Spectrometer Solenoid Recovery: Options for Moving Forward

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[with added slide 13]

Introduction

- As noted, SSD-M1 failed during magnet training quench on September 13, 2015
- Critical Questions for Moving Forward:
  1. Can we operate MICE Step IV with the SSD as is?
     - The August 2014 re-baseline constrained the optics to the extent that we do not believe that the Cooling Demonstration configuration can operate without restoring the lost match coil functionality
  2. Do we have a viable path to repair the magnet?
  3. How long is a repair or alternative mitigation? And can it fit within the time frame (by end US FY17) for deploying the cooling demonstration?
  4. What is the required cost of a repair or alternative mitigation? Does it fit within the contingency held within the US construction budget?
  5. Given the known “features” of the SS magnets (e.g. training behavior), are there steps in a repair that can significantly mitigate risk, overall experimental schedule, training schedule, and/or training costs?

Outline

- Addressing the Key Questions
  1. Step IV?
  2. Repair Path?
  3. Schedule?
  4. Cost?
  5. Risks?
- Potential Technical Paths Forward
- Process Moving Forward
- Conclusion

⇨ Discussion

1. Step IV?

Can we operate MICE Step IV with the SSD as is?

- Optics designs sufficient for characterizing absorber materials are in hand (assuming SSD M2 coil is operational):
  - Critical SSD checks:
    - SSD E-C-E quench and reasonable response of vessel
      - ⇨ He vessel and feedthrough integrity satisfactory
    - SSD M2 low current checkout
      - ⇨ No anomalous resistive behavior observed
      - – Next step is a careful ramp to high current
  - ⇨ Viable optics and likely viable magnet with M2 and E-C-E coils
- Plan is to proceed with modified Step IV run plan for ~1 year
  - ⇨ Time to prepare for a repair

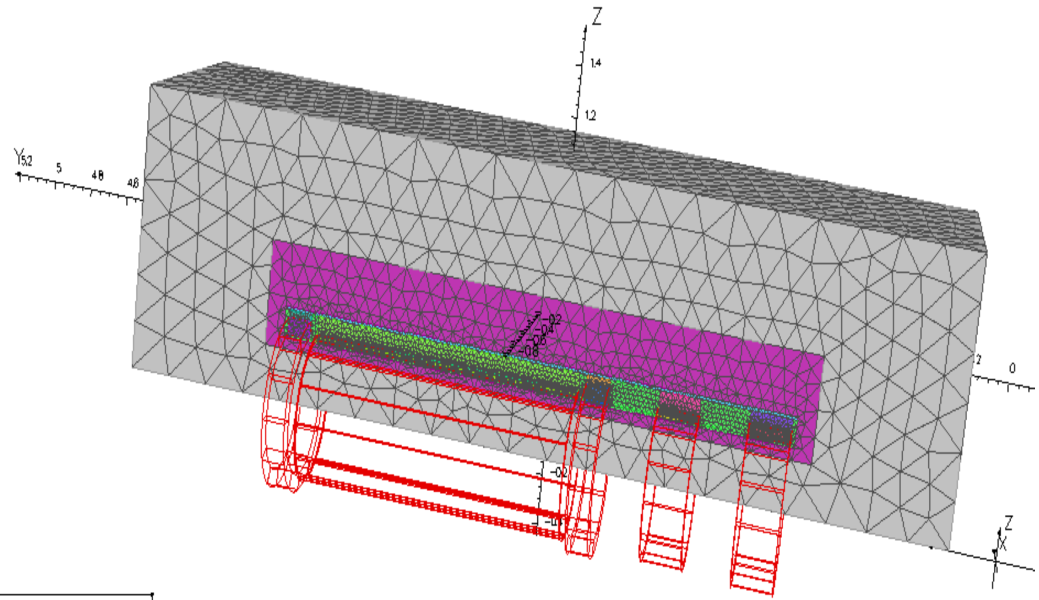
Answer: YES

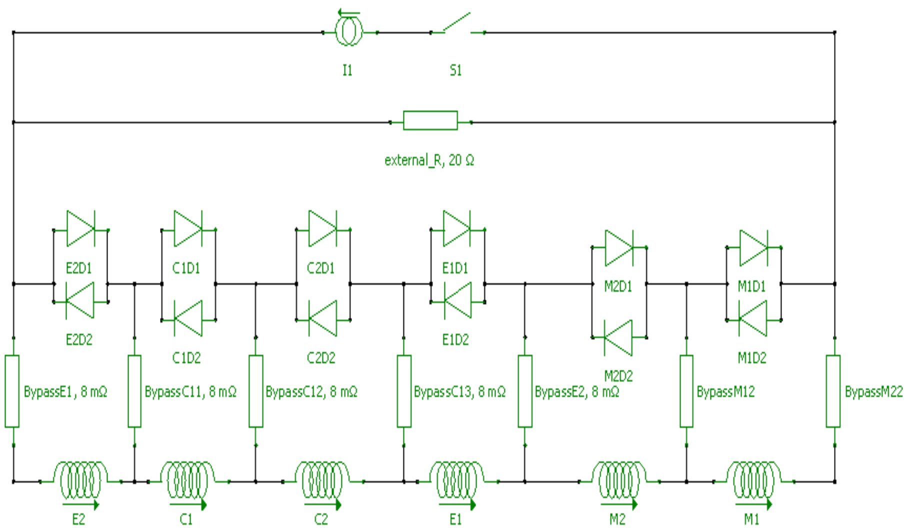
- Caveats:
  - Still need to validate magnet at currents required by alternative optics
  - Need to confirm that we have a power supply configuration that is “safe” for operations

PSU Configuration (Preliminary)

Heng Pan (LBNL)

- Quad model built in VF
- Quench initiated in the inner layer of the E2 coil.

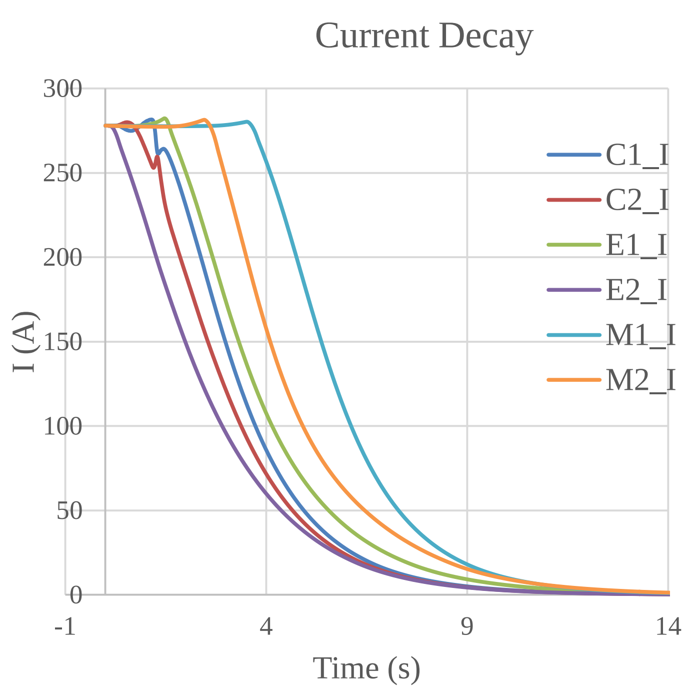


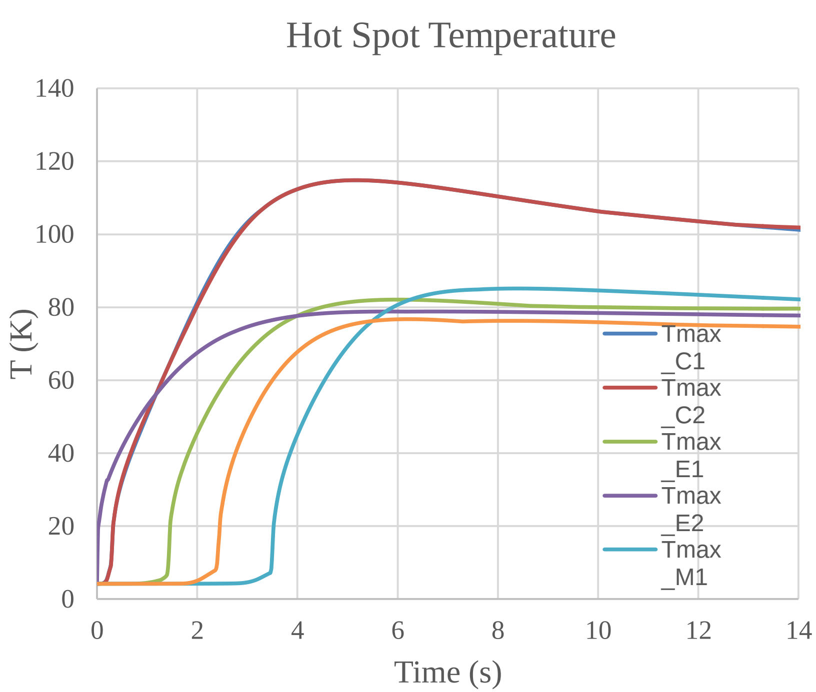


- All coils are powered by a single powers supply.
- A 20 Ω external resistor goes across all the coils.
- Switch opened when the overall voltage across the E2 coil exceeds 0.2V.

Current Decay & Hot Spots

Heng Pan (LBNL)



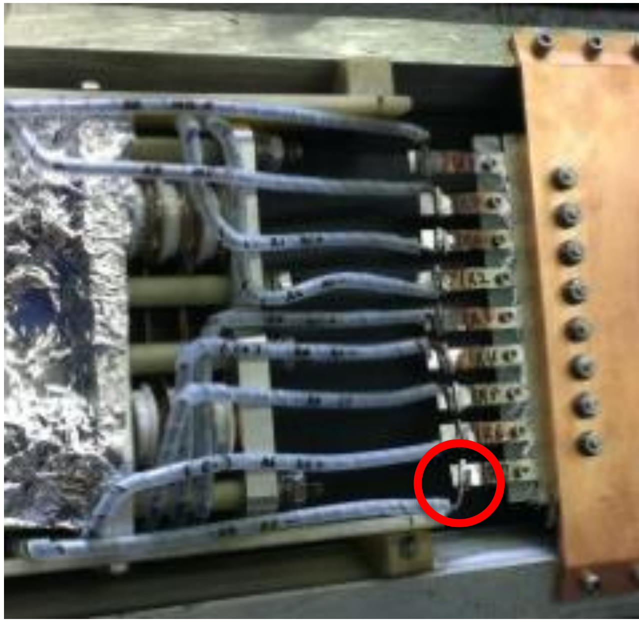


- C coil also has the highest hot spot temperature among the coils.

2. Repair Path?

Do we have a viable path to repair the magnet?

- Both magnets previously rebuilt
  - One previous failure very similar in scope to present case
  - A plausible repair path exists based on previous repair and our present understanding of the September 13th failure



Answer: YES

- Remaining question is whether a repeat of that rebuild is a "sufficient" and/or best option
  - Proposals to build an "improved" bobbin
    - Build and test prior to removal of magnet from channel (risk reduction)
    - Vacuum impregnated coils (vs. wet layup)
    - Active quench protection (heaters)
  - Insert separate function magnet in lieu of repair

Schedule?

- Baseline estimate of repair schedule:
  - Based on prior experience with previous repairs
  - Assume magnet available (i.e. warm and ready to remove from channel) on *August 1, 2016*
    - Base estimate for disassembly, cold mass repair and re-assembly:
      8 months base + 3 months contingency
    - Transport: 1.5 months (if repair not carried out locally)
    - Installation, pump-down, cool-down and training at RAL (assuming optimal installation/commissioning support):
      2 months

  ⇨ October 15, 2017

Answer: MAYBE

Cost?

- Baseline Repair (***very** preliminary)*
  - Air Shipment (required to achieve schedule): $100K rnd-trip
  - Cold mass removal, repair, re-installation:
    $700K base cost +35% contingency = $950K
  - LHe costs (cool-down+training):
    18 x 500L x 7000GBP/dewar x 1.55$/GBP = $200K
  - Misc. other costs = $100K
  - Total: ~$1.35M
- US Funding Availability
  - In $18M FY15-17 ramp-down plan, US project has
    ~$1.3M in unallocated management reserve
  - Potentially would be forced to reduce US experimental support in FY17 (particularly since no experimental running would take place)

Answer: Probably

Risk?

- Do we have a safe way to operate the two spectrometer solenoids as presently configured (assuming no further QA issues)? Maybe
- Can risks be mitigated by the repair strategy?
  - Re-do SSD cold-mass QA (except for winding)
  - Improve stabilization of existing leads/bus work
  - Add additional protection features

  Yes
- By addressing the above issues, do we convince ourselves that the magnet will be robust in operation? Maybe

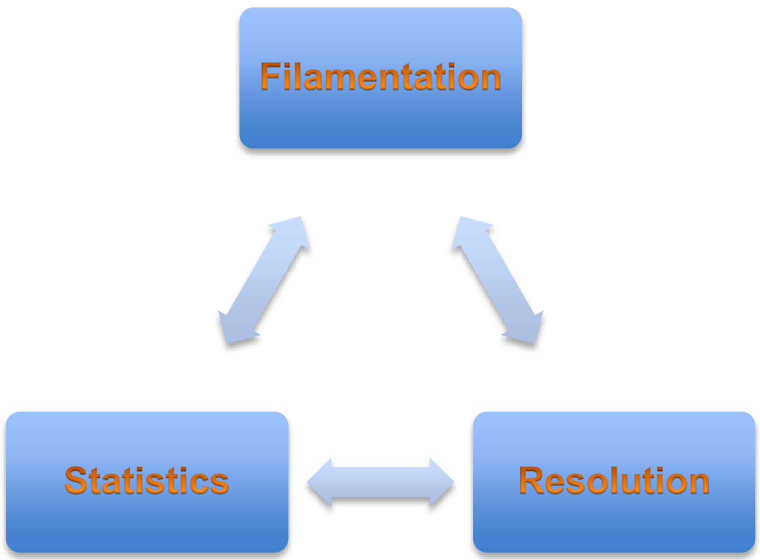
Overall Answer: Maybe

POTENTIAL TECHNICAL PATHS FORWARD

Potential Technical Paths Forward

- Option 1 – Repeat previous repair scenario
  - Assumptions
    - NO changes to magnet design
    - Repair starts at conclusion of Step IV running
    - Suitable repair team available – magnet moved to team location
  - Schedule
    - Magnet could be at RAL for installation/commissioning prior to end of US FY17. Would fully become RAL responsibility at end of US FY17.
  - Cost
    - Nominally appears to use 100% of MAP management reserve funds. Plausible.
  - Risk
    - QA issues (believed to be known) could be addressed
    - Surprises when cold mass is inspected?
    - Are we comfortable with sticking to the current design untouched?

- NOTE: You may hear a so-called "Option 0" referred to which is:
  - Run the Cooling Demo with SSD "as is".
  - I don't believe the optics team has any solution with the capability to achieve the Cooling Demo goals – for instance:



Potential Technical Paths Forward

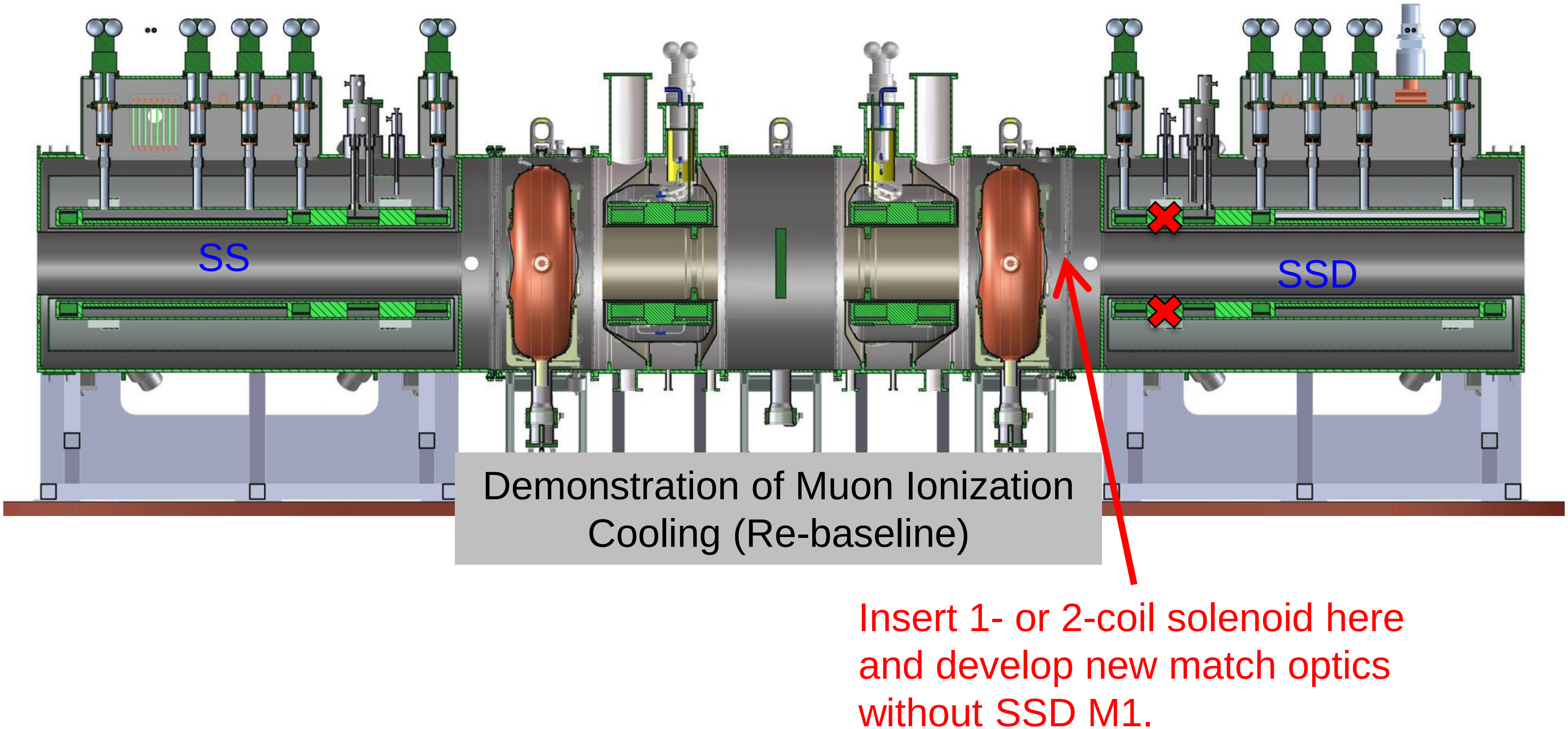
- Option 2 – Fabricate new cold mass
  - Assumptions
    - Only allow *modest* changes to cold mass design
      - Examples:
        - » Minor change in bobbin length to control thermal distortion
        - » Allow for vacuum-impregnation of coils
        - » Allow for addition of active quench heaters
    - Integration with existing cryostat starts at conclusion of Step IV running
    - All required superconductor is on hand (enough SC is in FNAL storage to wind 2 new cold masses)
  - Schedule
    - Cold mass fabrication could start as soon as revised drawings approved.
    - Budgetary quote from Al forging vendor indicates 10 week delivery.
    - With SC on hand, new cold mass could be machined, wound and outfitted before August 1, 2016 (preliminary estimate of 8 months)
    - Potentially could be cold-tested/trained in dewar in advance of August 1, 2016 (a realistic schedule needs to be confirmed)
      - Could also be carried out while magnet disassembly under way
    - Final Installation
      - Installation of prepped cold mass would likely save ~2 months in baseline disassembly/reassembly schedule for magnet (vs. slide 8)
      - A trained cold mass would likely save ~3 weeks in training time (vs. slide 8)
      - Consistent with completion before end of US FY17

Potential Technical Paths Forward

- Option 2 (cont'd) – Fabricate new cold mass
  - Cost
    - ***Very preliminary*** estimate of $500K to prepare a new cold mass with SC on hand
    - Would we want to wind 2 cold masses as risk mitigation???
    - Would still require most of the $700K base cost estimate to disassemble/reassemble the magnet
  - Risk
    - A chance to address identified risks with minimal modifications
    - Testing before installation would provide certainty – however, only one chance is realistic unless 2 bobbins are prepped
    - Opportunity – Potential reduction in training costs (save ~$150K)
    - Opportunity – Possibility of retrofitting existing SSD cold mass as a spare after SSD repair complete

Potential Technical Paths Forward

- Option 3 – Do **NO** repair and instead insert another solenoid in the cooling channel



Potential Technical Paths Forward

- Option 3 (cont'd)
  - Assumptions
    - Magnet can handle longitudinal forces of cooling channel
    - Magnet cryostat can be modified for integration into cooling channel
    - Magnet bore is sufficiently large
    - Magnet cooling can be managed in the RAL Hall
      (Is there a magnet available which can be operated without a refrigerator system?)
  - Schedule
    - One year to prep magnet
    - One year to prep PRY modifications
    - Installation should be fast
  - Cost
    - Would require further modification to the PRY extension
    - Would require additional design and fabrication work to integrate the new magnet
  - Risk
    - Modest as long as both SSU and SSD operating reasonably thru Step IV

Possibilities: ~~MuCool Test Area Magnet~~; new FC

Potential Technical Paths Forward

- Option 4 – Cut SSD open and repair
  - Assumptions
    - Would require acquisition of used refrigerator because thermal losses likely to exceed what could be handled with cryocoolers
    - Would require modifications to work with refrigeration system
  - Schedule
    - Relatively fast assuming that refrigeration system could be installed/commissioned during Step IV running
  - Costs
    - TBD
    - Utilize surplus refrigerator system to control overall costs
  - Risks
    - Not clear that this could be done safely without damaging the cold mass support structure

Potential Technical Paths Forward

- Option 5 – Construction of new SS magnet
  - Assumptions
    - Would allow for implementation of (some) lessons learned
    - Would not allow for a major change in configuration to a more reliable magnet style (e.g. high current SC cable with refrigerator)
  - Schedule
    - Difficult to imagine a scenario, with proper contingency assessment, that could deliver a magnet in time
  - Costs
    - Difficult to imagine a scenario where costs would not be significantly higher than a simple repair
  - Risks
    - Depending on scale of modifications from present design, would require an entirely new test program

Potential Technical Paths Forward

Any other ideas???

Process Moving Forward

- We have just recently finished the initial assessment of SSD
  - Reasonable confidence that we have a self-consistent understanding of the failure
  - Full confidence not achievable until we are able to inspect the cold mass directly
- We are presently assembling the information required for a full technical evaluation of repair options
  - Initial considerations are “wide open”
  - By mid-November must have a focused and realistic recovery plan

Process Moving Forward

- Next Step:
  - Technical Review targeted at November 23-24 at FNAL
    - Identify the desired baseline recovery plan
    - Preliminary cost
    - Preliminary schedule
    - Identification of required magnet team
    - Target at least one alternate plan
    - Have 1 session of open discussion (avoid missed options)
  - Fully document baseline option to submit to MPB sub-committee on the mid-December timescale
    - Present resource-loaded schedule and full risk assessment
    - Obtain approval to move forward
    - May need preliminary approval for long lead items

Conclusion

- 3 critical areas:
  - Cost
  - Schedule
  - Risk mitigation
- Executing a repair similar to those done previously nominally fits within the US program's constraints
- Looking forward to the committee's comments on the possible routes presented
  - Need guidance for what to prepare for the November technical review

NOW OPEN FOR DISCUSSION