U.S. DEPARTMENT OF ENERGY

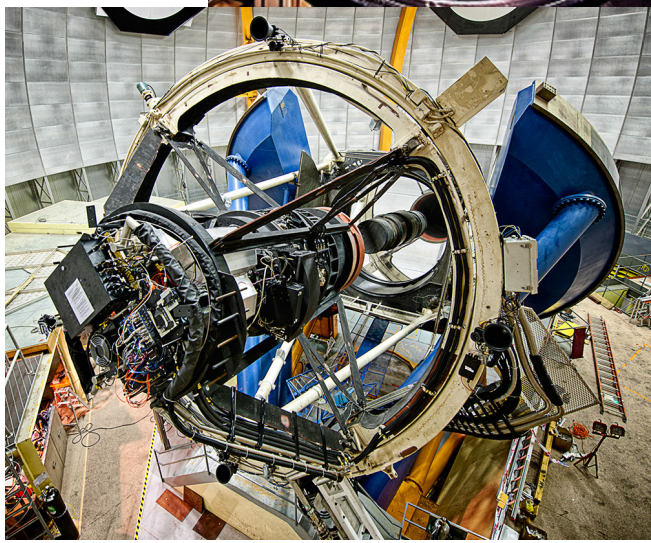
OFFICE OF SCIENCE

DOE High Energy Physics (HEP)

report to the

AAAC Panel

→ Update to Oct. 2016 report



26 January 2017

Glen Crawford (Research & Technology Division Director)

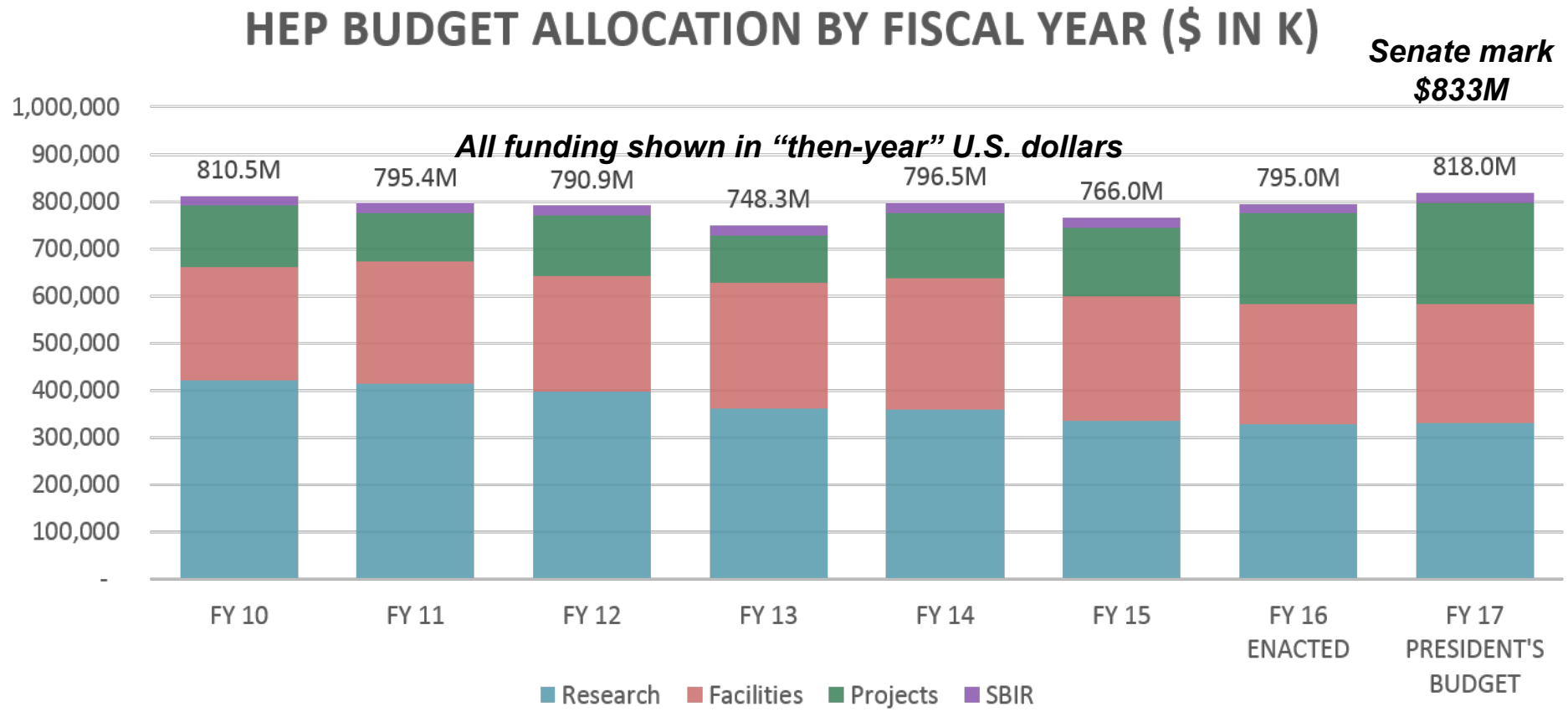
HEP Cosmic Frontier Program Managers:
Anwar Bhatti (IPA), Eric Linder (IPA), Michael Salamon, Kathy Turner

Overall HEP Budget Trend

- Significant dip in FY13 from Congressional sequestration
- FY15 request developed prior to P5 report release; FY16 Budget puts HEP squarely in P5 Scenario B.
- FY17 – is currently in a Continuing Resolution

House mark $823M

Senate mark $833M



→HEP must coordinate Projects, Facilities/Operations, and Research efforts to succeed in its mission In recent years have traded Research for Project investments

FY2017 Program Priorities

HEP: FY 2017 President's Request ($818M) aims to continue the successful implementation of the P5 strategy

- Investing in portfolio of high-priority projects at small, medium, & large cost scales
- Request is carefully balanced between support for projects ($212M), facility operations ($252M), and scientific research ($354M) in order to produce scientific results while "building for discovery"

Cosmic Frontier: Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

Priorities: Carry out P5 Plan

- Continue to advance leadership efforts in the dark matter, dark energy experiments & projects
- In last few years, moved from operating a broad, diverse suite of experiments to focusing the science & carrying out next generation (i.e. larger) experiments.
- We are working hard to understand the Operations and Research funding needs for these new projects and plan out-year budgets appropriately.

Cosmic Frontier Budget History – details

	FY15 Pres. Request	FY15 Actual	FY16 Pres. Request	FY16 Actual	FY17 Pres. Request	FY17 Current Plan (CR)
Research	**45,435**	**48,779**	**50,079**	**47,326**	**46,991**	**45,023**
Grants	*11,422*	*11,773*	*12,565*	*12,705*	*11,607*	*11,088*
Labs	*34,013*	*37,006*	*37,514*	*34,621*	*35,384*	*33,935*
Exp Operations	**7,238**	**9,185**	**7,120**	**10,274**	**8,925**	**9,850**
Projects	**41,000**	**46,403**	**58,701**	**67,780**	**70,200**	**69,500**
Major Projects (MIE)	**41,000**	**44,178**	**57,100**	**64,600**	**69,500**	**68,900**
LSSTcamera	*35,000*	*35,000*	*40,800*	*40,800*	*45,000*	*45,000*
DESI		*3,878*	*5,300*	*10,300*	*10,000*	*10,000*
DM-G2	*6,000*		*11,000*			
LZ		*3,050*		*10,500*	*10,500*	*10,500*
SuperCDMS-SNOLAB		*2,250*		*3,000*	*4,000*	*3,400*
Small Project		***1,025***	***1,601***	***2,035***	***0***	***0***
All			*1,601*		*0*	*0*
ADMX-G2		*925*		*935*		
SPT-3G		*100*		*1,100*		
Future R&D	***0***	***1,200***	***0***	***1,145***	***700***	***600***
All		*200*		*1,145*	*700*	*600*
SPT-3G		*1,000*				
TOTAL	**93,673**	**104,367**	**115,900**	**125,380**	**126,116**	**124,373**

Cosmic Frontier Status – Dark Energy

➔**Staged program of complementary suite of imaging & spectroscopic surveys**

***eBOSS* & *DES* continue operations*; BOSS* operations completed 2014, final results**
- Review of DES' science case for proposed 6th year of operations in Dec. 2016

LSST - stage IV imaging

- NSF-AST and HEP partnership
- LSSTcam MIE Project (HEP responsibility) received CD-3 in August 2015
- Operations planning activities ramping up: LSST commissioning phase (**Review Jan. 2016**) and facility operations phase (**proposal in summer 2017)**
- Science: Dark Energy Science Collaboration (DESC) – **Review of Operations plan April 2017**

DESI – stage IV spectroscopic

- HEP experiment, using NSF's Mayall telescope facility (NSF's NOAO is collaborator)
- DESI MIE Project received CD-3 in June 2016
- **Project Status & Operations Planning reviews (in series) planned for summer 2017**
- DESI science collaboration active

- **HEP has research-only activities on *Euclid, WFIRST, & supernova surveys***

Cosmic Frontier Status - Dark Matter (Direct Detection)

➔Staged program w/multiple technologies covering complementary phase space

Completed DOE operations support for current DM-G1 experiments in FY 2016.

HEP & NSF-PHY selected suite of 3 DM-G2 Projects (below) in July 2014
- Axion search; 2 WIMP searches over complementary mass range & technologies

ADMX-G2 (<MIE project) – axion search at U. Washington

- Carry out series of experiments with dedicated upgrades for each frequency range
- Status: **Commissioning completing; Operations starting**
- **FNAL is taking over Operations Management for Approved Range (0.5 to 2 GHz) operations**
- Status review Sept. 2016; **Follow-on review ~ summer 2017, after FNAL update of Operations Plans**

LZ (MIE Project) – Wimp search at Homestake Mine

- CD-2/3B approval August 2016; **CD-3 review for full fabrication start in Jan. 2017**

SuperCDMS-SNOLab (MIE; partner w/NSF-PHY) – Wimp search

- CD-1 approval December 2015; planning towards CD-2/3 in early FY18
- **Status mini-review Dec. 2016**

→ Operations planning activities ramping up for all DM-G2's

Cosmic Frontier Status – CMB, Cosmic/Gamma

CMB

- **SPT-3G (< MIE project) -** partnership with NSF (PLR, AST, PHY)
  - HEP contributed to detector & now operations
  - **Status: Commissioning completing and Operations starting**

- **HEP has research-only activities on a number of the current experiments**

- **CMB-S4 -** Collaboration has developed a Science Book; significant Lab-led LDRD efforts

Cosmic-ray, Gamma-ray

- **Operations continuing for Fermi/GLAST, AMS, and HAWC**

- **DOE operations funding completed in FY 2016 for VERITAS and Auger**

Cosmic Frontier
Interagency & International Activities

Interagency Coordination: NSF, NASA, DOE interact regularly about planning, overlaps, issues

Agency Joint Oversight Groups (JOG) & Agency Coordination Groups (ACG)

- International Finance Board for **FGST** w/NASA-AST, **Auger** (HEP effort completed)
- **DES, LSST:** JOG with NSF-AST
- **HAWC, SuperCDMS, VERITAS**: JOG with NSF-PHY (also CONACYT for HAWC)
- **SPT-3G**: JOG with NSF-PHY, NSF-AST & NSF-PLR
- **DESI**: ACG with NSF-AST

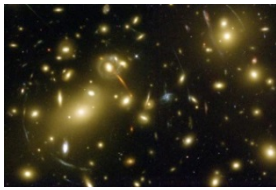
Tri-Agency Group (TAG) – DOE, NASA, NSF-AST meetings with US-leadership on LSST, WFIRST, Euclid to discuss commonalities, coordination, optimization of data, simulations, software - starting investigation of what needs to be done now to allow Joint Data Processing & share simulations across projects.

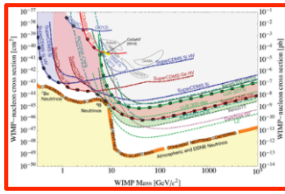
International: Making country-level agreements for science partnerships; Agency Bi-lateral meetings

Astro-Particle International Forum (APIF) – *Agency-level* group
Global Science Forum hosted through 2016; KIPAC (SLAC/Stanford) has taken over as host with Roger Blandford as Chair.

National Academies of Science Decadal Survey 2020 – Planning starting with Agencies & Community

Cosmic Frontier → looking towards the future





HEP "Cosmic Visions (CV)" groups in several areas

- Allows interactions with small HEP community groups as 2-way line of communication for HEP-funded efforts and directions recommended by P5

(NOTE: Of course, any HEP-funded R&D/technology plans need to be in the context of the larger non-HEP and global community)

CV-CMB

- Coordinate HEP technology R&D & planning efforts for future CMB-S4 (within purview of CMB-S4 CDT subpanel)

CV-DE

- Investigate future HEP directions following DESI & LSST project completion; optimizing science in DESI/LSST era and/or follow-on projects

CV-DM

- Coordinate and investigate HEP technology R&D to optimize science from DM-G2 experiments and for future DM-G3 planning

Planning for CMB-S4 (P5 recommendation)

→Following Snowmass & P5

- Community-based CMB-S4 collaboration developed a Science Book and a notional array
- HEP labs putting considerable LDRD into developing technology
- In the last year, HEP & NSF held discussions regarding possible avenues & processes for CMB-S4

Concept Definition Taskforce (CDT)

NSF and DOE presented plan in Oct. 2016 meeting to charge AAAC to carry out a CDT subpanel study.

- Charge letter (officially signed 11/21/16) by NSF-AST, -PHY,-PLR & DOE-HEP
- AAAC Chair Buell Jannuzi appointed Charles Lawrence (JPL) as CDT Chair; Members selected

→See: https://www.nsf.gov/mps/ast/aaac/cmbs4cdt.jsp

- Phone meetings (~ biweekly) & "assignments" have started – First meeting 12/8/16
- F2F meetings #1 & 2 scheduled for end January, early March

HEP Investigating Dark Matter Future Opportunities

P5 Recommendations

- **Search for dark matter (DM) particles is a high science priority**
- **Maintain diversity of project scales (i.e. ensuring we also have small projects in program)**

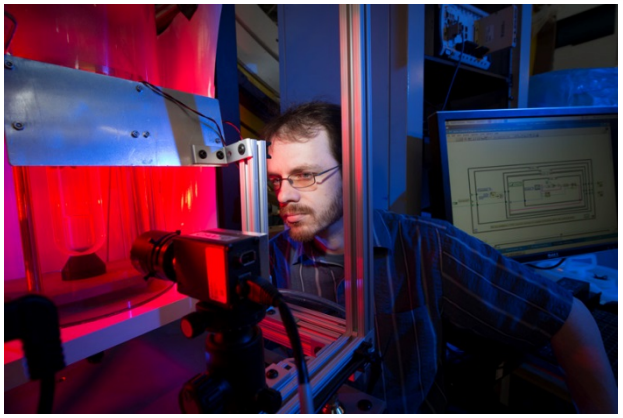
- It is important to cover all relevant phase space to the extent feasible.
- Majority of current efforts are aimed at WIMP/axion searches in Cosmic Frontier
- Accelerator-based experiments in Intensity Frontier are searching for dark sector particles
- LHC and other data searches for DM candidates (but aren't dedicated dark matter search experiments). There are also considerable theoretical studies of dark matter.

Path Forward: To respond to P5, HEP is interested in community input on the science case and experimental possibilities for small (whole project ~ $10 million or less) dark matter projects in unexplored parameter space (i.e. mass ranges or types of particles) not currently being (or on track to be) explored.
→ Can be non-accelerator or accelerator-based experiments!

The CV-DM group (group expanded to accelerator-based people) is spearheading a path to get this community input: Hold Community Workshop, followed by a White Paper by ~ June 2017
➔CV-DM Community Workshop being planned for March 23-25, 2017 at Univ of Maryland (www site public soon); see APS-DPF announcement on listserve on 1/11/17.

Based on results (and funding availability as always!), HEP could move forward with R&D to determine feasibility and process to select concepts to develop.

Cosmic Frontier related: Recent Prizes & Awards



January 2017:
Presidential Early Career Awards for Scientists and Engineers (PECASE) award to Eric Dahl (Northwestern & FNAL) for his work in dark matter detection
See
http://news.fnal.gov/2017/01/eric-dahl-anna-grassellino-honored-presidential-early-career-awards/

September 2016:
Julian Borrill (LBNL/UCB) won the NASA Exceptional Public Achievement Medal for "conceiving and implementing the mission-critical high performance computing system for Planck data analysis".
See
https://crd.lbl.gov/news-and-publications/news/2016/crds-julian-borrill-receives-nasas-exceptional-public-achievement-medal/

January 2016:
Roy Kerr, University of Canterbury, and Roger Blandford, Stanford University won the Crafoord Prize in Astronomy 2016 from the Swedish Royal Academy of Sciences *"for fundamental work concerning rotating black holes and their astrophysical consequences".*
http://www.crafoordprize.se/press/arkivpressreleases/thecrafoordprizesinmathematicsandastronomy2016.5.76308e0c152098549fa15a0.html

Roger D. Blandford

Summary

P5 developed compelling, realistic strategic plan with a community consensus vision
→The HEP FY 2017 Budget Request continues the implementation of the P5 vision

- Close coordination with the other agencies; significant partnerships.

Cosmic Frontier Program – Exciting Time!

- **4 MIE Projects in Fabrication Phase**
- **2 small Projects Fabrication → Finishing commissioning & starting Operations**
- **Research Support: Need to ensure Science work force to adequately carry out all phases of the Experiments (design, fabrication, operations, science analysis)**
- **Significant ramp-up in planning for Experiment Operations & Science**

Future Planning:

- **HEP Cosmic Visions Groups continuing**
- **Dark Matter – investigating small project for unexplored areas of phase space**
- **CMB - AAAC subpanel started to carry out a CMB-S4 Concept Definition Taskforce**
- **2020 Decadal Survey planning started**

BACKUPS

May 2014 P5 Strategic Plan Recommendations - Cosmic Frontier

- **Dark Energy**
  - **Complete LSST** as planned
  - **Build DESI** as a major step forward in dark energy science
- **Dark Matter**
  - Proceed immediately with a broad second-generation (G2) dark matter direct detection program **(DM-G2)** with capabilities described in the text
    - Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity
  - Support one or more third-generation (G3) direct detection experiments
    - Guide G3 by the results of the preceding (G1, G2) searches
    - Seek a globally complementary program and increased international partnership in G3 experiments (DM-G3 Project is in the P5 plan in later part of their 10 year plan)
- **Cosmic Microwave Background (CMB)**
  - Support CMB experiments as part of the core particle physics program
  - The multidisciplinary nature of the science warrants continued multi-agency support **(CMB-S4 Project** is in the P5 plan, starting about mid-way through their 10 year plan)
- Cosmic Rays and Gamma Rays
  - Invest in CTA only if the critical NSF Astronomy funding can be obtained
    - CTA has a broad science reach that transcends fields, with the dark matter detection capabilities of direct importance to particle physics; Using P5 Criteria, a de-scoped US component should be shared by NSF-AST, NSF-PHY and DOE.

Cosmic Frontier – Program Planning, P5 Implementation

P5 → science & project priorities in Dark Energy, Dark Matter (direct detection), CMB

- **Work proactively with our labs & community to carry out the program**

Develop Program following the P5 Plan & considering P5 Criteria:

- Science goals and how it will address DOE-HEP goals
- Make unique, significant, coherent contributions to facilities/experiments selected for the program at a level commensurate with expected science return on HEP physics goals
    - Roles & responsibilities in line with our contributions/expertise
    - **What does HEP community bring to the table?**

      Need to bring unique, visible, leadership contributions, especially if it's an area usually supported by another agency. Typically this is expertise in developing & delivering state-of-the art instrumentation, lab infrastructure & project management, "big data" computing facilities and expertise, and having a cohesive science collaboration to carry out all phases of the project/experiment and deliver precision results.
- For facilities with broader science program (e.g. astronomy facilities) than the interests of the HEP program, make project contributions at appropriate level & support research efforts for our science interests
- Balance & Stages: Staged implementation, results; varying project size; complementary and varying methods/technologies; balance between science areas and speculative/guaranteed results

FY 2014-2017 HEP Program - Budget Status

HEP Budget History ($K)	FY14 PRB	FY14 Actual	FY15 PRB	FY15 Enacted	FY16 PRB	FY16 Enacted	FY17 PRB
Energy Frontier	154,687	152,386	153,639	147,584	154,555	150,723	150,998
Intensity Frontier	271,043	250,987	251,245	264,224	247,196	243,121	234,144
Cosmic Frontier	**99,080**	**96,927**	**101,245**	**106,870**	**119,325**	**130,582**	**130,069**
Theory & Comp. Physics	62,870	64,275	58,850	59,274	60,317	59,083	59,656
Advanced Tech R&D	122,453	150,270	114,242	120,254	115,369	115,494	118,285
Accelerator Stewardship	9,931	9,075	19,184	10,000	14,000	9,000	13,744
SBIR/STTR	21,457	0	20,595	20,794	21,138	20,897	22,580
HEP Subtotal	741,521	723,920	719,000	729,000	731,900	728,900	729,476
Construction, Line Item	35,000	51,000	25,000	37,000	56,100	66,100	88,521
HEP TOTAL	**776,521**	**774,920**	**744,000**	**766,000**	**788,000**	**795,000**	**817,997**
Office of Science TOTAL	5,152,752	5,066,372	5,111,155	5,067,738	5,339,794	5,350,200	5,672,069

*FY14 SBIR/STTR was ~ $21M, so FY2014 actual was ~ $796M.
PRB = President's Request Budget

FY16: The enacted budget was above the Request and squarely in P5's Scenario B.
FY17: We are currently in a CR
➔Planning is difficult… We typically have plans for a full-year CR, the PRB and then the enacted budget

Research: Carefully planning to maximize science impacts; funding is flat in FY17 President's Request

Cosmic Frontier Program – Mission, Areas, Guidance

Cosmic Frontier: Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

Program Areas

- Study the nature of **Dark Energy**
- Direct Detection searches for **Dark Matter** particles
  - **CMB –** Inflationary era, Neutrino properties
- **Cosmic-ray & Gamma-ray & Other** studies – particle properties, high energy acceleration mechanisms, indirect searches for dark matter particles, computational cosmology

Program Guidance

FACA panels provide official advice:

- **HEPAP**– Primary advice for the program
  Subpanels: **P5 2014** (previously P5 2008, PASAG 2009)
- **AAAC (**Astronomy and Astrophysics Advisory Committee) - Advises DOE, NASA, and NSF and Provides Annual Report to Congress et al.
  - Subpanels: **CMB-S4 CDT** starting; (previous w/HEPAP: TFCR 2006, DETF 2006, DMSAG 2007

National Academy of Sciences (NAS)

- Reports: New Worlds New Horizons Decadal Review of Astronomy & Astrophysics (2010) "Mid-decade review" (2016)

Community science studies and input (e.g. Snowmass, Cosmic Visions groups)

Cosmic Microwave Background Stage 4 (CMB-S4) Concept Definition Taskforce (CDT) Charge Letter Summary

From: HEP, NSF-AST, NSF-PHY, NSF-PLR (signed 11/21/16)
To: Buell Jannuzi (AAAC Chair, from U. Arizona)

→We request that the AAAC establish a CMB-S4 CDT subcommittee to develop a concept for a CMB-S4 experiment.

Take as input the CMB-S4 Science Book & further information as appropriate, including global landscape of experiments on the ground, balloons, and space.

Specifically, the CDT is asked to deliver:

- **The Science Requirements and their rationale**
- **Measurement and Technical Requirements derived from Science Requirements**
- **Project Strawman Concept**
- **Options and Alternatives (prioritized to the extent possible) for:**
  - Concept design (e.g. sites, telescopes, detectors)
  - Concept staging and schedule
  - Collaboration and Data models and interfaces
- **R&D development needed, with priorities, to demonstrate technical readiness**
- **Cost ranges for strawman concept, including explanations for how developed**

CMB-S4 CDT Charge Letter cont.

The CDT should provide a report on the Science and Measurement Requirements to the AAAC by June 2017 and a final report to AAAC by October 2017 for consideration.

[The CDT's] deliberations and recommendations will inform the agencies on a concept for the CMB-S4 and contribute to the agencies' planning activities. The formation of the CDT does not imply any commitment by the agencies to specific funding or project status for CMB-S4.

Signed (completed 11/21/16)

Denise Caldwell, NSF-PHY
Eric Saltzman, NSF-PLR
James Siegrist, DOE-HEP
James Ulvestad, NSF-AST

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