# Fusion Nuclear Science Facility and Program

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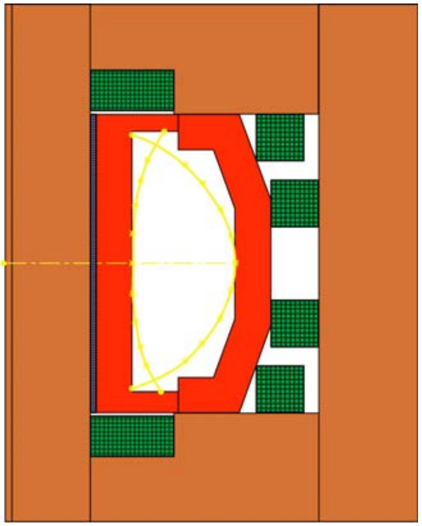
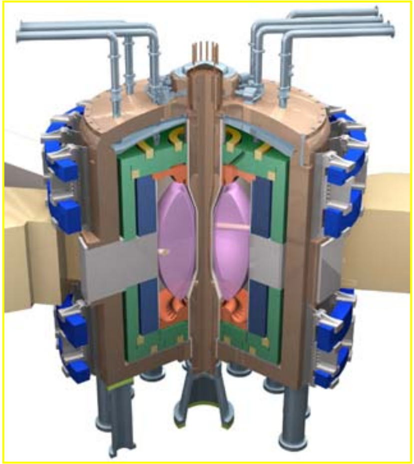
GENERAL ATOMICS

# Mission of a Fusion Nuclear Science Facility (FNSF) Two Candidates: FNSF-AT (FDF) and FNSF-ST (ST-CTF)

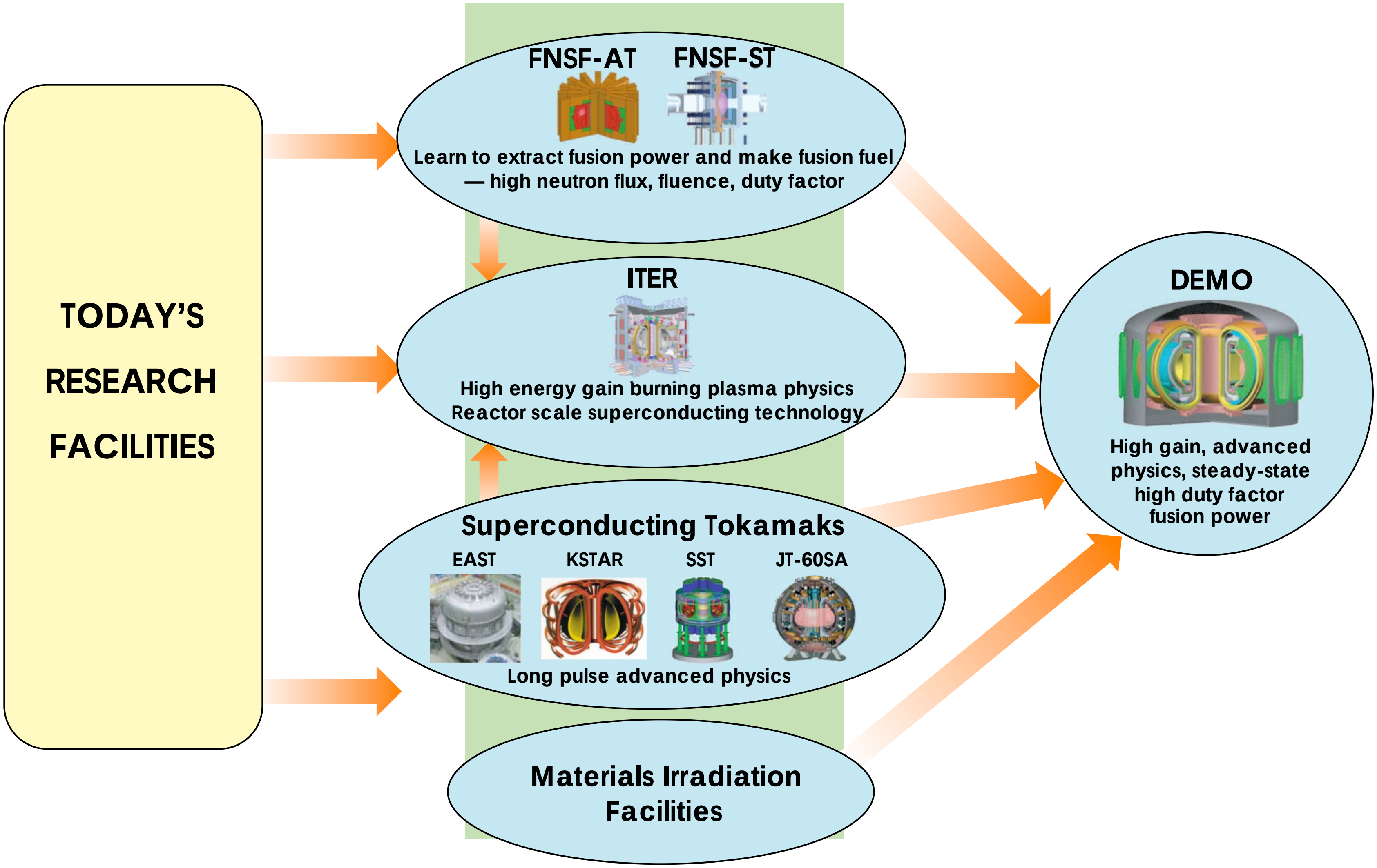
- **FNSF should:**
  - Produce significant **fusion power** (100-300 MW)
  - Demonstrate **fusion fuel self-sufficiency**
  - Show fusion can produce high grade **process heat and electricity**
  - Provide a **materials irradiation facility** to develop low activation, high strength, high temperature, radiation resistant materials
  - Enable research on **high performance, steady-state, burning** plasmas for Demo





- **By operating steady-state with**
  - Modest energy gain (1<Q<7)
  - Operate 30% of a year in 2 week periods
  - High neutron fluence (3-6 MW-yr/m$^2$)

# Research on FNSF, ITER, Superconducting Tokamaks, and Materials Irradiation Facilities Enables DEMO



# The FESAC Planning Panel Identified the Gaps That Must Be Filled Between ITER and a DEMO

## How Initiatives Could Address Gaps

Legend

| | |
|---|---|
| Major Contribution | 3 |
| Significant Contribution | 2 |
| Minor Contribution | 1 |
| No Important Contribution | |

| | G-1 Plasma Predictive capability | G-2 Integrated plasma demonstration | G-3 Nuclear-capable Diagnostics | G-4 Control near limits with minimal power | G-5 Avoidance of Large-scale Off-normal events in tokamaks | G-6 Developments for concepts free of off-normal plasma events | G-7 Reactor capable RF launching structures | G-8 High-Performance Magnets | G-9 Plasma Wall Interactions | G-10 Plasma Facing Components | G-11 Fuel cycle | G-12 Heat removal | G-13 Low activation materials | G-14 Safety | G-15 Maintainability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I-1. Predictive plasma modeling and validation initiative | 3 | 2 | | 2 | 2 | 3 | 1 | | 2 | | | | | | |
| I-2. ITER – AT extensions | 3 | 3 | 3 | 3 | 3 | | 2 | | 2 | 2 | 1 | 1 | | 1 | 1 |
| I-3. Integrated advanced physics demonstration (DT) | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 |
| I-4. Integrated PWI/PFC experiment (DD) | 2 | 1 | | 1 | 2 | | 2 | 1 | 3 | 3 | 1 | 1 | | 1 | 1 |
| I-5. Disruption-free experiments | 2 | 1 | | 2 | 1 | 3 | | 1 | 1 | 1 | | | | | |
| I-6. Engineering and materials science modeling and experimental validation initiative | | | | | | | 1 | 3 | 1 | 3 | 2 | 3 | 3 | 2 | 1 |
| I-7. Materials qualification facility | | | | | | | 1 | | | 3 | 2 | 1 | 3 | 3 | |
| I-8. Component development and testing | | | 1 | | | | 2 | 1 | | 3 | 3 | 3 | 2 | 2 | 2 |
| I-9. Component qualification facility | 1 | 1 | 2 | 1 | 2 | | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| FDF | 2 | 3 | 3 | 3 | 3 | | 3 | | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

*** A Fusion Nuclear Science Program and Facility Fills Nearly All the Gaps**

# The FNSF Objectives Are Complementary to ITER

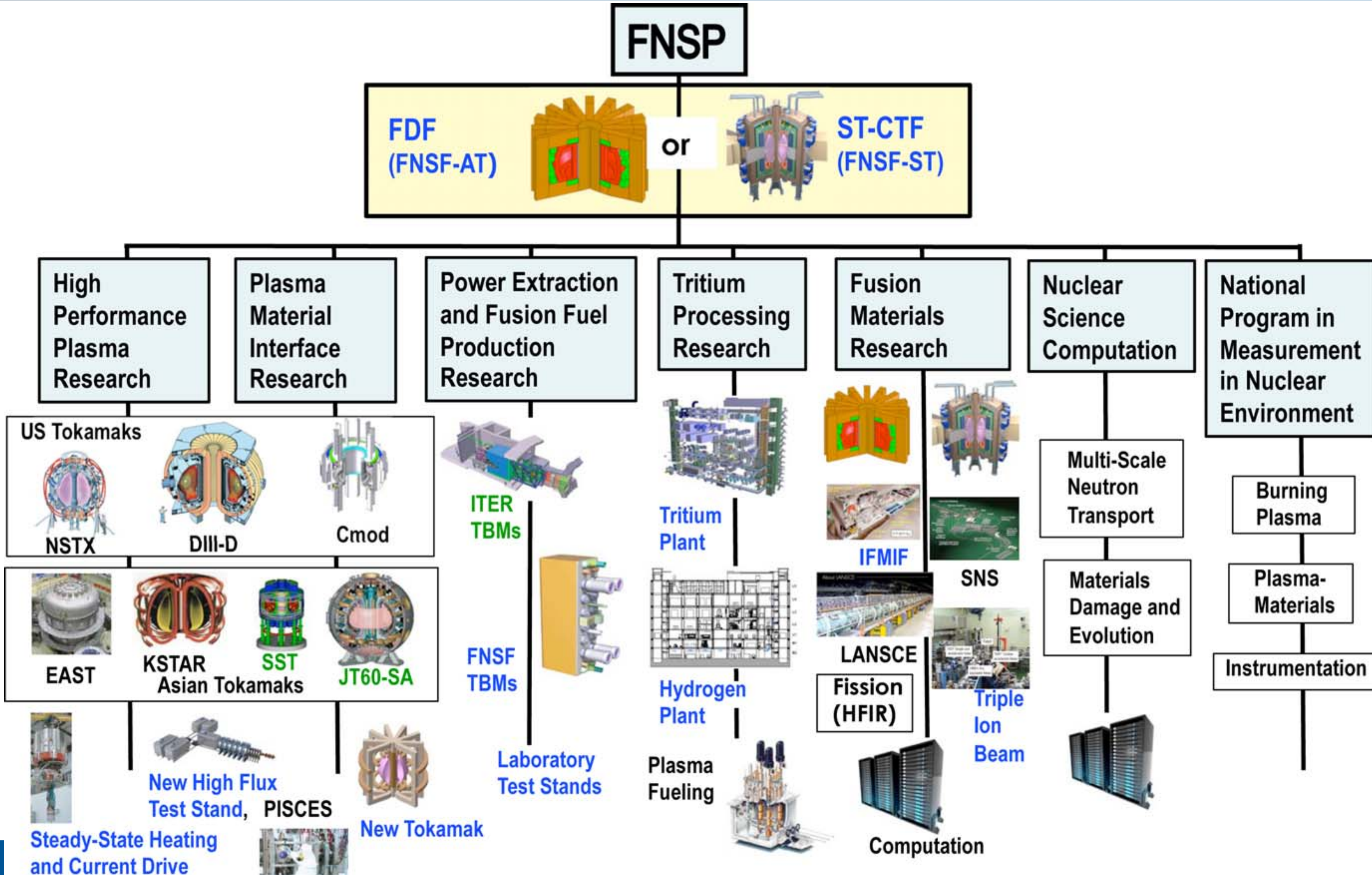
| Issue | Today's Exp'ts | ITER | FNSF -AT | Mat'Is Irrad Facs | ITER+ Mat'Is+ FNSF-AT | DEMO |
|---|---|---|---|---|---|---|
| High Gain Q > 10 | | 3 | 2 | | 3 | R |
| Alpha Containment & Physics | 1 | 3 | 2 | | 3 | R |
| Confinement at Large Size | 1 | 3 | 1 | | 3 | R |
| Pulsed Heat Loads | 1 | 3 | 1 | | 3 | R |
| Reactor Scale Superconducting Technology | 1 | 3 | | | 3 | R |
| Exhaust Power Handling ( ~10 $MWm^{-2}$) | 1 | 3 | 3 | | 3 | R |
| Tritium Handling and Safety | 1 | 3 | 3 | | 3 | R |
| Integrated Plasma Performance in SS | 1 | 2 | 2 | | 3 | R |
| Steady-State @ High Beta ($\beta_N$, $f_{bs}$) | 1 | 2 | 3 | | 3 | R |
| High Neutron Wall Loading ( $\Gamma_n$ ~ 2 $MWm^{-2}$) | 1 | 2 | 3 | | 3 | R |
| Tritium Self-Sufficiency (TBR > 1) | | 1 | 3 | | 3 | R |
| PFC and Divertor Materials Lifetime | 1 | 2 | 3 | | 3 | R |
| FW/Blanket Materials/Components Lifetime | | 1 | 3 | 1 | 3 | R |
| Materials Characterisation (>100 dpa) | | 1 | 2 | 3 | 3 | R |
| High Temperature Blankets (electricity, $H_2$) | | 2 | 3 | | 3 | R |

Key:

| | |
|---|---|
| 1 | Will help to resolve the issue |
| 2 | Will contribute significantly to resolution of the issue |
| 3 | Should resolve the issue |
| R | Solution is essential |

Today's Expt's = DIII-D, C-Mod, NSTX, JT-60U, JET, ASDEX-U, Tore Supra, JT-60 SA, KSTAR, EAST, SST-1

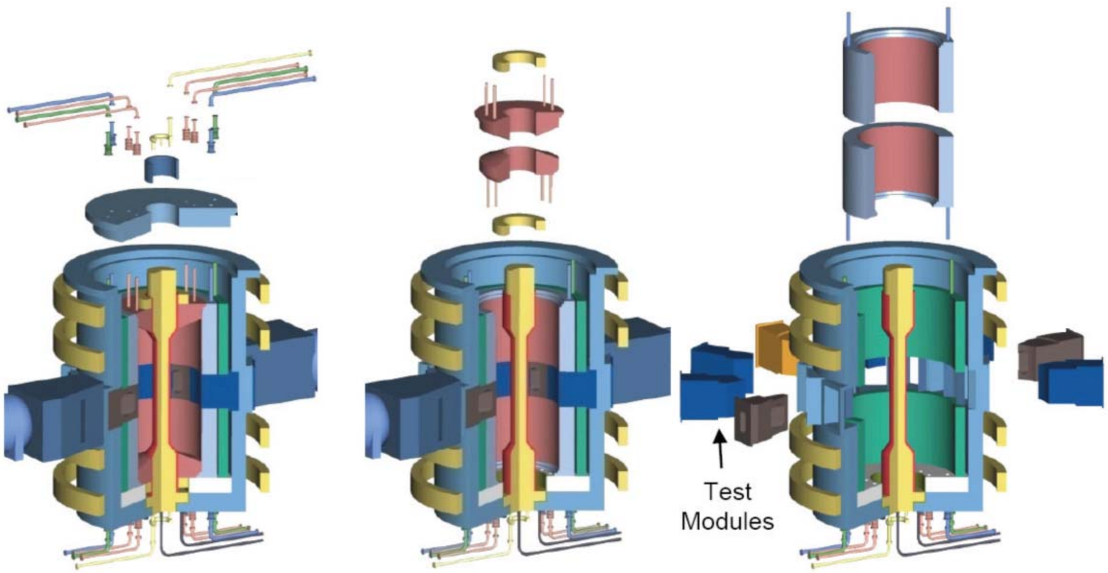
# An FNSF Can Be the Lead Element in a Broader Fusion Nuclear Science Program (FNSP)



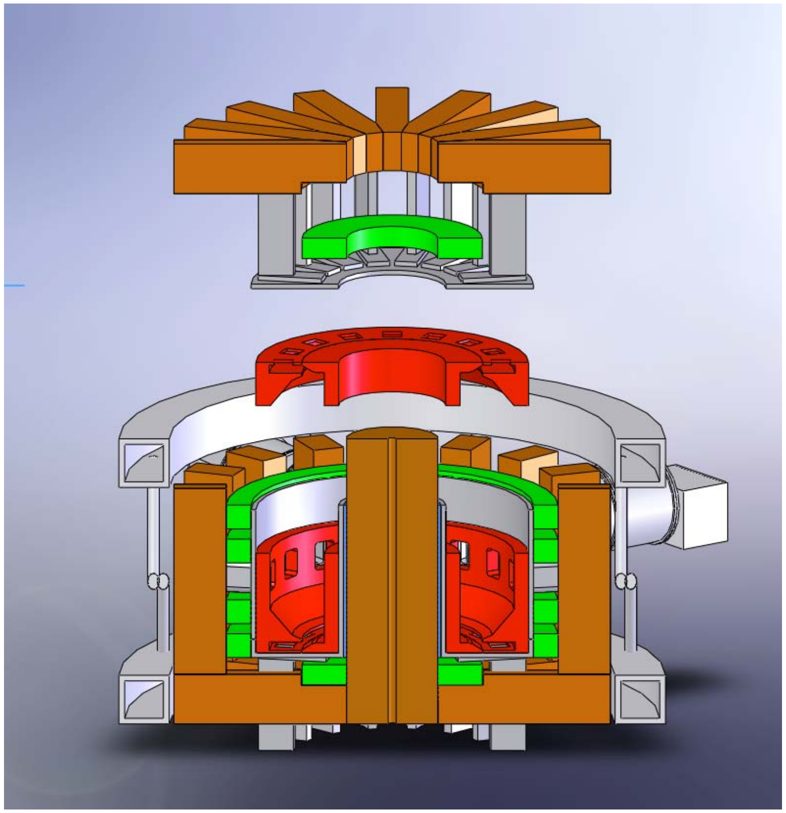



GENERAL ATOMICS

# FNSF Must be a Research Device: Maintainable, Flexible, Re-configurable




ORNL FNSF-ST



GA FNSF-AT (FDF)

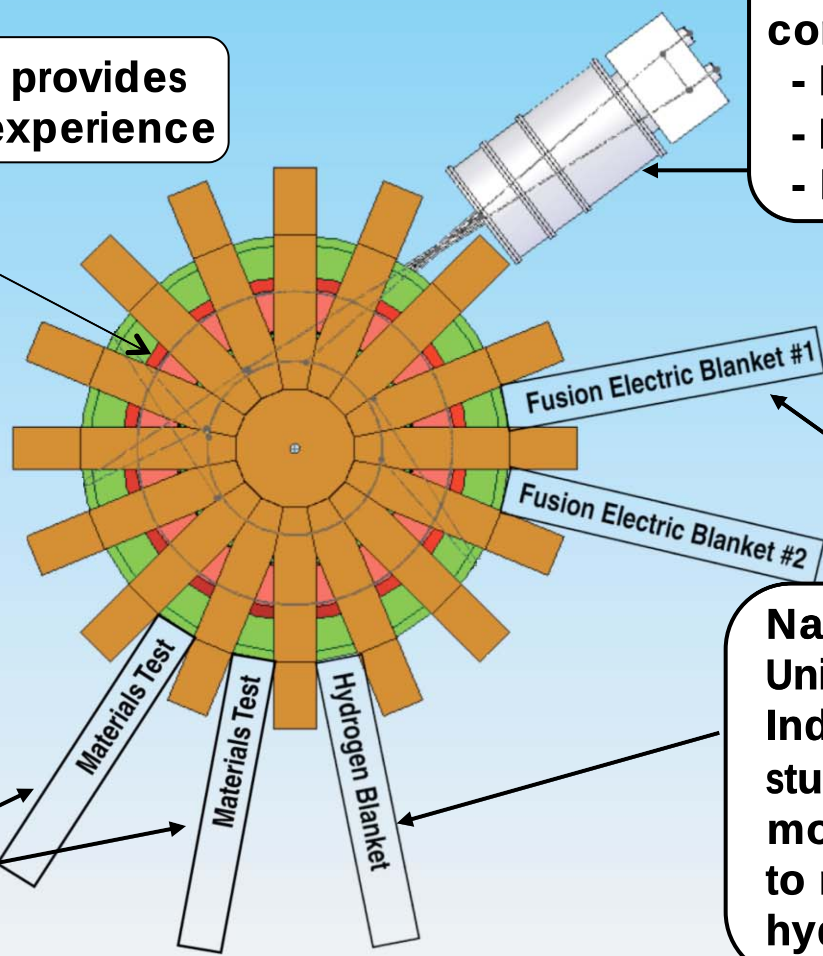
*A defining characteristic of device approaches

# FNSF Will Support Large National User Teams (Goal 1000 Users)

Full tritium breeding blanket provides fusion nuclear component experience

Off-axis current profile control
- ECCD
- Lower Hybrid
- NBCD

A national diagnostic development program will develop measurements that survive the neutron environment




National User Team of Universities, Labs, and Industry materials scientists will control and use materials irradiation port sites

National User Teams of Universities, Labs, and Industry will field and study test blanket modules to extract heat to make electricity and hydrogen

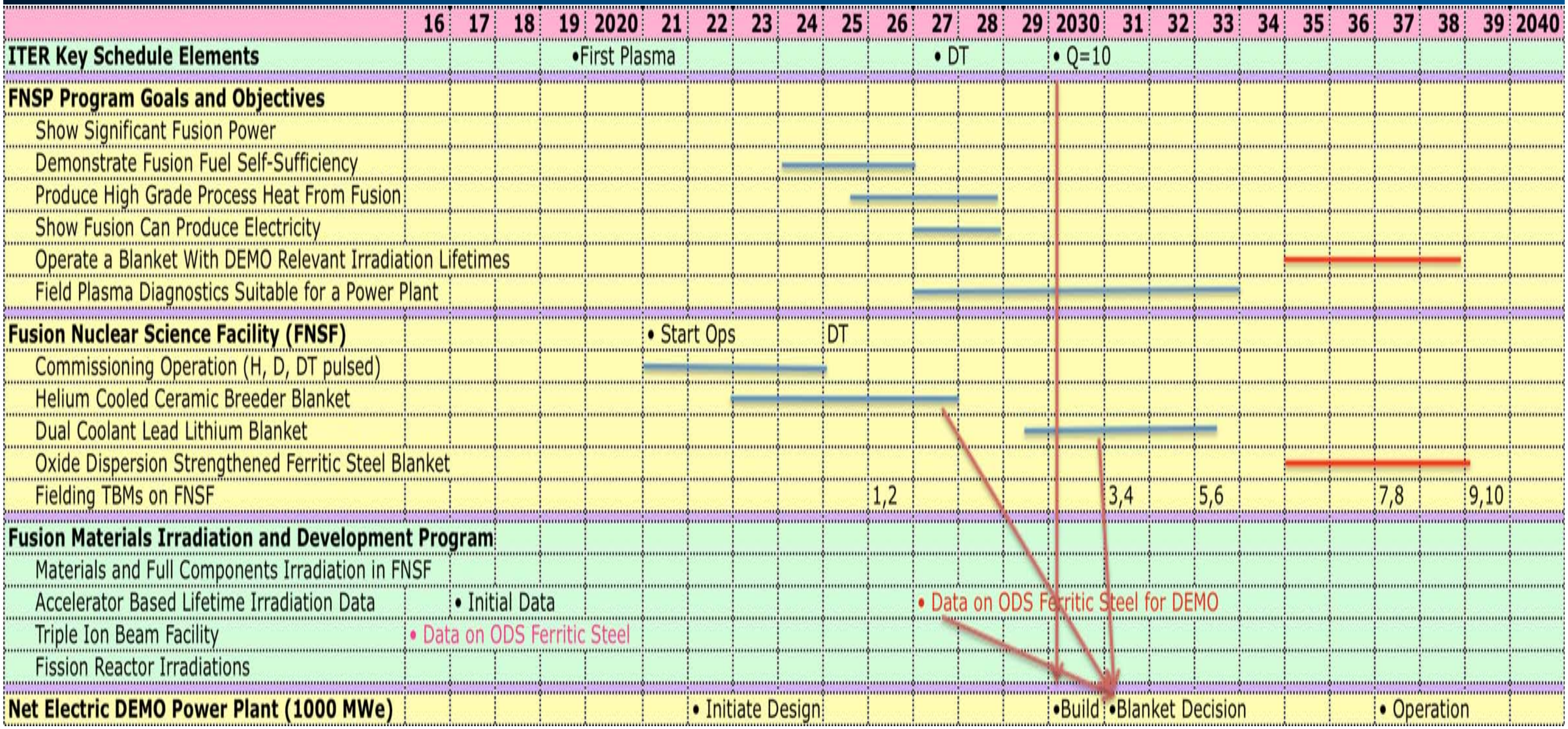


GENERAL ATOMICS

# The Research Program Envisions Three Main Blanket Phases and a TBM Program

| | START UP (years 1–4) H | D | DT | FIRST MAIN BLANKET (years 5–9) | | (years 10–11) | SECOND MAIN BLANKET (years 12–16) | | (years 17–18) | THIRD MAIN BLANKET (years 19–23) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fusion Power (MW) | 0 | 0 | 125 | 125 | 250 | | 250 | 250 | | 250 | 400 |
| $P_N/A_{WALL}$ ($MW/m^2$) | | | 1 | 1 | 2 | | 2 | 2 | | 2 | 3.2 |
| Pulse Length (Min) | 1 | | 10 | SS | SS | | SS | SS | | SS | SS |
| Duty Factor | 0.01 | | 0.04 | 0.1 | 0.2 | | 0.2 | 0.3 | | 0.3 | 0.3 |
| T Burned/Year (kG) | | | 0.28 | 0.7 | 2.8 | | 2.8 | 4.2 | | 4.2 | 5 |
| Net Produced/Year (kG) | | | | –0.14 | 0.56 | | 0.56 | 0.84 | | 0.84 | 1 |
| Main Blanket | He Cooled Solid Breeder Ferritic Steel | | | | | | Dual Coolant Pb-Li Ferritic Steel | | | Best of TBMs RAFS? | |
| TBR | | | | 0.8 | 1.2 | | 1.2 | 1.2 | | 1.2 | 1.2 |
| Test Blankets | | | | 1,2 | | | 3,4 | 5,6 | | 7,8 | 9,10 |
| Accumulated Fluence ($MW\text{-}yr/m^2$) | | | 0.06 | | 1.2 | | | 3.7 | | | 7.6 |

# A Fast Track Plan to Get to a Net Electric DEMO




DEMO design initiated by first plasma in ITER. DEMO construction triggered by Q=10 in ITER, first phase accomplishments in FNSF, and materials data on ODS Ferritic Steel. FNSF enables choice between two most promising blanket types for DEMO.



GENERAL ATOMICS

# FNSF Must Make Steady-State Fusion Power and a Series of Progress Elements Toward Fusion Energy

- **Produce significant fusion power in true steady-state** (< 3 dpa)
- **Show fusion can make its own fuel**
  - Initial result in < 3 dpa
  - Full blanket development program in 10-20 dpa
- **Extract high grade process heat from fusion reactions**
  - Initial result in < 3dpa, full results in 10-20 dpa
- **Show electricity produced from the process heat**
  - 300 kW from one of the first test blanket modules (< 3dpa)
- **Show fusion chambers can survive high plasma and neutron fluences**
  - Results obtained for three blanket types (10-20 dpa to each)
- **Develop plasma measurements suitable for a DEMO** (10-20 dpa)
- **Obtain high fluence irradiation data on materials, assemblies, welds, etc.** (30-60 dpa lifetime, survey 50,000 samples at 20 dpa)