

High Power Density Superconducting Motor For All-Electric Aircraft Propulsion



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Outline

- Introduction
- Motor configuration
- Simulation results:
 - Electromagnetic design
 - Conduction cooling
- Design for Cessna 172 propulsion
- Conclusion



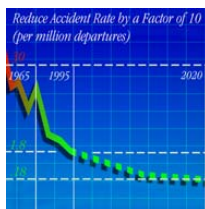
Introduction

- Need to develop environment friendly transportation systems
- Electrical energy is very attractive
- Need to increase power density of onboard components

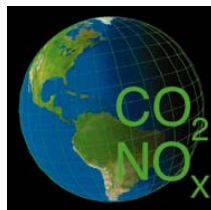
Objective :



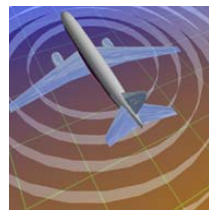
**Revolutionize
Aviation**



Increase Safety



Reduce Emissions



Reduce Noise



Increase Capacity

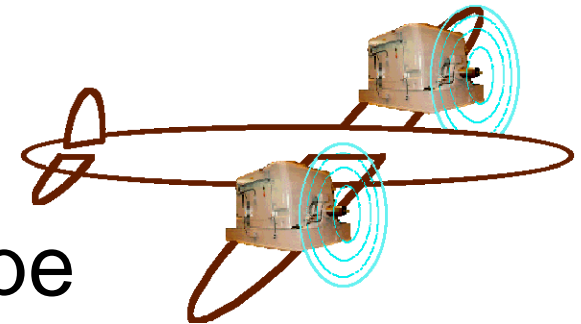


Increase Mobility

Problem statement



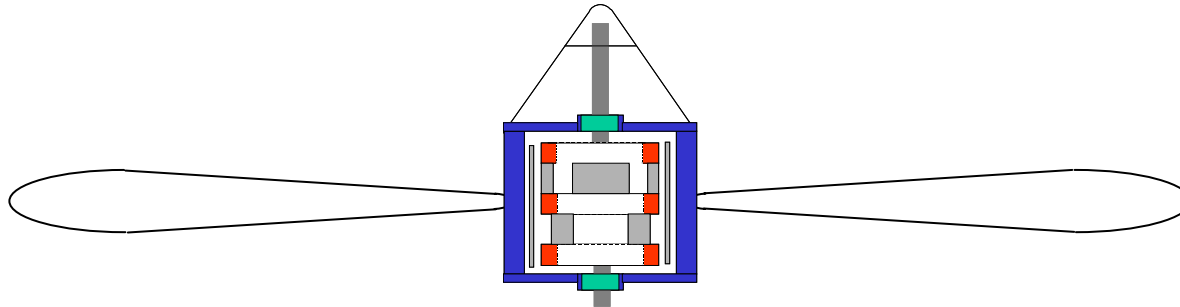
- Develop Low weight/volume electric motors for aircraft propulsion
- Application: Cessna 172 type



- General aviation
- Non polluting
- Quiet

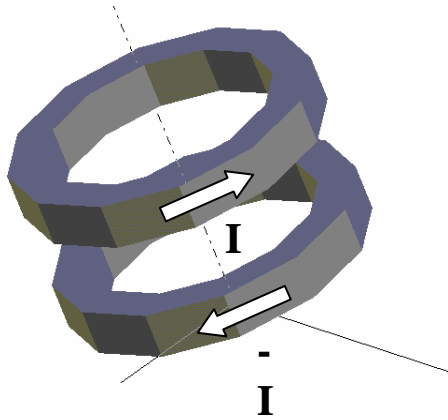
Problem statement

- Requirements:
 - Mechanic load: propeller
 - 200 hp
 - 2700 RPM
 - High power density
 - Compact and light
 - High temperature superconducting
 - Conduction cooled: no cryogenic bath

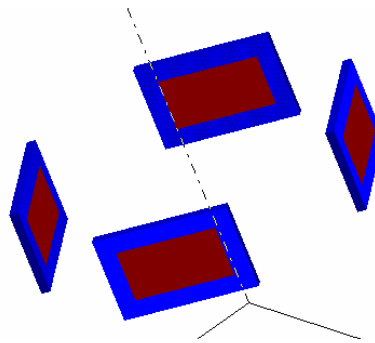


Rotating armature concept: propulsion motor
embedded into the propeller

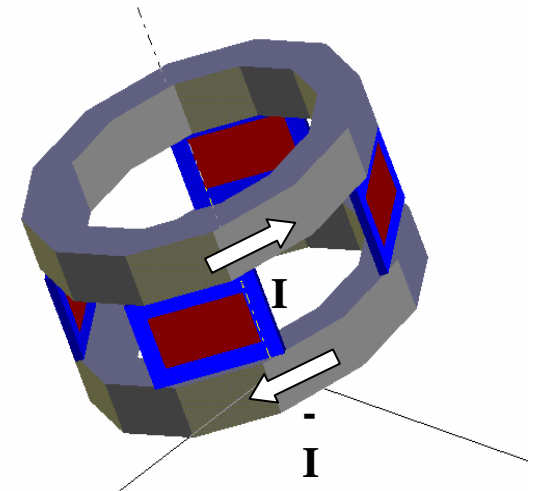
Unconventional HTS inductor: topology



Two HTS coils fed with opposite currents



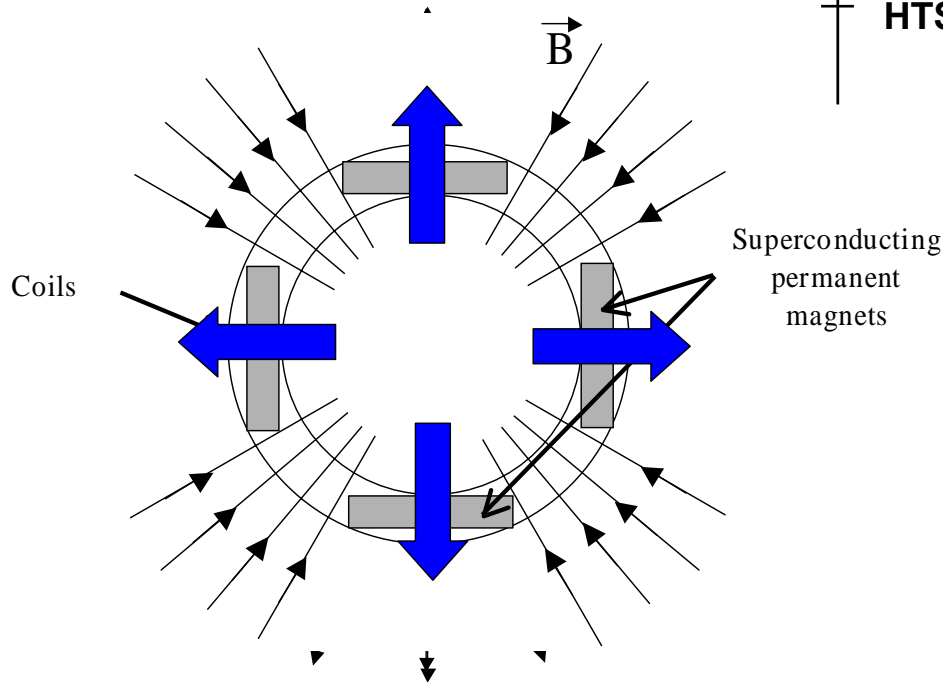
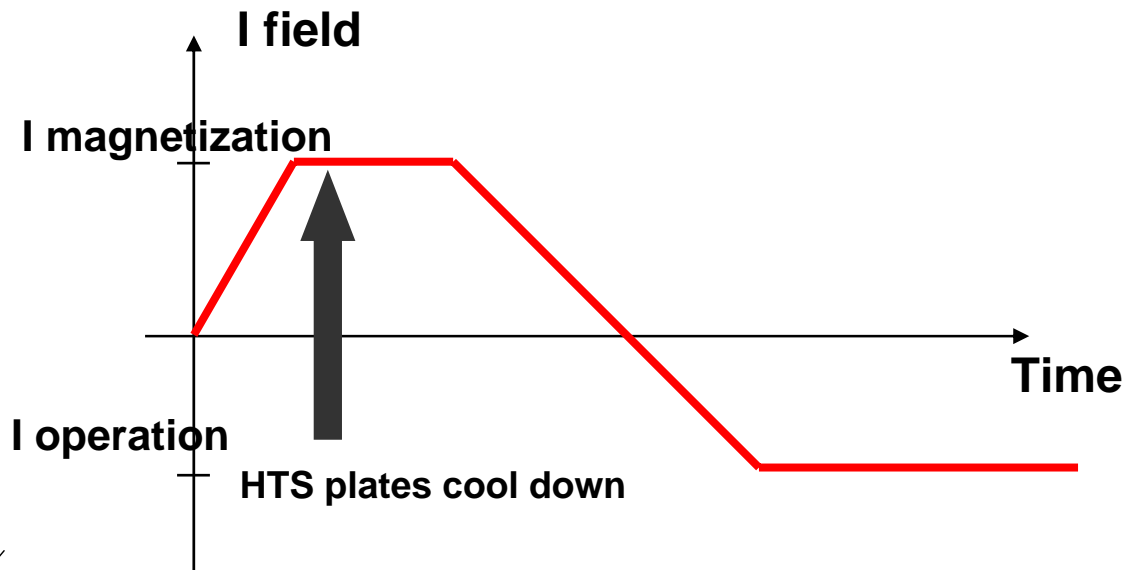
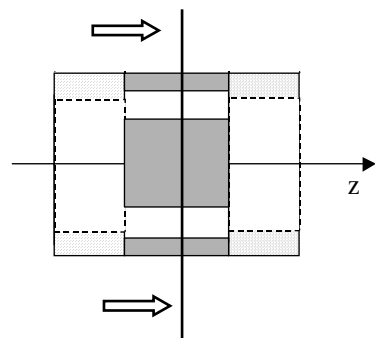
Four HTS bulk plates



Assembly

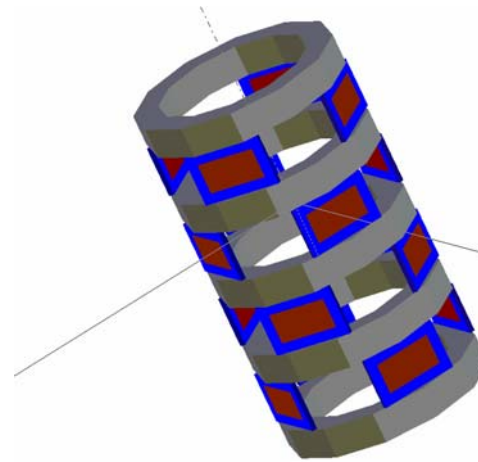
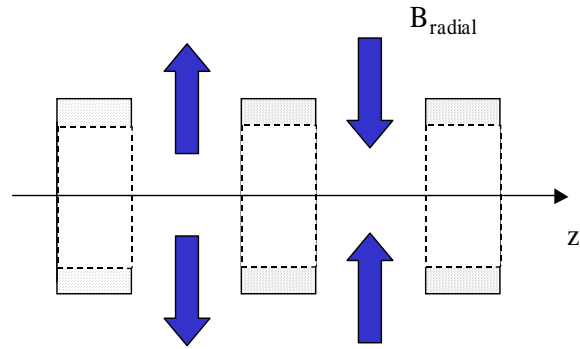
Superconducting plates to create flux density variation

Conceptual design of the HTS motor: principle



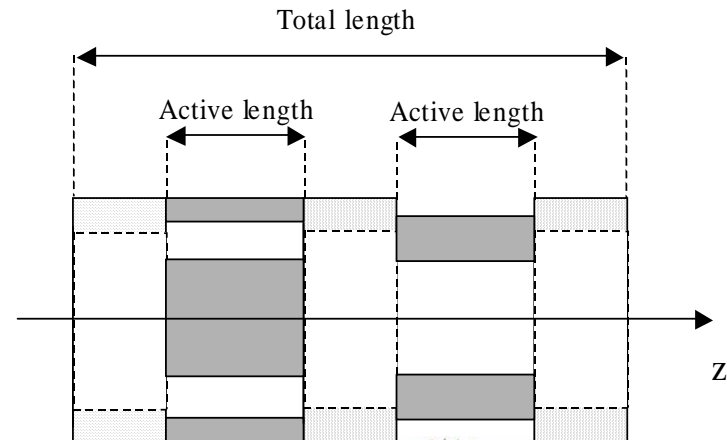
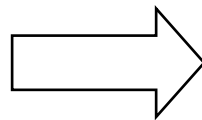
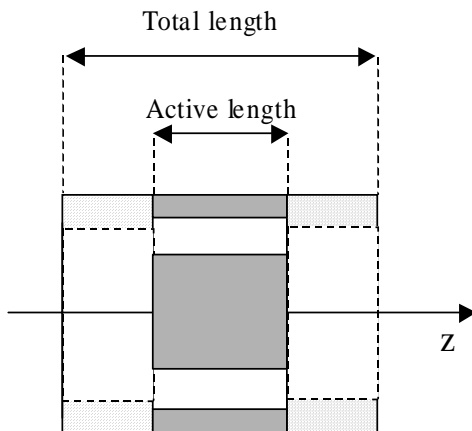
- 8 poles
- 4 poles come from trapped flux
- 4 poles come from shielding/concentration
- very high flux density

Multi-Pattern Concept



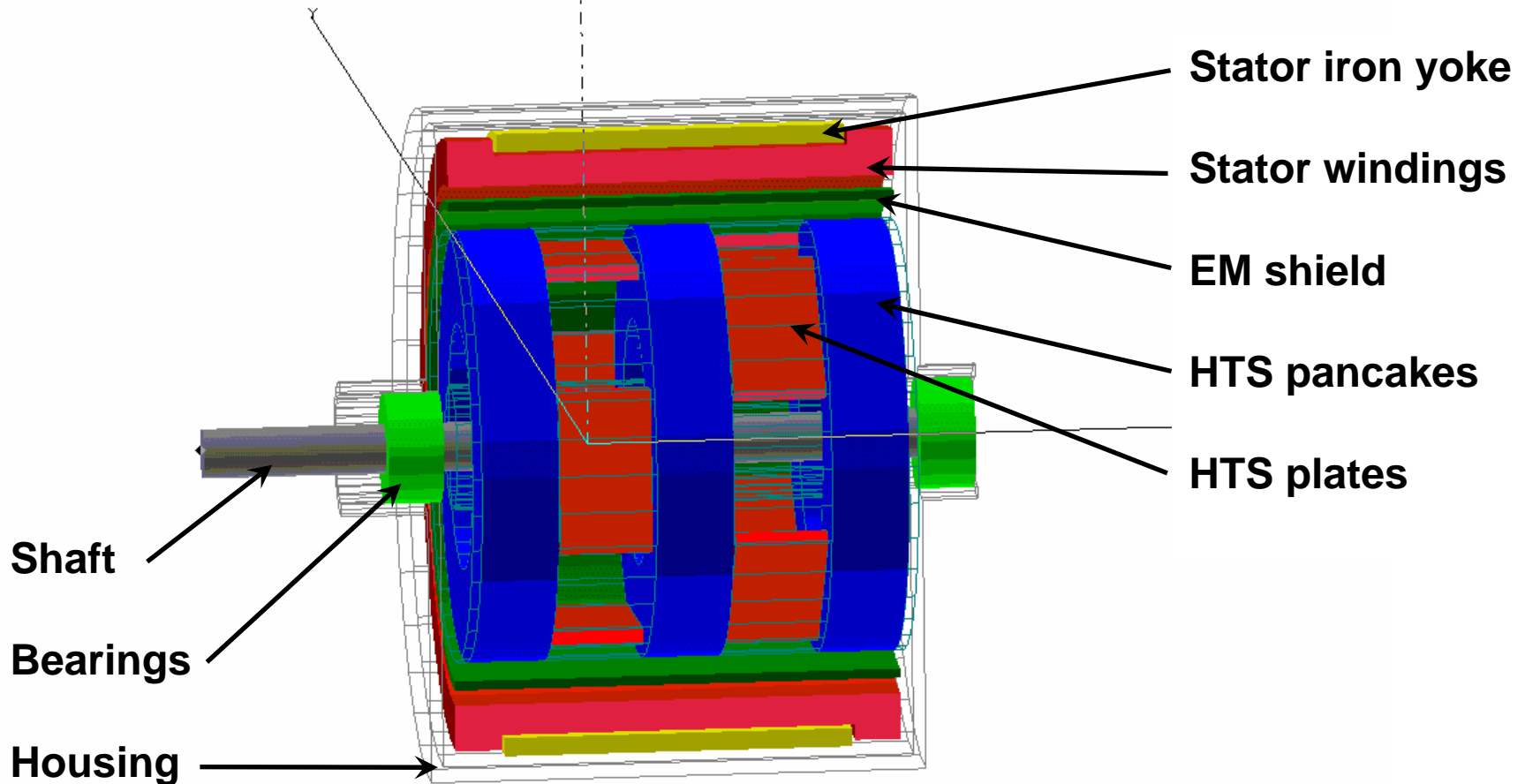
- Several elementary patterns can be stacked
- Power increases by steps
- Easy to manufacture
- Easy to cool down
- Iron free

$$T = \sqrt{2} \left(\frac{L_{act}}{L_{Tot}} B_r^0 \right) K_{arm} \pi r_0^2 L_{Tot}$$

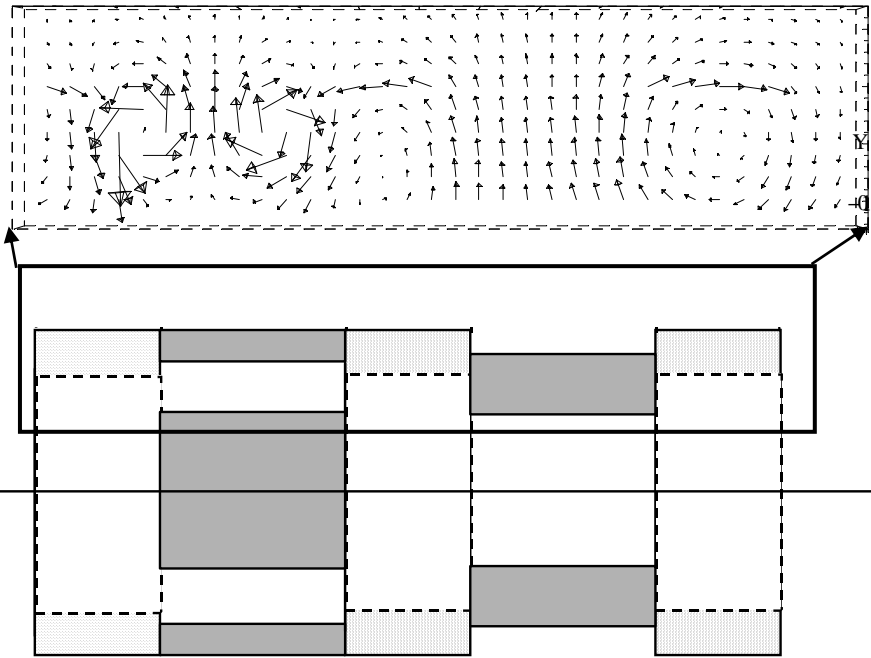


Conceptual design of the HTS motor

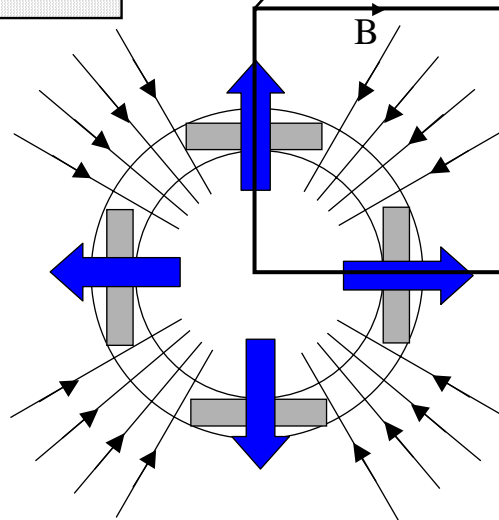
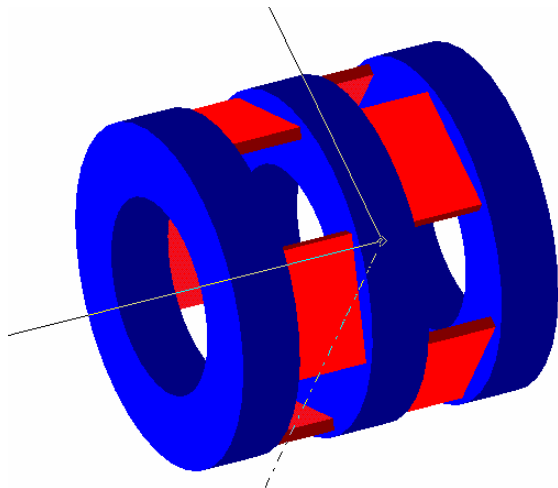
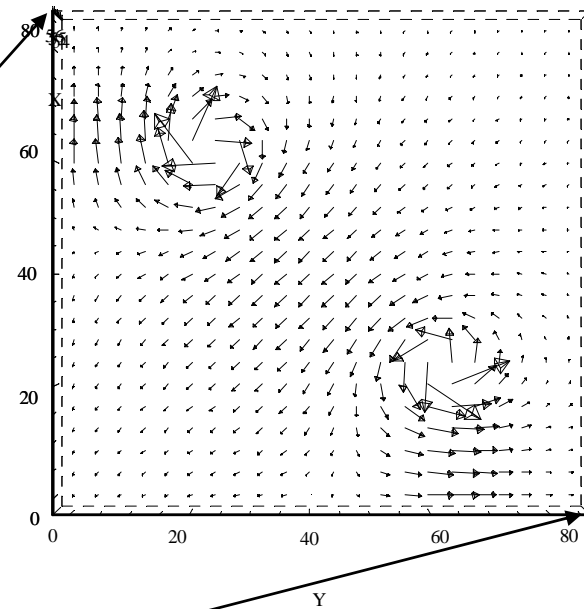
- Diagram of the machine



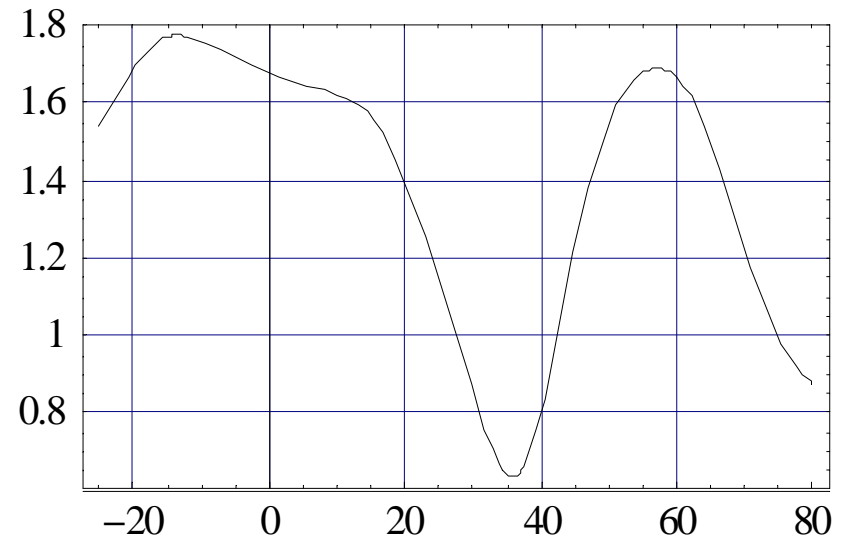
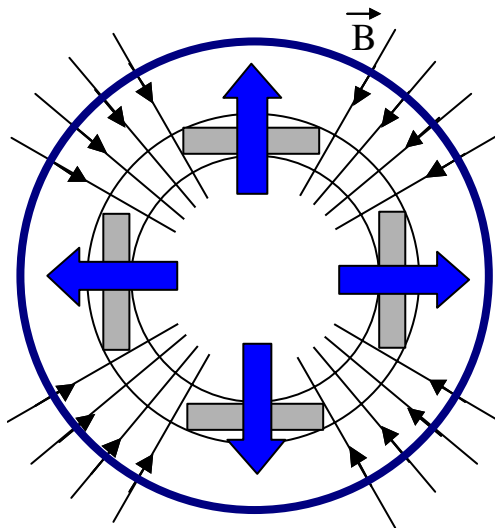
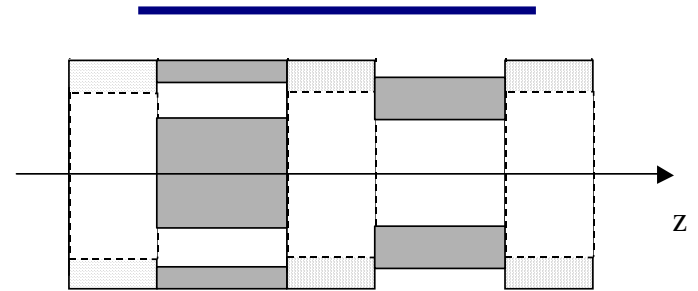
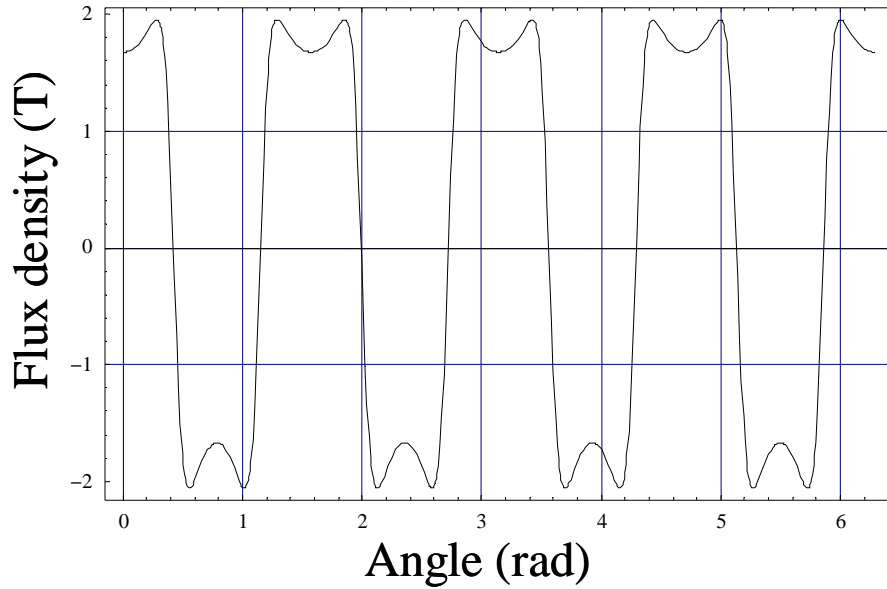
Electromagnetic Design: the inductor



Flux lines created by the inductor

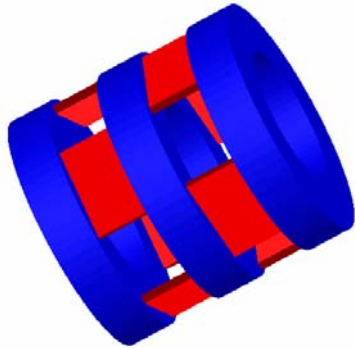


Air Gap Magnetic Field (10mm)

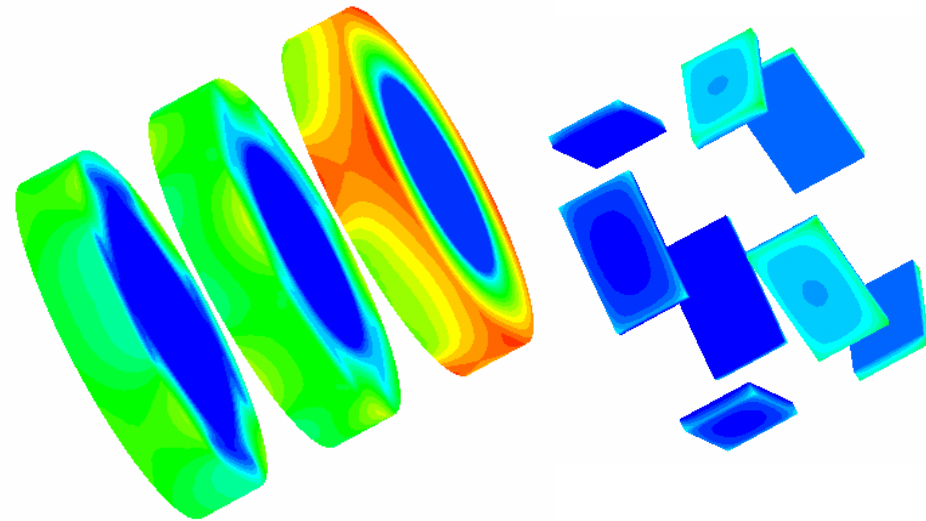
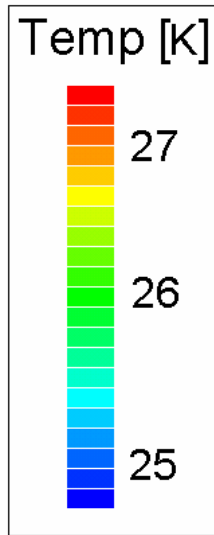


Conduction Cooling

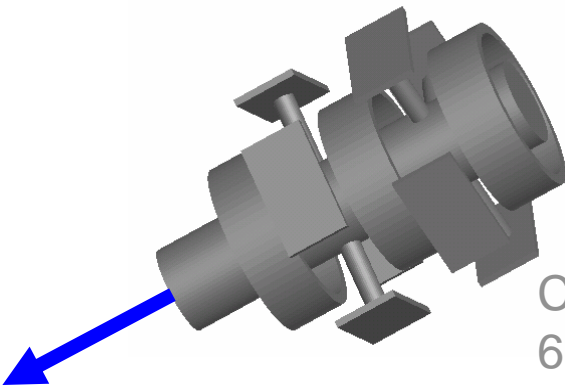
HTS Inductor



3 Pancakes made of Bi-2223
8 Plates made of YBCO



Conduction Apparatus Design



To the cold head

Constructed with 6061 Aluminum, encased in G10 to support forces

- 10 W of cooling power
- 3K of temperature variation
- Experiment to be carried out in the next months

Results

Design summary:

<u>Total size:</u>	L=160mm D=220mm
<u>Number of poles:</u>	p=8
<u>No-load field:</u>	B=1.3T
<u>Electric loading:</u>	K=300 kA/m
<u>EM torque:</u>	T=585 N.m
<u>Rotation speed:</u>	2700 RPM
<u>Power :</u>	P=220 hp
<u>Total mass:</u>	m=28 kg
<u>Power density:</u>	3.56 hp/lb
<u>Heat load:</u>	<10 W @ 30K
<u>Operating temperature:</u>	30 K
<u>Temperature gradient:</u>	<3 K

- **Cooling can be done with existing cryocooler**
- **Temperature can be increased to 50 K by using YBCO coated conductors**
- **Size and weight can be further decreased by increasing the no-load field**

Conclusion

- HTS technology is very attractive for aircraft applications
- Design a 200HP motor for Cessna172 propulsion
 - Weight 28kg + 60kg (cryocooler) to be compared to 160kg of the conventional engine
- Need to study stability of trapped field in bulk plates
- Need to validate the concept with an experiment

