R&D Towards 40 T at BNL

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High Field Solenoid Projects at BNL

- ~35 T HTS/Nb_3Sn s.c. solenoid for Muon Collider (PBL/BNL SBIRs)
  - 34 HTS coils already built and tested using over 3 km of conductor
- ~40T (~20^+T HTS) insert coil PBL/BNL SBIR (~20^+T comes from HTS)
  - 23 T already demonstrated in the background field of NHMFL

- ~25 T large aperture HTS solenoid for SMES (ARPA-E funded)
  - R&D would directly benefit high field solenoids for SMES

- A very brief summary of selected HTS R&D on related topics (e.g. quench protection, stress limit, radiation damage) and other HTS programs at BNL

PBL/BNL SBIR for Muon Collider

SBIRs from Particle Beam Lasers (PBL) with BNL as partner:

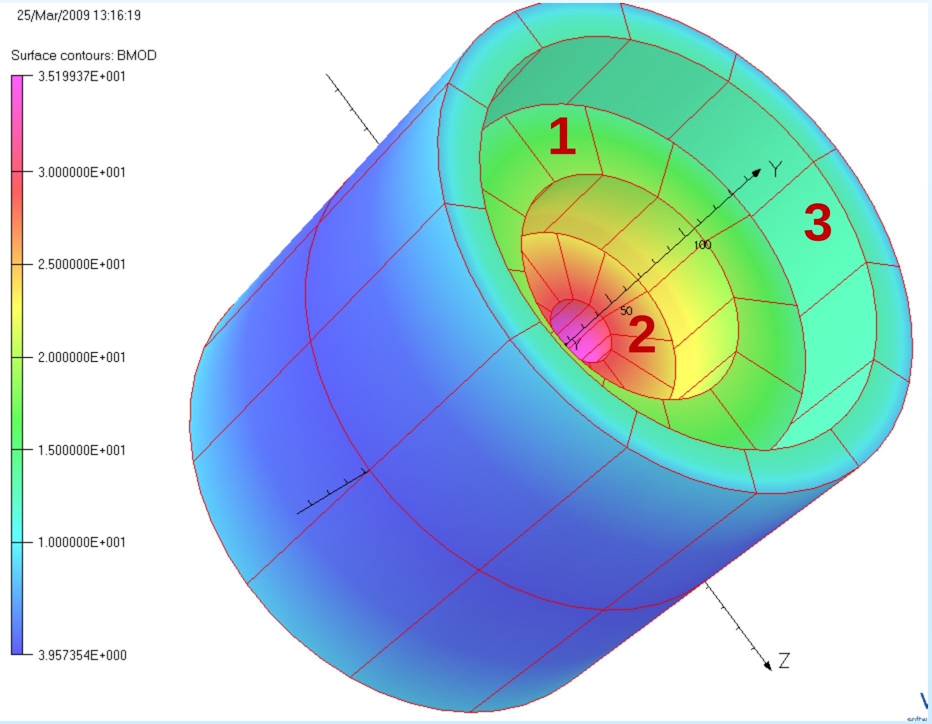
1. **~10 T HTS solenoid (middle): Phase II funded**
2. **~12 T HTS (inner): Phase II funded**
3. **12-15 T Nb_3Sn (outer): Phase I funded, Phase II will be applied**

20+ T All HTS Solenoid (1 & 2):

addresses challenges with high field HTS solenoids

35+ T All Superconducting Solenoid (1, 2 and 3):

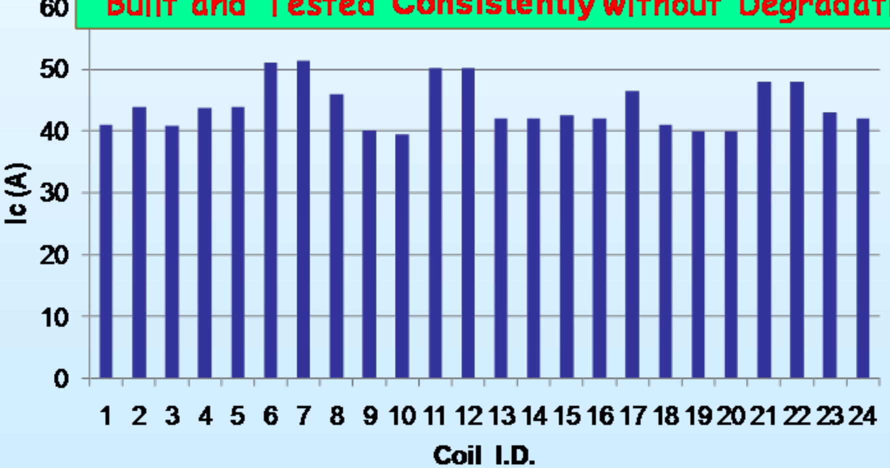
addresses challenges with high field superconducting solenoids



Status of BNL/PBL SBIR #1 (10 T HTS Outsert)

- 29 coils for 100 mm aperture solenoid have been wound with stainless steel insulation
- Each coil is made with 100 meters (total: ~2.9 km) of second generation (2G) HTS
- All coils have been individually tested at 77 K ; 24 good coils selected
- We should have the test result of the completed ~10 T solenoid in about four months

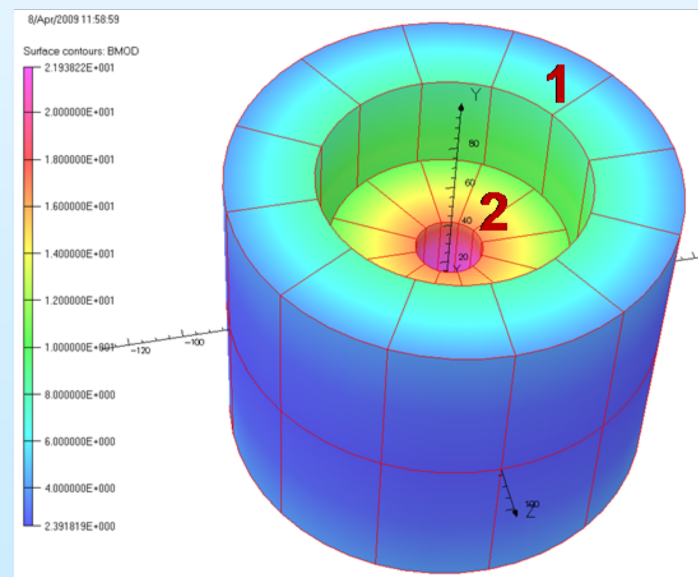
Proof: Coils with the second generation HTS Can be Built and Tested Consistently without Degradation



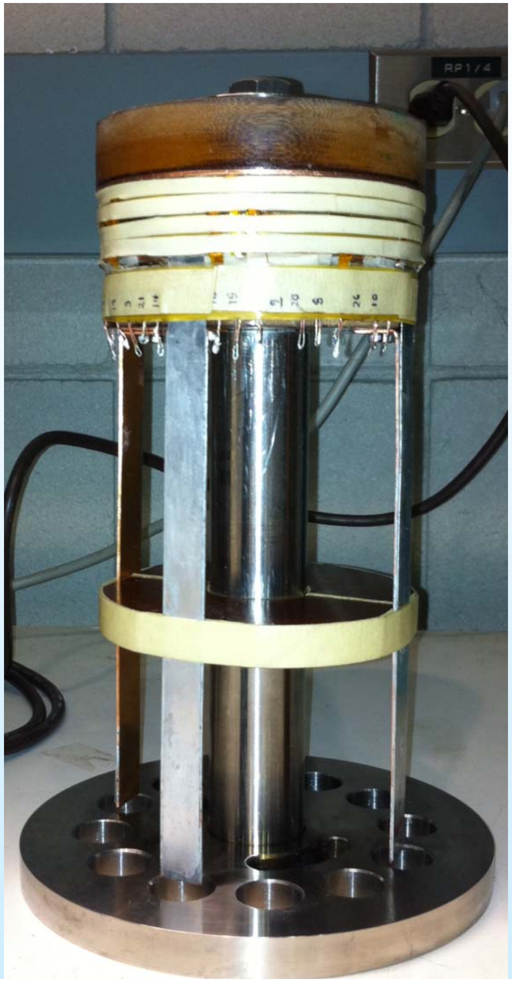
Field parallel ~0.5 T; field perpendicular ~0.3 T @40 A

Status of BNL/PBL SBIR #2 (10+ T HTS insert)

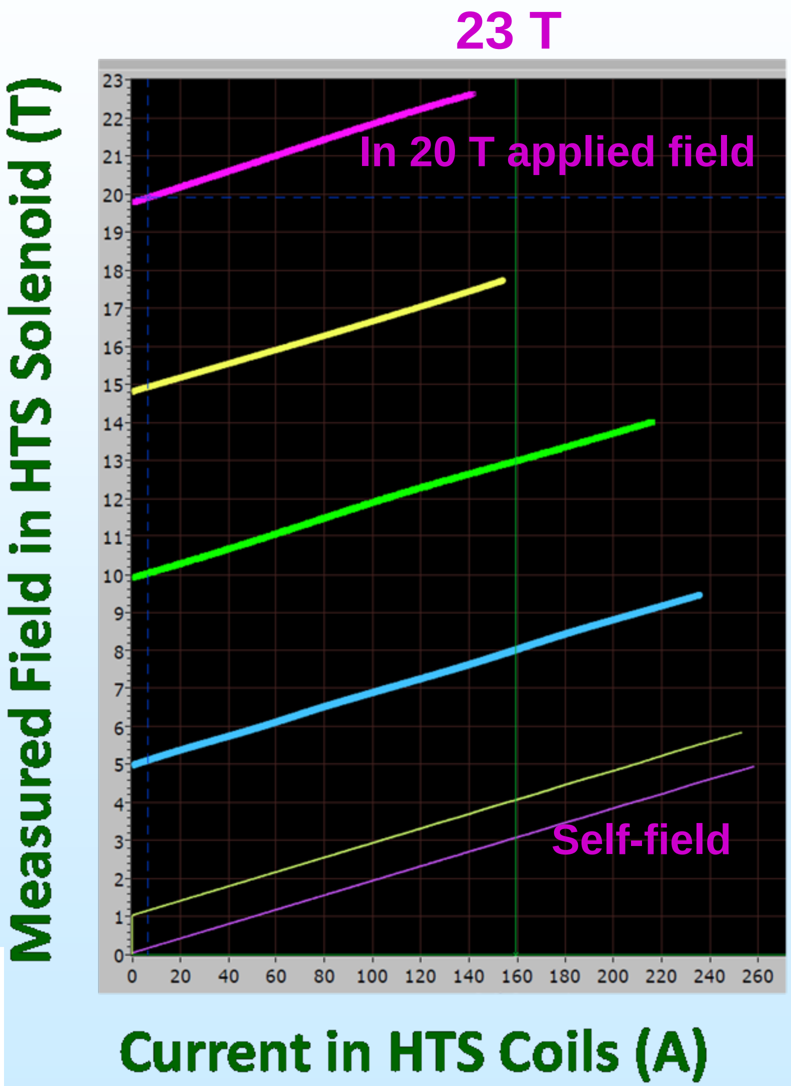
- Coil i.d. ~25 mm; o.d. ~95 mm (can go inside 100 mm solenoid)
- Inner solenoid needs 12 pancake coils
- 5 coils built and tested (3 with Kapton and 2 with ss insulation)
- Each coil is made with 50 meters of 2G HTS
- All coils tested at 77 K and four at 4 K



HTS PBL/BNL Insert Coil Test in the Background Field of NHMFL



Four HTS coils built for inner solenoid were used for insert coil test at NHMFL



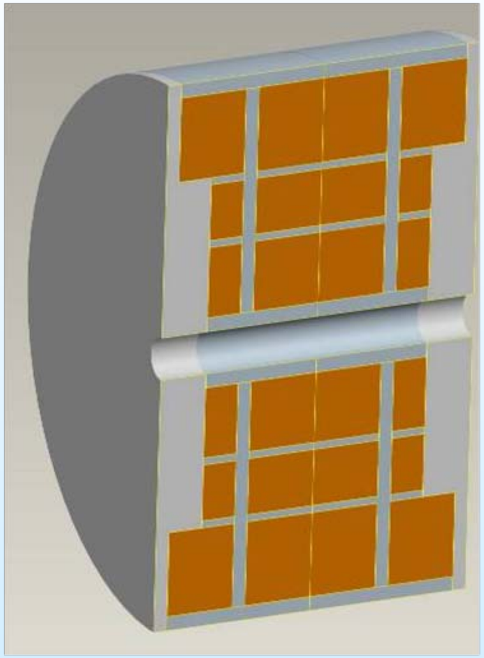
4 T @4K self field, and 23 T in 20 T background field

First demonstration of technology for 20-22 T HTS solenoid, as targeted in SBIR.

High Field HTS Solenoid for SMES (Partners: BNL, SuperPower & ABB)

R&D has just started on this high field, large aperture HTS solenoid for SMES

• Quench protection of a large magnetic energy storage device is a major issue



- Field: ~25 T
- Inner Diameter : ~100 mm
- Conductor: ~10 km, 12 mm wide 2G tape
- Stored Energy: 2.5 MJ

• There is going to be a significant R&D effort on conductor and magnet technology – funded by ARPA-E but very relevant to MAP

• **If demonstrated, then 50 T can be targeted with HTS insert and LTS outsert – relatively less challenging (funding must come from elsewhere)**

HTS Technology Development Program at BNL

HTS Quench Protection R&D at BNL (development of hardware and understanding)

Quench protection in HTS poses a major challenge. BNL has a comprehensive R&D program with funding from several sources – FRIB, SMES, PBL/BNL SBIR, base program and possible LDRD (all small but they add up)

NOVEL QUENCH DETECTION SYSTEM FOR HTS COILS*

Piyush Joshi[#], Sebastian Dimaiuta, George Ganetis, Ramesh Gupta, Yuko Shiroyanagi, Brookhaven National Laboratory, Upton, NY USA.

Abstract

As a part of High Temperature Superconducting (HTS) Magnet R&D, small coils are b
study quench properties in a sys
purpose, multi-channel quench
data logger, current ramp control
system was developed. This sy
compact, economical and easy to
on LabView and Field Programm
hardware from Nation

QUENCH PROPAGATION STUDIES USING SMALL BIFILAR YBCO COILS

Y. Shiroyanagi, W. B. Sampson, and A. K. Ghosh

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ABSTRACT

Quench propagation was studied in a small bifilar coil wound from YBCO tape. Measurements were made at 77 K in self-field and at 4.2 K with an applied field. The velocity of quench propagation at 4.2K was observed to be faster than at 77 K both in the longitudinal and transverse directions. During the course of this experiment the conductor damage limit characterized by $\int I^2 dt$ was also estimated. Details of the experiment and results are presented in this paper.

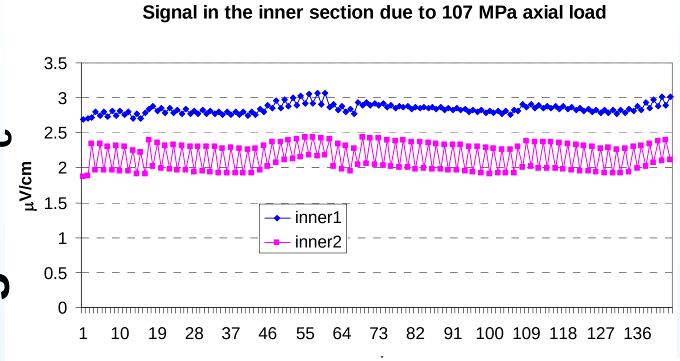
Influence of ~107 MPa Pressure on the Narrow Face of Conductor in 2G HTS Coil

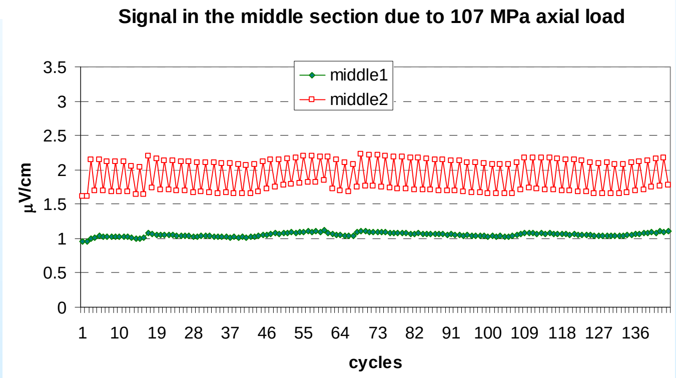
Load ON, Load OFF:

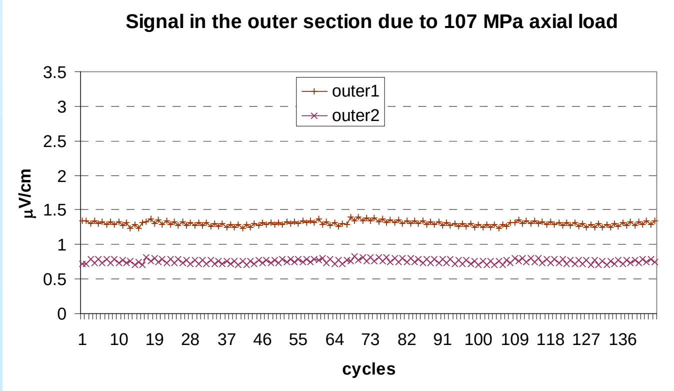
Measure change in Ic every ~1 m over ~6 m

HTS Coils

~0.5% reversible change in I_c



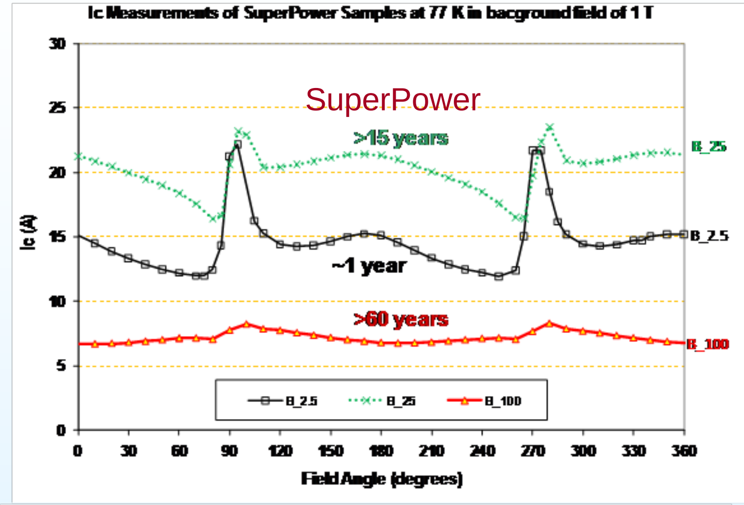




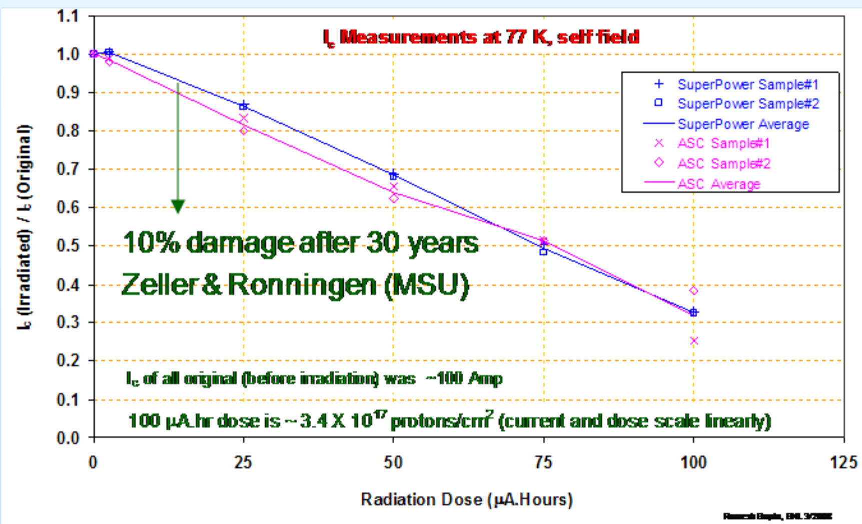
A negligible change in I_c means that at least 100 MPa load is acceptable

Radiation Damage Studies for FRIB
2G HTS from SuperPower and ASC

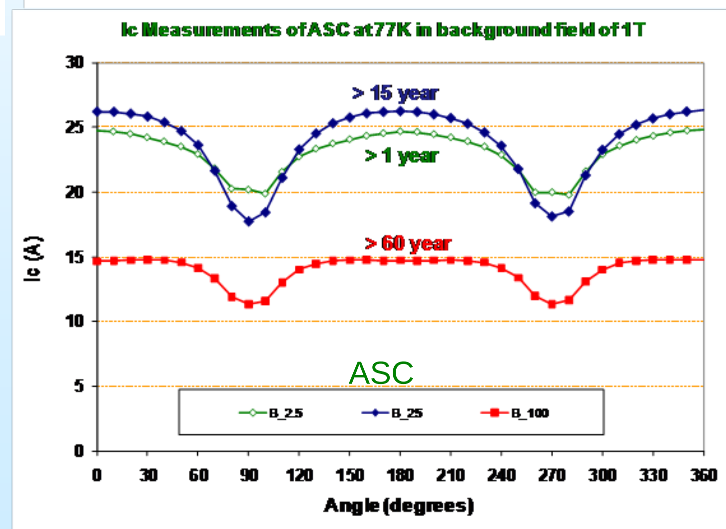
Figure 2. The BLIP facility.



ASC2008 – self field 77 K



PAC2011- in field 77 K



Next step: In field measurements at 40-50 K. MAP could be interested at 4 K

Wide Range of HTS Magnet R&D at BNL

- The level of involvement in this field may be gauged by the amount of HTS wire/tape coming in. Net total in all programs (normalized to 4 mm tape):
  - Obtained so far: ~20 km
  - Next two years (based on funded programs): ~35 km
- Successfully designed, built & tested a large number of coils & magnets:
  - Number of HTS coils built: ~100
  - Number of HTS magnet structures built and tested: ~10
- HTS Magnet R&D for a wide range of operating conditions:
  - High field (>20 T), low temperature: two funded programs
  - Medium field, medium temperature: three funded programs
  - Low field, High temperature: several in house, built and tested

HTS Magnet R&D at BNL is about an order of magnitude more than in other labs

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

http://www.bnl.gov/magnets/staff/gupta/

High Temperature Superconducting Magnets

Revolutionizing Next Generation Accelerators and Other Applications

Ramesh Gupta
Superconducting Magnet Division

466th Brookhaven Lecture

February 16th, 2011

http://www.bnl.gov/magnets/staff/gupta/

PAC 2011 Papers on HTS from BNL

A wide range of HTS R&D @ BNL presented at PAC2011:

1. Engineering Design of HTS Quadrupole for FRIB – Cozzolino, et al.
2. Design, Const. and test of Cryogen-free HTS Coil Structure – Hocker, et al.
3. Influence of Proton Irradiation on Second Generation HTS in Presence of Magnetic Field – Shiroyanagi, et al.
4. Novel Quench detection system for HTS Coils – Joshi, et al.
5. Measurements of the Effect of Axial Stress on YBCO Coils – Sampson, et al.
6. Open Midplane Dipole for Muon Collider – Weggel, et al.
7. Design Construction and Test Results of HTS Solenoid for ERL – Gupta, et al.
8. HTS Magnets for Accelerator and Other Applications – Gupta

A significant number of papers and presentations:

http://www.bnl.gov/magnets/staff/gupta/Talks/hts-talks.htm
http://www.bnl.gov/magnets/staff/gupta/Publications/htS-papers.htm

SUMMARY (1)
PBL/BNL Related

- High field HTS solenoids are very challenging with a number of technologies yet to be demonstrated. However, over the years we have made some progress.
- We have built and tested a large number of HTS coils (34) for PBL/BNL SBIR.
- We have demonstrated these coil will survive 23 T (NHMFL has demonstrated HTS coils to ~35 T).
- We hope to demonstrate a ~100 mm, 10 T HTS solenoid in a few months.
- We hope to demonstrate 10-12 T, ~25 mm insert HTS solenoid in ~6 month.
- We hope to demonstrate ~20-22 T HTS solenoid by combining two in ~10 month.
- We hope to test above in ~20 T resistive solenoid at NHMFL to test HTS magnet technology to field approaching 40 T in about a year or so.
- There is also a Phase I SBIR for ~15 T Nb_3Sn outsert. If that results into Phase II funding, then we plan to demonstrate ~35+ T all superconducting solenoid.
- If successful, then we would have solved a major technical issue of MAP.

SUMMARY (2)

- We are also building a large aperture ~25 T HTS solenoid for SMES. This is funded by ARPA-E as a high risk, high reward project. Technology developed in this program should directly benefit MAP.

- In addition BNL is pursuing a wide ranging R&D which provides a good synergy and brings overall progress in HTS magnet technology.

- Most of above projects are being carried out on a shoestring budget with no direct support from MAP. MAP could perhaps benefit more with a direct involvement and/or participation of BNL magnet division in various technical and strategic planning of magnet R&D. Surprisingly it is not currently despite its unique expertise with HTS technology.

- We all benefit from sharing our experiences in developing new technology when the funding is limited. We have already established a good collaboration with NHMFL – they have unique experience with high field solenoids and we have with HTS. We invite other groups to join us to work on specific topics.