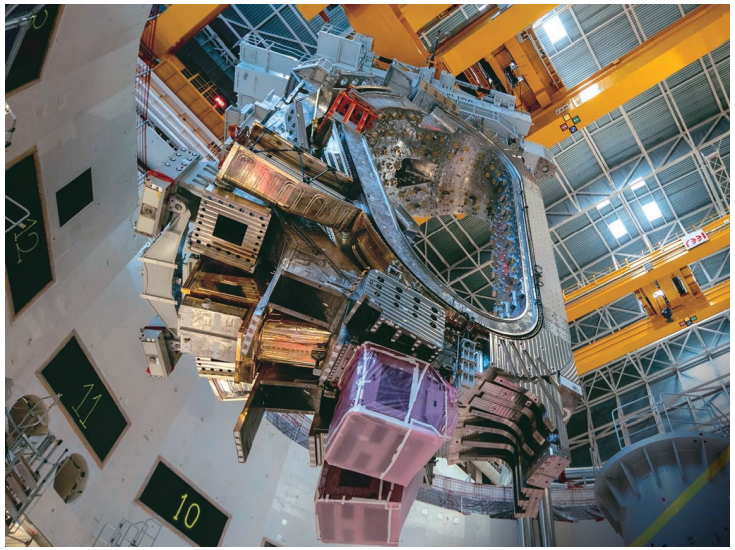




FROM ITER TO FUSION POWER PLANTS:

Designing the fusion fuel cycle of the future

F4E & Eurofusion Fuel Cycle Technology Mapping Workshop, 6 Feb 2025

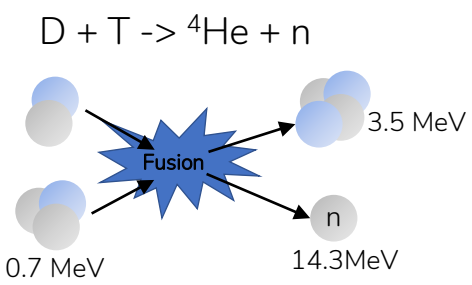
Ian Bonnett, Tritium Plant Project Leader, ITER Organisation

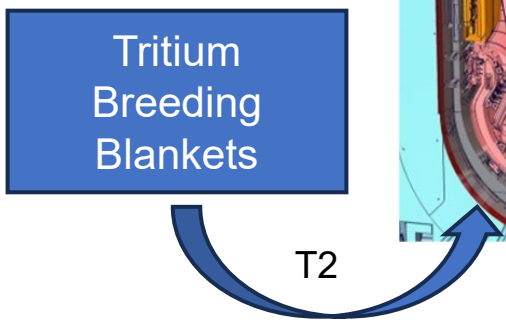
china eu india japan korea russia usa

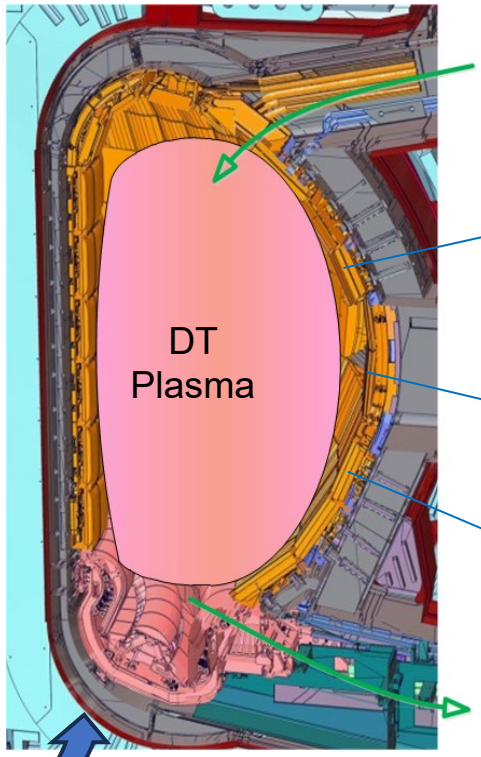
Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization

BACKGROUND TO THE FUSION FUEL CYCLE

Characteristics of magnetic fusion







Technology needs

Magnetic plasma resists injection of replacement fuel — ***Fuelling***

He “ash” and impurity build-up quenches fusion reaction — ***Tritium Processing***

Tritium is radioactive and expensive

Only a fraction (~1%) of the fuel burns per pass

Means we need to ***Cycle the fuel***

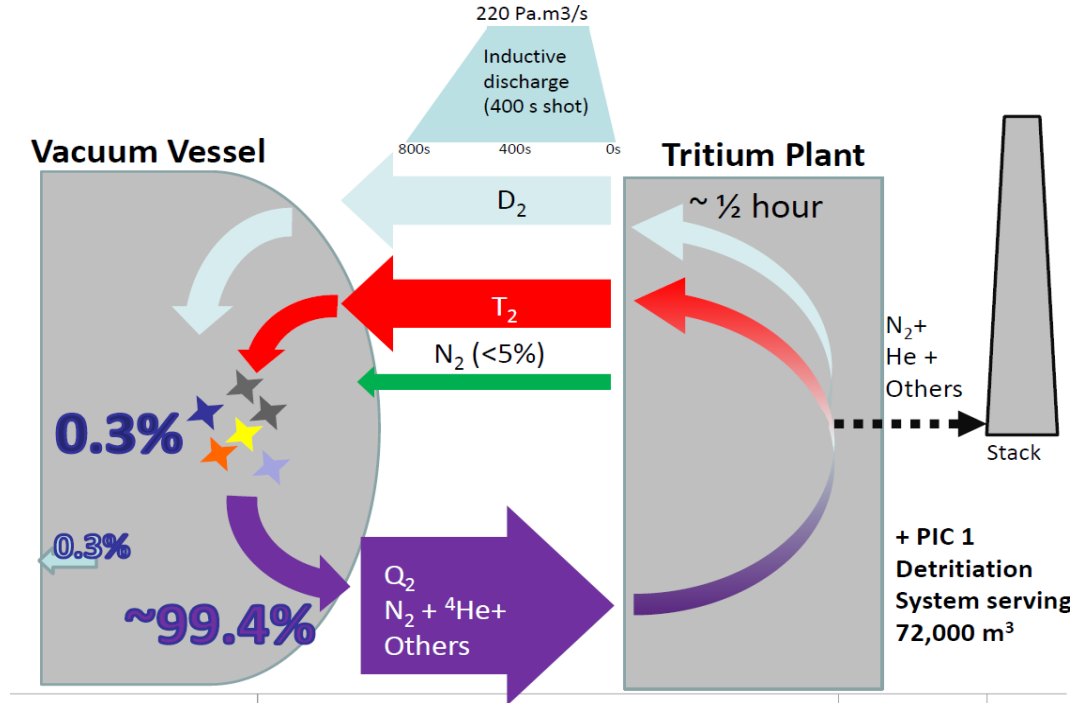
Vacuum must be maintained around plasma — ***Vacuum***

ITER TRITIUM PLANT

- ITER is an experimental facility
- Plasma Physicists want lots of parameters to explore
- Lots of flexibility….lots of complexity

ITER Talks (11): The Tritium Plant

YouTube · iterorganization
Mar 13, 2023



Flow & composition from vacuum pumps

He with trace DT (CVC)

DT with Ne

Argon/N2 with trace DT & impurities e.g. CQ4

HTO with trace DT & impurities e.g. NQ3, QI

Tritium Plant & Fueling

Flow & composition to clients

Pellet injection/gas puffing	>85% **T**, <15% D pellet >85% **D**, <15% T pellet >85% **D**, <15% T gas
Neutral Beam neutralizer	<1% T, >99% **D** gas
Neutral Beam Ion Source	<200ppm T in **D** gas <200ppm T in **H** gas
Effluent H_2 to Water Detritiation	**H** with <5ppm T gas

ITER FUEL CYCLE BLOCK DIAGRAM

Fuelling systems (green)

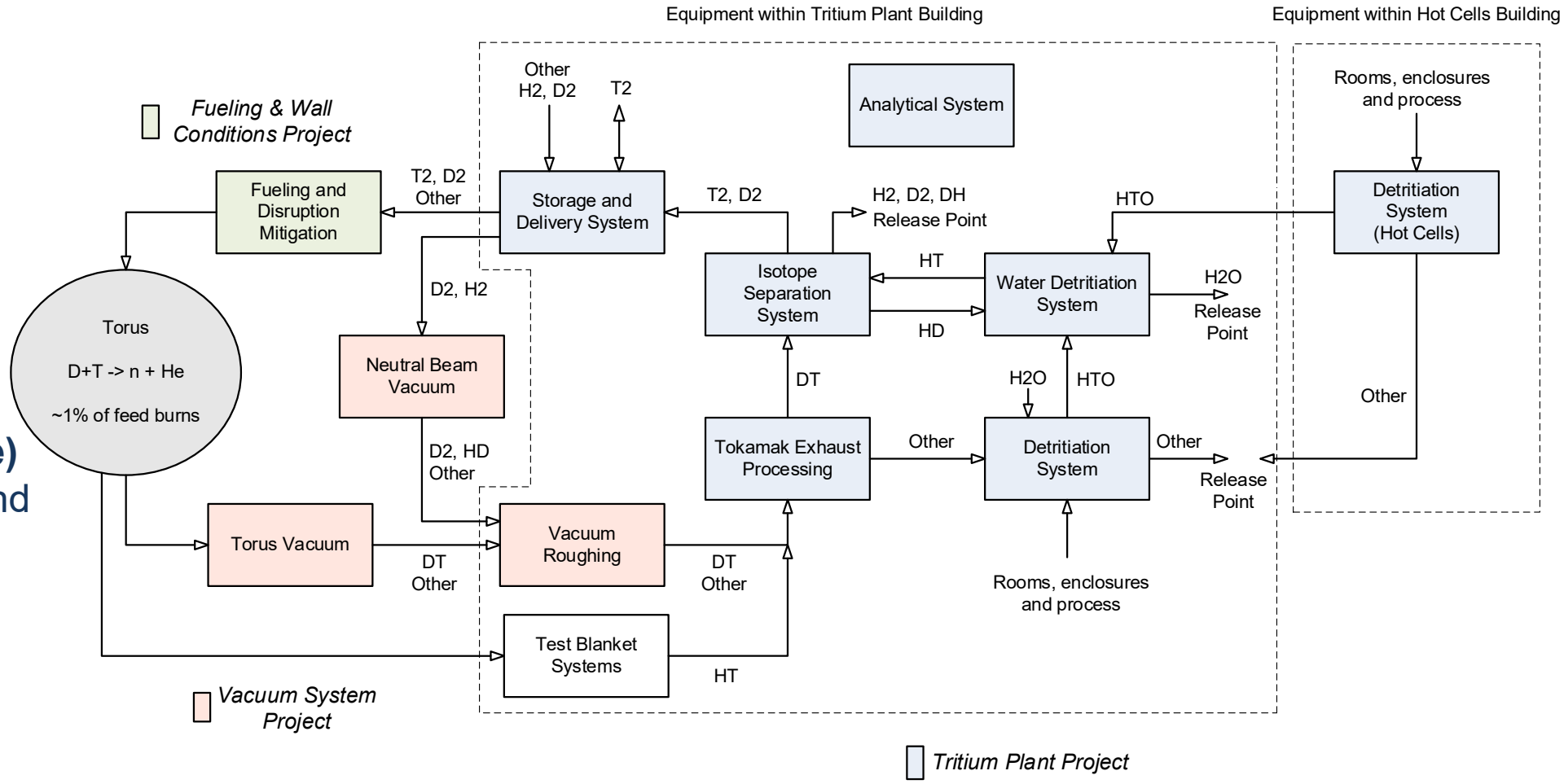
- D2 and T2 pellets for core fuelling
- Mix gas puffing for edge control
- Pellets for disruption mitigation

Vacuum systems (orange)

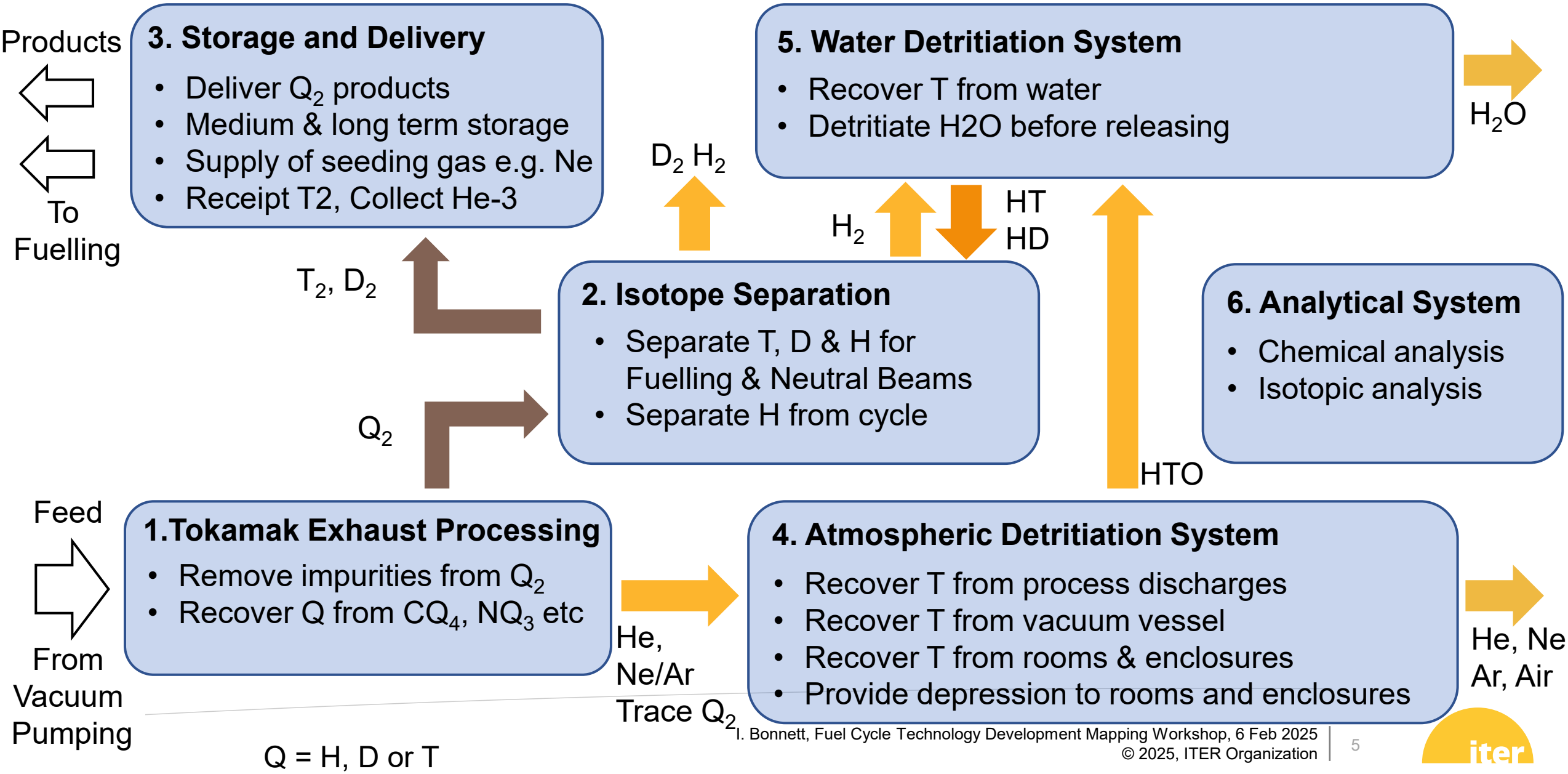
- Cryopumps for Torus and Neutral Beams
- Mechanical pumps

Tritium systems (blue)

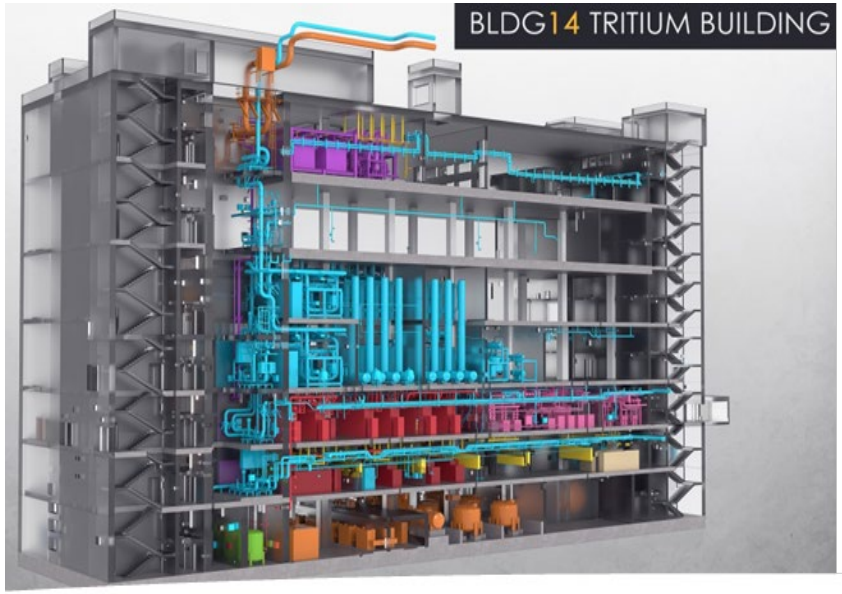
- See next slides

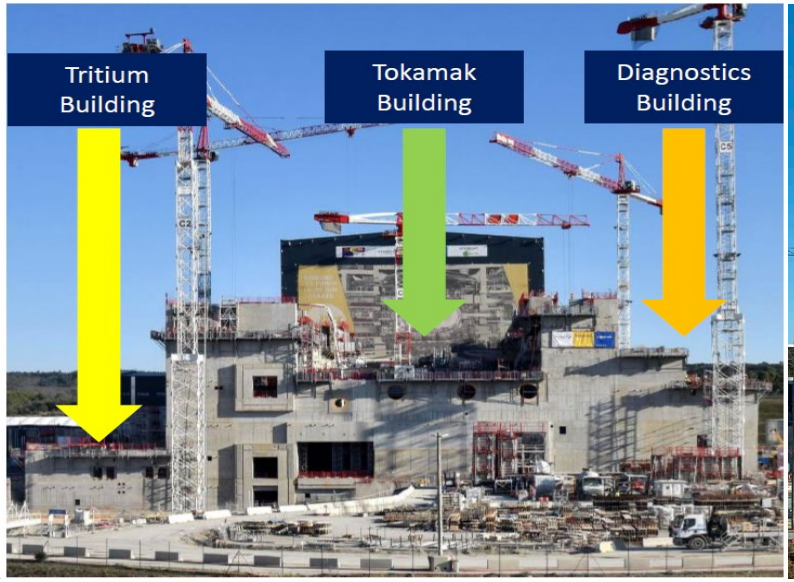


SIX SUB-SYSTEMS OF THE ITER TRITIUM PLANT



TRITIUM PLANT BUILDING





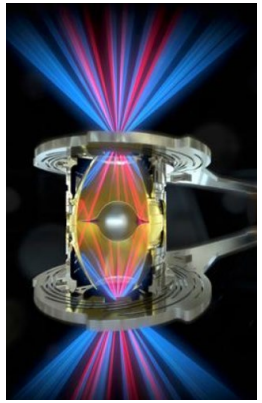
March 2019

March 2024

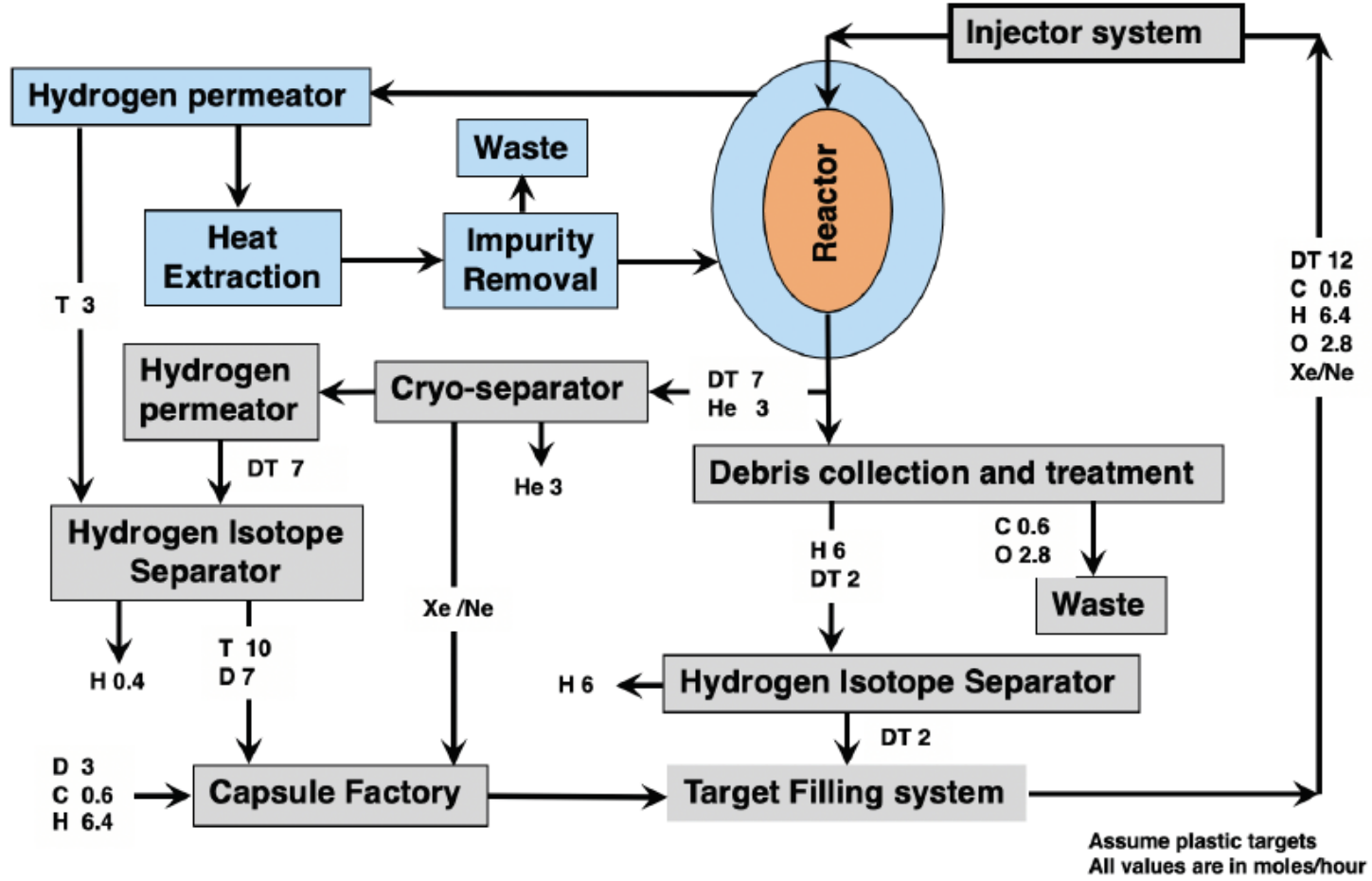
- Majority of the Tritium Plant located in the Tritium Building
- Building 100m long, 35m wide and 80m tall
- Tritium Plant occupies most of 6 floors of the building, with 2 levels below grade
- Part of the TBB also housed on Level 2

INERTIAL CONFINEMENT FUSION FUEL CYCLE

NIF targets are precisely controlled in a cryogenic cooling system that keeps the deuterium-tritium fuel frozen inside a millimeter-sized capsule.

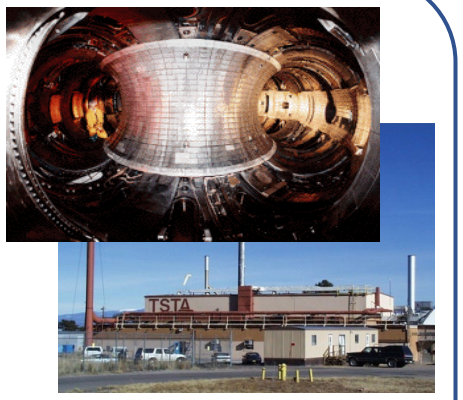


https://lasers.llnl.gov/science/



Fuel Cycle for an Inertial Fusion Energy Reactor: Isotope Separation and Breeder Blankets, Walter T. Shmayda et al. Submitted to the 2022 IFE community workshop to be held Feb 22–24, 2022 under the topic: Fuel Cycle

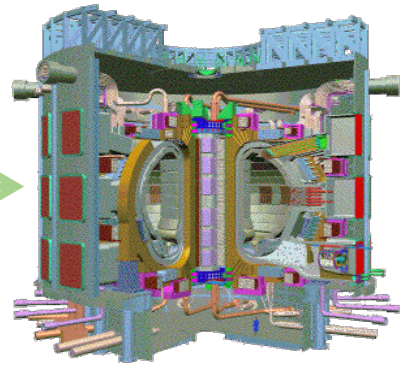
FROM ITER TO DEMO



State-of-the-art
Fusion power: 10's MW
Burn fraction: Nil

Pulse length: seconds
Annual duty cycle: ~5%

T_2 Fueling rate: 0.1 kg/h



ITER
Fusion power: 500 MW
Burn fraction: 0.3%

Pulse length: 3000 s
Annual duty cycle: 5%

T_2 Fueling rate: **1.06 kg/h**

DEMO
Fusion power: 2000 MW
Burn fraction: 1.15-3%?

Pulse length: Continuous
Annual duty cycle: 50%

T_2 Fueling rate: **~0.9 kg/h**

ITER Fuel Cycle same scale for DEMO, though a lot more complicated

ITER also achieves continuous fuel/processing at 2300s burns

For Demo / power plant

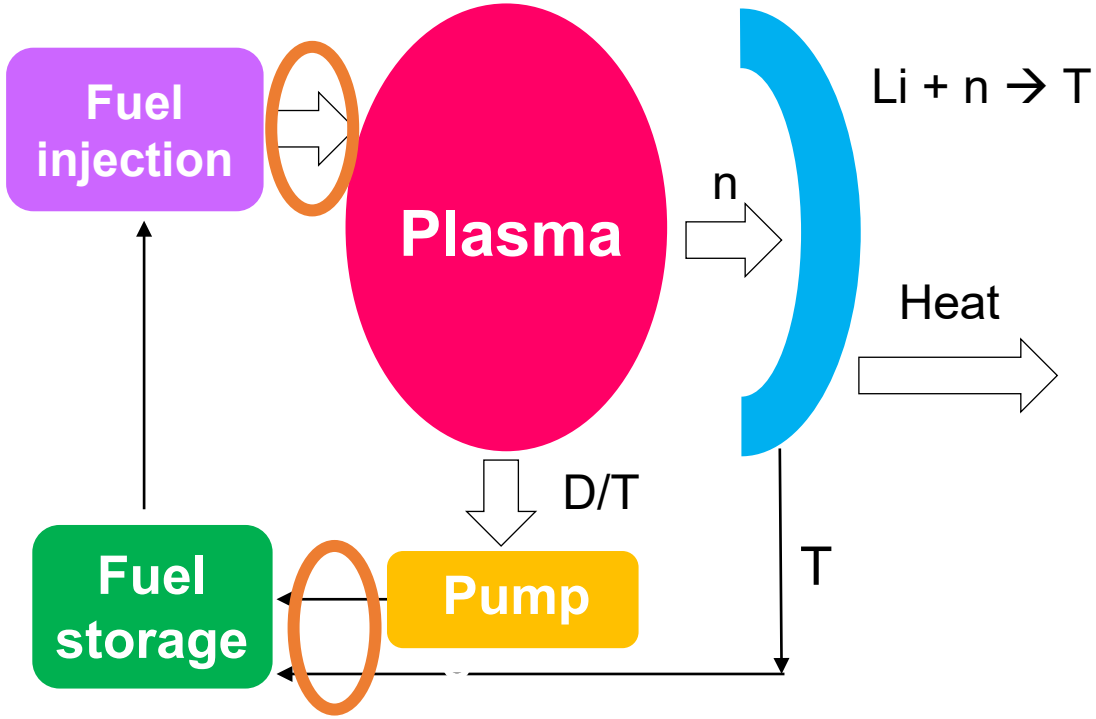
- × No Heating Neutral Beams
- × No Diagnostic Neutral Beam
- × No Multiple Seeding gas options
- × No separate D & T pellets
- × No routine GDC Boronization
- × Infrequent DMS operation
- × Low impurities (NQ3, CQ4)
- × No addition of H2 to DT cycle

Opportunities:

a) Simplifications
b) Reduction in size
c) Reduction in inventory
d) Safety improvements
e) Cost & delivery time savings

IDEAS FOR DEMO FUEL CYCLE – OPEN QUESTIONS

Chemical Engineering Rule #1: Mass in = Mass Out – Accum.



Less streams to process, less products to produce – Simplification of the Fuel Cycle

IDEAS FOR FUTURE FUEL CYCLE – OPEN QUESTIONS

1. Can pellet injectors avoid use of propellent?

2. Do we need to recycle trace tritium from detritiation systems in normal operation back into the ISS?
   - Consider an alternative approach for tritiated waste (incl. liquid)

3. Can we preferentially pump Helium ash rather than DT at the divertor?

4. In future, how does the Radwaste and Hot Cell detritiation systems interact with Fuel Cycle?

5. If Ne is the seeding gas, how do we separate He/Ne to recycle Ne on industrial scale?

6. What does debris removal look like for the inertial fusion fuel cycle?