

**Fundamental Commercialization Promote Technological Development
of the High Temperature Superconducting./
Development of High Magnetic Field Magnet System.**

**Development of High Stable Magnetic Field HTS
Magnet System Technology. [2016-2020]**

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Superconductivity, July 4, 2017 (NEDO)

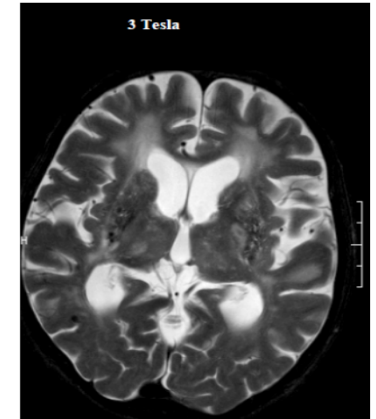
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- MR imaging with HTS 3T mini coil
- NEDO Project promoting practical application
- SUMMARY

○ Medical MRI Superconducting magnet

Features of MRI

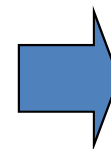
- The **M**agnetic **R**esonance **I**maging does not use X-ray radiation.
- For imaging protons, can vascular imaging without contrast agent, blood flow observation possible
⇒ It is very effective for diagnoses such as Brain disease or heart disease
- The state by the hemoglobin concentration imaging in **f- MRI**, it is can be observed a brain function in three dimensions
- Due to high magnetic field of by superconducting magnet , clear and detailed image is obtained, the capillary and organ condition be comes clear and contribute to early detection
- By highly uniform magnetic field, fat separating, soft tissue imaging such as high functionality



Typical MRI Images
with 3T system

Required for MRI

- ① **High magnetic field** ,
 High stable magnetic field ,
 High uniform magnetic field
- ② **Credibility** : non trouble, long-term maintenance
- ③ **Low Price** → The competition is X-rays CT



**Superconducting
magnet**

○ Why is a **HTS** MRI magnet necessary?

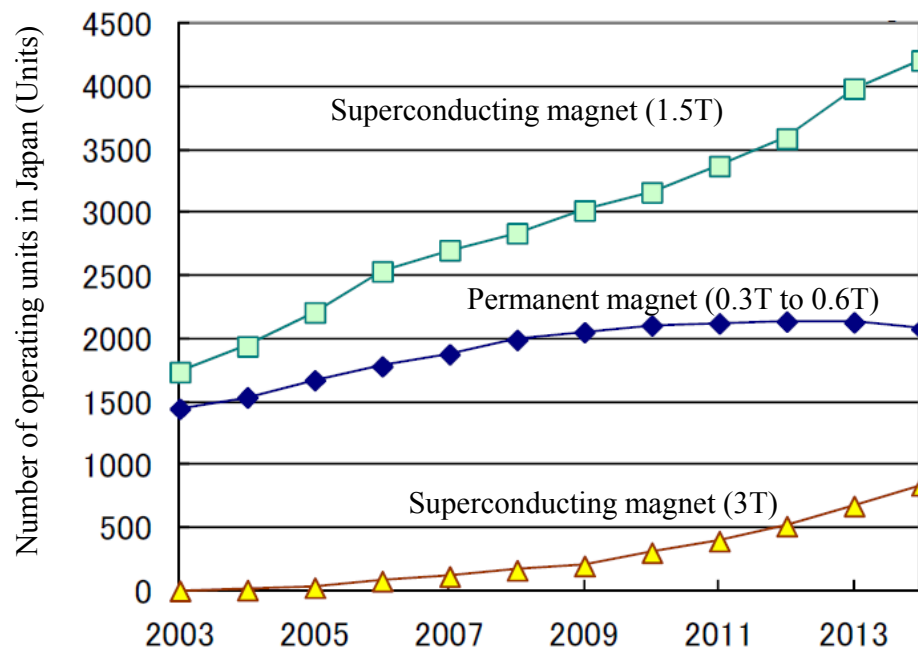
○ MRI apparatus superconductivity mainstream, and **high magnetic field** (high resolution) is required. The growth rate of the 3T magnet is higher.

○ Features of superconductivity, high magnetic field accrual (>3T), energy saving (R=0).

● In present, a NbTi superconducting magnet need liquid helium for cooling.

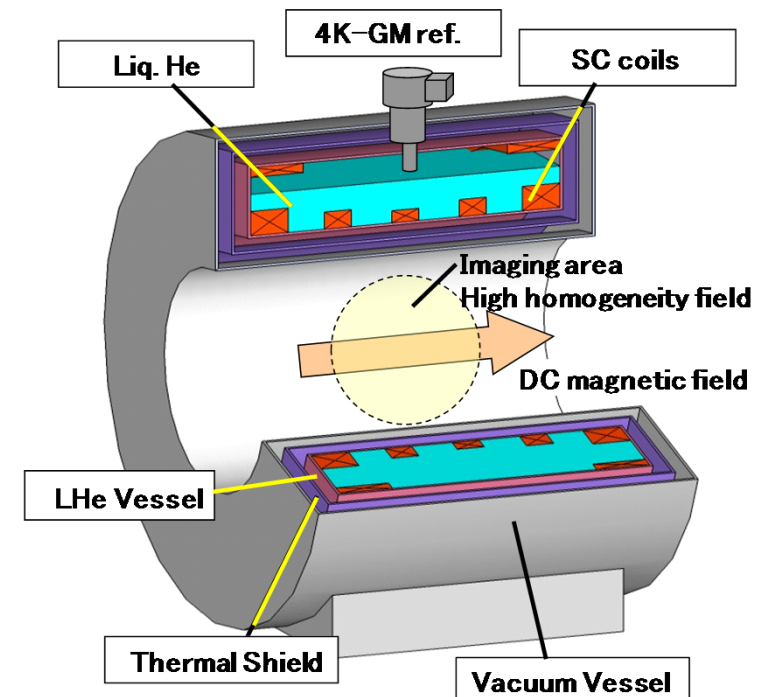
➡ These several years, **Supply Crisis** and **Price Increases** of helium, and also Nb material

◎ **High-Temperature Superconductivity**: **liquid helium less, Nb less** and using in high field



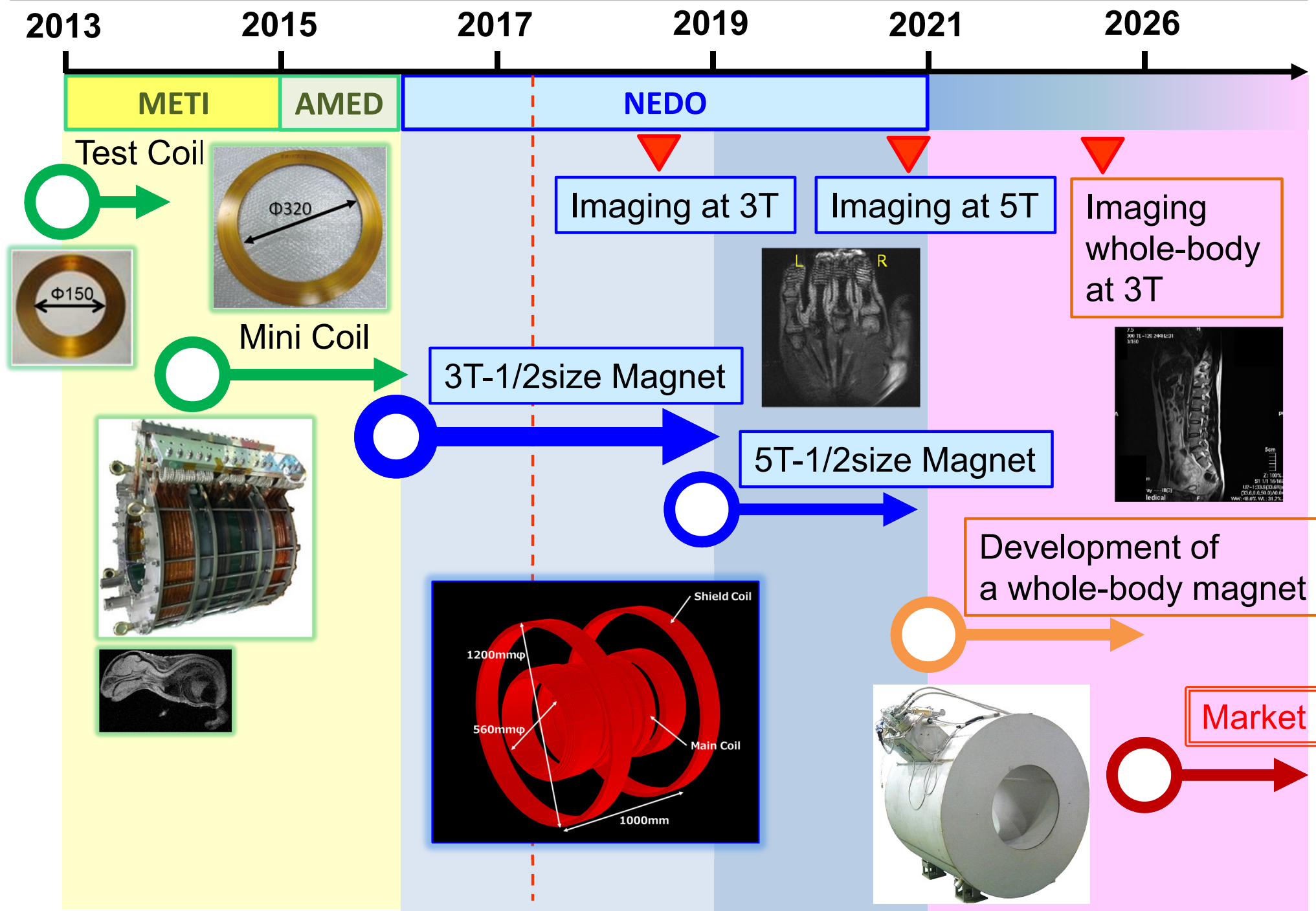
Number of MRI Magnets operating in Japan

(Edited from 'Gekkan Shin-Iryo' (Monthly New Medicine in Japan))



Structure of a Current model 3T-MRI Magnet

Outline Plan of up to Market



METI & AMED Projects : HTS-3T mini coil

- We designed it being conscious of a current MRI magnet.

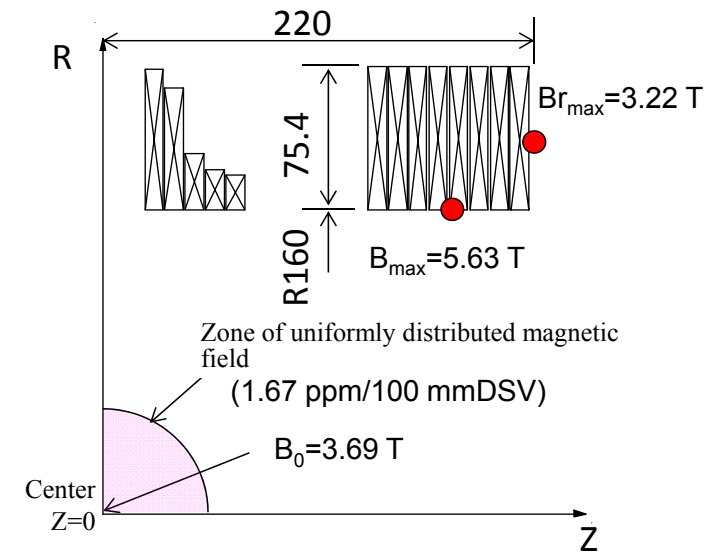
Central field is 2.9T

Uniformity is 1.7ppm/100mmDSV } → for Imaging possibility

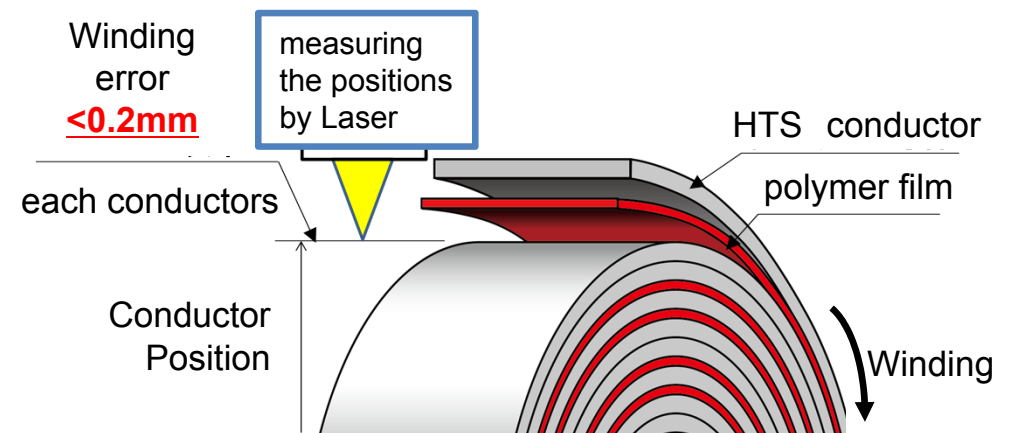
Stability is less than 10ppm/hr

Specification of the HTS 3T Model Coil

Inner diameter	320mm
Maximum Outer diameter	471mm
Axial length	440mm
Central field	3.0T
Maximum field	4.5T
Critical current of wire at field	351A (20K)/4.1T(36°)
Current density of coil	113A/mm ²
Inductance	32H
ReBCO wire Total Length	16km
Field uniformity on design	1.67ppm/100mmDSV
Total Weight	180kg

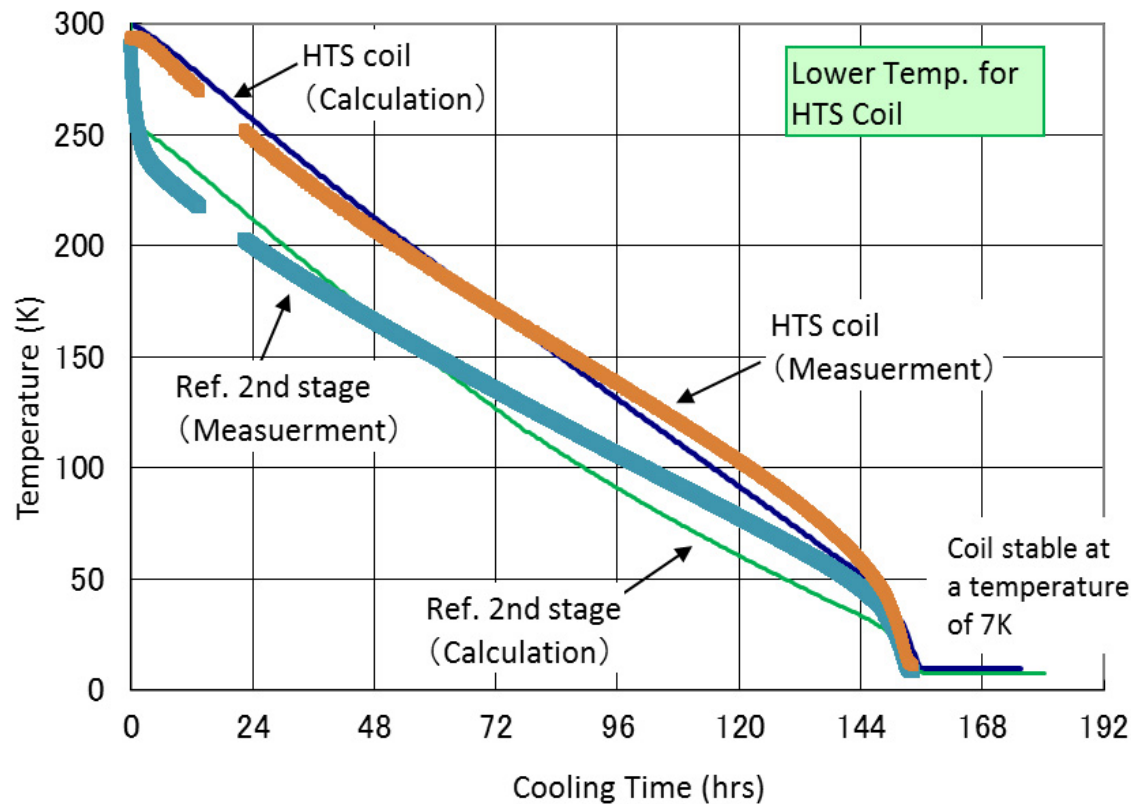


1/4 Cross Sectional View of HTS 3T Mini Coil



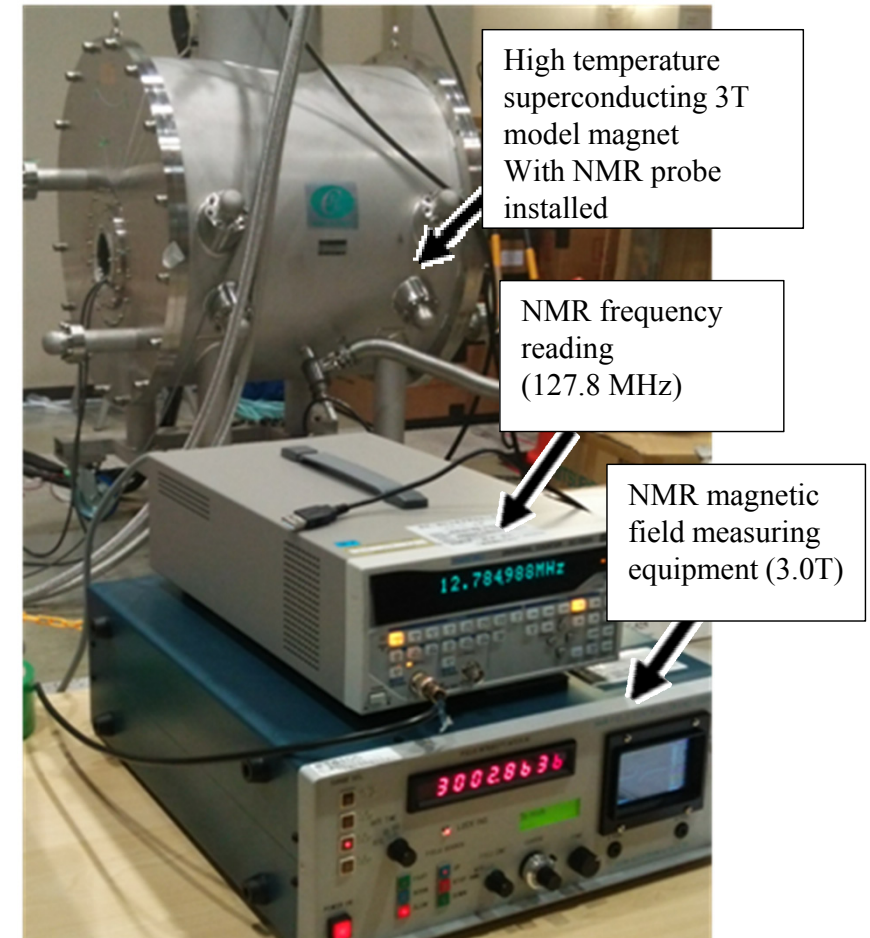
Producing high precision coils

Cooling and Excitation of 3T mini coil



Cooling Characteristics from Room temperature of the HTS 3T Model Coil

- The cooling of the coil was completed
Stable temperature is 7K at one week.
- 3T excitation time is 15 minutes at 0.2A/s.
Coil temperature increased about 2K.



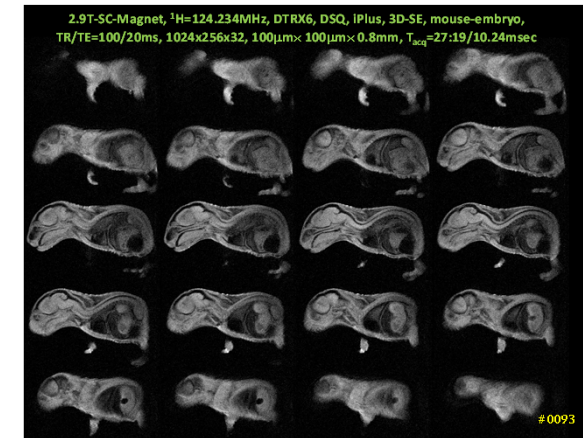
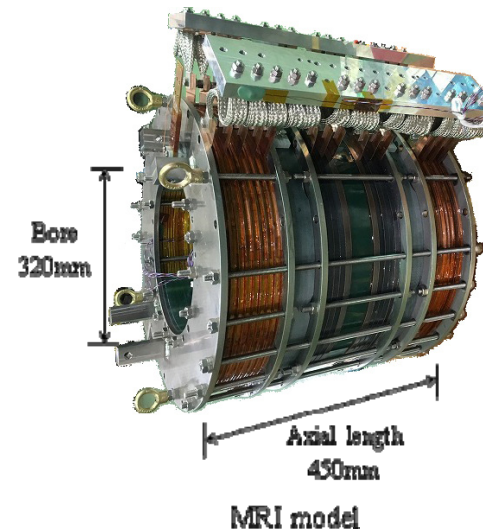
Photographic View of Test Setup for HTS 3T Model Magnet (At the Time of Generating Central Magnetic Field of 3T)

The public
information of
May 24, 2016

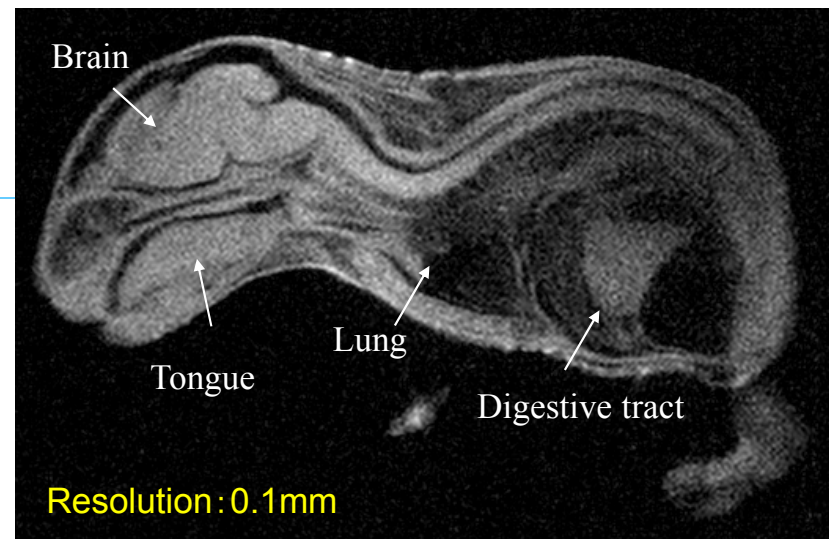
High-Tc Superconducting magnet for MRI

Succeed in World's first 3 Tesla MRI with High-Temperature Coils at Feb. 2016

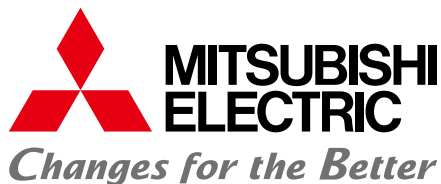
TOKYO, May 24, 2016 – Mitsubishi Electric Corporation (TOKYO: 6503), Kyoto University and Tohoku University announced today the world's first successful 3 tesla Magnetic Resonance Imaging (MRI) using a small model MRI with high-temperature superconducting coils that do not require cooling with increasingly scarce liquid helium. Mitsubishi Electric expects that the high-quality images made possible at this magnetic field strength will contribute to earlier detection of illnesses.



Multi-slice image



Mouse fetus image
(about 25mm long)



東北大学

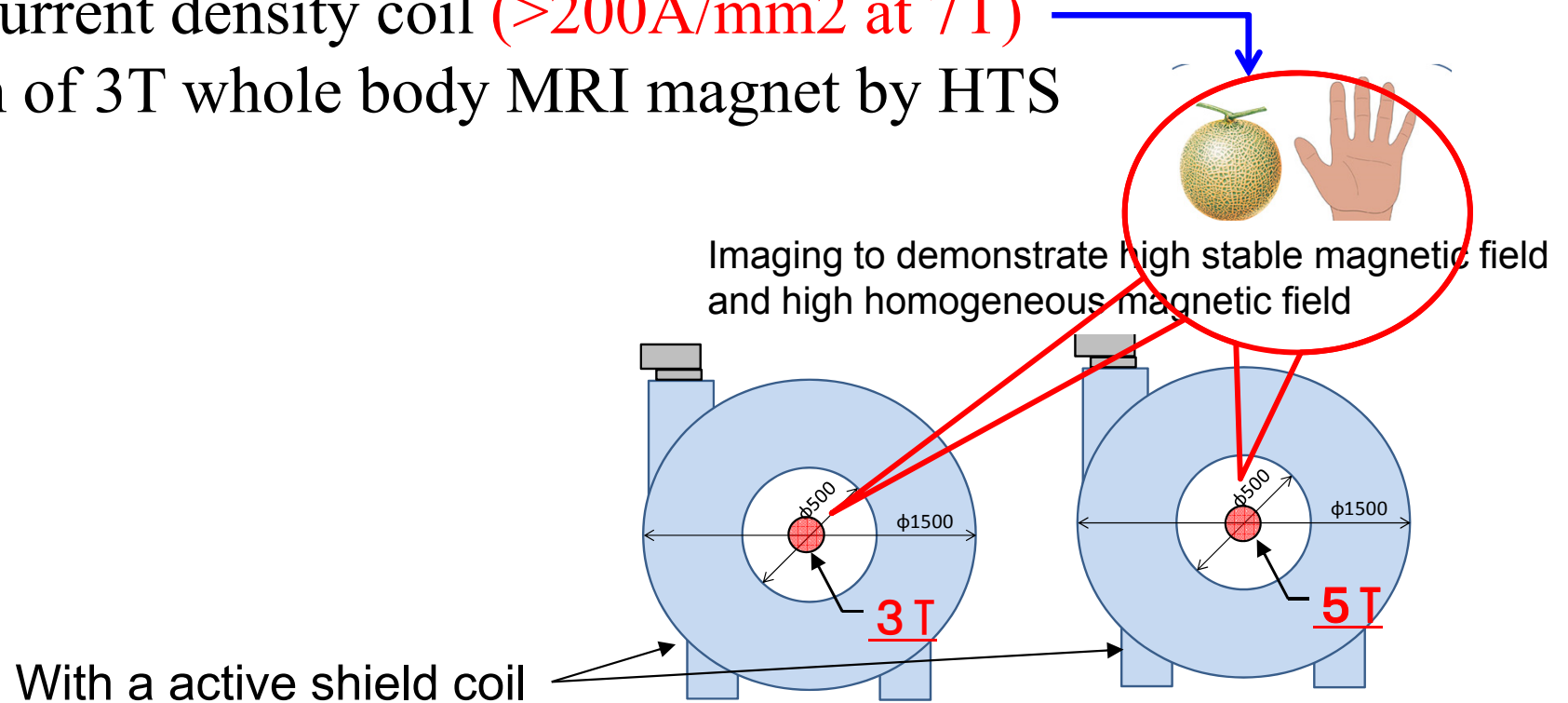
NEDO Project : Half size HTS magnet for MRI

Fundamental Commercialization Promote Technological Development

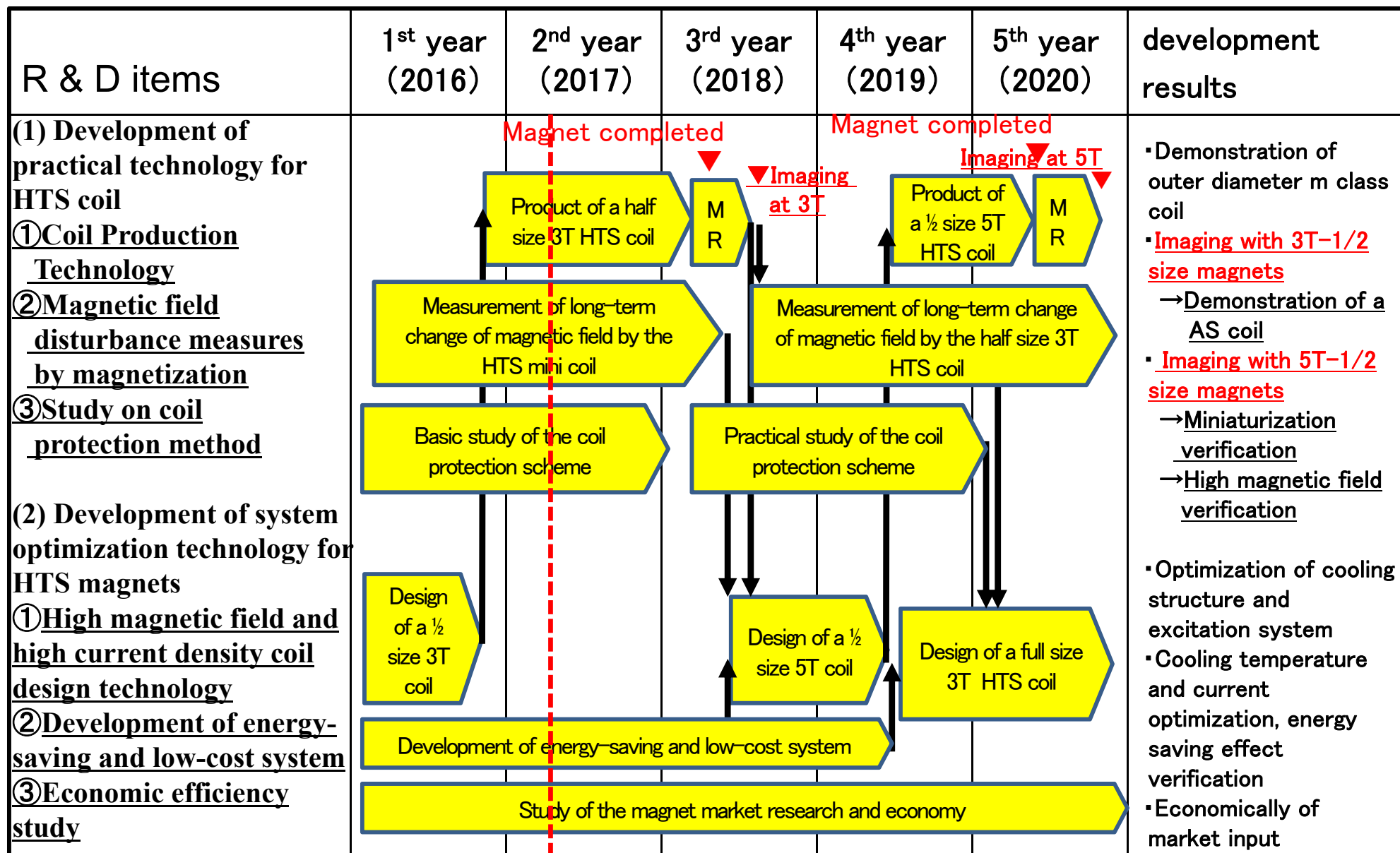
Development of a high temperature superconducting magnet system having high stable magnetic field

Main Objective

- Test producing 3T and 5T half size HTS coils for MRI
- Measurement of field uniformity and stability
- High current density coil (>200A/mm² at 7T)
- Design of 3T whole body MRI magnet by HTS

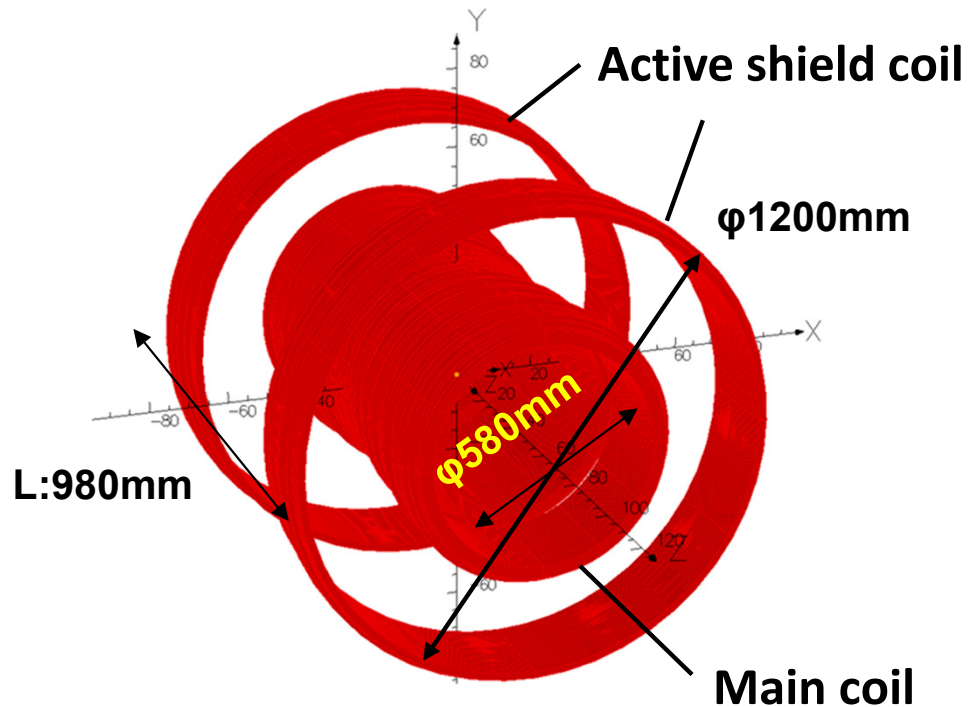


Development schedule



*AS: Active Shield

Design of the half size 3T HTS coil for MRI



A design of a half size HTS 3T-coil

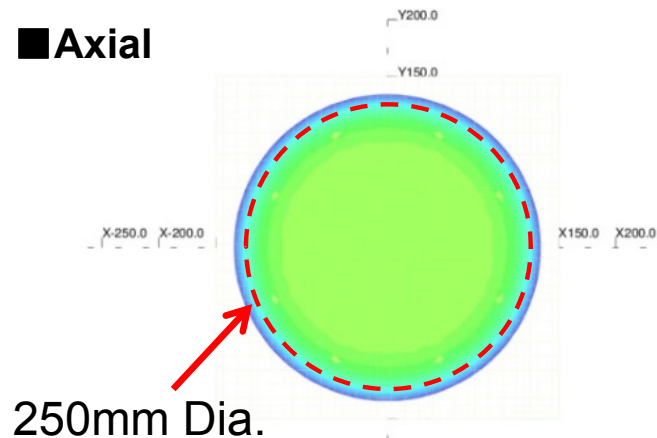
Specification of the half size 3T HTS Coil

Inner diameter	580mm
Maximum outer diameter	1200mm
Axial length	980mm
Operating central field	2.9T
Maximum field	Bzmax=4.2T, Brmax=2.9T
Current density of coil	121A/mm ²
Inductance	145H
Stored energy at operation	1.6MJ
ReBCO wire Total Length	70km
Field uniformity on design	1.7ppm/250mmDSV
Leak magnetic field area	2.5mX3.4m (0.5mT)

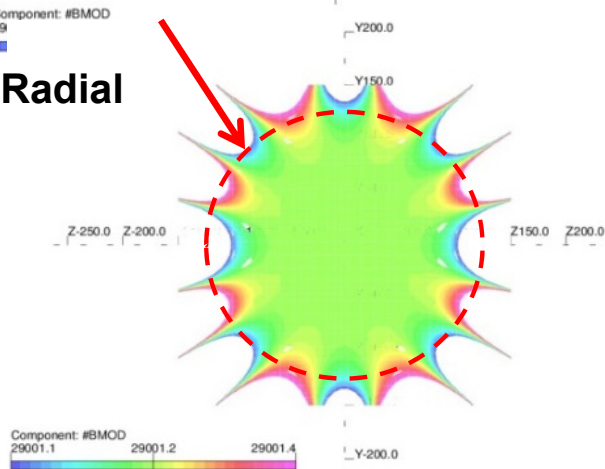
Cryostat is designed now.
Room bore is 480mm Dia.
Imaging is a region of 150 mm or more

Design of the half size 3T HTS coil for MRI

■ Axial



■ Radial

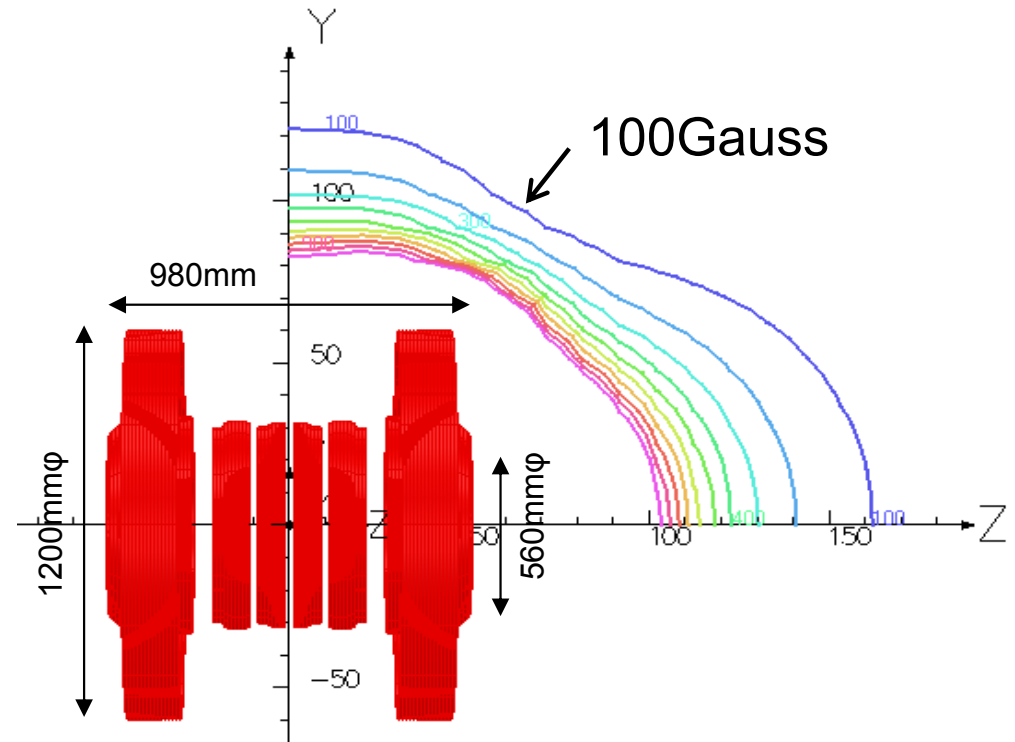


Error field coefficient

Z2	0.04
Z4	-0.26
Z6	-3.10
Z8	-16.68
Z10	-4.95
Z12	-0.15
Z14	0.77
Z16	-0.27
Z18	0.06
Z20	0.01

Unit: ppm

Magnetic field uniformity of the coil



Leak magnetic field region of the coil
(analysis result)

1.6mx1.2m (100G region)
3.2mx2.5m (5G region)

- Magnetic Field Distribution is 1.7 ppm/φ250 mmDSV on designed
- Leakage Magnetic Field regions are 1.6mx1.2m at 100gauss and 3.2mx2.5m at 5gauss.

SUMMARY

○ As a next-generation MRI, we started the research and development of high stable magnetic field coil system fundamental technology using the REBCO superconducting coil.

○ We successfully verified measures for issues in these particular subjects. World's first MRI Images of Mouse fetus using a HTS 3T Test Magnet at 2.9T were obtained.

○ Advance research and development to solve problems related to the manufacture of large-diameter magnets and obtain highly stable magnetic fields as NEDO project for practical application of the high temperature superconducting coils.

Thank you for your attention

ありがとうございました。

Acknowledgements)

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