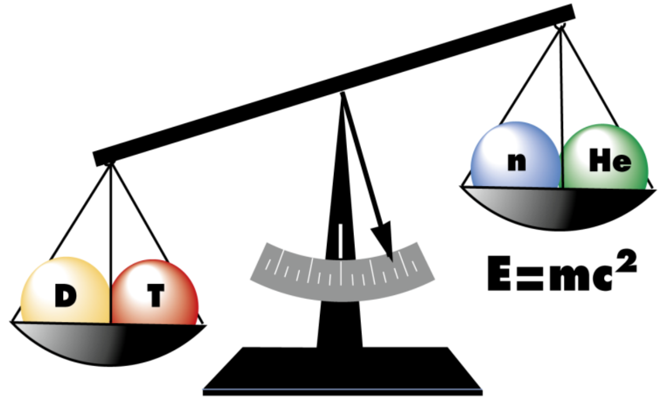
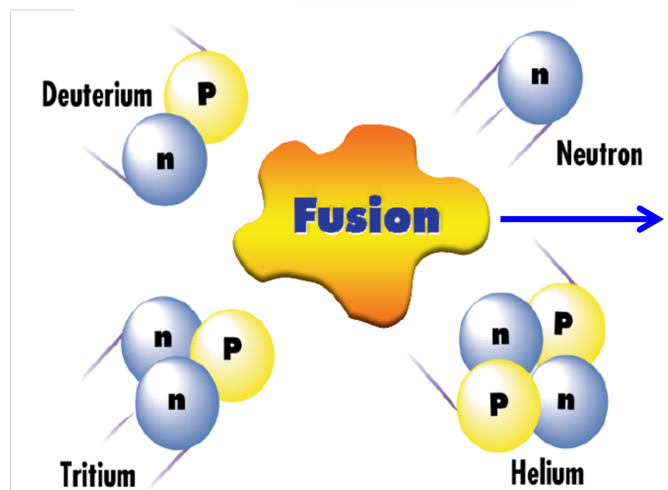
Fusion Requires Extraordinary Temperatures
(Hotter than the Sun)

Fire: Self-sustaining chemical reaction at > 1093° C

Fusion: Self-sustaining nuclear reaction at > 100,000,000° C

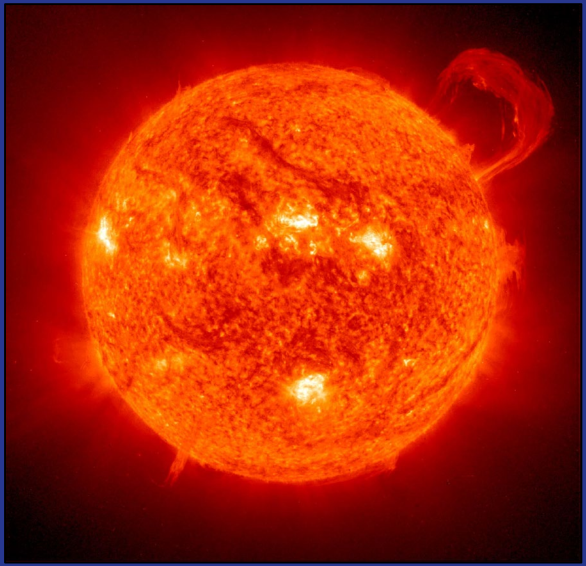




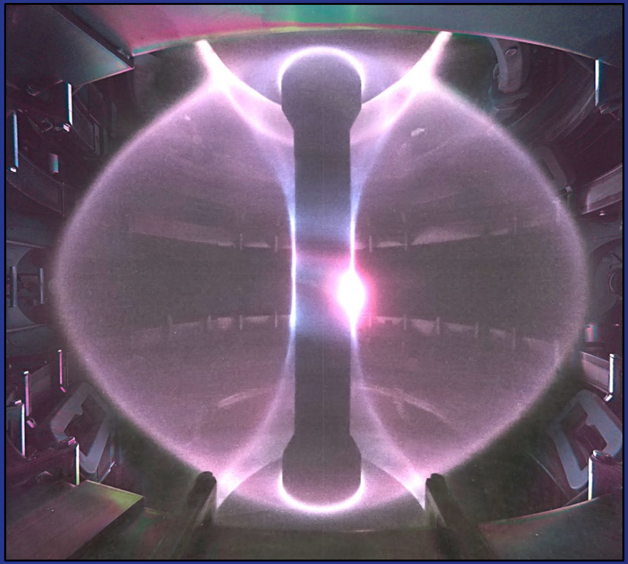
80% for electricity generation

20% to sustain the reaction

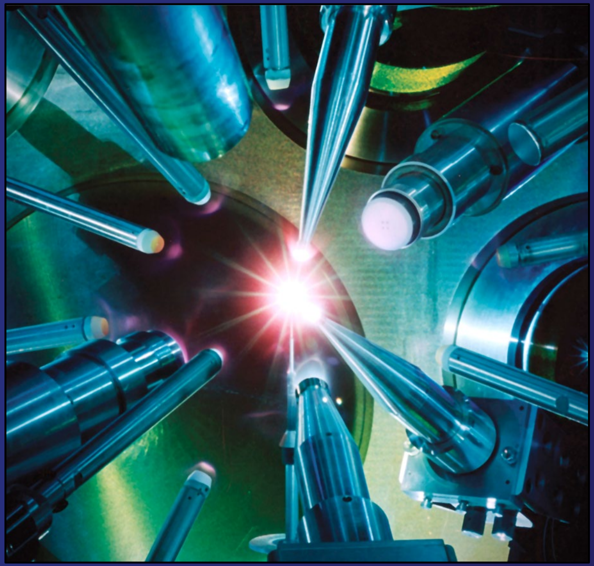
There Are Three Ways to Achieve Fusion



GRAVITY
The sun and other stars



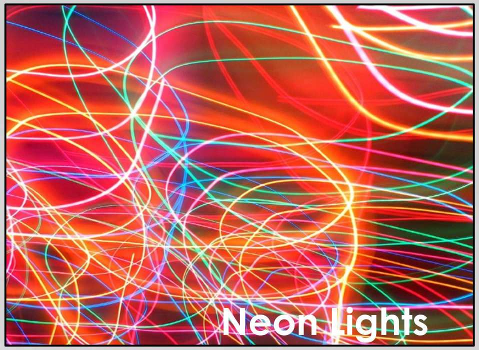
MAGNETIC FIELDS
Electrical current and superconducting magnets

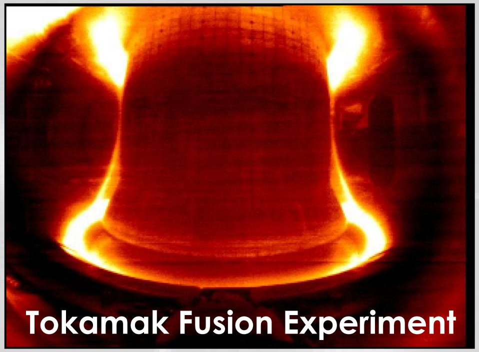


RAPID COMPRESSION
Lasers or electrical discharges

Superheated Gases Used in Fusion Are in the Plasma State – the 4th State of Matter

- **99% of visible universe is in a plasma state**
- **Plasmas on Earth**
  - Lightning
  - Neon and fluorescent lights
  - Laboratory experiments
- **Astrophysical plasmas**
  - Sun and solar wind
  - Stars, interstellar medium





Spinoff Technology from Fusion and Plasma Research is Making a Difference

Medical/Health

- MRI – Magnetic Resonance Imaging
- Laser surgery and tissue welding
- Diabetes treatment (continuous glucose monitoring)
- Skin disinfection
- Tumor reduction
- X-ray catheter
- Wound care, including on battlefields
- Dentistry (imaging, treatment for tooth decay and periodontal disease)
- Cancer fighting (proton beam therapy)
- Medical isotope separation and production
- Laser cavity drilling
- Blood clot treatment
- Grain sterilization and milk pasteurization (pulsed-power gammas)

MRI - Magnetic Resonance Imaging

Grain sterilization and milk pasteurization

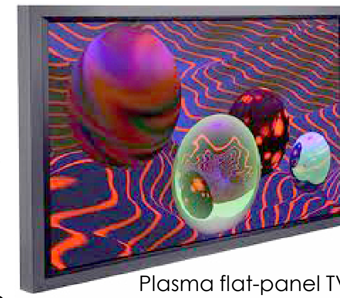
Environmental clean-up/ safe destruction of surplus weapons

- Toxic waste destruction
- Electron beam destruction of chemical waste
- Reducing auto pollution (microplasmatron fuel convertor)
- Smokestack emissions monitor
- Corrosion monitor for furnaces
- Plasma torch
- Waste vitrification
- Isotope separation
- Microwave cleaning and contamination removal
- Plasma-assisted catalyst (cuts diesel emissions)

Plasma Torch

Technology

- Advanced semiconductor chips and integrated circuits
- Plasma electronics – including plasma flat-panel TVs
- Microwave plasma light source
- Micropower impulse (hand-held) radar
- Plasma propulsion
- Superconductivity
- Nuclear Magnetic Resonance (NMR)
- Superconducting cyclotrons for isotope production and neutron radiography
- Superconducting synchrotrons for X-ray lithography
- Magnetic separation of materials (e.g. clay)
- Electromagnetic Aircraft Launch System (EMALS) for aircraft carriers



Plasma flat-panel TVs

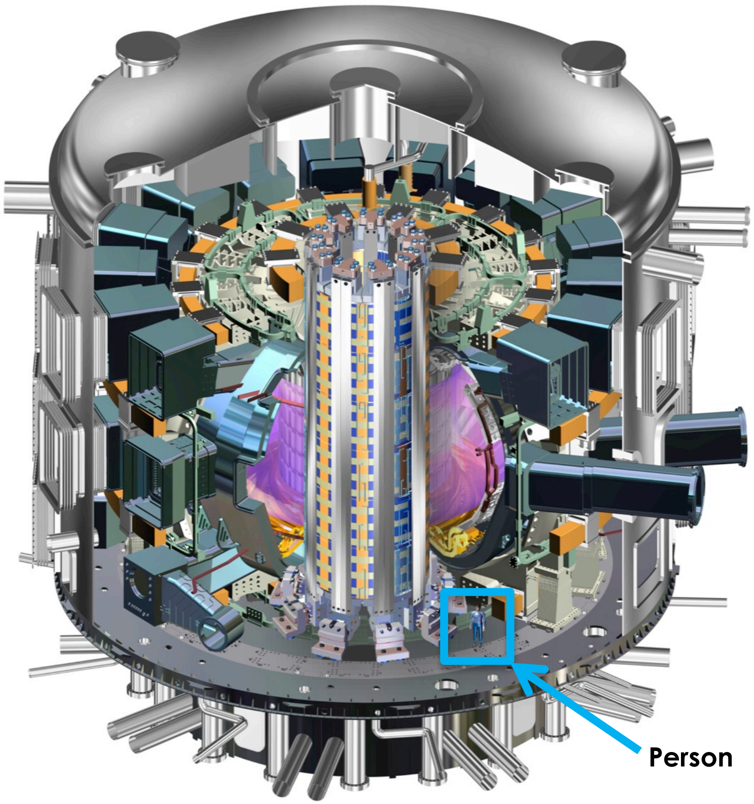
EMALS

Contribution to science

- High-performance supercomputers and networking communications
- Computational science
- High-density matter physics
- Atomic physics and X-ray lasers
  Space plasma physics
- Nonlinear dynamics and chaos
- Plasma physics

Atomic physics and X-ray lasers

Promise of Fusion Is Near — ITER Being Built Now

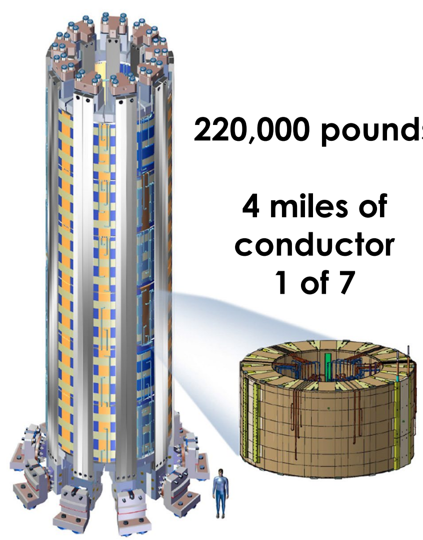


Partnership between 35 nations including U.S., EU, Japan, Russia, China South Korea and India

ITER Mission

"To demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes."

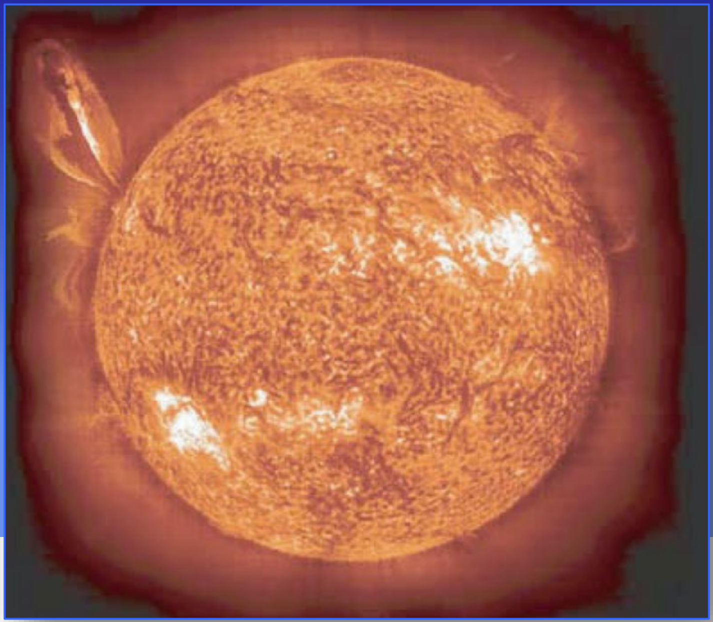
General Atomics is manufacturing the most critical technology for ITER



Superconductor is wound to high tolerance

Fusion – Energy for the Future of Mankind

Sun



Gravity compresses the plasma

DIII-D: Largest tokamak in the U.S.

Magnetic fields confine the plasma

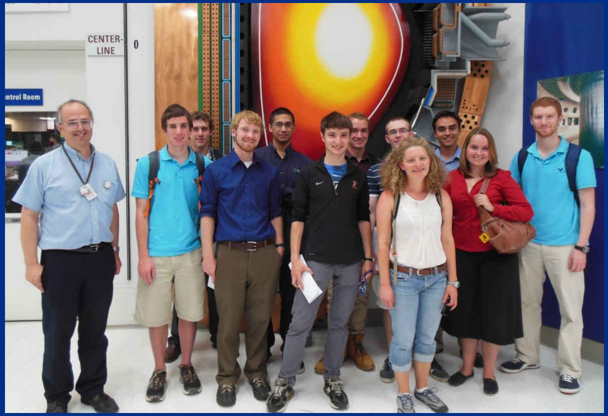
High temperature and high pressure

Fusion is an attractive source of electricity

- Inherently safe clean energy
- Can produce its own fuel
- No long-term waste
- Carbon free, no greenhouse gases

Infusing Fusion Into the Future

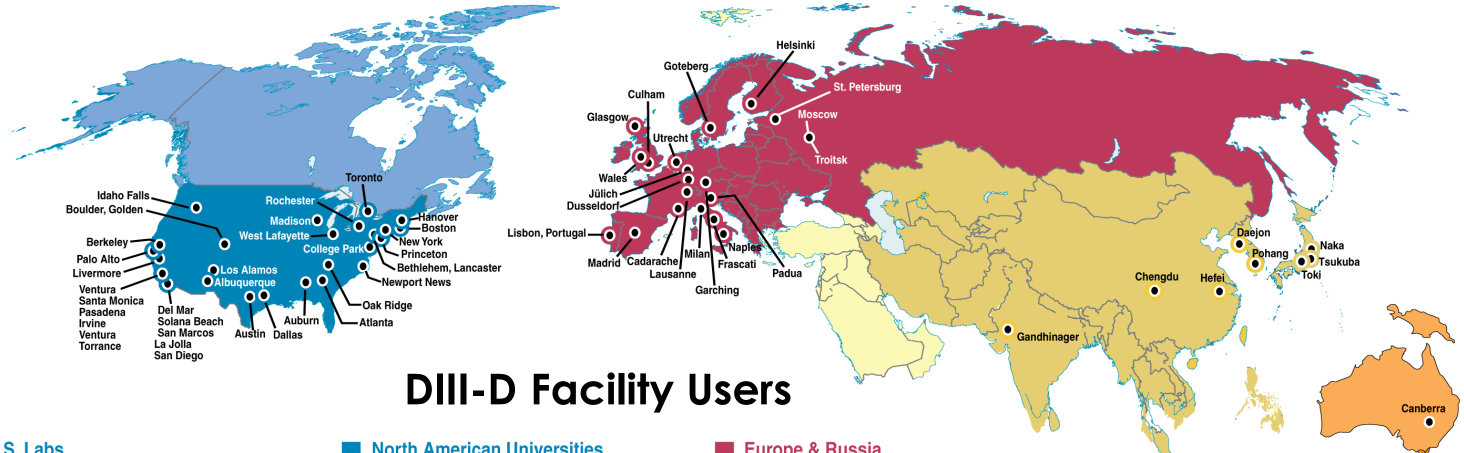
- General Atomics is proud to be part of the Science Undergraduate Laboratory Internship (SULI) program, a rewarding undergraduate scientific research program sponsored by the Department of Energy (DOE) in partnership with Princeton Plasma Physics Laboratory (PPPL)
- SULI offers selected applicants an opportunity to perform research under the guidance of laboratory staff scientists and engineers - training the next generation of fusion leaders



SULI class of undergraduates tour DIII-D National Fusion Facility in San Diego before launching summer research.

Students working inside DIII-D control room during operations.

International Team with Diverse Capabilities Is a Key Strength of the Program



DIII-D Facility Users

U.S. Labs

Idaho National Laboratory
Jefferson Lab
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Oak Ridge National Lab
Princeton Plasma Physics Laboratory
Sandia National Laboratory

U.S. Industries

American Physical Society
Beach Access Software (San Diego)
CompX (San Diego)
Eagle Harbor Technologies, Inc.
Far-Tech, Inc. (San Diego)
Fourth State Research (Austin)
General Atomics (San Diego)
IMSOL-X (San Diego)
Kalling Software (New York)
Tech-X Corporation (Boulder)
Tri Alpha Energy, Inc.

U.S. Academic Institutions

American Physical Society
Oak Ridge Institute for Science Education

South America

Centro Atomico Bariloche (Argentina)
University of Sao Paulo (Brazil)

North American Universities

Auburn University
Carnegie Mellon University
Columbia University
Georgia Tech (Atlanta)
Horizon Prep (San Diego)
Lehigh University
Massachusetts Institute of Technology
Oak Ridge Associated Universities
Palomar College
Princeton University
The College of William and Mary
University of Arizona
UC Berkeley
UC Davis
UC Irvine
UC Los Angeles
UC San Diego
University of Colorado, Boulder
University of Maryland
University of Texas
University of Toronto
University of Washington
University of Wisconsin
West Virginia University

Europe & Russia

Aalto University, Finland
CEA Cadarache (France)
Chalmers University of Technology (Sweden)
Ciemat (Spain)
Consorzio RFX (Italy)
D-TACQ Solutions Ltd (UK)
Eindhoven University (Netherlands)
ENEA C.R. Frascati (Italy)
EPFL (Lausanne, Switzerland)
Forschungszentrum Juelich (Germany)
Huazhong University of Science and Technology
IFP - Consiglio Nazionale delle Ricerche (Italy)
Institute of Control Sciences (Moscow)
Institute of Plasma Physics AS CR, Czech Republic
Instituto Superior Tecnico, Lisboa, Portugal
Istituto di Fisica del Plasma CNR-EURATOM (Italy)
ITER Organization
Kungliga Tekniska Hogskolan (Stockholm)
Max-Planck Institute for Plasma Physics
Politecnico di Milano (Italy)
RRC Kurchatov Institute
Technical University Munich
TRINITI lab
United Kingdom Atomic Energy Authority (CCFE)
Universita degli Studi di Padova
Università di Napoli Federico II
University of Seville
University of Strathclyde
University of York
VTT Technical Research Centre (Finland)

Asia

ASIPP Hefei, (China)
Dalian University of Technology, China
Insitute for Plasma Research (India)
Ishikawa National College of Technology (Japan)
ITER-India
Japan Atomic Energy Agency
KAIST (Korea)
Korea National Fusion Research Center
METU - Middle East Technical University (Turkey)
National Fusion Research Institute (Korea)
National Institute for Fusion Science, Japan
Peking University
Seoul National Unviersity
Southwestern Institute of Physics, China
Tohoku University
USTC (Hefei, China)

Australia

Australian National University (Sydney)

- ~ 600 Users
- ~ 35 Countries
- ~ 95 Institutions
- ~ 65 Grad Student Users
- ~ 40 Post Doc Users

The Magnetic Fusion Reactor

To fuse hydrogen atoms:

- **Make a plasma**
  Ionize the gas atoms
- **Heat the plasma**
  Use particle beams and electromagnetic energy (RF, microwave)
- **Hold onto the plasma**
  Use a magnetic field
- **Harness the energy**
  Use heat exchangers involving liquid metals and other fluids