DOE High Energy Physics (HEP) Program Report to the NRC OIR Study 31 July 2014

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HEP PROGRAM – MODEL, GUIDANCE, PLANNING, BUDGET

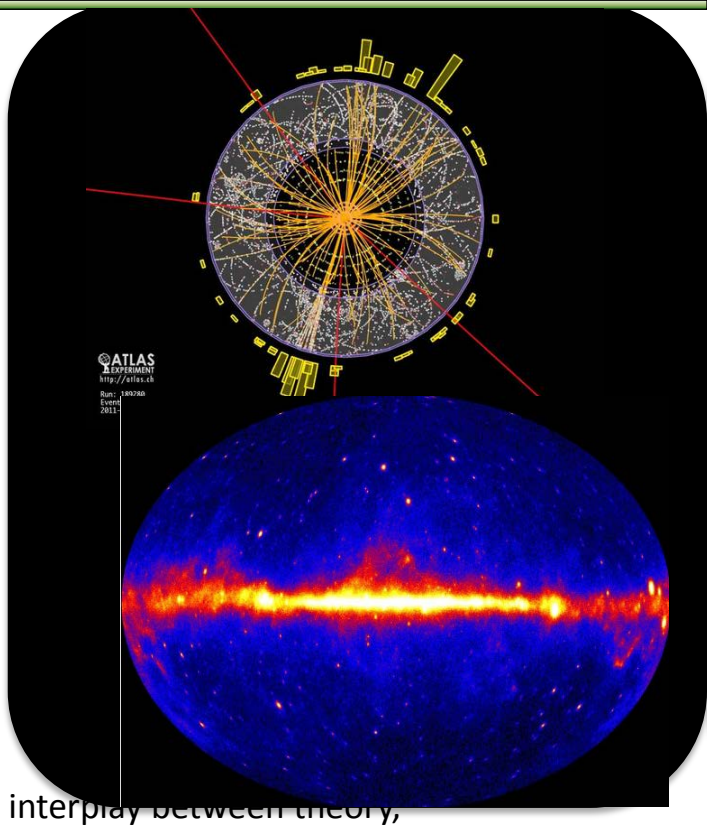
HEP's Mission:

To understand how the universe works at its most fundamental level, which is done by discovering the elementary constituents of matter and energy, probing the interactions between them, & exploring the basic nature of space and time.

RESEARCH AT THE ENERGY FRONTIER: HEP supports research where powerful accelerators such as the LHC are used to create new particles, reveal their interactions, and investigate fundamental forces, and where experiments such as ATLAS and CMS explore these phenomena.

RESEARCH AT THE INTENSITY FRONTIER: Reactor & beam-based neutrino physics experiments such as Daya Bay and LBNE may ultimately answer some of the fundamental questions of our time: why does the Universe seem to be composed of matter and not anti-matter?

RESEARCH AT THE 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.



THEORY AND COMPUTATION: Essential to the lifeblood of High Energy Physics, the interplay between theory, computation, and experiment drive the science forward. Computational sciences and resources enhance both data analysis and model building.

ACCELERATOR SCIENCE: Supports R&D at national labs and universities in beam physics, novel acceleration concepts, beam instrumentation and control, high gradient research, particle and RF sources, superconducting magnets and materials, and superconducting RF technology.

HEP Program Model

We are a science mission agency

- Provide science leadership and support to enable significant advances in specific science areas
- Provide lab environment with a variety of resources needed to design, build, operate selected facilities and projects
- Provide lab infrastructure, including computing facilities (NERSC, SCiDAC program etc) to support these projects
- Encourage scientific teams with expertise in required areas to participate in all phases, all the way to science results.
- Partnerships as needed to leverage additional science and expertise (e.g. use other agency's facilities)

In Particular

- We develop and support a portfolio of selected facilities and experiments to obtain the science results.
- We support a science collaboration in all stages of the project, leading to the best possible science results.

HEP Program Guidance

FACA panels & subpanels – official advice:

- **High Energy Physics Advisory Panel (HEPAP)**
  - reports to DOE and NSF
  - provides the **primary advice for the HEP program**
  - create subpanels for detailed studies (e.g. PASAG, P5)

- **Astronomy and Astrophysics Advisory Committee (AAAC)**
  - reports to NASA, NSF and DOE on areas of overlap

Recent Subpanels:

- P5 (2008) and now **P5 (2014)** – for strategic planning
- Particle Astrophysics Program Assessment Group (PASAG, 2009)

Other Interactions with community:

- National Academies of Science
- APS Division of Particles and Fields (DPF)
  - **Snowmass community science planning study (2013)**
- Specific studies, task forces also provide input to the program

Strategic Planning – Goals & Process

Strategic Planning Goals:

→HEP needs to have a compelling and executable strategic plan, with the community behind it

- Enabling world-leading facilities/experiments in the US while recognizing the global context and the priorities of other regions
- Recognizing the centrality of Fermilab while maintaining a healthy US research ecosystem that has essential roles for both universities and multipurpose labs
- Articulating both the value of basic research and the broader impacts of HEP
- Maintaining a balanced and diverse program that can deliver research results consistently

Process:

- APS-DPF led community planning process in 2013 ("Snowmass")
- HEPAP P5 Subpanel (Steve Ritz, Chair) used Snowmass and other inputs to develop a strategic plan for the field within different funding scenarios.
- **P5 report was delivered and approved by HEPAP in the May 22-23, 2014 meeting.**

HEPAP P5 Subpanel report

The P5 report "Strategic Plan for US Particle Physics in the Global Context"

-- The report represents a consensus vision developed by the particle physics to identify the most exciting and productive areas of research and how we pursue them. P5 recommended that we "pursue the most important opportunities wherever they are", "host unique, world-class facilities that engage the global scientific community" and "pursue a program to address the 5 science drivers".

- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical princip

- **The report recognizes the reality of a challenging funding landscape, where choices have to be made and resources stewarded carefully, and confronts those challenges head on.**
- **The promise/potential of HEP has never been greater – exciting science on the horizon.**
- **Plan includes a well-balanced portfolio of future small, medium and large-scale projects**
  - will provide the required balance of short-term and longer-term science goals

DOE/HEP will respond by developing & aligning the program along the P5 recommendations.

- **This will take some time, as we work with partners and stakeholders:** DOE management, HEP community, DOE Laboratories, Congress, OMB, other US and international Agencies

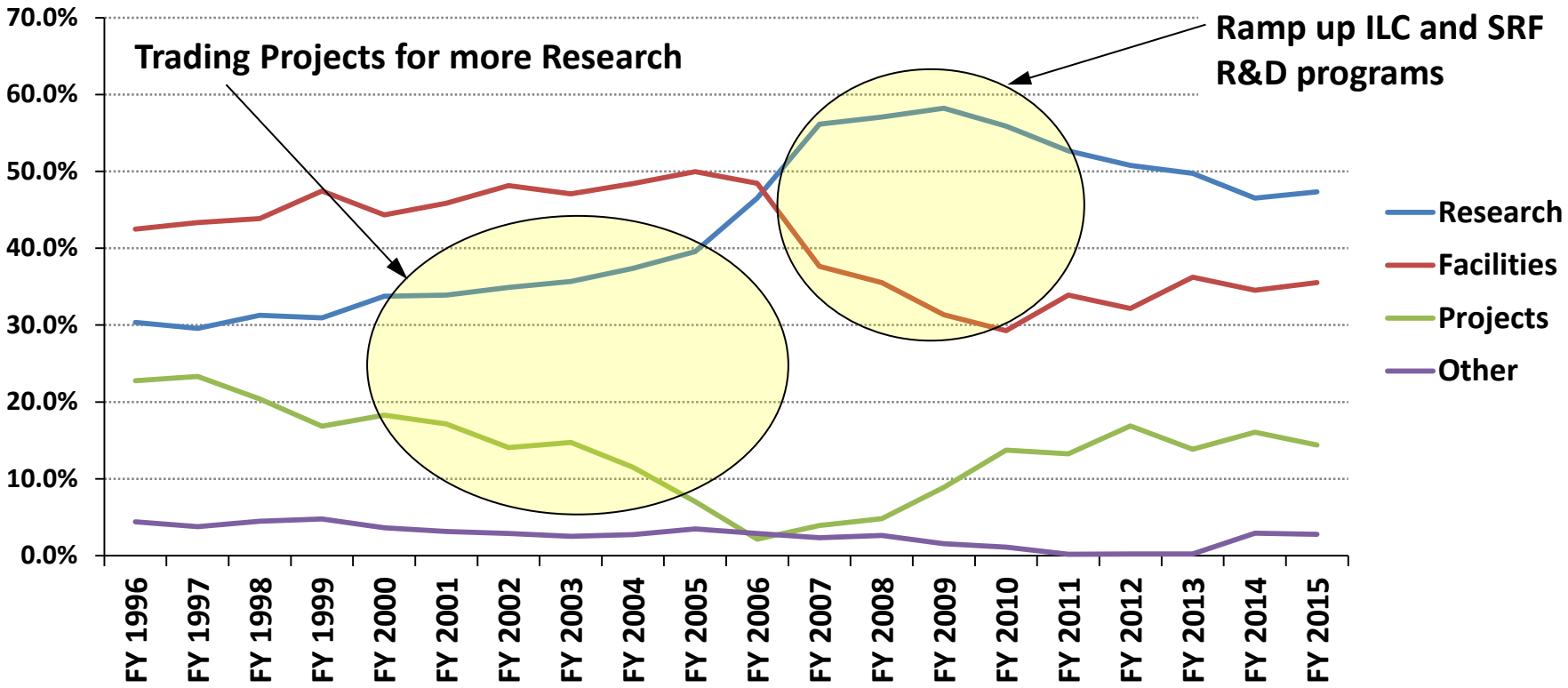
P5 Report – Program & Project Criteria

HEP will use P5 criteria (similar to PASAG) to develop the program

• **Program optimization criteria**
– **Science**: based on the Drivers, assess where we want to go and how to get there, with a portfolio of the most promising approaches.
– **International context**: pursue the most important opportunities wherever they are, and host world-leading facilities that attract the worldwide scientific community; duplication should only occur when significant value is added or when competition helps propel the field in important directions.
– **Sustained productivity**: maintain a stream of science results while investing in future capabilities, which implies a balance of project sizes; maintain and develop critical technical and scientific expertise and infrastructure to enable future discoveries.

• **Individual project criteria**
– **Science:** how the project addresses key questions in particle physics, the size and relevance of the discovery reach, how the experiment might change the direction of the field, and the value of null results.
– **Timing**: when the project is needed, and how it fits into the larger picture.
– **Uniqueness**: what the experiment adds that is unique and/or definitive, and where it might lead. Consider the alternatives.
– **Cost vs. value**: the scope should be well defined and match the physics case. For multidisciplinary/agency projects, distribution of support should match the distribution of science.
– **History and dependencies**: previous prioritization, existing commitments, and the impacts of changes in direction.
– **Feasibility**: consider the main technical, cost, and schedule risks of the proposed project.
– **Roles**: U.S. particle physics leadership

HEP - Recent Funding Trends



- In the late 90's the fraction of the budget devoted to projects was about 20%
- Many projects started since 2006 are coming to completion
- HEP Program requires new investments in projects/experiments to move the science forward and to continue US leadership in well defined research areas
- Need to maintain forward progress on new projects while minimizing the impact of research reductions to the extent possible

FY 13-15 High Energy Physics Budget

(dollars in thousands)

Description	FY 2013 Actual	FY 2014 Enacted	FY2015 Request
Energy Frontier	149,446	154,687	153,639
Intensity Frontier	274,412	275,043	251,245
Cosmic Frontier	80,063	99,080	101,245
Theory and Computation	66,398	62,870	58,850
Advanced Technology R&D	142,291	122,291	114,242
Accelerator Stewardship	3,132	9,931	19,184
SBIR/STTR	0	21,619	20,595
Construction (Line Item)	11,781	51,000	25,000
Total, High Energy Physics	**727,523***	**796,521**	**744,000**
Office of Science	**4,681,195**	**5,066,372**	**5,111,155**

***The FY 2013 Actual is reduced by $20,791,000 for SBIR/STTR, so ~ $748.3M should be used to compare to FY14/15.**

HEP Budget – FY13, 14

In the last few years --

- **Budget philosophy is to enable new world-leading HEP capabilities in the U.S. through investments on all three frontiers:** Accomplished through ramp-down of existing project operations and Research (~ -6%)
- **Impact of these actions:** Workforce reductions at universities and labs; Several new efforts were delayed
- **Program planning has been very difficult due to unstable budget environment.**

FY 2013 Budget:

We were not able to start new Major Item of Equipment (MIE) projects: LSST-camera, Belle-II.

FY 2014 Budget enacted:

- **MIE-fabrication start approved for LSST-camera**, Belle-II, Muon g-2
- Project Engineering & Design (PED) & Construction funds approved for Muon to Electron conversion (Mu2e) experiment
- Specific guidance in approved Budget for the additional $21M provided over the Request:
  - Long Baseline Neutrino Experiment (LBNE) - $26M in R&D,PED funds ($16M over Request)
  - Homestake Mine Operations - $15M provided (specific guidance was $5M over Request)

HEP Budget – FY15

FY 2015 Budget Request ($744M) supports:

- Full operation of existing HEP facilities and experiments
- Continue planned funding profiles of existing projects: **LSST-camera**, muon g-2, Belle-II, Mu2e
- New MIE-fabrication start requests: ATLAS and CMS detector upgrades
- Accelerator Stewardship subprogram initiated in FY2014
- Continue design studies for Long Baseline Neutrino Experiment (LBNE), **R&D for DM-G2, DESI**

- The FY15 Request is below P5 funding Scenario A
- The FY14 Appropriation is above P5 funding Scenario B
- **We are working to make adjustments to the HEP Program to align to P5 recommendations and argue for Scenario B funding.**

FY 2015 House & Senate bills

House $775M

Senate $774.5M

- Gave specific amounts for each area (e.g. Cosmic Frontier), which ties our hands somewhat
- **Provided $35M for LSST-camera and $6M for DM-G2 projects (both as planned)**

➢ HEP should adjust Budget Request to align with P5 recommendations

➢ HEP should develop a work plan to **advance dark matter program, CMB Stage IV and DESI**

COSMIC FRONTIER PROGRAM – MODEL, GUIDANCE, STATUS, BUDGET, P5 RECOMMENDATIONS & HEP PLANNING

Cosmic Frontier

Program thrusts:

- Studies of the nature of **Dark Energy** using imaging and spectroscopic surveys
- Direct detection searches for **Dark Matter** particles
- Study of the high energy universe and indirect dark matter searches using **Cosmic-ray, Gamma-ray** experiments
- **Other** efforts, including small contributions to
  - **CMB** experiments to study the nature of inflation, neutrino properties, and dark energy;
  - computational cosmology efforts;
  - other experiments

Future program:

- **Consider other possibilities and further develop/optimize program following the P5 report**

Cosmic Frontier – Guidance & Considerations

Build Program with:

- Staged implementation & results
- Mix of smaller, larger projects, using multiple methods and technologies as needed
- Balance between thrusts
- Balance of speculative efforts with ones that guarantee results

Considerations

PASAG → P5 Criteria:

- Science goals and how it will address DOE-HEP goals?
  - Experiments which are directly-aligned with goals
  - Experiments in which only part of the data is of interest to the HEP program
- What does HEP Community bring to the experiment? Visible, leadership contributions?

Other considerations

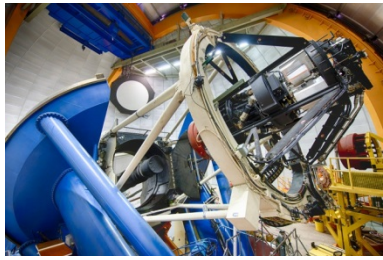
- Are HEP project contributions in line with % of the project relevant to our science goals?
- Are roles and responsibilities on the project in line with our contributions?
- Partnerships - plusses and minuses
- Don't "mayonnaise" funds all over many small efforts.
- Domestic vs off-shore

➔The PASAG criteria and the above considerations can be applied to determining what **projects** we support and at what level as well as **research funding priorities**.

Cosmic Frontier Status

Dark Energy

Make precision measurements to differentiate between Cosmological Constant and modification to General Relativity → Complementary suite of imaging, spectroscopy and supernova surveys

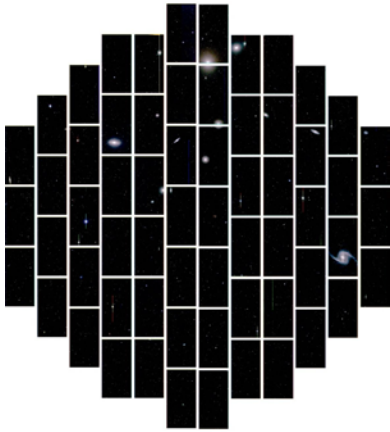


- **Operating** experiments using existing telescopes and cameras
  BOSS (spectroscopic) ends FY14, **DES** (imaging) started FY13, supernova surveys
- Fabrication: Large Synoptic Survey Telescope **(LSST)** - ground-based, imaging, Stage IV Dark Energy measurements; NSF/DOE partnership w/MOU; LSST-camera CD-3a (Fabrication Start) approved June 2014, Dark Energy Science Collaboration formed to plan, deliver science
- **Future Planning:** Mid-scale Dark Energy Spectroscopic instrument **(DESI)** Stage IV spectroscopic survey to complement LSST; CD1 review Sept. 2014

Dark Matter (direct detection)

- **Operating** 1st generation **(DM-G1) experiments - ADMX, LUX, CDMS-Soudan, DarkSide, COUPP**
- **Planning:** DOE and NSF announced selection in July 2014 of **DM-G2** experiments to move forward to fabrication phase→ **ADMX-G2, LZ, SuperCDMS-SNOLab**

DES Data taking started Aug. 2013



Cosmic-ray, Gamma-ray

- **Operating experiments: Fermi/GLAST, VERITAS, Auger, AMS**
- **Fabrication: HAWC** gamma-ray observatory starts full science operations in late 2014
- Community planning on **Cherenkov Telescope Array (CTA)**

Cosmic Microwave Background (CMB)

- **Operating - South Pole Telescope polarization (SPTpol)**
- **Fabrication starting** for **SPT-3G** experiment; assuming successful Sept. 2014 review
- Community planning for a **CMB Stage IV** experiment

HEP Budget - Cosmic Frontier

Funding (in $K)	FY 2012 Actual	FY 2013 Actual	FY 2014 Enacted	FY2015 Request
Research - univ + lab			46840	45435
Research - univ	12,881	12,233		
Research - lab	34,962	36,419		
Facilities - operating	8,505	10,111	7,500	7,238
Projects - MIE - HAWC	1,500	1,500		
Projects - MIE R&D, LSST camera	5,500	8,000		
Projects - MIE fabrication, LSST camera			22,000	35,000
Projects - future R&D, small fabrication	5,891	9,659	14,694	6,000
TOTAL - Cosmic available	**69,239**	**77,922**	**91,034**	**93,673**
Other			*8,046*	*7,572*
TOTAL - Cosmic			***99,080***	***101,245***

Cosmic Frontier – Dark Energy, CMB
(P5 Recommendations, OHEP Response)

P5 #16: Build DESI as a major step forward in dark energy science, if funding permits
- DESI should be the last project cut if budgets move from Scenario B to Scenario A (lowest)

- The P5 recommendation will be used to highlight the importance of the DESI and argue for the additional funds needed to implement it as a high priority.
- A successful Independent Project Review (IPR) will be used to show that DESI is ready to receive funding if it becomes available. The IPR is scheduled for Sept 9-11, 2014 to evaluate DESI's readiness for CD-1. (Fabrication funding is not in the FY15 Request)
- HEP will move forward in planning DESI in coordination with NSF, including upcoming discussions regarding the model for the DESI program.

P5 #17: Complete LSST as planned.

- Detailed plans by both DOE and NSF to carry out LSST exist. We will continue to execute the project according to the DOE-NSF agreement.
- Start of fabrication funding approved in FY14 & CD-3a fabrication start approved in June 2014.

P5 #18: Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multi-agency support.

- HEP will use this recommendation to open discussions with traditional CMB research support agencies (NSF, NASA) to come to agreement on any major DOE roles.
  - Going forward, these meetings would be followed by community planning meetings.
- A review of the proposed DOE responsibilities on the SPT-3G Project is being held Sept. 25-26

Cosmic Frontier – Dark Matter
(P5 Recommendations, OHEP Response)

P5 #19: Proceed immediately with a broad second-generation (G2) dark matter direct detection program 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.

- Coordinated HEP/NSF portfolio for the Direct Detection of Dark Matter (DDDM) will continue to be developed and implemented.
- The overall DDDM program will need to include DM-G2 project(s), operations of current experiments, background and material studies, and future R&D efforts.
- Selection of DM-G2 concept(s) was announced in July 2014: ADMX-G2, LZ, SuperCDMS-SNOLab selected for DOE/NSF coordinated dark matter program to go forward to fabrication phase.
- The P5 recommendation will be used to highlight the importance of an expanded DDDM program and argue for the additional funds needed to implement it as a high priority.

P5 #20: Support one or more third-generation (G3) direct detection experiments, guided by the results of the preceding searches. Seek a globally complementary program and increased international partnership in G3 experiments.

- HEP will concentrate on getting the DM-G2 experiment(s) successfully started. Actions for a specific DM-G3 program will take place later on.
- A robust Dark Matter R&D program is planned that will be directed in part to potential G3 technologies.

Cosmic Frontier – Cherenkov Telescope Array (CTA)
(P5 Recommendations, OHEP Response)

P5 #21: Invest in CTA as part of the small projects portfolio if the critical NSF Astronomy funding can be obtained.

P5 Comments:

- 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.

NSF-AST has said publicly that its budget is unable to accommodate this project as a strategic initiative; Only possibility is the competed mid-scale program.

➔**HEP doesn't plan to continue support of research or R&D efforts on CTA.**

- This could be re-considered if NSF moves forward on the project and requests a partnership with DOE, based on priorities, funding etc.

Cosmic Frontier P5 response – notes, plans, comments

Projects:

The Cosmic Frontier has high priority projects ready to go in the near term (DESI and DM-G2) and HEP is working towards getting the additional funds (over the lowest funding scenario) to do DESI and an expanded dark matter program.

Operating experiments:

To review the status of the operating experiments and ensure alignment with the P5 vision, we are planning a review of Cosmic Frontier operating experiments later in 2014 (last review was end of FY12).

Priorities for funding:

- Following the P5 criteria, it will be a priority to support projects in which HEP has a major/visible role and in which there are significant leaps in capabilities and/or science.
- The priority for research funding will be to sufficiently support the science collaborations to carryout the project fabrication + operations and to deliver the science.
  - Ensure some room in the research program for development of ideas for new projects that are aligned with the science drivers.
- Research efforts on projects that are aligned with P5 science drivers, but which don't have HEP participation, will also be considered, taking into account the above and based on funding availability.

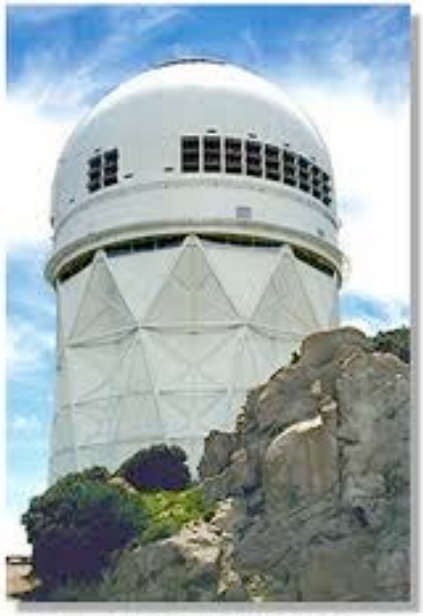
P5 #4: Maintain a program of projects at all scales (recommendation 4)

- The suite of projects recommended by P5 fulfills this recommendation & HEP will work to bring these projects to successful completion.
- As these projects complete, HEP will use a new project evaluation mechanism (e.g. the National Program Advisory Committee being considered by HEPAP) to select the next round of projects. We expect that the program will have a variety of project sizes as needed to address the science drivers.

Dark Energy Spectroscopic Instrument (DESI)

Guidance:

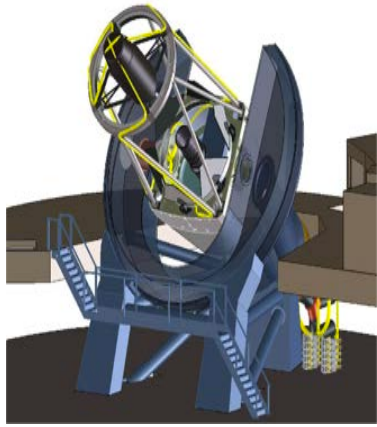
- HEP community dark energy science task force (August 2012) identified a wide-field spectroscopic survey to carry out a Stage IV dark energy program using the Baryon Acoustic Oscillations and Redshift Space Distortions methods as a high priority medium-scale project to maintain US leadership in this area.
  - DESI will complement the DES → LSST imaging surveys
- P5 #16: Build DESI as a major step forward in dark energy science, if funding permits
  - DESI should be the last project cut if budgets move from Scenario B to Scenario A (lowest)



Mayall 4-Meter Telescope

Current Model:

- Project is to build a new spectrograph for existing telescope (Mayall preferred)
- HEP provides operations support for use of the telescope facility
- LBNL hosts the Project Office and leads the Collaboration



Partnership: DOE, with foreign and private contributions

DOE-supported institutions: LBNL (Project Office) + SLAC, FNAL, ANL, BNL, universities

→ Now investigating additional partners

Dark Energy Spectroscopic Instrument (DESI)

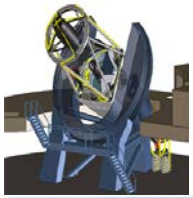
NRC OIR Study Question: Do you believe you're in P5 Scenario B that would support DESI?

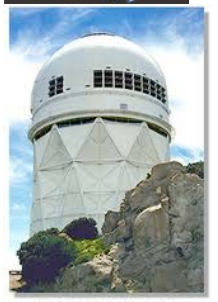
HEP status & planning:

- The FY2015 President's Budget Request is below the Scenario A (lowest) in P5.
- Funding for the DESI Project fabrication has not been requested in the FY2015 President's Budget and funding for the Project hasn't been identified for the Project.
- The P5 recommendation will be used to highlight the importance of the DESI and argue for the additional funds needed to implement it as a high priority.
- A successful Independent Project Review (IPR) will be used to show that DESI is ready to receive funding if it becomes available. The IPR is scheduled for Sept 9-11, 2014 to evaluate DESI's readiness for CD-1.
- HEP will move forward in planning DESI in coordination with NSF, including upcoming discussions regarding the model for the DESI program.

DESI Status:

9/18/12 -- Critical Decision 0 (CD-0) for MS-DESI experiment approved
Jan. 2013 – DOE and NSF signed a statement of agency principles
Dec. 2013 – NSF to defer decision on new partnerships for Mayall until after P5 reports
FY14 – R&D support continuing
Sept. 2014 – Independent Project Review for CD-1
FY15 – R&D support continues while working to identify funds for the Project



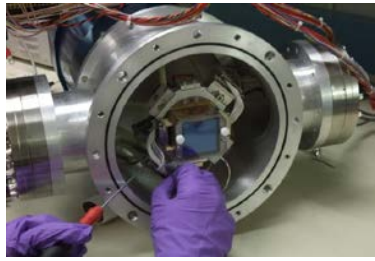


Mayall 4-Meter Telescope

Large Synoptic Survey Telescope (LSST)

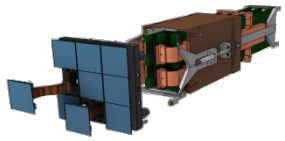
Guidance:

- **Top-ranked large ground-based project in NRC's Astro2010 NWNH report**
- **P5 #17: Complete LSST as planned.**



Science:

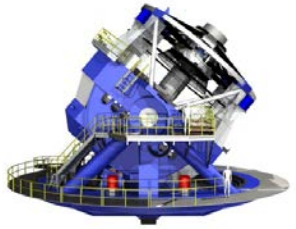
- DOE's interest is in Stage-IV precisions measurements of the nature of Dark Energy, causing the expansion of the universe to accelerate.
- The data will also be used by the wider community for a variety of astronomical measurements.
- The optical/NIR imaging survey will be used for a variety of dark energy methods, especially weak lensing.



LSST - Science Raft Tower, Part of the DOE deliverables

Project:

- New 8.4 m telescope facility & associated instrumentation on Cerro Pachon (8,800 ft)
- NSF is the lead-agency, responsible for telescope & data management;
- DOE is responsible for the 3-billion pixel imaging camera (LSSTcam), managed by SLAC.



Funding: DOE & NSF partnership (MOU July 2012), w/private and foreign contributions

HEP Management & Institutions

• LSSTcam Project: Managed by SLAC (Steve Kahn); major effort by BNL; LLNL, contributions from LBNL, FNAL, universities

• Research: Dark Energy Science Collaboration (DESC) formed; will prepare for and carry out precision analyses Spokesman: B. Jain (Penn) ,Deputy: G. Dubois-Felsman (SLAC)

Large Synoptic Survey Telescope (LSST)

HEP Status & Planning

- Response to P5 -- Detailed plans by both DOE and NSF to carry out LSST exist. We will continue to execute the project according to the DOE-NSF agreement.
- LSST-camera funding profile was designed to align with the NSF telescope/data management facility with a construction start in July 2014

Project Status

- Feb 2012 - Critical Decision 1 (CD-1) approved for LSST-camera
- Jan 2014 - FY 2014 Budget appropriation → LSST camera fabrication start approved!
  - FY 2014 Budget for NSF includes MREFC funds for LSST construction; NSB approved; Plan to start funding ~ August 2014
- June 2014 - CD-3a approved, which allows the spending of fabrication funds for long-lead procurements
- Dec. 2014 – CD-2 "Baseline" review scheduled
- NSF/DOE Joint Oversight Group (JOG) meets weekly; brief OSTP regularly

Large Synoptic Survey Telescope (LSST)

NRC OIR Study Questions:

-- Is the LSST camera construction on track?

Yes!

- The LSST-camera Project and HEP funding profile is set up to align with the NSF construction schedule.
- Fabrication start approval was granted in FY14 and spending fabrication funds for long-lead procurement of camera sensors was approved in June 2014.
- Contracts for camera sensors were awarded to e2v Technologies and the University of Arizona Imaging Technology Laboratory
- Contract for the L1/L2 lens assembly was awarded in Jun 2014 (to Arizona Optical Systems and Ball Aerospace & Technologies Corp.);
- Review in preparation for approval of performance baseline (scope, cost, and schedule) is being held in Nov 2014, with approval expected ~ Dec 2014/Jan 2015.

Large Synoptic Survey Telescope (LSST)

NRC OIR Study Questions:

-- Is DOE interested in being involved in other ground-based resources that might enhance dark energy science from LSST, such as spectroscopic follow-up?

DOE defers to our community to determine if other resources are needed to enhance the science return.

The Snowmass and P5 reports identified three science needs (SN, galaxy photoz's and novel tests of gravity) with corresponding observational needs not provided in our current program.

- SN and photoz's - need spectroscopy with large telescopes
- Gravity tests - observations needed are more diverse, involving spectroscopy (typically at lower redshift, and therefore with smaller telescopes), high resolution imaging, and observations at other wavelengths.

We don’t have a formal or informal proposal at this time and would need one. If the community wants to do this, we would expect an organized, coordinated plan, i.e. from the LSST-DESC, DES, DESI Collaborations.

Large Synoptic Survey Telescope (LSST)

NRC OIR Study Questions:

-- Can DOE advise us on ways we can provide input on coordinating LSST follow-up?

The OIR Study could help define the science possibilities, issues and possibilities.

If additional facilities/observations are needed to enhance the science, we expect that a coordinated plan at the appropriate level would optimize resources.

Coordinated plans - possibilities
Agency agreements on facility uses
Facility/Collaboration-to-Facility/Collaboration agreements
- Need to understand the current parameters for observing time and of data for each facility when planning agreements

SUMMARY

- **An exciting time for HEP and the field**
- **P5 developed compelling, realistic strategic plan with a consensus vision for US HEP**
- **HEP will be moving forward to implement it.**