EXPLORE SCIENCE
SMD Science and Small Spacecraft Missions

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NASA SCIENCE
AN INTEGRATED PROGRAM

Joint Agency
Satellite Division

Planetary
Science

 Astrophysics

Earth
Science

Heliophysics
Science by the NUMBERS

RESEARCH
~10,000 U.S. Scientists Funded
~3,000 Competitively Selected Awards
~$600M Awarded Annually

TECHNOLOGY DEVELOPMENT
~$400M Invested Annually

EARTH-BASED INVESTIGATIONS
20 Airborne Missions
8 Global Networks

SPACECRAFT
98 Missions
82 Spacecraft

SMALLSATS/CUBESATS
30 Science Missions
24 Technology Demos

SOUNDING ROCKETS
15 Science Missions
6 Tech/Student Missions

BALLOONS
9 Science Missions
5 Technology/Student

~10,000 U.S. Scientists Funded
~3,000 Competitively Selected Awards
~$600M Awarded Annually

- 20 Airborne Missions
- 8 Global Networks
- 98 Missions
- 82 Spacecraft
- 30 Science Missions
- 24 Technology Demos
- 15 Science Missions
- 6 Tech/Student Missions
- 9 Science Missions
- 5 Technology/Student
Jan. 2019 – Near-collocated measurements of vertical rain reflectivity profiles from RainCube (top) and GPM’s Ka-band radar (bottom) RainCube points Nadir while GPM scans along-track.
Sept. 11, 2018 – TEMPEST-D 167 GHz brightness temperatures of Hurricane Florence

Dec. 8-12, 2018 – TEMPEST-D 87 GHz near-global brightness temperatures in ISS orbit
RainCube/TEMPEST-D Observing Typhoon Trami

Spacecraft constellation separated by 5 minutes revealing 3D storm structure

Illustration of complementary nature of these sensors flown in constellation for observing precipitation
CSIM-FD
Compact Solar Irradiance Monitor Flight Demonstration

Measuring solar spectral irradiance (SSI), and how solar variability impacts the Earth’s climate, contributing to long-term continuity measurements from SORCE SIM and TSIS SIM

CSIM is 11 kg based on a Blue Canyon Technologies bus

TSIS-1 is 363 kg built by LASP mounted to the ISS

SORCE is 290 kg based on an Orbital LEOStar-2 bus

Uncorrected CSIM data (channels A and B) compared to TSIS data in a portion of the UV spectrum

UV comparison of the first CSIM scan showing excellent agreement to the TSIS spectrum
Mar. 2019 – OCSD laser swept across and recorded by the CubeSat Multispectral Observation System (CUMULOS) SWIR camera on the ISARA spacecraft from 2,414km. The star R Doradus can be seen moving across the frame.

Courtesy: The Aerospace Corporation
MarCO
Mars Cube One

Nov. 2018 – Early adoption of ISARA Reflectarray antenna technology enables MarCO’s mission

ISARA image showing deployment of Reflectarray antenna and Earth

Nov. 26, 2018 - MarCO-B image of Mars from approximately 4,700 miles away during its flyby
SMD: Instruments and Sensor Development
STMD: Platform Technologies

STMD Platform Technologies

Late Stage / Flight Validation
- InVEST
- LSITP
- Aircraft
- ICEE
- Rockets
- HFORT
- Balloons

Mid-Stage
- IIP
- AIST
- SLIT
- DALI
- SESAME
- HTIDS
- ACT
- HFORT
- HOTTECH
- MATISSE
- ADYN
- CLDTECH
- SAT
- APRA

Early Stage / Transformational
- HTIDS
- IIP
- PICASSO
- APRA
- RTF
- DSI
- SLIT

STMD Programs (FY18)
- CC: Centennial Challenges
- CIF: Center Innovation Fund
- FOP: Flight Opportunities Program
- GCD: Game-Changing Development
- NIAC: NASA Innovative Advanced Concepts
- SBIR: Small Business Innovative Research
- SSTP: Small Spacecraft Technology Program
- STRG: Space Technology Research Grants
- TIP: Tipping Point
- TDM: Technology Development Mission

STMD Investments (FY18)
- Non-SBIR: 123 projects
- SBIR/STTR: 199 projects
- Total: 364 projects
<table>
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<th>Heliophysics</th>
<th>Earth Science</th>
<th>Planetary Science</th>
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<td>Instrument Concepts for Europa Exploration (ICEE)</td>
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NASA SMD Small Mission Opportunities
https://science.nasa.gov/researchers

- NSPIRES is the interface: https://nspires.nasaprs.com/external/
  - Register through NSPIRES for E-mail Notifications in your field of interest
  - Find announcement of all SMD NASA Funding Opportunities
  - Submit proposals/ participate in investigation evaluations

- Yearly Program Solicitation NRA (NASA Research Announcements - typically grants):
  - RESEARCH OPPORTUNITIES IN SPACE AND EARTH SCIENCES (ROSES) NRA
  - Target ROSES publication date is February 14 of the relevant year

- Episodic Solicitation of Mission of Opportunities (MOA) Announcement of Opportunity (AO):
  - Omnibus Stand Alone Missions of Opportunity Notice (SALMON-3)
  - Individual MOA are issued as Program Element Appendix (PEA) AO
Earth Sciences Division

Earth System Science Pathfinder (ESSP)
- Earth Venture (EV) class investigations
- Last AO was SALMON-3 PEA-N
  - Earth Venture Instruments
  - Earth Venture Sub-Orbital
  - Earth Venture Mission

ROSES
- Earth Science Technology Office’s (ESTO)
  - In-Space Validation of Earth Science Technologies (InVEST) (ROSES A.51)
  - Instrument Incubator Program (ROSES A.49)
  - Airborne Instrument Technology Transition (ROSESA.30)
Heliophysics Division

Missions of Opportunity

• Explorers Science Missions
  • Small Complete Missions
  • Partner Missions of Opportunity
  • Last AO released as SALMON-3 PEA-M

• Solar Terrestrial Probes (STP)
  • Small Complete Missions - ESPA-Class Rideshare on launch of Strategic Mission #5 (IMAP)
  • Technology Demonstration Mission of Opportunity (SALMON-3 PEA-L)
  • Science Mission of Opportunity (SALMON-3 PEA-M)

ROSES

• H-FORT (Heliophysics Flight Opportunities for Research and Technology), B.9
• H-TIDeS (Heliophysics Technology and Instrument Development for Science), B.8
Planetary Science Division

SIMPLEx (Small Innovative Missions for Planetary Exploration)
• Last Released as SALMON-3 PEA-J

ROSES
• PICASSO (Planetary Instrument Concepts for the Advancement of Solar System Observations) Roses C.12
• MatISSE (Maturation of Instruments for Solar System Exploration) ROSES C.13
• DALI (Development and Advancement of Lunar Instrumentation Program) ROSES C.23
Astrophysics MO Released with every APD Explorer AO

- SmallSats up to $35M
- Last AO was SALMON-3 PEA-O

ROSES

- APRA (Astrophysics Research and Analysis) ROSES D.3
- ASSS (Astrophysics Science SmallSat Studies), ROSES D.12
SmallSat Program Opportunities

Investing up to $30M for Earth Science Constellations

First Major Investment in Astro SmallSat Missions

Investing up to $65M for ESPA-class Payloads

Investing up to $55M in Deep Space SmallSat Missions

Earth Venture Missions (EVM/EVI) and In-Space Validation of Earth Science Technologies (InVEST)

Astrophysics Small Explorer (SMEX) and Astrophysics Science SmallSat Studies

Heliophysics Technology Demonstration Mission of Opportunity

Small Innovative Missions for Planetary Exploration (SIMPLEX)

SmallSat/CubeSat commercial engagement opportunities are essential to NASA Science’s balanced portfolio, achieving distinct science objectives
Small Spacecraft Coordination Group

Formed to advise the SMD, STMD, and HEOMD AAs on strategy to guide cross-agency initiatives, policies, and programmatic scope

Integrated Small Spacecraft Strategic Plan

Release at SmallSat 2019

NASA Strategic Plan

Science
New Observation Methods

Exploration
Strategic Knowledge Gaps

Technology
Spacecraft Subsystems
An integrated and coordinated strategy supporting the NASA strategic plan objectives of Discover, Explore, Develop, Enable
To date: (June 2019)
176 CubeSats missions
• 91 CubeSats launched
• 43 CubeSats manifested
• 53 CubeSats unmanifested

2019 CSLI Selections
16 Missions Selected from Round 10 Solicitation

Future Rideshare Accommodations
In addition to ISS and CRS flight accommodations
• Rideshare on 4 SMD Primary missions
• SLS accommodations

Landsat-9 (2020) - ESPA
JPSS-2 (2022) - ESPA & LOFTID
SPHEREx (2023) - ESPA
and IMAP (2024) - ESPA Grande
SLS EM-1, 2

Venture Class Launch Service
Budgeting $10M- $15M per launch in the AO process

Rocket Lab’s Electron LV
• Successful launch 12/16/18
• carrying 10 CubeSat missions for NASA

Virgin Orbit’s Launcher One
• Target VCLS launch Sept 2019
• carrying 11 CubeSat missions for NASA
NASA Awards Venture Class Launch Services Contracts

- Two companies are working to provide new commercial launch capabilities for SmallSats/CubeSats
  - Rocket Lab USA Inc.
  - Virgin Orbit
- Increases frequency NASA can utilize SmallSats/CubeSats for scientific research
- Opens doors for commercial launch services dedicated to transporting smaller payloads
Ways NASA is Engaging the Community for Mission Success

• Small Spacecraft Coordination Group to advise on agency strategy & policy

• Engaging commercial NewSpace industry to partner on science and technology

• Utilize Small Spacecraft Systems Virtual Institute (S3VI) to support community

• https://www.nasa.gov/smallsat-institute
International Partnerships

• NASA’s history of international collaboration started in 1958

• Spans science missions, testing, launch services, and data analysis with many international government, academic, and commercial organizations

• Enables development of international standards in key interfaces, allowing partners to make contributions based on own designs, requirements

• Brings value and evolves with success and failure toward capability resilience; advances human understanding
Thoughts on Achieving a SmallSat Utopia…

Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity

Rapid Industry Production
High Reliability
PI Leadership Development
Broad Technology Infusion
New Measurements with Greater Risk

Rapid/Regular Space Access
Greater Productivity at Low Cost
Constellations for Sustained Observations
Technology Validation for Science
Miniaturized Subsystems

Global Network Infrastructure
Public/Private Partnerships
Exploration Objectives
Decadal-Class Science
Real-Time Data Analytics

Years to mainstream adoption:
- less than 2 years
- 2 to 5 years
- 5 to 10 years
- more than 10 years
- obsolete before plateau

This chart is a composite, derived from Gartner published Hype Cycles.
The particular combination and comparison of items made here has not been reviewed by Gartner.

As of June 2019
Useful websites

https://science.nasa.gov/researchers
https://science.nasa.gov/researchers/sara/faqs
https://science.nasa.gov/researchers/volunteer-review-panels
https://nspires.nasaprs.com/external/
https://www.nasa.gov/smallsat-institute
Some advice (my personal opinion)

Volunteer to be on a panel to learn how proposals are written and evaluated.

Register through NSPIRES for email notifications in your field of interest.

Apprentice to a successful team.