Laser Inertial Fusion Energy

Presentation to Fusion Power Associates,

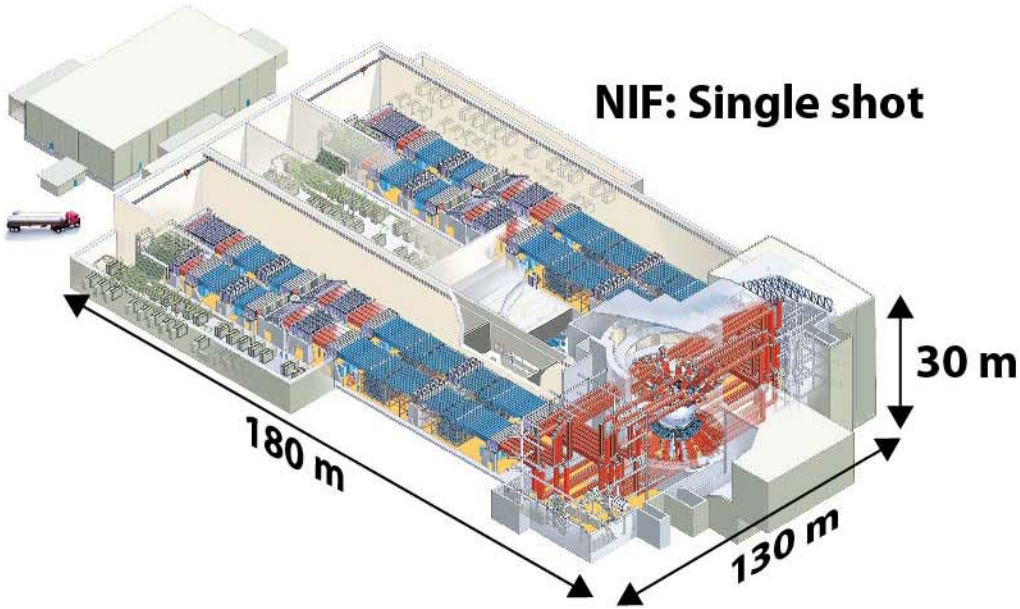
Washington DC, December 2010

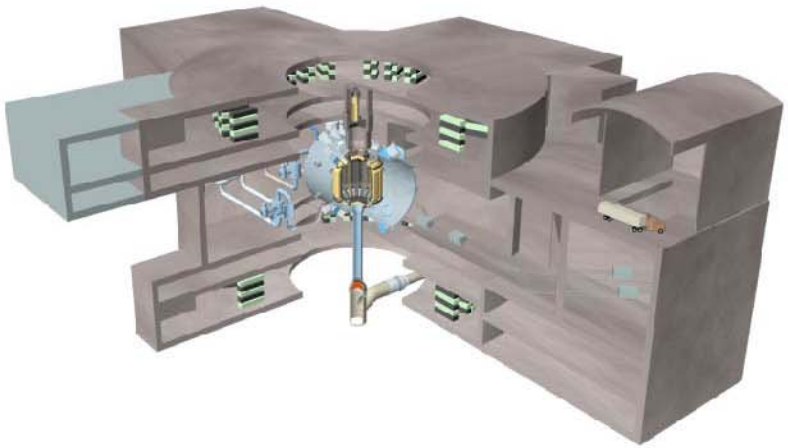
Mike Dunne
LLNL

in partnership with LANL, GA, LLE, U Wisc, U Illinois, UCSD, PPPL, NPS, SRNL

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Experience with NIF, and evidence from the ignition campaign, are being used to define a path for LIFE





Similar:
- Physical size
- Laser energy
- Target performance
- Concept of operations (LRUs, ...)

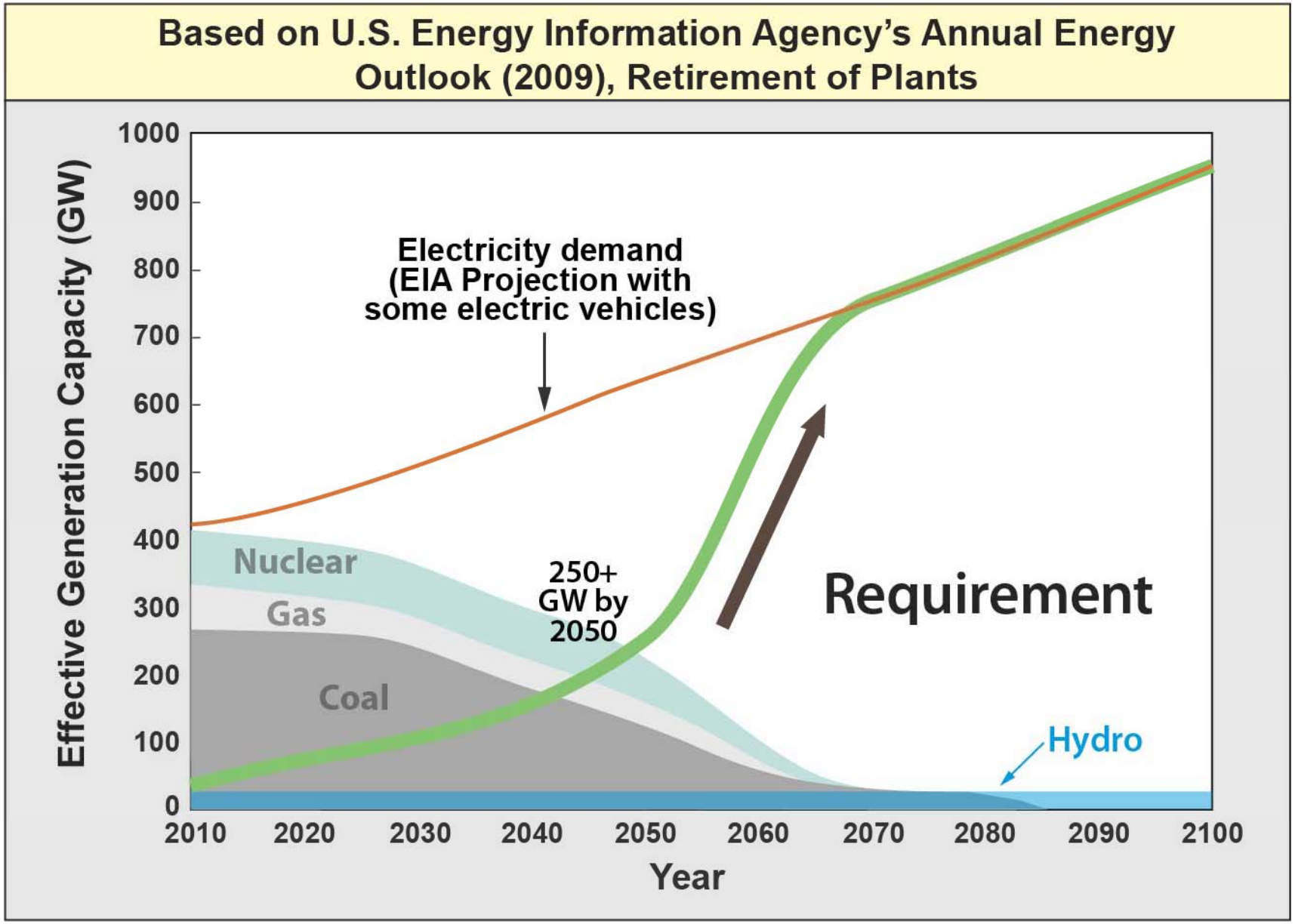
The design is being driven by the end-user requirement

Utilities (CEO/VP level)
• Pinnacle West Capital Corporation • PG&E Corporation • MidAmerican Energy Company • We Energies • Nuclear Management Company, LLC • Constellation Energy • Dominion Generation • Exelon Generation Company • Southern California Edison

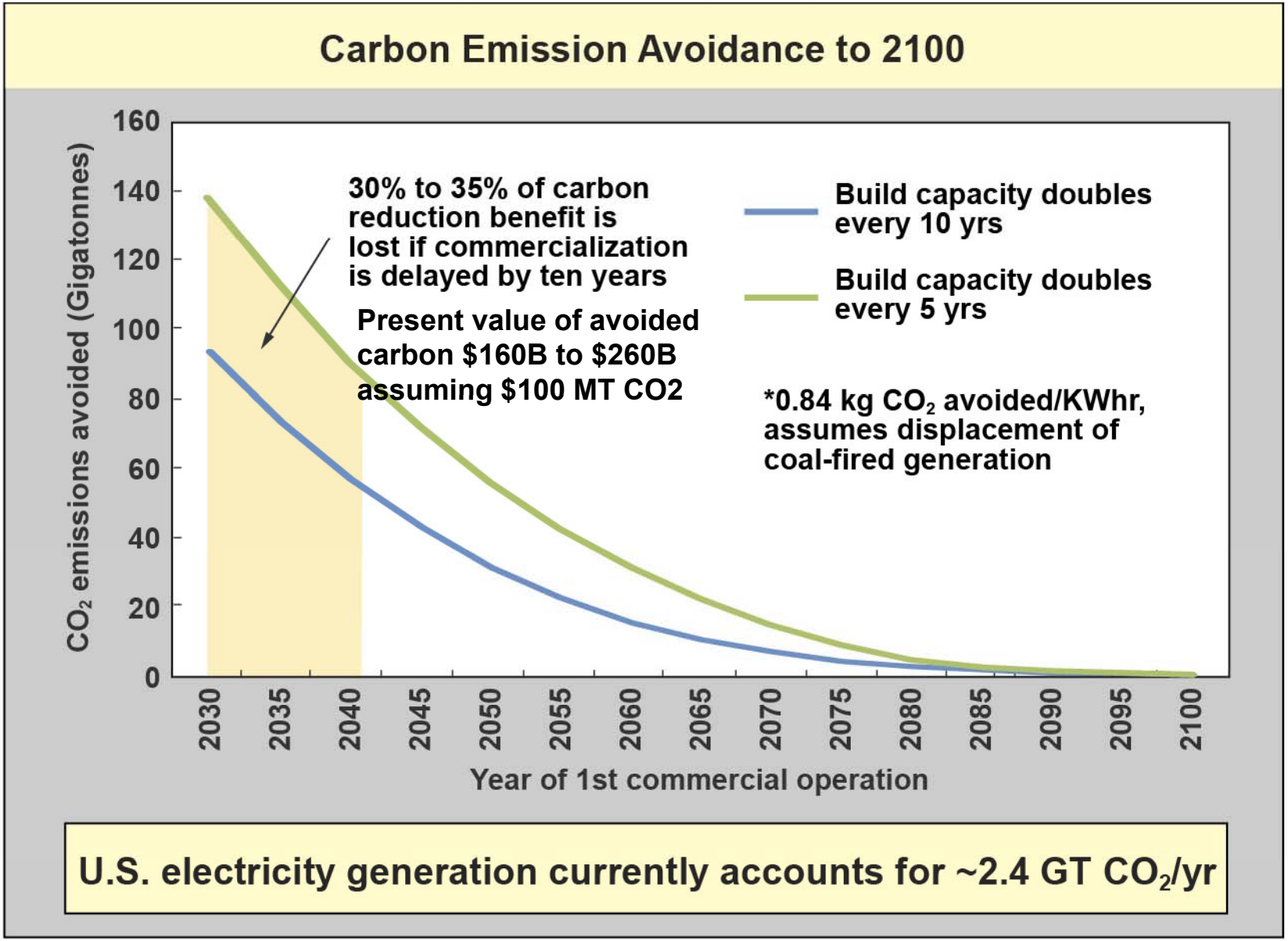
Plant Primary Criteria (partial list)
Cost of electricity
Rate and cost of build
Licensing simplicity
Reliability, Availability, Maintainability, Inspectability (RAMI)
High capacity credit & capacity load factor
Predictable shutdown and quick restart
Protection of capital investment
Meet urban environmental and safety standards (minimize grid impact)
Public acceptability
Timely delivery

This can drive a very different design solution and delivery path to conventional approaches based on technical performance alone

Modeling of US grid shows early market entry is key to the impact of fusion energy

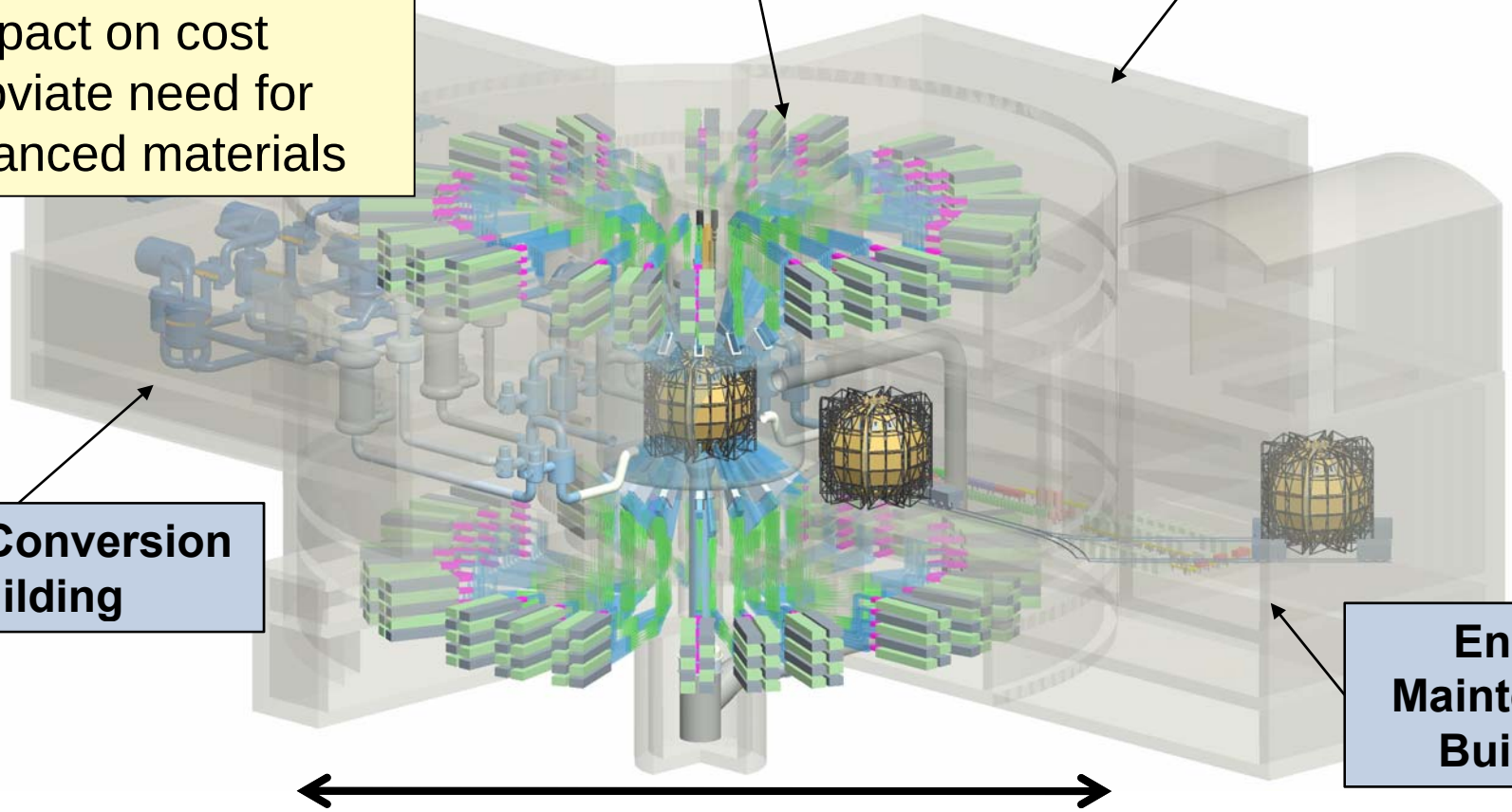


Modeling of US grid shows early market entry is key to the impact of fusion energy



An integrated, self-consistent plant design for LIFE has been developed to meet the Primary Criteria

- Modular
- Factory built units
- RAMI
- Vendor readiness
- Impact on cost
- Obviate need for advanced materials

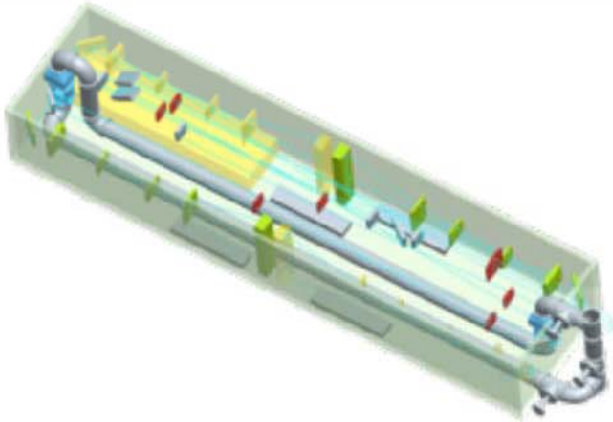


A new approach is required to meet the Primary Criteria set for robust power production

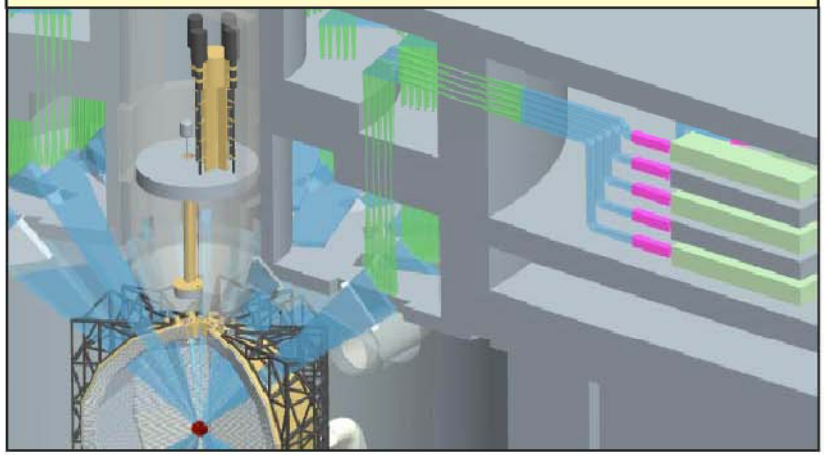
Replaceable chamber, decoupled from the vacuum and optics

Tubular, gas protected chamber using conventional materials

Beam-in-a-box (~10m long) to allow hot-swap during operations

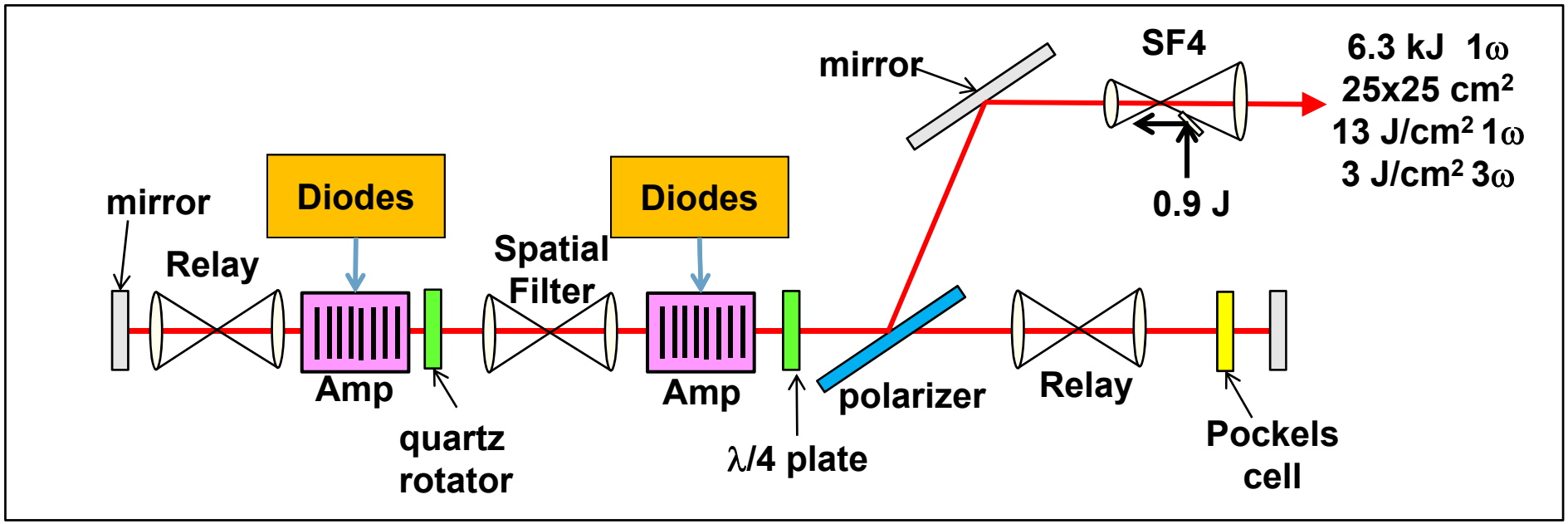


Dual neutron pinhole to allow personnel in laser bays

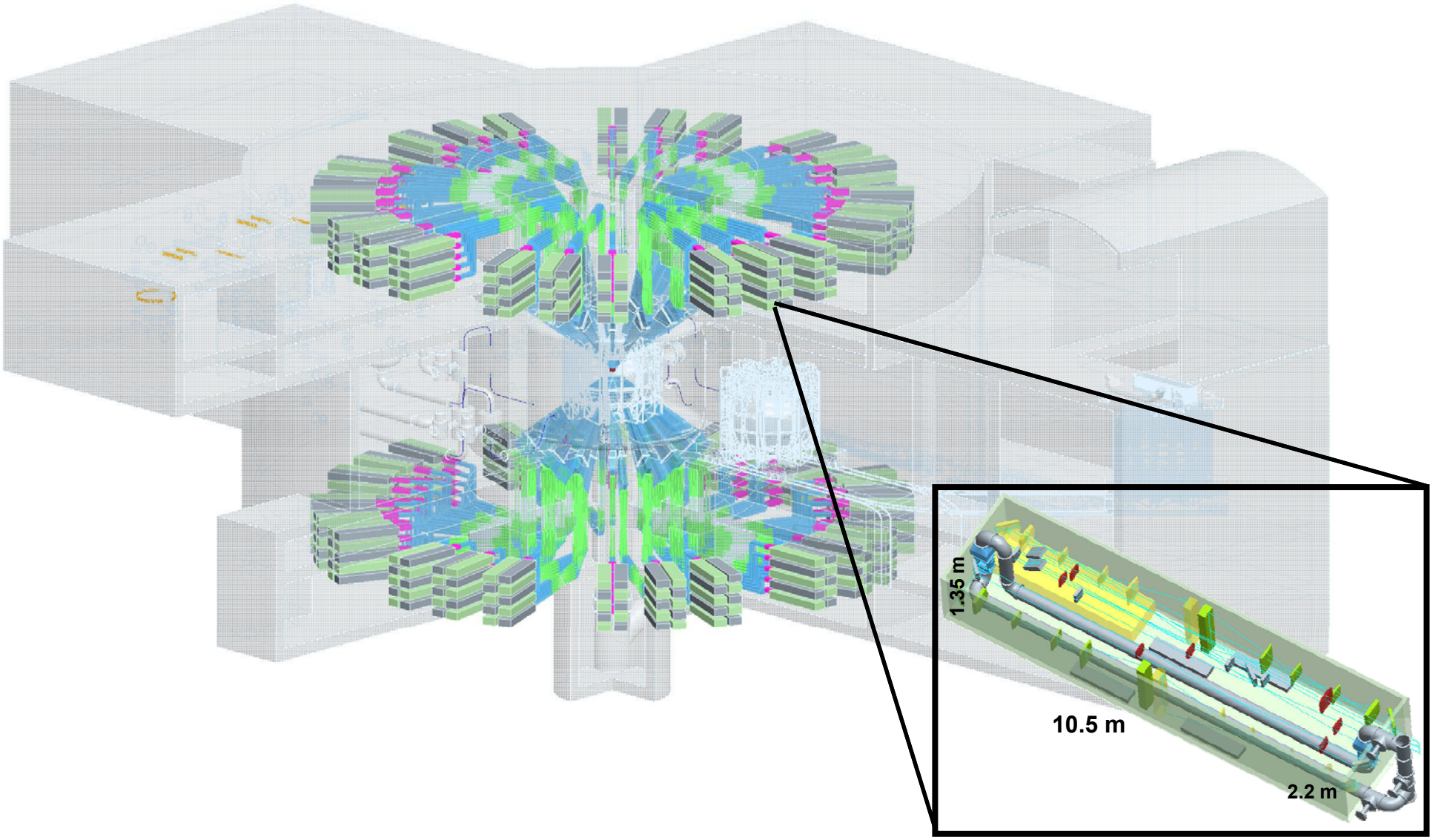


LIFE laser design has been developed to balance commercial and technical requirements

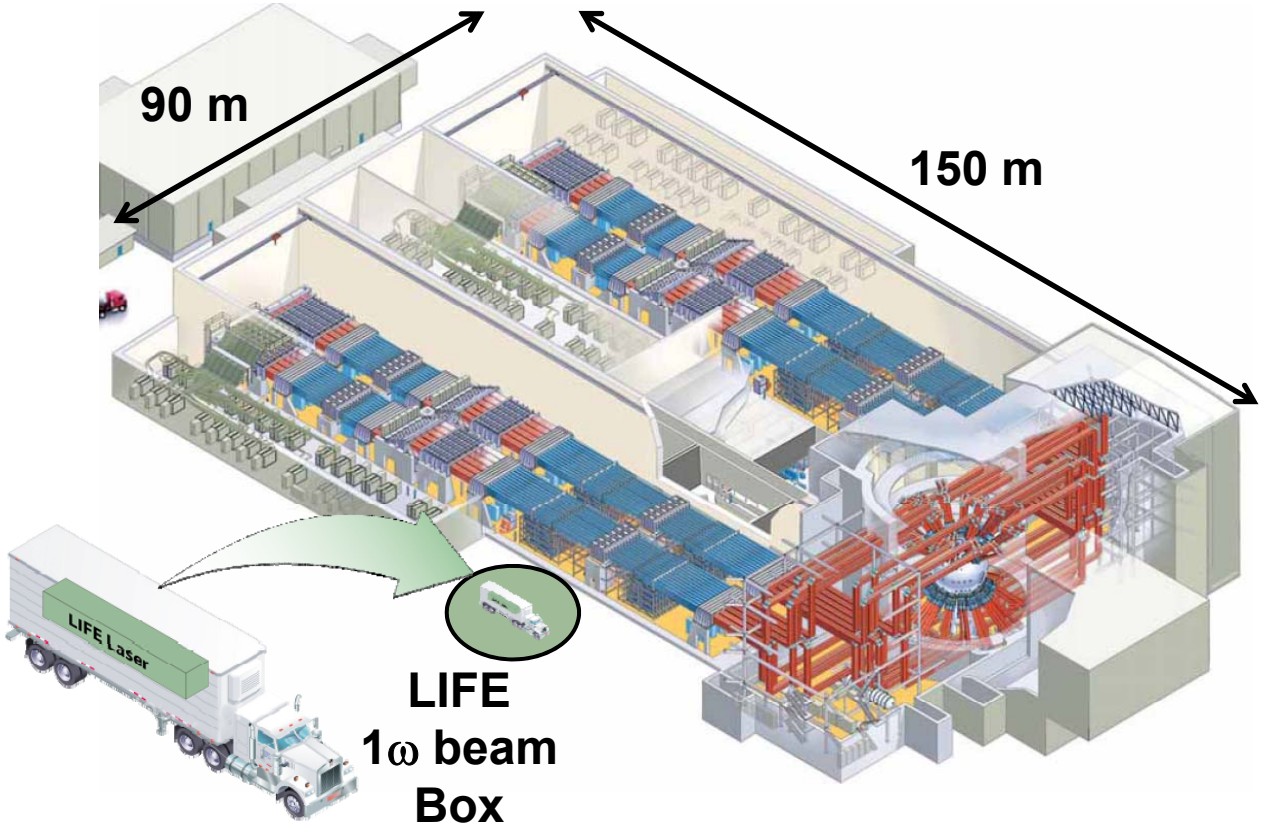
Capital Cost	Diode vendors now quoting 2-3¢/W
Supply chain	Competitive market, multiple end-users
Time to market	Conventional glass technology
Reliability	3ω fluence = 1/3 NIF
Availability	Hot-swap beam box (~10m long)
Maintainability	Factory build and repair
Performance specification	Set by NIF demonstrations



The point design uses a modular laser system, removing the need for a NIF-style switchyard

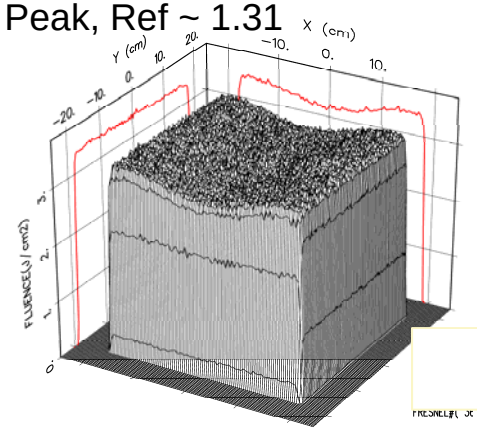


The design achieves high performance at 3x lower fluence than NIF (3ω), and meets economic goals

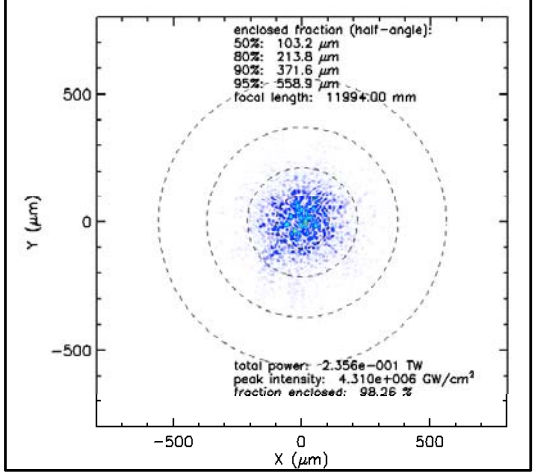


Tripler output

3ω = 4.3 kJ
Contrast ~ 4.5%
Peak, Ref ~ 1.31

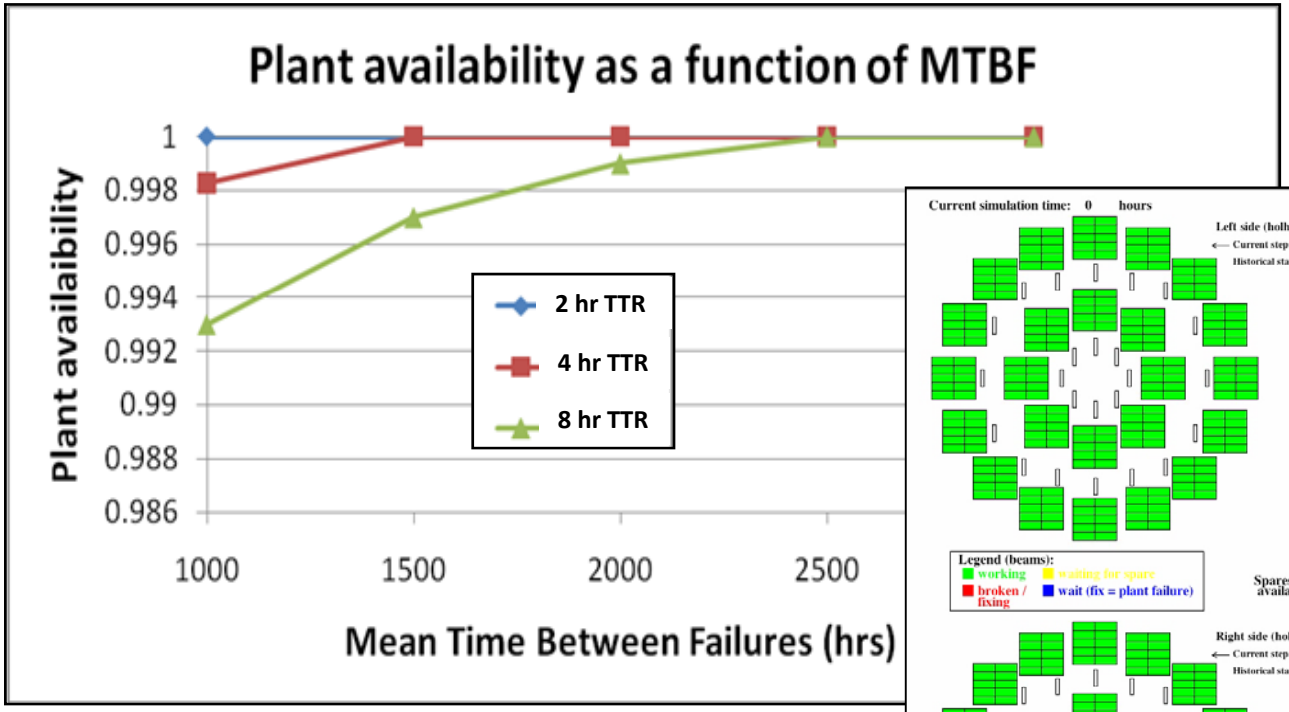


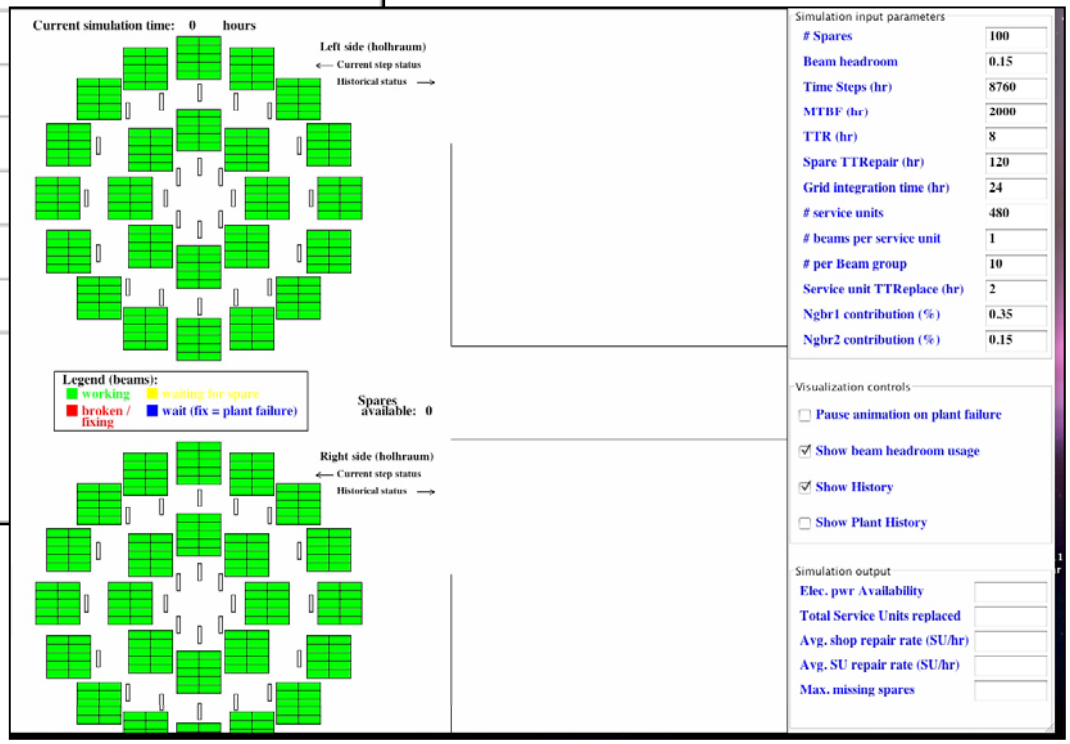
Output Farfield



- Efficient and cost effective supply chain
- Offsite beamline factory
- Truck-shippable 1w beamline
- Low-overhead installation
  - Kinematic placement
  - Minimal interfaces

Modular design enables very high plant availability by decoupling the laser reliability

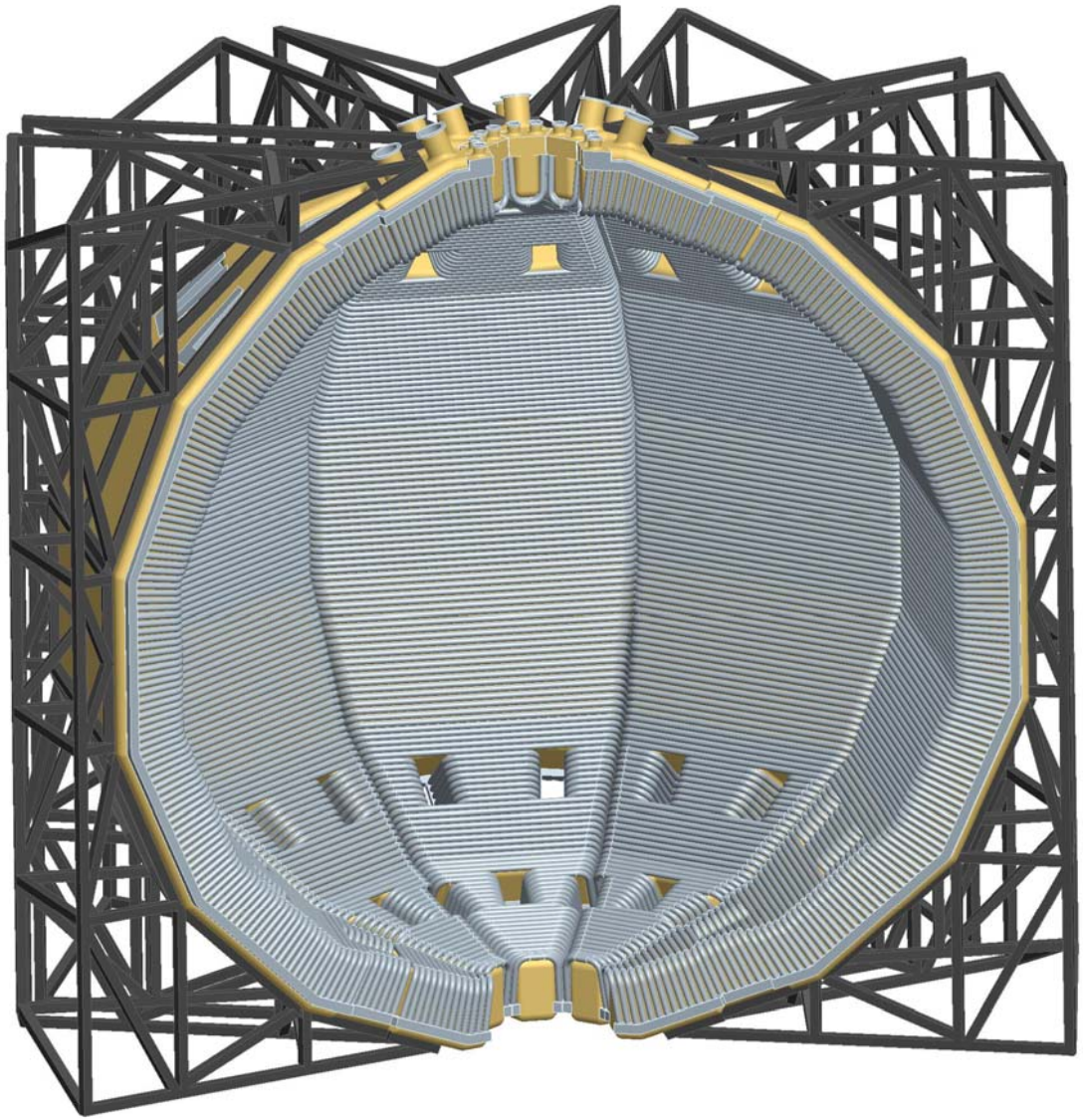




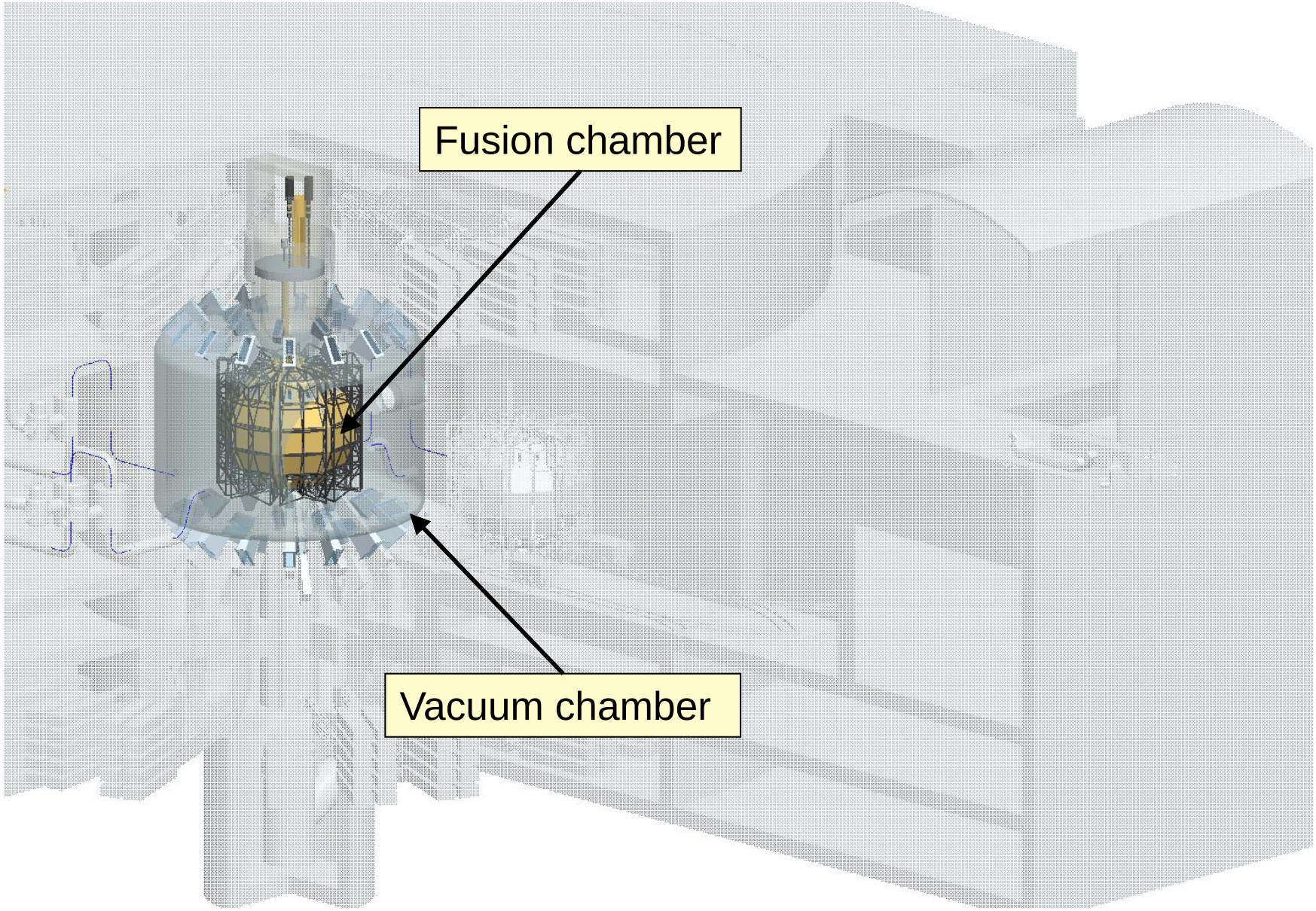
- Commercial solid state laser systems ~ 10,000 hrs
- Modular design allows realistic performance goals for a high power system

The LIFE "chamber" is a network of horizontal tubes, protected by Xenon gas. It is modular and NIF scale.

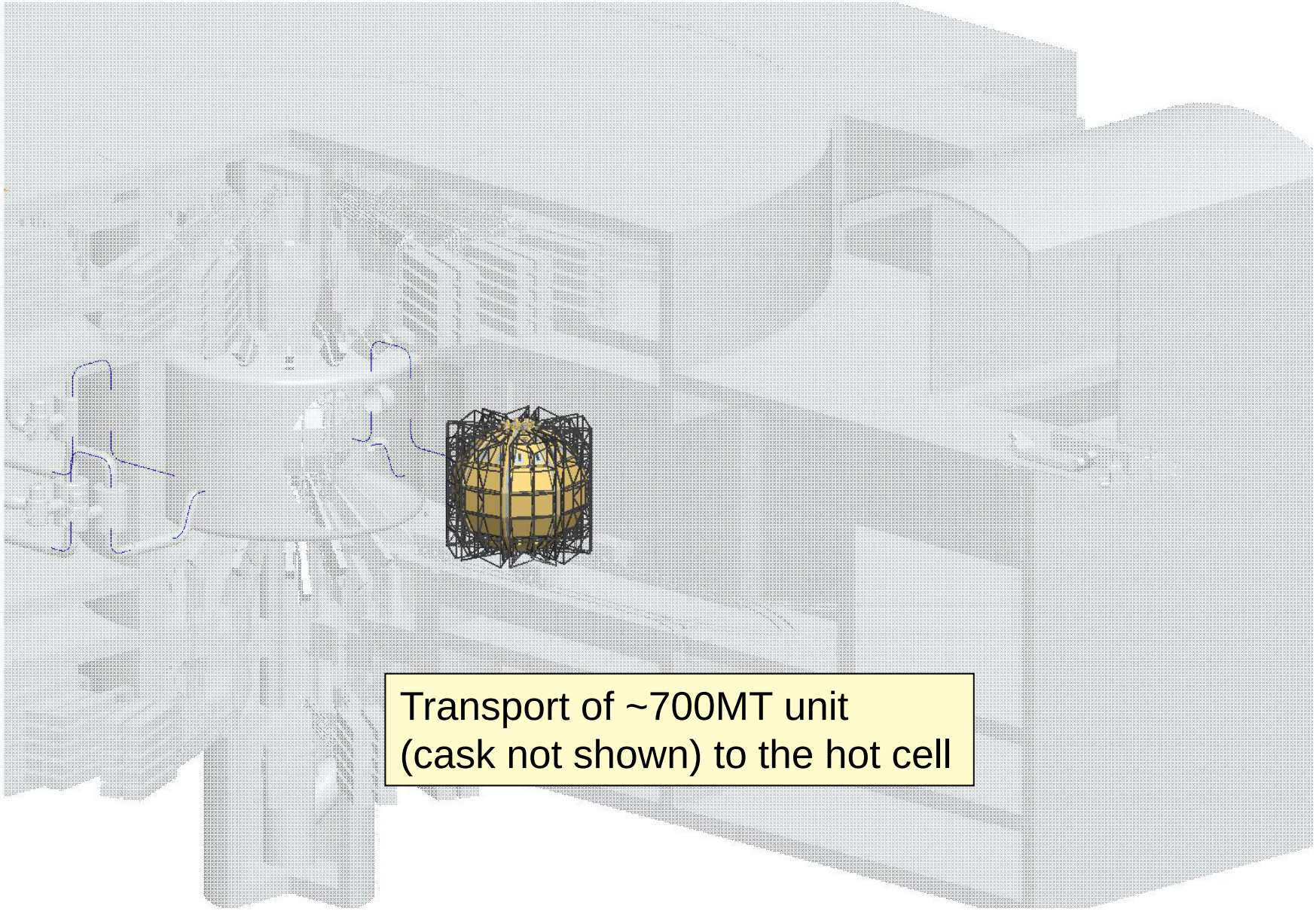
- Modular design. Truck-shippable, factory-built
- Wall survival ≥ 4 years
  - Ions stopped in ~10cm gas
  - X-ray heating mitigated (to ~800C first wall)
  - Conventional steel for LIFE.1
- Very low Tritium content
  - 10's g in the engine
  - 100's g in the separation and storage systems
- Very low clearing ratio (~1%)



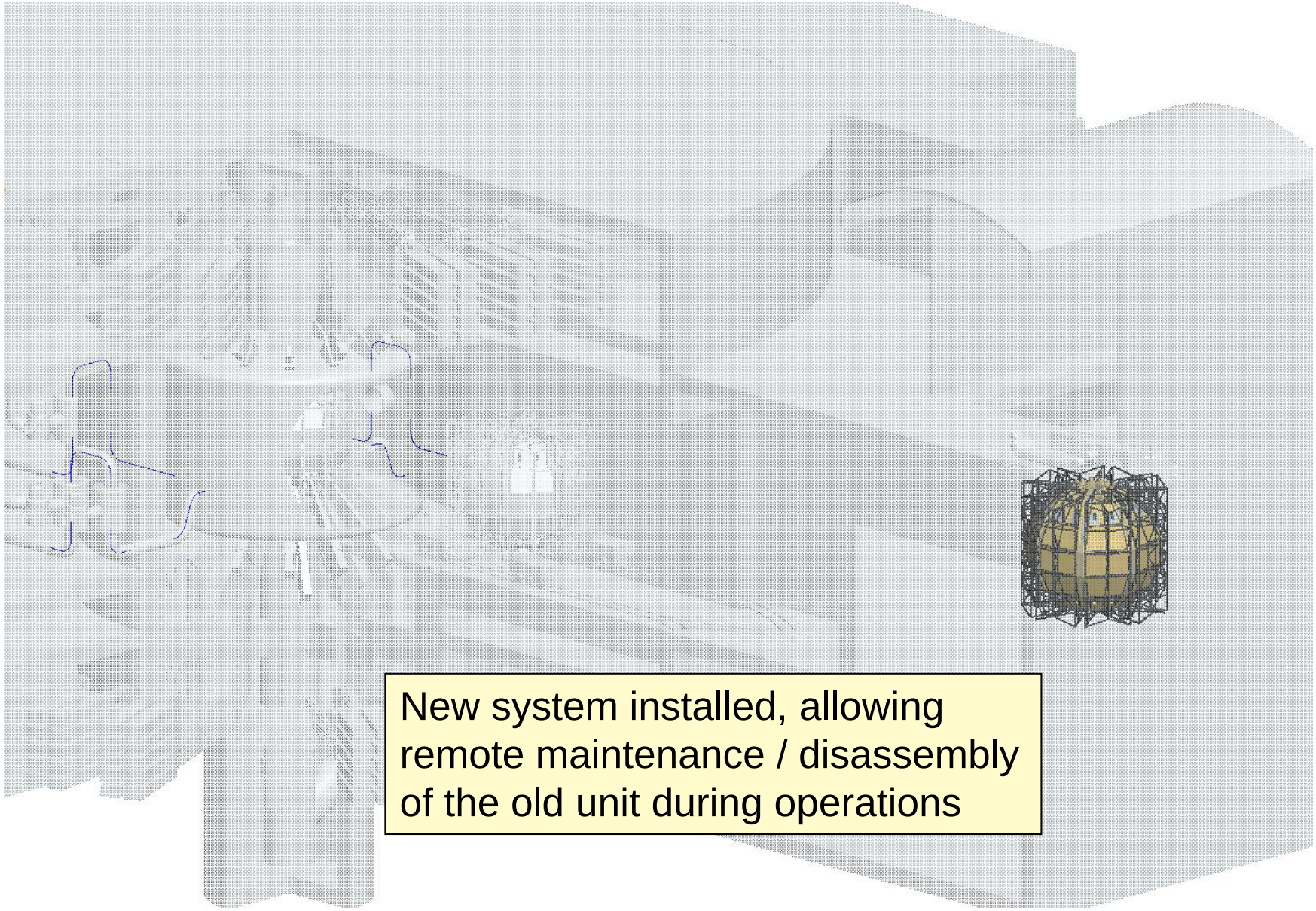
The chamber system can be transported as a single unit for maintenance



The chamber system can be transported as a single unit for maintenance

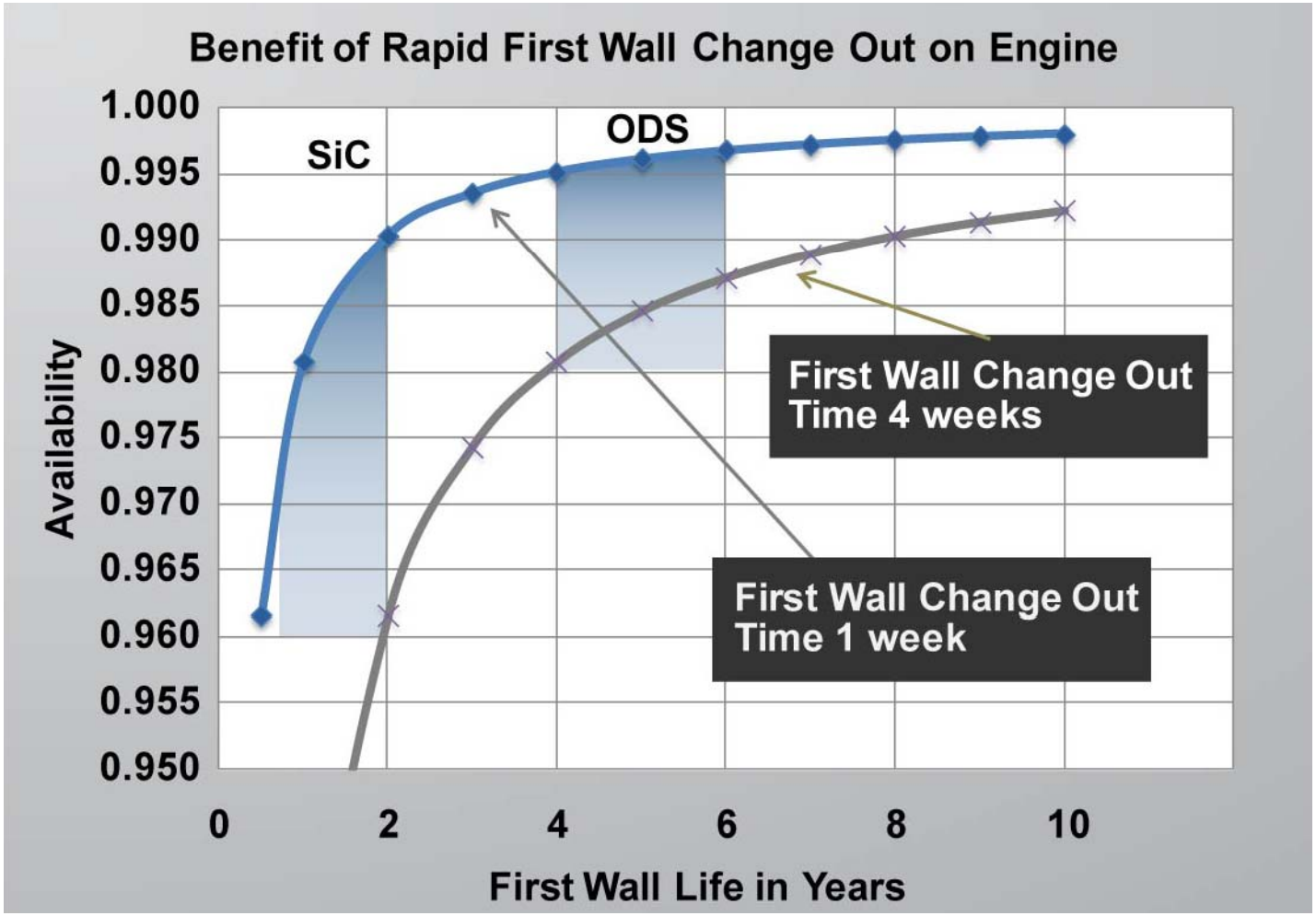


The chamber system can be transported as a single unit for maintenance



New system installed, allowing remote maintenance / disassembly of the old unit during operations

… because chamber modularity results in high plant availability



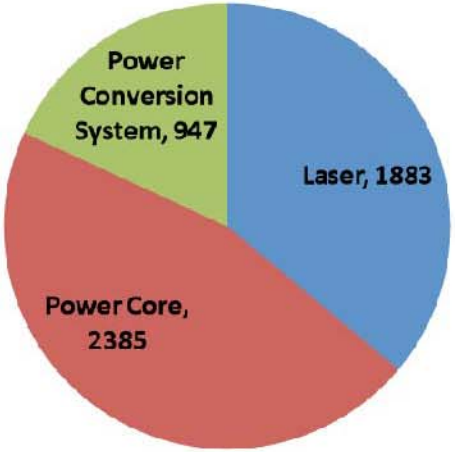
Calculated wall lifetime (LIFE.2)

The design has been optimized using an integrated technology and economics model

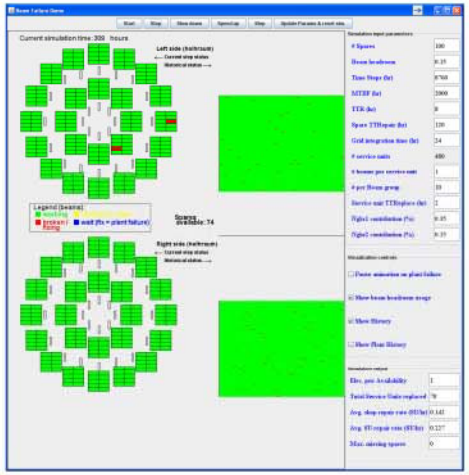
Economic factors

Capital cost
Availability
Reliability
Maintainability
Fuel / consumable costs
Licensing
Supply chain
Environmental cost
Time to market

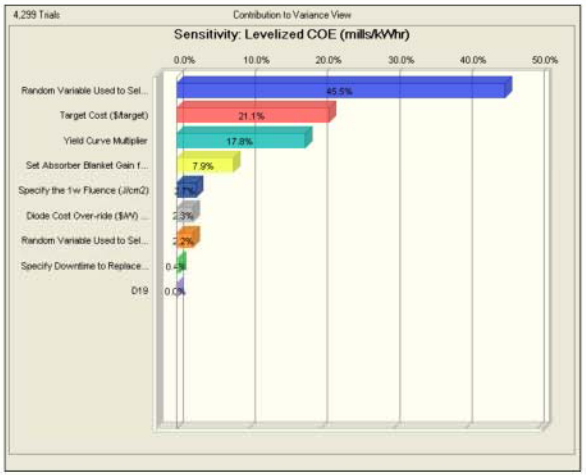
Fusion plant capital cost areas



Monte Carlo availability

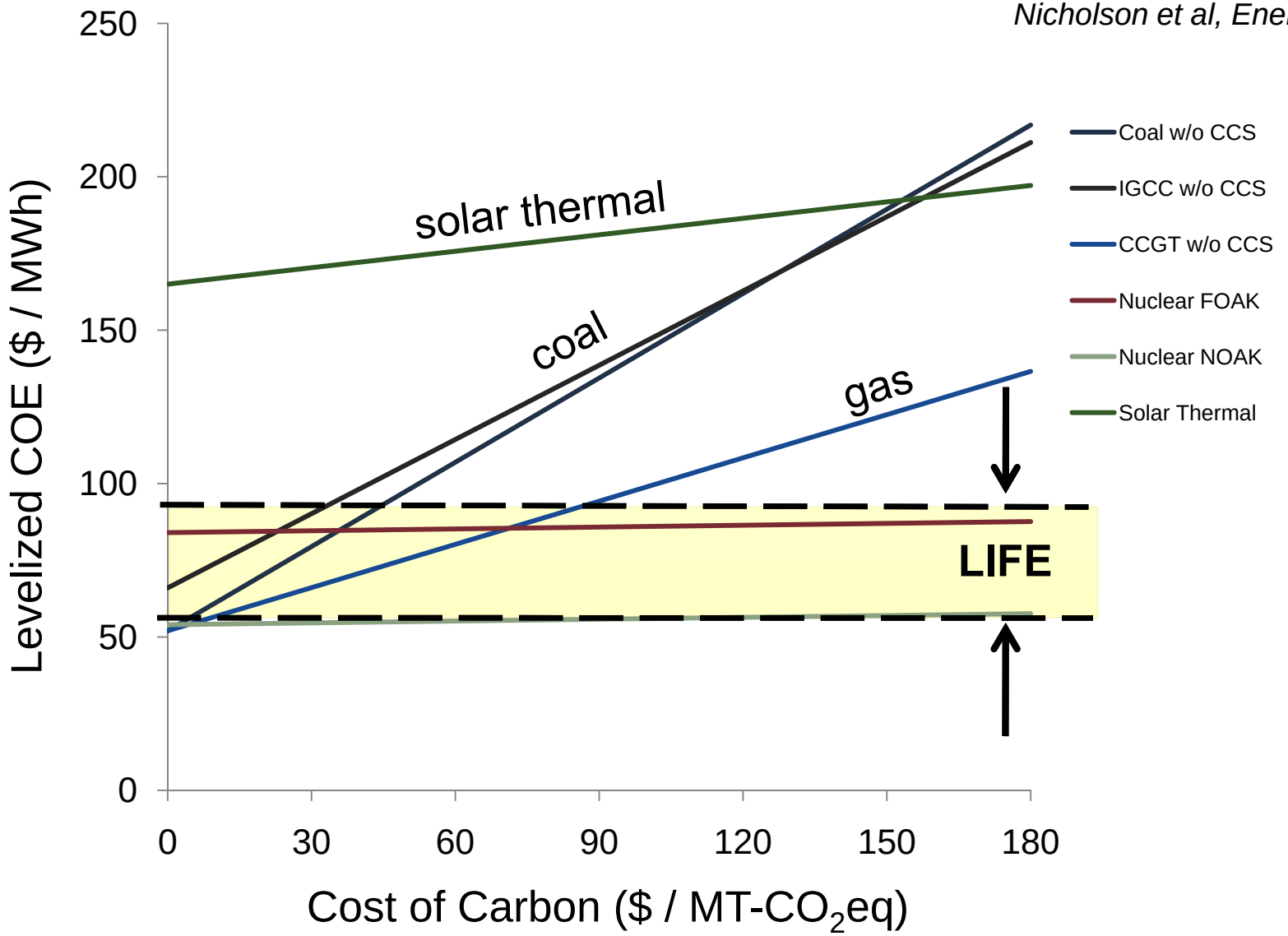


Technology investment impact

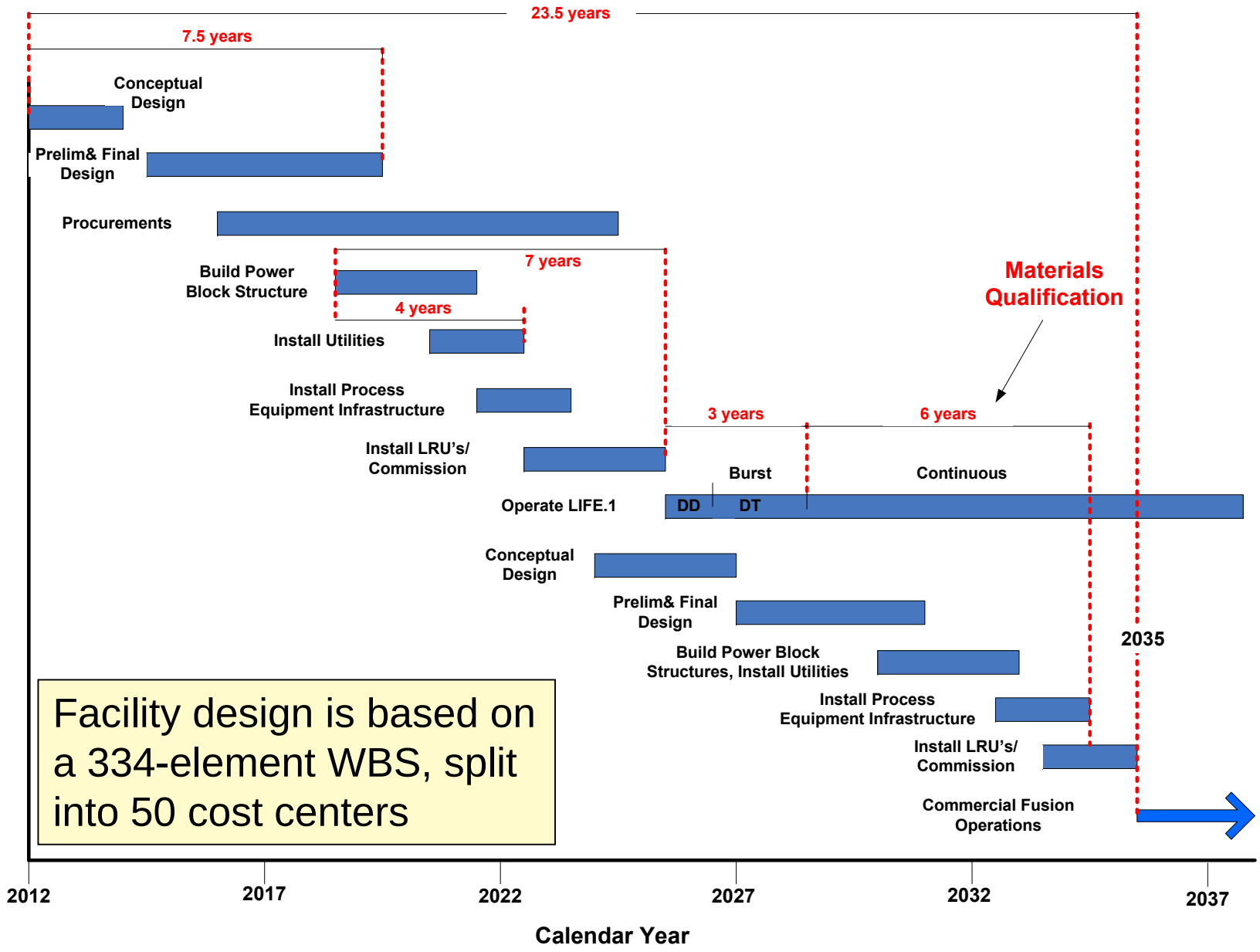


Cost of Electricity less than coal for CO_2 > $40/MT, and less than gas for > $90/MT. Could be 50% better.

Nicholson et al, Energy (2010)

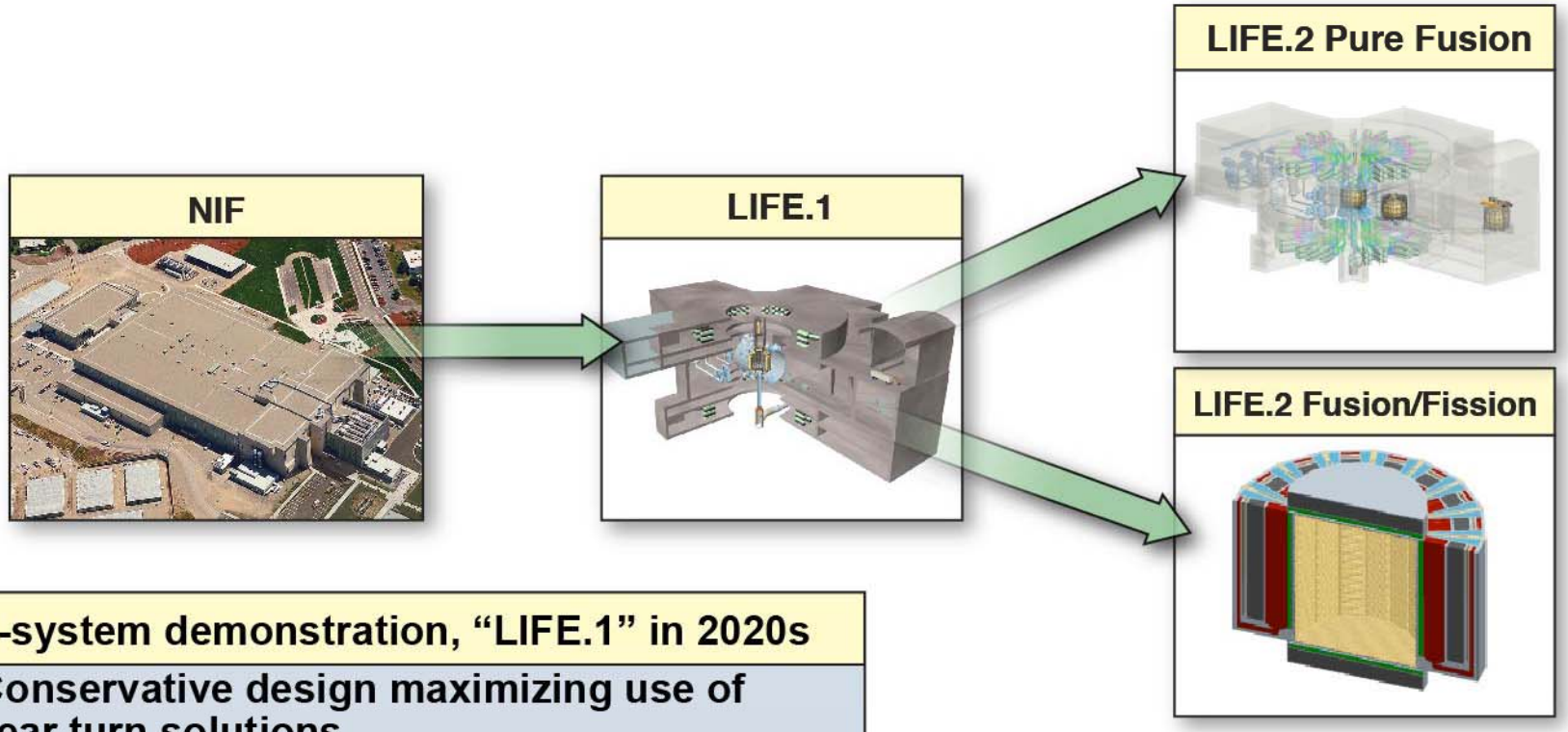


Outline delivery schedule, consistent with NIF experience and likely licensing timescales – meets the Primary Criteria



Facility design is based on a 334-element WBS, split into 50 cost centers

Development Path -



Full-system demonstration, "LIFE.1" in 2020s

- Conservative design maximizing use of near turn solutions
- Fully integrated development and vendor readiness program
- Steady state, integrated fusion operations (~500 MW_{th})
- Define the plant availability growth program
- Materials / structure qualification for commercial plant

Commercial GWe plants, "LIFE.2" from 2030s

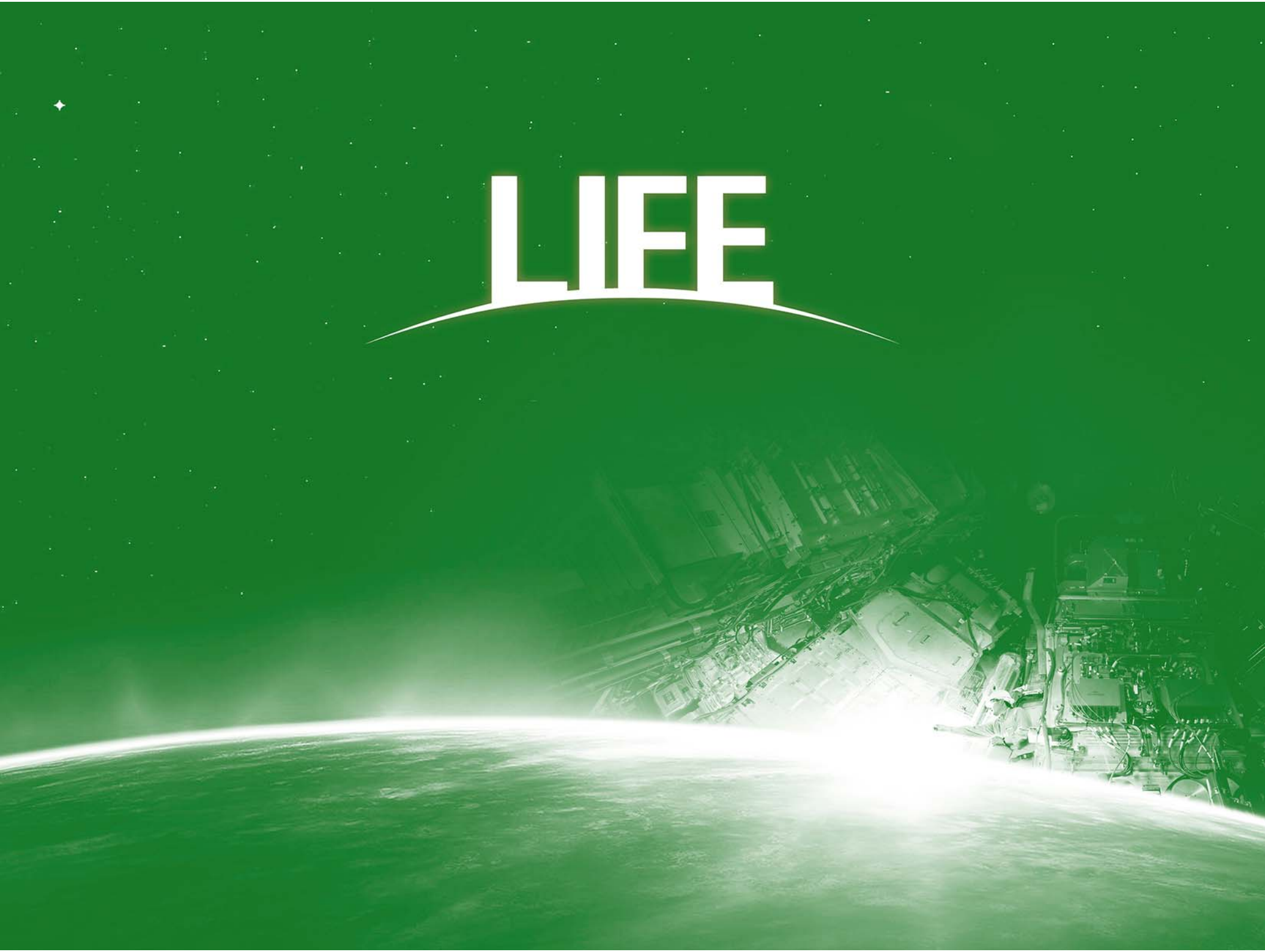
- Deliver baseload power to grid at relevant size (~ 1GWe)
- Uses systems and materials qualified on LIFE.1
- Defines capital and operating costs for rollout

Final thoughts

- Consideration of end-user requirements must drive IFE development
- Technologically, IFE success will depend on our ability to integrate interdependent sub-systems
- Future development must be tackled as part of a facility delivery project

- LIFE provides a solution consistent with 2030's commercial delivery:
  - Designed to meet the Utilities' Primary Criteria
  - NIF provides the at-scale physics evidence
  - LRU approach protects capital investment, and enables high availability
  - Licensing approval managed as an integral part of the process

- Public/private delivery partnership, and nation-wide focused effort is essential


LIFE