EXPLOR\E
SOLAR SYSTEM&BEYOND
Draft Planetary Science Technology Development Plan

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Planetary Exploration Science Technology Office (PESTO)
Science Mission Directorate
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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

Chapter 1 – Overview
Chapter 2 – Current Technology Status
Chapter 3 – Technology Prioritization
Chapter 4 – Technology Development Implementation
Chapter 5 – Sustainment
Chapter 6 – Communication Plan
Appendices

Comprehensive Technology Strategy Draft can be found at:
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

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
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)

<table>
<thead>
<tr>
<th>Instrument Technology</th>
<th>Majority of Portfolio</th>
<th>Supplement Portfolio</th>
<th>Synergistic</th>
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<tbody>
<tr>
<td>PSD / ESSIO</td>
<td></td>
<td>STMD</td>
<td>SMD other divisions</td>
</tr>
<tr>
<td>PICASSO, MatISSE, DALI, SMD, Cross-Cutting</td>
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<table>
<thead>
<tr>
<th>Platform Technology</th>
<th>STMD</th>
<th>PSD</th>
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<tr>
<td>STMD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBIR, NIAC, TP/ACO, CIF/ECI, GCD</td>
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</tbody>
</table>

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)

### 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

### Other Potential Technology Success

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

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**Potential Future Programs**

- Additional funding, STMD Suborbital Experiments
- TDO Discovery, New Frontiers, or PSD Direct/Flagship, or STMD Tech Demo Missions
- New Frontiers, Discovery, SIMPLEx, SALSA, LTVIP, PRISM,
Funding Programs Available

PSD Funded Programs

- MatISSE
- PSTAR
- PICASSO
- RPS Tech
- Mars Tech

Application, Color
- General
- Mars
- Lunar

Mission Specific
- Mars Exploration Program

STMD Collaboration
- GRAM
- ESM
- Software/Spacecraft Tech

Funding, Outline
- PSD
- ESSIO
- APD
- ESD
- HPD
- STMD
- SMD-Cross Divi.

Funding, Shape
- Competed All
- Competed NASA
- Directed
**Funding Programs Available**

**PSD+ESSIO+SMD Cross-Divisional Funded Programs**

- **High TRL**
  - LTVI
  - ADI
  - SALSA
  - PRISM

- **Mid TRL**
  - DALI
  - MatISSE
  - PSTAR

- **Low TRL**
  - PICASSO
  - FINESST
  - EPSCoR

**Mission Specific**
- **Mars Exploration Program**
  - RPS Tech

**STMD Collaboration**
- **GRAM**
- **ESM**

**Software/Spacecraft Tech**

**Funding, Outline**
- PSD
- ESSIO
- APD
- ESD
- HPD
- STMD
- SMD-Cross Divi.

**Application, Color**
- General
- Mars
- Lunar

**Funding, Shape**
- Competed All
- Competed NASA
- Directed

**Instruments**
- Both
- Spacecraft/Ground Technology
Funding Programs Available

PSD+ESSIO+SMD Cross-Divisional Funded Programs+STMD

High TRL
- LTVI
- ADI
- SALSA
- PRISM
- Tech Demo Miss.
- RPS Tech
- ACO
- TP
- GCD
- STMD Collaboration
  - PRIZES
  - Challenges & Crowdsourcing
  - SBIR/STTR III
  - FO
  - Mars Tech

Mid TRL
- DALI
- MatISSE
- CIF
- PSTAR
- TP
- GCD
- ESM
- Software/Spacecraft Tech

Low TRL
- PICASSO
- FINESST
- EPScR
- NIAC
- STRG
- STMD Collaboration
  - GRAM
  - ESM

Application, Color
- General
- Mars
- Lunar

Funding, Outline
- PSD
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- SMD-Cross Divi.

Funding, Shape
- Competed All
- Competed NASA
- Directed

Instruments
Both
Spacecraft/Ground Technology
Funding Programs Available

- **Funding Programs Available**
- **ALL SMD+STMD**
- **Tech Demo Miss.**
- **Mars Exploration Program**
- **Software/Spacecraft Tech**
- **Mission Specific**
- **Funding, Outline**
  - General
  - Mars
  - Lunar
- **Funding, Shape**
  - Competed All
  - Competed NASA
  - Directed

**Application, Color**
- **Mission Specific**
- **Funding, Outline**
  - PSD
  - ESSIO
  - APD
  - ESD
  - HPD
  - STMD
  - SMD-Cross Divi.

**Funding Programs**
- **SBIR/STTR III**
- **FO**
- **APRA**
- **H-LCAS**
- **RPS Tech**
- **Mars Tech**
- **ACO**
- **GCD**
- **PRISM**

**Application Areas**
- **Instruments**
- **Both**
- **Spacecraft/Ground Technology**

**Programs**
- **SBIR/STTR III**
- **FO**
- **APRA**
- **H-LCAS**
- **RPS Tech**
- **Mars Tech**
- **ACO**
- **GCD**
- **PRISM**
- **H-LCAS**

**Tech Demo Miss.**
- **Tech Demo Miss.**

**Mission Specific**
- **Mars Exploration Program**

**Software/Spacecraft Tech**
- **Software/Spacecraft Tech**

**Funding, Outline**
- **Funding, Outline**

**Funding, Shape**
- **Funding, Shape**

**Application, Color**
- **Application, Color**

**Funding Programs**
- **Funding Programs**

**Application Areas**
- **Application Areas**

**Programs**
- **Programs**

**Tech Demo Miss.**
- **Tech Demo Miss.**

**Mission Specific**
- **Mission Specific**

**Software/Spacecraft Tech**
- **Software/Spacecraft Tech**

**Funding, Outline**
- **Funding, Outline**

**Funding, Shape**
- **Funding, Shape**
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

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

**Includes drilling**
Overlap between OWL & Planetary Science Technology Focus Areas

- 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 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

1. Gather Technology Focus Areas from stakeholders/beneficiaries
2. Reduce Technology Focus Areas based on previously defined "How Technology Focus Areas Identified"
3. Share "Prioritized Technology Focus Areas" with stakeholders/beneficiaries
4. Commission study/workshop on each Technology Focus Area
5. Share results of Technology Focus Area Study/Workshop on PESTO website
6. Reduce instruments and technologies in each Technology Focus Area based on:
   - figures of merit
   - programmatic needs
7. Share prioritized instruments and technologies in each Technology Focus Area
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
  o Plan for technology to be ready when needed
  o Design in reduced Sustainment costs
  o Consider 3rd party Sustainment
  o 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
  o Communicate technology development to mission planners
  o Facilitate interactions at technical exchanges (Technology Showcase)
  o Support transition into flight projects, where applicable
  o Track infusion success stories
  o 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
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
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!
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

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

*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
*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)
- George 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

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 / BlinkSpace
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
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/)
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 (AD²) 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*)
    - AD² 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/
• 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)
• 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 & Crowdsourcing
- 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