National Aeronautics and Space Administration

NASA

EXPLORE SOLAR SYSTEM & BEYOND

Comprehensive Planetary Science Technology Development Plan

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Planetary Exploration Science Technology Office (PESTO)

Science Mission Directorate

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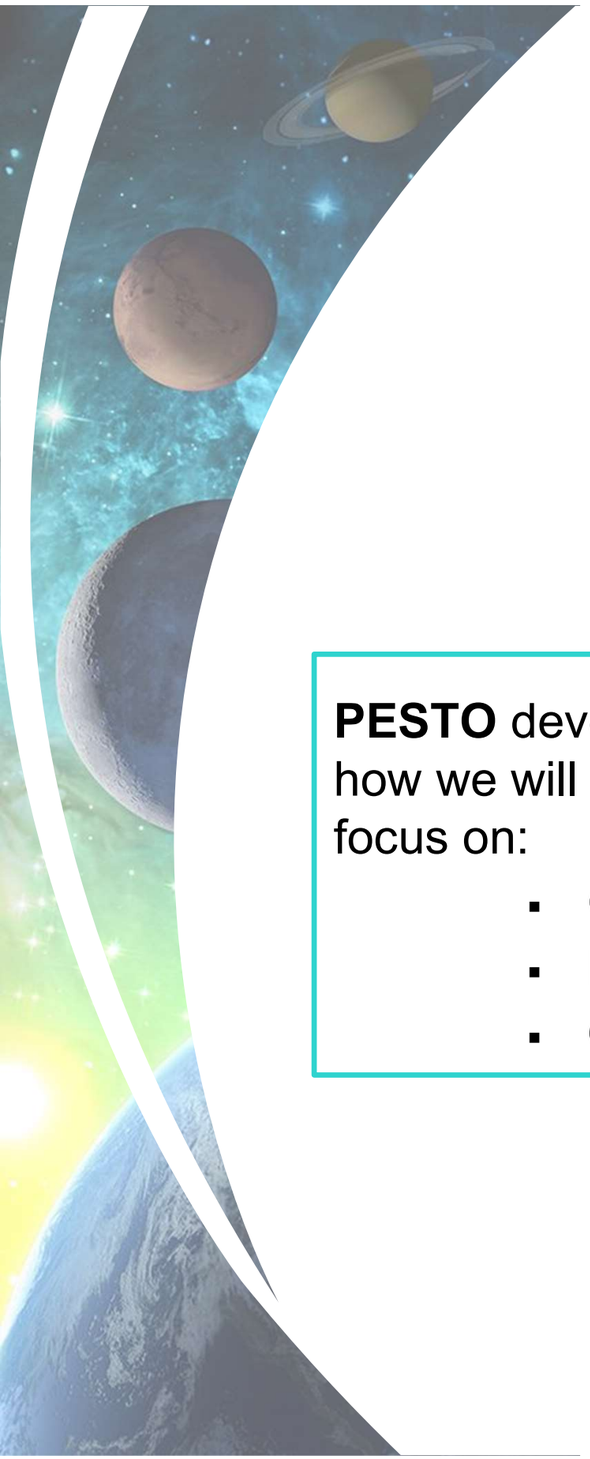
PESTO Planetary Exploration Science Technology Office



Planetary Science Technology Development Plan

Vision

PESTO developed a comprehensive Planetary Science Technology Development strategy to outline how we will create widely available advanced capabilities to explore the solar system. The Plan will focus on:

- Gaining new understandings that answer priority science questions
- Reaching new destinations
- Operating in new environments in new ways

PESTO
Planetary Exploration Science Technology Office

Planetary Science Technology Development Plan

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PESTO
Planetary Exploration Science Technology Office

Chapter 1 – Overview

Outline

- Goals and Objectives
- Stakeholders
- PESTO Charter and Purpose
- Organizational Chart

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Planetary Science Technology Strategic Goals & Objectives

1. Invest in innovative Technology Development for Planetary Science

a) Prioritize technology development that enables new and/or enhanced Science based on guidance from the Decadal Survey and direction for the next decade.

b) Enhance our focus on high intellectual risk/high impact technology investments.

c) Execute a balanced technology development portfolio that grows new science enabling technology, matures technology to infusion, and maintains strategic technology capabilities until they can be transitioned to missions or other funding.

d) Recommend technology investments needed, for benefit of PSD, within NASA (e.g., STMD, ESDMD, and SMD) and leverage these investments.

2. Enable Technology Maturation for Planetary Science Missions

a) Facilitate technology development from prototype to mission by providing funding opportunities and science collaboration opportunities.

b) Create destination focused solicitations and specific mission concepts that feed into unique PSD mission needs.

The NASA Planetary Science strategic objective is to advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.

Planetary Science Technology Strategic Goals & Objectives - cont'd

3. Forge Interconnectivity and Partnerships

a) Leverage and encourage technology advancement from collaborative external organizations both inside and outside NASA, including commercial and non-space industries to meet the future Planetary Science needs.

b) Seek technology development input from agency priorities such as Moon to Mars and from both inside and outside of NASA.

4. Communicate Planetary Science Technology Status and Plans

a) Oversee Planetary Science technology development projects, including needs, goals, plans, solicitations, risks, schedule and funding.

b) Ensure the Planetary Science technology programs, goals, plans, budget, solicitations, selection strategies and community contributions are shared transparently both inside and outside NASA.

c) Ensure technology development data are accessible to all (consistent with SPD41).

d) Encourage innovation and entrepreneurship.

The NASA Planetary Science strategic objective is to advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.

Planetary Science Technology Stakeholders

Stakeholders for Planetary Science Technology Development Plan are:

- SMD
  - PSD
  - ESSIO

Beneficiaries for Planetary Science Technology Development Plan are:

- Within NASA
  - SMD
  - STMD
  - ESDMD
- Outside NASA
  - The science community
  - The Assessment Groups (AGs)
  - Department of Energy
  - National Science Foundation

PESTO Charter and Purpose

Planetary Exploration Science Technology Office (PESTO) is a NASA Headquarters office managed at GRC to:

Recommend technology investment strategy for future planetary science missions, including

- Instruments
- Spacecraft Technology
- Mission Support Technology

Manage planetary science technology development (non-mission specific, non-nuclear, competitively funded, TRL<6)

- Write solicitations (PICASSO, DALI, MatISSE, etc…)
- Conduct review panels

Coordinate well-rounded, novel/high impact portfolio of planetary science-relevant technology needs & opportunities

- Within NASA: PSD, ESSIO & SMD and with STMD & ESDMD
- Within science community: outreach and partner with academic, small business, and technology groups

Promote technology infusion and technology pipeline

- Infusion starts before solicitations are written, ends with mission adoption
- Study infusion successes and obstacles; recommend changes

Planetary Exploration Science Technology Office

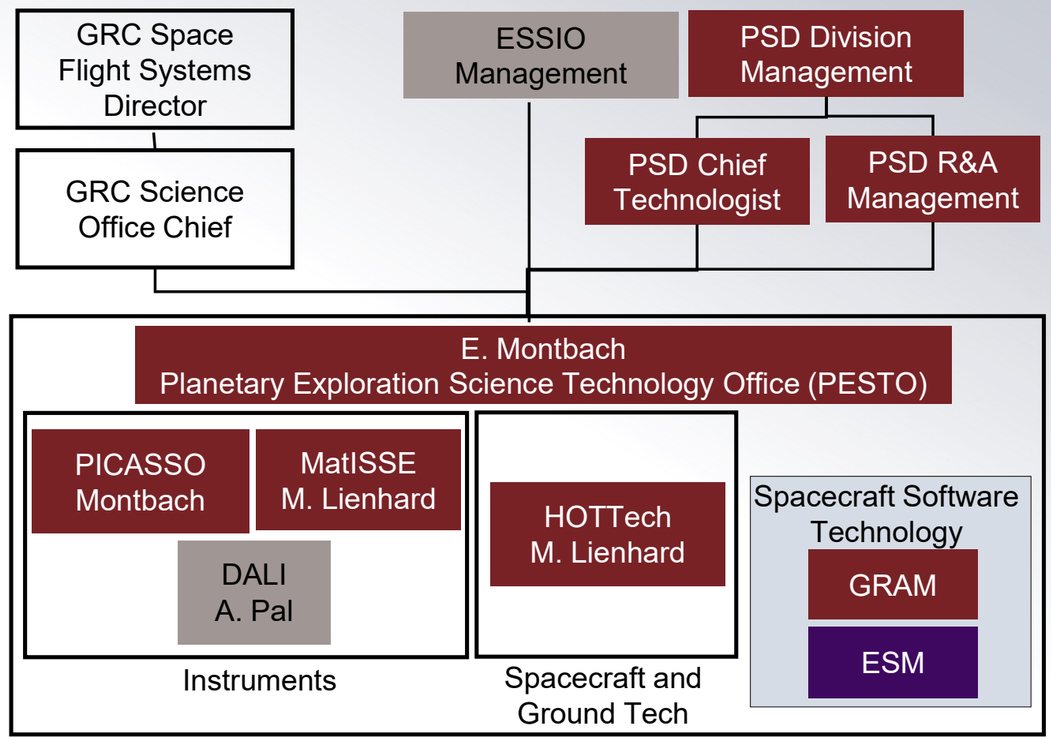
Recent Technology Infusions

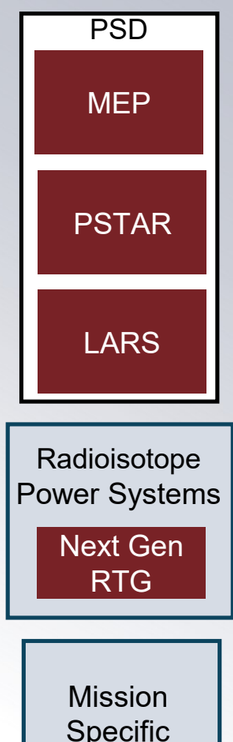
- Psyche: Gamma-Ray and Neutron Spectrometer (GRNS) — MatISSE
- Europa Clipper: Mapping Imaging Spectrometer for Europa (MISE) — MatISSE
- Interstellar Mapping and Acceleration Probe (IMAP) (HPD Mission): Interstellar Dust Experiment (IDEX) — MatISSE
- Dragonfly Gamma Ray Neutron Spectrometer (DraGNS) — MatISSE
- PRISM selected: Dating an Irregular Mare Patch with a Lunar Explorer (DIMPLE) — DALI
- Instruments for Artemis Astronaut Deployment selected: Lunar Environment Monitoring Station (LEMS) — MatISSE
- Lunar Trailblazer's High-resolution Volatiles and Minerals Moon Mapper (HVM3) — DALI
- MatISSE

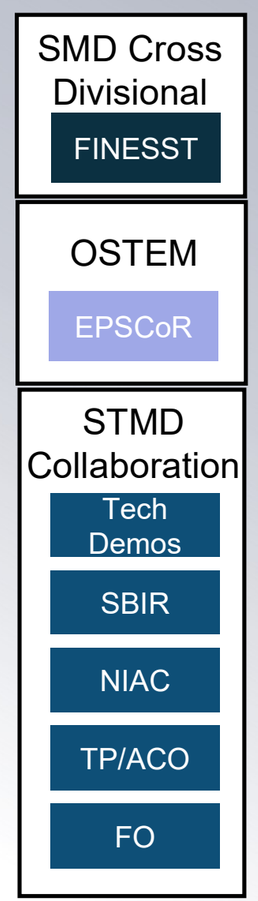
PESTO is a NASA Headquarters office managed at GRC to:

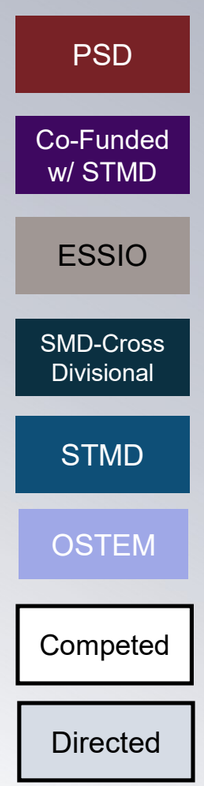
- Recommend Strategic Tech Investments to PSD
- Manage PSD Technology Programs
- Coordinate PSD Technology Development Investments
- Promote PSD Technology Infusion

PESTO Structure and Planetary Tech Dev Programs









Chapter 2 – Technology Priorities

Outline

- Planetary Science Technology Development Strategy
- Relationship Among Funding Plans
- Strategy for Developing and Infusing Technology
- Funding Programs Available
- How Technology Investments Identified
- Prioritized Technology Focus Areas & Overlap with OWL
- Decision to Invest
- Prioritization Process

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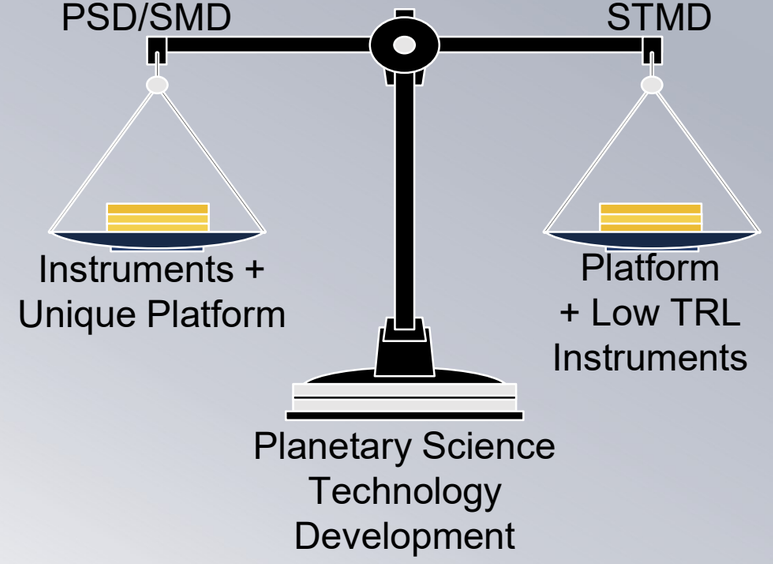
NASA Directorate Interactions

SMD / STMD

- SMD is focused on technology development needed for future science missions, *including science instrument development (TRL1-6) and platform technologies (TRL1-6) unique to science applications*
- STMD focuses on ubiquitous platform technologies (TRL 1-7) and includes instrument investments (TRL1-3)
- SMD provides desired SMD Technology Priorities to STMD and invests across STMD programs
- Coordination between the two Mission Directorates is managed by SMD and STMD Chief Technologists
- STMD is in the process of reformulating their technology development structure



SMD / ESDMD

- Technology Coordination & Integration Group (TCIG)
  - Cross Directorate working group with representatives from each directorate
  - SMD Chief Technologist represents SMD

Relationship Among SMD Divisions

Technology Federation

- PSD is a division within 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
- While meeting with the Technology Federation, the division Technology Offices
  - Identify SMD Technology Priorities that are recommended for STMD investment
  - Discuss interactions and overlap between Technology Offices
  - Develop overlapping division Technology Plans for specific focus areas
- The Technology Federation produces unified SMD Technology Plans that streamline and focus investment between divisions within SMD and between SMD and STMD
  - The Chief Technologist of SMD will coordinate with their counterpart in STMD to provide SMD's technology development needs

Technology Development Coordination

- PESTO will track investments in relevant work throughout the Agency, including Planetary Science missions; the Earth Science, Heliophysics, and Astrophysics divisions and the Space Technology, Exploration Systems Development, Space Operations, and Aeronautics Mission Directorates
- PESTO will maintain awareness of relevant work in industry and academia and other government agencies
- The PESTO Manager is the SMD Small Business Innovative Research (SBIR) Planetary Science Topic Manager and will ensure strategic continuity for investments with the Planetary Science Technology Strategy
- PESTO will provide technical need statements to other organizations (such as programs in STMD) to help influence external investments as appropriate
- PESTO will maintain staff that are cognizant of mission needs for technology areas, who will represent those needs to partnering organizations and help develop technology project requirements

PS Strategy for Developing and Infusing Technology

Developing Technology (TRL ≤ 6)

PICASSO, MatISSE, DALI, SMD Cross-Cutting

NIAC, SBIR, ECI, CIF, FO, Prizes & Challenges

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

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

HOTTech, COLDTech, Potential Future Programs

Technology Demonstrations enable new technologies to be less risky to missions

- Further development through potential paths to maturing technology 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 technology and scientist connections through events like Technology Showcase
- Investigate incentives for including new tech
- Develop TRA process that is standardized, transparent and utilized by community
- Work with NASA proposal panels to ensure new tech is understood

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

Other Potential Technology Success

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

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

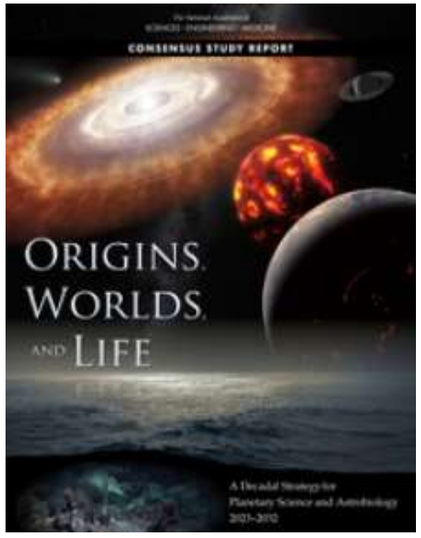
PESTO discussions with community about technology needs and goals

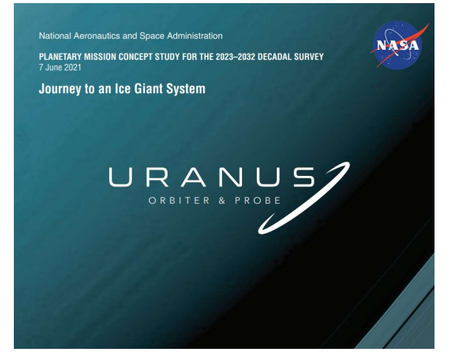
Planetary Science Discussions

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 Acquisition and Handling

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 Platforms
- Subsurface Access**

Higher-efficiency power conversion technology for radioisotope system

Development typically occurs with:

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

- 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

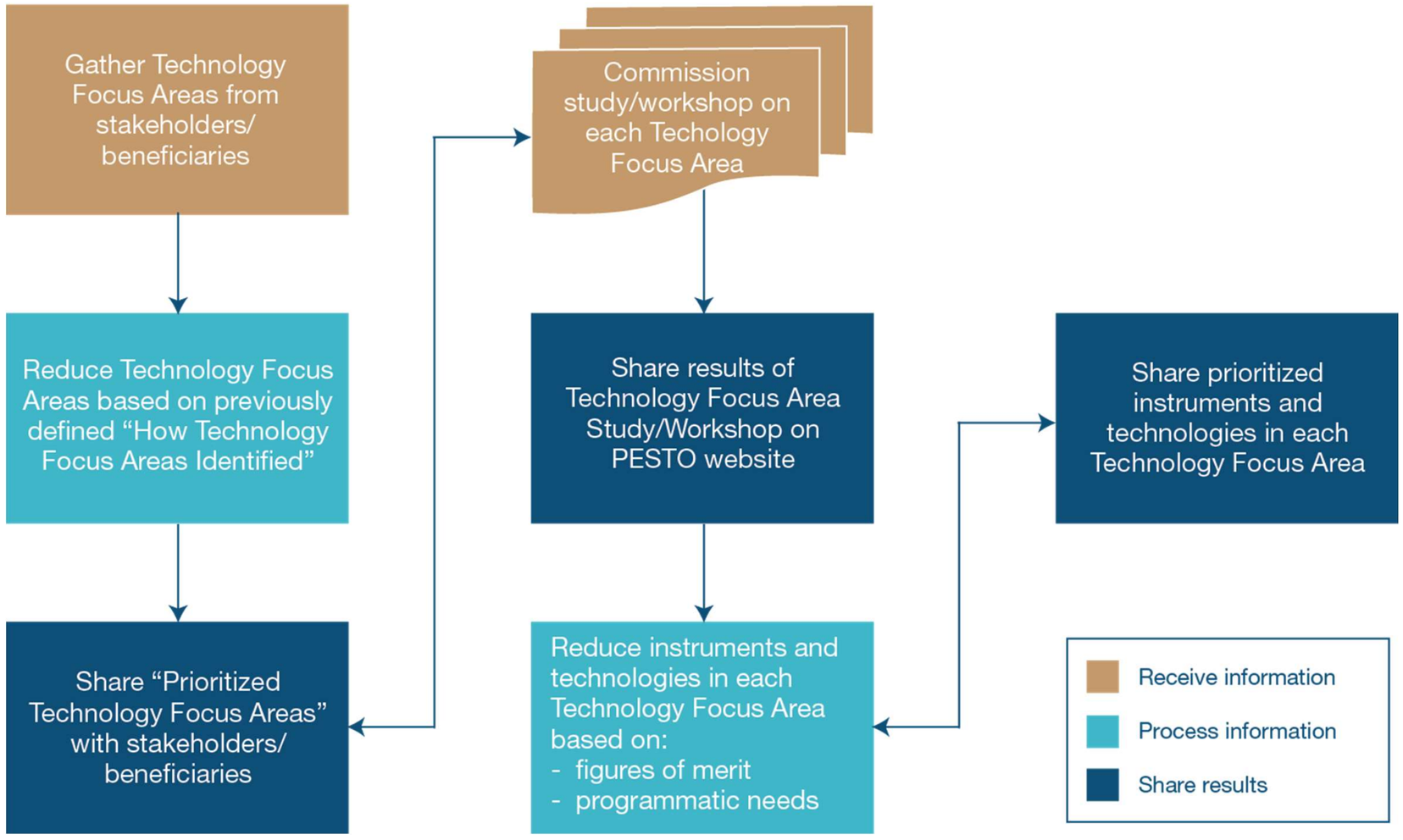
Investment Process

- 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



Chapter 3 – Current Technology Status

Outline

- Instrument Programs
- Vehicle Programs
- Directed Investments

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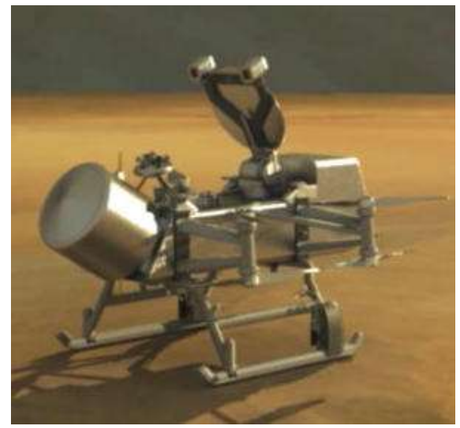
Instrument Programs

New spacecraft-based instrument that enhance or enable scientific return

- PICASSO -
  - All destination in solar system except earth and sun
  - Enter TRL 1-3; Advance TRL at least 1 level
  - Solicited yearly, NoDD and DAPR Program
  - Typical awards are $1M for 3 years. PY'23 budget $11M



NASA Dragonfly:
DraMS (mass spectrometer) and DraGNS (Gamma-Ray and Neutron Spectrometer) Instruments have heritage from MatISSE

- MatISSE -
  - All destination in solar system except Earth, Sun, and Moon
  - Enter TRL ≥ 4; Advance TRL at least 1 level
  - Solicited every EVEN year ('20,'22,'24)
  - Typical awards are $1M/year for 3 years. PY'23 budget $7M

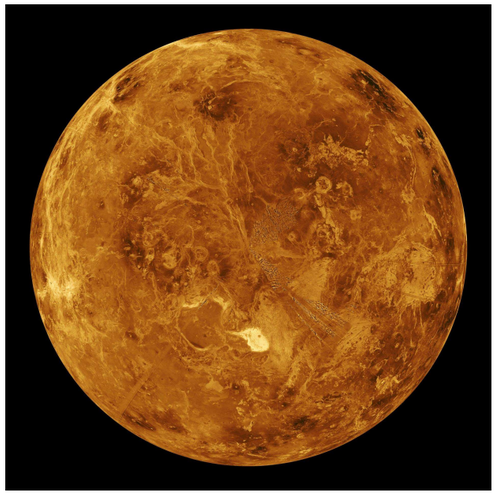
- DALI -
  - For lunar missions including expected commercial ventures and NASA's Artemis Program
  - Enter TRL ≥ 4; Advance TRL at least 1 level
  - Solicited yearly
  - Typical awards are $1M/year for 3 years. PY'23 budget $25M

Vehicle Technology Programs

New spacecraft-based instrument components and systems that would enhance or enable the scientific return

- COLDTech
  - Development of spacecraft-based technology for surface and subsurface exploration of ocean worlds such as Europa and Enceladus
  - Autonomy for landed operations, technology to enable communication through many kilometers of ice thickness; and radiation-hard digital devices
  - COLDTech was solicited in ROSES 2020 (11 funded tasks)

- HOTTech
  - Development of technologies for the robotic exploration of high-temperature environments such as the Venus surface, Mercury, or the deep atmosphere of Gas Giants
  - Platform technologies targeted for development include electronics, memory, and passive electronic devices, radio frequency transmitters, power generation, power storage, actuators, and sensors
  - The HOTTech program ran competitive solicitations in ROSES 2016 (12 funded tasks*) and ROSES 2021 (8 funded tasks)



*Tasks = projects

Vehicle Technology Programs, cont.

- PSTAR
  - Testing and application of technologies for remote searches for, and identification of, life and life-related chemistry in extreme environments (including lunar and planetary surfaces)
  - These technologies include, but are not limited to:
    - Sample acquisition and handling techniques
    - Sample manipulation
    - The use of mobile science platforms
    - Techniques for autonomous operations
    - Self-contained deployment systems
    - Intelligent systems and human/robotic interfaces
    - Communication and navigation systems
    - Instrument packages
  - (Technology development is not required in PSTAR and only makes up a small percentage of the portfolio)

Directed Investment

Global Reference Atmospheric Model (GRAM)

- Develops latest generalized planetary atmosphere models that can be used for scientific analysis and mission planning
- GRAM is used by many Entry, Descent, and Landing and Aerocapture proposals, and is also used by active flight/development projects
- Funded by SMD

Entry Systems Modeling project (ESM)

- Develops mission-focused models and simulation tools that improve performance, reduce risk, and enable new capabilities for planetary entry, descent, and landing (EDL) across the Solar System
- Modeling products resulting from ESM activities have been infused into NASA's spaceflight missions that require EDL
- Jointly funded by STMD/SMD

Chapter 4 – Technology Development and Infusion Strategy

Outline

- Instrument Heritage Study
- Technology Infusion Definitions
- Near, Mid, Far Developments
- Technology Development Pipeline
- Infusion of New Technologies
- Technology Demonstration Opportunities

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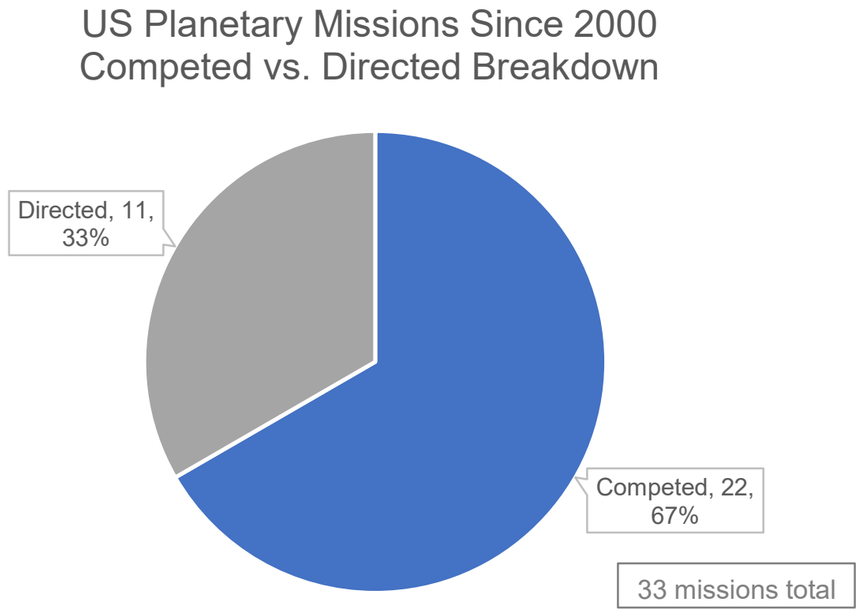
Instrument Heritage Study

Technology infusion to missions was evaluated in detail as part of the “Planetary Science Instrument Heritage Study” in 2019 and the results can be found on the PESTO website

- The results shown are based on email responses from 65 of the 90 PSD instrument PIs since 2000, supplemented with information from CADRe and public sources
  - Total of 126 US planetary instruments flown since 2000
    - Instruments flew on 33 US missions and 4 non-US missions
    - US missions included 23 competed, 11 directed



Instrument Heritage Study, cont.

- Aerospace and PESTO has performed a thorough investigation of NASA planetary instruments launched since 2000 including: funding, heritage, instrument types, destinations, and management organizations
- For PSD, the destination with the greatest number of missions/instruments has been Mars, followed by the moon and asteroids, while the inner and outer planets have been studied the least
- Organizationally, there is a good balance of in-house/out-of-house development to make for successful NASA missions
  - Instrument PIs and PMs are more likely to come from different organizations
- The most common instrument types are optical imagers
  - Often the first step in reconnaissance and good for science and public outreach
- Instruments were slightly more likely to use development funding (from any source) than not
  - Others relied on heritage of instruments that did
  - For 32 of the total 126 instruments development funding information is still unknown
- Most planetary instruments tend to draw heritage from other planetary instruments
  - From other mission types, heliophysics instrument heritage is the most common, followed by earth science and then astrophysics

Technology Infusion - Definitions

For the purposes of the Technology Development plan, infusion is defined as:

- Infusion - Technology has been selected for use on a flight mission or ground system and is necessary for mission success. The objective for the technology is to accomplish the mission.
- Proposed Infusion - Technology was selected for use on a flight mission as a critical component needed for mission success, but the proposed mission was not (or has not yet been) selected.
- Demonstration - Technology has been included on a flight mission or ground system but is NOT necessary for mission success. The objective for the technology is to demonstrate the capability of the technology.
- Transition - Technology has been selected for additional funding to continue technology development via another program or organization; e.g., a project originally funded via PSD's PICASSO Program becomes a project funded via the MatISSE Program. Planned Future of Technology Infusion

Near, Mid, Far Developments

- Due to technology taking decades to develop we must think of missions beyond current decadal

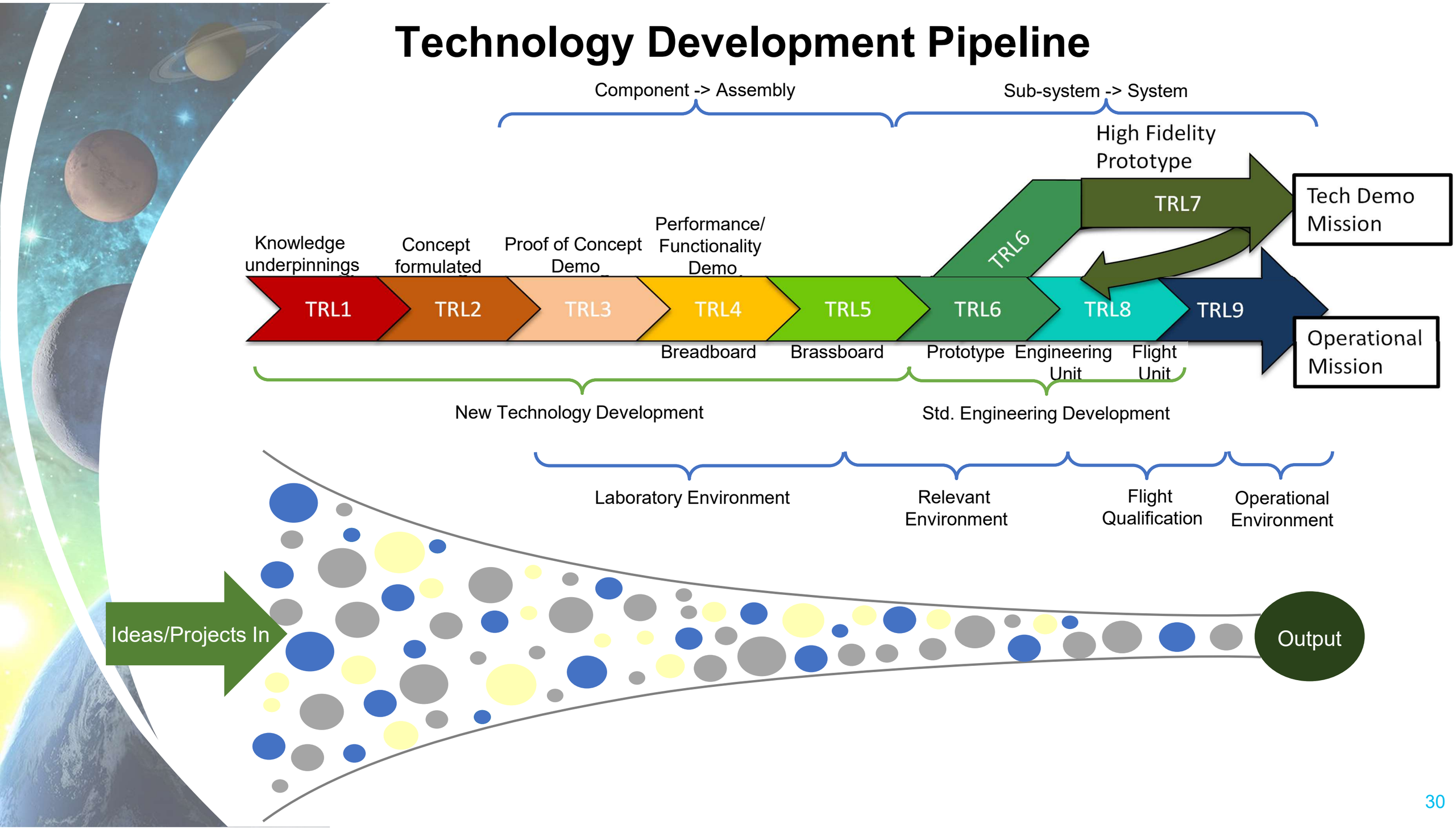
- Strategic technology development pipeline
  - Larger percentage of early TRL to fill the pipeline
  - Amount of high intellectual risk/high impact varies by program
  - This type of development pipeline is currently utilized for instrument development and has been historically used for platform technology development through heritage programs
    - Potential future focused programs for platform technologies will be considered going forward

- PSD funded technology is typically technology that is uniquely needed by PSD and not funded elsewhere
  - Leverage developments from other directorates, divisions and government agencies
  - Leverage opportunities for public/private partnerships where there is mutual benefit

	Awards Since 2018	Average / Solicitation
PICASSO	48	9.6
MatISSE	19	6.3
DALI	35	5.8
Total	102	

Example Instrument Development Pipeline

Technology Development Pipeline



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

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
- Potential paths to maturing technology to TRL 6 include:
  - Additional funding: MatISSE, DALI
  - Strategic directed technology funding
  - Suborbital experiments (STMD Flight Opportunities)
  - Missions with CLPS, ESTO, HESTO or Aeronautics, where applicable

Opportunities for Technology Demonstrations

- Add-on Tech Demo for PSD Directed/Flagship
- Add-on Tech Demo for Discovery
- Add-on Tech Demo for New Frontiers
- STMD Technology Demonstration Missions (TDM)
- SMD other divisions Technology Demonstration

Chapter 5 – Sustainment

Outline

- Balancing Technology Development Completion and Sustainment
- Instrument Sustainment Guidance

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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

Instrument Sustainment Guidance

Recommendations for PI led path to sustainment

- Develop roadmap to technology development completion
- If possible, leverage other funding vehicles such as SBIR phase 2E-3
- Commercialization for either:
  - Specific PSD application, or
  - Terrestrial application
- Perform periodic risk assessments with vendor/supplier
- Maintain critical knowledge, expertise, capabilities (continuity, train next gen, early career, transition plan), knowledge transfer
- Document knowledge gained through publications

Chapter 6 – Communication

Outline

- Communication Paths
- Community Outreach
- Community Interaction
- Forge Interconnectivity and Partnerships
- Technology Strategy Communication

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Communication Paths

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

From NASA → Community

- PESTO Website (https://www1.grc.nasa.gov/space/pesto/) is the reference for sharing technology projects and activities
- TechPort (https://techport.nasa.gov/home)
- Technology highlights are made publicly available (https://science.nasa.gov/technology)
- Ongoing communication with AGs

From Technologists → Community

- Fulfilling OSDMP requirements
- Link to publication of results in TechPort (https://techport.nasa.gov/home) (*may need be uploaded to ERS by PI then transferred by PESTO*)

From Technologists/Community → NASA

- Ongoing communication with PESTO through the Planetary Science Advisory Committee (PAC)
- Ongoing communication with PESTO through the AGs
- Ongoing input from the Science Community to PESTO through SME studies/workshops

Community Outreach

Annual Planetary Science Technology Symposium

- PESTO will hold an annual symposium to showcase the projects in the technology programs it manages
- The symposium will be a conference-like, hybrid event open to the public and consist of presentations, keynotes, and panel discussions

PSD Technology Showcase

- PESTO will hold an alternating year in person Technology Showcase
- The goal of the Technology Showcase is to create a forum for Technology Developers to meet and make connections with Scientists and Mission Managers

Community Outreach/Accessibility – Townhalls

- As topics arise for the PESTO solicitations, PESTO will hold Town Halls to communicate details to the public about its portfolio
- Potential topics include, but are not limited to; Technology Readiness Level (TRL), Dual Anonymous Peer Reviewed (DAPR), Open Science Data Management Plan (OSDMP)

Community Interaction

- 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 Annual Planetary Science Symposium)

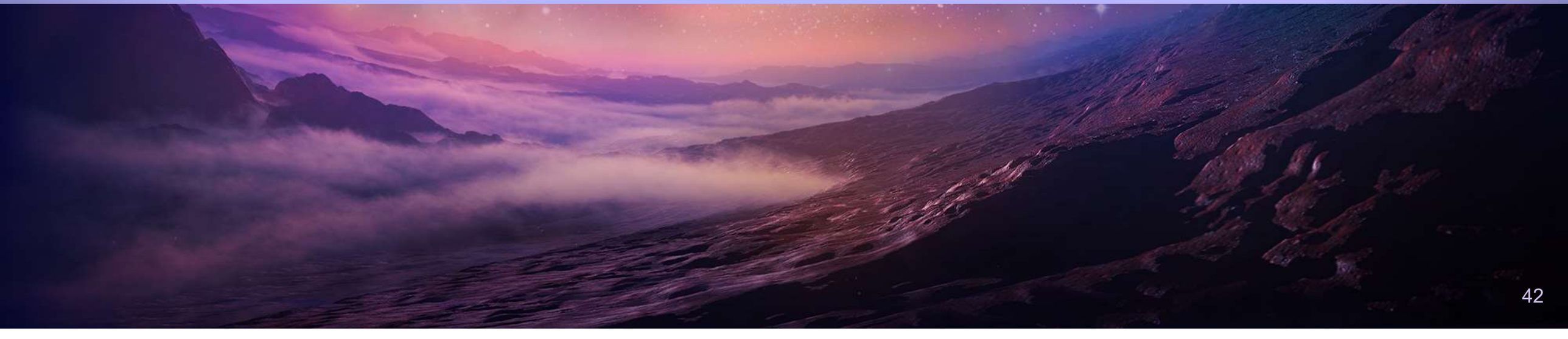
Forge Interconnectivity and Partnerships

- Leverage and encourage technology advancement from collaborative external organizations both inside and outside NASA, including commercial and non-space industries to meet future Planetary Science needs
  - Be on the look out for technology infusion possibilities into other SMD divisions, other NASA directorates, and government agency missions
  - Leverage similar work in other divisions and government agencies and create regular interactions by attending other directorate technology conferences and review meetings
- Maintain cognizance of technology in commercial and international arenas by reviewing technical reports, discussions with the community, interactions with the PESTO community of practice group
- Identify a level engagement with outside NASA to define a "look outside of NASA" process that agrees with capabilities within PESTO

Technology Strategy Communication

- The Technology Development Plan will be published on the PESTO website
- The Technology Investment Process will be revised on a five-year cadence, and the community will be engaged using the Prioritization Process previously discussed, including:
  - Announce intentions through conference presentations and the Planetary Science Advisory Committee (PAC) to interact with community to reevaluate the Technology Development Plan
  - 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
  - Provide results from technology studies through conference presentation and on the PESTO website
- Ongoing engagement with entities such as the AGs and the Technology Federation will inform revisions to the Technology Development Plan and Technology Investment Process
- The results of the study/workshop for each prioritized technology will be published on the PESTO website as the results are available

Explore With Us!



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Appendix

Outline

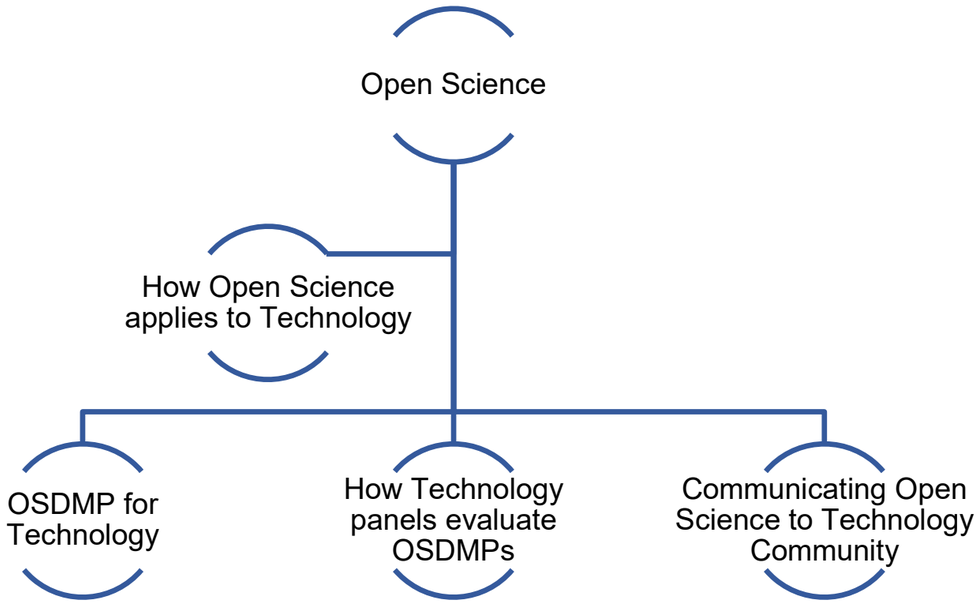
- Open Science
- Technology Readiness Level (TRL)
- References
- Funding Programs in SMD – Definitions
- Funding Programs in STMD – Definitions
- OWL Recommended Technologies

PESTO
Planetary Exploration Science Technology Office

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

OWL Recommended Technologies

	Decadal list	NASA Taxonomy	Applicable Destinations
Instrumentation	General in situ instruments	TX08: Sensors and Instruments	Venus, Moon, Mars, small bodies, ocean worlds, gas giants, ice giants
	General remote sensing instruments	TX08: Sensors and Instruments	All
	Instruments for search for evidence of life	TX08: Sensors and Instruments	Mars, ocean worlds, Venus (Moon and small bodies for false positives)
	In situ sample handling, pre-processing and analysis	TX08: Sensors and Instruments	Venus, Moon, Mars, small bodies, ocean worlds, giant planets
General Technology Areas	Autonomy	TX10: Autonomous Systems, TX17: Guidance, Navigation, and Control (GN&C)	All
	Challenging environments	TX08: Sensors and Instruments, TX12: Materials, Structures, Mechanical Systems, and Manufacturing, TX14: Thermal Management Systems	Earth, Moon, Venus, Mars, small bodies, ocean worlds
	Cold/cryogenic sample return	TX08: Sensors and Instruments, TX14: Thermal Management Systems	Moon, Mars, Venus, small bodies, ocean worlds
	Communication systems	TX05: Communications, Navigation, and Orbital Debris Tracking and Characterization Systems	All
	Entry/deorbit, descent and landing systems	TX09: Entry, Descent, and Landing	Venus, Moon, Mars, small bodies, ocean worlds
	In situ mobility (aerial/surface)	TX04: Robotic Systems	Venus, Moon, Mars, small bodies, ocean worlds
	Launch, cruise and encounter optimization	TX01: Propulsion Systems	All
	Planetary defense	TX04: Robotic Systems	Small bodies
	Planetary protection and contamination control	TX04: Robotic Systems	Moon, Mars, small bodies, ocean worlds
	Radioisotope thermoelectric generator/Radioisotope power systems	TX03: Aerospace Power and Energy Storage	All
	Solar array and batteries	TX03: Aerospace Power and Energy Storage	**All**
	Subsurface access	TX04: Robotic Systems	**Earth, Moon, Mars, small bodies, ocean worlds**
	Technology System Engineering and Integration	TX02: Flight Computing and Avionics, TX10: Autonomous Systems	**All**