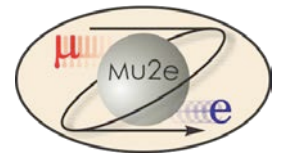




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## Lessons Learned

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L2 for Solenoids  
10/22/2014



# Outline

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- Introduction
- Sources of Information including Interviews
- General Conclusions
- How we are applying lessons to the Mu2e Solenoids

# Introduction

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- Reviewers at the CD3a Review as well as the Fermilab Director's Review stressed the importance of gathering information on previous and ongoing superconducting magnet procurements.
- Areas of inquiry:
  - Unforeseen technical difficulties with the magnet designs resulting in change orders
  - Unanticipated (technical or otherwise) difficulties with the vendors
  - Ambiguity on fabrication mishap responsibility
  - Advantage/disadvantage to various types of vendor contracts
  - Need for “boots on the ground” at vendor site
  - How much should one set aside for risk contingencies

# Sources of Information

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- From personal experience
  - We have personal experience from LHC-IR and other Fermilab magnet campaigns
  - Reality check on how long it really takes to wind coils, assemble magnet
- From existing documentation
  - We have read the “Lesson learned” from the NSLS-II at BNL
  - Vendors did not stray very far from supplied reference designs
  - Tended to treat them as final designs when they were actually preliminary in nature
- From our Acquisition Oversight Committee
  - Members involved with procurement campaigns and/or were members of magnet review committees.
- By interviewing technical and procurement experts who were involved with the procurement of any magnets or magnet components from outside vendors

# Interviews

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- Interviews conducted over the phone or in person by members of the Mu2e technical management team.
- Who we have interviewed so far:
  - PNNL wide aperture magnet for mass spectroscopy
  - US ITER on ITER CS
  - INFN on CMS and BABAR
  - RHIC (BNL) accelerator magnets
  - JLAB (7 magnet fabrication campaigns)
    - We have our own experience with JLAB as we assumed responsibility for 1 magnet
- NOTE
  - Conversations were frank and informative
  - Where there were problems, we tried to come to an understanding of “what happened” and how to avoid problems in Mu2e.

# PNNL Magnet for Mass Spectroscopy

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- Lab is acquiring superconducting magnet from outside vendor
  - High field magnet, combination of Nb<sub>3</sub>Sn and NbTi.
- Buyers are not magnet experts. Built to Specification, fixed price
- Vendor responsible for superconductor
  - From a third party vendor
- Primary issue: Delay in magnet delivery. There is a one year schedule contingency in project which is nearly used up
- Causes of delay
  - Conductor delayed by 2-4 months
  - Myriad of little delays lost 1-2 days/month
  - Helium shortage delayed testing
  - Problem with one NbTi low field coil
    - Probably a potting problem
    - Potted in wax, they are able to re-pot
- Project back on track

# US ITER Central Solenoid

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- Large Magnet fabrication Project with US vendor
- Fabricate and test 7 ITER CS coils
- Contract Started in July 2011
- Essentially build to print, with some cost/scope to develop tooling
- Also includes cost of full power testing on site.
- Cost plus contract
  - Essentially guaranteed 10% profit as long as they deliver on schedule
  - Schedule penalties and incentives affect profit only
  - Any schedule delays generated by US ITER taken into incentive equation
- Since build to print most of the risk is held by US ITER
  - They shared with us roughly how much they are holding in contingency
- Strong QA plan, with hold points and travelers, approved by ITER international
- They have a vendor management plan which spells out roles and responsibilities
- They have a person at vendor all the time.

# CMS and BABAR

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- One of our collaborators was heavily involved in both magnet procurements in European industry
- Essentially build to specification contract
- Conductor provided by 3<sup>rd</sup> party
- Three types of extra costs
  - Buyer changes to the design post contract. Buyer bears the cost
  - Changes to the manufacturing process discovered along the way. Cost may be shared between buyer and seller
  - Fabrication mistakes Cost born by vendor. (Because these are build to spec, I would say responsibility is easier to define)
- Contingencies from 1-15% on the two jobs.
  - Varies greatly from job to job
  - Low rate only applies if both the buyer and seller are skilled
    - Seller doesn't make bad mistakes
    - Buyer chooses seller who understands the job, and has appropriate skills to carry out project



# RHIC Magnet Procurements

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- Phone Conversation with Mike Anerella and Peter Wanderer
- Centered on procurement of arc magnets
- Summarize discussion:
- Contract is with US vendor with no previous experience with fabricating superconducting magnets
- BNL supplied conductor as well as some tooling and magnetic measurement equipment
- BNL had in-house already built several successful pre-production magnets
  - Plan for vendor was to learn from BNL how to build magnets, take over production

# RHIC Magnet Procurements II

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- Contract had three phases, with different contract structure
- 1 st phase was on the job training with vendor. Cost plus
  - This turned out to be a bit expensive.
- Second and third phases fixed price with incentives
- Vendor facility was near BNL, allow BNL frequent visits
  - Also had someone onsite
- Although build to print, there were several modifications to the fabrication
  - Vendor learned how to improve tooling
  - Other lessons learned during fabrication
  - Cost was ~neutral except for administrative cost which were born by BNL/RHIC
- Since build to print, BNL assumed much of the risk
- Vendor would pay if BNL could demonstrate fabrication errors
  - There were a few instances where this was the case
  - Requiring detective work by BNL engineering and physics staff.

# JLAB magnets

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- Met with Cesar Luongo Sept 19<sup>th</sup>
- There are 7 new magnets
  - 5 different vendors
    - Fermilab is one of the vendors who took over when problems arose
- JLAB supplied conductor
  - SSC conductor in a copper tray, conductor completed by third party vendor
- Tight geometry constraints, unusual geometries ==> complicated magnets
- Contracts :Fixed price
  - Bid package from reference design + specification documentation
  - Vendor largely responsible for tooling.
- In meeting, Cesar went through each procurement status
- Schedule incentive clauses were not effective
- All but one contract is behind schedule
- Technical problems with most procurements
  - Mismatch between vendor capabilities and magnet complexity

# Some general conclusions

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There are a wide range of magnets, different types of contracts, with wide range of issues. Many, but not all, apply to the Mu2e program.

- Some common themes:
  - Have a clearly defined deliverable. Spell out buyer and seller responsibilities.
  - Vendor oversight is absolutely essential. Frequent in-person visits. You don't necessary need continuous boots on the ground if the right QA/QC is in place.
  - If there are problems you will be able to get a vendor to honor its fixed price contract, but demanding on-time delivery is very difficult, even with incentive clauses.
  - Buyer must have ability to match the job to the vendor capabilities. This is particularly true with tooling which is often the vendors responsibility. Sometimes vendors hungry for work may agree to job without knowing what they are getting into. You have to judge whether the vendor can perform the job you want. It is important to have a skilled team to evaluate the vendors. Visit the facility prior to awarding contract, ask a lot of questions and listen to the type of questions the vendors ask you.

# Some general conclusions

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- More common themes:
  - If possible use design principles familiar to vendors, for example from existing successful magnets. Tight physical interfaces, complicated out of the box designs need extra time and an R&D plan. Include prototyping using production tooling in the procurement proposal.
  - In most, essentially all cases, conductor comes from a 3<sup>rd</sup> party vendor. Magnet vendors don't want to take responsibility for conductor. In one case we know, the vendor assumed responsibility to get the job, but was not in position to really assume it. They are trying to back out of the responsibility. Regardless what the contract states, it is on you to make sure the conductor works!

# Some general ideas of contingency

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- Buyer-originated change orders are prevalent
  - We have a solid example where 10-15% was enough, even cases where contingency was less.
    - This applies to well thought out acquisitions with experienced vendors
  - Then there are examples where cost with x2 or more the original anticipated cost.
    - See discussion on next slides.
- Beware of schedule delays
  - Oversight and vigilance can head off many of them
  - The rest needs to be accounted for in risk register

# Ways we are applying these lessons

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## Design/Evaluation Team

- We have a strong design team, with large fabrication experience and several years of design and studying large solenoid fabrication. The leaders of the design effort are members of the evaluation team. A senior member of the Fermilab procurement department is also part of this team.
- Part of our team (INFN Genoa) has large experience with similar procurements. We have also contracted a former senior person from Ansaldo (Roberto Penco) for consultation particularly for the Transport Solenoid. Members of our Acquisition Oversight Committee also have large experience in magnet fabrication.

# Ways we are applying these lessons

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## Finding/Evaluating the right vendor

- Our magnet designs are based on proven concepts from existing successful magnets. PS/DS are based on similar design which result in common tooling and a simpler approach to the fabrication plan.
- Vendor search started several years ago with a “Request for Information” market survey. This prepared vendors for the eventual “Request for Proposal”. It gave us an initial cost and schedule estimate and valuable information about vendor capabilities.
- Procurement specification calls for the fabrication and analysis of prototype coils built with production tooling.
- For PS/DS our short list of vendors all have a strong record of magnet fabrication. We visited every vendor during the evaluation period. The one we are about to chose has demonstrated to us that they understand the job.



# Ways we are applying these lessons

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## QA and Vendor oversight

- We have a person dedicated to overseeing the PS/DS as part of our design/evaluation team.
- We have incorporated QA plan into procurement plan.
  - A member of the AOC is a QA professional (Jamie Blowers)
- We will have a significant presence at the vendor with a combination of frequent site visits, a strong QA program with our sign offs and continuous engagement with reference design team back at Fermilab.
- Based on our successful QA program executed for our conductor R&D campaign we will have:
  - Continuous monitoring/early intervention
    - Part of the requisite traveler program with sign offs and hold points
  - Documentation mandated in the procurement specification and written into the contract
  - Frequent site visits

# Ways we are applying these lessons

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## Schedule

- The time frame for the final design and fabrication proposed by the PS/DS bidders is reasonable based on our team's experience from other magnet campaigns. We consider carefully the anecdotal examples of "time slipping away" and intend to keep the vendor on track as much as possible.
  - Bi-weekly meetings
  - Frequent site visits as well
  - Contract is structured with progress payments
- Because of our prototype conductor program run by us, we have confidence in the vendors delivering conductor that meets our specs. We understand their abilities to meet a schedule and have folded these expectations into our delivery schedule for the vendor. Conductor availability is not expected to drive the fabrication schedule.

# Ways we are applying these lessons

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## Buyer/Seller Responsibilities clearly defined

- We spelled out shared responsibilities in our procurement specification. This sharing is called out in the specification “Responsibility Matrix” and is agreed and confirmed during multiple pre-contract signing meetings.
- We have written a draft vendor management plan to cover this and other organizational details. Plan will be implemented prior to contract signing.

# Ways we are applying these lessons

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## Contingencies

- We have assigned a 15% estimate uncertainty contingency to account for change orders
- Additional risk-based contingency of ~\$3.5M has been added to cover threats and impacts on our schedule.
  - Separate talk on risk analysis included in this breakout session.

# Conclusion

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- Lessons learned has been a very valuable exercise for the Mu2e solenoid project.
- Much of the information was gained from interviews.
  - Greatly appreciate the candor of interviewees
  - Would have been very difficult to obtain information otherwise
  - Have established a network that will be useful as we continue with the procurements
- There was a wide range of procurement experiences amongst the 5 groups that we interviewed
  - Most successful were able to keep the change order contingencies to a manageable level
  - 15% seems to be a reasonable percentage for well structured procurements.
- We believe that we are adapting or in some cases have already adopted these lessons into our procurement strategy.
- We believe our procurement is structured most like the successful ones that we interviewed
- Lessons learned is organic
  - We will continue to follow the trajectories of other ongoing procurements