The University of Texas at Austin
Center for Electromechanics

CENTER FOR ELECTROMECHANICS

AN OVERVIEW

Robert Hebner, Ph.D.

Center for Electromechanics

University of Texas at Austin


The University of Texas
At Austin

UT Austin Leadership

“My purpose is to chart a path where The University of Texas sets the standard among public universities in education and research. To reach that goal, we must prepare students to be successful leaders, conduct research with unprecedented global impact, influence and transform the health-care system, and nurture a campus culture where every voice is heard and valued.”

President Gregory L. Fenves

Facts and Figures

- 51,000 students
- 24,000 faculty & staff
- 18 colleges & schools
  - 170 undergraduate fields
  - 154 master's programs
  - 86 doctoral programs
  - 223 graduate programs

- Research Impact
  - $1.1 billion awarded in sponsored research in past 2 years
    - ~$2.6 to economy for each research dollar
  - $40 million in licensing revenue in past 2 years

International Facts

Study Abroad

- 3,000+ students per year to 78+ countries
- 2nd in nation for number of students studying abroad

International Students

- 5,000+ students from 120+ countries
- Top 25 in nation for number of international students

J. J. Pickle Research Campus

Vision

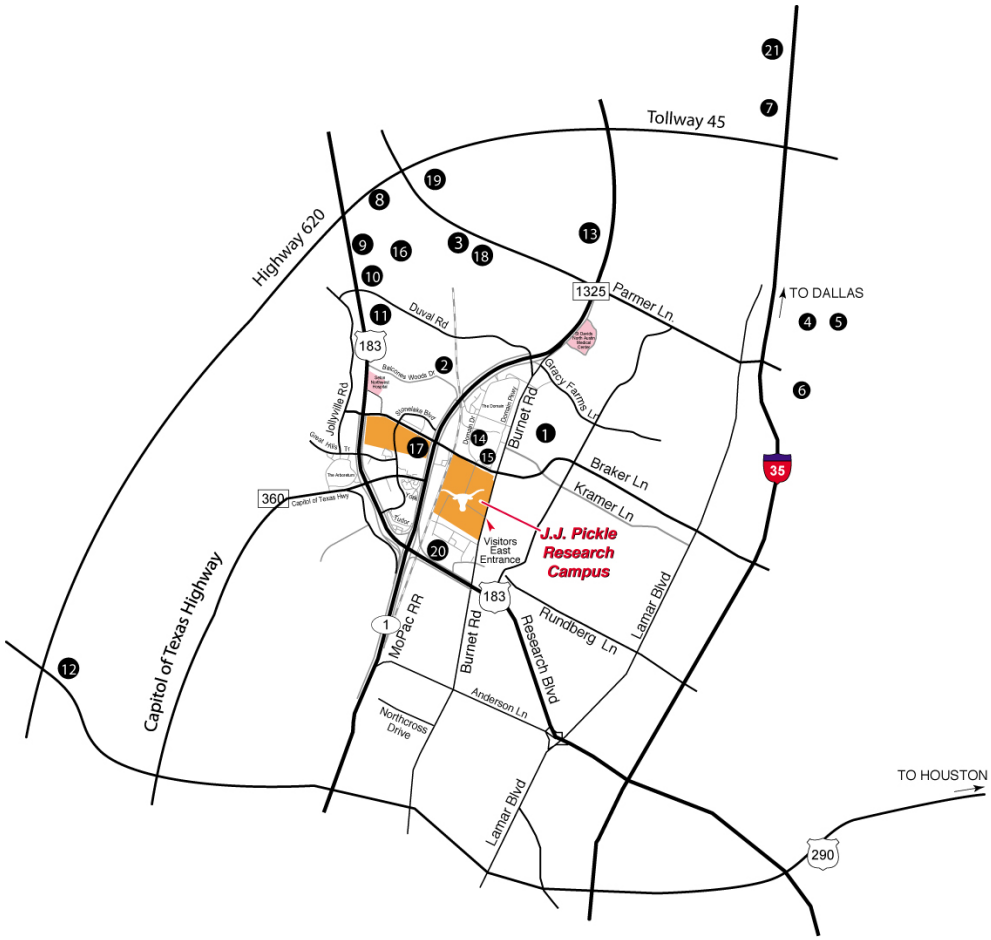
- To be the leading academic research campus in the nation, with unique focus, capabilities, and partnerships that create and sustain leadership in the breadth, scale, and impact of research conducted at UT.

We achieve this vision by providing a mutually beneficial environment for industry and UT interaction.

Diverse Technology Portfolio

- About 40% of UT's research conducted on this campus
- Approximately 2000 researchers
- Research units include
  - **Bureau of Economic Geology:** Energy, environment, economics
  - **Center for Electromechanics:** Electric power, electrified transportation, novel motors
  - **Center for Energy and Environmental Resources:** Energy efficiency, air quality
  - **Center for Water and the Environment:** Ground water, water quality, waste water
  - **Ferguson Laboratories:** Concrete durability, steel structure performance
  - **Institute for Geophysics:** Geo-energy sources, planetary geophysics,
  - **Microelectronics Research:** Device structures, integrated circuits, packaging
  - **Nuclear Engineering Teaching Laboratory:** Nuclear power, materials testing
  - **Texas Advanced Computing Center:** High performance computer center
  - **Center for Space Research:** Partner in GRACE mission

Technically Innovative Environment



1. IBM
2. National Instruments
3. Apple
4. Dell
5. GM Innovation Center
6. Samsung
7. Emerson Processing
8. URS Corp
9. Flextronics
10. Luminex
11. Cisco
12. 3M
13. Hospira
14. Hanger Orthopedics
15. SunPower
16. Valence
17. Austin Technology Incubator
18. Oracle
19. Ebay/PayPal
20. AT&T Labs
21. Teco-Westinghouse

In the midst of multinational corporations, midsized companies, and start-ups.

Asset for Research

- Larger scale R&D
  - No room on main campus
- Convenient Industry access
  - A strategic interface between industry and the university
- Culture of innovation
- Nimble governance structure

Center for Electromechanics

Core View

Vision

- For CEM
  - To be internationally renowned in our mission area.
- For CEM's people
  - To be internationally renowned in their area of expertise.

Mission

- Perform leading edge basic and applied research in electrical and mechanical engineering, with a special emphasis on applied engineering leading to prototype development of electromechanical devices or systems with high specific power, force and/or energy storage or other unique attributes. Imbedded in this mission is educating and developing students and CEM staff members into engineering leaders of tomorrow.

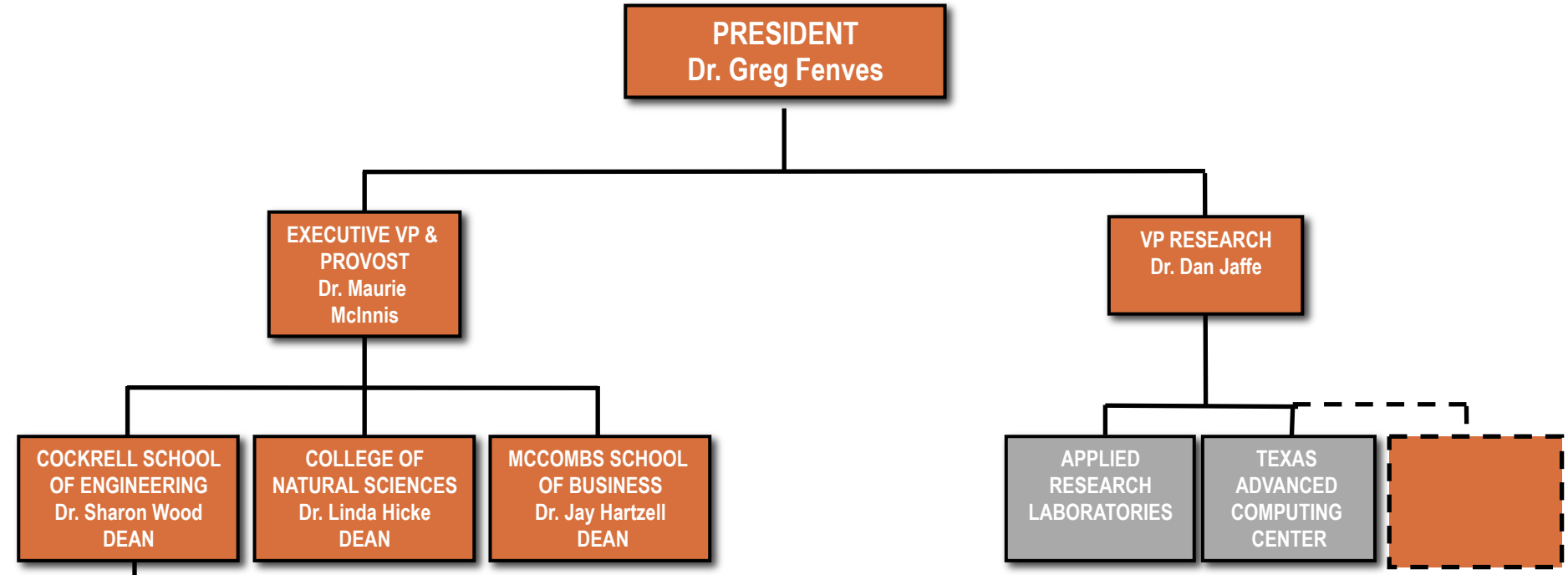
Basics

- Multidisciplinary research center in the Cockrell School of Engineering
- Approximately $10 M/year
  - Funded by research contracts
    - Typically about 50% industry, 50% government
  - Last year was a bad year
    - Less than $5M
    - But have “approved” contracts in the queue that exceed last years’ income
- Staff consists of full time researchers, students, academic faculty, and administrators

UT Expects CEM to

- Perform and publish world-class research
- Design, build, and test first-of-a-kind devices and systems
- Transfer products to industry
  - Spinout companies
- Educate students
- Provide technology and advice to the government

CEM at UT



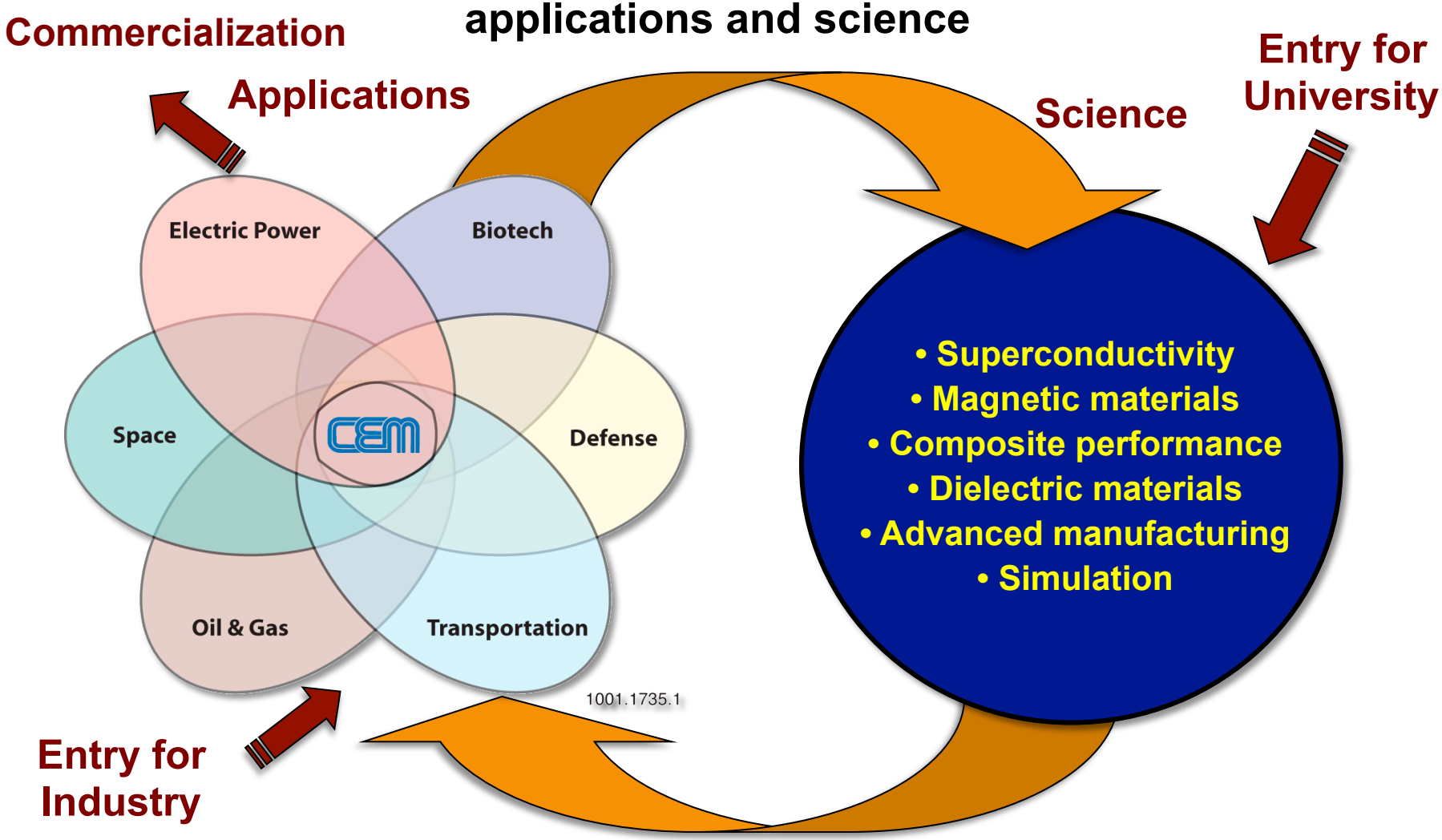
Budget: ***$10M - $15M/year***
Gov't ≈ Industry

Staffing: ***~ 40 Affiliated***
50-75 UT Collaborators

NDA's: ~ 200

Innovation Process

CEM uses successful spiral between applications and science



Significant New Growth

- ARL-South
  - A research collaboration among the Army Research Laboratory, UT, universities across the south, and industry
  - Headquartered at CEM
- UT investments in key areas of CEM activities
  - Power electronics
  - Additive manufacturing
  - Vehicle technology
  - Gas turbine technology

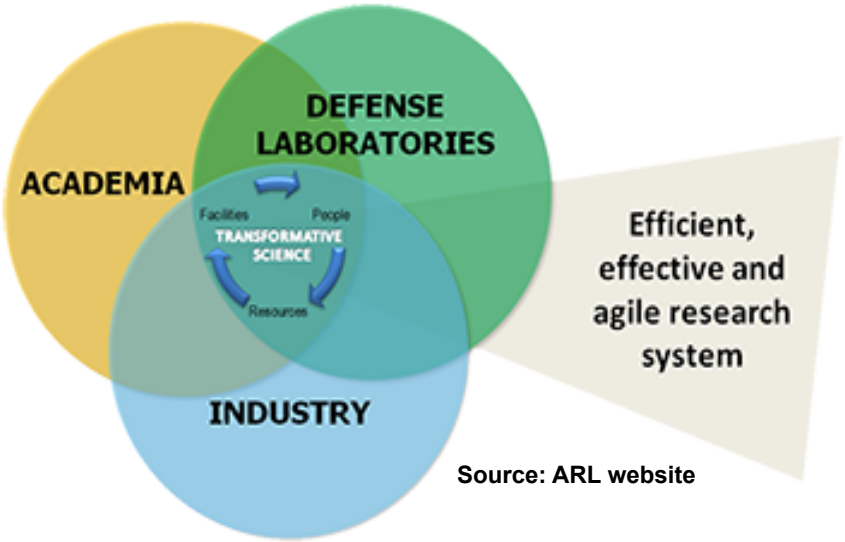
ARL-South

- The Army Research Laboratory announced in December 2016 the formation of ARL-South
  - Collaboration first, not funding first
  - ARL staff embedded with partners
    - Broaden staff opportunities
- Targeted interaction with university researchers in Texas and surrounding states
- Centered at UT-Austin (housed at CEM)
- Initial emphasis
  - Additive manufacturing
  - Power and energy
  - Cybersecurity
  - Biosciences

} CEM involvement

The ARL Approach

- ARL recognizes the need for government, industry, university collaboration
  - Government
    - Funding
    - Leadership
    - Applications
  - Industry
    - Competitive goods and services
  - University
    - R&D
    - Institutional product is knowledge



Source: ARL website

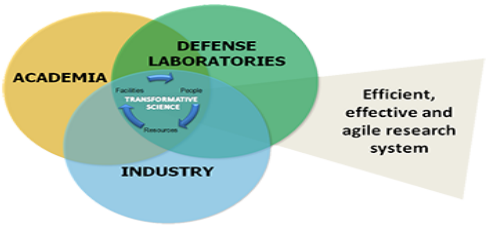
- Personal experience
  - Easier to form teams to write proposals than teams that conduct a successful R&D program
  - This approach forms the R&D team first

20th Century Innovation Approach

- Company-owned innovation communities
  - Bell Laboratories
  - Xerox Parc
  - DuPont Laboratories
  - GE R&D
  - Westinghouse Research Laboratories
- Changed the world as we knew it
- Weaknesses
  - Challenge to be nimble
  - Capturing benefit
    - Commercial boundaries vs. research boundaries
    - Management beholden to older technology

G-U-I Model – Dominant in Early 21st Century

- Governments invest in and team with industry and/or research universities
  - Silicon Valley
  - Boston
  - Austin
- Social media enhances technology development/dissemination
  - But primarily in established communities
    - Conferences spark communities which collaboratively advance technology
      - ❖ Will use social media internally

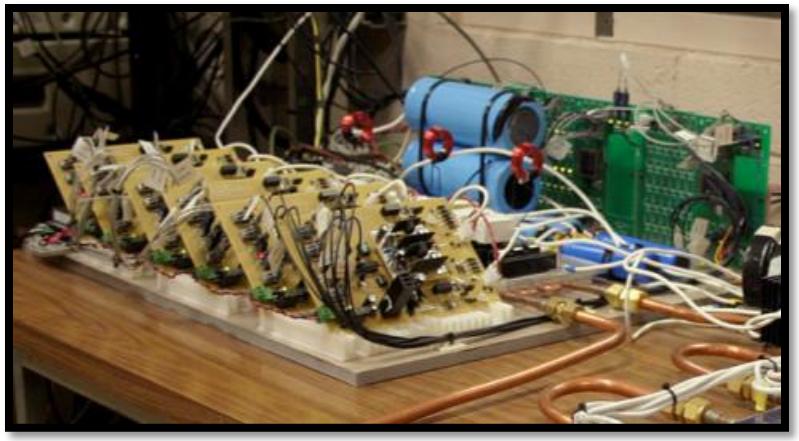


From ARL website

ARL is trying to prosper in this environment, rather than trying to hang on to an obsolete innovation model in a changing world.

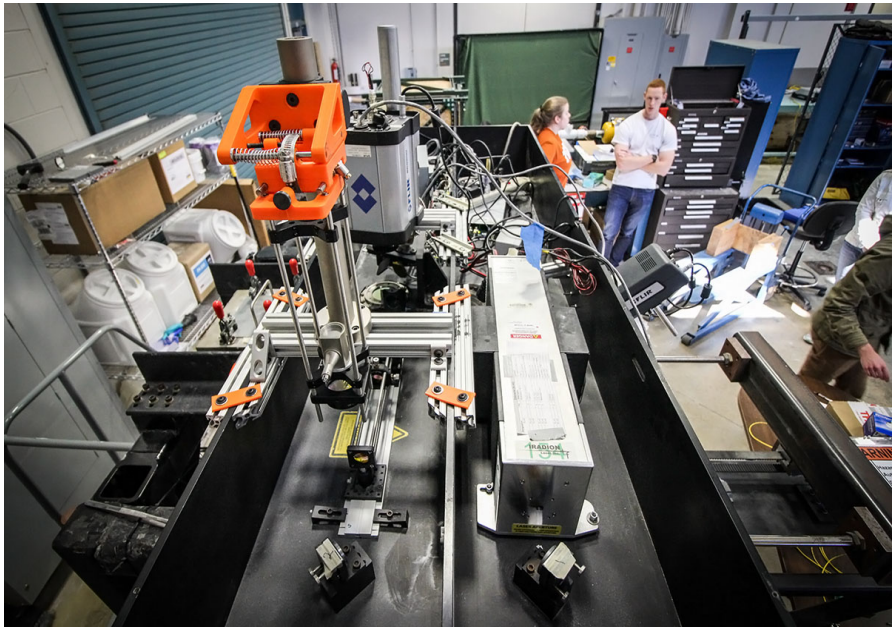
Power Electronics

- Key area for CEM, but historically understaffed
- UT Recruited Alex Huang from NC State
  - Collaborate to develop world class program
- Current activities
  - Soft switching
  - Packaging materials
    - Role of nanotechnology
      - In cooperation with the Army Research Laboratory
  - Drives for unique electrical machines
  - Power electronics and power systems
    - Including
      - Wheeled vehicles
      - Ships



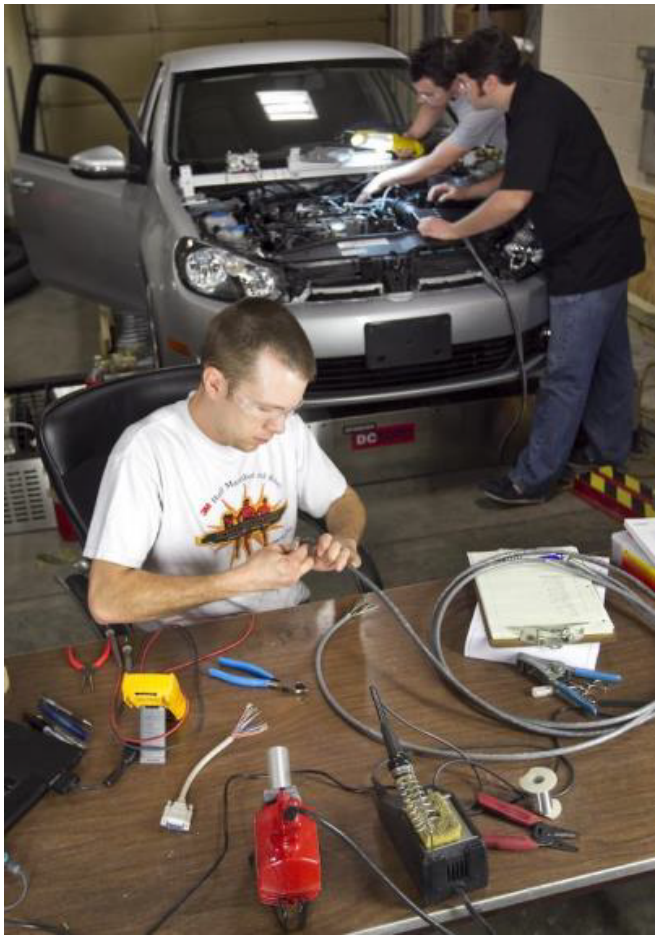
Additive Manufacturing

- Concentrate experimental facility at CEM
  - World leading capability, but dispersed
- Core activities
  - Build to spec
  - Metrology
  - Deposition physics
  - Design for additive manufacturing
- Partners
  - Army Research Laboratory
  - Air Force Research Laboratory
  - Sandia
  - Industry
    - Material and equipment suppliers
    - Users



Vehicular Technology

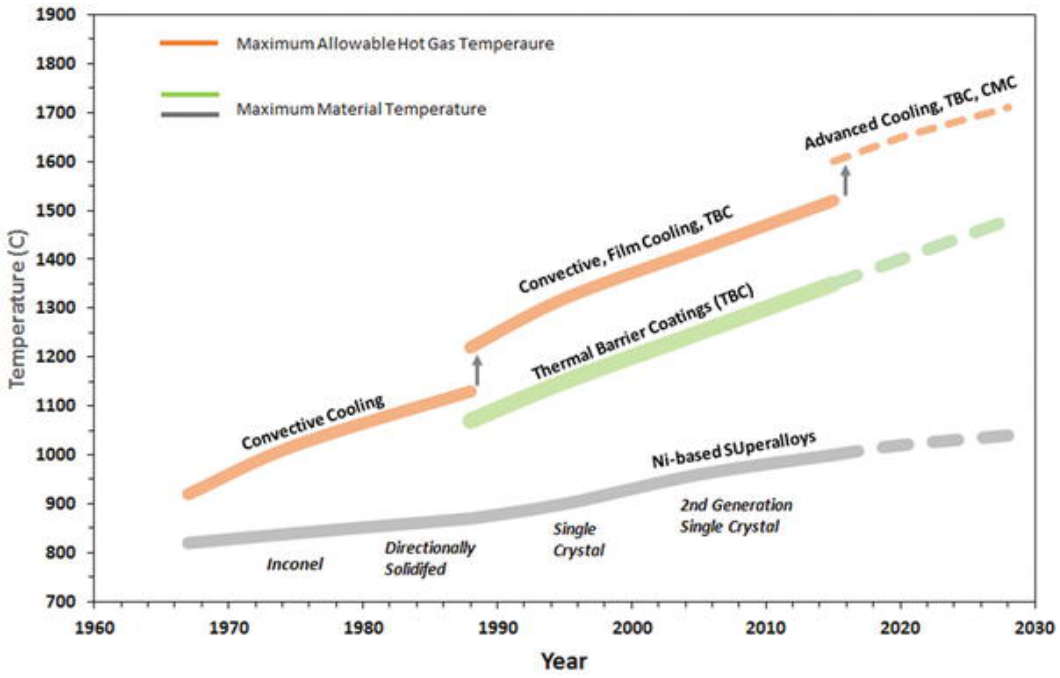
- Vehicles are expected to change significantly in next decade
  - CEM has a major vehicle program generally centered on drive train
  - UT has recruited a recognized academic program that focuses on controls
    - Significantly expands vehicle research at UT that includes
      - ❖Autonomous vehicle technology
      - ❖Engine research
      - ❖CEM vehicle development
    - Move-in – Summer 2018



Gas Turbine Technology

- Collocating
  - CEM's work on gas turbines as power sources
  - ME's work on cooling gas turbines
    - Programs collaborated for years
- Facilities modifications have significantly slowed progress

Turbine airfoil cooling is critical to increased operating temperatures.



From: Clarke et al., MRS Bulletin (2012)

CEM Research and Development

- The short presentations by research leaders are intended to provide you with insight into the research being pursued and its importance.
- The laboratory tours will let you meet students and researchers and see the capability that exists.
- The wrap-up dinner is for informal discussions to explore what you learn today.
- The rest of this presentation highlights work we have completed that is not likely to be covered elsewhere, but provides insight as to the type of work we do.

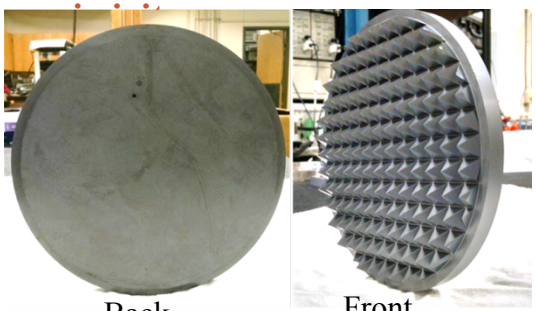
Blackbody Source for In-Situ Calibration of the ITER ECE Diagnostic

The Electron Cyclotron Emission (ECE) diagnostic will measure the plasma electron temperature in ITER

Requirements	Values
High emissivity	> 0.95 : 100- 500 GHz > 0.75 : 500-1000 GHz
Temperature	700^0 – 800 ^{0}C
Temperature uniformity	+/- 10 ^{0}C
Heating time to reach equilibrium temperature	< 1 hour
Short term stability (24hrs)	+/- 2 ^{0}C
Long term stability (3yrs)	+/- 10 ^{0}C
Operational life time	5000 hrs over 20 years
High vacuum environment	ITER VQC 1B (restricted material use)
High radiation environment	Inside Diagnostic Shield Module (near plasma)

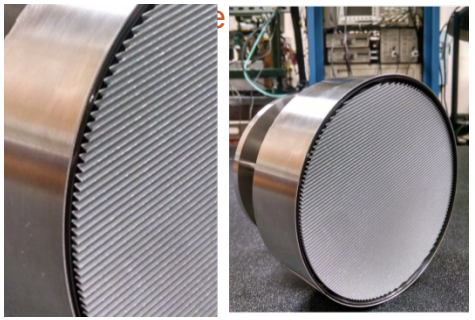
Calibration source test prototype

Blackbody emitter: SiC with surface pattern to enhance



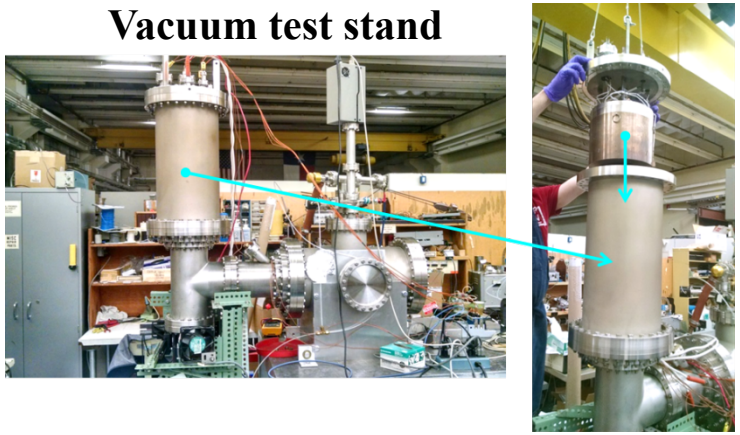
Back Front

Heater: Encapsulated Molybdenum heater with grooved

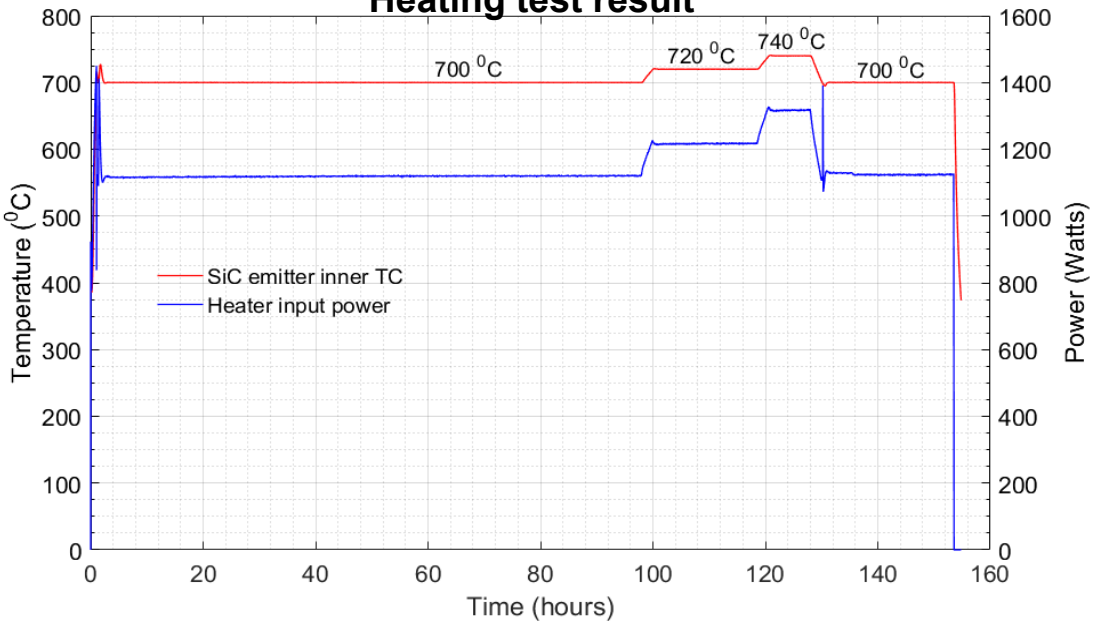


Met Preliminary Requirements

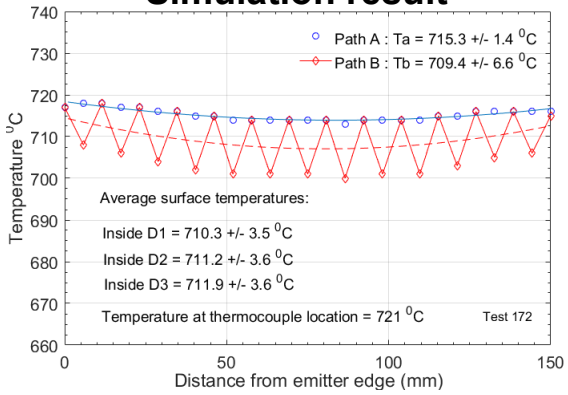
Vacuum test stand



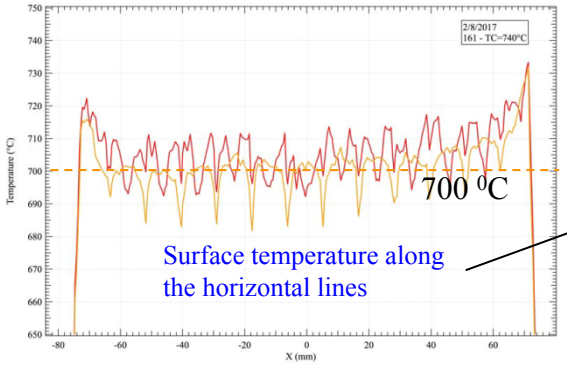
Heating test result



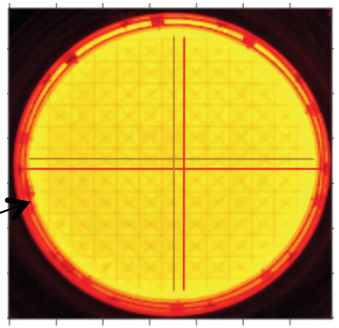
Simulation result



Test result



@ > 700 ^{0}C



DC Supercomputer

- $14 million dc computer donation to UT
- CEM role
  - Project capture
  - DC system design
  - Efficiency determinations
- Operational
  - For a few months
- Power dense
  - Four racks have computing power of 18 racks in older system

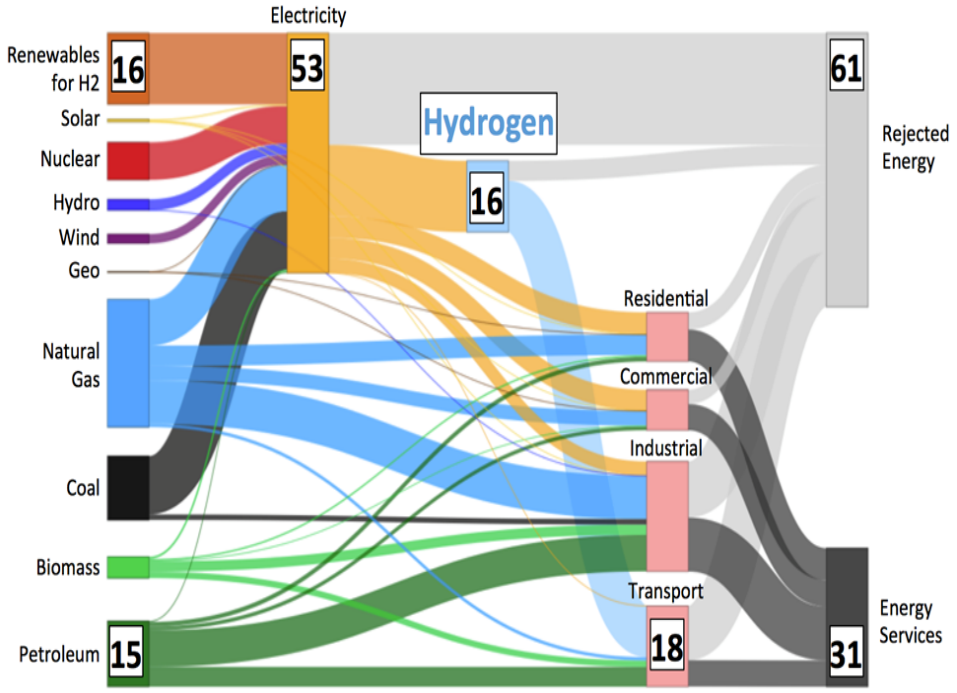
And provides input data for an experiment on solar penetration in power distribution systems.

Power System Load Control

- Exploring the potential for seamless load management
  - Collaboration with the Netherlands
  - Two students at UT from University of Twente
- Two papers on technology for cooperative control of residential loads
- Concept
  - Financial incentive for permitting variable demand
  - Utility chooses demand dynamically within range set by consumer
- Controls can work to make the amount of flexibility interesting
- Eliminates aggregators

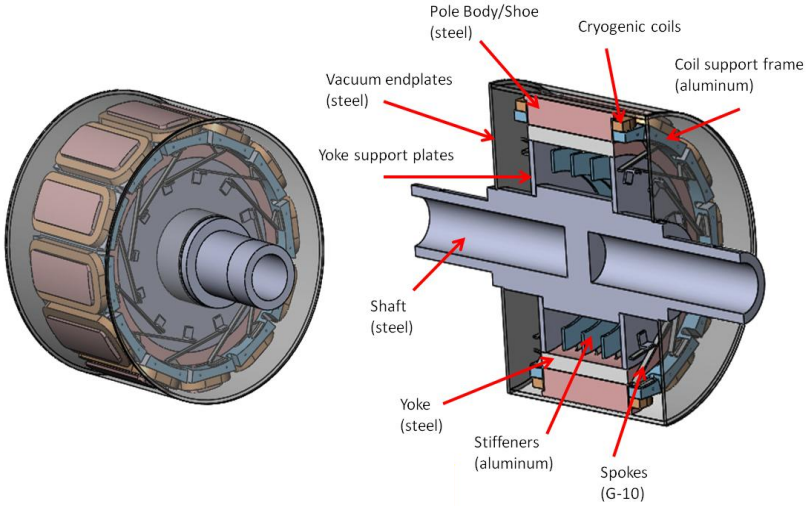
Hydrogen Economy

- Air Liquide, Alstom, Anglo American, BMW GROUP, Daimler, ENGIE, Honda, Hyundai, Kawasaki, Royal Dutch Shell, The Linde Group, Total and Toyota agreed to stimulate a H2 economy.
  - Corporate investment: ~ $1.5 B/ year
  - Some countries, e.g. Germany, matching some domestic corporate investment
- Toyota gave UT small grant to study vehicles
  - Switching to H2 reduces rejected energy by 8% (Paper in review)



Superconducting Wind Power Generator

- 2 MW Direct Drive Design
- High torque (1 MN-m), low speed (20 rpm)
- Wound superconducting field coils on rotor
- 30 K operating temperature limited to field coil assemblies
- Design Challenges:
  - Mechanical support of cryogenic coils for torque loading
  - Thermal insulation/isolation of cryogenic coils
    - Heat leaks to warm rotor components
    - Small magnetic air gaps limit insulation options
- Result:
  - Successful design and validation of mechanical support with very low therma heat leak
  - Heat transfer across magnetic air gaps exceeds design goal. Additional cooling capacity required.



Takeaway

- CEM is
  - Focused on research that makes a difference
  - Expert in electromechanics
    - Applications in many fields
  - Insightful at taking advantage of the opportunities for growth and technical diversity offered by UT
  - Experienced in the manufacturing of first-of-a-kind components and systems