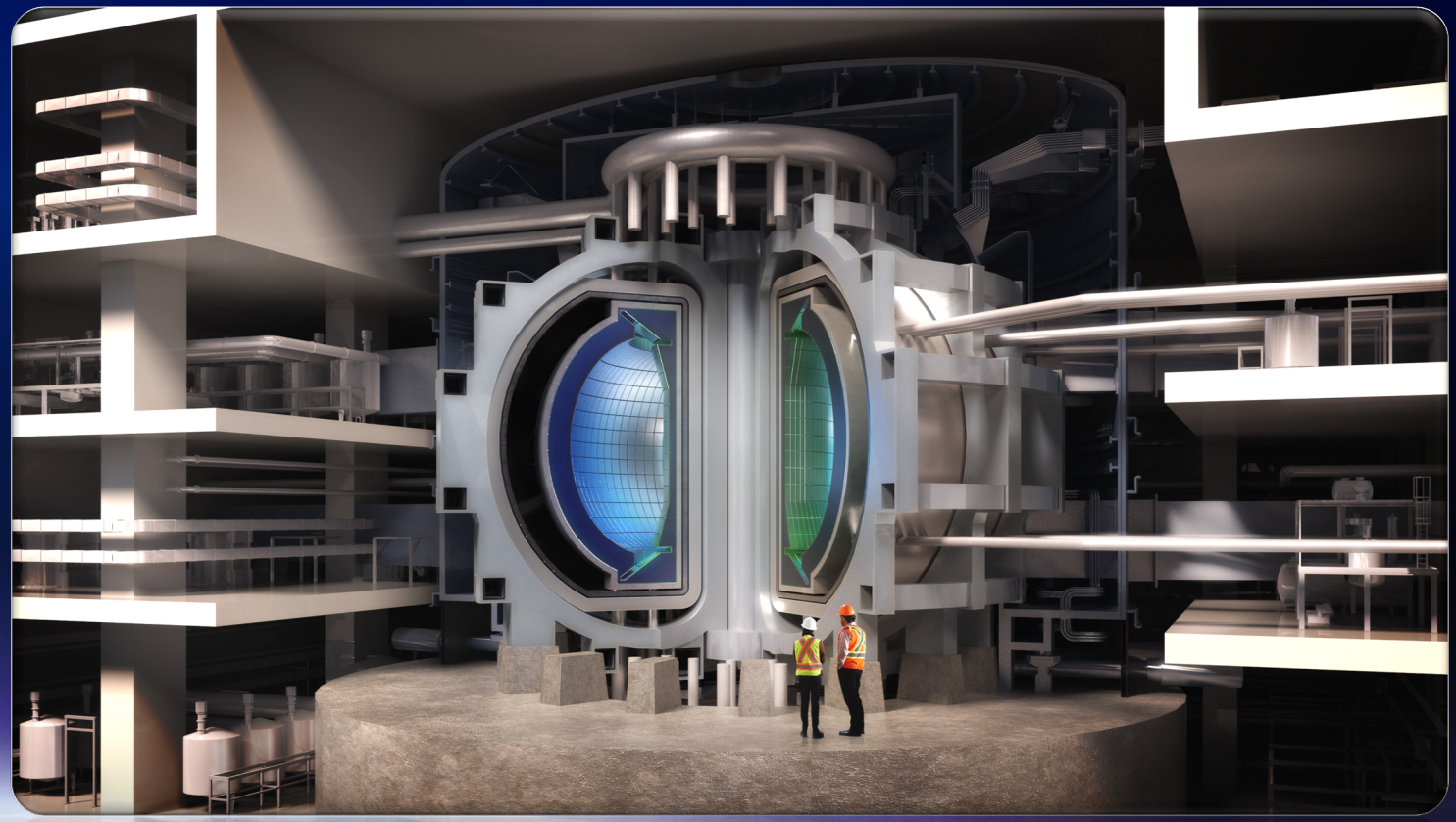
Overview of GA Efforts to Design and Build a Fusion Pilot Plant

Presented at

Fusion Power Associates
43rd Annual Meeting
and Symposium:
The Road Ahead



By

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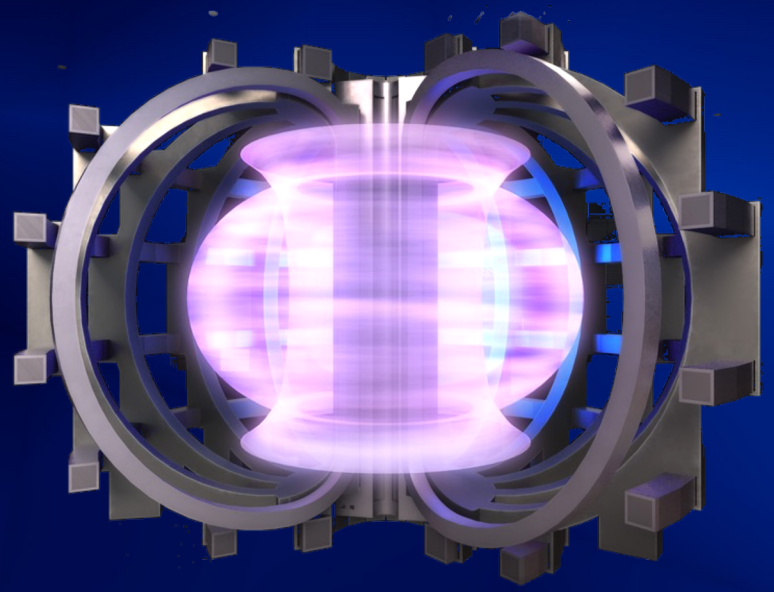
The Steady-State Tokamak Offers Key Attractive Features



- ✓ **200 MWe**
- ✓ **Steady-State fusion**
- ✓ **Continuous operation and power production**

- **Cost effective by maximizing fusion performance**
  - Fusion power density ~ p^2 → levering for given field
  - High fraction of self-driven current at high pressure
  - Efficient current drive minimizes recirculating power
- **Robustness against operational transients**
  - High plasma pressure at reduced current avoids instabilities that could interrupt facility operation
- **Avoidance of cyclic stresses & fatigue**
  - High availability, minimized maintenance costs, long facility lifetime

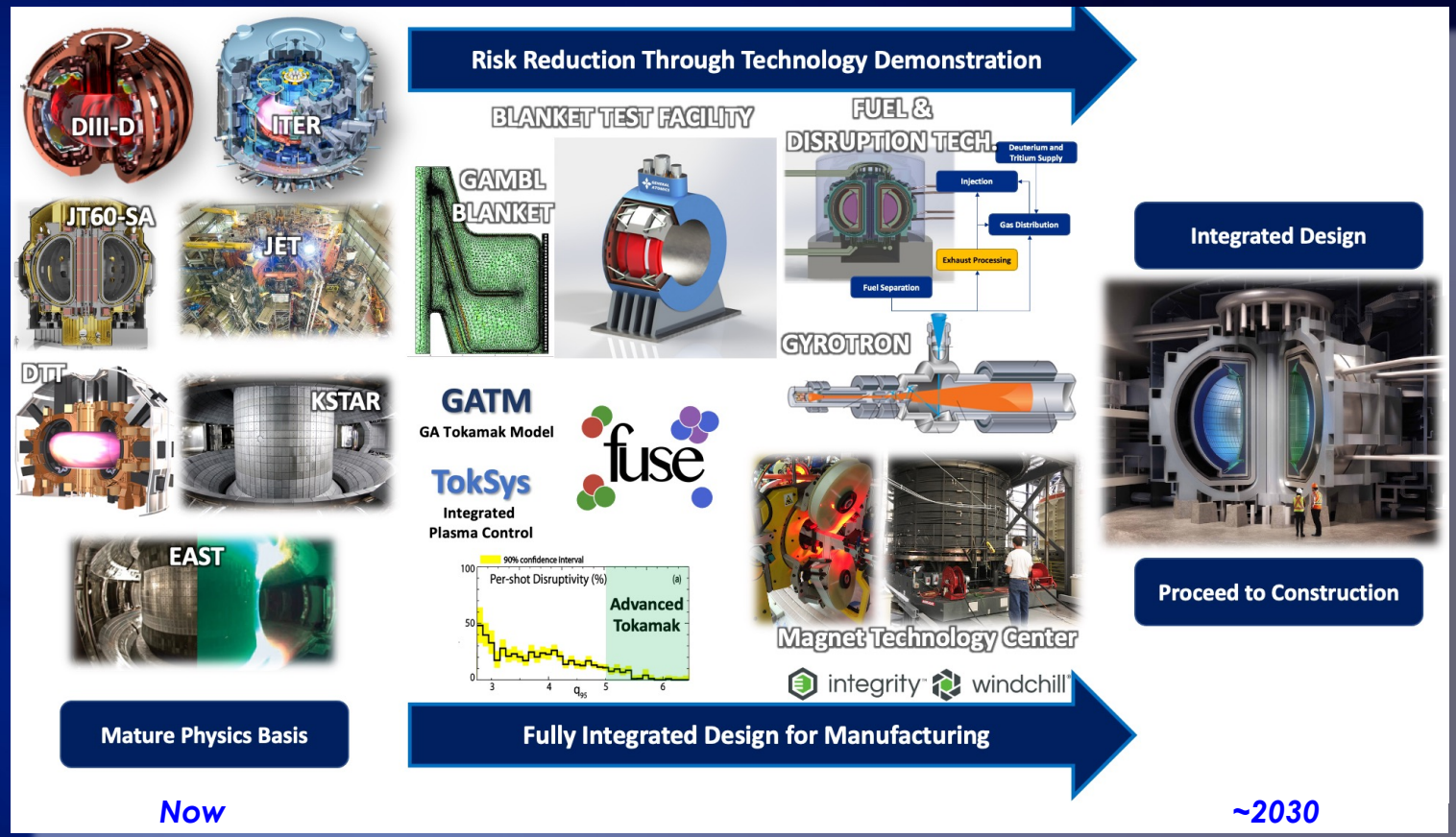
The Path to Fusion Commercialization for Carbon-free Energy Requires Multiple Developments and Considerations

- **Produce net electricity from fusion**
  - Most rapidly done by minimizing capital cost using approaches with a firm scientific basis
- **Design so pilot scales to commercial plant**
  - Economical competitiveness for electricity
  - Establishes supply chain
  - Embracing workforce development social considerations
- **Close remaining science & technology gaps**
  - Use of existing/emerging facilities
  - Advanced computation for high fidelity simulations
  - Test stands demonstrating function in relevant environment

Success demands broad engagement and strong partnerships with transparent integration and coordination

FPP Design Maturation Staged in Parallel with Technology Demonstrations

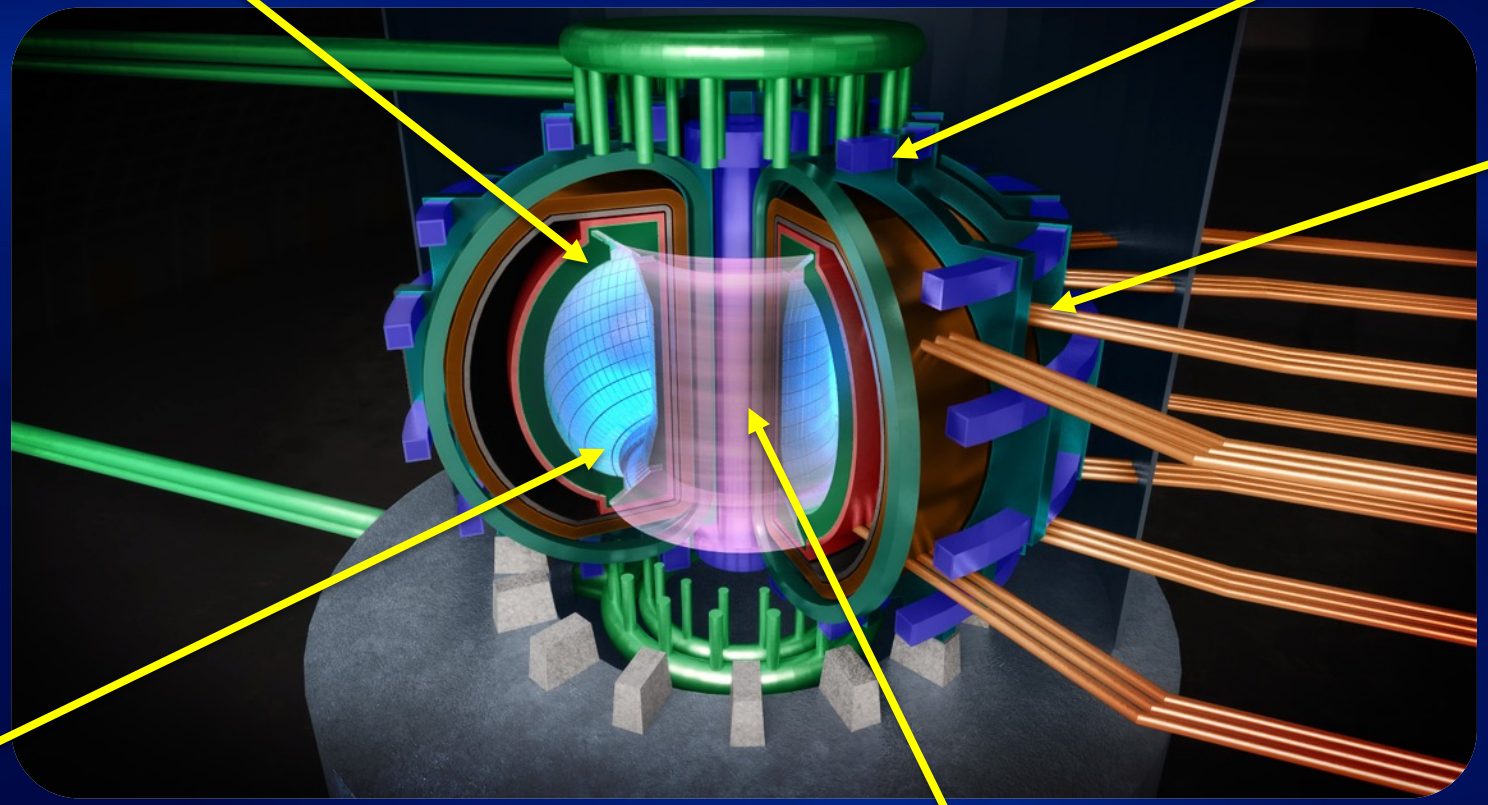
- **Leverages**
  - Mature physics basis
  - Validated modeling
  - Worldwide experience of tokamak operation and performance
- **Mature critical technologies**
  - Tritium breeding
  - Fuel cycle
  - Power extraction
  - H&CD systems



GA and Partners Are Addressing Challenges with Innovations

Innovative blanket concept to maximize TBR

Magnet joints for maintenance



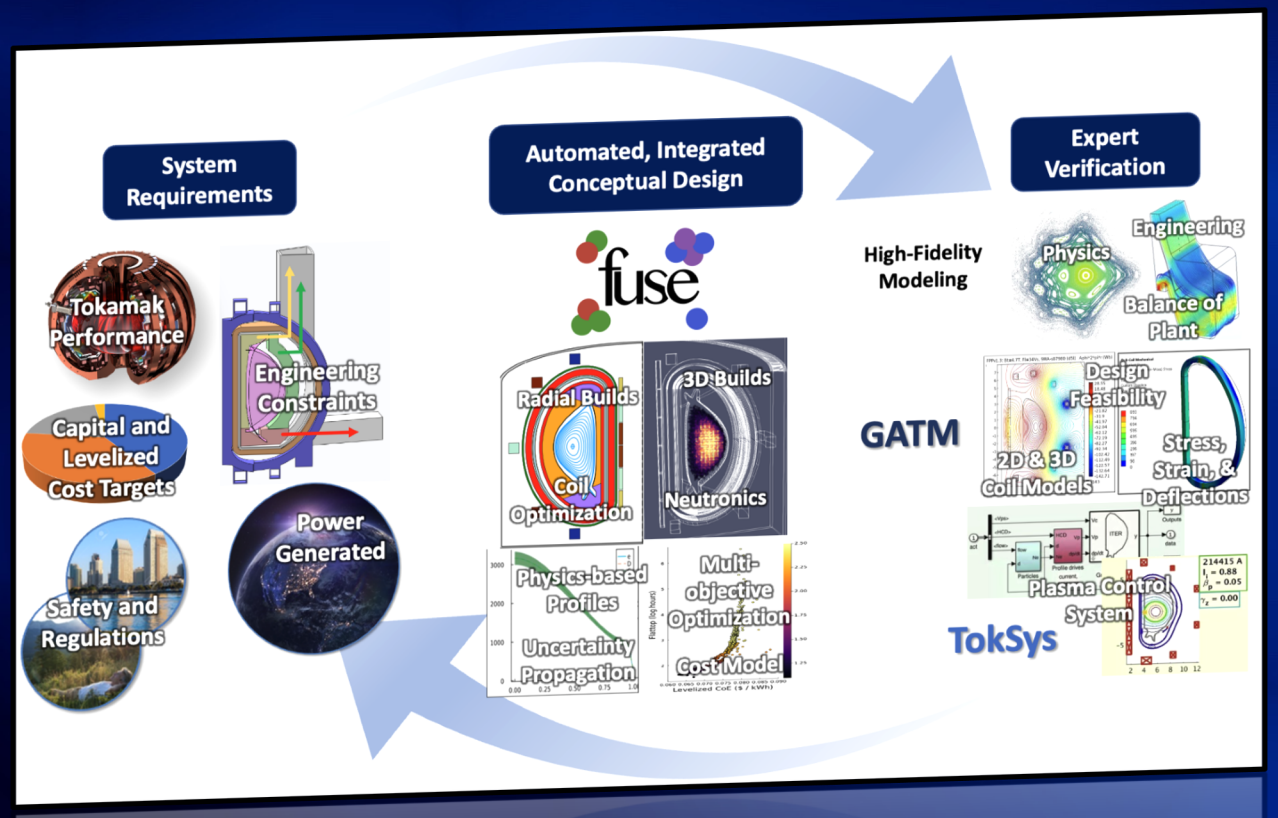
New components to increase H&CD efficiency

Efficient power conversion (high temp >800°C)

Test new materials for first wall in relevant environment

Validated science integrated into design workflow

Rapid Design Cycle Enabled by Automated Approach Coupling Physics Simulations and Engineering Constraints

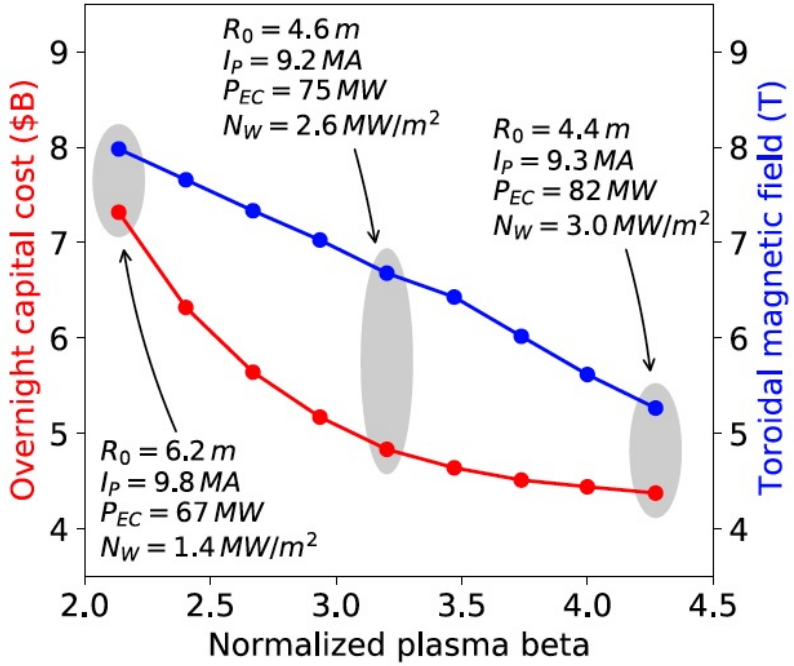


- **Fusion Synthesis Engine (FUSE): GA's proprietary integrated modeling and whole facility design tool**
  - Uses HPC to enable high fidelity FPP designs with unprecedented speed
  - Includes models for physics, engineering, control, and costing
  - First principles, reduced models and machine learning as needed
  - GA Tokamak Model (GATM) to design magnet-plasma system in COMSOL
  - Toksys to design algorithms for PCS

Rapid Design Capability Enables Us to Carry a Range of Design Points Forward

- **Higher performance than ITER in more compact device**
  - Need to tension risks between:
    - Physics (normalized beta, confinement)
    - Engineering (magnetic field, stresses, heat flux)

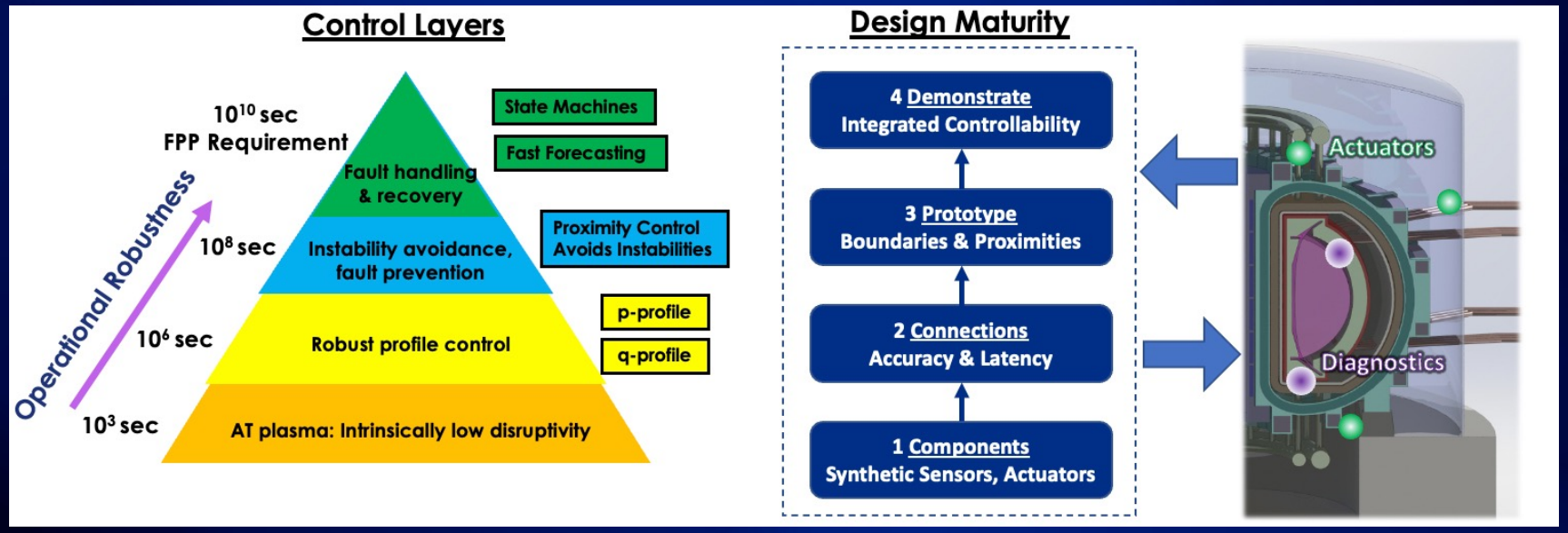
- **Risk-weighted capital cost optimization drives toward higher beta solutions**
  - Cost of magnet system dominates relative to increase H&CD



R/a	3.5	P_{NET} (MWe)	200
f_{BS}	0.8	P_{FUSION} (GW)	1.0
$f_{GW,ped}$	0.7	Q_{PLASMA}	13
T_{i0} (keV)	29	H_{98}	1.5
η_{CD}	0.36	Breeder	PbLi
η_{TH}	0.4	Coolant	Helium

Diagnostics and Control Are Integral to the FPP Design

- **Develop diagnostic approaches and proxies consistent with FPP environment**
- **Explicitly include uncertainty into design of control system and fault management**
  - Build from scenario with lowest fault rate (AT) to meet demanding regime of FPP
  - Demonstrate faster than realtime forecasting and fully integrated controllability



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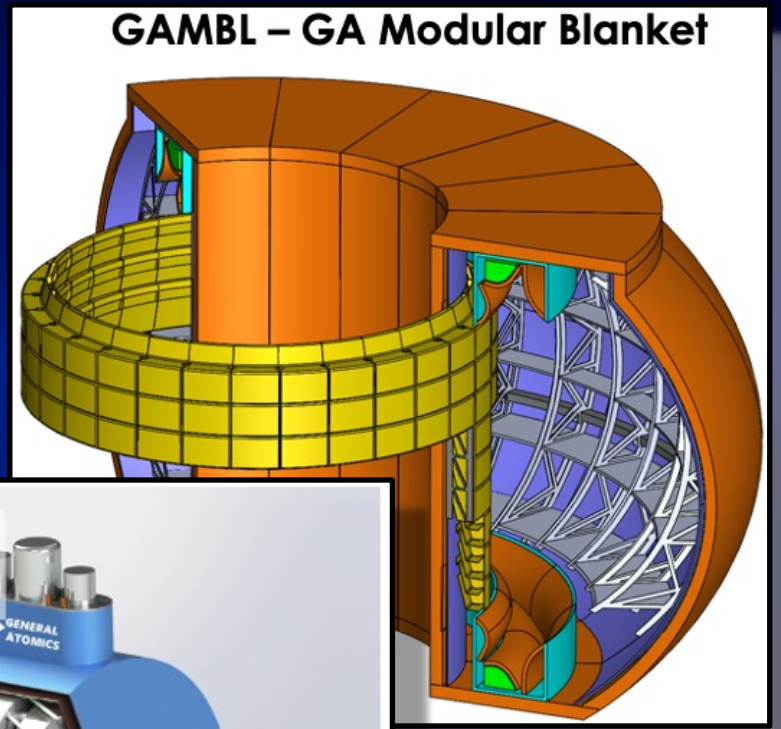
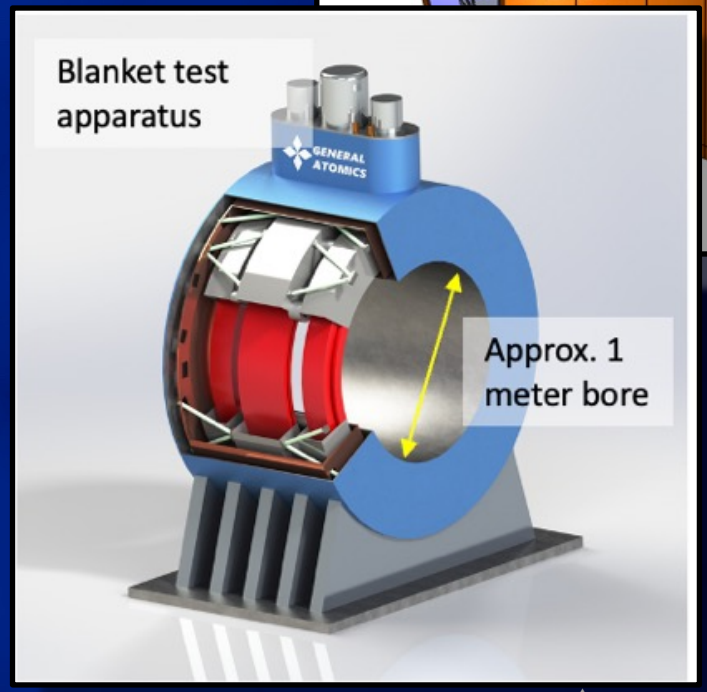
Relevant-Scale Blanket Module to Be Tested in a Purpose Built Blanket Test Apparatus

- **GA pursuing dual-cooled PbLi blanket with SiC[1] and W/SiC and embedded He cooling for first wall**
  - Low activation
  - Reduced waste and decay heat challenge for maintenance
  - High temperature strength for high thermal efficiency
  - Low corrosion
  - Helium hermiticity at pressure needed to cool a fusion first wall

- **Irradiation testing for blanket lifetime & maintenance**





[1]M. Tillack, *et. al.*, Fus. Eng. and Design **180**, 113155 (2022)

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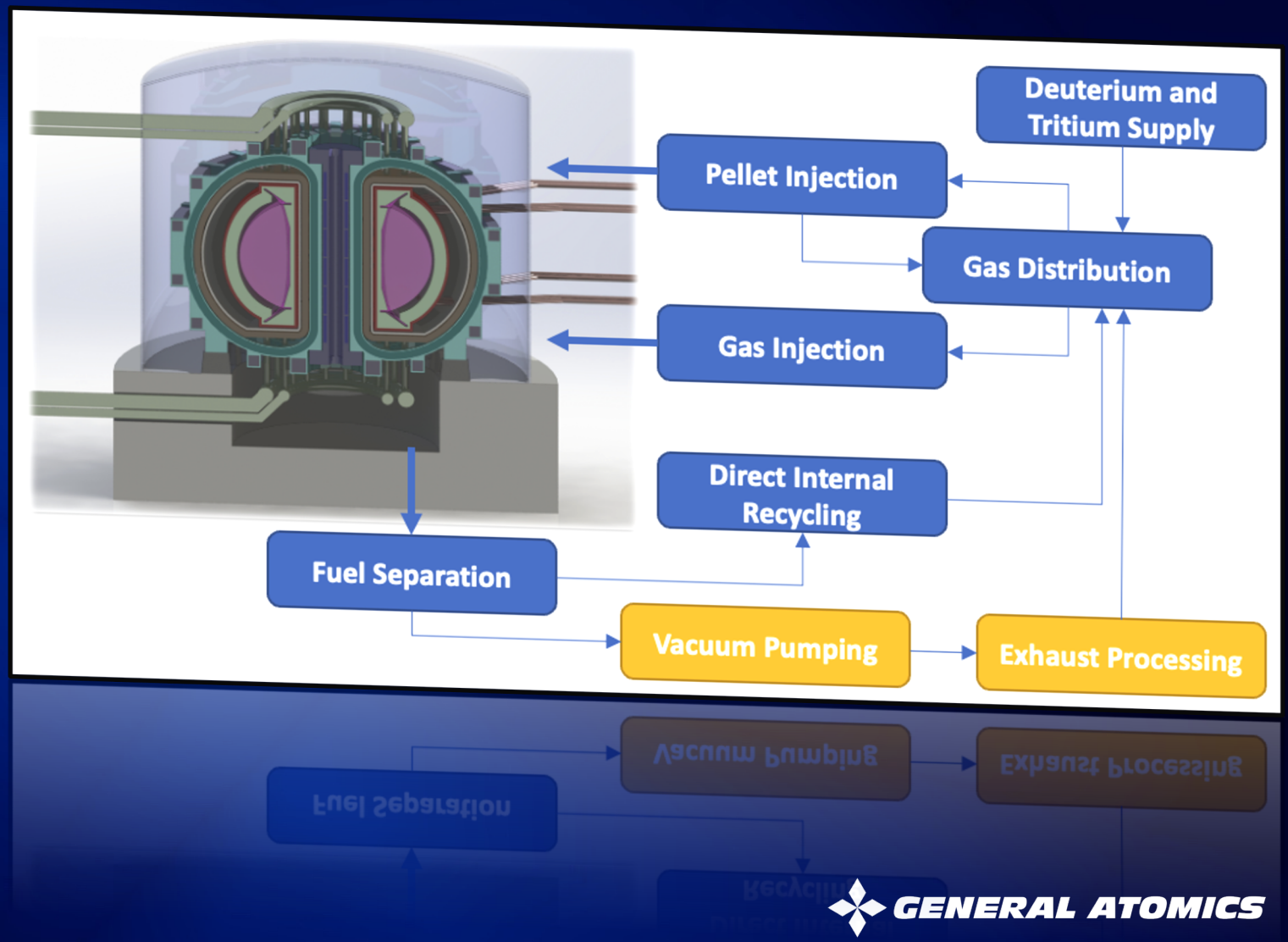
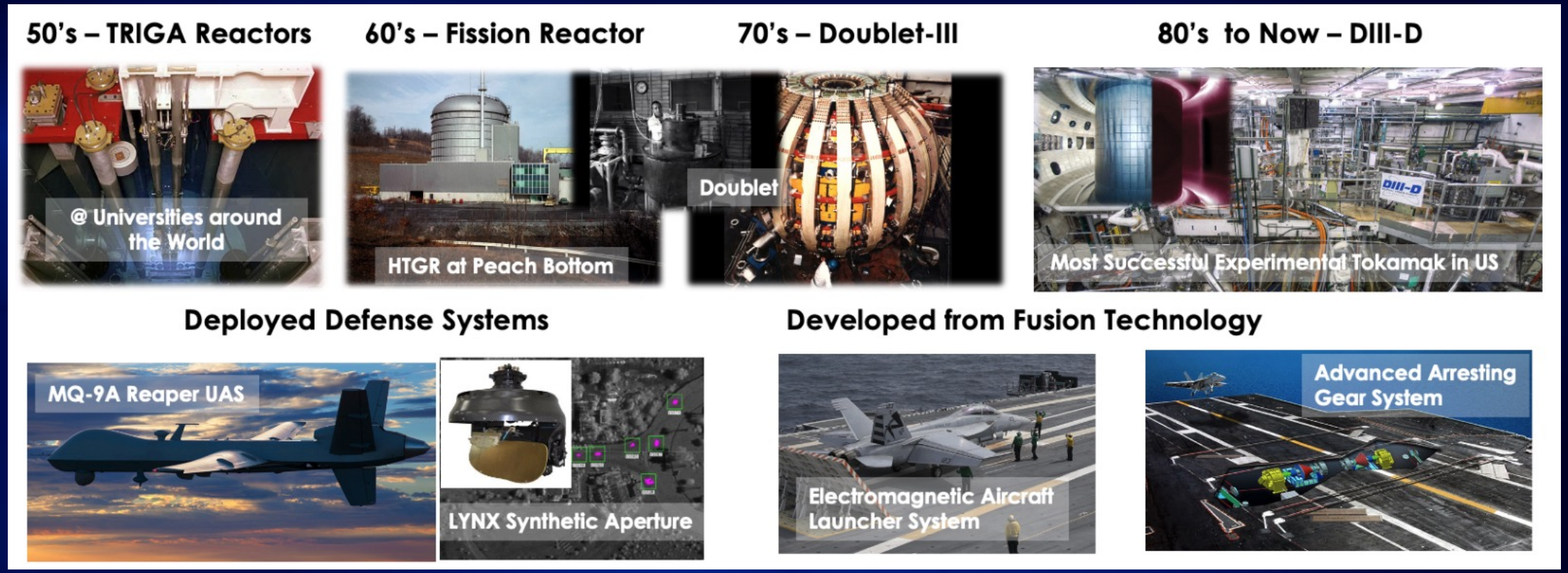
Perform Integrated Demonstration of a Closed, Steady-State, Tritium Compatible Direct Internal Recycling Fueling Loop for FPP

- **Develop pellet system for deep core fueling with increased injection speed**
  - Increases density peaking and bootstrap fraction for AT scenario

- **Improve isotope separation with metal foil pump and reduce footprint of tritium processing facility**
  - Maximize direct internal recycling of hydrogenics



General Atomics Has a Proven Track Record of Bringing Technology from the Lab to the Field

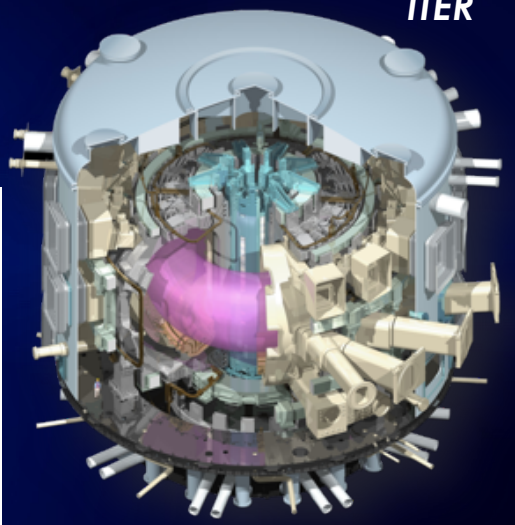


- **We are taking advantage of that expertise to ensure:**
  - Our FPP concept provides operating experience for first commercial plant
  - Is designed to minimize modifications between FPP and FOAK
  - Maximizes probability for competitive LCOE while keeping capital cost low

Commercial Fusion Will Greatly Benefit from Enhanced Public-Funded Research and Ready Access to Results from Decades of Progress

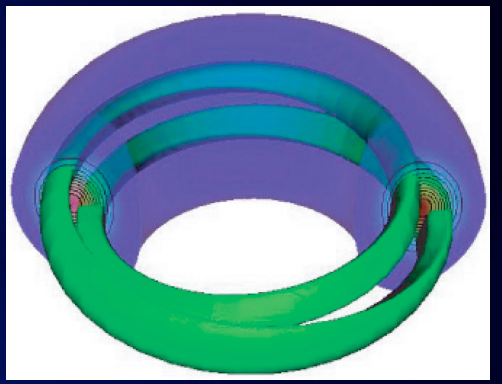
- Grows key facility capabilities to address gaps
- Provides continuity and leverages extensive lab resources
- Facilitates opportunities for testing and qualification of private sector solutions
- Enables private efforts to effectively build on progress
  - Acceleration of advances in both private and public sector

ITER

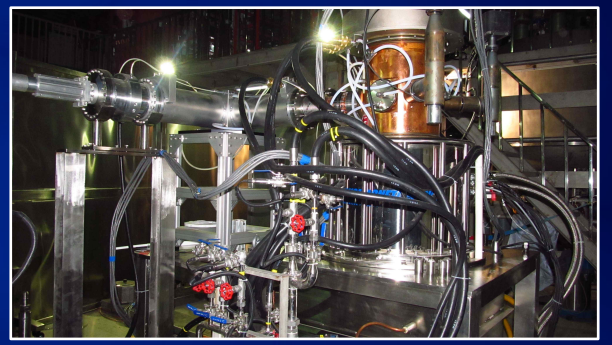


Experimental Programs

Theory & Simulation



Test Facilities



HPC resources

General Atomics Welcomes Partners to Participate in Our Fusion Pilot Plant Effort

- Steady-state advanced tokamak leverages key synergies for robust, safe and economical fusion
  Clean energy 24/7
- Deploying fusion energy requires innovation
  Innovation is in our DNA
- Successful fusion energy requires close collaboration
  Strong partnerships, effective coordination