



Mu2e Operations

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for the Operations Planning Team

Mu2e Italia
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Project → Operations

- In general, the Project provides the materials and labor up until the point a subsystem has met its Key Performance Parameter (KPP)
 - As the KPP is completed, ownership and responsibility for operations is transferred to the collaboration and FNAL
- Mu2e Operations is broken up into phases
 - “Pre-operations” → time period before KPP completed (i.e., now)
 - Pre-operations is ongoing now, while the Project is ongoing
 - “Operations” → time period after KPP completed
 - Final installation and prepare for beam
 - Commission with beam on target
 - Physics data taking
 - Summer shutdown

Operations planning

- ✗ Mu2e was asked by DOE to develop an “Operations Plan” (OP) with:
 - a review of the **preliminary OP** , which took place on **5-6 May 2020**
 - a review of the **detailed OP** sometimes in mid-2022

Operations planning team, organized by Mu2e Spokespersons and FNAL:

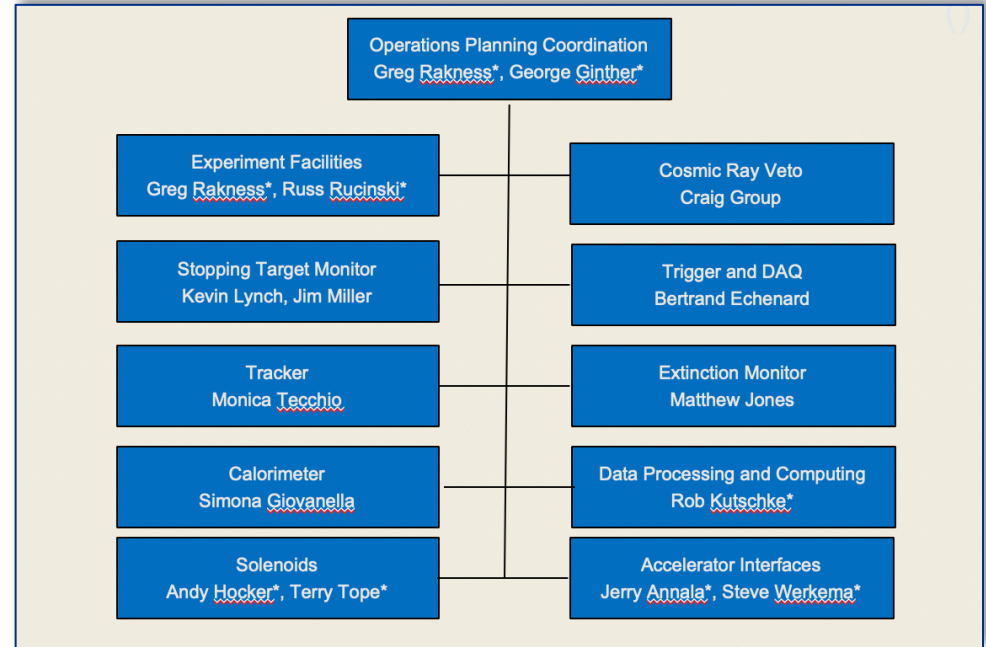
- **Bob Bernstein** (FNAL): Mu2e Co-spokesperson (since 20 March 2020)
- **Doug Glenzinski** (FNAL): Mu2e Co-spokesperson (through 20 March 2020) & CPO
- **Jim Miller** (U. Boston): Mu2e Co-spokesperson
- **Greg Rakness** (FNAL): Mu2e Ops co-Coord & Head of Mu2e Prelim Ops Planning
- **George Ginther** (FNAL): Deputy Head of Mu2e Preliminary Operations Planning and member of Mu2e Project Integration Coordination team
- **Jemila Adetunji** (FNAL): Mu2e Quality Manager
- **Jerry Annala** (FNAL): AD Muon Department Head
- **Karen Byrum** (ANL): Mu2e Project Head Electrical Integration
- **Ray Culbertson** (FNAL): PPD Mu2e Group Leader
- **Gary Drake** (FNAL): Mu2e Lead Electrical Engineer
- **Bertrand Echenard** (Caltech): Mu2e Trigger Working Group Co-Leader
- **Simona Giovannella** (INFN Frascati): Mu2e Project L3 Calorimeter Crystals
- **Craig Group** (U. Virginia): Mu2e Project L3 CRV Module Fabrication
- **Dee Hahn** (FNAL): Mu2e ES&H Coordinator
- **Andy Hocker** (FNAL): Mu2e Project L2 Solenoids Deputy Project Manager
- **Matthew Jones** (Purdue): Mu2e Project L4 Extinction Monitor FEE & DAQ
- **Rob Kutschke** (FNAL): Mu2e SCD Computing Liaison and Comp & SW Coordinator
- **Fran Leavell** (FNAL): Project Controls Lead
- **Raymond Lewis** (FNAL): ES&H PPD Division Safety Officer
- **Kevin Lynch** (CUNY York): Stopping Target Monitor
- **Russ Rucinski** (FNAL): Mu2e Lead Mechanical Engineer
- **Monica Tecchio** (U. Michigan) – Mu2e Tracker electronics systems dev & testing
- **Terry Tope** (FNAL): Mu2e Project L3 Cryogenics Distribution
- **Steve Werkema** (FNAL): Mu2e Project L2 Accelerator Project Manager

Planning and development of the supporting documentation for the preliminary review: requirements, Work Breakdown Structure, Resource Loaded Schedule

Includes representatives from collaboration, FNAL Particle Physics, Accelerator, Scientific Computing, and Technical Divisions, ES&H and Quality Sections, and Mu2e Project

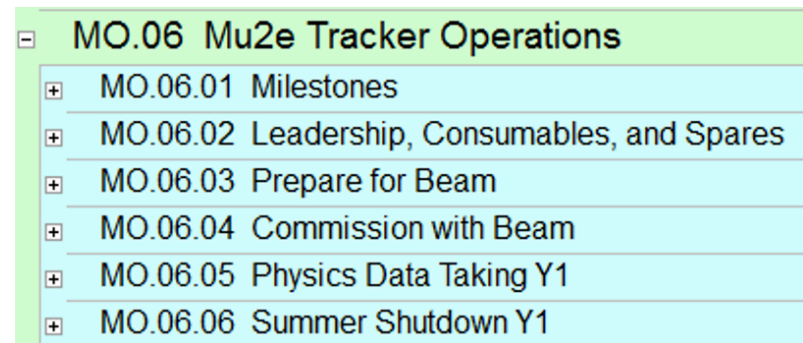
Mu2e Operations L2/L3 organization

- Operations WBS parallels Project structure: L2 for each distinct sub-system representing different technologies



- Common L3's defined for all subsystems to facilitate coherent planning and roll-up
- Main phases of work:
 - prepare for beam
 - commission with beam
 - physics data taking
 - summer shutdown

Example implementation in p6:



Calorimeter: involved institutions

Institutions expressing interest in calorimeter operations:

1. Caltech
2. JINR, Dubna
3. INFN-LNF, Frascati
4. HZDR, Dresden
5. INFN-Lecce
6. Marconi University, Rome
7. INFN -Pisa
8. INFN-Trieste

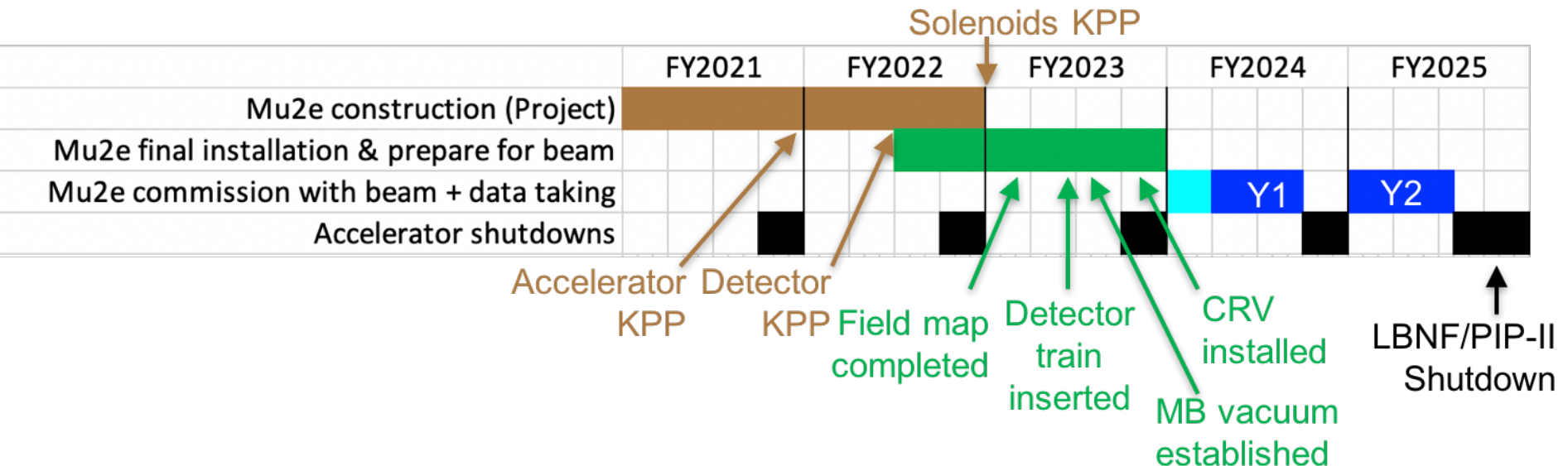


Mu2e Operations Responsibilities by Institution (draft 23 December 2019)

	Proton Beamline & Extinction	Solenoids & Field Mapping	Tracker	Calorimeter	Cosmic Ray Veto	Extinction Monitor	Stopping Target Monitor	TDAQ	Software & Computing	Calibrations & Data Processing	Analysis Preparations	Data Analysis & Internal Review	Miscellaneous
Argonne National Laboratory													
Boston University													
Brookhaven National Laboratory													
University of California, Berkeley													
University of California, Davis													
University of California, Irvine													
California Institute of Technology													
City University of New York													
Joint Institute for Nuclear Research, Dubna													
Duke University													
Fermi National Accelerator Laboratory													
Laboratori Nazionali di Frascati													
INFN, Genova													
Helmholtz-Zentrum Dresden-Rossendorf													
University of Houston													
Institute for High Energy Physics, Protvino													
Kansas State University													
Lawrence Berkeley National Laboratory													
INFN Lecce & Universita' del Salento													
Lewis University													
University of Liverpool													
University College London													
University of Louisville													
University of Manchester													
LNF & Universita' Marconi Roma													
University of Michigan													
University of Minnesota													
Institute for Nuclear Research, Moscow													
Muons, Inc.													
Northern Illinois University													
Northwestern University													
Novosibirsk State University / Budker Institute of Nuclear Physics													
INFN, Pisa													
Purdue University													
University of South Alabama													
Sun Yat-Sen University													
INFN, Trieste													
University of Virginia													
University of Washington													
Yale University													
No. Contributing Institutions (of 40 total)	3	4	7	8	6	3	5	4	20	18	18	32	8

Status of calorimeter at project handoff

- Calorimeter Ops begins with Project Detector KPP:
Calorimeter installed in an extracted position and cosmic ray data collected using TDAQ



Status of calorimeter at project handoff

- At Project handoff we expect to have:
 - each channel tested with a scope and digital board readout
 - slice test of ½ disk at a time with cosmics and laser runs (low and high rates) before moving to Mu2e assembly hall
 - entire calorimeter powered in an extracted position
 - Cosmic Rays data taking with TDAQ
 - laser system operational
 - source plumbing installed and operated (calib not performed)
 - calorimeter operated with cooling station at room temperature
 - preliminary version of Detector Control System (DCS) tested
 - Needed ORCs done (HV/LV supplies, electronics, source and laser)

Summary of calorimeter operations requirements

To reach its performance, we need to achieve the following requirements through a 3-step commissioning phase (extracted, inserted, beam):

1. Number of single readout dead channels at % level
2. Dark current on SiPMs < 2 mA \Rightarrow Noise level < 2 MeV/channel
3. Noisy channels below 1%
4. Continuous and reliable monitoring of:
 - DCS detector parameters: LV/HV, SiPM temperatures and currents
 - DCS calorimeter environmental parameters: temperature, ionization dose, neutron flux on calorimeter surface and crates
 - DQM detector parameters: dead channels, noise level, energy and time offsets, detector response
5. Calibration with laser, cosmics, source and physics data to achieve:
 - Equalization of time/energy at < 50 ps/1% level
 - Energy scale at 1% level
6. Calibration of energy/time scale w.r.t. tracker (relevant for PID)

See docdb-22786 for details

Calorimeter activities: prepare for beam, phase 1

- Calo Operations tasks in 'Extracted Position':
 - Refinement of procedures and software development for DCS/DQM/Source/Laser/Cosmics
 - Documentation for experts/shifters

**EMC@room
temperature**

@ End of Month 3: Ready to begin overnight cosmics data taking

- Calibration: cosmics/laser on a regular basis, occasional source runs
 - ⇒ Time/Energy equalization @ <50ps/2% level
 - Long term monitoring for stability check
 - Offline developments: data/MC comparison, calo+tracker data
 - Remote uploading of config, firmware for digital electronics
 - Fixing of bad channels before insertion (~3 weeks, if needed)
- @ End of **Month 8: Ready to move in 'Inserted Position'**

ESH Hazard Mitigation Requirements

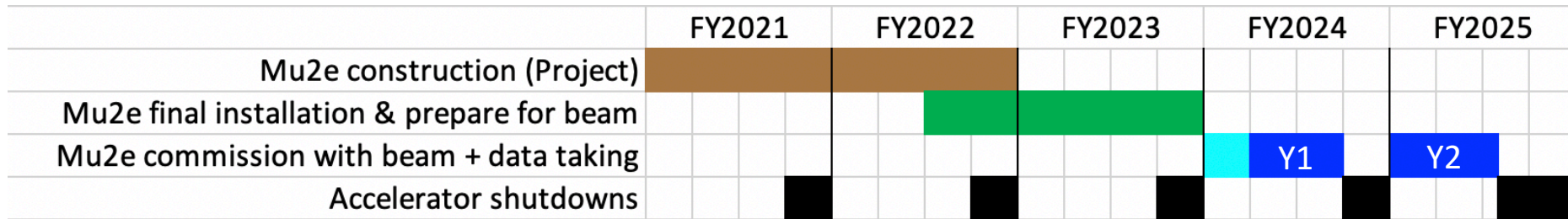
Hazard Description	Mitigation	Notes
Deuterium-tritium (DT) generator	Shielded and locked	Only while without beam
Calibration source exposure	Minimize operation in access mode, personal dosimeter required	Only while DT operating and FC-770 circulating
Laser, primary source and primary distribution	Training, enclosed area, PPE	All phases
Laser secondary distribution	Warning labelling on launching fibers	During access periods
High Voltage exposure	Fermilab Electrical Safety Program	All phases
Low Voltage, high current	Fermilab Electrical Safety Program	All phases
Moving heavy equipment	Operation restricted to qualified personnel	During movement of detector train or during maintenance
Fall	Fall protection system, training, PPE	During calorimeter servicing

Risks/Opportunities

Event description	Probability / year (%)	Date risk could be retired	Technical Impact	Response	M&S Cost Impact (k\$)	FTE Cost impact (FTE)	Schedule Impact (weeks)	Mitigation(s)	Notes
Calorimeter full system to be tuned beyond KPP	10%	After Detector KPP	Noisy/dead channels, swapped cables	Replace SiPM/FEE/boards, correct cable connections	\$20k	0	2 weeks	Spares and trained personnel available	Cost includes replacement of ~25 (2%) readout channels (2 SiPMs+2 FEE), 2 DIRAC+MEZZANINE boards
Irradiation larger than expected	20%	Never	SiPM, FEE boards damaged	Replace damaged components	\$80k	3	3 weeks	Spares and trained personnel available	Full replacement of innermost ring of disk0 (~100 channels). Easier than random replacement (see previous risk)
Inadequate cooling of detector	5%	Never	SiPM dark current too high	Decrease HV working point	0	1	1 week	Tune chiller working point	
Laser fiber coating damaged during disk movements, maintenance	10%	Never	Deterioration of light tightness	Replace broken fiber	0	2	1 week	Skilled personnel, no light inside DS	Spare bundles up to final distribution system, spare fibers in bundles to crystals
Pile-up in crystals larger than expected	10%	Never	Reduced cluster capabilities in innermost region	Study pile-up algorithm using two independent laser sources	\$14k	2	4 weeks	Perform pile-up MC studies, reduce beam intensity	Cost of an additional laser head
Leak in the Cooling System inside DS	1%	Never	DS vacuum level compromised	Extract detector train, clean and repair the circuit	\$10k	1	4 weeks	Check leaks before operating in vacuum, safety system emptying cooling circuit if pressure drops down, coolant safe for detectors, quick evaporating	Cost includes crate lines and pipes. Impact does not include extraction/insertion of detector train (see next risk for this)
Leak in the Source System inside DS	<0.1%	Never	DS vacuum level compromised	Extract detector train to let the coolant evaporate	\$79k	0,5	6 weeks	Check leaks before operating in vacuum, source circuit empty while not calibrating, coolant safe for detectors, quick evaporation	Small leaks, vacuum not compromised: source calibration will not be performed until the next planned shutdown. Cost is extract/insert detector train

Summer shutdown: working assumption

- For the first summer shutdown, we assume that we will extract the detector train to perform maintenance on the tracker and calorimeter
 - Requires considerable resources in Facilities, CRV, and STM to extract detector train and insert detector train
 - ... in addition to the work by the Tracker and Calorimeter
 - Nominal summer shutdown is 12 weeks, so this is also a useful exercise to understand the durations needed for these task



Mu2e Detector & Computing Ops: total effort

Mu2e DETECTOR AND COMPUTING OPS EFFORT	Begin prep for beam after KPP (**partial FY**)	Prepare for beam	Comm w/beam + physics Y1 + summer Y1	From docdb-32497
	FY22	FY23	FY24	Notes
SUBTOTALS	13.9	33.4	23.8	excluding shifts
Engineer	1.7	5.5	4.9	
Technician	5.2	14.9	7.0	
Other	2.5	4.3	2.6	
Scientist	4.5	8.7	9.2	
Scientist (uncosted)	18.5	25.9	27.1	excluding shifts
Shifts	4.8	4.8	4.8	costed subtotal
Operations shifter	4.8	4.8	4.8	1 shifter 24/7
Exp Shifter (uncosted)	1.0	9.5	9.5	2 shifters 24/7 starting in Q2 FY23
TOTALS				including shifts
TOTAL costed effort (FTE)	18.7	38.2	28.5	
TOTAL uncosted effort (FTE)	19.5	35.4	36.7	
TOTAL Scientist effort (FTE)	24.0	44.1	45.9	scientists (costed + uncosted + shifts)
TOTAL effort (FTE)	38.2	73.6	65.2	

- In this table “Uncosted” effort = comes from the collaboration
 - Labeled in green
 - Total includes needed operations effort, including shifts

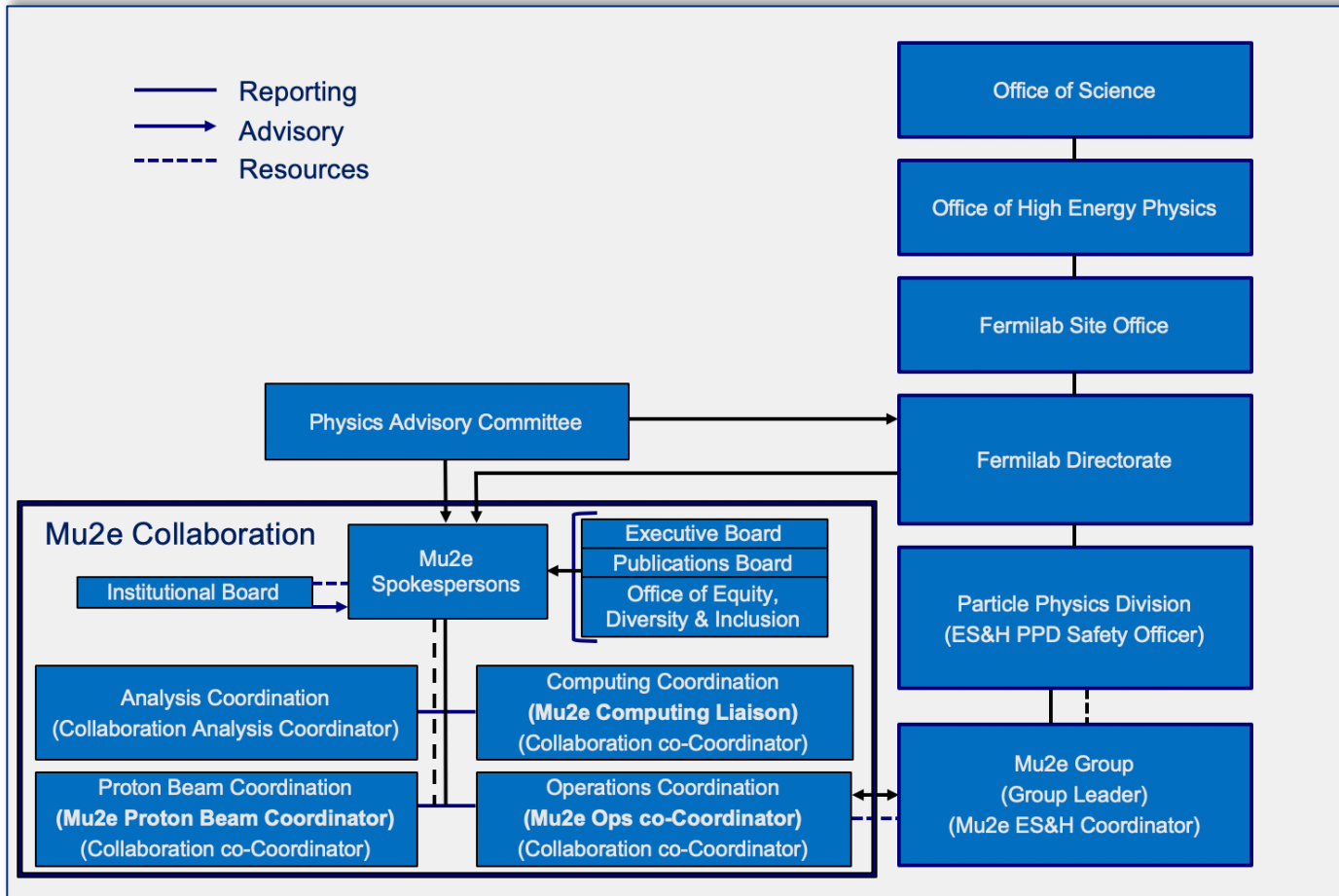
Physics running: working shift model

- Working model assumes that steady-state running of the experiment is done with a central shift crew + subsystem on-call experts
 - Shift model to be discussed with collaboration
- Solenoid strategy: once magnets are cold, goal = keep them cold
 - 1x Operations shifter 24/7
- Experiment strategy: central shifters + subsystem on-calls
 - 2x Experiment shifters 24/7 in ROC 1W when taking data
 - 1x on-call per subsystem when system powered
 - 2x Run Coordinators (one primary, one secondary)
 - In prelim ops plan, experiment shifts start with cosmic rays during Prepare for Beam... subsystems expected to join as soon as they are ready
- Computing: processing, data quality, and calibration/alignment
 - 1x Data Processing on-call
 - 1x DQM monitor per subsystem
 - 1x Calibration + alignment monitor per subsystem

Summary of outcome of review

- Closeout presentation: one recommendation and several comments
 - See docdb-33083 for presentation
 - Final report received 1 week ago
- Recommendation: “Apply the same methodology used by the Detector and Computing Operations team for cost escalation to the Accelerator Operations scope and update the operations plan to include detailed budget data before the next operations review.”
- Some comments snippets
 - “Levels of management reserve and baseline uncertainties consistent with the expectations of a preliminary operations plan. It is important to continue a conservative approach to contingency in the development of the detailed operational plan.”
 - “... more emphasis on development of the trigger in future reviews”
 - “... the role... of non-lab personnel in the main phases of work could be more clearly defined and specified”
 - “Magnetic fringe fields... will introduce hazards at levels that are unfamiliar to many of the staff and users of the facility... Care should be taken to ensure that all persons who enter the building are trained to understand the potential hazards. This is especially important for students and new employees. In addition, policies and procedures should be developed to rigorously control loose ferromagnetic materials in the vicinity of the solenoids.”
- We interpret the closeout report as an endorsement of Mu2e Ops planning procedure

Mu2e DOE, Fermilab PPD, and Collaboration



Fermilab provides line-management oversight of safety, M&S budget, and lab personnel

Collaboration establishes priorities, develops work plans and procedures, and participates in work

Operations, Proton Beam, and Computing coordinated by pairs of people: one appointed by Fermilab (w/concurrence of spokespersons) and one appointed by collaboration

