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Tritium Gas Processing for Magnetic Fusion

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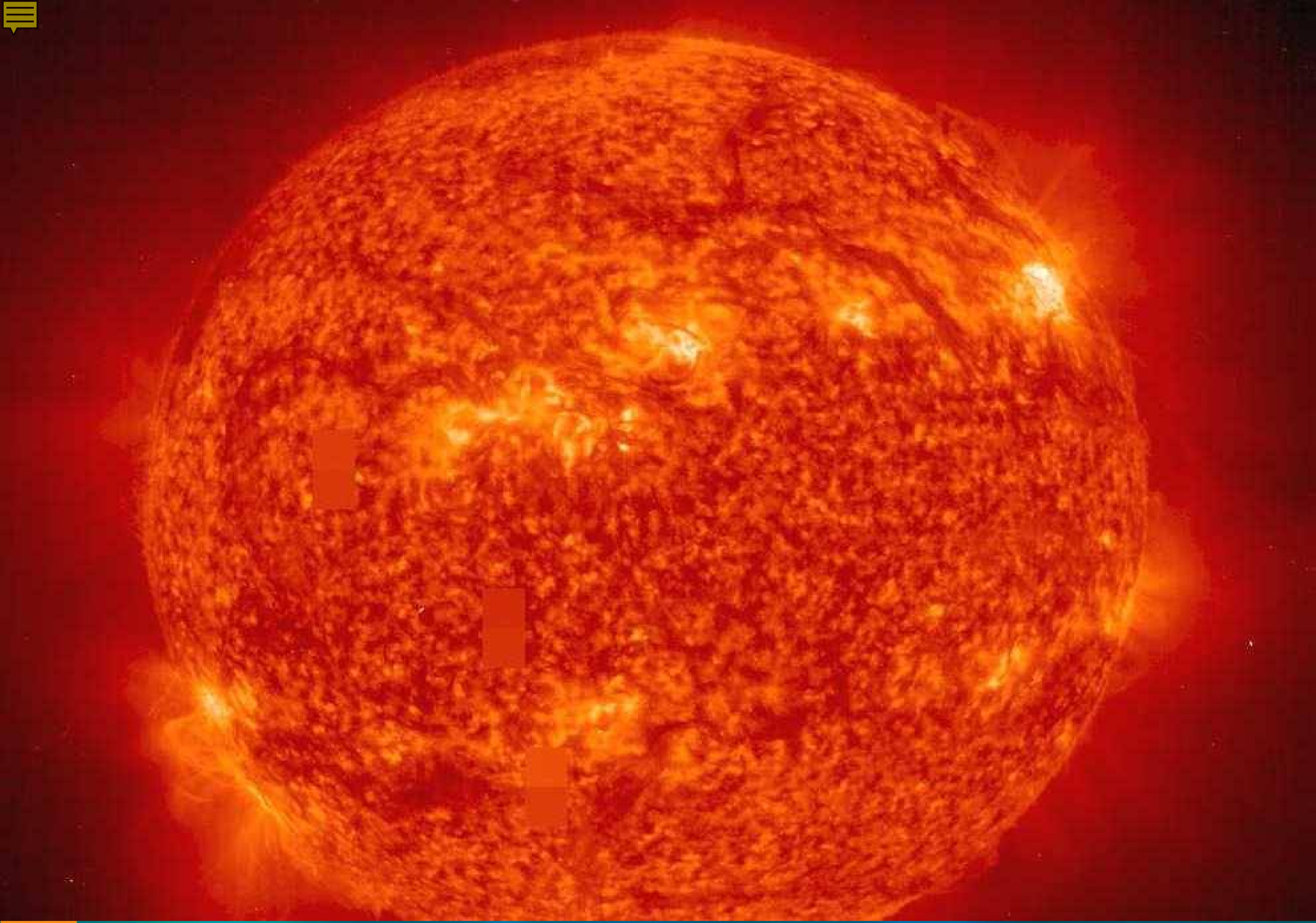
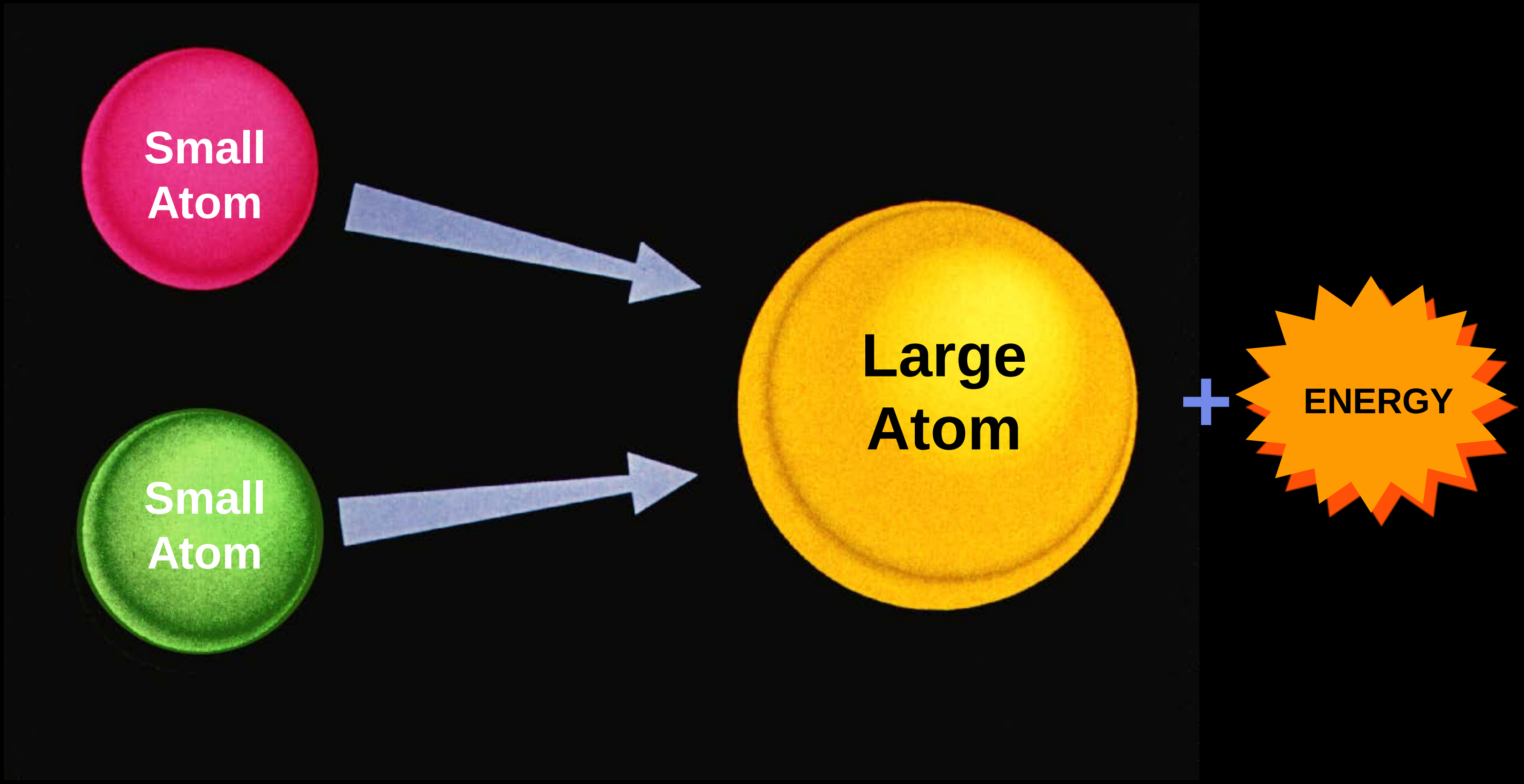
Presentation Outline

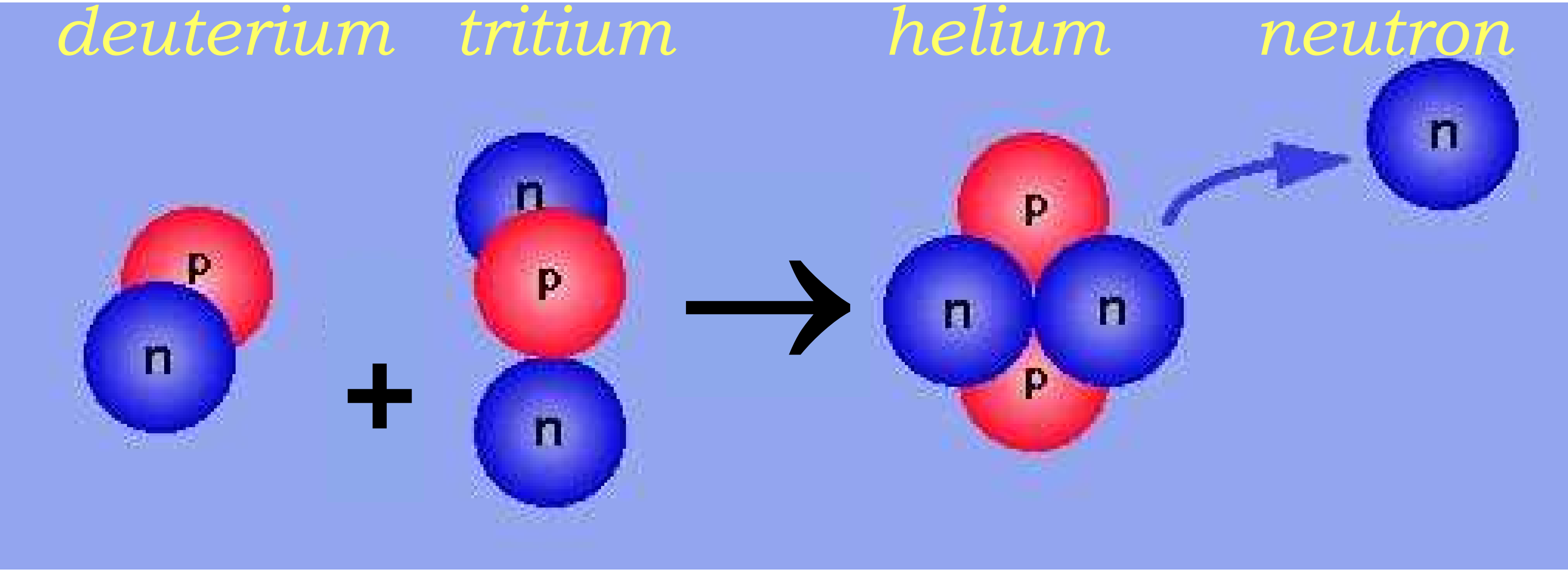
- **Background Information**
- **Simplified Fusion Fuel Cycle**
- **Select Requirements Fuel Cycle**
  - **Confinement**
  - **Process**
- **Summary**



What is Fusion?

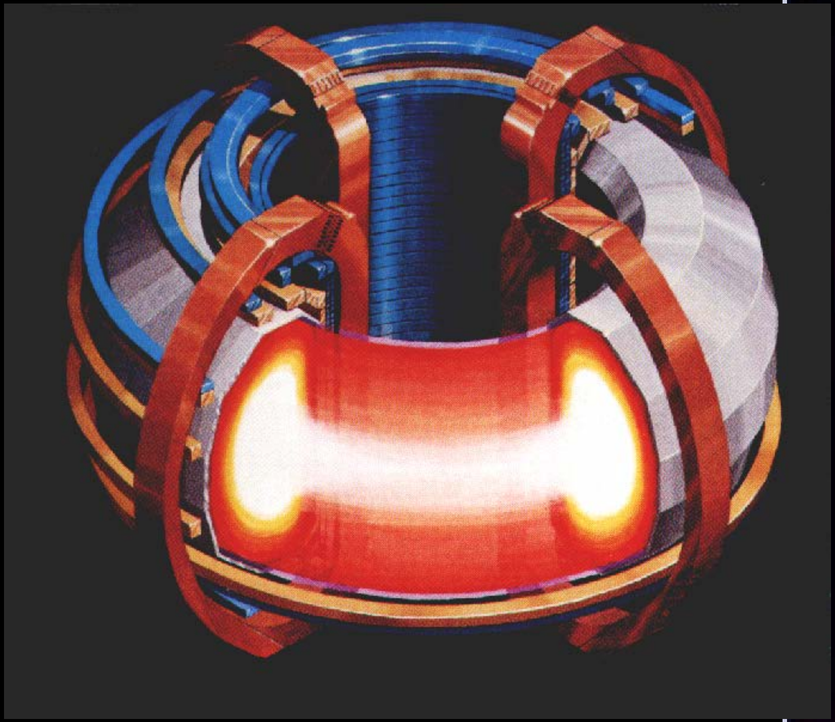


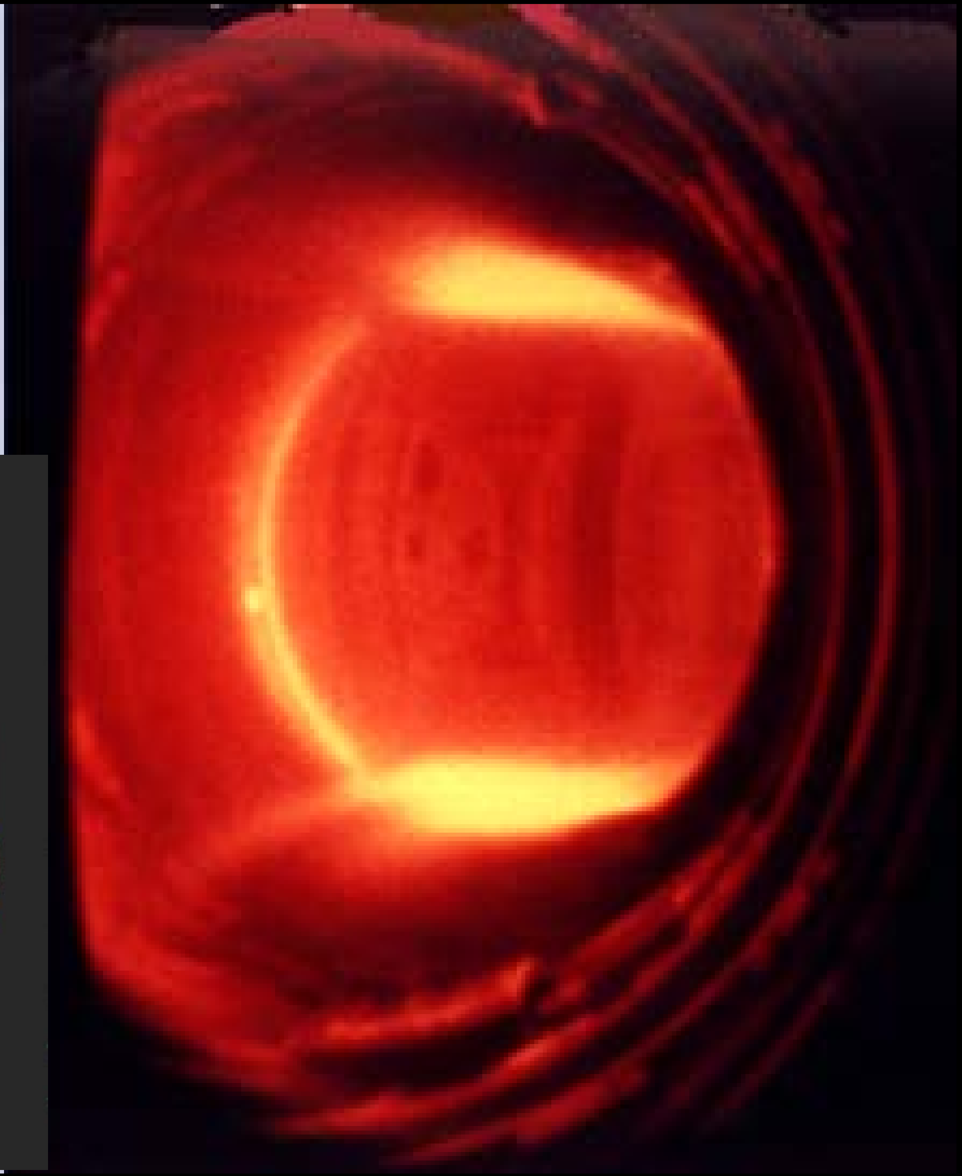
Fusion

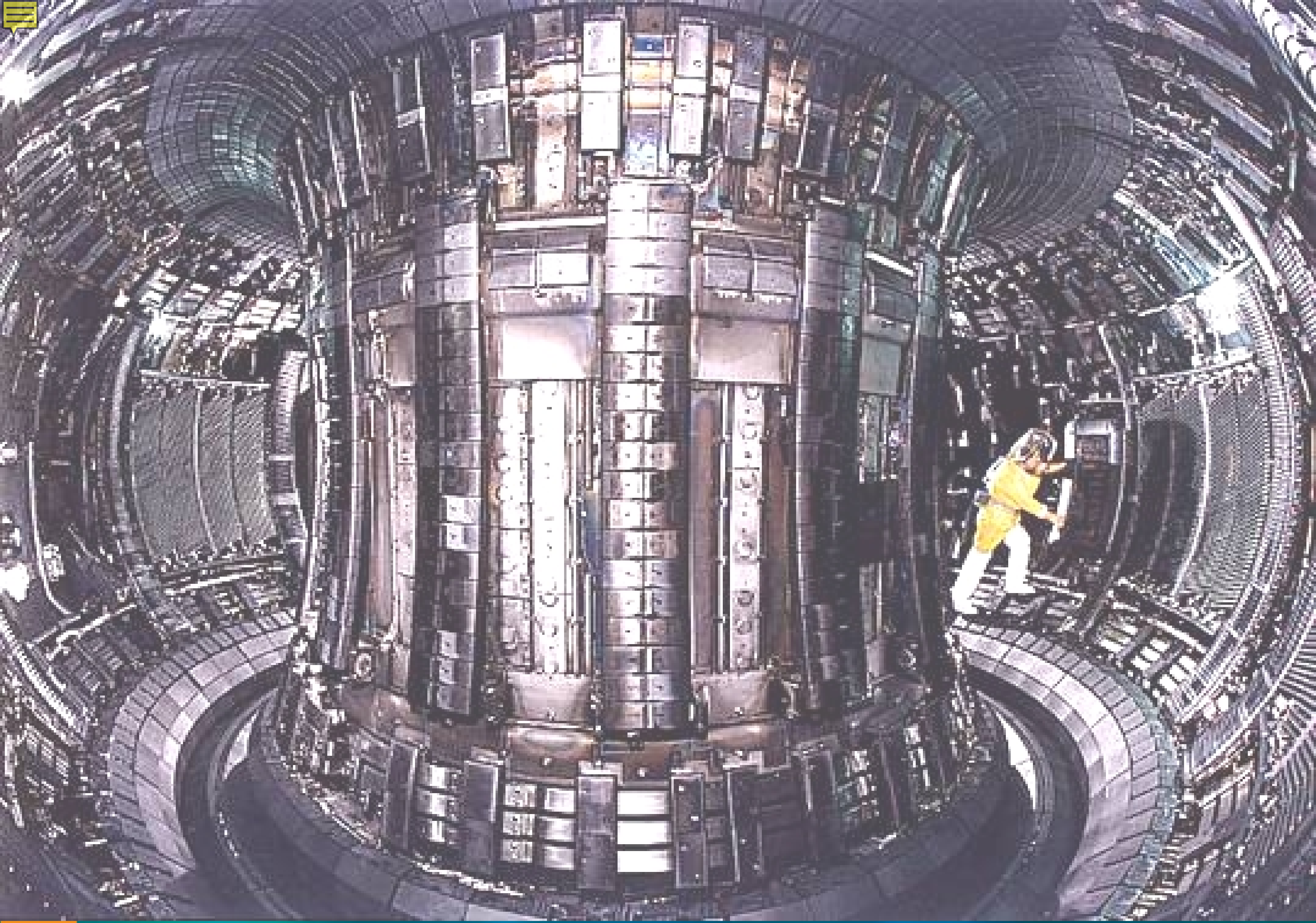


- **The energy released from 1 gram of fused DT equals the energy from about 2400 gallons of oil**

Toroidal Magnetic Confinement of Plasma







ITER Construction Site (Cadarache, France)

Key Technology Challenges

- Major issues areas include:
  - Temperature Gradient
  - Heat loads
  - Plasma Control
    - *Diagnostic instrumentation*
  - Tritium retention and in-vessel dust control
  - Magnet performance
  - Fuel cycle

Tritium Technical Challenges

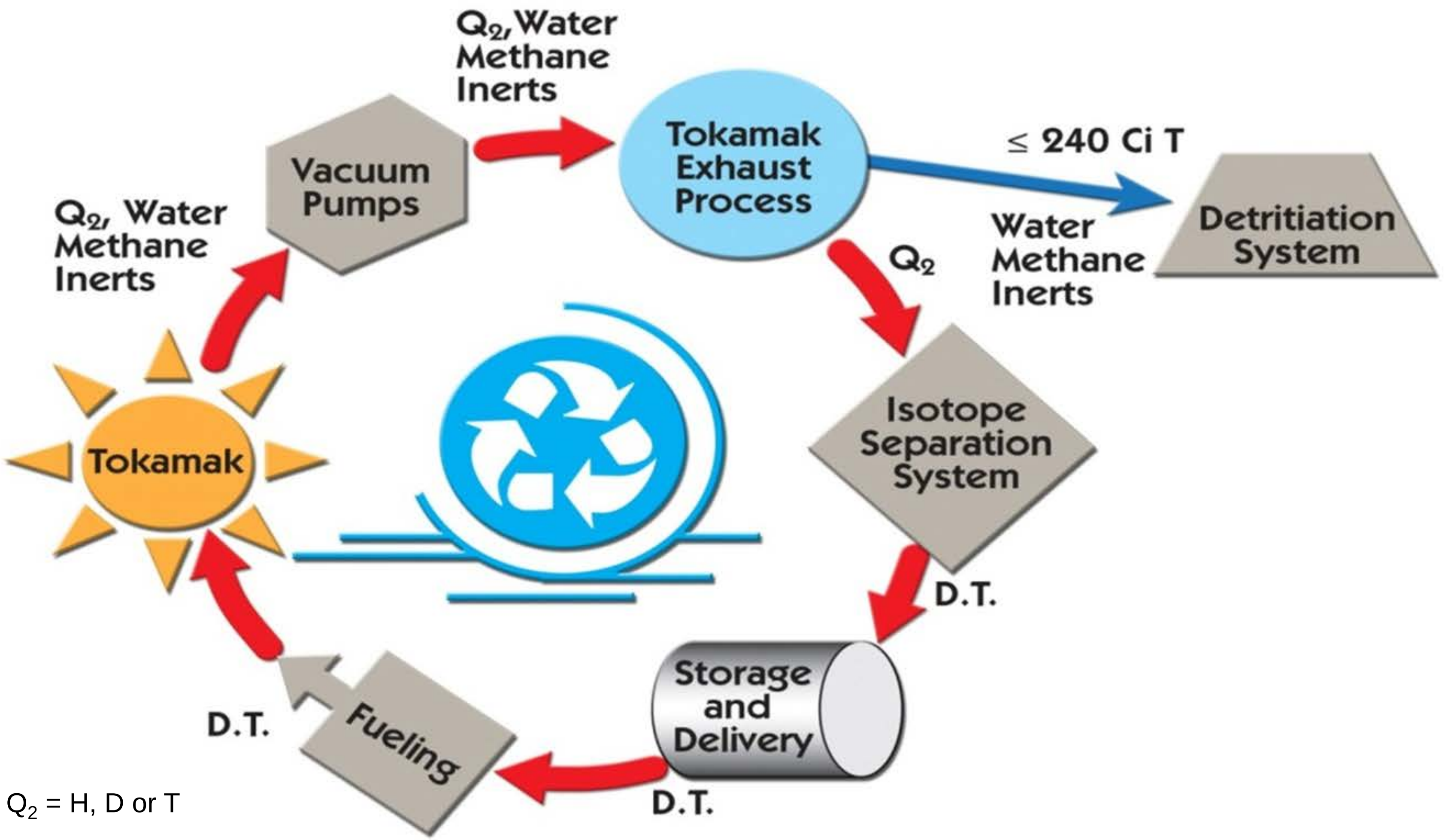
- (Kilograms per day) must be effectively processed over a range of temperatures, pressures and compositions while observing stringent accountancy, availability and environmental release constraints.
- Three key technological challenges for each tritium process in the Fusion Fuel Cycle are:
  A. Contain the tritium within physical boundaries and minimize contamination of the surroundings;
  B. Maintain control of tritium process;
  C. Sustain the fusion fuel cycle by recycling the tritium fuel needed to perpetuate the fusion reaction

Fuel Cycle

- Primary Process Requirements to sustain the Fusion Fuel Cycle :
  – Provide 'fuel quality' mixtures to the machine (H-H, D-D, D-T)
  – Provide 'tritium-free' gas for release to the environment.
- Other requirements of the Fuel Cycle:
  – Process large quantities of hydrogen isotopes over a wide range of pressures and concentrations:
    - *Pump/evacuate,*
    - *Separate,*
    - *Purify,*
    - *Concentrate, and*
    - *Store*

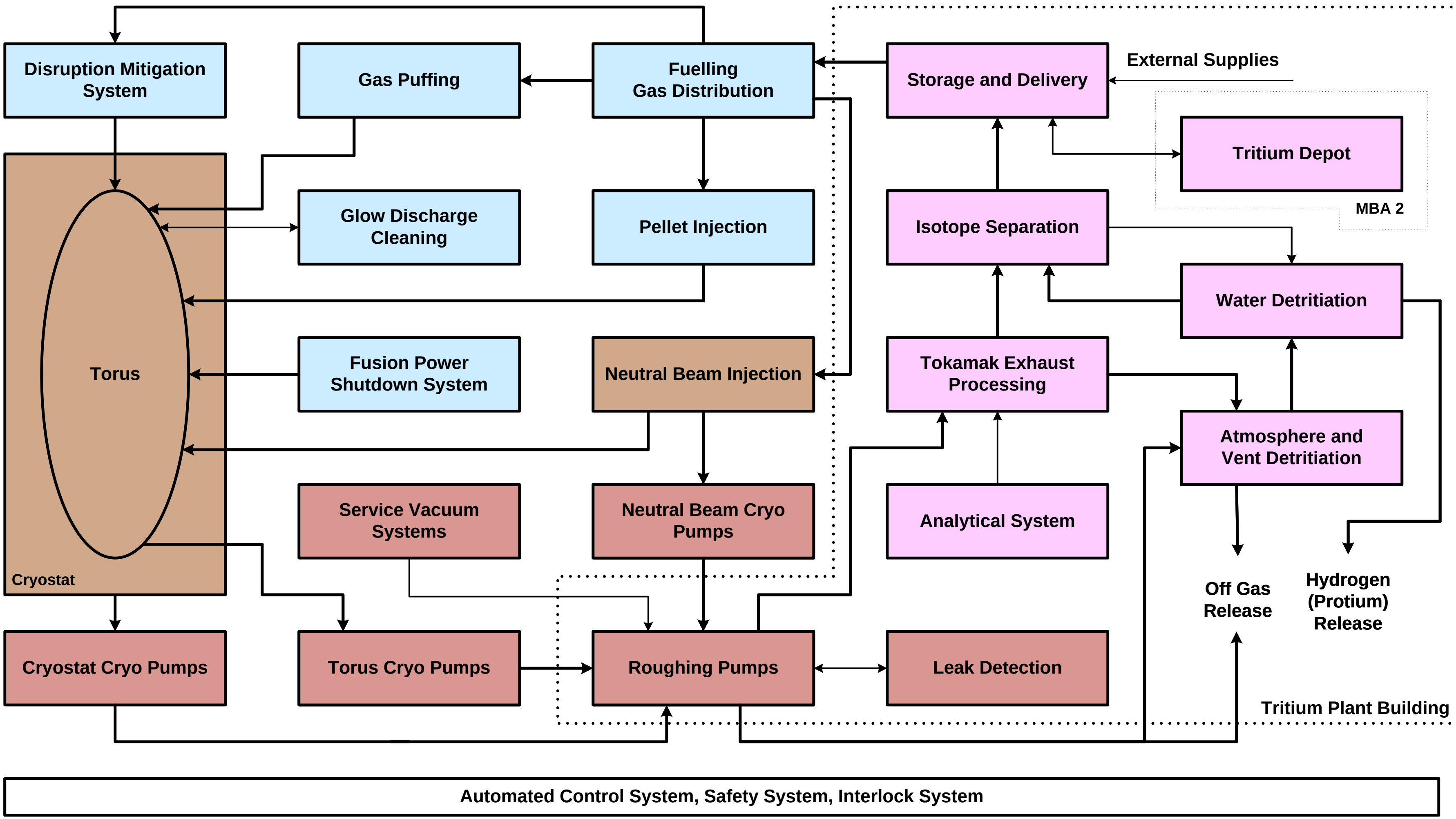
Simplified Magnetic Fusion Fuel (re) Cycle

ITER Fuel Cycle:



Note: Q_2 = H, D or T

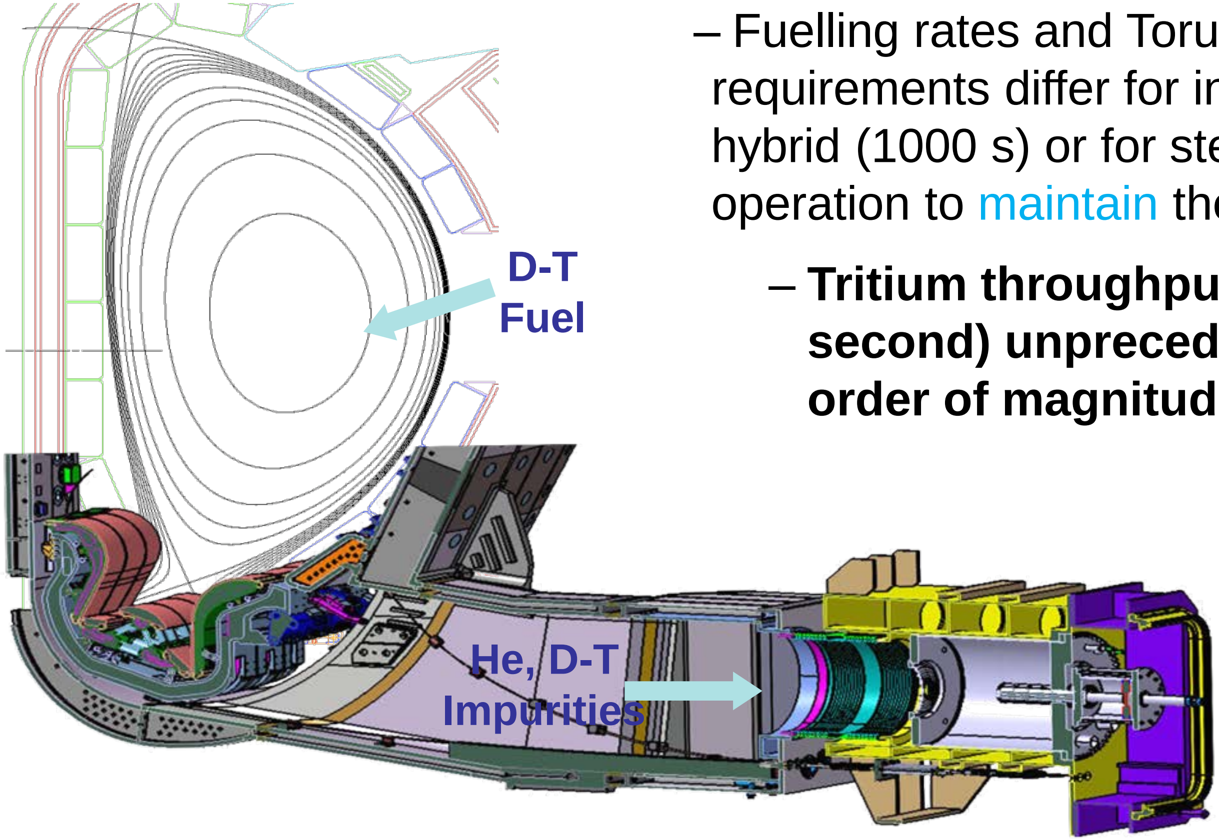
Block Diagram of a DT Fuel Cycle (ITER as example)



Selected Fuel Cycle Requirements (ITER)

Tritium site inventory: Low (< 4 kg)

Plasma tritium inventory: ~ 0.2 g

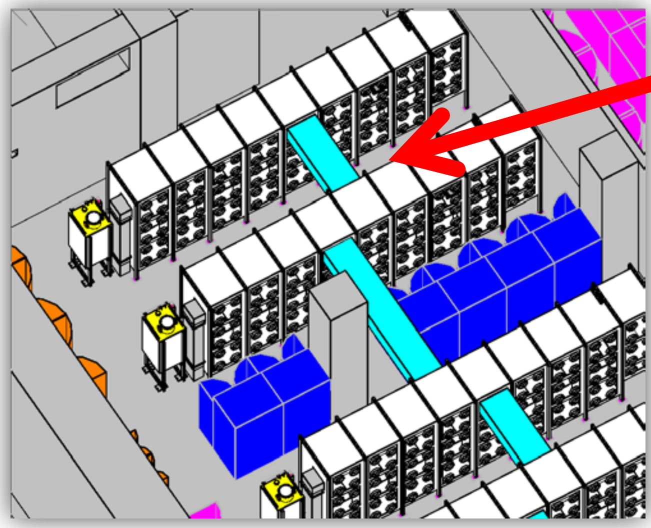


– Fuelling rates and Torus pumping requirements differ for inductive (450 s), for hybrid (1000 s) or for steady state (3000 s) operation to maintain the plasma operation

  – **Tritium throughput (1 liter (STP) per second) unprecedented by about an order of magnitude**

Tritium Confinement Requirements for TEP

- Confinement is one of the most important safety objective
  - Basic targets of confinement
    - *Prevent spreading of radioactive material in normal operation*
    - *Keep radiological consequences in off-normal conditions within acceptable levels*
  - Confinement function is achieved by a coherent set of physical barriers and / or auxiliary techniques
    - Example:

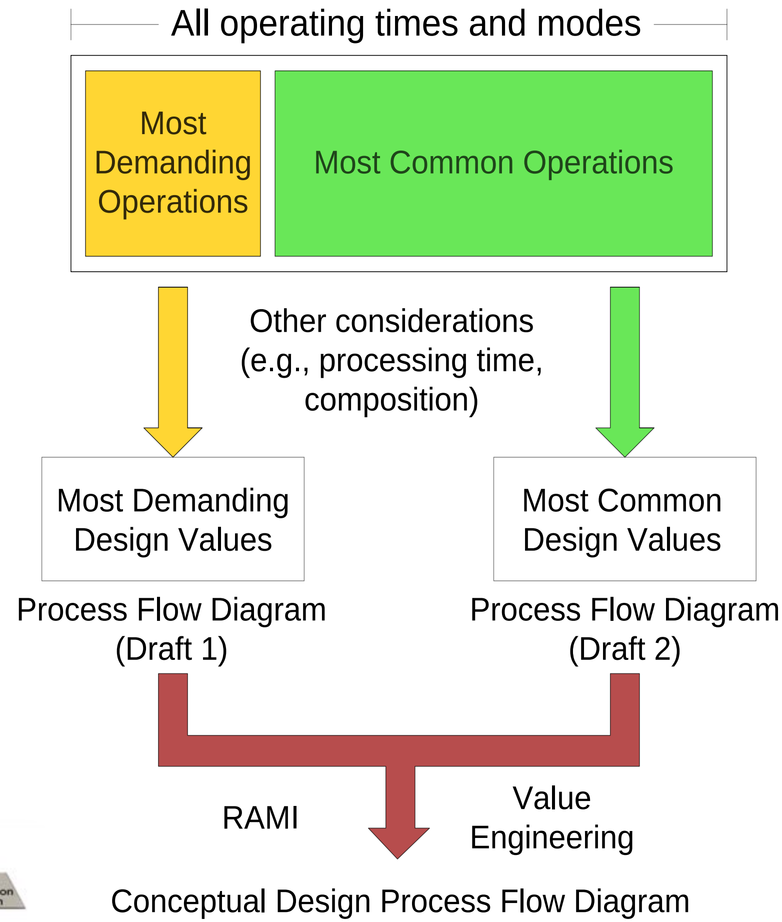


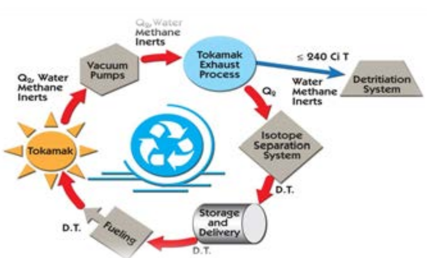
First confinement system
Inert glovebox and its extensions

Second confinement system
Filtered venting and detritiation systems operating on rooms surrounding gloveboxes, bounded by building walls and slabs

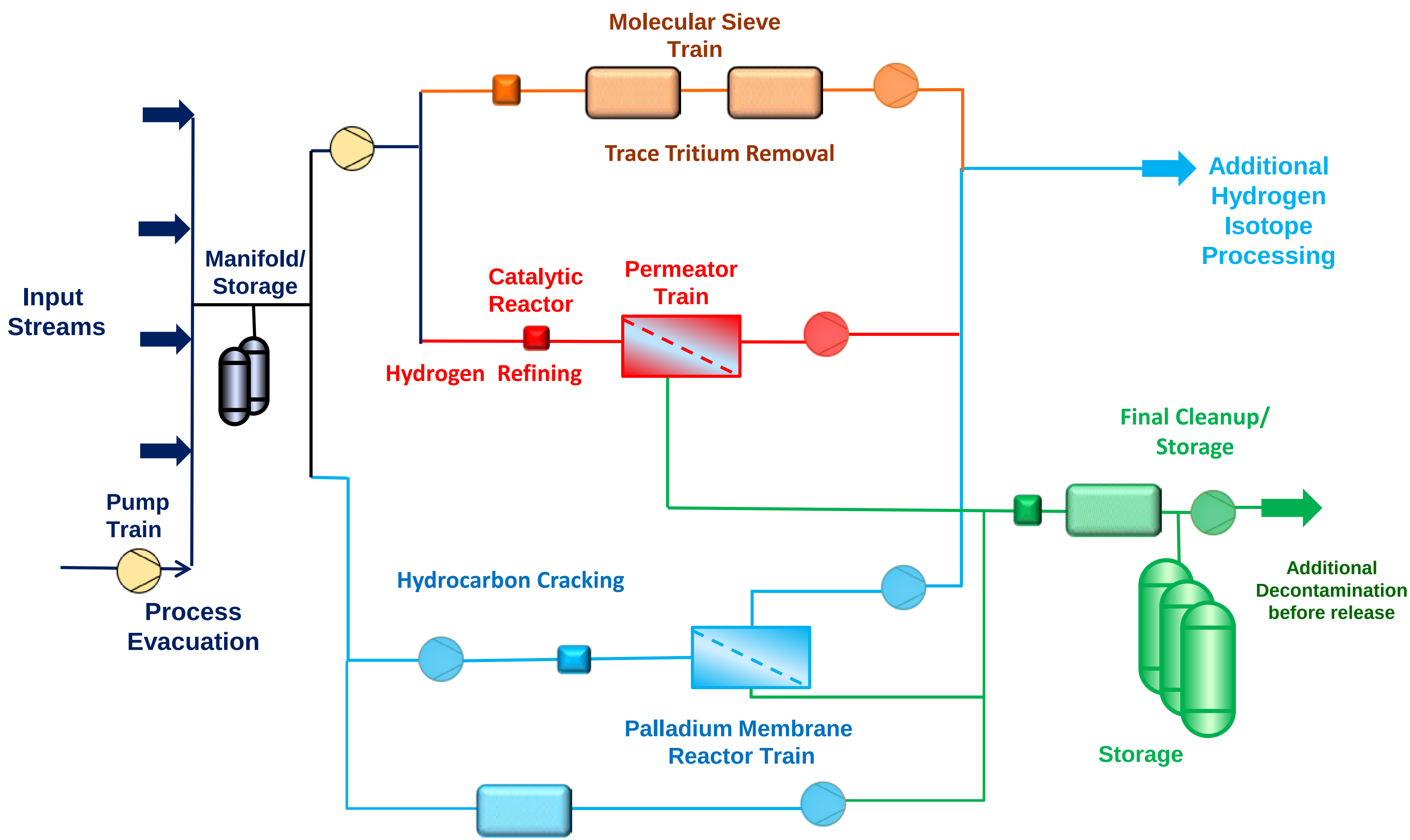
Design Approach

- Fusion is a long journey – designs must be robust, but not overly expensive or complex
  - Able to explain to regulatory authorities
- One solution is to analyze operational scenarios
  - Identification of most demanding and most common operations
    - *Most common requirements at highest reliability and availability (RAMI)*
- Critical item: Document design values and assumptions
  - As example: segregation of gases due to staged regeneration of cryopumps considered
    - *"Hydrogen likes" at 100K*
    - *"Air likes" at 300K*
    - *"Water likes" at < 470K*





Example Simplified Diagram



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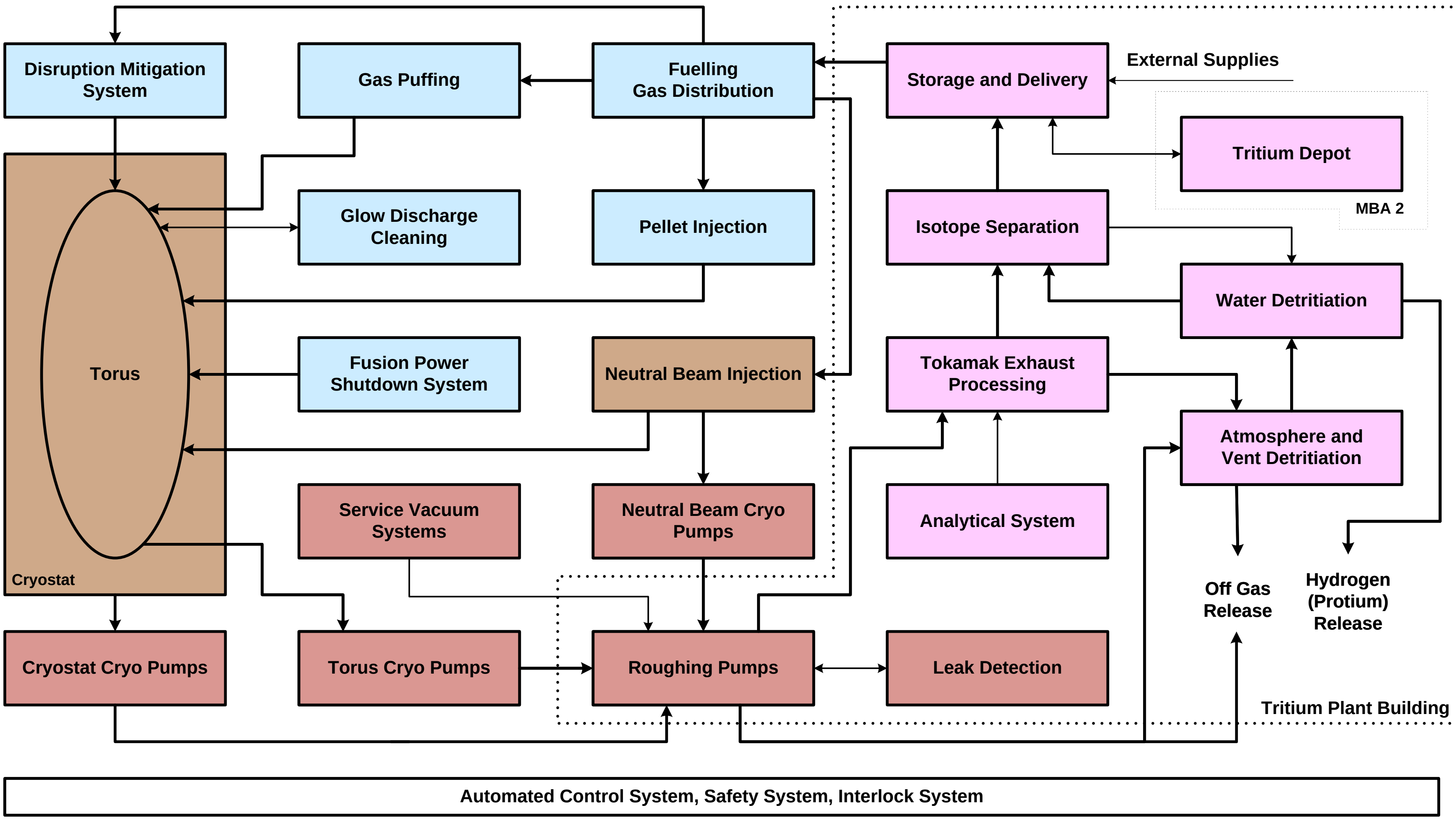

Summary

- Fusion Fuel Cycle systems constitute a rather complex chemical plant
  - Unprecedentedly high throughputs with closed loop tritium processing systems
- Deuterium/tritium processing cover wide range in physical chemistry
- Fuel Cycle systems are currently being designed for ITER
  - Engineering & design involves integration of R&D to appropriately respond to challenging requirements for tritium processing
- Still much to be done
  - This community needs to maintain, and to further develop, knowhow on tritium handling and tritium technology
    - *Fuel Cycle design needed near term (Safety Report, building interfaces)*
  - Tritium testing, commissioning, operation more than 10 years from now