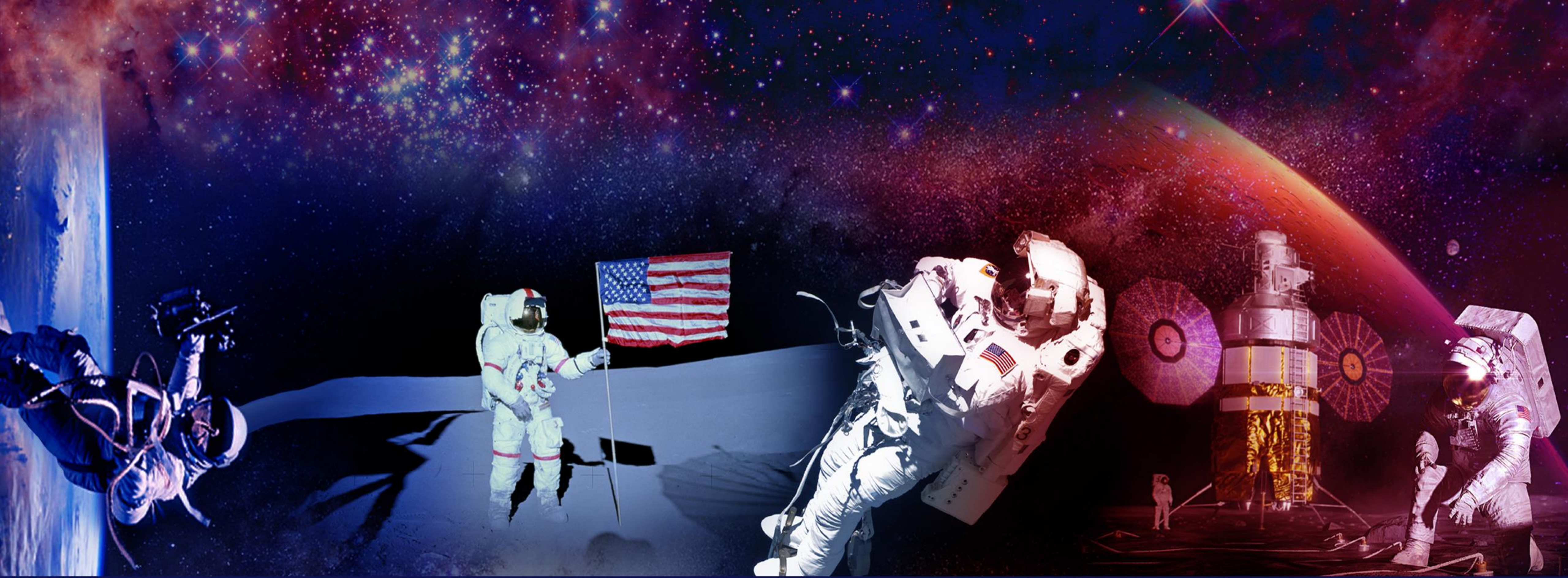
8 Play button icons show "touchpoints" between roadmaps

9 Commercial Lunar Payload Services lander icon indicates manifested hardware related to activity

10 Capability objectives, figures of merit, or key performance parameters are in the bottom right corner

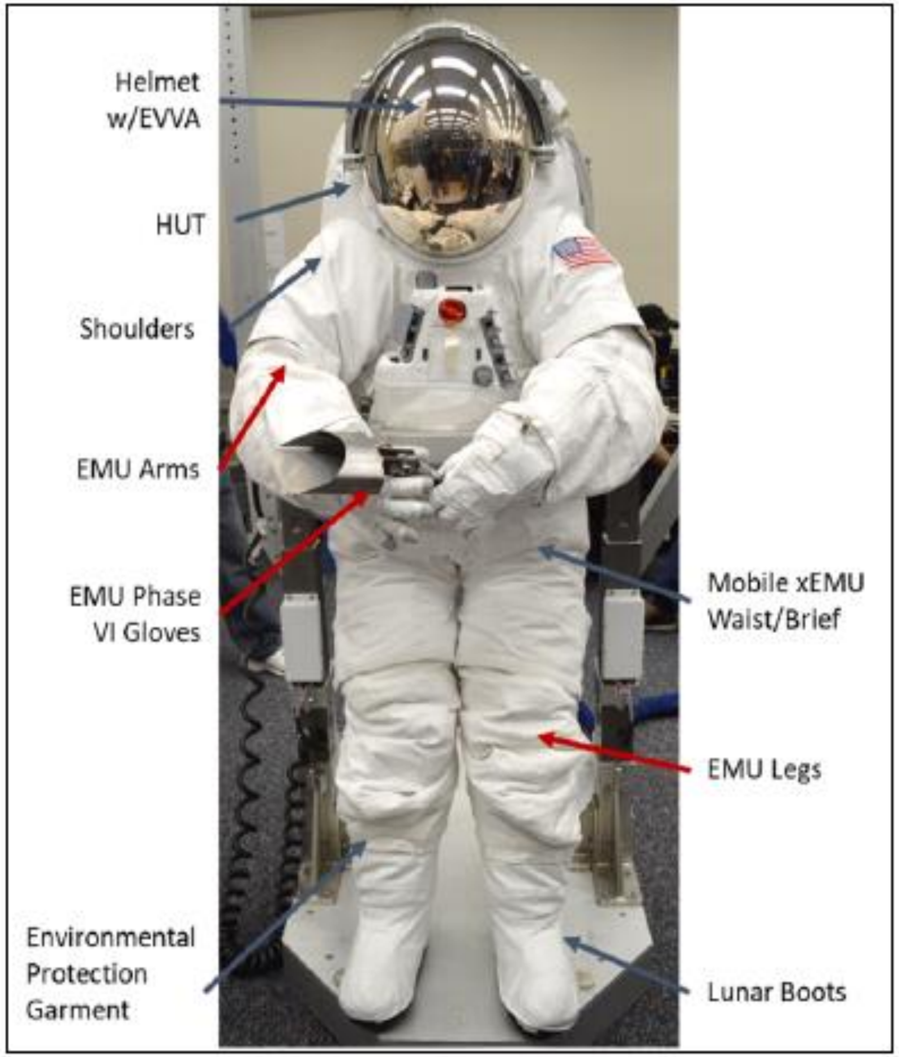
Ground
ISS / LEO
Lunar orbit
Lunar surface
Mars transit
Mars surface
Notes
Decision point
Deliverable/Milestone
Partially Funded
Funded
Unfunded
Artemis missions
ESDMD
STMD
Industry
Risk
Touchpoint
TRL

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



Pressure Garment System Roadmap

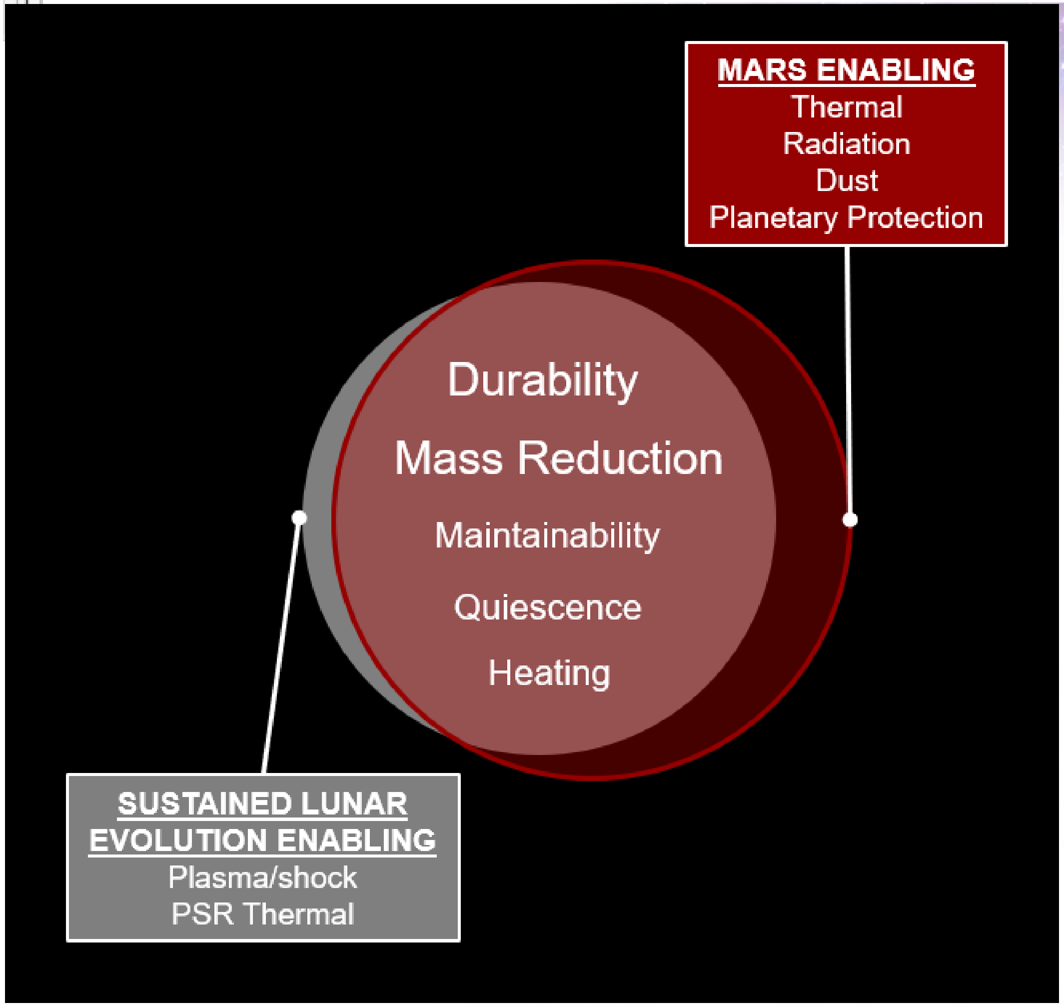
EVA PGS Roadmap



xPGS Assembly

- Pressure Garment
  - 2018 – xEMU demonstration pressure garment
    - New Hard Upper Torso (HUT)
    - New Shoulders
    - New Helmet
    - New Extra-Vehicular Visor Assembly (EVVA)
    - EMU design for lower torso, arms, gloves, and boots
  - 2019 – Changes to accommodate mission goals
    - Improved lower torso mobility
    - Lunar boots to meet thermal requirements
    - New Environmental Protection Garment (EPG) for dust protection
    - Enhanced Cycle Life Performance

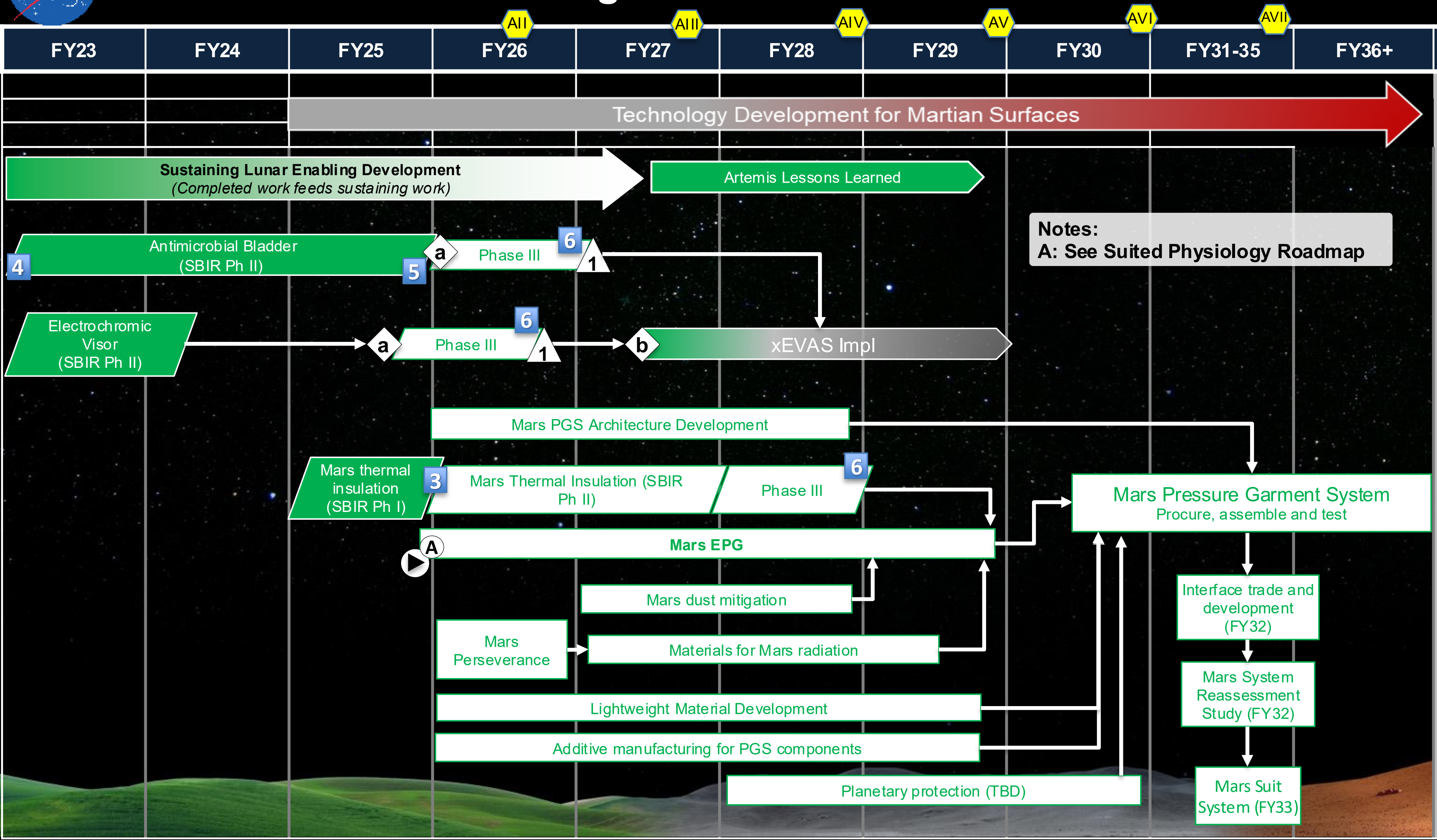
EVA PGS Roadmap



PGS Roadmap overlapping areas

- Scope
  - Organized by mission applicability not technology areas
  - Mars EVA PGS - Enabling
    - Capabilities and technologies that are unique to Mars EVA
    - Capabilities and technologies that enable Mars EVA and enhance Lunar
      - Enhance logistics, crew safety, and/or performance
  - Lunar EVA PGS – Sustained Lunar Evolution Enabling
    - Capabilities & technologies required to enable a long duration Lunar mission
      - Supporting durability, maintainability, cycle life
      - Enabling broader operational range

Mars EVA PGS – Enabling



Additional Information

Deliverables and Milestones

1. Infusion Readiness Assessment

Decision Points a

a. Assess infusion potential to pursue maturation to TRL 6

b. Infuse into xEVAS - partner with Vendor

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

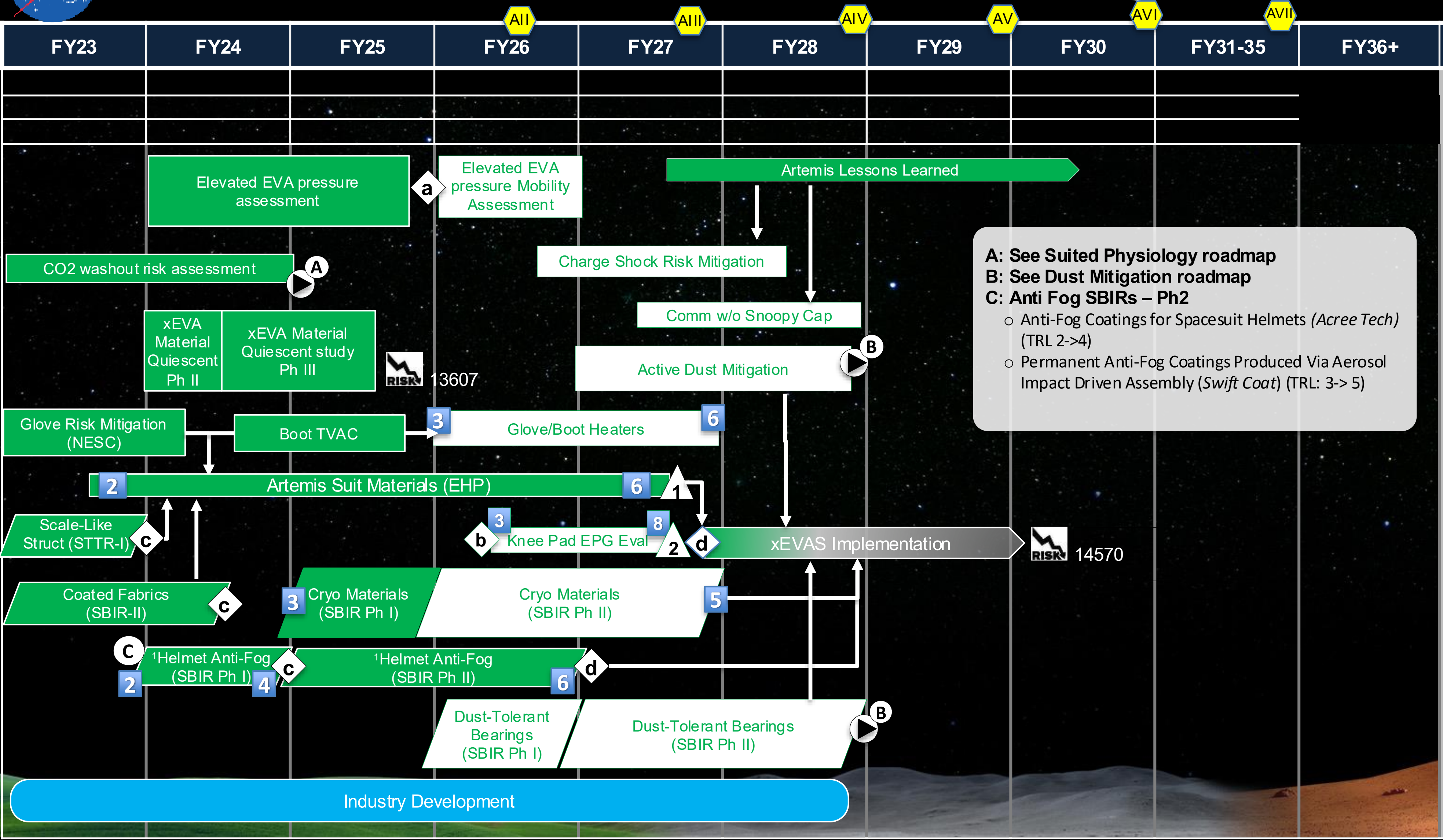
Objectives (FOM/KPPs):

8-hour EVA, < TBD lbs. dry mass, 100 EVA operational life (TBC)

Gap # Metric: TBS

See acronyms list at front of document. All mission information is notional and for planning purposes only

Lunar EVA PGS – Sustained Lunar Evolution Enabling



Additional Information

Deliverables and Milestones

1. Infusion Readiness Assessment
2. EPG Knee Pad H/W for Flight

Decision Points a

a. Assess need for a DTO to evaluate Mobility with elevated EVA pressure
b. Assess need for a DTO to evaluate candidate EPG materials
c. Assess infusion potential to pursue maturation to TRL 6
d. Infuse into xEVAS - partner with Vendor

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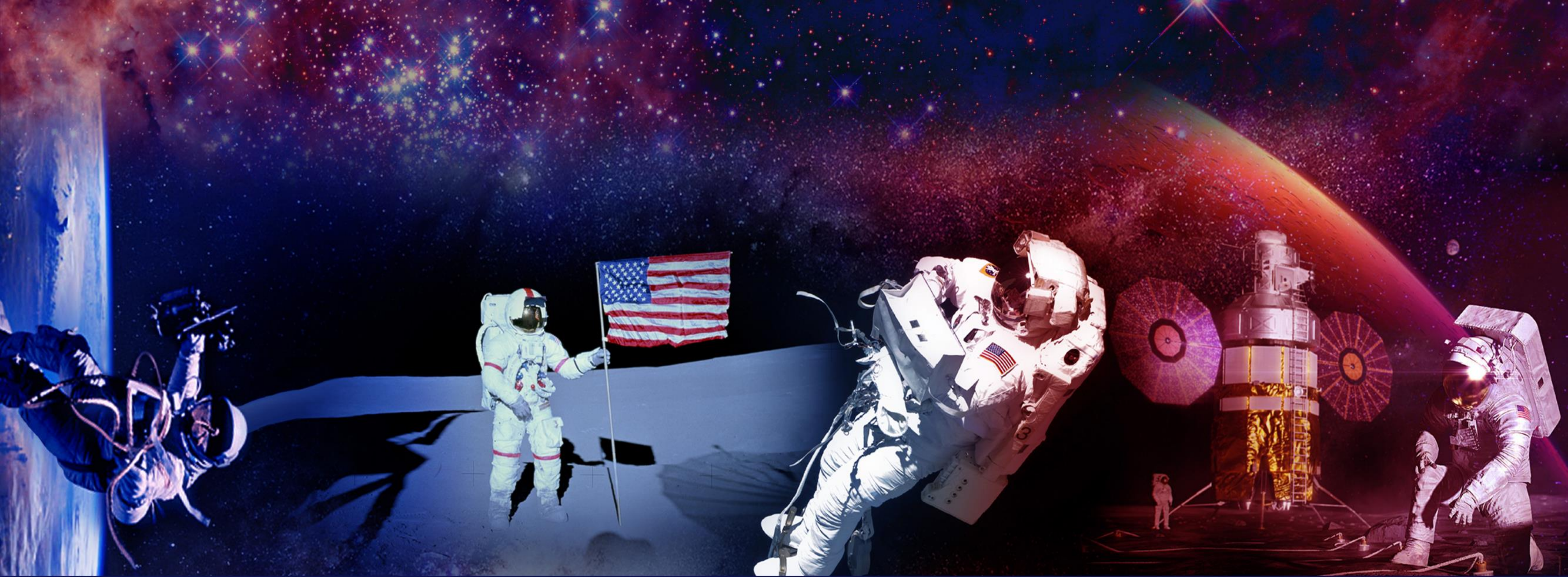
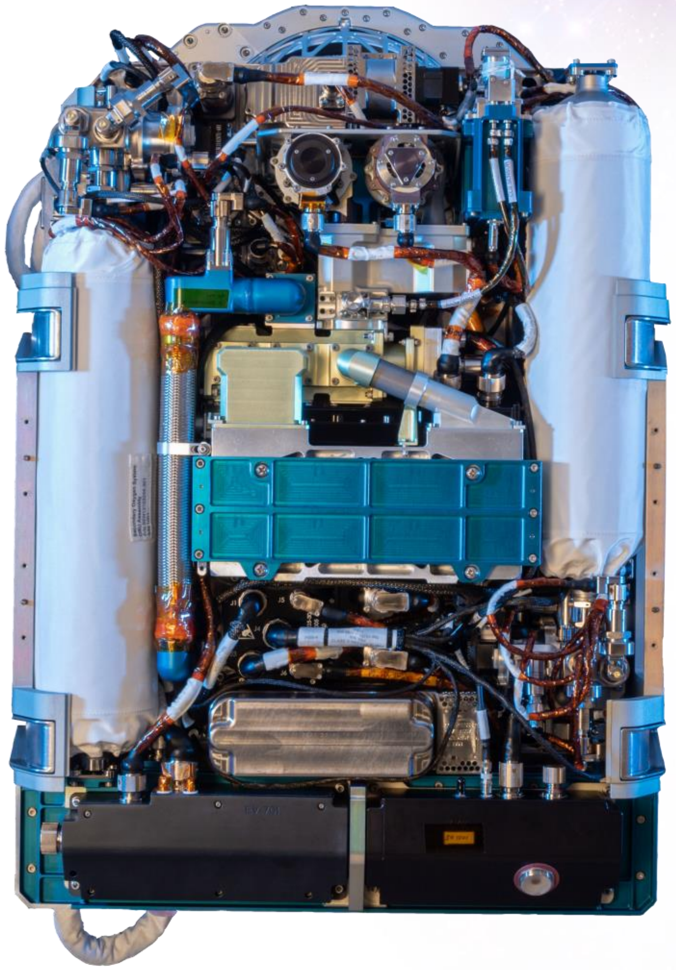


Life Support System Roadmap

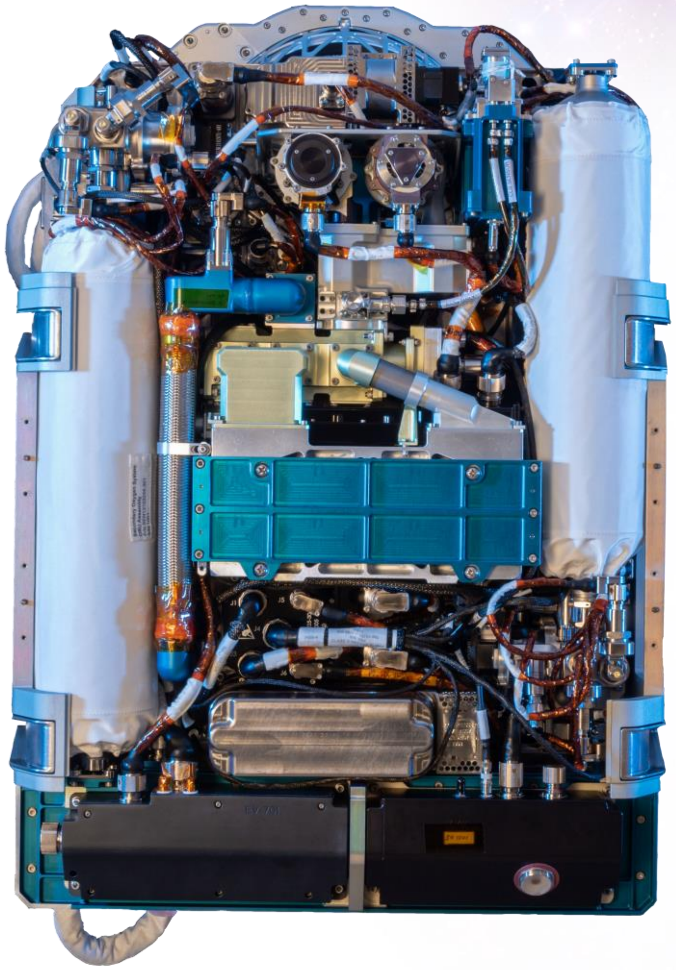
EVA PLSS Roadmap



xEMU PLSS

- Portable Life Support System (PLSS)
  - An integrated system packaged into a backpack worn by a Crew Member
  - PLSS functions include:
    - Oxygen (O2) storage and pressure regulation for breathing and environmental habitability
    - CO2 washout and removal
    - Trace contaminant control
    - Thermal control for the CM and space suit avionics
  - xEMU PLSS Goal
    - Enable an exploration-forward design for use in microgravity at the ISS and in lunar gravity on the Moon
      - Increased robustness & reliability
      - Reduced consumables use
      - Improved maintainability at the operational destination

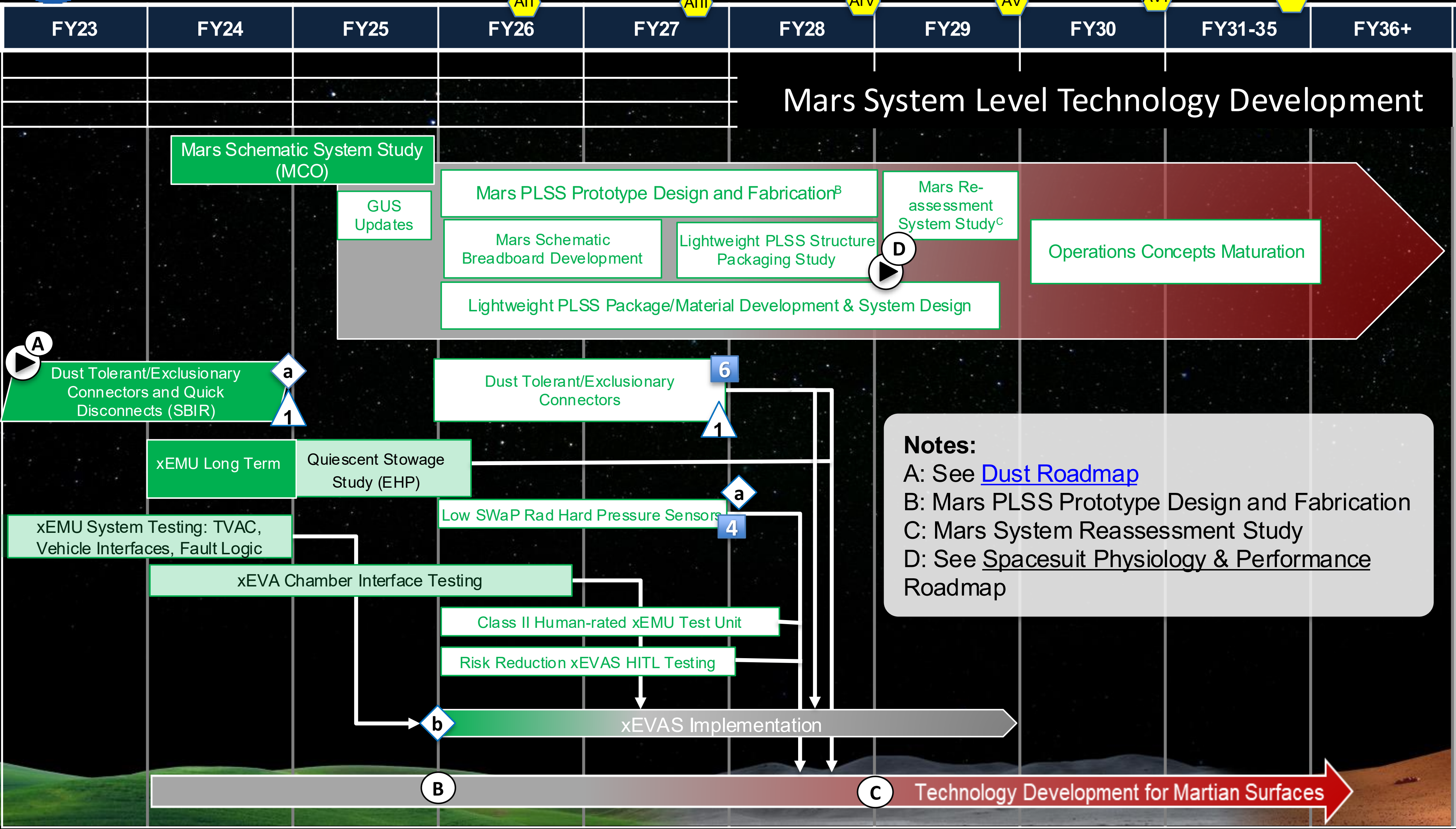
EVA PLSS Roadmap



xEMU PLSS

- Scope
  - For Mars PLSS Development
    - Technology upgrades will be required prior to a Martian mission
    - Due to PLSS Complexity
      - It took ~20 years to progress xEMU PLSS: Schematic -> Component development -> System integration -> Maturation
      - Critical that the roadmap communicates functional capability development needs and funding opportunities
  - PLSS Roadmap
    - Addresses current PLSS technology risks and existing gaps in long duration lunar and Martian-ready capabilities
    - Divided into 4 Swim lanes:
      1. **Cross-Subsystem & System Architecture Development**
      2. **O2 Supply & Ventilation**
      3. **Thermal Control**
      4. **Avionics & Power**

EVA PLSS: Cross Subsystem Development and System Architecture



Additional Information

Deliverables and Milestones

1. Project Infusion Readiness Assessment (PIRA)

Decision Points a

a. Assess infusion potential to pursue maturation to TRL 6

b. Infuse into xEVAS - partner with Vendor

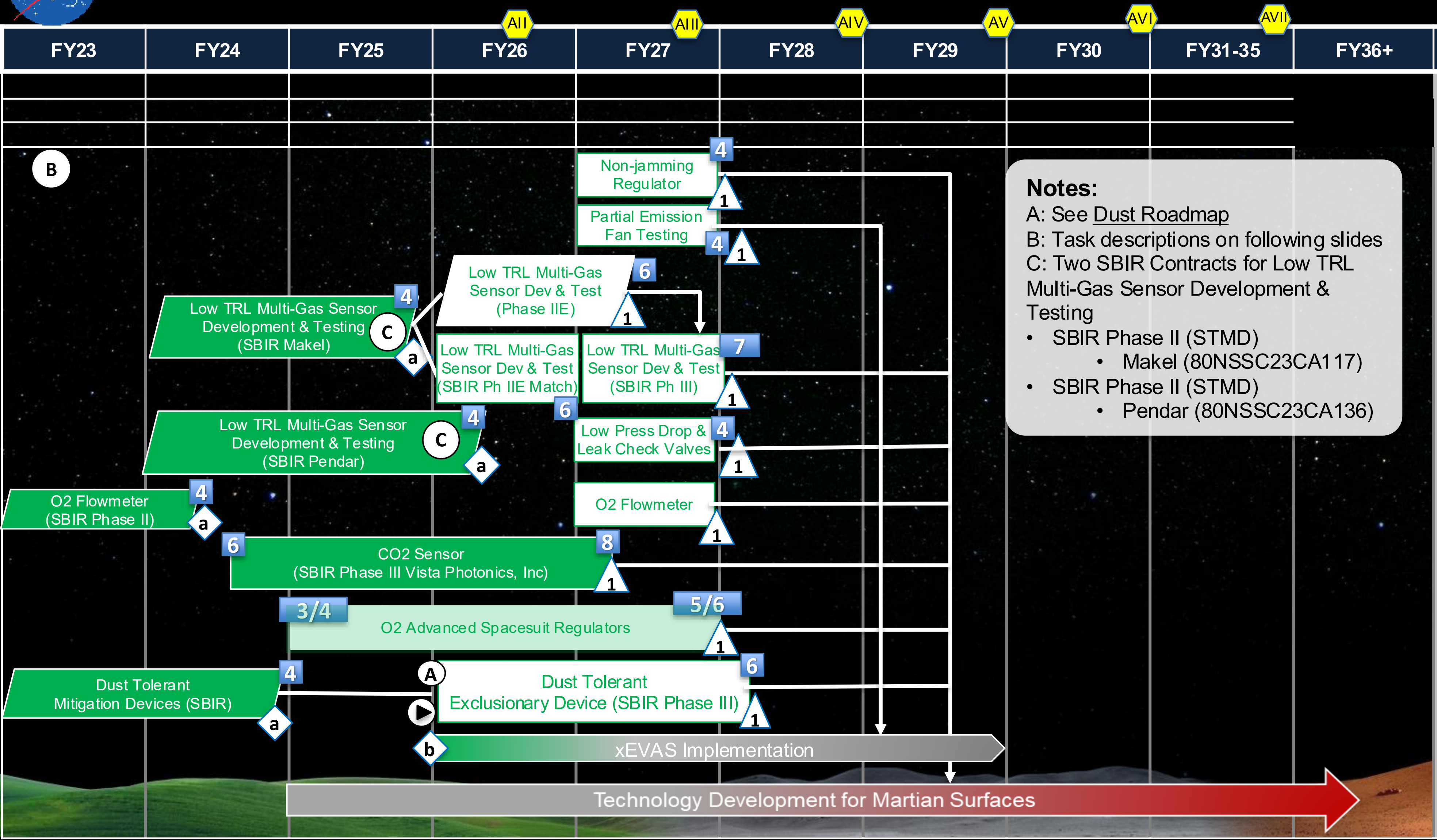
Ground · ISS / LEO · Lunar orbit · Lunar surface · Mars transit · Mars surface · Notes · Decision point · Deliverable/Milestone · Partially Funded · Funded · Unfunded · Artemis missions · ESDMD · STMD · Industry · Risk · Touchpoint · # TRL

Objectives (FOM/KPPs):

PLSS System Performance: 8-hour EVA, < 150 lb dry mass, 100 EVA operational life
Mars System includes operation in a 9 Torr CO2 environment
Connectors and Quick Disconnect should withstand 1000 cycles in dusty environment
Sensors must withstand lunar and Martian radiation environments

See acronyms list at front of document. All mission information is notional and for planning purposes only

EVA PLSS: Oxygen Supply and Ventilation (Slide 1 of 3)



Additional Information

Deliverables and Milestones

1. PIRA

Decision Points a

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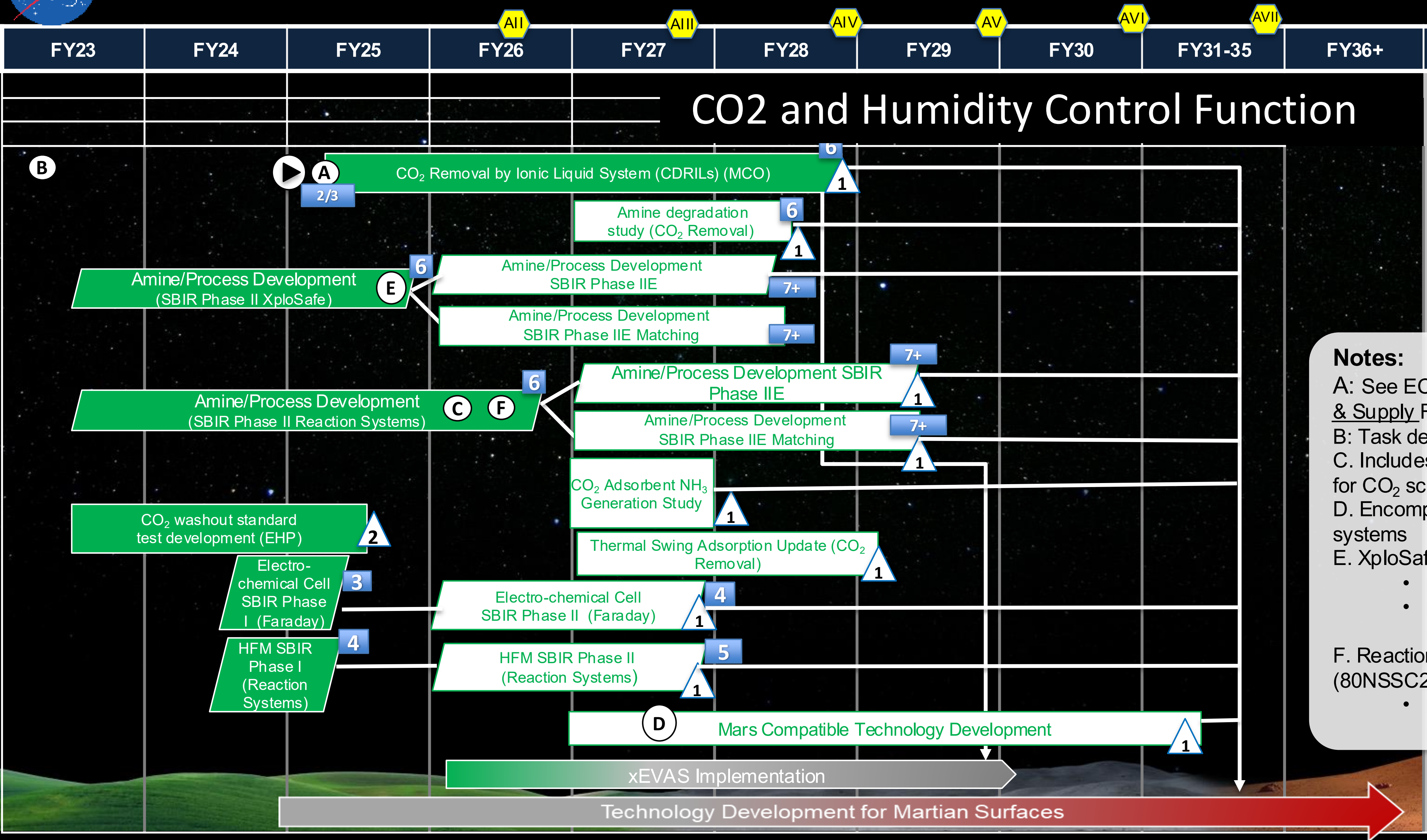
Objectives (FOM/KPPs):

Actuators should demonstrate 1,000,000 cycles, actuation for at extension > 50 lb

Gas sensors that can detect multiple gas constituents in addition to CO_2 (e. g. NH_3, O_2, H_2O)

Regenerable CO_2 and humidity control in a 9 Torr CO_2 Martian Atmosphere

EVA PLSS: Oxygen Supply and Ventilation (Slide 2 of 3)



Additional Information

Deliverables and Milestones #

1. PIRA
2. CO2 Washout Standard

Decision Points a

a. Assess infusion potential to pursue maturation to TRL 6

b. Infuse into xEVAS - partner with Vendor

Notes:

A: See ECLSS-CHP SCLT O2 Generation & Supply Roadmap

B: Task descriptions on following slides

C. Includes using additive manufacturing for CO_2 scrubber canisters

D. Encompasses CO_2, TCC, and Thermal systems

E. XploSafe Phase II (80NSSC23CA167)
- Phase IIE – SBIR STMD
- Phase IIE Matching (Commercial Funding)

F. Reaction Systems Phase II (80NSSC23CA146)
- Phase II complete FY26 & pursue Phase IIE thereafter

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Objectives (FOM/KPPs):

Actuators should demonstrate 1M cycles, actuation for at extension > 50 lb

Gas sensors that can detect multiple gas constituents in addition to CO_2 (e. g. NH_3, O_2, H_2O)

Regenerable CO_2 and humidity control in a 9 Torr CO_2 Martian Atmosphere

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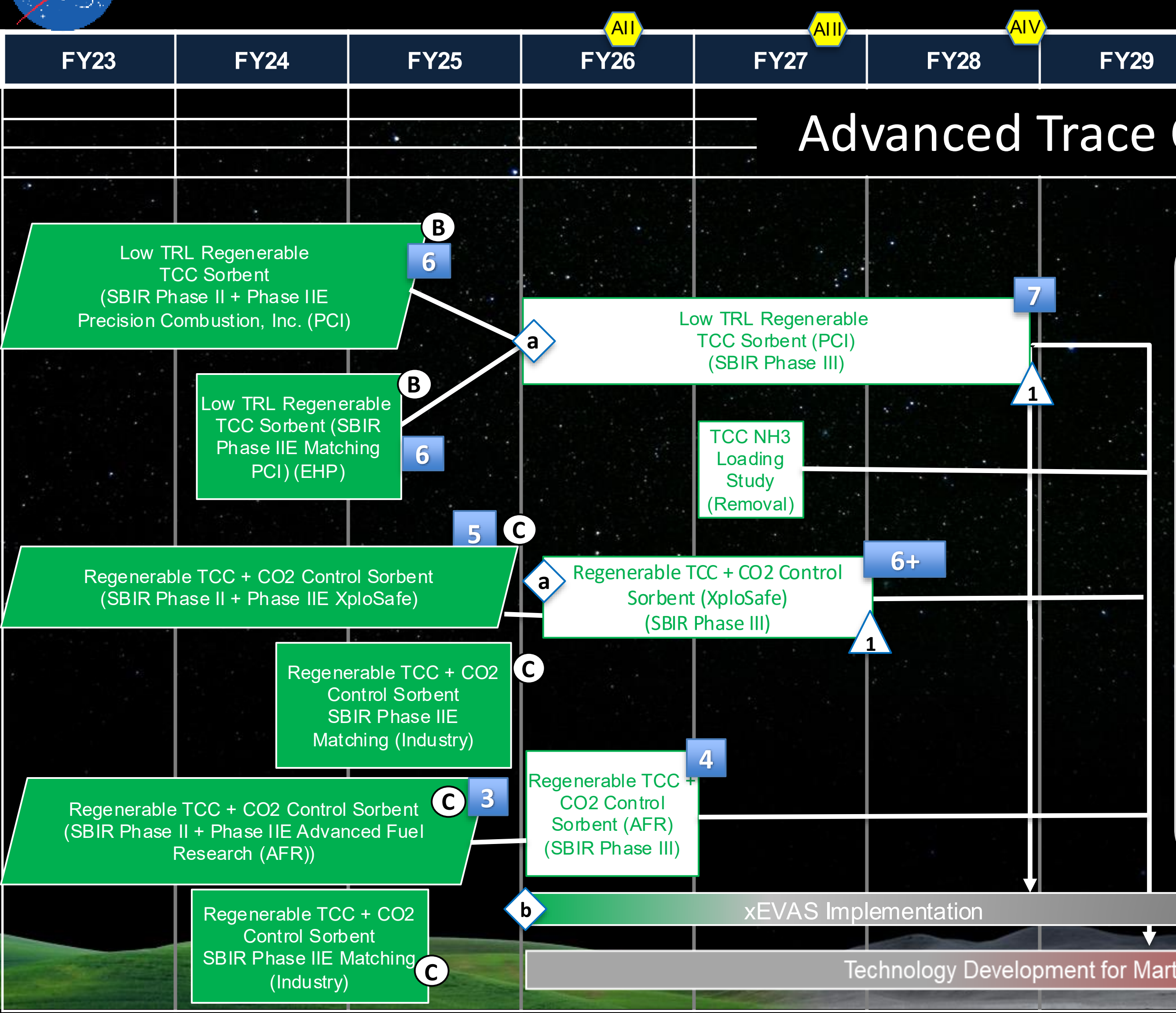
EVA PLSS: Oxygen Supply and Ventilation (Slide 3 of 3)



Notes:

A: Task descriptions on following slides

B: One SBIR Company Completed work on Regenerable TCC Sorbent

- Precision Combustion Inc.(PCI)
  - SBIR Phase II & IIE (80NSSC21C0533)
  - SBIR Phase IIE Matching (EHP) (80NSSC24CA015)

C: Two SBIR companies are working on a combined solution to CO2 and TCC

- XploSafe
  - SBIR Phase II + Phase IIE (80NSSC21CO579)
  - SBIR Phase III (Commercial Funded)
- Advanced Fuel Research Inc.
  - SBIR Phase II + Phase IIE (80NSSC21C0508)
  - SBIR Phase III (Commercial Funded)

Additional Information

Deliverables and Milestones #

1. PIRA

Decision Points a

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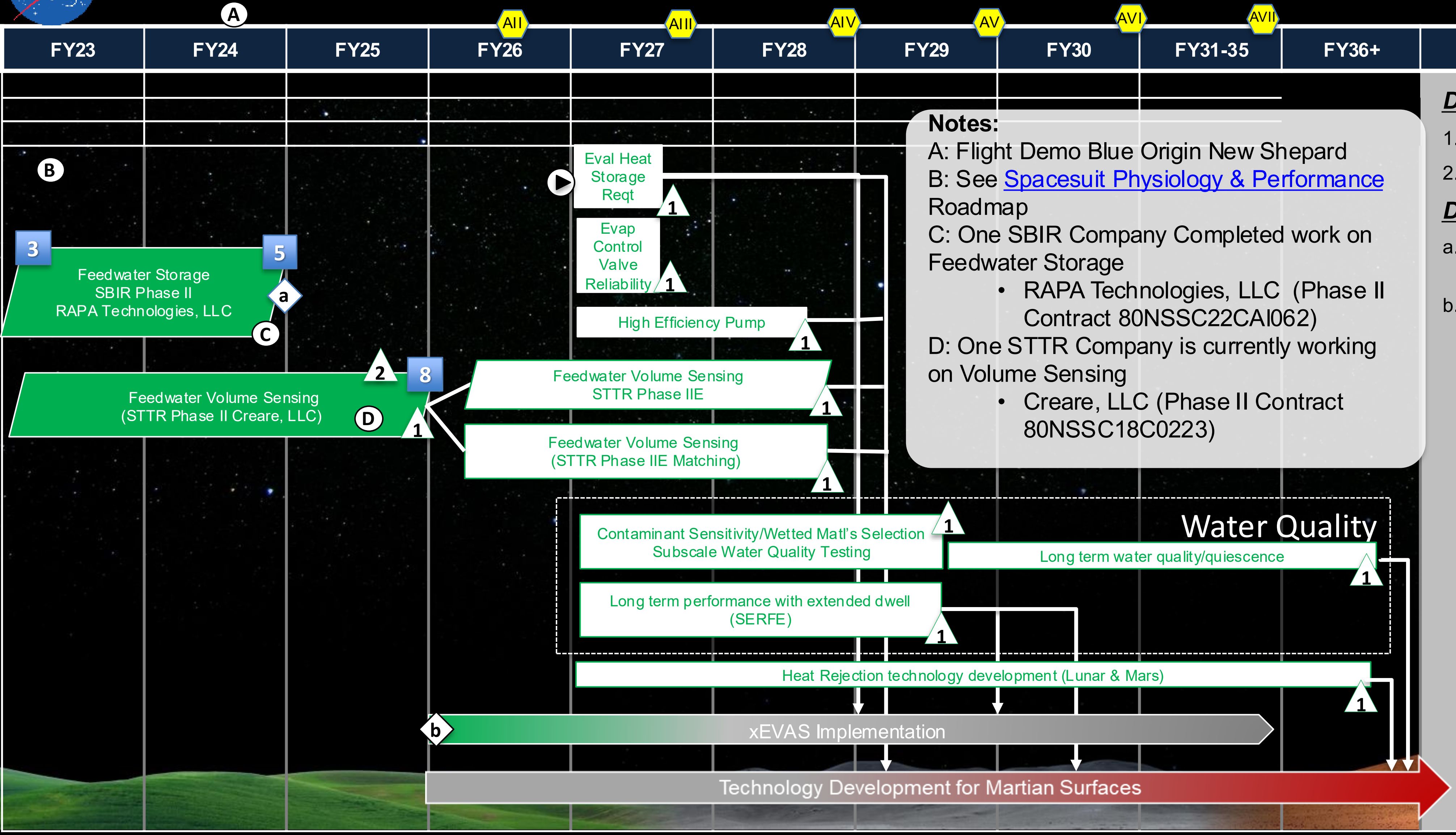
Regenerable CO_2 and humidity control in a 9 Torr CO_2 Martian Atmosphere

EVA PLSS: Thermal Control



Notes:

A: Flight Demo Blue Origin New Shepard

B: See Spacesuit Physiology & Performance Roadmap

C: One SBIR Company Completed work on Feedwater Storage

- RAPA Technologies, LLC (Phase II Contract 80NSSC22CA1062)

D: One STTR Company is currently working on Volume Sensing

- Creare, LLC (Phase II Contract 80NSSC18C0223)

Additional Information

Deliverables and Milestones

1. PIRA
2. CREARE sensor flight demo unit

Decision Points a

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Objectives (FOM/KPPs):

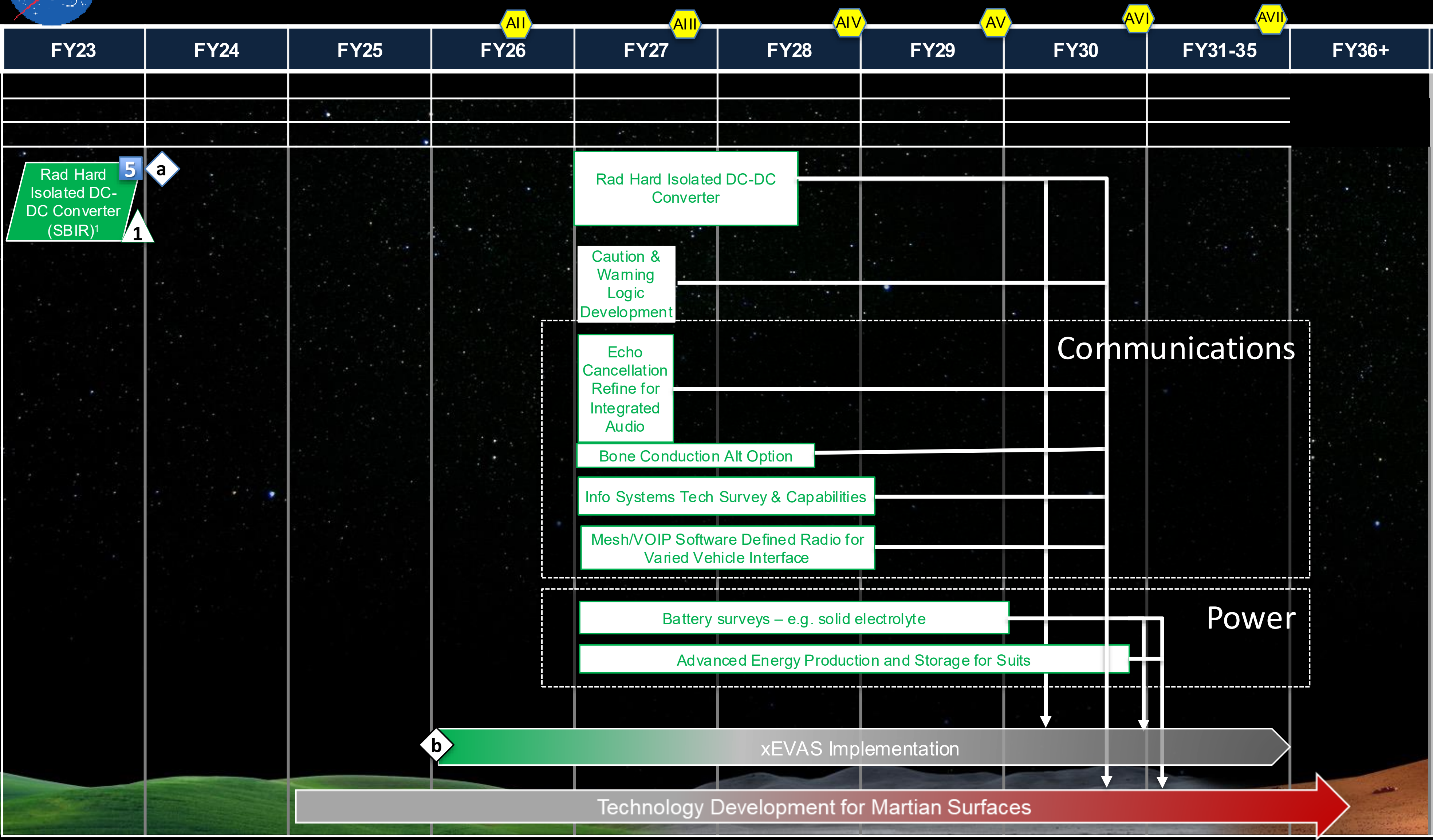
Heat rejection technologies that operate in the 9 Torr Mars atmosphere

Low power and mass feedwater supply sensors with an accuracy better than 100 mL

Water loop operation without maintenance > 800 hours

See acronyms list at front of document. All mission information is notional and for planning purposes only

EVA PLSS: Avionics and Power



Additional Information

Deliverables and Milestones

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Objectives (FOM/KPPs):

Integrated audio (off the crew) solutions without feedback and high speech recognition scores
High energy density suit power supply
Information systems to provide crew autonomy

Conclusion

- EVA Spacesuits symbolize human space exploration
- Unique environments of Mars constrain design solutions
- EVA Technology Roadmaps
  - Serves as a guide for spacesuit technology development required to explore Mars
  - Provides enhancement to lunar mission capability as well
  - Provides a graphical view of the development path for each subsystem
  - Helps spacesuit developers
  - Helps to communicate NASA’s technology needs and intended priorities
  - Fosters collaborations across human spaceflight disciplines and with commercial and academic partners
  - Provides NASA’s programs and technical organizations with vital information between now and future Mars missions as they make decisions on resources and closing technology gaps

Acknowledgements

The authors would like to give credit to the engineers that work hard to develop, design, test, and evaluate technology.

They embody the Crew and Thermal Systems Division motto,

“Pioneering Technology to Live and Work in Space.”