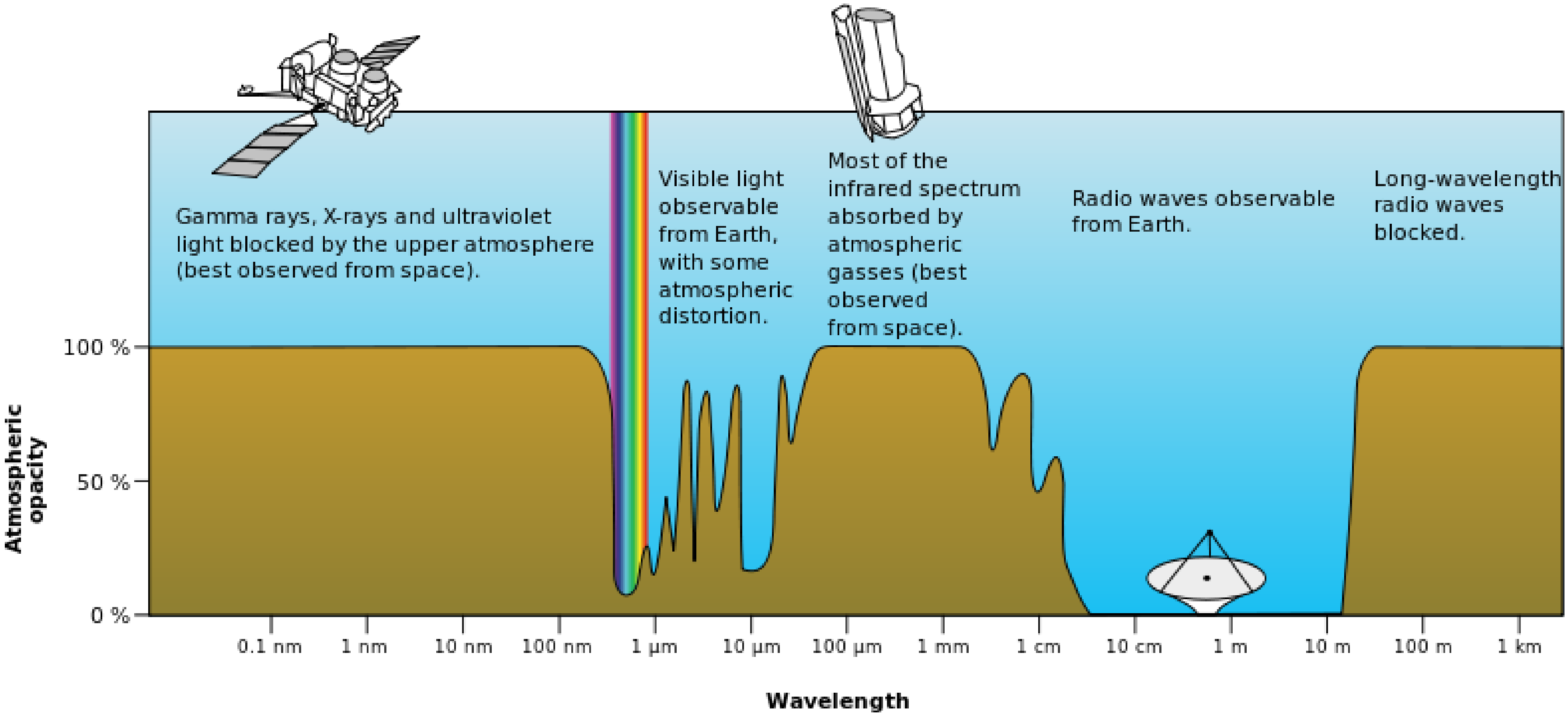


Kavli – AUI #2 Meeting

T. Beasley

THE KAVLI FOUNDATION NRAO Associated Universities Inc

Motivation for KA Meetings – RMS Futures

- Decadal Survey is approaching – time to explore the scientific opportunities ahead, and our connections to the broader astronomy community.

- Goal: bring US RMS community, together, consider major science opportunities, community options and choices for next decade

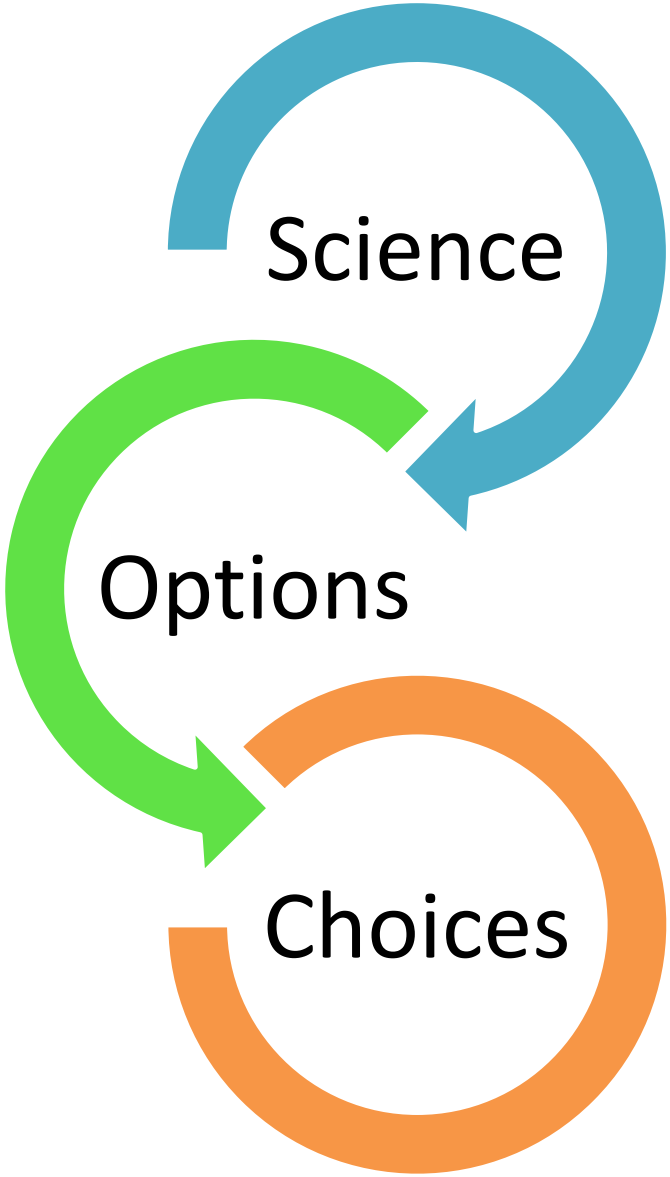
- Similar planning processes underway at NASA, US OIR community – attempting similar approaches for RMS ASTRO2020

- 2014: Independent Organizing Committee – generated 3M plan

KA Meetings

Org Committee:

Beasley
Blandford
Carlstrom
Haynes
Hewitt
Lazio
Readhead
Reid



KA1 – Chicago 2015 Dec 15-17

Science

- Cradle of Life
- Formation & Evolution of Galaxies
- Fundamental Physics
- Cosmology & Cosmic Dawn
- Also: Facilities under construction

- Focusing on: science opportunities…
- Mainly – ground-based RMS, although no restrictions…
- ~120 attendees, thanks to SOC & contributors
- **https://science.nrao.edu/science/meetings/2015/2020futures/home**
- Identified areas for further consideration

KA2 – Baltimore

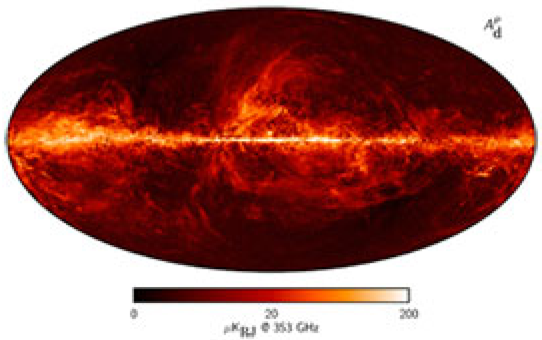
- AAS Jan 2016 KA OC – discuss "Options" to consider in depth. Decision to include "Midscale/Other" opportunity to see options emerging from smaller groups and collaborations.

- Focusing on: "Flagship" initiatives, addressing major science opportunities, broad/international collaboration and major funding requirements – "NSF MREFC", etc.

- Four sessions:

Futures II Focus Area: Cosmic Microwave Background

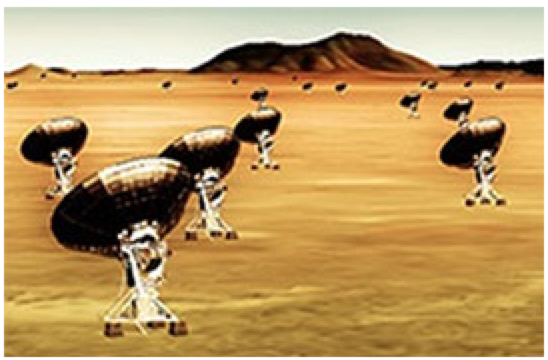
Zeeshan Ahmed, Chair



The scientific case is being developed for a next generation ground-based cosmic microwave background (CMB) experiment, CMB-S4, consisting of dedicated telescopes at the South Pole, the high Chilean Atacama plateau, and possibly a northern hemisphere site, all equipped with new superconducting cameras that will provide a dramatic leap forward in cosmological studies, crossing critical thresholds in testing inflation, the number and masses of the neutrinos or the existence of other ‘dark radiation’, providing precise constraints on the nature of dark energy, and testing general relativity on large scales.

Futures II Focus Area: Next Generation Very Large Array

Eric Murphy (NRAO), Chair



Inspired by dramatic discoveries from the Jansky Very Large Array (VLA) and the Atacama Large Millimeter/submillimeter Array (ALMA), the community has initiated discussion of a future large area radio array optimized for imaging of thermal emission to milli-arcsecond scales that will open new discovery space from proto-planetary disks to distant galaxies. This next generation Very Large Array (ngVLA) is currently envisioned to include: (a) ~10x/30x the effective collecting area of the VLA/ALMA; (b) frequency coverage spanning 1.2 – 116 GHz; (c) interferometric baselines up to 300 km to achieve milli-arcsecond resolution, with consideration for longer baselines and Very Long Baseline Interferometry; and (d) a dense antenna core on km-scales providing high surface brightness imaging.

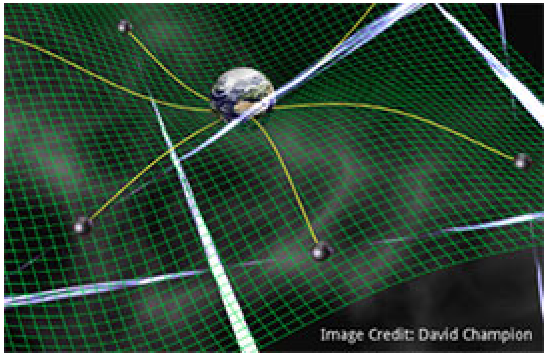
Futures II Focus Area: Hydrogen Epoch of Reionization Array (HERA)

Aaron Parsons (UC, Berkeley), Chair

New instruments dedicated to observing the large-scale structure of the Universe during and prior to the epoch of reionization are being proposed that incorporate the lessons learned from the Murchison Widefield Array and the Precision Array for Probing the Epoch of Reionization. Cosmic reionization corresponds to the epoch when the neutral intergalactic medium is reionized by the first luminous objects. Probing this last unexplored phase of cosmic evolution offers extraordinary discovery potential for the field of cosmic structure formation. The substantially larger collecting area of the proposed second and third-generation HERA instruments would yield an order-of-magnitude or more sensitivity, be capable of robust statistical characterization, and yield the first images of large-scale neutral hydrogen structure.

Futures II Focus Area: Pulsars & Transients

Chair David Kaplan



The North American NanoHertz Observatory for Gravitational Waves and the International Pulsar Timing Array are monitoring a set of pulsars that form a Galactic scale gravitational-wave observatory and offer the potential to observe long-period gravitational waves via their effects on pulse light-travel times. These and other instruments will also continue to use pulsars to further explore the physics of extreme environments. Known radio transients include stellar flares, pulsars, and gamma-ray burst afterglows. Hypothesized classes of radio transients may enable transformational exploration of known phenomena – extrasolar planets emitting Jovian-like radio bursts and giant-pulse emitting pulsars in other galaxies – as well as the more exotic, such as prompt emission from gamma-ray bursts and evaporating black holes. New instruments and facilities are envisioned that combine the wide fields-of-view and wavelength agility required to transform our ability to study the Universe via radio transients.

	Wed, Aug 3		Thur, Aug 4		Fri, Aug 5
8:00 AM	Registration				
8:15 AM					
8:30 AM			HERA (Baltimore Ballroom)	Pulsars (Maryland Ballroom B)	CMB Summary
8:45 AM					
9:00 AM	Welcome				
9:15 AM	Plenary (Baltimore Ballroom)				
9:30 AM					ngVLA Summary
9:45 AM					
10:00 AM					
10:15 AM	Break				
10:30 AM	CMB (Maryland Ballroom B)	ngVLA (Baltimore Ballroom)	Break		Break
10:45 AM			HERA (Baltimore Ballroom)	Pulsars (Maryland Ballroom B)	HERA Summary
11:00 AM					
11:15 AM					
11:30 AM					
11:45 AM					Pulsars Summary
12:00 PM					
12:15 PM					
12:30 PM					
12:45 PM	Lunch		Lunch		Lunch
1:00 PM					
1:15 PM					
1:30 PM					
1:45 PM					

1:30 PM					
1:45 PM					
2:00 PM	CMB (Maryland Ballroom B)	ngVLA (Baltimore Ballroom)	HERA (Baltimore Ballroom)	Pulsars (Maryland Ballroom B)	Midscale Summary
2:15 PM					
2:30 PM					
2:45 PM					
3:00 PM					Panel Discussion
3:15 PM					
3:30 PM	Break		Break		
3:45 PM	CMB (Maryland Ballroom B)	ngVLA (Baltimore Ballroom)	Midscale		
4:00 PM					Conclusion
4:15 PM					
4:30 PM					
4:45 PM					
5:00 PM					
5:15 PM					
5:30 PM	Reception (Watertable Ballroom)				
5:45 PM					
6:00 PM					
6:15 PM					
6:30 PM					
6:45 PM			Conference Dinner (Pratt Street Ale House)		
7:00 PM					
7:15 PM					
7:30 PM					
7:45 PM					
8:00 PM					
8:15 PM					
8:30 PM					

Compress Day 3?

Communiity Environmental Parameters

- Science themes in broader US community *(~10yrs from now)*
- Major domestic initiatives (e.g. LSST, JWST, GSMT)
- Major international endeavors (e.g. SKA, international projects)
- Funding opportunities (NSF/other)
- These factors influence:
  - Number vs size of proposals from RMS community
  - Partnerships/internationality
  - University recruitment
  - NSF funding
  - NRAO scientific & technical development – we stand in support

Mid-scale Research Infrastructure

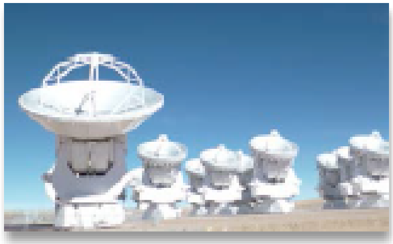
The National Science Foundation's (NSF) S&E activities rely increasingly on infrastructure that is diverse in space, cost and implementation time -- everything from major observatories to nationwide sensor networks to smaller experiments.

NSF funds relatively small research infrastructure projects -- up to $20 million -- through its individual scientific directorates. Large infrastructure projects -- above $100 million – are funded through another mechanism: the Major Research Equipment and Facilities Construction (MREFC).

There are many important potential experiments and facilities that fall between these amounts; this gap results in missed opportunities that leave essential science undone. The long-term consequences of that neglect will be profound for science as well as for our nation's economy, security and competitiveness. We need a new approach to research infrastructure, one more dynamic and flexible in response to this new reality.

One relatively simple approach is to lower the threshold for MREFC expenditures and develop an agile, yet carefully monitored, process for funding experimental research capabilities in the mid-scale range.

Windows on the Universe: The Era of Multi-messenger Astrophysics



We have arrived at a special moment in our quest to understand the universe. For years, we have been making observations across the known electromagnetic spectrum -- from radio waves to gamma rays -- and many great discoveries have been made as a result. Now, for the first time, we are able to observe the world around us in fundamentally different ways than we previously thought possible. Using a powerful and synthetic collection of approaches, we have expanded the known spectrum of understanding and observing reality. Just as electromagnetic radiation gives one view of the universe, particles such as neutrinos and cosmic rays provide a different view. Gravitational waves give yet another.

Together, these different windows will provide unique insights into the nature and behavior of matter and energy and help to answer some of the most profound questions before humankind, such as how the universe began and why it is accelerating.

These research goals and topics are clearly at the heart of the fundamental mission of the National Science Foundation (NSF): to promote the progress of science. NSF's longstanding investments in ground-based astronomy, particle astrophysics and gravitational physics puts it clearly in the center of the action for all of these messengers. As the one agency engaged in all three types of multi-messenger astrophysics, NSF is uniquely positioned to promote the interagency and international collaborations needed to advance understanding in this field.

MREFC Account Funding, by Project

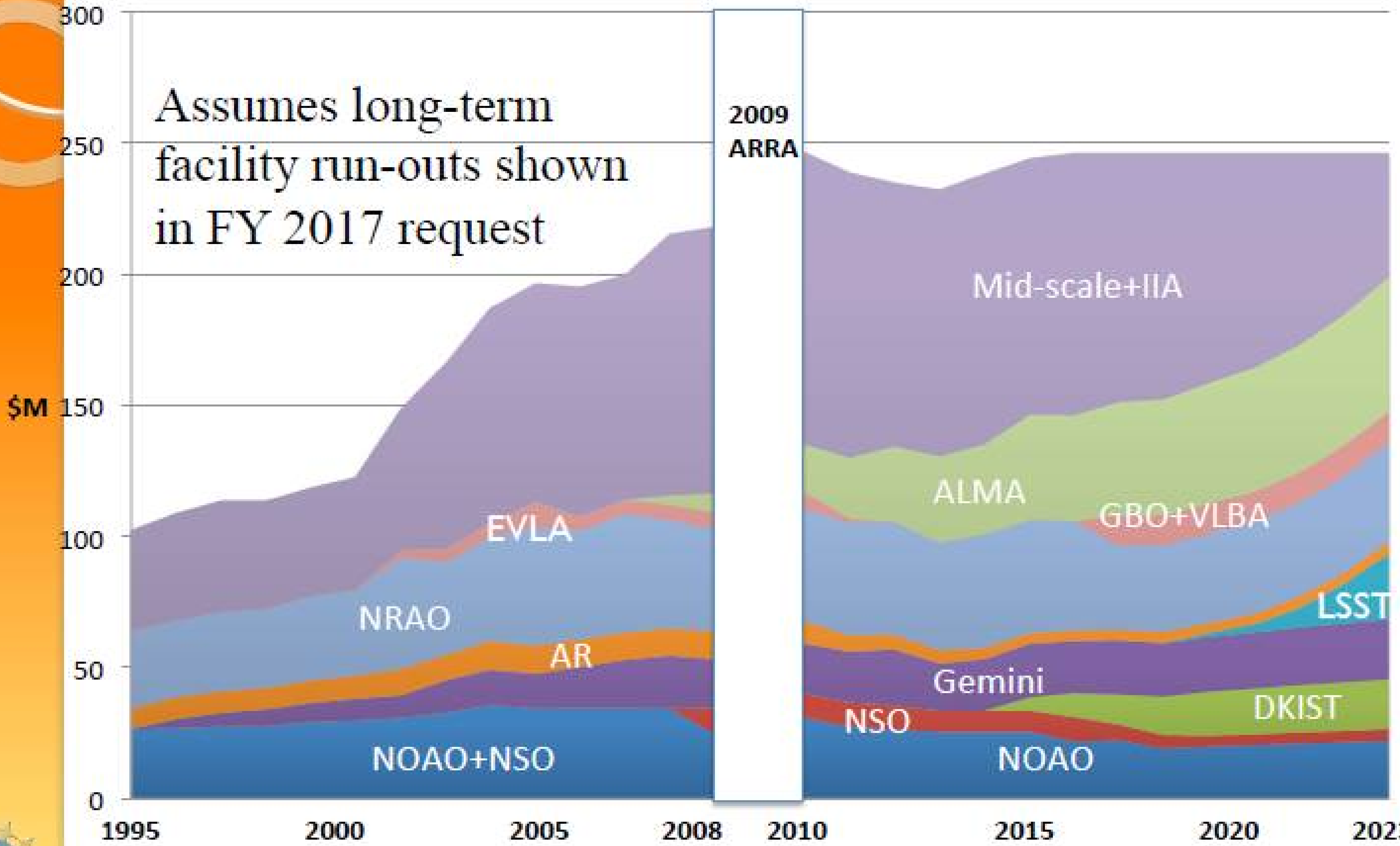
(Dollars in Millions)

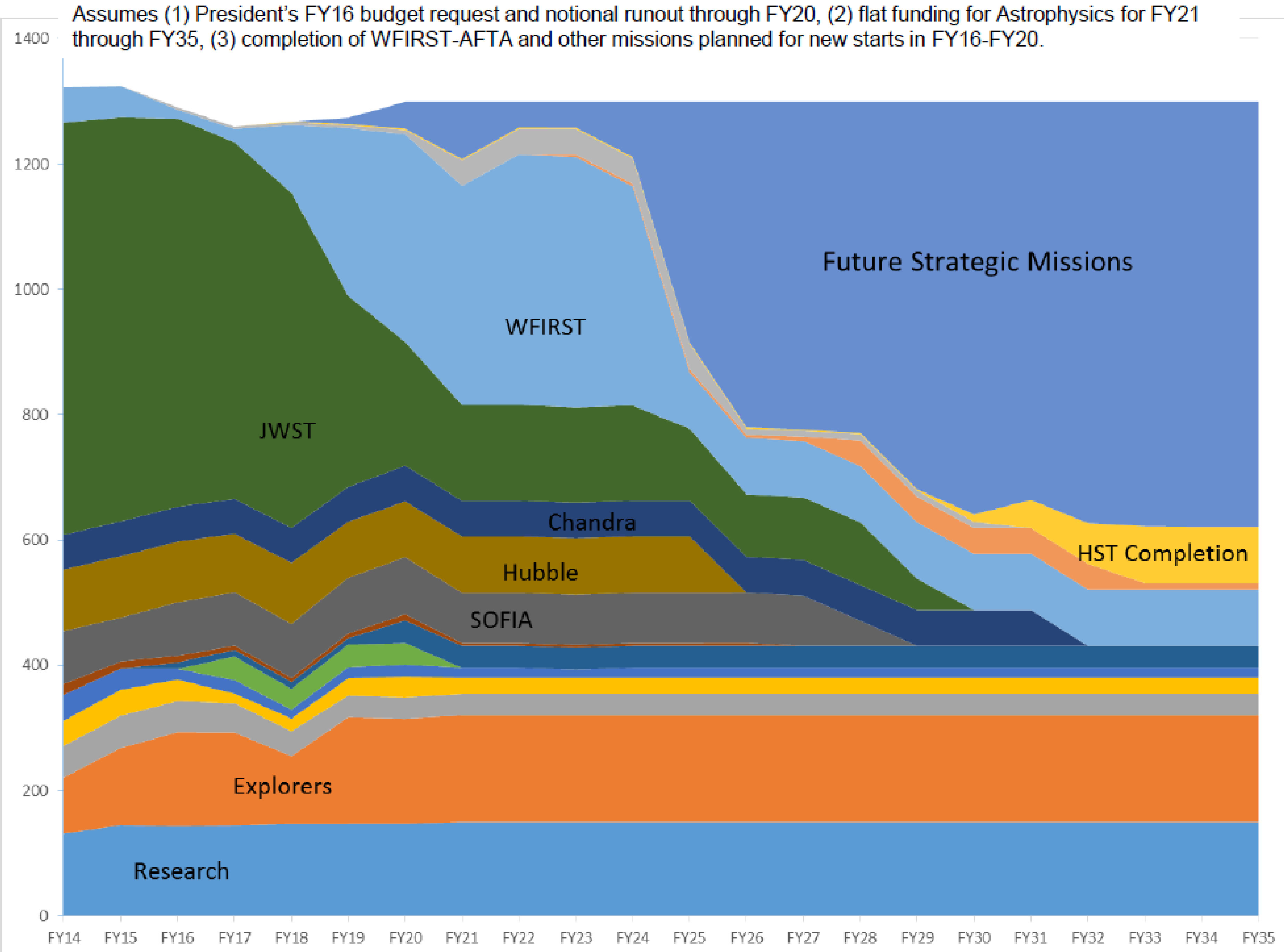
	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	FY 2018 Estimate	FY 2019 Estimate	FY 2020 Estimate	FY 2021 Estimate	FY 2022 Estimate
DKIST	$25.12	$20.00	$20.00	$20.00	$16.13	-	-	-
LSST	79.64	99.67	67.12	55.80	47.89	45.75	39.90	9.73
NEON[1]	40.00	80.64	-	-	-	-	-	-
RCRV	-		106.00	105.00	44.50	-	-	-
Total	**$144.76**	**$200.31**	**$193.12**	**$180.80**	**$108.52**	**$45.75**	**$39.90**	**$9.73**

Totals may not add due to rounding.

AST: GSMT (???) CTA (??) LIGO++ (???)

AST, Hypothetical 0%/yr increase after FY16





Assumes (1) President's FY16 budget request and notional runout through FY20, (2) flat funding for Astrophysics for FY21 through FY35, (3) completion of WFIRST-AFTA and other missions planned for new starts in FY16-FY20.
Future Strategic Missions
WFIRST
JWST
Chandra
Hubble
SOFIA
HST Completion
Explorers
Research
1400
1200
1000
800
600
400
200
0
FY14
FY15
FY16
FY17
FY18
FY19
FY20
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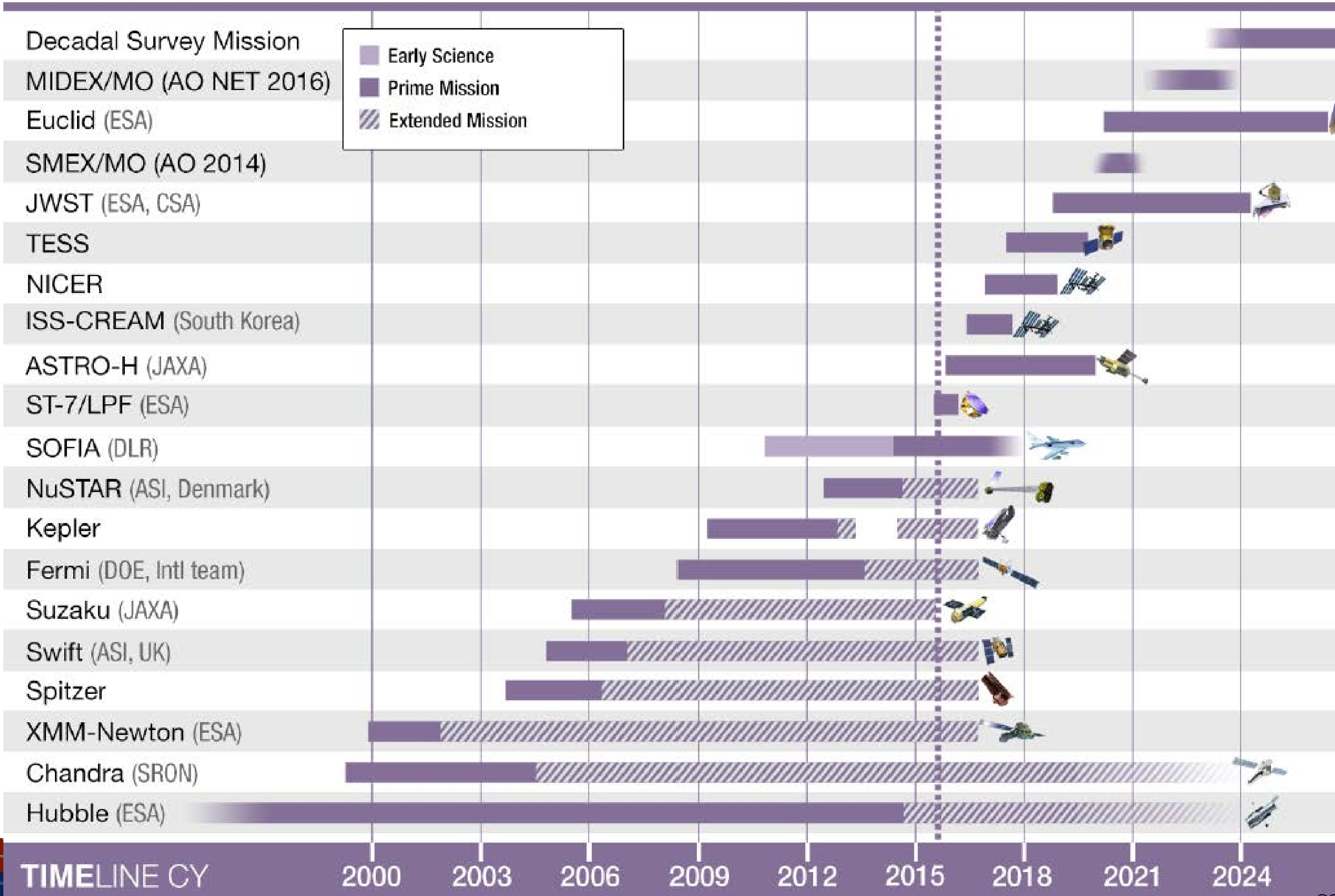
FY35

Astrophysics Timeline



Dates beyond 2016 are contingent upon the results of the 2016 Senior Review

US vs World: **Differences** & *Similarities* (TJB opinions)

- **Science is at start and finish of all great projects. Other normal benefits (IP, training etc.) expected, but Science rules. Clear requirements flowdown.**
- **Broadest-possible community support required.**
- **Performance standards are only increasing – critical.**
- **Partnership + Coherent governance structures.**

- *Great opportunities appear on all scales…. Large and small $$.*
- *NSF responds to community input. And political input.*
- *US Science Funding, NSF implementation are evolving. Evolve.*
- *ASTRO2020 – take high-quality range of choices (all scales) forward, addressing 2020's development and 2030's planning.*

This Meeting

- **Hoping to See: Vision + Details of Instruments/capabilities to achieve science opportunities seen in KA1 – science-driven!**
- **Path to achieve the science.**
- **Realistic SWOT (Strengths, Weaknesses, Opportunities, Threats)**
- **(Growing) Connection to US/International research themes.**
- **Placement in global context? (e.g. SKA)**
- **(NRAO/AUI: support all)**

Future of RMS - Third Meeting

- August 2017 – West Coast
- "CHOICES" – converged concepts at varying levels of sophistication (keeping eye on science directions…) + thematic supporting meetings.

BIG THANKS TO:

- Kavli Foundation/Chris Martin/Miyoung Chun
- Associated Universities Inc./Ethan Schreier

QUESTIONS?