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Advanced Superconductor Motor Demonstrator (ASuMED)

Enric Pardo, Institute of Electrical Engineering, Slovak Academy of Sciences

28 February 2018

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When did you fly last time?

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When did you fly last time?

Holidays

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When did you fly last time?

Holidays

Business

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When did you fly last time?

Holidays

Business

You fly more often than 20 years ago

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When did you fly last time?

Holidays

Business

You fly more often than 20 years ago

Not to mention 30 years ago!

Flights are longer

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Flights are longer

Asian tourists in Bratislava

It is only the beginning

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European Commission
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Every day, more people in developing countries can afford a flight

It is only the beginning

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European Commission
Grant No 723119

Every day, more people in developing countries can afford a flight

China and India:

Five times the people in the European Union

It is only the beginning

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Every day, more people in developing countries can afford a flight

China and India:

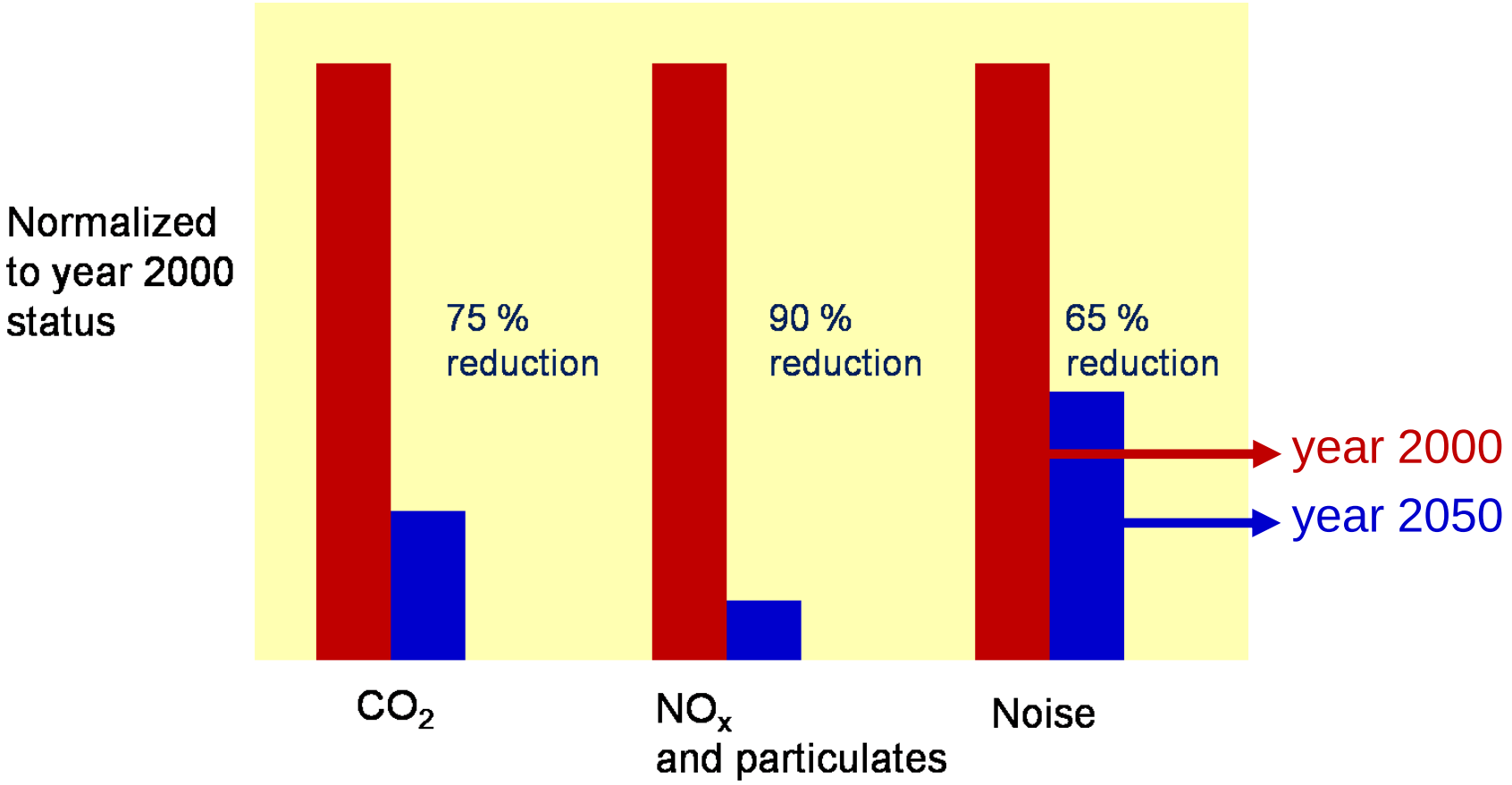
Five times the people in the European Union

A lot of emissions!

The European Commission wants to reduce emissions

Funded by the European Commission Grant No 723119

ACARE Flightpath 2050 emission targets



The European Commission wants to reduce emissions

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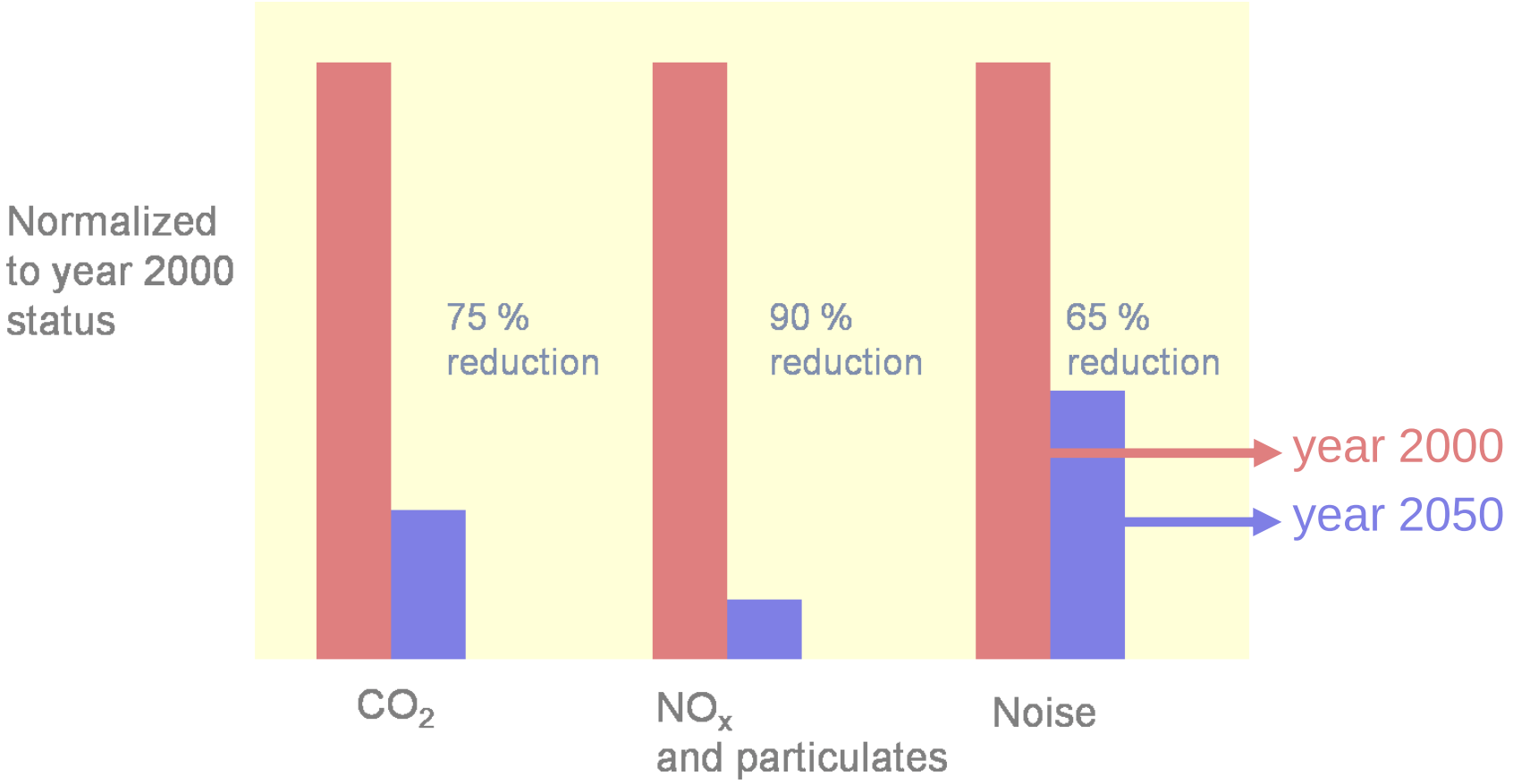
ACARE Flightpath 2050 emission targets

Drastic reductions need drastic improvements



Reduction achievable by hybrid distributed propulsion

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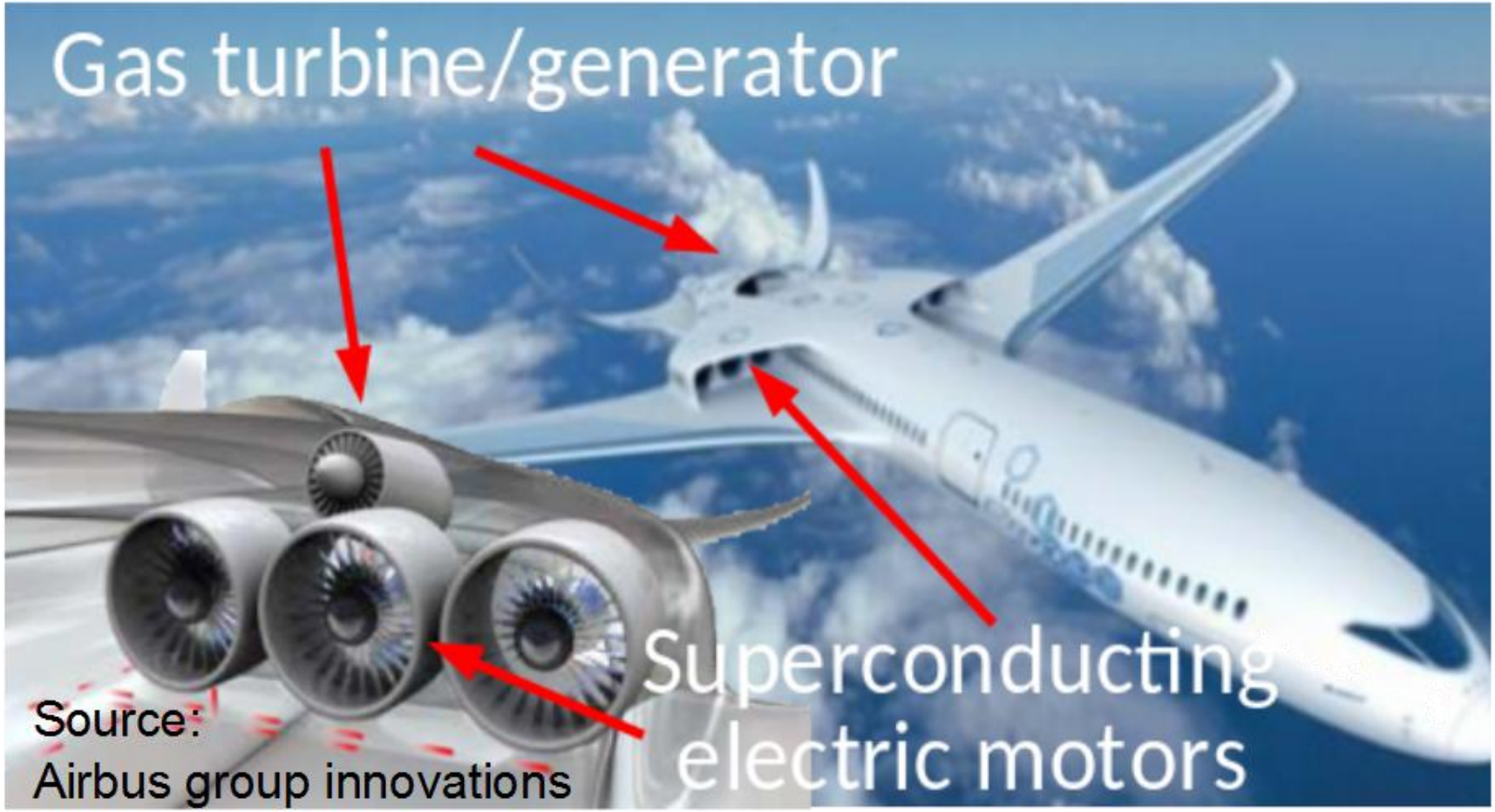

Reduction achievable by hybrid distributed propulsion

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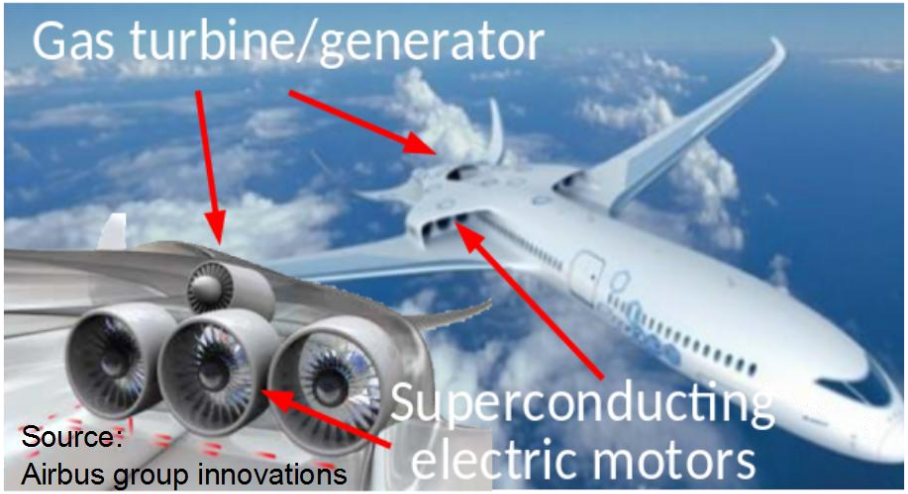

Reduction achievable by hybrid distributed propulsion

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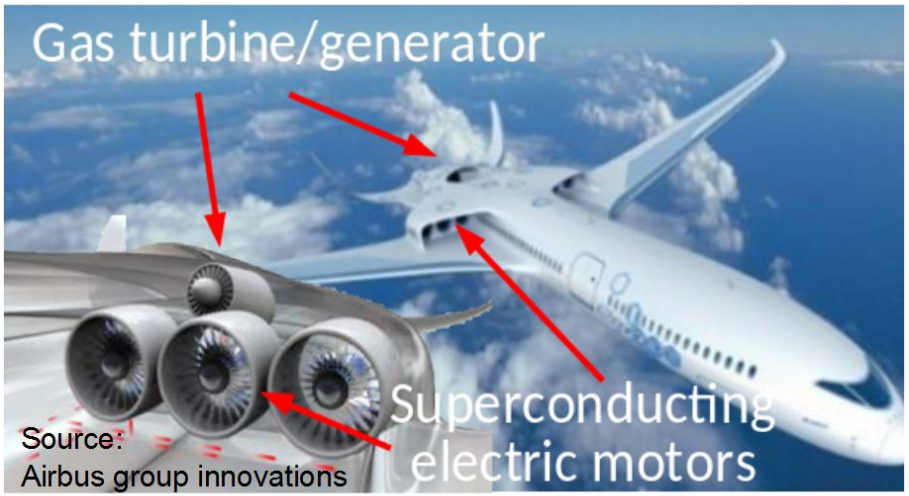

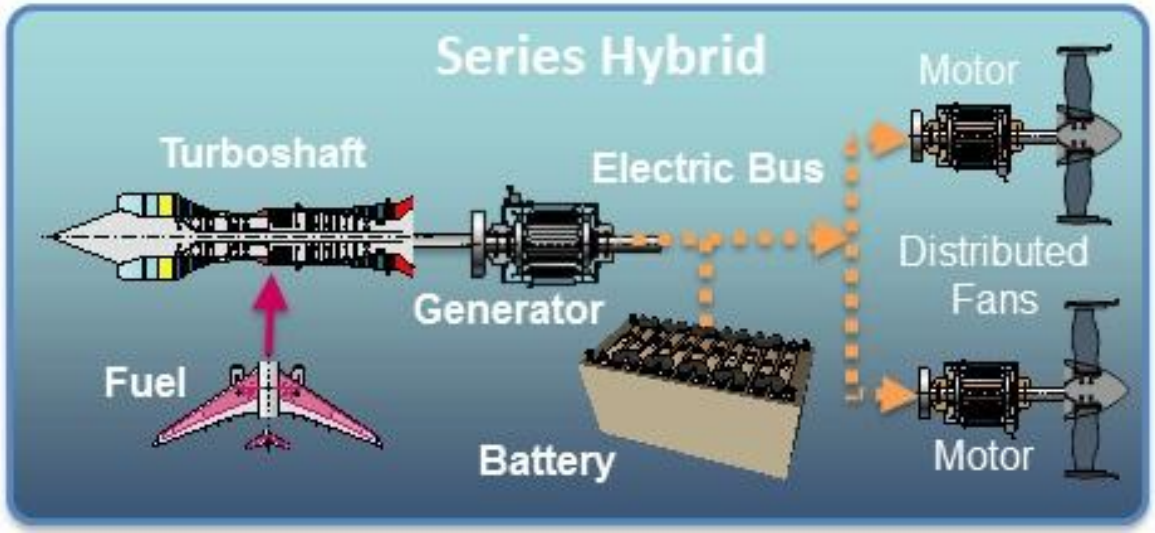

Picture from James L. Felder, NASA Glenn Research Center, "NASA Hybrid Electric Propulsion Systems Structures,"

Reduction achievable by hybrid distributed propulsion

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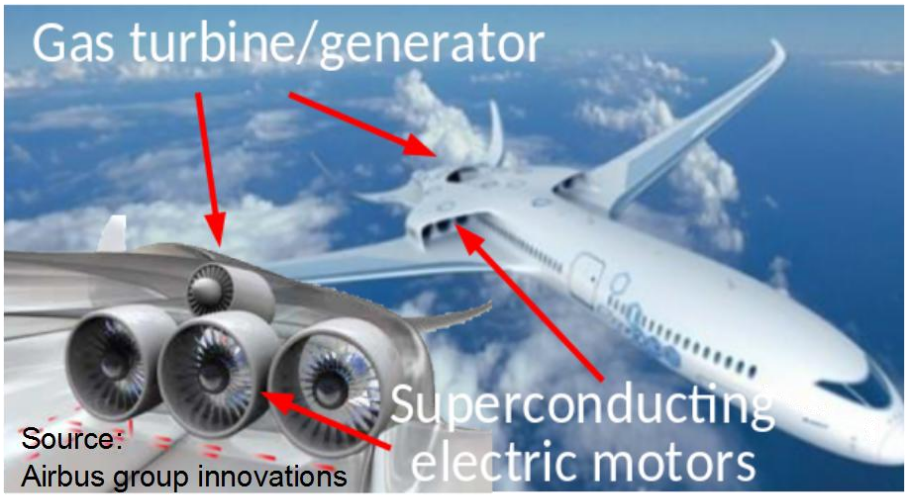

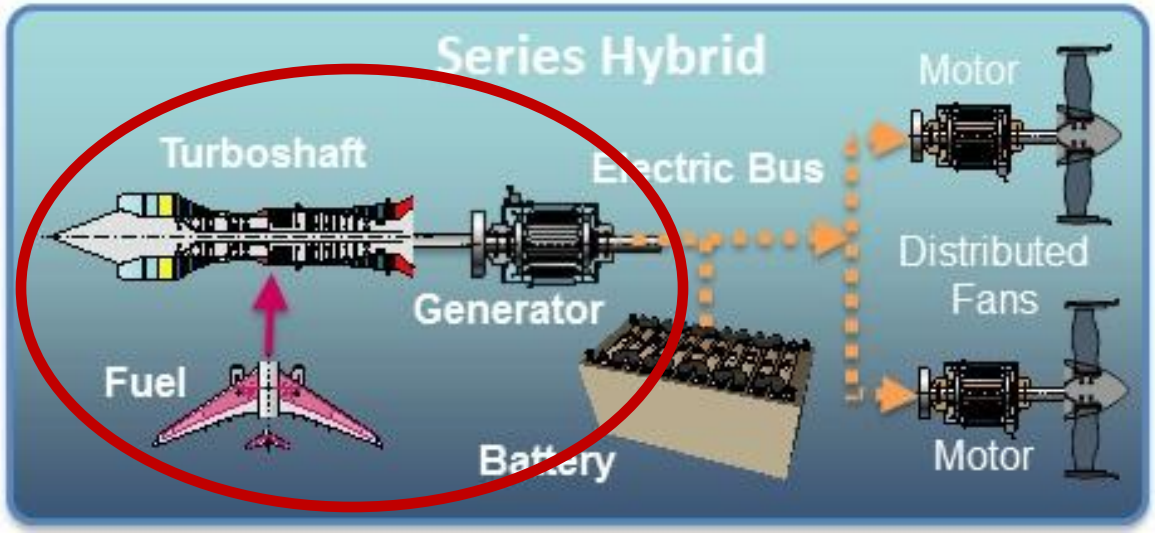

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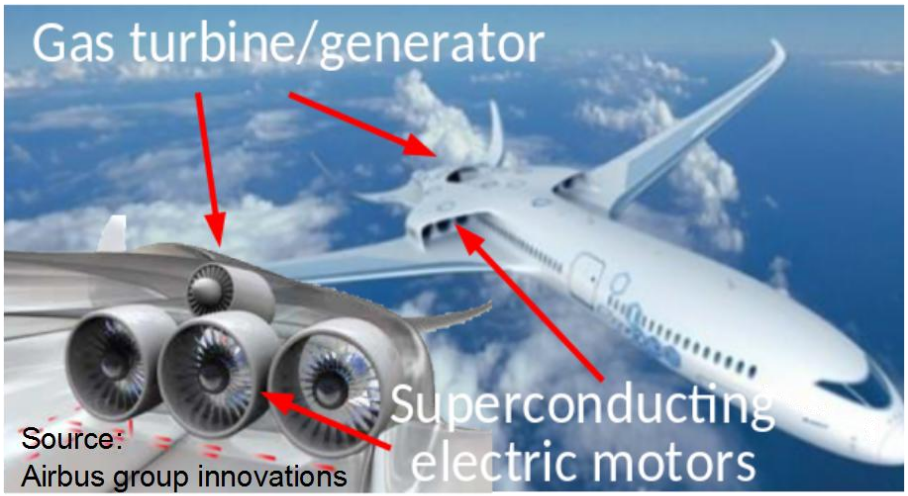

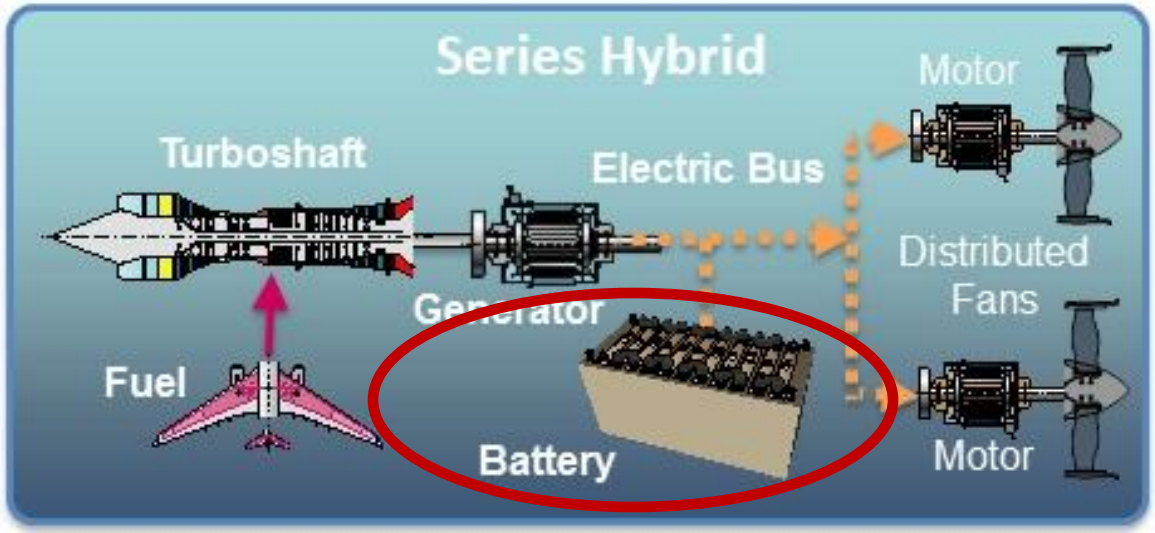

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Reduction achievable by hybrid distributed propulsion

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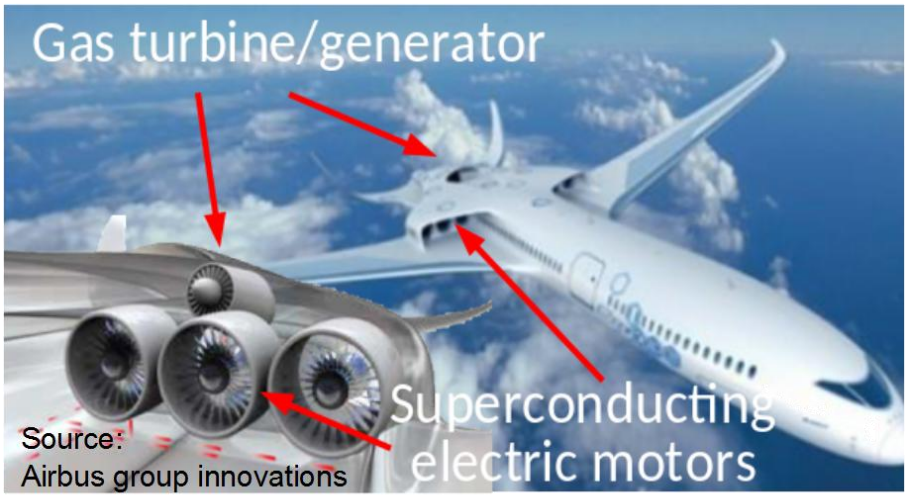

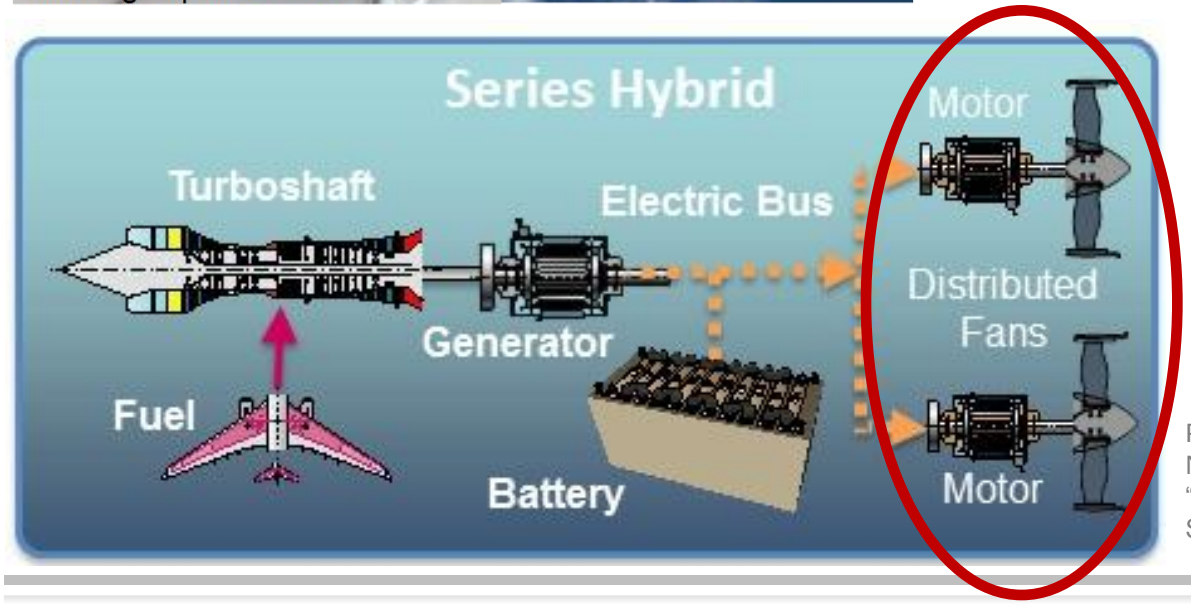

Picture from James L. Felder, NASA Glenn Research Center, "NASA Hybrid Electric Propulsion Systems Structures,"

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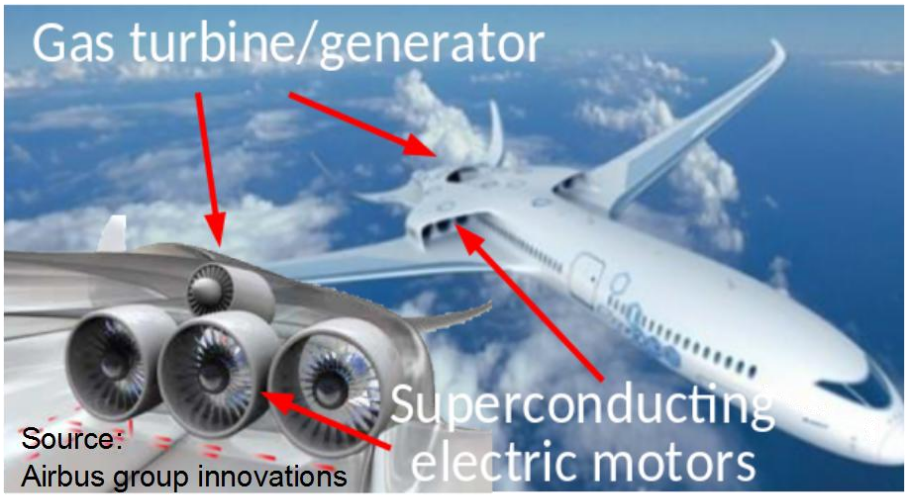
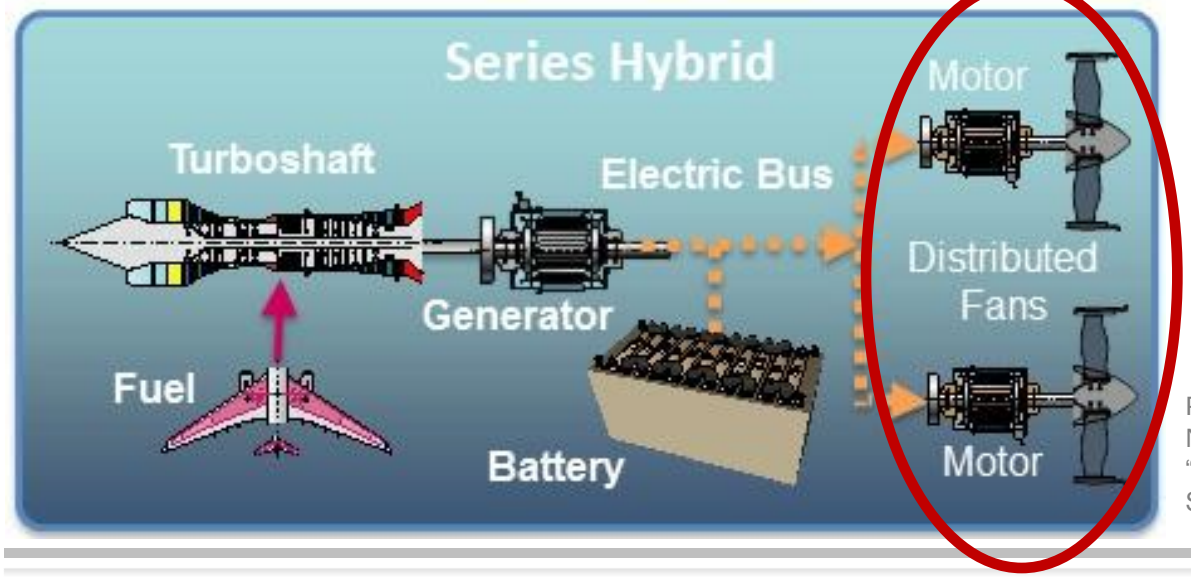


Superconducting motors are necessary



Picture from James L. Felder, NASA Glenn Research Center, "NASA Hybrid Electric Propulsion Systems Structures,"

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NASA and Boeing concepts

If EUROPE does not do them, others will

Boeing-NASA

Superconducting
elecric motors

Superconducting generator

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Advanced Superconductor Motor Demonstrator (ASuMED)

Enric Pardo, Institute of Electrical Engineering, Slovak Academy of Sciences

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ASuMED

Your future Horizon 2020 project

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Your future Horizon 2020 project

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ASuMED

- Goals of project
- Why superconductors
- Consortium
- Our role

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Your future Horizon 2020 project

Goals

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Superconducting motor

for lab demonstration of:

1 MW

20 kw/kg

around **50 kg**

Goals

Funded by the
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Grant No 723119

Superconducting motor

for lab demonstration of:

1 MW

20 kw/kg

around **50 kg**

Could fit in the engine part of your car but with 10 times its power

Goals

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Grant No 723119

Superconducting motor
for lab demonstration of:

1 MW

20 kw/kg → State-of-the art of conventional motors: around **5 kw/kg**

around **50 kg**

Could fit in the engine part of your car but with 10 times its power

Conventional synchronous motor

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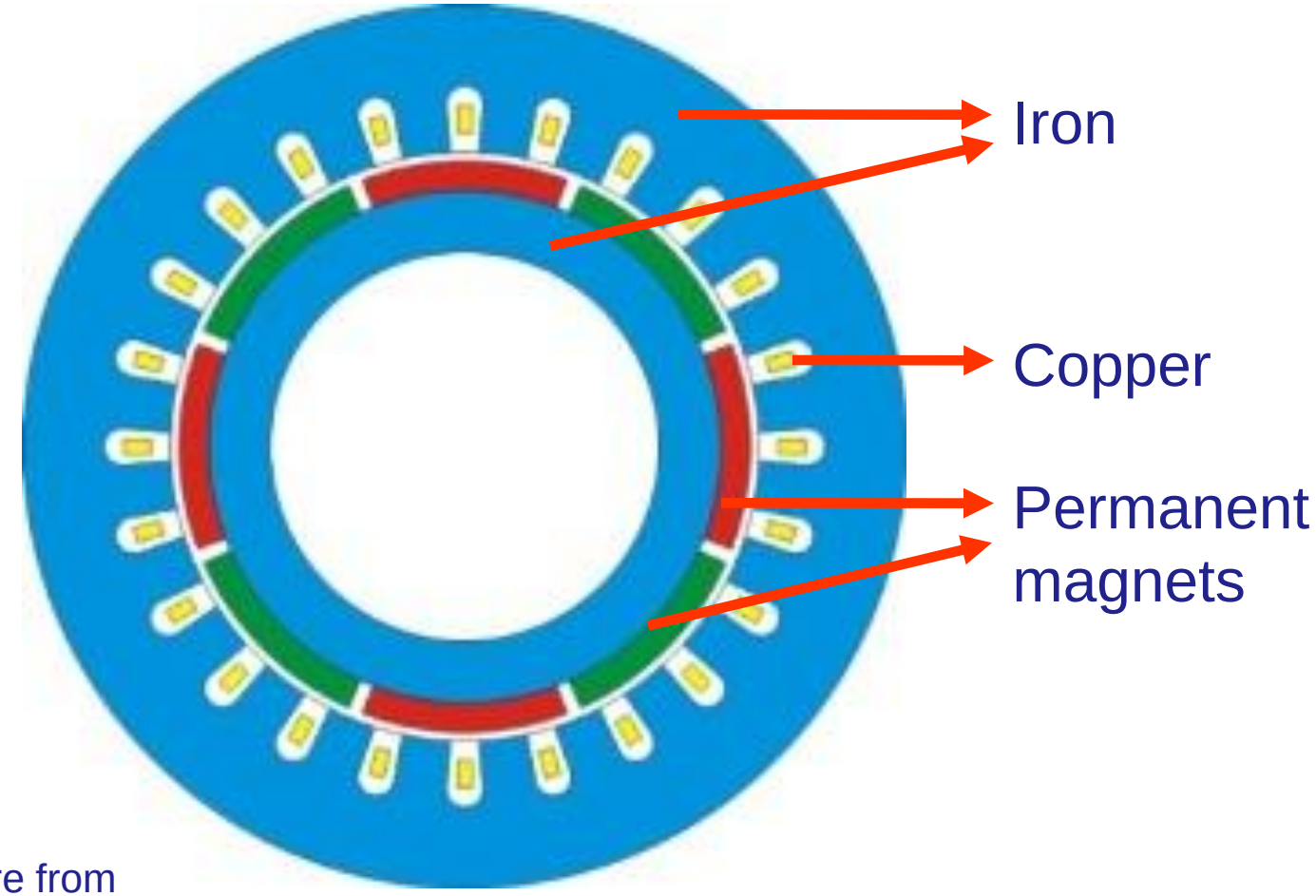

Picture from
OSWALD

ASuMED

- Goals of project
- Why superconductors
- Consortium
- Our role

Your future Horizon 2020 project

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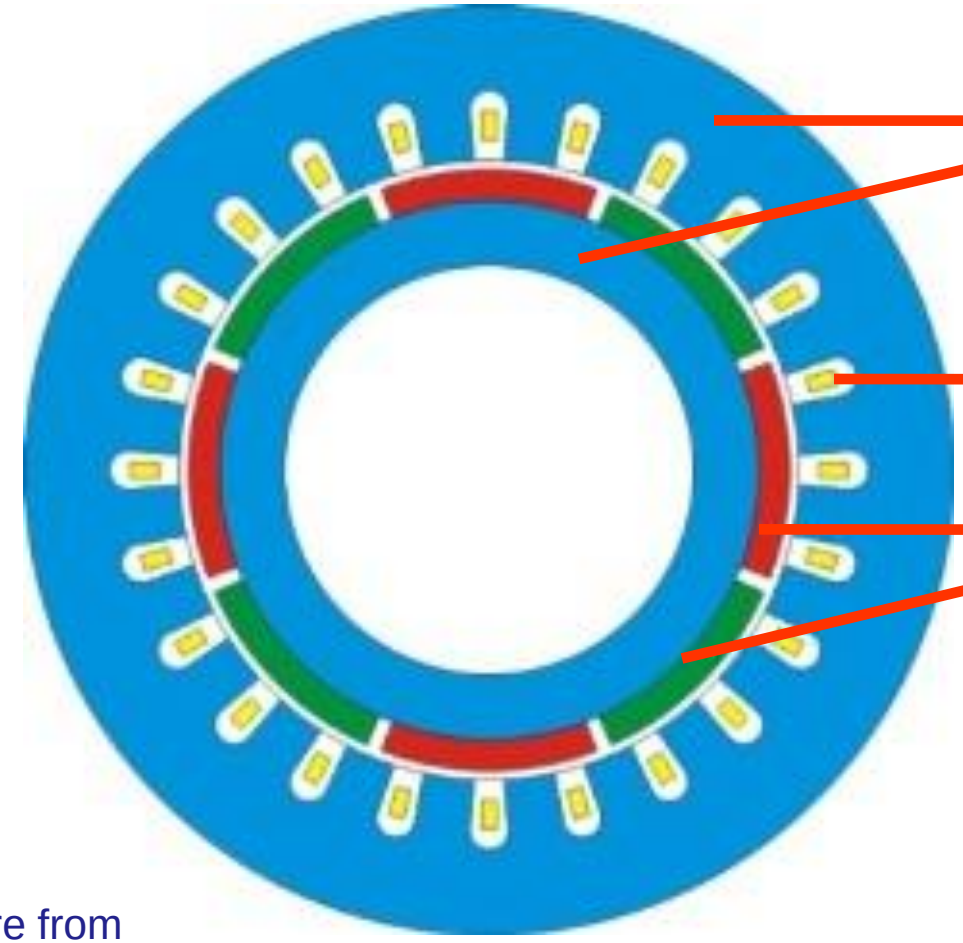

Picture from
OSWALD

Superconducting stator

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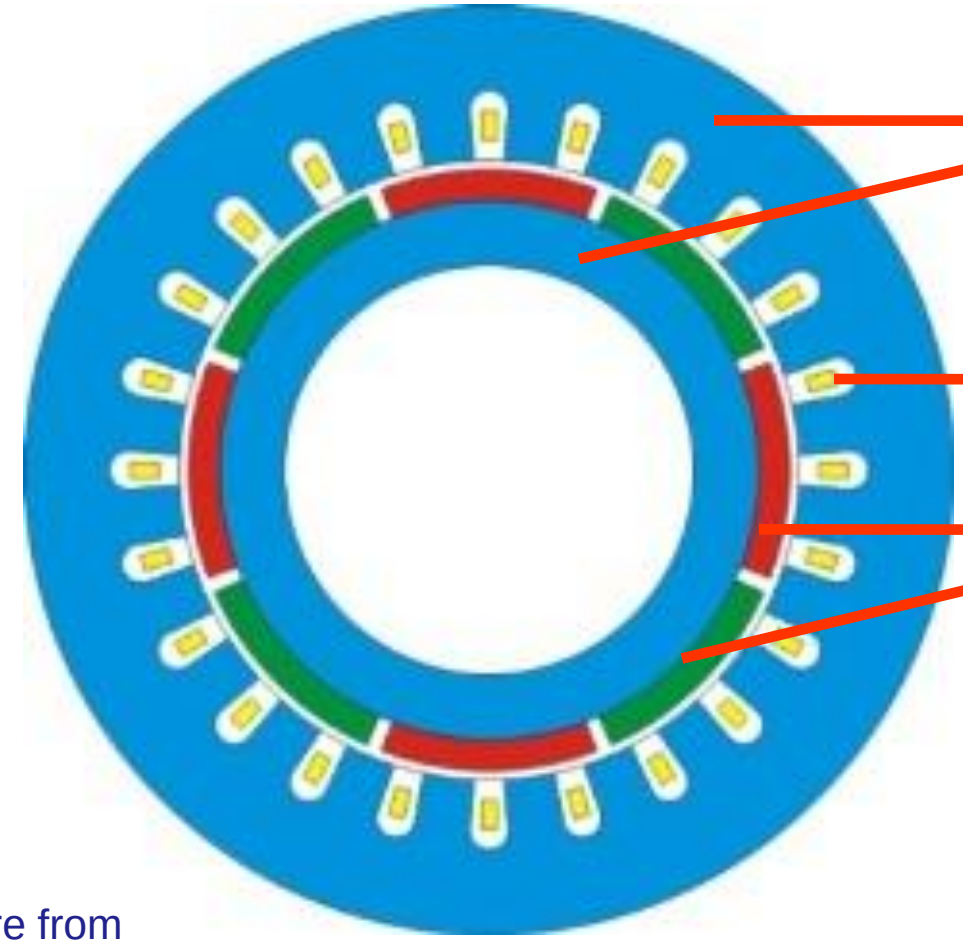

Iron

Change copper by superconductor

Permanent magnets

Picture from OSWALD

Superconductors can carry very high current densities

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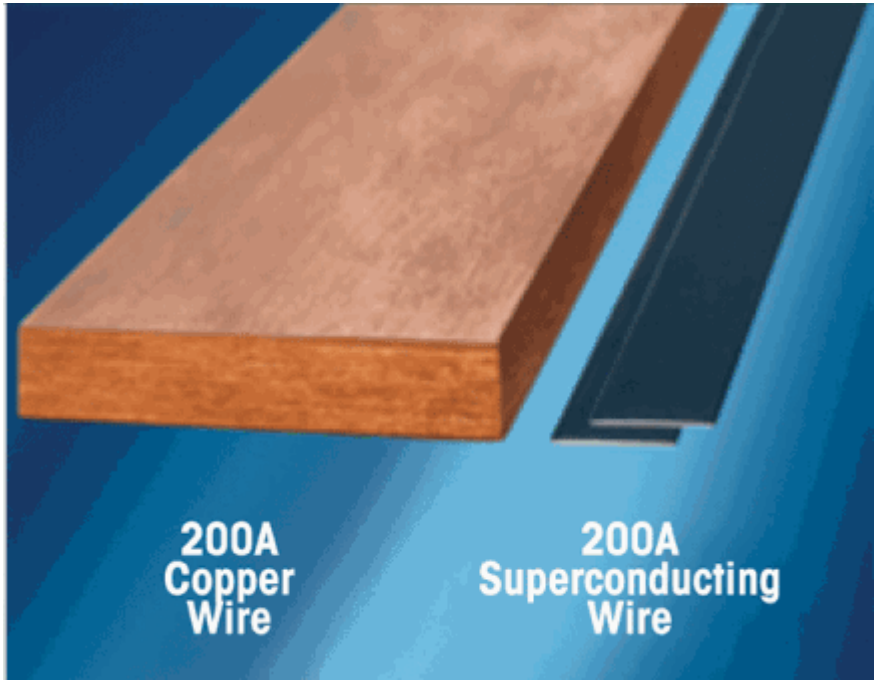
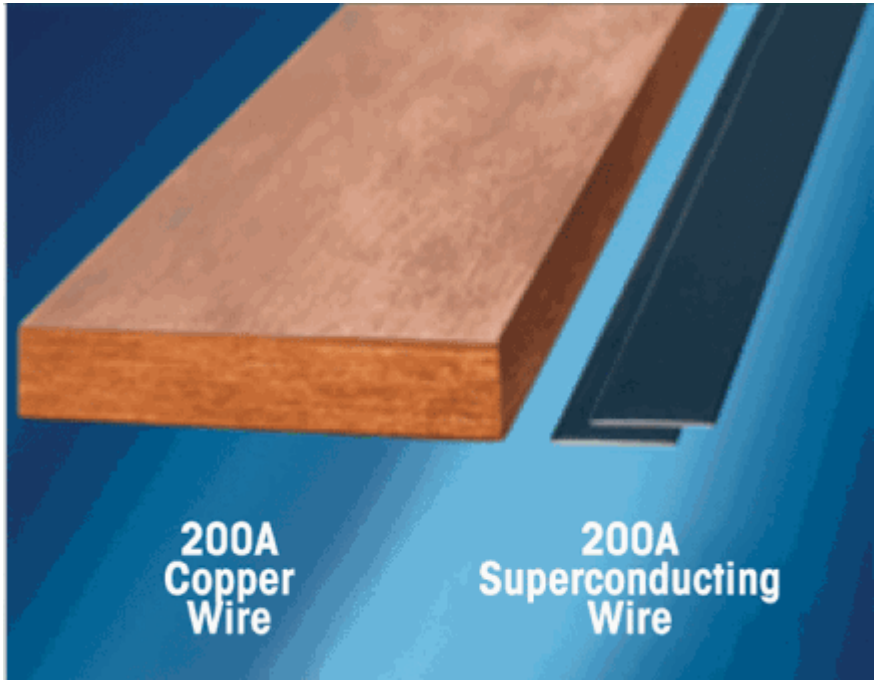


You can increase the power of the stator

Superconductors can carry very high current densities

Funded by the
European Commission
Grant No 723119



You need low temperatures

You can increase the power of the stator

Superconductors can carry very high current densities

Funded by the
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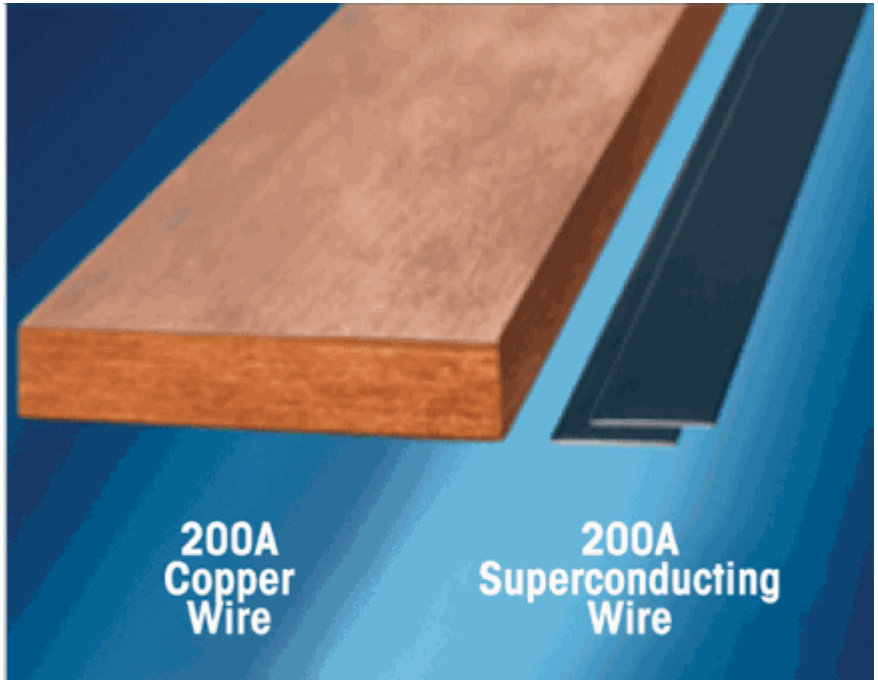

You need low temperatures

REBCO superconducting at **90 K** (-183 ºC)

You can increase the power of the stator

Superconductors can carry very high current densities

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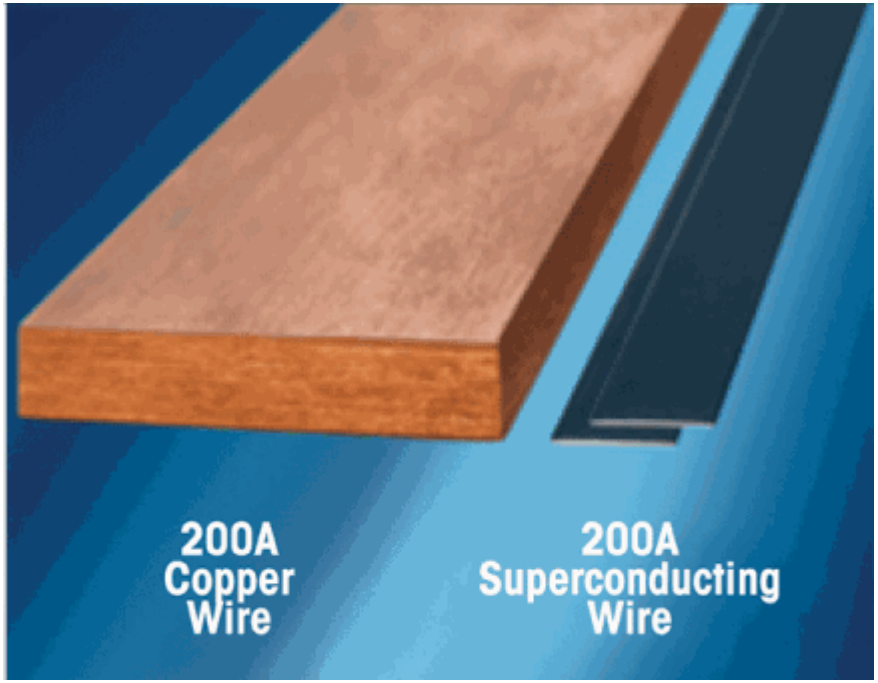

You need low temperatures

REBCO superconducting at **90 K** (-183 ºC)

Required performance maybe down to **20 K** (-253 ºC)

You can increase the power of the stator

Superconductors can carry very high current densities

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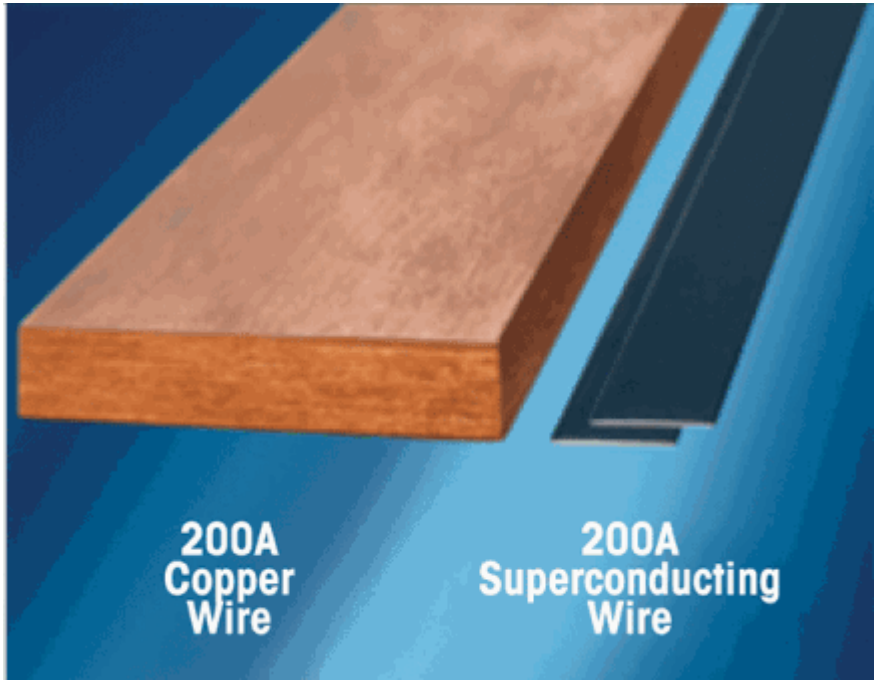

You can increase the power of the stator

You need low temperatures

REBCO superconducting at **90 K** (-183 ºC)

Required performance maybe down to **20 K** (-253 ºC)

Possible to cool down by:

- Liquid hydrogen: **could seve as fuel**
- Cryocoolers

Superconducting rotor

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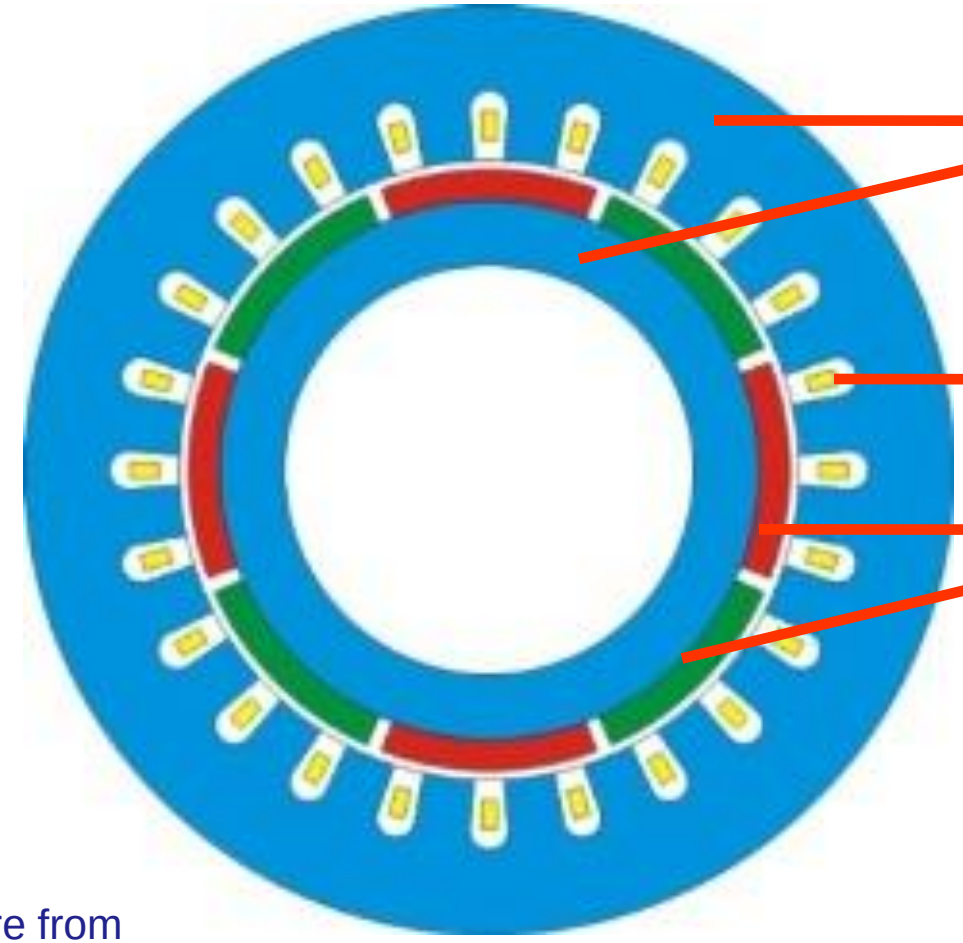

Picture from
OSWALD

Superconducting magnets are 10 times stronger than conventional

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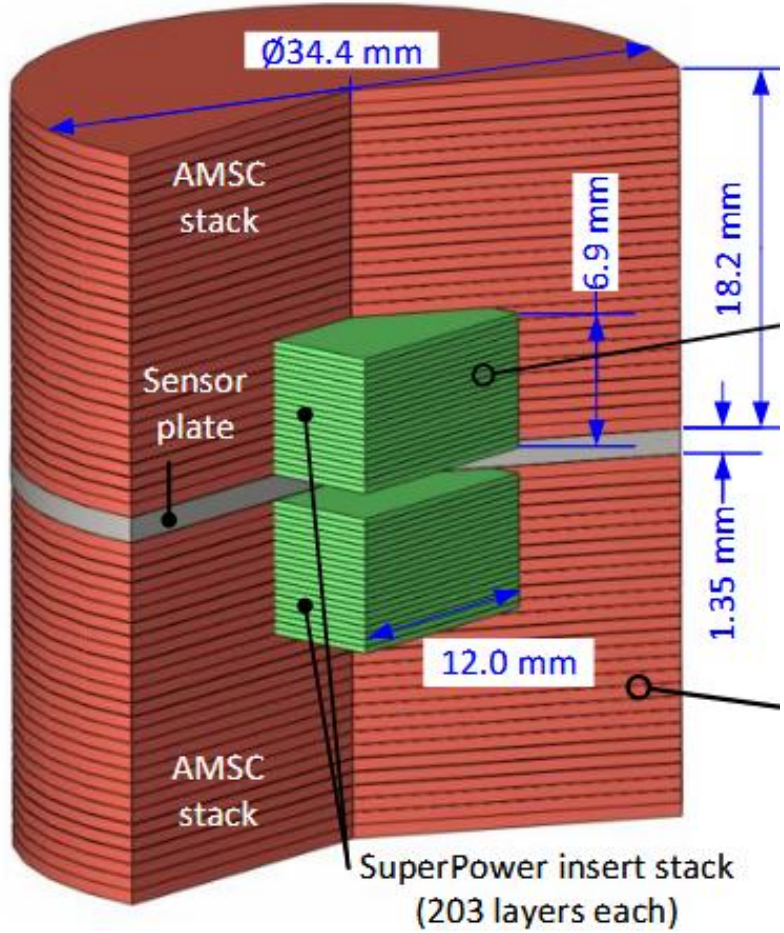

World record: **17.7 T**

University of Cambridge

[A Patel et al. 2017 arXiv]

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ASuMED

- Goals of project
- Why superconductors
- Consortium
- Our role

Your future Horizon 2020 project

Advisory board

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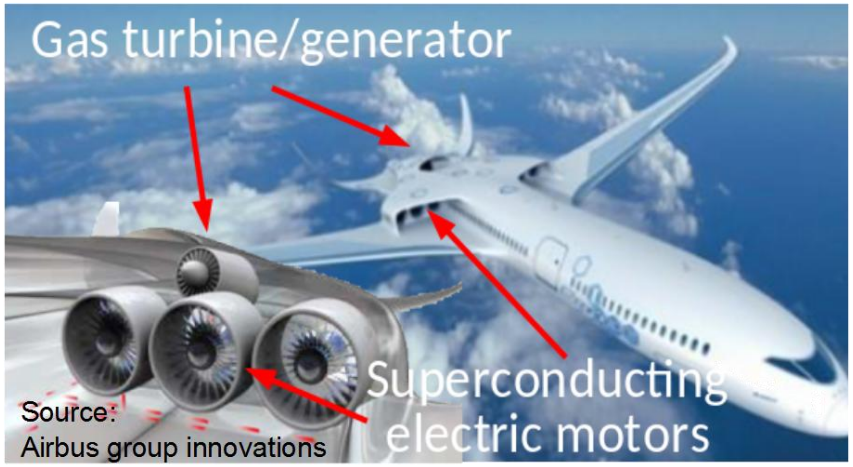
AIRBUS



Advisory board

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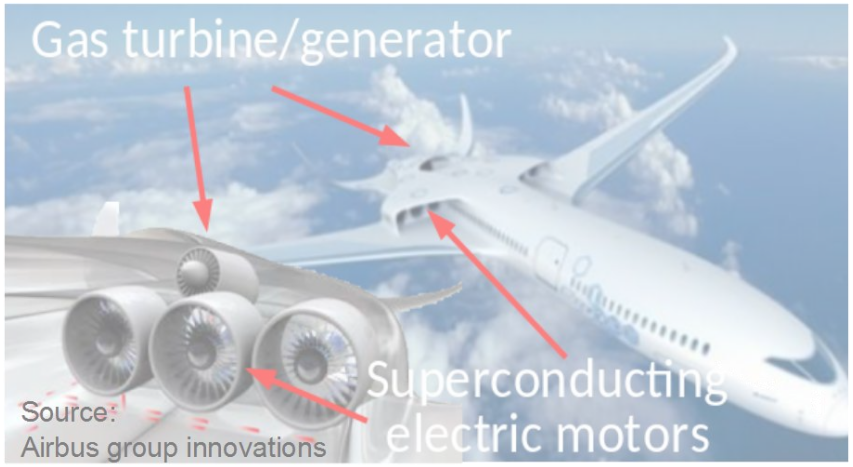
AIRBUS

SIEMENS



Consortium

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OSWALD Elektromotoren GmbH

Project coordinator

Consortium

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OSWALD

OSWALD Elektromotoren GmbH

Project coordinator





High performance electric motors

Experienced in superconducting motors

Consortium

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Aircraft engines

https://www.rolls-royce.com/products-and-services/civil-aerospace/airlines/trent-7000.aspx#latest-updates

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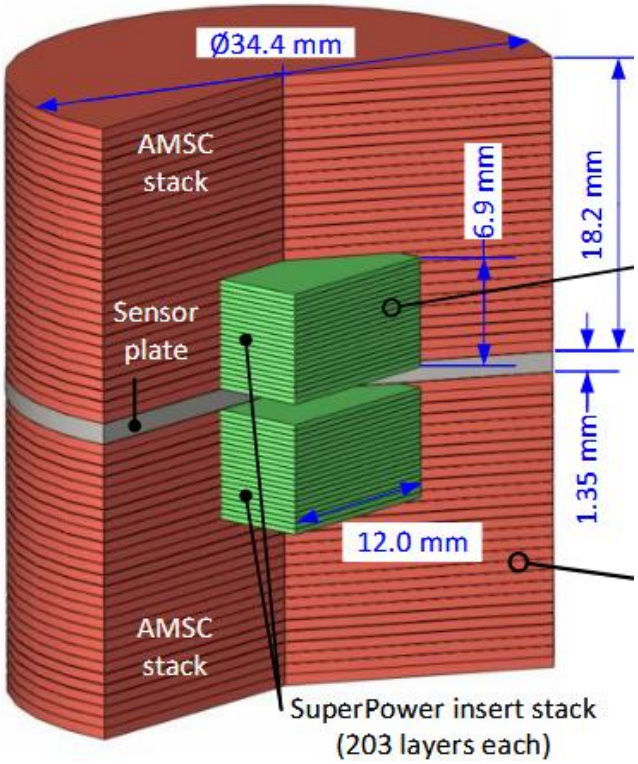
Consortium

UNIVERSITY OF CAMBRIDGE



World record superconducting magnets

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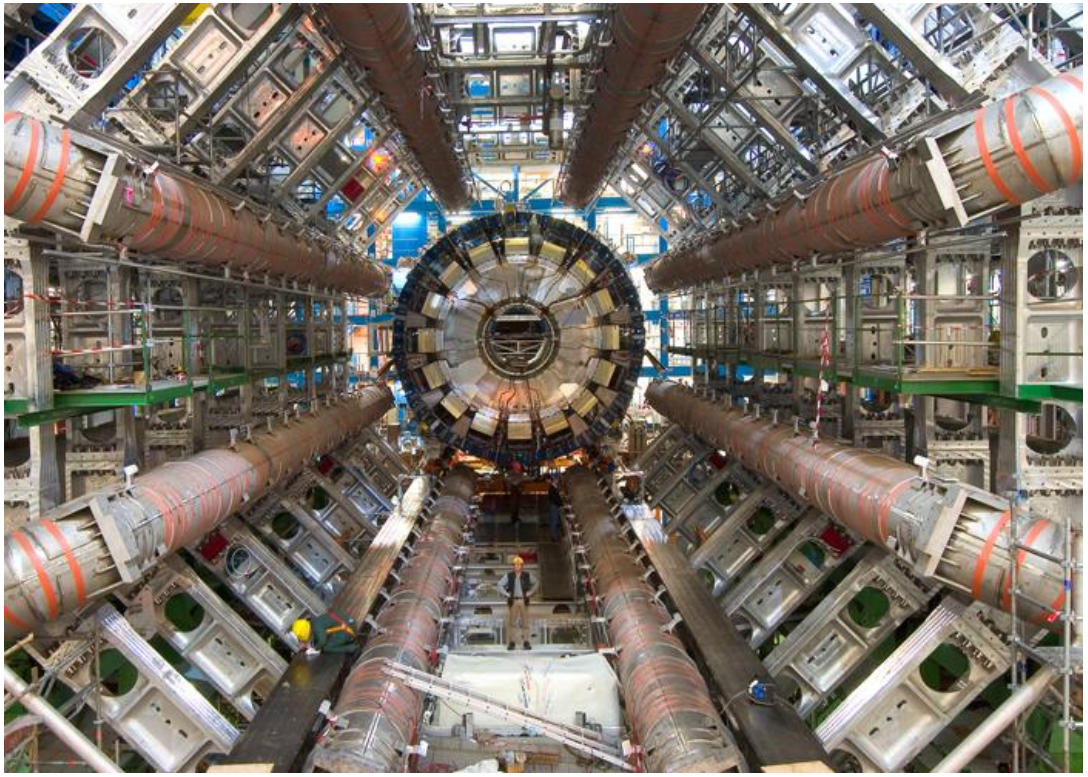
Consortium

DEMACO

Highly specialized cryostats

ATLAS magnets in CERN



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Consortium

Air Liquide
creative oxygen

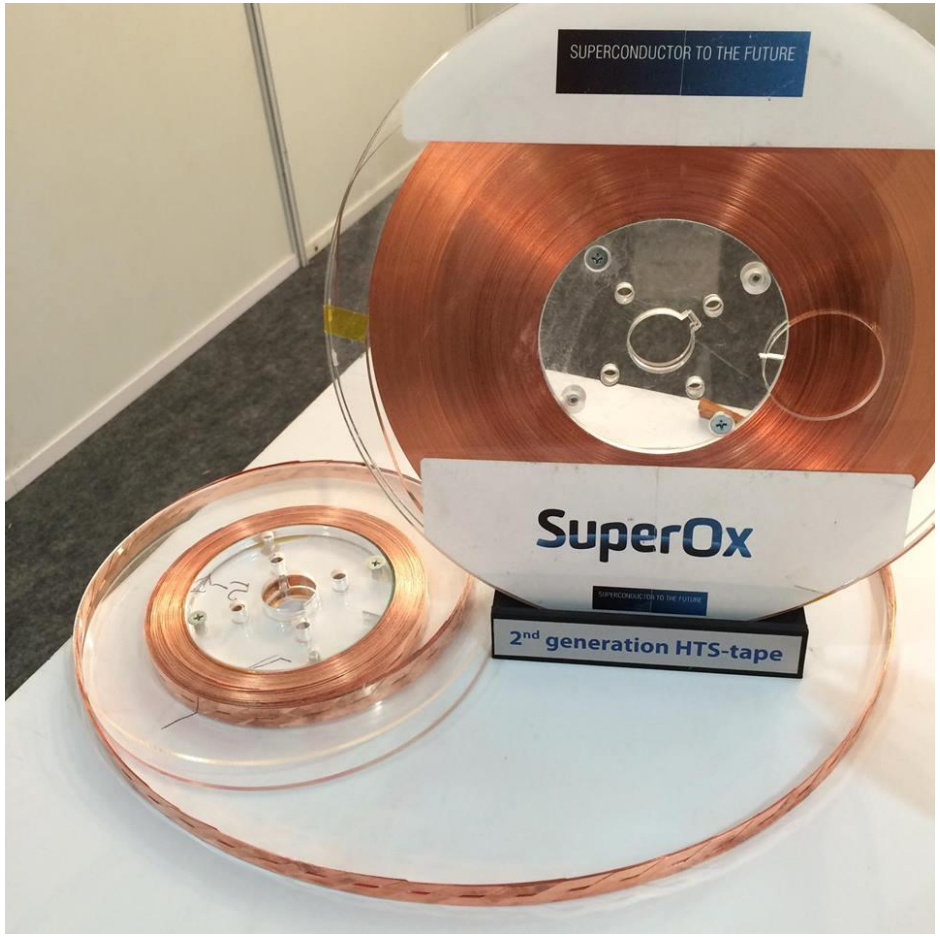
Experienced in cryocoolers for Aerospace

[DOI: 10.1016/j.cryogenics.2008.03.010]

Consortium

SuperOx

REBCO
Superconducting tape



Consortium

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Karlsruhe Institute of Technology

Computer modelling

Superconducting tape characterization

Consortium

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hochschule aschaffenburg
university of applied sciences

Aschaffenburg University

Experienced in inverters for Motors

Consortium

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K & S Project Management

Management of Horizon 2020 projects

Consortium

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European Commission
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Institute of Electrical Engineering, Slovak Academy of Sciences

Computer modelling

Stator characterization

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ASuMED

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Electro-magnetic modeling of superconducting stator

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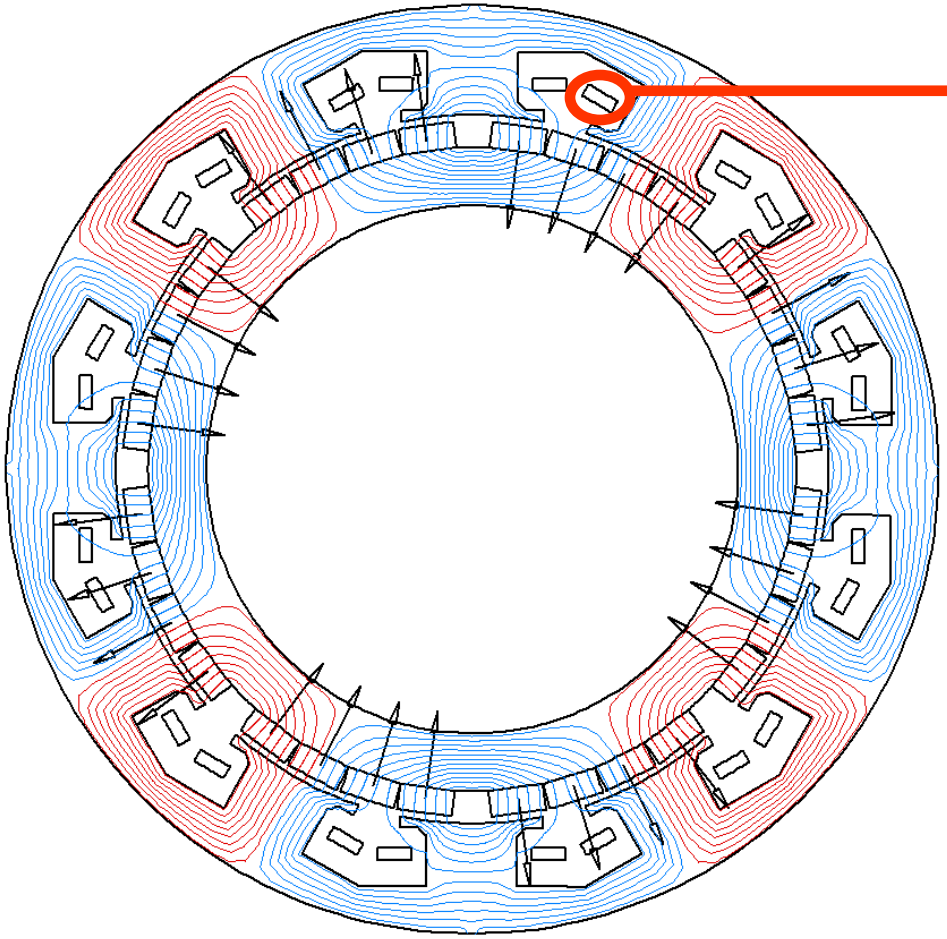

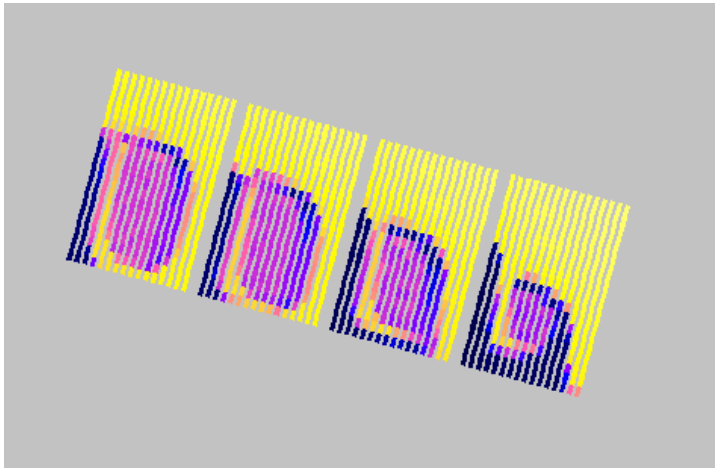

Motor from previous project from OSWALD

Superconductors are highly non-linear

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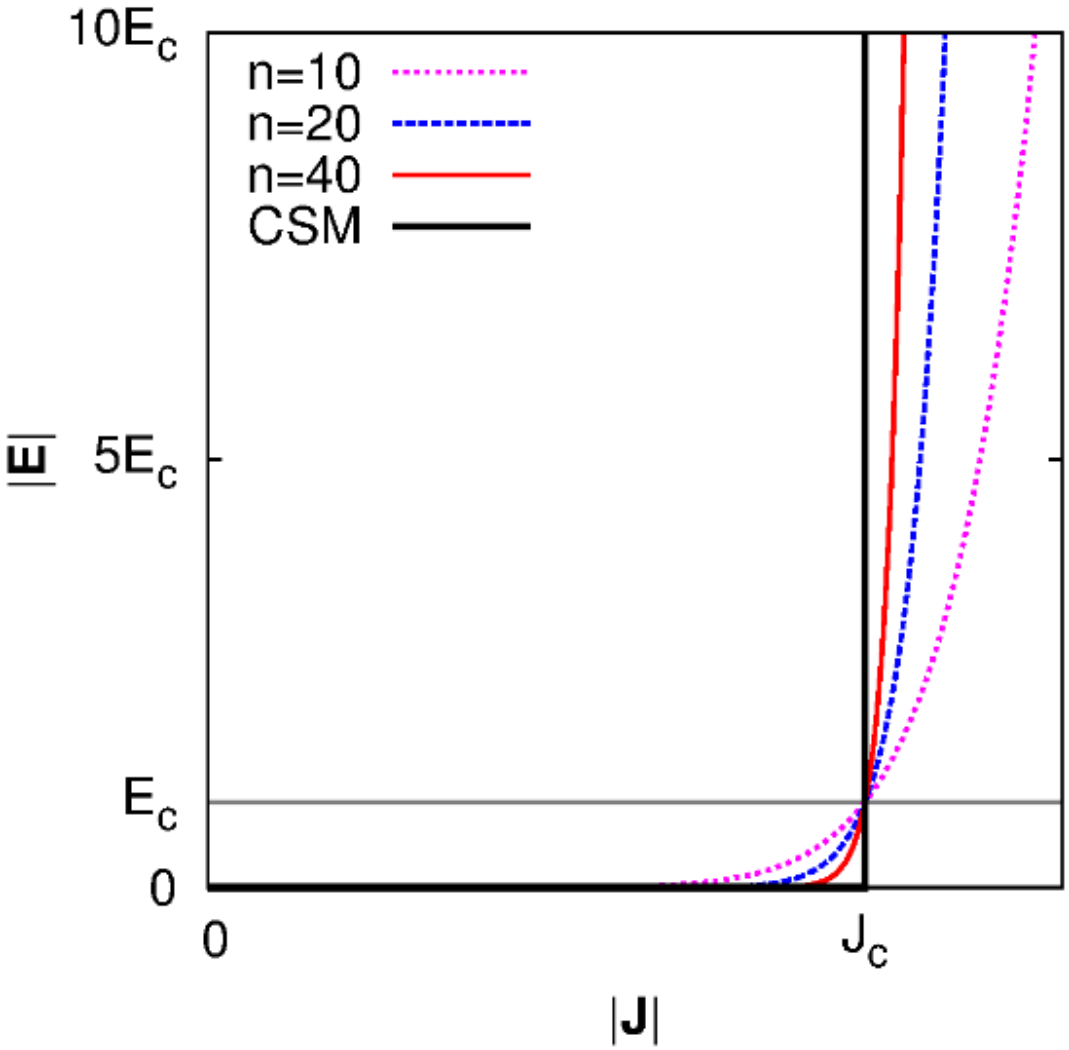
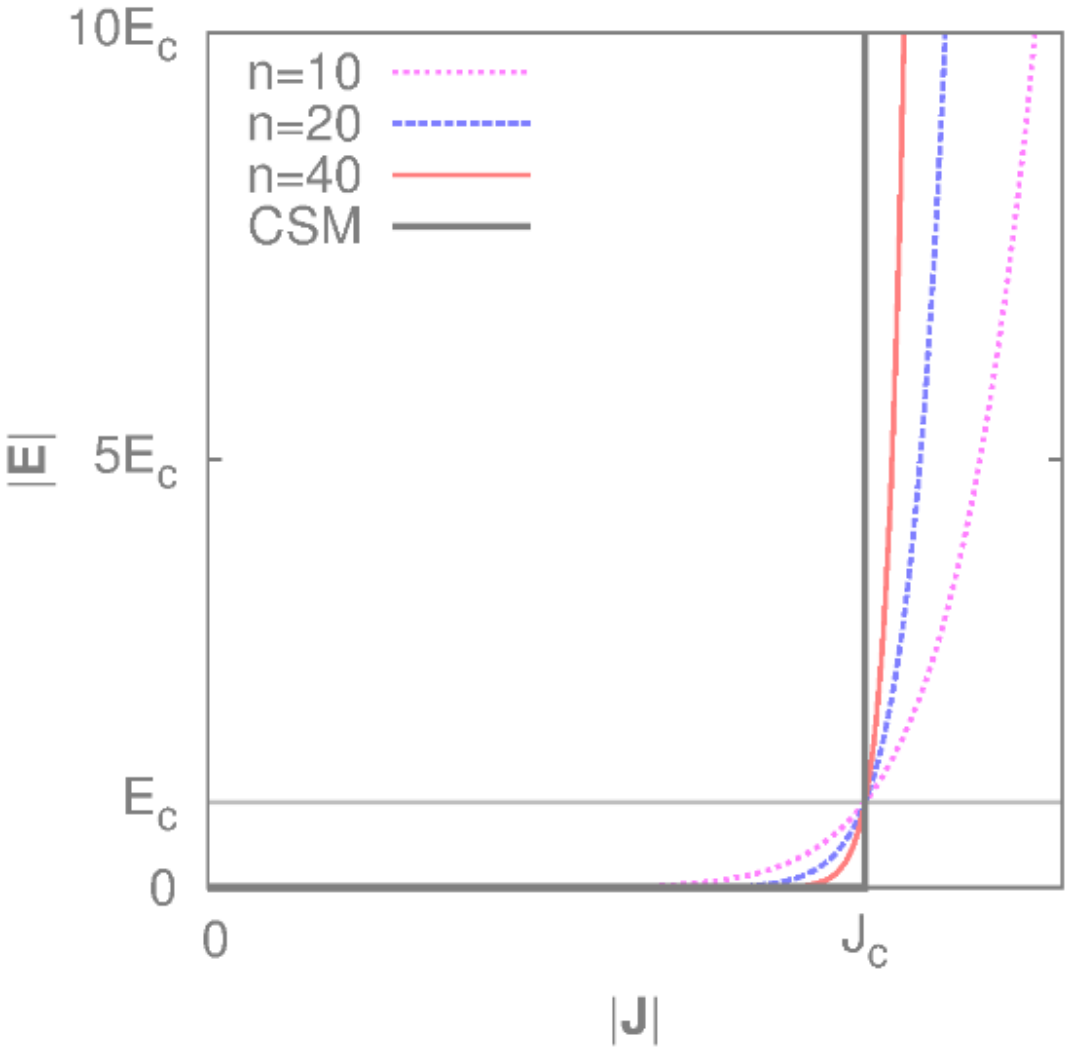


Current density above J_c:

There is resistivity and energy loss

Superconductors are highly non-linear

Funded by the European Commission Grant No 723119



Current density above J_c:

There is resistivity and energy loss

Energy loss reduces efficiency

Produces heating at low temperatures

Why our own code?

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Programmed in C++

Faster than commercial

Optimized for parallel computing

We do not pay licenses

AUREL supercomputer

We develop our own maths

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European Commission
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Equations of **J**

$$\mathbf{E}(\mathbf{J}) = -\frac{\Delta \mathbf{A}}{\Delta t} - \nabla \phi$$

$$\nabla \cdot \mathbf{J} = 0$$

for given **E(J)** relation

are the Euler-Lagrange equations of

$$L = \int_V \mathrm{d}V \left[\frac{1}{2} \Delta \mathbf{J} \cdot \frac{\Delta \mathbf{A}_J}{\Delta t} + \Delta \mathbf{J} \cdot \frac{\Delta \mathbf{A}_a}{\Delta t} + U(\mathbf{J}) + \nabla \phi \cdot \mathbf{J} \right]$$

We develop our own maths

Funded by the
European Commission
Grant No 723119

Equations of **J**

$$\mathbf{E}(\mathbf{J}) = -\frac{\Delta \mathbf{A}}{\Delta t} - \nabla \phi$$

$$\nabla \cdot \mathbf{J} = 0$$

for given **E**(**J**) relation

We develop our own maths

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Equations of **J**

$$\mathbf{E}(\mathbf{J}) = -\frac{\Delta \mathbf{A}}{\Delta t} - \nabla \phi$$

$$\nabla \cdot \mathbf{J} = 0$$

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are the Euler-Lagrange equations of

$$L = \int_V \mathrm{d}V \left[\frac{1}{2} \Delta \mathbf{J} \cdot \frac{\Delta \mathbf{A}_J}{\Delta t} + \Delta \mathbf{J} \cdot \frac{\Delta \mathbf{A}_a}{\Delta t} + U(\mathbf{J}) + \nabla \phi \cdot \mathbf{J} \right]$$

[E Pardo, J Souc, L Frolek SuST 2015]
[E Pardo, M Kapolka J Comp. Phys. 2017]

We develop our own maths

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Equations of **J**

$$\mathbf{E}(\mathbf{J}) = -\frac{\Delta \mathbf{A}}{\Delta t} - \nabla\phi$$

$$\nabla \cdot \mathbf{J} = 0$$

for given **E(J)** relation

are the Euler-Lagrange equations of

J change between two time instants

A from Δ**J**

A from applied field

scalar potential

$$L = \int_V \mathrm{d}V \left[\frac{1}{2}\Delta\mathbf{J} \cdot \frac{\Delta \mathbf{A}_J}{\Delta t} + \Delta\mathbf{J} \cdot \frac{\Delta \mathbf{A}_a}{\Delta t} + U(\mathbf{J}) + \nabla\phi \cdot \mathbf{J} \right]$$

$$U(\mathbf{J}) = \int_0^{\mathbf{J}} \mathrm{d}\mathbf{J}' \cdot \mathbf{E}(\mathbf{J})'$$

[E Pardo, J Souc, L Frolek SuST 2015]
[E Pardo, M Kapolka J Comp. Phys. 2017]

Non-linear eddy currents in coils

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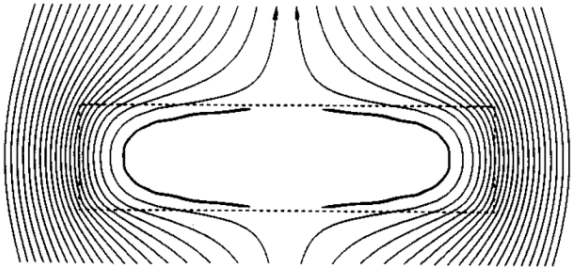
1 tape



Brandt 1996 PRB

Non-linear eddy currents in coils

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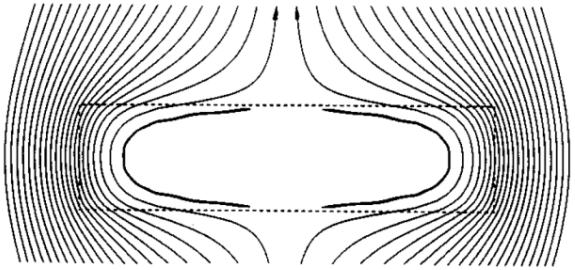
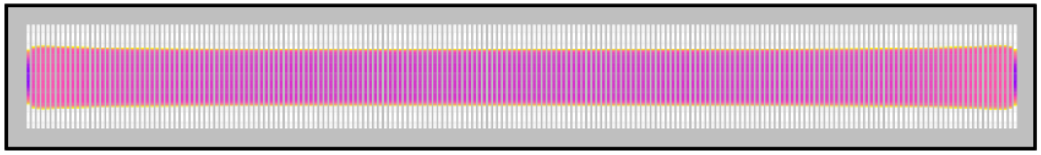
1 tape



Brandt 1996 PRB

100 tapes



Pardo 2008 SuST

World record

Non-linear eddy currents in coils

Funded by the
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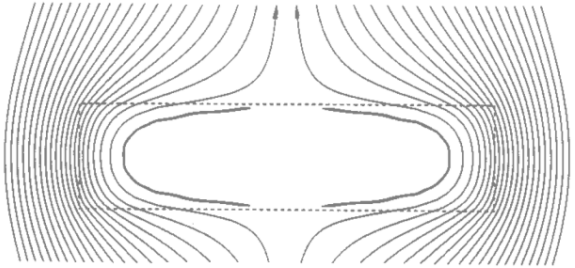
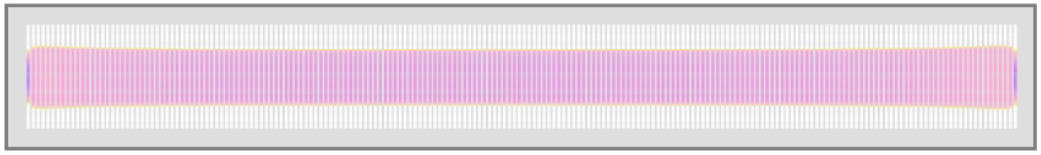
Grant No 723119

1 tape



Brandt 1996 PRB

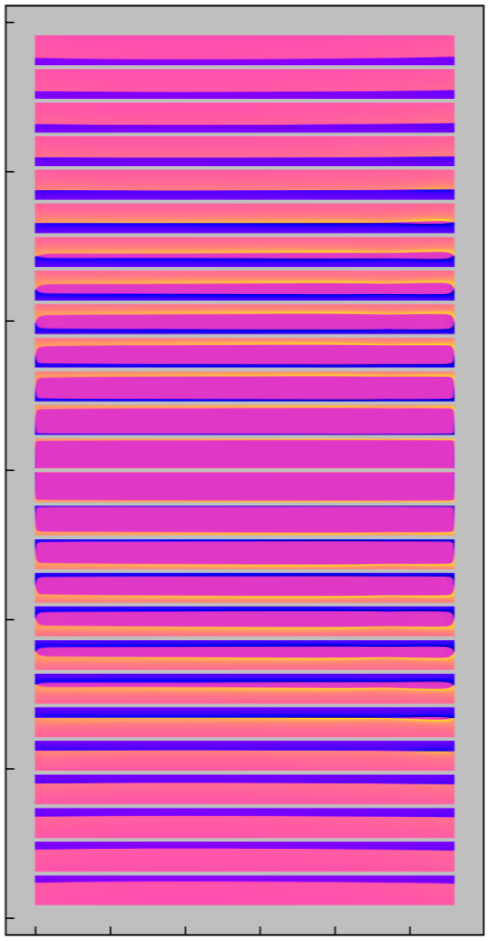
100 tapes



Pardo 2008 SuST

World record

10 000 tapes



Pardo 2016 SuST

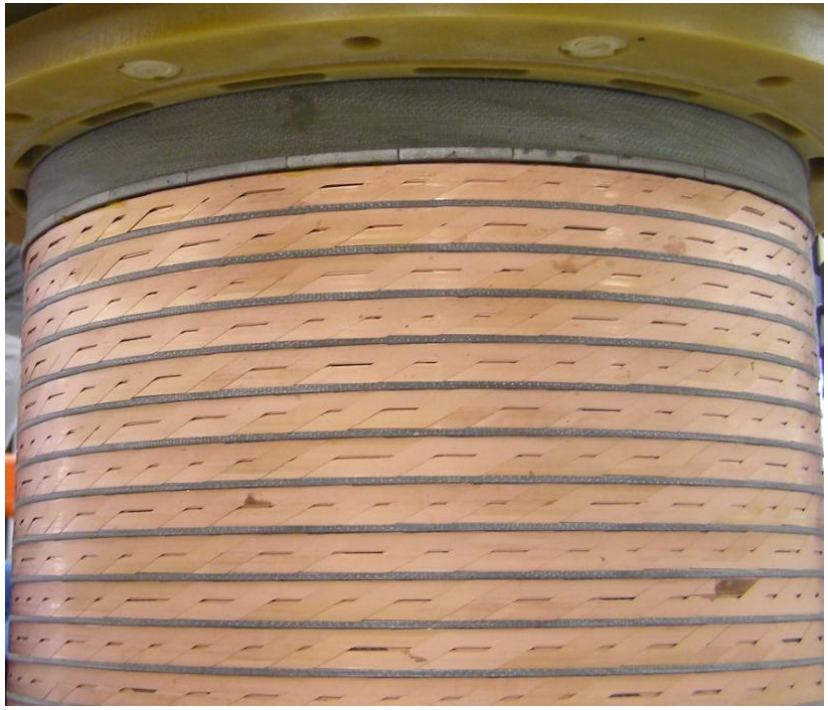
World record

Fully superconducting transformer

Funded by the European Commission Grant No 723119

1 MVA 11 kV/415 V 3-phase transformer

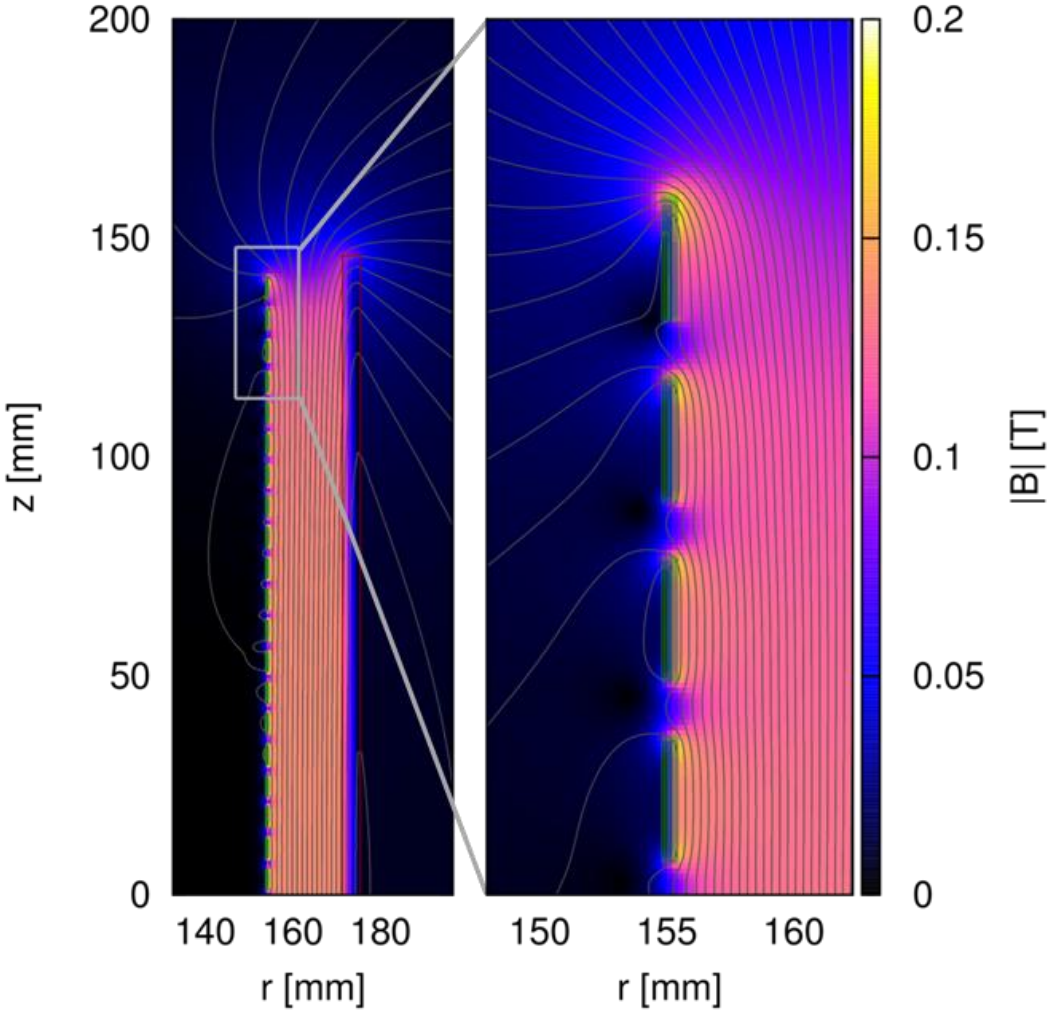
Roebel cable in low-voltage winding



Consortium leaded by
Victoria University of Wellington

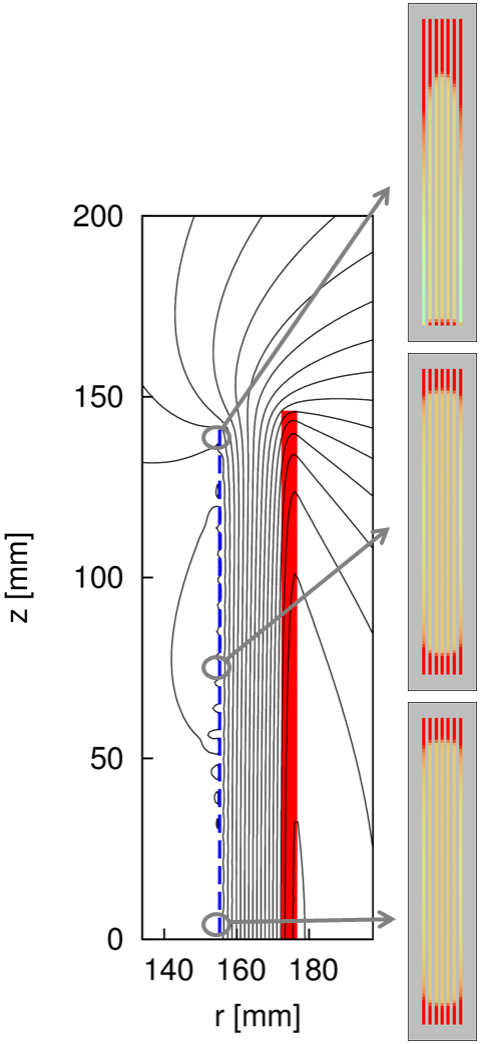
Non-linear eddy currents in transformer

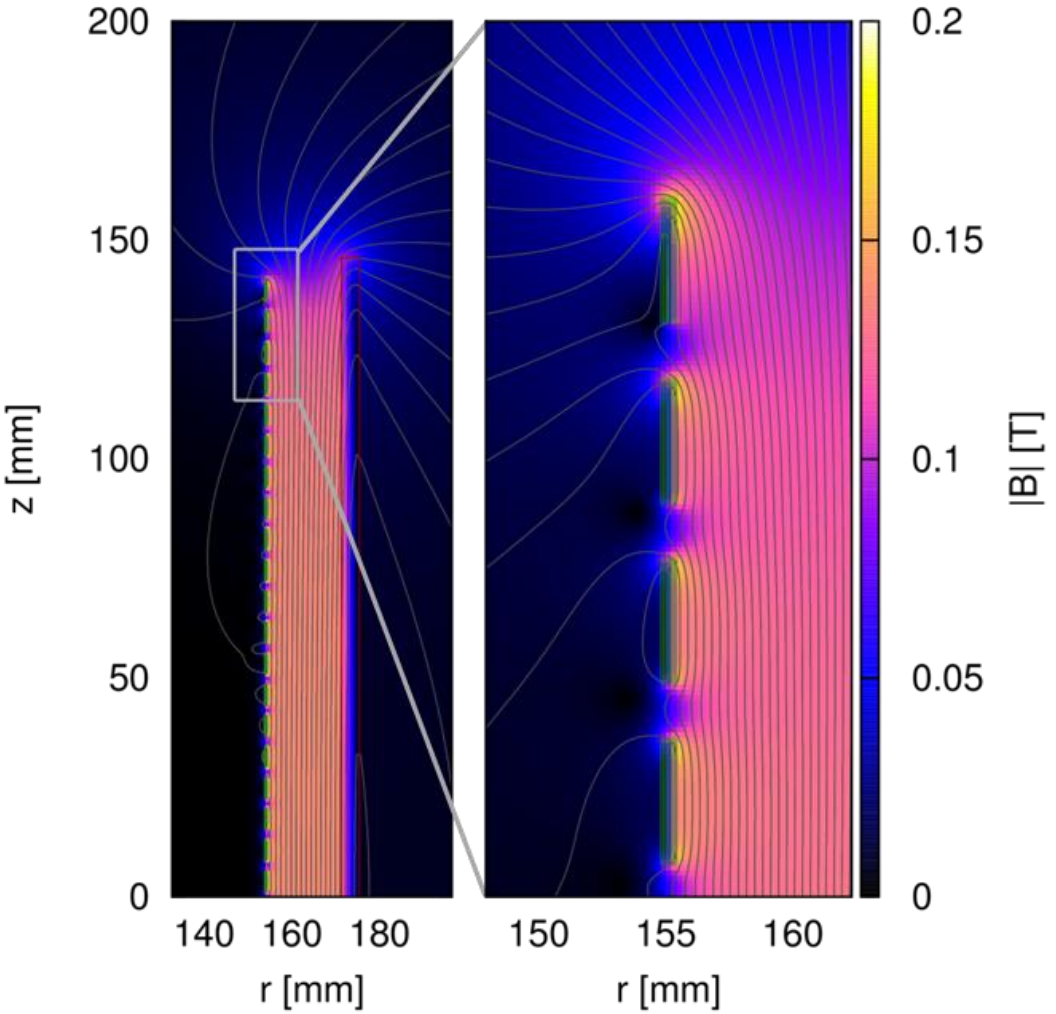
Funded by the European Commission Grant No 723119



Non-linear eddy currents in transformer

Funded by the European Commission Grant No 723119





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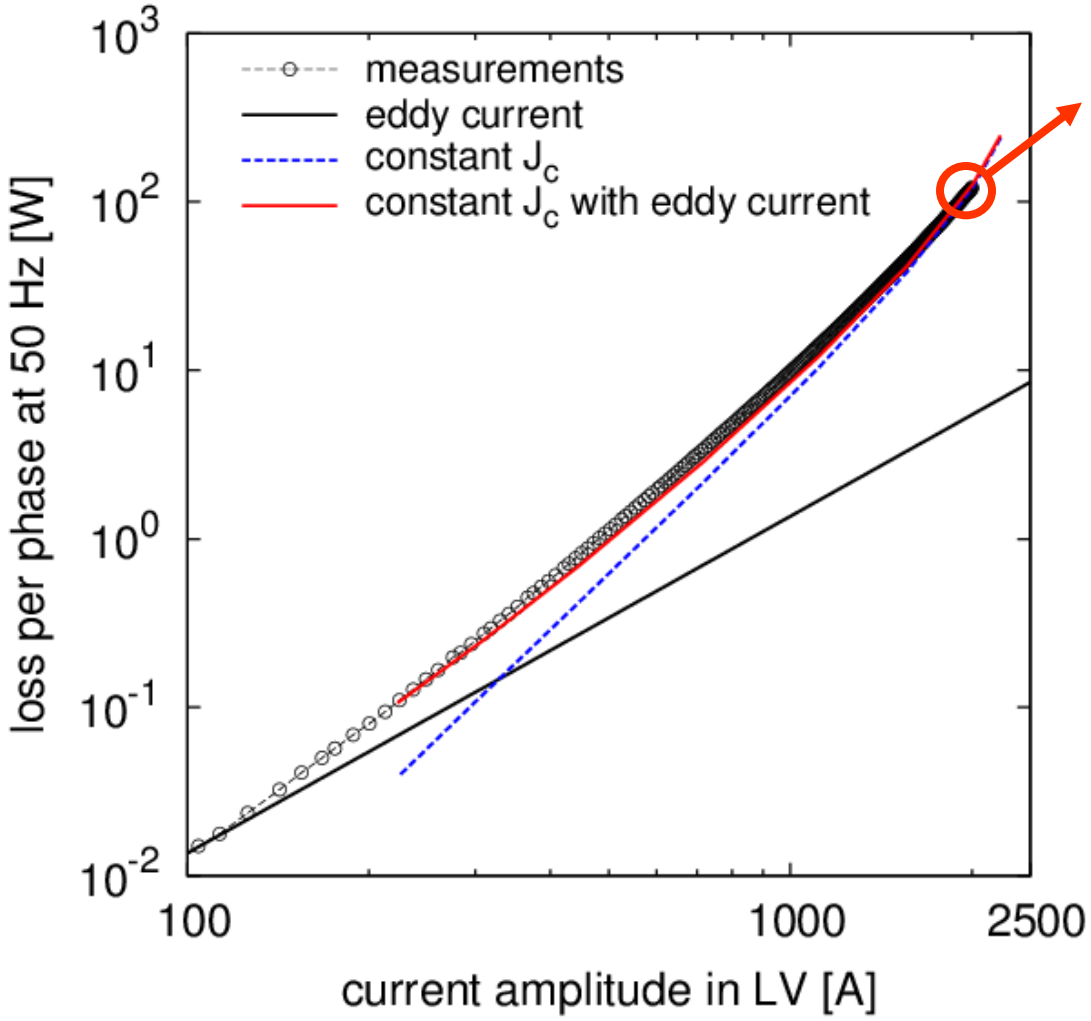

Exellent agreement at rated current

Copper current leads cause eddy current loss

consistent
with estimations

[Pardo et al. 2015 SuST]

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Grant No 723119

ASuMED

Your future Horizon 2020 project

Funded by the
European Commission
Grant No 723119

ASuMED

Your future Horizon 2020 project

A good consortium

Funded by the
European Commission
Grant No 723119

Balanced proportion of industry and academy

A good consortium

Funded by the
European Commission
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Balanced proportion of industry and academy

There should not be overlapping

A good consortium

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Balanced proportion of industry and academy

There should not be overlapping

Each partner has
a particular task and role

- Lab test
- Computer modelling
- Sample preparation
- Device design
- ...

ASuMED

Your future Horizon 2020 project

- Joining as partner
- Create a project as coordinator
- Project progress

You should be a good partner

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You should be a good partner

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European Commission
Grant No 723119

Coordinator asks:

Who do I know that could do this task?

You should be a good partner

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Grant No 723119

Coordinator asks:

Who do I know that could do this task?

Why should they contact you?

You should be a good partner

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Coordinator asks:

Who do I know that could do this task?

Why should they contact you?

Because you are the only one in the world who can do that

You should be a good partner

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Grant No 723119

Coordinator asks:

Who do I know that could do this task?

Why should they contact you?

Because you are the only one in the world who can do that

OR

You are in a long-term collaboration with the coordinator or a very important partner

Then, you need to:

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Be **highly specialized**

Then, you need to:

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European Commission
Grant No 723119

Be **highly specialized**

Become a **world leader** of a narrow field

Then, you need to:

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European Commission
Grant No 723119

Be **highly specialized**

Become a **world leader** of a narrow field

Start collaborations with important labs who already have Horizon 2020 projects

Then, you need to:

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Get well known:

Make presentations
in the best conferences worldwide

Then, you need to:

Funded by the
European Commission
Grant No 723119

Get well known:

Make presentations
in the best conferences worldwide

Publish regularly in most-read journals

Then, you need to:

Funded by the
European Commission
Grant No 723119

Get well known:

Make presentations in the best conferences worldwide

Publish regularly in most-read journals

Companies: have an exhibitor stand at conferences

Then, you need to:

Funded by the
European Commission
Grant No 723119

Get well known:

Make presentations in the best conferences worldwide

Publish regularly in most-read journals

Companies: have an exhibitor stand at conferences

Do always a good and reliable job!

ASuMED

Your future Horizon 2020 project

Joining as partner

Create a project as coordinator

Project progress

Become coordinator

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You need to have your own public-funded research projects

Become coordinator

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You need to have your own public-funded research projects

Structural funds are not enough

Become coordinator

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You need to have your own public-funded research projects

Structural funds are not enough

All future partners need to know you well

Become coordinator

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You need to have your own public-funded research projects

Structural funds are not enough

All future partners need to know you well

You could contract a company to do the management

Become coordinator

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You need to have your own public-funded research projects

Structural funds are not enough

All future partners need to know you well

You could contract a company to do the management

You take the decisions and lead the research

ASuMED

Your future Horizon 2020 project

- Joining as partner
- Create a project as coordinator
- Project progress

You are
in a collaborative project

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You are
in a collaborative project

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Be collaborative

Constructive attitude is always best

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Make tasks for other partners and share them

Project progress

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Make tasks for other partners and share them

Face-to-face meetings: 2-4 times a year

Project progress

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Make tasks for other partners and share them

Face-to-face meetings: 2-4 times a year

Telco meetings: 1-4 times a month

If you make more telcos,
you need less face-to face meetings

Reporting
to the European Commission

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Annual reports

- Research
- Financial

Reporting
to the European Commission

Funded by the
European Commission
Grant No 723119

Annual reports

- Research
- Financial

Deliverables:

- Report
- Sample
- Prototype
- Database
- ...

Reporting
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Annual reports

- Research
- Financial

Deliverables:

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- ...

Milestones

Reporting
to the European Commission

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Annual reports

- Research
- Financial

Deliverables:

- Report
- Sample
- Prototype
- Database
- ...

Milestones

Midterm report

Midterm report

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Funded by the
European Commission
Grant No 723119

Report and meeting between

- European Commission officer
- Coordinator
- Optionally: the most importnat partners

Midterm report

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Report and meeting between

- European Commission officer
- Coordinator
- Optionally: the most importnat partners

Go or no-go decision from the officer

Midterm report

Funded by the
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Report and meeting between

- European Commission officer
- Coordinator
- Optionally: the most importnat partners

Go or no-go decision from the officer

You really need to do the work

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I wish that your new project will take off soon!

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Thank you
for your attention!

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Would you like to know more?

http://asumed.oswald.de