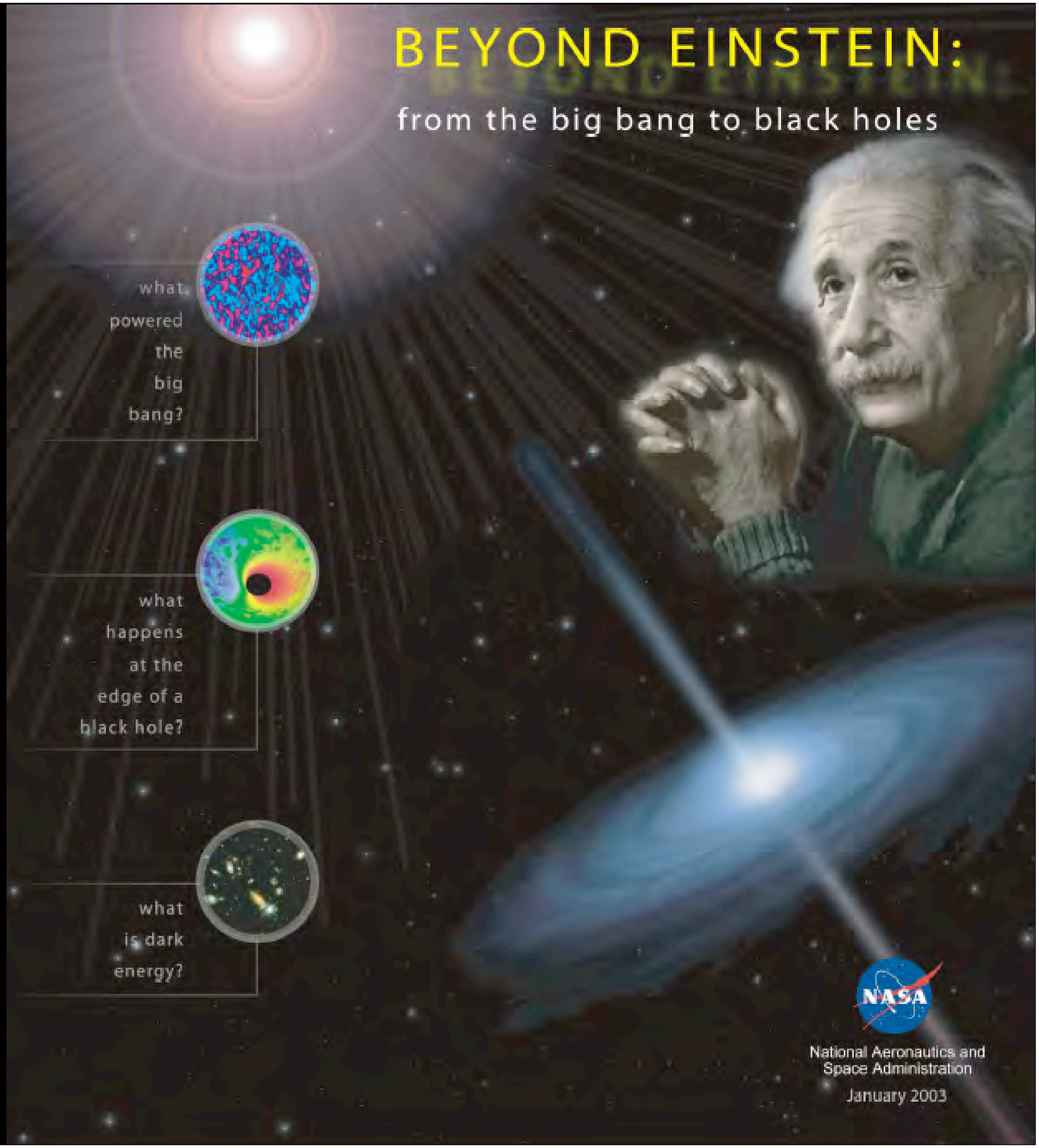
Restarting the Exploration of the Universe:

The National Academy's Beyond Einstein Report and the Future of Space Astronomy

Joel Primack

University of California, Santa Cruz



OUTLINE

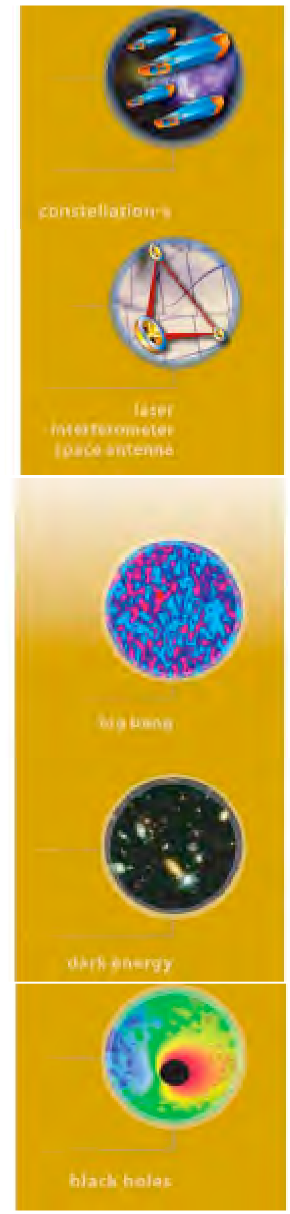
Summary of the Beyond Einstein report

- Five Mission Areas
- Findings and Recommendations
- 1st start: JDEM
- 2nd start: LISA

} **DO BOTH!**

My recommended DOE response

The Beyond Einstein Program



Einstein Great Observatories: Facility-class missions

- **Constellation-X**

Uses X-ray-emitting atoms as clocks to follow matter falling into black holes and to study the evolution of the Universe.

- **Laser Interferometer Space Antenna (LISA)**

Uses gravitational waves to sense directly the changes in space and time around black holes and to measure the structure of the Universe.

Einstein Probes: Moderate-sized, scientist-led missions

- **Inflation Probe**

Detect the imprints left by quantum effects and gravitational waves at the beginning of the Big Bang.

- **Dark Energy Probe**

Determine the properties of the dark energy that dominates the Universe.

- **Black Hole Probe**

Take a census of black holes in the local Universe.

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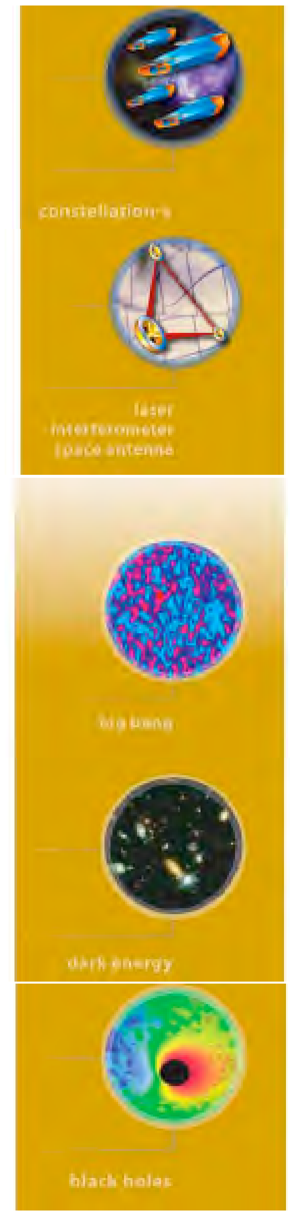
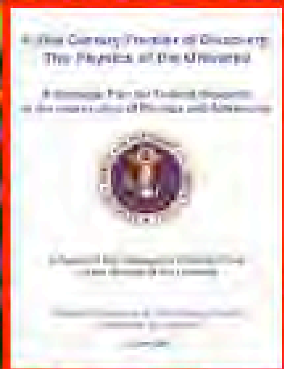


Timeline: From Q2C to BEPAC



2003: National Science and Technology Council Convenes an Interagency Working Group on The Physics of the Universe; Congress forms 3-agency Astrophysics Advisory Committee (AAAC)

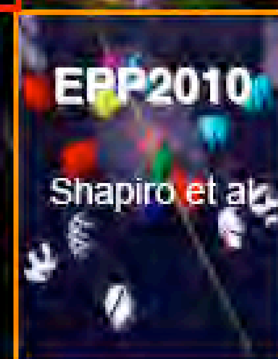
March 2004: OSTP's *The Physics of the Universe: A Strategic Plan for Federal Research at the Intersection of Physics and Cosmology* (cross-agency implementation plan)

2004: NSF launches community-based process for UG Lab, funds design and development for LSST

DUSEL

2005: CAA midterm report re-affirms AANM and Q2C priorities

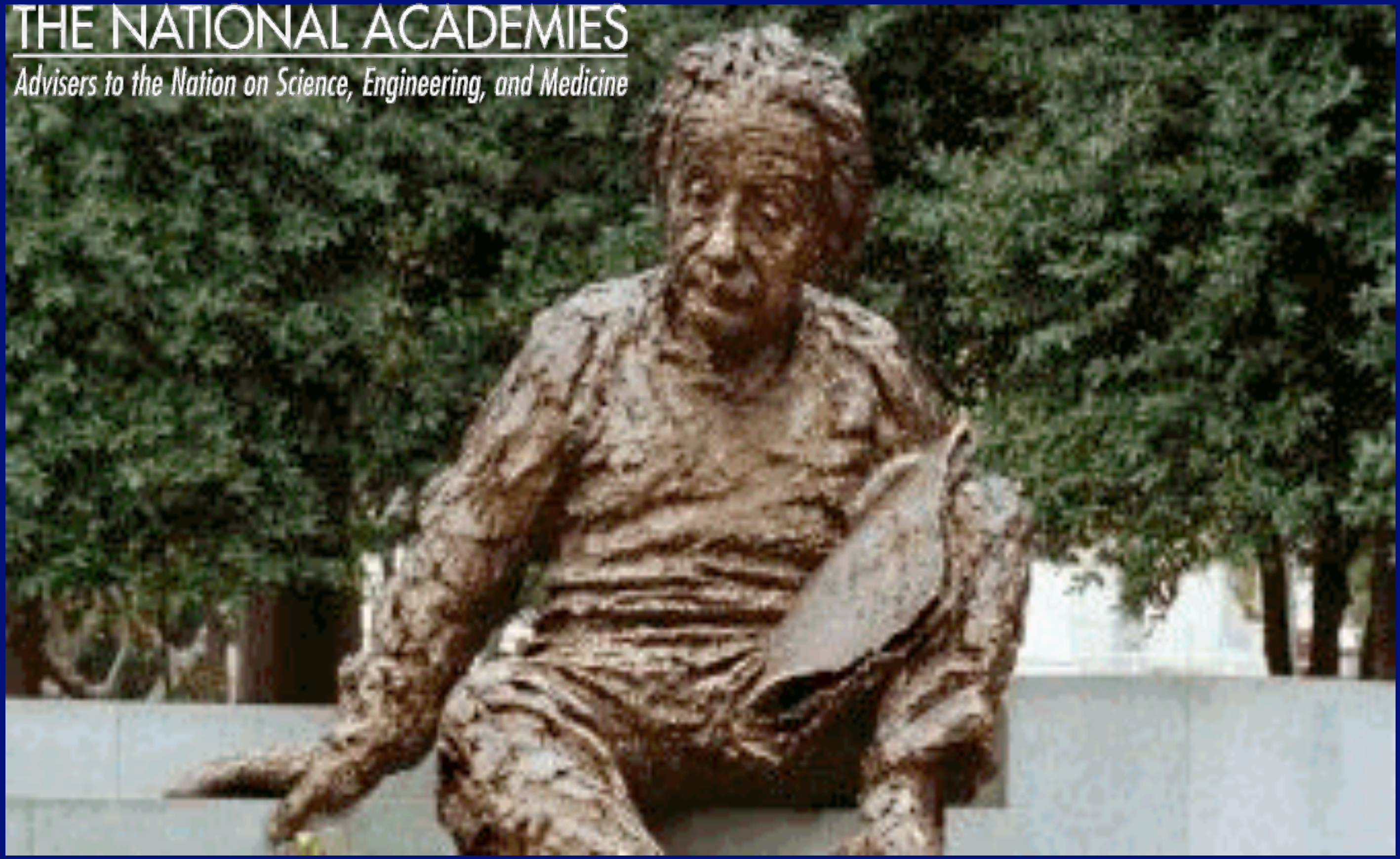
April 2006: *Revealing the Hidden Nature of Space and Time – Charting the Course for Elementary Particle Physics* embraces Q2C science as part of EPP



October 2006: HEPAP P5 Roadmap includes JDEM, LSST, Dark Matter, UG Lab, Neutrinos, …

November 2006: BEPAC to identify first Beyond Einstein mission

Mike Turner



NASA's Beyond Einstein Program: An Architecture for Implementation

Committee Charge

1. Assess the five proposed Beyond Einstein missions (Constellation-X, Laser Interferometer Space Antenna, Joint Dark Energy Mission, Inflation Probe, and Black Hole Finder probe) and **recommend which of these five should be developed and launched first**, using a funding wedge that is expected to begin in FY 2009. The criteria for these assessments include:
   - Potential scientific impact within the context of other existing and planned space-based and ground-based missions; and
   - Realism of preliminary technology and management plans, and cost estimates.

2. **Assess the Beyond Einstein missions** sufficiently so that they can act **as input** for any future decisions by NASA or the next Astronomy and Astrophysics Decadal Survey **on the ordering of the remaining missions**. This second task element will assist NASA in its investment strategy for future technology development within the Beyond Einstein Program prior to the results of the Decadal Survey.

Committee Members

- Eric Adelberger, *U Washington*
- William Adkins, *Adkins Strategies, LLC*
- Thomas Appelquist, *Yale*
- James Barrowman, *NASA (retired)*
- David Bearden, *Aerospace Corp.*
- Mark Devlin, *U Pennsylvania*
- Joseph Fuller, *Futron Corp.*
- Karl Gebhardt, *U Texas*
- William Gibson, *SWRI*
- Fiona Harrison, *Caltech*
- Charles Kennel, *UCSD*, *co-chair*
- Andrew Lankford, *UC Irvine*
- Dennis McCarthy, *Swales (retired)*
- Stephan Meyer, *U. Chicago*
- Joel Primack, *UC Santa Cruz*
- Lisa Randall, *Harvard*
- Joseph Rothenberg, *Universal Space Network, co-chair*
- Craig Sarazin, *U Virginia*
- James Ulvestad, *NRAO*
- Clifford Will, *Washington University*
- Michael Witherell, *UC Santa Barbara*
- Edward Wright, *UCLA*

Committee Staff

- Brian Dewhurst, *Study Director, BPA*
- Sandra J. Graham, *Study Director, SSB*

Oversaw Review

- Martha Haynes, *Cornell*
- Kenneth Keller, *JHU*

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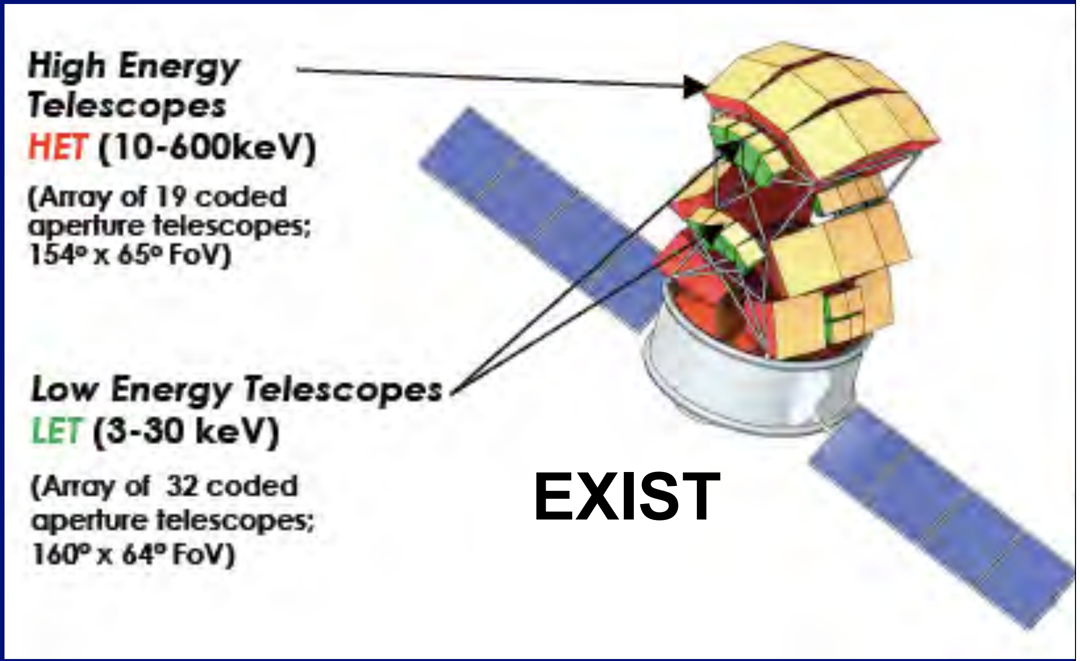
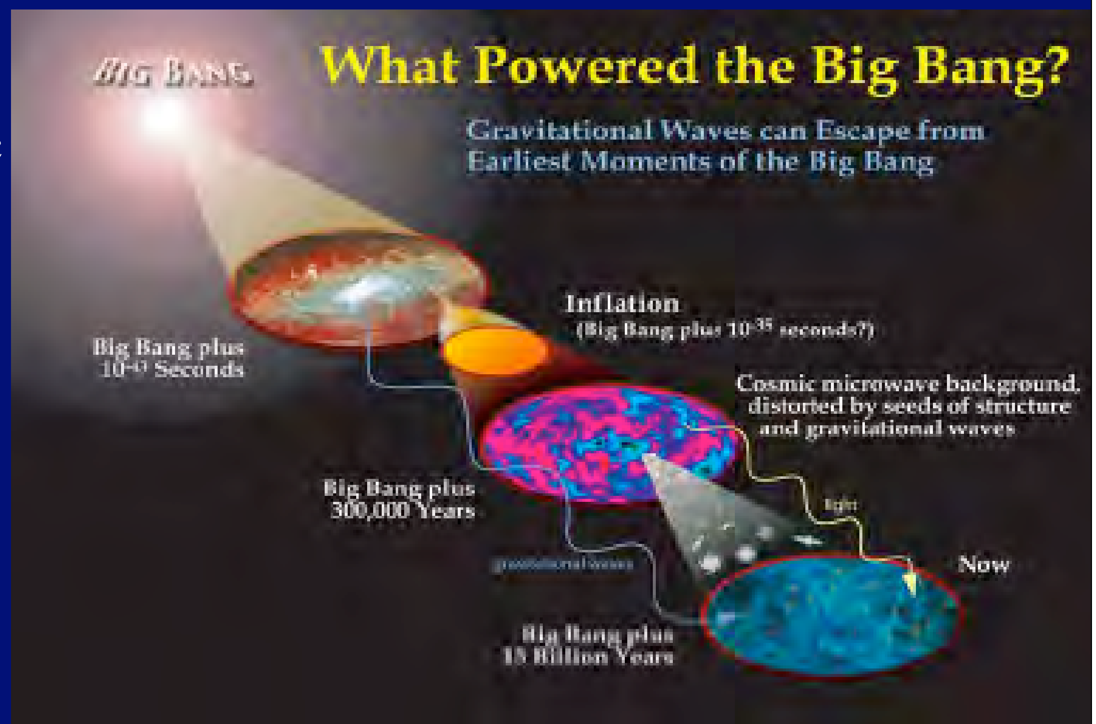
Black Hole Finder Probe: Science Goals

- Beyond Einstein science
  - perform a census of black holes throughout the Universe
  - determine how black holes evolve
  - observe stars and gas plunging into black holes
  - determine how black holes are formed
- Broader science
  - discover the origin of the 511 keV electron-positron annihilation line toward the center of the Milky Way
  - determine the rate of supernova explosions in the Milky Way
  - discover new types of hard x-ray sources revealed by a high-sensitivity survey
- Missions: EXIST, CASTER

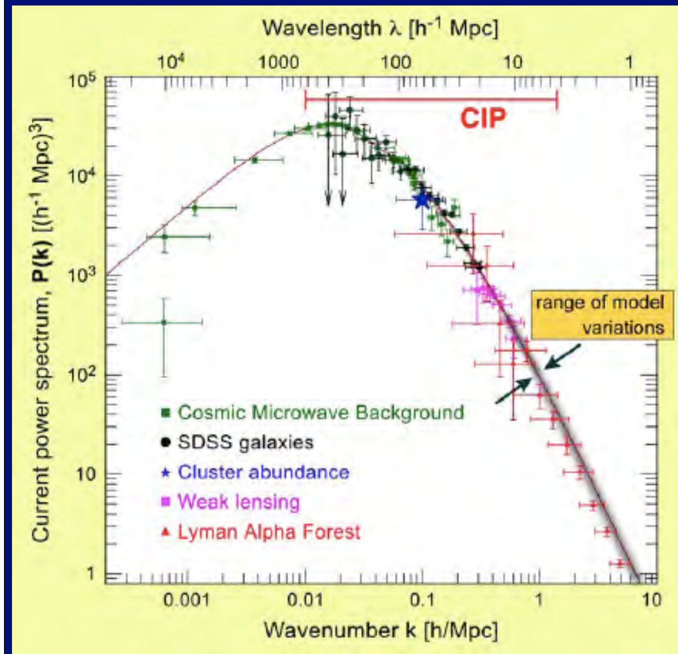


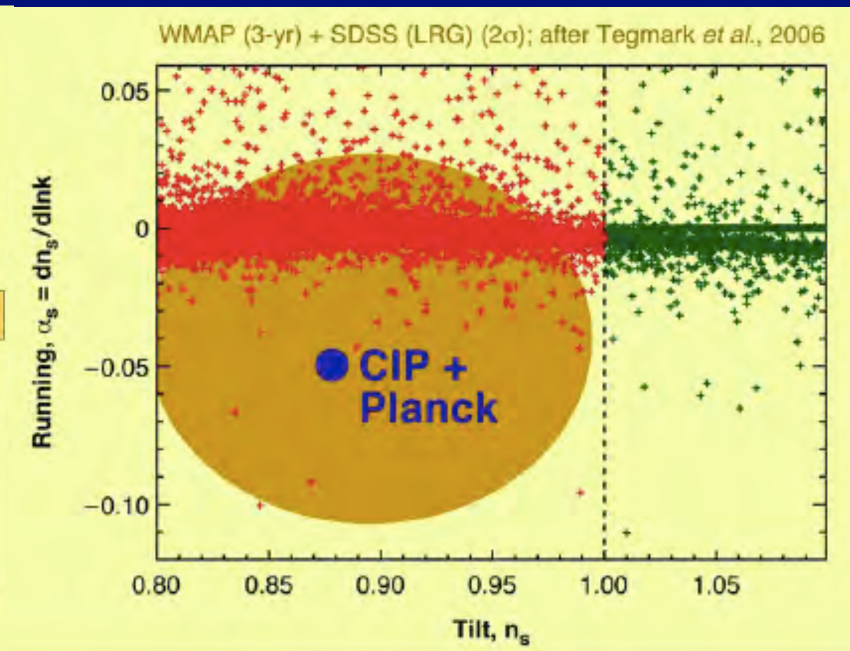
Inflation Probe: Science Goals

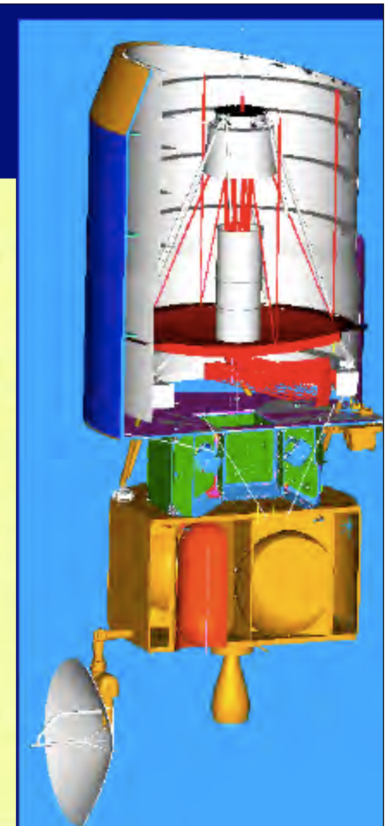
- Beyond Einstein science
  - constrain the physics of inflation
  - detect gravitational waves sourced by inflation (CMB probes)
  - detect baryonic oscillations in the matter power spectrum (CIP)
- Broader science
  - determine the nature of galactic dust, galactic magnetic fields, and electron spectrum
  - determine when the universe was reionized
  - investigate the history of star formation for 3<z<6
  - determine the masses of the three kinds of neutrinos
- Missions:
  - Cosmic Inflation Probe
  - 3 CMB Probes



Cosmic Inflation Probe







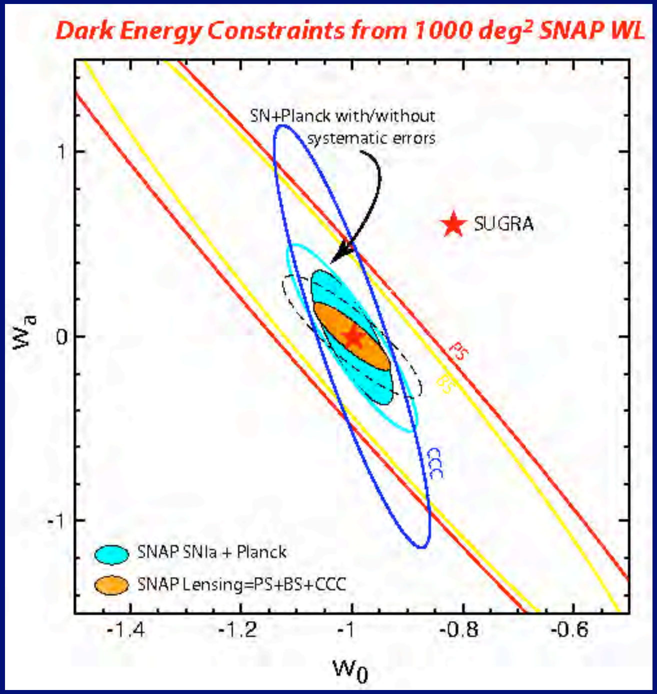
- Dark Energy: CIP will measure the baryonic oscillations (the counterpart to the CMB fluctuations) at high-z. If dark energy is important there (i.e., not a cosmological constant), CIP will be in the unique position to provide the only measure of dark energy at high-z.
- Star Formation History: CIP will measure SFR for over 10 million galaxies from 3<z<6.5, providing unprecedented numbers on the star formation history of the early universe.
- Neutrino Mass: CIP will measure the total mass of all neutrinos down to ~0.05eV 2σ–the current limit is 0.7eV.

Constellation-X: Science Goals

- Beyond Einstein science
  - investigate motion near black holes
  - measure the evolution of dark energy using clusters of galaxies
  - determine where most of the atoms are located in the Warm Hot Intergalactic Medium (WHIM) and detect baryons
  - determine the relationship of supermassive black hole (SMBH) growth to formation of galactic spheroids
  - determine whether dark matter emits energy via decay or annihilation
- Broader Science
  - determine the equation of state of neutron stars
  - determine the size of the magnetic fields in young neutron stars
  - examine how supermassive black holes affect galaxies
  - discover where heavy elements originate
  - investigate the activity of Sun-like stars and how they affect their environments
  - investigate how comets and planets interact with the Solar wind

Joint Dark Energy Mission: Science Goals

- Beyond Einstein science
  - precisely measure the expansion history of the universe to determine whether the contribution of dark energy to the expansion rate varies with time
- Broader science
  - investigate the formation and evolution of galaxies
  - determine the rate of star formation and how that rate depends on environment



- Missions
  - SNAP: SN & WL
  - Destiny: SN & WL
  - ADEPT: SN & BAO
  - [DUNE: WL & BAO]

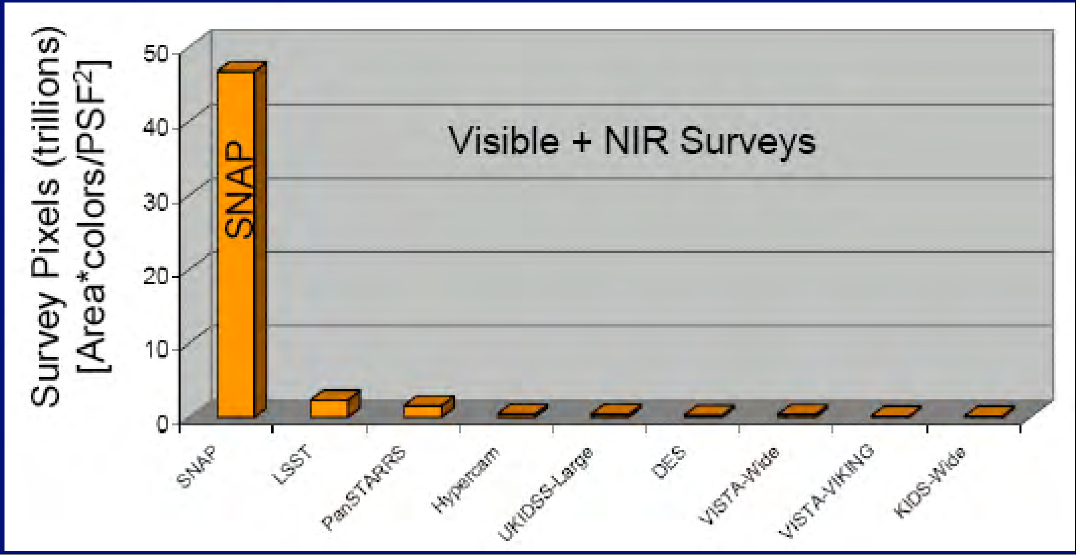


TABLE 2.E.3 JDEM: Beyond Einstein Science Programs

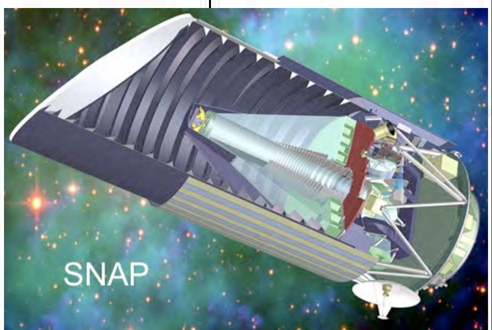
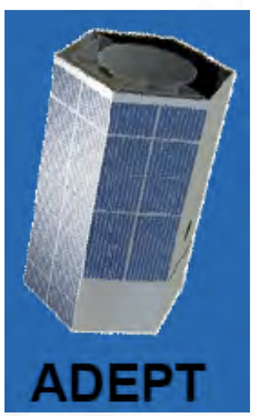
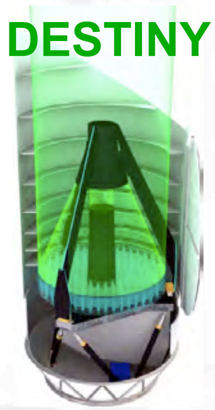
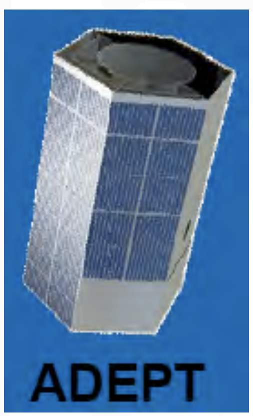
Science	Program	Program Characteristics		Program Significance
Science Definition Programs	SNAP and DESTINY SN & WL  	Science Question	What is the nature of dark energy?	Combining SN light curves with WL results will provide a measure of the expansion rate of the universe to ~1%. This level will provide over a factor of ten improvement compared to the current knowledge of the dark energy contribution and may establish that dark energy does not arise from a cosmological constant, that it varies dynamically with time, or that it arises from a modification of general relativity.
		Measurements	Light curves of Type Ia supernovae (SN) with $0.3<z<1.7$ via deep field survey of 3-7.5 sq.deg.; gravitational WL via wide field survey of 1000-4000 sq.deg.	
		Quantities Determined	Expansion history of the universe; history of growth of structure	
	ADEPT SN & BAO  	Science Question	What is the nature of dark energy?	ADEPT combines BAO with SN light curves to provide a measure of the expansion rate of the universe to approximately 1%. This level will provide over a factor of ten increase compared to the current knowledge of the dark energy contribution and may establish that dark energy does not arise from a cosmological constant or that it varies dynamically with time.
		Measurements	Baryon acoustic oscillations (BAO) derived from redshifts and positions of 100,000,000 galaxies with $1<z<2$ and light curves of Type Ia supernovae (SN) with $0.8<z<1.3$ via a full-sky spectroscopic survey	
		Quantities Determined	Expansion history of the universe	

TABLE 2.E.4 JDEM: Broader Science Examples

Program	Program Characteristics		Program Significance
SNAP and DESTINY 	**Science Question**	How did galaxies form and evolve?	After HST there will be no large diffraction-limited optical or near-IR telescope in space. The low background and large field of views offered by SNAP and DESTINY will provide the most detailed and important information ever for understanding how galaxies formed and acquired their mass.
	Measurements	Photometric surveys in 5 (DESTINY) to 9 (SNAP) optical and NIR bands	
	Quantities Determined	Deep field survey over 3 sq. deg. (DESTINY) to 7.5 sq. deg. (SNAP); Wide field survey over 1000 sq.deg. (DESTINY) to 1000-4000 sq.deg. (SNAP)	
ADEPT 	**Science Question**	At what rate did stars form, and how did that rate depend upon environment?	There has never been a full-sky spectroscopic survey from space; consequently, ADEPT has large discovery potential. It will characterize the star formation rate of the universe down to a sensitive limiting flux, finding the most extreme star forming galaxies in the universe. The epoch that ADEPT probes is the most active when galaxies acquire their mass. Very little is known about star formation in the smallest galaxies.
	Measurements	Full-sky IR spectroscopic survey	
	Quantities Determined	Redshift and emission fluxes for over 100 million galaxies	

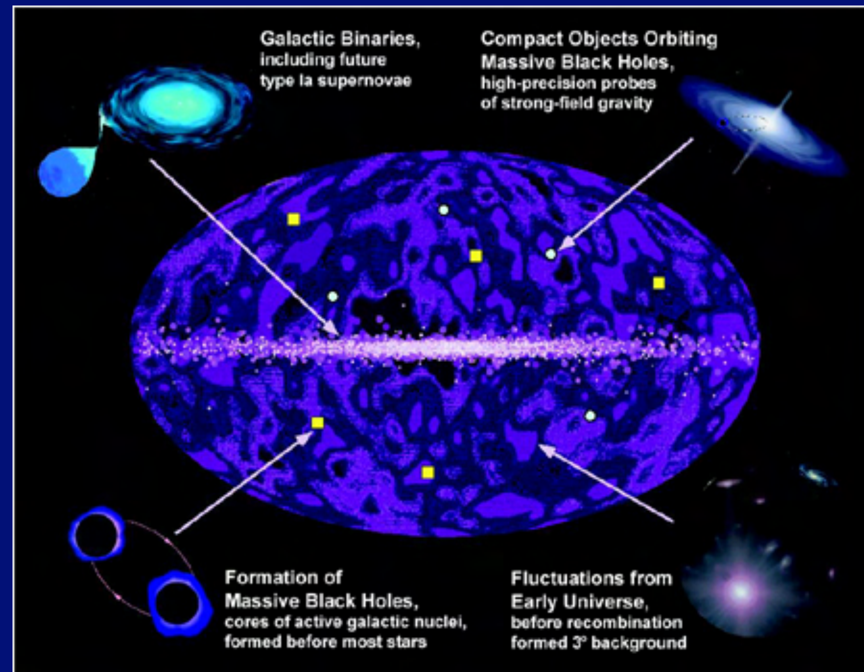
Broader Science was crucial to JDEM priority

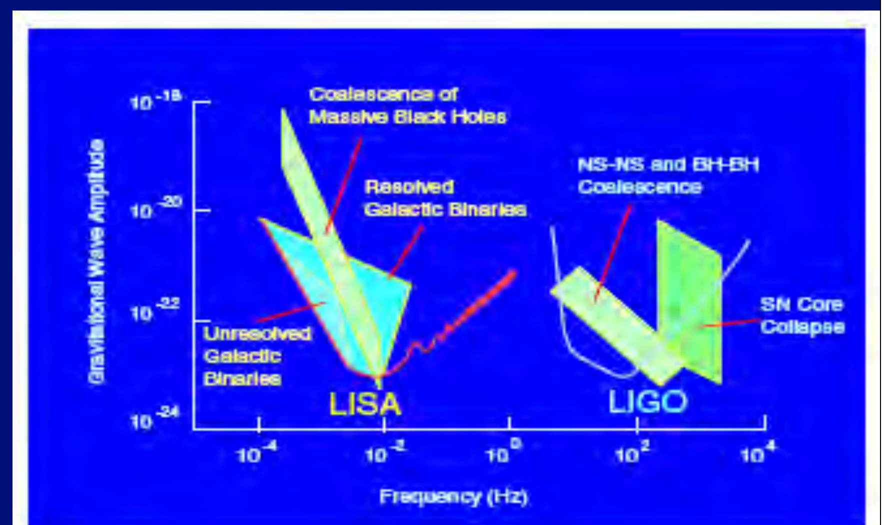
TABLE 2.E.5 JDEM: Summary of Scientific Evaluation

Factors	Potential Contributions to Science	
	Beyond Einstein	**Broader Science**
Revolutionary Discovery Potential	A measurement that discovers that the expansion history of the universe is not consistent with a cosmological constant will have a fundamental and revolutionary impact on physics and astronomy.	Wide field optical and NIR surveys will offer tremendous discovery potential. A spectroscopic survey would open the emission-line universe, and an imaging survey would produce the richest dataset ever for studies of galaxy evolution.
Science Readiness & Risk	Systematic uncertainties may limit JDEM to modest improvements over ground-based studies.	Because of the exquisite datasets that JDEM surveys will produce, there is little risk to the broader science impact.
Mission Uniqueness		
Versus Other Space Missions	A comparable European space mission concept is under discussion but is not yet approved.	There are no comparable spectroscopic or imaging surveys to the proposed JDEMs.
Versus Ground	JDEM affords better control of systematic uncertainties than ground-based experiments for supernova and weak lensing studies, and better statistics for baryon acoustic oscillations.	Wide-field cameras based on the ground cannot access the near-IR and have much poorer resolution at optical wavelengths due to atmospheric effects.

LISA: Science Goals

- Beyond Einstein science
  - determine how and when massive black holes form
  - investigate whether general relativity correctly describes gravity under extreme conditions
  - determine how black hole growth is related to galaxy evolution
  - determine if black holes are correctly described by general relativity
  - investigate whether there are gravitational waves from the early universe
  - determine the distance scale of the universe
- Broader science
  - determine the distribution of binary systems of white dwarfs and neutron stars in our Galaxy





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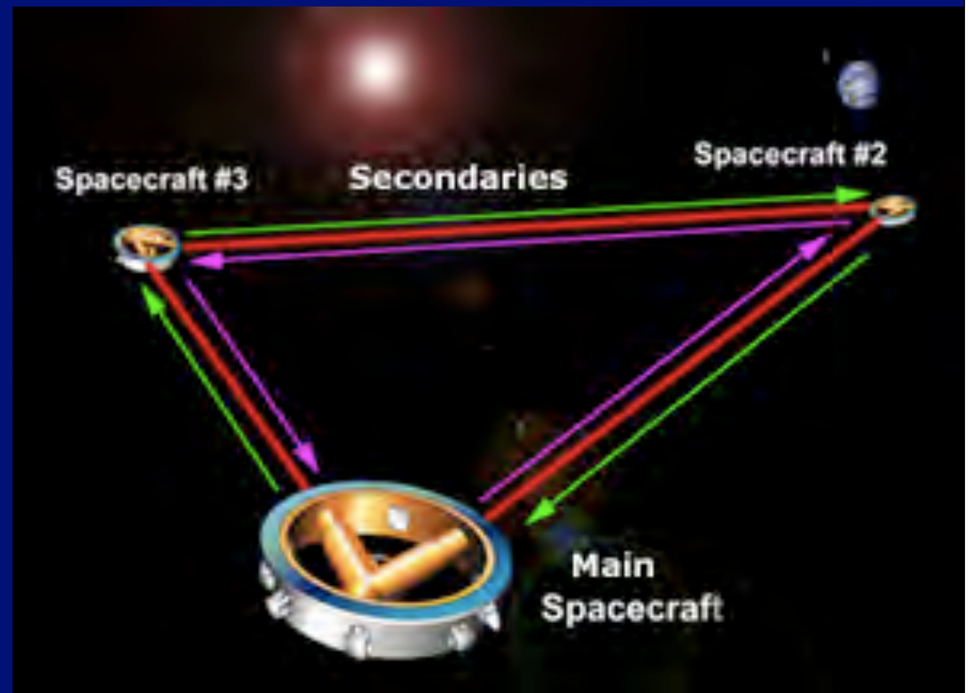


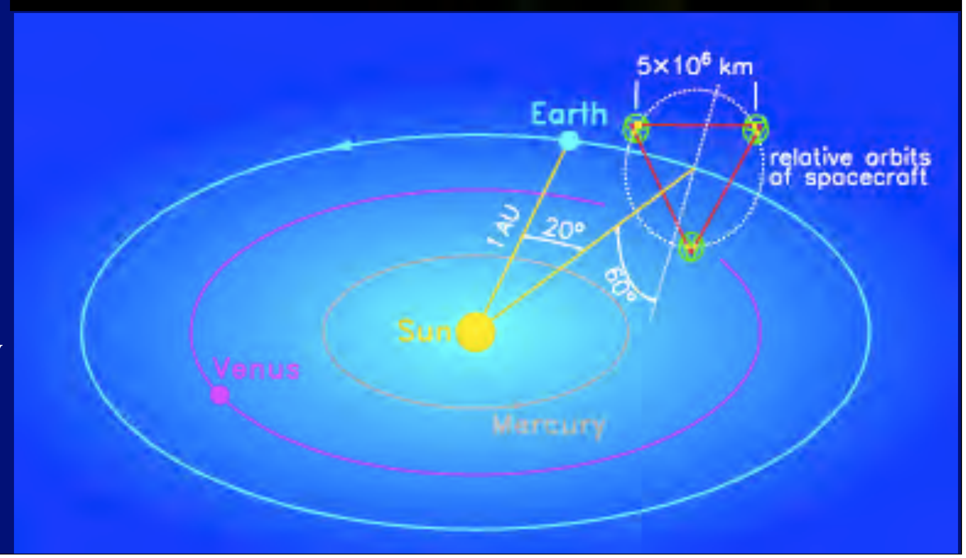
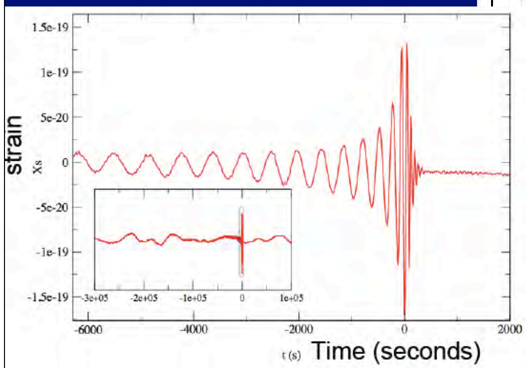
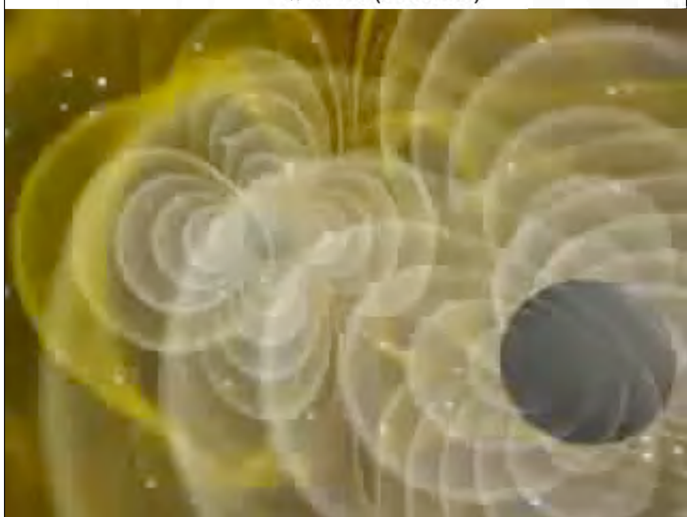


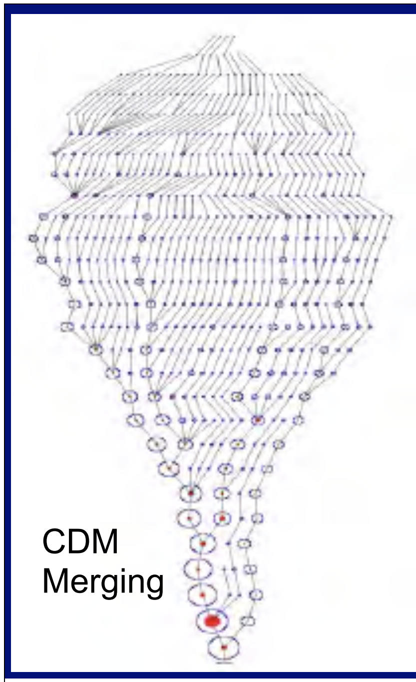
TABLE 2.F.3 LISA: Beyond Einstein Science Programs

Science	Program	Program Characteristics		Program Significance
Science Definition Programs	Formation of Massive Black Holes	Science Question	How and when do massive black holes form?	Observations will detect massive black hole binary mergers to z=15 and shed light on when massive black holes formed
		Measurements	Gravitational waveform shape as a function of time from massive black-hole binary inspiral and merger	
		Quantities Determined	Mass and spin of black holes as a function of distance	
	Test General Relativity in the Strong-Field Regime	Science Question	Does general relativity correctly describe gravity under extreme conditions?	Measurement of the detailed gravitational waveform will test whether general relativity accurately describes gravity under the most extreme conditions
		Measurements	Gravitational waveform shape as a function of time from massive black-hole binary inspiral and merger	
		Quantities Determined	Evolution of dynamical spacetime geometry, mass and spin of initial and final holes	
	History of galaxy and black hole co-evolution	Science Question	How is black hole growth related to galaxy evolution?	Observations will trace the evolution of massive black hole masses as a function of distance or time, and will shed light on how black hole growth and galactic evolution may be linked
		Measurements	Gravitational waveform shape as a function of time from massive black-hole binary inspiral and merger	

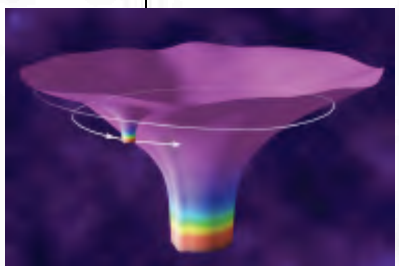


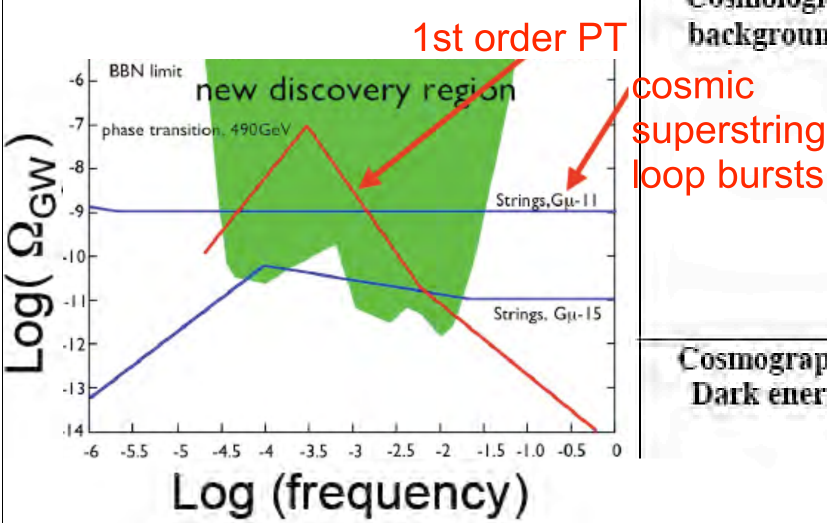


Joan Centrella et al. NASA/GSFC
Visualization: Chris Henze, NASA/Ames



Science	Program	Program Characteristics		Program Significance
		Quantities Determined	Mass as a function of distance	
Additional Beyond Einstein Science	Map black-hole spacetimes	Science Question	Are black holes correctly described by general relativity?	Observations will yield maps of the spacetime geometry surrounding massive black holes, and will test whether they are described by the Kerr geometry predicted by general relativity. They will also measure the parameters (mass, spin, shape) of the holes, and test whether they obey the no-hair theorems of GR
		Measurements	Gravitational waveform shape from small bodies spiraling into massive black holes (EMRI)	
		Quantities Determined	Mass, spin, multipole moments, spacetime geometry close to hole	
	Cosmological backgrounds	Science Question	Are there gravitational waves from the early universe?	First-order phase transitions or cosmic strings in the early universe could leave a background of detectable waves
		Measurements	Stochastic background of gravitational waves	
		Quantities Determined	Effective energy density of waves vs. frequency	
	Cosmography, Dark energy	Science Question	What is the distance scale of the universe?	If redshift of source or host galaxy can be determined, then precise, calibration-free measurements of the Hubble parameter and other cosmological parameters could be done, significantly constraining dark energy
		Measurements	Gravitational waveform shape and amplitude measurements yield luminosity distance of sources directly	
		Quantities Determined	Luminosity distance	





$$\text{Distance} \cong c \frac{1}{\text{frequency}^2 \times t_{\text{chirp}} \times \text{amplitude}}$$

Evaluation of Science Impact

Five criteria for evaluation:

- Advancement of Beyond Einstein research goals
  - Find out what powered the Big Bang
  - Observe how black holes manipulate space, time and matter
  - Identify the mysterious dark energy pulling the Universe apart
- Broader science contributions.
- Potential for revolutionary discovery.
- Science risk and readiness.
- Uniqueness of the mission candidate for addressing its scientific questions.

Finding 1

- The Beyond Einstein scientific issues are so compelling that research in this area will be pursued for many years to come. All five mission areas in NASA's Beyond Einstein plan address key questions that take physics and astronomy beyond where the century of Einstein left them.

Findings 2 and 3

- The Constellation-X mission will make the broadest and most diverse contributions to astronomy of any of the candidate Beyond Einstein missions. While it can make strong contributions to Beyond Einstein science, other BE missions address the measurement of dark energy parameters and tests of strong-field General Relativity in a more focused and definitive manner.
- Two mission areas stand out for the directness with which they address Beyond Einstein goals and their potential for broader scientific impact: LISA and JDEM.

Finding 4

- LISA is an extraordinarily original and technically bold mission concept. LISA will open up an entirely new way of observing the universe, with immense potential to enlarge our understanding of physics and astronomy in unforeseen ways. LISA, in the committee’s view, should be the flagship mission of a long-term program addressing Beyond Einstein goals.

Finding 5

- The ESA-NASA LISA Pathfinder mission that is scheduled for launch in late 2009 will assess the operation of several critical LISA technologies in space. The committee believes it is more responsible technically and financially to propose a LISA new start after the Pathfinder results are taken into account. In addition, Pathfinder will not test all technologies critical to LISA. Thus, it would be prudent for NASA to invest further in LISA technology development and risk reduction, to help ensure that NASA is in a position to proceed with ESA to a formal new start as soon as possible after the LISA Pathfinder results are understood.

Finding 6

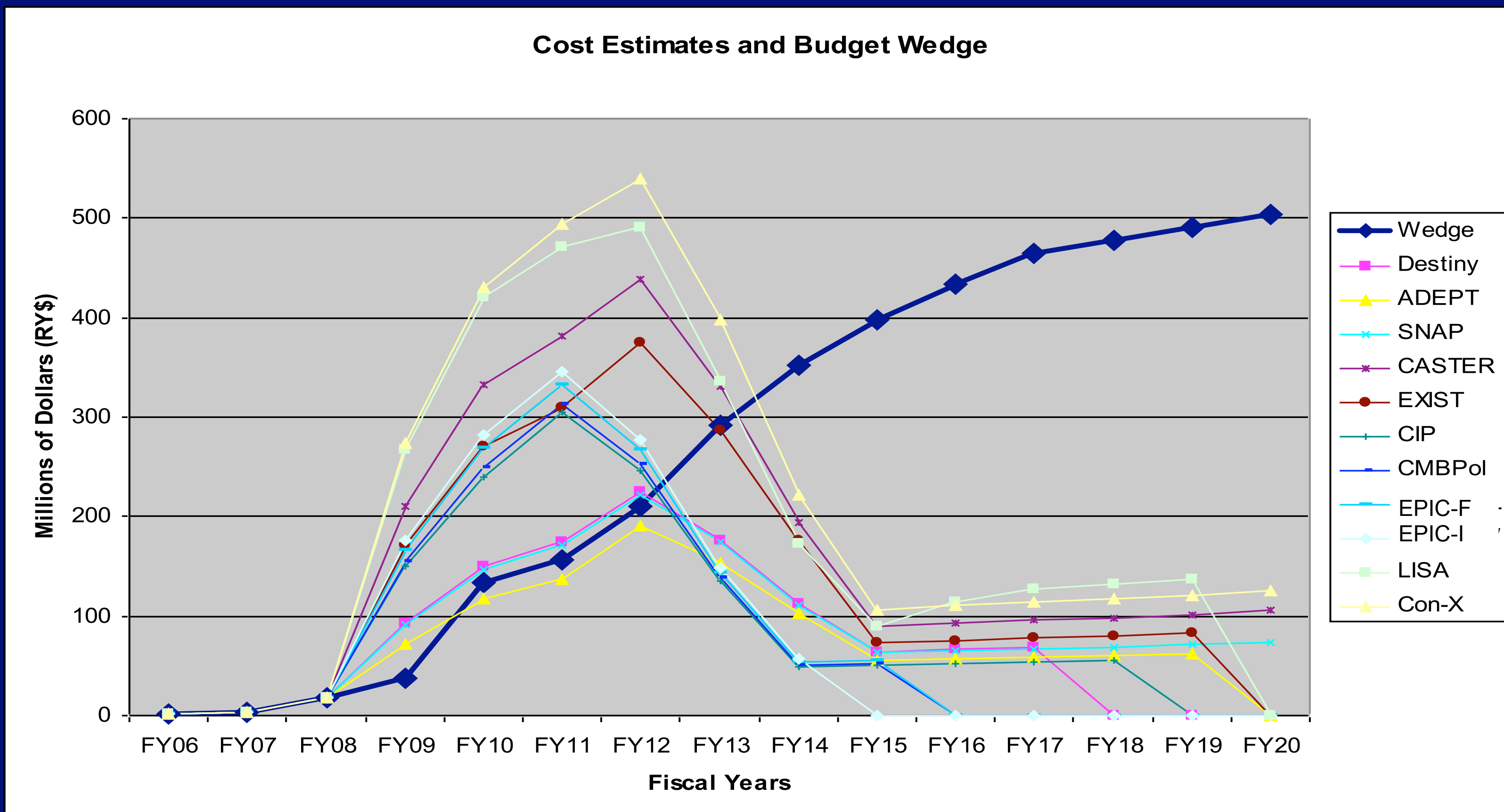
- A JDEM mission will set the standard in the precision of its determination of the distribution of dark energy in the distant universe. By clarifying the properties of 70 percent of the mass-energy in the universe, JDEM's potential for fundamental advancement of both astronomy and physics is substantial. A JDEM mission will also bring important benefits to general astronomy. In particular, JDEM will provide highly detailed information for understanding how galaxies form and acquire their mass.

Finding 7

- The JDEM mission candidates identified thus far are based on instrument and spacecraft technologies that have either been flown in space or have been extensively developed in other programs. A JDEM mission selected in 2009 could proceed smoothly to a timely and successful launch.

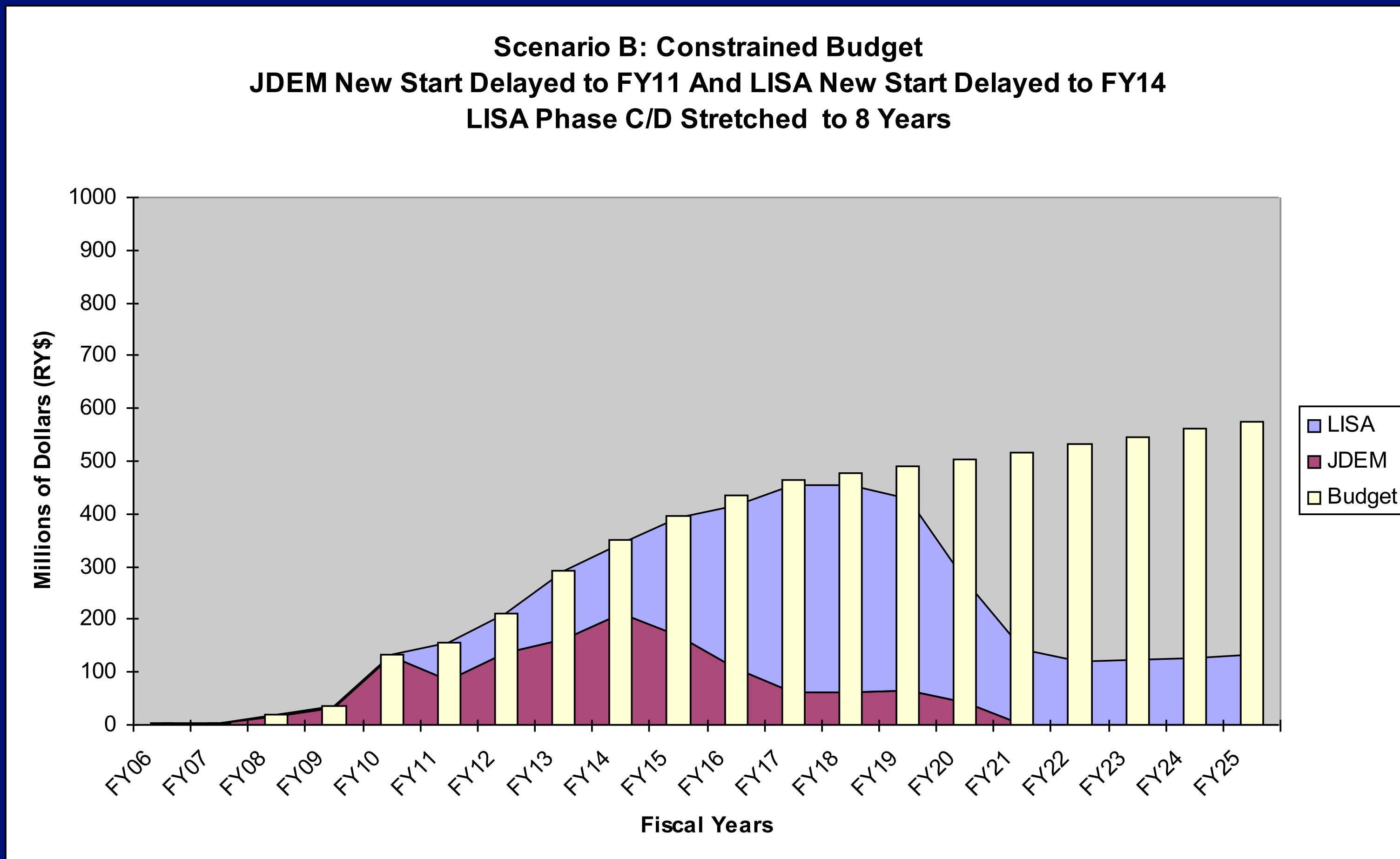
Finding 8

- The present NASA Beyond Einstein funding wedge alone is inadequate to develop any candidate Beyond Einstein mission on its nominal schedule…



Finding 8 continued

- However, both JDEM and LISA could be carried out with the currently forecasted NASA contribution if DOE's contribution that benefits JDEM is taken into account and if LISA's development schedule is extended and funding from ESA is assumed.



Recommendation 1

- NASA and DOE should proceed immediately with a competition to select a Joint Dark Energy Mission for a 2009 new start. The broad mission goals in the Request for Proposal should be
- (1) to determine the properties of dark energy with high precision and
- (2) to enable a broad range of astronomical investigations.

  The committee encourages the Agencies to seek as wide a variety of mission concepts and partnerships as possible.

Recommendation 2

- NASA should invest additional Beyond Einstein funds in LISA technology development and risk reduction, to help ensure that the Agency is in a position to proceed in partnership with ESA to a new start after the LISA Pathfinder results are understood.

Recommendation 3

- NASA should move forward with appropriate measures to increase the readiness of the three remaining mission areas—*Black Hole Finder Probe, Constellation-X, and Inflation Probe*—for consideration by NASA and the NRC Decadal Survey of Astronomy and Astrophysics.

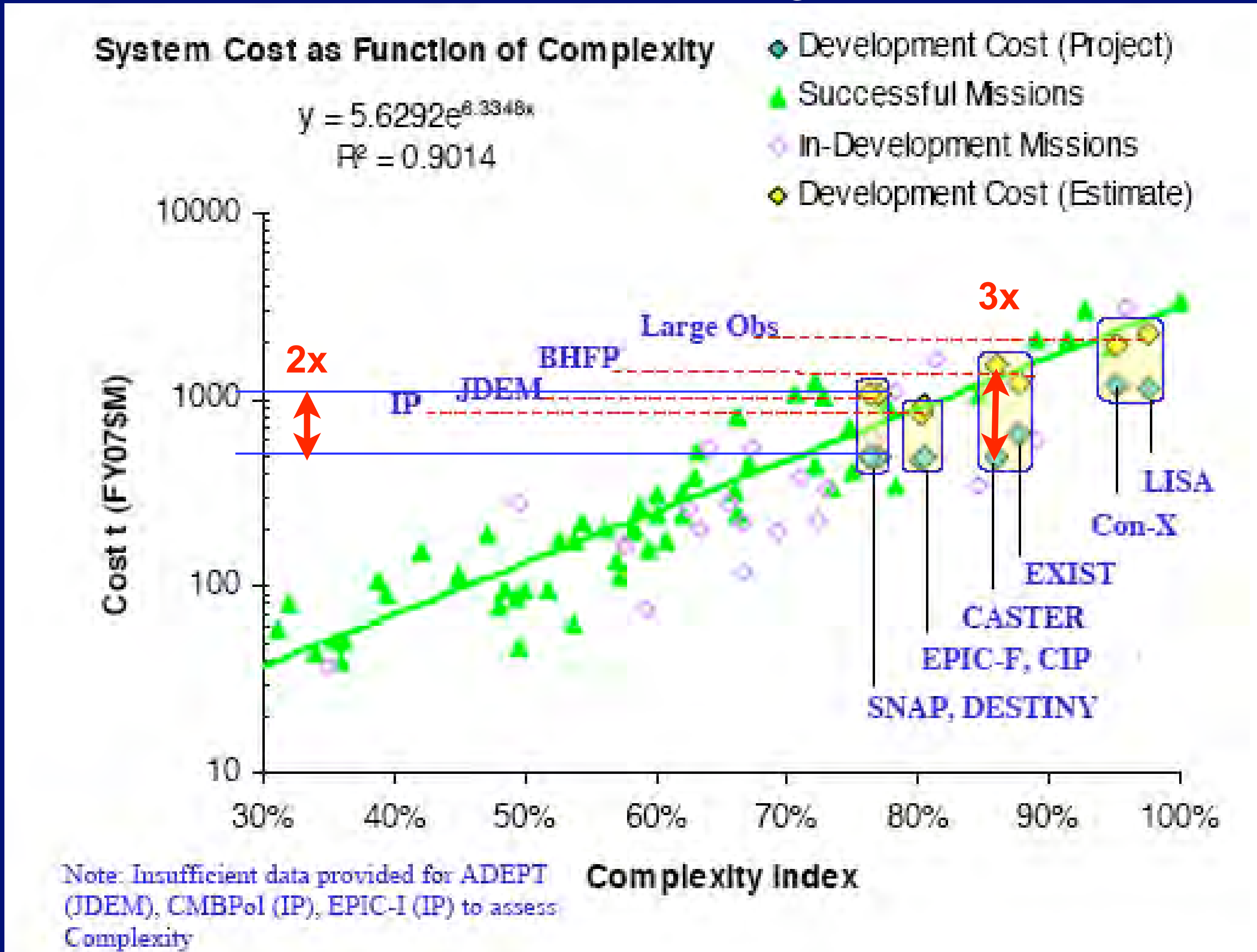
Committee Cost Estimates and Budget Analysis

There are four “bins” of complexity beginning with JDEM on the low end and culminating with the large observatories (LISA and Con-X) as most complex. Approximate development cost (Phase B, C, and D) and schedule regimes are as follows for the Beyond Einstein mission areas:

• Large Observatories (LISA and Con-X)	$2B	8 years
• BHFP (EXIST, CASTER)	$1.5B	7 years
• JDEM (SNAP, ADEPT, DESTINY)	$1B	6 years
• IP (CIP, CMBPol, EPIC-F, EPIC-I)	$1B	6 years

Note that inclusion of launch service ($200M or $300M) and MO&DA (varies but on the order of $25M per year) is above and beyond the development cost numbers noted above.

Committee ICE vs. Project Estimates



NASA Science Funding Crisis and DOE Opportunities

my personal comments

DOE Opportunities and Choices
Support for Astrophysics: EPP2010, P5, AAAC
NASA's 2003 Plans for US Space Astrophysics
2004 Vision for Space Exploration (VSE)
No extra NASA funding provided for VSE
Drastic Cuts in NASA Space Astrophysics
Demise of US Space Astrophysics leadership:
three nightmares
Possible Path Forward

DOE Opportunities and Choices

DOE's role in JDEM will cost at least $400 M, comparable to a large accelerator experiment and an order of magnitude larger than GLAST, DOE's previous large space astrophysics mission. With JDEM, Astrophysics can no longer be supported by discretionary funds; it will become part of DOE's mission.

Choice: accept JDEM as a special case, or embrace Astrophysics as a core DOE science mission.

Advantages of embracing Astrophysics: close connections with particle physics and physicists, DOE - HEP gets more credit for achievements and larger budget, U.S. preserves international Astrophysics leadership.

EPP2010: Revealing the Hidden Nature of Space and Time

Finding 4: Elementary particle physicists have an extraordinary opportunity to make breakthrough discoveries by engaging in astrophysics and cosmology research that probes energies and physical conditions that are not available in an accelerator laboratory.

Three major research challenges that are ripe for pursuit:

- The direct detection of dark matter in terrestrial laboratories, the results of which could then be combined with measurements of dark matter particles produced in accelerators.
- The precision measurement of the CMB polarization, which would probe the physics during inflation.
- The measurement of the key properties of dark energy.

Action Item 4: Scientific priorities at the interface of particle physics, astrophysics, and cosmology should be determined through a mechanism jointly involving NSF, DOE, and NASA, with emphasis on DOE and NSF participation in projects where the intellectual and technological capabilities of particle physicists can make unique contributions. A larger share of the current U.S. elementary particle physics research budget should be allocated to the three research challenges articulated above.

P5 Report: The Particle Physics Roadmap - October 2006

- Priorities: 1. LHC, 2. ILC, 3. a phased program to study dark matter, dark energy, and neutrino interactions

- We have arrived at a budget split for new investments of about 60% toward the ILC and 40% toward the new projects in dark matter, dark energy, and neutrinos through 2012 .

- Phase I of a Stage IV Program: We recommend that the DOE work with NASA to ensure that a dark energy space mission can be carried out and that the three potential approaches to the mission have been properly evaluated. Phase I of a Stage IV Program: We recommend a decision process soon after the completion of the technical and cost studies to formulate and recommend an aggressive and financially realistic Stage IV program.

- P5 is strongly enthusiastic about dark energy science and supports an agressive experimental program.

Astronomy and Astrophysics Advisory Committee
Annual Report - March 2007

- AAAC appreciates the growing interest in astrophysics within DOE HEP and recommends that HEP continue to enhance their support of programs at the interface of astronomy and particle physics in response to the recommendations of EPP2010.

- AAAC recommends that the HEP further develop their support for R&D and programs in the areas of dark energy and dark matter, giving particular attention to supporting DETF Stage III near-term projects that provide a framework for much more expensive Stage IV projects (JDEM and LST).

- AAAC strongly endorses increased support for the dark matter detection efforts.

- AAAC recommends that NSF and NASA, possibly with OSTP assistance, expedite their plan to solicit proposals for the operation of the National Virtual Observatory.

NASA Space Science 2003

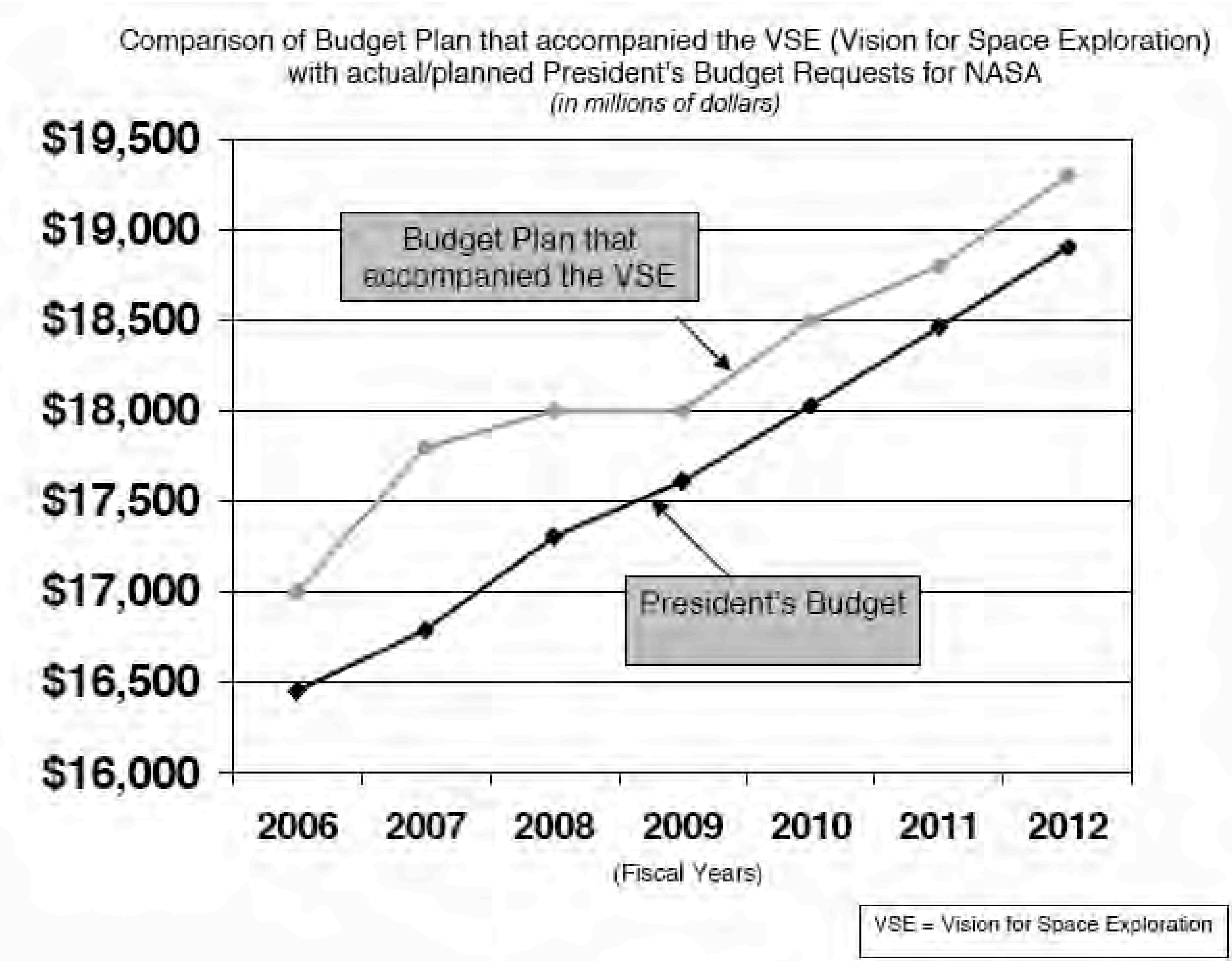
Robust Astrophysics Program

Balanced mix of R&A, and flagship, mid, and small missions including HST, Chandra, Spitzer, WMAP and other Explorers, and future missions including
JWST, SOFIA, GLAST, Kepler, NuSTAR, WISE
Beyond Einstein: JDEM, Inflation Probe, BH Probe, Con-X, LISA
Navigator: Terrestrial Planet Finder, Space Interfer. Mission (SIM)

Diverse Solar System Exploration Program

Ambitious Earth Observation Program

despite costly & wasteful International Space Station sold as “science”



Source: Charter for House Science Subcommittee hearing May 2, 2007

PANEL
ON
PUBLIC
AFFAIRS

THE MOON-MARS PROGRAM

The cost of overcoming technological challenges could far exceed budgetary projections. Many approved science programs could be jeopardized.

Issue

On January 14, President Bush announced a new vision for NASA, starting with a human return to the Moon by 2020 to be followed by human exploration of Mars and other destinations. The impact of the president's proposal on scientific programs within NASA and other agencies could be substantial and must be assessed carefully.

Recommendations

Extraordinary scientific and technological difficulties confront President's Bush's vision for a Moon-Mars initiative. The budget for the proposed program remains very imprecise and is expected to grow substantially. The constraints that inevitably will be imposed on other federal scientific programs are already evident, especially within NASA. Before the United States commits to President Bush's proposal, an external review of the plans should be carried out by the National Academy of Sciences.

The APS

Executive Summary

Very important science opportunities could be lost or delayed seriously as a consequence of shifting NASA priorities toward Moon-Mars. The scientific planning process based on National Academy consensus studies implemented by NASA roadmaps has led to many of NASA's greatest scientific—and popular—successes. We urge the Federal Government to base priorities for NASA missions on the National Academy recommendations.

APS Executive Board Statement

Reestablishing a human presence on the Moon and sending astronauts to Mars represents a major national challenge. However such a program could only achieve its full significance as part of a balanced program of scientific exploration of the universe and studies of the interaction between humankind and its environment. In recent years, NASA has captured the public's imagination

NASA Space Astrophysics 2007 Budget Changes

> $3 billion cut from coming years Space Astrophysics

Zeroed out or indefinitely postponed: NuSTAR, SOFIA,

Beyond Einstein: JDEM, Inflation Probe, BH Probe, Con-X, LISA,

Navigator: Terrestrial Planet Finder, Space Interfer. Mission (SIM)

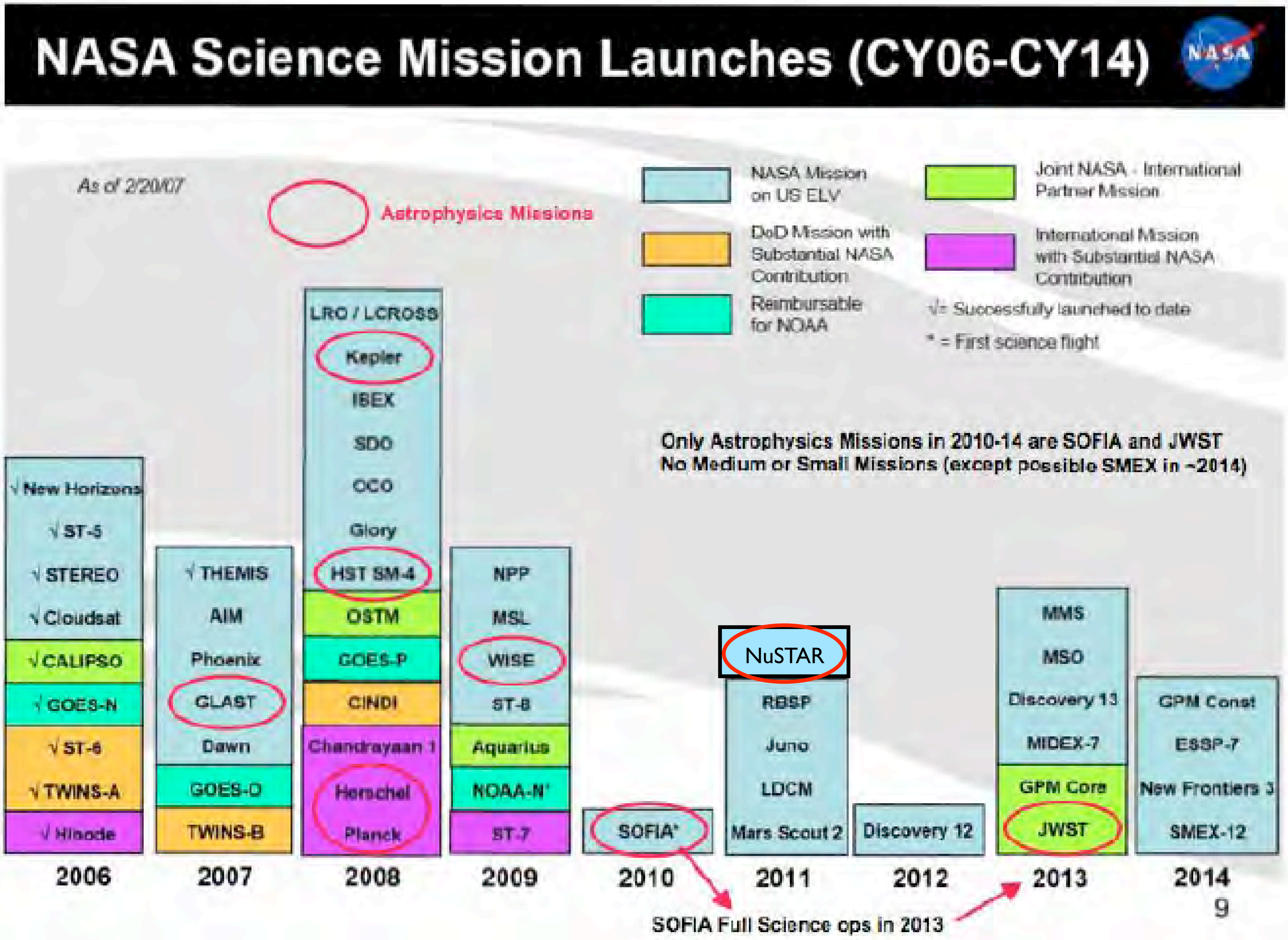
Recent Developments

SOFIA refunded

Beyond Einstein NRC study to choose 1st for > 2015 launch

SMD Assoc Admin Alan Stern and John Mather appointed

NuSTAR X-ray Explorer mission restarted



G. Illingworth testimony at House Science Subcommittee hearing May 2, 2007

The National Academy of Sciences recently released the results of the first-ever Decadal Survey on Earth Science. The report, which was requested by NASA, NOAA, and USGS, states that *"the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, will decrease by some 40 percent"* by the end of the decade. The report also states that *"…the United States' extraordinary foundation of global observations is at great risk."* Many of the measurements that may be lost with these sensors provide critical information on weather and climate. Some of the planned replacement sensors are less capable than existing sensors. Moreover, between 2000 and 2006 NASA's Earth Science budget decreased by more than 30% when adjusted for inflation. The proposed FY 08 budget does not provide outyear funding that would enable development of even the first few of the 15 new, high-priority NASA missions recommended in the Decadal Survey.

Source: Charter for House Science Subcommittee hearing May 2, 2007

Problems and Dangers:

No small or med US Astrophysics missions 2009-2015

and ending of Chandra and Spitzer ⇒

likely significantly reduced science output

Cuts in R&A funding immediately impact renewing and new investigators

Lack of technology development funds

Ending of Delta II after 2009 will increase launch cost

Inability to respond to 2010 Astronomy Decadal Study

Three Nightmares for U.S. Space Astrophysics

1. Moon-Mars eats all available funds

2. Demise of Earth Observation from space becomes issue in 2008 Presidential campaign; next Administration cuts Space Astrophysics to fund Earth Observation

3. Next Administration repudiates Bush Moon-Mars, drastically cuts NASA budget

Consequence:
U.S. abdicates Space Astrophysics leadership

Possible Solution

Astronomers and Particle Physicists strongly support the recommendations of the NAS/NRC Beyond Einstein report.

Space Astrophysicists, Earth Observation Scientists, and Particle Physicists work together to plan much more ambitious science programs to preserve U.S. leadership and competitiveness.

DOE shares responsibility for developing selected major astrophysics missions especially relevant to fundamental physics and energy in the universe, including JDEM and LISA, with NSF and DOE developing LSST.