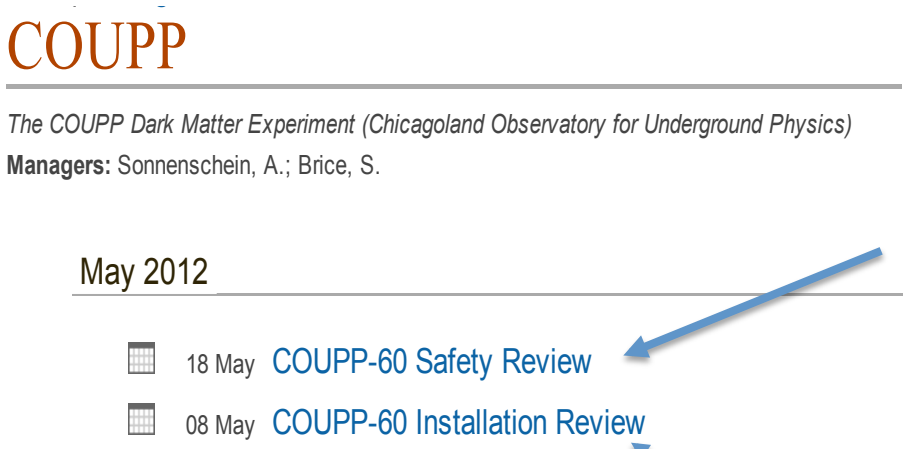
COUPP-60 Safety Review: Project Overview.

May 18, 2012

Andrew Sonnenschein
Fermilab

https://indico.fnal.gov Then go to “Experiments” and “COUPP”



Today’s review, focused on risk identification and mitigation, especially safety-related risks, but also including risks that would significantly impact resource requirements and schedule. What demands are made on SNOLAB?

Last week’s review at Fermilab, focused on readiness for move to SNOLAB, including physics background issues not discussed today. Were the problems identified in testing phase at Fermilab sufficiently resolved to warrant move to SNOLAB now?

COUPP-60 Safety Review

chaired by Tom O'Malley (SNOLAB)

Friday 18 May 2012 from **08:00** to **18:00** (Canada/Eastern)
at SNOLAB

Material document

Friday 18 May 2012

08:30 - 08:55 Committee meets in Camera *25'*
Speaker: O'Malley Tom
Material: **Slides**

08:55 - 09:00 Introduction *05'*
Speaker: Tom O'Malley (SNOLAB)

09:00 - 10:00 COUPP-60 Project Overview *1h00'*
Speaker: Andrew Sonnenschein (Fermilab)

10:00 - 10:45 Safety Assessment *45'*
Speaker: Erik Ramberg (Fermi National Accelerator Laboratory)
Material: **Slides**

10:45 - 11:00 Break

11:00 - 11:45 CF3I Exposure Risks and Mitigation *45'*
Speaker: Del Allspach (Fermilab)

11:45 - 12:15 COUPP-60 Pressure Vessel Design and Seismic Response *30'*
Speaker: Herman Cease (Fermilab)

12:15 - 13:00 Lunch

13:00 - 13:45 COUPP Operations *45'*
Speaker: Hugh Lippincott (Fermilab)
Material: **Slides**

13:45 - 14:15 COUPP4 Lessons Learned *30'*
Speaker: Eric Vazquez Jauregui (SNOLAB)

14:15 - 14:30 Break

14:30 - 15:30 Committee meets in Camera *1h00'*

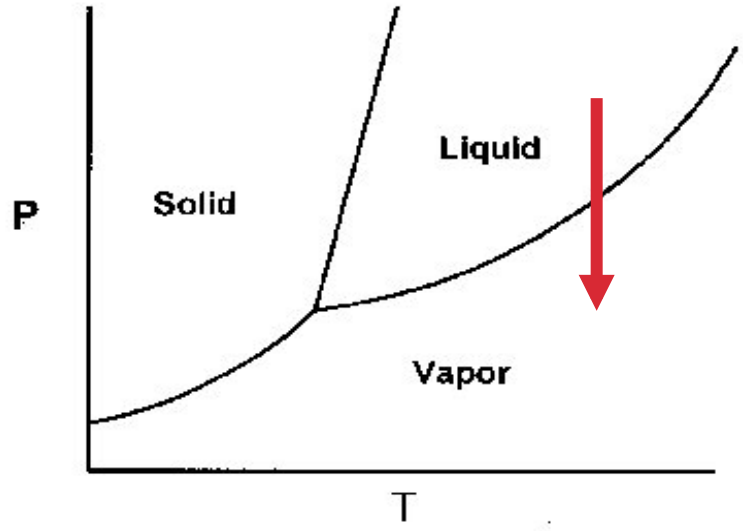
15:30 - 16:30 Debrief and discussions *1h00'*

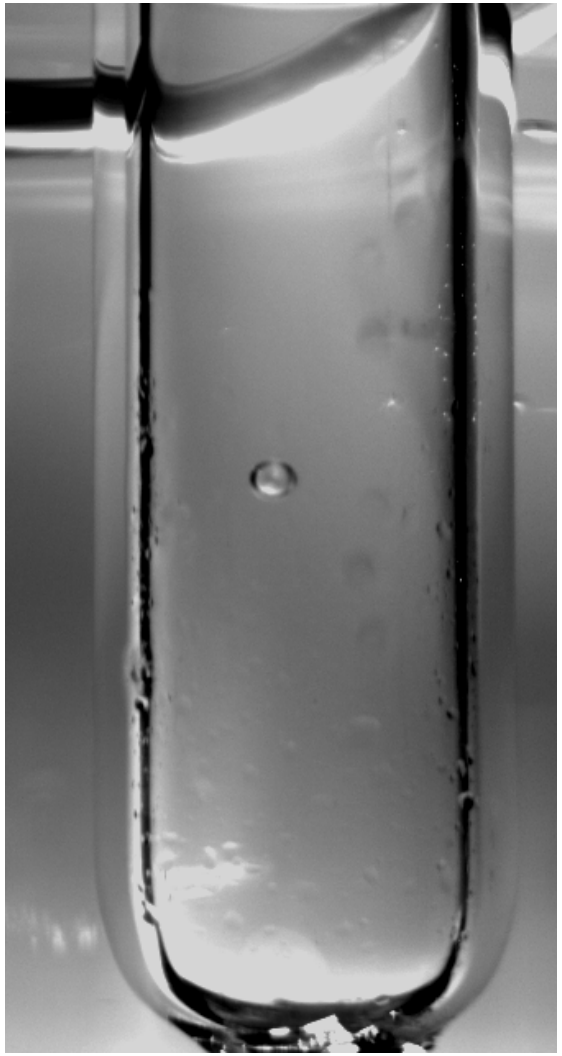
Contents:

- COUPP detector operating principle, history
- Description of the COUPP-60 system.
- Testing at Fermilab– problems found, responses.
- Current work status.
- Overview of planned installation at SNOLAB.
- The COUPP collaboration– who does what; COUPP-60 project organization.
- Schedule.
- Funding.
- Risk Register– includes safety, cost, schedule, quality
- Discussion of highest risk items
- Conclusion

COUPP: Operating Principle

1. Prepare volume of target liquid in a very clean, smooth glass container. Eliminate surface bubble nucleation sites!
2. Reduce the pressure of the liquid until it becomes superheated.
3. Record video images and sound while waiting for a bubble to appear.
4. When a bubble does appear, immediately pressurize the liquid to stop the bubble from growing.
5. Repeat cycle.

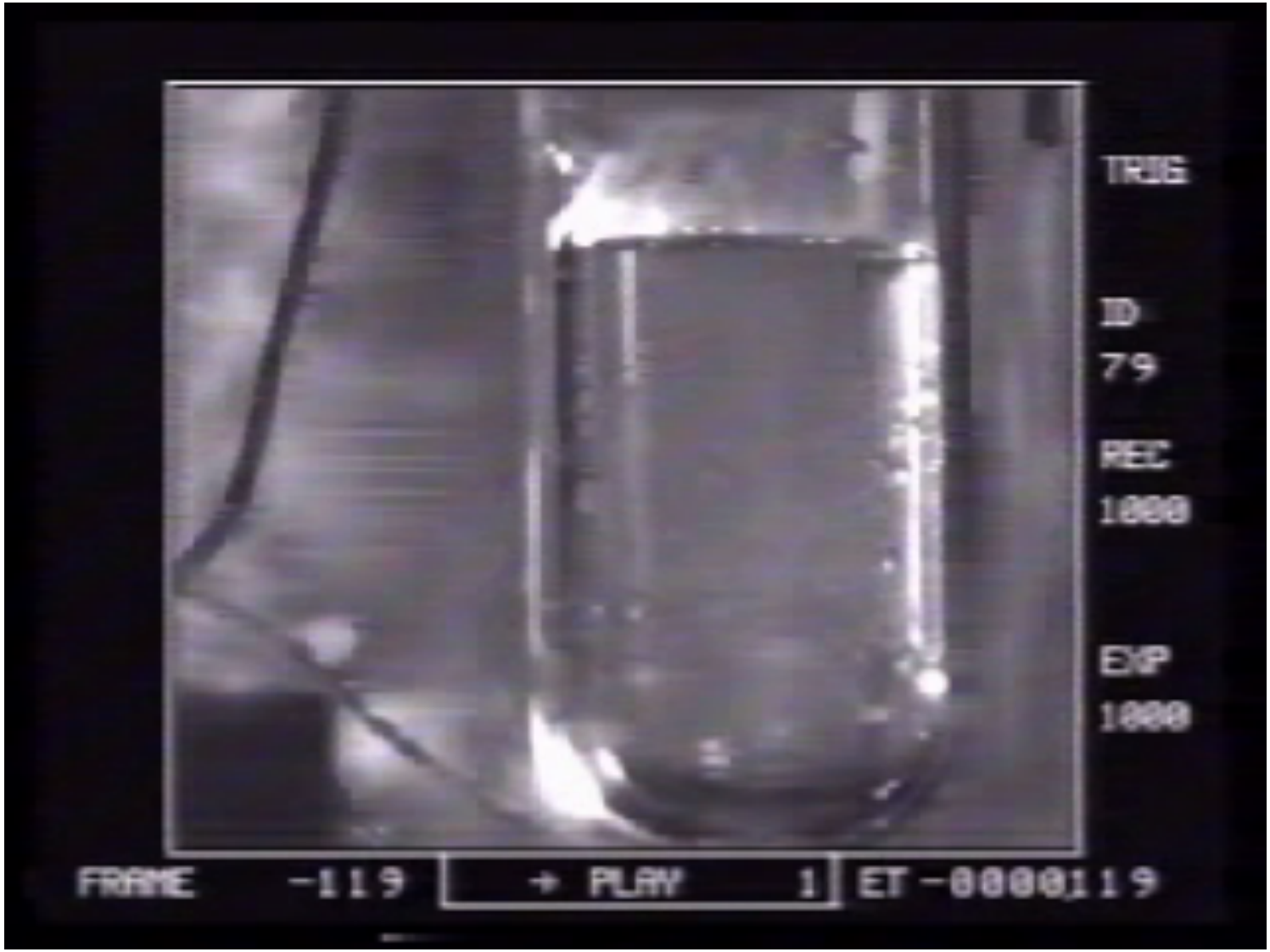




High Speed Bubble Chamber Movie

1000 frames/ second

^{241}Am-Be neutron source



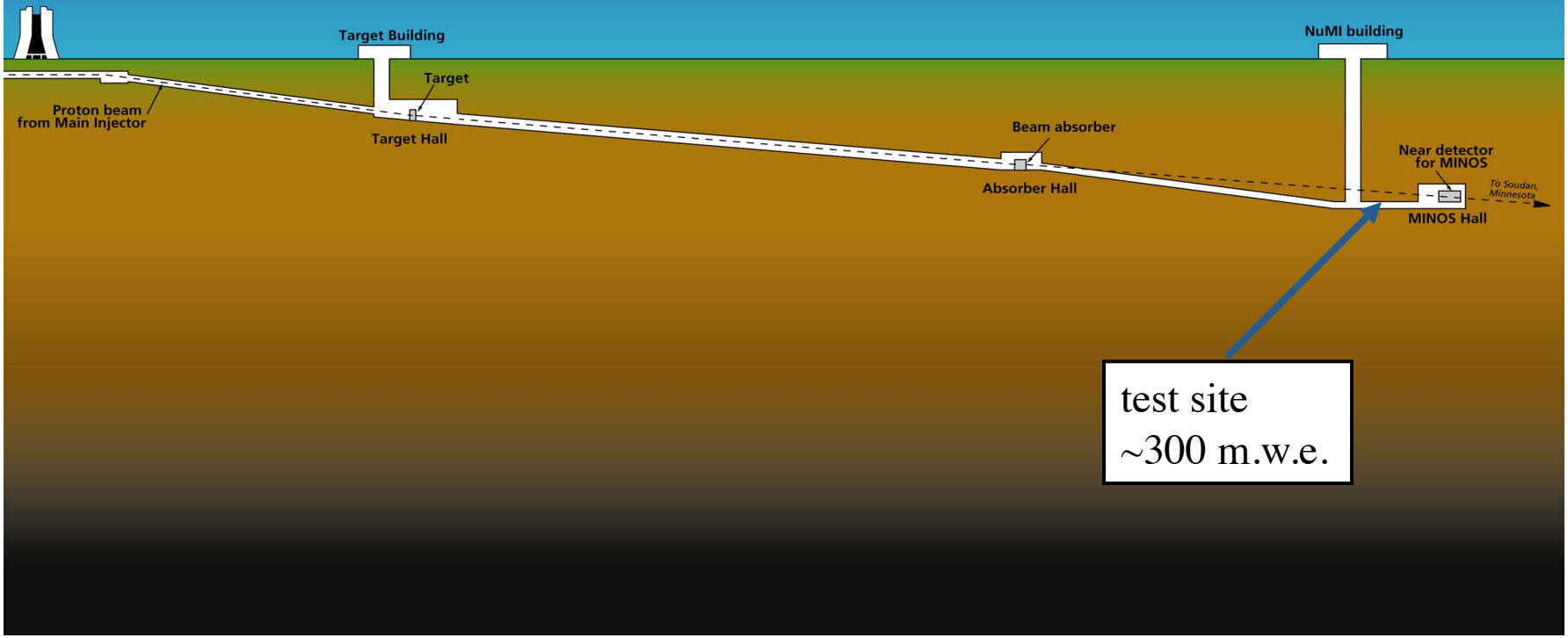
COUPP Timeline

	2003	2005	2007	2009	2011	2013
Mass	18 g	2-Kg		4-Kg		60-kg
Site	U. Chicago	Fermilab/ NuMI			SNOLAB	
Depth	10 m.w.e.	300 m.w.e.			6000 m.w.e.	
Backgrounds	7000 events/kg-day	77 events/kg-day		0.7 events/kg-day	0.04 events/kg-day	
Physics		Best spin-dependent (W-p)			Best spin-independent?	
Technical Developments	Continuously sensitive bubble chamber	10^{-10} gamma rejection Pressure balancing of inner/outer vessel	Radon reduced	Fused silica inner vessel wall events eliminated Retroreflective illumination	>99% accoustic alpha rejection	

- Active mass increased by 4 orders of magnitude 2003-2011
- Backgrounds decreased by 5 orders of magnitude

NuMI Tunnel Project

at Fermilab



Small Chamber Runs at Fermilab 2005-2010

- Small chamber initially installed at Fermilab NuMI tunnel in 2005. Served as R&D platform and proof-of-principle.

- Rebuilt several times to incorporate new features-
  - Higher purity materials
  - External muon tagger
  - Acoustic sensors
  - Pressure and temperature control upgrades

- Required early consideration of safety and operational issues related to running underground at a “remote” site.

- Inner fused silica vessel containing CF3I and H2O. Has a flexible bellows element to equilibrate with external pressure.

- Outer conventional steel pressure vessel.

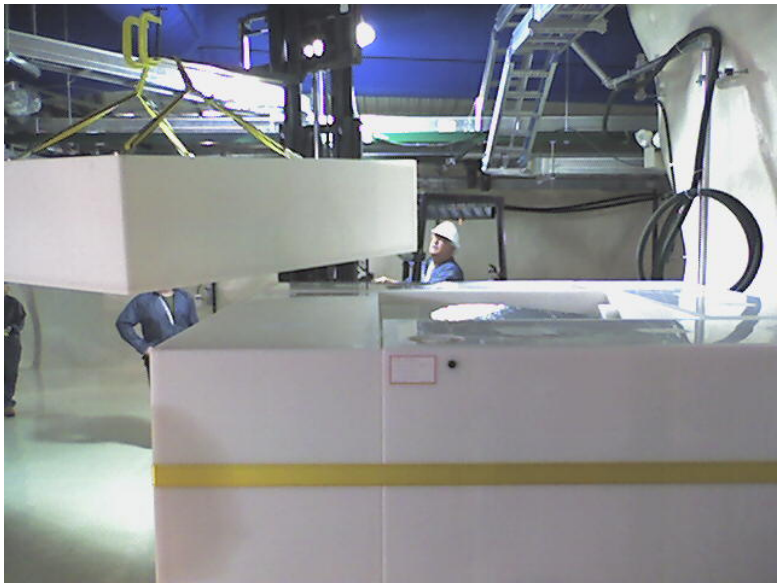
- Space between vessels filled with hydraulic working fluid (propylene glycol)

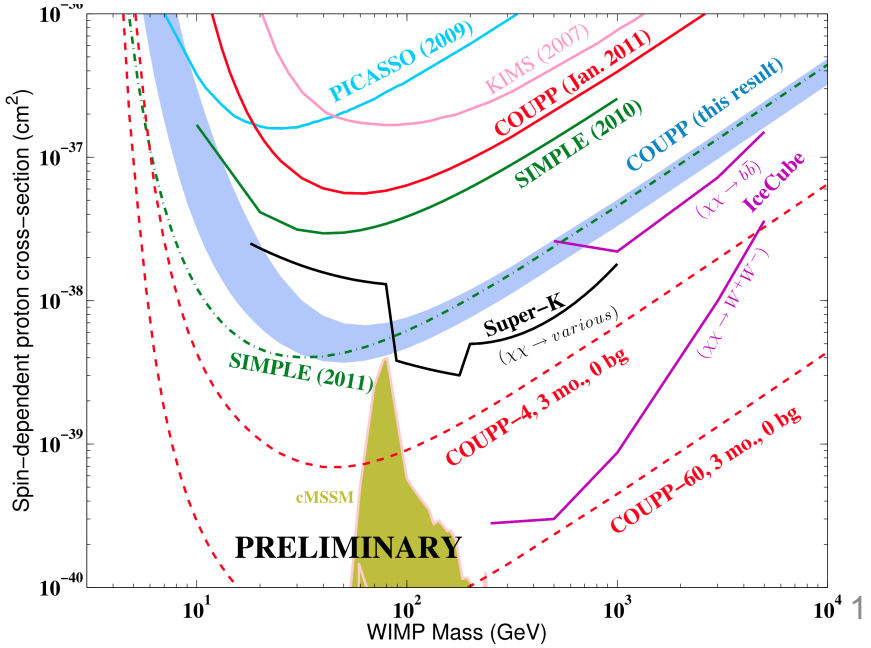
COUPP-4 At SNOLAB!

• 4-kg Detector transferred to SNOLAB in Summer 2010 after runs at Fermilab indicated that neutrons from cosmic rays had become limiting background.

• First physics run ended June 2011. Important new physics result for spin-dependent WIMP search.

• Discovery of unexpected sources of neutron backgrounds: glass windows, acoustic sensors. These are now being replaced with cleaner materials.



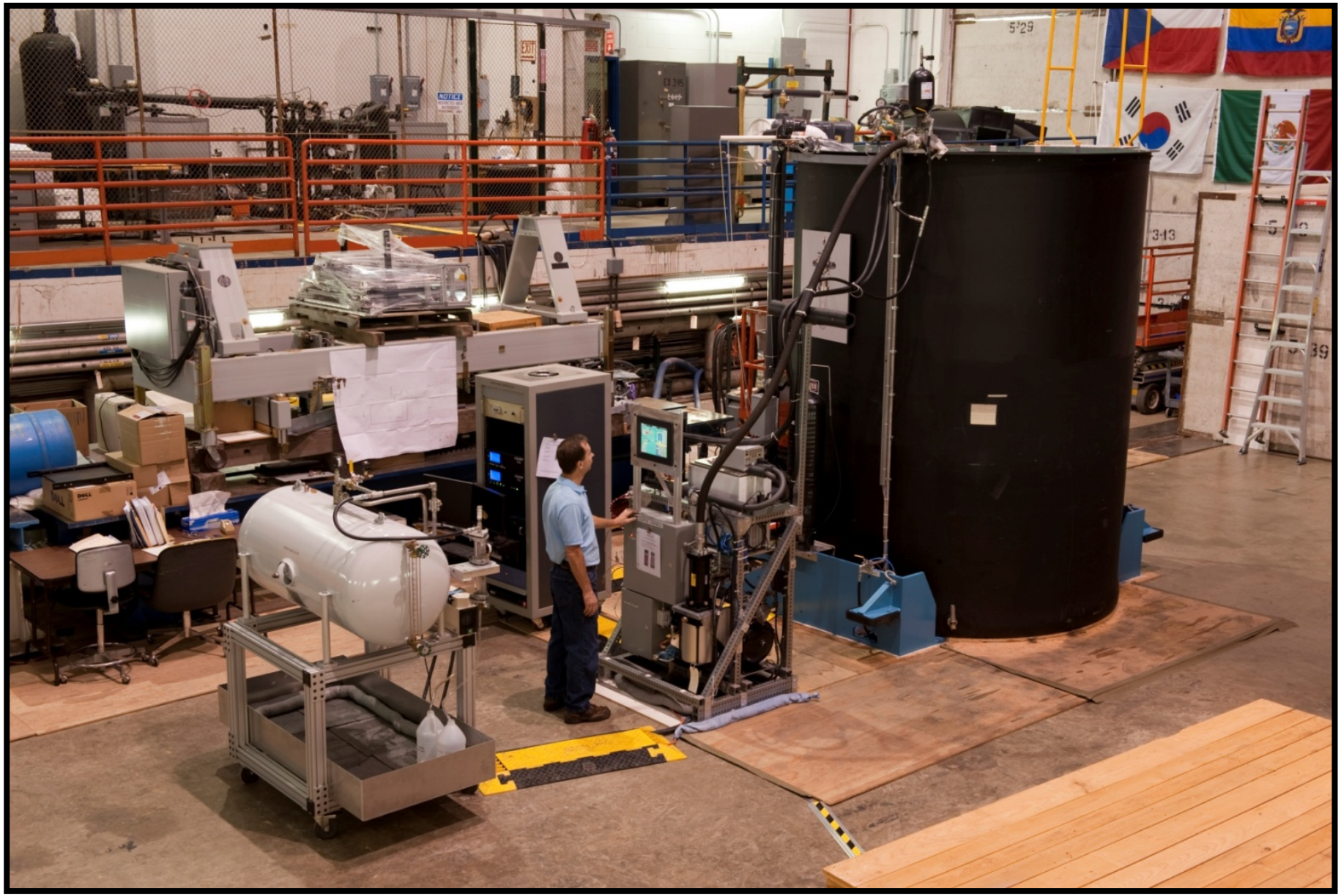


COUPP-60

- Scale up of COUPP-2/4kg concept to larger volume (60 kg nominal target mass)

Inner Vessel

COUPP-60 System Test



COUPP-60 Current Status

• Testing at Fermilab completed in Fall 2011, including runs above ground and runs at shallow depth (NuMI tunnel).

• Revealed a number of problems which were described in May 8 Fermilab (See slides on Indico). The problems included:

- **Chemical instability** of CF3I target liquid under intense illumination.
- Impurities in CF3I supply causing **excess surface bubbling**.
- Some parts of chamber were poorly illuminated.
- Video cameras were too slow and resolution not good enough.
- Vulnerabilities in hydraulic system, including hydraulic hose failures, pump control problems.

• A plan was proposed to DOE to fix problems and deploy the detector at SNOLAB. Proposal was funded in FY11-FY12.

• Implementation is underway (following slides)

Work Plan- As Proposed to DOE in FY11

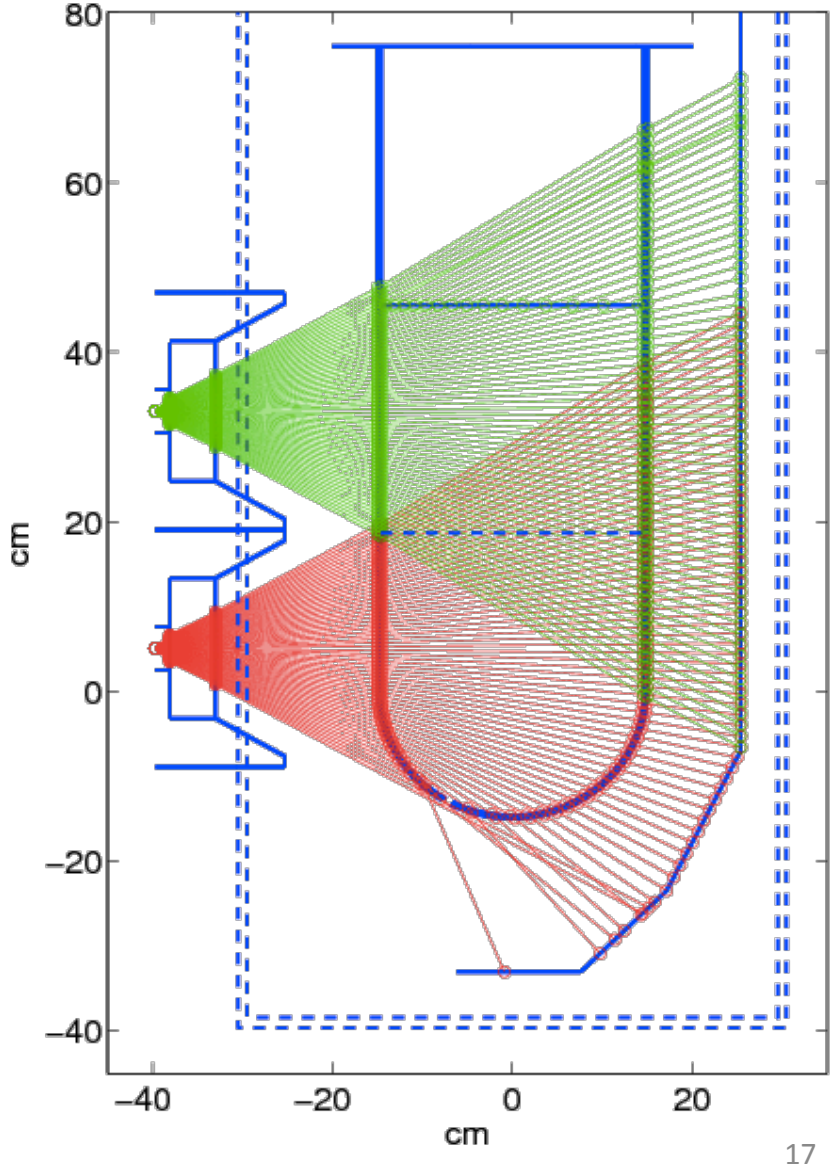
1. Produce a comprehensive safety plan for the SNOLAB installation of COUPP-60. The critical issue for this study is the strategy for avoiding high levels of human exposure to CF3I in case of equipment failures... ✔ See Del Allspach's talk in this review. We propose additional ventilation equipment to mitigate risk of exposure.
2. Work with SNOLAB to complete utility lines and the COUPP water shielding tank to anticipate the arrival of the COUPP-60 detector. These items are primarily the responsibility of SNOLAB, with Fermilab providing interface requirements. Work in progress. Drawings finished (Ramberg's Talk). Parts ordered. Assembly started ✔
3. Materials screening program for radiopurity. Retrofitting and removal of internal neutron sources from both COUPP-4 and COUPP-60. After extensive radiopurity studies at U. Chicago, acoustic sensor material was fabricated at Virginia Tech. Sensors manufactured and test at IUSB. Now being installed on COUPP-4, with COUPP-60 sensors expected later in summer. Fused silica pressure vessel windows have been procured for both detectors, with the COUPP-4 retrofit now complete. COUPP-60 windows arrived at Fermilab last week.

Work Plan- Continued

4. Redesign of the COUPP illumination system to improve the quality of photography, while reducing the required amount of illumination power to a level which will avoid chemical changes in the CF3I. Includes new LED illumination array and reflector panel. Hardware is now complete, including retroreflector panel and LED illumination ring. Testing is planned in July on a full mockup of final optical system.
5. The video cameras will be replaced with higher frame rate, higher resolution cameras. New camera has been chosen and testing has begun. Mounting hardware prototype is finished.
6. Continue R&D on chemical purity and chemical compatibility issues, with goal of demonstrating stability of CF3I and acceptable levels of surface bubbling. Benchtop R&D in 2011 indicated that addition of Na_2SO_3 to water would prevent darkening of fluid by CF_3I photolysis. We also tested purification of CF_3I with molecular sieve, removing CO_2 suspected to cause excess surface boiling. Both chemistry improvements were successfully tested in 2011 COUPP-60 run at NuMI.

Optics Redesign Simulation

- 4.4 pixels/mm^2 (w/ 5.5 μm pixels on 6mm wide sensor)
- 38kg CF_3I visible by bottom row (w/ 90^o field of view)
- 74kg CF_3I visible by two rows

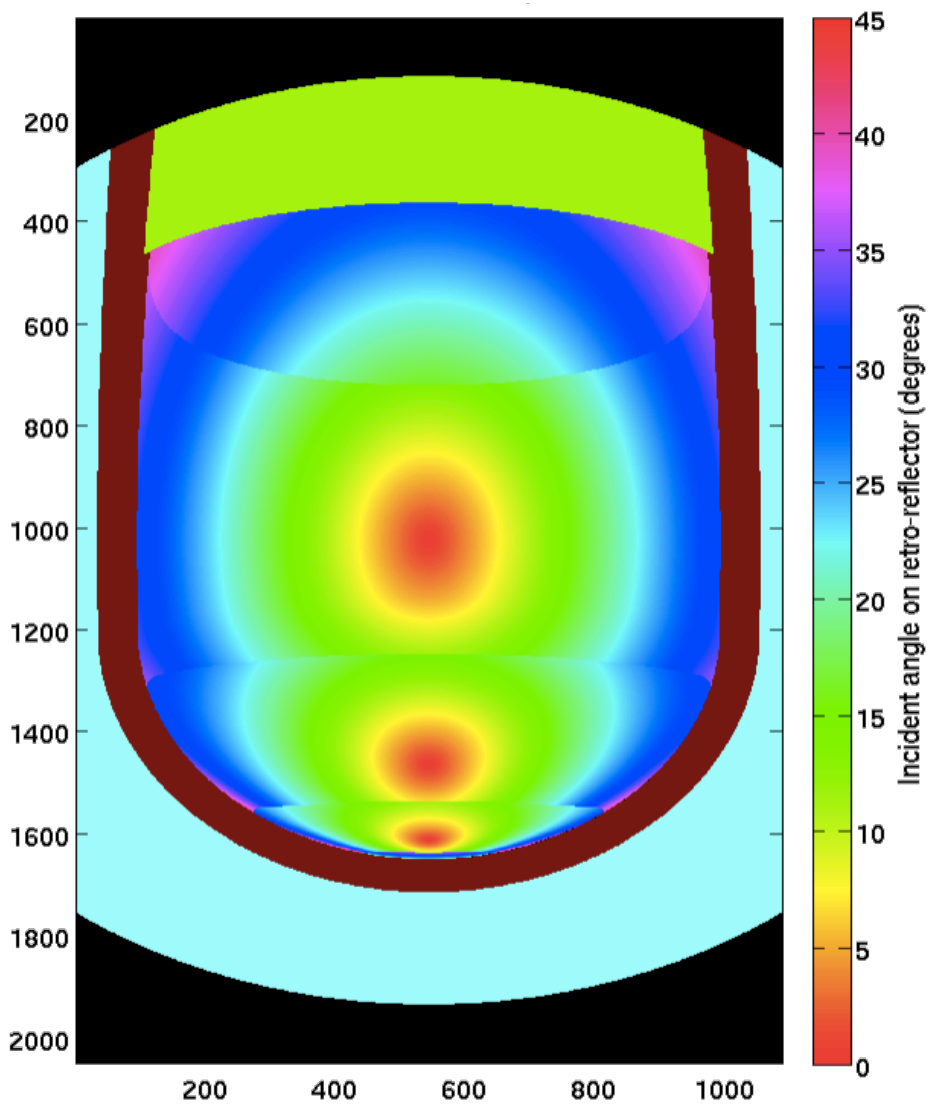


Optics Redesign Simulation

- Typical angle on retro-reflector < 30^{o}
  (> 40% max intensity)

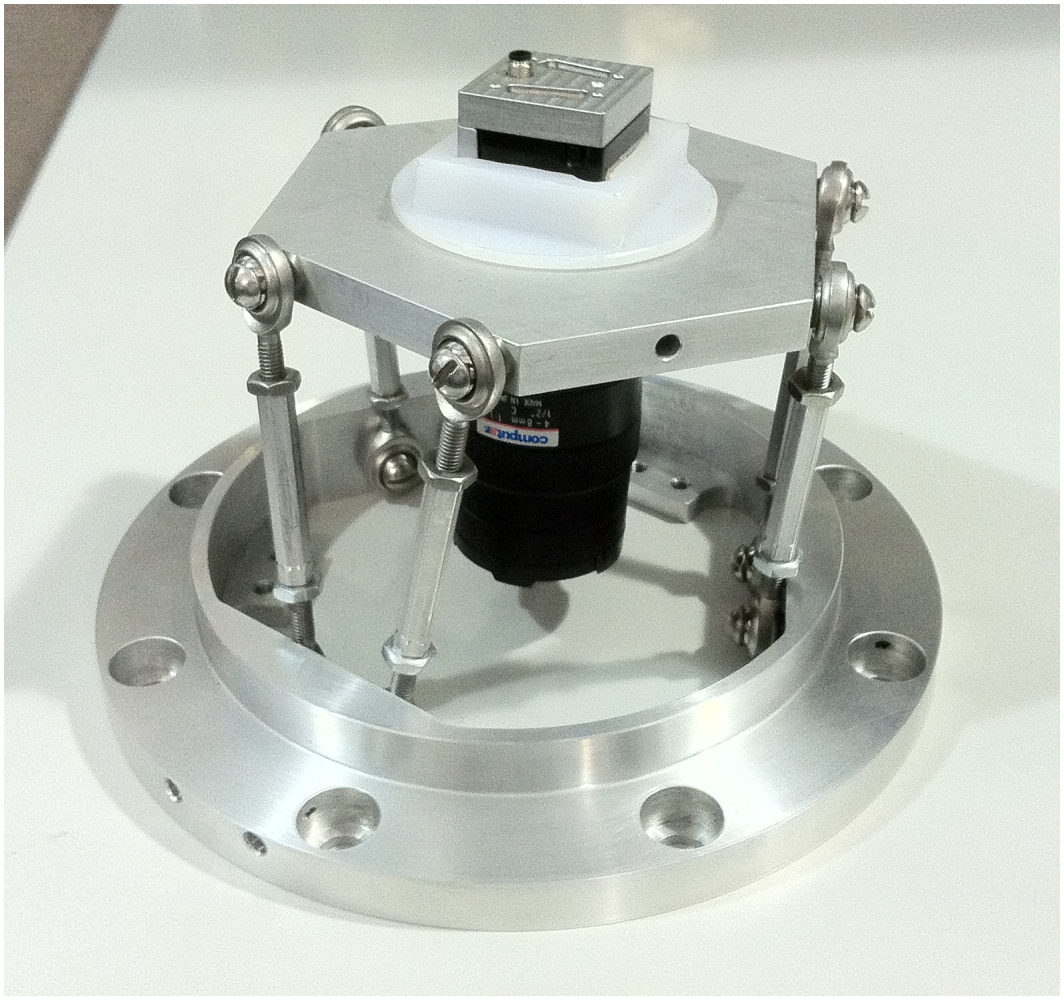
- Complimentary views between cameras
  - Dim spots at edge of one view are near-center in second camera

Basler Ace, 1088x2048, 340fps
Computar 4-8mm 1/2" lens
(5mm zoom shown)



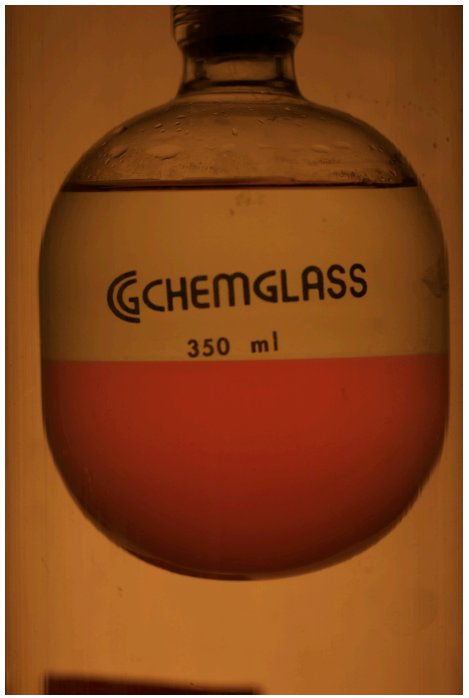
Camera Hexapod Mount

- 6 degrees of freedom
- Allows adapters for multiple camera models, will initially use Basler *Ace* with Computar 4-8mm lens



COUPP-60 Tests at Fermilab in 2011

- Goals: avoid photodissociation of CF_3I, reduce surface boiling:
  - Added Na_2SO_3 to water at 5 mMol/L.
  - Removed CO_2 from CF3I with molecular sieve.
- Results (Fall, 2011):
  - No observed image darkening after 50 day run.
  - Surface rate decreased from 150 cts per hour to 15 counts per hour at 7 keV threshold. Total residual rate (bulk+ surface) dominated by NuMI beam coincidences.

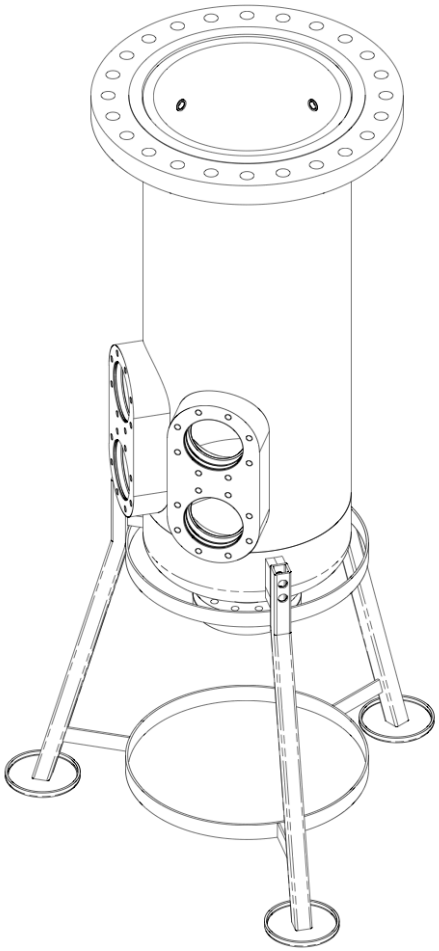


CF_3I breakdown under illumination

Work Plan Continued

7. We will study a possible upgrade to the COUPP-60 pressure vessel which would simplify the optical scheme and allow viewing of approximately twice as much target volume by adding additional windows and doubling the number of video cameras. We decided to go ahead and build this after initial investigations indicated potential for lower backgrounds, better optics, improved safety aspects. ✔

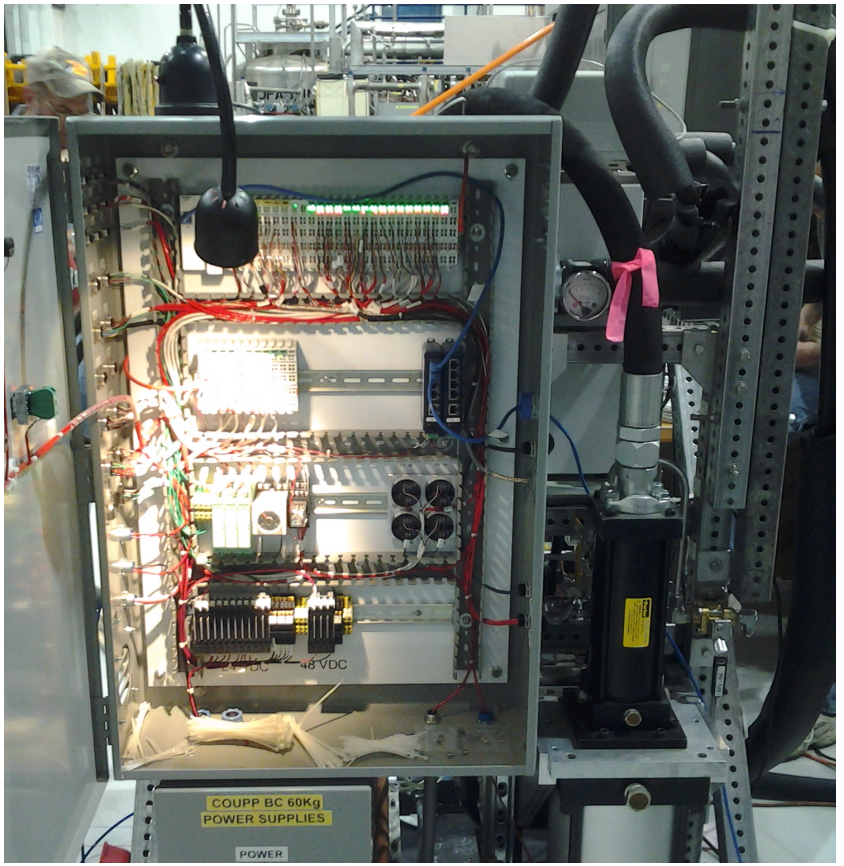
- Meets Canadian codes. Will be TSSA approved and registered in Ontario.
- Stainless steel from Outokumpu (supplier for Miniclean). Samples show < 1 ppb ^{238}U, corresponding to <1 event per year from neutrons in COUPP-60
- Fused silica windows for photography. Four ports allow imaging of 75 kg of CF3I.
- Contract awarded to All- Weld (Toronto) in January.
- Acceptance testing scheduled at All- Weld on week of June 11.



Work Plan Continued:

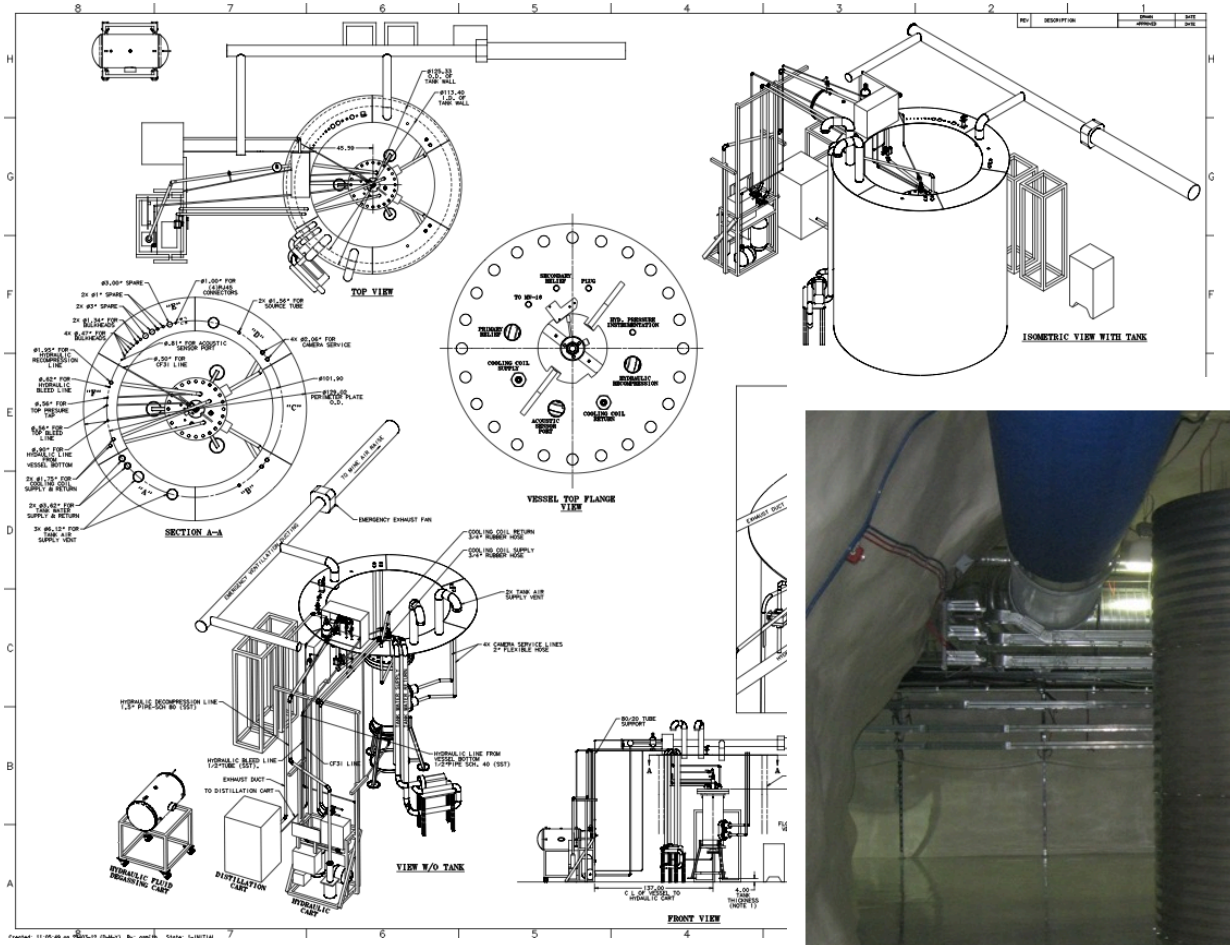
8. Control system upgrades. New instruments were added for remote monitoring, failure detection (e.g. glycol leak, CF3I leak, blocked pump), and better software for remote monitoring and alarms was added (iFix). These changes will improve our ability to operate the detector remotely.

   New capability to automatically isolate glycol leaks from detector before damage occurs. Changes made to isolate line power from low voltage following SNOLAB standards.



Next Steps: SNOLAB Assembly

- Equipment at Fermilab is being prepared for shipment over summer. First parts to arrive in June. Last parts in August.
- Lippincott talk details the assembly sequence.



COUPP-60 Project Management

- Formal project management plan drafted in Fall, 2011. Defines roles and responsibilities for Project Manager and four Subsystem Managers:
    - Project Manager- Sonnenschein. Reports to Fermilab Particle Physics Division Head.
        - Bubble Chamber Components & DAQ - Dahl
        - Bubble Chamber Installation- Lippincott
        - Site Preparation- Ramberg
        - COUPP4 & Calibration- Brice
- Most important project management tool is a detailed WBS linked to budget and schedule information. This is maintained using web-based software (www.clarizen.com) that allows project team to independently update plan as new information comes in.
- We review schedule information each week and budget each month.
- Project status is reported to Fermilab management and DOE on monthly basis.

Schedule

- Schedule was developed from the bottom up using a detailed, resource loaded WBS.
- Project Manager and Subsystem Managers can independently see and update the schedule at any time using Web-based Project Management software (Clarizen)
- Software sends automatic reminders on what tasks are open to the responsible manager.
- Progress is discussed in weekly collaboration meetings/ phone conferences.
- Milestone reports are generated each month, allowing schedule drift to be tracked over time.

WBS Example

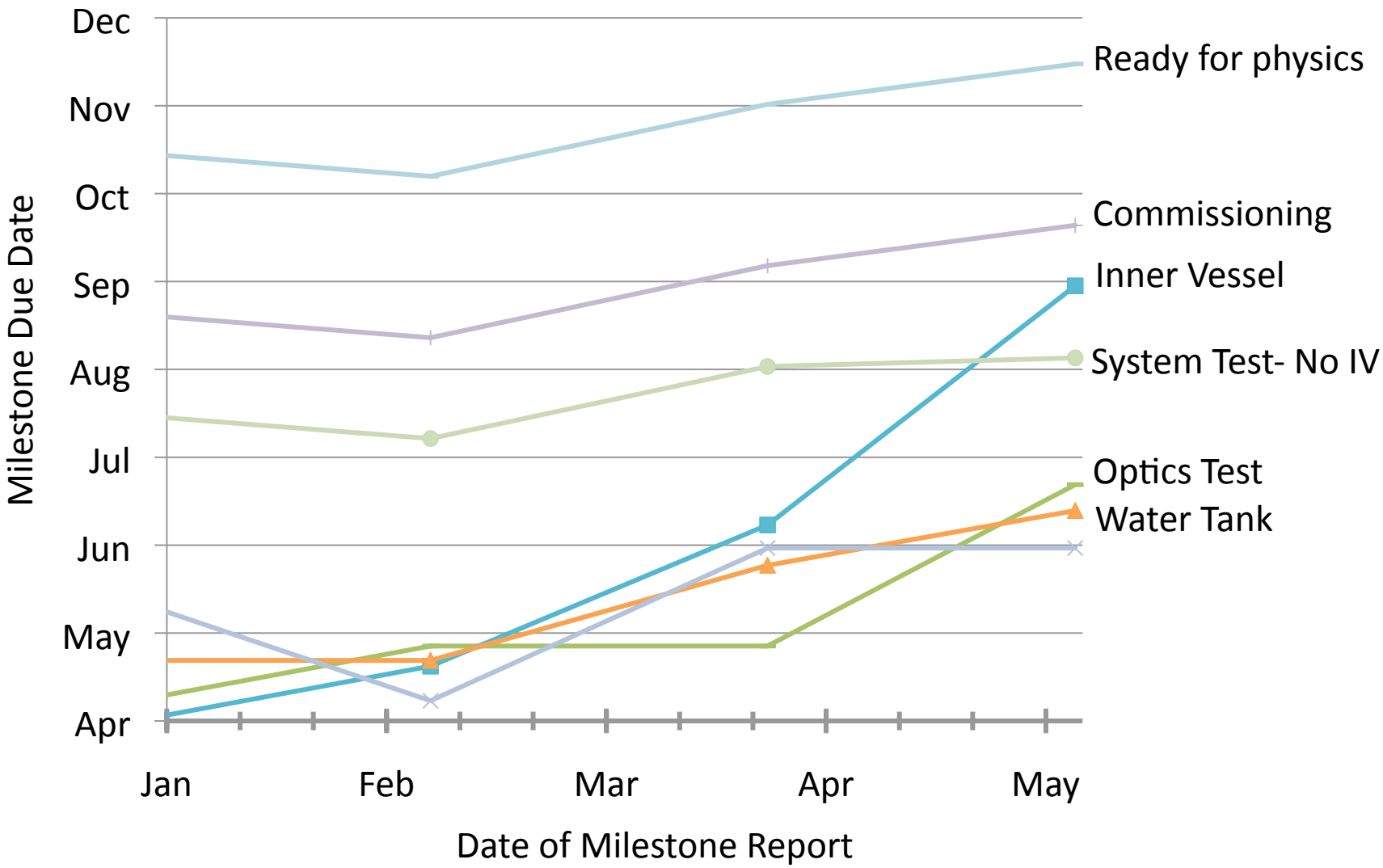
- Tasks have assigned resources (people + money), schedule information and brief descriptions of the scope of the work. Level of detail and quality of information vary, with more attention paid to critical path items.

Name	Manager	Start Date	Duration	% Complete	M&S	Travel	Total Estimate Cost
COUPP	Sonnenschein	12/07/10	501 d	10	359,764	68,500	813,083
Area 1: Chamber Components	Dahl	12/07/10	402 d	23	159,014	1,000	260,674
Area 2: COUPP-60 Installation	Lippincott	12/07/10	501 d	18	105,600	52,000	315,526
Chemical Tests	Lippincott	07/01/11	207 d	21	10,000		58,122
NuMI run fall 2011	Lippincott	07/01/11	131 d	100	10,000		58,122
Make decision regarding purification	Lippincott	11/01/11	120 d	0			
CF3I	Lippincott	03/01/12	120 d	0	51,000		59,160
Purchase storage vessel	Lippincott	03/01/12	60 d	0	1,000		1,160
Purchase CF3I	Lippincott	05/24/12	60 d	0	50,000		58,000
Disassembly of bubble chamber at NuMI	Lippincott	10/14/11	63 d	100			5,851
High Purity Fluid Skid	Lippincott	12/07/10	407 d	28	6,500		20,179
Move from NuMI to Lab 3	Lippincott	12/27/11	1 d	100			
Disassembly and inspection	Lippincott	01/19/12	20 d	100			1,938
Cleaning	Lippincott	02/16/12	10 d	50			4,886
Reassambly	Lippincott	03/01/12	10 d	0	2,000		5,228
Crate	Lippincott	05/17/12	5 d	0	1,100		4,184
Ship to SNOLAB	Lippincott	05/24/12	5 d	0	1,400		1,624
Ship underground	Lippincott	05/31/12	5 d	0			
Consumables	Lippincott	12/07/10	1 d	0	2,000		2,320
Assemble underground	Lippincott	06/07/12	5 d	0			

Milestone Report- May 7, 2012

Name	Due Date
Pass NuMI Chemical Test	11/15/11
New Outer Vessel Vendor Selection	12/06/11
CIRTE Chamber Ready	02/01/12
New Camera Decision	04/11/12
2nd Generation Acoustic sensors ready	05/15/12
Pass SNOLAB Safety Review	05/23/12
Start COUPP-4 Run 2	05/25/12
Outer Vessel Ready	06/12/12
Water Tank Ready	06/25/12
Pass Optics and Illumination Test	07/04/12
Pass Video Acquisition Test	08/15/12
System Test-- No IV	08/17/12
Inner Vessel Ready	09/11/12
Start Commissioning	10/02/12
Ready for Physics Runs	11/27/12

Milestone Tracking- Last 4 Months



Schedule– The Big Picture

Schedule table from FY11 DOE Proposal

FY09	Complete fabrication and testing at D0
FY10	Commissioning of 60-kg detector at NuMI, 4-kg detector at SNOLAB
FY11	Installation of underground infrastructure for COUPP-60 COUPP-4 running and refurbishment at SNOLAB Acoustic sensor R&D Chemistry R&D, Optics improvements for COUPP-60
FY12	Recommission COUPP-60 underground at SNOLAB COUPP-4 calibration runs at SNOLAB
FY13	COUPP-60 Running at SNOLAB

Funding

- DOE
  - Base KA-13 funding covers 4 scientist FTEs at Fermilab.
  - 1095 k$ received in FY11-FY12 for COUPP-60 installation. This fully funds the installation of the detector at SNOLAB according to current budget, with modest contingency for dealing with unexpected problems.
  - Additional KA-15 R&D funds (~ 100 k$ in FY12) help with COUPP-4 and calibration work.
- NSF
  - Continuing base funding for students at U. Chicago and IUSB, postdocs at Chicago and Engineering at IUSB.
  - 600 k$/year from DUSEL S4, last three years
  - NSF renewal of KICP– more student, postdoc support, some equipment.
  - NSF contribution pays for much of COUPP-4 operations, all of acoustic sensor development work.

COUPP60 Budget Status As of May 1st

- Funding received (FY11 + FY12): 1095 k$
- Obligated $ as of 5/1/12: 563 k$
- Remaining funds: 532 k$
- Estimated future costs: 442 k$
- Contingency: 90 k$ (20.3% of estimated costs)

** However– estimated cost has risen over time. Contingency on remaining work has eroded from 30% at start of project to 20% now ***

Expected Future Non-Labor Costs

- Includes all individual items costing more than 5 k$

	K$
Travel	82
CF3I	50
Safety vent	18
Crating and shipping	13
Engineering for TSSA certification	10
Labview licenses	9
Access platforms, stairs	8
Protective equipment	5
Tubes & fittings	5
Total	200

=> About ½ of remaining 442 k$ budget is M&S

Risk Matrix Sorted by Probability* Impact

Red= safety related. P= probability score. I= impact score.

Risk	Cost [K$]	Schedule [Wks]	Probability	P	I	P*I
FY13 Funding delay	200	26	0.25	5	4	20
Glycol leak >1 liter per hour, IV damage, silica intact	100	26	0.1	4	4	16
Over budget for installation	200	26	0.1	4	4	16
Break Inner Vessel During Operations	250	52	0.05	4	4	16
Break Inner Vessel During Shipping	250	52	0.05	4	4	16
Water tank construction delay	0	12	0.5	5	3	15
Delay in utilities installation	0	12	0.5	5	3	15
Delay in inner vessel	0	8	0.5	5	3	15
Illumination system test fails	30	12	0.25	5	3	15
DAQ system test fails	30	12	0.25	5	3	15
Delay shipping glycol & water modules	0	8	0.25	5	3	15
Additional safety systems required by stakeholders	100	16	0.25	5	3	15
Outer Vessel vendor delivery delay or quality issues	0	8	0.25	5	3	15
Seismic event with significant damage	1000	100	0.01	3	5	15
TSSA approval delay	30	12	0.1	4	3	12
Significiant lost time injury- no CF3I exposure	50	12	0.01	3	4	12
CF3I significant release, safety vent turns on, no injury	200	26	0.01	3	4	12
Glycol leak <1 liter per hour	20	6	0.2	5	2	10
Minor injury- hands, feet, etc.	0	1	0.1	4	2	8
CF3I release, small quantity, no signficiant operator exposure	20	4	0.05	4	2	8
CF3I large release, safety vent system fails, operators exposed	1000	100	1.00E-04	1	5	5

Top Ranked Risks

- Budget overruns/ Funding delays
  - Contingency margins are tight– currently 90 k$ in reserve (20%). With unexpected probled, funding may not carry us much past the fiscal year boundary, may not be sufficient to operate the detector for long once installed.
  - Need better understanding of operations budget– what $$ may be needed to mitigate against the other risks in the table in FY13?
  - Keep up communication with NSF, DOE.
  - Successful outcome of this meeting will reduce one of major cost risks– are we building the right safety infrastructure?
- Glycol leaks.
  - Have been a persistent problem in COUPP, including most recent run at NuMI of COUPP60.
  - Installing more control system features and alarm capabilities to guard against leaks when system unattended. Automatic isolation of pressure vessel from external plumbing if external leak is detected.
  - Need physical presence at SNOLAB by experts who can respond quickly, especially in first six months.
  - Planning month-long run without inner vessel to test leak integrity of system.

Top Risks- Continued

- Beak inner vessel in shipping.
  - Inner vessel quartz would take 1 year to replace.
  - With labor, cost would be >200 k$.
  - Mitigation: Engineering note on shipping plan by Russ Rucinski (inner vessel designer). Peer review.
  - Will “hand carry” vessel to SNOLAB.
- Break inner vessel in operations.
  - Can be caused by glycol leaks or CF3I leaks or operator mistake.
  - Control system interlocks have been programmed. To be tested without inner vessel in place.
  - Operator procedures need careful study, review. Considerable experience now from Fermilab running. No broken vessels!

People Working on COUPP

- **Fermilab: Engineering, construction, operations, project management, calibrations, physics data analysis.**
  - **Scientists & postdocs:** Steve Brice, Dan Broemmelsiek, Mike Crisler, Erik Ramberg, Peter Cooper, Hugh Lippincott, Andrew Sonnenschein (Project Manager), Jeter Hall.
  - **Engineering:** Del Allspach, Herman Cease, Russ Rucinski, Rich Schmitt, Dan Markley.
  - **Technicians:** Mark Ruschman, Pete Simon + others
- **U. Chicago: Calibrations, R&D, operations, simulations, physics data analysis, radiopurity measurements**
  - **Faculty & postdocs:** Juan Collar (Spokesman), Eric Dahl, Russell Neilson
  - **Grad student:** Alan Robinson.
- **IUSB: Acoustic sensors development, construction, testing.**
  - **Faculty:** Ilan Levine. **Engineering:** E. Behnke. **Students:** Joshua Behnke, Tonya Benjamin, Austin Connor, Cale Harnish, Emily Kuehnemund, Timothy Moan, Thomas Nania
- **Virginia Tech: Piezoelectric materials.**
  - **Faculty** Shashank Priya . **Postdoc**: Students
- **SNOLAB: Simulations, operations, water tank design and construction, utilities**
  - **Postdoc:** Eric Vazquez Jauregui**. Engineering:** Ken McFarlane, Peter Liimatainen
  - **Underground construction:** Brian Morissette + others

Conclusions

- COUPP program has been remarkably successful, especially the COUPP4 SNOLAB phase.
- Several significant problems discovered in Fermilab testing of COUPP-60. Solutions seem now to be in hand, having passed critical tests in the fall.
- Pending the outcome of this review, I believe we are in good shape to start assembling COUPP-60 at SNOLAB (critical safety issues and suggested mitigation to be addressed in other talks)
- Schedule calls for assembly over the summer. We seem to have manpower available to do this (Lippincott talk). Contribution of SNOLAB staff is critical for water tank, utilities.
- Budget shows signs of stress but is believed to be sufficient.
- Most important technical risks involve fluid leaks, which can lead to mechanical damage to inner vessel.