On the program, vision, and budget for the fusion and plasma sciences

E.J. Synakowski
Associate Director, Office of Science
For Fusion Energy Sciences
U.S. Department of Energy

Presented to the Fusion Energy Sciences Advisory Committee

February 28, 2012
**Ambition**: Fusion contributes to energy and climate solutions by mid-century

**Office of Science role**: Establish the plasma sciences broadly for fusion as well as discovery
This budget was developed in part considering the Administration’s high priority of investment in research relevant to clean energy with near-term payoff.

With this as backdrop, the Administration affirms a strong commitment to ITER, recognizing its importance to fusion and potentially to the energy economy in the second half of this century, the U.S.’s leading scientific role in getting us to this point, and international commitments.

Cuts are realized in a large majority of the non-ITER part of the program. Exceptions are where modest increases are proposed in international research and materials.

With this proposal, a program structure is maintained that can lead to where we need to be in 10 years.
Fusion and plasma science elements are intimately linked

Mission

The mission of the Fusion Energy Sciences (FES) program is to expand the fundamental understanding of matter at very high temperatures and densities and to develop the scientific foundations needed to develop a fusion energy source. This is accomplished by the study of the plasma state and its interactions with its surroundings.

Priorities

- Advance the fundamental science of magnetically confined plasmas for fusion energy
- Pursue scientific opportunities and grand challenges in high energy density plasma science
- Support the development of the scientific understanding required to design and deploy fusion materials
- Increase the fundamental understanding of plasma science beyond burning plasmas
After more than 50 years of research, fusion is ready to embark on the ultimate test – determining the scientific and technical viability of fusion on earth.

ITER is the scientific vehicle for this test. It will enable the study of high gain fusion plasmas, fusion systems that release more energy than is required to initiate and control them.

The U.S. has had a major, leading role in developing the scientific basis girding ITER, its design, and its operating scenarios.

The FY’13 budget proposal is for a program that will be highly impactful for ITER construction, fusion research and the plasma sciences overall, preserves a structure that can effectively engage the world in the ITER era, and is fiscally responsible.
High-level considerations and budget overview
Overarching consideration: where we need to be in ten years

- Total FES budget request is $398.3M. Compare to $401M appropriated in ‘12.

  - The U.S. needs to lead in burning plasma science ➔ Support ITER project at $150M, an increase of $45M over FY 12. Maintain DIII-D run time with no upgrades at this time. However, the Alcator C-Mod facility will cease operations in FY’13

  - Position the U.S. to assert leadership in present gaps ➔ Modest increases in international opportunities on long-pulse facilities, both tokamak and stellarator. In materials science, continue support of the NSTX Upgrade project and DIII-D to enable an informed decision on an FNSF later this decade, and begin a modest initiative in materials science

  - Steward the broader plasma sciences ➔ Overall FES Program structure is maintained as the non-ITER program faces an overall reduction of about 16%, including closure of the Alcator C-Mod program. Joint programs with NNSA and NSF in non-MFE research are maintained at a reduced level
In the next decade:

- ITER will be constructed, and the frontier of burning plasma science will be there. Liken it to LHC in high energy physics – if the U.S. is not engaged, we will lose out.

- First-of-a-kind, $B$-class research facilities in magnetic fusion will be online in Europe and Asia. The class of physics they will enable will include but extend beyond what U.S. facilities are capable of exploring. The U.S. domestic program can and must be sensibly levered to take advantage of these research resources.

- The U.S. has a leadership opportunity in fusion materials science.

This budget proposal makes steps in engaging these changes in a constrained budgetary environment.
What we have going our way in this budget that can make this happen

- A student population of over 400 students
- Outstanding facilities in DIII-D and NSTX-U
- Viable core elements elsewhere, with leverage opportunities within the U.S.
- A clearly defined gap in fusion materials
- International research relationships at the emergent facilities that are strong and will enable growth
- Materials science research opportunities with high potential for leverage with BES

Examples of what we have to overcome

- Loss of a major facility, Alcator C-Mod, with student education
- Reductions in effort in nearly every area except international research and materials

Examples of what we can do to mitigate the effects of the losses

- Increase student education opportunities at DIII-D and NSTX-U
- Vigorously develop, and understand limits, of research opportunities overseas
- Develop leverage with NNSA, BES, and ASCR
FESAC “Priorities, Gaps, and Opportunities” report points to fusion materials as the next leading frontier to be mastered in parallel with ITER.

To increase our impact in materials science, both nuclear and non-nuclear.

- Lever common interests in MFE, IFE, NE, SC, NNSA
- Complementarity of DIII-D and NSTX-Upgrade will inform the decision on a Fusion Nuclear Science Facility later in this decade.
- Launch a prerequisite computational materials and beam line programs. Strong university role.

U.S. research has to evolve if we are to retain a world leadership position in fusion: {
}fusion materials science, and extracting fusion power{
Note, from the narrative:

“The U.S. remains committed to the scientific mission of ITER, while maintaining a balanced research portfolio, and will work with ITER partners to accomplish this goal.”
Ultimately, the U.S. fusion’s path forward will be expressed in terms of scientific elements and will include changes of emphasis.

- Burning plasma science and stewarding broader plasma science will be key elements, but program scope may have to be reduced for lower funding level scenarios.

- Major domestic facilities will still engage in plasma dynamics and control, but will shift focus towards challenging metrics relevant to fusion materials science.

- Leverage between domestic and international research opportunities in MFE will become even more important in tough budget times, if the U.S. is to obtain access to the leading scientific questions in the next decade.
**Research: $154,200M**
- DIII-D, C-Mod, NSTX
- International Collaborations
- High Energy Density Laboratory Plasmas (HEDLP)
- Outreach and Education
- Validation Platforms (Experimental Plasma Research (EPR))
- Madison Symmetric Torus (MST)
- Theory and Modeling
- SciDAC
- General Plasma Science
- Diagnostics
- SBIR/STTR

**Facility Operations: $221,476M**
- ITER at $150M
- 10 weeks of DIII-D Operations
- 0 run weeks of Alcator C-Mod Operations due to shutdown
- 0 run weeks of NSTX Operations due to upgrade
- NSTX Major Item of Equipment (MIE) Upgrade project
- General Plant Projects (GPP)/General Purpose Equipment (GPE)/Infrastructure

**Enabling R&D: $22,648M**
- Plasma Technology
- Advanced Design
- Materials Research

*Smaller Scale MFE includes Validation Platforms (EPR) and MST
**Other includes SBIR/STTR, GPP/GPE/Infrastructure, Outreach, Education & Diagnostics
FY 2013 FES Congressional Request ($398.324M): Non-ITER

**Research:** $154,200M
- DIII-D, C-Mod, NSTX
- International Collaborations
- High Energy Density Laboratory Plasmas (HEDLP)
- Outreach and Education
- Validation Platforms (Experimental Plasma Research (EPR))
- Madison Symmetric Torus (MST)
- Theory and Modeling
- SciDAC
- General Plasma Science
- Diagnostics
- SBIR/STTR

**Facility Operations:** $71,476M
- 10 weeks of DIII-D Operations
- 0 run weeks of Alcator C-Mod Operations due to shutdown
- 0 run weeks of NSTX Operations due to upgrade
- NSTX Major Item of Equipment (MIE) Upgrade project
- General Plant Projects (GPP)/General Purpose Equipment (GPE)/Infrastructure

**Enabling R&D:** $22,648M
- Plasma Technology
- Advanced Design
- Materials Research

*Smaller Scale MFE includes Validation Platforms (EPR) and MST
**Other includes SBIR/STTR, GPP/GPE/Infrastructure, Outreach, Education & Diagnostics
## Fusion Energy Sciences
### FY 2013 Congressional Budget
(Budget Authority in thousands)

<table>
<thead>
<tr>
<th>Science</th>
<th>FY 2011 Actual</th>
<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIII-D Research</td>
<td>30,716</td>
<td>30,300</td>
<td>26,703</td>
</tr>
<tr>
<td>C-Mod Research</td>
<td>10,056</td>
<td>10,454</td>
<td>8,396</td>
</tr>
<tr>
<td>International Research</td>
<td>6,105</td>
<td>7,435</td>
<td>8,946</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>4,115</td>
<td>3,519</td>
<td>3,519</td>
</tr>
<tr>
<td>Other</td>
<td>8,085</td>
<td>11,919</td>
<td>9,193</td>
</tr>
<tr>
<td>NSTX Research</td>
<td>16,107</td>
<td>17,549</td>
<td>16,836</td>
</tr>
<tr>
<td>Experimental Plasma Research</td>
<td>17,745</td>
<td>11,000</td>
<td>10,500</td>
</tr>
<tr>
<td>HEDLP</td>
<td>25,727</td>
<td>24,741</td>
<td>16,933</td>
</tr>
<tr>
<td>MST Research</td>
<td>7,005</td>
<td>6,000</td>
<td>5,750</td>
</tr>
<tr>
<td>Theory</td>
<td>25,663</td>
<td>24,348</td>
<td>20,836</td>
</tr>
<tr>
<td>SciDAC</td>
<td>7,057</td>
<td>8,312</td>
<td>6,556</td>
</tr>
<tr>
<td>General Plasma Science</td>
<td>14,810</td>
<td>16,780</td>
<td>13,151</td>
</tr>
<tr>
<td>SBIR/STTR</td>
<td>-</td>
<td>8,326</td>
<td>6,881</td>
</tr>
<tr>
<td><strong>Total, Science Research</strong></td>
<td><strong>173,191</strong></td>
<td><strong>180,524</strong></td>
<td><strong>154,200</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Facility Operations</th>
<th>FY 2011 Actual</th>
<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIII-D</td>
<td>35,699</td>
<td>38,319</td>
<td>33,260</td>
</tr>
<tr>
<td>C-Mod</td>
<td>17,518</td>
<td>18,067</td>
<td>7,848</td>
</tr>
<tr>
<td>NSTX</td>
<td>32,559</td>
<td>32,134</td>
<td>29,393</td>
</tr>
<tr>
<td>Other, GPE, and GPP</td>
<td>4,568</td>
<td>975</td>
<td>975</td>
</tr>
<tr>
<td>MIE: U.S. Contributions to ITER Project</td>
<td>80,000</td>
<td>105,000</td>
<td>150,000</td>
</tr>
<tr>
<td><strong>Total, Facility Operations</strong></td>
<td><strong>170,344</strong></td>
<td><strong>194,495</strong></td>
<td><strong>221,476</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Enabling R&amp;D</th>
<th>FY 2011 Actual</th>
<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Technology</td>
<td>14,501</td>
<td>13,911</td>
<td>11,666</td>
</tr>
<tr>
<td>Advanced Design</td>
<td>2,752</td>
<td>4,337</td>
<td>1,611</td>
</tr>
<tr>
<td>Materials Research</td>
<td>6,469</td>
<td>7,729</td>
<td>9,371</td>
</tr>
<tr>
<td><strong>Total, Enabling R&amp;D</strong></td>
<td><strong>23,722</strong></td>
<td><strong>25,977</strong></td>
<td><strong>22,648</strong></td>
</tr>
</tbody>
</table>

| **Total, Fusion Energy Sciences** | **367,257** | **400,996** | **398,324** |
Total available in solicitations is $26M

Labs, universities, and industry R&D groups may compete for all solicitations except:

- NSTX Research—Labs only in FY13
- Theory/Modeling—Universities and industry groups in FY13
On ITER

The driving force

International project construction and status

International commitments

U.S. obligations, US. ITER Project performance, and impact on the international ITER schedule
ITER is the keystone for establishing the scientific and technological feasibility of magnetic fusion energy.

ITER will advance every element of the FES program, and will be the world’s first entry into Burning Plasma Science.

The scientific question of how to optimize the plasma distribution function in a burning plasma is at the center of ITER’s plasma science.

Will create the world’s first sustained self-heated plasma: numerical goal of \( Q = 10 \), pulsed, 500 MW; \( Q = 5 \) steady-state.

U.S. research has had a defining impact on ITER design and operating scenarios.

Designs will be completed with industry input for the majority of U.S. hardware needed for first plasma.

Many technologies will be at reactor scale, or will enable first studies at reactor scale.

<table>
<thead>
<tr>
<th></th>
<th>FY2012 Enacted</th>
<th>FY2013 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITER Project</td>
<td>$105M</td>
<td>$150M</td>
</tr>
</tbody>
</table>
International Organization management changes have made an enormous positive impact

Poloidal winding building construction

The ITER Device

Site construction is underway

New project leadership, instituted with U.S. leadership

Director General Motojima

Rich Hawryluk

Rem Haange

Headquarters Building
“Why does the ITER project need to grow in such a challenging budget?”

- ITER is the capstone of over 50 years of research in magnetic fusion. This time is critical for its success, and for fusion’s success.

- The project is moving out smartly in construction, and the U.S. needs to keep pace to the best of its ability. Now and the coming years is when contracts need to be placed so that ITER construction can be completed on time.

- The U.S. is at the very edge of having a negative impact on the international schedule at a time when the other Members have demonstrated extraordinary commitment. Further reductions in the U.S. ITER budget will yield an international schedule slip with unpredictable consequences on the political front, and will add to costs for everyone.
<table>
<thead>
<tr>
<th>Member</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Highly committed to ITER and fusion overall. Their plan to aggressively invest in fusion requires ITER success, including schedule success. Expressed interest in fusion comes from highest levels of government, including a visit by China’s President and Vice Premier to their leading fusion laboratory.</td>
</tr>
<tr>
<td>European Union</td>
<td>They are in for 45% of the cost. The EU recently committed to $1.3B additional Euro of ITER funding to a total of $2B Euros over the next two years, despite extraordinary financial times. They have recently forged a deal with JA to trade in-kind contribution obligations to help entire project stay on schedule discussions.</td>
</tr>
<tr>
<td>India</td>
<td>They fight hard every year for their budget in a complex process, but outward indications of support are very strong. They see ITER is a vehicle for advancing their whole fusion R&amp;D enterprise.</td>
</tr>
<tr>
<td>Japan</td>
<td>Their FY’12 funding of $224M has been approved. This is more than a 3-fold increase in funding over FY’11, despite the earthquake and tsunami.</td>
</tr>
<tr>
<td>Russia</td>
<td>Cash is in-hand, and they are eager to spend and get on with the project fully and to stay on schedule</td>
</tr>
<tr>
<td>South Korea</td>
<td>Strong commitment; Eager to demonstrate industrial capabilities. Catalyzing trade of obligations between EU and JA. Strident about sticking to schedule.</td>
</tr>
</tbody>
</table>
A significant portion of U.S. ITER funding is spent with U.S. industry, universities, and national labs

Funding in FY12 will be utilized to:

- allow the US to progress as needed to remain a viable partner in this collaboration
- retain or create jobs in >300 industries and universities and 8 National Laboratories in 37 states
- provide US industry experience with advanced manufacturing techniques

Funding to DOE Labs
March 2006 – December 2011
Total ~$168M

Funding to Industries and Universities
March 2006 – December 2011
Total ~$171M

Attracting business
- The EU has let a contract to Oxford Instruments for its superconducting strand ($58M; New Jersey)
- Luvata Connecticut's supplying US TF strand to the EU ($26M)
An understandable concern is: can the U.S. program be impactful with the proposed reductions in the non-ITER budget, and are we positioning ourselves to get good scientific return during the ITER era?

The view of FES and Office of Science regarding these questions is “yes,” but there is loss, and near-term choices will be important.
DIII-D has had an enormous influence on establishing a scientific understanding and optimization of magnetically confined plasmas.

**General Atomics, La Jolla, CA**

DIII-D research is at the heart of plasma dynamics and control: it forms the basis of many research scenarios and control tools for ITER and reactors.

The Operations funding reduction will halt all major facility upgrades and defer system refurbishments, but still allow for 10 weeks of operation in FY2013.

<table>
<thead>
<tr>
<th></th>
<th>FY2012 Enacted</th>
<th>FY2013 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIII-D</td>
<td>30,300</td>
<td>26,703</td>
</tr>
<tr>
<td><strong>Operations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY’12 Enacted</td>
<td></td>
<td>FY’13 Proposed</td>
</tr>
<tr>
<td>DIII-D</td>
<td>38,319</td>
<td>33,260</td>
</tr>
</tbody>
</table>

A leader in the transformation of fusion plasma science to a predictive enterprise.

Collaboration value extremely high: universities at ground level of program planning and execution. High impact on overseas research.
The commitment to the National Spherical Torus Experiment Upgrade is high

NSTX compact, low aspect ratio geometry
→ candidate for materials volume neutron source
→ tests of toroidal effects on transport, waves, and MHD

High plasma pressure/magnetic pressure
→ transport important to a burning plasma is highlighted
→ Validation platform for astrophysics

NSTX Upgrade is on track for project completion on time

<table>
<thead>
<tr>
<th>Research</th>
<th>FY2012 Enacted</th>
<th>FY2013 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSTX</td>
<td>17,549</td>
<td>16,836</td>
</tr>
<tr>
<td>Operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSTX</td>
<td>15,004</td>
<td>6,593*</td>
</tr>
<tr>
<td>Construction Projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSTX Upgrade</td>
<td>17,130</td>
<td>22,800</td>
</tr>
</tbody>
</table>
Increase toroidal field: 0.5T > 1.0T
Increase pulse length: 1.0 s > 5 s
Increase plasma current: 1 MA > 2 MA
Increase NB heating: 5-9MW > 10-18MW

New solenoid
Inner TF bundle, TF joint, OH & inner PF coils

Upgraded TF coil support structure

Existing outer TF coils

Reinforce umbrella structure

Exst’g outer PF coils – 6 total

New PF coil support structure

Second NBI
Existing NBI

Also...modify coil power system, protection system & ancillary support systems
Alcator C-Mod closes in FY2013. It has been a test-bed for materials science and wave physics relevant to advanced reactor scenarios.

The Alcator C-Mod facility is shut down in FY2013. No operations will be conducted and the funding will provide for the safe shutdown of the facility.

FY2013 will see analysis of data taken in FY2012 and publication the results. A transition of research staff into collaborative activities on other domestic and international experiments will begin.

FES will work with MIT regarding student impacts, enabling those in their last stage of research to finish, and supporting relocation of those in the middle of their research projects.
We need to grow our internationally based research efforts

First-of-kind superconducting tokamaks (based on U.S. designs) now in China (EAST, Hefei) and South Korea (K-STAR, Daejeon). Also superconducting stellarators (Japan and Germany). China, South Korea, and Germany have offered the U.S. a leadership seat at their program governance table.

U.S. teams, formed by national labs, private industry, and universities, will participate on-site and with remote data centers.

This will lead to a research team model to be implemented on ITER.

How we respond with labs and universities in the next decade will be a major factor determining our place on the world stage.

These efforts will define our work approach on ITER.

FESAC input will be considered in developing the details and approach.

Major unique scientific opportunities need to fill fusion gaps and teach us how to engage internationally for ITER.

<table>
<thead>
<tr>
<th>Research</th>
<th>FY2012 Enacted</th>
<th>FY2013 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Research</td>
<td>7,435</td>
<td>8,946</td>
</tr>
</tbody>
</table>
Emergent opportunities for plasma control research, with superconducting magnetic technology, reside overseas

**K-STAR**  
Daejeon, S. Korea  
Goal: 300 s pulse 2 MA

**EAST**  
Hefei, China  
Goal: 1000 s 1 MA

The U.S. DIII-D control system has been implemented on K-STAR and EAST devices

**LHD stellarator**  
(Japan – operating)

**W7-X stellarator**  
(Germany – 2014)
FESAC Greenwald panel report, “Priorities, Gaps, and Opportunities (2007)” pointed to the needs and opportunities for the U.S. in fusion materials science, including closing the fuel cycle and harnessing fusion power.

A FESAC panel report at the end of February will inform FES’s strategy for moving forward in this area.

- An initiative in fusion materials research is proposed
- The level of support for design studies of future facilities and for the Virtual Laboratory for Technology (VLT) will be reduced.
- The level of support for advanced technologies for future facilities will be reduced.

<table>
<thead>
<tr>
<th></th>
<th>FY2012 Enacted</th>
<th>FY2013 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Technology</td>
<td>13,911</td>
<td>11,666</td>
</tr>
<tr>
<td>Advanced Design Studies</td>
<td>4,337</td>
<td>1,611</td>
</tr>
<tr>
<td>Materials Research</td>
<td>7,729</td>
<td>9,371</td>
</tr>
<tr>
<td>Total Funding, Enabling R&amp;D</td>
<td>25,977</td>
<td>22,648</td>
</tr>
</tbody>
</table>
Advances in validated simulation are critical for fusion’s future success.

How we use validated simulation as instruments of scientific discovery is a great question for science overall.

How we execute our simulation efforts in terms program governance, including the relation between universities and labs, is critical.

- Theory and computation is an important element of every aspect of the fusion and plasma sciences.
- In FY2013, the scope of the Theory program will be narrowed.
- SciDAC: the scope and balance of the portfolio will be maintained, but fewer Centers may be selected for an award following the FY2012 recompetition of a significant portion of the FES SciDAC program.

<table>
<thead>
<tr>
<th></th>
<th>FY2012 Enacted</th>
<th>FY2013 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory and modelling</td>
<td>24,348</td>
<td>20,836</td>
</tr>
<tr>
<td>SciDAC</td>
<td>8,312</td>
<td>6,556</td>
</tr>
</tbody>
</table>
Experimental Plasma Research Portfolio and MST are nearly flat-funded

<table>
<thead>
<tr>
<th></th>
<th>FY’12 Enacted</th>
<th>FY’13 Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madision Symmetric Torus</td>
<td>6,000</td>
<td>5,750</td>
</tr>
<tr>
<td>Experimental Plasma Research</td>
<td>11,000</td>
<td>10,500</td>
</tr>
</tbody>
</table>

- Maintains critical level of effort to enable connections between non-tokamak and tokamak configurations
- Validation and verification emphasis maintained
- National lab/university teaming among confinement concepts is being developed to address questions of universal importance to magnetic fusion

From EPAct plan

Major elements of the U.S. magnetic configuration portfolio
HEDLP program specifics will be informed by the outcome of a competitive merit review of much of the program in FY2012 and FY2013, the forthcoming NRC Inertial Fusion Energy (IFE) study report and the Department’s response to it, and programmatic priorities.

In GPS, commitments to NSF/DOE interagency activities will be maintained. Program balance of the laboratory GPS projects will be critically reviewed through competitive peer review.
On program planning
Ultimately, the U.S. fusion’s path forward will be expressed in terms of scientific elements and will include changes of emphasis.

- Burning plasma science and stewarding broader plasma science will be key elements, but program scope may have to be reduced for lower funding level scenarios.

- Major domestic facilities will still engage in plasma dynamics and control, but will shift focus towards challenging metrics relevant to fusion materials science.

- Leverage between domestic and international research opportunities in MFE will become even more important in tough budget times, if the U.S. is to obtain access to the leading scientific questions in the next decade.
- Mandated by legislative language accompanying the FY’12 appropriation

- Technical community input is needed

- What we have in hand includes ReNeW reports, the “Priorities, Gaps, and Opportunities” analysis, and FESAC’s new input on international research and fusion materials science.
On gathering input and developing the report

- **FES will present a charge to FESAC to seek advice in time to be impactful.** A charge or charges is/are being developed, and your thoughts on this will be welcome.

- **Timing:** clarification on a couple of fronts will be beneficial
  - the Administration approach to ITER and the domestic program
  - the House and Senate marks this year

- **Input from individuals on programmatic concerns and possible future structures** is welcome at any time.

- **Plan will be developed by FES and shared with FESAC for comment,** likely in the fall of ‘12.
The nurturing of a domestic program that enables a high degree of leverage and influence in the world, and will engage ITER in as scientifically constructive a manner as possible, with a high return for the U.S.

Such a program must include a vigorous international component if U.S. scientists are to have access to research questions that will remain inaccessible within the U.S. alone.

The development of a capability to make major contributions in fusion materials science and harnessing fusion power.

A priority of maintaining program breadth if budgets permit, noting that the prospect of further non-ITER program reductions may make it impossible to maintain present program scope.
Establishing the scientific basis for fusion requires strong domestic research and leverage across national and institutional boundaries.

Plasma control science: self-heated at reactor scale
ITER
- Integrated simulation at all relevant scales
- \( \tau_{\text{pulse}} \approx 500-3000 \text{ s} \)
- Long pulse plasma control
- \( \tau_{\text{pulse}} \approx 1000 \text{ s}, 1/3 \text{ reactor scale} \)
- Discovery Science

Leverage:
- International, cross-agency
- Present day

Fusion nuclear science: integrated
Component: fuel cycle
- Validated understanding: dpa's, fuel cycle, heat flux
- Fusion materials science: elements
- High heat fluxes
- Nuclear effects
- Science basis for fusion nuclear science facility design

Science basis for burning plasma control & prediction
Plasma science foundation for discovery

Burning plasma era

The foundation: present day
- Domestic Confinement Experiments, low and moderate aspect ratio
- Simulation of individual processes
- Validation platforms
- Discovery science with Joint U.S. programs
Thank you