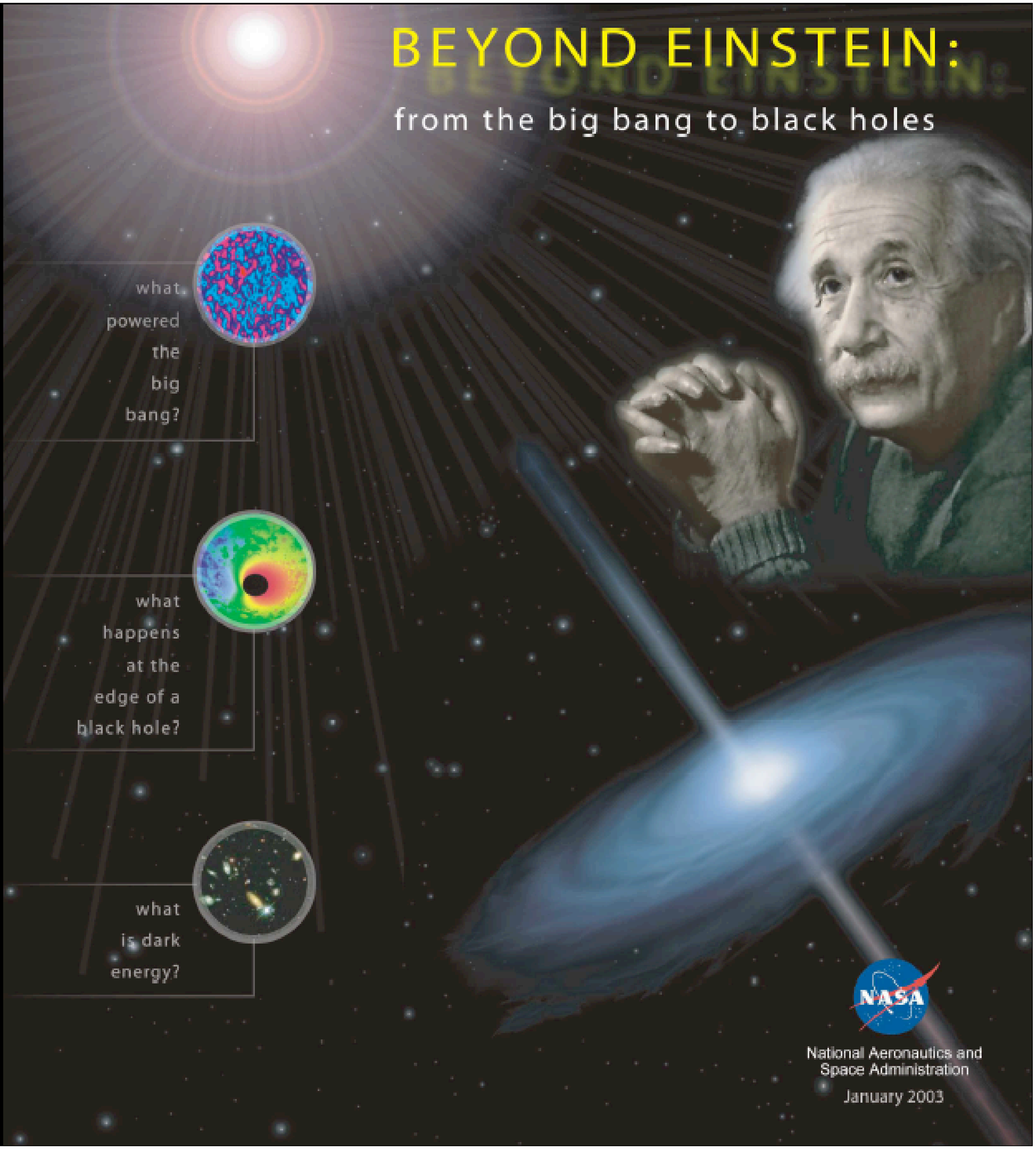
Restarting the Exploration of the Universe:

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

Joel Primack

University of California, Santa Cruz

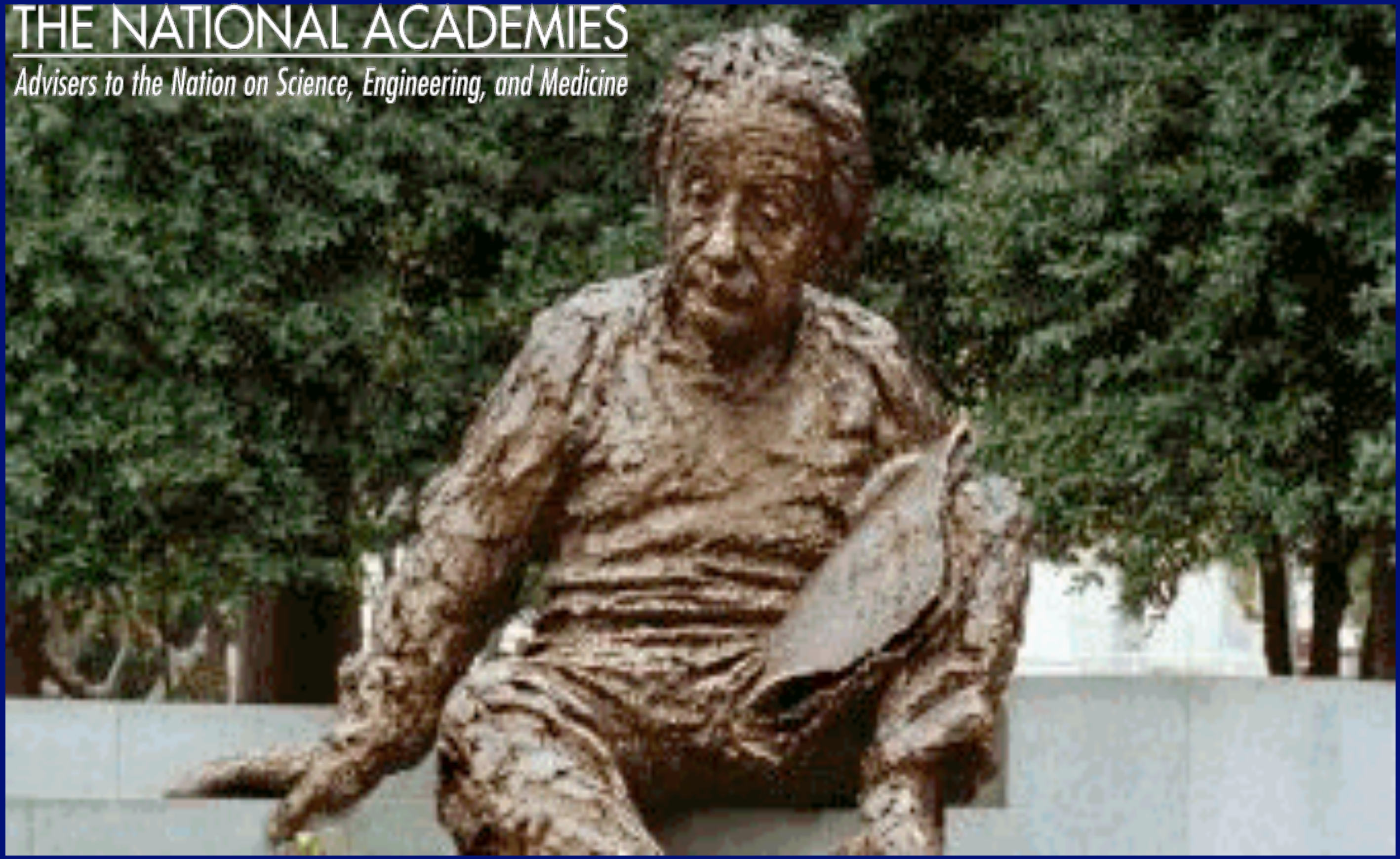


Restarting the Exploration of the Universe:

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

Joel Primack - University of California, Santa Cruz

In 2003, NASA's Beyond Einstein program included ambitious space missions to understand the nature of the dark energy that has been accelerating the expansion of the universe, test general relativity, and discover gravity waves from the mergers of supermassive black holes and from the cosmic inflation that preceded the Big Bang. All of these, plus space missions to map our home galaxy and investigate whether planets around other stars have life, were indefinitely postponed when President Bush decided in January 2004 that NASA's highest priority is to put astronauts back on the moon and eventually send them to Mars. Under pressure from Congress, the National Academy of Sciences was commissioned in 2006 to report on how to restart the Beyond Einstein program. This colloquium by one of the members of this recently released Academy study will summarize and explain the research strategy the report proposes and its implications for continued U.S. participation in the exploration of the universe.



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.

Executive Summary Conclusion

The committee strongly believes that future technology investment is required and warranted in all of the Beyond Einstein mission areas. The candidates for **JDEM**, the committee's **first priority mission area**, need continued funding until NASA and DOE conduct a competition and selection for a JDEM. Furthermore, the committee believes that the competition to select a JDEM should be open to other mission concepts, launch opportunities, measurement techniques, and international partnerships.

The **next highest priority** for funding from the current 2009 Beyond Einstein NASA budget wedge is to accelerate the maturation of those mission critical **LISA** technologies that are currently at low technology readiness levels. This funding will be needed until and if NASA initiates a post-Pathfinder mission start for LISA.

The current Beyond Einstein budget profile will not support technology development beyond JDEM and LISA. The committee did not develop a priority order for the remaining mission areas and believes all their component missions require additional technology maturity before they can be fully evaluated. Their technology development should continue to be supported in the broader astrophysics program, at least at a level that allows a sound appraisal by the next Astronomy and Astrophysics 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*

Committee Members

Astrophysics Physics Eng/Mgmt

- 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*

NASA's Structure and Evolution of the Universe Roadmap 2003

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.

• The **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: Fully competed, moderate-sized, scientist-led missions launched every three years

• **Dark Energy Probe**: Determine the properties of the dark energy that dominates the Universe.

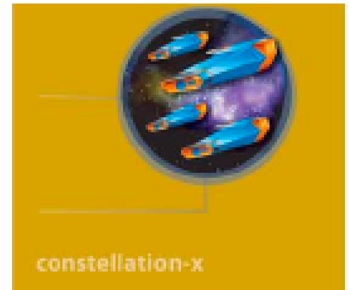
• **Inflation Probe**: Detect the imprints left by quantum effects and gravitational waves at the beginning of the Big Bang.

• **Black Hole Probe**: Take a census of black holes in the local Universe.
These missions will answer sharply focused questions. Competition ensures flexibility and keeps costs low by selecting methods and technologies

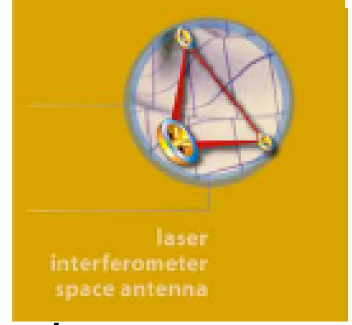
The Beyond Einstein Program

Einstein Great Observatories: Facility-class missions

- **Constellation-X**

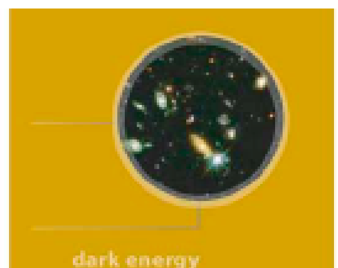


- **Laser Interferometer Space Antenna (LISA)**

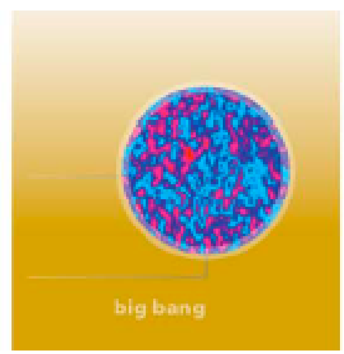


Einstein Probes: Moderate-sized, scientist-led missions

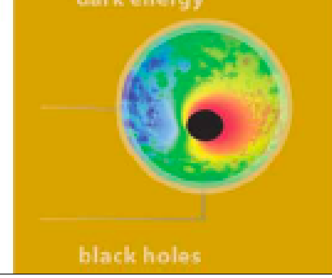
- **Dark Energy Probe**



- **Inflation Probe**

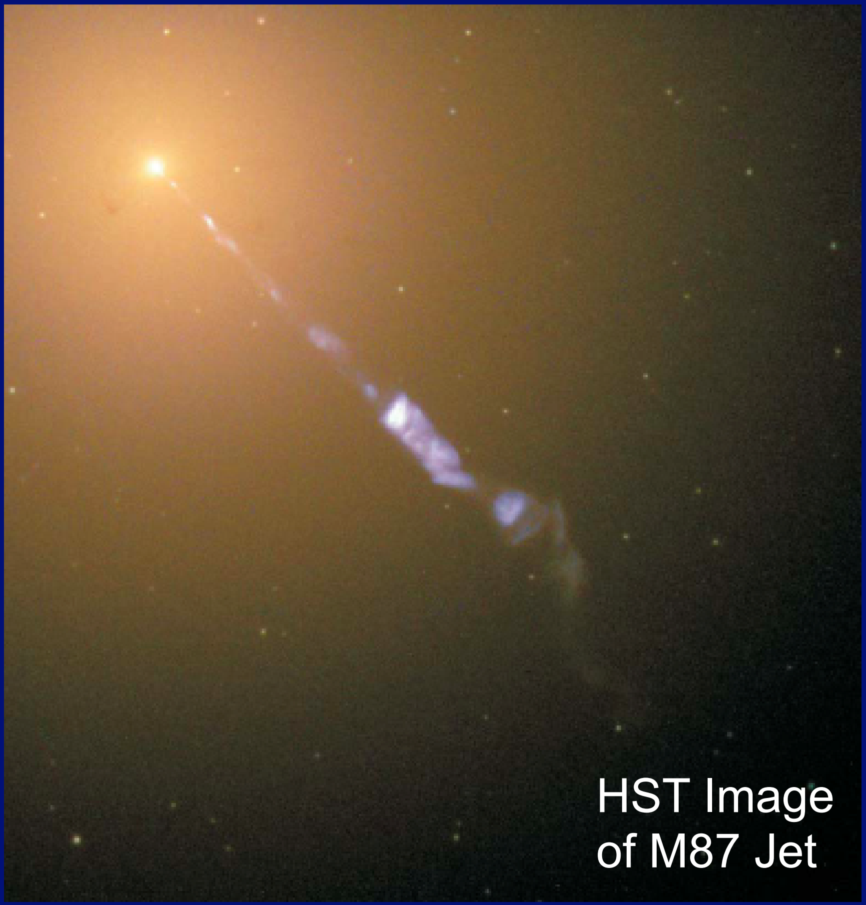


- **Black Hole Probe**



Black Hole Finder Probe: Science Goals

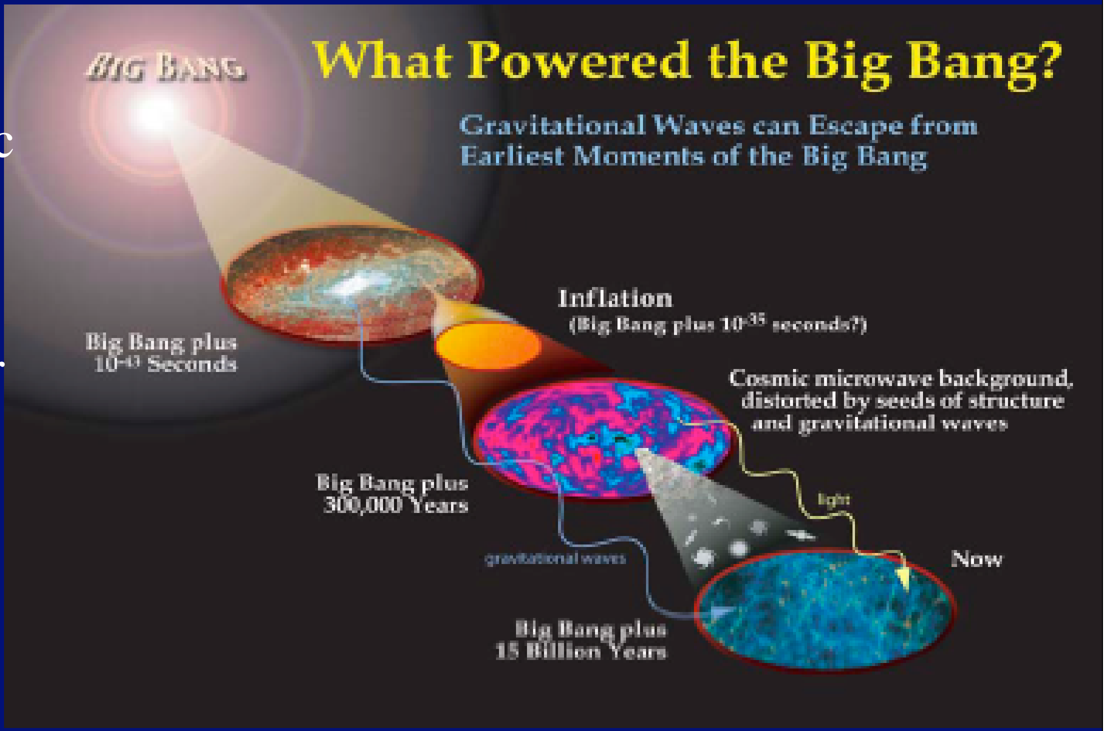
- Beyond Einstein science
  - perform a census of black holes throughout the Universe
  - determine how black holes evolve
  - observe stars and gas plunging into black holes
  - determine how black holes are formed
- Broader science
  - discover the origin of the 511 keV electron-positron annihilation 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


HST Image of M87 Jet

- Missions: EXIST, CASTER

Inflation Probe: Science Goals

- Beyond Einstein science
  - detect gravitational waves sourced by inflation
  - constrain the physics of inflation
  - detect baryonic oscillations in the matter power spectrum
- 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

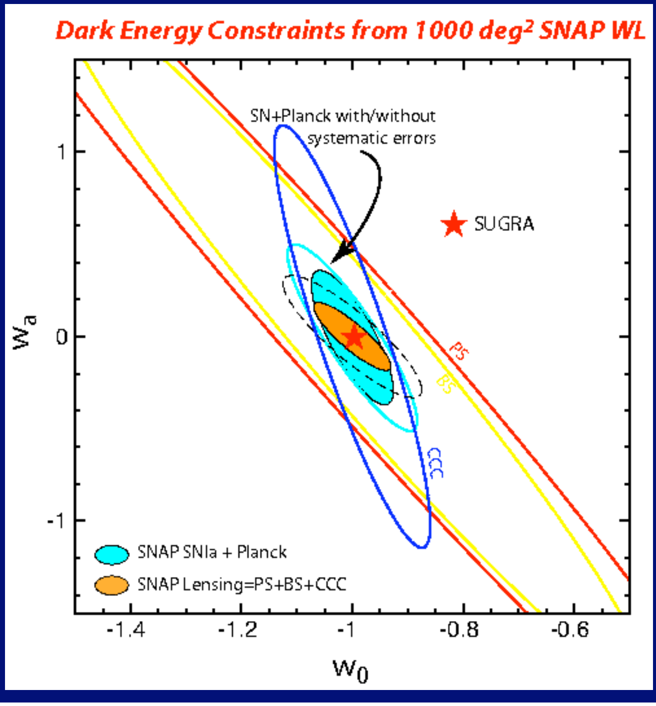


Constellation-X: Science Goals

- 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



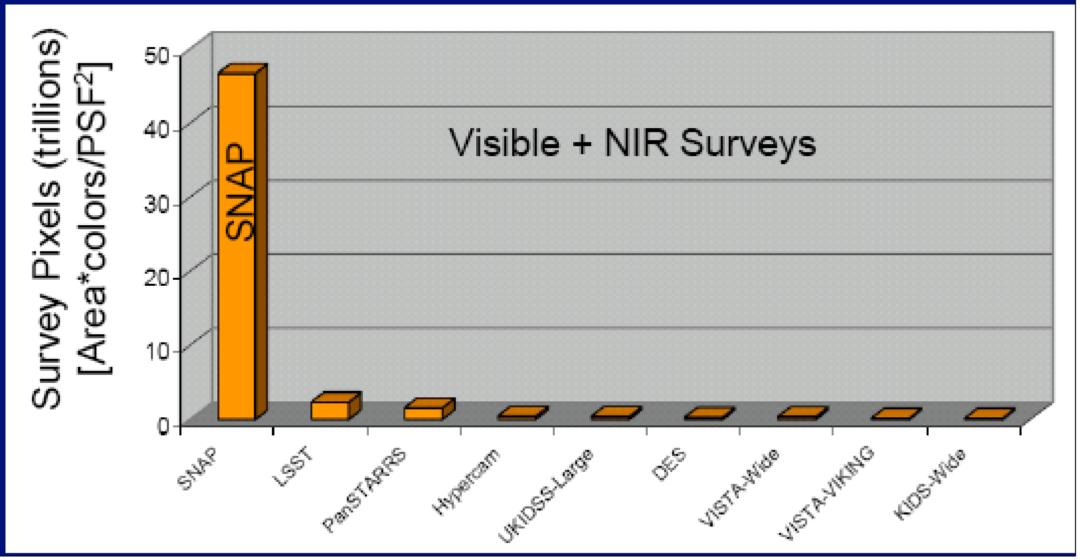


TABLE 2.E.3 JDEM: Beyond Einstein Science Programs

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	

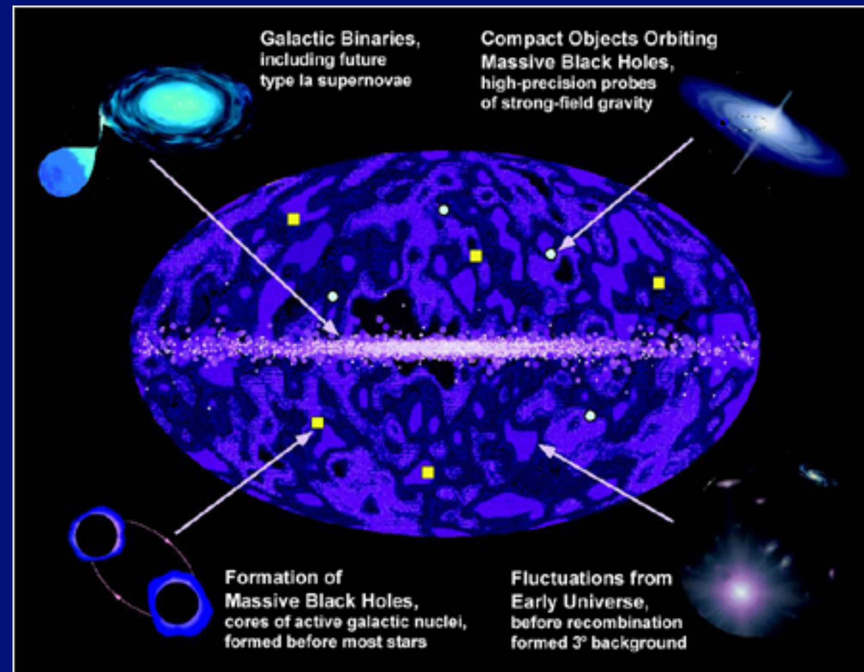
Broader Science was crucial to JDEM priority

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



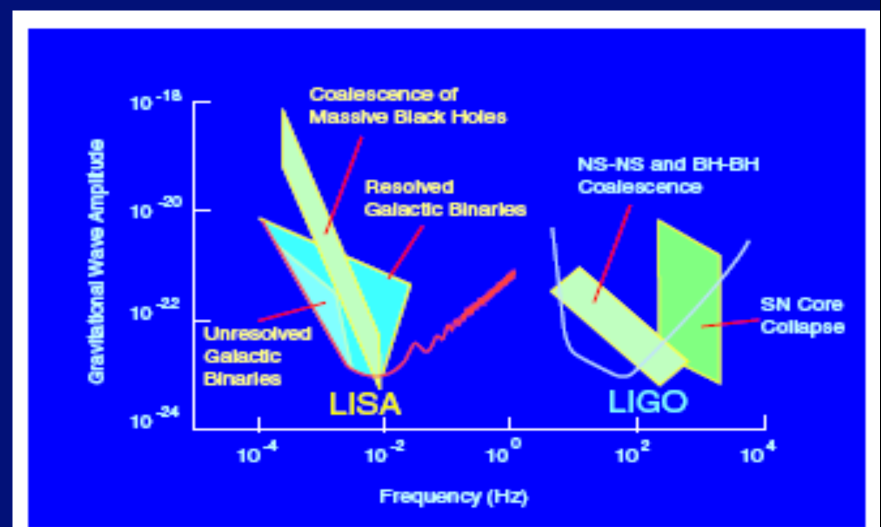


TABLE 2.F.3 LISA: Beyond Einstein Science Programs

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	

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	

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.

Evaluation of Technical Readiness

- Technical Evaluation consisted of two parts
  - Technical readiness, including the following elements: the instrument, spacecraft, operations, and technical margins.
  - Management readiness, including: team organization, schedule and other special challenges.

- The committee, supported by SAIC, evaluated the technical readiness levels of the relevant scientific and engineering components for the 11 mission concepts.

- The mission candidates provided information on their missions in response to the committee's Request For Information (RFI) and to further questions from the committee.

- *The mission teams worked to meet difficult deadlines imposed by the committee's tight schedule, and the committee appreciates their efforts.*

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

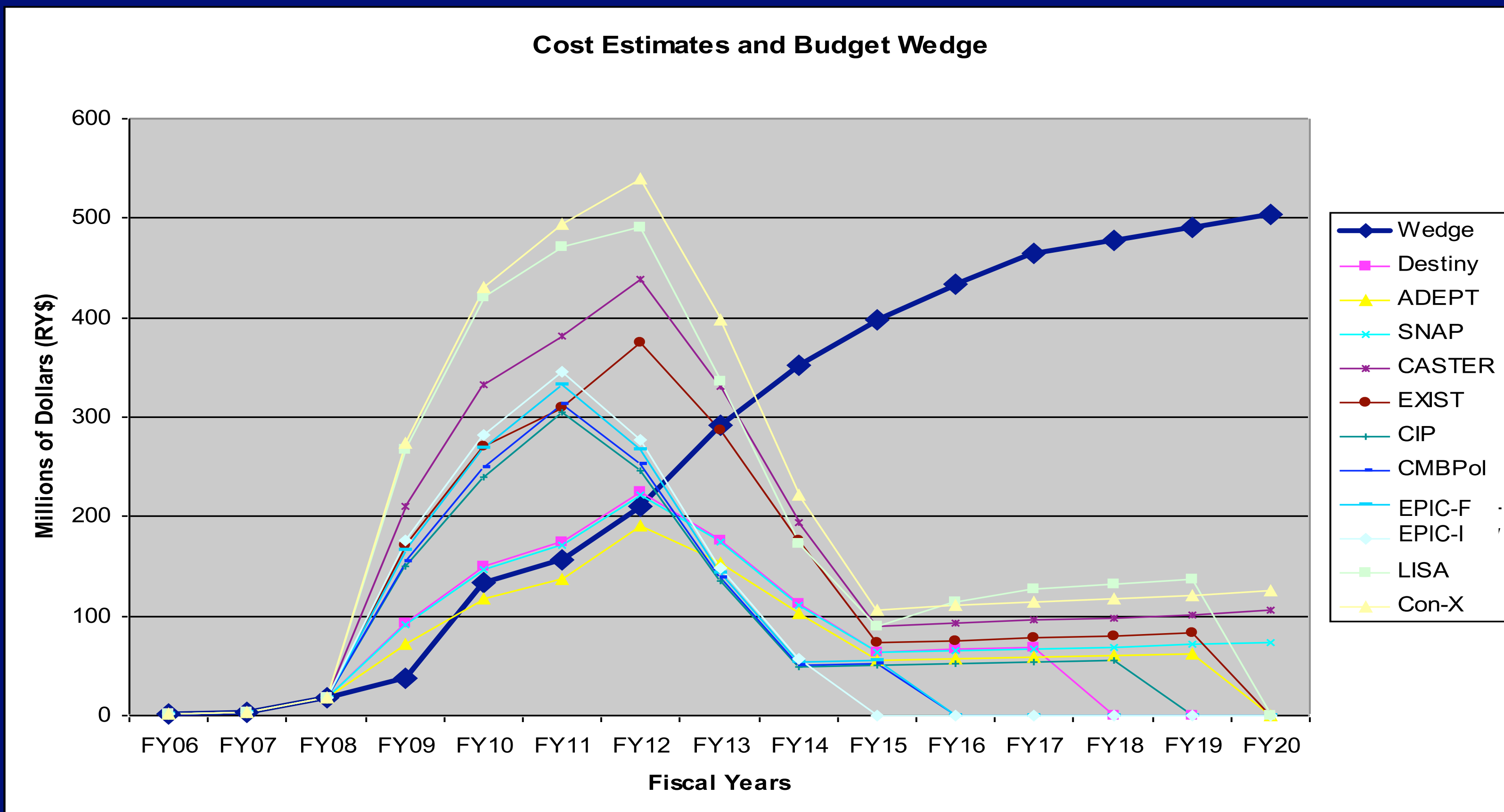
- A JDEM mission will set the standard in the precision of its determination of the distribution of dark energy in the distant universe. By clarifying the properties of 70 percent of the mass-energy in the universe, JDEM's potential for fundamental advancement of both astronomy and physics is substantial. 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.

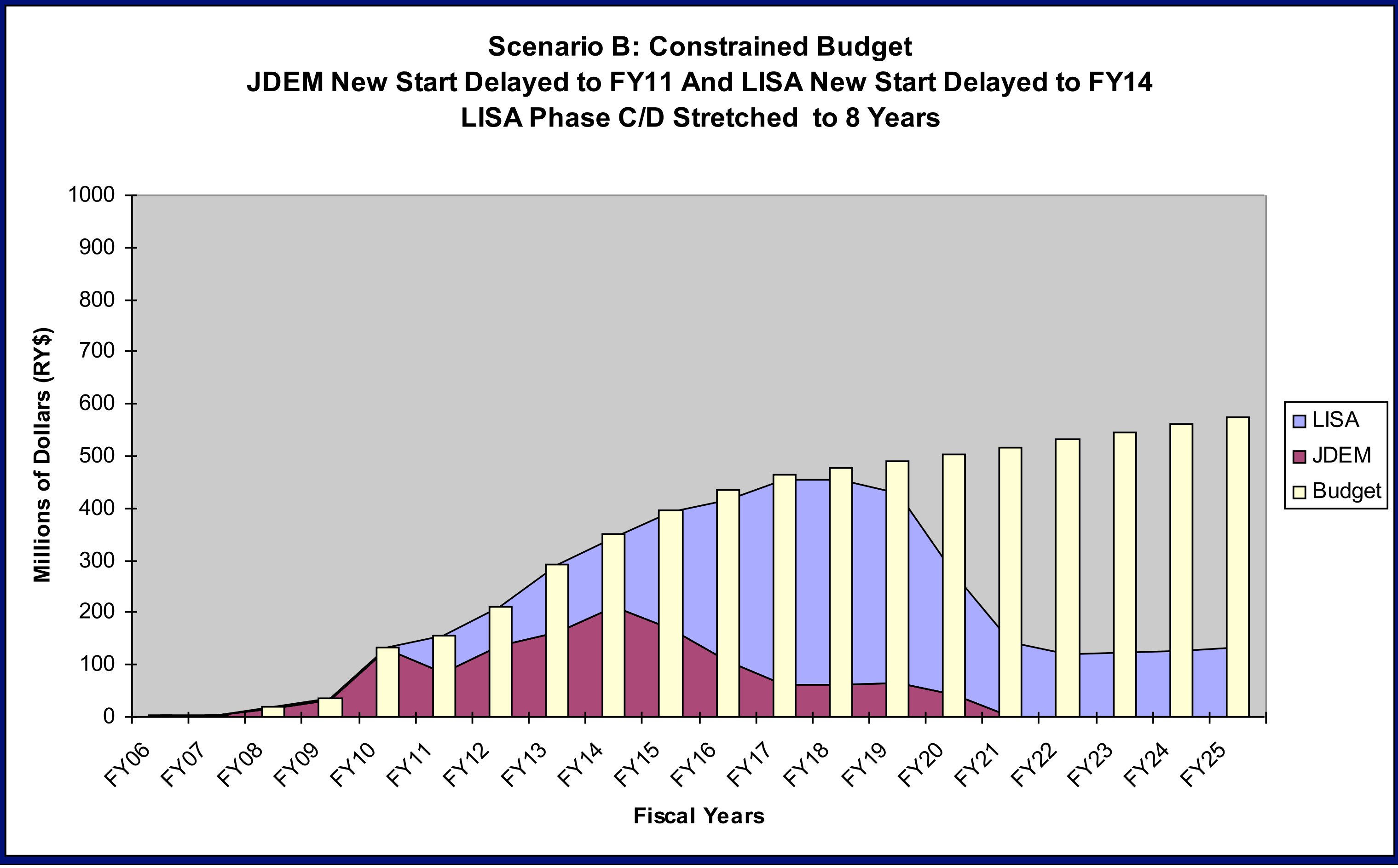
Finding 8

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



Finding 8 cont.

- 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.

Selection Summary

- JDEM is the mission providing the measurements most likely to determine the nature of dark energy, and LISA provides the most direct and cleanest probe of spacetime near a black hole.
- Constellation-X, in contrast, provides measurements promising progress on at least two of the three questions, but does not provide the most direct, cleanest measurement on any of them. It was the committee's judgment that for a focused program like Beyond Einstein, it is most important to provide the definitive measurement against at least one of the questions.
- The committee concludes that JDEM is technologically mature enough to succeed on the timescale specified in the charge. LISA requires additional technology development and a successful pathfinder mission before it is ready for development.
- The committee recommends JDEM for a 2009 start.

Committee Cost Estimates and Budget Analysis

Cost Realism Assessment Methodology

1. Acquire and normalize data for the individual mission concepts.
2. Perform independent estimates of probable costs and development time to undertake the individual mission concepts.
   1. Used SAIC's QuickCost model to develop ICE
   2. Cross-checked with NAFCOM model for consistency
3. Compare individual estimates with a complexity-based model (Aerospace Corp's CoBRA) to aggregate individual mission concepts into a range of cost for the Beyond Einstein mission areas.
4. For the recommended mission sequence develop a budget profile compared with the expected funding wedge to assess affordability and mission ordering options.

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:

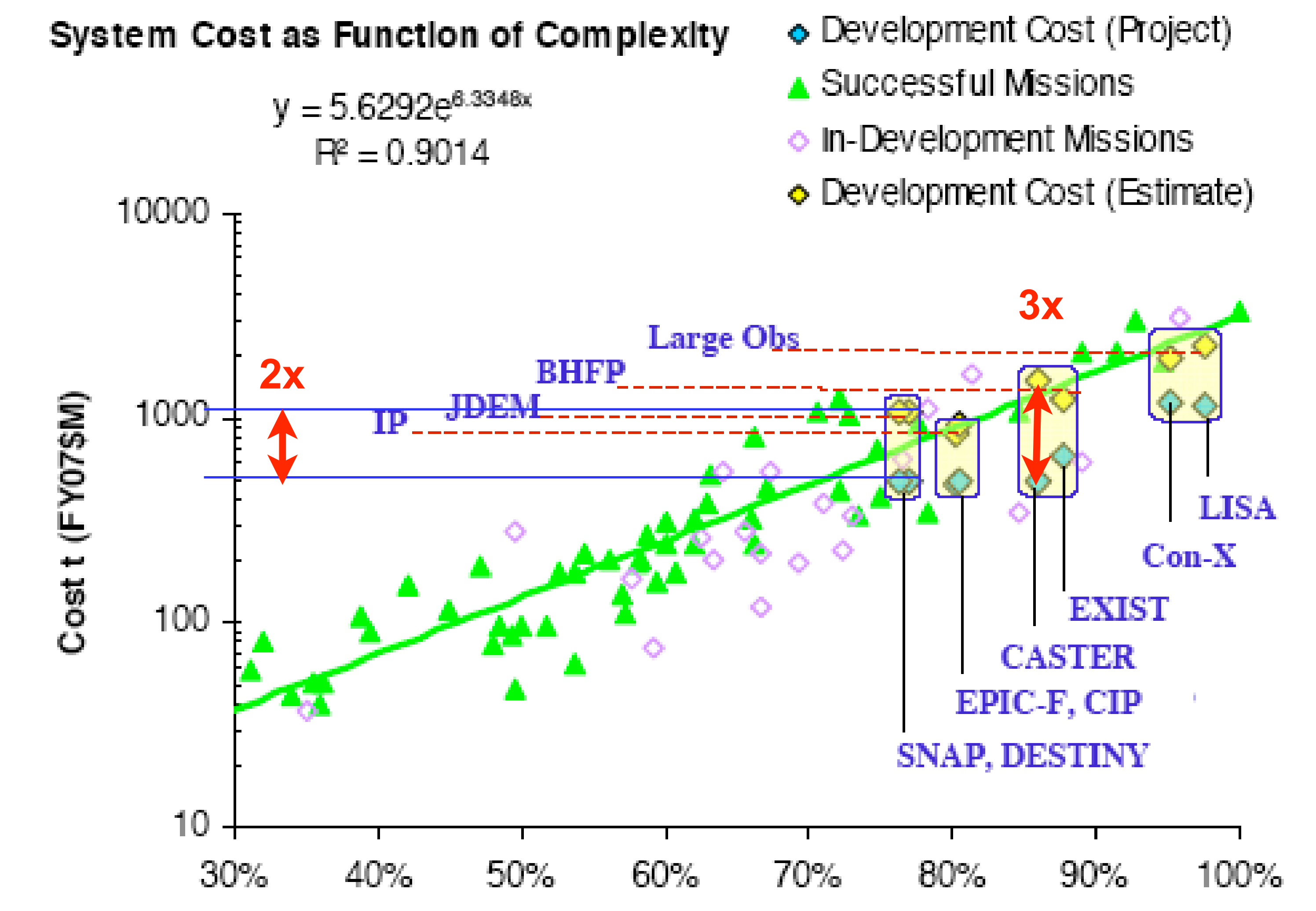
• Large Observatories (LISA and Con-X)	$2B	8 years
• BHFP (EXIST, CASTER)	$1.5B	7 years
• JDEM (SNAP, ADEPT, DESTINY)	$1B	6 years
• IP (CIP, CMBPol, EPIC-F, EPIC-I)	$1B	6 years

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.

Summary of Cost Estimate Results

	Joint Dark Energy Mission			Black Hole Finder Probe		Inflation Probe					
	Destiny	ADEPT	SNAP	CASTER	EXIST	CIP	CMBPol	EPIC-F	EPIC-I	LISA	Con-X
DDT&E + Production (Excluding Phase A/B) at 70% Confidence	$1,132	$973	$1,116	$1,588	$1,290	$876	$910	$980	$1,030	$2,318	$2,059
Launch Services	$200	$200	$200	$300	$300	$200	$200	$200	$200	$300	$300
Partnering Credits (DOE for JDEM/ESA for LISA)	($400)	($400)	($400)	$0	$0	$0	$0	$0	$0	($500)	$0
Acquisition Subtotal	$932	$773	$916	$1,888	$1,590	$1,076	$1,110	$1,180	$1,230	$2,118	$2,359
MO&DA	$198	$293	$410	$584	$389	$260	$103	$111	$57	$641	$695
Life Cycle Cost at 70% Confidence	$1,130	$1,066	$1,326	$2,472	$1,978	$1,336	$1,213	$1,290	$1,287	$2,759	$3,054
Project Estimated Life Cycle Cost--FOR REFERENCE ONLY	*$834*	*$1,000*	*$724*	*$993*	*$1,095*	*$683*	*$700?*	*$800*	*?*	*$2,045*	*$2,162*
Estimated Phase C/D Duration (months)	69	63	63	76	69	60	62	62	63	73	77
NAFCOM DDT&E + Production (Excluding Phase A/B) at 70% Confidence--FOR REFERENCE	-----	-----	-----	-----	-----	*$762*	-----	*$910*	-----	*$1,861*	*$1,630*
Other Metrics of Interest											
DDT&E + Production in 2007$ Including Phase B/C/D for COBRA Comparison	$1,085	$933	$1,070	$1,523	$1,237	$840	$872	$939	$987	$2,223	$1,974
Estimated Phase B/C/D Duration (months) Including Phase B for COBRA Comparison	81	75	75	88	81	72	74	74	75	91	95
Dry Mass (kg) Model Input	2551	1800	1571	13740	9000?	1409	1600?	1611	1810	1282	5882

Committee ICE vs. Project Estimates



Note: Insufficient data provided for ADEPT (JDEM), CMBPol (IP), EPIC-I (IP) to assess Complexity

NASA Science Funding Crisis

my personal comments

Great 2003 Plans for US Space Astrophysics
Bush's 2004 Vision for Space Exploration (VSE)
No extra NASA funding provided for VSE
Drastic 2007 cuts in NASA Space Astrophysics
Demise of US Space Astrophysics leadership:
three nightmares
Possible path forward

NASA Space Science 2003

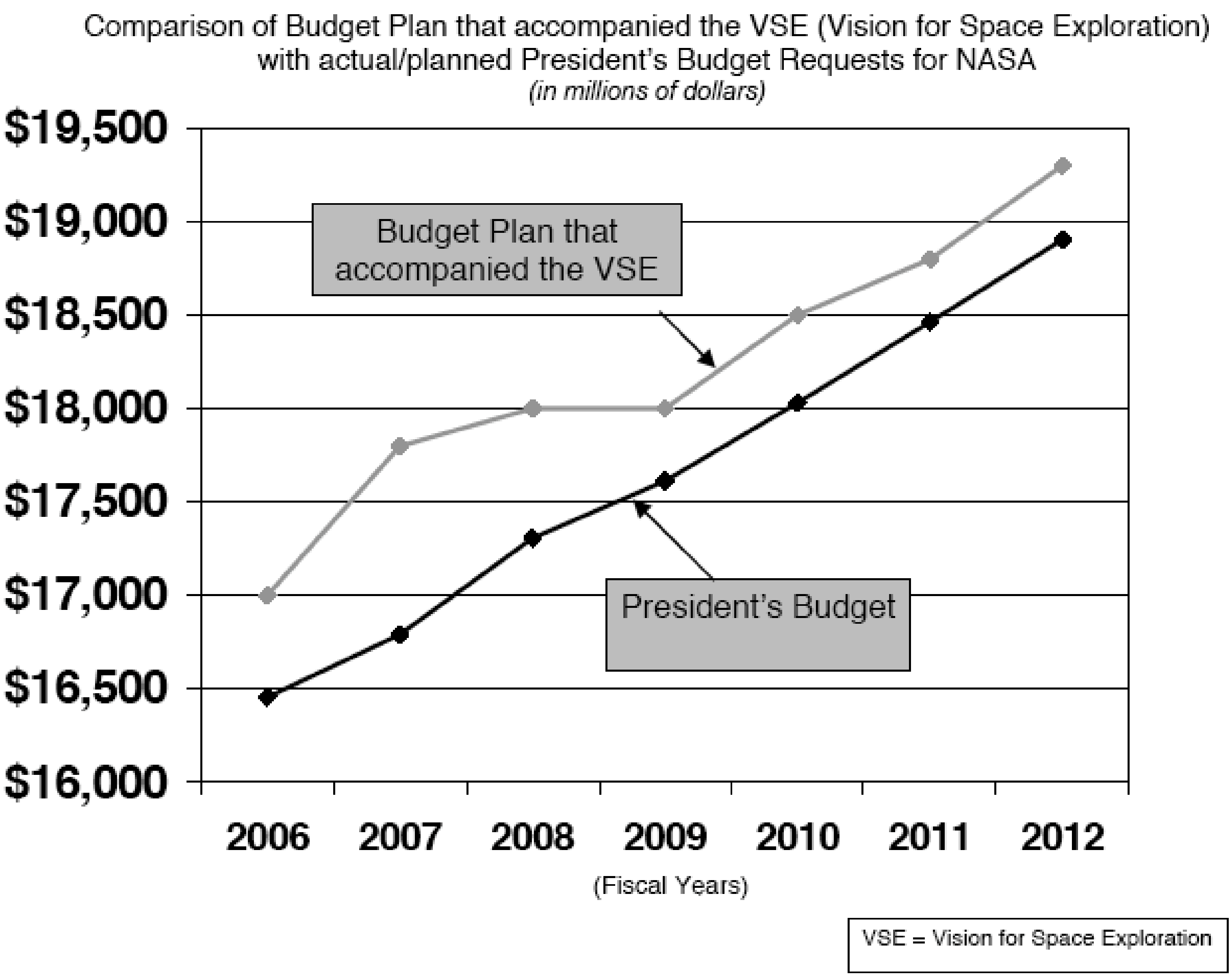
Robust Astrophysics Program

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

November 2004

THE MOON-MARS PROGRAM

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

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

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

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

The American Physical Society is the nation's primary organization of research physicists with 43,000 members in industry, universities, and national laboratories.

APS Discussion Papers

The APS occasionally produces discussion papers on topics currently debated in Congress in order to inform the debate with the perspectives of physicists working in the relevant issue areas. The papers are overseen by the APS Panel on Public

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 through its spectacular scientific successes with the Hubble Space Telescope, the Mars Rovers, and Explorer missions that have revolutionized our understanding of the universe.

The technical hurdles facing the Moon-Mars initiative are formidable, and the program's overall costs are still unknown. Further, the rapid pace currently envisioned for this program may require a wide redistribution of the science and technology budgets that could significantly alter the broad scientific priorities carefully defined for NASA and the other federal agencies. Launching such a massive program without broad consultation and a clear idea of its scope and budget may hurt rather than enhance, as intended, the scientific standing of the U.S. and the training of its scientists and engineers.

Before the United States commits to President Bush's proposal, an exhaustive external review of the plans should be carried out by the National Academy of Sciences and their likely budgetary impact estimated by the Government Accountability Office (GAO). *(Adopted June 2004.)*

THE MOON-MARS PROGRAM

American Physical Society Panel on Public Affairs (POPA) Task Force on NASA Funding for Astrophysics

Authors

Roger Blandford, Stanford	SSB (Co-Chair Comm. on Astronomy and Astrophysics)
Fiona Harrison, Cal Tech	SScAC
Garth Illingworth, UCSC	SScAC
Margaret Kivelson, UCLA	SSB
Bob Lin, UC Berkeley	Director of Space Sciences Laboratory, UC Berkeley
Michael S. Lubell, CCNY	APS Director of Public Affairs
Chris McKee, UC Berkeley	Co-chair of 2002 NAS Astronomy Decadal Study
Bernard Sadoulet, UC Berkeley	Chair-elect of APS Division of Astrophysics
David Stevenson, Cal Tech	President, Planetary Sciences Section, AGU
Joel Primack, UCSC, Chair	POPA; Vice-Chair APS Forum on Physics and Society

NOVEMBER 2004

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,

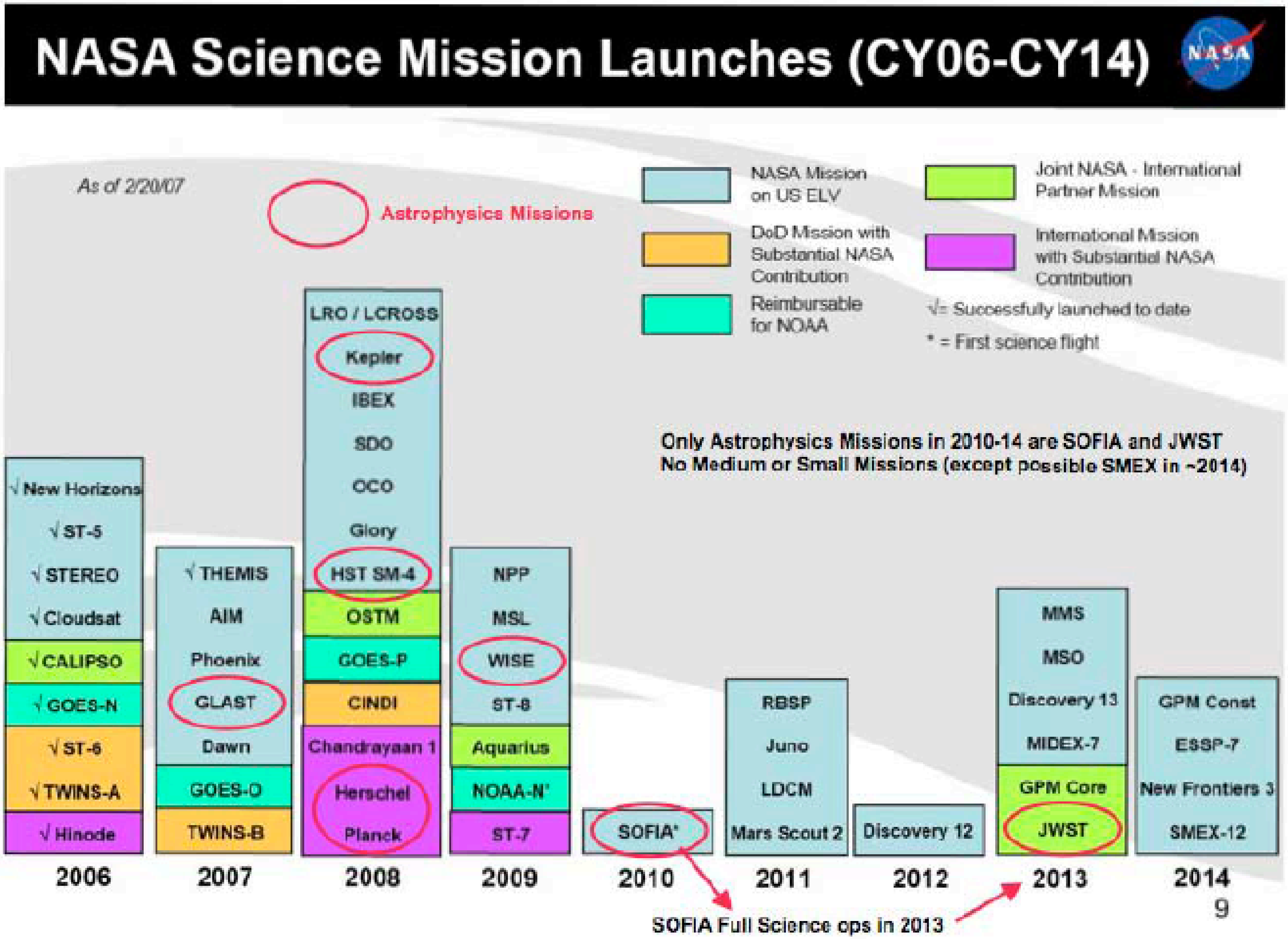
Navigator: Terrestrial Planet Finder, Space Interfer. Mission (SIM)

Recent Developments

SOFIA refunded

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

SMD Assoc Admin Alan Stern and John Mather appointed



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, which are to be flown on NPOESS, are less capable than existing sensors and may affect future abilities to forecast El Nino events, hurricanes and weather forecasts in coastal areas. Moreover, the decadal survey notes that 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 Decadal Study

Three Nightmares for US 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:
US abdicates Space Astrophysics leadership

Possible Solution

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

Space Astrophysicists and Earth Observation Scientists work together to plan much more ambitious NASA science programs to preserve US leadership and competitiveness

Join with aerospace companies (except Boeing?) to lobby for much more ambitious US Space Science program

Aim to influence Transition to next Administration