Key Science Themes

Protect & Improve Life on Earth

Discover Secrets of the Universe

Search for Life Elsewhere
Science Decadal Surveys

• Astronomy and Astrophysics

• Planetary Science

• Heliophysics
  2003, 2012, (2024)

• Earth Science and Applications from Space
  2007, 2018, (2029)

• Biological and Physical Research in Space
  2011, (2022)
FY19 Astrophysics Funded Missions
Revised February 21, 2019

- Spitzer 8/25/2003
- Swift 11/20/2004
- NuSTAR 6/13/2012
- Fermi 6/11/2008
- Kepler 3/7/2009
- XMM-Newton (ESA) 12/10/1999
- Chandra 7/23/1999
- Spitzer 8/25/2003
- Euclid (ESA) 2022
- XMM-Newton (ESA) 12/10/1999
- Swift 11/20/2004
- NuSTAR 6/13/2012
- Fermi 6/11/2008
- Kepler 3/7/2009
- XMM-Newton (ESA) 12/10/1999
- Chandra 7/23/1999
Science payload completed three months cryogenic testing at end of 2017.

Spacecraft and sunshield integration complete January 2018.

Spacecraft element including sunshield will complete environmental testing in Summer 2019.

Science payload and spacecraft integration planned for Fall 2019.

Launch scheduled for 2021.

Webb overrun covered using offsets from Astrophysics Probes.
Wide-Field Infrared Survey Telescope

Work continues with FY19 funding

2016 – Completed Mission Concept review and began Phase A

2018 – Completed Mission Design review / System requirements Review and began Phase B

2019 – Completing Preliminary Design Reviews

2020 – Complete Confirmation Review and begin Phase C

Mid-2020s -- Launch

Science Program includes

• Dark energy and the fate of the universe through surveys measuring the expansion history of the universe and the growth of structure

• The full distribution of planets around stars through a microlensing survey

• Wide-field infrared surveys of the universe through General Observer and Archival Research programs

• Technology development for the characterization of exoplanets through a Coronagraph Technology Demonstration Instrument

WFIRST is 100 to 1500 times faster than Hubble for large surveys at equivalent area and depth
Spectro-Photometer for the History of the Universe Epoch of Reionization and Ices Explorer (SPHEREx)

- Awarded: February 2019
- Launch: 2023
- Prime Mission: 2 Years
- PI: James Bock (Caltech)

Science include:
- Survey the entire sky every 6 months
- Optical and infrared survey mission (96 bands/pixel)
- Observe hundreds of millions of galaxies
  - Measure redshifts to probe the statistical distribution of inflationary ripples
  - Measure spatial fluctuations in the Extragalactic Background Light to support studies of the origin and history of galaxy formation.
- Survey Galactic Molecular Clouds for water and organic molecules (H₂O, CO, CO₂, CH₃OH)
TESS by the numbers:

- 8 confirmed planets have been published in peer-reviewed journals
- 364 *new* planet candidates have been identified for follow-up ground-based confirmation
- 64 *previously known* planets have been re-detected
- 34 TESS papers have so far been submitted to preprint servers; many of which are focused on astrophysics topics other than exoplanets

• TESS sky survey is more than 25% complete (currently observing sector 10 out of 26)
• TESS data is public at MAST
• GI program is underway during prime mission (Cycle 1 underway, Cycle 2 proposals received)

http://archive.stsci.edu/tess/  
https://heasarc.gsfc.nasa.gov/docs/tess
Chandra X-ray Observatory (Chandra)
Fermi Gamma-ray Space Telescope (Fermi)
Hubble Space Telescope (Hubble)
Neutron star Interior Composition Explorer (NICER)
Nuclear Spectroscopic Telescope Array (NuSTAR)
Neil Gehrels Swift Observatory (Swift)
Transiting Exoplanet Survey Satellite (TESS)
X-ray Multi-mirror Mission-Newton (XMM-Newton)

Not in Senior Review: SOFIA, Spitzer
• SOFIA’s 5-year prime mission will be completed at the end of FY19
• At the end of a prime mission, NASA usually assesses the science performance, management of a program and proposed future science to decide on an extension of the program through a Senior Review Process, as required by the NASA Authorization Act of 2005
• The Explanatory Statement accompanying the FY2018 Consolidated Appropriations Act, however, forbade NASA from placing SOFIA in the 2019 Senior Review
• Given that the program has finished 5 years of operations, the time is appropriate to review 2 aspects of the SOFIA Project:
  • SOFIA’s maintenance and operations paradigm
  • SOFIA’s science progress and science prospects
• The reviews will not consider closeout or cancellation of SOFIA
Decadal Survey Planning

• NASA has initiated studies for large (Flagship) and medium (Probe) size mission concepts to inform the 2020 Decadal Survey Committee in an organized and coherent way

• Primary purpose is to provide the Decadal Survey Committee with several well-defined mission concepts to inform their deliberations

HabEx  LUVOIR  Lynx  Origins
Recent and Near-Term Planned ESD Launches (1 of 2)

**TSIS-1: DEC 15, 2017**

The Total and Spectral Solar Irradiance Sensor (TSIS-1) is measuring the total amount of sunlight that falls on Earth, and how that light is distributed among the ultraviolet, visible and infrared wavelengths.

**GRACE-FO: May 22, 2018**

Obtaining high resolution global models of Earth's gravity field, including how it varies over time.

**ECOSTRESS: June 29, 2018**

Providing insight into plant-water dynamics & how ecosystems change with climate via high spatiotemporal resolution thermal infrared radiometer measurements of evapotranspiration (ET).
Investigate important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion.

Quantifying polar ice-sheet contributions to sea-level change & measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change.

Characterize the effects of changing climate and land use on ecosystem structure and dynamics, providing the first global, high-resolution observations of forest vertical structure.

Investigate important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion.
Earth Science Division’s Venture Opportunities

### EVS: Sustained Sub-Orbital Investigations
- (~4 years)

<table>
<thead>
<tr>
<th>Mission</th>
<th>Mission Type</th>
<th>Release Date</th>
<th>Selection Date</th>
<th>Major Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV-1, aka EVS-1</td>
<td>5 Suborbital Airborne Campaigns</td>
<td>2009</td>
<td>2010</td>
<td>N/A</td>
</tr>
<tr>
<td>EVM-1, CYGNSS</td>
<td>Smallsat constellation</td>
<td>2011</td>
<td>2012</td>
<td>Launched Dec 2016</td>
</tr>
<tr>
<td>EVI-1, TEMPO</td>
<td>Geosynchronous hosted payload</td>
<td>2011</td>
<td>2012</td>
<td>Delivery NLT 2017</td>
</tr>
<tr>
<td>EVI-2, ECOSTRESS &amp; GEDI</td>
<td>Class C &amp; Class D ISS-hosted Instruments</td>
<td>2013</td>
<td>2014</td>
<td>Delivery NLT 2019</td>
</tr>
<tr>
<td>EVS-2</td>
<td>6 Suborbital Airborne Campaigns</td>
<td>2013</td>
<td>2014</td>
<td>N/A</td>
</tr>
<tr>
<td>EVI-3, MAIA &amp; TROPICS</td>
<td>Class C LEO Instrument &amp; Class D Cubesat Constellation</td>
<td>2015</td>
<td>2016</td>
<td>Delivery NLT 2021</td>
</tr>
<tr>
<td>EVM-2, GeoCarb</td>
<td>Geostationary hosted payload</td>
<td>2015</td>
<td>2016</td>
<td>Launch ~2021</td>
</tr>
<tr>
<td>EVI-4</td>
<td>Instrument Only</td>
<td>2016</td>
<td>2018</td>
<td>Delivery NLT 2021</td>
</tr>
<tr>
<td>EVS-3</td>
<td>Suborbital Airborne Campaigns</td>
<td>2017</td>
<td>2018</td>
<td>N/A</td>
</tr>
<tr>
<td>EVI-5</td>
<td>Instrument Only</td>
<td>2018</td>
<td>2019</td>
<td>Delivery NLT 2023</td>
</tr>
<tr>
<td>EVM-3</td>
<td>Full Orbital</td>
<td>2019</td>
<td>2020</td>
<td>Launch ~2025</td>
</tr>
<tr>
<td>EVI-6</td>
<td>Instrument Only</td>
<td>2019</td>
<td>2020</td>
<td>Delivery NLT 2024</td>
</tr>
</tbody>
</table>

### EVM: Complete, self-contained, small missions
- (~4 years)

### EVI: Full function, facility-class instruments Missions of Opportunity (MoO)
- (~18 months)

**Open solicitation - In Review**

**Completed solicitation**

EMIT, PREFIRE selected for EVI-4
2017 Decadal Survey Snapshot

- Endorses existing balances in ESD portfolio
- Prioritizes observations rather than specific missions and allows implementation flexibility
- Encourages and notes value of international partnerships
- Recommends “Continuity Measurement” ($150M full mission cost cap) as an addition to the existing Venture-class program
- Identifies 5 mandatory observables (Aerosols; Clouds, Convection, & Precipitation; Mass Change; Surface Biology & Geology; Surface Deformation & Change)
- Introduces a new competed “Explorer” flight line at $350M cost cap
- Calls for “Incubator Program to mature specific technologies in preparation for next Decadal
NASA Heliophysics System Observatory

- Solar Orbiter (ESA)
- Parker Solar Probe
- Voyager (2)
- STEREO
- SOHO (ESA)
- ACE
- SDO
- IMAP
- ICON
- GOLD (SES)
- Van Allen Probes (2)
- THEMIS (3)
- ARTEMIS (2)
- Van Allen Probes
- MMS (4)
- SET-1 (USA)
- TIMED
- SET-1 (USAF)
- IRIS
- TIMED
- AIM
- THEMIS
- MMS
- SET-1
- TIMED
- IRIS
- TIMED
- AIM
- THEMIS
- MMS
- SET-1
- TIMED
- IRIS

Institutions:
- ESA
- JAXA
- NASA
- USAF
- ISS: AWE

Instruments:
- GOLD
- SDO
- SOHO
- TIMED
- IMAP
Heliophysics Programs (2018-2030)

Living With a Star
- Parker Solar Probe
  - August 2018
- Solar Orbiter Collaboration (with ESA)
  - February 2020

Solar Terrestrial Probes
- Space Environment Testbeds (SET-1)
  - NET June 2019
- Interstellar Mapping and Acceleration Probe (IMAP)
  - NET 2024*

Explorers
- Global-scale Observations of the Limb and Disk (GOLD)
  - January 2018
- Ionospheric Connection Explorer (ICON)
  - NET Q1 2019
- Science MO ’18
  - NET 2024*
- Tech Demo MO ’18
  - NET 2024*

Research Program
- ELFIN-STAR, Sep 2018
  - MinXSS, Dec 2018
- BITSE, Sep 2019
- AZURE – Mar 2019, x2
- TOOWINDY – Jun 2019, x2
- CLASP-2 – Apr 2019
- ShIELDS – Apr 2019
- CuPID – 2019
- RockOn – Jun 2019

* notional
Space Weather Science Applications Program

• Establishes an expanded role for NASA in space weather science under single budget element
  • Consistent with recommendation of the NRC Decadal Survey and the 2019 National Space Weather Strategy and Action Plan

• Competes ideas and products, leverages existing agency capabilities, collaborates with other national and international agencies, and partners with user communities

• Main areas of the Space Weather Science Applications Program are:
  • Collaboration – MOU with NOAA & NSF
  • Competed Elements – ROSES, SBIR
  • Directed Components – CCMC and HEC
Discovery Program

- **NEO characteristics**
  - NEAR (1996-1999)

- **Mars evolution**
  - Mars Pathfinder (1996-1997)

- **Lunar formation**

- **Nature of dust/coma**
  - Stardust (1999-2011)

- **Solar wind sampling**
  - Genesis (2001-2004)

- **Comet Internal Structure**

- **Lunar Internal Structure**
  - GRAIL (2011-2012)

- **Mercury Environment**

- **Main-belt Asteroids**
  - Dawn (2007-TBD)

- **Exoplanets**
  - Kepler (2009-TBD)

- **Lunar Surface**
  - LRO (2009-TBD)

- **ESA/Mercury Surface Strofio**

- **Mars Interior**
  - InSight (2018)

- **Trojan Asteroids**
  - Lucy (2021)

- **Metal Asteroid**
  - Psyche (2022)

- **Martian Moons**
  - MMX/MEGANE (2024)

- **Comet Diversity**
  - CONTOUR (2002)

- **Lost Aug 15 2002**

- **Lunar Surface**
  - Strofio (2018)

- **Currently Operating**

- **Deep Impact**
  - 2005-2012

- **Trojan Asteroids**
  - Lucy (2021)

- **Metal Asteroid**
  - Psyche (2022)

- **Martian Moons**
  - MMX/MEGANE (2024)
# New Frontiers Program

<table>
<thead>
<tr>
<th>Mission</th>
<th>Description</th>
<th>Launch Date</th>
<th>Arrival Date</th>
<th>Principal Investigator</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; NF mission</td>
<td><strong>New Horizons</strong></td>
<td>Pluto-Kuiper Belt</td>
<td>January 2006</td>
<td>July 14, 2015</td>
<td>PI: Alan Stern (SwRI-CO)</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; NF mission</td>
<td><strong>Juno</strong></td>
<td>Jupiter Polar Orbiter</td>
<td>August 2011</td>
<td>July 4, 2016</td>
<td>PI: Scott Bolton (SwRI-TX)</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; NF mission</td>
<td><strong>OSIRIS-REx</strong></td>
<td>Asteroid Sample Return</td>
<td>September 2016</td>
<td>December 2018</td>
<td>PI: Dante Lauretta (UA)</td>
</tr>
</tbody>
</table>
Upcoming Missions

Small Innovative Missions for Planetary Exploration (SIMPLEx)
• Step-1 reviews were completed before shutdown
• Step-1 selection to be scheduled NET April 12, 2019

New Frontiers #4 Down-selection
• New Step-2 evaluation schedule incorporates a four-week slip in site visits
• Plenary Meetings have been rescheduled
• Down-selection announcement still expected in July 2019

Discovery 2019
• Draft AO released before shutdown
• Comment period extended to February 11, 2019
• Final AO release expected NLT April 1, 2019
• Step-1 proposal due date rescheduled to July 1, 2019
Science

Objective | Description
--- | ---
Ice Shell & Ocean | Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.
Composition | Understand the habitability of Europa's ocean through composition and chemistry.
Geology | Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.
Recon | Characterize scientifically compelling sites, and hazards for a potential future landed mission to Europa.

Europa Clipper Overview

Will conduct approximately 45 low altitude flybys (25 – 100 km altitude) to characterize the habitability of the Icy Moon Europa through global regional coverage.
SPIRIT AND OPPORTUNITY

By the Numbers

SPIRIT

6 YEARS lifespan
124,838 raw images
4.8 MILES traveled
30 DEGREES steepest slope

OPPORTUNITY

14+ YEARS lifespan
217,594 raw images
28 MILES traveled
32 DEGREES steepest slope

Updated February 4, 2019
Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)

Landed on Nov 26, 2018
First vortices sensed by Lander
Returnable cache of samples from a geologically diverse site of ancient habitability. Coordinated, nested context and fine-scale measurements are critical for ISRU and technology demonstration required for future Mars exploration. Seeking Signs of Life: Mars 2020 Rover.
ASSESS
[CENTER FOR NEAR EARTH OBJECT STUDIES]

SEARCH, DETECT & TRACK
[GROUND-BASED & SPACE-BASED OBSERVATIONS, IAWN]

MITIGATE
[DART, FEMA EXERCISES]

CHARACTERIZE
[NEOWISE, GOLDSTONE, Arecibo, IRTF]

PLANETARY DEFENSE

PLAN & COORDINATE
[SMPAG, PIERWG, DAMIEN IWG]
Double Asteroid Redirection Test (DART)

DART Spacecraft
- 540 kg Arrival Mass
- 20m² ROSA
- NEXT Thruster, DRACO Imager
- 6.0 km/s Closing Speed

Cubesat
- 6U Argomoon Design
- WFOV and NFOV Imagers
- Agenzia Spaziale Italiana

Earth Based Observations
- ~7M mile Range at Impact

Didymos-A
- 1996 GT
- S-Type Apollo
- 780 meter size

Didymos-B
- ~160 meter size
Space Policy Directive – 1
Reinvigorating America’s Human Space Exploration Program

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.

Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.”
Path to the Lunar Surface

- 2018: ISS-Sustainable Low-Earth Capability, Small Commercial Landers
- 2022: Power & Propulsion Element, Orion Crewed Exploration
- 2024: Enhanced Science and Exploration Capability, Lunar Lander Descent Module Demo
- 2026: Lunar Lander System Test, Gateway Supports Human Landing

Timeline:
- 2024: Moon Mission
- 2026: Mars Sample Return
- 2027: Mars Human Missions

Note: MARS 2020 and INSIGHT are part of the Mars exploration program.
QUESTIONS?