National Aeronautics and Space Administration

EXPLORE
SOLAR SYSTEM & BEYOND

Draft Planetary Science Technology Development Plan

Dr. Erica N. Montbach, Dr. Michael Lienhard, Ms. Anna Maria Pal, Dr. Shahid Aslam, Dr. Majd Mayyasi, Dr. Andrew Maynard, Dr. Jeffrey Hall, Dr. Leonard Dudzinski

Planetary Exploration Science Technology Office (PESTO)

Science Mission Directorate

March 13, 2024

erica.n.montbach@nasa.gov

PESTO
Planetary Exploration Science Technology Office

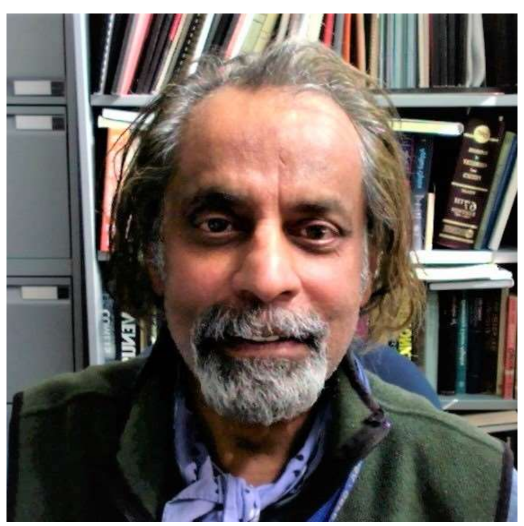
PESTO Team

Erica Montbach
Manager PESTO, COLDTech, SBAG

Michael Lienhard
Program Officer, MatISSE, HOTTech, VEXAG

Anna Maria Pal
Program Officer, DALI, LEAG, MExAG

Leonard Dudzinski
PSD Chief Technologist



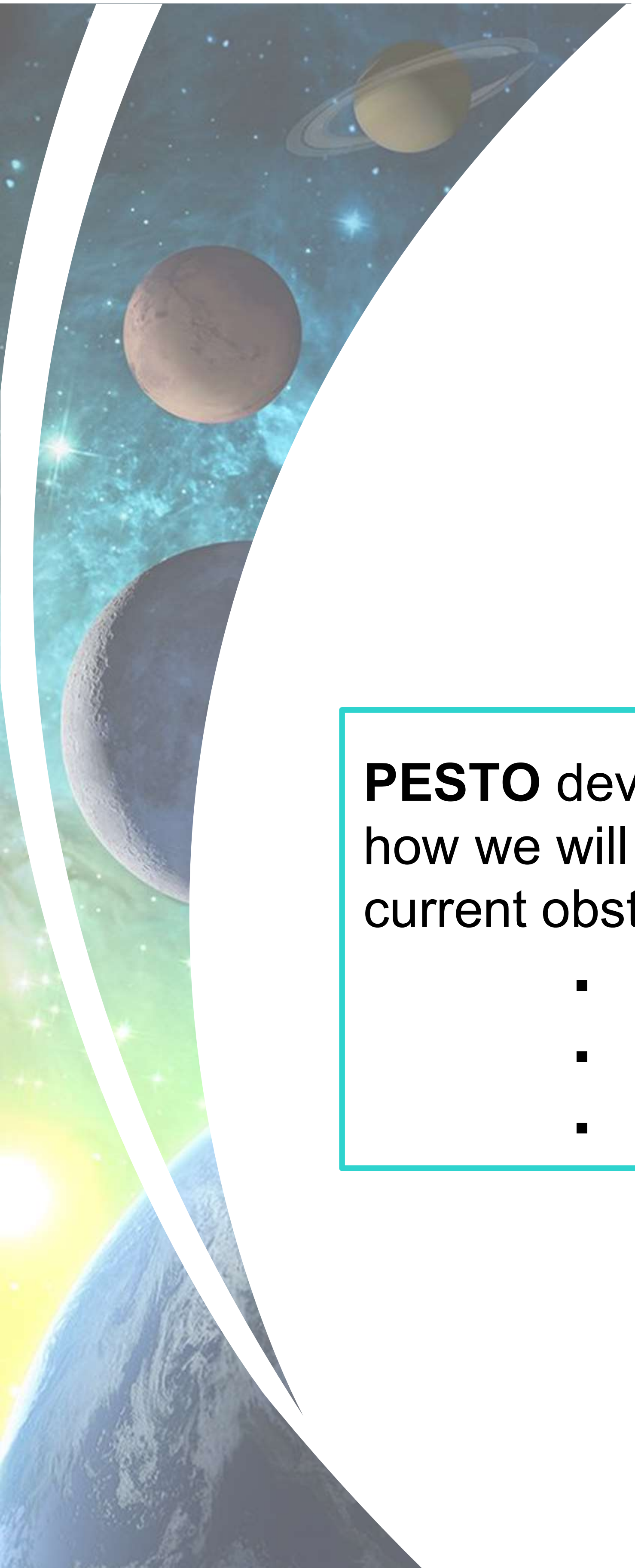
Shahid (Ish) Aslam
Program Officer, PICASSO

Majd Mayyasi
Participating Scientist, MAPSIT**, ExMAG**

Jeffrey Hall
Associate Directorate Technologist at JPL, OPAG

Tiffany M. Morgan
MEP Deputy Director, MEPAG

PESTO
Planetary Exploration Science Technology Office



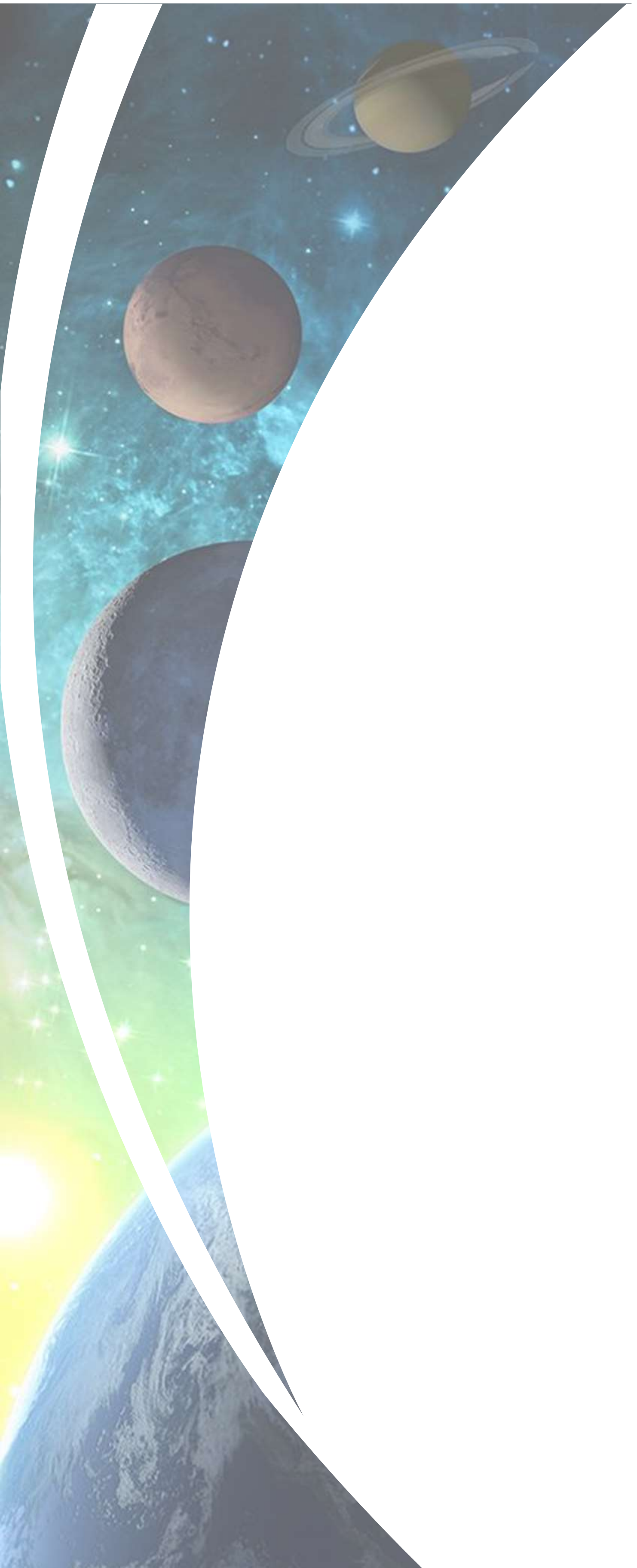
Planetary Science Technology Development Plan

PESTO
Planetary Exploration Science Technology Office

Executive Summary

PESTO developed a comprehensive Planetary Science Technology Development strategy to outline how we will create widely available advanced capabilities to explore the solar system that overcome current obstacles to:

- Gain new understandings that answer priority science questions
- Reach new destinations
- Operate in new environments in new ways



Planetary Science Technology Development Plan

Contents

Comprehensive Technology Strategy Draft can be found at:

PESTO
Planetary Exploration Science Technology Office

Planetary Science Technology Strategic Goals

1. Invest in innovative Technology Development for Planetary Science
2. Facilitate Technology Maturation to Planetary Science Missions
3. Forge Interconnectivity and Partnerships
4. Communicate Planetary Science Technology Status and Plans

Summarized from Comprehensive PS Tech Dev Plan

Planetary Science Technology Stakeholders

Owners for Planetary Science Technology Development Plan are:

- Science Mission Directorate
  - Planetary Science Division (PSD)
  - Exploration Science Strategy Integration Office (ESSIO)

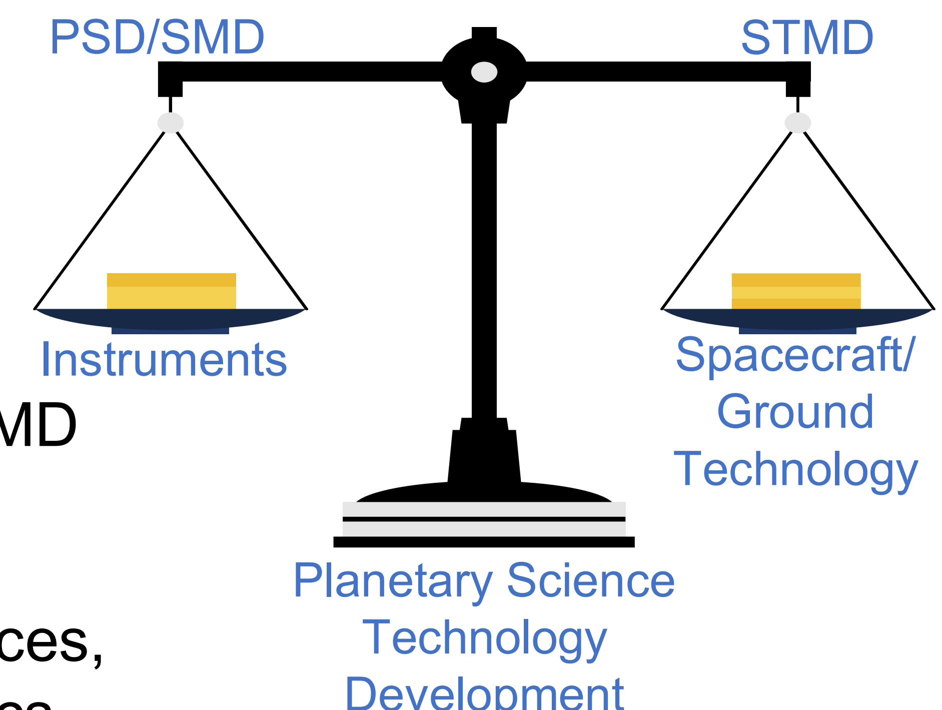
Stakeholders for Planetary Science Technology Development Plan are:

- Within NASA
  - Science Mission Directorate (SMD)
  - Space Technology Mission Directorate (STMD)
  - Exploration Systems Development Mission Directorate (ESDMD)
- Outside NASA
  - The science community
  - The Assessment Groups (AGs)
  - Department of Energy
  - National Science Foundation

Planetary Science Technology Development Strategy

Types of Technology Development Funded by Planetary Science

- Instrument technologies needed for future science missions
- Platform technologies needed for unique science applications, coordinated with STMD
- Investments are:
  - Competitively awarded through ROSES
  - Directed when needed



SMD/STMD Interactions

- SMD provides desired technology focus areas of interest to STMD
- SMD has strong involvement across STMD programs
- PSD is a division in SMD. Other SMD divisions are Earth Sciences, Heliophysics, Biological and Physical Sciences, and Astrophysics
- SMD Division Technology Offices interact and meet as part of the Technology Federation, which is managed and run by the SMD Chief Technologist
- STMD's focus is on platform technologies Technology Readiness Level (TRL) 1-7 and includes TRL1-3 instrument investments

PS Strategy for Developing and Infusing Technology

Developing Technology (TRL ≤ 6)

	Majority of Portfolio	Supplement Portfolio	Synergistic
Instrument Technology	PSD / ESSIO	STMD	SMD other divisions
Platform Technology	STMD	PSD	SMD other divisions

PICASSO, MatISSE, DALI, SMD Cross-Cutting

NIAC, SBIR, ECI, CIF

SBIR, NIAC, TP/ACO, CIF/ECI, GCD

HOTTech, COLDTech, Potential Future Programs

Technology Demonstrations enable new technologies to be less risky to missions

- Potential paths to further technology maturation to TRL 6
- PIs may propose to Technology Demonstration Opportunities (TDOs)

Additional funding, STMD Suborbital Experiments

TDO Discovery, New Frontiers, or PSD Direct/Flagship, or STMD Tech Demo Missions

Infusing Technology

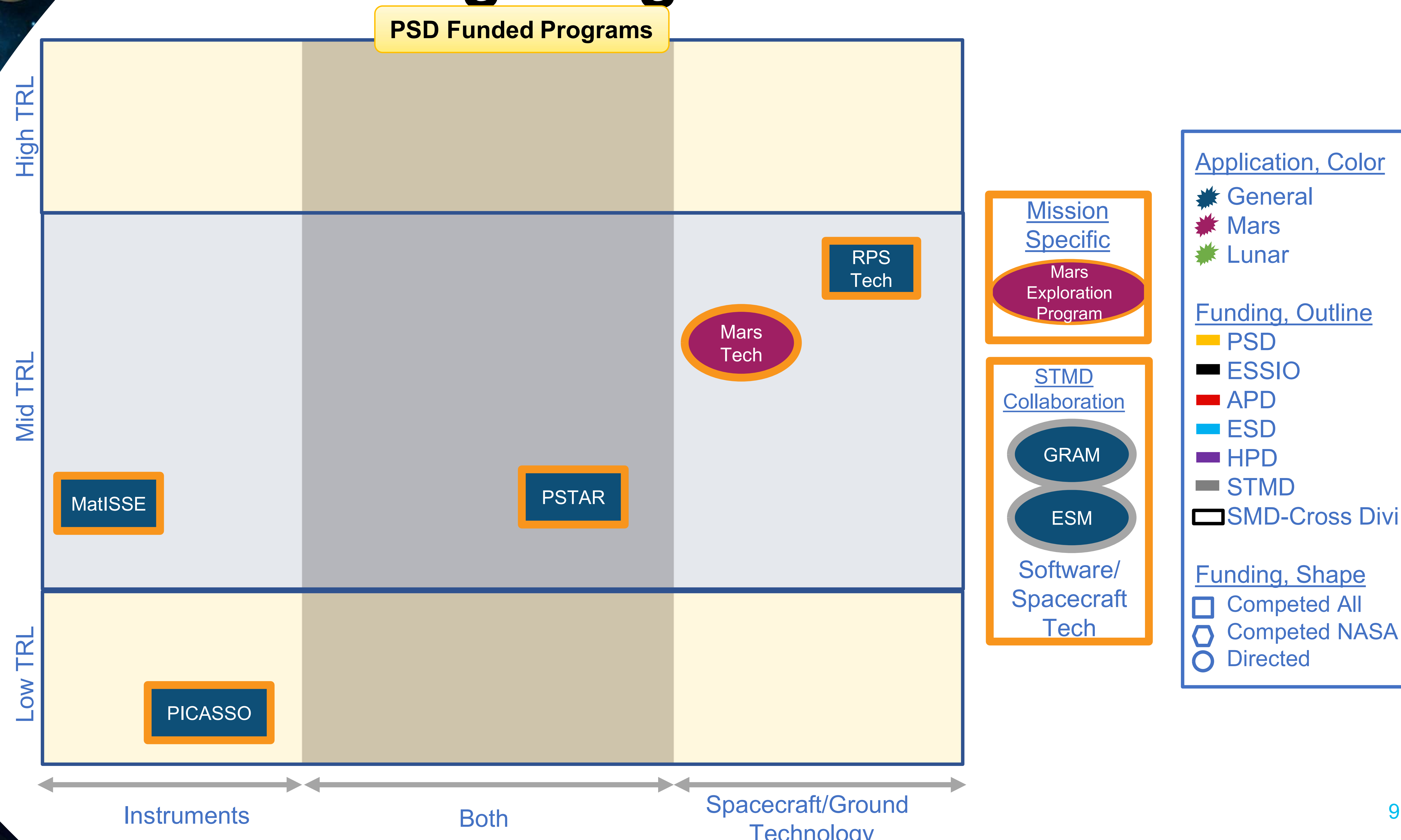
- PESTO facilitates forging connections between technology and scientist through events like Technology Showcase and Yearly Review
- Investigate incentives for including new technology
- Develop TRA process that is standardized, transparent and utilized by community
- Work with NASA proposal panels to ensure new technology is understood
- PESTO forges connections with NASA centers to communicate tech needs and understand center work

New Frontiers, Discovery, SIMPLEx, SALSA, LTVIP, PRISM,

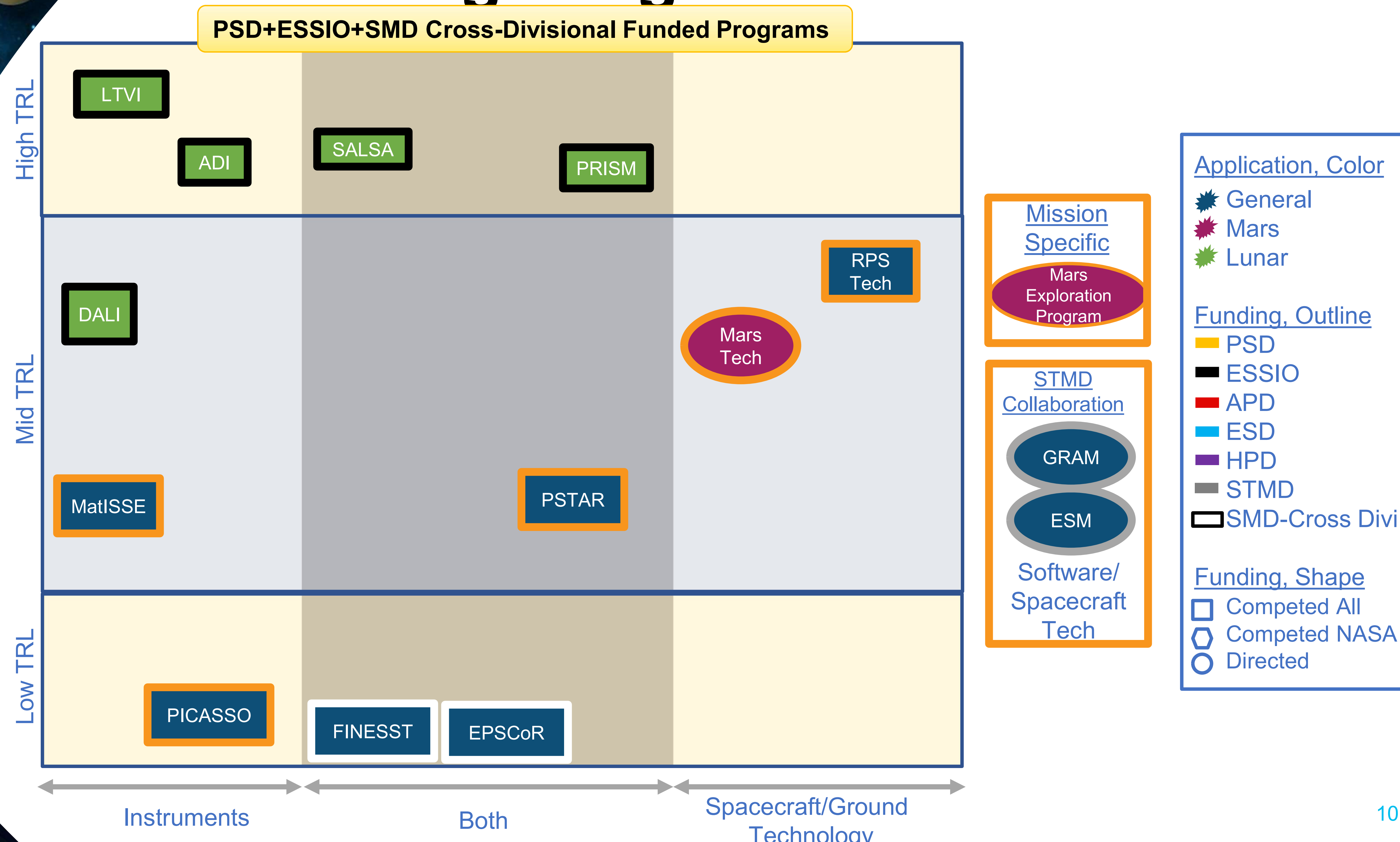
Other Potential Technology Success

- Encourage commercialization by advocating for relevant TP and SBIR Phase III projects

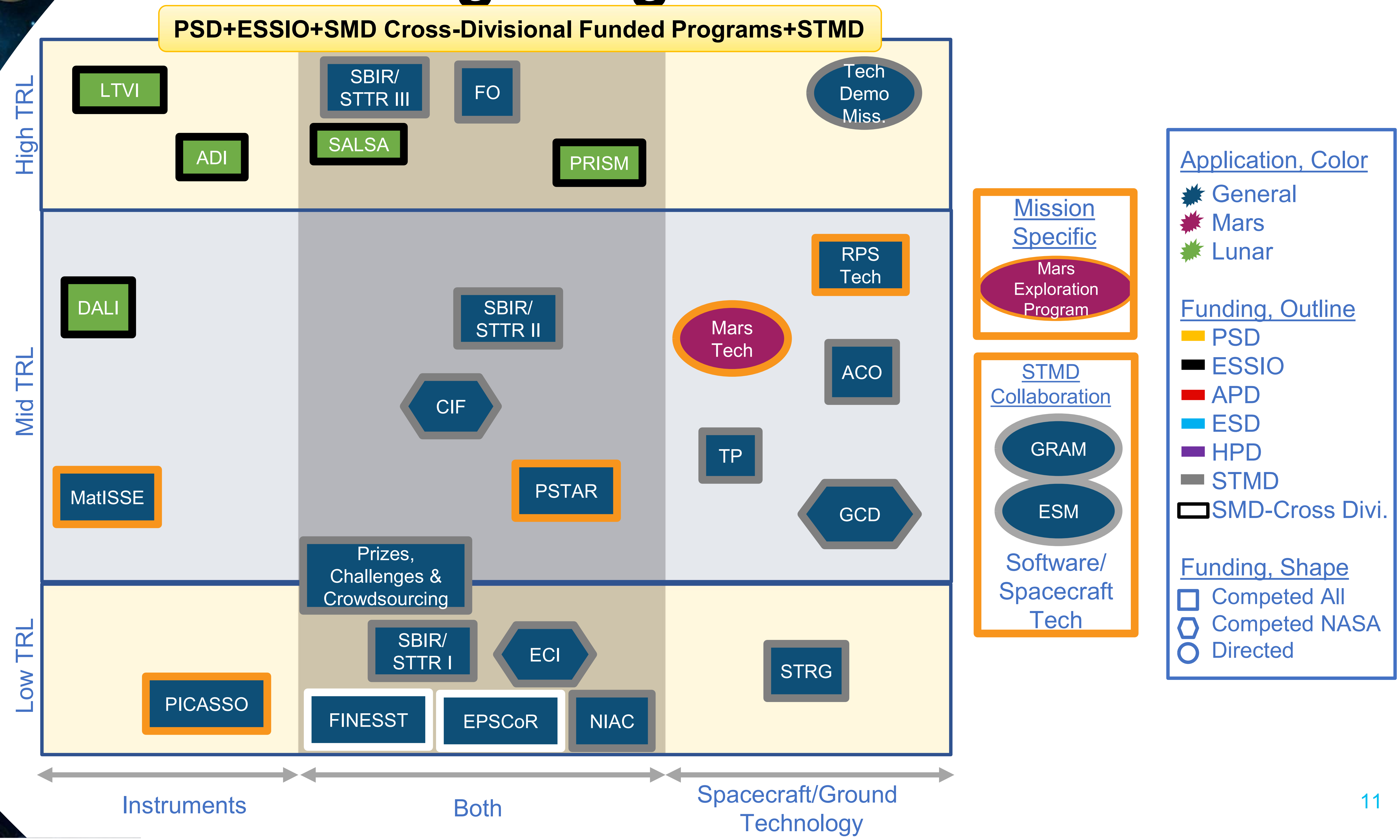
Funding Programs Available



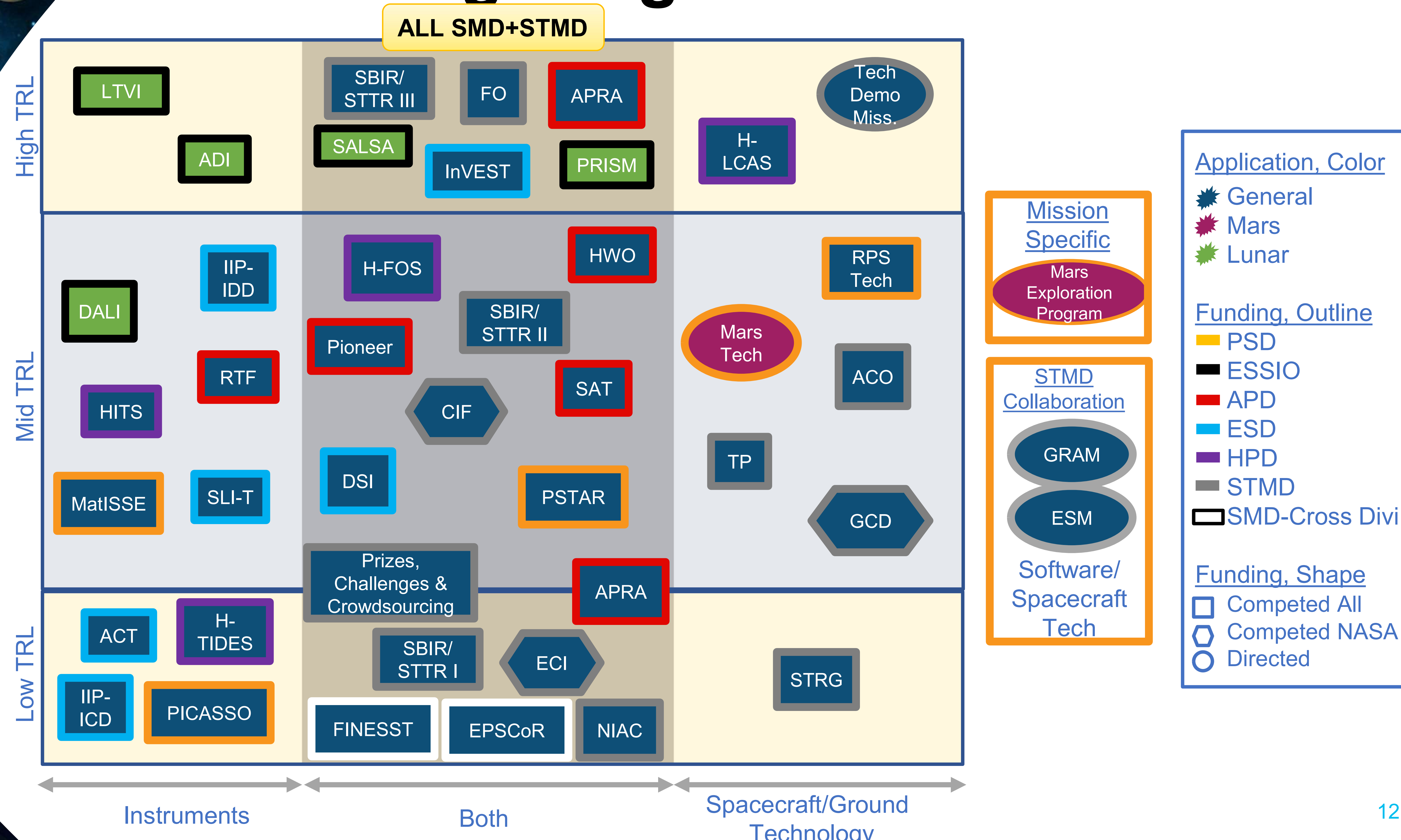
Funding Programs Available



Funding Programs Available



Funding Programs Available



How Technology Focus Areas are Identified

Decadal Survey Review

Planetary Science Division Program Scientists review Origins, Worlds, and Life Decadal Survey (OWL) and identify technology needs

Mission Study Reports

PESTO reviews of Mission Study Reports and identification of stated technology needs

AG Technology Development Plans/Roadmaps

PESTO reviews of pre-Decadal Technology Development Plans/Roadmaps and grouping of AG technology needs

Community Discussion

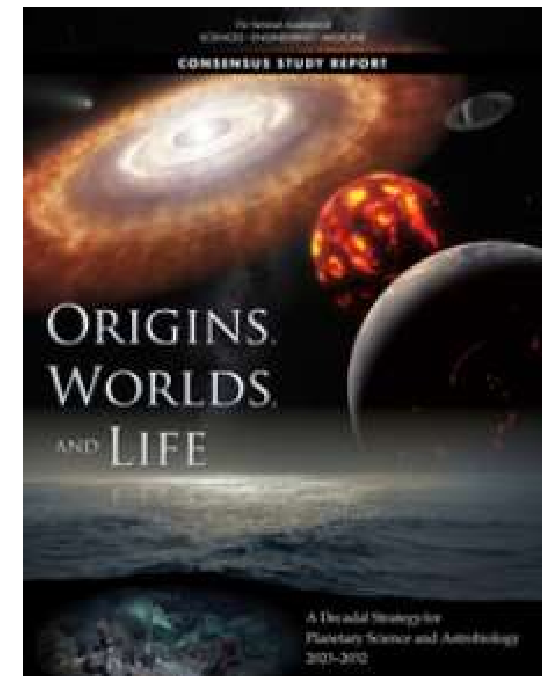
PESTO discussions with community about technology needs and goals

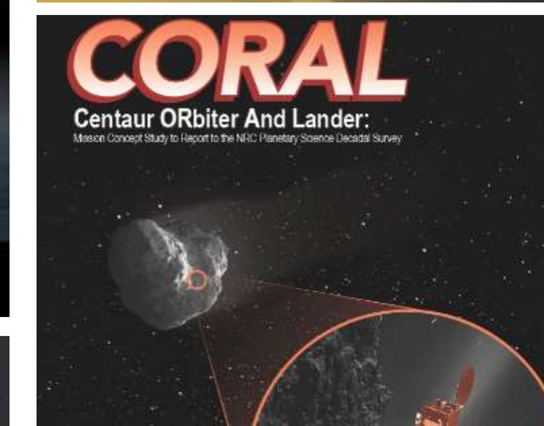
Planetary Science Discussions

PESTO discussions with groups within Planetary Science about technology needs and goals

Planetary Science Funded Studies

PESTO will use these to verify/document technology needs





Prioritized Technology Focus Areas*

Instrumentation, with an emphasis on:
- In Situ Search for Life/Astrobiology

Sample Containment and Return
- Planetary Protection and Contamination Control
- Thermal Protection and Control
- Sample Manipulation

Autonomy
- Global Positioning System (GPS) deprived navigation
- Surface (planetary) operations
- On-board science data processing
- Ground Operations

Robotics, with an emphasis on Advanced Mobility for:
- Aerial Rovers in Extreme Environments
- Subsurface Access in Extreme Environments**

Higher-efficiency radioisotope power system technology

Development typically occurs with:
- ROSES programs:
  - PICASSO
  - MatISSE
  - DALI
- SBIR
- Potential future focused programs

Development typically occurs with:
- STMD
- SBIR
- TP
- ACO
- RPS program (for last item)
- Potential future focused programs

*These are priority developments, however, future investments are not limited to these technologies
**Includes drilling

Overlap between OWL & Planetary Science Technology Focus Areas

Technology Topic Areas

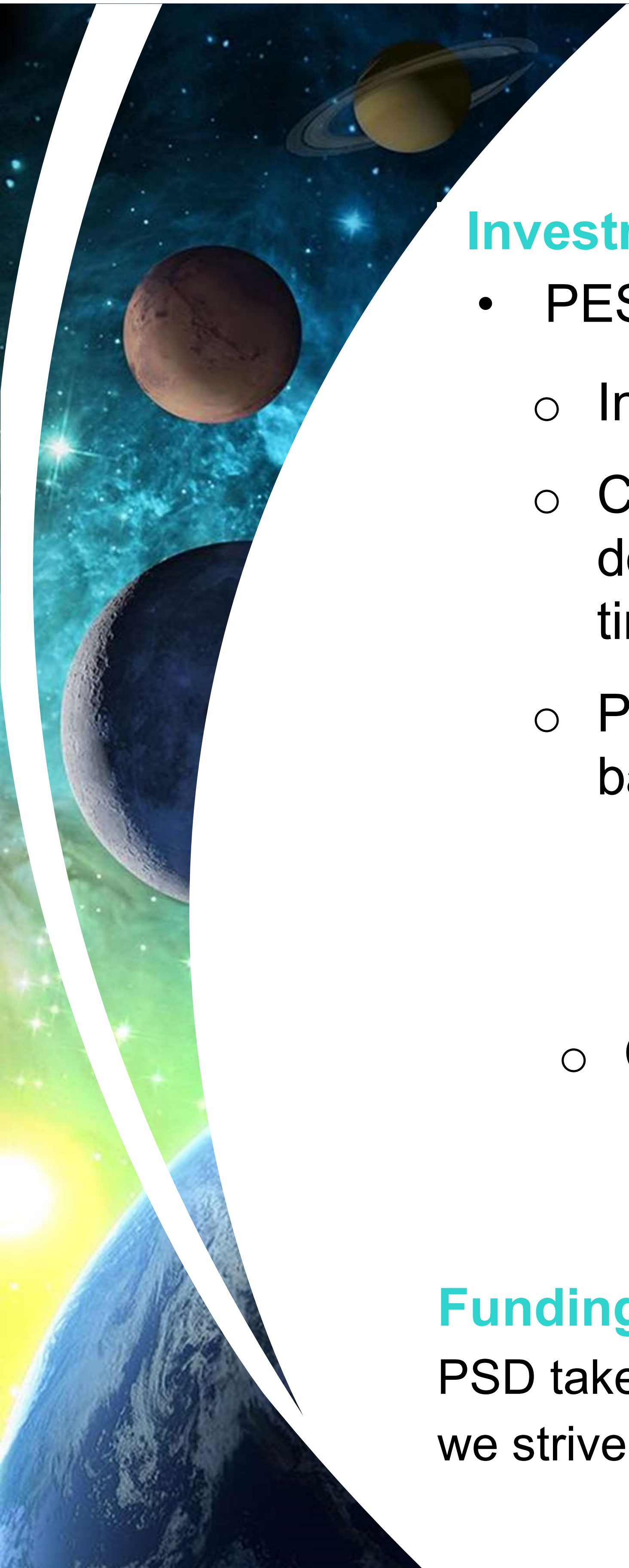
Instruments

- General In Situ
- General Remote Sensing
- Search for Evidence of Life
- In situ sample handling, pre-processing and analysis

General Technology Areas

- Autonomy
- Planetary defense
- Challenging environments
- Planetary protection and contamination control
- Cold/cryogenic sample return
- Radioisotope thermoelectric generator/ Radioisotope power systems
- Communication systems
- Solar array and batteries
- Entry/deorbit, descent and landing systems
- Subsurface access
- In situ mobility (aerial/surface)
- Technology System Engineering and Integration
- Launch, cruise and encounter optimization

- This list of technology areas fulfills the needs of priority missions in the decadal survey or are high reward technology areas that can make a big difference in the decades that follow



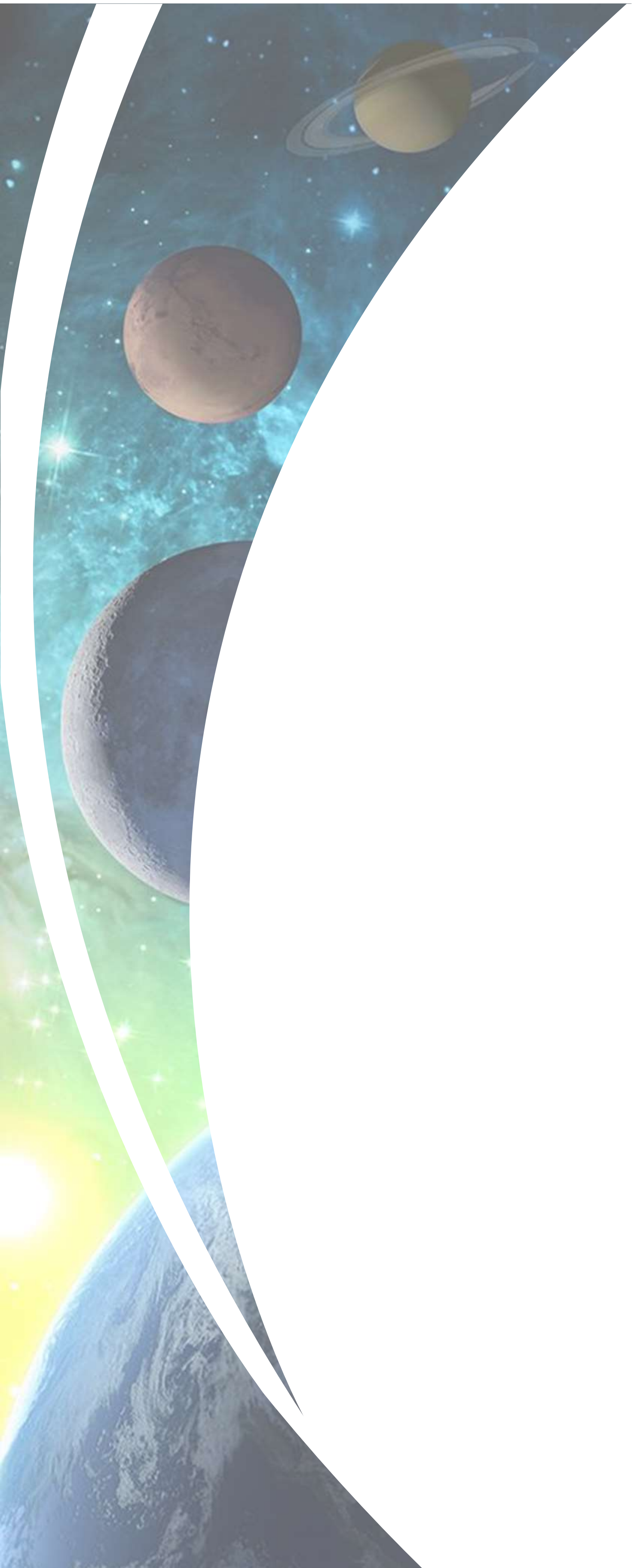
Decision to Invest

Investment Process

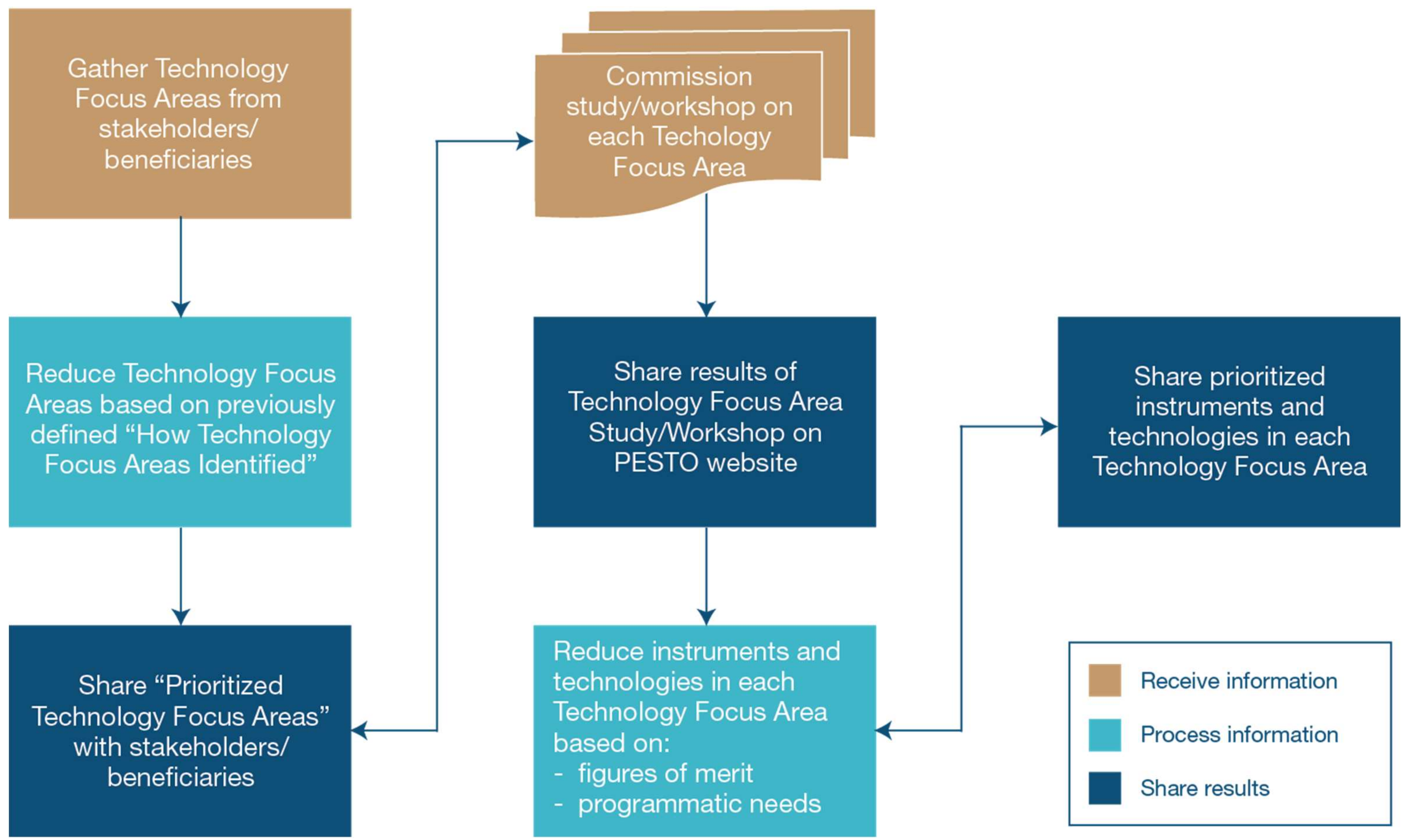
- PESTO will use the Prioritization Process, where:
  - Interact with community and Decadal Survey to identify Technology Focus Areas
  - Commission technology studies for SME's evaluation of a Technology Focus Areas, documenting the state of the art, priority needs/opportunities, and estimated investment and time needed to mature to TRL 6
  - PSD reduce specific instruments and technologies provided by the technology studies based on:
    - Figures of merit
    - Programmatic needs
  - Create resulting list of prioritized instruments and technologies for Technology Focus Areas
    - For strategic NASA technologies, investments may be allocated directly while building on existing capabilities

Funding level for Technology Development

PSD takes the Technology Development funding recommendation from the Decadal Survey seriously and we strive to reach Technology Development funding of 6-8% of full PSD budget over the next decade



Prioritization Process



Development and Demonstrations

Near, Mid, Far Developments

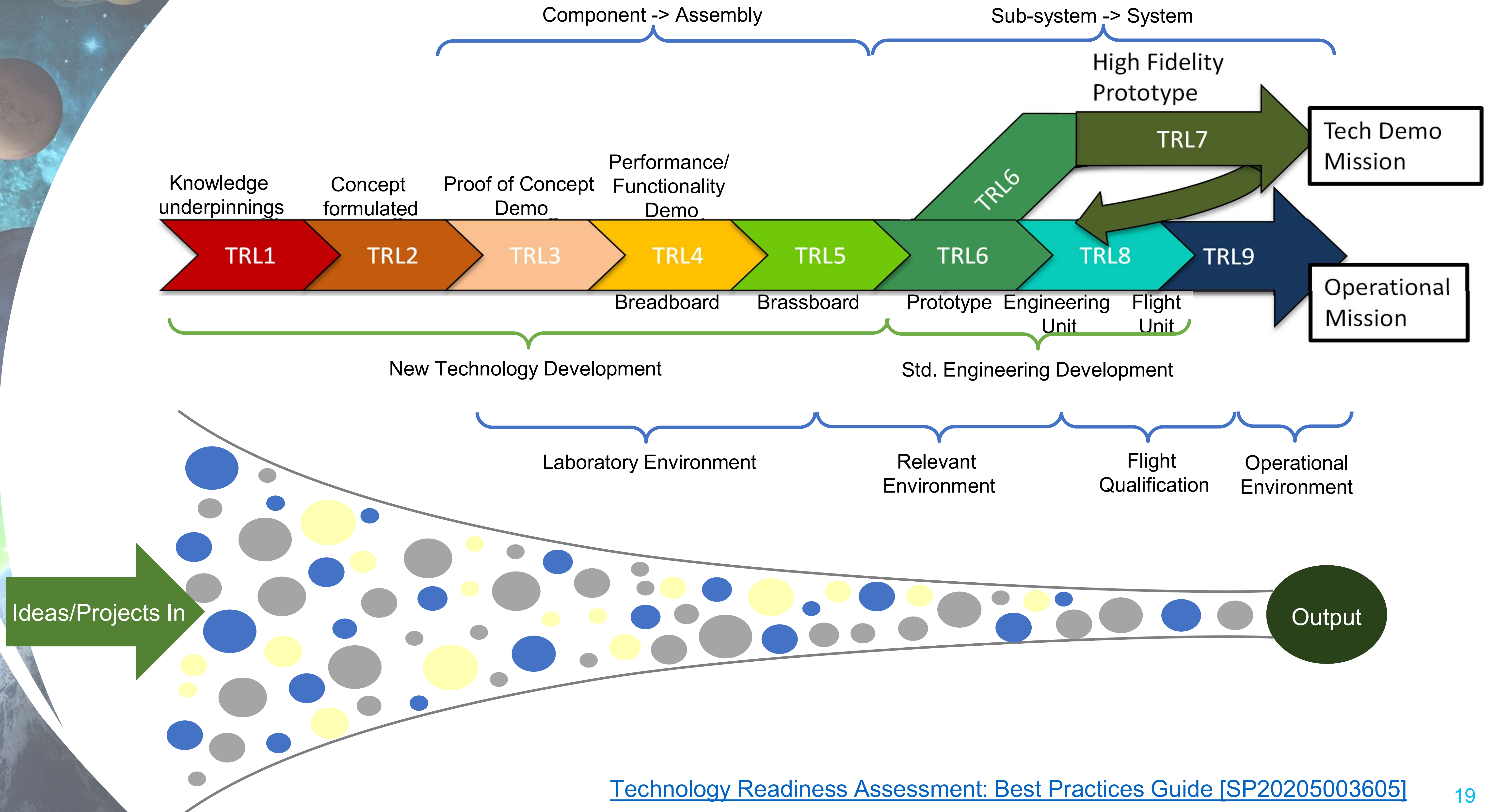
- Due to technology taking decades to develop we must think of missions beyond current decadal
- Maintain strategic technology development pipeline
- PSD funded technology is typically technology that is uniquely needed by PSD and not funded elsewhere

Technology Demonstration Opportunities

- Technology Demonstrations enable new technologies to be less risky to missions
  - It is difficult to demonstrate TRL 6 without a defined destination as part of a mission
- Seek opportunities
  - PSD mission
  - Other division and other directorate

Summarized from Comprehensive PS Tech Dev Plan

Technology Development Pipeline



Technology Readiness Assessment: Best Practices Guide [SP20205003605]

Infusion of New Technologies

- Identify what has worked so far and what has not worked
- Strive to identify new approaches to improving new technology infusion into future missions
- With the goal to improve infusion rates in the future, develop new approaches to new technology infusion into future missions
  - Investigate incentivizing including new technology
  - Socialize broadly new technology with the scientific community
  - PESTO facilitates forging technology and scientist connections through PSD Technology Showcase, AG attendance and presentations, and the PSD Yearly review
  - Work with NASA proposal evaluation panels (such as TMC) to understand new tech
  - Develop technologies that offer competitive advantage for competed AOs
  - Develop technologies that enable new science for directed flagship missions
  - Technology Readiness Assessment process that is standardized, transparent and utilized equally by community
  - PESTO forges connections with NASA centers to communicate tech needs and understand center work
  - Encourage commercialization by advocating for relevant TP and SBIR Phase III projects

Balancing Technology Development Completion and Sustainment

- Create a plan early in development process to reduce Sustainment costs
  - Plan for technology to be ready when needed
  - Design in reduced Sustainment costs
  - Consider 3rd party Sustainment
  - Identify potential commercial applications
- Identify when Tech Dev will be complete and refine that plan over time
- Maintain portfolio of instruments
- Incentivize technology for infusion
  - Communicate technology development to mission planners
  - Facilitate interactions at technical exchanges (Technology Showcase)
  - Support transition into flight projects, where applicable
  - Track infusion success stories
  - Work in collaboration with STMD to be aware of emerging new technologies

Communication

We aim to track the projects we invest in and to transparently communicate technology status to the community

Communication Paths

- Multiple potential paths for communication from NASA and to NASA, including but not limited to:
  - PESTO website, TechPort, Technology Highlights, AGs, OSDMP, Planetary Science Advisory Committee (PAC), SME studies/workshops

Communication Outreach

- Planetary Science Technology Yearly Review
  - PESTO will hold a yearly virtual review of the projects in the technology programs it manages
- PSD Technology Showcase
  - PESTO will hold an alternating year in person Technology Showcase
- Community Outreach/Accessibility – Townhalls
  - As topics arise for the PESTO solicitations, PESTO will hold Townhalls to communicate details about Programs

Summarized from Comprehensive PS Tech Dev Plan

Communication Cont.

Forge Interconnectivity and Partnerships

- Leverage and encourage technology advancement from collaborative external organizations both inside and outside NASA
- Maintain cognizance of technology in commercial and international arenas
- Identify a level engagement with outside NASA

Technology Strategy Communication

- Technology Development Plan will be published on the PESTO website
- The Technology Investment Process will be reviewed every 5 years, and the community will be engaged using the Prioritization Process previously discussed
- The results of the study/workshop for each prioritized technology will be published on the PESTO website as the results are available

Summarized from Comprehensive PS Tech Dev Plan

Diversity, Equity, Inclusion and Accessibility

- Utilize the Dual Anonymous Peer Review (DAPR) process for all programs starting 2025 (PICASSO program became DAPR in 2024)

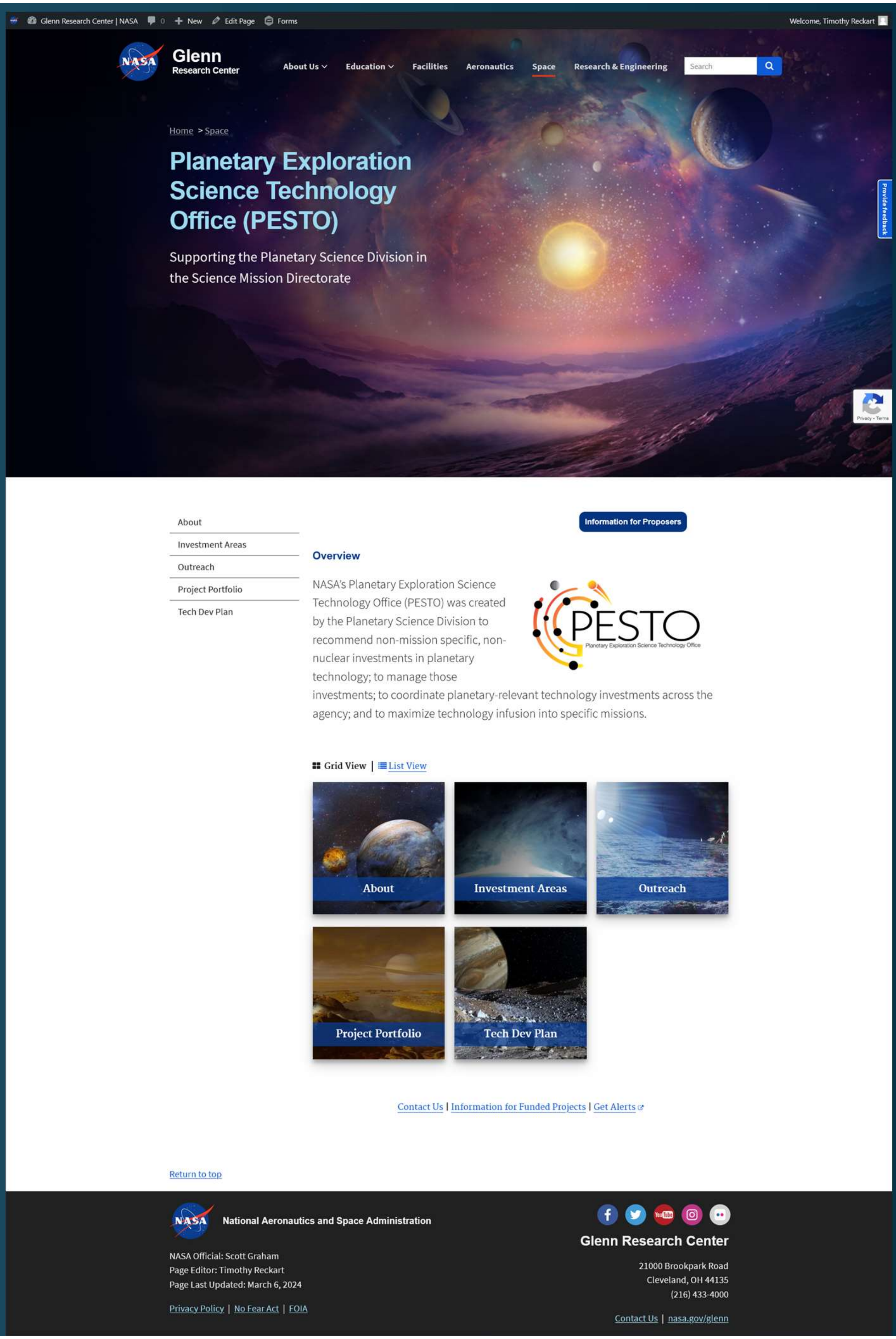
- Organize the PSD Technology Showcase to foster direct discussions between technologists, scientists, and mission managers about the technologies’ potential application to specific future missions. Activities deliberately occur around same size booths/tables to foster an equitable experience for all business/universities sizes and the showcase is open to scientists with all levels of mission concept ideas, with low registration overhead

- Present a proposal writing workshop to the community which would provide direction and information on how to write a potentially winning technology proposal, with an emphasis to support early career PIs

- Review if an inclusion plan is a fit for each program, if an inclusion plan does become required it will be rolled out gradually with preliminary notice to the community

- Attract PIs from underserved communities by communicating with a broad community base about program opportunities (via the PESTO website, PSD Technology Showcase, AG presentations and discussions, and the PSD Yearly review)

Updated PESTO Website Released!



PESTO Website

Comprehensive Technology Strategy Draft can be found at:

Feedback on Comprehensive Draft can be provided at:

PESTO Website

Technology Award Status

Outline

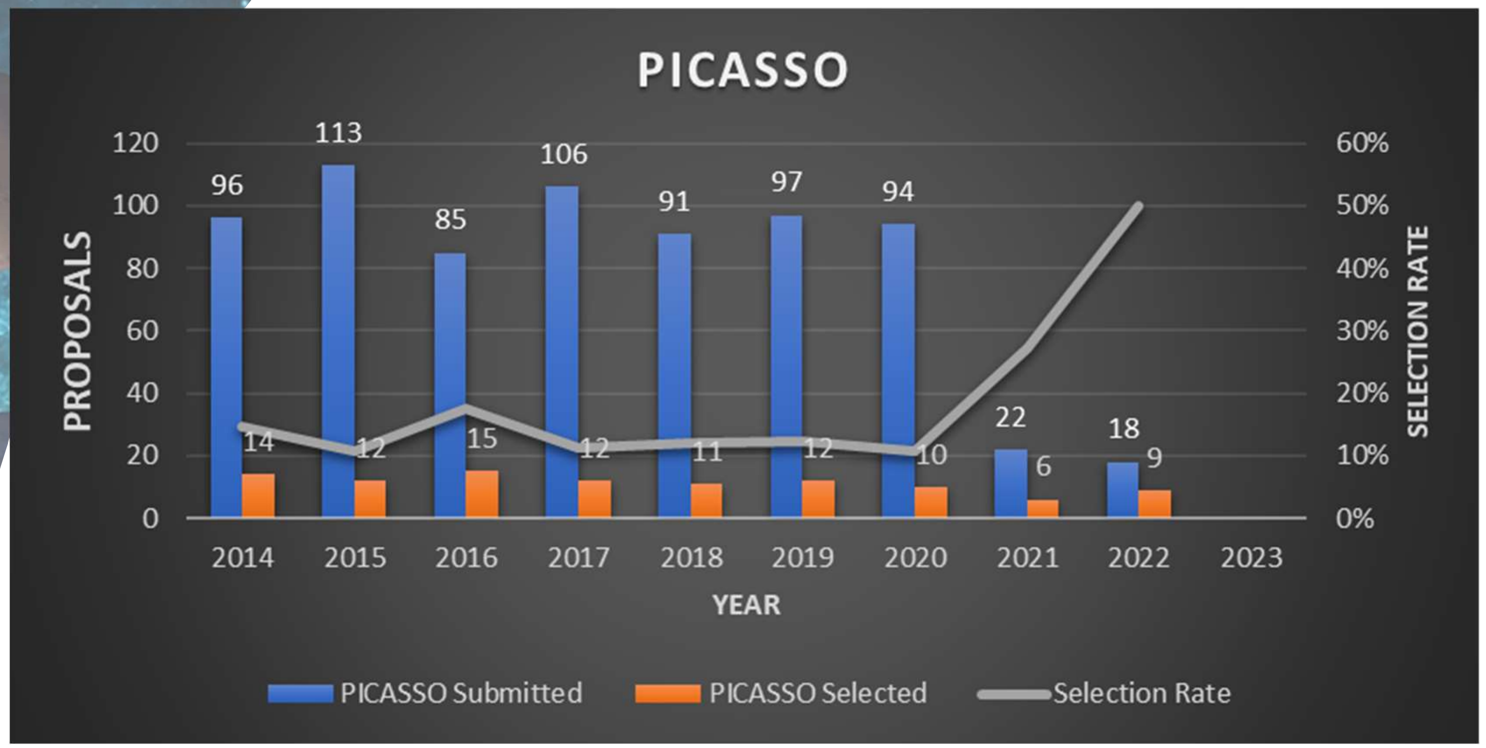
- Instrument Programs
- Platform Technology Programs

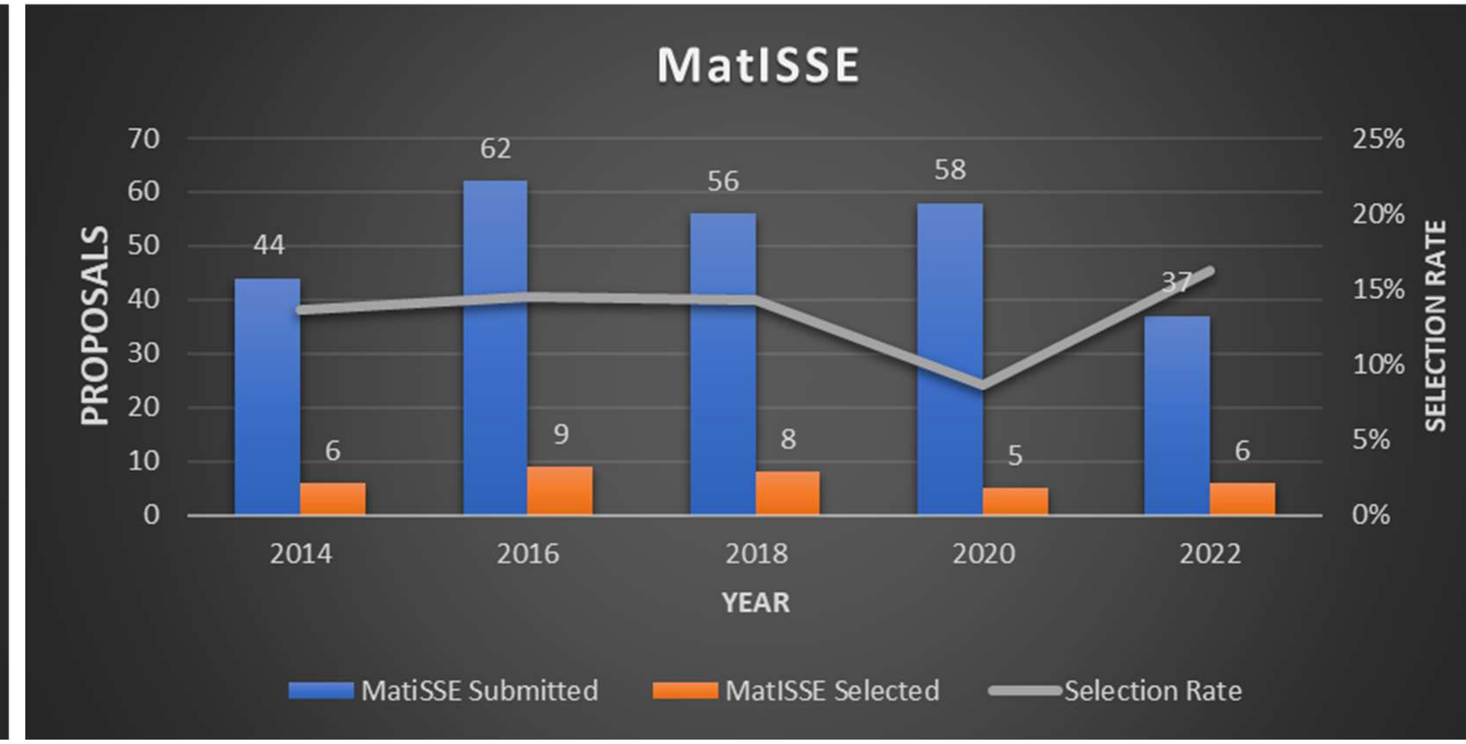
Announcing PICASSO23 and DALI23 Selections

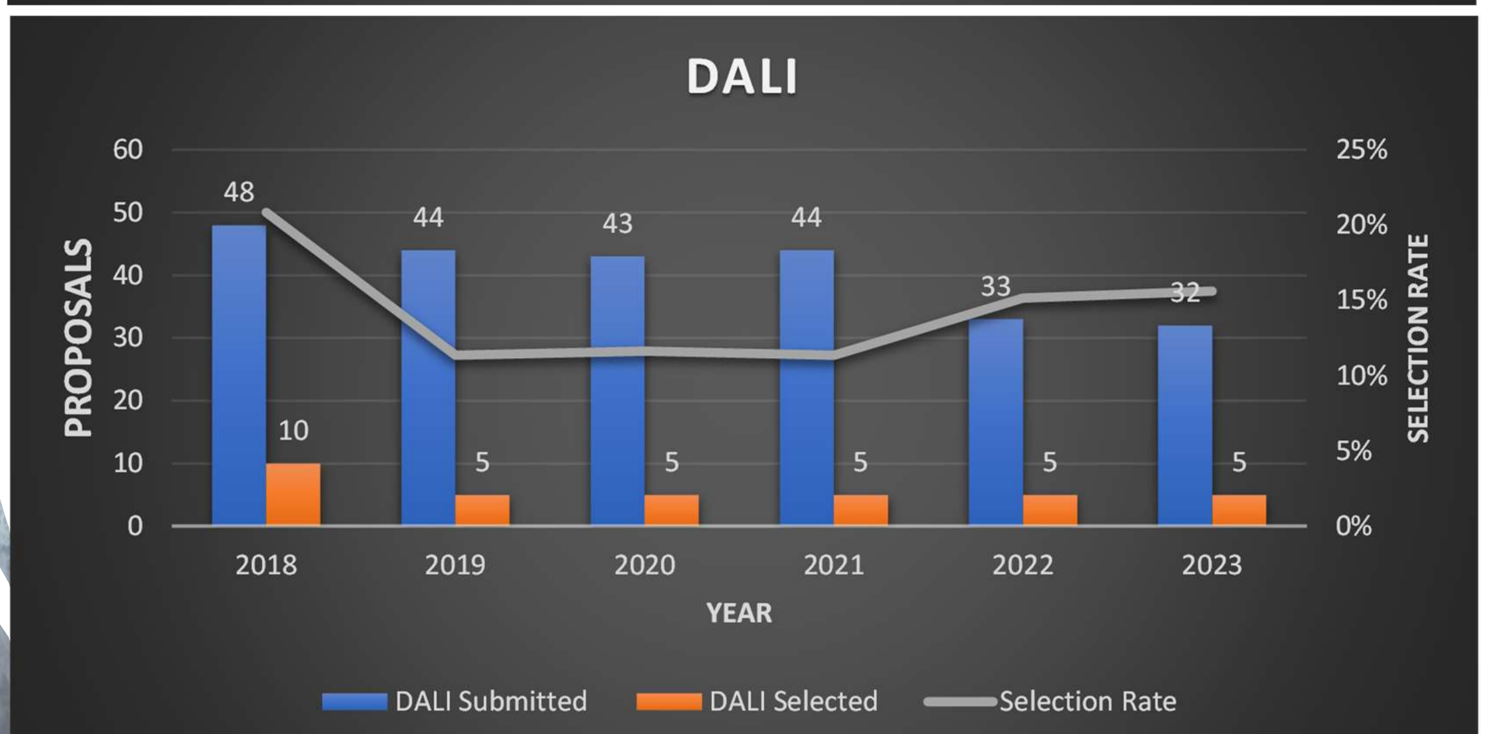
Program	PI Name	Title	Institution	Instrument Type
23-PICASSO23*	James Eshelman	Multispectral Organic Detection and Near-Infrared Exobiology Tool	Montana State University**	Raman
23-DALI23_2-0004	Stuart George	CEPS- Compact Electron Proton Spectrometer	JSC	Spectrometer
23-DALI23_2-0021	Hao Cao	A Miniaturized Low-Power Magnetometer System for Lunar Surface Observations	UCLA	Magnetometer
23-DALI23_2-0036	Jason Kriesel	Ultra-low Sample Volume Capillary Absorption Spectrometer (CAS) for Lunar Volatiles and Water Isotope Analysis	Optoknowledge Services, Inc	Spectrometer
23-DALI23_2-0040	Jeffrey Gillis-Davis	Maturation of a Compact LIBS Spectrometer for Lunar Investigations	Washington University	Spectrometer
23-DALI23_2-0016	David Stillman	Systemic Pulse Artemis Radar for Crustal Imaging (SPARCI)	SWRI	Ground- Penetrating Radar (GPR)

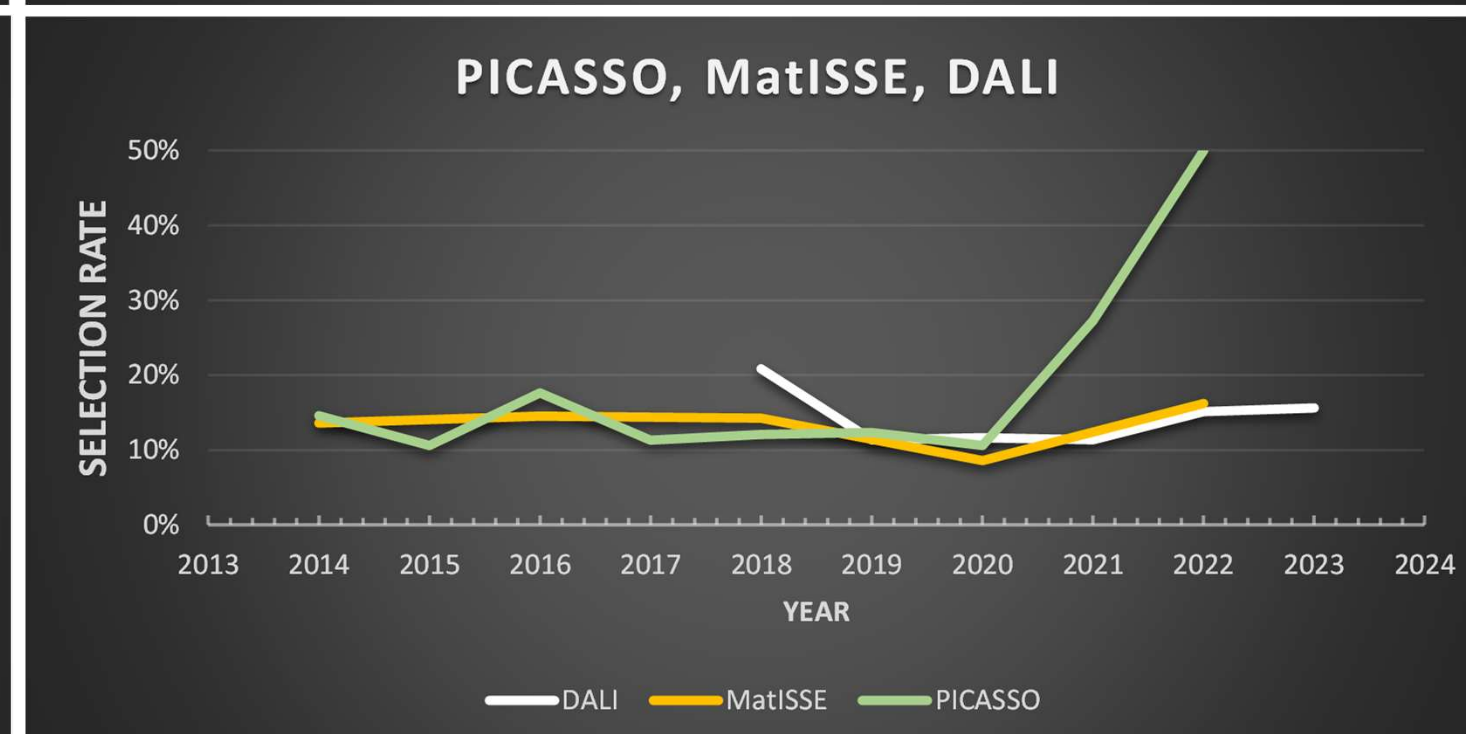
*PICASSO23 solicitation is open until March 29, 2024
**PI has changed institution and is now at Honeybee Robotics; grant is still pending
DALI23 projects will begin April 1, 2024

PICASSO*, MatISSE, DALI Statistics









*PICASSO23 solicitation is open until March 29, 2024

Platform Technology FY23 Selections – PSD Focus

NIAC Phase I Awards

- Ge-Cheng Zha/Coflow Jet
  - Mars Aerial and Ground Global Intelligent Explorer (MAGGIE)
- Steven Benner/ Foundation For Applied Molecular Evolution
  - Add-on to Large-scale Water Mining Operations on Mars to Screen for Introduced and Alien Life
- Geoffrey Landis/NASA GRC
  - Sample Return from the Surface of Venus
- Peter Cabauy/City Labs, Inc.
  - Autonomous Tritium Micropowered Sensors
- Aaswath Pattabhi Raman/UCLA
  - Electro-luminescently Cooled Zero-boil-off Propellant Depots Enabling Crewed Exploration of Mars

Managed by STMD

Entrepreneurs Challenge – Lunar Surface Payloads

- Visual-Inertial Position & Navigation for Moon / Skyline Nav AI
- Lunar Anti-Dust Microgrid Payload / Front Range
- Lunar Fuel Refinery and Exporter / Cislune
- Mote Lunar Landing Support System / Space Initiatives
- Robotic Utility Transmission Infrastructure / BlnkSpace

Platform Technology FY23 Selections – PSD Focus

SBIR (167 awards made in 2023)

- S13.01 Robotic Mobility, Manipulation and Sampling
- S13.03 Extreme Environments Technology
- S13.04 Contamination Control and Planetary Protection
- S13.05 In Situ Instruments and Instrument Components for Lunar and Planetary Science (SBIR)
- S13.07 Energy Storage for Extreme Environments

Managed by STMD

Comprehensive Technology Strategy Draft can be found at:

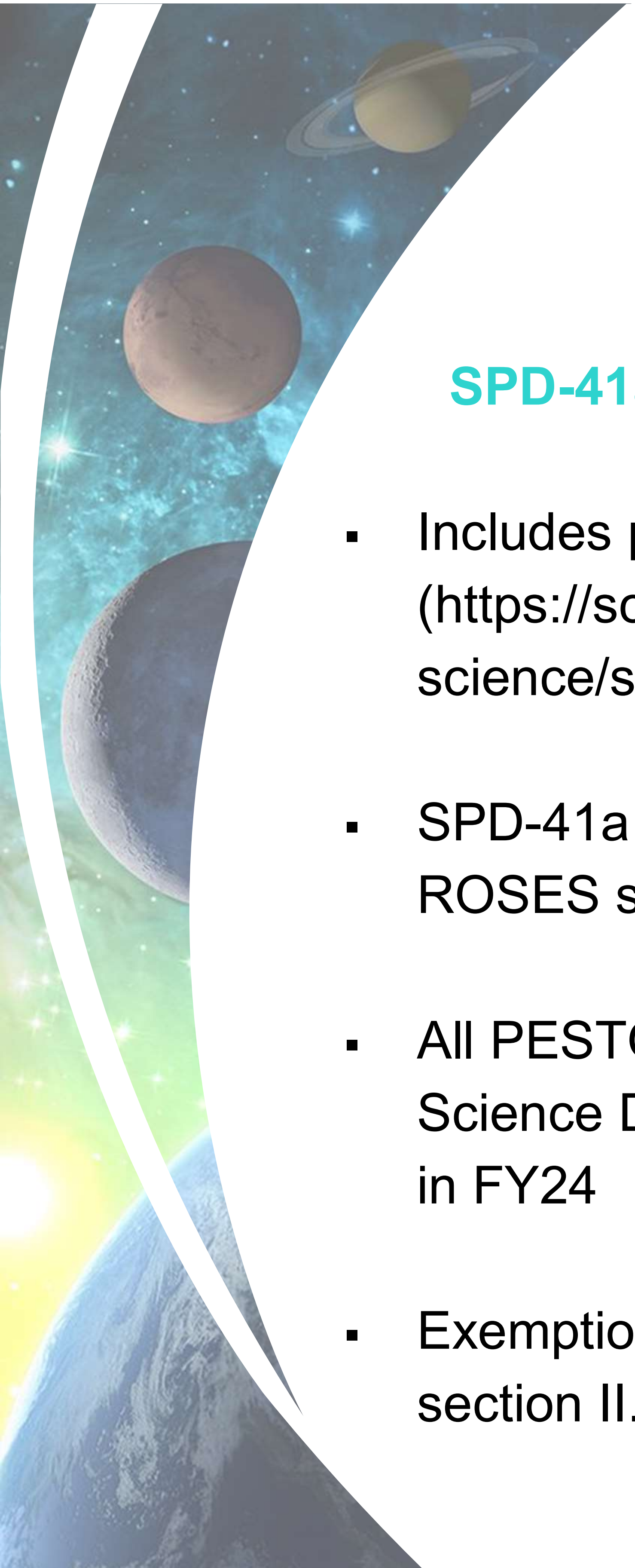
Feedback on Comprehensive Draft can be provided at:

PESTO Website

Appendix

Outline

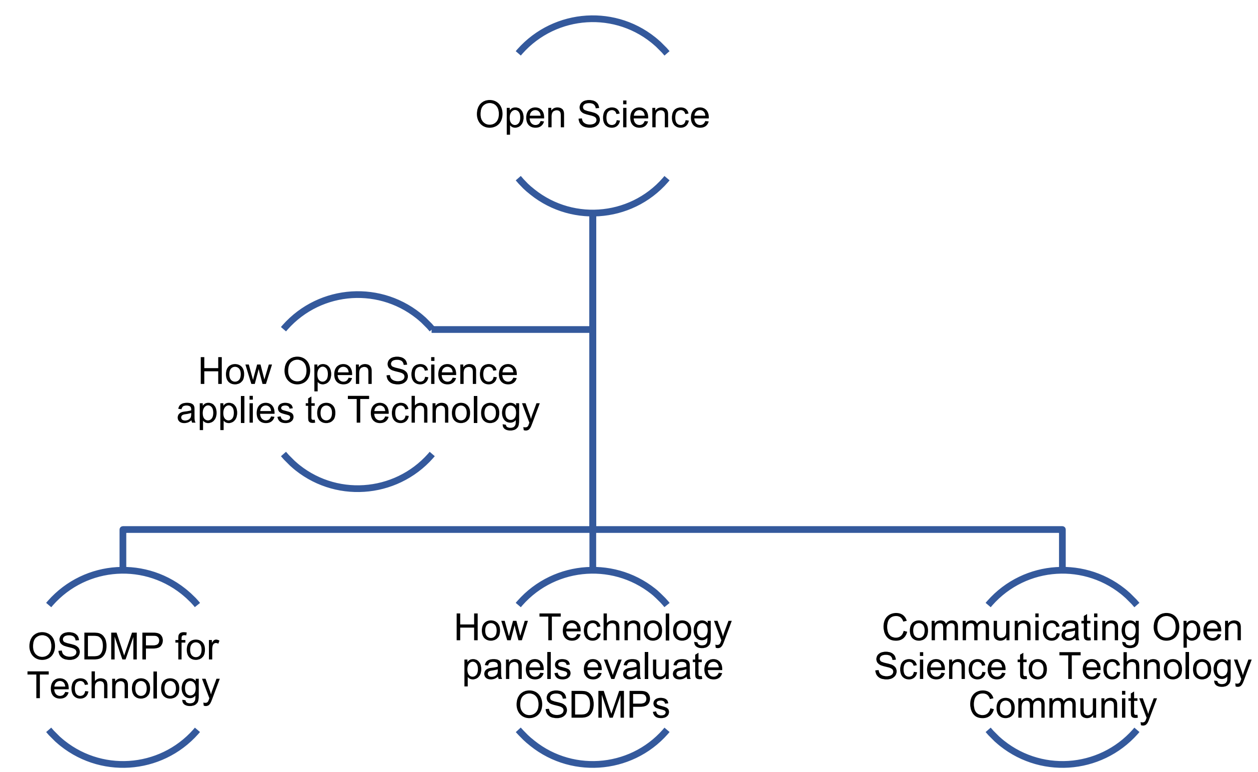
- Open Science
- Technology Readiness Level (TRL)
- References
- Funding Programs in SMD – Definitions
- Funding Programs in STMD – Definitions
- OWL Recommended Technologies



Open Science

SPD-41a applies to all SMD technology programs

- Includes publications, data and software (https://science.nasa.gov/researchers/open-science/science-information-policy/)
- SPD-41a pulls together all previous requirements from ROSES solicitation, Bayh-Dole Act and others
- All PESTO program proposals will have Open Science Data Management Plan (OSDMP) starting in FY24
- Exemptions to SPD-41a can be found at SPD41a section II. C. (https://science.nasa.gov/spd-41/)



TRL

Communication of Technology Readiness Levels (TRL)

- TRL is used to communicate technology status
- PESTO Technology development covers idea generation through mission adoption (TRL 6 by PDR)
- It is important that technologies are evaluated in a standardized and transparent process that is utilized equally by community
  - Guidance provided in [Technology Readiness Assessment: Best Practices Guide [SP20205003605]]()
  - Technology developer determines TRL through TRA process to determine program eligibility
    - Low TRL [1-3]: more speculative, more awards/investments, typically lower resources to advance
    - Mid TRL [4-6]: most promising technologies developed with fewer awards, typically larger awards
  - Communicating Advancement Degree of Difficulty (AD^2) to stakeholders (programs, mission planners, and the community) to ensure technology has the resources available to develop on schedule ([NASA Systems Engineering Handbook Rev 2]())
    - AD^2 identifies how difficult it is for technology to move from one TRL to the next TRL
- Technology Development Goal is Mission Infusion
  - Technologist encouraged to understand mission opportunities for their technologies to maximize infusion success

References

- SMD: https://science.nasa.gov/technology/
- PSD: https://science.nasa.gov/planetary-science/
- STMD: https://www.nasa.gov/space-technology-mission-directorate/
- Moon to Mars: https://www.nasa.gov/moontomarsarchitecture/
- Artemis: https://www.nasa.gov/humans-in-space/artemis/
- NASA Taxonomy: https://www.nasa.gov/otps/2020-nasa-technology-taxonomy/
- Origins Worlds and Life Decadal Survey and Mission Concept Studies https://science.nasa.gov/planetary-science/resources/documents/
- Lunar and Planetary Institute: https://www.lpi.usra.edu/
- NASA Analysis and Assessment Groups: https://science.nasa.gov/science-committee/subcommittees/nac-planetary-science-subcommittee/analysis-groups/
- NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES): https://nspires.nasaprs.com/external/
- Templates for ROSES: https://science.nasa.gov/researchers/templates-planetary-science-division-appendix-c-roses-proposals
- TechPort: https://techport.nasa.gov/home
- Open Science Initiative: https://science.nasa.gov/researchers/open-science/science-information-policy/
- Technology Readiness Assessment: Best Practices Guide [SP20205003605]
- NASA Systems Engineering Handbook Rev 2 (Advancement Degree of Difficulty)
- Mars Exploration Future Plan https://mars.nasa.gov/files/mep/Mars_Exploration_Program_Future_Plan.pdf
- SMD Program Officers: https://science.nasa.gov/researchers/sara/program-officers-list/
- PESTO Contacts
- Senior Advisor for Research and Analysis (SARA): sara@nasa.gov

Funding Programs in SMD – Definitions

Planetary Science Division

- EPSCOR: Established Program to Stimulate Competitive Research
- MatISSE: Maturation of Instruments for Solar System Exploration
- PICASSO: Planetary Instrument Concepts for the Advancement of Solar System Observations
- PSTAR: Planetary Science and Technology from Analog Research
- RPS: Radioisotope Power Systems
- MEP: Mars Exploration Program

Exploration Science Strategy Integration Office (ESSIO)

- DALI: Development and Advancement of Lunar Instrumentation
- ADI: Artemis Deployed Instruments
- PRISM: Payloads and Research Investigations on the Surface of the Moon
- SALSA: Stand-Alone Landing Site-Agnostic
- LTVI: Lunar Terrain Vehicle Instruments Program

Earth Science Division

- ACT: Advanced Component Technology
- DSI: Decadal Survey Incubation
- IIP-ICD: Instrument Incubator Program - Instrument Concept Demonstration
- IIP-IDD: Instrument Incubator Program - Instrument Concept Demonstration
- InVEST: In-Space Validation of Earth Science Technologies
- SLI-T: The Sustainable Land Imaging – Technology

Heliophysics Division

- H-FORT: Heliophysics Flight Opportunities for Science and Technology
- H-FOS: Heliophysics Flight Opportunities Studies
- HITS: Heliophysics Innovation in Technology and Science
- H-LCAS: Heliophysics Low-Cost Access to Space
- H-TIDeS: Heliophysics Technology and Instrument Development for Science
- H-USPI: Heliophysics U.S. Participating Investigator

Astrophysics Division

- APRA: Astrophysics Research and Analysis
- HWO: Astrophysics Habitable Worlds Observatory (HWO) Systems Technologies program
- Pioneers: Pioneers Astrophysics and sub-orbital science investigations program
- RTF: Nancy Grace Roman Technology Fellowship Program
- SAT: Strategic Astrophysics Technology

Cross Divisional

- FINESST: Future Investigators in NASA Earth and Space Science and Technology
- EPSCOR: Established Program to Stimulate Competitive Research

Funding Programs in STMD – Definitions

- ACO: Announcement of Collaborative Opportunity
- CIF: Center Innovation Fund
- ECI: Early Career Initiative
- FO: Flight Opportunities
- GCD: Game Changing Development
- NIAC: NASA Innovation Advanced Concepts
- Prizes, Challenges & Crowdsource
- TP: Tipping Point
- SBIR: Small Business Innovation Research
- STRG: Space Technology Research Grants
- STTR: Small Business Technology Transfer
- Tech Demo Miss: Technology Demonstration Missions
- Projects
    - ESM: Entry Systems Modeling
    - GRAM: Global Reference Atmospheric Model

TRL – Technology Readiness Level