

# Systematic Optimization of the DOE Laboratory Components of the HEP Program

November 30, 2017

Office of High Energy Physics U. S. Department of Energy Office of Science

### **Purpose and Outline**

The purpose of this talk is to:

1) Inform HEPAP and the community about an extensive, deliberative process developed and executed to position the HEP National Lab Programs to support an outstanding HEP program. The first phase of the process is complete and the decisions taken; neither are open for discussion.

2) Invite HEPAP discussion about how community-based processes can be more proactive in evaluating and helping OHEP maintain an optimized program.

- Motivation
- Development and Timeline
- Methodology
- Outcomes & Lessons Learned
- Maintaining Optimization



## HEP is engaged in three efforts aimed at sharpening the Labs' focus on sustainability and efficiency

#### **Effort 1: Cost of Doing Business Reviews**

- Has long been part of the Budget Briefings
   – as a request to provide detail on
   laboratory overheads and an analysis of how planned changes in the overheads
   would impact the lab's ability to maintain staffing in a flat budget
  - Has sharpened in recent years, calling attention to discrepancies between the labs
    - Reduced high pass-through fees at several labs
    - Helped slow overhead growth at one lab
    - Urged several labs to actually look at the ECI before escalating wages
    - Urged labs to identify other, similar labs and compare practices

### Effort 2: 7-Year "Sustainability" Planning Exercises

- Initiated in 2015, this is a 7-year core R&D planning exercise that is updated each year at the Budget Briefings.
  - 7-year effort tables, resolved into 21 R&D thrusts, 7 staff types
  - ANL, BNL, LBNL, SLAC participated the first year; plans were of varying quality
  - HEP provided feedback, and at least one lab needed to resubmit
- Repeated again in 2016 and 2017 at the Budget Briefings
  - Quality is better; still some room for improvement

### Effort 3: Laboratory Optimization Process – initiated in 2016



### Why is a Systematic Optimization Needed?



#### Macroeconomic pressures complicate the issues



### The Challenge Posed to the Labs February 2016



#### FY15 Lab Research Funding:

Subprogram Fraction by Laboratory

(\$ in thousands)	ANL	BNL	FNAL	LBNL	SLAC	LLNL	LANL	PNNL	PPPL	TJNAF	Total
Energy Frontier	3,350	6,198	18,752	5,975	3,942	-	-	-	-	-	38,217
Intensity Frontier	2,605	4,105	17,983	1,450	4,495	650	1,008	800	-	-	33,096
<b>Cosmic Frontier</b>	1,940	1,100	9,650	7,846	14,985	895	385	205	-	-	37,006
Theory & Comp.	2,808	3,625	14,190	4,965	9,954	-	400	50	-	-	35,992
Adv. Tech. R&D	6,012	7,282	29,384	17,234	15,639	-	200	-	200	50	76,001
Acc. Stewardship	50	5	20	616	620	200	-	-	-	15	1,526
Lab Totals	16 765	22 215	80 070	38.086	40 635	1 745	1 002	1.055	200	65	

\* Funding levels include University Service Accounts

	ANL	BNL	FNAL	LBNL	SLAC	LLNL	LANL	PNNL	PPPL	TJNAF
Energy Frontier	20%	28%	21%	16%	8%	(0%)	(0%	(J7%	(0%	(02%
Intensity Frontier	16%	18%	20%	4%	9%	37%	51%	76%	(0%	(12%
Cosmic Frontier	12%	5%	11%	21%	30%	51%	19%	19%	(0%	(17%
Theory & Comp.	17%	16%	16%	13%	20%	(9%	20%	5%	(0%)	(it%
Adv. Tech. R&D	36%	33%	33%	45%	32%	()9%	10%	( <i>DPM</i> )	100%	77%
Acc. Stewardship	>1%	5 >1%	>1%	2%	1%	11%	(0%	(i)%	(0%	23%

- Percentages calculated vs. individual Laboratory totals

**ENERGY** Office of Science

Research Program Principal Elements and Issues - 2/4/2016



## One month later, 7-Year sustainability data provided by the labs revealed the disconnect had grown





### Goals of the Laboratory Optimization Process

- Raise awareness of systemic issues, align expectations
- Agree upon the criteria that define "value to the HEP mission"
- Inventory the present capabilities in the system
- Develop 10-year visions for the individual HEP lab programs
- Assess the value of capabilities in the system
- Harmonize projects, operations, and R&D—both in OHEP planning and in the field
- Develop a 10-year national vision for HEP lab programs
- Identify realignments needed to focus resources on strongest programs
- Identify new or repurposed organizational structures needed to drive optimization
- Identify near- and far-term implementation strategies
- Identify larger (i.e. full ecosystem) issues, and possible routes forward



### Lab Optimization Process – overview

#### 2015 and before

Cost of Doing Business Annual Exercise; Seven-Year Sustainability Exercise

#### <u>2016</u>

- February 4, 2016: Inaugural 5-lab meeting
  - Process discussions with labs & SC-2
- October 27, 2016: Formal launch of Lab Optimization Process
  - Initial tests of scoring

### <u>2017</u>

- Data calls
- Analysis
- Triage
- November 29, 2017: Initial roll out to labs
  - <u>2018</u>

- February, March
  - Labs present implementation plans at Budget Briefings
- October 1, 2018
  - Initial Fin Plans reflect most Optimization actions
- Early 2019
  - Studies completed, remaining actions implemented



Analysis & Selection ~13 months

Development

~9 months

Implementation ~12 months

### Lab Optimization Process—Development (1 of 3)

#### 2015 and before

- Cost of Doing Business Annual Exercise
- Seven-Year Sustainability Exercise

#### <u>2016</u>

- February 4, 2016: Inaugural 5-lab meeting
  - Showed 10-year planned project profiles, R&D by Thrust and Lab, discussed long-range systemic challenges
    - H-L Diagonalization Process suggested

#### Feedback from lab participants:

- Meeting: "VERY useful"; "Labs got a sense where they fit, we all saw that a five-year planning horizon is insufficient"; "Scared the [redacted] out of the labs"
- H-L Process: ..." level of trust is not sufficient to have a "pure" Lab driven process"; "[OHEP should] look, but don't touch [a lab-driven process]"; "Given a national program with international consequences, how best should an independent and objective DOE-HEP deploy its labs?"

#### March: Lab FY 2018 Budget Briefings

- April
  - First OHEP process counterproposal
    - Scope, metrics, thresholds, CBA process
- June
  - Second lab process proposal:
    - Develop a 10-Year Vision; framework for

evaluating lab capabilities

Two 5-lab retreats to reconcile, discuss

#### July, August

- Second OHEP process counterproposal
  - Two-panel process:
    - Steering Committee (Information Gathering)
    - Independent Committee (Selection)

#### September

- SC-2 brief; instructed to drop second panel
  - Process split:
    - Labs: Vision
    - OHEP: Data gathering, Selection

#### October 27, 2017

- Framework finalized for Lab Optimization Process

#### November, December

- Metrics, scoring methodology developed; internal OHEP trial
- Labs briefed, asked to comment
- Initial Lab Capability lists developed

#### <u>2017</u>

- January
  - Activity list, metrics, scoring method finalized
  - Second iteration of lab capability lists



### Scope and Definitions

#### Scope

All R&D capabilities within the HEP Lab Programs [at ANL, BNL, FNAL, LBNL, SLAC], meeting one of the following thresholds:

- A **facility** is a distinct piece of lab physical infrastructure that either (1) has cost HEP \$5M or more to construct, or (2) costs HEP **\$1M** annually or more to operate. While physical co-location of equipment is often a strong determinant in defining a facility, it is more important that the facility be defined by the purpose(s) which the facility serves.
- A **competence** is a specific scientific or technical competence embodied in multiple employees, of which HEP funds at least 3 FTEs. Use a long-term categorization whenever possible. Whenever possible, define a competence in terms of its abstracted functions and skills, rather than the specific experiment(s) in which it is currently engaged.

The generic term "capability" refers to either a facility or a competence. The thresholds above are set to limit the total number of capabilities that may be considered in the Optimization Process.

#### Defining capabilities in a *recognizably interchangeable* manner is central to the process.



### Capability Merit Criteria and Scoring

- **Relevance** to HEP Program. Note that capabilities may be applicable in more than one "Type".
  - Type 1 World Leading R&D. This category includes R&D which is not needed to meet P5 projects, but which is relevant for HEP in the longer-term and is world-leading in quality. A high score indicates the results of the R&D are expected to be relevant to HEP beyond the P5 time horizon, and are world-leading in quality.
    - Examples: Plasma wakefield acceleration, superconducting magnets.
  - Type 2 Necessary for implementing P5. This category includes capabilities needed for all phases of the "Scenario B" P5 projects, including experimental operations and executing the science. A high score indicates the capability is optimally matched to the needs of the experiment or R&D effort.
    - Examples: Detector facilities, physics analysis capabilities to carry out the science for each for the P5 experiments.
  - Type 3 Seeding the future program. This category includes nascent efforts that are not connected with implementing P5, are not yet mature enough to be world-leading, but which are believed to hold potential for transforming HEP. A high score indicates a strong potential to grow into a transformative capability that benefits HEP in the future.
    - Examples: QIS, advanced instrumentation.
  - Type 4 Non-HEP needs. This category includes work for others and other non-HEP uses of a capability. A high score indicates the capability is
    optimally matched to the needs of the non-HEP use.
    - Example: LCLS-II use of SRF capabilities, industrial use of test facilities.
- Impact (Scientific and Technical Excellence)
  - The quality and impact of the research provided by the capability in the recent past;
  - The scientific significance and merit of research enabled by the capability;
  - The future promise for research enabled by the capability.
- Synergy & Leverage with other HEP and non-HEP-funded infrastructure and programs
  - Degree of synergy and leverage available from other HEP and non-HEP efforts at the Lab or at other institutions
  - Opportunity for cross-fertilization and generating new ideas/techniques for HEP through contact or collaboration with other non-HEP efforts at the Lab or at other institutions
    - Examples: A computation & modeling group jointly funded by multiple Offices; an instrumentation group jointly funded by multiple Offices.
- o Uniqueness
  - The extent to which the capability cannot be found anywhere else in the US HEP system (including both national laboratories and universities).

A note on scoring. Scoring for the above four criteria is 0-5, with 5 being the highest score. Scores should be assigned **in full view of the national set of** capabilities in HEP. An average score of "3" means that the capability is as relevant, impactful, beneficially leveraged, and/or unique w.r.t. the end use as any other in the US. An extraordinary score of "5" should only be assigned if the capability is unmatched in the US w.r.t. the criteria.



### Completeness

- Can the P5 vision be accomplished with the facilities and capabilities at hand?
   What is superfluous? What is missing?
- Will the investments lead to excellence in the decades beyond P5's vision?

### Diversity & Competition

- Is the configuration of lab, university, and industry investments optimized to:
  - Identify and develop innovative ideas, no matter the source;
  - Organize and execute the best ideas as large-scale experiments;
  - Optimally take advantage of the different characteristics (cost, R&D mandate, and proximity of synergistic programs) of each institution; and
  - Educate and train the required workforce?
- Is there an efficient level of competition? For goals that have significant risk, are there multiple, non-duplicative R&D paths being pursued?



What is the minimal level of detail needed to perform a systematic optimization?

### Typical Financial View

- B&R Codes
  - HEP Program
  - R&D, Ops, Projects
  - Lab, University, etc.
  - Exp or grant, lab, etc.
- Little is "recognizably interchangeable" at this level
  - Further detail needed
  - E.g., where are the computing activities?



(FY 2016; Image is deliberately illegible)



Towards a more detailed assessment of the HEP program

### • HEP Program (7)

- "Capabilities": Competences (46) or Facilities (23)
  - "Types" or "Tiers" of activities carried out by the C or F (4 Types):
    - "Activities" or "Rating Categories" (52 + "other")
      - » Data: Merit, Cost, FTEs, description, ...



- Most lab capabilities support multiple activities
  - Capabilities were "homed" in a single program, but could have multiple activities spanning different programs
  - Average ~ 2.8 activities per capability
  - An illustration: BNL's Silicon Detector capability
    - The lab indicated it supported 3 activities (in FY 2016)

Lab 🔹	Call T	Capability Name	🗾 Tier	Rating Category	Comments
BNL	Lab	Detector R&D: Silicon detector	Т3	T3: Energy Frontier	Silicon detector R&D for future collider partially support
BNL	Lab	Detector R&D: Silicon detector	T2	T2: ATLAS Ph 2 Upgrade	passthrough: Univ=\$0.8M; add PD
BNL	Lab	Detector R&D: Silicon detector	T1	T1: Detector R&D	

• Stakeholders provided estimates of future usage:

Respondent	Institution	Use Description	Usage Estimate 🔽 👻
		LGAD device development for fast timing layer. Design of timing	
		enhanced LGAD devices is vital for this next generation detector	Major LHC Phase-II Project. Approval of this project depends
Christopher Tully	Detector R&D	technology.	heavily on this competence being available for this project.
Henry Frisch	University of Chicago	LAPPD development and testing	(blank)
		Proposed contributions to the ATLAS Phase-II upgrade for the	
Karl Jakobs	International ATLAS Collaboration	Silicon Strip detector.	Phase-II upgrade time scale (2018 - 2026)
		Proposed contributions to the ATLAS Phase 2 upgrades for the	
		Silicon Strip detector. Will be used to readout the Silicon Strip	
Srini Rajagopalan	US ATLAS	detector during the High Luminosity (HL-LHC) operations.	Potential support for Upgrade projects over next ten years.

 These inputs, together with the OHEP Program Managers' knowledge of the capabilities, were central to understanding the roles and value of each capability in context.



### **Detailed Taxonomies:** Lab Capability lists

Lab 🔽	Program	Activity Class or Facility Class	Facility or Competen	Count of				
	Accelerator	Accelerator Beam Test	Facility	1	🗏 FNAL	Accelerator	■Accelerator Beam Test	Facility
		Advanced Accelerator Concepts	Competence	1			Accelerator Facility Operations	Competenc
	Computing	■ CompHEP	Competence	1			Beam Physics and Modeling	Competenc
		HPC Hardware	Facility	1			Conventional Magnet Testing	Facility
	Cosmic	Detector Commissioning and Ope	ration Competence	1			General RF Test	Facility
		Detector Design and Subsystem Face State Stat	brication Competence	1			High Power Target Test	Facility
		Frontier Physics Research	Competence	1			■ Magnets	Competend
		■Software & Computing	Competence	2			other accelerator facility	Facility
	Detector	Detector Electronics, (incl ASICs)	Competence	1			■ RF systems	Competend
		Detector R&D	Competence	1			□ Sources & High Power Targets	Competend
			Facility	1			Superconducting Magnet Fabrication	Facility
		Detector R&D - TES	Competence	1			□ Superconducting Magnet Test	Facility
		Electronics Asslv and Test	Facility	1			□ Superconducting RF	Competend
		General Use Cleanroom	Facility	1			Superconducting RF Fabrication	Facility
	Energy	Detector Design and Subsystem Face	abrication Competence	2			Superconducting RE Testing	Facility
	81	Detector Integration and Testing	Competence	1			GCompHEP	Competence
		Frontier Physics Research	Competence	1		- computing	= HPC Hardware	Eacility
		Software & Computing	Competence	1			Detector Commissioning and Operation	Competence
	Elintonsity	Detector Design and Subsystem Er	brication Compotence	2		Cosnie	Detector Design and Subsystem Entrication	Competence
	Cincensity	Detector Design and Subsystem a	Competence				Detector Design and Subsystem rabication	Competence
		Detector integration and resting	Competence	1			Detector integration and resting	Competence
	Theory	Frontier Physics Research     Theory DF Higgs	Competence	1		Detertor	Frontier Physics Research	Competenc
	l neory	E Theory PS Higgs	Competence	1		Detector	B Detector - otner	Competenc
		E Theory PS New Phenomena	Competence	1			E Detector Assembly	Facility
		E Theory Particle Astrophysics and C	osmology Competence	1			Detector Beam Test	Facility
		E Theory Phenomenology Collider	Competence	1			Detector Electronics, (incl ASICs)	Competenc
		Theory Phenomenology Dark Mat	er Competence	1			Detector R&D	Competenc
		Theory QCD Perturbative	Competence	1			Detector Test	Facility
BNL	Accelerator	Accelerator Beam Test	Facility	1		Energy	Detector Commissioning and Operation	Competenc
		Advanced Accelerator Concepts	Competence	1			Detector Design and Subsystem Fabrication	Competenc
		Magnets	Competence	1			Detector Integration and Testing	Competenc
		Superconducting Magnet Fabrication	on Facility	1			Frontier Physics Research	Competenc
		Superconducting Magnet Test	Facility	1		Intensity	accelerator-based facility	Competend
	Computing	CompHEP	Competence	1				Facility
		HPC Hardware	Facility	1			Detector Commissioning and Operation	Competenc
		■ SciDAC	Competence	1			Detector Design and Subsystem Fabrication	Competenc
	Cosmic	Detector Commissioning and Ope	ration Competence	1			Detector Integration and Testing	Competenc
		Detector Design and Subsystem Face Action Provide Action Provided Action Pr	brication Competence	1			Frontier Physics Research	Competenc
		Frontier Physics Research	Competence	1		■other	□Alignment/Metrology	Competenc
	Detector	Detector Electronics, (incl ASICs)	Competence	2			Material Science Lab	Facility
		Detector R&D - Scintillating Liquid	Competence	2			other competence	Competenc
		Detector R&D - Silicon	Competence	1			Project Management	Competenc
		Detector Test	Facility	1		■Theory	Theory Other	Competenc
		General Use Cleanroom	Facility	1			Theory Particle Astrophysics and Cosmology	Competence
	Energy	Detector Commissioning and Ope	ration Competence	1			Theory Phenomenology Collider	Competence
	81	Detector Design and Subsystem E	brication Competence	1			Theory Phenomenology Dark Matter	Competenc
		Detector Integration and Testing	Competence	1			Theory Phenomenology Neutrinos	Competenc
		Frontier Physics Research	Competence	3			Theory OCD Lattice	Competence
		Software & Computing	Competence	1			Theory QCD Partice	Competence
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		Frontier Physics Research	Competence	2				
		software & Computing	Competence	1		N R · Thi	is is not the full list of	f 275
	eother	Project Management	Competence	1		IN.D IIII		213
	Theory	Theory Phenomenology Collider	Competence	1				
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		Theory Phenomenology Neutrino	s Competence	1		1	,,.	
		Theory QCD Lattice	Competence	1	-			



ELBNL	Accelerator	Accelerator Beam Test	Facility
		Advanced Accelerator Concepts	Competence
		Beam Physics and Modeling	Competence
		General RF Test	Facility
		Magnets	Competence
		Superconducting Magnet Tect	Eacility
			Facility
	Computing	HPC Hardware	Competence
	Cosmic	Detector Commissioning and Operation	Competence
		Detector Design and Subsystem Fabrication	Competence
		Detector Integration and Testing	Competence
		Frontier Physics Research	Competence
		Software & Computing	Competence
	Detector	Detector Assembly	Facility
		Detector Electronics, (incl ASICs)	Competence
		Detector Test	Facility
	Energy	Detector Commissioning and Operation	Competence
		Detector Design and Subsystem Fabrication	Competence
		Detector Integration and Testing	Competence
		Software & Computing	Competence
	Intensity	Detector Commissioning and Operation	Competence
		Detector Design and Subsystem Fabrication	Competence
		Detector Integration and Testing	Competence
		Frontier Physics Research	Competence
		Software & Computing	Competence
	■other	other competence	Competence
	Theory	Theory Other	Competence
		Theory Phenomenology Collider	Competence
		Theory Phenomenology Dark Matter	Competence
		Theory Phenomenology Neutrinos	Competence
	• • • • • • • • • •	Theory QCD Perturbative	Competence
SLAC		Accelerator Beam Test	Compotonco
		Advanced Accelerator Concents	Competence
		Beam Physics and Modeling	Competence
		Conventional RF Fabrication	Facility
		General RF Test	Facility
		■RF systems	Competence
		Sources & High Power Targets	Competence
	Computing	■CompHEP	Competence
		HPC Hardware	Facility
		Detector Commissioning and Operation	Competence
		Detector Design and Subsystem Fabrication	Competence
		Detector Integration and Testing	Competence
		Softwara & Computing	Competence
	Detector	Detector Assembly	Facility
		Detector Beam Test	Facility
		Detector Electronics, (incl ASICs)	Competence
		Detector R&D - Noble Liquid	Facility
		Detector R&D - Silicon	Competence
		■General Use Cleanroom	Facility
	Energy	Detector Commissioning and Operation	Competence
		Detector Design and Subsystem Fabrication	Competence
		Detector Integration and Testing	Competence
		EFrontier Physics Research	Competence
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		Detector Integration and Testing	Competence
		EFrontier Physics Research	Competence
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	⊡other	eother competence	Competence
		Project Management	Competence
	Theory	Theory Other	Competence
		Theory Particle Astrophysics and Cosmology	Competence
		Theory Phenomenology Collider	Competence
		Ineory Phenomenology Dark Matter	Competence
		Ineory Phenomenology Neutrinos     Theory OCD Perturbative	Competence

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### **Detailed Taxonomies:** Activity, Thrust\*, and Activity/Facility Class

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	UKINL	12	Dark EnergyFuture			Accelerator	Facility	Superconducting Wagnet Test	Intensity	/ New Phenomena	Computing Coffware & Cimulations		12	T2: CMS Ph 1 Upgrade
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		12	HL-LHC Accelerator		-	Computing	Competence	SCIDAC	Intensity	/ Neutrinos	EXU-200		12	12: Dark MatterFuture
		12	ILC K&D		-	Computing	Facility	HPC Hardware	Intensity	/ Dark Matter	HPS and related Dark Sector K&D		12	12: DES Operations
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Competence Advanced Accelerator Concepts

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#### Lab Data Calls:

- FY 2016 Utilization
  - (Facilities only) The number of wall-clock hours in FY2016 that this facility was used for this purpose (n.b. not FTE-hours). If needed: assume 100% utilization on a single-shift Monday-Friday operating basis is equivalent to 2080 hours per year.
- Cost

- For a **competence**, this is the fully burdened annual cost of the competence in FY 2016, including associated costs required to carry out the primary activities of the competence:

- Include labor costs directly associated with the competence,
- Include M&S costs needed for the competence to carry out its primary activities,
- Include any pass-through funds to universities,
- Include overhead charges associated with the above, but
- Exclude LDRD, GPP, and other non-HEP funding sources, but record the amount and source in the Comments column,
- Exclude pass-through funds to other Labs, but record the amount and receiving lab in the Comments column, and
- Apportion the total of all included costs by Rating Category and by activity type: R&D, Operations, or Project Participation.
- Record the total number of FTEs represented by this competence on the Staff and Upgrades worksheet.
- For a **facility**, this is the fully burdened annual operating cost of the facility in FY 2016:
  - Include labor costs for equipment and facility maintenance,
  - Include labor costs for operating the facility,
  - Include the cost of consumables, equipment replacement, and warranties,
  - · Include overhead charges associated with the above, but
  - · Exclude the cost of the R&D activities themselves; this should be reported under a separate competence, and
  - Apportion the total of all included costs by Rating Category and by activity type: R&D, Operations, or Project Participation.
  - Record the total number of FTEs needed to operate the facility on the Staff and Upgrades worksheet, and
  - · Record the total estimated cost of deferred maintenance and any upgrades needed to meet P5 obligations on the Staff and Upgrades worksheet.

#### • FTEs

- The number of FTEs represented by the capability in FY 2016.
  - For a competence, this is simply the total number of FTEs that this competence represented in FY 2016.
  - For a facility, this is simply the total number of FTEs devoted to maintenance and facility operations in FY 2016, but excluding effort spent on the experiments and R&D that used the facility.
    - If a significant change in FTEs has occurred since the end of FY 2016, make a note in the Comments column, and report the current number.

#### Deferred Maintenance and Required Upgrades to meet P5 Obligations

- This is the sum of:
  - · An estimate of the deferred maintenance costs required to bring the facility up to "nominal" operating conditions, and
    - An estimate of facility upgrades (if any) required to meet both current and currently-anticipated P5 obligations (i.e. meeting a Type 2 end use). Briefly describe the upgrade and the Type 2 end use(s) that require the upgrade in the Comments column.
      - You may describe upgrades to meet a Type 1,3, or 4 end use by listing the purpose and cost in the Comments column, but do not include the amount in Column D.

#### **Stakeholder Data Calls:**

- Which capabilities are being used/planned for use in the next 10 years
- Short description of use
- Estimate of utilization



### Lab Optimization Process—Calls, Analysis, Selection (2 of 3)

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### <u>2017</u>

#### January

- Activity list, metrics, scoring method finalized
- Second iteration of lab capability lists
- Capability lists finalized
- Lab data call: Merit and cost by capability and activity
- February, March
  - OHEP data call: Merit by capability and activity
  - Feedback to labs at budget briefing
  - Stakeholder data call: 10-year use projections by capability
    - 164 OFA PMs, Proj Mgrs, Expt Spokes, Fac Mgrs, Collab Leaders, Senior PIs,
- April
  - Initial database construction, integrity checks

#### • May, June

OHEP detailed review of data set; questions to labs



- OHEP Priority Scoring
- June
  - Stakeholder data set released to labs; request to review
  - HEPAP Priority Scoring
- July, August
  - Labs Priority Scoring
  - Database cleanup and analysis

#### September, October, November

- OHEP deliberates for 8 weeks at a series of triage meetings
  - Capability-by-capability and activity-byactivity, grouped by classes of activity
- OHEP selects Lab Optimization actions, develops implementation

#### November 29-30, 2017

- Initial actions roll out to labs
- Homework assignments

### Data Calls

### • Lab

- Capabilities & activities
- Merit & Cost
- FTEs, DM
- OHEP
  - Merit by activity
- Stakeholder
  - 10-year Usage by capability
- Priority
  - Ranking of activities



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### Scope of the Data Received

### • Making CBA projections over the next 10 years requires knowing:

- (Everything, everywhere, over 10 years, tagged by: {HEP thrust, tier, activity, class}, measured by: {cost, FTEs, merit, utilization, \$ sources, priority, description, DM/RU, …}) → O(10<sup>8</sup>) entries
  - Thresholded (>1M\$/year cost per capability)
  - Factorized (Longitudinal x transverse; separated Cap, Act, and Util tables)

#### • 4+1 data calls, 236 input spreadsheets

- Lab Data Call: 18,142 data entries
  - Capabilities (Competences, Facilities), merit & cost of each Activity
- OHEP Scoring: 2,330 data entries
  - Merit of each activity of each capability
- Stakeholder Data Call: 2,838 data entries
  - Utilization data over the next 10 years for Capabilities
- Priority Data Call: 4,165 data entries
  - Relative scoring of the importance of Activities
- Sustainability Data Call: 8,589 data entries

#### • Gathered in a database of 62 linked tables with 98,195 entries and a set of tools

- Automated data aggregation & validation
- A model linking Optimization & Sustainability data sets to estimate future values
- A model of capability utilization
- Priority analysis and MC error estimation
- Realignment impact estimation





### **Merit Scoring**

- Average of Labs' scores = 4.5
- Average OHEP's scores = 3.9
  - Guidance: "as good as any other lab in the US" = 3.0
- Merit Scores were correlated
  - R = Relevance
  - I = Impact
  - S = Synergy
  - U = Uniqueness
- Consequently, the four merit scores were combined into a single score: "Benefit"
  - B = 0.35\*R+0.35\*I+0.15\*S+0.15\*U
- And aggregated as mean-subtracted, scaled (to unit s.d.) scores to partially compensate for rater-to-rater variation
- OHEP and labs scoring was somewhat correlated (R=0.24)
  - See plot at right





### Cost & Merit Data in One Slide

(Illustrations are intentionally illegible-provided to show the scope and density of data)





## To understand the community's use patterns for the capabilities, a Stakeholder Data Call was made

- Who was asked
  - A list of 164 entities was generated by the OHEP PMs
    - Collab. leads, Expt. spokes., Proj. mgrs/dirs./sci., fac. mgrs, ctr. coord., PAC Chairs, and senior university PIs

### Response Rate

- 90 responses from 164 requests (~55%)
  - Additional response coordination occurred so coverage is slightly better than 55%
- What was requested
  - Which lab capabilities are needed and how much is needed over the next 10 years
- Statements of usage were then converted into a numerical model of usage
  - Tagged by: activity, capability, HEP program, activity or facility class, type of source, probable accuracy, and source.



### Stakeholders' View of the HEP Lab Network

(Caveats: This is lab-centric, biased towards "visible" capabilities, and incomplete)





T1: Various	
T1: Energy Frontier	
T1: Intensity Frontier	Priority ranking of the Activities
T1: Cosmic Frontier	Combined replying of the E2 Activities in the LIED Program
F1: Theory	Combined ranking of the 52 Activities in the HEP Program
T1: HEP Computing	
T1: Detector R&D	
T1: Accelerator R&D	
T2: Various	• The 52 Activities of the HEP Program were ranked via the priority scoring exercise
T2: ATLAS (pre-Ph 1)	• 02 Persondants from OHED HEDAD and the Labs provided scores of 0.5 for each activity
T2: ATLAS Ph 1 Upgrade	<sup>3</sup> S Respondents from OHEP, HEPAP, and the Labs provided scores of 0-5 for each activity
T2: ATLAS Ph 2 Upgrade	• The results were combined and CLs estimated by standard bootstran resampling techniques
T2: CMS (pre-Ph 1)	The results were combined, and easy standard bootstrap resumping teeninques
T2: CMS Ph 1 Upgrade	• The "resolving power" of this exercise (range/standard deviation) >5
T2: CMS Ph 2 Upgrade	
T2: Energy Frontier	
T2: DUNE/protoDUNE	7
T2: LBNF	
T2: Mu2e and g-2	Combined Program Priority Scoring, with 68% confidence intervals
T2: NOVA	N=2.000: Ns=4.165 w/resampling
T2: PIP-II	20.000
T2: SBN Portfolio	
T2: Small Projects Portfolio	
T2: CMB-S4	18.000
T2: ADMX	
T2: Current DF, DM & CMB Expt	
T2: Dark EnergyEuture	
T2: Dark MatterFuture	
T2: DES Operations	
T2: DESI	
T2: I \$ \$ T	
T2: 123 T	$\overline{\mathbf{O}}$
T2: SuperCDMS-SI	
T2: Theory	
T2: CompHEP	
T2: E0(FF)	
T2: HI-IHC Accelerator	
T2: Accelerator R&D	
T3: Various	
T3: Energy Frontier	4.000
T3: Intensity Frontier	
T3: Cosmic Frontier	200
T3: Theory	
T3: HEP Computing	Activity
T3: Detector R&D	0.000 <b>()</b> (0.000
T3: Accelerator R&D	
TA: Industry	
T4: ICIS-II	N.B. The ordered list at left does <b>not</b>
ΤΛ: ΟΕΔ	
TA: Stowardship	correspond to the abscissa of the plot!
14. WI O	1



### Sample Triage Lists

(Composite of two different triage lists)

						verage o	Average of	Average of	Average of	Sum of	Sum of	Sum or	Projected 5-
						OHEP	Lab Priority	Net Priority	Scaled	Total	Delta(Co	Total	year
Lab	Program	Capability Name	RecID	Capability Description	$\geq$	riority			Benefit	Cost	st)	FTEs -	Utilization
					5	2						This Use	
					5	> 0.2	0 0.45	0.25	-0.39	0.00	0.00	0.00	0.00
					$\leq$	S 0.2	9 0.67	0.26	-0.41	0.89	0.66	3.15	0.00
ANL	Energy	Energy Frontier, Intensity Frontier / Sc	uting:Energy	Data intensive computing, I/O, HPC applica	ation	S 0.2	9 0.30	0.26	-0.84	1.75	1.29	3.00	0.06
ANL	Computing	ALCF	F:Computing	A national computing facility, providing acc	-	S 0.2	9 0.67	0.26	0.47	2.40	1.76	5.63	0.10
ANL	Cosmic	Cosmic Frontier / Computing and Sirr	ation:Cosmic	Large-scale HPC simulations and general of		0.3	2 0.83	0.28	0.42	0.00	0.00	0.00	0.00
ANL	Cosmic	Cosmic Frontier / Cosmology Simula	ions:Cosmic	Advanced statistical methods and machine	$\leq$	> 0.3	3 0.43	0.33	-1.14	0.00	0.00	0.00	0.88
ANL	Computing	Center for Computational Excellence	e:Computing	Edge services for HEP applications and HE	₽ <b>&gt;</b>	5							
BNL	Computing	LQCD Software	:Computing	SciDAC and exascale computing project fo		3							
BNL	Intensity	IF Software & Computing	uting:Intensity	Intensity Frontier computing models; suppo	ort 🗠 🔹	5 0.3	8 0.44	0.36	-0.01	13.57	0.08	57.17	0.51
BNL	Energy	EF Software & Computing	puting:Energy	Software for ATLAS and future colliders: fr		0.4	0 0.50	0.41	-0.49	2.57	0.03	8.46	0.00
BNL	Computing	Software for Distributed Computing	g:Computing	Software development for GRID, cloud cor	$\leq$								
BNL	Computing	BNL Scientific Data and Computing C	r:Computing	ATLAS Tier-1 computing center, providing l	JS A	0.5	1 0.56	0.55	0.20	3.64	0.82	14.02	1.34
FNA	Computing	Large Scale Distributed Computing an	e:Computing	The expertise, skill, and ability needed to pro	Children .		3 0.63	0.61	-1.11	0.00	0.00	0.00	0.00
					· ·	0.0	0.05	0.01		0.00	0.00	0.00	0.00

#### Triage lists formed the *starting point* for discussion about each group of capabilities.

TINCE	Comparing	Comparing Facility Evolution Flocb Ex	e comparing	The expertise, technical competencies, and
FNAL	Computing	Energy Deposition Calculations and N	e:Computing	The expertise in energy deposition calculation
FNAL	Computing	Computing Facility Expertise in Desigr	s.:Computing	Staff with experience and expertise in architered
FNAL	Computing	Advanced Computer Science, Visualia	a:Computing	As the lead lab for HEP, Fermilab has signifie
LBNL	Cosmic	Cosmic Frontier -CMB, Computing a	ware:Cosmic	Leveraged HPC computign at NERSC for
LBNL	Intensity	Intensity Frontier- Computing and Sof	ware:Intensity	Daya Bay: data transfer from Daya Bay to LBA
LBNL	Energy	Energy Frontier, Computing and softw	tware:Energy	Major contributions to ATLAS core soft
LBNL	Computing	Computing facilities: PDSF, NERSC a	t:Computing	A national computing facility, providing access
LBNL	Cosmic	Cosmic Frontier -Dark Energy, Comp	ware:Cosmic	Lead institution for DESI computing; leading
LBNL	Intensity	Intensity Frontier- Muon Physics, Cor	ware:Intensity	Design, implement and maintain pattern re-
LBNL	Cosmic	Cosmic Frontier -Dark Matter, Comp	ware:Cosmic	LBNL is supporting both LUX and LZ experience
LBNL	Computing	Advanced computing for HEP	P:Computing	Edge services for HEP applications and HEP
SLAC	Computing	Simulations - Geant4	4:Computing	Detector Simulations (Geant4)
SLAC	Computing	Stanford Research Computing Center	er :computing	Joint Research computing effort of the ind
SLAC	Cosmic	Simulations - cosmic	smic:Cosmic	Cosmological Simulations 🖌
SLAC	Intensity	Software & Computing - IF	g - IF:Intensity	LArTPC reconstruction and simulation 🕅
SLAC	Energy	Software & Computing - EF	g - EF:Energy	Databases, scalable analysis data storage
SLAC	Computing	Computing Hardware	re:computing	Accelerator, ATLAS, BaBar, Fermi, KIPZ
SLAC	Cosmic	Software & Computing - CF	- CF:Cosmic	Computing infrastructure and Analysis sug

ζ	0.56	0.73	0.63	-0.36	2.80	0.19	7.10	0.60
1	0.58	0.86	0.55	0.08	7.42	2.01	1.11	0.00
5	0.58	0.75	0.61	0.20	1.22	0.01	2.50	0.72
	0.58	0.53	0.65	0.26	0.00	0.00	0.00	0.00
2	0.59	0.67	0.62	0.33	3.90	0.74	12.20	1.75
5	0.60	0.71	0.62	0.54	1.32	0.32	5.00	3.98
	0.61	0.64	0.69	-0.63	1.20	0.00	5.00	0.14
$\geq$	0.62	0.60	0.66	0.31	2.81	0.21	12.67	1.07
5	0.63	0.77	0.66	-0.06	1.80	-0.04	7.80	1.00
5	0.67	0.64	0.68	0.21	1.26	-0.02	2.50	3.06
	0.67	0.91	0.71	0.64	3.40	0.07	9.00	0.25
2	0.68	0.96	0.67	1.02	3.10	0.85	8.89	1.43
5	0.68	0.59	0.73	0.41	1.80	0.03	14.12	0.34
$\leq$	0.69	0.68	0.72	-0.07	1.90	0.22	10.00	4.66
2	0.70	0.78	0.75	0.37	2.20	0.06	5.80	0.34
5	0.74	0.63	0.78	0.30	0.53	0.00	2.08	1.15
í –	0.75	0.91	0.80	0.46	1.60	-0.03	3.50	1.00
5	0.75	0.95	0.80	0.43	1.80	0.02	7.10	0.05
5	0.79	0.95	0.84	0.64	2.70	0.04	10.15	0.71



- Capabilities were grouped by activity class and facility class and reviewed together along major topical themes (e.g., accelerator, detector R&D, experiment operations, computing, etc.)
  - Data was summarized onto triage sheets which formed the starting point of the triage discussions
- For each class of capability, typical discussion questions included:
  - Of each capability: in what activities is it engaged? How has the activity profile changed since FY 2016 (the year reported in data calls)?
  - Of similar capabilities: which is/are the best? What did the most recent Comparative Review / Institutional Review say about it? Can similar items be consolidated? Does the system have sufficient capacity if X is ramped down?
  - Of "small" capabilities: are any "sub-critical"? What do they leverage?
  - Of capabilities which combine to form a major Core Competence: is the workforce correctly configured and will it evolve to meet the needs of the next decade? What is the condition of the facilities?
  - Of low-utilization and low-priority capabilities: are the low values credible?
     Why are the scores low? What purpose does this capability serve?



- The Triage discussions identified 59 distinct realignment actions
- OHEP leadership deliberated over 3 weeks which would be implemented
  - The overwhelming majority of the actions were selected for implementation
  - Labs were briefed on a subset of these actions on 11/29/2017
  - In several cases, additional steps are needed before realignment actions can be identified and implemented, for example:
    - Lab Thrust Area Comparative Reviews
    - Basic Research Needs Workshops
    - Lab-specific homework
    - OHEP-specific homework (when system-wide)



### Lab Optimization Process—Implementation (3 of 3)

#### • November 29, 2017: Five Lab Meeting

- Initial roll out to labs actions common to all five labs discussed
- Timetable, Notables, homeworks discussed

#### November 30, 2017: HEPAP

- Inform HEPAP and HEP community; seek advice on future process
- December
  - Initial roll out to labs actions specific to each lab discussed in lab teleconferences

### <u>2018</u>

- February, March
  - Labs present implementation plans for initial actions at Budget Briefings
- June
  - Lab FWPs incorporate majority of Optimization Actions
- October 1, 2018
  - Initial Fin Plans reflect most Optimization actions

### <u>2019</u>

#### • Early 2019

- All studies completed, actions implemented
- Additional Notables as needed

### <u> 2022</u>

Ramp-downs for largest actions complete



### Initial Set of Realignment Actions Common to all Five Labs

#### Energy Frontier

- Ensure no additional charges for engineering and technical efforts for the CMS and ATLAS Phase I upgrade projects are being charged to research B&R codes. Since Both have passed CD-3, component R&D for the upgrade projects should be complete.
- Ensure no additional charges for engineering and technical efforts for CMS and ATLAS Phase II upgrades are being charged to research B&R codes after FY 2018.
- The HL-LHC ATLAS and CMS CD-1 reviews will be charged to evaluate the efficiency of the projects' fabrication plans, e.g., is the number of fabrication sites justified?

#### • Theory

- Lab management must do a much better job explaining the theory group's integration with lab's program.
- Computing
  - An internal OHEP computing WG is examining the HEP computing effort looking for enhanced inter-laboratory collaboration and economies of scale. Please assist with data calls when asked.

#### Detector Facilities and R&D

- Optimization analysis for detector capabilities {lab-specific list} indicated relatively low priority and/or projected utilization for these capabilities. Please come prepared to discuss these capabilities at the lab budget briefing with particular attention to how the lab plans to either (1) improve the priority and/or utilization within the HEP portfolio, or (2) provide a long-term view of how these capabilities will impact HEP plans/capabilities.
- A Basic Research Needs workshop on HEP-oriented long-term Detector R&D is planned. Priority Research Directions and the research roadmap identified at this workshop will inform HEP funding priorities for years to come. Participate!

#### Accelerator Facilities and R&D

- Optimization analysis for accelerator capabilities {lab-specific list} indicated relatively low priority and/or projected utilization for these capabilities. Please come prepared to discuss these capabilities at the lab budget briefing with particular attention to how the lab plans to either (1) improve the priority and/or utilization within the HEP portfolio, or (2) provide a long-term view of how these capabilities will impact HEP plans/capabilities.
- A Basic Research Needs workshop on security applications of accelerators is planned. Priority Research Directions and the research roadmap identified at this workshop will inform HEP funding priorities for years to come. Participate!



- For realignments already defined:
  - Labs prepare plans to implement actions already defined
    - Discuss plans with OHEP in Feb/Mar 2018 at Budget Briefings
    - Implement in FY 2019, with gradual ramp-in this year

### • For realignments to come:

- Homework is needed for some questions that were clearly indicated, but not well resolved by the Lab Optimization process:
  - Accelerator Modernization Review at FNAL
  - Detector Workforce Review at FNAL
  - OHEP Analysis of Computing Workforce
  - ...

### Maintaining optimization

- Will come back to this during the discussion



- Further elaboration of the HEP Program into a set of Capabilities and Activities proved quite useful
  - Labs had quite different ways of conceptualizing their programs!
  - Having a "snapshot" of the cost by capability and activity very useful
    - First time seeing the program as a whole at this level of detail
    - Exposed underlying cross cut activities in detail (e.g. computing)
  - Detailed merit scoring in this large data-call context was not effective
    - Likely a result of repetitive task fatigue
    - Insignificant distinction between R, I, S, and U metrics
- Stakeholder survey highly informative
  - Revealed connections, utilization, visibility issues, and more
    - Needs a more structured input process if repeated
- Priority scoring was an unexpectedly useful exercise
  - Provided a useful ranking, and insight into the differing priorities of OHEP and the Labs



### The Challenge Posed to the Labs February 2016

### **Research Sustainability**

- HEP plan to increase laboratory research funding is not expected to keep pace with projected cost-of-business increases
  - Plans must realistically accommodate research FTE reductions while maintaining a viable workforce capable of achieving planned work
    - Current fully burdened lab PD/Scientist: ~\$150k/~\$300k





## One month later, 7-Year sustainability data provided by the labs revealed the disconnect had grown





### Silver Linings: One year later, 7-Year sustainability data provided by the labs revealed the disconnect had **improved**





### Silver Linings: Fermilab is implementing Capability and Activitylevel tracking in the lab's strategic planning process

#### Lab Activities in the Strategic Planning Database

- Lab Activity:
  - · Work done by the laboratory to accomplish lab objectives. Research-, project-, or operations-funded lab activities are aligned with HEP thrusts.
  - Lab activities include overhead-funded activities (i.e. activities associated with lab management systems).

Edit	LA-ID	Lab Activity	Activity Group	
B DOE-SC C	Core Capability : Acc	elerator Science and Technology	(28)	
DOE-SC Core Capability : Advanced Computer Science, Visualization and Data (9)				For FY 2017 the lab ha
DOE-SC Core Capability : Large Scale User Facilities / Advanced Instrumentation (24)				144 lab activities (lab
DOE-SC Core Capability : Mission Support (28)				activities for each core
B DOE-SC Core Capability : Particle Physics (55)				capability shown on the

- Lab activities have significant overlap with lab capabilities
  - · The lab activities database served as a starting point for defining lab capabilities for the HEP Lab Optimization Process.

Fermilab

has

the left).

2/21/2017 Erik Gottschalk | Managing for Success 19

#### Improvement Plan for Workforce Planning

- · The lab capabilities database will be key feature for future workforce planning framework by linking to existing databases in the lab's framework.
- Critical and endangered skills database
  - Divisions and sections identify critical and endangered skills
  - Estimate needs for the next 3 years
  - Action plan (e.g. crosstrain, contractor, new hire, outsource, retrain, etc.)
- Employee skills database
  - Employee self assessment of skills
  - Annual lab-wide "skills talent review"
  - Enables identification of personnel skills across the lab
- Budget Planning System
  - Oracle cloud resource budgeting system startup in FY17
  - Projects upload resource needs for duration of project
  - Divisions upload projected labor supplied to projects
- Lab wide risk management
  - Early identification and tracking of potential resource risks
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### Goals of the Laboratory Optimization Process

Status

- Raise awareness of systemic issues, align expectations
- Agree upon the criteria that define "value to the HEP mission"
- Inventory the present capabilities in the system
- Develop 10-year visions for the individual HEP lab programs
- Assess the value of capabilities in the system
- Harmonize projects, operations, and R&D—both in OHEP planning and in the field
- Develop a 10-year national vision for HEP lab programs
- Identify realignments needed to focus resources on strongest programs
- Identify new or repurposed organizational structures needed to drive optimization
- Identify near- and far-term implementation strategies
- Identify larger (i.e. full ecosystem) issues, and possible routes forward



Q

- Labs engaged frankly and constructively throughout a long, high-stakes process
  - Many constructive discussions and inputs during process definition and execution
  - Easily 1-2 FTE-years invested in data gathering alone
  - Actions total 5-10% of FY2016 funding
- The labs maintain an outstanding commitment to excellence on an international scale
  - Unanimous commitment to providing outstanding science for the taxpayer dollar
  - Commitment to the idea that optimization on a system-wide basis is necessary and beneficial, when done properly



### Opportunities for Improvement (For HEPAP discussion)

#### Opportunities for improvement

- Competition + reduced probability of success → labs "diversify" hoping to keep a hand in each game
  - More aggressive system-wide management of "initiatives"?
- − Visibility issues → inefficient exploitation of technology investments
  - MIE Project process documentation and review reforms?
- Expensive infrastructure and niche skills replicated multiple places; complicated by episodic demand
  - System-wide management of key infrastructure and skills sets?
- Many capabilities are funded with the long-term remit of a 'core competence'
  - What part of the competence or facility must be treated this way? Why?
  - What part should be funded by the work scope?
  - When is a "Center" model an appropriate funding mechanism to foster collaboration and broad use?

#### Maintaining optimization is an ongoing task

- Need to regularly assess the program system wide and generate actionable information to keep it optimized
  - Maintain an elaborated list of P5-traceable R&D objectives
  - Maintain an up-to-date picture of the state of the art
  - Maintain a global view of what tools and resources are available and how to best to deploy them
  - Maintain a national view of how the workforce must evolve to handle ever more complex experiments
- Mechanisms for input, evaluation, and advice
  - Via multi-institutional task forces?
  - Through organized actions of APS-DPF, -DPB, etc.?
  - Via targeted NAS studies?
  - Through HEPAP topical subcommittees?
  - By repeating the Lab Optimization process following each P5?
  - ...?



Additional Materials



Systematic Optimization of the DOE Laboratory Components of the HEP Program

A deliberative 2-year long process undertaken jointly between OHEP and the five largest DOE Lab programs has resulted in a set of actions to strengthen the HEP program. The lab HEP programs at ANL, BNL, FNAL, LBNL, and SLAC were resolved into 275 distinct capabilities. The activities of these capabilities were then inventoried by cost, merit, utilization, priority, and other factors, with data inputs collected from the Labs, the HEP community, and other key stakeholders. Over the course of two months of triage and selection meetings, realignment actions designed to strengthen the HEP program were identified, and important system-wide issues requiring further input and study were identified. In total, the realignment actions involve an estimated 5-10% of the five labs' DOE OHEP funding, and will impact every aspect of the HEP program. Implementation of the actions will ramp up in FY 2018, and be complete within a few years. The labs' full and constructive engagement in this high-stakes process is compelling evidence of their continuing commitment to deliver outstanding science.



### Capability Partitioning Scheme for Frontier R&D

(Use of this scheme is mandatory; use "other" with caution)



#### List of all possible competences

Energy Frontier Detector Design and Subsystem Fabrication	Intensity Frontier Detector Design and Subsystem Fabrication	Cosmic Frontier Detector Design and Subsystem Fabrication
Energy Frontier Detector Integration and Testing	Intensity Frontier Detector Integration and Testing	Cosmic Frontier Detector Integration and Testing
Energy Frontier Detector Commissioning and Operation	Intensity Frontier Detector Commissioning and Operation	Cosmic Frontier Detector Commissioning and Operation
Energy Frontier Software & Computing	Intensity Frontier Software & Computing	Cosmic Frontier Software & Computing
Energy Frontier Higgs Physics Research	Intensity Frontier Muon Physics Research	Cosmic Frontier Dark Matter Research
Energy Frontier Indirect Dark Matter Physics Research	Intensity Frontier Neutrino Physics Research	Cosmic Frontier Dark Energy Research
Energy Frontier New Physics Searches	Intensity Frontier Flavor Physics Research	Cosmic Frontier High Energy Cosmic Particle Research
Energy Frontier Physics Research Other	Intensity Frontier Physics Research Other	Cosmic Frontier Physics Research Other



### Capability Partitioning Scheme for Theory

(Use of exactly one of these schemes is mandatory; use "other" with caution)



