# Perspectives from the University Fusion Association

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# Some comments on the NAS charge

- Responsive to areas of present critical university concern
  - -- Current health and status of university programs as well as the broader fusion community
  - -- Strategic planning offers possibility for a program vision that nurtures and expands fusion research within US academia

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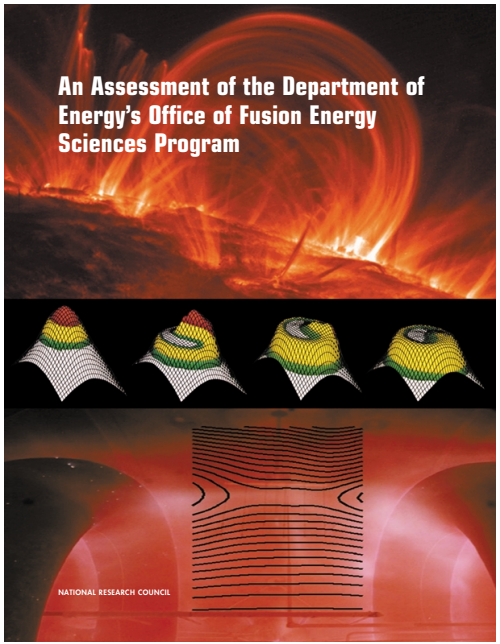
*Charge represents an enormous opportunity for addressing critical issues that the university fusion community faces*

# UFA background

- Founded in 1979
- Self-organized university fusion research advocacy body
- Representatives elected by the community
- Represents fusion researchers from ~ 40 to 50 institutions across the country
- Primarily engaged in magnetic confinement research
- Long UFA history of community led activities impacting program content and direction

# Past status/health of university fusion research




National Research Council 1999

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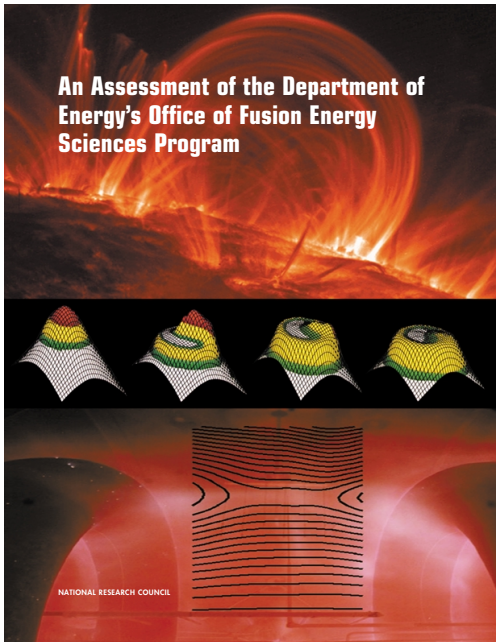


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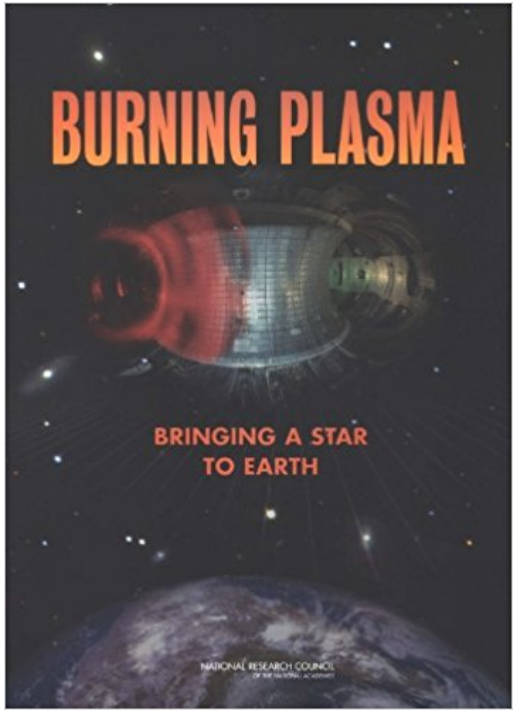


National Research Council 2004

"Extending beyond the needs of the burning plasma experiment is a pressing need to replace aging personnel in fusion and plasma sciences in the universities and the national laboratories."

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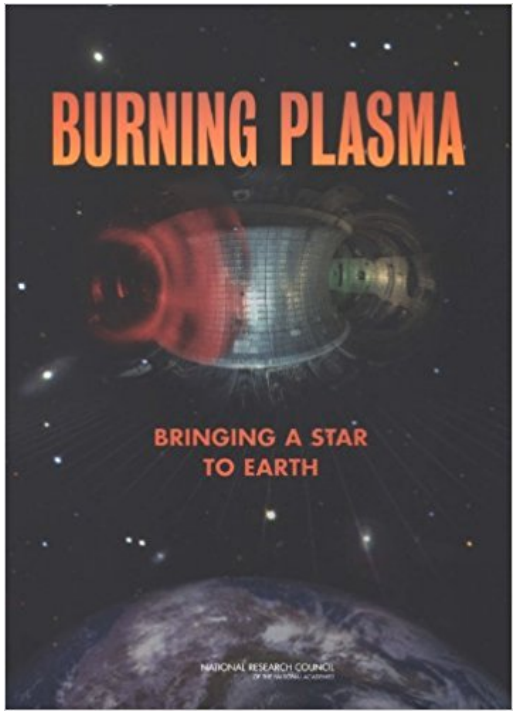


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# Fusion science work force is important, but the need for a strong academic presence is more fundamental

- Energy is a critical issue for mankind. Academia engages big issues, and therefore a strong presence for fusion energy within academia is essential to nurture a broad-based conversation that extends well beyond technical challenges. Who rebuts “fusion never”?
- The multidisciplinary environment inherent to academia provides unique opportunities for innovation and collaboration.
- Must have leadership opportunities that can compete with numerous compelling ideas in other disciplines. It is essential to not just stop erosion, rather strategize for a growing academic presence.

# Gauging current university fusion status/health

- UFA undertook long process engaging both university researchers and the larger fusion community concerning these topics

- UFA Round Table discussion 2015
- UFA Fusion Forum 2015
- UFA 2017 Status Report submitted to FESAC 2017

# UFA 2017 Status Report is an out growth of Round Table and Fusion Forum discussions of 2015

Some of the major themes that emerged from those discussions were:

- University fusion energy research programs are contracting
- Plasma research efforts are shifting to non-fusion areas
- Few new faculty lines are being created to focus on fusion research
- Growth prospects are very limited without a clear indication of stable future research funding

These concerns were discussed anecdotally for a number of years, but UFA's recent efforts help clarify and quantify the challenges

# Working group formed to address these important issues

## Provide a quantitative assessment of the themes discussed in 2015

Survey of 14 institutions representing over 80% of FES university funding

- Collect data on university program funding history
- Collect data on the prospect of new faculty hires
- Collect data on faculty age demographics

Analyze publically available relevant federal funding data and correlate with survey finding

# Participating institutions represent major historical players in fusion

Auburn University
Columbia University
Lehigh University
Massachusetts Institute of Technology
New York University
University of California, Berkeley
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
University of Illinois, Urbana-Champaign
University of Maryland
University of Texas at Austin
University of Washington
University of Wisconsin, Madison

# Status report key findings

- University fusion funding trends
- Sustainment of faculty lines
- University program vision and strategy

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# Key findings: University fusion funding trends

Substantial reductions in Fusion Energy Sciences (FES) funding have occurred for most university fusion programs surveyed over the past five years. On-campus experimental research activities have borne the brunt of the reduced funding.

There is small growth in off-campus experimental research activities relative to the large decreases in on-campus funding leading to overall program contraction and decline. Funding trends reported by universities are corroborated by analysis of federal funding data available to the working group. This decline presents a significant challenge to the long-term sustainment of a healthy fusion program at our universities.

# Context: DOE-FES is the dominant steward of fusion science at universities

Federal funding for all physical sciences at universities and colleges:

46% – NSF, 21% – DOE, 15% – DOD, 14% – NASA

(from NSF National Center for Science and Engineering)

Unlike most physical sciences, FES's funding has a direct one-to-one impact on the health of fusion research in academia

Fusion has a minority position within academia, which makes is especially vulnerable as declining support exacerbates the fierce competition for resources on campuses, including faculty positions

# Status report key findings

- University fusion funding trends
- Sustainment of faculty lines
- University program vision and strategy

# Key findings: Sustainment of faculty lines

A key metric for the health of any academic field is prospects for long-term university investment in faculty lines. The surveyed universities report poor prospects for hiring new fusion faculty, despite a 10% decrease in the number of faculty dedicated to fusion research at their institutions over the past five years. This retirement loss rate is approximately double the national average

Over the last 12 years, the faculty's average age has risen from 53 to 56, and up to 30% of the current faculty at the surveyed institutions are anticipated to retire within the next five years. Extrapolating the reported faculty demography, faculty hiring prospects, and the current loss of university based fusion research forecasts a bleak future for university participation in fusion science research.

# Status report key findings

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# Key findings: University program vision and strategy

The absence of a long-term strategy for university-based fusion research, and in particular how university research evolves going forward into the era of burning plasma physics on ITER, contributes to the poor prospects for faculty hires. This absence in conjunction with recent fusion program funding trends, and program uncertainties create a discouraging atmosphere for long-term university investment in fusion science research.

# UFA has made several constructive recommendations to address these problems that should be acted upon

- University situation is critical, but we still have a world leading university workforce that can still be built upon for a future vigorous program
- These challenges are occurring at a time of great scientific opportunity and fertility with strong enthusiasm among students and university researchers to tackle the exciting scientific challenges of the field.

# Recommendations

- Large facility engagement and collaboration
- Funding stability
- Strategic planning
- University-based experimental facilities

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University engagement on FES user facilities must be strong and viable moving forward into the era of burning plasma physics. New and improved modes of participation in off-campus research based on fusion user facility participation must be developed by the fusion community in partnership with the Office of Science that lead to enhanced university leadership roles; this leadership must be recognizable by the broader scientific community. Models used in other scientific disciplines can inform the best approach for fusion science.

Over the last several years funding opportunity announcements in many programs within FES have become irregular, with a few notable exceptions, e.g. NSF/DOE Partnership in Basic Plasma Science and the Early Career Research Program. The absence of predictable annual opportunities to compete for research funding is particularly damaging to university programs given the decision-making structure and the long time horizon of universities. We recommend the Office of Science develop and sustain more predictable funding opportunities. Stable funding is a hallmark of a strong research field that drives faculty and student interest, signals growth potential to university administrations, and encourages long-term resource investment.

# Recommendations

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# Recommendations

The recent FES Ten-Year Perspective and community workshops identify several research thrusts that are critical to the development of fusion energy. While these thrusts are clearly important, the vision and strategy for fusion science is not yet comprehensive. We recommend continued development of a shared long-term vision and strategy for fusion science through a broadly-based initiative led by the Office of Science, the fusion science community, and other stakeholders. Within this long-term strategy, clear paths that encourage and foster university investments in fusion research must be explicitly identified and developed. This can, in part, be accomplished by explicit and strong university leadership in planned National Research Council studies for both fusion and broader plasma science.

World-leading research programs in fusion physics can be and are being carried out economically in small to medium scale facilities. In order to maximize innovation and to foster the essential role of academia in fusion science, we recommend that the developed strategy for university fusion research promote new ideas and innovations in fusion science and technology through peer-reviewed initiatives that are best conducted using on-campus experimental facilities.

# Present activities addressing the recommendations

- Large facility engagement and collaboration
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- Working group formed --- preliminary report developed to inform longer term process and final report

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- Working group formed --- preliminary report developed to inform longer term process and final report
- Planned Round Table discussion on current modes of collaboration – Sept. 2017
- Planned university community wide survey to broadly canvas all interested parties on current modes of collaboration – Oct. 2017
- Complete final summary report by late spring 2018 to act as input for NAS final report

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# Madison Workshop:
# Points of Unanimous Agreement/Consensus

- Agreement that there are many exciting opportunities for US leadership
- Critical need for a strategic plan/roadmap for fusion research going forward
- The community should lead a on-going strategic planning process and set scientific priorities; This will ensure strong community support for the generated strategic plan; This process needs to be done with FES engagement

# Madison Workshop:
# Points of Unanimous Agreement/Consensus

- The US program has strengths but it is not healthy overall (universities and technology). The trajectory is in the wrong direction in general
- Burning plasma is still an essential step for our field
- Also, agreement on many technical areas of strategic importance and possible future US leadership: HTSC, Stellarators, PMI, Theory/Computation, others...

# Austin Workshop: Near-term actions

- PC is identifying issues and strategic areas that should receive attention prior to Austin meeting
  - -- Form sub-groups (including members outside of PC) to work these issues in prep for Austin
- Technical & programmatic evaluation metrics, risks, costs, timelines for elements identified as impactful in Madison:
  - -- HTS magnet development for fusion applications
  - -- QS stellarators
  - -- Others…

# Austin Workshop: Near-term actions

- Framework and Governance for community-led strategic plan
  -- P5 example
  - Use unprioritized “Science Questions” and “Science Drivers” as compelling lines of inquiry for next 1-2 decades.
  - Then use two sets of prioritization criteria:
    - Optimization of program: Science, international context, sustained productivity
    - Evaluation of individual projects: Science, timing, uniqueness, cost vs. value, history and dependencies, feasibility, roles/leadership
  - Formulate program-wide recommendations, project specific recommendations, and consider flat, reduced, increased budget scenarios.

# Possible community input for Austin

- Solicit 2 page whitepapers (again)
  - Proposed vision & mission statements for US fusion program
  - Key science and technical drivers and questions addressed by proposed mission
  - 10 and 20 year goals/sub-goals
  - Strategic elements, wedges, growth/decrement areas, logical sequencing/timeline of proposed strategic plan
  - International context + impact on other NAS sub-questions
  - **Differences in plan with/without US a partner in ITER**
  - …other
- PC/sub-group reviews strategic whitepapers
  - Looks for common themes among proposals, consolidates into smaller number of proposals / aggregates proposers
  - Proposed mission/vision/goals/sequencing/in-out-of-ITER presented at Austin meeting, assess via parallel break-outs

PC open to input/guidance on any of these issues from the NAS committee

# Present activities addressing the recommendations

- Large facility engagement and collaboration
- Funding stability (not discussed)
- Strategic planning
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# On-campus experimental facilities provide obvious leadership, recognized within & outside institution

- Continuing need for multi-configuration research
  - Validation to develop predictive fusion science
  - Develop and test innovative and exploratory concepts
- Opportunities beyond confinement configurations
  - Plasma-material interface
  - Enabling technologies

Tactical plan should identify opportunities suited for on-campus facilities as part of overall fusion program strategy

# Role of alternate magnetic configurations was discussed at the Madison Workshop

- Alternate magnetic configuration research discussed and received support by many groups, but further discussion of alternates as a program element is needed.
- Need for evaluation of metrics both on the physics and technical issues to fusion pointed out by some groups

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UFA strongly encourages/supports this as an important topic for further discussion and possible consensus building at Austin given it's possible impact for on-campus experiments

# Personal viewpoint

- The following are my own thoughts on a possible strategic program element to address the current university situation

# Stellarators offer the possibility for university intellectual leadership doing world leading fusion research

- Rich 3D theory/computational opportunities as well as experimental validation opportunities at small/medium facility scale
- 3D magnetic field offers huge magnetic design space to scientifically explore: Possible optimization of thermal confinement, energetic particle confinement, MHD stability, turbulent transport, and others
- In collaboration with our national laboratory colleagues

Result: Steady-state
Well-confined
High fusion energy gain

Challenges:
Experimental validation
Find optimum

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These challenges represent significant new opportunities

Result: Steady-state
No current drive
High fusion energy gain

Challenges:
Experimental validation
Find optimum

# Possible new and potentially transformative university-based stellarator research

- Begin a national optimization/design study NOW

  Focused on design that complements international effort

  (e.g., quasisymmetry, incorporate new ideas such as

  turbulent transport optimization, magnet simplification

  energetic particle confinement, strong flow…)
- Construct small/mid-scale facilities to test these ideas as motivated by optimization study and build these experiments at universities
- Lays ground work for future performance class experiment (integration step)

# Motivated by challenges in fundamental plasma physics encouraging long term university resource investment

- This possible strategic element is driven by major magnetic plasma confinement physics questions
  -- Turbulence, energetic particle confinement, impurity transport, symmetry effects, MHD, others
- The connections to other areas of science offers the possibility of high impact and could reverse current, divorcing trend of fusion's further isolation in academia
  -- Astrophysics, space/magnetoshperic plasmas, nonlinear dynamics and complex systems

# Closing comments

- Current university situation requires immediate attention, but ideas are in place to help address the issues discussed
- Our scientific focus at this point in time needs to maintain the intellectual breath of confinement physics and stress innovation/predictive capability given the long time scale to a fusion reactor
- Any new strategy for fusion needs to emphasize explicitly the critical role of university research and offer paths to foster growth of fusion in academia

# Backup slides

# Faculty hiring prospects are poor indicating challenges in maintaining a healthy fusion research program

| Institution | Change in Faculty | | Prospect for Hiring Fusion Faculty | Fusion Faculty | | Non-Fusion Faculty | | Change in On-Campus Funding | Change in Off-Campus Funding |
|---|---|---|---|---|---|---|---|---|---|
| | Fusion | Non-fusion | | # | Avg Age | # | Avg Age | | |
| 4 | +2 | +3 | very poor | 7 | 53 | 11 | 60 | +4% | 0% |
| 9 | +2 | +2 | very poor | 4 | 46 | 5 | 49 | –21% | 35% |
| 14 | +2 | | poor | 3 | 44 | 0 | – | +600% | no activity |
| 6 | | +1 | very poor | 3 | 54 | 4 | 46 | –46% | 0% |
| 12 | | +0.5 | poor | 3 | 50 | 0 | – | 0% | no activity |
| 11 | | | zero | 0 | – | 5 | 61 | 0% | 0% |
| 10 | | | neutral | 2 | 54 | 0 | – | 0% | no activity |
| 13 | –1 | | zero | 1 | 45 | 0 | – | 0% | no activity |
| 7 | –1 | | poor | 6 | 59 | 0 | – | –40% | 0% |
| 8 | –1 | –1 | neutral | 6 | 70 | 2 | 55 | –8% | 17% |
| 1 | –1 | –2 | +1, possible | 4 | 60 | 3 | 60 | –25% | 0% |
| 3 | –2 | –1 | +1, likely | 3 | 59 | 3 | 58 | –11% | 5% |
| 2 | –4 | +1 | +1, possible | 8 | 55 | 4 | 52 | –23% | 4% |
| 5 | –2 | –2 | very poor | 4 | 62 | 4 | 60 | –75% | no activity |
| **Total or Average** | **–6** | **+1.5** | **poor** | **54** | **56** | **41** | **56** | | |

- Two institutions account for 67% of all new hires
- The other institutions had a combined net loss of 9.5 faculty positions (12% loss)
- Only three institutions report the possibility of hiring faculty with a fusion focus
- Faculty population continues to "gray" with mean age of 56
- Expected or anticipated retirements of ~ 30% with prospect for replacement poor