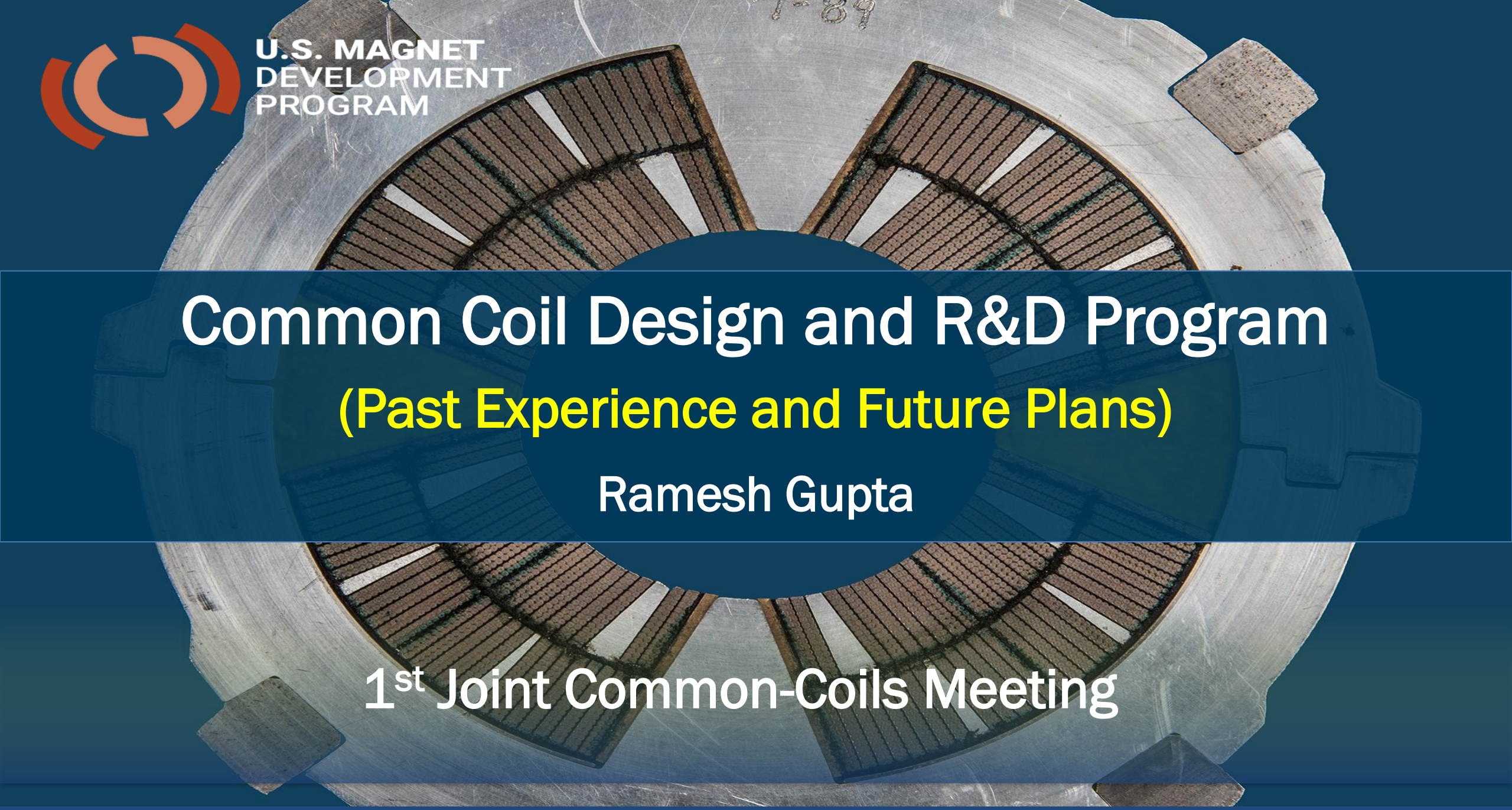


U.S. MAGNET DEVELOPMENT PROGRAM

# Common Coil Design and R&D Program

## (Past Experience and Future Plans)

Ramesh Gupta

## 1st Joint Common-Coils Meeting

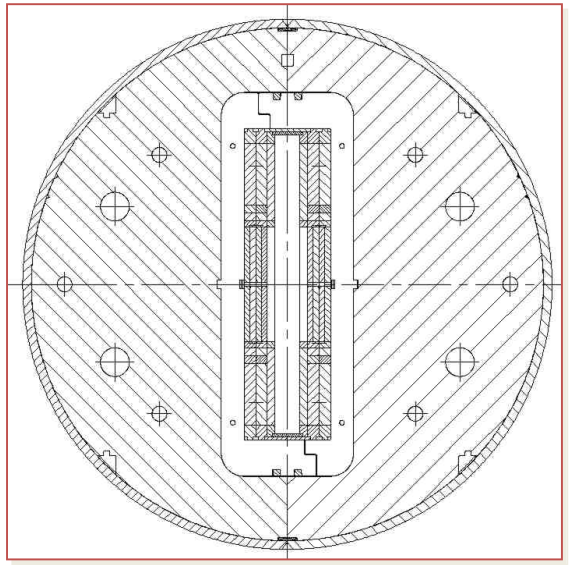
# Overview & Summary

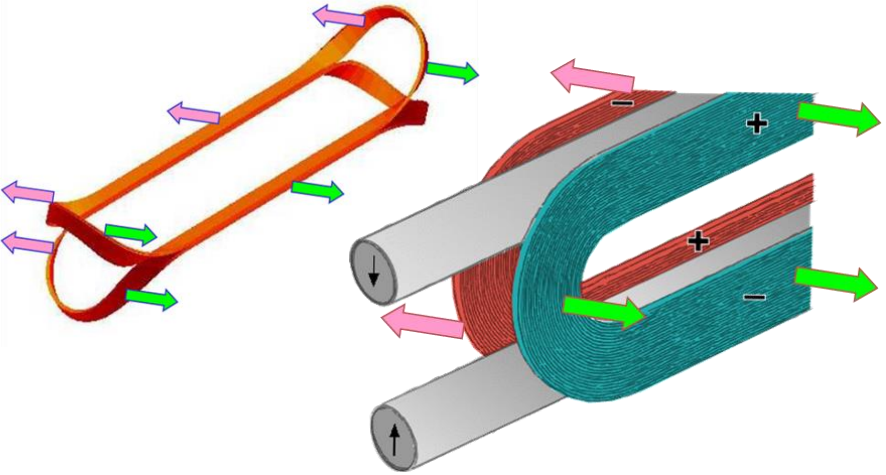
**Note: This will not be a technical presentation/discussion (will do that in future)**

- **The intended goal is to help devolve a general vision and specific plans**
  - **Opportunities: common coil design offers a few opportunities which are not possible with other designs (R&D programs, technologies, manufacturing)**
  - **Challenges: common coil design is still considered a new design with no field quality dipole built and tested (necessary to increase acceptability)**
- **Review past programs**
  - **What has worked (both in design and in experiments), and what was missed**
- **Suggested guidelines for building a plan**
  - **Demonstrate some thing in short term (simple design helps) and plan for a long-term program (keep final goal in mind). Both goals can be integrated.**

# Take Advantage of Some Unique Features of the Common Coil Design

Modular design allows coils of different width, etc.





- **Identical design** can be used for many coils (splice in low field region)
- **Spacing (aperture)** can be changed for a higher field configuration
- **Conductor friendly design** with large bend radii allows both "**React & Wind**" and "**Wind & React**" technologies
- **Efficient segmentation** between HTS and LTS coils for 20 T dipole or possibly between $Nb_3Sn$ and NbTi 14 T dipoles (to be examined)
- **Mechanically handles the large Lorentz forces well** with coil layers moving as a block (creating little internal strain on conductor despite large movement). Only need to minimize relative deflections not the total (very different from the cosine theta or block coil designs)
- **Stressed management with simple structure** as demonstrated recently in various designs and experimental programs
- **Simple magnet geometry** and **simple tooling** allows faster and lower costs for both for starting R&D and for large-scale manufacturing
- **Allows rapid-turn-around, lower-cost** program for systematic studies and high-risk, high-reward novel R&D (important at this stage)

U.S. MAGNET DEVELOPMENT PROGRAM

# A Unique Common Coil Design Dipole at BNL

## (facilitates low-cost, rapid-turn-around variety of R&D)

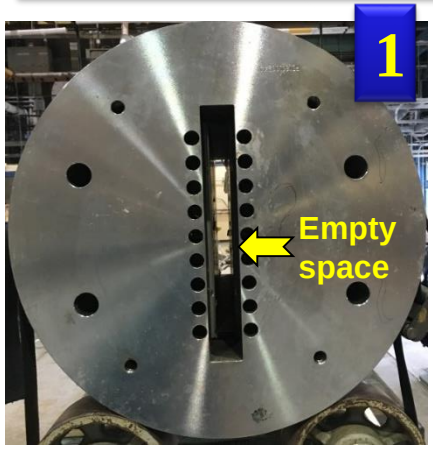
BNL common coil design experience has been very productive for low, cost rapid-turn around R&D for a variety of purpose.

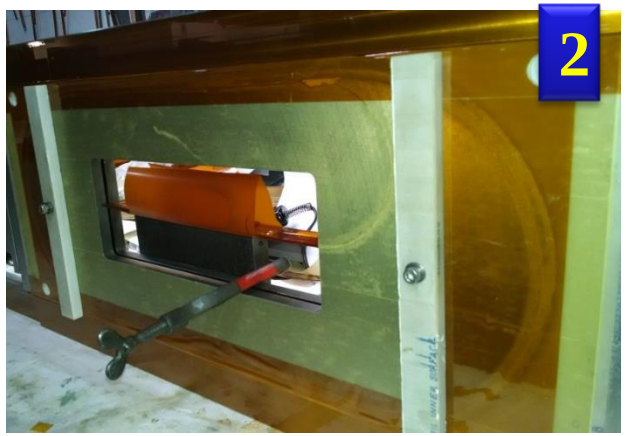
Identical design may not work everywhere, but a similar approach may.

For example, fully open space may be replaced by removable insert for a field quality coils; or build a structure that can be disassembled easily.

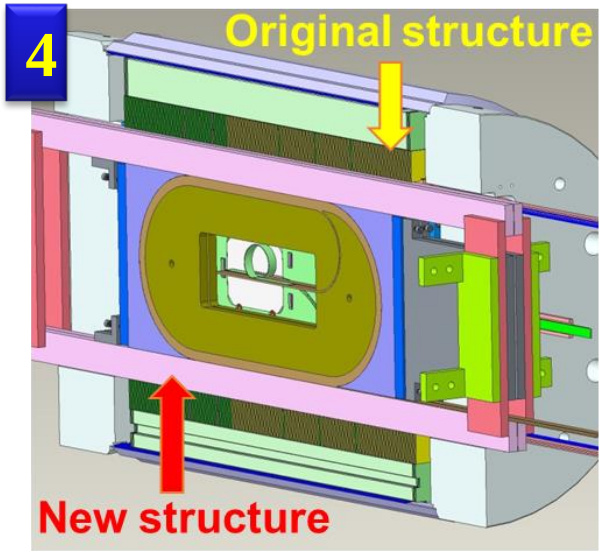
**Five steps for testing new design**

1. Magnet (dipole) with a large open space
2. Coil for high field testing
3. Slide coil in the magnet
4. Coils become an integral part of the magnet
5. Magnet with new coil(s) ready for testing



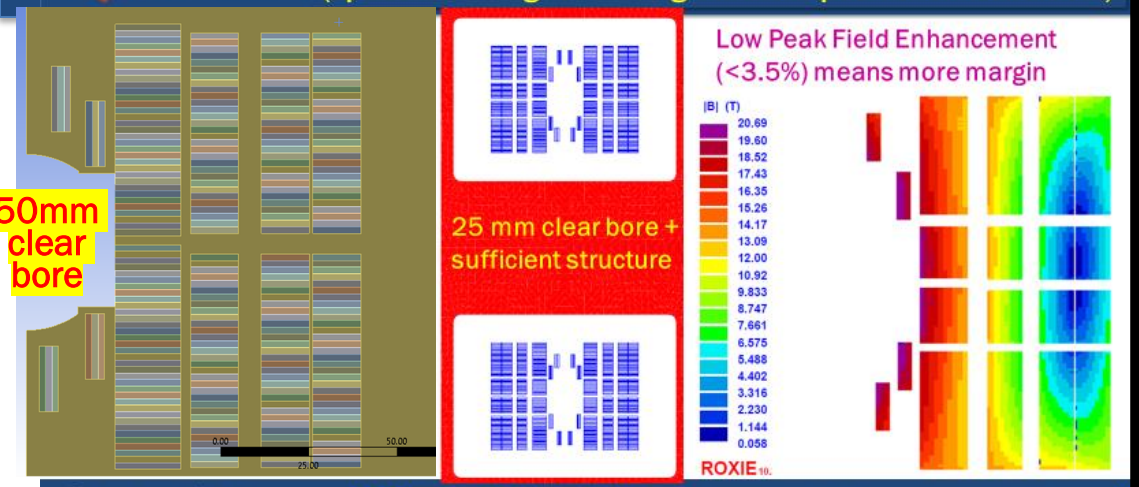








# Recent Progress in MDP

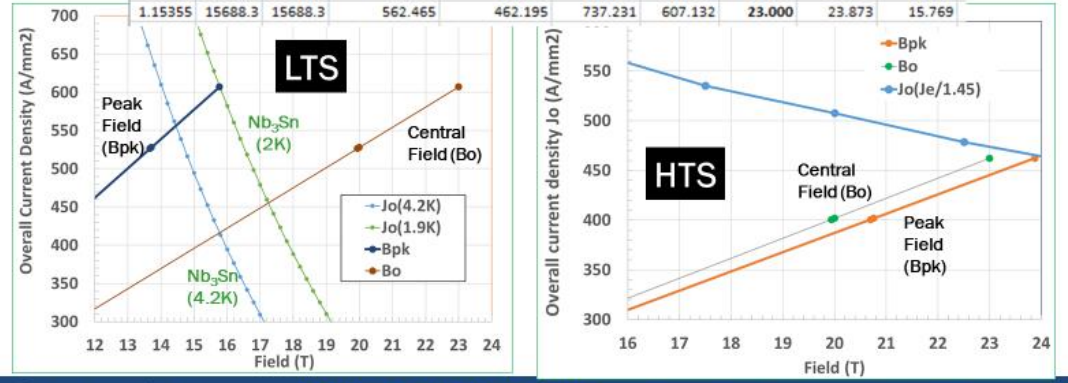
## New 20 T HTS/LTS Hybrid Design (May 2022)
(spacers in magnetic design takes input from mechanical)




- All $Nb_3Sn$ coils identical
- Well balanced margin between HTS & LTS coils

## Magnetic Design (May 2022) with 15% Margin

| I(HTS), A | I(Nb3Sn) | Je(HTS), A/mm^2 | Jo(HTS), A/mm^2 | Je(Nb3Sn) | Jo(Nb3Sn) | Bo (T) | Bpk(HTS), T | Bpk(Nb3Sn) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13600 | 13600 | 487.60 | 400.672 | 639.10 | 526.316 | **19.938** | 20.695 | 13.670 |
| 13642.2 | 13642.2 | 489.107 | 401.914 | 641.079 | 527.947 | 20.000 | 20.759 | 13.712 |
| 15688.3 | 15688.3 | 562.465 | 462.195 | 737.231 | 607.132 | **23.000** | 23.873 | 15.769 |




- Excellent field quality
- Simple stress-managed structure

## Magnetic Design (May 2022) Good Field Quality

| MODEL | mdp_may2022-v2 |
|---|---|
| BI2212R | BI2212 |
| Bare w | 1.52 |
| Bare h | 18.35 |
| Insulation | 0.15 |
| Ins w | 1.82 |
| Ins h | 18.65 |
| Ins Area | 33.943 |
| Current | 13600 |
| Je (A/mm^2) | 487.60 |
| Jo (A/mm^2) | 400.67 |
| Bpeak (T) | 20.6951 |

| MDPH2 | $Nb_3Sn$ |
|---|---|
| Bare w | 1.6 |
| Bare h | 13.3 |
| Insulation | 0.15 |
| Ins w | 1.9 |
| Ins h | 13.6 |
| Ins Area | 25.840 |
| Current | 13600 |
| Je (A/mm^2) | 639.10 |
| Jo (A/mm^2) | 526.32 |
| Bpeak (T) | 13.6701 |
| Bo | 19.9382 |

NORMAL RELATIVE MULTIPOLES (1.D-4):

| | | | | | |
|---|---|---|---|---|---|
| b 1: | 10000.00000 | b 2: | -0.00000 | b 3: | 0.05059 |
| b 4: | -0.00000 | b 5: | 0.09440 | b 6: | 0.00000 |
| b 7: | -0.78244 | b 8: | 0.00000 | b 9: | -0.92602 |
| b10: | 0.00000 | b11: | -0.18313 | b12: | -0.00000 |
| b13: | -0.02800 | b14: | 0.00000 | b15: | -0.01273 |
| b16: | 0.00000 | b17: | -0.00410 | b18: | -0.00000 |
| b19: | -0.00094 | b20: | 0.00000 | | |

All harmonics <1 unit

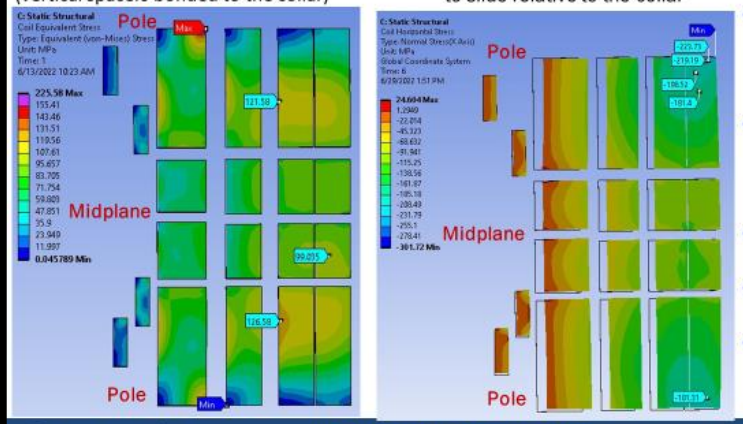
SKEW RELATIVE MULTIPOLES (1.D-4):

| | | | | | |
|---|---|---|---|---|---|
| a 1: | 0.00000 | a 2: | -0.00405 | a 3: | 0.00000 |
| a 4: | -0.02333 | a 5: | -0.00000 | a 6: | -0.15914 |
| a 7: | 0.00000 | a 8: | 0.20675 | a 9: | 0.00000 |
| a10: | 0.08678 | a11: | -0.00000 | a12: | 0.00779 |
| a13: | 0.00000 | a14: | 0.00593 | a15: | -0.00000 |
| a16: | 0.00258 | a17: | 0.00000 | a18: | 0.00056 |
| a19: | -0.00000 | a20: | 0.00019 | a | |

## Developing Mechanical Structure

Original Case
(vertical spacers bonded to the collar)

SST vertical separators are allowed to slide relative to the collar



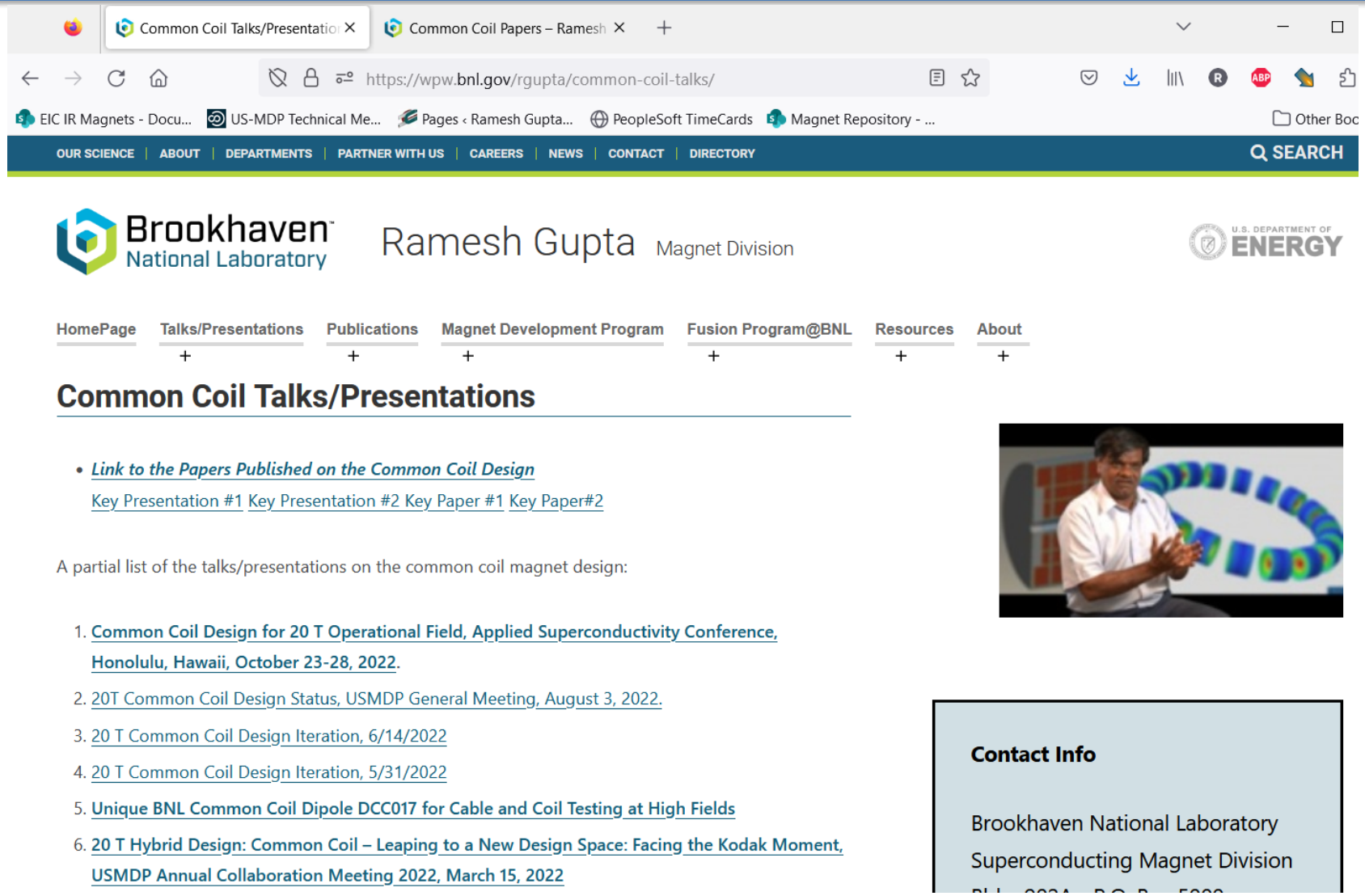

- Stresses and Strain are within acceptable limits at most places See John Cozzolino's presentation
- However, at pole the exceed the limit either in HTS or in LTS, depending on the contact (bonded or sliding)
- Attempt to make things better for decreasing the local peak
- Enhanced peaks are because of the bending of the coil layer.
- The two cases show that it can be balanced out

# References

https://wpw.bnl.gov/rgupta/common-coil-talks/

https://wpw.bnl.gov/rgupta/common-coil-papers/

https://wpw.bnl.gov/rgupta/mdp-design/



# Overview & Summary

**Note: This will not be a technical presentation/discussion (will do that in future)**

- **The intended goal is to help devolve a general vision and specific plans**
  - **Opportunities: common coil design offers a few opportunities which are not possible with other designs (R&D programs, technologies, manufacturing)**
  - **Challenges: common coil design is still considered a new design with no field quality dipole built and tested (necessary to increase acceptability)**
- **Review past programs**
  - **What has worked (both in design and in experiments), and what was missed**
- **Suggested guidelines for building a plan**
  - **Demonstrate some thing in short term (simple design helps) and plan for a long-term program (keep final goal in mind). Both goals can be integrated.**