National Aeronautics and Space Administration

Science Exploration with SmallSats and CubeSats

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Jet Propulsion Laboratory/California Technical Institute

Seminar at Korea Aerospace Research Institute (KARI)

April 10, 2019

Key Science THEMES

Protect & Improve Life on Earth

Discover Secrets of the Universe

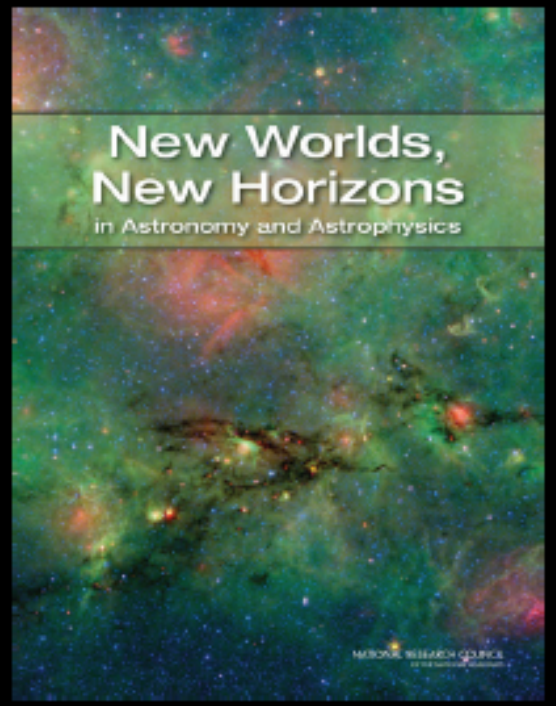
Search for Life Elsewhere

NASA SCIENCE

AN INTEGRATED PROGRAM

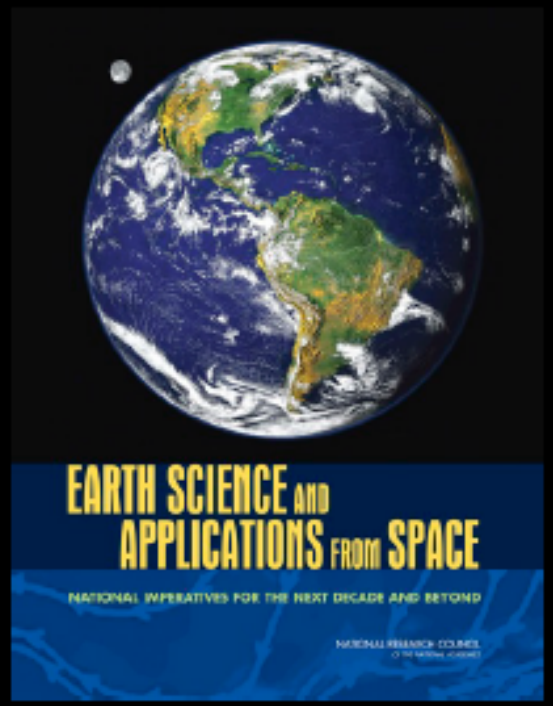
The Decadal Surveys

Astrophysics



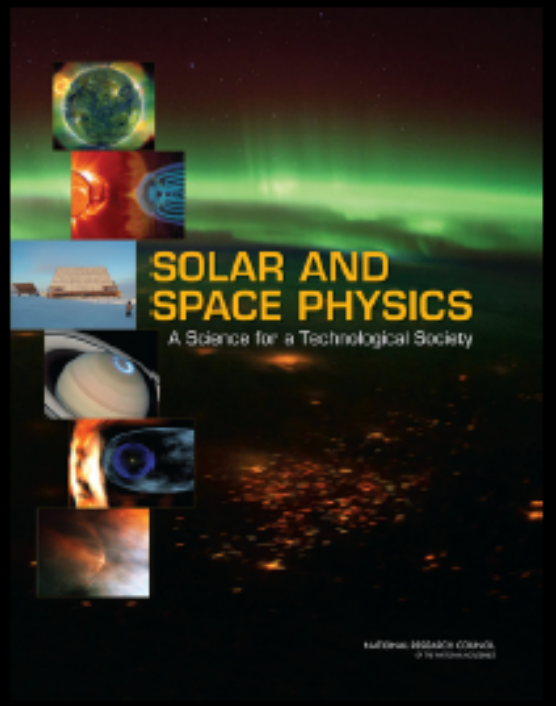
2012 – 2021

Earth Science



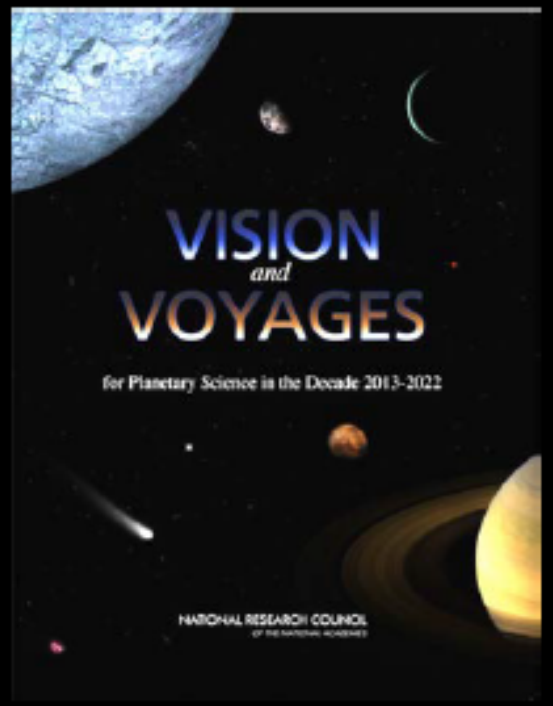
2007 – 2016

Heliophysics



2012 – 2021

Planetary

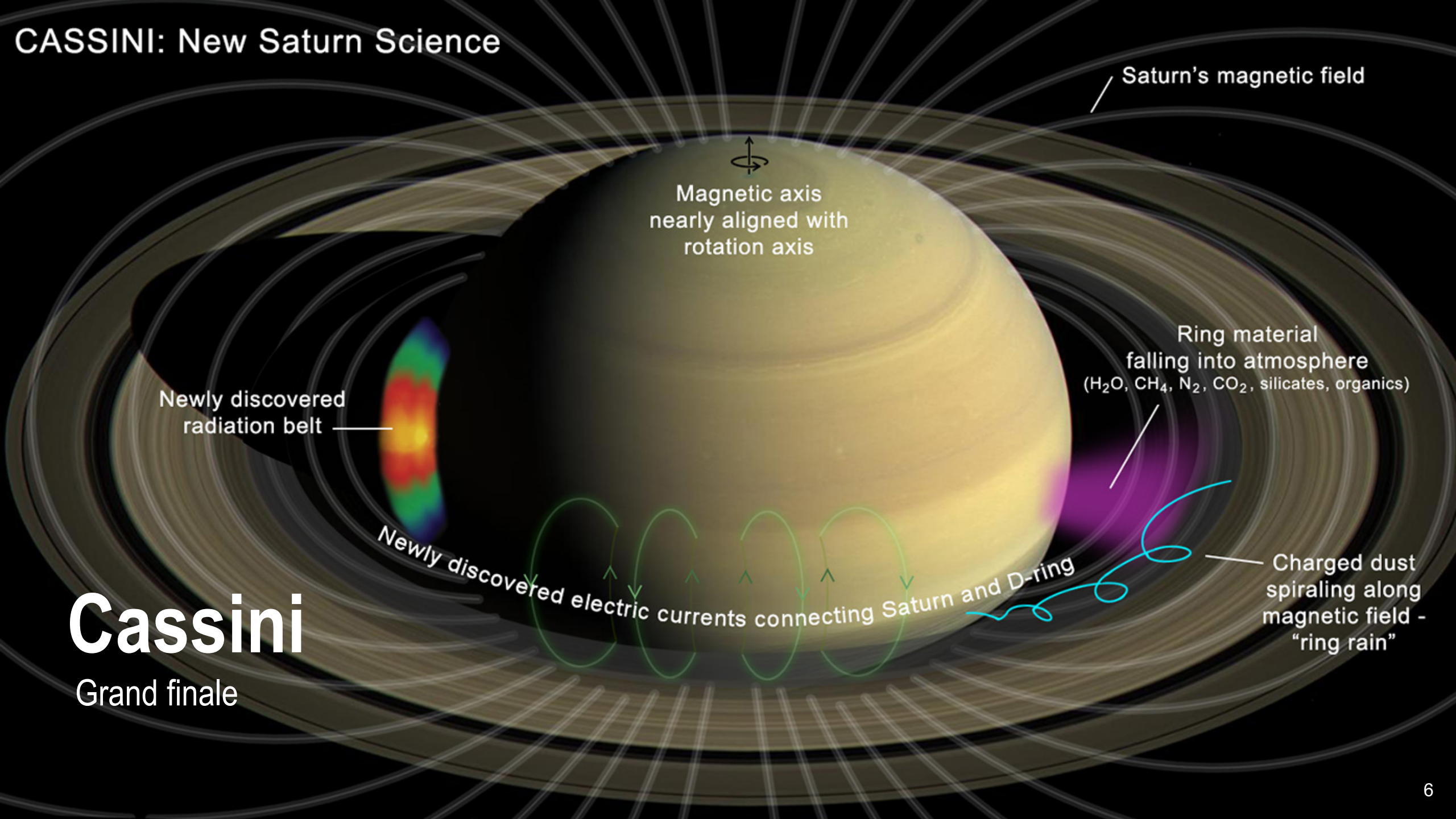


2013 – 2022

Organized by the National Academies on behalf of NASA establishing USA national priorities for scientific observations, as identified by the community, within a 10-year time frame

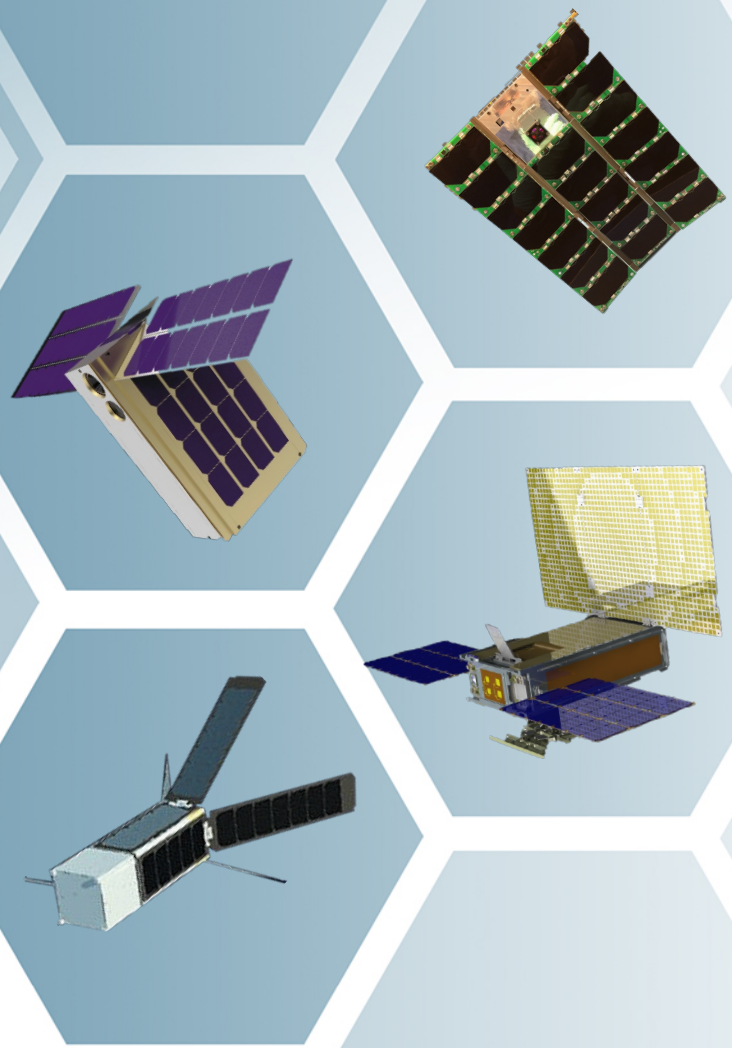
History of Great Discoveries

Large Strategic Missions



Cassini

Grand finale



Importance of Small, Innovative Missions

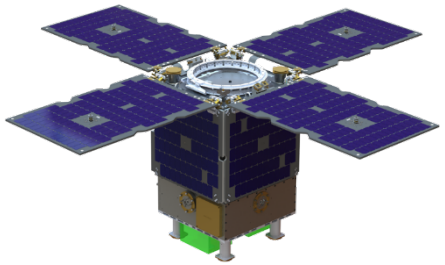
- **Expand** science programs to take advantage of small satellite rapid innovation to achieve breakthrough science
- **Enable** fast access to space with focused science measurements to fill a critical gap between large flight projects
- **Leverage** technology investments to further improve potential of science instruments
- **Partner** with commercial entities to acquire new capabilities of small satellite platforms

Definition of SmallSat and CubeSat

- Shift in launch cost
  - Launch to GTO as secondary spacecraft up to 300 kg
  - Constellations fit many spacecraft in a single launch
- Shift in risk tolerance
  - Shorter development times, reduced testing, and commercial or lower-TRL parts
  - Redundancy in numbers for constellations
- Set cut-off at 180 kg per NASA's Small Spacecraft Technology Program, but mass is really a proxy for other delimiters

CubeSats (< 20 kg)

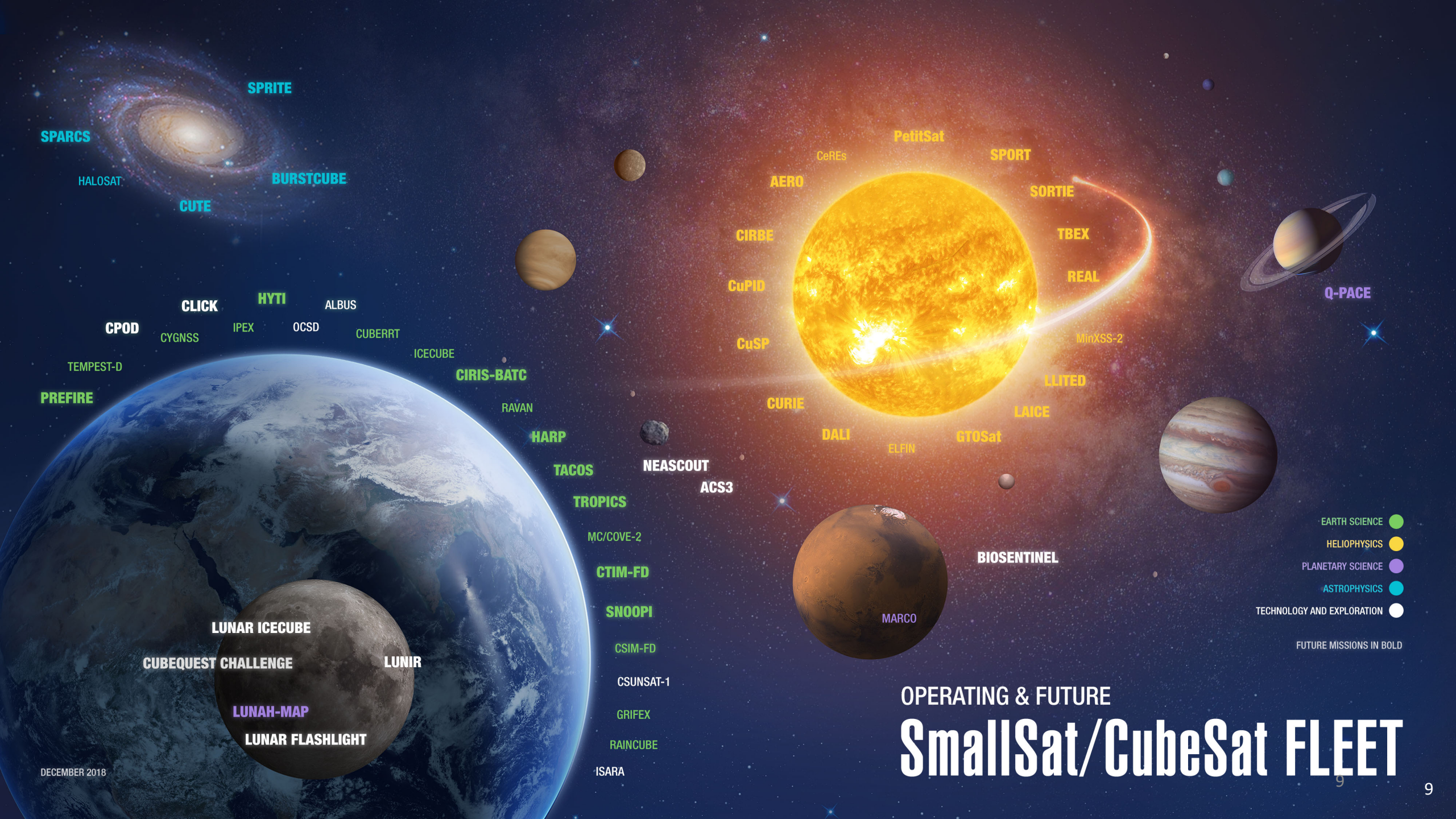
- Typically limited by volume rather than mass
- Constrained to specific form factor
- Plug-and-play commercial parts available
- Traditionally high-risk "unclassified" missions with 3-7 year lifetimes



Surrey Satellite Technology US LLC

Micro/minisats (< 180 kg)

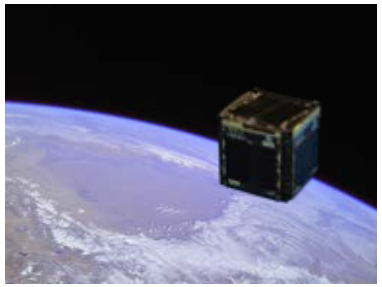
- Can be limited by either mass or volume
- Can accommodate more traditional space-qualified components with longer lifetimes (if they fit!)
- No set form factor, just volume limit by launch constraints

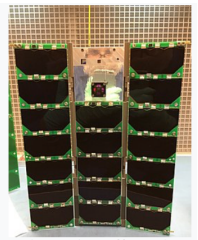

SPRITE
SPARCS
HALOSAT
BURSTCUBE
CUTE
CLICK
HYTI
ALBUS
CPOD
IPEX
OCSD
CYGNSS
CUBERRT
ICECUBE
TEMPEST-D
CIRIS-BATC
PREFIRE
RAVAN
HARP
TACOS
NEASCOUT
ACS3
TROPICS
MC/COVE-2
CTIM-FD
SNOOPI
CSIM-FD
CSUNSAT-1
GRIFEX
RAINCUBE
ISARA
LUNAR ICECUBE
CUBEQUEST CHALLENGE
LUNIR
LUNAH-MAP
LUNAR FLASHLIGHT
DECEMBER 2018
PetitSat
CeREs
SPORT
AERO
SORTIE
CIRBE
TBEX
CuPID
REAL
CuSP
MinXSS-2
LLITED
CURIE
LAICE
DALI
GTOSat
ELFIN
Q-PACE
BIOSENTINEL
MARCO
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
TECHNOLOGY AND EXPLORATION
FUTURE MISSIONS IN BOLD
OPERATING & FUTURE
SmallSat/CubeSat FLEET

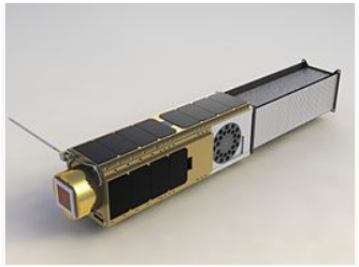
9

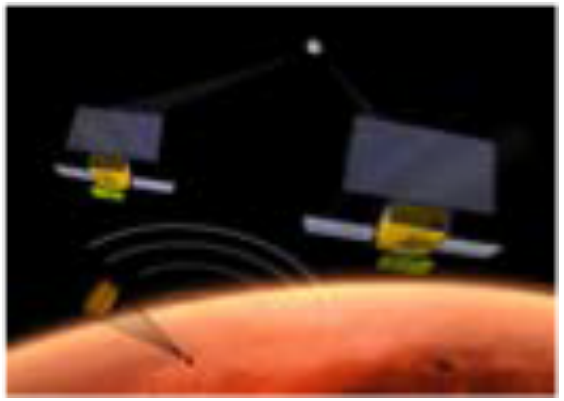
NASA-sponsored Small Missions
Completed

- Earth
  - IPEX
- Heliophysics
  - MinXSS
- Planetary
  - O/OREOS
  - MarCO (A/B)







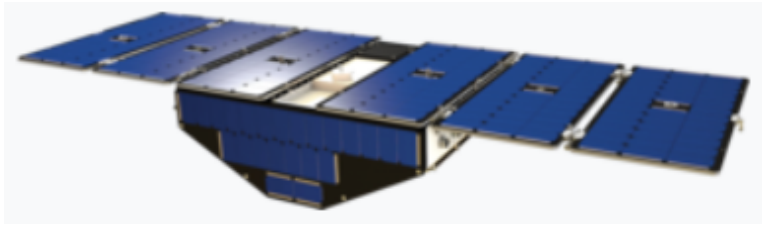


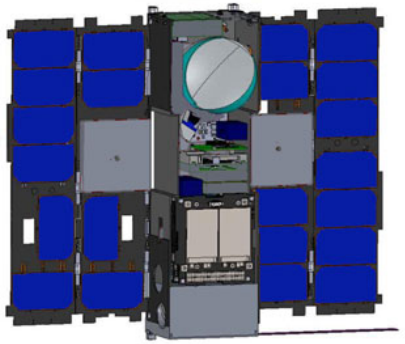
JPL-led or JPL participation

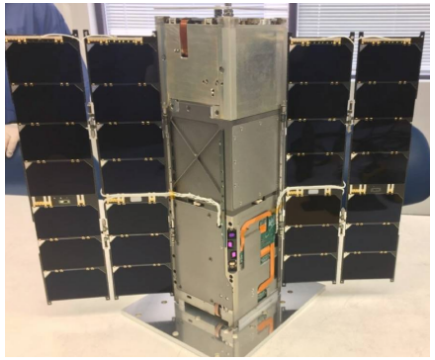
Note: Small Spacecraft Systems Virtual Institute Maintains Mission Inventory https://www.nasa.gov/smallsat-institute

NASA-sponsored Small Missions
Operations Phase

- Earth
  - CYGNSS,
  - GRIFEX,
  - IceCube,
  - MC/COVE-2,
  - MiRaTA,
  - RAVAN







JPL-led or JPL participation

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NASA-sponsored Small Missions
Implementation Phase

- Earth
  - CIRAS, CIRiS-BATC, CSIM-FD, CubeRRT, HARP, LMPC (AC9), PREFIRE, RainCube, TEMPEST-D, TROPICS
- Planetary
  - ArgoMoon, BioSentinel, LunIR, LunaH-Map, Lunar Flashlight, Lunar IceCube, NEAScout, Q-PACE
- Heliophysics
  - AERO, CeREs, CIRBE, CuPID, CURIE, CuSP, DALI, ELFIN, GTOSat, LAICE, LLITED, PetiSat, REAL, SORTIE, SPORT, TBEx
- Astrophysics
  - BurstCube, CUTE, HaloSat, SPARCS

JPL-led or JPL participation

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NASA-sponsored Small Missions
Study Phase

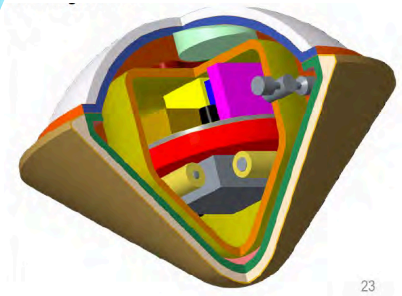
- Planetary
  - Aeolus, APEX, BOLAS, Ross (was CAESAR), Chariot, CubeX, Cupid's Arrow, CUVE, JUMPER, SNAP
- Heliophysics
  - AWE, FOXSI, MEME-X, MUSE, PUNCH, SunRise, TRACERS

JPL-led or JPL participation

Note: Small Spacecraft Systems Virtual Institute Maintains Mission Inventory https://www.nasa.gov/smallsat-institute

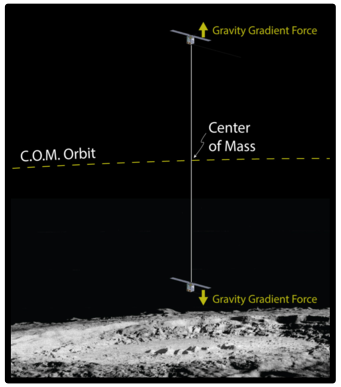
Planetary Science Deep Space SmallSat Studies (PSDS3)

10 studies selected to develop mission concepts that explore Venus, Earth's moon, asteroids, Mars, and the outer planets. Examples of PSDS3 SmallSats/CubeSat Mission Concepts



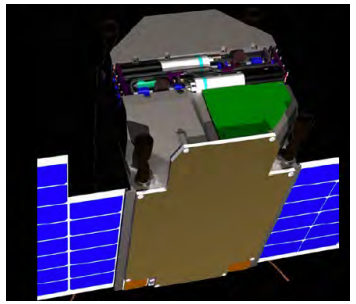
SNAP (PI Sayanagi, Hampton U)

- Lightweight probe mission for ice giants.
- Payload: Ultra-Stable Oscillator, Atmospheric Structure Instrument, NanoChem



BOLAS (PI Stubbs, GSFC)

- Innovative tether mission design for lunar orbit.
- Two 12 U tethered by 25 km Kevlar cable
- Enables stable orbit; measure particles in lunar regolith magnetic field.



Mars Micro Orbiter (PI, Malin, MSSS)

- Small Mars orbiter in 55 deg orbit.
- 3 on-board cameras, vis and 2 IR.
- Diurnal coverage for meteorology and dust storms.
- Based on 12U spacecraft, launched on Centaur aft bulkhead carrier.

PROVE (PI Hewagama, UMD)

- 6U cubesat designed using Morehead State Univ. Bus.
- Rendezvous with SP or LP comet.
- Visible Imager, IR imaging radiometer for gases.

https://www.jpl.nasa.gov/news/news.php?feature=6791

CubeSat
Current and Upcoming Technologies

Power – 10s of W_e for upcoming systems

- Solar power limited by maximum area of deployed solar arrays and by ability to dissipate waste heat
- Developing low temperature battery/ultracapacitor

Telecom – 1 Mbps common now (for Earth orbiters), IRIS

- Optical communication being developed – potential for Gbps communication
- Developing inflatable antenna

Attitude Control System – most CubeSats have 1-2 degree pointing accuracy

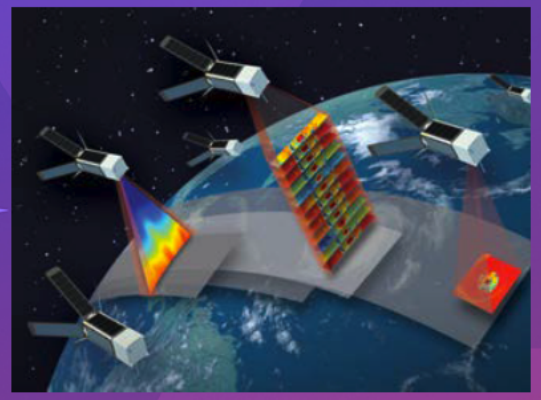
- Upcoming missions achieving 0.1 degree or better
- Developing miniaturized star trackers

Propulsion – cold gas allows for ~10 m/s ΔV

- Maturing chemical and electric propulsion (MEP) that is compatible with CubeSat requirements

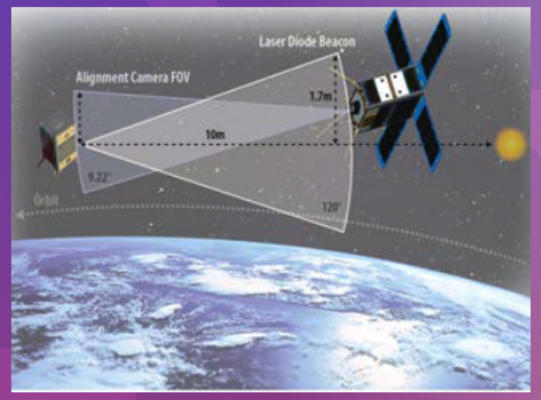
Thermal – most CubeSats have passive thermal systems

New Program Opportunities Across SMD



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

Three InVEST-17 Awards Announced July 20, 2018



Astrophysics Small Explorer (SMEX) and Astrophysics Science SmallSat Studies

First Major Investment in Astro SmallSat Missions

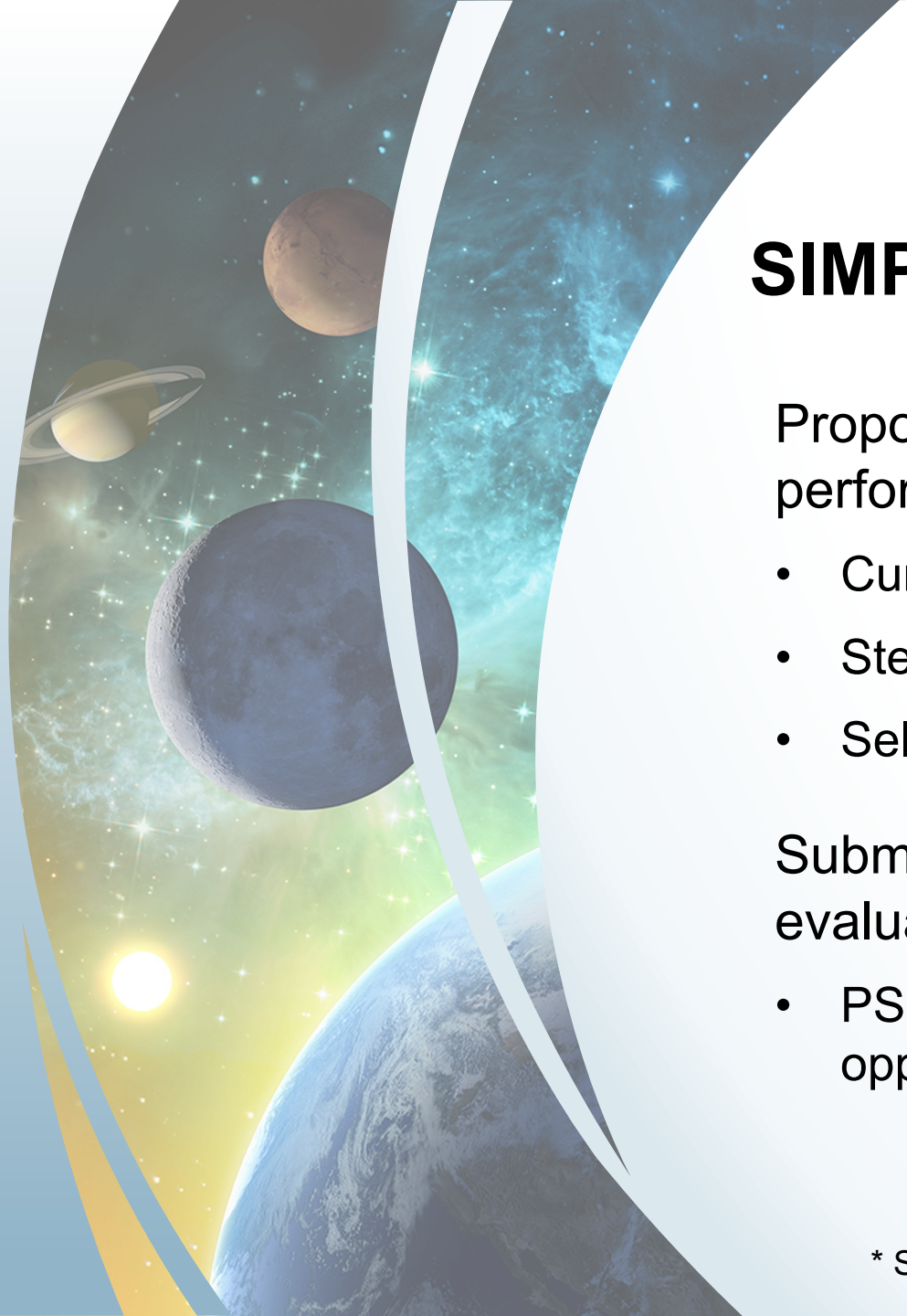
Heliophysics Technology Demonstration Mission of Opportunity

Investing up to $65M for ESPA-class Payloads

Small Innovative Missions for Planetary Exploration (SIMPLEx)

Investing up to $55M in Deep Space SmallSat Missions

SmallSat/CubeSat commercial engagement opportunities are essential to NASA Science's balanced portfolio, achieving distinct science objectives



SIMPLEx* Mission of Opportunity Status

Proposals accepted at any time, but evaluations are performed periodically

- Current submission reviews completed prior to shutdown
- Steering committee scheduled for end of March, 2019
- Selections rescheduled NET April 12, 2019

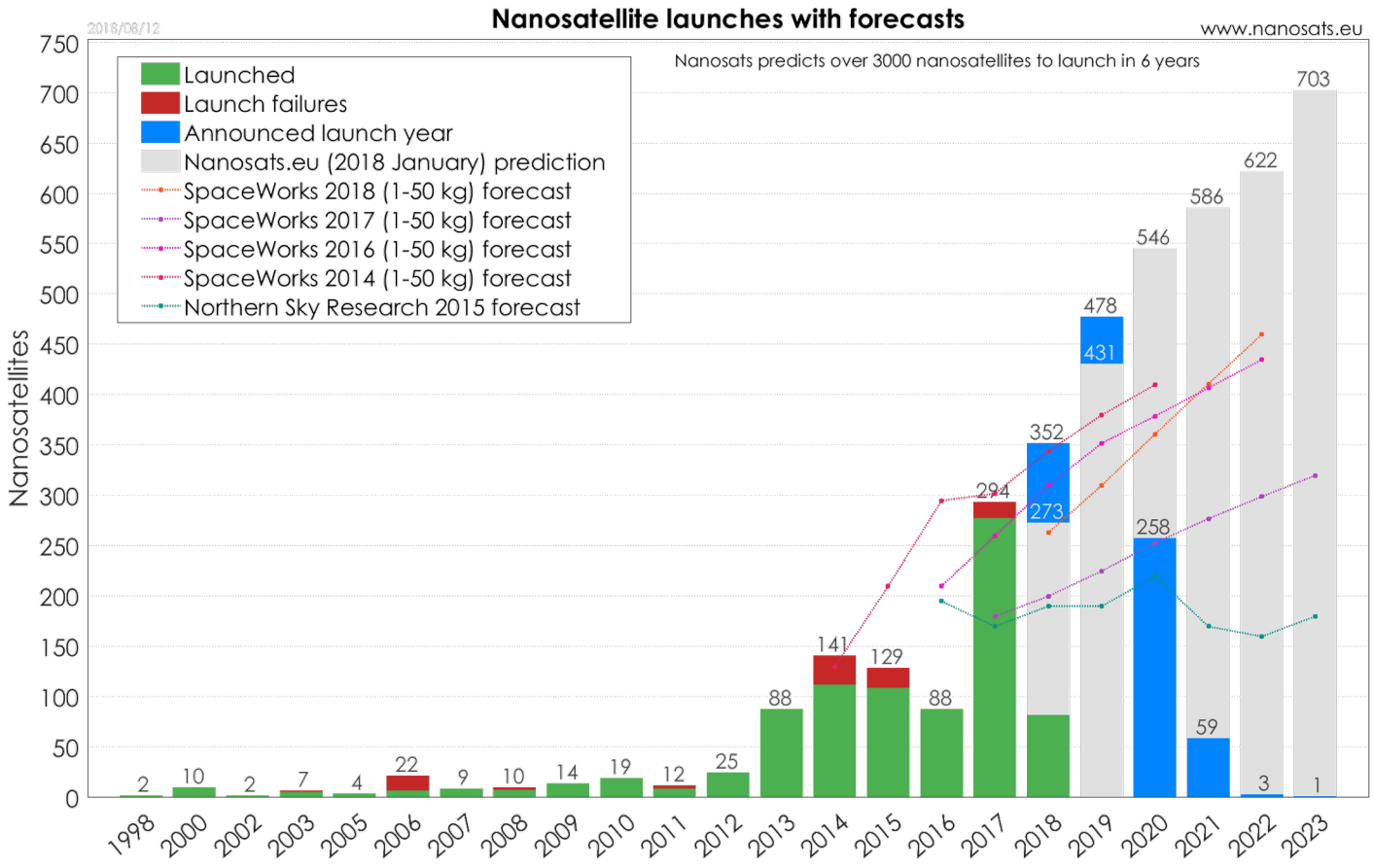
Submission cutoff date for next round of proposal evaluations is NET July, 2019

- PSD will inform community of exact cutoff date, launch opportunities, and any changes to solicitation

* Small Innovative Missions for Planetary Exploration (SIMPLEx)

A Look Forward

- Many science missions beyond LEO just on the horizon
- Bigger launch vehicles → more room for secondary payloads
- Stronger partnerships with government and commercial companies
- Value in distributed networks and constellations will be realized



https://www.nanosats.eu/img/fig/Nanosats_years_forecasts_2018-08-12_large.png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