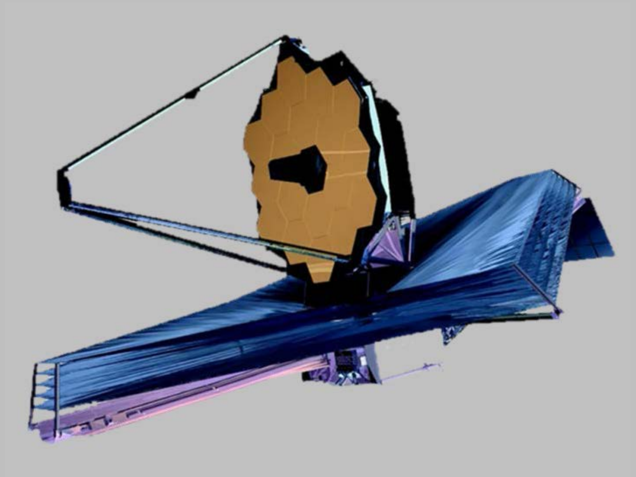
The US Space Astronomy Future

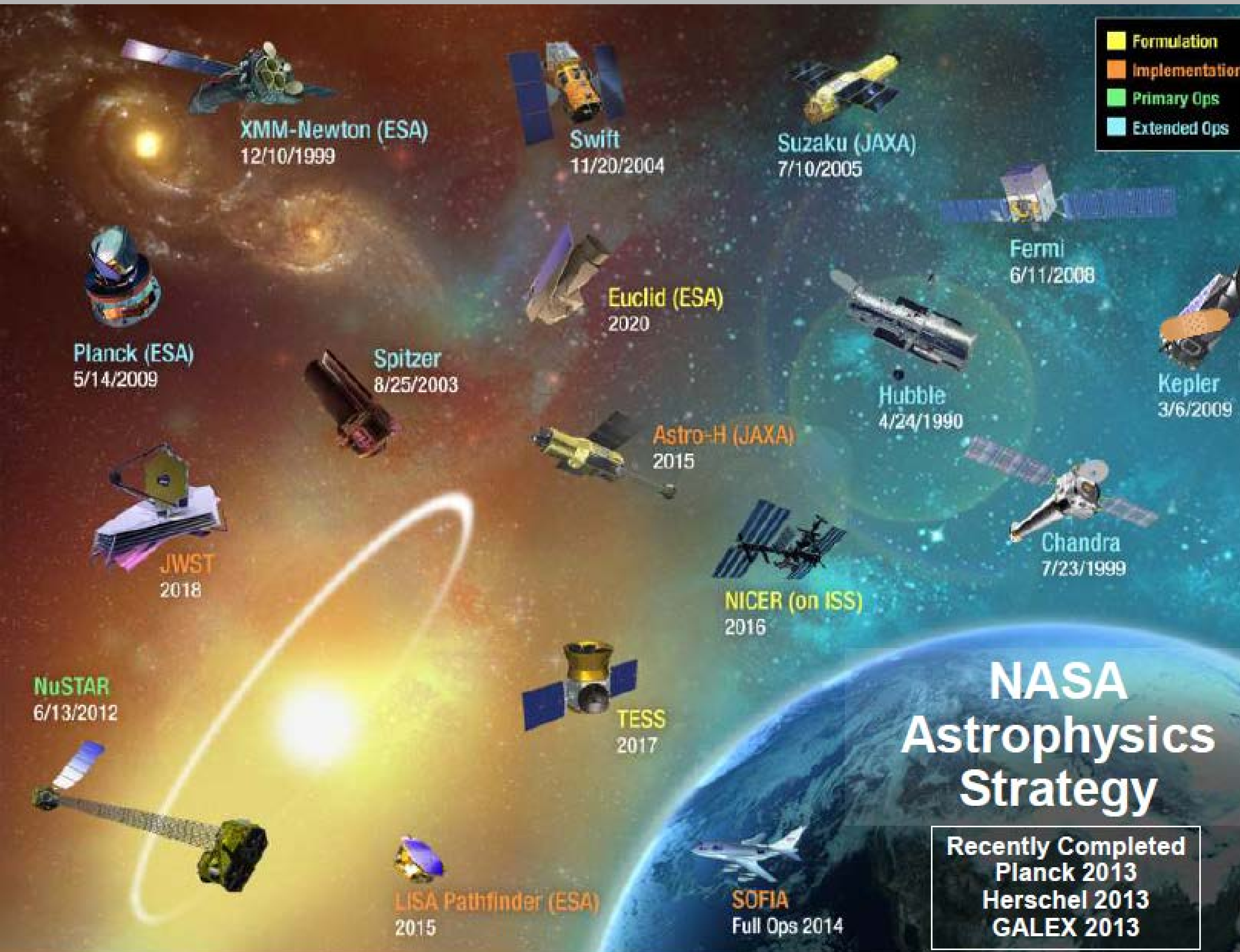
Jason Rhodes (Caltech/JPL)

1st COSPAR Symposium, Bangkok

November 12, 2013



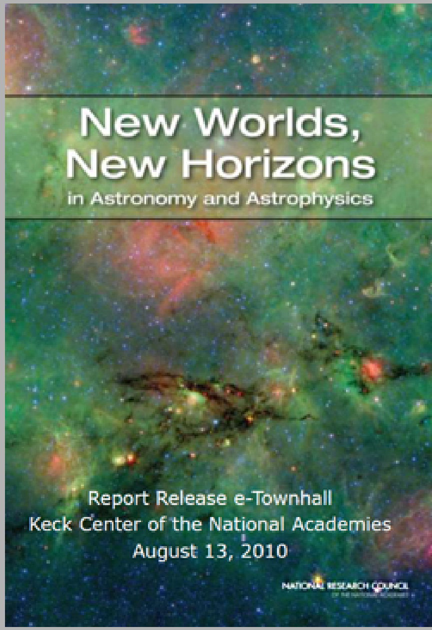
The Big Picture



From Paul Hertz, presentation to CAA, Nov. 2013

Decadal Survey (2010)

"Astro2010: New Worlds New Horizons" sets the stage for priorities in 2010-2020 (and beyond)



Recommendations to NASA:

- JWST is endorsed
- Pursue WFIRST to study dark energy, planets, and infrared surveys
- Enhance the Explorer program for shorter term opportunities
- Get started on LISA (gravitational waves)
- IXO (advanced X-Rays), inflation probe (CMB), exoplanet probe technology development

The budget reality (and JWST costs) were not what the Decadal Panel envisioned so not all of the decadal program can be carried out

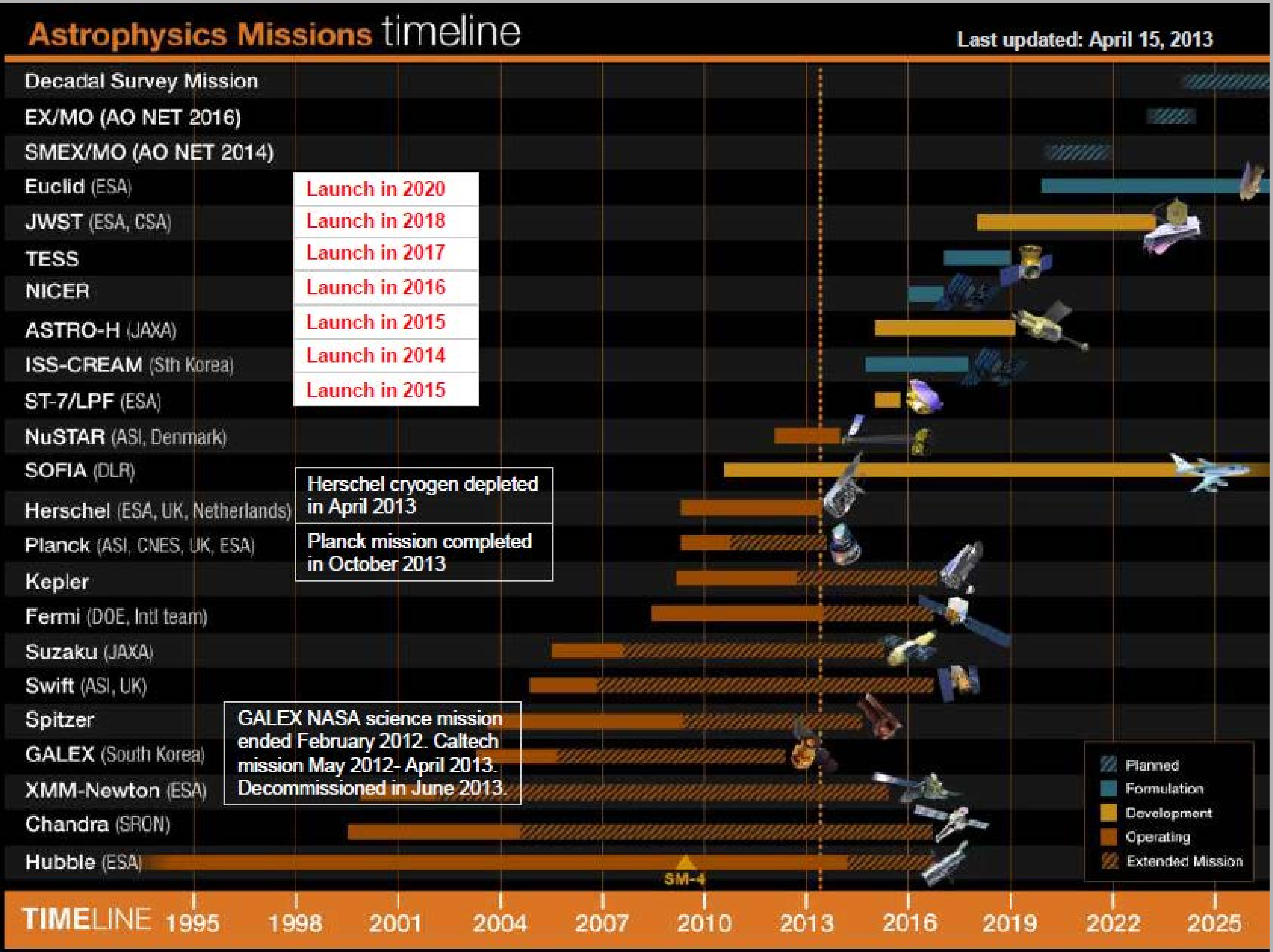
Science themes were identified and drive NASA's space astrophysics priorities

The Questions

NASA Strategic Plan (2011)

1. **How did our Universe begin and evolve?**
   - **What are the contents? Dark matter and dark energy?**
2. **How did galaxies, stars and planets come to be?**
   - **How and when did the first stars form?**
   - **How do galaxies evolve and what role does dark matter play?**
   - **How do planets form and how many of them are there?**
3. **Are we alone?**
   - **Are there planets in the habitable zones and if so how many?**
   - **Can we measure the atmospheres of exoplanets?**

NASA’s Timeline



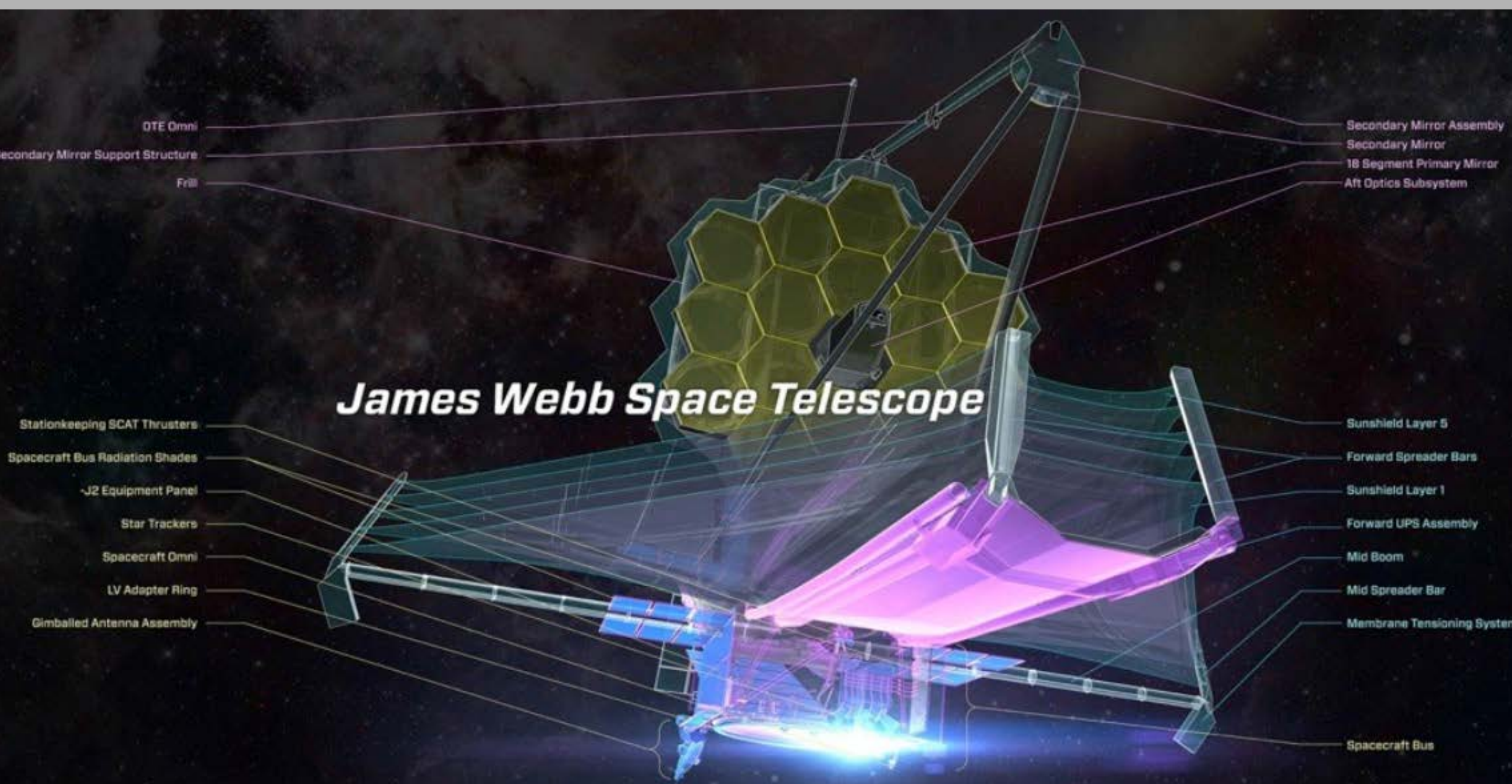
From Paul Hertz, presentation to CAA, Nov. 2013

30 Year Roadmap

- NASA process being conducted in 2013
- Takes Astro2010 as a starting point
- Presents a compelling 30 year vision with waypoints at 10 and 20 years
- Science based with nominal mission ideas
- Identify challenges and technology needs
- Seek community input (town hall)
- Complete report by December 2013

James Webb Space Telescope JWST

- The most ambitious space astrophysics mission ever
- NASA's flagship and crown jewel
- After a rocky few years, on track for 2018 launch for 5 year nominal mission (extended mission expected)



- 6.6m primary mirror
- 4 instruments
- 0.6 to 28.5 µm
- Deployable mirror
- Multinational effort
- L2 orbit and passively cooled to 50K

JWST (2)

- First light and imaging of the first galaxies at z>10
- Assembly history and evolution of galaxies and black holes
- Role o
- Exopla
  Object
- Birth o

In transit

Instruments:
NIRCam
NIRSpec
MIRI
Near-Infrared In

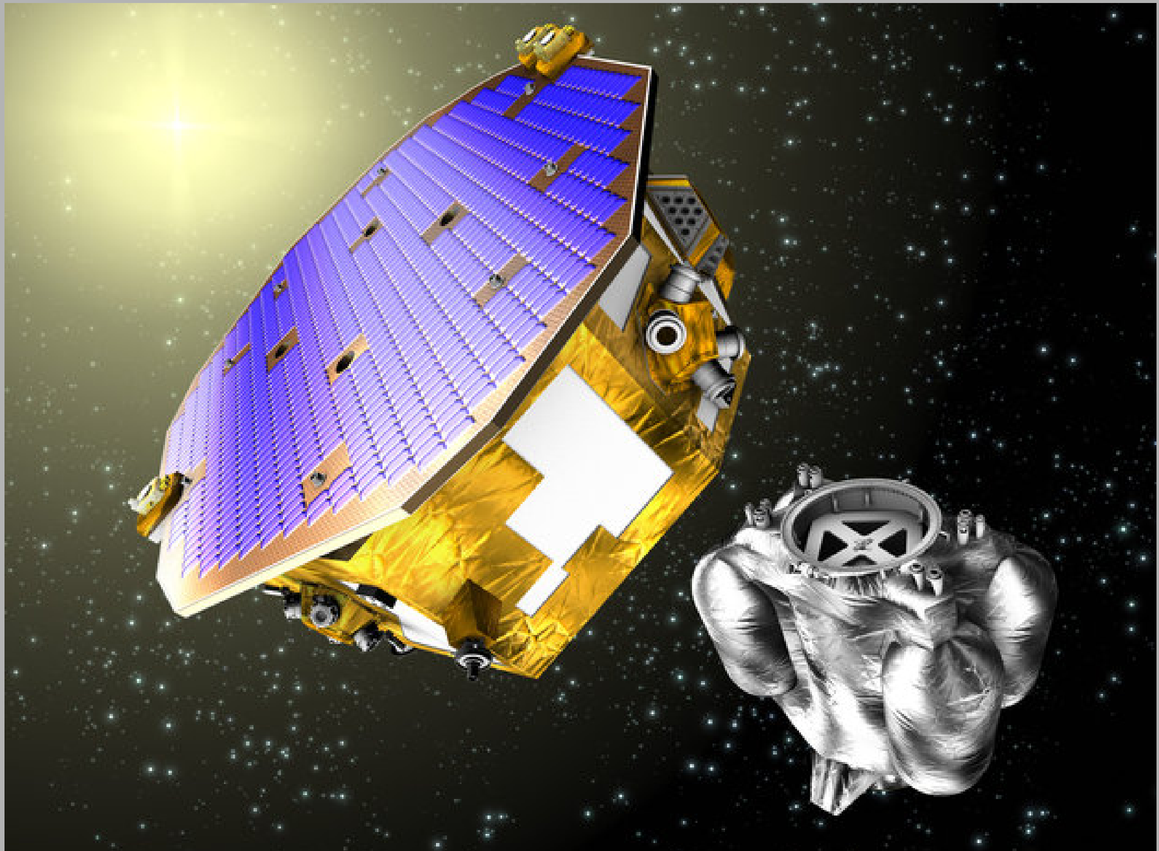
LISA Pathfinder (with ESA)

- Technology pathfinder for Laser Interferometry Space Antenna (LISA) like future mission
- Will study gravitation waves for 6-month nominal mission after 2015 launch
- Will demonstrate key technologies with 2 test masses in drag-free gravitational free fall
- Entirely new and unique window on the Universe

Tech demo:

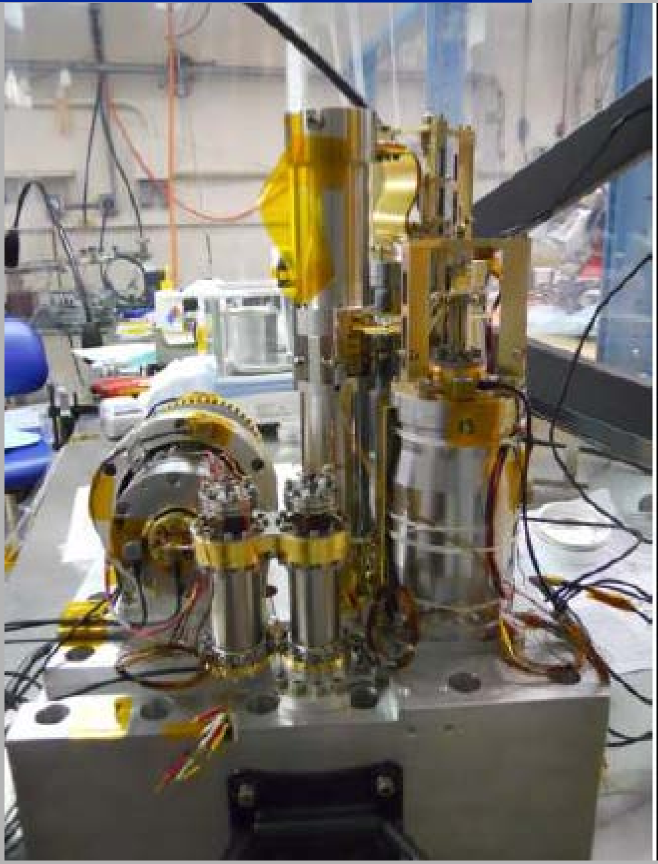
- Inertial sensors
- Micro-propulsion
- Laser metrology

NASA will provide the Disturbance Reduction System (DRS) to keep the spacecraft flying in formation with the test masses



Astro-H (with JAXA)

- X-Ray telescope planned for 2015
- NASA will help provide the Soft X-Ray Spectrometer (SXS) for high resolution X-Ray Spectroscopy

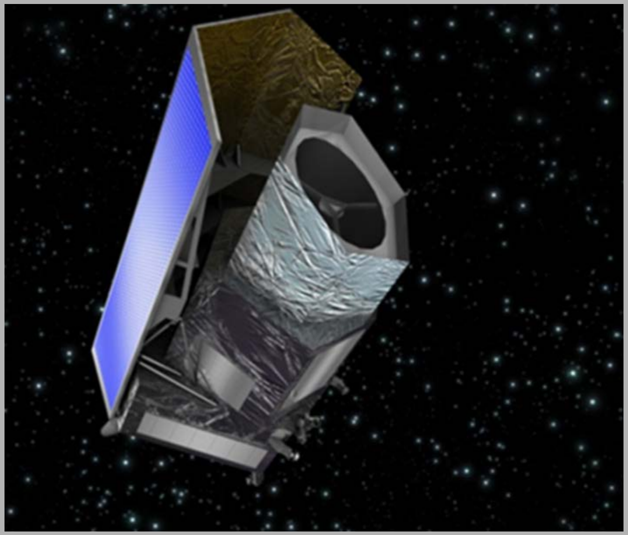


Science Goals:

- Trace the growth history of the largest structures in the Universe
- Provide insights into the behavior of material in extreme gravitational fields
- Determine the spin of black holes and the equation of state of neutron stars
- Trace shock acceleration structures in clusters of galaxies
- Investigate the detailed physics of jets

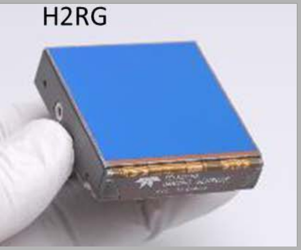
Euclid (with ESA)

JPL



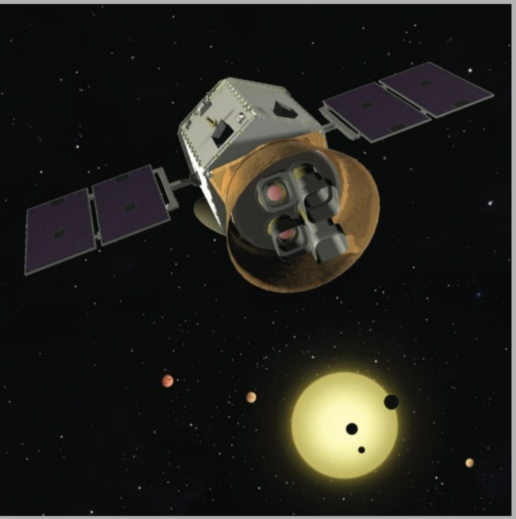
- ESA led mission to map the ‘dark universe’ scheduled for 2020 launch
- 6 year primary mission at L2
- Visible (VIS) and Near infrared Spectrometer Photometer (NISP) instruments
- 15,000 square degree survey

Euclid will study dark energy via weak gravitational lensing and galaxy clustering (baryon acoustic oscillations and redshift space distortions; BAO & RSD)



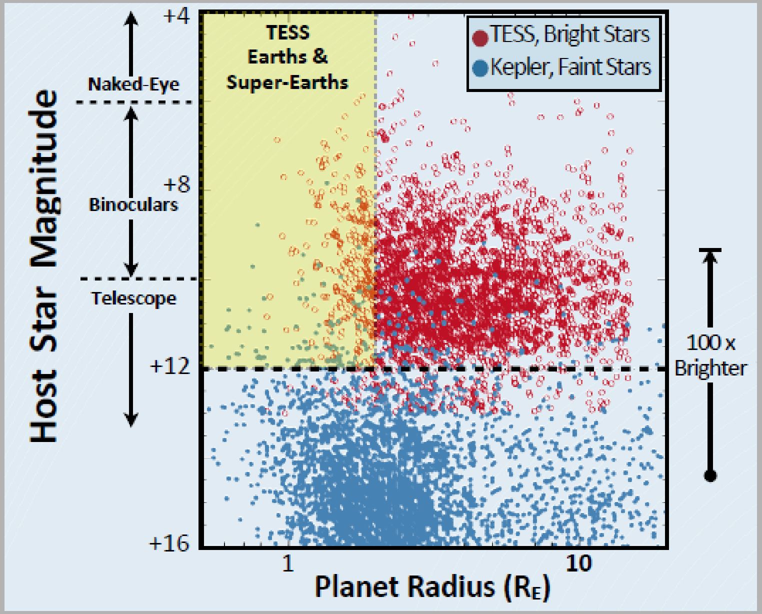
- NASA Contribution is 16 flight detectors, cable, readout electronics for NISP
- 54 US scientists in Euclid Consortium

TESS: Transiting Exoplanet Survey Satellite



- Explorer with 2017 launch for a 2 year mission
- 4 wide field telescopes each with a 16 Mpixel camera
- Will survey 500,000 bright, nearby stars
- Expect to find 10^3 to 10^4 transiting exoplanets of Earth size or larger with orbital periods up to 2 months

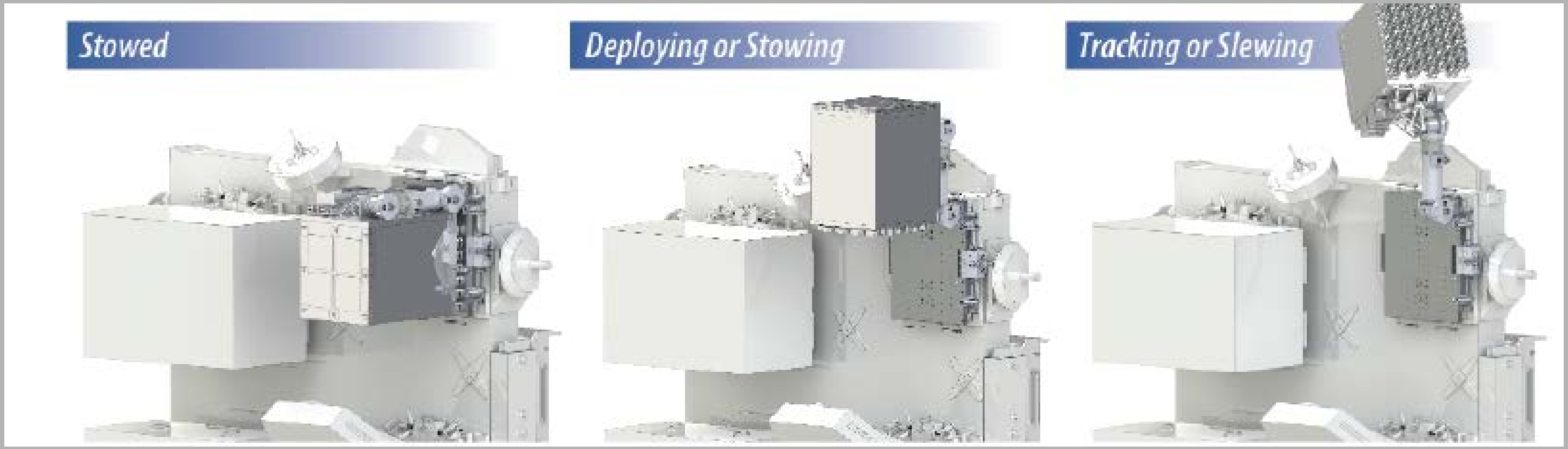
- TESS will find targets for JWST and possible future follow-on missions
- Find the best (most easily characterizable) 1000 small exoplanets
- All-sky survey of bright stars



From TESS PI George Ricker (MIT)

NICER (ISS)

- Neutron Star Interior Composition Explorer (NICER) will fly in 2016 on the International Space Station (ISS)
- Explorer Mission of Opportunity (MOO), first to go on ISS
- Will study the gravitational, electromagnetic, and nuclear-physics environments of neutron stars
- Also rapid response of X-ray transients and a guest observer program
- Rotation-resolved spectroscopy of the thermal and non-thermal emissions of neutron stars in the soft (0.2-12 keV) X-ray band

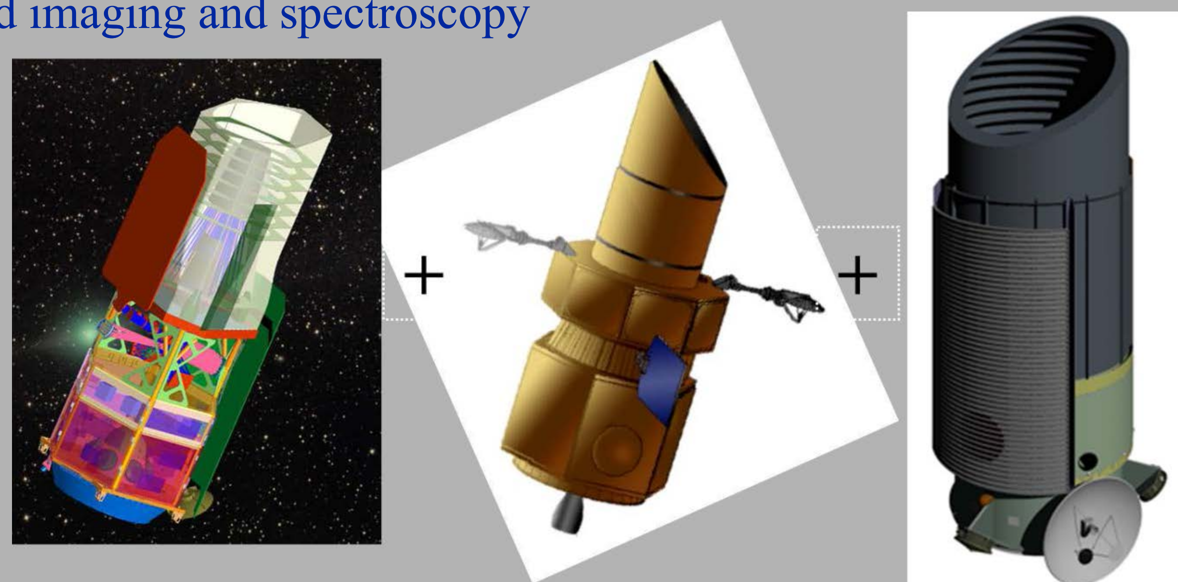


From NICER in SPIE, July 2012

WFIRST-AFTA (1)

- Wide Field Infrared Survey Telescope (WFIRST) was the top-ranked large space mission priority in Astro2010
- A surplus spy telescope was gifted to NASA in 2011, and may be used for WFIRST
- The 2.4m telescope is the Astrophysics Focused Telescope Asset (AFTA)
- WFIRST resulted from the shared hardware needs of several high-priority and ambitious science programs
- Wide field, near infrared imaging and spectroscopy

WFIRST=



JDEM-Ω MPF NIRSS

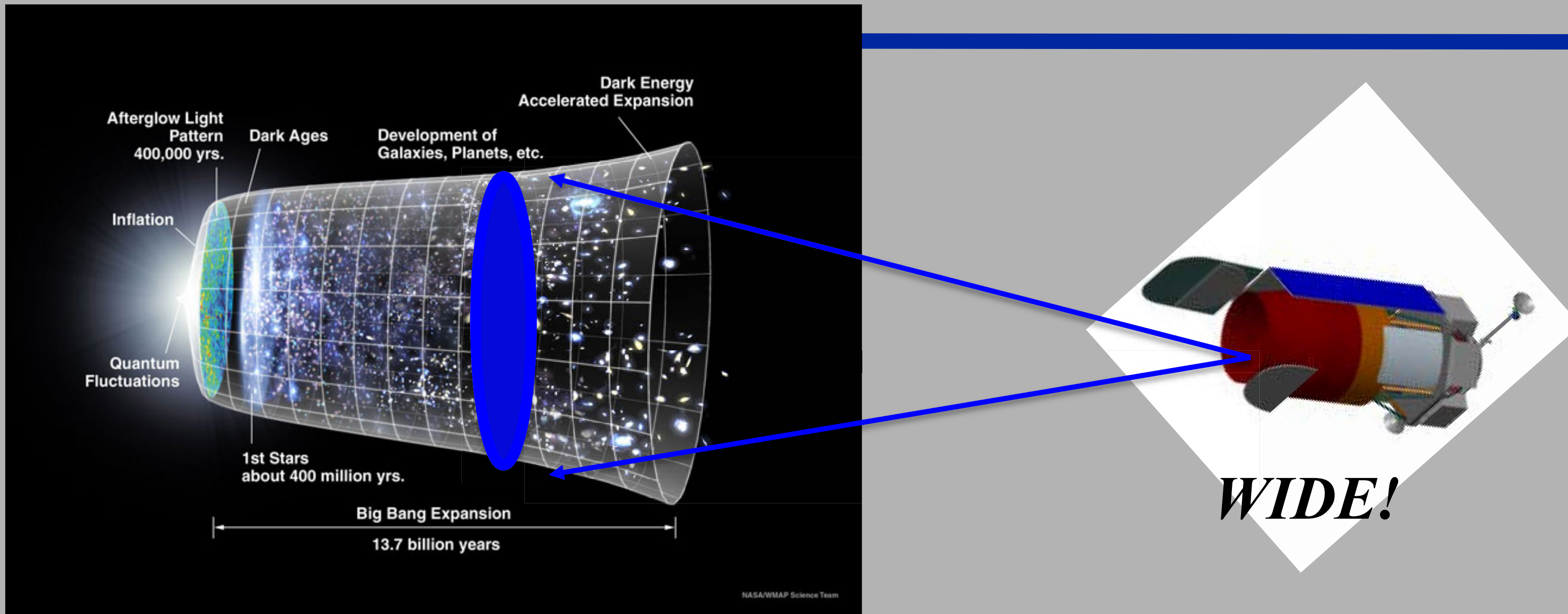
What is dark energy?

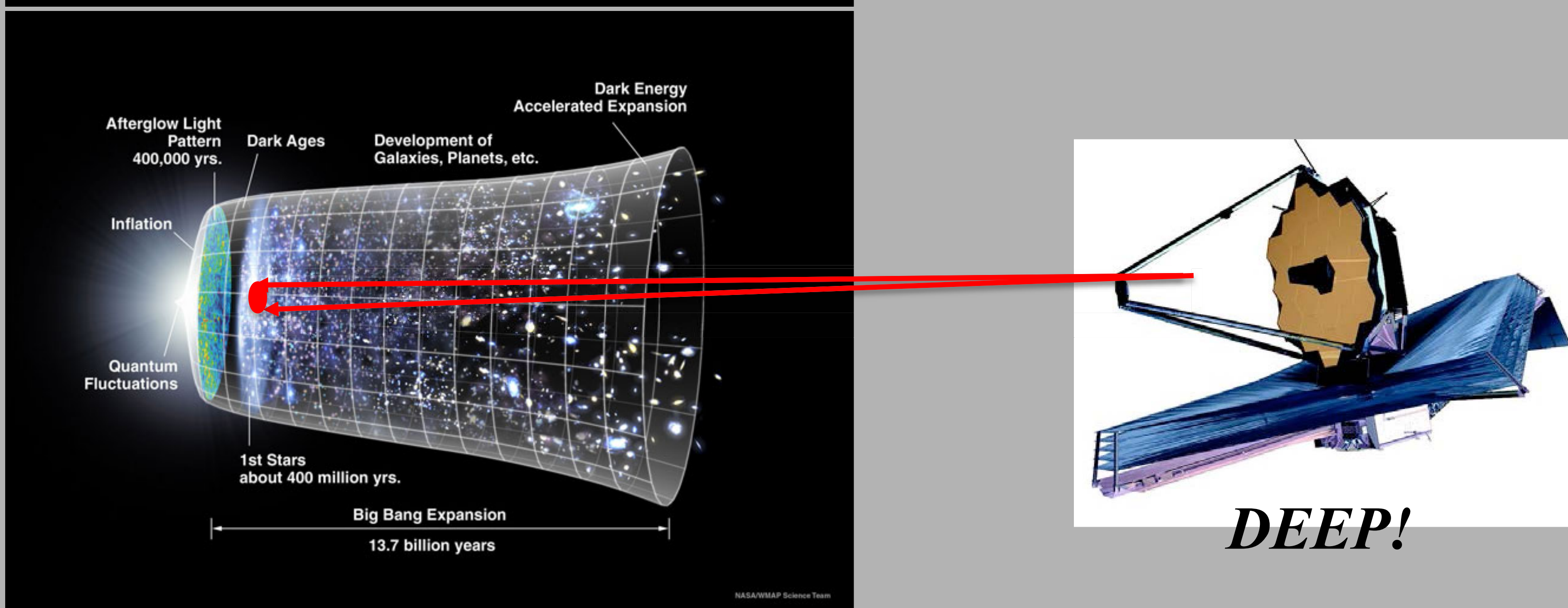
Is our solar system special?

Are the planets around nearby stars like those of our own solar system?

How do galaxies form and evolve?

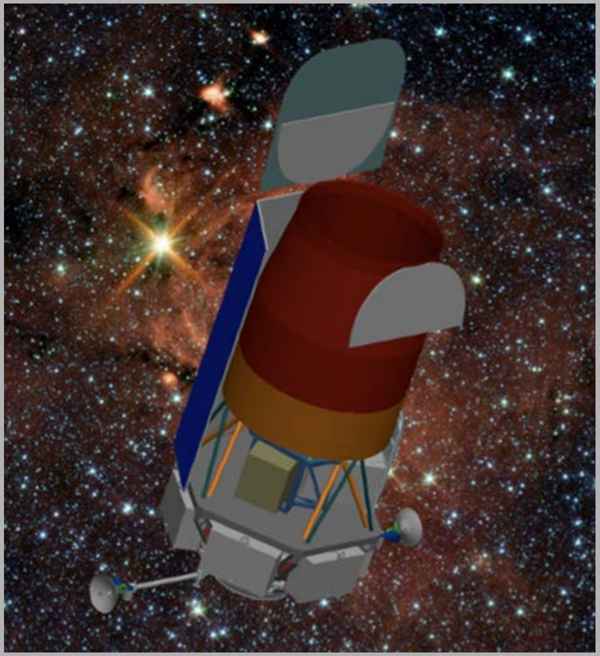
AFTA Complements JWST





WFIRST –AFTA (2)

- Could launch in 2023 for a 5 year nominal/10 year extended mission
- Instrumentation (0.7-2μm):
  - 0.28 square degree imager focal plane for imaging/spectroscopy (18 H4RG-10μm devices, 288 Mpix)
  - Integral Field Unit for spectroscopy
  - Coronagraph for exoplanet imaging (10^{-9} contrast)



Science Program:

Dark Energy

- Supernova
- Weak lensing
- Galaxy Clustering (Baryon Acoustic Oscillations and Redshift Space Distortions)
- Galaxy Clusters

Exoplanets

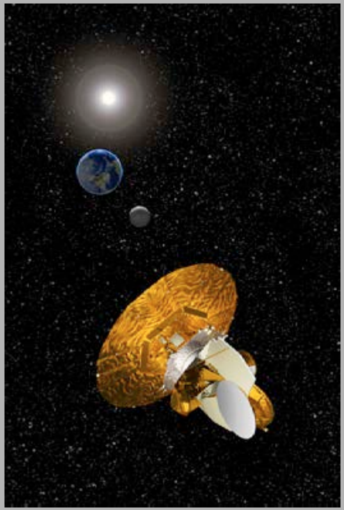
- Microlensing
- Coronagraphic imaging

Infrared Surveys

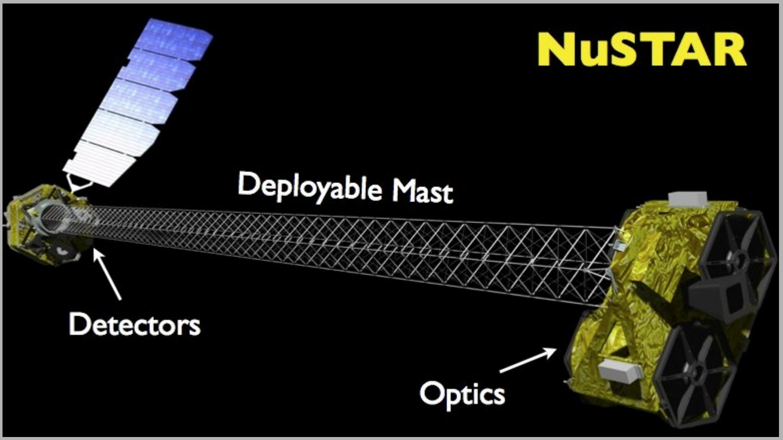
- Galaxy evolution
- Galactic archaeology
- Star formation
- Search for rare/transient objects

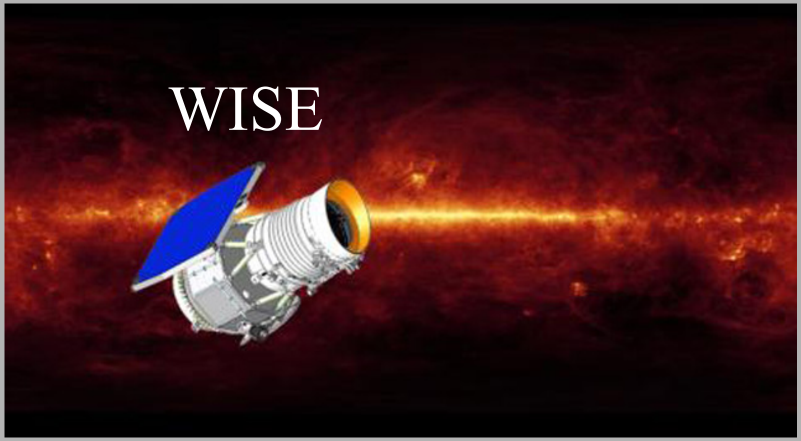
Explorers

- 90 missions since 1958
- Support different classes of missions
  - Mission of opportunity (MOO; not full mission, but an instrument or participation in other mission)
  - Small Explorer (SMEX)
  - Explorer
  - Mid-Ex
- Cadence of every ~ 2 years for a call for a MOO and Explorer
- 2014 SMEX/MOO Announcement of Opportunity
- 2016 Explorer/MOO Announcement of Opportunity



WMAP

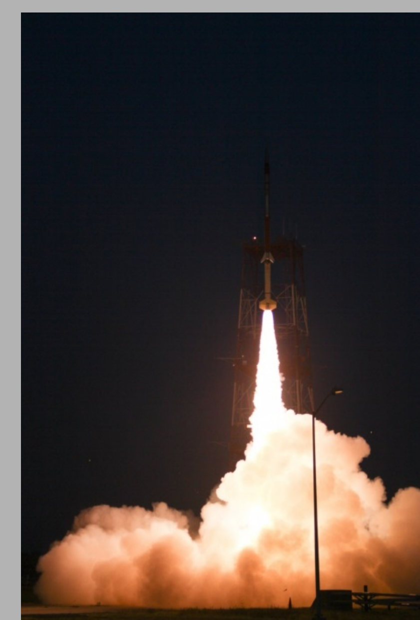




Balloons, Planes (and more)

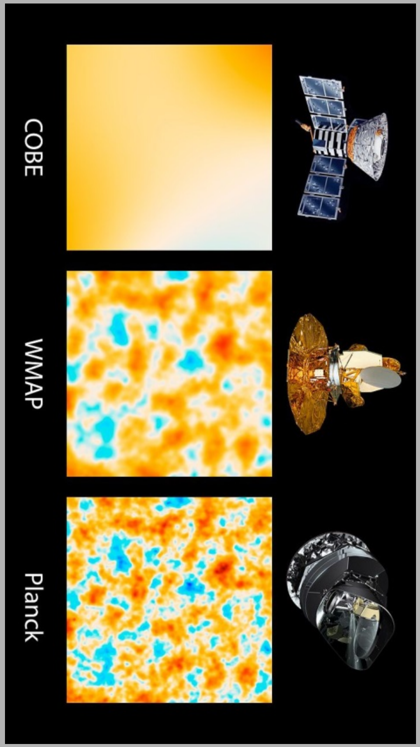
- NASA has a robust balloon program
  - Flights in the US and in Antarctica yearly
  - Tests of an Ultra Long Duration Balloon (ULDB) for flights up to 100 days are underway
- NASA conducts Sounding rocket launches (e.g. CIBER)
  - Short duration, sub orbital experiments

- Airborne observations (SOFIA) provide observing modes and wavelength coverage not available from the ground
- Alternative methods of access to space-like observing conditions are being studied
  - Tethered balloons at up to 20km or higher
  - Airships (lighter than air, stationary) at 20km
- The ISS remains a viable option for astrophysics instrument implementation



Ultimate Goals- A Complete Map

- Technology path to large (10-30 meter) telescopes in space, large arrays (degree scale, many Gpix), massively multiplexed ($>10^4$) spectra, large cryogenic arrays for mid and far infrared
- The CMB contains more information, especially in the polarization, but we can come close to exhausting this information with foreseeable technology
- Some of the Universe will always be obscured by the galaxy
- Measuring nearly all the unsecured galaxies (shapes, spectra, fluxes) is within our technological reach in the coming decades
- Within the galaxy, mapping the size, frequency, and orbits of exoplanets is within reach
- We can begin to image some of the nearest exoplanets and take spectra of the atmospheres- signs of life
- Complete map of the Universe



It is within our reach to exhaust the ability of current probes to tell us about the contents of the Universe and whether we are alone.