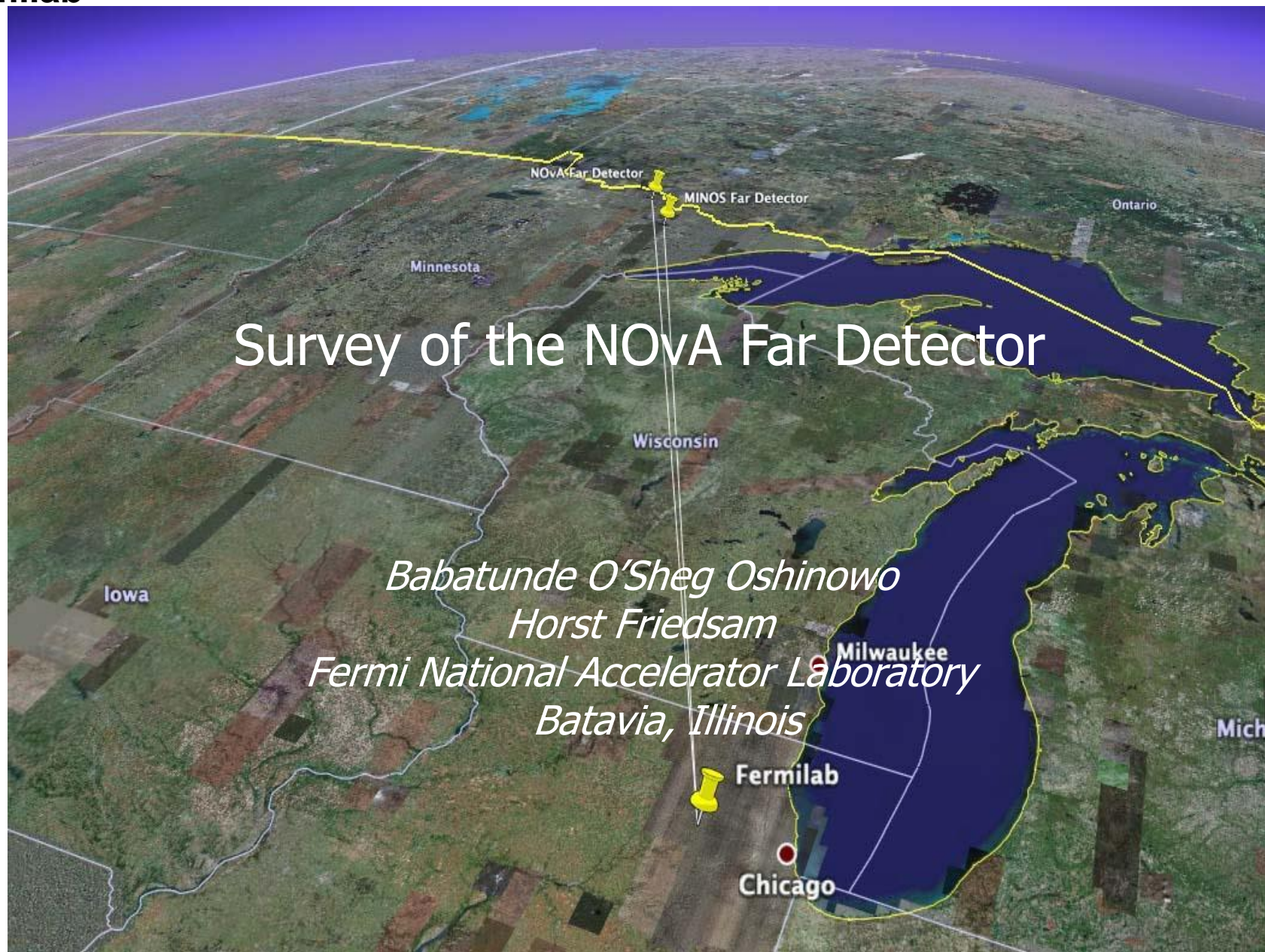




Survey of the NOvA Far Detector

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Horst Friedrichs
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The NOvA Experiment

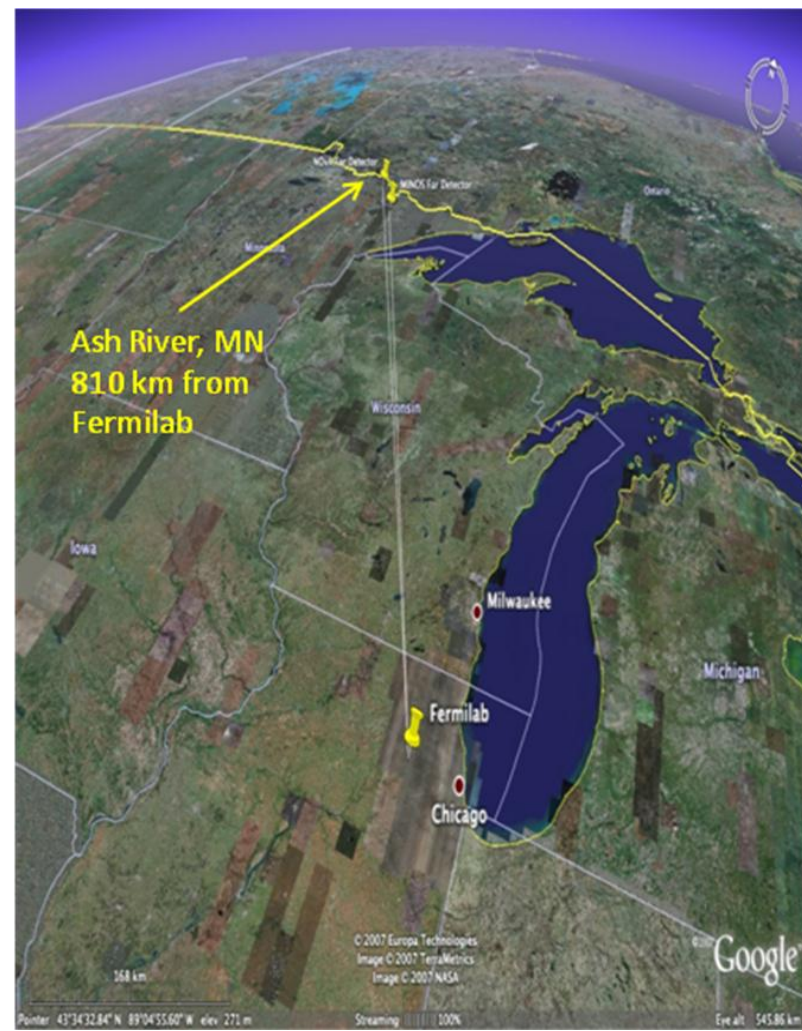


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NOvA: NuMI Off-Axis ν_e Appearance Experiment

ν_e = electron neutrino

- North America's most advanced neutrino experiment
- NOvA is a second-generation experiment on the NuMI beamline
- The NOvA project also includes accelerator upgrades to bring the NuMI beam intensity from 400 kW to 700 kW
- Uses two detectors to look for changes in the neutrino beam as it travels:
 - Far Detector** in Ash River, Minnesota
 - Near Detector** at Fermilab
- Run for 6 years : 2015 – 2021



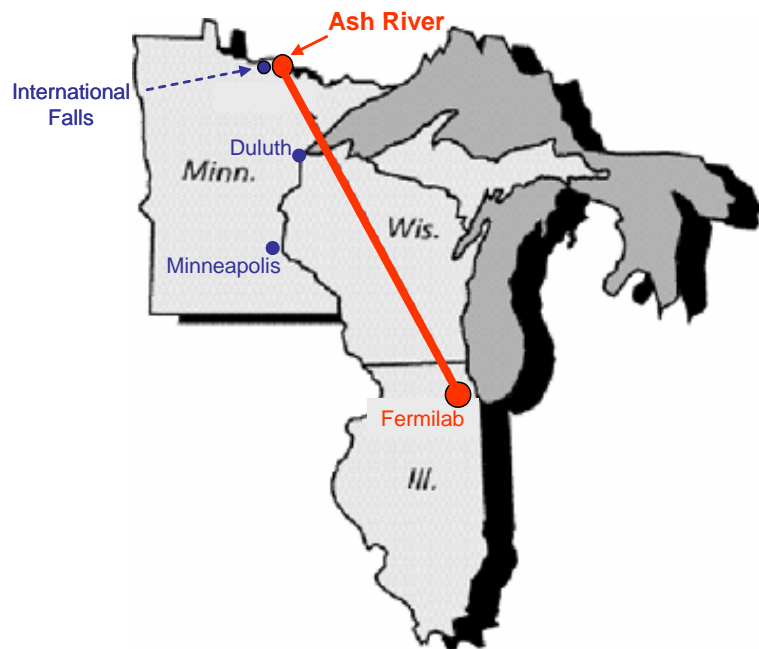


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Far Detector Site



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- This site is at 810 km from Fermilab, about 11 km off-axis
- The Ash River site is the farthest available site from Fermilab in the U.S. along the NuMI beamline





NOvA Detectors

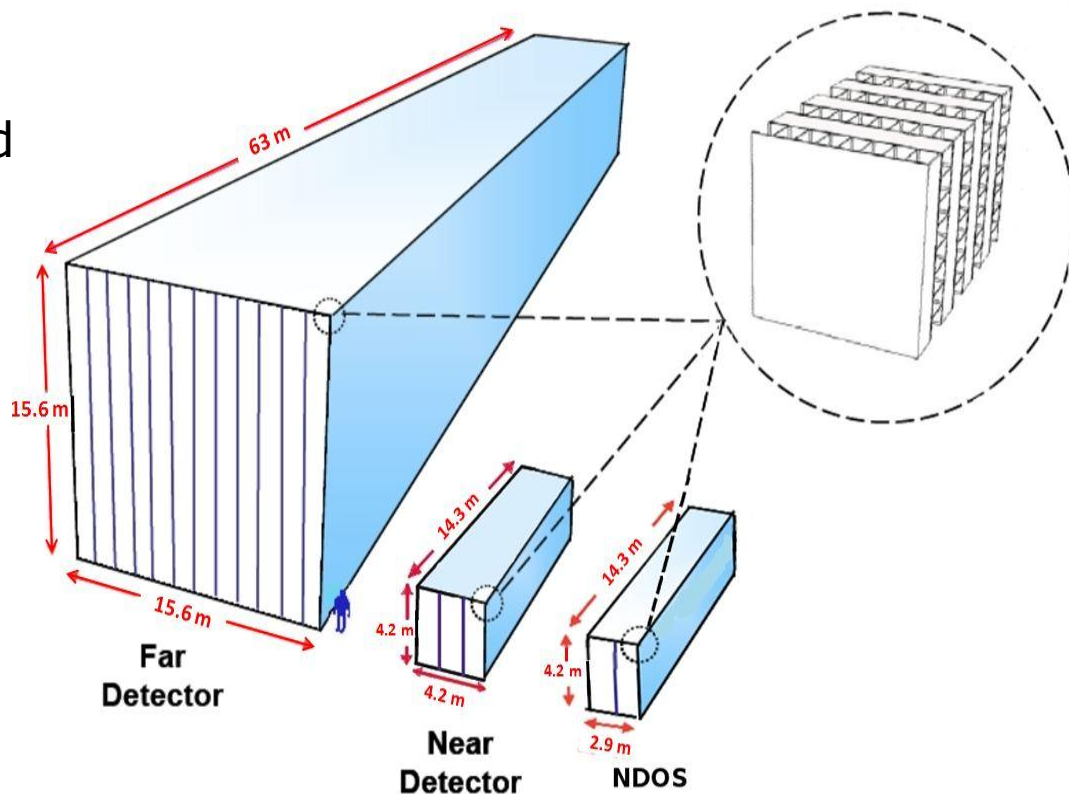


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NOvA Detectors:

- A 14 kTon Far Detector sited 14 mrad off the NuMI beam axis at a distance of 810 km at a distance of 11 km (Assembly underway at Ash River)
- A 0.3 kTon Near Detector identical to the far detector sited 14 mrad off the NuMI beam axis at a distance of 1 km from the NuMI Target (Begin installation Spring 2013)
- An 84 Ton NDOS (Near Detector On the Surface) identical to the Near Detector sited on the surface 107 mrad off the NuMI beam axis in the NOvA Near Detector Surface Building at Fermilab (IWAA2010; Completed and running since November 2010)



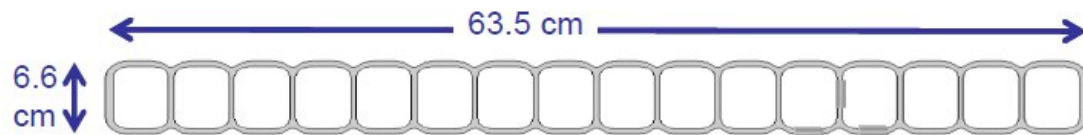


NOvA Detector



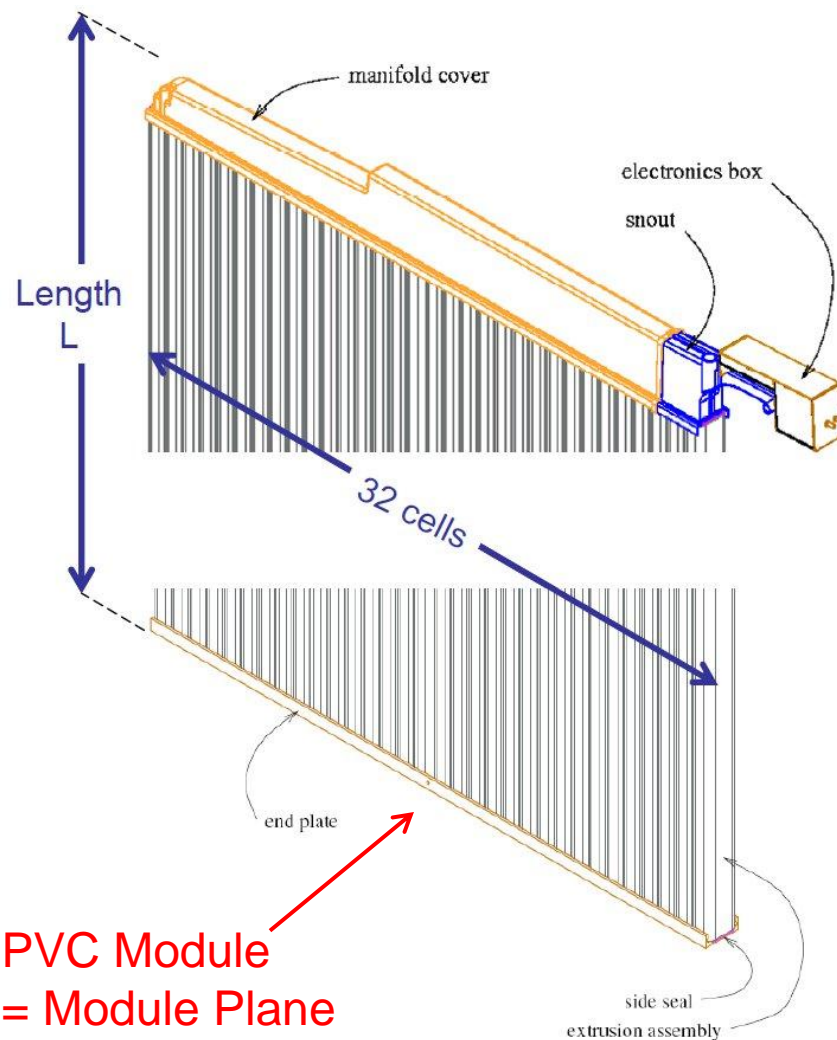
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← PVC Extrusion

- The NOvA detectors are constructed from planes of PVC modules
- Extrusions have a cellular structure, with 16 isolated cells per extrusion
- A module of 32 cells is constructed from two 16-cell PVC extrusions glued together
 - $L = 15.6 \text{ m}$ for Far Detector
 - $L = 4.2 \text{ m}$ for Near Detector
- Modules are capped by a Manifold and an End Plate/Cap to contain the liquid scintillator
- Twelve (12) extrusion modules get placed side by side on a flat assembly table to form one plane of the Far Detector



PVC Module
= Module Plane



NOvA Block



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- 32 planes make 1 NOvA **block**
- 5 blocks make 1 **super block**
- NOvA block (**B**) configuration is as follows:

$$\mathbf{B} = \mathbf{v}_0 \mathbf{h}_1 \mathbf{v}_2 \mathbf{h}_3 \mathbf{v}_4 \mathbf{h}_5 \mathbf{v}_6 \mathbf{h}_7 \mathbf{v}_8 \mathbf{h}_9 \mathbf{v}_{10} \dots \mathbf{v}_{20} \mathbf{h}_{21} \mathbf{v}_{22} \mathbf{h}_{23} \mathbf{v}_{24} \mathbf{h}_{25} \mathbf{v}_{26} \mathbf{h}_{27} \mathbf{v}_{28} \mathbf{h}_{29} \mathbf{v}_{30} \mathbf{h}_{31}$$

where **v** are planes of vertical modules and
h are planes of horizontal modules
number of planes is counted from 0 (Upstream)
to 31 (Downstream)

- Block assembly starts from plane (or layer)
31 (**h₃₁**) on the assembly table and ends
with plane 0 (**v₀**)



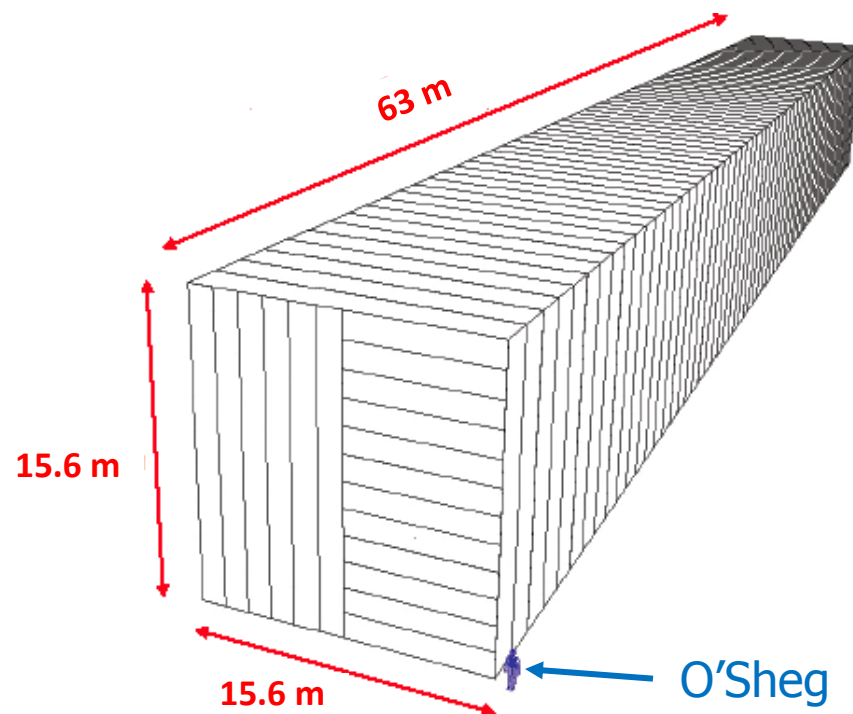


- The Far Detector (**FD**) consists of 29 blocks:

FD \rightarrow **B₀B₁B₂B₃B₄ B₅.....B₂₅B₂₆B₂₇B₂₈B₂₈**

where the number of blocks is counted 0 (Upstream) to 28 (Downstream)

- The NOvA Far Detector consists of 928 (15.6 m square) planes
- Twelve (12) modules make up a plane, and the planes alternate in having their long dimension vertical and horizontal





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NOvA Far Detector Building



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The NOvA Far Detector building contains

- The Detector Hall at the south end
- Block Assembly area at the north end





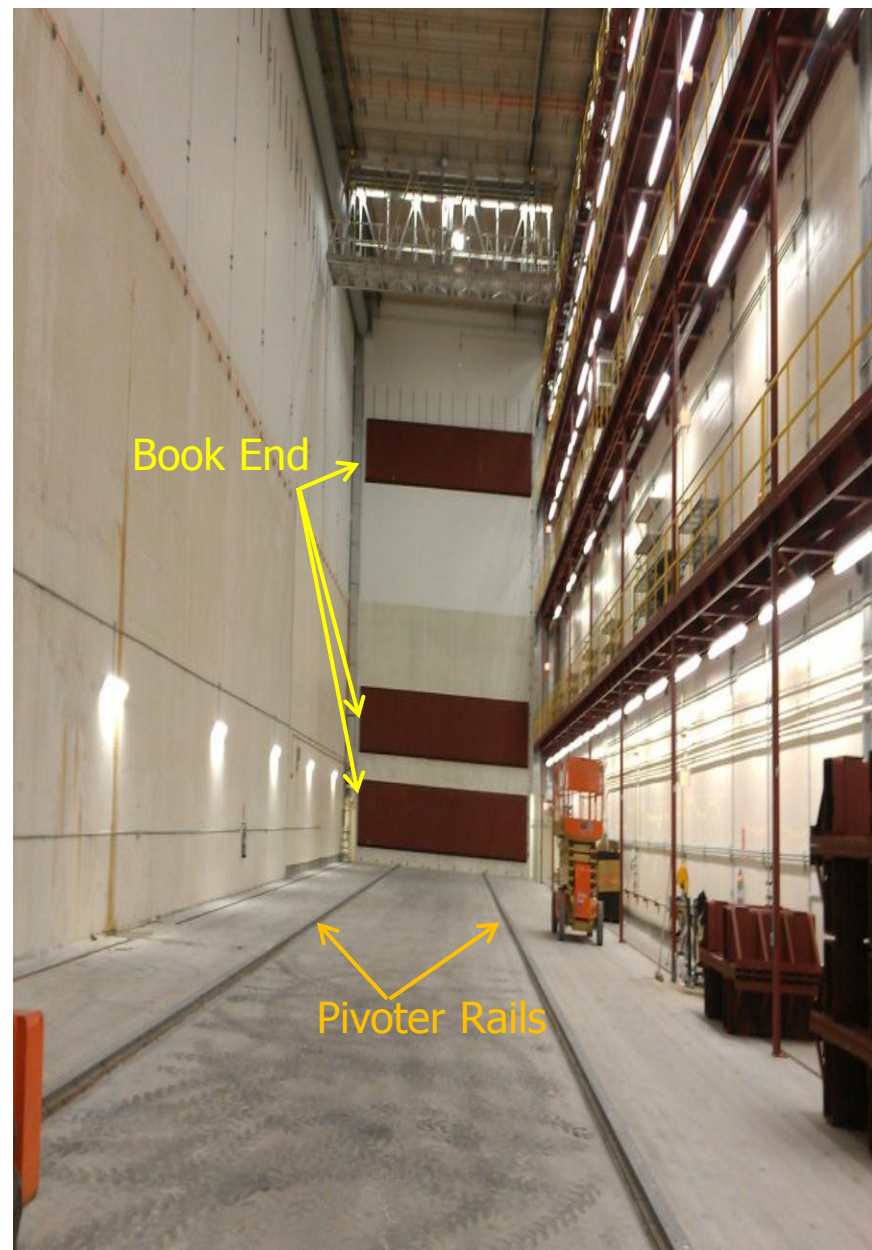
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The NOvA Detector Hall



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- The Detector Hall will house all the 29 NOvA blocks.
- The first block will rest on the Book End on the South Wall
- The Pivoter Rails are used by the Pivoter to transport each block to the far south end





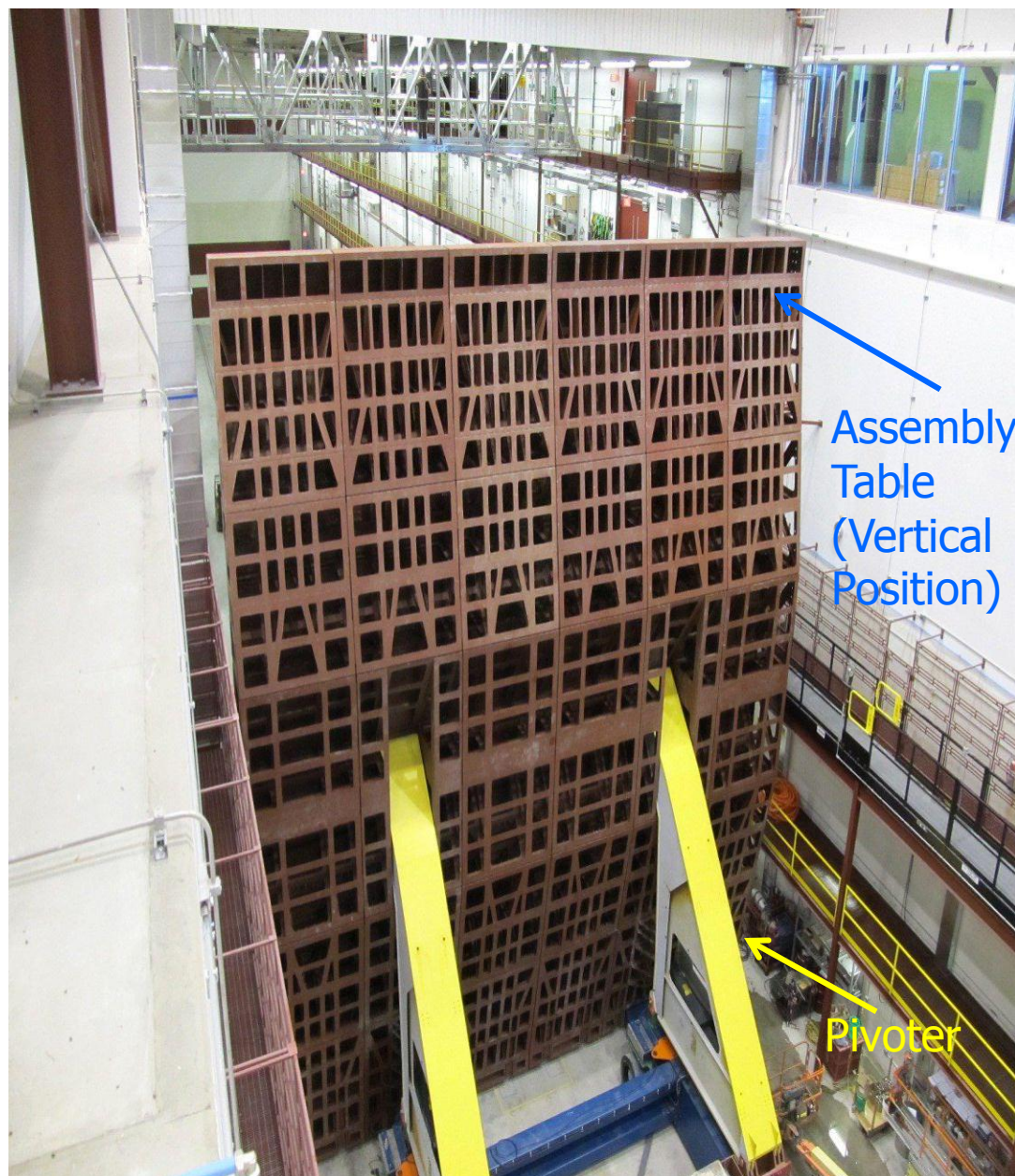
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Block Assembly Area



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- The Block Assembly area houses the NOvA Block Pivoter machine and the Pivoter Assembly Table that is used to build all the blocks
- All block are assembled on the assembly table while it is in its horizontal position





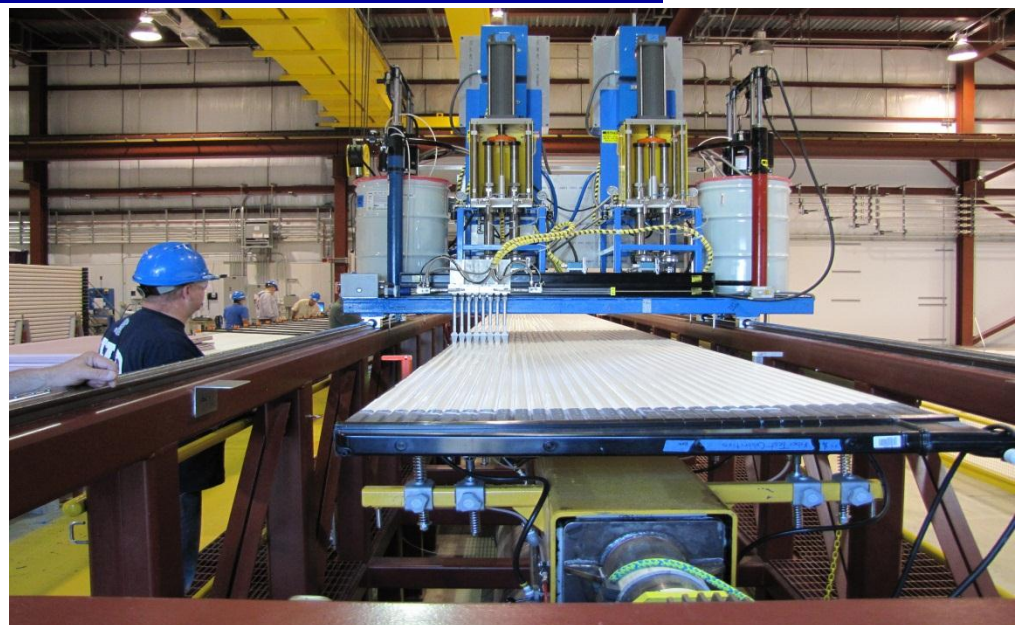
Block Assembly



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- Installation of the NOvA Far Detector is underway
- The Block assembly starts at the glue machine where glue is applied to the extrusion modules
- The modules are then transported to the assembly table by the lifting fixture to be glued to the next modules to form planes (layers)
- Alignment Posts attached to the assembly table are used as guides for the module installation
- The block is assembled in its horizontal position starting first with the downstream end
- Each plane is scanned with the Laser Scanner once the plane is completed





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Block Assembly



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- Once a block has been finished, the last module is painted black, the block Pivoter is used to move the block into place within the detector building to the south wall
- It then pivots 90° to set the block upright to the ideal location
- The block will then be filled with Liquid Scintillator





Survey of NOvA Far Detector

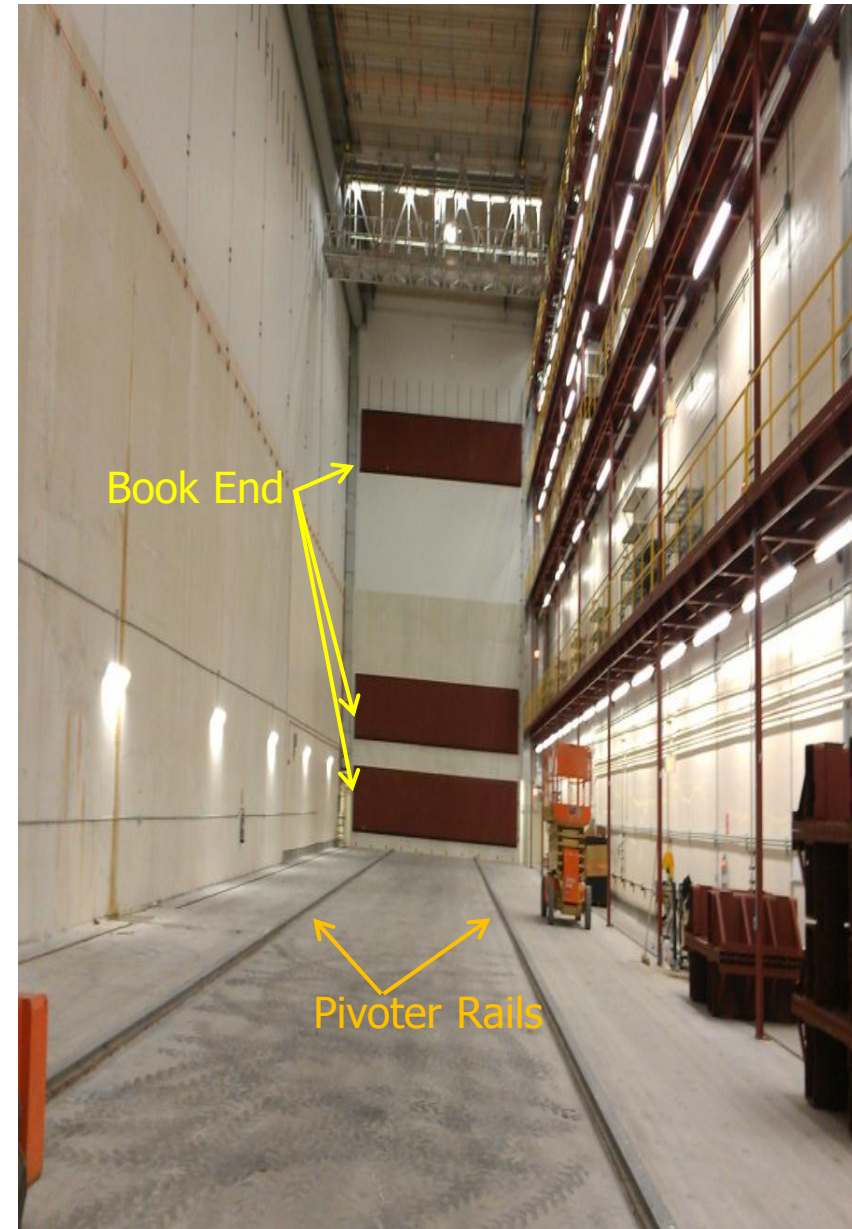
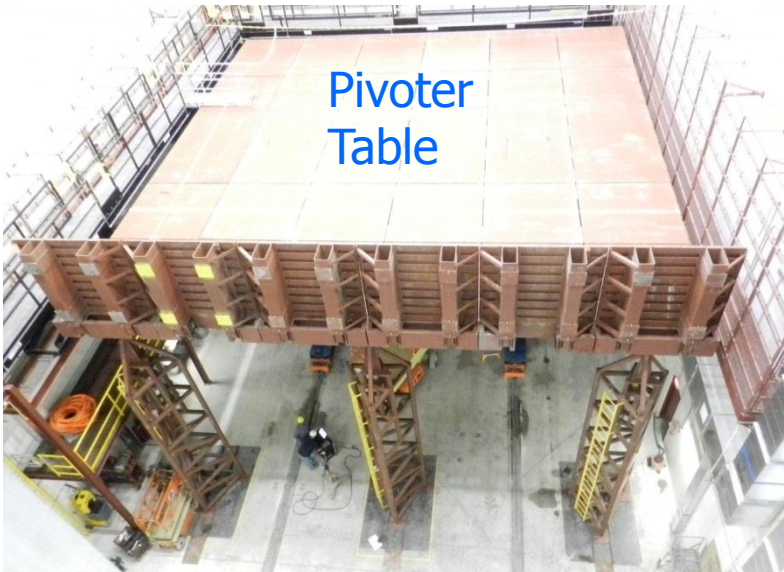


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Purpose:

- Establish a surface geodetic control network
- Establish a precision horizontal and vertical control network in the Far Detector building
- Floor Flatness measurements
- Book End as-built measurements
- Pivoter Rail measurements
- Pivoter Table Flatness measurements
- Block measurements





□ All Survey for the Far Detector was done with:

- An API Tracker3 Laser Tracker and Spatial Analyzer™
- Leica Absolute Tracker AT401
- Trimble S6 Total Station
- Geodimeter Total Station
- Leica DNA03 Digital level
- Trimble GPS Receivers
- Leica HDS6100 Laser Scanner system and its associated software





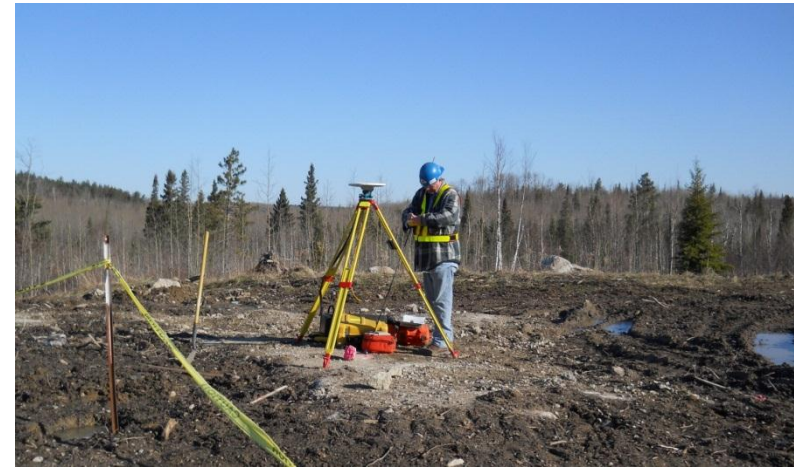
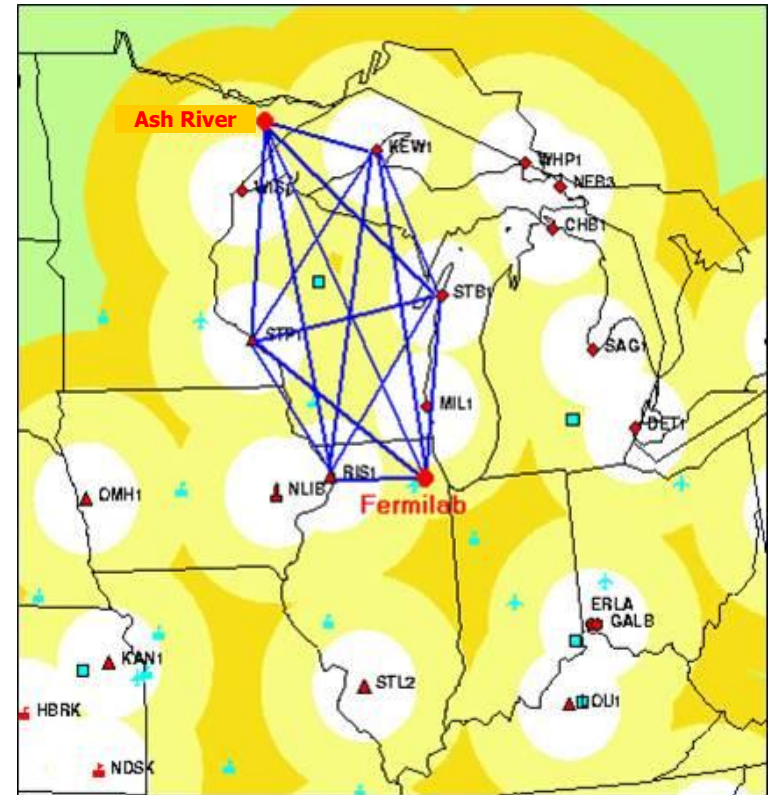
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Far Detector Surface Geodetic Network



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- Established a GPS surface geodetic control network that connects points at Fermilab to Ash River
- Tie surface control network to the National Geodetic Survey's **C**ontinuously **O**perating **R**efERENCE **S**tations (CORS) precision geodetic network
- All long baselines are known to better than 1 cm horizontally and vertically
- The network based on the NAD83 (North American Datum 1983) for horizontal datum and the NAVD88 (North American Vertical Datum 1983) for vertical datum



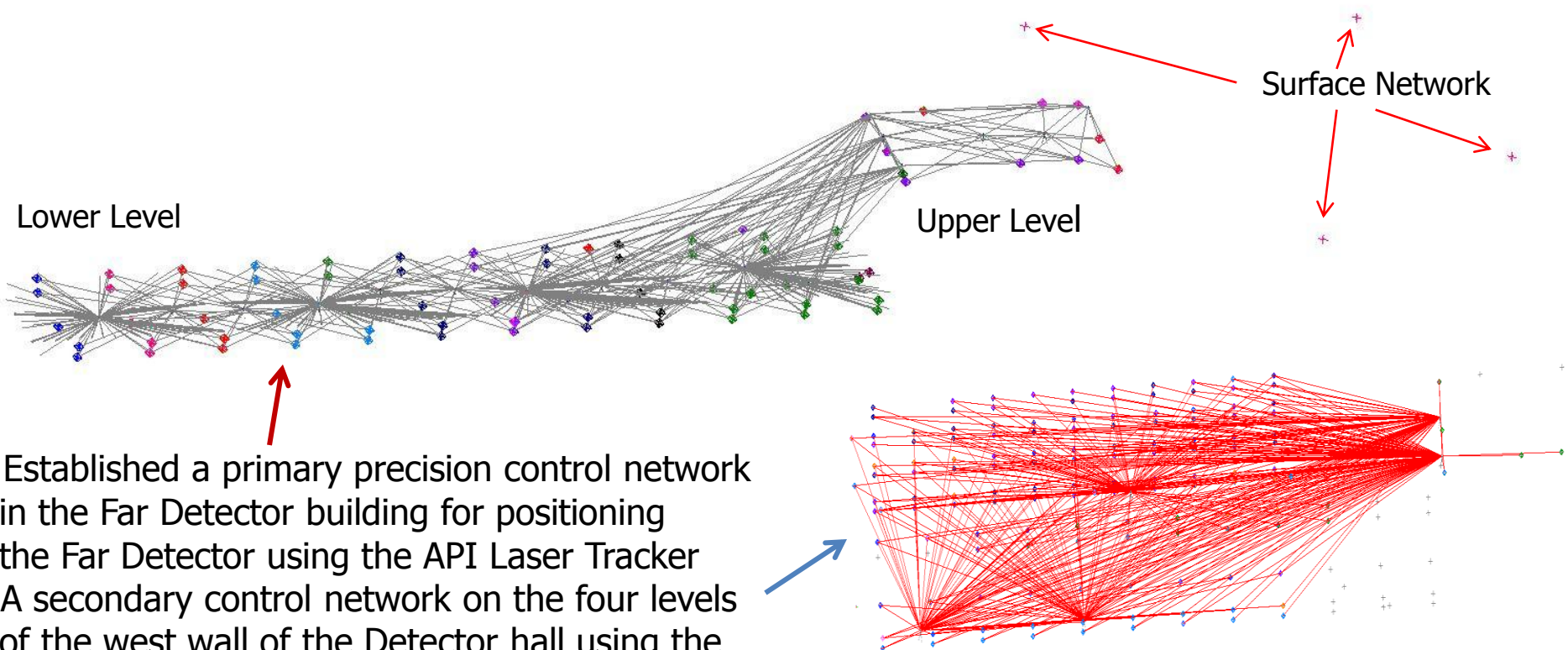


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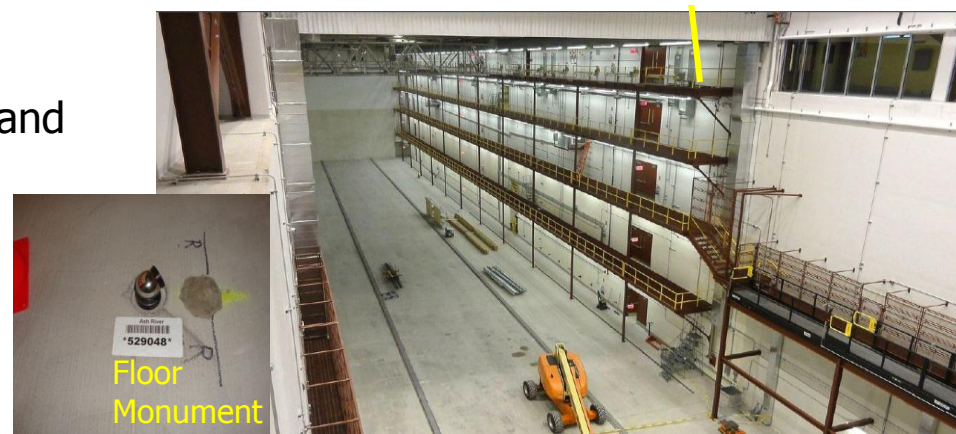
Far Detector Building Control Network



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- Established a primary precision control network in the Far Detector building for positioning the Far Detector using the API Laser Tracker
- A secondary control network on the four levels of the west wall of the Detector hall using the Leica AT401
- Primary network consists of 49 floor monuments and 36 wall monuments in the Far Detector Hall and the Detector assembly area. Secondary network consists of 44 wall monuments
- Tied the new building control network to the surface network using the Geodimeter Total Station



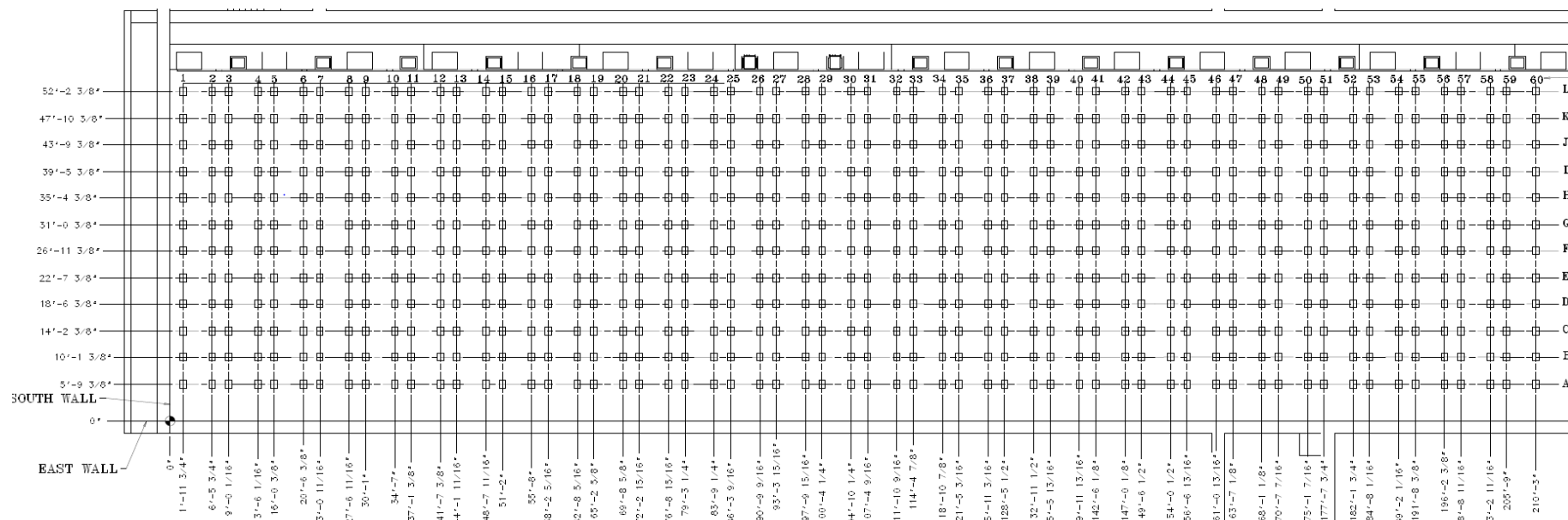


Floor Flatness Measurements

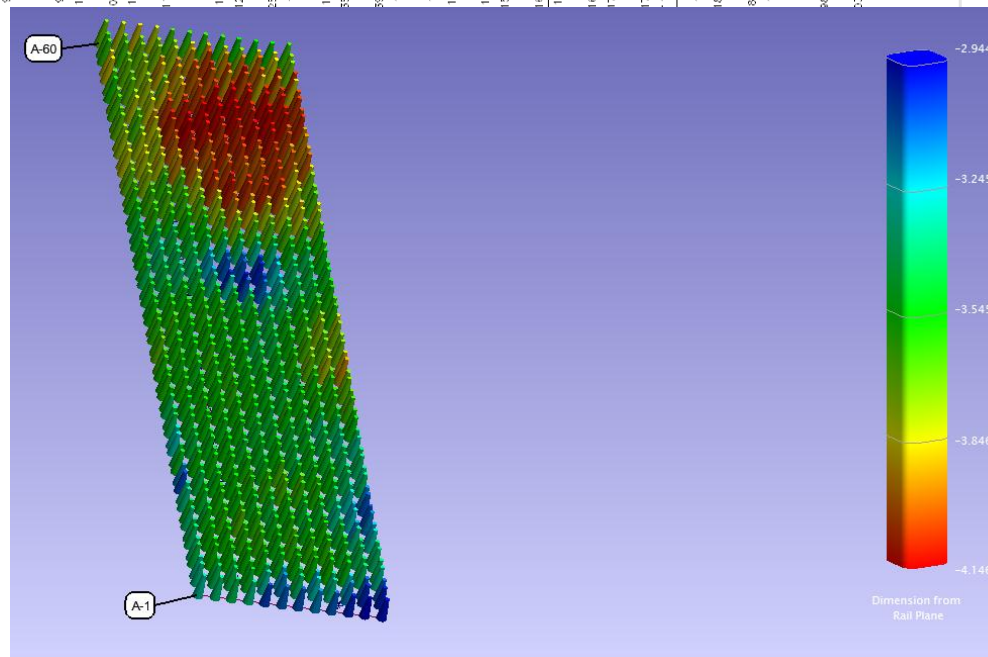


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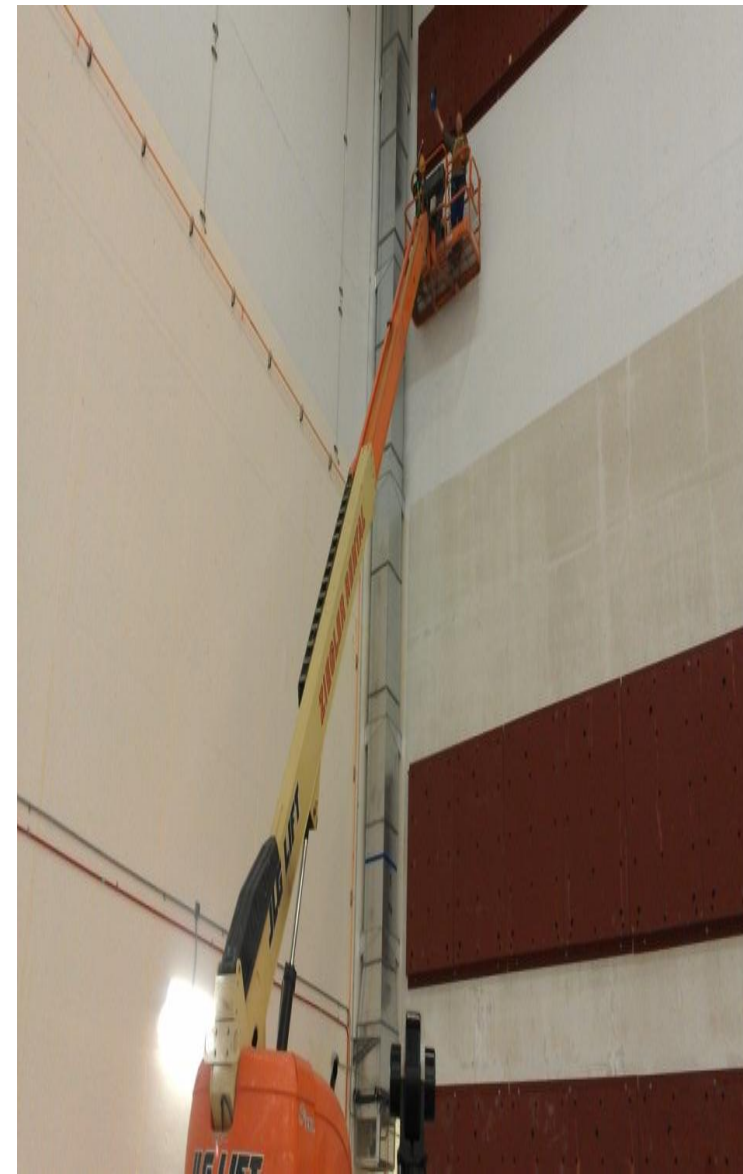
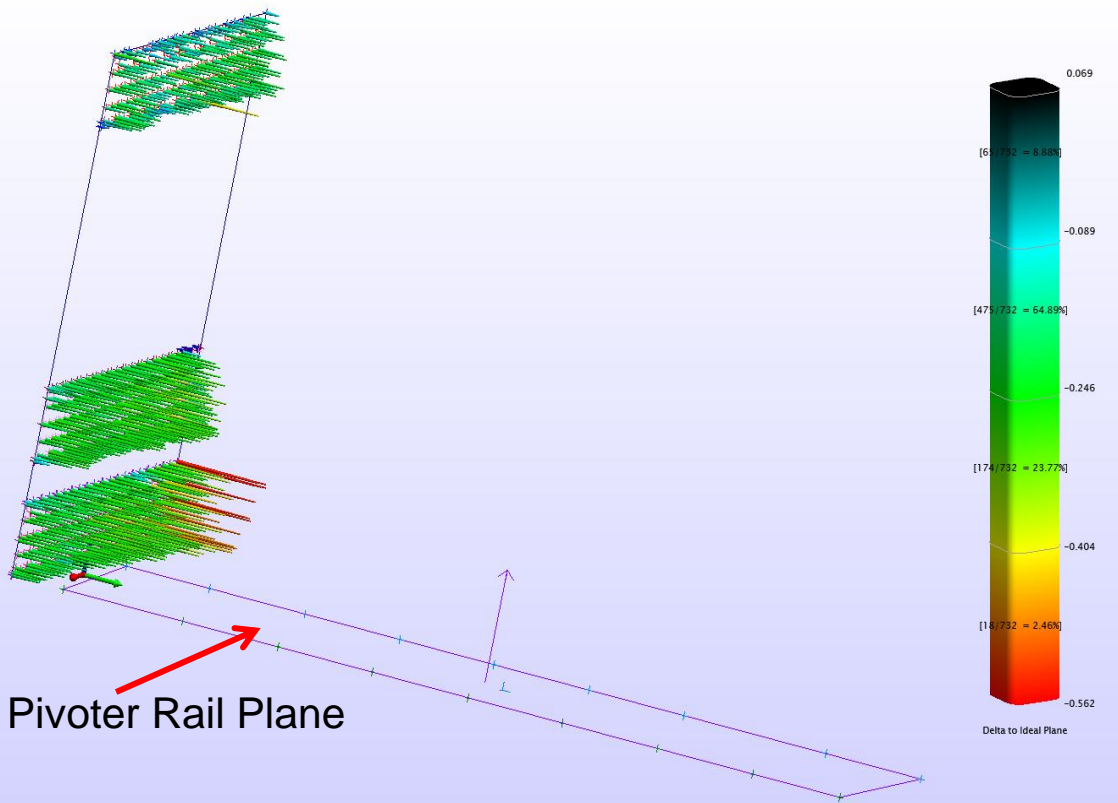


- Floor Flatness measurements using 720 grid points in the Detector Hall made with the Laser Tracker
- These measurement results will be used for shimming the Pivoter Table pallets that the blocks sit on





- The surface of the three sections of the Book End on the South Wall were measured with the Laser Tracker
- Deltas from the ideal plane defined by the Top Book End was reported to use for possible adjustments





- The surfaces of the two Pivoter Rails were mapped with the API Laser Tracker
- A plane fitted to the Pivoter Rails measurements was used to define the NOvA Far Detector Building Local Coordinate System





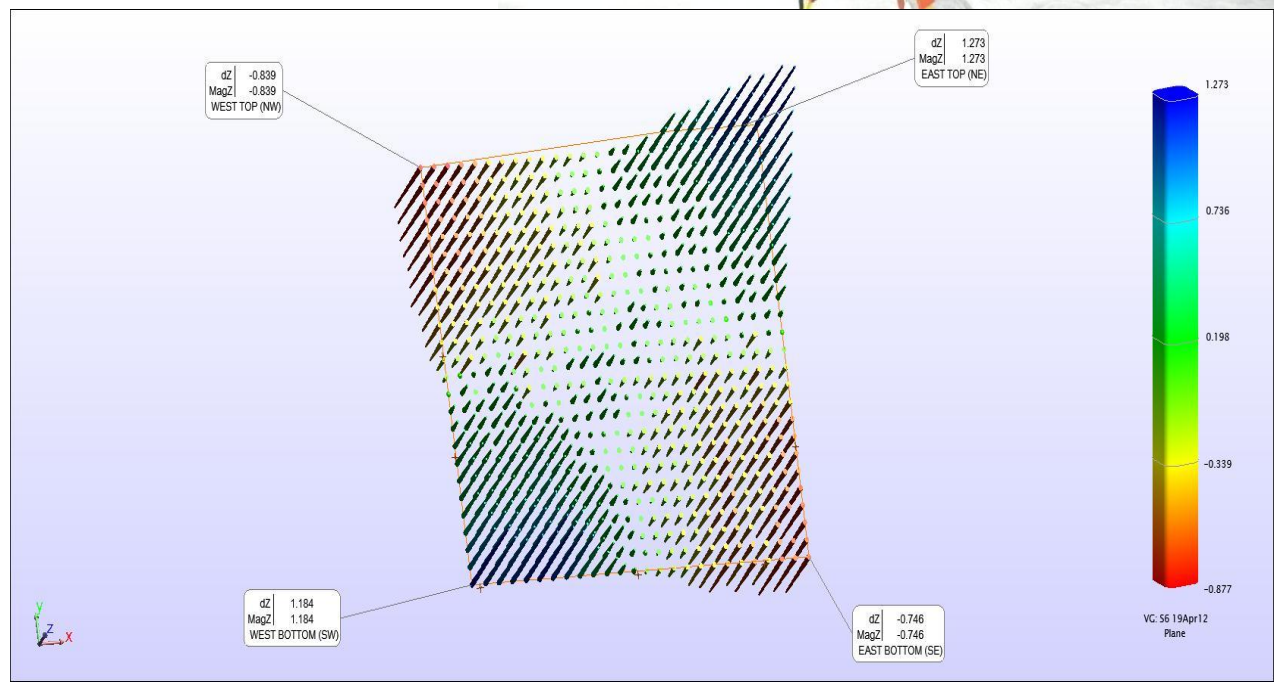
Pivoter Table Survey



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- The surface of the Pivoter Table was first measured with the Trimble S6 Total Station using 24" x 24" (61 cm x 61 cm) grids
- Measurement of the Table Top was made with the Table in the vertical position





Pivoter Table Survey



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- Flatness measurement of the east side of the Pivoter Table was made using the Laser Tracker with the Table in the vertical position
- Measurements were made at spots where the alignment posts were installed

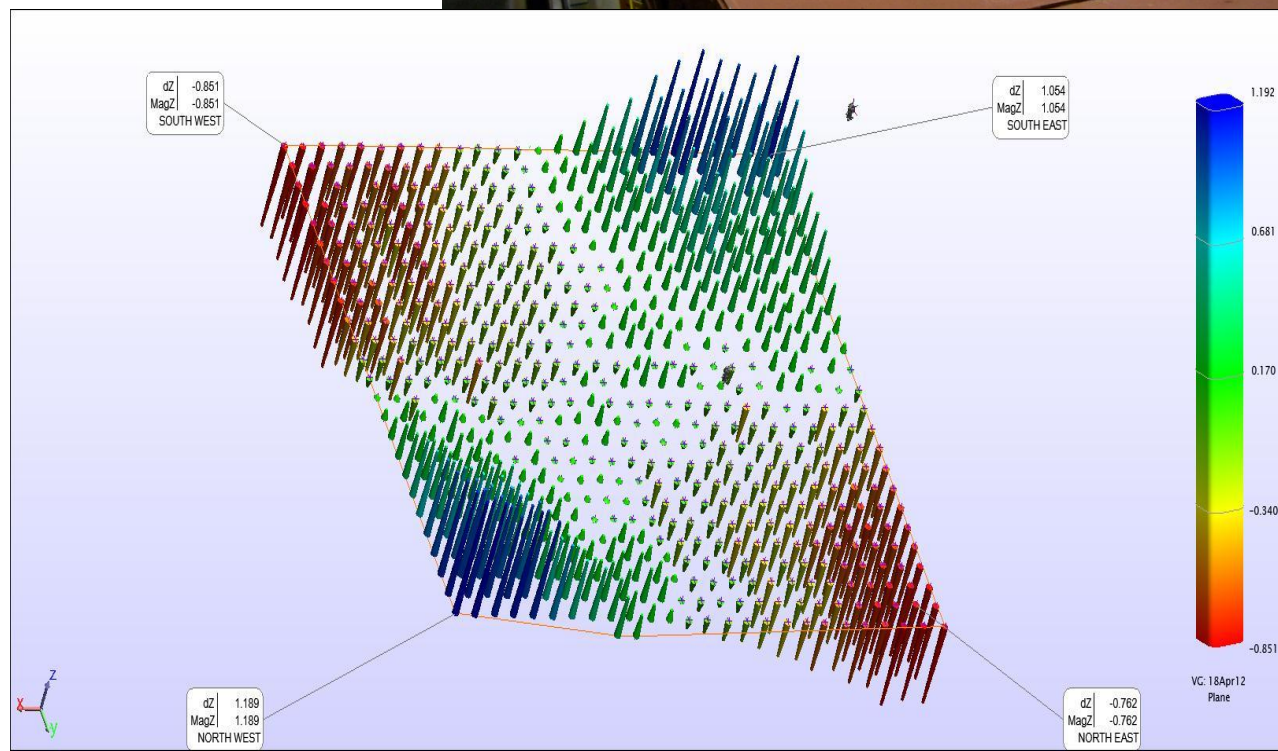




Pivoter Table Survey

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- The surface of the Pivoter Table was measured with the Laser Tracker using 24" x 24" (61 cm x 61 cm) grids
- Measurement of the Table Top was made with the Table in the horizontal position
- Based on these measurements, the Table surface was shimmed accordingly and covered with plywood



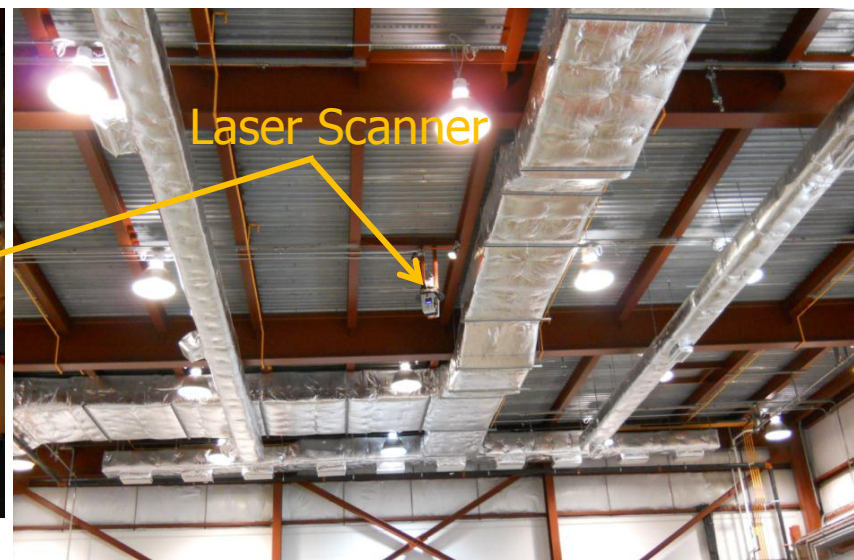


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NOvA Block Plane Measurements

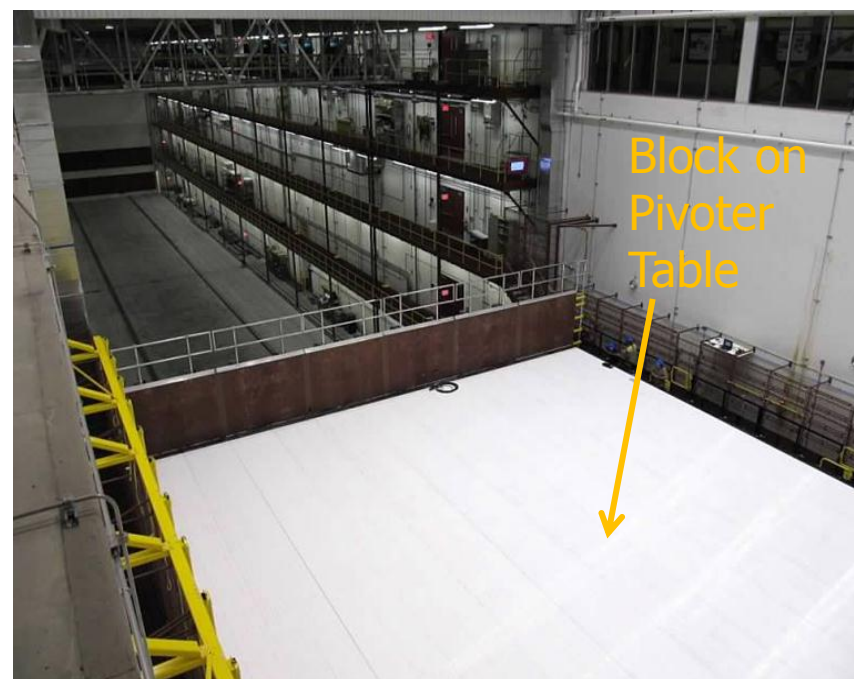


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- The surface of each of the 32 planes of the NOvA Block is scanned with the Laser Scanner located on the ceiling inverted directly above the Pivoter Assembly Table (See next presentation by Horst Friedsam)

- ❑ Overall Block Survey Tolerance:
 - Relative 2 mm (Horizontal) edge to edge;
 - Relative 0.75 mm or better (Vertical) between adjacent pieces
 - Angular tolerance of $\pm 2 \text{ mm}/15.6 \text{ m}$
 $= \pm 0.13 \text{ mrad}$





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What's Next?



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- The first block, Block 0, was completed on September 5, 2012
- Block 0 was tilted to its vertical position on September 10, 2012 and moved to the Detector Hall south wall Book End
- Installation of Block 1 is underway
- After Block 1 is completed and moved to the Detector Hall, the first two blocks will be filled with Liquid Scintillator
- The blocks will be surveyed before and after filling with Liquid Scintillator using the Laser Tracker at the lower level and Trimble S6 at the higher level
- 28 more blocks to go!





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Status NOvA Far Detector



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- The first super block is scheduled to be completed by the end of the year
- The Far Detector is scheduled to begin taking data in 2013
- Data taking will continue as the detector is completed in spring of 2014
- The NOvA experiment will run for six year : 2015 – 2021





Acknowledgment



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- ❑ I would like to thank
 - Alignment and Metrology Department members who participated in the NOvA Far Detector survey
 - Dr. Pat Lukens, Dr. Ting Miao and David Pushka - NOvA Collaboration

Questions?

