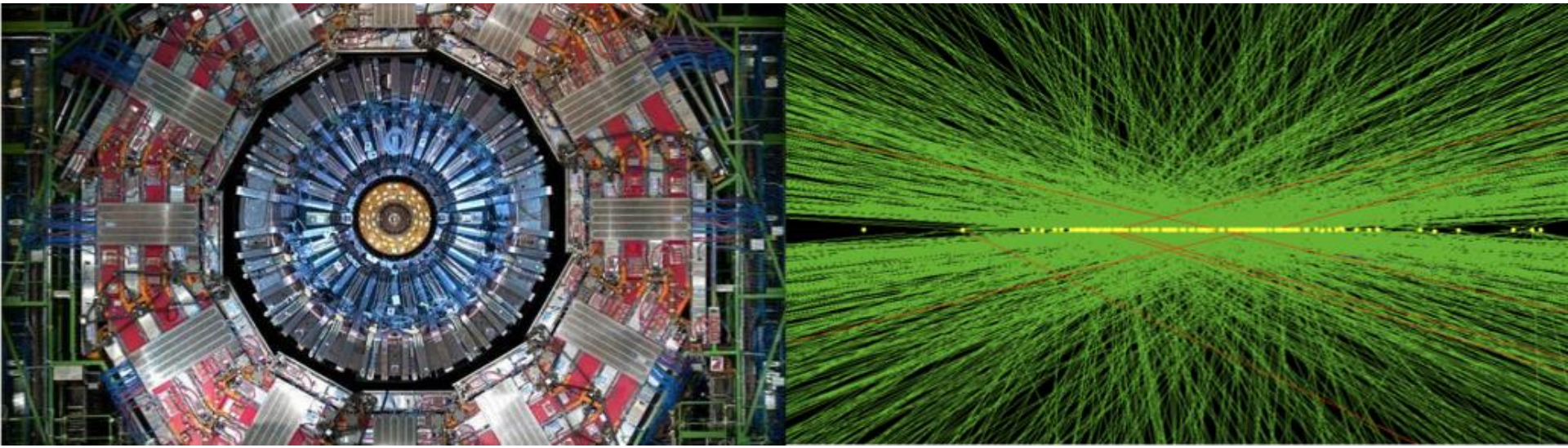
B05 - Path Forward and Summary

Steve Nahn

CD1 Review

October 23rd, 2019



Outline

- Path forward to CD-2
  - Technical stepstones
  - Managerial stepstones
  - Considerations for CD-3
- Reprise and Summary

Path Forward beyond CD-1

- CD-3a March 2020
  - Scope $13,040k (BAC)
    - Silicon Sensors for OT and CE $11,941k
    - LYSO Crystals for MTD $525k
    - Carbon Fiber materials for OT $574k
  - All items will have undergone Production Readiness Reviews
- CD-2 November 2020
  - LS3 schedule change and budget forecast in Nov 2020 may provide impetus to move this later in FY21
  - Revisit this in CY20Q1/Q2

CD-2 Performance Baseline

*"The objective is to provide the acquisition executive, for approval at CD-2, a **complete and accurate baseline** that can reasonably and confidently be achieved."*

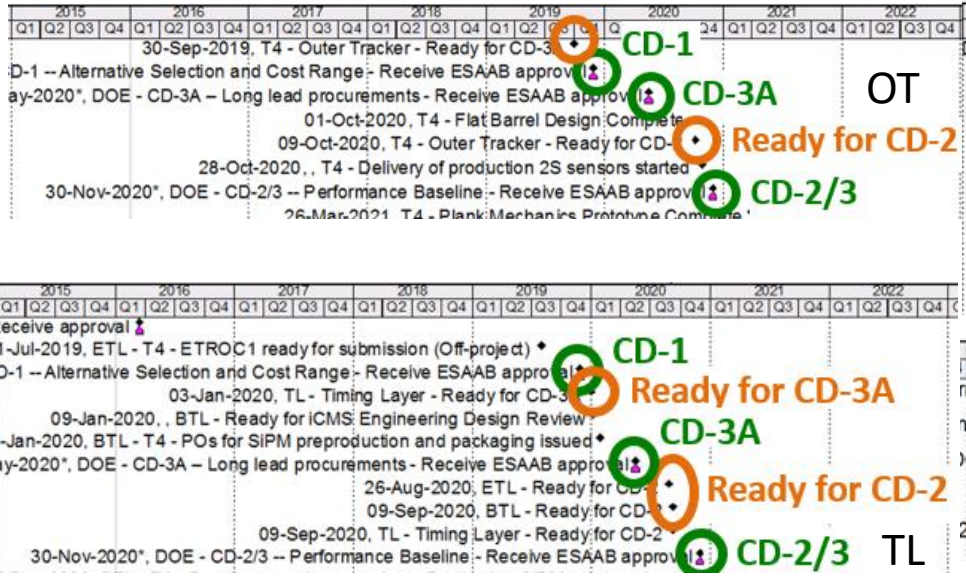
[DOE G 413.3-5A]

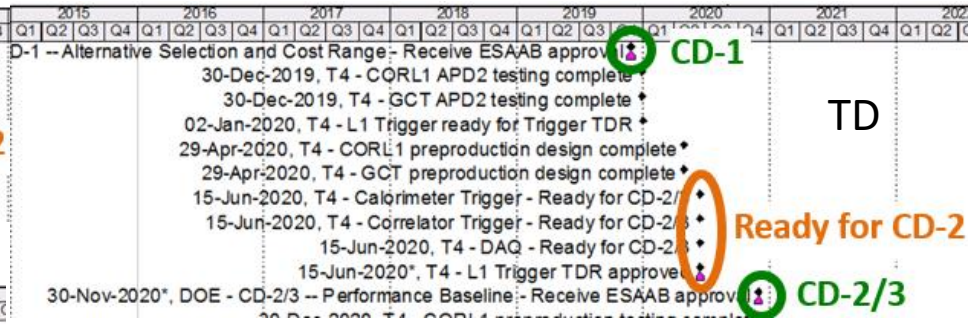
CD-2 Performance Baseline

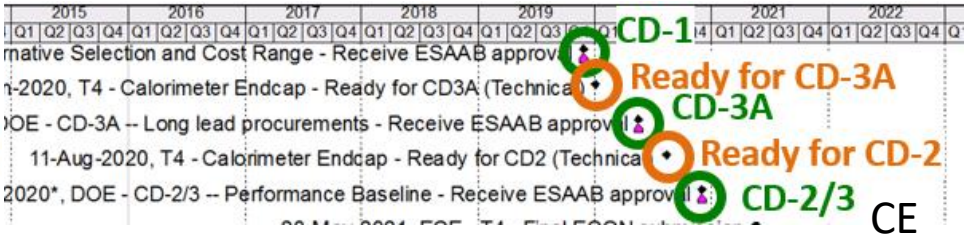
Scope	**Work breakdown structure (WBS) encompasses all project scope** and/or contractual scope requirements/work authorization defined to levels sufficient to support detailed cost and schedule estimates under formal change management procedures and configuration management.
Design	**Is mature when a point estimate can be developed, can establish a high-quality, reliable cost and schedule estimate for a PB, and is ready for an independent review**. Refer to DOE O 413.3B, Figure 3, page C-6, Facility Design Maturity General Guidelines for CD-2.
Key Performance Parameters	**Primary KPPs defined, understood, and agreed** to by the AE, Program sponsor, and FPD, and forms the requirements of the prime contract.
Cost	**Total Project Cost (TPC) established with 70-90% confidence level.** Higher confidence level should be considered for changes to the PB. Refer to DOE O 413.3B, page C-21.
Schedule	**Project completion date established with 70-90% confidence level.** Higher confidence level should be considered for changes to the PB. Refer to DOE O 413.3B, page C-21.
Documentation	**All baseline documentations should be complete,** approved by an appropriate authority, and effectively organized to enable traceability of supporting plans, assumptions, and analyses from the lowest to the highest level, and summary statement of the PB should be contained in the Project Execution Plan (PEP) or in the program requirements document (PRD) for NNSA projects.

Technical Steps to CD-2

- **"high-quality, reliable cost and schedule estimate"**
  - Refinement of resource estimates based on prototyping validation of nearly-final designs and components
- Each L2 area has delineated "Ready for CD-2" using technical milestones
  - Can easily follow technical progress necessary to refine M&S and Labor estimates and durations
    - Constraining the milestone allows determination of "CD-2 critical path"







Management Steps to CD-2

- **"All baseline documentations should be complete"**
  - Mainly Revision of existing CD-1 documents

DOE Required Documents at CD-2

Acquisition Strategy
Project Execution Plan
Preliminary Design Report (TDR – Technical Design Report)
Hazard Analysis Report (HAR)
Integrated Safety Management Plan
Quality Assurance Plan (QAP)
Identify general Safeguards and Security requirements for the recommended alternative (included in PEP)
Lifecycle Costs with Alternative Assessment (included in PEP)
National Environmental Policy Act (NEPA) exemption
Risk Management Plan

Other Documents

Project Management Plan
Risk Register
Project Organization Chart
Assumptions Document
WBS Dictionary
Milestone Dictionary
Configuration Management Plan
Procurement Management Plan
Monthly Status Reports
Statement of Work (SOWs)
Science & Technical Requirements and Specifications
Status/Progress on prior review recommendations
Milestone Waterfall Chart (sorted by level/date)
Critical Paths
Resource Profile Graphs
At Project Level
At each Level 2

- Informally a continual process
- Focused effort starts June 2020

Management Steps to CD-2

- **"Total Project Cost (TPC) and Project completion date established with 70-90% confidence level"**
  - Rework schedule to accommodate changes due to LS3 shift
    - To first order, increases float to need-by dates
  - Update all cost estimates to base year 2019 or 2020
  - Revise labor estimates based on production-like assembly experience
- Ongoing work, augmented by focused workshop for each L2 area (May-June time frame) and follow-up project-wide review workshop

Management steps to CD-2

- "formal change management procedures and configuration management"
- Initiate EVMS cycle this fall – 12 months before CD-2
  - Based largely on framework developed for Phase 1
  - Full Control Account Structure already in place
  - CAMs identified, many have Phase 1 experience, most have had some training already
  - Tools and Procedures already exist, developed for other O413.3b projects at the lab

Earned Value Management paradigm

- EVMS is a whole system for execution of a project
  - Project planning: WBS, OBS, RAM, WAD, BOEs, Gantt…
  - Project monitoring: Statusing, PMTs, VARs, CPR5, CPI, SPI
  - Project modification: Change Control
  - Practices follow Lab wide standards, Surveillance renewed annually
- Focusing on "statusing"
  - Monthly process of updating the working schedule, comparing it to the baseline, and analyzing/explaining deviations from the plan
  - Previous discussions/trainings
    - CAM Bootcamp, July 3 2014 (Phase 1, Mu2e, g-2)
    - Phase 1 - HL LHC Workshop April 5, 2016
    - OPSS EVM training Fermilab training program required for all CAMs
      - "For CD-1" 6/12/2017, 7/31/2018, 5/8/2019
      - Full training 9/11/2018
    - June 2019 HL LHC Workshop June 10, 2019
  - Planning more training in 2020 once practice has started

Statusing pre-requisites

- Stability
  - Cannot being doing rapid developments and maintain consistent baseline
- Factorization into Control Accounts (reporting level) which are subdivided into Chargable Task Codes (collection level)
  - By CD-2, will need
    - each discrete activity will need to have an associated “Performance Measurement Technique”
    - Discrete activities have “limited duration” (< 60 working days)
      - no matter how one calculates the status, it is done in 3 cycles
      - Most of the schedule is there already

CTC: 402.*AB*.*FnnnST*

A = L2, 1=PM, 2=OT, …

L = L3: 2=MGMT, 3 = Sensors…

F= Funds: 1 = OPC, 2 = MIE

nnn just counts CTCs

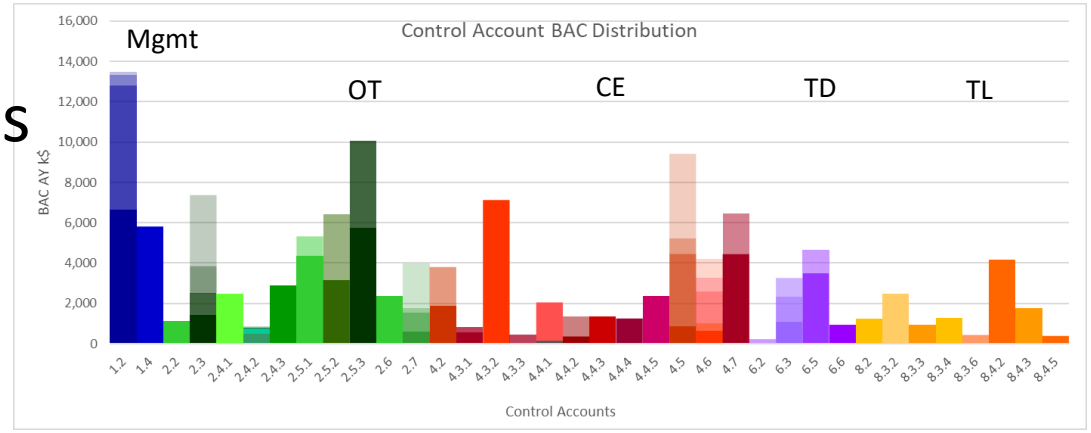
S is Site: 0=CERN, 1 = FNAL, 2= UNIV

T = Type: 1 = Labor, 2 = M&S, 3 = Travel, 4= COLA

Code Value	Description
A	Level of Effort Task
B	Milestones
C	% Complete
D	Units Completed
E	50-50
F	0-100
H	User Defined
K	Planning Package

402 RAM

- Budget fully distributed into 36 Control Accounts
  - Also CTCs established, ready to integrate into cost processing tool (Cobra)

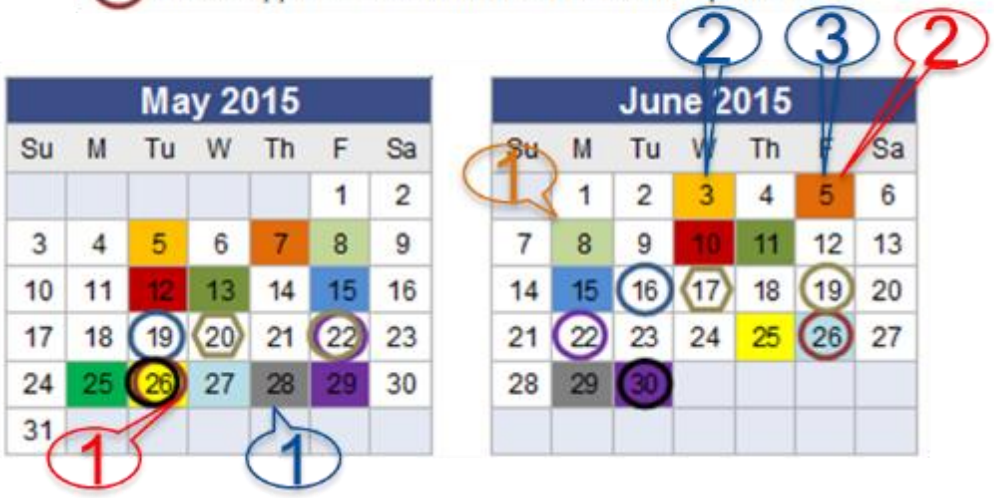


Total	124,630,119
402.1 PM - Project Management (at DOE CD1)	19,281,816
Nahn, Steve	19,281,816
PM - Project Office (DOE)	13,468,195
PM - Common Fund Contribution (DOE)	5,813,621
402.2 OT - Outer Tracker (at DOE CD1)	42,871,529
Narain, Meenakshi	15,379,014
OT - Module Sites	5,324,064
OT - Module Assembly	10,054,950
Heintz, Ulrich	7,371,148
OT - Sensors	7,371,148
Spiegel, Lenny	6,406,966
OT - Module Components	6,406,966
Gershtein, Yuri	857,430
OT - Test Systems	857,430
Gruenendahl, Stefan	6,366,701
OT - FB Mechanics	2,380,031
OT - Integration and Testing	3,986,670
Merkel, Petra	1,125,217
OT - Management	1,125,217
Canepa, Anadi	5,365,054
OT - Macro Pixel Sub-Assembly	2,468,116
OT - DAQ	2,896,938

402.6 TD - Trigger and DAQ (at DOE CD1)	9,087,893
Dasu, Sridhara	3,266,174
TD - Calorimeter Trigger	3,266,174
Mommsen, Remi	939,529
TD - Data Acquisition (DAQ)	939,529
Berryhill, Jeffrey	215,167
TD - Management	215,167
Tran, Nhan	4,667,023
TD - Correlator Trigger	4,667,023
402.8 TL - Timing Layer (at DOE CD1)	12,716,408
Wayne, Mitchell	2,474,076
BTL - SiPMs	2,474,076
Neu, Chris	1,245,677
TL - Management	1,245,677
Bornheim, Adi	1,730,894
BTL - Assembly	1,293,636
BTL - Integration and Commissioning	437,258
Maravin, Yurii	936,334
BTL - Concentrator Cards	936,334
Golf, Frank	1,754,080
ETL - Assembly	1,754,080
Apresyan, Artur	4,575,348
ETL - Frontend ASICs	4,184,576
ETL - Integration and Commissioning	390,773

402.4 CE - Calorimeter Endcap (at DOE CD1)	40,672,474
Akchurin, Nural	11,815,623
CE - Silicon Prototyping and Development	822,076
CE - Silicon Production	7,126,403
CE - Silicon Quality Control	444,553
CE - Module Components	2,051,899
CE - Standard Module Assembly Site 1	1,370,692
Paulini, Manfred	4,983,295
CE - Module Factories	1,358,597
CE - Standard Module Assembly Site 2	1,258,023
CE - Module Assembly at UCSB	2,366,675
Mans, Jeremiah	3,807,266
CE - Management	3,807,266
Kolberg, Ted	4,196,710
CE - Scintillator Calorimetry	4,196,710
Hirschauer, James	6,446,786
CE - Electronics and Services	6,446,786
Gecse, Zoltan	9,422,794
CE - Cassettes	9,422,794

Earned Value (Monthly) Cycle



- **Independently Updated**
  - **Progress (BCWP)**
  - **Cost (ACWP)**
- **Combined in Cobra**

- Rather relentless cycle, skipping a cycle is not an option
  - Results go into DOE PARS every month, are reported to Agencies every month
  - Non-intuitive for most new CAMs – good to get experience early

Collection of Work Performed

- Turnaround report = google sheet extracted from P6
- CAM Instructions:
  - Was this activity started in the current period?
    - If so, enter actual start date
  - Was this activity finished in the current period?
    - If so, enter actual finish date
    - If not, optionally enter expected finish date
  - Was any progress made at all in the current period?
    - Update Percent complete, based on the PMT
  - Use comment field to indicate actions like "reduce duration to keep end date fixed" etc
- L2s hold monthly "statusing meetings"
  - Keeps team appraised of progress elsewhere

Activity ID	Activity Name	Activity Type	Activity Status	Planned Duration	BL Start	BL Finish	Start	Finish	Actual Start	Actual Finish	Expect. Finish	Act. % Comp.
OT310092	Setup PQC infrastructure (Rochester)	Task Depe	In Progress	250d	2-Oct-17	28-Sep-18	02-Oct-17 A	1-Mar-19	2-Oct-17			42%
OT310260	Supervise Rochester QC Center - FY18	Task Depe	In Progress	250d	2-Oct-17	28-Sep-18	02-Oct-17 A	28-Sep-18	2-Oct-17			92.00%
OT310270	Maintain Rochester QC Center - FY18	Task Depe	In Progress	250d	2-Oct-17	28-Sep-18	02-Oct-17 A	28-Sep-18	2-Oct-17			92.00%
OT310280	Maintain Brown QC Center - FY18	Task Depe	In Progress	250d	2-Oct-17	28-Sep-18	02-Oct-17 A	28-Sep-18	2-Oct-17			92.00%
OT310290	Purchase semiautomatic prober	Task Depe	Not Started	30d	2-Jan-18	13-Feb-18	1-Aug-18	12-Sep-18				0%
OT310300	Supervise Brown QC Center - FY18	Task Depe	In Progress	250d	2-Oct-17	28-Sep-18	02-Oct-17 A	28-Sep-18	2-Oct-17			92.00%
OT310320	Irradiate Novati SBIR phase 2 material with neutrons - Lab	Task Depe	Not Started	10d	3-Nov-17	16-Nov-17	1-Aug-18	14-Aug-18				0%
OT310325	Irradiate Novati SBIR phase 2 material with neutrons - M&	Task Depe	Not Started	10d	3-Nov-17	16-Nov-17	1-Aug-18	14-Aug-18				0%
OT310330	Measure Novati SBIR phase 2 wafers (Brown)	Task Depe	Not Started	60d	3-Nov-17	5-Feb-18	1-Aug-18	24-Oct-18				0%
OT310340	Measure Novati SBIR phase 2 wafers (Rochester)	Task Depe	Not Started	60d	3-Nov-17	5-Feb-18	1-Aug-18	24-Oct-18				0%
OT310350	Train personnel on semiautomatic prober	Task Depe	Not Started	20d	14-Feb-18	13-Mar-18	13-Sep-18	10-Oct-18				0%
OT310360	Irradiate Novati SBIR phase 2 material with protons - Labo	Task Depe	Not Started	10d	20-Nov-17	5-Dec-17	1-Aug-18	14-Aug-18				0%
OT310365	Irradiate Novati SBIR phase 2 material with protons - M&S	Task Depe	Not Started	10d	20-Nov-17	5-Dec-17	1-Aug-18	14-Aug-18				0%
OT310390	Evaluate neutron-irradiated Novati SBIR phase 2 material	Task Depe	Not Started	30d	19-Dec-17	5-Feb-18	13-Sep-18	24-Oct-18				0%
OT310420	Purchase process QC equipment (Brown)	Task Depe	In Progress	60d	2-Jan-18	27-Mar-18	02-Jul-18 A	8-Oct-18	2-Jul-18			40%
OT310450	Evaluate proton-irradiated Novati SBIR phase 2 material	Task Depe	Not Started	30d	7-Mar-18	17-Apr-18	8-Nov-18	21-Dec-18				0%
OT310470	Revise Labview code for interstrip tests	Task Depe	In Progress	60d	2-Apr-18	25-Jun-18	02-Apr-18 A	21-Aug-18	2-Apr-18	21-Aug-18		100%
OT310480	Write Labview code for process QC	Task Depe	In Progress	60d	25-Apr-18	19-Jul-18	25-Oct-17 A	9-Nov-18	25-Oct-17			80%
OT310490	TS - Novati SBIR Phase 2 Complete	Finish Mil	Not Started	0d		17-Apr-18		21-Dec-18				0%
OT310520	Write code to automate visual inspection	Task Depe	Not Started	60d	1-Oct-18	27-Dec-18	12-Nov-18	12-Feb-19	1-Aug-18			10%
OT310530	Maintain Rochester QC Center - FY19H1	Task Depe	Not Started	123d	1-Oct-18	29-Mar-19	1-Oct-18	29-Mar-19				0%
OT310540	Supervise Rochester QC Center - FY19H1	Task Depe	Not Started	123d	1-Oct-18	29-Mar-19	1-Oct-18	29-Mar-19				0%
OT310550	Maintain Brown QC Center - FY19H1	Task Depe	Not Started	123d	1-Oct-18	29-Mar-19	1-Oct-18	29-Mar-19				0%
OT310560	Supervise Brown QC Center - FY19H1	Task Depe	Not Started	123d	1-Oct-18	29-Mar-19	1-Oct-18	29-Mar-19				0%
OT310580	Define and setup tracking system for sensor QC	Task Depe	Not Started	60d	2-Jan-19	27-Mar-19	13-Feb-19	8-May-19				0%
OT310721	TS - Sensor QC Site Setup Complete (Rochester)	Finish Mil	Not Started	0d		28-Sep-18		1-Mar-19				0%
OT310860	Purchase long term test setup (Rochester)	Task Depe	Not Started	20d	28-Mar-18	24-Apr-18	25-Oct-18	21-Nov-18				0%
OT310870	Purchase PQC setup (Rochester)	Task Depe	Not Started	60d	2-Jan-18	27-Mar-18	1-Aug-18	24-Oct-18				0%
OT310880	Purchase switch matrix and probe cards for process QC (B	Task Depe	Not Started	40d	28-Mar-18	22-May-18	9-Oct-18	5-Dec-18	1-Aug-18			20%
OT310890	Purchase long term test setup (Brown)	Task Depe	Not Started	20d	23-May-18	20-Jun-18	6-Dec-18	8-Jan-19				0%
402.2W.3.2 OT - PS-P Sensors				**174d**	**20-Jul-18**	**13-Feb-19**	**4-Sep-18**	**15-May-19**				
402.2W.3.2.1 OT - PS-P Sensor Prototypes				**174d**	**20-Jul-18**	**13-Feb-19**	**4-Sep-18**	**15-May-19**				
OT320100	Perform process QC for HPK prototype PS-P sensors (Lot (	Task Depe	Not Started	60d	20-Jul-18	12-Oct-18	12-Nov-18	12-Feb-19	1-Aug-18	31-Aug-18		100%
OT320110	Perform process QC for HPK prototype PS-P sensors (Lot (	Task Depe	Not Started	60d	20-Jul-18	12-Oct-18	12-Nov-18	12-Feb-19	1-Aug-18	31-Aug-18		100%
OT320120	Irradiate HPK prototype PS-P sensors with protons - M&S	Task Depe	Not Started	15d	17-Aug-18	7-Sep-18	12-Dec-18	7-Jan-19	1-Aug-18	8-Aug-18		100%
OT320130	Irradiate HPK prototype PS-P sensors with protons - Labor	Task Depe	Not Started	15d	17-Aug-18	7-Sep-18	12-Dec-18	7-Jan-19	1-Aug-18	8-Aug-18		100%
OT320140	Irradiate HPK prototype PS-P sensors with neutrons- M&S	Task Depe	Not Started	10d	31-Aug-18	14-Sep-18	28-Dec-18	14-Jan-19	1-Aug-18	8-Aug-18		100%

Collection of Actuals

- Financial information available from Project Office financial officer
- Three sources
  - Invoices to FNAL – each PO Line has a CTC
    - POs based on SOWs with resources from RLS
  - Fermilab labor charging to CTCs
  - Accruals: L2s/PIs estimate invoice lag
    - Many Variance reports attributed to missing inaccurate (both over- and under-) accruals

HL-LHC CMS DETECTOR UPGRADE PROJECT 402
All Purchase Order (excluding FINAL Closed POs/lines) Report By Vendor
As of 11/6/18
CTC/Task (Multiple Items)

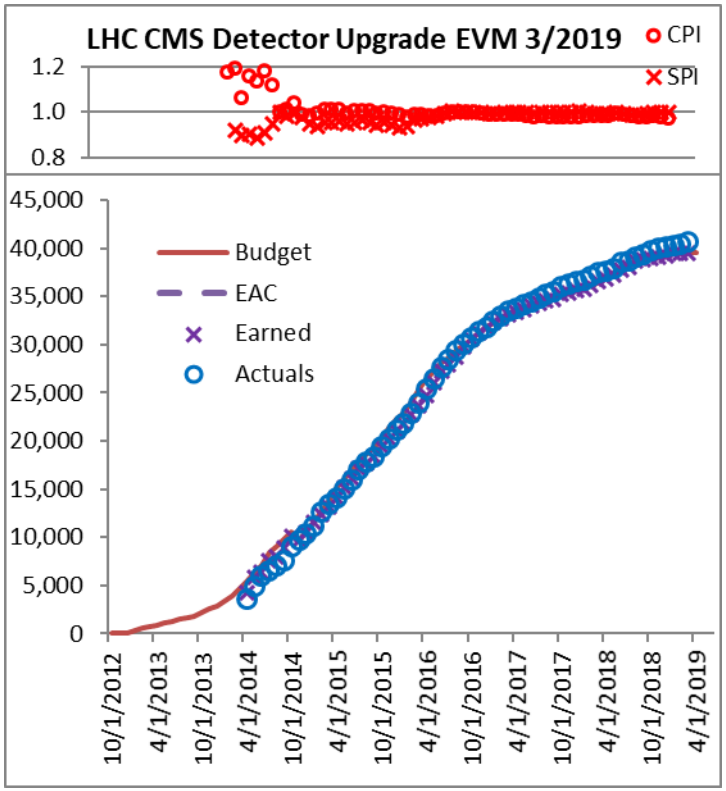
Row Labels	$ Ordered	$ Billed	$ Real Open	Remaining funds
IOWA UNIVERSITY OF	20,000.00	20,000.00	0.00	0.0%
BOSTON UNIVERSITY	75,502.00	72,822.08	2,679.92	3.5%
ROCHESTER, UNIVERSITY OF	250,817.00	246,049.15	4,767.85	1.9%
PURDUE UNIVERSITY	8,791.00	2,500.00	6,291.00	71.6%
PRINCETON UNIVERSITY	152,143.00	119,251.41	32,891.59	21.6%
CALIFORNIA AT DAVIS UNIVERSITY OF	106,711.00	39,482.46	67,228.54	63.0%
RUTGERS, STATE UNIVERSITY	317,923.00	166,203.40	151,719.60	47.7%
BROWN UNIVERSITY	961,189.00	405,142.00	556,047.00	57.8%
Grand Total	**1,893,076.00**	**1,071,450.50**	**821,625.50**	**43.4%**

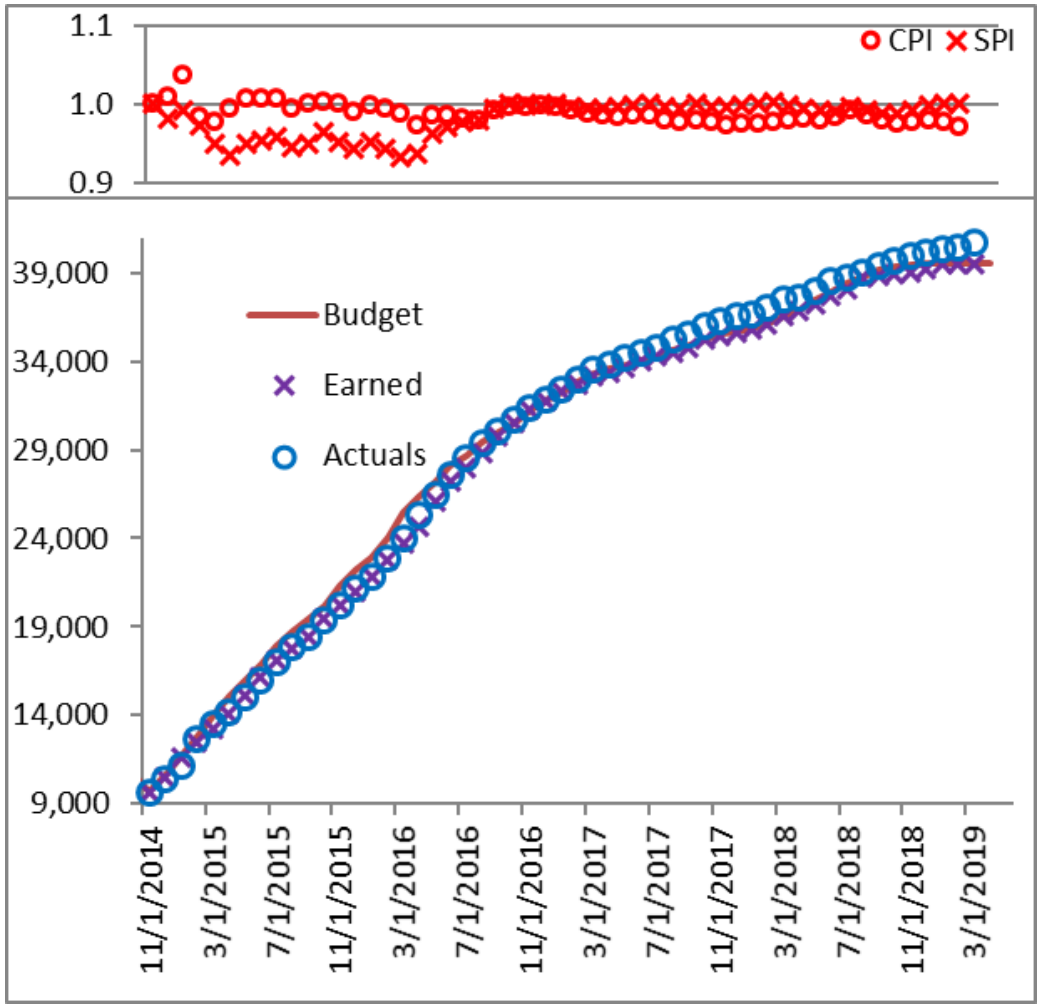
HCAL POs — 401 — Contact: Jay Dittmann (Jay_Dittmann@baylor.edu)

Vendor Name	PuS	Task Number	Pu Line $	PO SHIP $	PO DIST $	Item Description	Total Obl.	OCT18-19 INVOICE	NOV18-19 INVOICE	TOTAL INVOICED	NOV18-19 ADD'L ACCRUALS	Amt. Remaining
BROWN UNIVE	615706	401.20001	1	1	1	401.02.02.01REIMBURSEMEI	$4,000.00			4,000.00		$0.00
BROWN UNIVE	615706	401.20011	2	1	1	401.02.03.04.05.02 REIMBUI	$3,000.00			3,000.00		$0.00
BROWN UNIVE	615706	401.20011	3	1	1	401.02.03.04.05.03 REIMBUI	$1,500.00			1,500.00		$0.00
BROWN UNIVE	615706	401.20031	4	1	1	401.02.05.15.04REIMBURSEI	$47,700.64			47,700.64		$0.00
BROWN UNIVE	615706	401.20013	5	1	1	401.02.03.10 · OPTICAL FIBE	$33,140.00			33,140.00		$0.00
BROWN UNIVE	615706	401.20003	6	1	1	401.02.02 · HCAL MANAGEI	$10,000.00			10,000.00		0.00
BROWN UNIVE	615706	401.20003	7	1	1	401.02.02 · HCAL MANAGEI	$9,000.00			9,000.00		0.00
BROWN UNIVE	615706	401.20013	8	1	1	401.02.03.10 · OPTICAL FIBE	$17,200.00			17,200.00		0.00
BAYLOR UNIVE	621759	401.20143	1	1	1	401.02.04.09 · HB/HE NGCC	$3,200.00			3,200.00		$0.00
BAYLOR UNIVE	621759	401.20133	2	1	1	401.02.04.12 · INTEGRATEC	$9,700.00			9,700.00		$0.00
BAYLOR UNIVE	621759	401.20023	3	1	1	401.02.04.07 · CJE CARDS T	$5,000.00			5,000.00		$0.00
BAYLOR UNIVE	621759	401.20023	4	1	1	401.02.04.07 · CJE CARDS N	$3,000.00			3,000.00		$0.00
BAYLOR UNIVE	621759	401.20133	5	1	1	401.02.04.12 · INTEGRATEC	$8,000.00			8,000.00		$0.00
BAYLOR UNIVE	621759	401.20133	6	1	1	401.02.04.15 · RBX LEVEL TE	$8,000.00			8,000.00		$0.00
BAYLOR UNIVE	621759	401.20003	7	1	1	401.02.02 · HCAL MANAGEI	$23,348.00			23,348.00		$0.00
BAYLOR UNIVE	621759	401.20003	8	1	1	401.02.02 · HCAL MANAGEI	$34,500.00			34,500.00		$0.00
BAYLOR UNIVE	621759	401.20023	9	1	1	401.02.04.06 · HB/HE RADIA	$201,762.00	2,354.52		201,762.00		$0.00
BAYLOR UNIVE	621759	401.20003	10	1	1	WBS 401.02.02 · HCAL MAN	$44,000.00	7,454.15		23,140.12		20,859.88
IOWA UNIVER	615650	401.20011	1	1	1	WBS 401.02.03.04.04 PROTC	$24,810.00			$24,810.00		$0.00
IOWA UNIVER	615650	401.20011	2	1	1	WBS 401.02.03.04.04 PROTC	$22,500.00			$22,500.00		$0.00
IOWA UNIVER	615650	401.20011	3	1	1	WBS 401.02.03.04.05 HF FR	$40,823.00			$40,823.00		$0.00
IOWA UNIVER	615650	401.20011	4	1	1	WBS 401.02.03.04.05 HF FR	$4,578.00			$4,578.00		$0.00
IOWA UNIVER	615650	401.20011	5	1	1	WBS 401.02.03.04.05 HF FR	$9,000.00			$9,000.00		$0.00
IOWA UNIVER	615650	401.20011	6	1	1	WBS 401.02.03.04.05 HF FR	$2,500.00			$2,500.00		$0.00
IOWA UNIVER	615650	401.20071	7	1	1	WBS 401.02.04.08 CALIBRAT	$26,724.00			$26,724.00		$0.00
IOWA UNIVER	615650	401.20071	8	1	1	WBS 401.02.04.10 COOLING	$26,928.00			$26,928.00		$0.00
IOWA UNIVER	615650	401.20071	9	1	1	WBS 401.02.04.11 READOUT	$24,684.00			$24,684.00		$0.00
IOWA UNIVER	615650	401.20013	10	1	1	WBS 401.02.03.07 CALIBRAT	$5,880.00			$5,880.00		$0.00
IOWA UNIVER	615650	401.20013	11	1	1	WBS 401.02.03.07 CALIBRAT	$9,630.00			$9,630.00		$0.00

Phase 1 experience

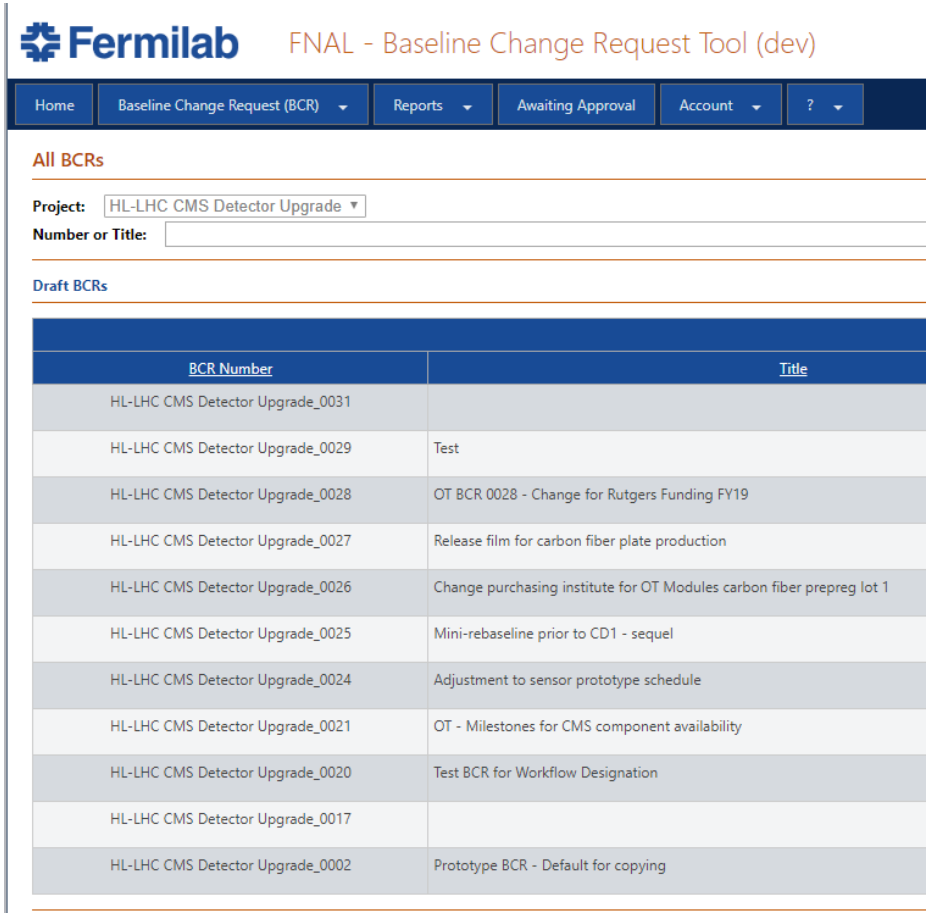
- Performance at the final monthly PMG





Baseline Change

- Another wake-up call for L2s and L3s used to simply making changes
  - Facility with P6 by project team (L3s/CAMs) helps understand cost and schedule impacts earlier
    - Mitigates “false starts”
- Departure from “Home-grown” Phase 1 BCR process to new Lab-wide tool
  - Some practice already within the project



EVMS Rollout in Project

- Establish “practice baseline” and enforce Baseline Change after schedule amended based on CD-1 Review outcome
  - Hopefully not large effort
- Start collecting BCWP and ACWP in the Fall
  - 3 month education period to get CAMs to understand what they are doing
- Enforce VAR/EAC reporting starting in January 2020
  - 6 months of full reporting before a likely CD-2 Director’s Review in Summer of 2020

CD-3 Ready for Construction

*"The purpose of the Construction or Execution Readiness Review is to assess the **readiness for construction or execution** and to confirm the completeness and accuracy of the Performance Baseline"*

[DOE G 413.3-9]

CD-3 Ready for Construction

Scope	**Assess completeness and quality of design specifications**, whether bid packages are sufficiently clear and well defined, technology readiness to proceed, if any process testing is planned and its potential impact to the design
Design	**Assess whether identified technologies are at sufficient level of maturity to be included in construction**, **sufficient cost and schedule for implementation are in the baseline, and the associated risks are captured in the Risk Registry.** Assess whether any design activities to be performed during construction as appropriate as to type and amount of design to be performed, the design basis for this additional work, and the basis to proceed with construction.
Cost and Schedule	**Determine reasonableness of resource loading, cost assumptions**, and if any potential trends or planned changes are adequately identified to provide firm basis to proceed with construction. **Assess whether the Critical Path is reasonably defined,** reflects an integrated schedule with reasonable durations, and has a suitable lead between completion and CD-4.
Documentation	**Review and revise all documents** to reflect relevant approved changes. Documents include ISM, HAR,QAP, PEP, PMP, AS, CMP, ProcMP … **Ensure effective use of certified EVMS system and associated Project Controls and Change Controls Protocols**

Plus items relating to Construction, Funding Profile/Budget, Safety, Value Management/Engineering, Contract Management, **Startup Planning and Operational Readiness**, Sustainable Design, Lessons Learned

Readiness for CD-3

- CD-3 is chiefly driven by full design completion
  - For remaining open options, cost and schedule implications should be well documented and covered in the Risk Register
- "Ready for CD-3" also mapped out by technically driven milestones in RLS
- Original plan was to combine CD-2 and CD-3 review
  - Still the preferred option, but November 2020 looks unlikely from a technical standpoint
    - Will explore both speeding up and really understanding if what drives later dates is absolutely necessary for CD-3
  - Also subject to considerations mentioned for CD-2
- Project focus has been to get through CD-1
  - Revisit question of CD-3 in 6 month timescale

Project Status - reprise

Design Maturity Estimate

Conceptual Design
Management
Alternatives for satisfying the requirements have been evaluated and a preferred alternative has been selected.
Cost and schedule range developed.
Lessons learned from other experiments are incorporated into the design or planning as relevant.
Preliminary Hazard Analysis performed.
Preliminary risk analysis performed and documented in Risk Register.
Technical
Conceptual Design Report completed.
Conceptual design satisfies Mission Need.
R&D tasks identified that will guide the design selection and address risks.
Preliminary Design
Management
Activity-based resource-loaded baseline cost and schedule fully developed, including a full contingency analysis.
Interfaces have been identified.
Lessons learned from other experiments are incorporated into the design or planning as relevant.
Make/buy evaluation complete.
Preliminary QA plan developed
Value engineering performed.
Technical
Baseline design/methodolgy/architecture choice has been made.
Component designs/methods at the 30% level of design completion.
Preliminary design/methodology/architecture is sufficiently developed, incl. preliminary design drawings of major components, final drawings of long lead items.
Technical Design Report completed.
Final Design
Management
Hazard Analysis has been updated and approved.
Interfaces have been updated and documented.
Risks have been updated and listed in the Risk Register.
Technical
Component designs at the 80% - 90% level of design completion.
Final design drawings/methodology/architecture are complete at the 80-90% level.
Final Design Reviews complete and all recommendations have been addressed.
Specifications are complete
Detailed Design
Management
ES&H Reviews completed as necessary.
Technical
All interface documents and drawings completed and signed by all relevant parties.
Component designs/methodology/architecture are complete and reviewed for manufacturability.
Component fabrication drawings are complete and reviewed by the Project.
Construction Readiness
Management
Commissioning plan in place.
Installation plans in place.
QA procedures defined. Travelers in final draft form.
Verification and acceptance test plan complete.
Technical
Detailed Design complete.

- Revamped Maturity algorithm
  - Same criteria, but separate "Management" from "Technical" aspects
  - Removed (arbitrary) assignment of absolute completeness
  - Each criteria evaluated at L3, rolled up for full project

Average

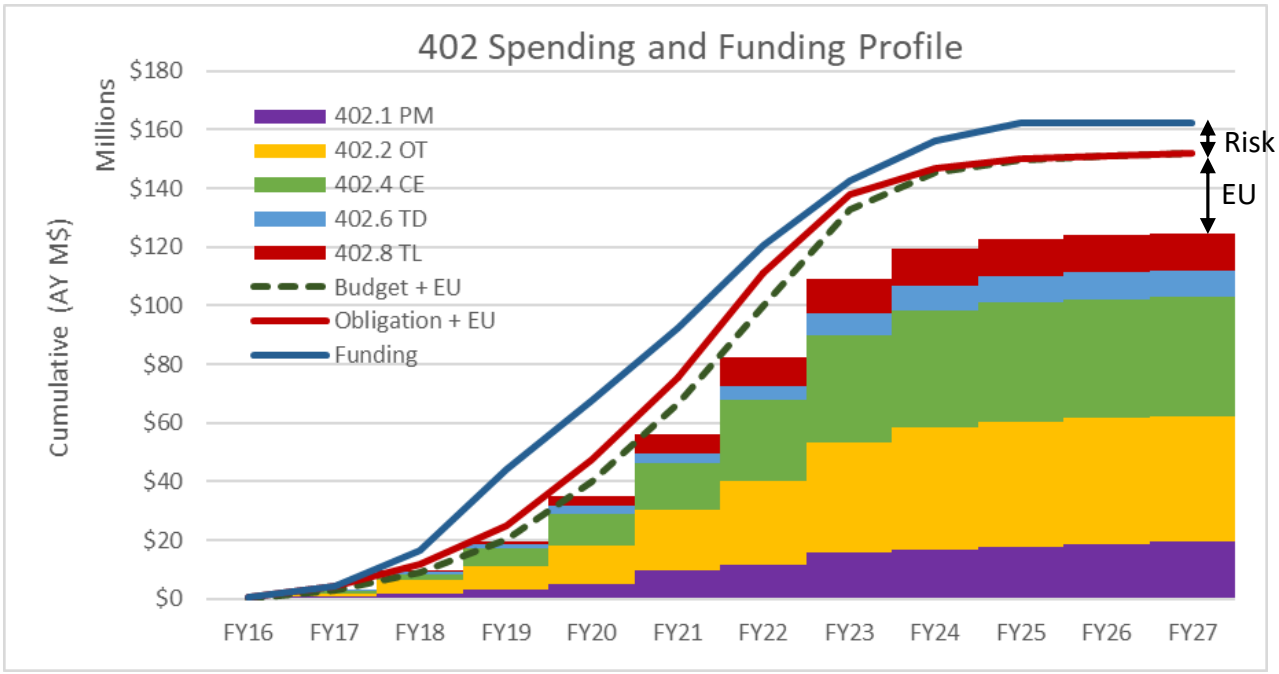
	OT		CE		TD		TL		Total	
	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech
Conceptual Design	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Preliminary Design	100%	100%	97%	88%	93%	83%	90%	90%	95%	90%
Final Design	96%	94%	46%	33%	100%	60%	38%	21%	70%	52%
Detailed Design	50%	32%	0%	9%	0%	30%	0%	8%	13%	20%
Construction Readiness	25%	31%	8%	10%	75%	50%	8%	10%	29%	25%

BAC Weighted

	OT		CE		TD		TL		Total	
	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech	Mgmt	Tech
Conceptual Design	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Preliminary Design	100%	100%	96%	89%	94%	91%	90%	90%	97%	94%
Final Design	99%	91%	47%	34%	100%	67%	38%	21%	72%	59%
Detailed Design	50%	31%	0%	10%	0%	40%	0%	8%	20%	21%
Construction Readiness	26%	30%	9%	11%	75%	50%	8%	10%	22%	22%

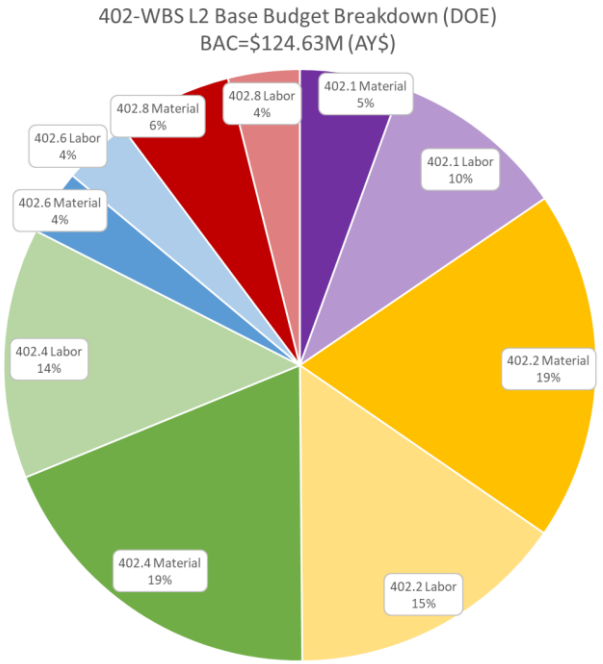
- All subsystems well beyond Conceptual level needed for CD-1, approaching Preliminary design (CD-2)
  - Details of technical progress in L2 talks and breakout

Full Project Cost



- Ramps from prototyping into production, then tapers
- Funds $162.05 M covers TPC

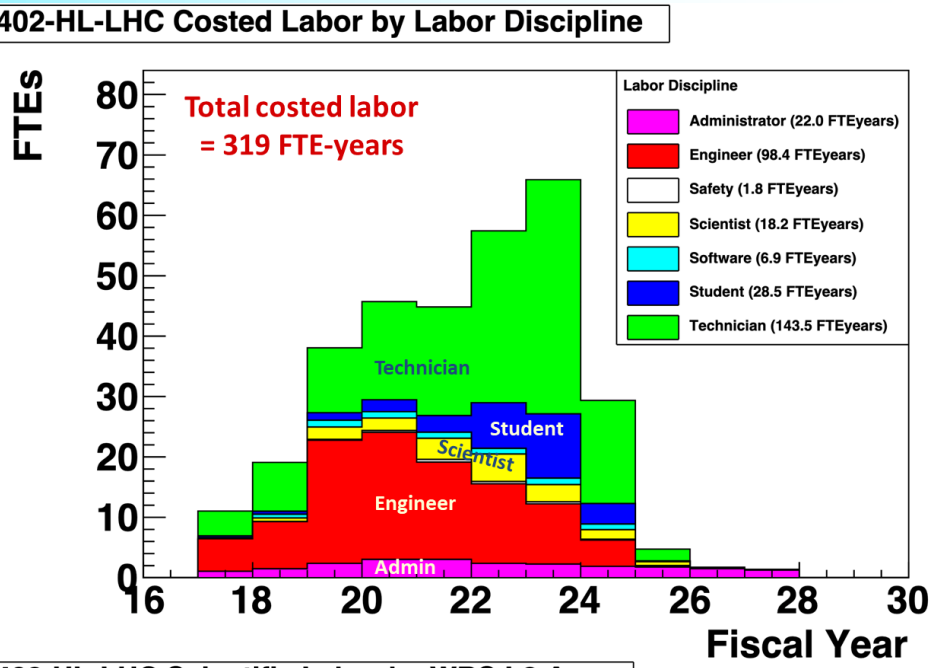
TPC (AY k$)	Material		Labor		Risk	TPC
	BAC	EU (%)	BAC	EU (%)		
402.1 PM	$6,918	9%	$12,363	8%	$0	$20,897
402.2 OT	$23,841	25%	$19,030	20%	$3,582	$56,344
402.4 CE	$23,617	26%	$17,055	24%	$3,436	$54,252
402.6 TD	$4,455	31%	$4,633	23%	$1,105	$12,631
402.8 TL	$7,855	19%	$4,864	36%	$1,952	$17,901
Grand Total	$66,686	23%	$57,946	20%	$10,075	$162,025

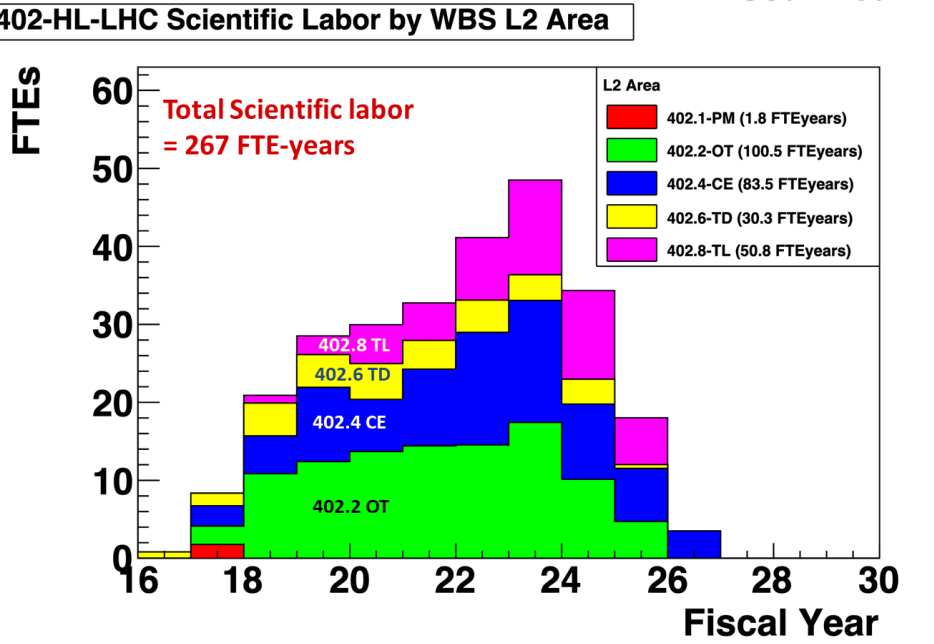


Labor Profile

- Ramp up through prototyping, increase in techs and students as we proceed into production phase

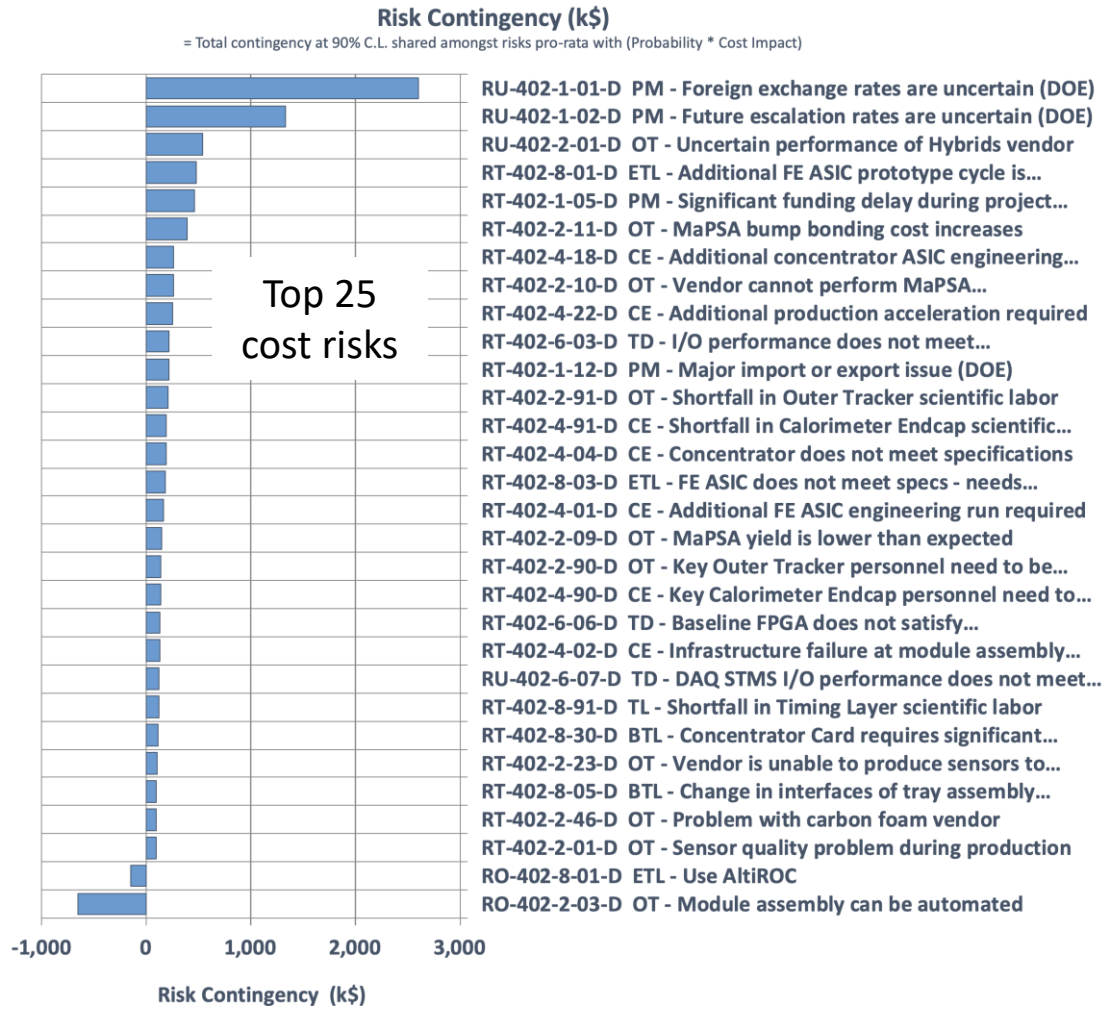
- 45.5% scientific labor
  - 12.6% Management WBSs
    - Not as vulnerable to decrease in Research Budget
  - 32.9% Technical WBSs
    - Each L2 area carries a risk of loss of up to 20% of the scientific labor at 30% probability





Cost risks

- Main risk changes in past 12 months are
  - Reviewed and updated full spectrum of risks
  - New: detailed risk analyses of BTL & ETL
  - Re-aligned with the evolving iCMS plans
  - Held external risk reviews
  - Escalation, overheads, and exchange rate risks decreased (we have advanced by one year)



Risk-based contingency ≈ $10.07M (8.1% of BAC)

Was $10.4M at DOE IPR, June 2018

Total Project Cost – CD-1 Range

- For base cost + estimate uncertainty use AACEI / DOE* estimate classes
  - Mapped to Fermilab maturity categories
- For risk-based contingency, range is taken from the MC spread in risk cost
  - Lower (70% CL) to higher (95% CL)

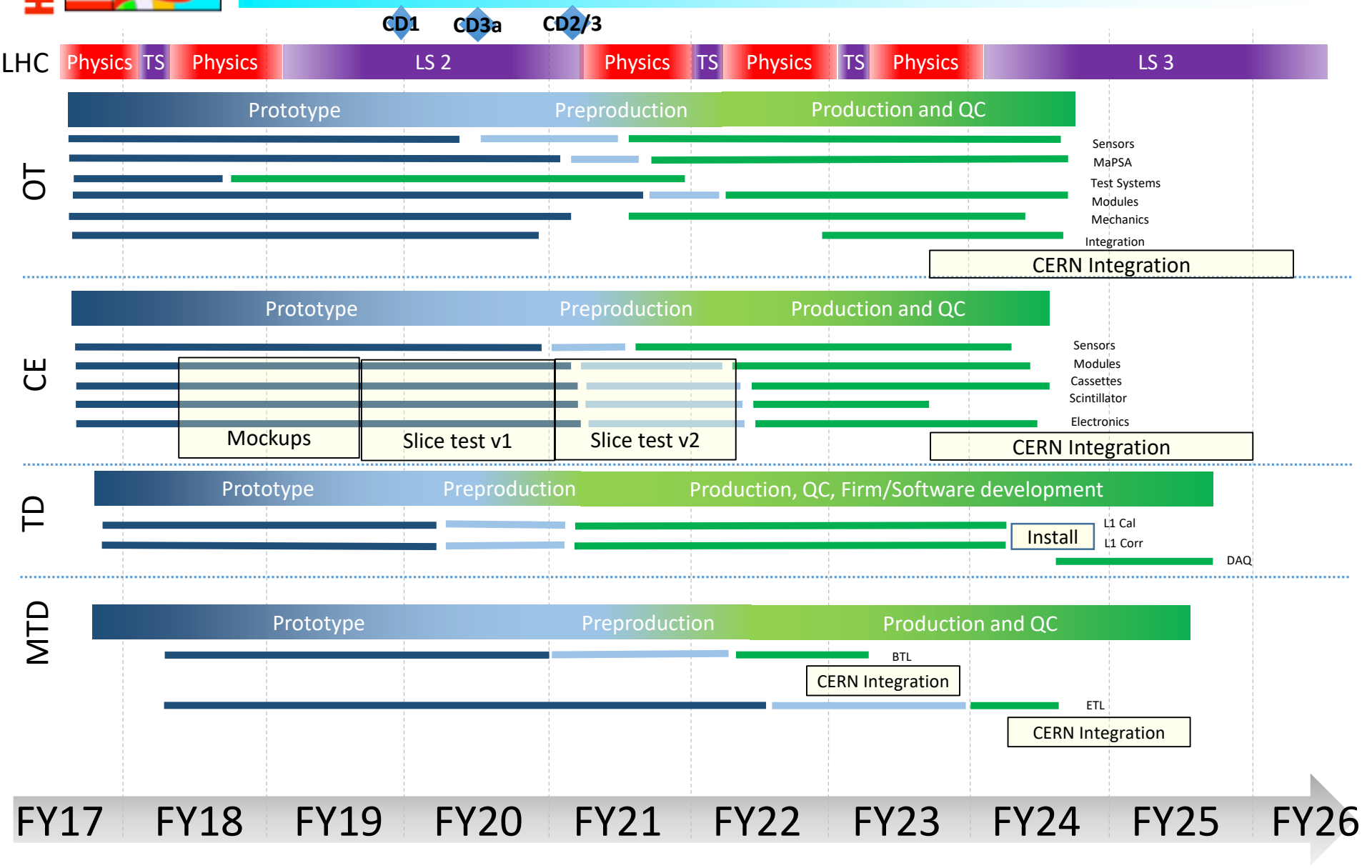
	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**DEGREE OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 70%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	70% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Component of cost estimate	AACEI / DOE Estimate Class*	Fermilab Estimate Class	Point estimate (M$)	Low range of cost estimate Methodology*	Low range (M$)	Upper range of cost estimate Methodology*	Upper range (M$)
Base cost + Estimate Uncertainty	Class 1	L1/M1 (Actual) L2/M2 (LoE)	**47.09**	**-6.5%** (AACEI: -3% to -10%)	**44.0**	**9%** (AACEI: +3% to +15%)	**51.3**
	Class 2	L3/M3 (Advanced) L4/M4 (Preliminary)	**74.47**	**-10%** (AACEI: -5% to -15%)	**67.0**	**12.5%** (AACEI: +5% to +20%)	**83.8**
	Class 3	L5/M5 (Conceptual)	**30.39**	**-15%** (AACEI: -10% to -20%)	**25.8**	**20%** (AACEI: +10% to +30%)	**36.5**
Risk-based contingency	90% C.L. from PRA risk MC		**10.07**	70% C.L. from PRA risk MC	**7.2**	95% C.L. from PRA risk MC	**11.4**
CD-1 point estimate of TPC			**162.03**	**CD-1 lower cost range**	**144.1**	**CD-1 upper cost range**	**183.0**

* AACEI: Association for the Advancement of Cost Engineering International. See: DOE G 413.3-21, Cost Estimating Guide, Section 4 and Appendix H.

Cartoon Schedule at L3



Schedule Summary

- Activities have been sequenced with logical links to provide a workable and predictive schedule
  - Minimal interdependence between L2 schedules
  - International dependencies, review dates, and expectations imported into synchronization milestones

Subsystem	Float to CMS need-by date (m)	Float to CD-4 (m)
Outer Tracker	5.7 (Modules)/11.4 (Flat Barrel)	37
Calorimeter Endcap	7.2	44
Trigger/DAQ	9.1	44
MTD	11.0 (BTL) / 14.2 (ETL)	54 (BTL)/41 (ETL)

- Finalizing schedule part of moving to a baseline at CD-2
  - LHC schedule discussion will be in the past
  - Component delivery schedules will be updated
  - Duration estimates will be refined from prototyping experience

Status vis a vis the charge

- Acquisition strategy is in place, still valid Charge #1
- Conceptual Design complete, satisfies performance requirements Charge #2, and with substantial base of supporting documentation justifies stated cost range and project duration Charge #3
  - TPC 162.03 matches funding guidance, CD4 has significant float
- Plans make efficient use of collaboration resources and qualified vendors as appropriate Charge #4
- Project has requisite management and technical experience to produce a credible cost and schedule baseline Charge #5
- ESH aspects and documentation have both been bolstered substantially since last IPR Charge #6,7
- Project has responded to all recommendations Charge #8

The big picture

- We believe that
  - We have a complete and accurate schedule and cost estimate
  - Our design is sufficiently mature to support the Cost Range
- We welcome your feedback and are available for questions to help with your assessment

nahn@fnal.gov 781 363 1351 24/7

- Thanks for your efforts
  - Reviews are hard on the reviewers too.

PROJECT STATUS		
Project Type	**MIE / Line Item / Cooperative Agreement**	
CD-1	**Planned: 11/27/2019**	**Actual:**
CD-2	**Planned: 11/30/2020**	**Actual:**
CD-3	**Planned: 11/30/2020**	**Actual:**
CD-4	**Planned: 9/30/2027**	**Actual:**
TPC Percent Complete	**Planned: 15%**	**Actual:**
TPC Cost to Date	**$18,283K**	
TPC Committed to Date	**$21,666K**	
TPC	**$162,050K**	
TEC	**$74,435K**	
Contingency Cost (w/ Mgmt. Reserve)	**$37,390K**	**35% to go**
Contingency Schedule on CD-4	**37 months**	**64.9% to go**
CPI Cumulative	**.99***	
SPI Cumulative	**1.04***	

*Approximate, formal EVMS not started