NOνA Project Overview

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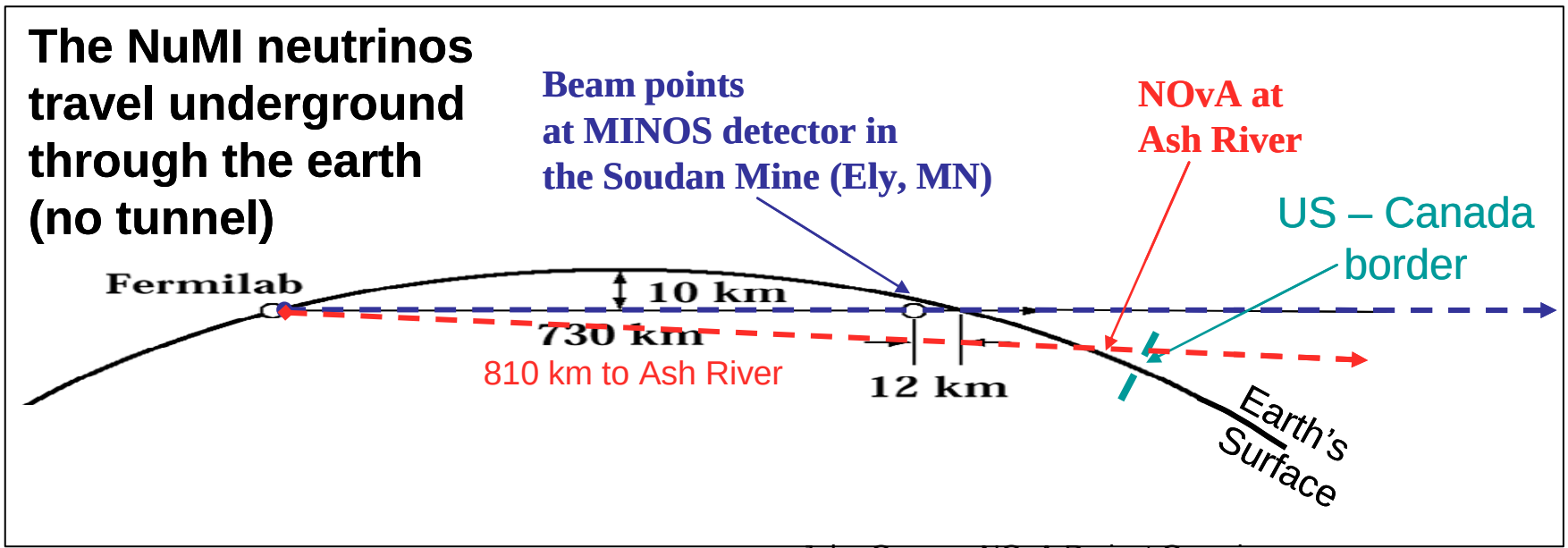
Project Manager

May 11, 2009

NOνA = NuMI Off-Axis ν_e Appearance

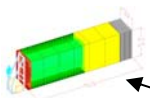
and NuMI = Neutrinos at the Main Injector

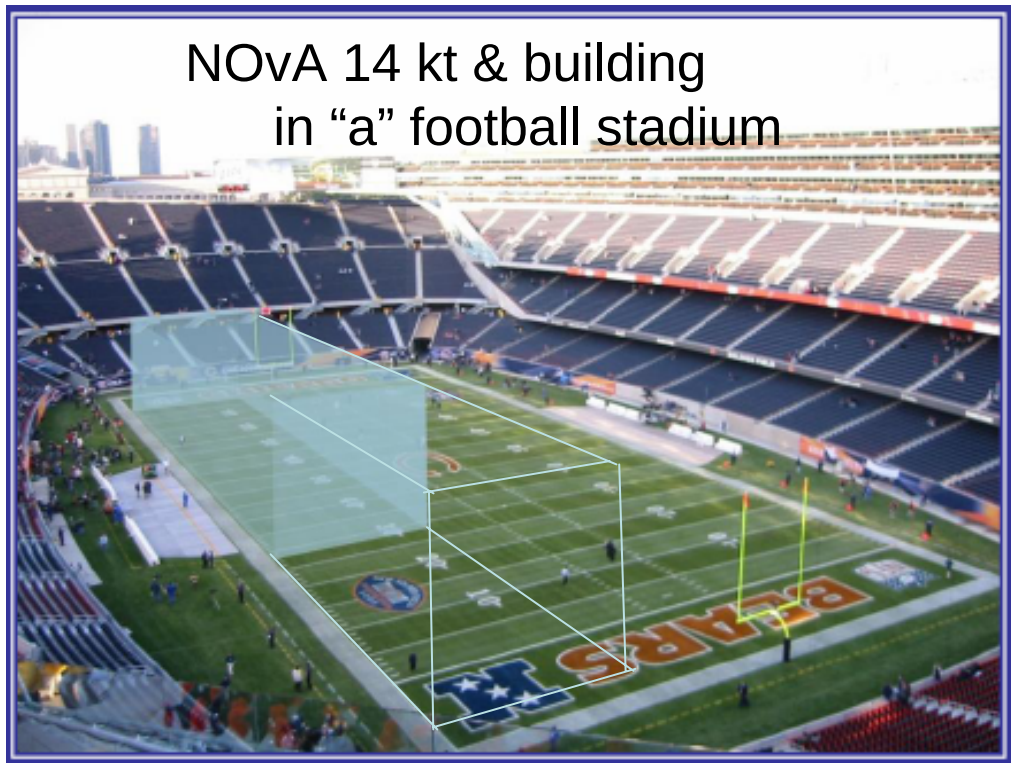
- We are looking for muon neutrinos changing (oscillating) to electron neutrinos
  - partial History:
    - 1930 - Neutrinos postulated by Wofgang Pauli (named by Enrico Fermi in 1933)
    - 1956 - Neutrinos first detected by Reines and Cowen using fission reactor as a source
    - 1962 - Two types of neutrinos detected (Steinberger, Lederman, Schwartz) at Brookhaven National Lab
  - The oscillation implies that neutrinos have mass (a very new discovery – 1998 in Japan)
  - NOvA: muon to electron oscillation gets at the mass hierarchy (which mass is larger?)
  - NOvA: If we see a big enough signal, we can also investigate CP violation in neutrinos (related to the matter – antimatter asymmetry in the universe)
- The NuMI neutrinos go underground from Fermilab to Minnesota
  - Through the Earth is OK since neutrinos don't interact very often with matter.



NOvA Detectors and Neutrino Beam

- **We need:**
  - **A new Far Detector** (14,000 tons)
    - (near the US/Canada border) designed to discriminate between the two types of neutrino interactions.
      - 810 km from Fermilab because we sit at the place where most of the muon neutrinos have disappeared
      - Detector has to be big to see any events at all, since neutrinos don't interact often with matter
      - This is a greenfield site, so building a detector hall is a big part of the project
  - **A new Near Detector at Fermilab**
    - to measure the neutrino components in the NuMI beam before any oscillations occur
      - It is much closer to the beam origin and sees a larger rate, therefore it can be small -- only 220 tons





  - **All the beam** (number of protons) **we can get on the NuMI target**
    - Proton interactions make neutrinos
    - More beam gives more neutrino events
    - This requires an upgrade to the Fermilab accelerator complex
    - 700 kW or 36 x 10^{20} protons will be delivered to NOvA over 6 yrs

NOvA Project History

- **November 28, 2005 DOE CD-0 approved**

- **April 4, 2006 DOE CD-1 Review to validate conceptual design & cost estimate.**
  - $ 197–256 M cost range for 25 kiloton detector with best estimate at $247M.
  - Results: Overall, the committee judged that the project was **ready for CD-1**.
- **December 20, 2006 OMB instructs DOE to combine NOvA detector & "Fermilab Proton Plan 2"** (original name for the accelerator part of NOvA)
  - New TPC set at $ 260 M by Jan 1. (with limited input from NOvA & Fermilab !)
  - Took several months for two projects to be combined into one team and one schedule

- **May 11, 2007 CD-1 approved by Office of Science (Ray Orbach)**
  - Cost range of $ 244 – 293 M for a 20 kiloton detector, now includes Accelerator part
  - TPC guidance set at $ 260 M
  - Phased CD-3a / 3b planned, CD-4 in FY13
- **June 19, 2007 DOE-FSO / Fermilab Directorate Joint Review of NOvA EVMS**
  - Results: overall consensus was that the NOvA project had a considerable amount of the performance management system already in place, and was only lacking a few products or further development of existing materials.

NOvA Project History continued

- **October 23-25, 2007 DOE CD-2/3a Review (Lehman IPR)**
  - Integral cost and FY obligation profile matched funding profile ($ 260 M TPC)
  - Results: **ready for CD-2 but needed additional flexibility either in scope or cost.**
    - CD-3a list of critical path and long leadtime items endorsed.
  - Discussions with OHEP resulted in a new cap of $ 270 M and an agreement to write the PEP for a 14 kt base scope.

- **November 26-30, 2007 DOE OECM CD-2 (EIR)**
  - Reviewed the same RLS and cost as the IPR review in October ($ 260 M, 15 kt)
  - Results: **project could be successfully executed and the performance baseline validated** once the project team resolved the 5 major findings and had an acceptable plan in progress to resolve the other 18 findings.
    - 5 major findings resolved by December 15, 2007.

- **Scheduled, then cancelled: Dec 19, 2007 DOE CD-2 ESAAB**
  - **Congress passed the FY08 Omnibus Bill: "zero for NOvA"**
    - **January, 2008: shutdown of project**
      - **Fermilab people assigned to other tasks, Purchase Orders to universities de-obligated**

NOvA Project History continued

- **February, 2008: OHEP asks us to re-plan for FY09 start**
  - President's FY09 budget has NOvA at $ 37 M
  - We were given a new funding profile from OHEP, ~ slip one year
  - TPC increased to $ 278 M to include one more year of escalation
  - Project to restart on Feb 1, 2009, allowed for a Continuing Resolution in FY09

- **April 30 Lehman CD-2 mini-Review**
  - Results: Overall, judged that the project was **ready for CD-2**. The project had revised the project cost and schedule following being zeroed out in the FY 2008 budget.

- **June-Aug Interactions with EIR:** Evidence Files, CD-2 mini-Review
  - Project provided Evidence Files for 5 major findings and 11 findings
  - August 6 Out-Brief Result:
    The project team's response to the CAP recommendations was generally satisfactory, and the resulting documents were updated appropriately.
    The revised project planning and documentation was sufficient for CD-2, **Approve Performance Baseline.**

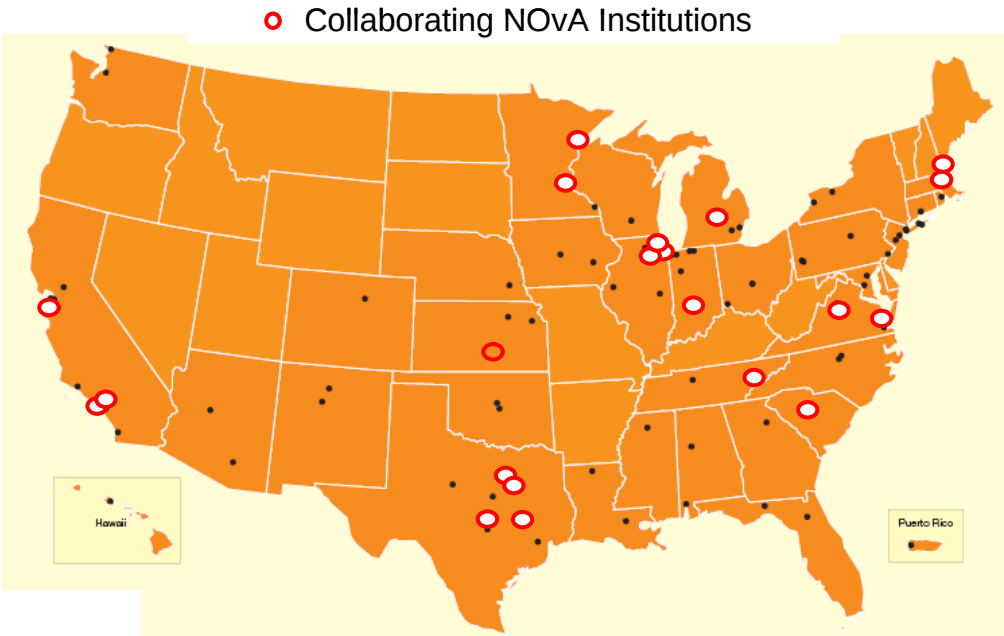
NOvA Project History continued

- **July 1, 2008 President signs Supplementary Appropriations Bill**
  - $ 9.234 M for a NOvA restart
  - We try an early restart by advancing our Feb 1, 2009 scheduled items to Sept 1, 2008
    - Restart proves difficult since personnel were scattered to other projects in the interim
- **August 19, 2008 ESAAB for CD-2 Board recommends approval**
- **September 15, 2008 CD-2 approved by Office of Science (Ray Orbach)**

- **October 1, 2008 FY09 Continuing Resolution begins**
  - NOvA is funded
- **October 24, 2008 CD-3a approved by Dennis Kovar**
  - $ 23.9 M of items for NOvA
- **March, 2009 Recovery Act:** allocates $ 55M of funds to support NOvA
- **March, 2009 Full FY09 Appropriation Budget enacted:** $27.8 M to NOvA
- **At this moment the project has ~ $89 M of obligation authority**
  - This is way more than planned in our RLS for FY09
  - Will require a major re-planning effort to take advantage of this funding
  - We also have a new DRAFT funding profile for FY10-13, TPC is not changed
- **Scheduled: July 21-23, 2009 CD-3b IPR by Lehman**
  - Plan to update our RLS via ETC changes prior to this review to match new profile

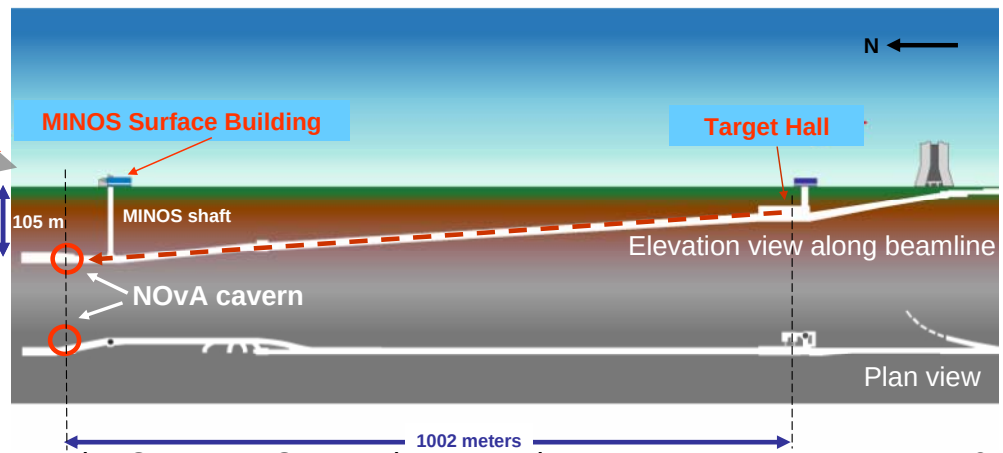
Our Organization is related to the Work

- FRA is an association of 104 universities and other national labs in 34 states
  - ~1300 scientists in the U.S., another 1,000 around the world
- 20 of the U.S. institutions are on NOvA
  - 107 scientists and engineers from U.S. institutions outside Fermilab are on NOvA
  - 74 are from Fermilab, 8 others from outside the U.S.
- **This is very much a collaborative effort**
  - **We collaborate because we are all interested in doing the science**
  - **We rely on one another for technical expertise across the project scope**



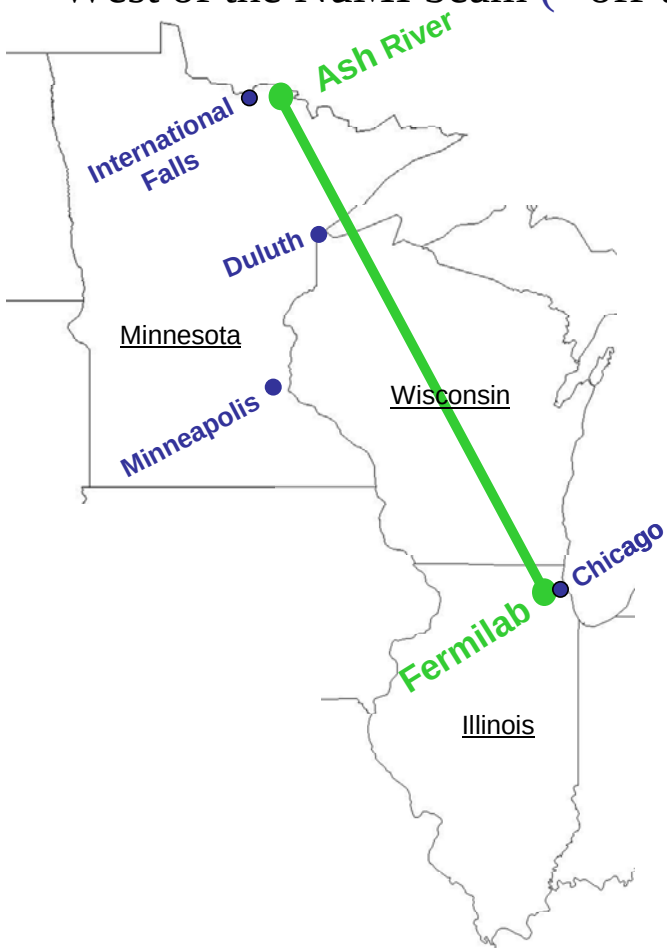
Accelerator and NuMI Upgrades

- **NOvA adds items to an extensive existing accelerator infrastructure**
  - Fermilab is the lead institution here
- **Existing Main Injector & Recycler**
  - Dotted yellow circle in picture
  - Previous ~ $250 M project completed in 1999 for the Tevatron Collider (the other circle in the picture)
  - NOvA:
    - Cycle time reduced by using the Recycler as proton storage ring and by using more RF stations in the Main Injector
    - Faster cycling gives more protons/second
- **Existing NuMI Beamline**
  - Dotted red arrow in picture
  - Previous ~ $175 M project completed in 2004
    - This includes an underground tunnel at Fermilab with space for Near Detectors 300 feet below the surface
  - NOvA:
    - New target, move focusing horn, …
- **NOvA Result:**
  - Increase beam power from 400 to 700 kW
  - More protons to make more neutrinos



Ash River Site

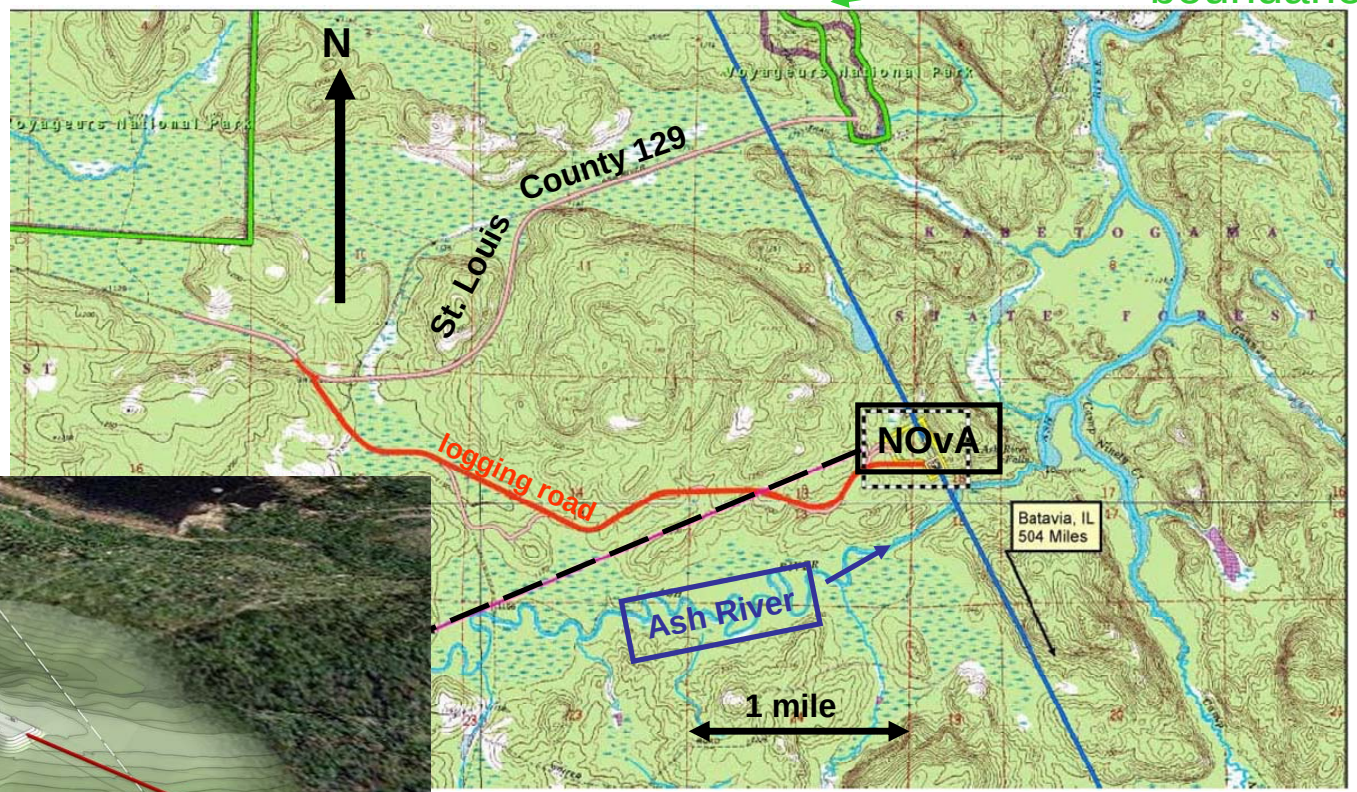
- Farthest site from Fermilab within the US and accessible by road
  - Farther = longer baseline = better science
  - 810.5 km from Fermilab, just 1.5 miles south of Voyageurs National Park
  - West of the NuMI beam (“off-axis”)



Ash River Site (Fermilab and U of Minnesota lead)

- We build a 3.6 mile access road and a building for 14 kt detector
  - EA completed, the FONSI was signed on June 11, 2008
  - US ACE Wetlands Permit issued December 24, 2008

National Park boundaries



NOvA site is on a hill

Far Detector Building

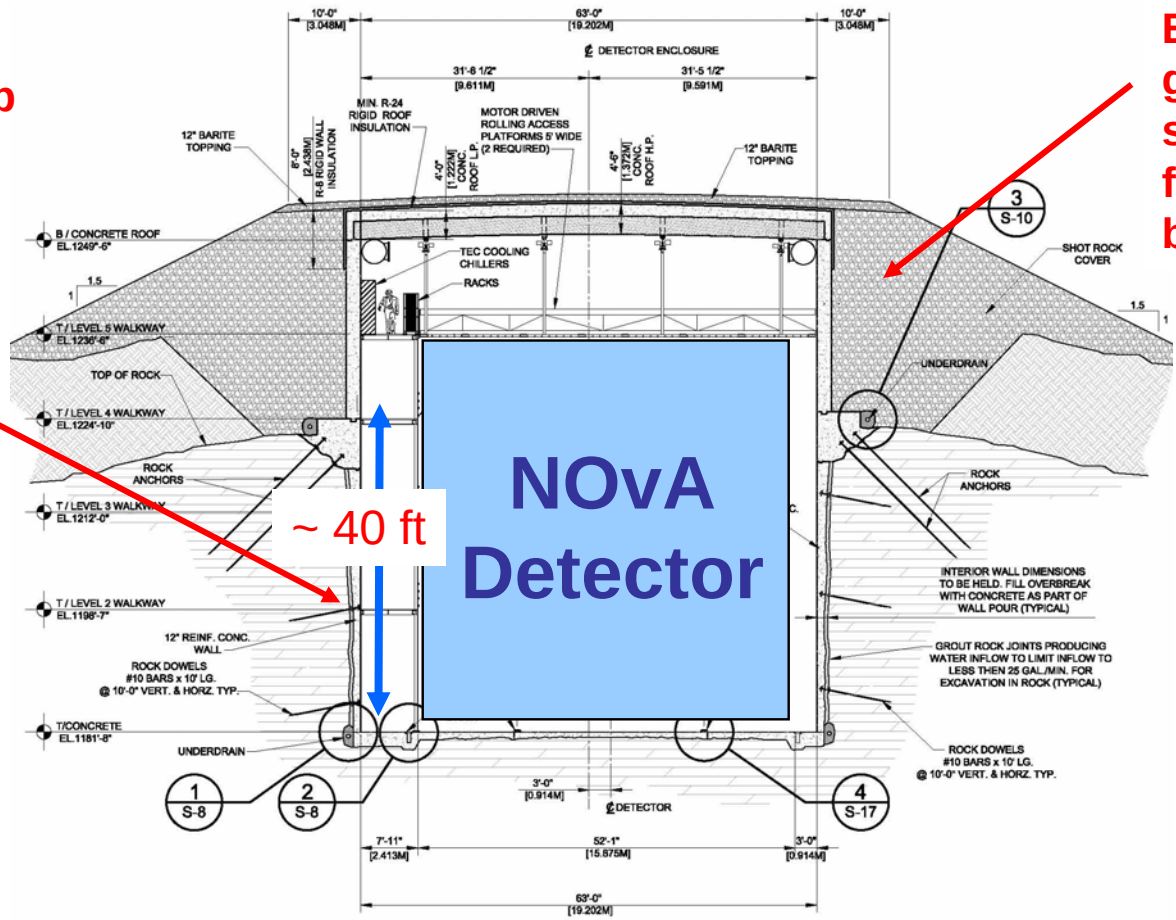
(Fermilab (design) and U of Minn (construction) lead)

Building cross section as seen by the neutrino beam

63 ft wide by 71 ft high **by 471 ft into the page**

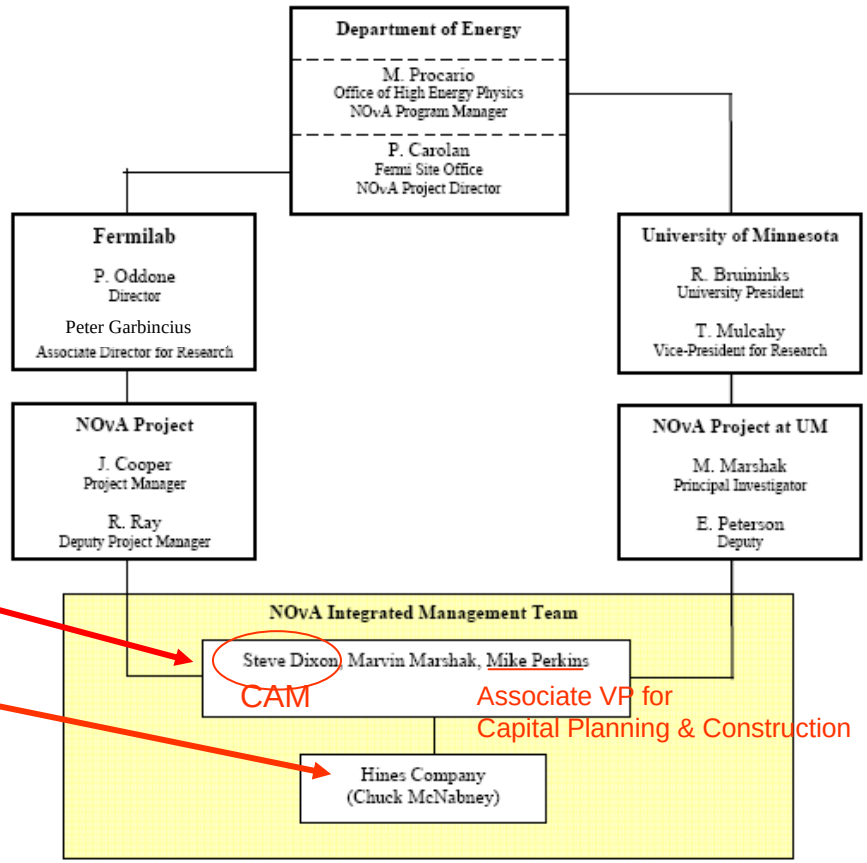
Bathtub 40 ft deep In solid granite (for 100% secondary Containment)

Excavated granite with voids shields detector from cosmic ray backgrounds



Ash River Organizational Wrinkle

- **The University of Minnesota received a DOE Cooperative Agreement grant for the building** (Marvin Marshak is P.I.)
  - UM acquired the land and easements for the access road & will own and operate the building
  - The grant is part of the NOvA TPC
- Official part of the Acquisition Strategy adopted as part of the CD-1 approval on May 11, 2007
- **MOU between Fermilab & University**
  - Integrated Construction Team
  - Use U of Minn procurement rules, but consensus with Project on larger questions
    - Successful consensus on
      - University's project management firm
      - A&E design firm
      - Final design for bid package
      - Construction contractor
  - In the MOU, U of Minn agreed to and now reports monthly to Project Office
    - Earned Value computation is being done



MOU on Cooperative Agreement

- EVMS text in MOU:

V. Narrative and Financial Reporting to the NOνA Project Office

The Fermilab NOνA Project is responsible for monthly reporting to the DOE of the project status and will include UM information on the CA in these narrative and financial status reports. NOνA Project change control procedures will be exercised by the Fermilab NOνA Project Office using the allocation of contingency information provided by UM. NOνA Change Control procedures require reporting to DOE when the sum of contingency usage passes certain thresholds, so a running total of all contingency usage is required.

UM will provide monthly reports, as well as episodic updates on NOνA construction activities. Reports will include both narrative and quantitative construction and financial data.

- NOνA CAM has complete details & can explain operational procedures in place

XI. Approvals

Marvin L. Marshak, University of Minnesota, School of Physics and Astronomy

12/18/07
Tim Mulcahy, Vice-President for Research

12/12/2007
Allen Goldman, University of Minnesota, Head, School of Physics and Astronomy

12.14.07
Michael Perkins, University of Minnesota, Associate Vice President, Capital Planning and Construction Management

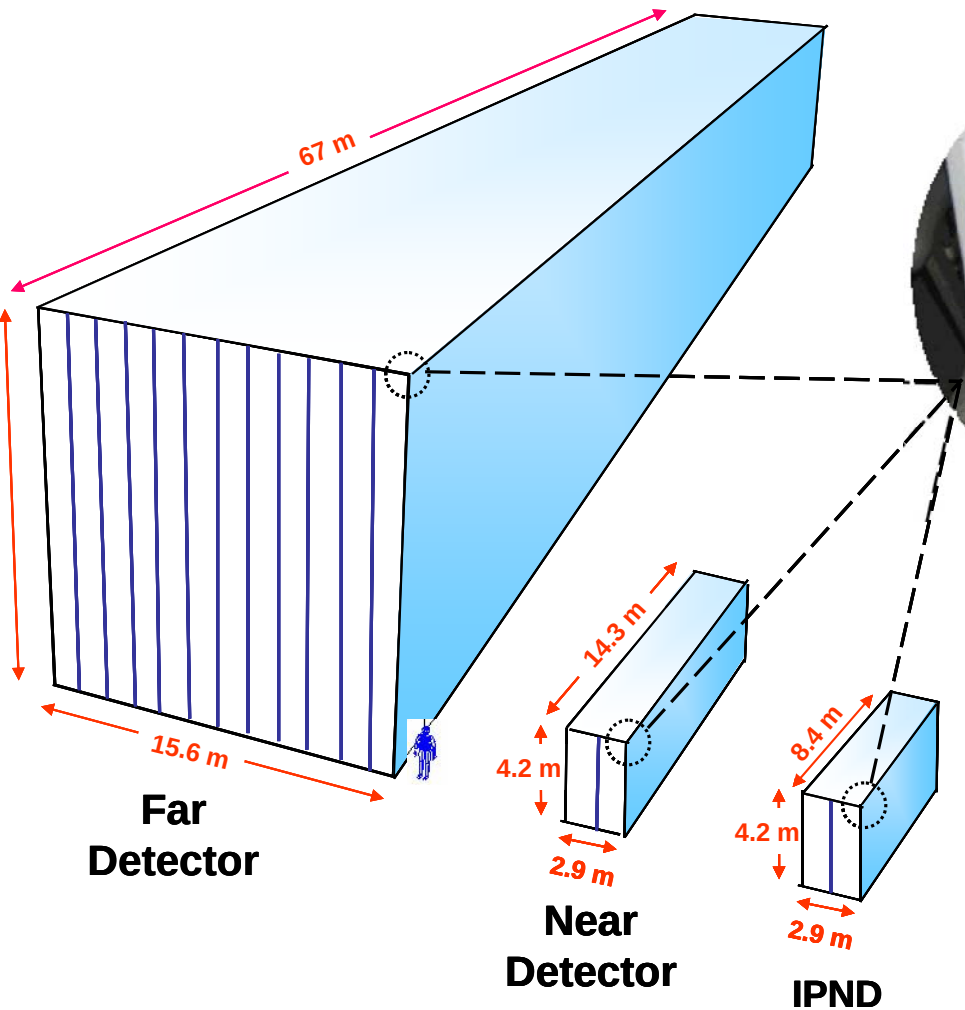
Steven L. Crouch 12/13/07
Steven Crouch, Dean, Institute of Technology

12/7/07
John Cooper, Fermilab, NOνA Project Manager

10 Dec 07
James Strait, Fermilab, Head, Particle Physics Division

Hugh Montgomery, Fermilab, Associate Director for Research

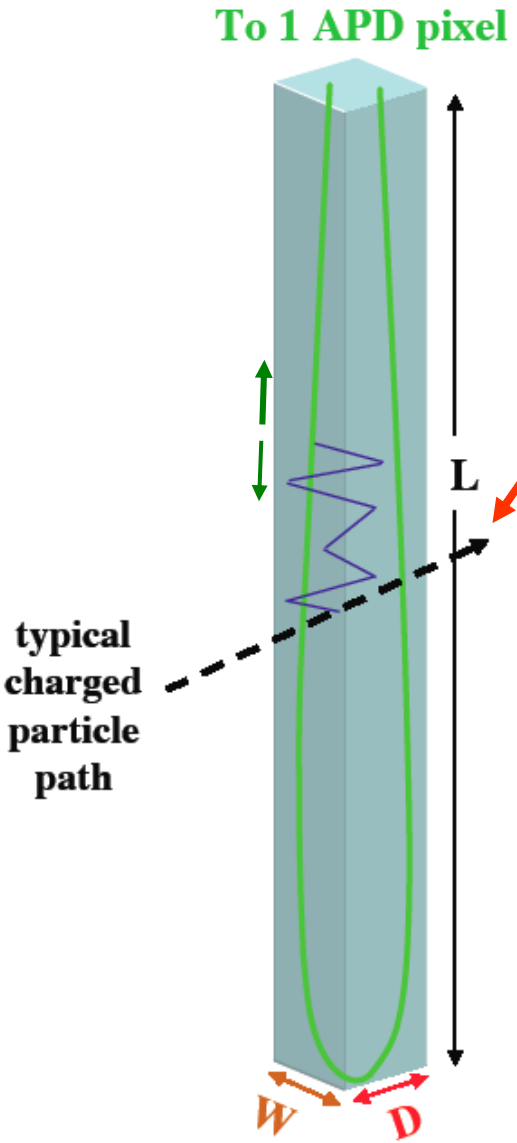
NOvA assembles 3 Detectors



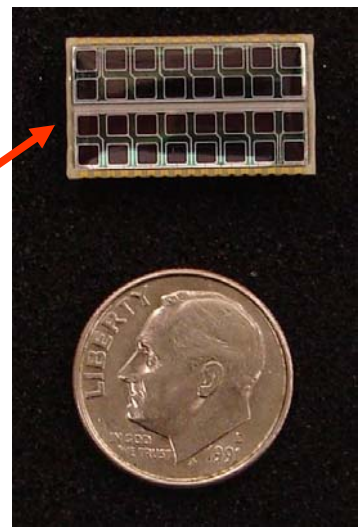
All have successive layers of vertical and horizontal PVC cells bonded together with adhesive

- 14,000 ton **Far Detector**
  - 12 by 12 extrusion modules
  - 930 layers
- 222 ton **Near Detector**
  - 2 by 3 extrusion modules
  - 206 layers
  - Will be 300 feet underground at Fermilab
- 90 ton **Integration Prototype Near Detector** (IPND), R&D goal in 2009-10
  - 2 by 3 extrusion modules
  - 124 layers, reuse all in Near Detector
  - Will be on the surface at Fermilab

NOνA Basic Detector Element



- Liquid scintillator in a highly reflective PVC plastic cell
  - Passage of charged particles through scintillator create light
  - Light bounces off reflective PVC walls until captured in a thin wavelength-shifting fiber
  - The fiber is U-shaped and both ends terminate in one pixel of a 32-pixel avalanche photodiode (APD)
- Simple construction, just repeat 357,120 times !
  - Cells are 50 feet long

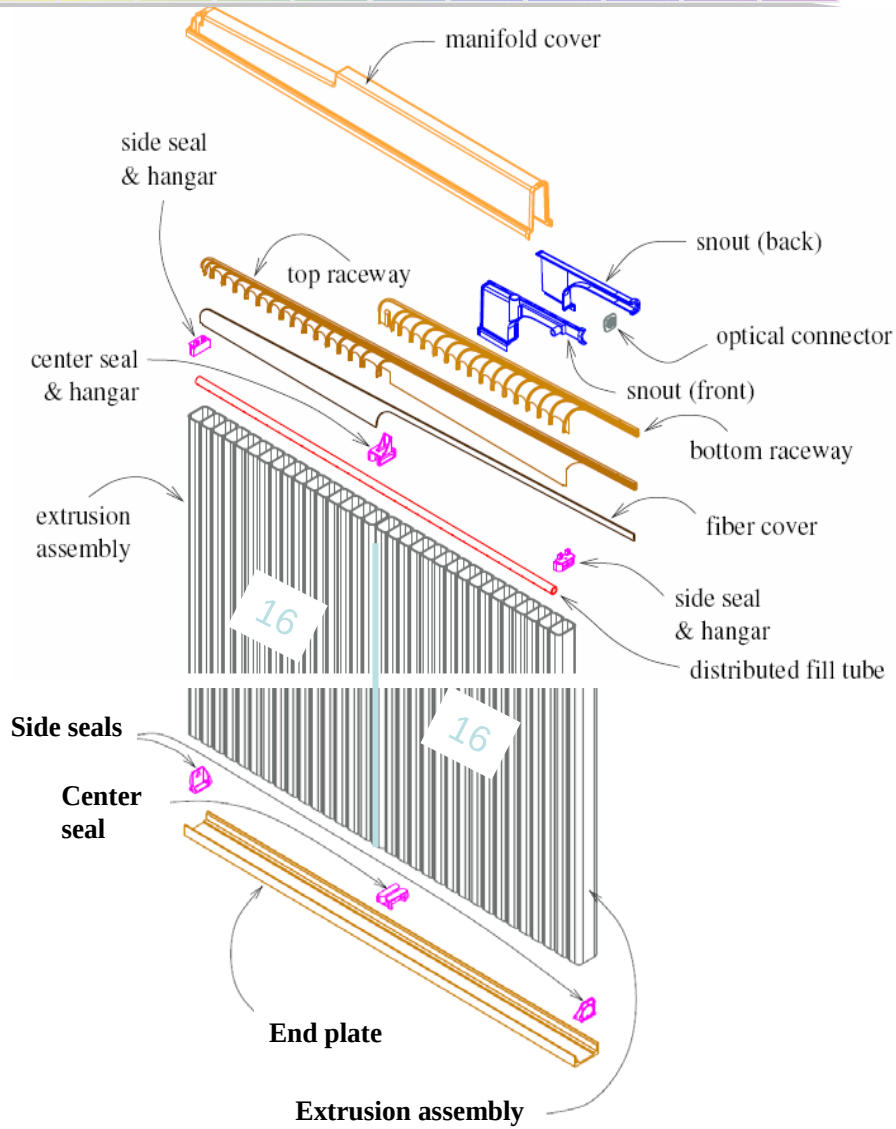


PVC Extrusions

- Custom **16 cell** PVC die built
- Custom PVC resin is extruded into 15 m long units.
  - 15% Titanium Dioxide for reflectivity
  - 15 meter long extrusions just fit into a 53 ft long semi-trailer truck
- **4,300 tons** of PVC in final detector
- Argonne National Lab leads

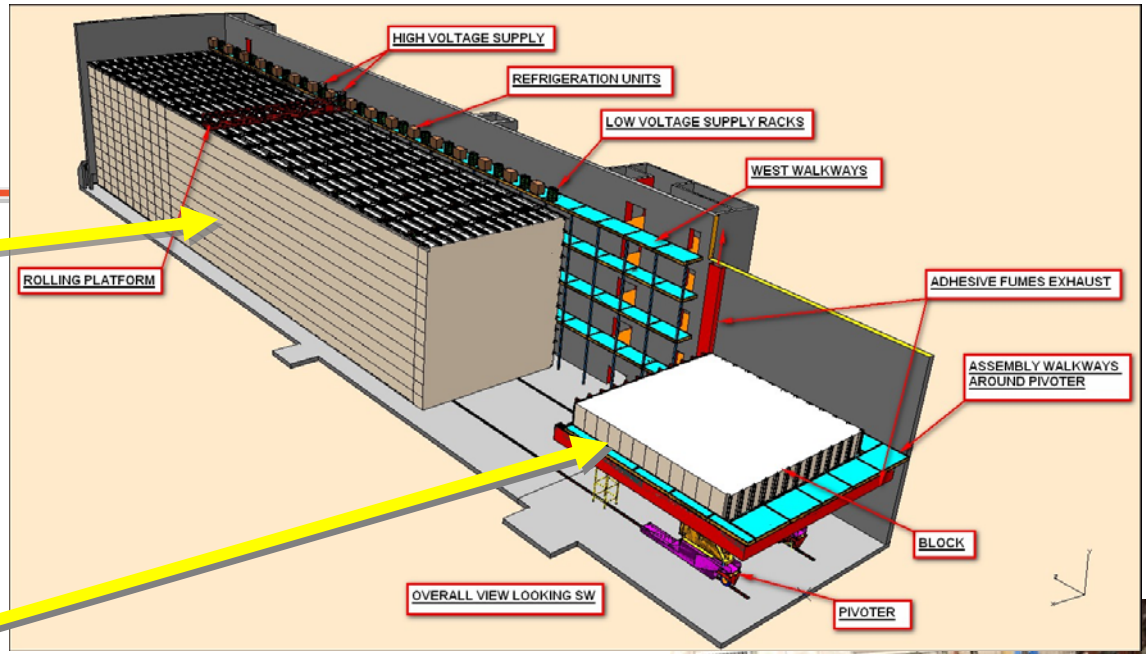
Extrusion Modules, Scintillator & Electronics

- **2 PVC modules + fiber are raw materials for Extrusion Modules**
  - 13,000 kilometers of fiber (Michigan State University leads)
  - 12,000 modules with complicated ends (U of Minnesota, Twin Cities leads)
    - Automated assembly required
- **3 million gallons of scintillator**
  - Mineral Oil, Pseudocumene, waveshifting powders, toll blending (Indiana University leads)
- **Electronics**
  - 12,000 Front End Boards (Harvard)
    - Custom integrated circuit on each board for APD readout (Fermilab)
    - Thermo-electric cooler for each APD keeps APD at ~ zero degrees Fahrenheit
  - 200 Data Collection Modules (Fermilab)
    - Each collect serial data from 64 FEBs
  - Power supplies for all (U of Virginia)
  - Vertical Slice integration, (Caltech)

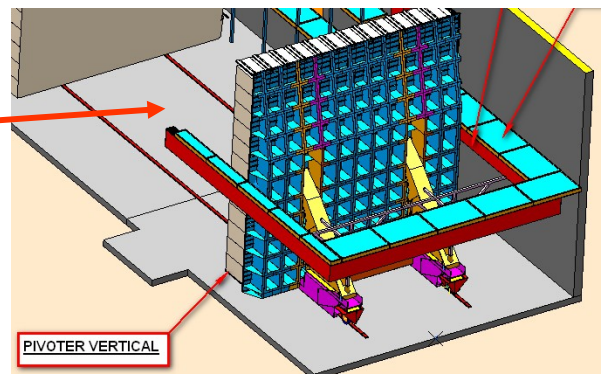


Detector Assembly

- **Unique Structure**
  - **5 stories high**
  - 220 feet long, 930 layers
  - 14,000 tons
  - **MADE of PLASTIC**
  - Filled with liquid
  - Assembly 30 **Blocks**
    - 1 block has 31 planes
    - Each plane has 12 extrusion modules
  - Argonne Nat'l Lab, Fermilab design



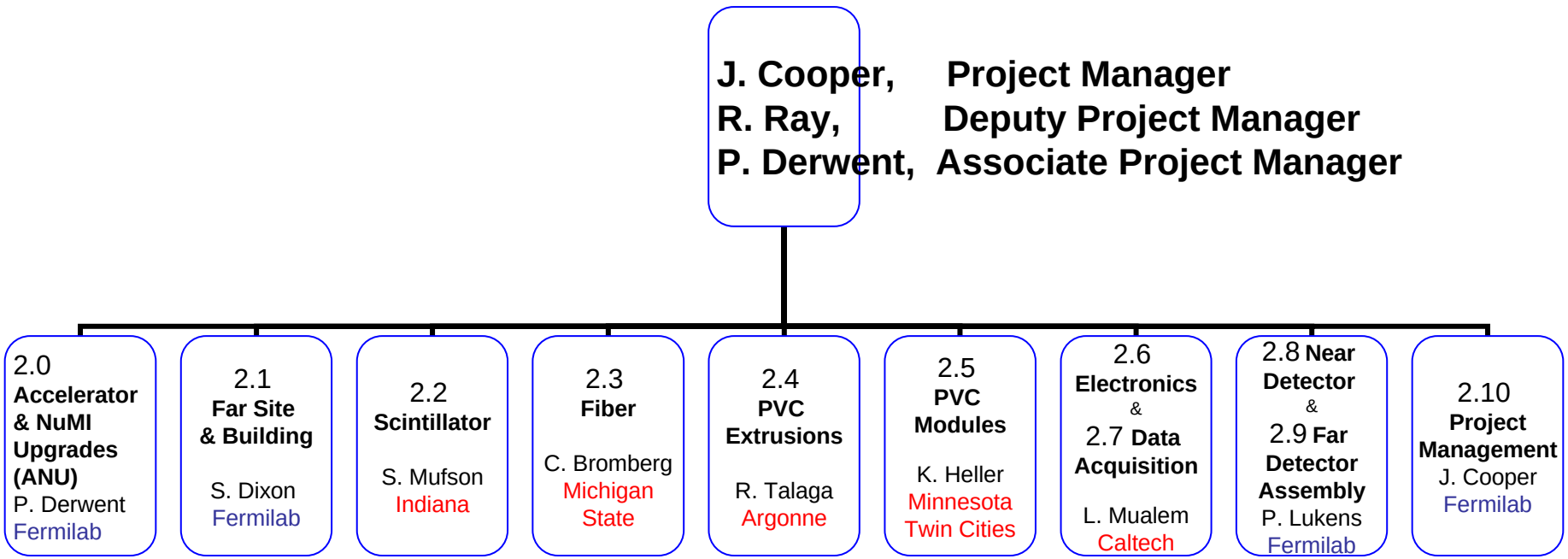
  - **Vacuum Lifter & Adhesive Machine** (Argonne Nat'l Lab)
    - Moves extrusion modules to block after applying adhesive
  - **Block Pivoter** (Fermilab)
    - Lifts 143 ton blocks from flat assembly position to vertical detector position



NOvA WBS/OBS

(Work Breakdown Structure / Organizational Breakdown Structure)

- **The WBS follows the work described on previous slides**
  - WBS 2.x for the construction project, similar WBS 1.x for R&D/Ops
  - WBS 1.8, 2.8 & 2.9 has an additional integration responsibility
- **The OBS follows the lead institutions for the work**



- **These "Level 2" managers are technical managers and CAMs**
  - 3 other CAMs are Level 3 managers in WBS 2.0
  - All CAMs have other non-project responsibilities

Summary

- **NOvA has a CD-2 baseline with a TPC of $ 278 M**
  - And has CD-3a for a limited $ 24 M set of critical path / long leadtime items
  - CD-3b Review scheduled for July 21-23
  - Trying to match CD-3b to FRA EVMS Certification by Oct 1, 2009
    - This date is assumed in our baseline schedule, risks are documented

- **NOvA has completed ~ $ 20.9 M through FY08**
  - **The project is ~ 10% complete**

- **NOvA has ~ $ 89 M of funding authority**

- **NOvA began exercising FRA EVMS with the October 2008 report**
  - Some parts have been in place since CD-1 (May 07)
  - Most other parts came on line during calendar 2008
  - Some parts were tweaked in January 09 to match changes Fermilab FRA Procedures
    - We have done January, February, March 2009 under a fixed set of FRA procedures