

# **PRESENTATION TO NRC BURNING PLASMA PANEL**

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**In response to request by panel co-chair John Ahearne as follows:**

**“We have heard from the plasma science community about the science of plasmas and from the Europeans about ITER. What we need is some sense of what the applications community, such as potential industry, see for the future of fusion”**

## **BOTTOM LINES**

### **FUSION IS NOT ON THE RADAR SCREEN OF THE U. S. ELECTRIC UTILITIES**

- **To get attention from utilities requires evidence that fusion will produce competitive, publicly-acceptable power plants on some reasonable schedule**

### **U. S. INDUSTRY IS INTERESTED IN PERFORMING GOVERNMENT-SPONSORED FUSION R&D AND IN MANUFACTURING COMPONENTS**

- **HOWEVER, OPPORTUNITIES HAVE BEEN SCARCE**
- **CONSTRUCTION OF ITER WOULD ATTRACT INTEREST FROM INDUSTRY**
- **EVIDENCE THAT U. S. GOVERNMENT IS SERIOUS ABOUT FUSION DEVELOPMENT WOULD ALSO ATTRACT INTEREST FROM INDUSTRY**

### **GENERAL ATOMICS, FOR HISTORICAL REASONS, IS UNIQUE WITH RESPECT TO INDUSTRIAL PARTICIPATION IN FUSION PROGRAM**

## **POTENTIAL APPLICATIONS OF FUSION**

### **POTENTIAL APPLICATIONS OF FUSION INCLUDE:**

- **CENTRAL STATION ELECTRIC PLANTS**
- **PRODUCTION OF HYDROGEN OR SYNTHETIC FUELS**
- **DESALINATION OF SEA WATER**
- **HEAT OR RADIATIONS FOR CHEMICAL PROCESSING**
- **FISSILE FUEL PRODUCTION FOR FISSION REACTORS**
- **FISSION PRODUCT DEACTIVATION**
- **HAZARDOUS WASTE PROCESSING**
- **RECYCLING OF MATERIALS**
- **FUSION-FISSION HYBRID POWER PLANTS**

**VERY LITTLE RECENT ANALYSIS OF THE NON-ELECTRIC APPLICATIONS**

**A FESAC PANEL, UNDER CHAIR KATHRYN McCARTHY (INEEL) IS UNDERWAY**

**THE PRIMARY GOAL OF THE FUSION PROGRAM HAS ALWAYS BEEN PURE FUSION CENTRAL STATION ELECTRIC POWER**

## **THE ELECTRIC UTILITIES**

### **FUSION IS NOT ON THE RADAR SCREEN OF THE ELECTRIC UTILITIES**

**SINCE “DEREGULATION,” THE FOCUS OF THE U. S. ELECTRIC UTILITIES HAS BEEN ALMOST EXCLUSIVELY ON SHORT TERM PROFITS**

- **MOST UTILITIES HAVE DISBANDED THEIR R&D DEPARTMENTS**
- **EPRI WAS DIRECTED TO FOCUS ON NEAR-TERM R&D**
- **EPRI CANCELLED ITS SMALL (~\$4M/YR) FUSION EFFORT IN THE MID-80S**

**FOR THE NEXT “X” DECADES, U. S. UTILITIES ARE DEPENDING ON**

- **NATURAL GAS TURBINES**
- **COAL**
- **MODEST ADDITIONS OF RENEWABLES**

**THE “NUCLEAR UTILITIES” ARE HAMPERED FROM ADDING NEW NUCLEAR FISSION POWER PLANT CAPACITY BY**

- **MODEST DEMAND GROWTH**
- **HIGH CAPITAL COST**
- **COMPETITIVE ECONOMICS**
- **PUBLIC ACCEPTANCE FEARS**
- **LITIGATION FEARS**
- **UNRESOLVED WASTE DISPOSAL ISSUE**

**EPRI DID PREPARE TWO REPORTS ON FUSION, IN 1992 AND 1994**

- **Report of the 1992 EPRI Fusion Panel, TR-101649, November 1992**
  - **“Key criteria for comparing alternative fusion technologies”**
  - **Assumes implicitly that the science of all approaches is equally credible though not all equally proven**
- **Criteria for Practical Fusion Power Systems, BR-104469, Spring 1994**

## **SUMMARY OF 1992 EPRI FUSION PANEL REPORT**

**Panel Members: R. L. Hirsch (chairman), Floyd Culler, Nari Hingorani, John Taylor, Thomas Schneider and Dwain Spencer (All EPRI)**

**The panel classified fusion concepts into four categories and made the following comments:**

- **“Relatively large devices with large superconducting magnets”**
  - **“The primary engineering problems requiring attention for these concepts are materials lifetime, ash removal and impurity control, and maintenance procedures”**
  - **“Tokamak and Stellarator are examples of this type”**
  
- **“Compact Concepts”**
  - **“. . . have higher power density in the plasma core, which may lead to more favorable economics but can exacerbate materials lifetime problems ... have simpler mechanical configurations, easing maintenance ... tend to be smaller and/or lower field strength.**
  - **“Within this type the Field Reversed Configuration and the Spheromak have especially interesting reactor configurations”**
  
- **“Inertial Confinement Fusion”**
  - **“The use of renewable chamber walls could greatly ease materials lifetime problems, although the problem of transporting the beams and pellets into the chamber several times a second will require considerable engineering development”**
  - **“Development of cost-effective, low-maintenance driver technologies is another development challenge”**
  - **“The possibility of driving more than one reactor chamber from a single driver and the prospects of varying reactor output by varying pulse repetition rate are interesting features of the inertial fusion concepts”**
  
- **“Colliding Beam Designs”**
  - **“This approach appears to have fewer high tech components and simpler overall geometries ... also these concepts are more compatible with the use of fusion fuel cycles with fewer and lower energy neutrons, thus easing the materials lifetime problems”**

**THE 1992 PANEL LISTED A SET OF “OPERATIONAL CONSIDERATIONS TO BE USED IN ASSESSING FUSION CONCEPTS FROM THE POINT OF VIEW OF THEIR DESIRABILITY TO AN ELECTRIC UTILITY” AS FOLLOWS:**

- **Complexity**
- **Aspects of the configuration that can limit availability**
- **Fuel choice and cycle (fewer lower energy neutrons better)**
- **Energy balance, including subsystem efficiencies**
- **Safety**
- **Waste**
- **Siting considerations**
- **Plant size options**
- **Fuel cycle flexibility**
- **Power density**
- **Power conversion efficiency**
- **Development path cost and schedule**

## **SUMMARY OF 1994 EPRI FUSION PANEL**

### **Panel Members:**

**Jack Kaslow, EPRI, Chair**  
**Merwin Brown, Pacific Gas and Electric Company**  
**Robert Hirsch, EPRI**  
**Ralph Izzo, Public Service Electric and Gas Company**  
**John McCann, Consolidated Edison of New York**  
**Dennis McCloud, TVA**  
**Bill Muston, Texas Utilities Electric**  
**Art Peterson, Niagara Mohawk Power Company**  
**Steve Rosen, Houston Lighting and Power Company**  
**Thomas Schneider, EPRI**  
**Peter Skrgic, Allegheny Power System, Inc.**  
**Bruce Snow, Rochester Gas & Electric Corporation**

**PANEL SAID “In a thorough review of practical fusion power system characteristics, three criterion groups of overarching importance emerged: (1) Economics, (2) Public Acceptance, and (3) Regulatory Simplicity**

### **ECONOMICS**

**“To compensate for the higher economic risks associated with new technologies, fusion plants must have lower life-cycle costs than competing proven technologies at the time of commercialization”**

### **PUBLIC ACCEPTANCE**

**“A positive public perception can best be achieved by maximizing fusion power’s environmental attractiveness, economy of power production, and safety”**

### **REGULATORY SIMPLICITY**

**“Any permitting/licensing process for fusion power plants should be designed to allow issuance of permits/licenses prior to major capital commitment and for the life of the plant”**

## **U. S. INDUSTRY**

**U.S. INDUSTRY IS INTERESTED IN PERFORMING GOVERNMENT-FUNDED FUSION R&D AND IN THE MANUFACTURING OF COMPONENTS FOR FUSION DEVICES**

**HOWEVER, OPPORTUNITIES HAVE BEEN SCARCE**

**THE MOST RECENT OPPORTUNITIES FOR INDUSTRY WERE PARTICIPATION IN THE ITER DESIGN AND PROTOTYPING PRIOR TO U.S. WITHDRAWAL FROM THE PROJECT**

**A SUMMARY “OPPORTUNITIES IN THE CONSTRUCTION PHASE OF THE INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR” BASED ON A SURVEY OF OVER 40 U.S. COMPANIES SHOWED THE FOLLOWING INTEREST AREAS:**

- **MOST INTEREST**
  - **Magnet System, including superconductor and cable**
  - **Divertor System and Plasma Facing Components**
  - **RF Systems and Power Supplies**
  - **Blanket and Limiter**
  
- **SIGNIFICANT INTEREST**
  - **Systems Integration**
  - **Electron Cyclotron Heating**
  - **Electrical Systems**
  - **Control Systems**
  - **Balance of Plant**
  - **Construction Management**
  - **Safety and Environmental Systems**
  - **Heat Transport Systems**
  
- **NICHE INTEREST**
  - **U. S. Home Team Management**
  - **Assembly**
  - **Cryostat**
  - **Cryogenic Systems**
  - **Remote Handling Systems**
  - **Vacuum Systems**
  - **Vacuum Vessel**
  - **Diagnostics**



**ASKED TO LIST “THE MOST IMPORTANT REASONS WHY THEIR COMPANIES MIGHT WISH TO PARTICIPATE IN ITER CONSTRUCTION,” THE MOST FREQUENTLY LISTED REASONS WERE:**

- **There is a match to our corporate capabilities**
- **Participation will advance corporate capability**
- **Participation will enhance corporate ability to compete internationally**
- **The company will gain experience leading to other commercial spinoffs**

**THE FULL REPORT, INCLUDING THE NAMES OF THE COMPANIES SURVEYED IS PUBLISHED IN JOURNAL OF FUSION ENERGY, JUNE 1999 ISSUE.**

## **INDUSTRY IN THE 1990s PLAYED A STRONGER ROLE IN THE U.S. FUSION PROGRAM THAN IT DOES TODAY**

- **THE DOE FUSION ENERGY ADVISORY COMMITTEE (FEAC) HAD 7 OF ITS 15 MEMBERS FROM INDUSTRY IN 1994, NONE FROM GENERAL ATOMICS; TODAY THE DOE FUSION ENERGY SCIENCES ADVISORY COMMITTEE (FESAC) HAS 2 OF ITS 17 MEMBERS FROM INDUSTRY, BOTH FROM GENERAL ATOMICS**
- **FROM 1994 TO 1998 THERE WAS AN INDUSTRY-ORGANIZED INDEPENDENT FUSION INDUSTRIAL COUNCIL, U.S. (FICUS) WITH MEMBERS FROM 17 INDUSTRIES**
- **UNTIL THE U. S. WITHDREW FROM ITER THERE WAS AN ITER INDUSTRY COUNCIL (IIC) SET UP AND MANAGED BY THE U.S. ITER HOME TEAM**

## **PARTIAL LISTING OF U.S. INDUSTRIES THAT WERE INVOLVED IN FUSION DURING THE 1990s:**

- **BECHTEL**
- **NORTHROP GRUMMAN**
- **LOCKHEED MARTIN**
- **MCDONNELL DOUGLAS**
- **BOEING**
- **STONE & WEBSTER**
- **HOUSTON LIGHTING AND POWER**
- **W.J. SCHAFER ASSOCIATES**
- **SAIC**
- **GENERAL ATOMIC**
- **BABCOCK AND WILCOX**
- **RAYTHEON ENGINEERS AND CONSTRUCTORS**
- **EVERSON ELECTRIC COMPANY**
- **FLUOR DANIEL**
- **CHICAGO BRIDGE AND IRON**
- **WESTINGHOUSE**
- **VARIAN ASSOCIATES**
- **ROCKWELL INTERNATIONAL**
- **TRW**

**GENERAL DYNAMICS**  
**Space Systems Division**

**REQUIREMENTS FOR  
INDUSTRIAL INVOLVEMENT IN THE  
UNITED STATES FUSION PROGRAMS**

**General Dynamics**  
**Space Systems, Energy Programs**  
**S. Locke Bogart**  
**23 May 1990**

**REQUIREMENTS FOR INDUSTRIAL INVOLVEMENT IN THE  
IN THE UNITED STATES FUSION PROGRAMS**

**Basic Requirements - The Three Ps**

- **Profit**
- **Policy**
- **Participation**

**REQUIREMENTS FOR INDUSTRIAL INVOLVEMENT IN THE  
IN THE UNITED STATES FUSION PROGRAMS**

**Profit**

- **The Private Sector Must See Good Potential for Profit**
  - **Performance of Contract Research and Development (CRAD)**
  - **Evolution to Product Lines**
  - **Spinoff to Other CRAD and/or Product Lines**
- **If this Criterion is Not Met, Then the Remaining Are Irrelevant**

**REQUIREMENTS FOR INDUSTRIAL INVOLVEMENT IN THE  
IN THE UNITED STATES FUSION PROGRAMS**

**Policy**

- **There Must be a Clear Articulation of Support by the Executive Branch**
- **The Congress and its Constituents Must Exhibit Similar Support**
- **This Commitment Must be Manifested in Sound, Multi-Year Program Plans**

**REQUIREMENTS FOR INDUSTRIAL INVOLVEMENT IN THE  
IN THE UNITED STATES FUSION PROGRAMS**

**Participation**

- **Industry Must Have Limited Involvement in:**
  - **Planning**
  - **Decision Making**
  - **Resource Allocation**
- **Technical Participation Must be More Than Build-to-Print**
  - **Science and Engineering**
  - **Design**
  - **Construction/Fabrication**
  - **Operation**

**REQUIREMENTS FOR INDUSTRIAL INVOLVEMENT IN THE  
IN THE UNITED STATES FUSION PROGRAMS**

**Current Industrial Perspective of Fusion**

- **No Profits (No Business)**
- **No Policy (Hunter Legacy)**
- **No Participation (Laboratory Ownership/Domination)**



**REQUIREMENTS FOR INDUSTRIAL INVOLVEMENT IN THE  
IN THE UNITED STATES FUSION PROGRAMS**

**What it Will Take**

- **Definition and Adoption of a National Policy**
- **Participation by Industry in Programmatic Activities**
- **Profits That Will Flow From the Above**

## **SPINOFFS**

**FUSION RESEARCH HAS RESULTED IN MANY CONTRIBUTIONS TO OTHER COMMERCIAL AREAS OF INDUSTRIAL INTEREST, PRIMARILY THOSE BASED ON PLASMA PROCESSES, LASER APPLICATIONS AND DIAGNOSTICS.**

**THESE HAVE BEEN DOCUMENTED ELSEWHERE, INCLUDING:**

- **DOE BROCHURE “INVESTMENT IN AN ENERGY SOURCE FOR TOMMOROW – FUSION – YIELDS IMPORTANT BENEFITS TODAY**
- **“Plasma Science: From Fundamental Research to Technological Applications” National Research Council, 1995**
- **“Plasma Processing and Processing Science” National Research Council, 1995**
- **S. O. Dean, “Applications of Plasma and Fusion Research” J. of Fusion Energy, Vol 14, No. 2, pp 251-279, 1995**