The New Charge for Non-Fusion-Energy FES Applications

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on behalf of
Fusion Energy Sciences

Presented to FESAC
March 12, 2015
New Charge: The WHAT
Charge from Congress

- Explanatory statement accompanying the FY 2015 enacted budget appropriation (Public Law 113-325):
  - The agreement further directs the Office of Science to submit to the Committees on Appropriations of the House of Representatives and the Senate not later than 180 days after enactment of this Act a report on the contribution of fusion energy sciences to scientific discovery and the development and deployment of new technologies beyond possible applications in fusion energy.
• **Charge letter to FESAC from Acting Director of the Office of Science (February 4, 2015):**
  
  – Consider a wide range of connections between research performed through the FES portfolio and other scientific disciplines and technological applications.
  
  – Applications beyond fusion energy will naturally focus on the curiosity-driven research areas of the FES portfolio (e.g., basic plasma science, low temperature plasma, space and astrophysical plasma, etc.) but may also involve spin-offs from anywhere in this portfolio.
  
  – Consider scientific and technical applications of fusion and related plasma science to other branches of science.
  
  – Consider contributions to new scientific developments and technologies beyond possible applications in fusion energy related, but not limited, to areas such as energy and the environment, materials science, medical diagnostics and treatment, biology, national security, and industry.
  
  – Comment on how well the contributions of FES are advancing the interests of society and meeting its needs, and ensuring the Nation’s competitiveness in the physical sciences and technology.
New Charge: The WHY

• Possible political considerations

• Regardless, this is a opportunity for our field to describe our broader impacts, connections to other fields of science, and benefits and applications to society
New Charge: The HOW

- Previous examples in fusion energy sciences field
- Examples in other scientific fields
• **Technology Spinoffs from the Magnetic Fusion Energy Program** (DOE/OER/OFE report, February 1984)
  - Computers
  - Man-machine interface
  - Metal forming
  - Isotope separation
  - Electrical welding
  - Astronomy
  - Ultraviolet sources
  - Electric power
• *The Fusion Connection* (DOE/OER/OFE report, 1985)
  
  – Contributions to Industry, Defense, and Basic Science Resulting from Scientific Advances Made in the Magnetic Fusion Energy Program
FES previous example #3

(General Atomics, 1989)
INVESTMENT IN AN ENERGY SOURCE FOR TOMORROW

FUSION

YIELDS IMPORTANT BENEFITS TODAY

Benefits Today

Research funded by the U.S. Department of Energy to develop fusion—
the energy process of the Sun and other stars—has fostered a new
broad of physics—plasma, and has resulted in the invention of
technologies to produce and manipulate plasma for many purposes.

Products manufactured using plasma science and technology impact our
daily lives in many significant ways.

PLASMA PROCESSING OF CHIPS AND CIRCUITS
Small, fast computer chips (such as the Pentium® chip) and associated
miniature integrated circuits have led to a revolution in the personal
computer industry. Approximately 40% of the steps required to produce
such chips and circuits use plasma processing.

COATINGS OF MATERIALS
Polymer films for recording media, and longer-lasting products ranging from
machine tools to medical implants, result from coatings placed on materials by such
technologies as plasma spray and sputtering.

WASTE PROCESSING
New, efficient technologies for destroying or sterlizing toxic and radioactive waste,
using plasmas and high power microwaves, are entering the marketplace.

PLASMA ELECTRONICS
Plasma flat panel video displays such as viewing maps, and plasma switches for
electricity transmission, are part of a huge new industry using plasma electronics.

OTHER APPLICATIONS
Plasma and fusion research is affecting many other areas, including biomedical
applications, the development of new materials, the creation of new technologies,
and contributions to many branches of science.

Plasmas can be produced over a wide range of temperatures (from near
room temperature to the temperatures of the stars) and also over a wide
range of densities (from above atmospheric down to near perfect
vacuum). Plasmas are also produced from a wide range of elements
(from all gases to almost all metals). This variety allows a vast range of
possible applications, due to the thousands of different chemical
combinations possible.

Fusion research requiring very high
temperature and large experiments, and other
applications accomplished at much lower temperature
and with smaller equipment, depend on the
same basic scientific principles and utilize similar
technologies on differing scales.

(PREPARED BY ARGONNE NATIONAL LAB AND FUSION POWER ASSOCIATES FOR DOE, 1996)
**Coatings and Films**

Many commercial materials require coatings to reduce corrosion or to provide thermal protection. Plasma spray and intense ion beam technologies permit rapid deposition of uniform coatings on large, complex objects, such as turbine blades of aircraft engines. These technologies are also used for depositing diamond coatings on cutting tools and electronic circuits and for depositing polymer films on recording media. The estimated world market for coating technologies exceeds $50 billion a year.

**Waste Processing**

The disposal and/or destruction of toxic waste is a massive societal problem. Burning or chemical processing of such waste often results in the production of additional toxic material. Plasma can be used to melt solid waste and transform it into solid, non-leachable glass or ceramics. Plasma and beam technologies can be used to decompose toxic molecules in a gas. Melted (radioactive and toxic) waste is being processed by plasma torches. Cryogenic and microwave technologies, developed for fusion research, are also being used for efficient cleaning of surfaces, e.g., removal of paint from aircraft. The estimated world market for toxic waste processing alone exceeds $50 billion a year.

**Plasma Electronics**

Plasma electronics covers the range from plasma flat panel displays to arc-switching devices used in the power generation and transmission industry. Plasma flat panel displays permit compact, high quality full-color, full-motion videos, such as moving maps for transportation navigation. Arc-switching technologies improve efficiency and reduce maintenance costs in the electric power industry. The estimated world market for these applications exceeds $40 billion a year.

**Contributions to Science**

The development of plasma science has impacted many other areas of science, including astro, solar and magnetospheric physics; atomic physics; lasers, nonlinear dynamics and chaos; and numerical computation and modeling. Fusion researchers have pioneered the field of supercomputer networking.

The fundamentals of plasma science, and the technologies required to study plasmas, underlie the many practical applications coming into use today, and eventually will lead to fusion as an energy source for tomorrow.

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**Plasma Processing of Chips and Circuits**

The speed of computer chips and integrated circuits is increased, and their size reduced, if plasma processes are used instead of chemical processing in their production. This has resulted in powerful computers becoming available to the average citizen. Advances in plasma technologies continue to reduce the size and cost of these products. The estimated world market for high performance chips and circuits exceeds $30 billion a year.

**New Materials**

Plasmas and ion beams are used as the source of ions which, when implanted in the surface of materials, can result in new properties, such as increased hardness, decreased friction, increased smoothness, increased fatigue life, etc. Applications range from machine tools, ball bearings, and automotive components, to implants and prosthetics. Plasma and microwave technologies are also used to greatly reduce the time required to process high performance ceramics, itself a $5 billion a year industry. Plasma alter the normal pathways through which chemical systems evolve from one stable state to another, thus providing the potential to produce materials with properties that are not attainable by any other means. Materials, including carbon fiber composites, that are more resistant to thermal shock have been developed due to the requirements of high temperature plasma experiments.

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**Biomedical Applications**

A wide range of medical applications can trace their origins to plasma and fusion research, from magnets used in magnetic resonance imaging (MRI) to tomography and interventional imaging first developed to diagnose plasma experiments. Laser surgery and tissue welding, and their associated computerized controls and interpretable diagnostics, also have connections to fusion research.

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**New Technologies**

Fusion and plasma research has opened up a wide range of new technologies and applications. High efficiency ultraviolet and visible light sources, created from plasmas, are in use for rapid drying of special inks, coatings, and adhesives, as well as for lighting large areas with reduced energy consumption. For example, the visible light from a golf-ball-shaped plasma produced by microwaves, yields as much light as 250 one-hundred watt bulbs at a fraction of the corresponding energy consumption.

Fusion scientists developing high speed digitizers for diagnosing laser-produced plasma, have applied the technology to a new radar device, with a cost of about $20. These devices, which can fit in the palm of the hand, have many applications such as low cost surveillance systems and sensors.
Summary of Opportunities in the Fusion Energy Sciences Program (FESAC, 1999)

- Chapter 4: Near-Term Applications
  - Microelectronics and flat panel displays
  - Materials and manufacturing
  - Environmental applications
  - Biomedical and food-safety applications
  - Plasma propulsion
• FuSAC report (NRC, 2001)
  – Chapter 4: Interactions of the Fusion Program with Allied Areas of Science and Technology
• **The Surprising Benefits of Creating a Star** (Oct 2001)
  – 17-page brochure; published by GA (R. Callis, editor)
Plasmas and the technologies they enable are pervasive in our everyday life. Each one of us touches or is touched by plasma-enabled technologies every day. Products from microelectronics, large-area displays, lighting, packaging, and solar cells to jet engine turbine blades and biocompatible human implants either directly use or are manufactured with, and in many cases would not exist without, the use of plasmas. The result is an improvement in our quality of life and economic competitiveness.

[borrowed from talk by M. Kushner]

Chap 1: Science Challenges and Societal Benefit
• **The Plasma Universe**, by Curt Suplee (Cambridge University Press, 2009, 88 pp)
  – Chapter 6: *Putting Plasmas to Work*
    • A plasma to read by
    • Walls of light
    • Withdrawal and deposits
    • Plasmas and human health
    • When push comes to shove

• Publication was sponsored by APS-DPP for its semi-centennial annual meeting (Nov 2008)
  – Edited by A. Bhattacharjee
  – Copyrighted by APS-DPP
High Energy Physics example #1

- “Interactions with and Connections to Other Branches of Physics and Technology” (14 pp, Chapter 9 of NRC/NAS report, 1998)
  - Cosmology
  - Astrophysics
  - Nuclear physics
  - Atomic physics
  - Condensed-matter physics
  - Fluid dynamics
  - Mathematics and computational physics
• Accelerators for America (symposium report, 2010)
  – Energy & environment
  – Industry
  – Medicine
  – National security
  – Discovery science
- **HEP Science Connections & Partnerships Overview (2013)**
  - Non-HEPAP task force charged to update the 1998 NRC report (especially in the neglected areas of climate research, biosciences, economics, and national security)
  - Draft report: *Connections of Particle Physics with Other Disciplines* (C. Callan and S. Kachru, Feb 2014)
• **Opportunities in Nuclear Science: A Long Range Plan for the Next Decade** (NSAC report, 2002)
  – Chapter 4, Section 4: Impacts and Applications
• *The Frontiers of Nuclear Science: A Long Range Plan* (NSAC report, 2007)
  – Chapter 5: **The Broader Impacts of Nuclear Science**
  – Connections to other fields; applications
• **Nuclear Physics: Exploring the Heart of Matter** (NRC/NAS decadal report, 2012)
  – Chapter 3: **Societal Applications and Benefits**
  – Sidebar highlights:
    • Diagnosing cancer with PET
    • The Fukushima event—a nuclear detective story
    • Nuclear crime scene forensics
Dedicated page (Benefits of NP) and subpage (Applications of Nuclear Science) on the Office of Nuclear Physics web site

Examples from
- Medicine
- Homeland security
- Industry
- Sciences
- Workforce development
New Charge: The WHEN

- **Congressional language**: 180 days after FY 2015 budget enactment
  - Dec 10, 2014 + 180 days = ~ June 10, 2015

- **Extension**: Possible to request this
New Charge: The WHO

• Charge will be addressed by a subcommittee
  – Being set up by FESAC chair, in consultation with FES

• Input will be solicited from the entire FES community