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# Status of the ITER Tokamak Exhaust Process System

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*The views and opinions expressed herein do not necessarily reflect those of the ITER Organization, US ITER or the US Government.*

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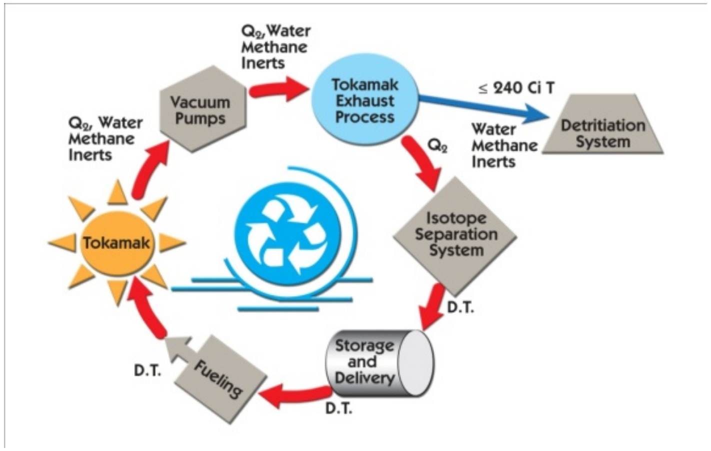
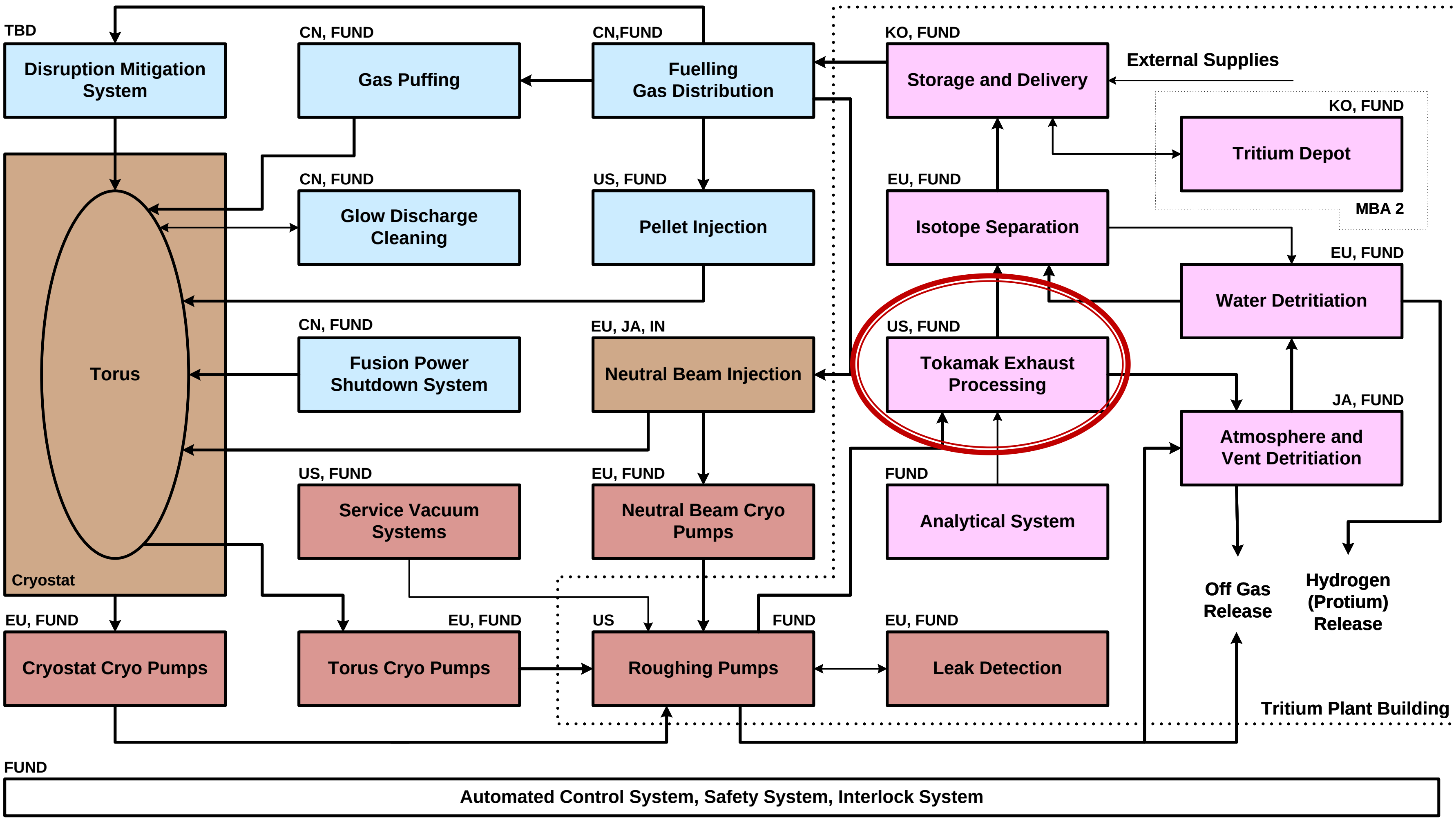
# Presentation Outline

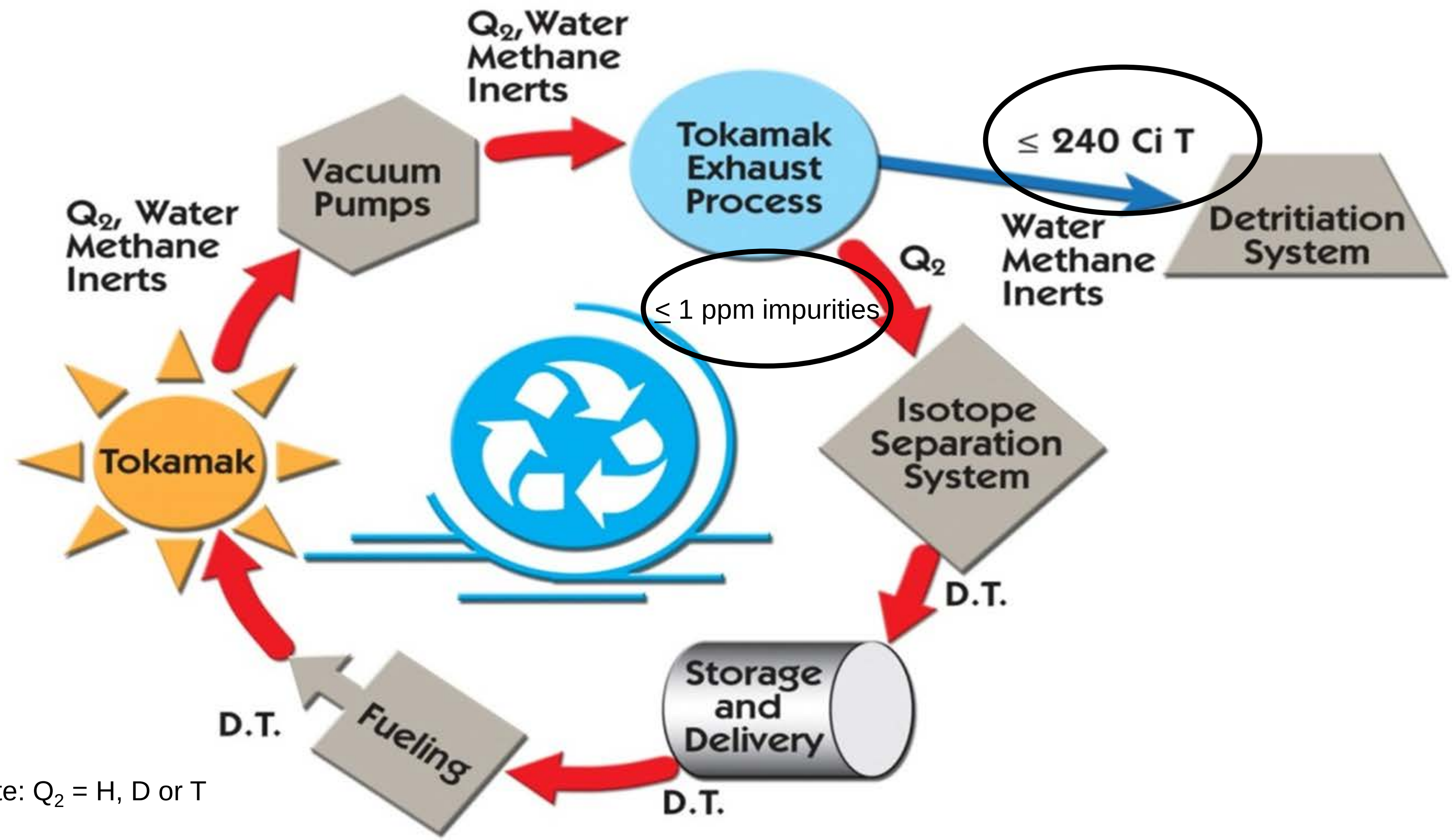
- Overview of ITER DT Fuel Cycle
- Select ITER requirements Fuel Cycle
- Process Requirements
- Design Approach
- Simplified Process Flow Diagram
- Spatial Interface
- Risk Mitigation Activities
- Potential Impacts on TEP Design
- Summary



# Block Diagram of the ITER DT Fuel Cycle



## ITER Fuel Cycle:

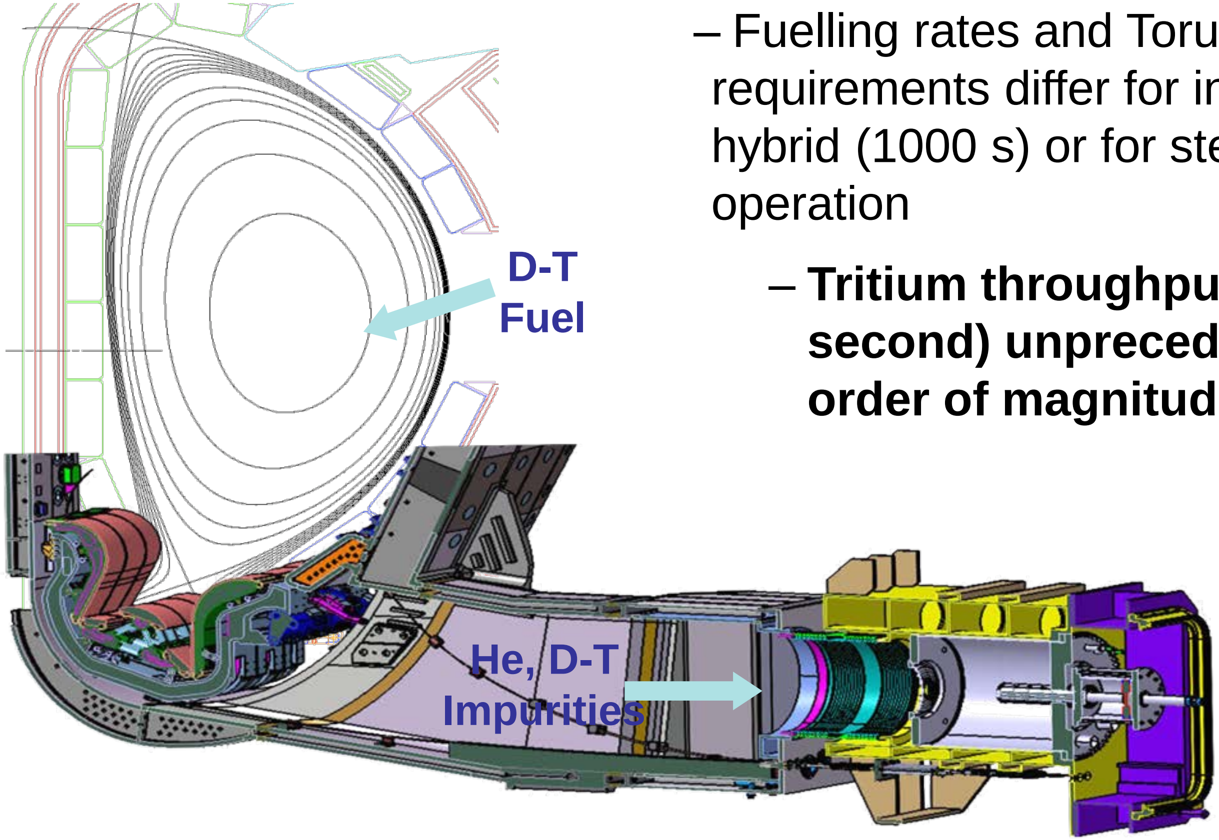



Note: $Q_2$ = H, D or T

# Selected ITER/Fuel Cycle Requirements

Tritium site inventory: < 4 kg

Plasma tritium inventory: ~ 0.2 g

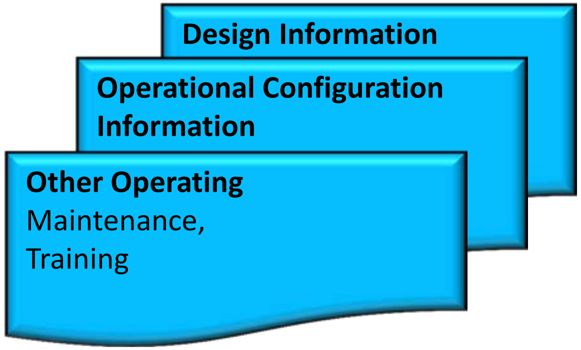


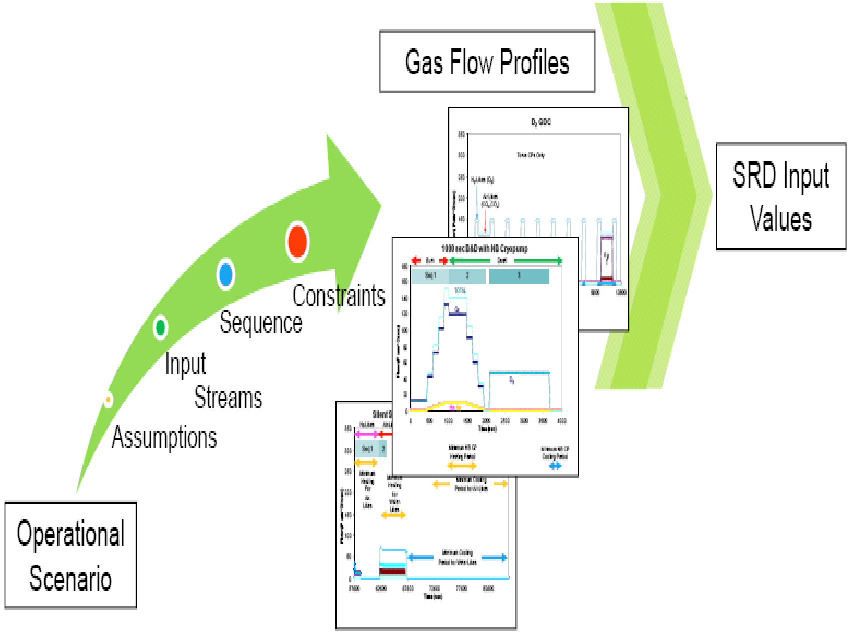

– Fuelling rates and Torus pumping requirements differ for inductive (450 s), for hybrid (1000 s) or for steady state (3000 s) operation

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

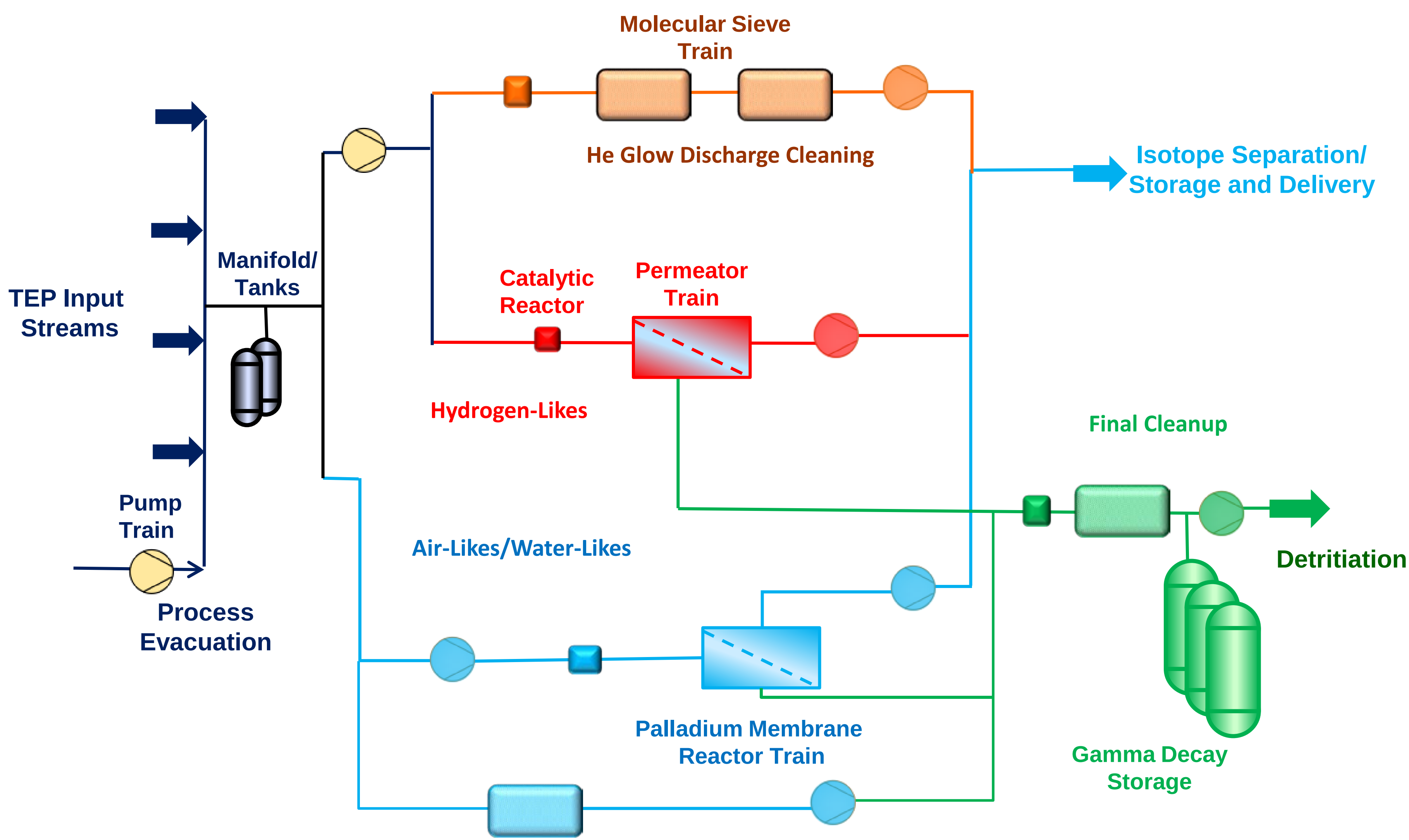
# TEP – Process Requirements Design Approach

- Identify requirements in ITER documentation hierarchy
  - In compliance with the Tritium Plant System Requirements Document
- Perform ITER operational scenarios analysis to further define additional TEP process requirements
  - TEP Individual System Requirement Document
- Identification of technology options to meet the requirements
  - Incorporated technology into draft PFDs
  - Evaluation of each PFD
- Selected technologies that best meets requirements



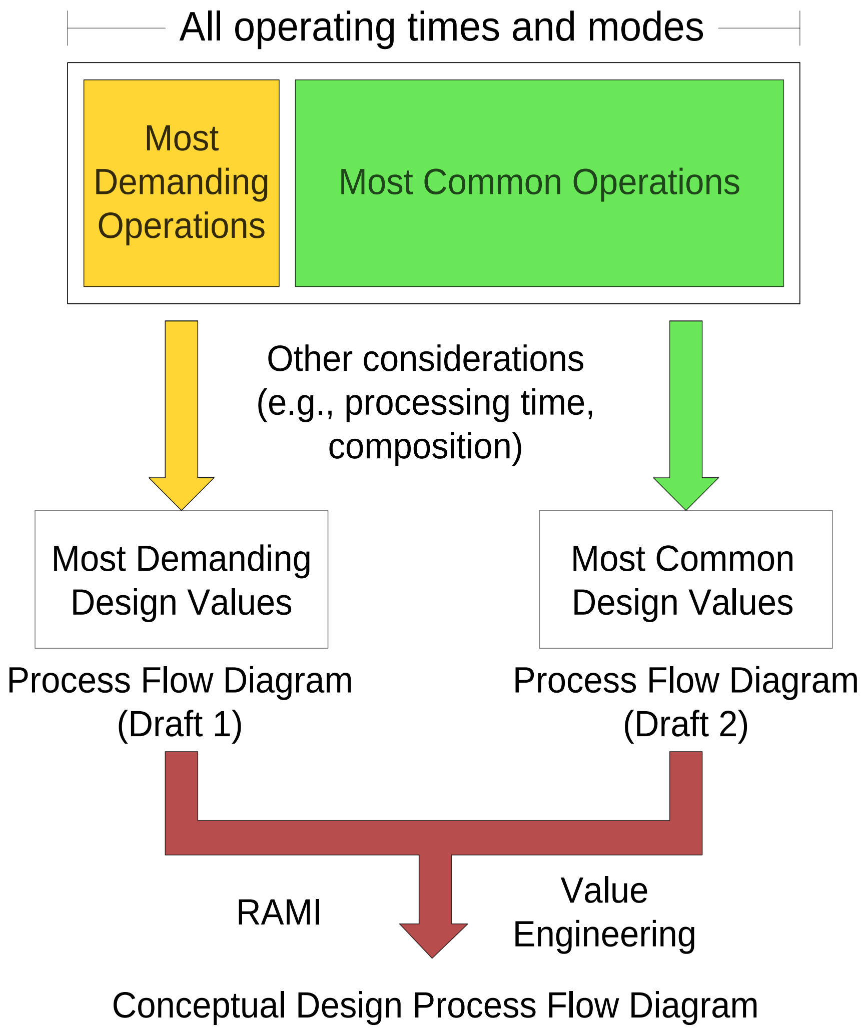



# Tokamak Exhaust Process Simplified Diagram



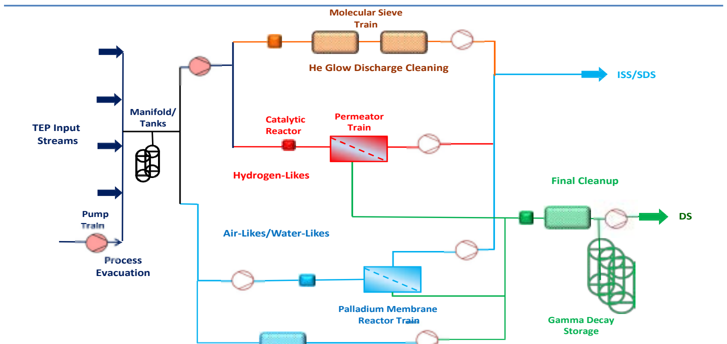
# TEP – Design Approach

- After technology selected, analyze ITER operational scenarios
  - Identification of most demanding and most common operations
    - *Most common requirements at highest reliability and availability (RAMI)*
- Critical item: Document design values, operational scenarios 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*
- Monitor changes for potential impacts



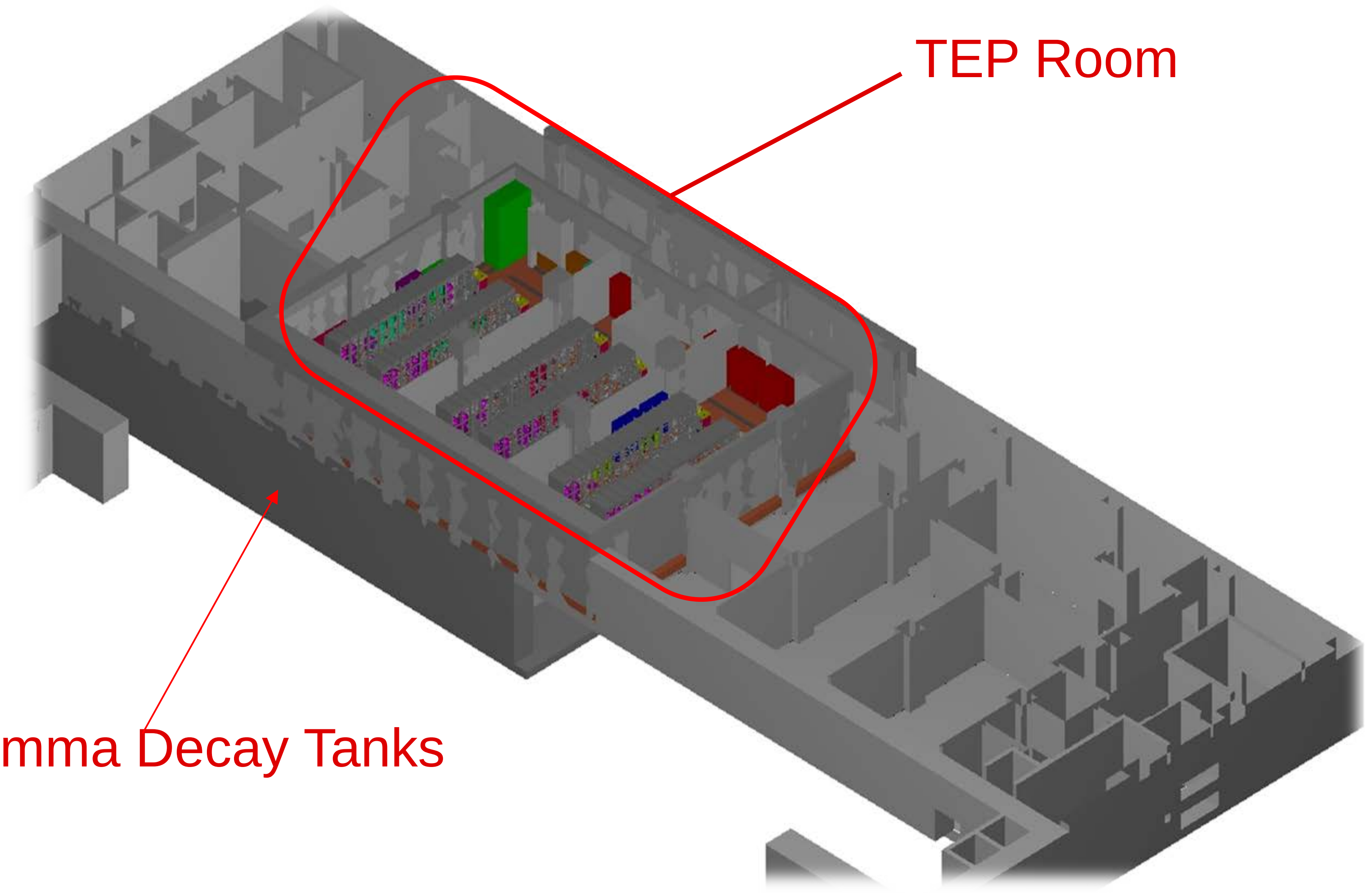
# Potential Design Impacts

- Potential Impacts to the TEP Process Flow Diagrams (PFDs)
  - ITER may have:
    - *No carbon in divertor*
  - Potential input change
    - *R&D being performed for Roughing Pump System – cryo-viscous compressor (CVC)*
    - *Potential for additional segregation of gases*
  - Highly Tritiated Water System
    - *R&D testing being performed*
    - *May incur change in input to TEP*



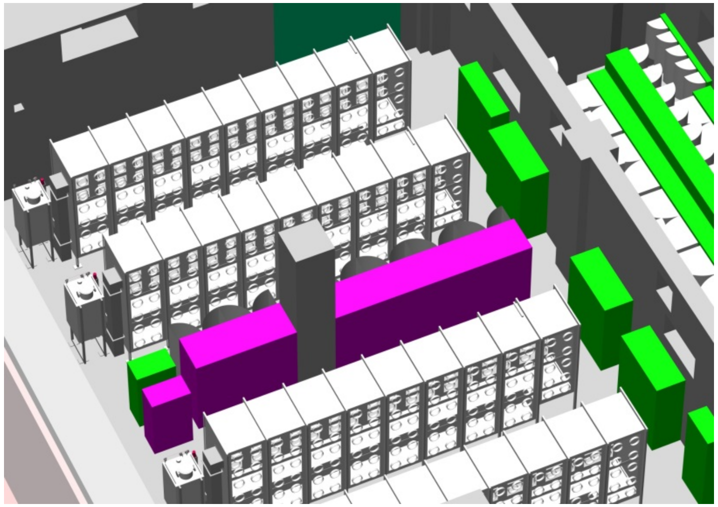

- **So far, impacts to process requirements can be accommodated by the TEP conceptual design.**

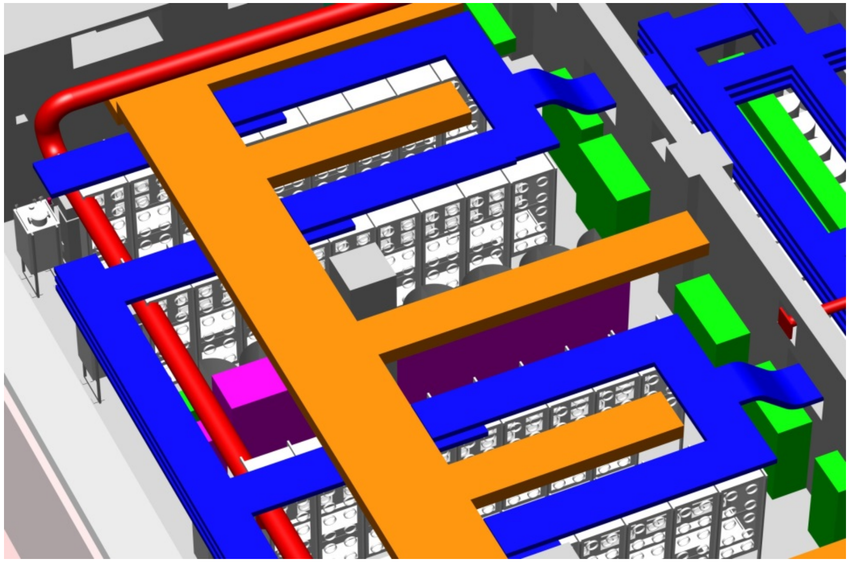
# TEP Space Allocation



# TEP – Spatial Interface

***Very demanding interface management***





***Very successful Design coordination Between the US and the IO To mitigate the space limitation risk***

# Risk Management in TEP

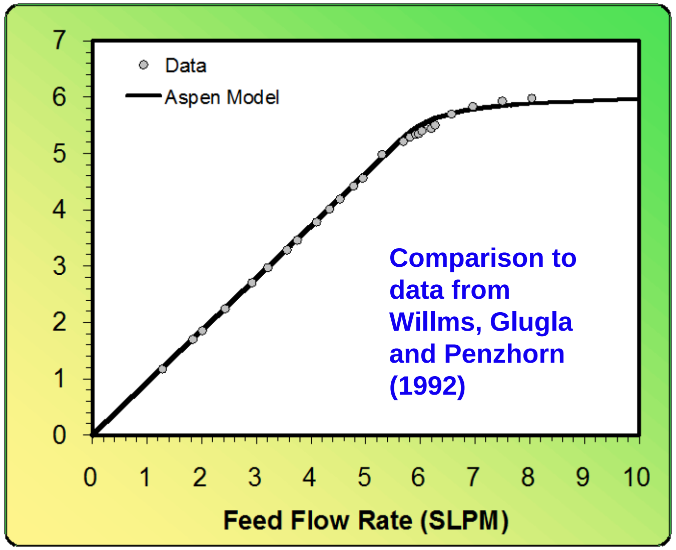
- Design has risks
  - Space limited - congested
  - Flow rates faster
    - *Up to 10X current processing*
    - *Unique input concentrations*
- Risk mitigation is of paramount importance
  - Focus on High risks
  - Focus efforts where they will make the biggest difference
    - *For Conceptual / Preliminary Design the risk focus is on the technologies of Permeators and PMRs*

# TEP – Risk Reduction Activities

- Risk: Ability to design Permeator and Palladium Membrane Reactor (PMR) for 10x flow rate with unique input concentrations

- Mitigation Strategy: Computer simulation modeling
  - Modeling is important part of ITER acceptance of TEP design
  - The models were developed using the Aspen Engineering Suite of products
  - Modules include
    - *Permeator, Palladium Membrane Reactor, Molecular Sieve Beds (ambient and cryogenic), pumps, oxidation reactor, tanks and feed scenario generator*
  - Modules were benchmarked
    - *R&D results and published data.*
  - Quality Assurance was performed

- The simulation computer model demonstrated that TEP conceptual design system can meet the design requirements while satisfying process constraints and operating schedule obligations



# TEP – Risk Reduction Activities

- Risk: Ability to manufacture Permeator and Palladium Membrane Reactor for 10x flow rate with unique input concentrations
  - Mitigation Strategy: Industry Input in Design
    - *Industry Evaluation of Manufacturability and Performance of Specialty Engineered Components – Permeator and Palladium Membrane Reactor*
      - Sought industry best practices.
    - *'Best Value' Procurement awarded*

- **Results:**
  - Confirmed basic technology and design concepts are viable and able to be commercially fabricated
  - Recommended a few design improvements and additional testing
- **This will be evaluated before finalization TEP preliminary design**

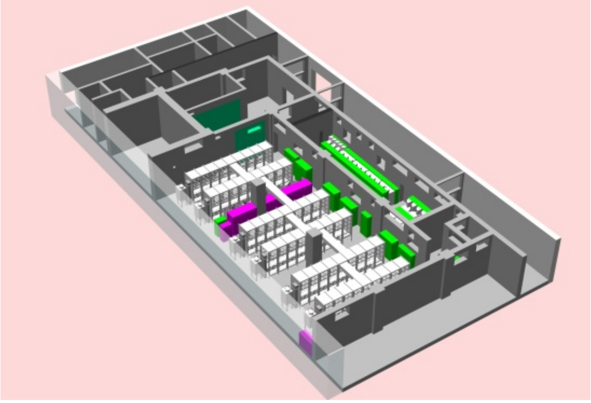
# TEP – where are we now?

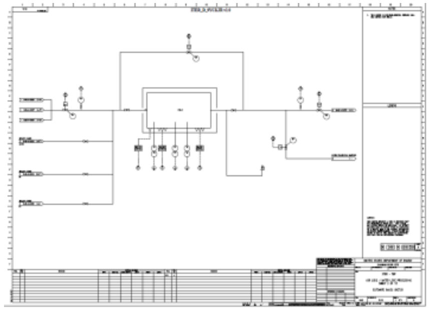
| WBS | Description | Design | | | | Fab | Acceptance Test |
|---|---|---|---|---|---|---|---|
| | | R&D | Conceptual | Preliminary | Final | | |
| 1.3.2 | Tokamak Exhaust Process | IO (LANL) | IO (SRNL/LANL) | IO (IO/SRNL/LANL) | US (SRNL) | US (Industry/ SRNL) | US (SRNL) |
| | | Complete | Complete | Initiated | | | |

- US for IO:
  - Conceptual Design - Complete
    - R&D - Catalyst selection, scale-up demonstration, and technology selection
  - Preliminary Design – In Progress
    - Assist IO to provide design documentation for Preliminary Design
- US Scope, through its partner lab SRNL - Scheduled:
  - Final Design
  - Procurement
    - Multiple contracts with Industry
  - Assemble and Testing
  - Ship to France

# Summary

- **TEP has complex interfaces**
  - Unprecedentedly high throughputs
  - Space management is an issue
  - Details and assumptions are documented
- **First Phase of TEP design has been successful**
  - Conceptual Design approved
    - *Technology selected – permeator, palladium membrane reactor, molecular sieve beds*
    - *Process flow diagram developed*
    - *Computer simulation modeling confirms the conceptual design meets design criteria*
  - Industry input confirmed manufacturability and ability to meet design requirements
  - Preliminary design is in progress
- **Still much to be done**
  - Incorporate R&D from other systems, changes to input criteria, etc.
  - Add details during preliminary design (meat to the bone)





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