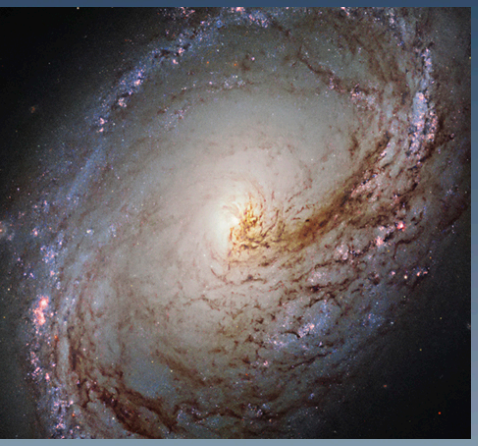
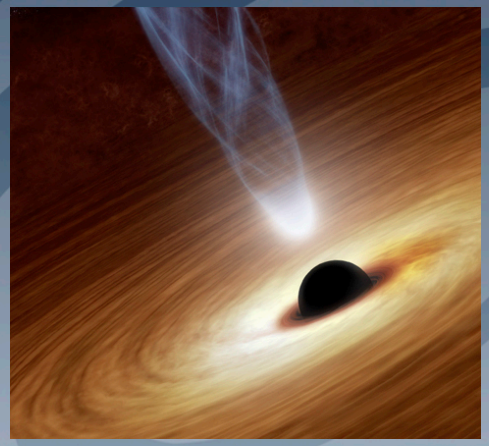
National Aeronautics and Space Administration

Astrophysics

NASA Astrophysics Program: Present and Future






11th International LISA Symposium

Irchel Campus, University of Zurich
Zurich, Switzerland

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

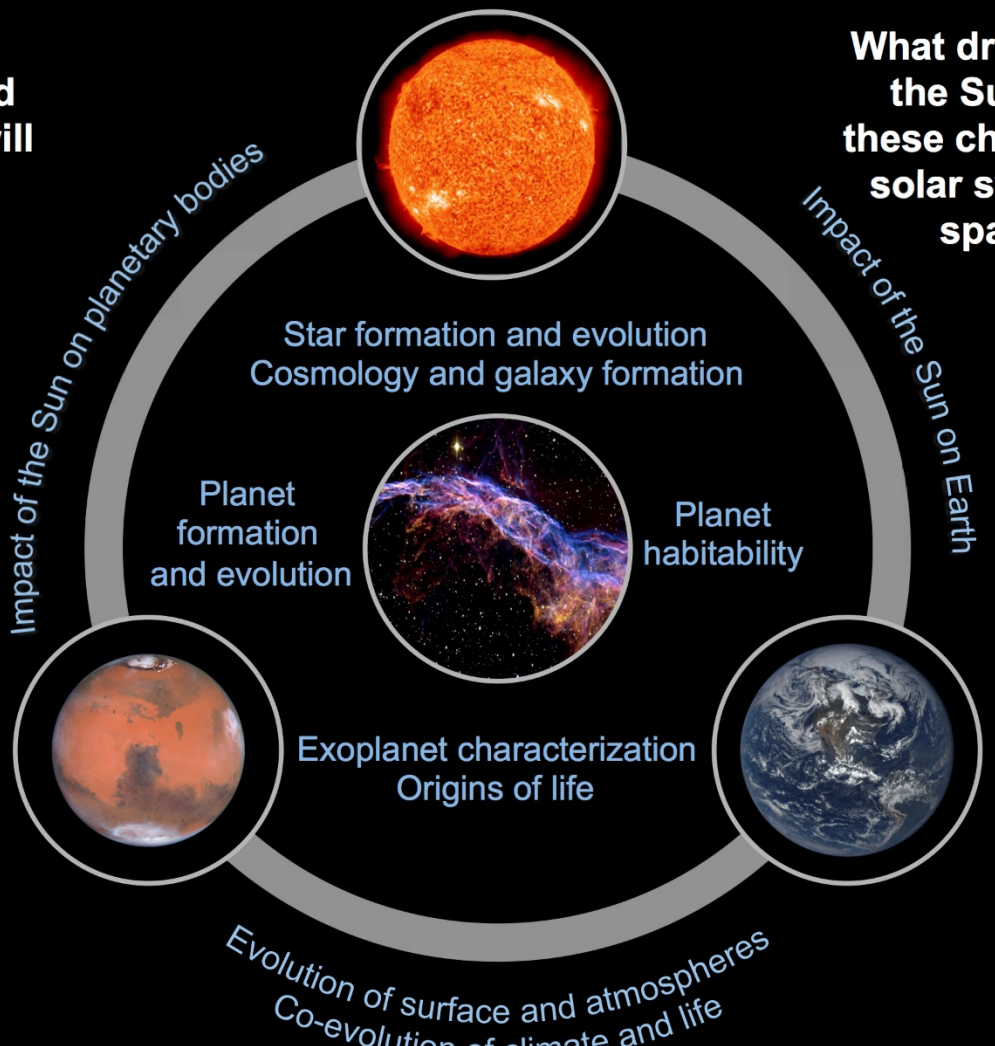
September 6, 2016

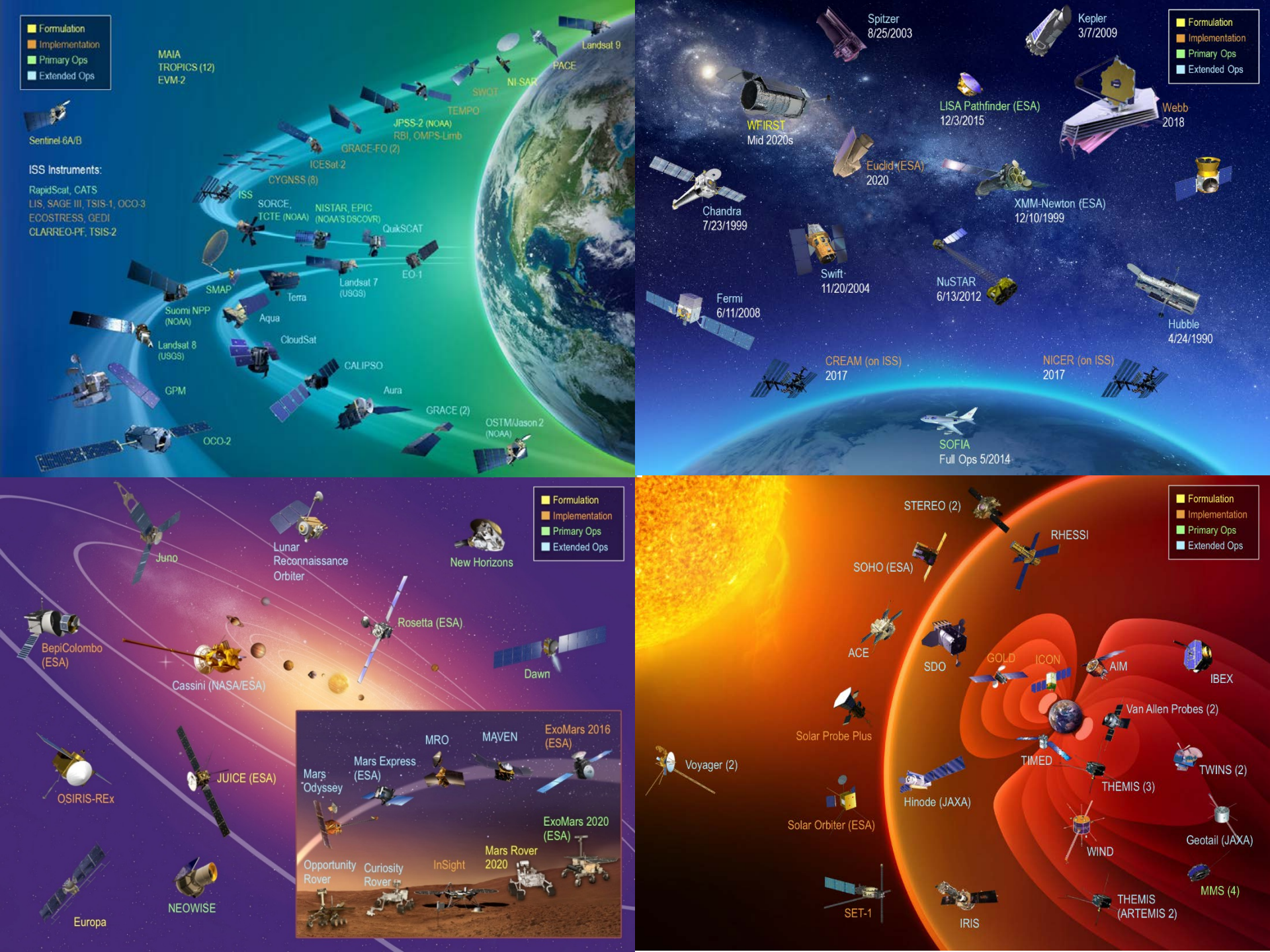
National Aeronautics and Space Act of 1958

The aeronautical and space activities of the United States shall be conducted so as to contribute materially to the following objectives:

- The expansion of human knowledge of phenomena in space.
- The development and operation of vehicles capable of carrying instruments through space.
- The establishment of studies of the benefits to be gained from space activities for scientific purposes.
- Cooperation by the United States with other nations and groups of nations in work done and in the peaceful application of the results.

NASA Science Is Interconnected

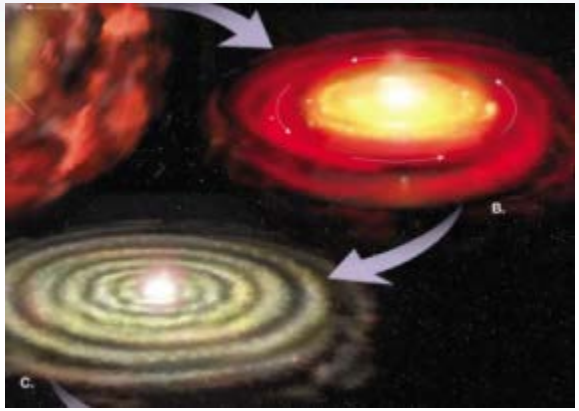



Formulation
Implementation
Primary Ops
Extended Ops
MAIA
TROPICS (12)
EVM-2
Sentinel-6A/B
ISS Instruments:
RapidScat, CATS
LIS, SAGE III, TSIS-1, OCO-3
ECOSTRESS, GEDI
CLARREO-PF, TSIS-2
Landsat 9
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS (8)
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA'S DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2
Spitzer
8/25/2003
Kepler
3/7/2009
WFIRST
Mid 2020s
LISA Pathfinder (ESA)
12/3/2015
Webb
2018
Euclid (ESA)
2020
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
Swift
11/20/2004
NuSTAR
6/13/2012
Fermi
6/11/2008
Hubble
4/24/1990
CREAM (on ISS)
2017
NICER (on ISS)
2017
SOFIA
Full Ops 5/2014
Juno
Lunar
Reconnaissance
Orbiter
New Horizons
BepiColombo
(ESA)
Rosetta (ESA)
Cassini (NASA/ESA)
Dawn
OSIRIS-REx
JUICE (ESA)
Europa
NEOWISE
MRO
MAVEN
ExoMars 2016
(ESA)
Mars Express
(ESA)
Mars
Odyssey
ExoMars 2020
(ESA)
Mars Rover
2020
Opportunity
Rover
Curiosity
Rover
InSight
STEREO (2)
RHESSI
SOHO (ESA)
ACE
SDO
GOLD
ICON
AIM
IBEX
Van Allen Probes (2)
Solar Probe Plus
Voyager (2)
TIMED
TWINS (2)
THEMIS (3)
Hinode (JAXA)
Solar Orbiter (ESA)
Geotail (JAXA)
WIND
MMS (4)
SET-1
IRIS
THEMIS
(ARTEMIS 2)

Why Astrophysics?

Astrophysics is humankind's scientific endeavor to understand the universe and our place in it.

1. How did our universe begin and evolve?

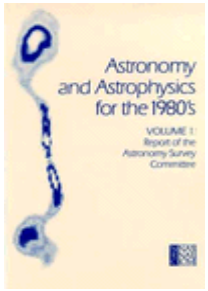


2. How did galaxies, stars, and planets come to be?

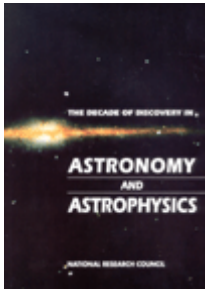
3. Are We Alone?

These national strategic drivers are enduring

1972



1982

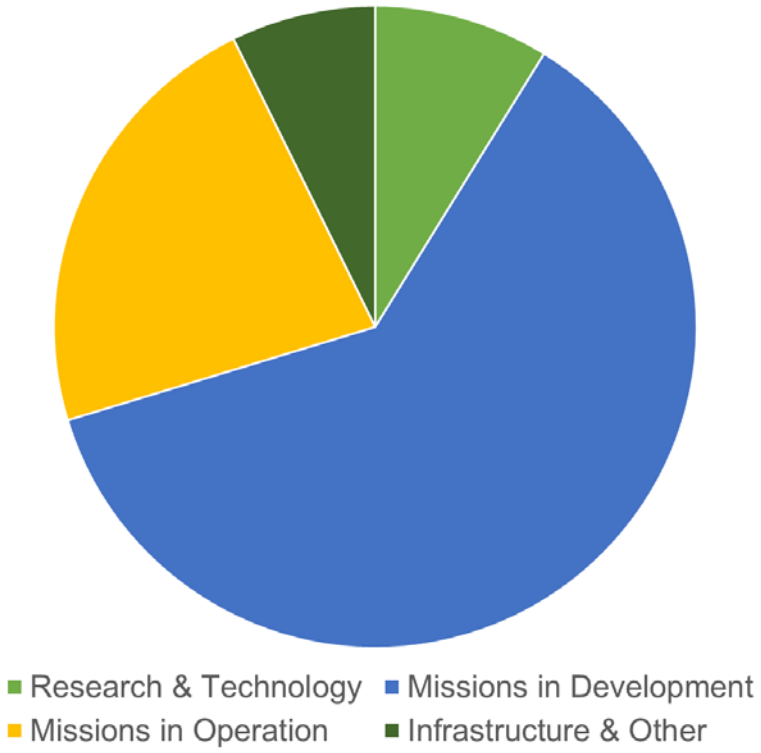


1991

2001

2010

NASA Astrophysics



FY 2016
Total US$ 1,333 M

Missions in Development includes James Webb, ISS-NICER, ISS-CREAM, TESS, Euclid, WFIRST

Missions in Operation includes Hubble, Chandra, XMM-Newton, Spitzer, Swift, Fermi, Kepler, NuSTAR, SOFIA, LISA Pathfinder

Infrastructure & Other includes data archives, suborbital balloons, ground-based telescopes, management

Research & Technology includes basic technology, strategic technology, theory, data analysis, fellowships

Astrophysics Missions in Development

ISS-NICER
2/2017

NASA Mission

Neutron Star Interior Composition Explorer

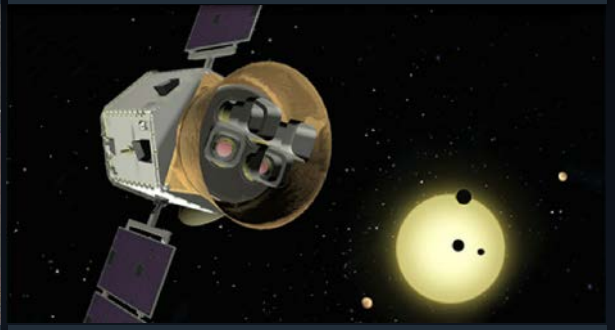
ISS-CREAM
6/2017

NASA Mission

Cosmic Ray Energetics And Mass

TESS
12/ 2017

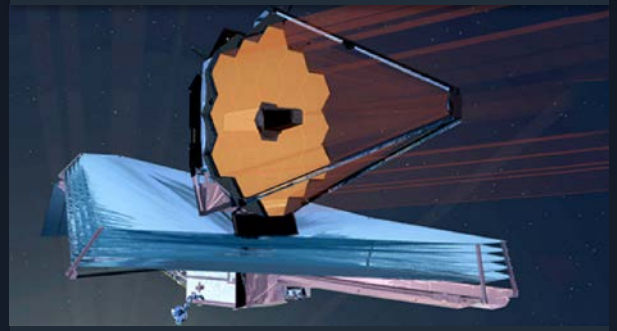
NASA Mission



Transiting Exoplanet Survey Satellite

Webb
10/2018

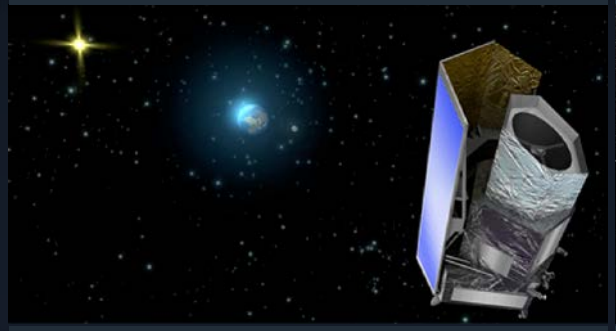
NASA Mission



James Webb Space Telescope

Euclid
2020

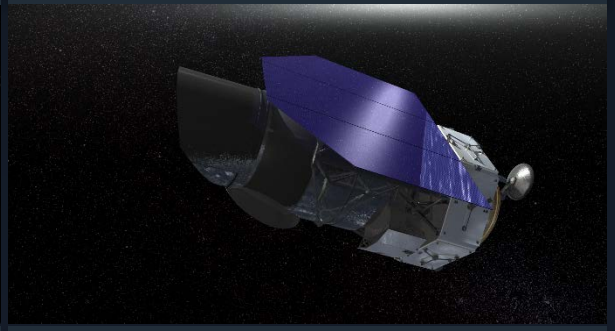
ESA-led Mission



NASA is supplying the NISP Sensor Chip System (SCS)

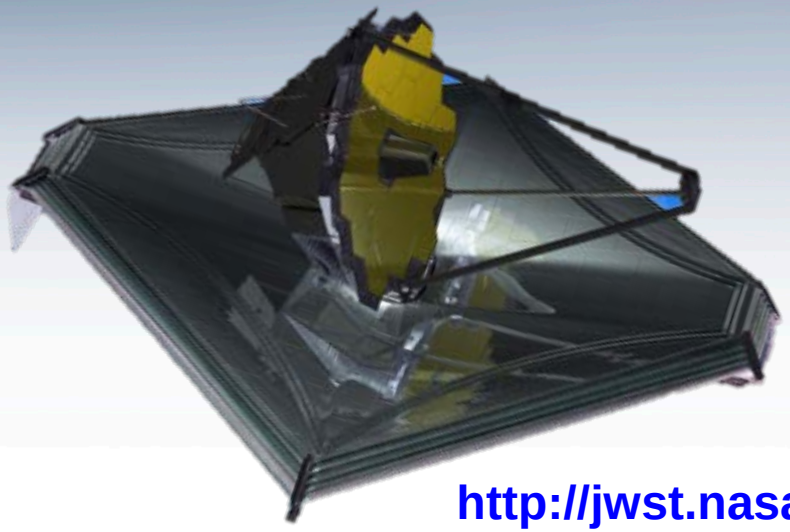
WFIRST
Mid 2020s

NASA Mission



Wide-Field Infrared Survey Telescope

James Webb Space Telescope



http://jwst.nasa.gov/

Large Infrared Space Observatory

Top priority of 2000 Decadal Survey

Science themes: First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life

Mission: 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield

Instruments: Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph

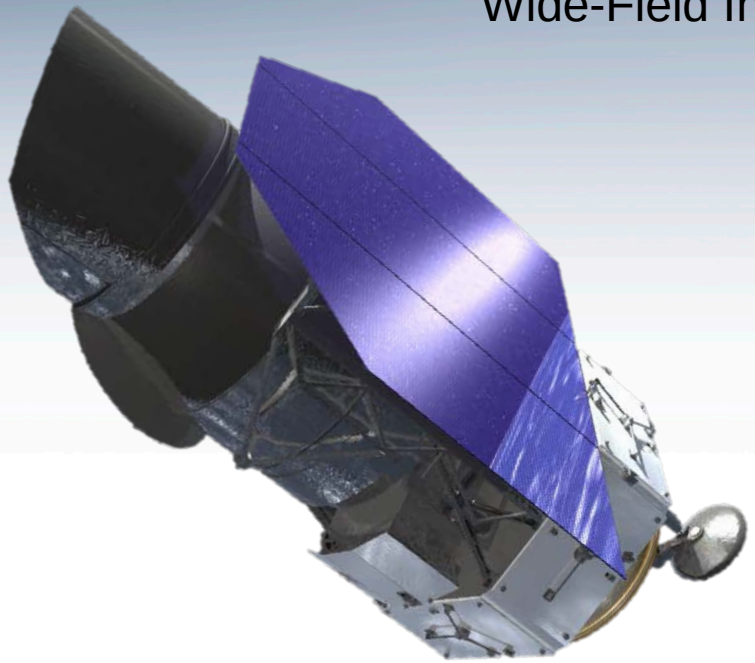
Operations: 2018 launch for a 5-year prime mission

Partners: ESA, CSA

JWST remains on track for an October 2018 launch

WFIRST

Wide-Field Infrared Survey Telescope



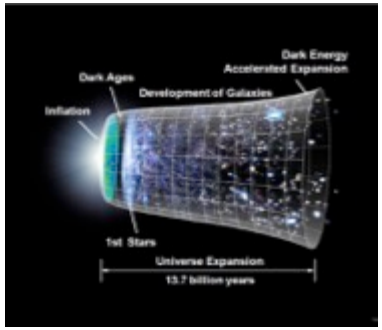
WFIRST highest ranked large space mission in 2010 Decadal Survey

- Study Dark Energy, Exoplanet Census, NIR Sky Survey

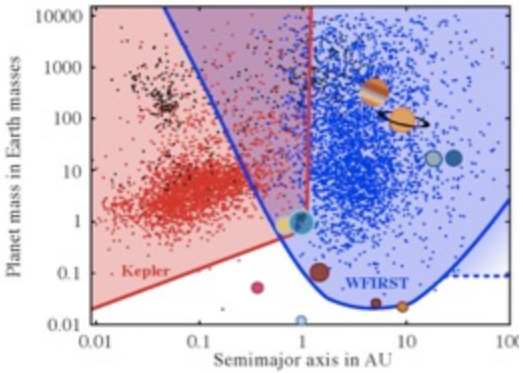
Use of 2.4m telescope enables

- Hubble quality imaging over 100x more sky
- Imaging of exoplanets with 10^{-9} contrast with a coronagraph

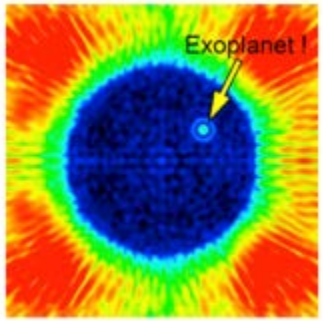
Dark Energy



Exoplanets



Microlensing

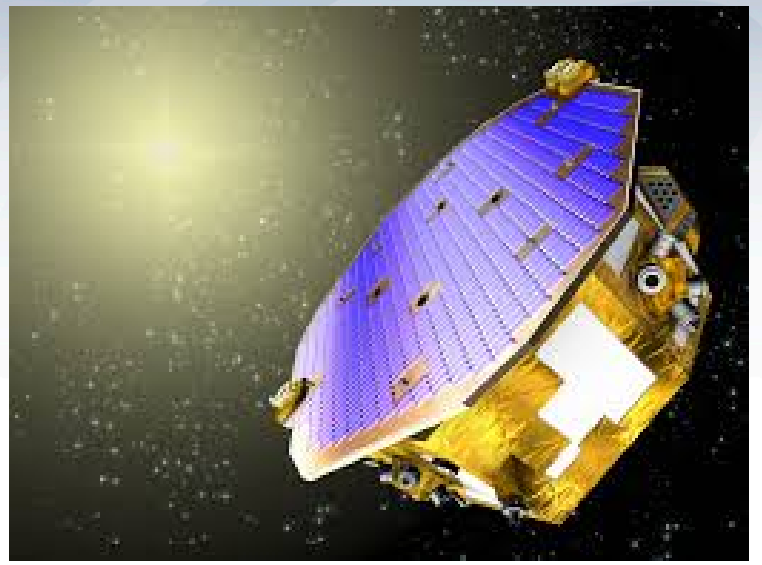


Coronagraph

Astrophysics

http://wfirst.gsfc.nasa.gov/

The Era of Gravitational Wave science has begun



- LIGO/VIRGO collaboration detection of gravitational waves from two merging black holes opens a new exciting probe of the Universe which is complementary to traditional electromagnetic approaches.

- What is NASA doing?

National Aeronautics and Space Act of 1958

The aeronautical and space activities of the United States shall be conducted so as to contribute materially to the following objectives:

- The expansion of human knowledge of phenomena in space.
- The development and operation of vehicles capable of carrying instruments through space.
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- Cooperation by the United States with other nations and groups of nations in work done and in the peaceful application of the results.

National Aeronautics and Space Act of 1958

The aeronautical and space activities of the United States shall be conducted so as to contribute materially to the following objectives:

NASA may do the following:

- The expansion of human knowledge of phenomena in space.

  Study astrophysics including gravitational waves

- The development and operation of vehicles capable of carrying instruments through space.

  Build and operate space observatories including LISA

- The establishment of studies of the benefits to be gained from space activities for scientific purposes.

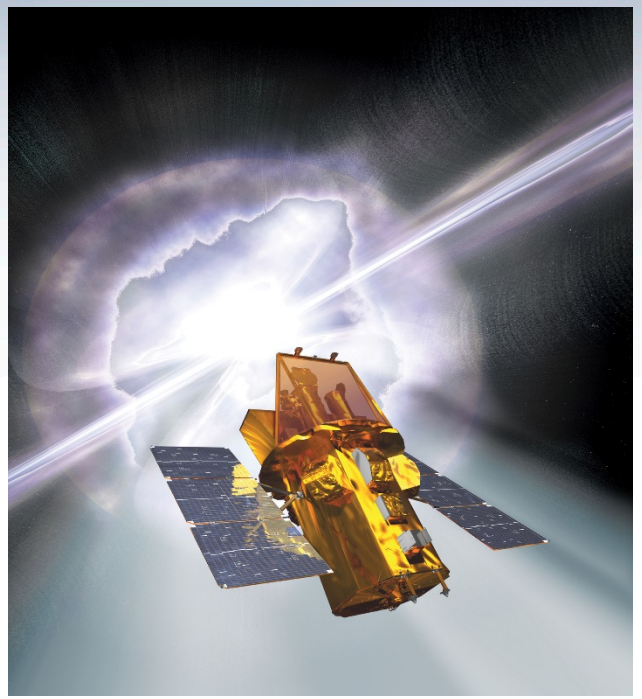
  Ask the Decadal Survey to prioritize missions such as LISA

- Cooperation by the United States with other nations and groups of nations in work done and in the peaceful application of the results.

  Partner with ESA and other nations on missions like LISA

What is NASA doing?

Searching for EM Counterparts



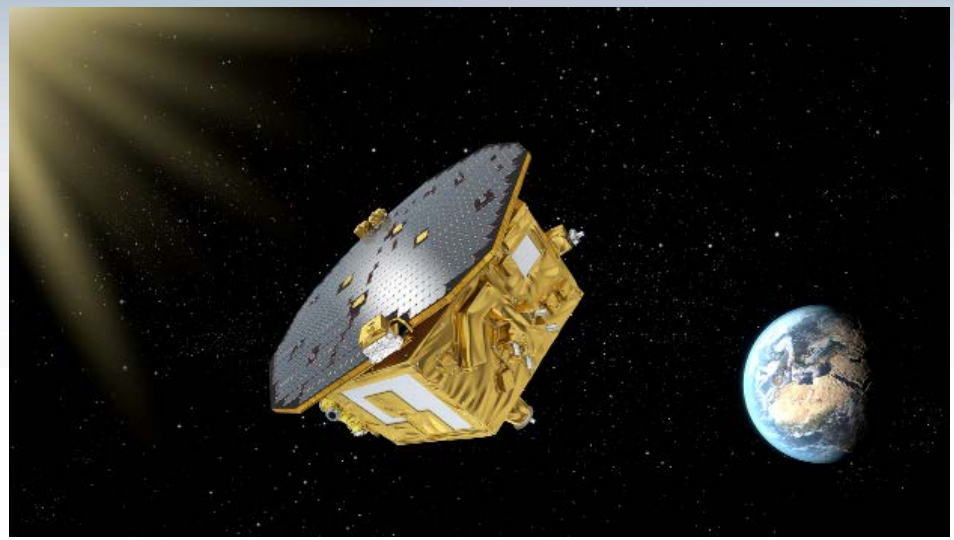
SWIFT Gamma-ray Burst Explorer

- BAT, Hard X-rays
- XRT, X-rays
- UVOT, Optical/UV
- Field of View: 2 sr (BAT)
- Location accuracy: 1 arcmin

Fermi Gamma-ray Space Telescope

- LAT, Gamma-rays
- GBM, hard X-rays
- Field of View: 2.4 sr (LAT)
- Location accuracy: 30 arcsec
- Field of View: 8 sr (GBM)
- Location accuracy: 15 degrees

ESA's LISA Pathfinder with NASA's Disturbance Reduction System (DRS)



Artist Concept: ESA- C.Carreau

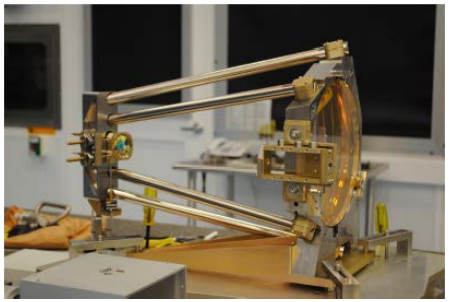
http://sci.esa.int/lisa-pathfinder/

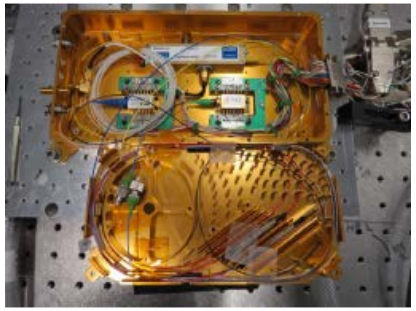
NASA's contribution to LPF consists of:

- The Disturbance Reduction System (DRS) as part of the Space Technology 7 (ST7) program, led by the Jet Propulsion Laboratory
- Data analysis and operations, led by the Goddard Space Flight Center

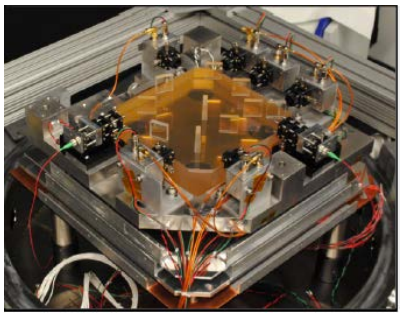
GW Technology Development

- Investments are being made in four major technologies:
  - Telescope (NASA's Goddard Space Flight Center)
  - Lasers (NASA's Goddard Space Flight Center)
  - Phasemeters (Jet Propulsion Laboratory)
  - Microthrusters (Jet Propulsion Laboratory)





- Additional investments are being made in
  - Optical bench (GSFC/Univ. of Florida)



Partnering on ESA's L3 Gravitational Wave Observatory

- ESA's L3 gravitational wave observatory draws on many years of joint studies with NASA
- The 2010 U.S. Decadal Survey recommended LISA, a partnership with ESA to "open low-frequency gravitational wave window for detection of black hole mergers and compact binaries and precision tests of general relativity."
  - This prioritization followed several previous U.S. reviews of the LISA mission priority including the 2003 NASA Technology Readiness and Implementation Plan (TRIP) review and the 2007 NRC Beyond Einstein Program Assessment Committee (BEPAC) review.
- But the Decadal Survey put several conditions on initiating a mission:
  - ESA's selection of a gravitational wave observatory as an L-class mission.
  - A successful LISA Pathfinder mission.
- When ESA selected the gravitational theme for L3 in 2013, NASA announced its willingness and desire to be a partner.

NASA's L3 Study Team (L3ST)

- Following the successful launch of the LISA Pathfinder in December 2015, NASA formed an L3 Study Team (L3ST) with membership drawn the US astrophysics community
- The goals of the L3ST are:
  1. Analyze the options for NASA participation in the L3 mission and work with the European L3 consortium on proposals to ESA; and
  2. Prepare a report to the 2020 U.S. Decadal Survey on NASA's participation, including possible options, in the L3 mission as a minority partner.
- Recent and ongoing L3ST activities:
  - Delivery of an Interim report with technology analysis
  - Development of a science report to update the LISA science case in preparation for the 2020 U.S. Decadal Survey.
  - Splinter meeting of the L3ST with the eLISA Consortium on Wednesday September 6, 1400-1700.

http://pcos.gsfc.nasa.gov/studies/L3/

L3ST Interim Report

- An Interim report on options for NASA participation in ESA's L3 mission was delivered to Astrophysics Director on June 20, 2016.
- The report identifies the major areas of interest for the US for gravitational wave technology development and provides an analysis of their respective benefits and limitations.
- The report will assist NASA in its discussions with ESA and will guide future NASA strategic investments in gravitational wave technology.

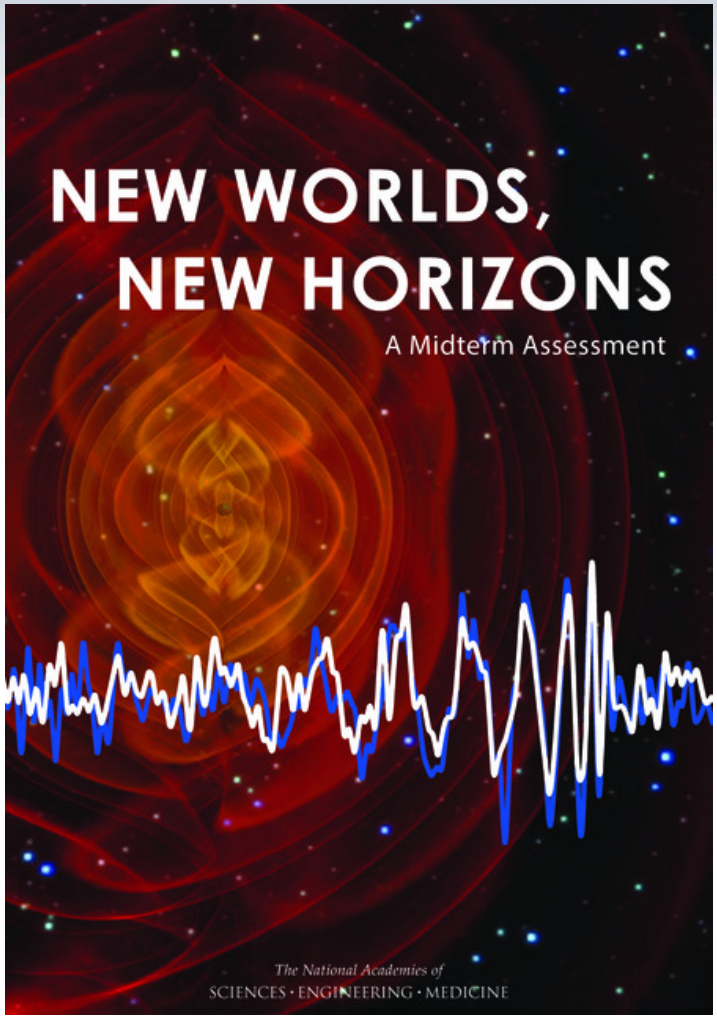
http://pcos.gsfc.nasa.gov/studies/L3/L3ST_Interim_Report-Final.pdf

What is NASA doing for GW?

- ✓ **Searching for EM counterparts** to LIGO sources
- ✓ **Supporting DRS operations on LISA Pathfinder**
- ✓ **Investing in development of GW technologies** relevant for a future space-based GW Observatory through directed and competitive programs (Strategic Astrophysics Technology Program, Astrophysics Research and Analysis Program)
- ✓ **Funding data analysis, simulations, and modeling** relevant for a future space-based GW observatory thru competitive programs (Astrophysics Research and Analysis Program, Astrophysics Theory Program, Theoretical and Computational Astrophysics Networks Program)
- ✓ **Establishing the U.S. L3 Study Team** to analyze the options for NASA participation in the L3 mission, work with the European L3 consortium on proposals to ESA, and prepare a report to the 2020 U.S. Decadal Survey on NASA's participation in the L3 mission as a partner
- ✓ **Discussing with ESA** the U.S. role on the L3 mission

2016 Decadal Mid-Term Assessment Report

Released August 15, 2016



"The science of LISA is even more compelling than in 2010 with the success of Advanced LIGO in making a direct detection of gravitational waves."

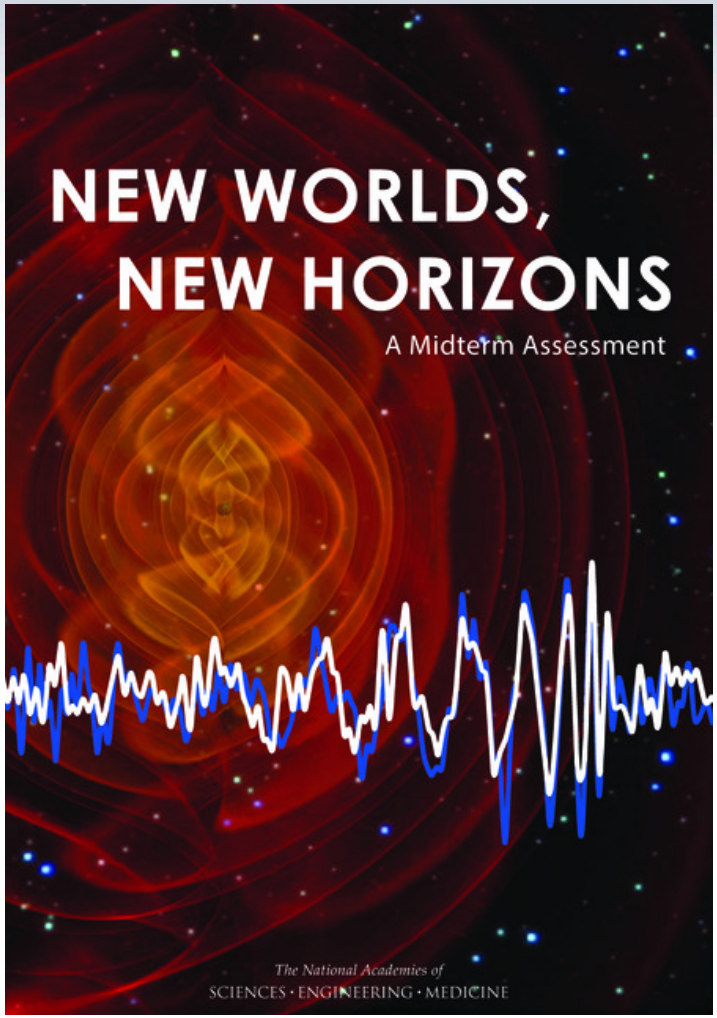
"Results of the LPF mission have demonstrated the feasibility of many of the key technologies needed to carry out a space gravitational wave mission, and ESA has selected a gravitational wave theme for the L3 large mission opportunity. These developments address two of the main conditions identified in NWNH for U.S. participation in a gravitational wave mission."

"The newly formed NASA L3 study team would best serve its function by participating in the planning and organization with ESA scientists and by identifying a range of options for U.S. participation in the L3 mission."

http://www.nap.edu/download/23560

2016 Decadal Mid-Term Assessment Report

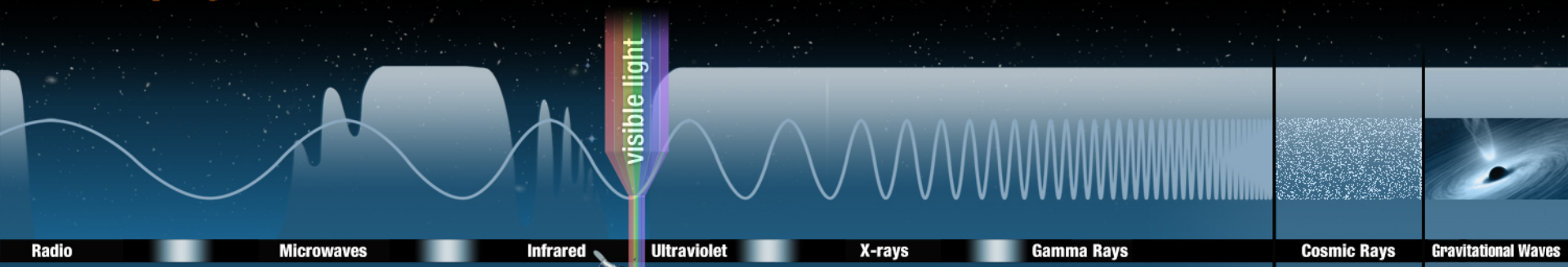
Released August 15, 2016



RECOMMENDATION 4-4: NASA should restore support this decade for gravitational wave research that enables the U.S. community to be a strong technical and scientific partner in the European Space Agency (ESA)-led L3 mission, consistent with the Laser Interferometer Space Antenna's high priority in the 2010 report *New Worlds, New Horizons in Astronomy and Astrophysics* (NWNH). One goal of U.S. participation should be the restoration of the full scientific capability of the mission as envisioned by NWNH.

http://www.nap.edu/download/23560

Astrophysics Mission Portfolio 2016



Hubble

Chandra

XMM-Newton (ESA)

Spitzer

Swift

Fermi

Kepler

AMS

NuSTAR

SOFIA

LISA Pathfinder (ESA)

NICER

CREAM

TESS

JWST

Euclid (ESA)

WFIRST

Athena (ESA)

L3 (ESA)

- Pre-Formulation
- Formulation
- Development
- Operating