

Directing transformation:

The science of Energy and Fusion

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U.S. DEPARTMENT OF

ENERGY

Office of Science

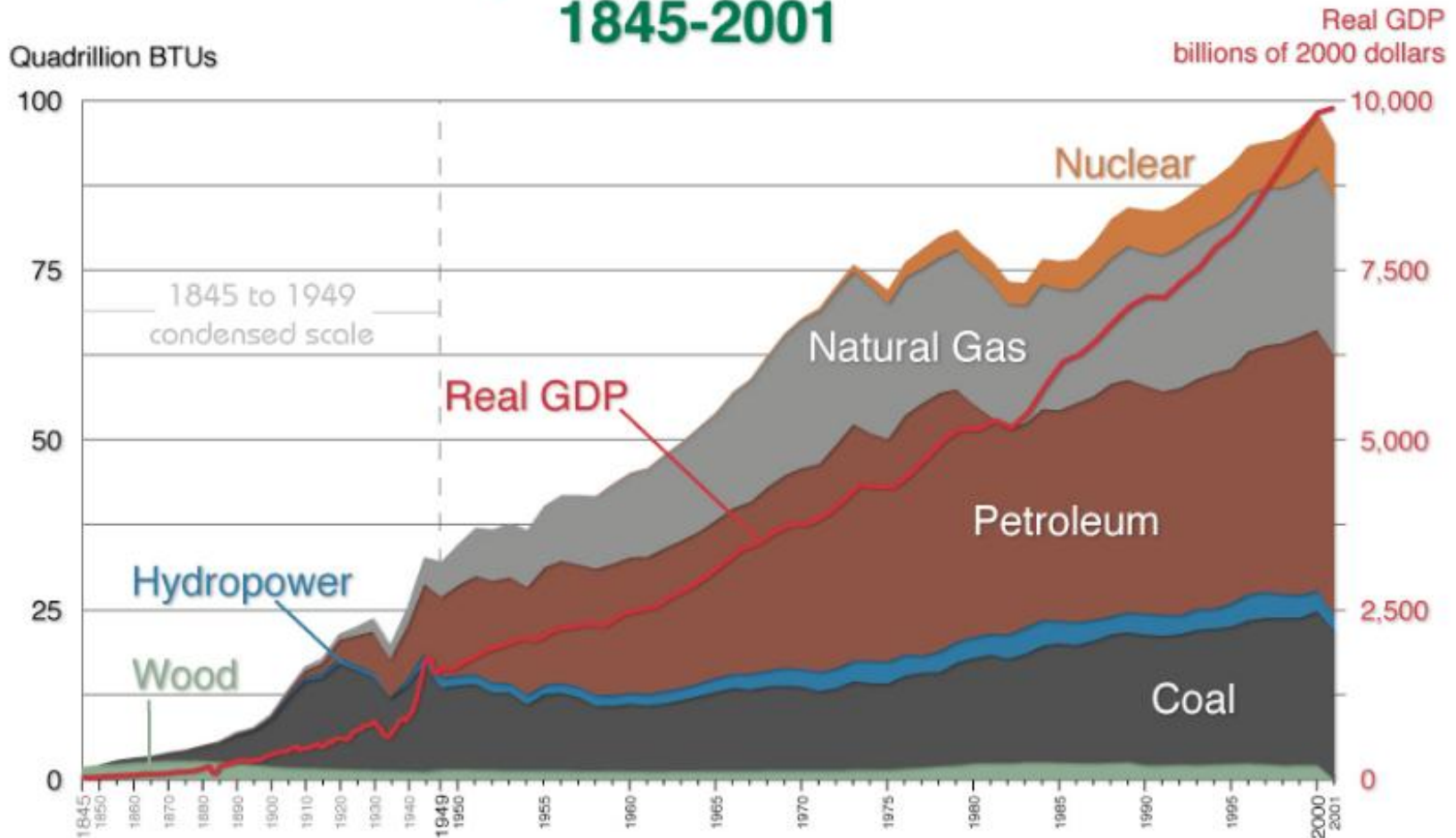
For the 2nd Monaco-ITER International
Fusion Energy Days
Principality of Monaco
December 2, 2013



*We live in an unprecedented era of transformation:
with benefit, burden, and promise*

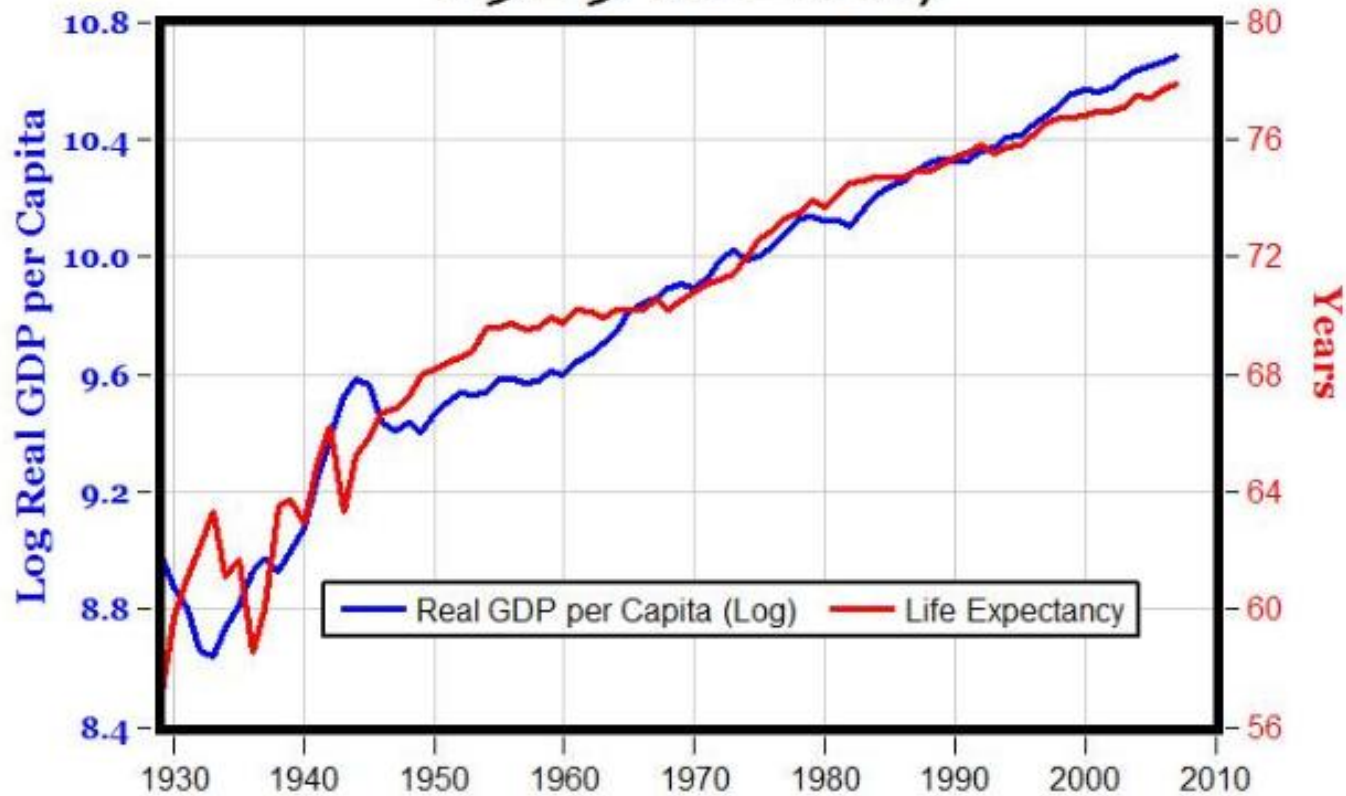
This is an age of transformation:
energy transforms economies

US Consumption by Source v. Real GDP 1845-2001

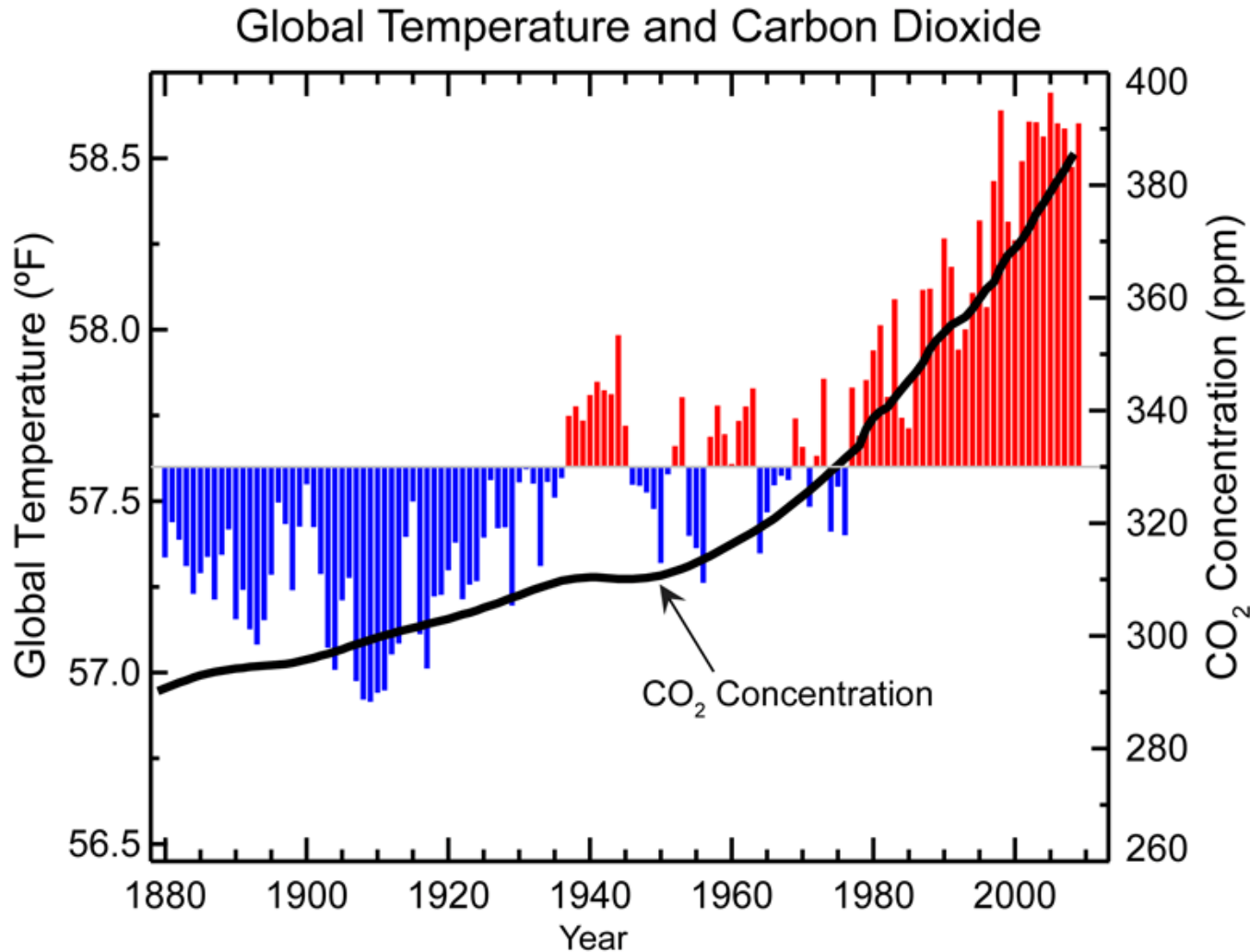


This is an age of transformation:
energy transforms life quality

U.S. Life Expectancy vs. Real GDP per Capita (log) 1929 to 2007



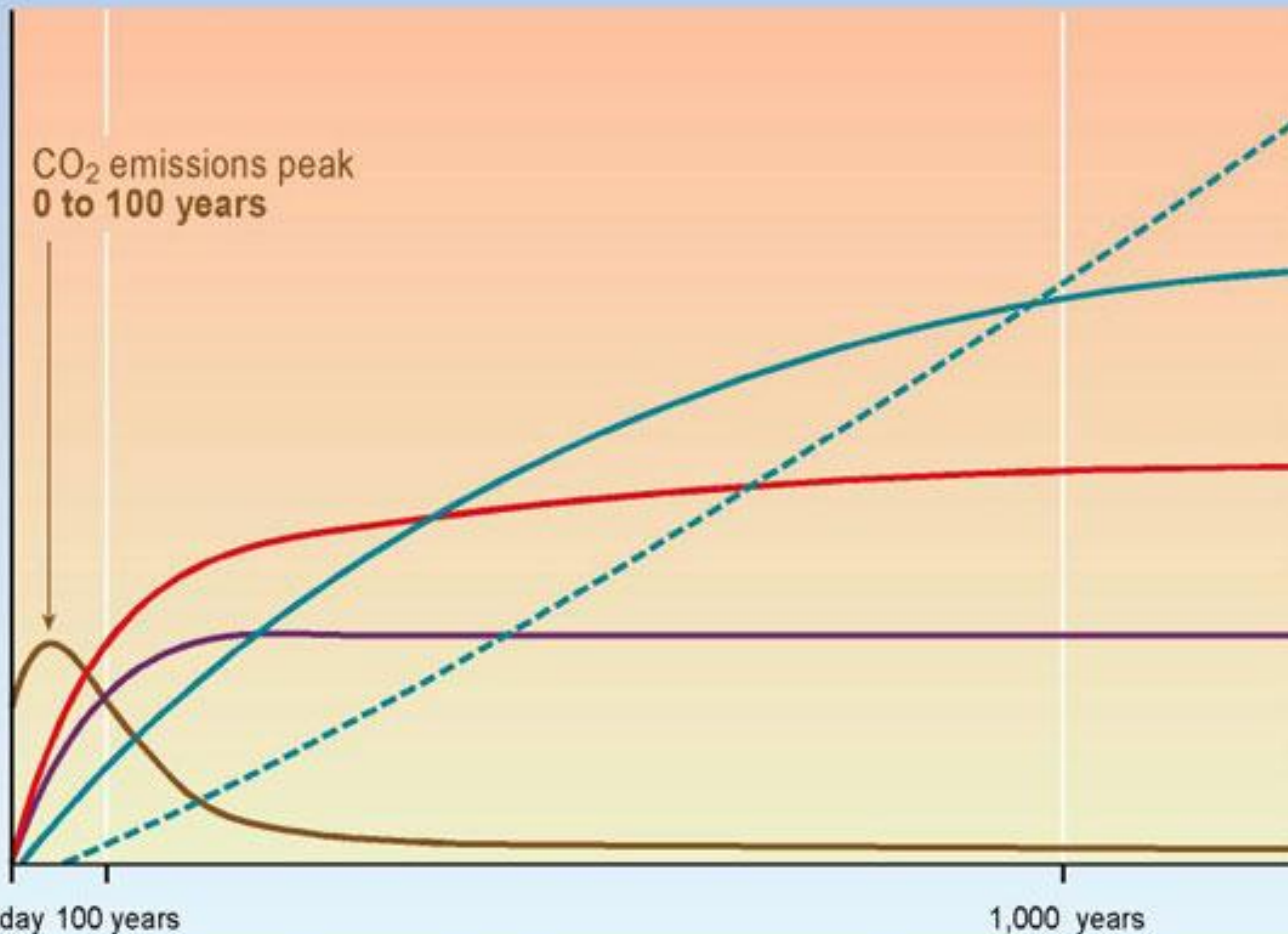
This is an age of transformation:
global impacts are measurable



This is an age of transformation: *consequences are predictable*

CO₂ concentration, temperature, and sea level continue to rise long after emissions are reduced

Magnitude of response



Time taken to reach equilibrium

Sea-level rise due to ice melting:
several millennia

Sea-level rise due to thermal expansion:
centuries to millennia

Temperature stabilization:
a few centuries

CO₂ stabilization:
100 to 300 years

CO₂ emissions

Today 100 years

1,000 years

This is an age of transformation:
energy science and innovation will be key

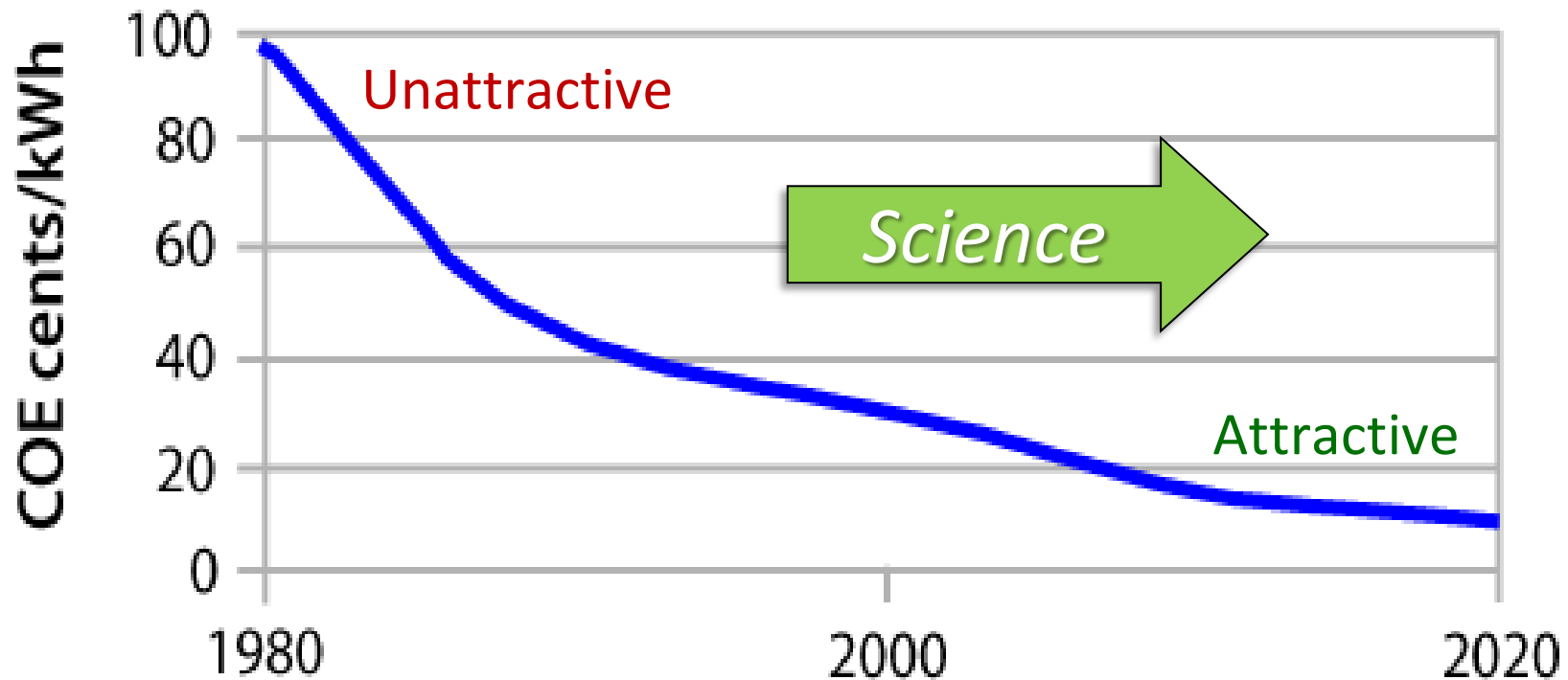
Secretary of Energy Moniz: “The President’s FY 2014 Budget requests resources to... support research, development, and deployment of the energy technologies of the future that will reduce greenhouse gas emissions and increase energy security...**We need to support cutting edge research across the board that will help create the clean energy economy of tomorrow...**”

“DOE’s science programs provide the technical underpinnings to accomplish the Department’s missions and form part of the backbone of basic research in the physical sciences in the United States...”

Fusion research in the US is one such science program.

This is an age of transformation:
energy science increases attractive options

Photovoltaic Cost of Energy



This is an age of transformation:
science improves performance

Experimentally validated supercomputing yields
a 10% improvement in fuel efficiency

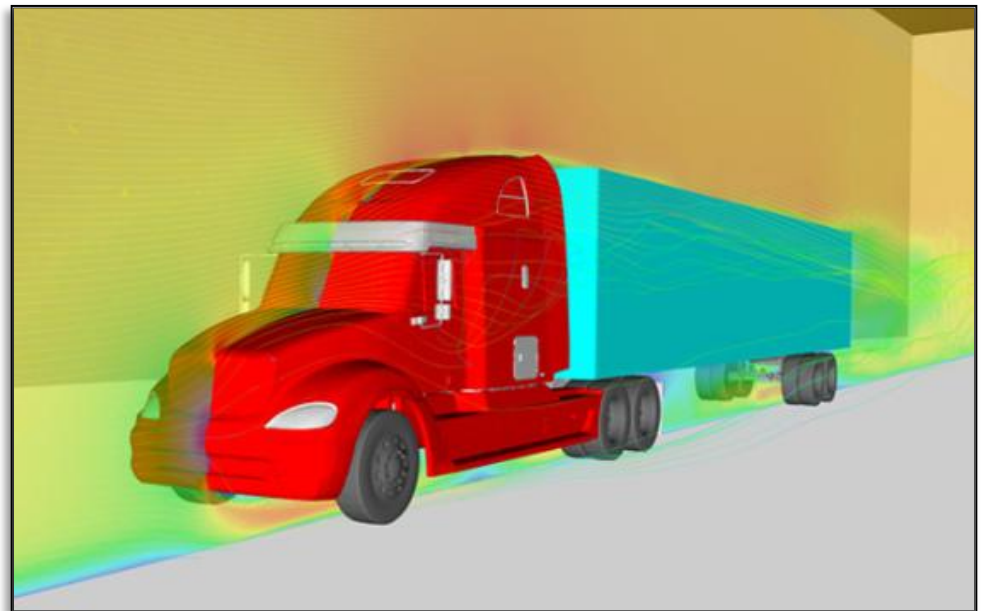
Potentially

2.5 million tons
annual CO2 reduction

2.8 billion
annual fuel gallons saved

\$8.3 billion
annual fuel cost savings

NAVISTAR[®]

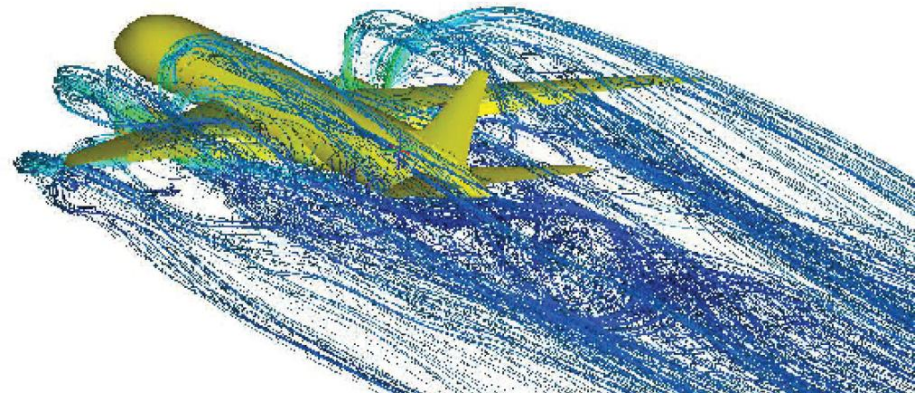


This is an age of transformation:
science reduces development costs

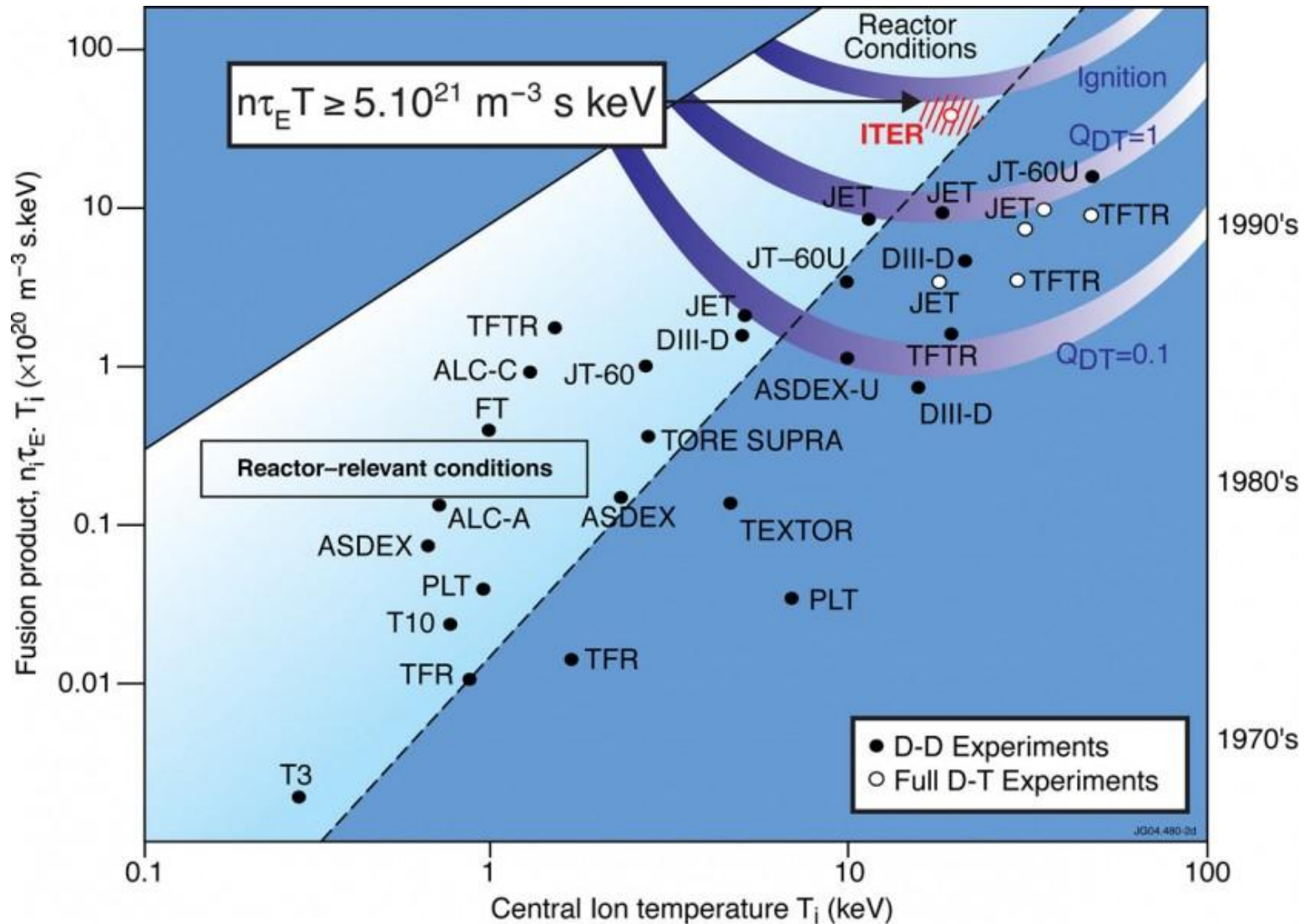
10-fold reduction in prototyping of wing designs

“ By using supercomputers to simulate the properties of the wings on recent models such as the 787 and the 747-8, we only had to design seven wings, ***a tremendous savings in time and cost***, especially since the price tag for wind tunnel testing has skyrocketed over the past 25 years.”

- Doug Ball, Boeing (chief engineer for enabling technology and research)

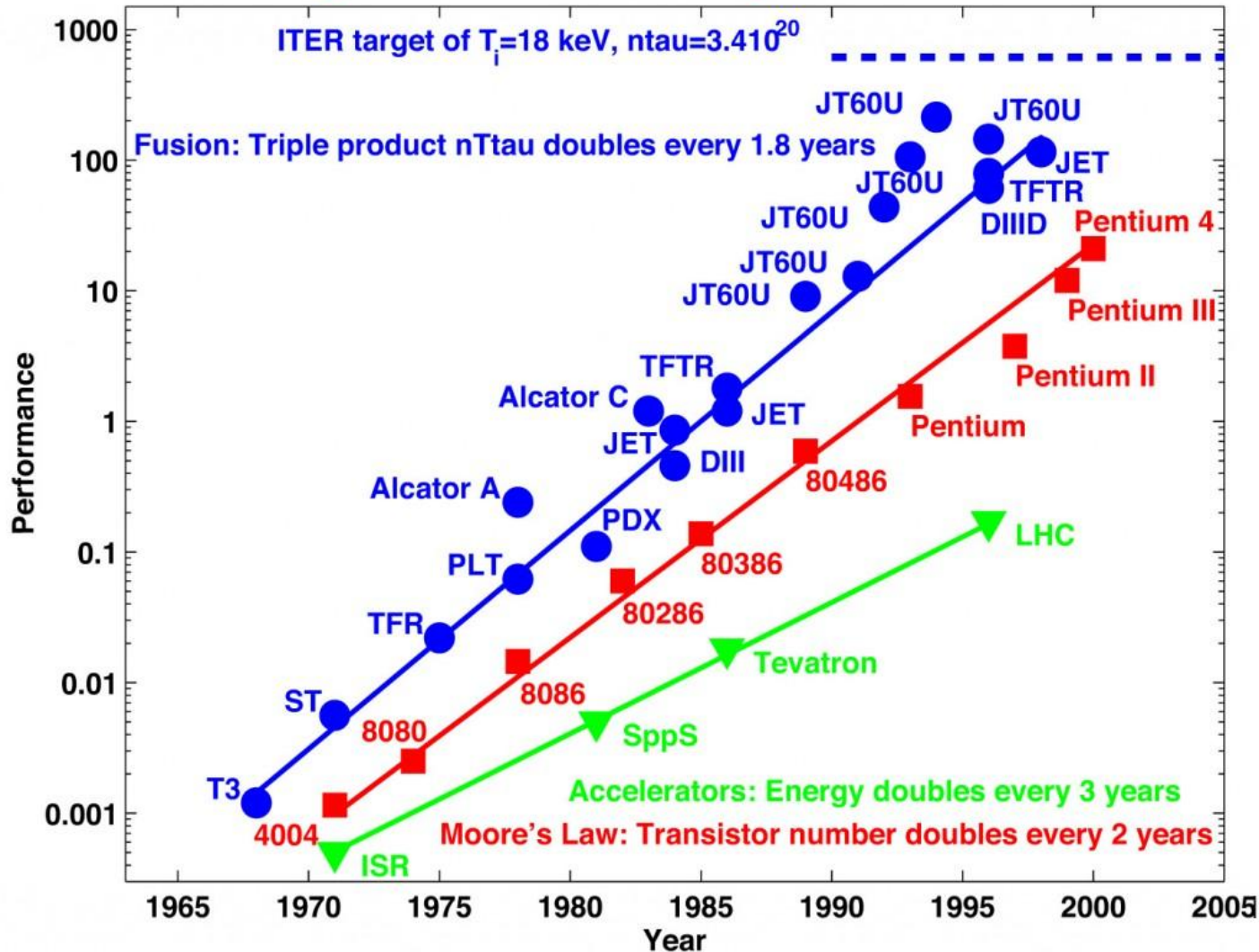


Scientific advance has made fusion an option:
the fusion reactor regime is within striking distance

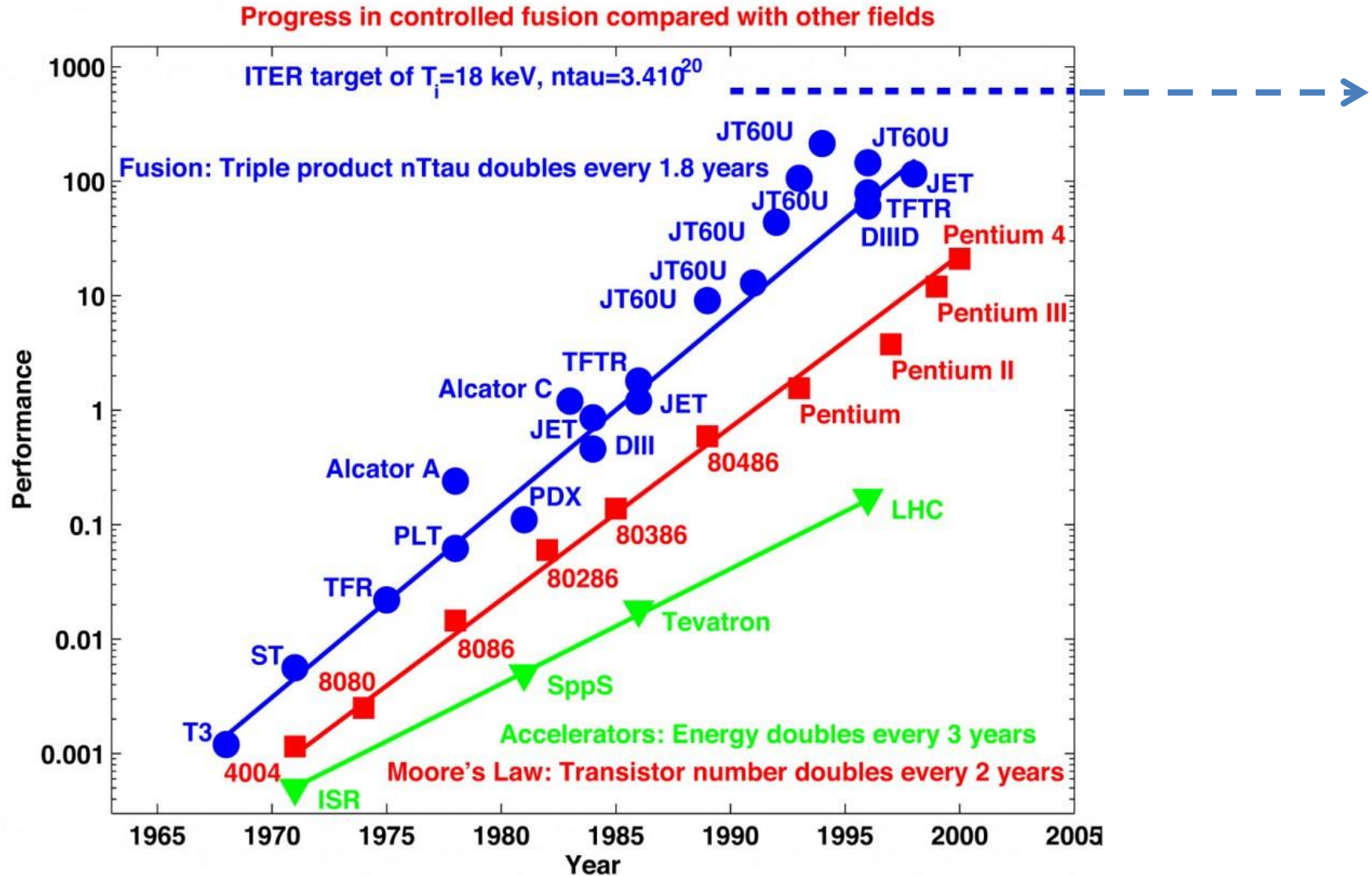


Scientific advance has made fusion an option: *fusion's progress rivals computer chips*

Progress in controlled fusion compared with other fields

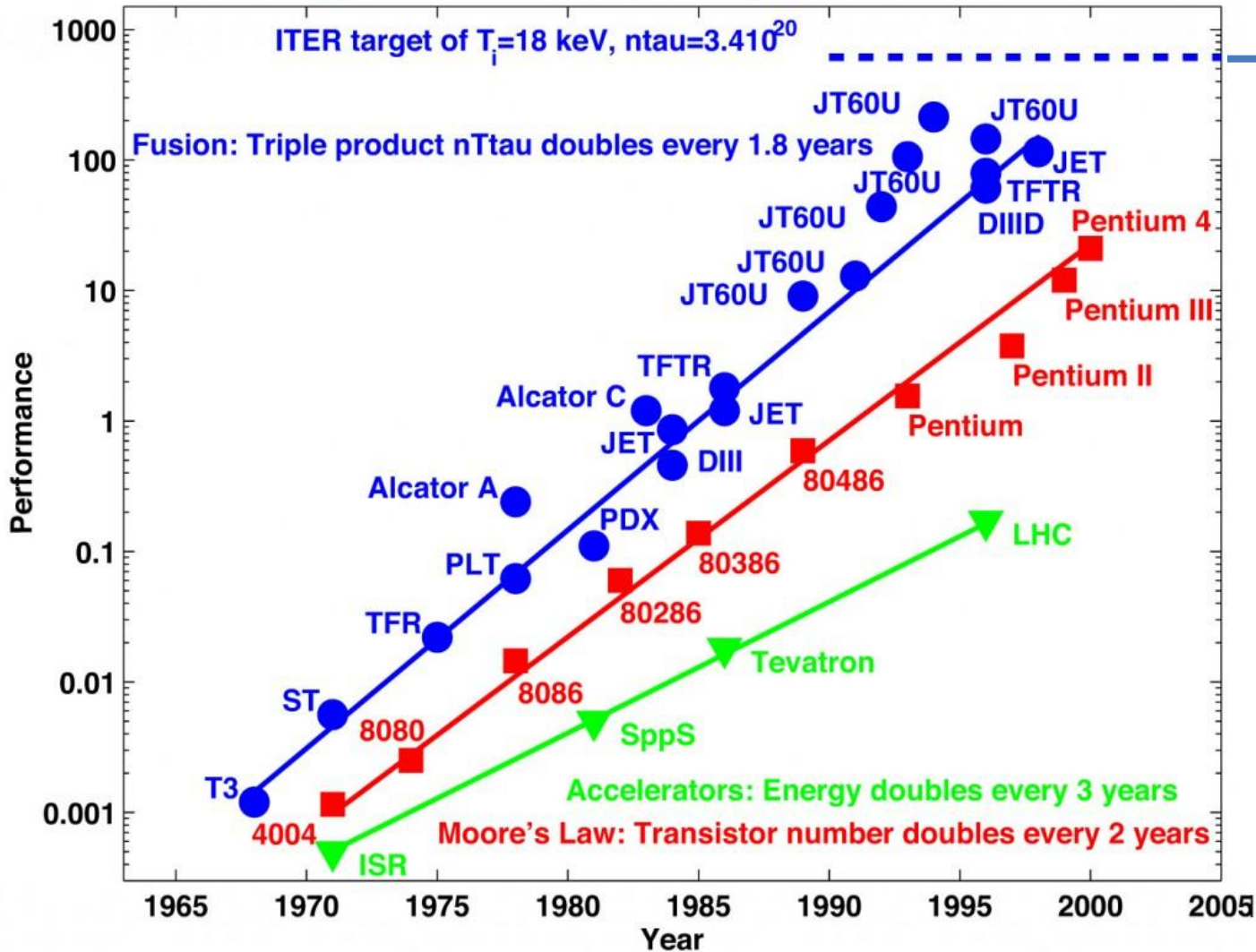


Scientific advance has made fusion an option: *...but further transformation is required*



Scientific advance has made fusion an option: *...but further transformation is required*

Progress in controlled fusion compared with other fields



→ Like aviation,
 fusion must
 undergo even
 further
 scientific
 transformation
 to reduce
 development
 steps:

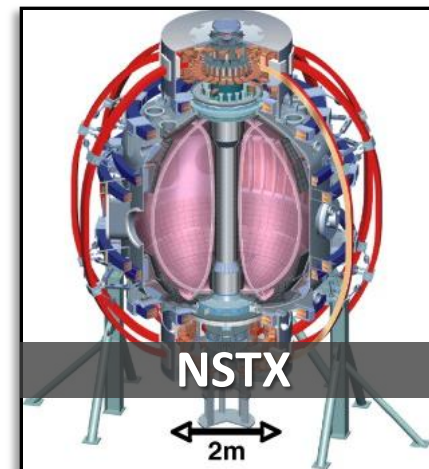
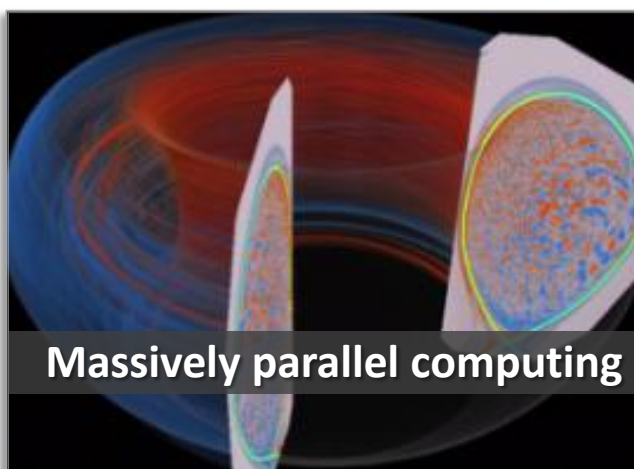
*validated
 predictive
 capability*

Burning Plasma Science in the U.S.:

Foundations

Science that will drive economics of fusion:

- Heating and containment, maximum fuel pressure
- confinement system size , complexity, efficiency
- attractiveness and cost



Burning Plasma Science in the U.S.:
Long pulse

Science that will drive economics of fusion:

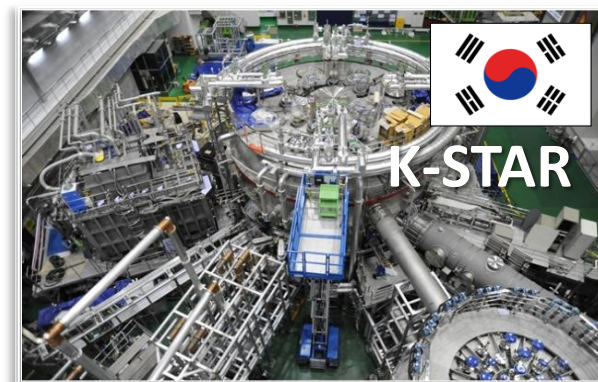
Maintaining the magnetic cage:

External + internal B (tokamak) vs. entirely external B (stellarator)

Fusion materials:

Solid vs liquid, tritium breeding, closing the fuel cycle

Operating superconducting facilities



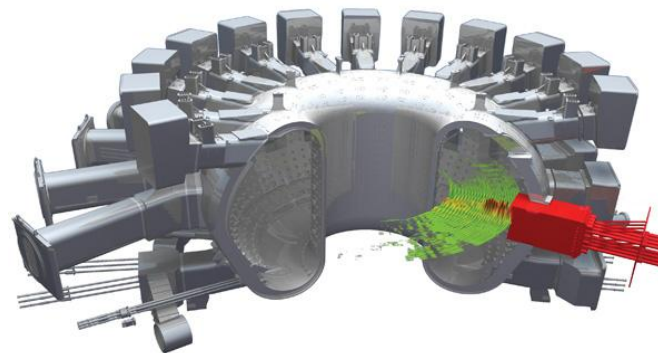
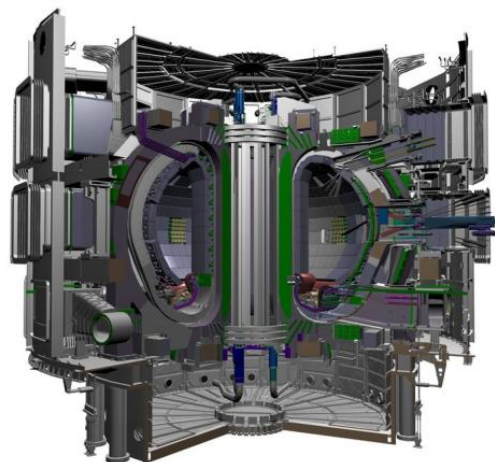
Anticipated: WEST, JT60-SA

Burning Plasma Science in the U.S.:
Self-heating

Science that will drive economics of fusion:

Foundations and Long Pulse science ***under reactor conditions***

→ Establish validated, predictive capability and attractive control strategies, essential for reducing development costs





High power burning plasma science:
fusion's leading frontier

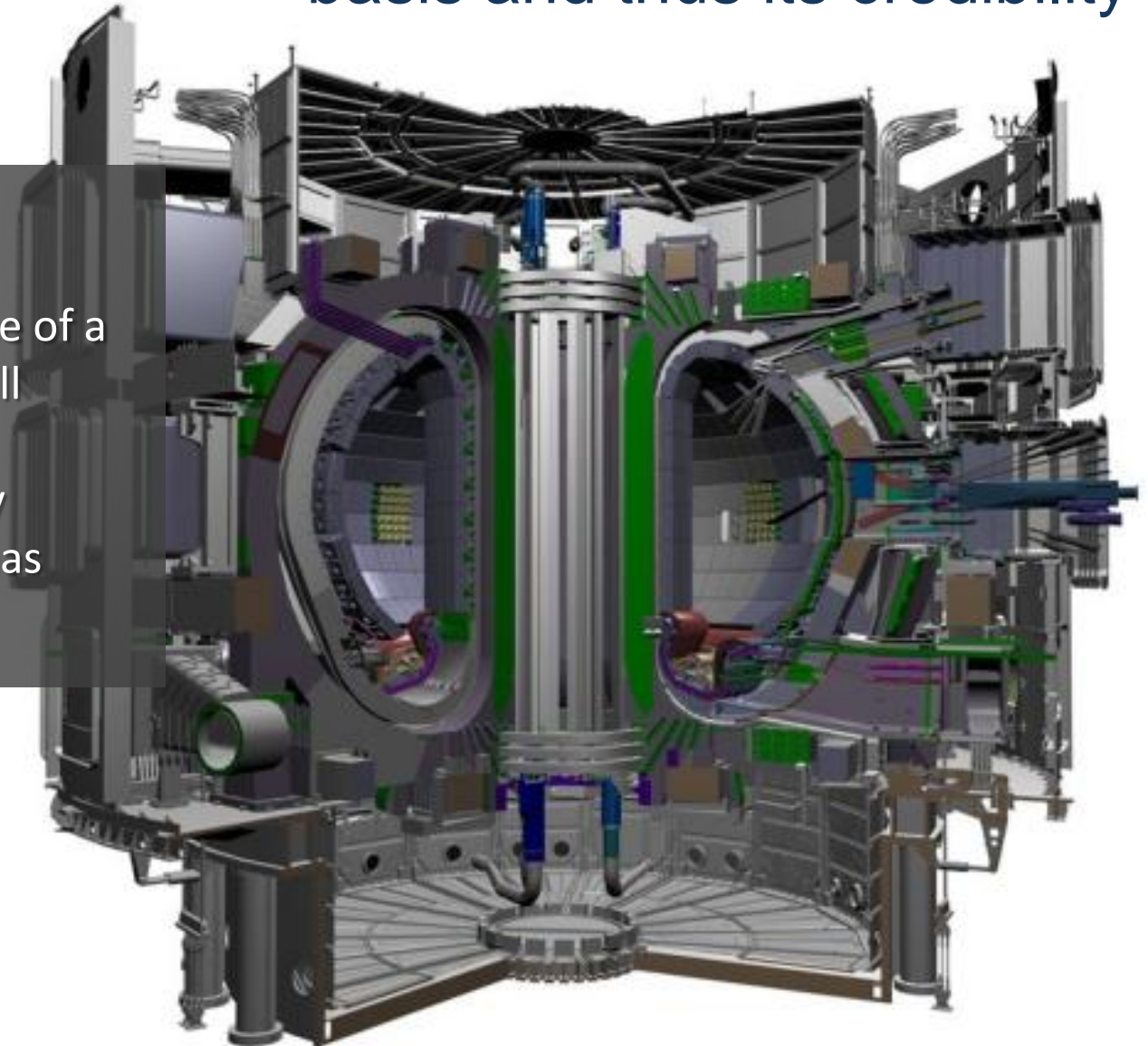
“All fusion reactors require a burning plasma. The key challenge is to confine the hot and dense plasma while it burns.”

Burning Plasma: Bringing a Star to Earth, p. 1
National Research Council

High power burning plasma science is essential for establishing fusion's science basis and thus its credibility

ITER:

The fundamental science of a burning plasma. ITER will establish the science of robustly and attractively controlling fusion plasmas that heat themselves



ITER can be a vehicle for transforming international cooperation

International partnership is essential



- Challenges are too big, too complex to go it alone;
- Grand challenge is optimizing the complex sociology of seven Members operating as a smartly functioning, directed whole
- We must learn how to educate a generation to carry this class of research forward

This age of transformation brings benefit, burden, and promise

Unprecedented change in the last 150 years

quality of life

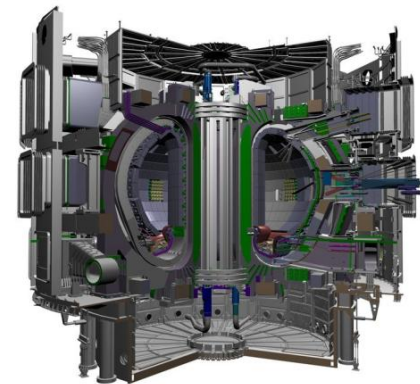
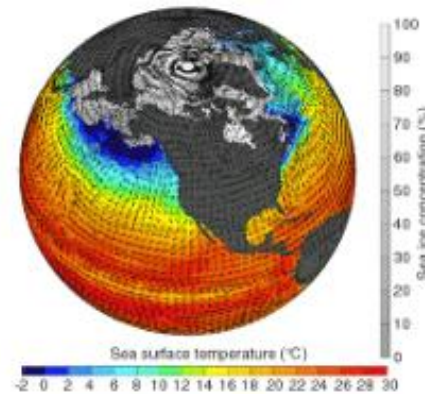
our planet

anticipating
the future

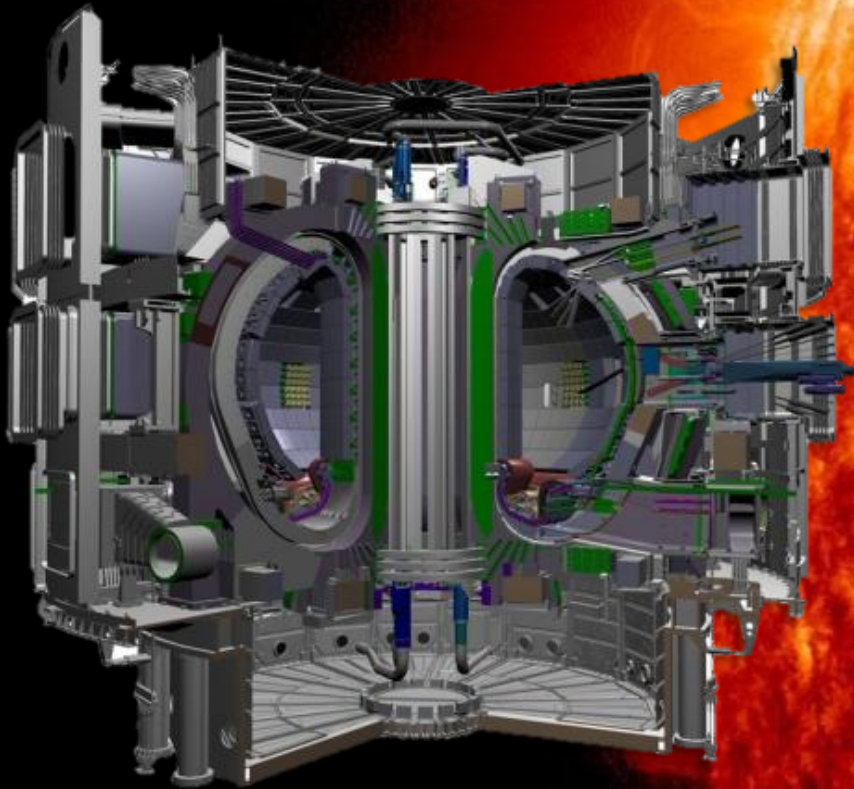
energy
options



<http://www.samefacts.com/2012/03/climate-change/the-rights-of-polar-bears/>



ITER, together with a vigorous world program in fusion science, can be a truly transformative scientific instrument



Thank you

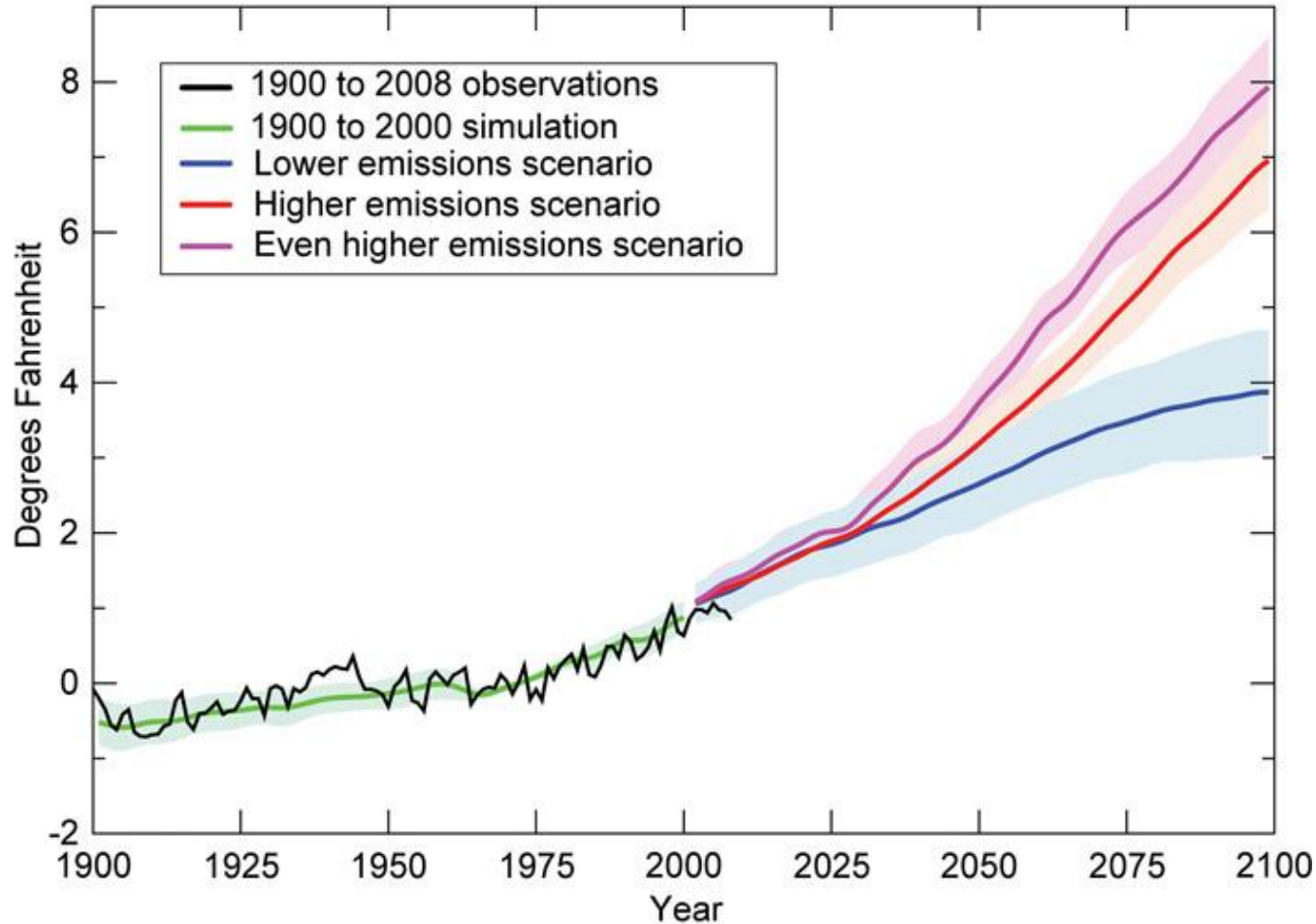


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This is an age of transformation:
consequences are predictable

Global Average Temperature



U.S. Burning Plasma Science priorities:

Foundations

Focuses on U.S. capabilities targeting key scientific issues, establishing predictive capability

Long Pulse

Building on U.S. capabilities furthered by international partnership

High Power

ITER is the keystone

