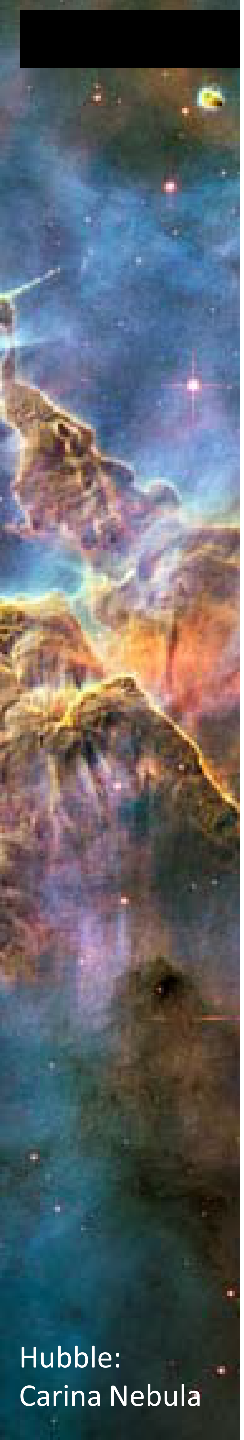
[redacted]



Hubble:
Carina Nebula

NIAC
NASA Innovative Advanced Concepts

MAARSS

High Temperature Superconductor Coil Expansion Test Using 2G YBCO

Test Day: Friday August 23, 2013

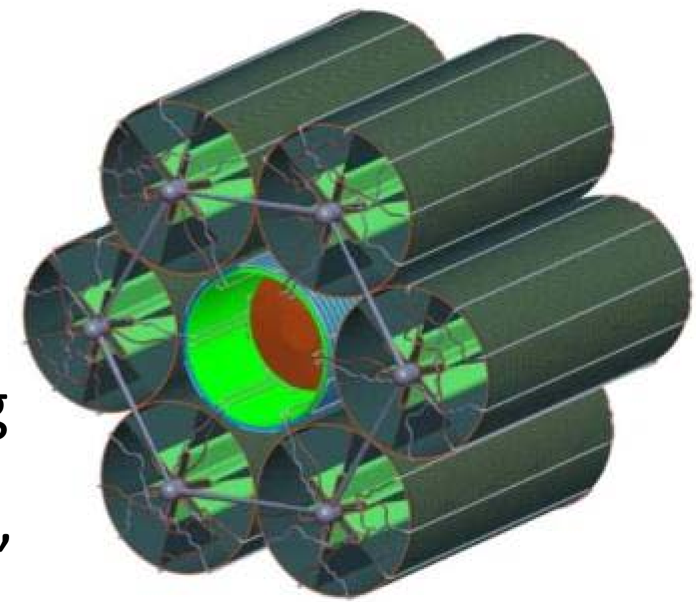
Engineering Design and Development
EP4/Shayne Westover & Coop/Pooja Desai, EP5/Frank Davies
Engineering Test Support
EP6/Cindy Situ, Mike Reddington

[redacted]

[redacted]

Overview of MAARSS project

- **Objective**: Protect humans from space radiation for extended missions in deep space
- **Possible Solution:** Deflect charged particles away from habitat region with high temperature superconducting electromagnets
- Use Lorentz forces to “inflate” or expand the protective shield/coils for a light weight approach



Assembled 6:1 configuration

$$F = q\,(E + v \times B)$$

[redacted]

Proof of Concept

- Sensitivity testing previously conducted to evaluate superconductor operation and Lorentz forces
- Next test – demonstrate coil expandability

Sept & Dec 2012

Aug 2013

[redacted]

Analysis

- Ran a case on a solenoid and verified results with hand calculations

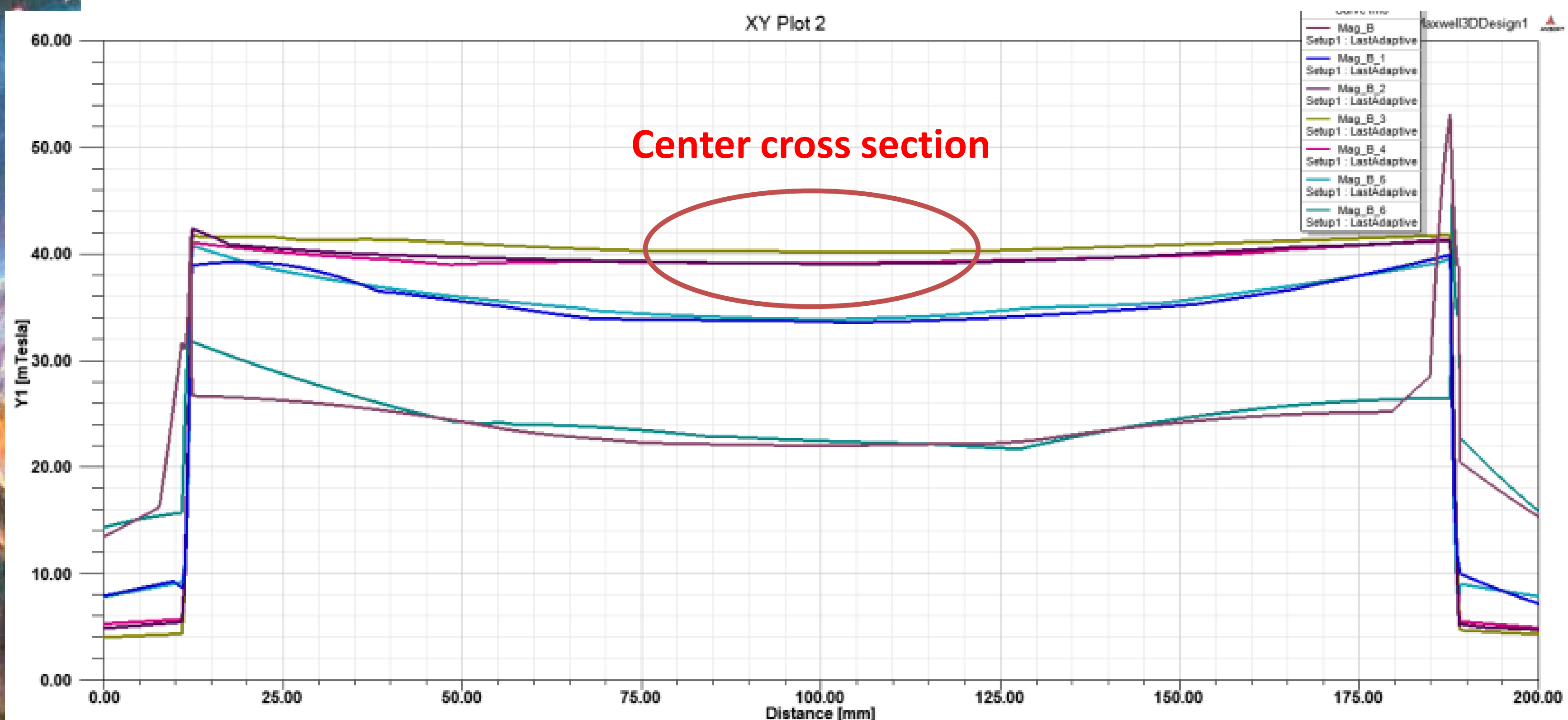
$$B = u_0\left(\frac{N}{\sqrt{4R^2 + L^2}}\right) \mathrm{I} \text{ (for a solenoid)}$$

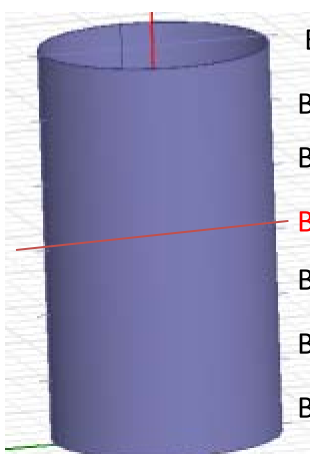
- *Where*

B = magentic field,
u_0 = permeability constant
N = number of turns on a solenoid
R = radius of the coil,
L = length of coil,
I = current

[redacted]

Solenoid Case



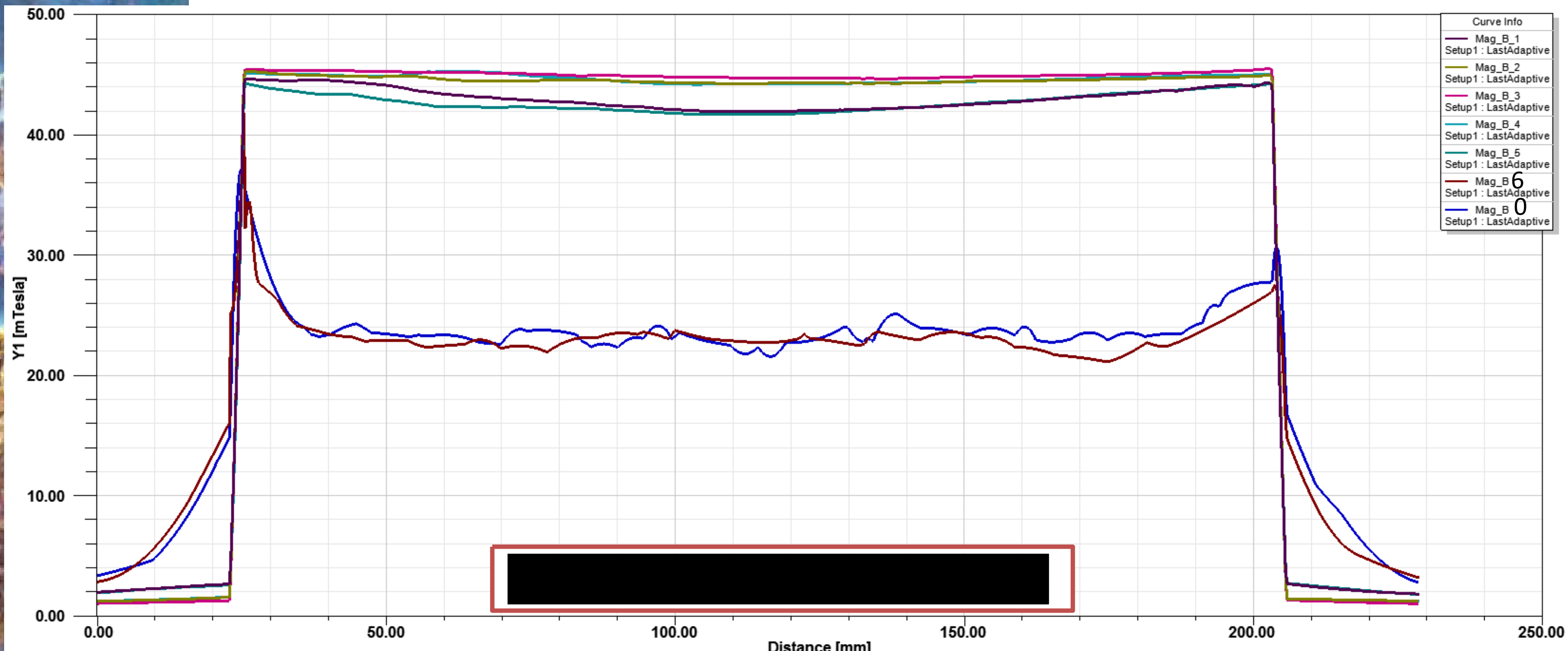


*Coil has 47 turns, 120 amps
*12 inches in length
*7 inches in diameter
*Material: copper

Calculated (center cross section):
B = 40.017 mTesla, 400.17 G
P_B = 0.0924 psi

Sw analysis: 40.5 mTesla, 405 G
P_B = 0.0946 psi

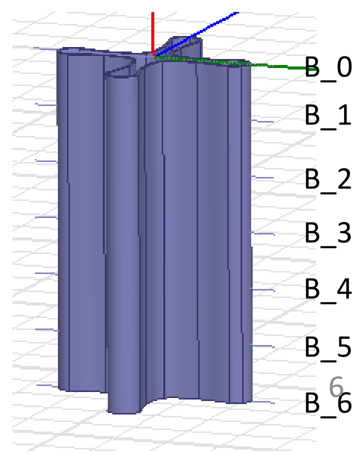
Simulation with Star Shaped Coil



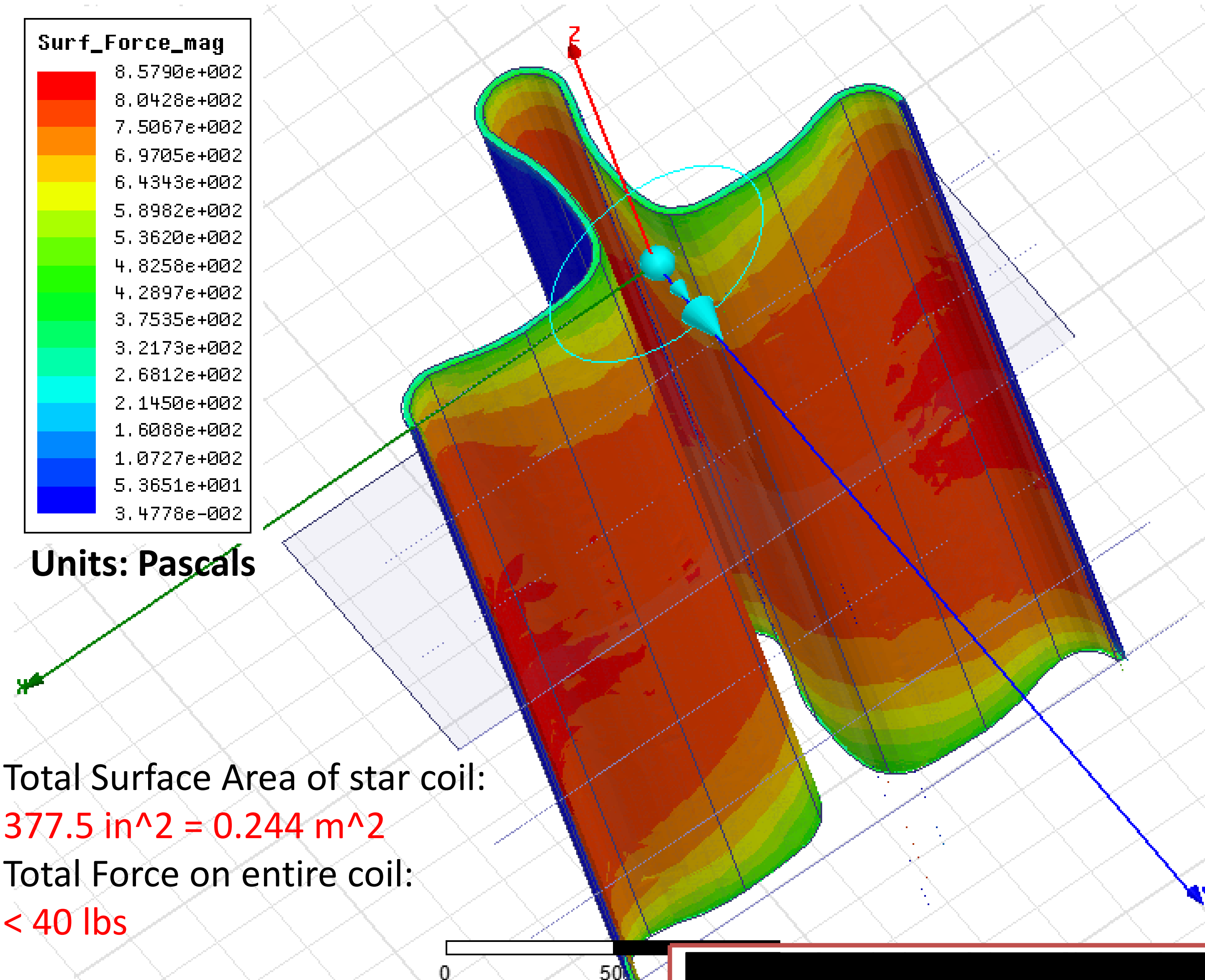
β field is approximately 46 mT (460 G) in the middle of the Coil (~slightly higher than the cylindrical coil case)

Magnetic pressure would then be around **0.122** psi.

*120 amp power supplied.



Surface Force Magnitude



Units: Pascals

Total Surface Area of star coil:

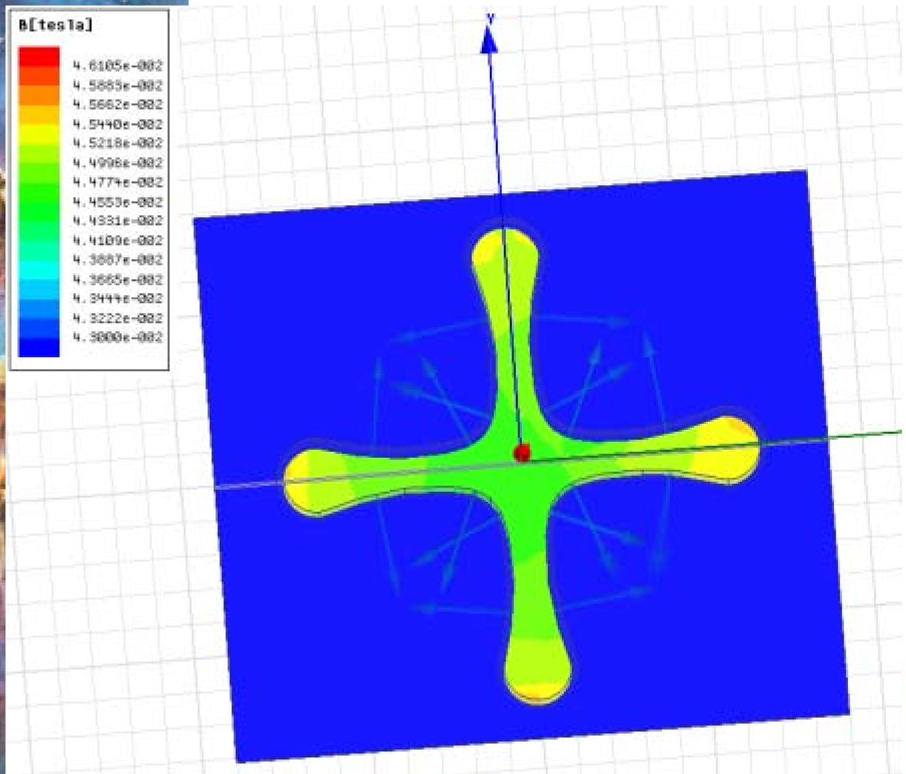
377.5 in^2 = 0.244 m^2

Total Force on entire coil:

< 40 lbs

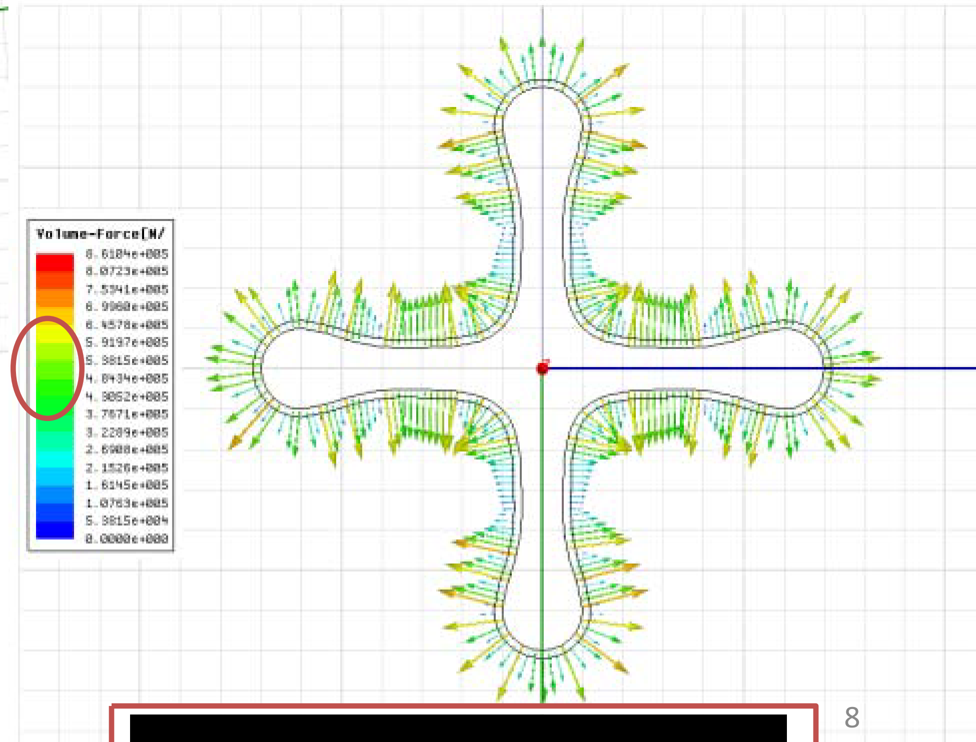
[redacted]

Additional Plots



Magnetic Field

Volume Force Density :
3*10^5 – 6*10^5 N/m^3

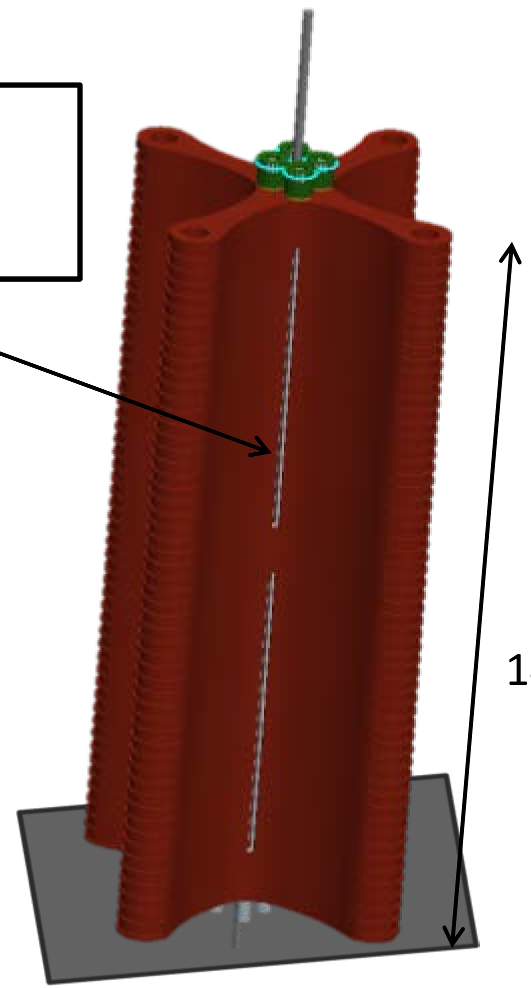


[redacted]

[redacted]

Assembly

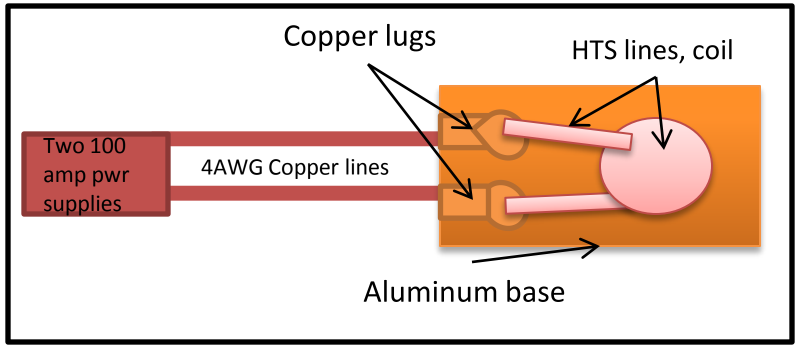
Blankets attached to coil and harness to provide structural stability



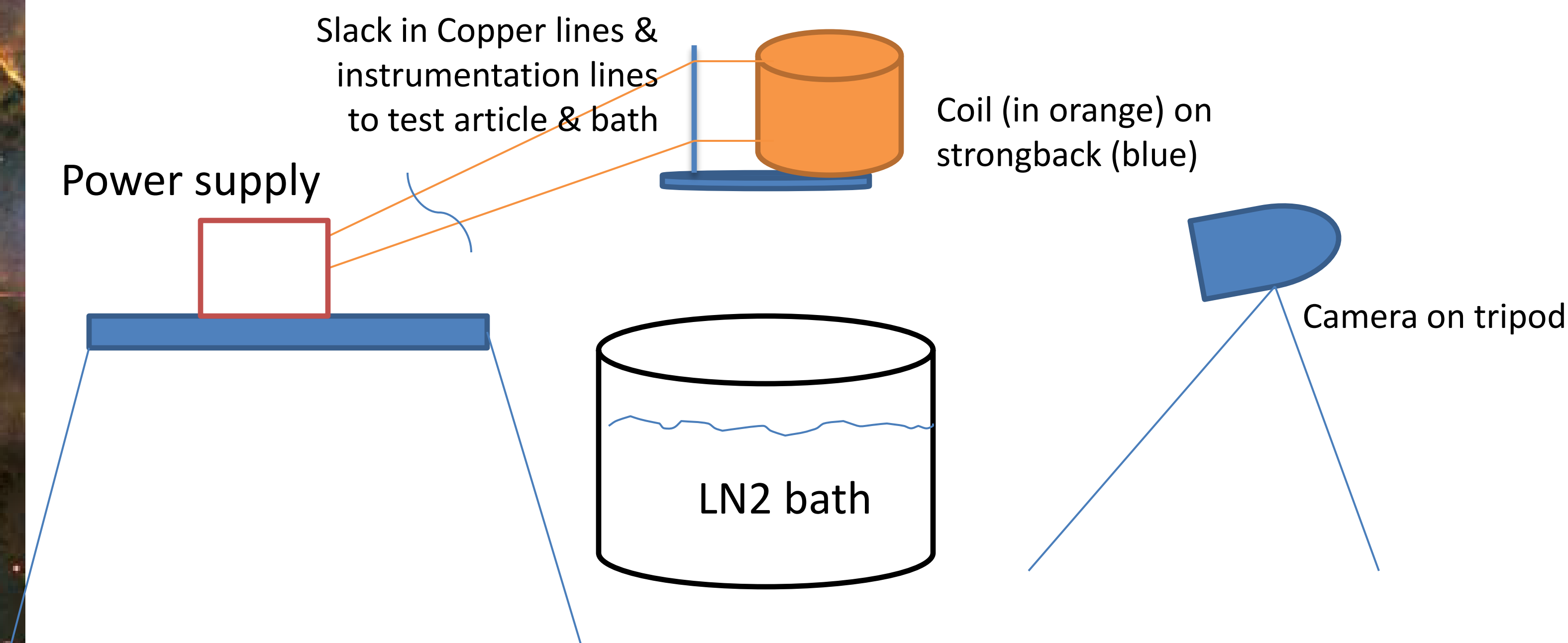
14 in

Entire assembly to be dunked in LN2

Test Setup



Top View



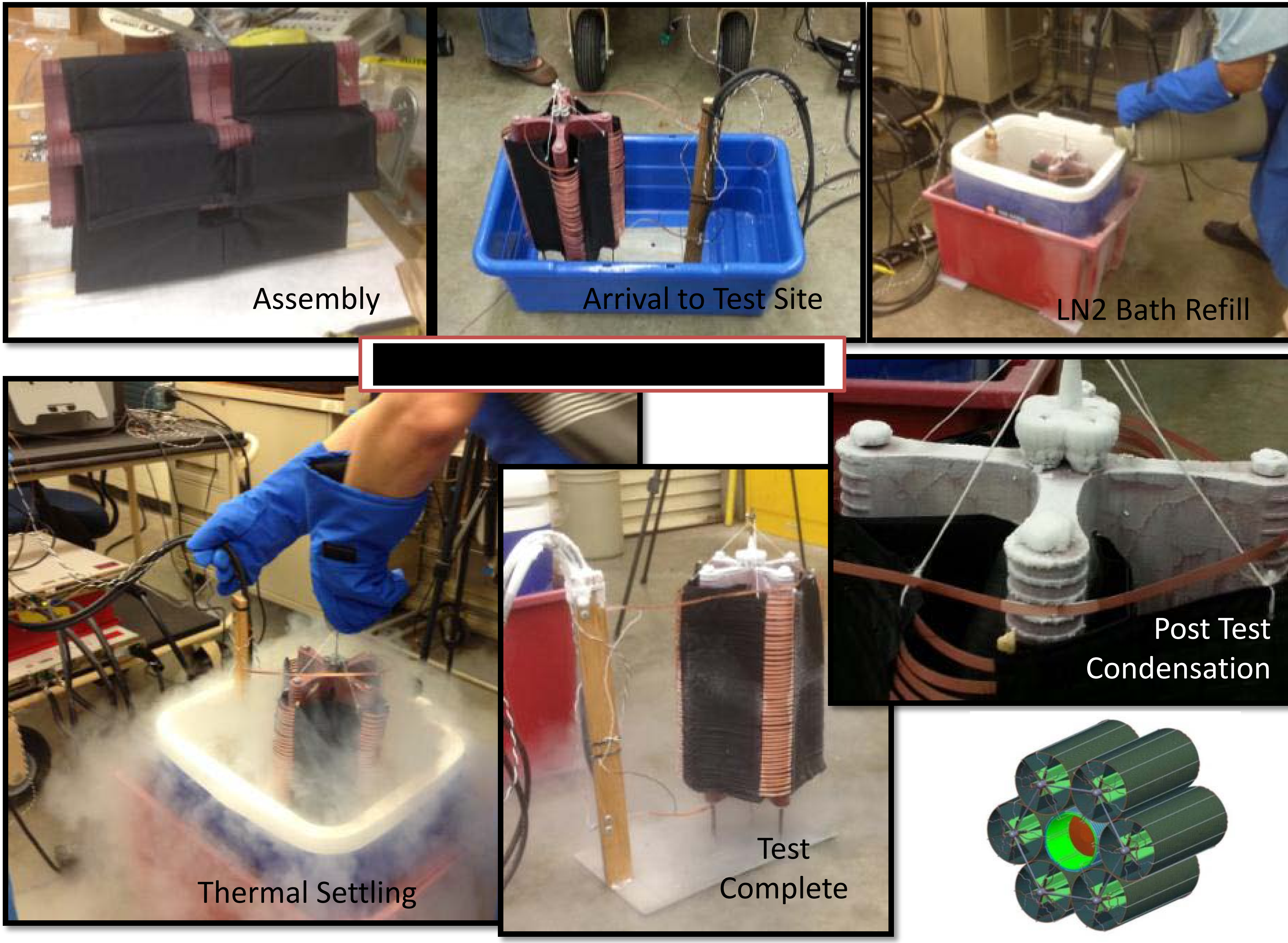
[redacted]

Coil Design Specs

- Cylindrical Specs
  - 45 turns (originally designed for 47 turns)
    - 1 turn was lost due to bent superconductor during assembly process
    - 1 turn was lost due to coil to blanket design fitting during assembly
  - Coil length of ~12 inches
  - Star shape (7 inch diameter tip to tip) expanded to 8.75 inches
  - Current increase to 120 amps

[redacted]

[redacted]


Assembly
Arrival to Test Site
LN2 Bath Refill
Thermal Settling
Test
Complete
Post Test
Condensation

[redacted]

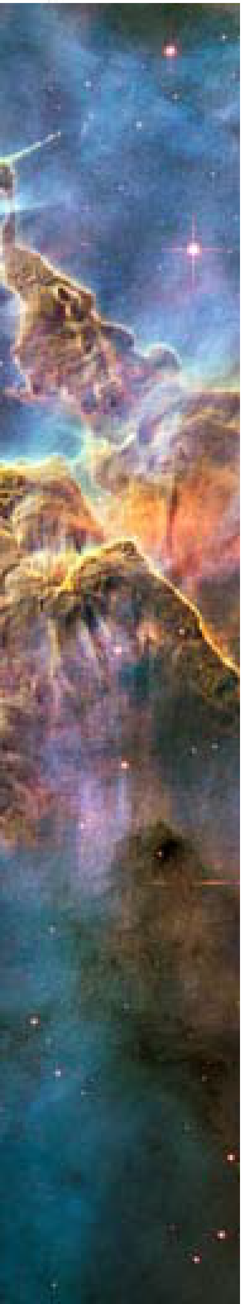
Test Results Summary

- Demonstrated the following:
  - Partial coil expansion with 114 amps
  - In place, on the fly coil splice
  - YBCO quench to failure

- Design points to address
  - Mechanical resistances
    - Blanket binding in vertical orientation due to gravity
    - Condensation build up on mechanical parts

Design modifications required to demonstrate scaled full coil expansion in LN2 and gravity environment

[redacted]

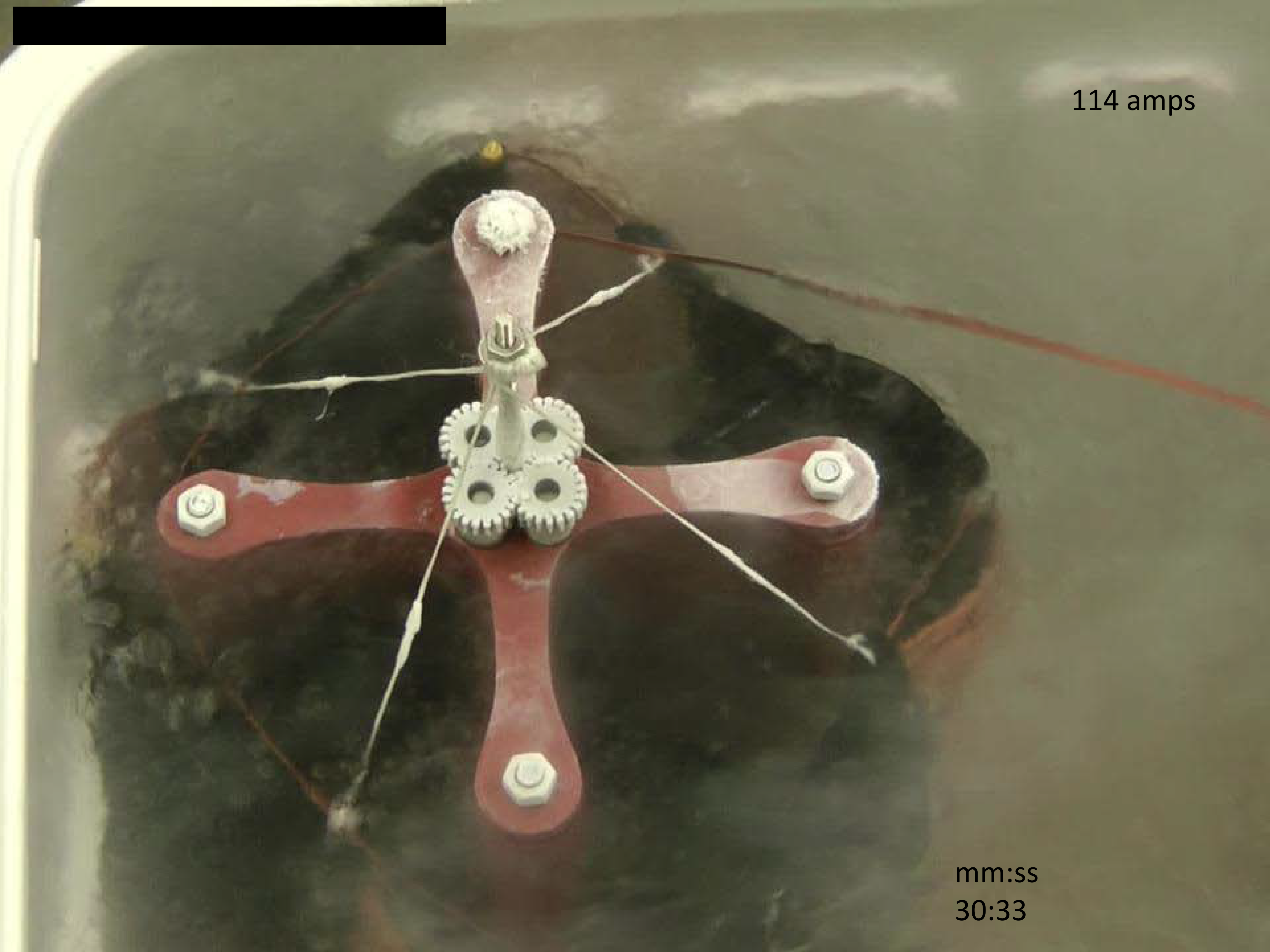


Cycle between the next two slides to see partial inflation

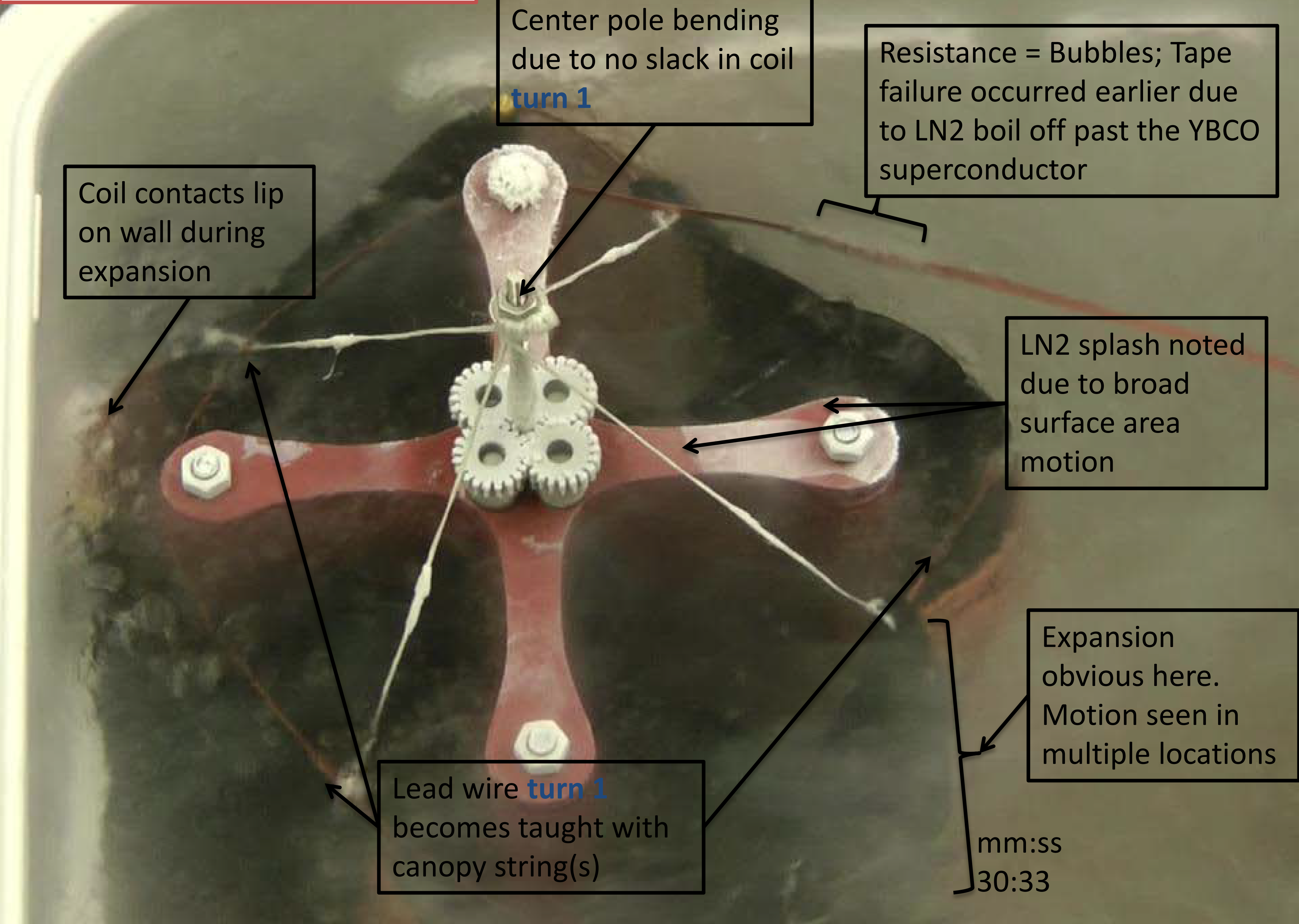
The third slide following points out the visible changes


20 amps
mm:ss
30:32

[redacted]



[redacted]



Center pole bending due to no slack in coil turn 1
Resistance = Bubbles; Tape failure occurred earlier due to LN2 boil off past the YBCO superconductor
Coil contacts lip on wall during expansion
LN2 splash noted due to broad surface area motion
Expansion obvious here. Motion seen in multiple locations
Lead wire turn 1 becomes taught with canopy string(s)
mm:ss
30:33