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A New Hydrogen Processing Demonstration System

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35th Tritium Focus Group (TFG) Meeting
Princeton Plasma Physics Laboratory (PPPL), Princeton, NJ
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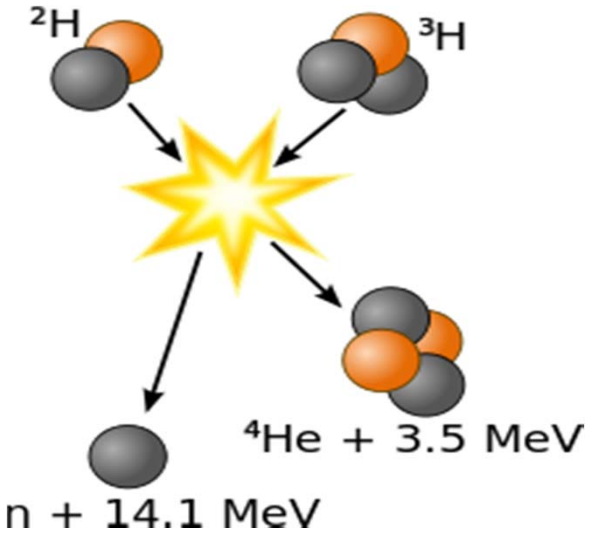
Overview: Compare and Contrast Tritium Process Systems

Background

- D (Deuterium) – Discovered in 1931
- T (Tritium) – Discovered in 1934
- Various uses for tritium
- D-T Fusion Reaction
  - D + T = He + n + 17.59 MeV



Beginning Research

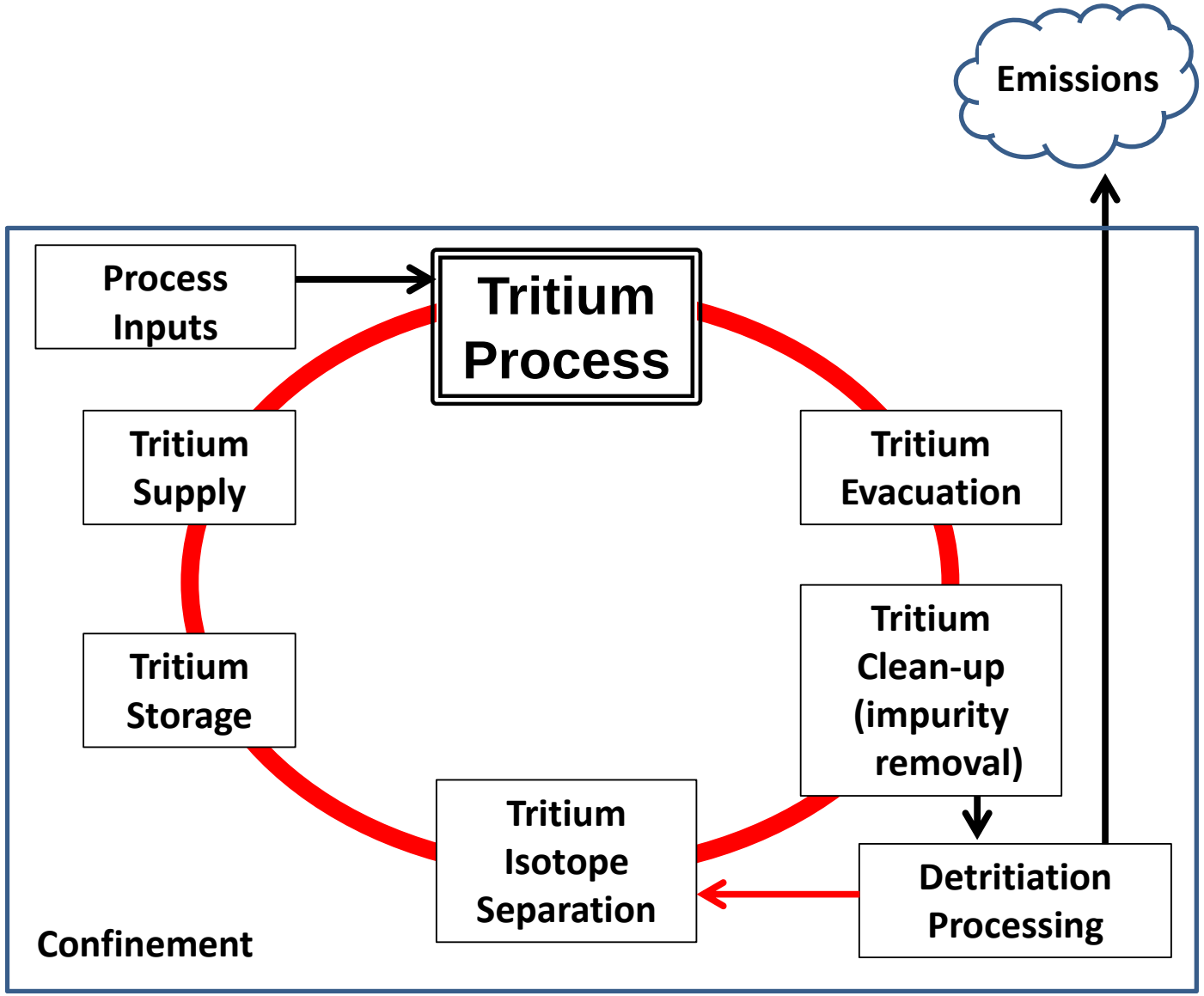
US Cold War Defense Programs

- D + T = He + n + 17.59 MeV
- 1940's during WWII
  - US Manhattan Project
- US Nuclear Deterrent

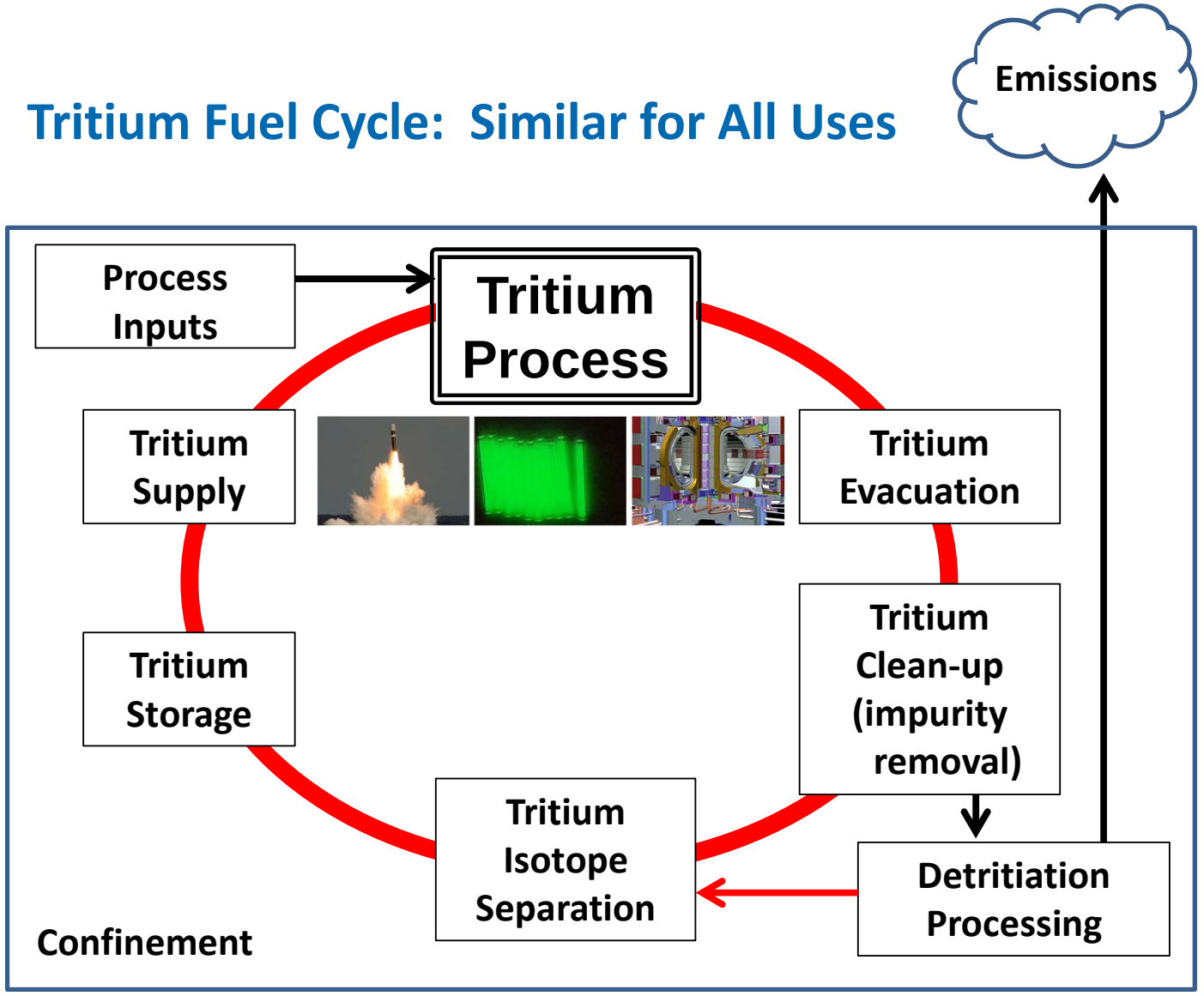
Fusion Energy

- D + T = He + n + 17.59 MeV
- 1950's
  - US Atoms for Peace
- Electric Power Generation

Tritium Fuel Cycle: Similar for All Uses

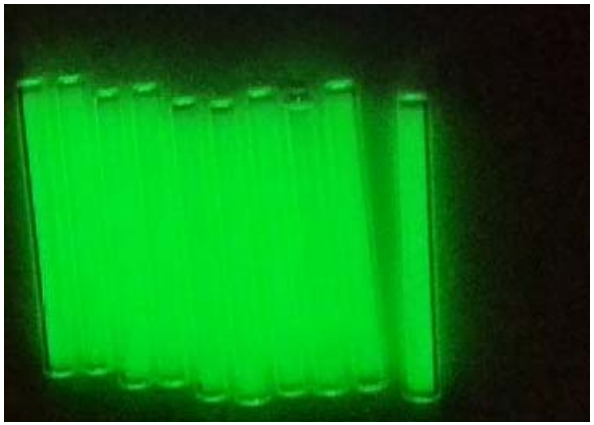


Tritium Fuel Cycle: Similar for All Uses

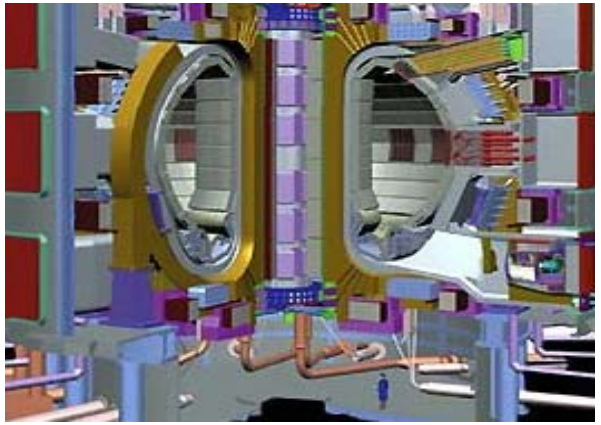


Tritium Fuel Cycle: Tritium Process

- Defense Programs
  - Components



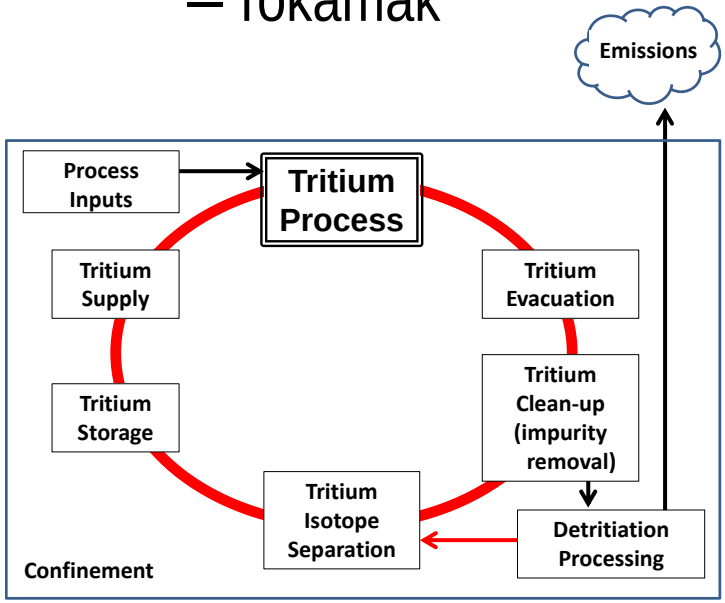
- EXIT Signs
  - Glass Tubes



- ITER
  - Tokamak

The Illusion

"Once the Tritium Process has been defined, all that is left to debate is what processes and equipment to use for the rest of the facility. Let's focus funding on plasma science and materials development."



Tritium Supply

Cold War Defense Programs

- Produced Material
- Department of Energy Nuclear Weapons Complex
- 1950's: Savannah River Plant

Fusion Energy

- Waste Product from CANDU Electricity Generation
- Tritium Removed from Heavy Water
- Chalk River Lab Distribution

Tritium Facility Siting and Emissions

Cold War Defense Programs

- Far from Large Population Centers
- Large Land Areas
  - Public far from Site Boundary
  - On-Site Waste Disposal

Fusion Energy

- Research Based at Universities/Technology Centers
- Typically More Urban
  - Close to Public
- Waste Shipped Off-Site
- Low Allowable Emissions

Tritium Process Inventory

Cold War Defense Programs

- "Large" Inventories to Meet Stockpile Demands
  - Asset: Flexibility; Ready Supply
- Process Design Focus
  - Production; not Minimum Inventory

Fusion Energy

- "Low" Inventories to Meet Safety Basis Requirement
- Minimum to Meet Process Needs
- More Tritium, More Cost!
- More Tritium, More Risks!

Tritium Processing: Batch Versus Continuous

Cold War Defense Programs

- Component Filling
  - Inherently Batch Process
- "Baseline" Process Flow Rates

Fusion Energy (ITER)

- Continuous During Test Reduces Inventory Needed
- Much Higher Process Flow Rates

Discussion: Tritium Evacuation

Cold War Defense Programs

- Typically Commercially Available Equipment
  - Vacuum Pumps
  - Compressors
- Metal Hydride Technology

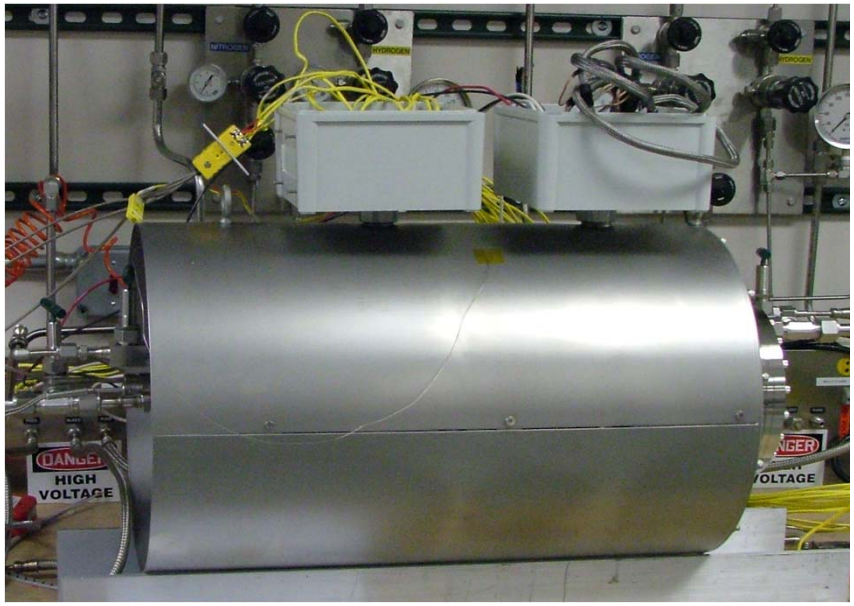
Fusion Energy (ITER)

- Large Pumping Speeds
- Continuous Duty Cycle
- Custom Pump Development
- Multiple, Sequenced Pumps

Discussion: Tritium Clean-Up/Gas Processing

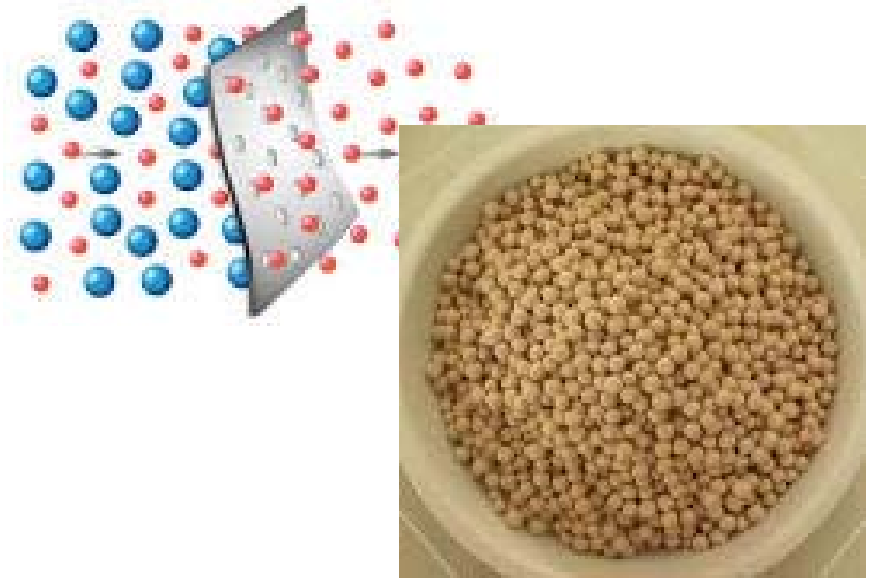
Cold War Defense Programs

- Main Separation: Pd/Ag “Diffuser (Permeator) System
- Eventually, Catalytic Oxidation and Absorption
- Water “Cracking” Via Hot Metal



Fusion Energy (ITER)

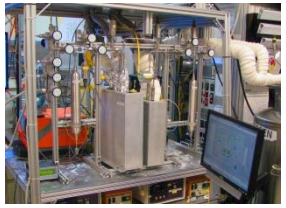
- Main Separation: Pd/Ag Permeator (Diffuser) System
- Eventually, Catalytic Oxidation and Absorption
- Water Detritiation Process



Discussion: Tritium Isotope Separation

Cold War Defense Programs

- Various Methods Used
  - Thermal Diffusion Columns
  - Batch Cryogenic Distillation
- Thermal Cycling Absorption Process (TCAP)



Fusion Energy (ITER)

- Cryogenic Distillation
  - Continuous Process
  - Four Column Design

(Not ITER Separation System)

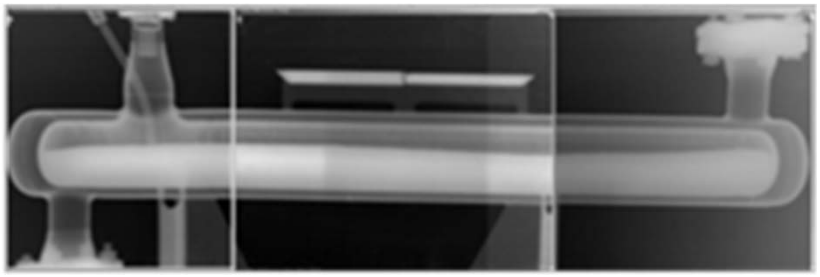
Discussion: Tritium Storage

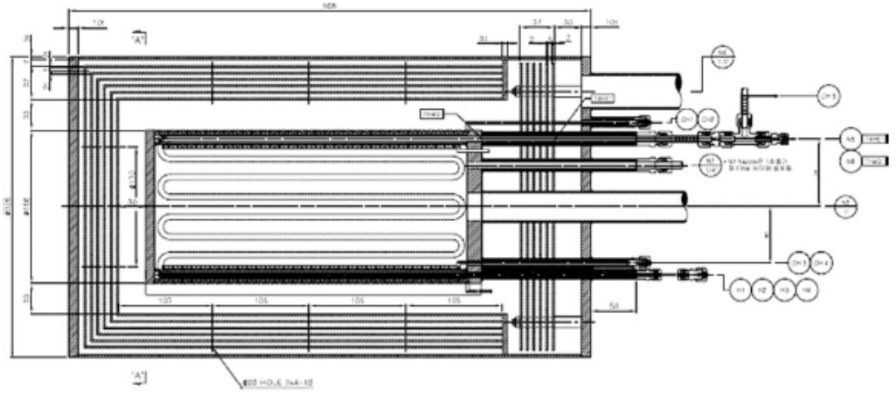
Cold War Defense Programs

- Old Processes
  - Sub-atmospheric Tanks
- New Processes
  - Metal Hydride Storage Beds
  - Large Capacity Beds: > 300 gram

Fusion Energy (ITER)

- Metal Hydride Storage Beds
  - DU (depleted Uranium)
  - 70 g Limit

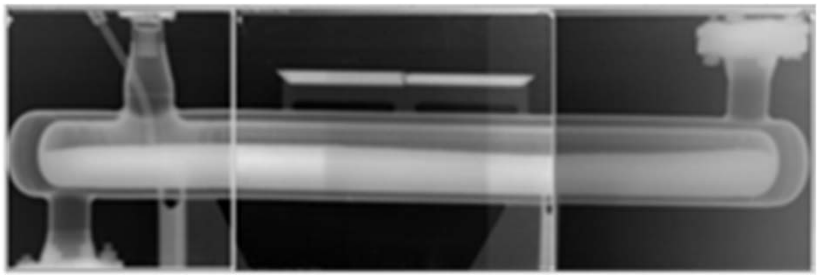




Discussion: Tritium Supply

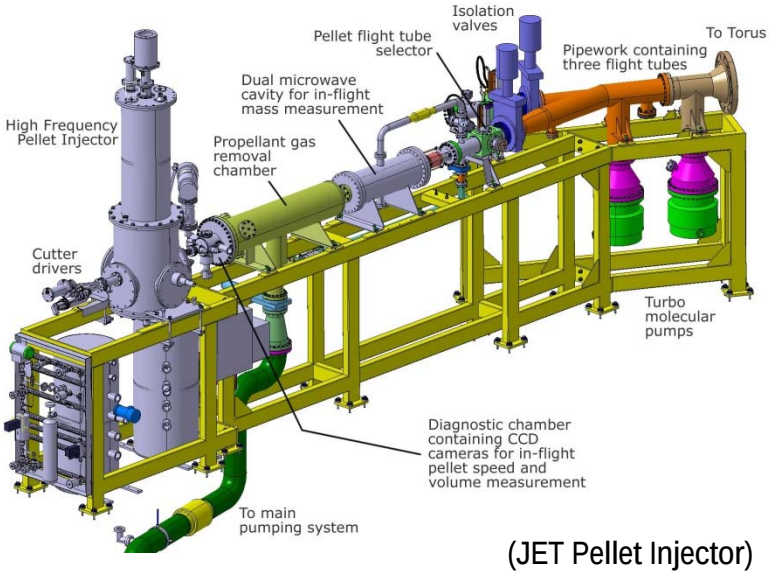
Cold War Defense Programs

- Pumps, Compressors, Metal Hydride Beds
- Compress Mixtures



Fusion Energy (ITER)

- Cryogenic Pellet Injectors
  - High Feed Rates
  - Inject D and T Separately



(JET Pellet Injector)

Discussion: Rate-Inventory Matrix

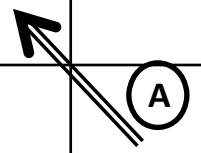
- Relative System Inventories and Tritium Processing Rates

	Low Inventory Systems	**High Inventory Systems**
High Processing Rates	Fusion Research Tritium Systems	
Low Processing Rates		US Cold War Tritium Systems

Discussion: Rate-Inventory Matrix

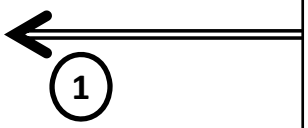
- Improvements to Cold War Processing Systems
  - Is Lower Inventory, Faster Systems the Right Path?

	Low Inventory Systems	**High Inventory Systems**
High Processing Rates	Fusion Research Tritium Systems	
Low Processing Rates		US Cold War Tritium Systems



Discussion: Rate-Inventory Matrix

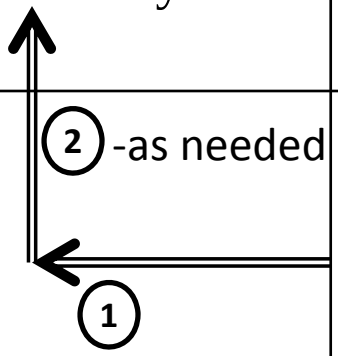
- All Processes Benefit from Lower Process Inventories
  - Less Public Dose from Accident Scenarios

	Low Inventory Systems	**High Inventory Systems**
High Processing Rates	Fusion Research Tritium Systems	
Low Processing Rates		Cold War Tritium Systems

Discussion: Rate-Inventory Matrix

- Not All Processes Need Fast Processing Rates
  - "Right-Size" Processes Based on Need

	Low Inventory Systems	**High Inventory Systems**
High Processing Rates	Fusion Research Tritium Systems	
Low Processing Rates		Cold War Tritium Systems



Conclusions: Part 1

Tritium Process Technology Development

- Initiated as Part of US Nuclear Weapons Defense Programs

All Tritium Processes Contain Similar Processing Operations

- Fusion Research Needs Exceed Existing Technology Base
- New Processes and Technologies Under Development

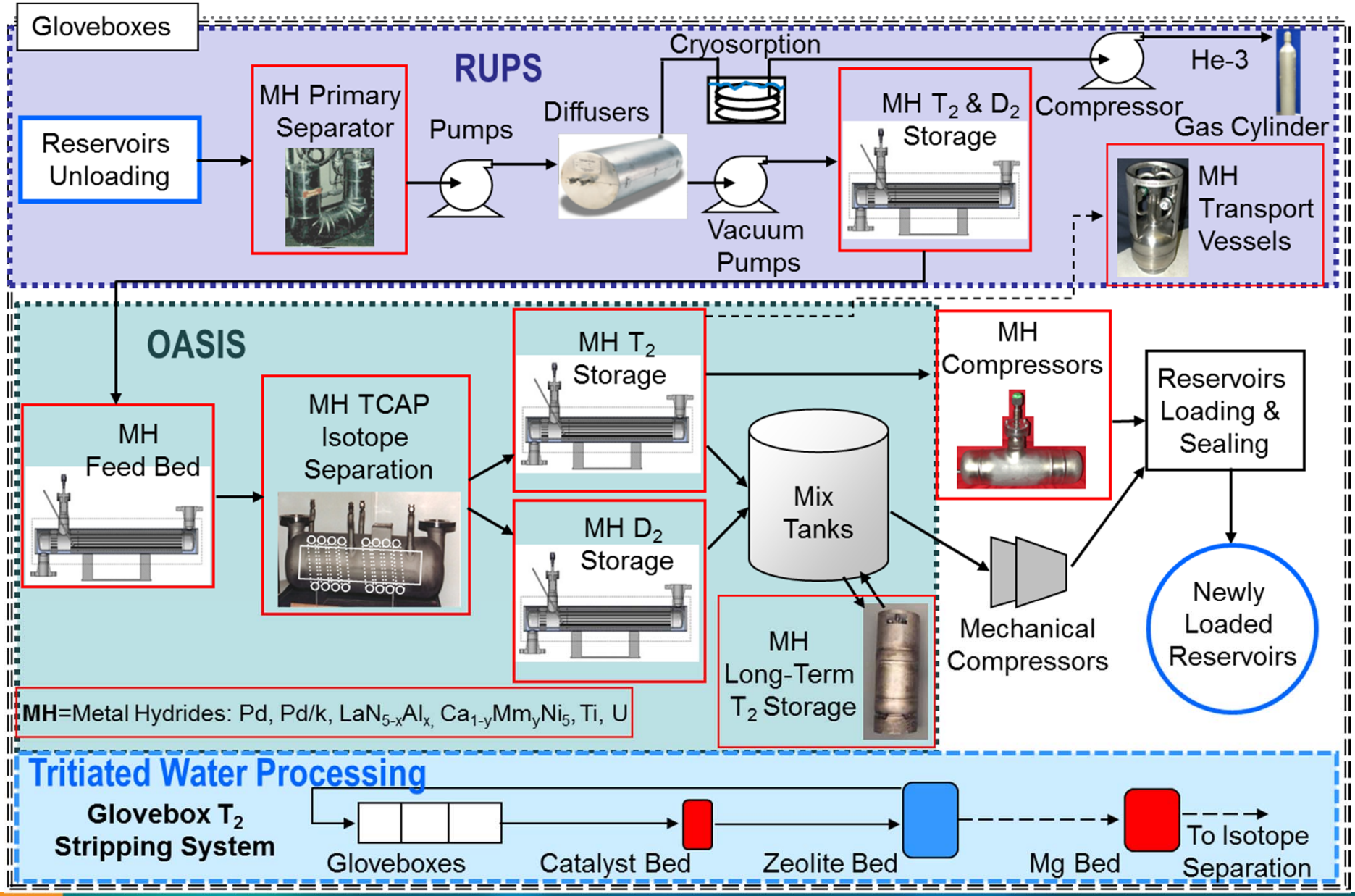
US Cold War Era Facility Design Basis Outdated

- Revised Processed to be Developed for Reduced Inventories
  - Improved Safety to the Public
- Need for Faster Processes: "Right-Size" Processes
- Still Need Technology Development for Tritium Processes
  - Tritium Releases to the Public Dominate System Designs
  - Yes: Continue Plasma Science and Materials Research Too!

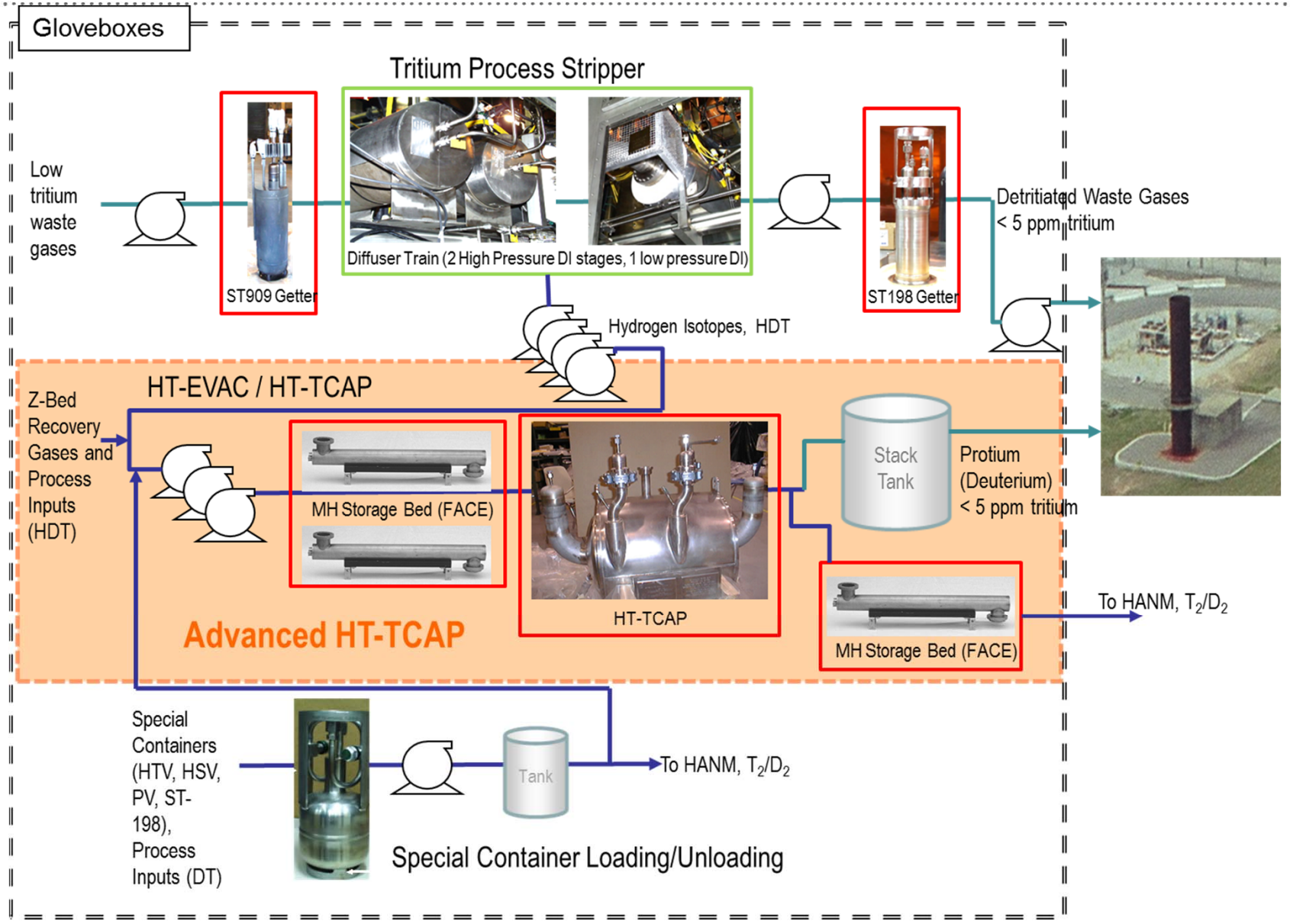
Part 2: Overview

- Hydrogen Processing Demonstration System (HPDS)
- Enabling Activities/Tasks
  - Revised Unloading Purification System (RUPS – this talk)
  - Optimized, Advanced Storage and Isotope Separation (OASIS – this talk)
  - Reduced Area Confinement and WAter Processing (RACWAP - not discussed)
    - *Anita promises to make me change the acronym!*
  - Advanced HT Isotope Separations (not discussed)
- Plans
  - HPDS Cold Test Concept and Plans

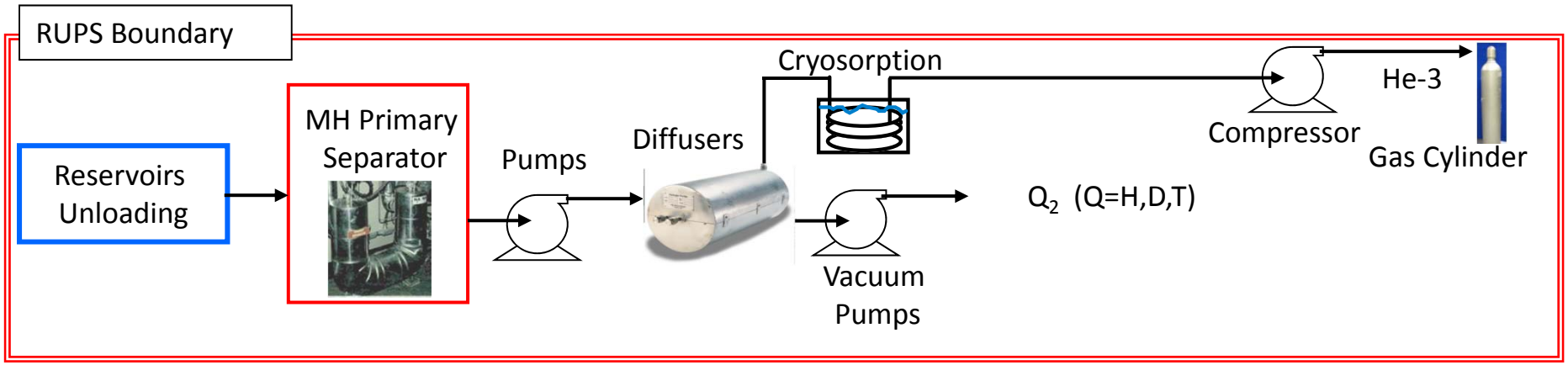
Tritium Processing at SRS: The Largest Metal Hydride Based Tritium Facility in the World



H Area New Manufacturing – Tritiated Waste Gas Processing

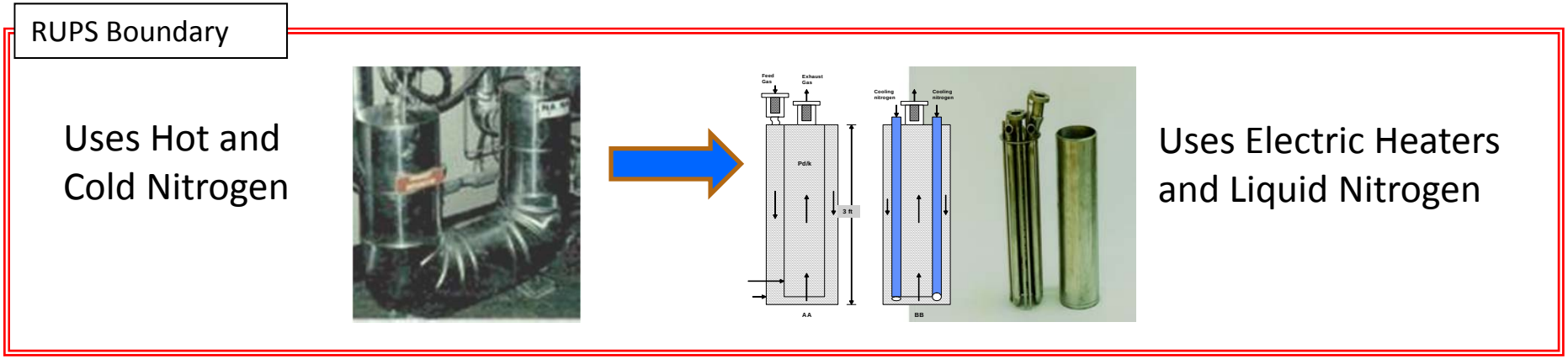


Revised/Reservoir Unloading Purification System (RUPS)

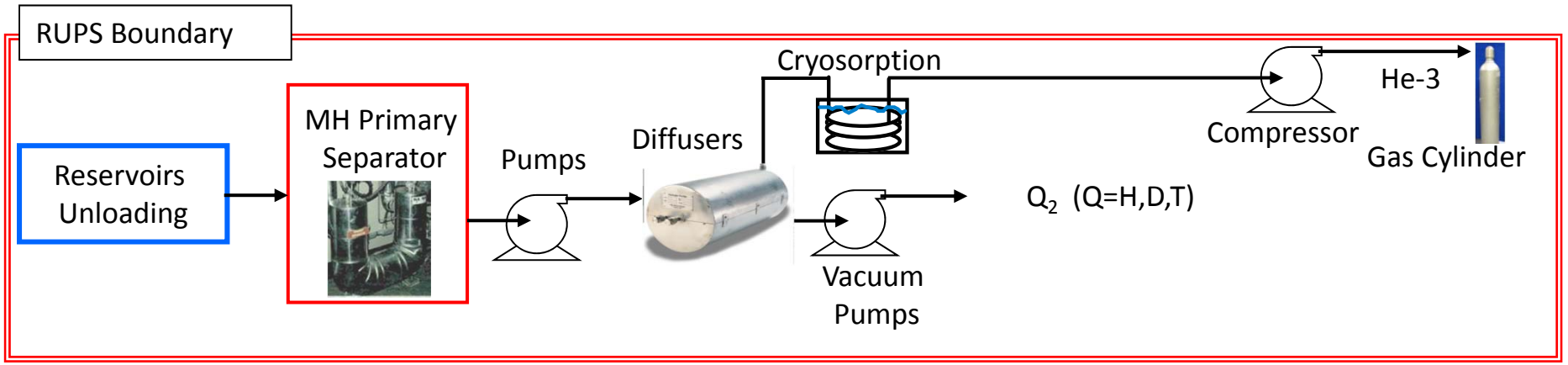


Previous Development Path: Piece-wise Component Replacement

- **Replace existing unit operation with equivalent replacement**

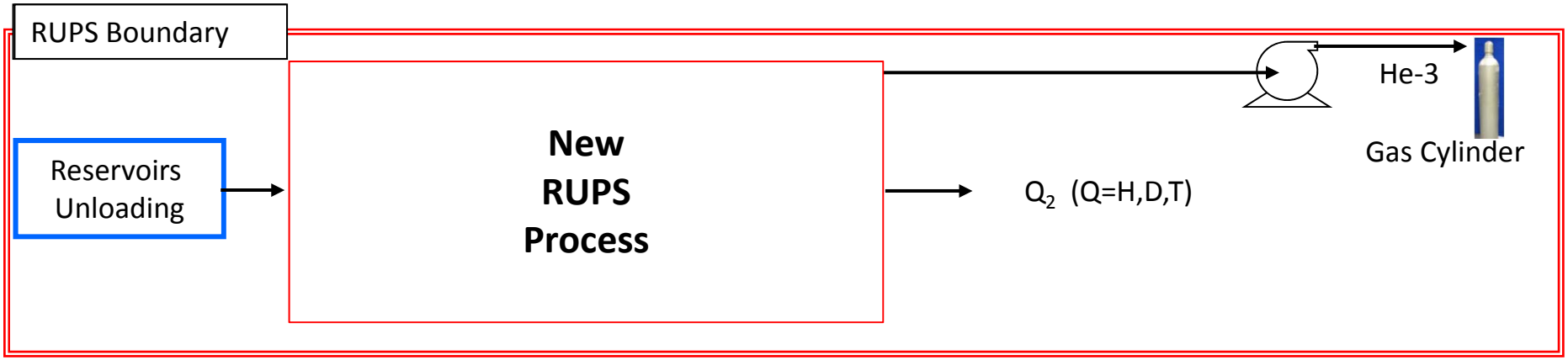


Revised/Reservoir Unloading Purification System (RUPS)



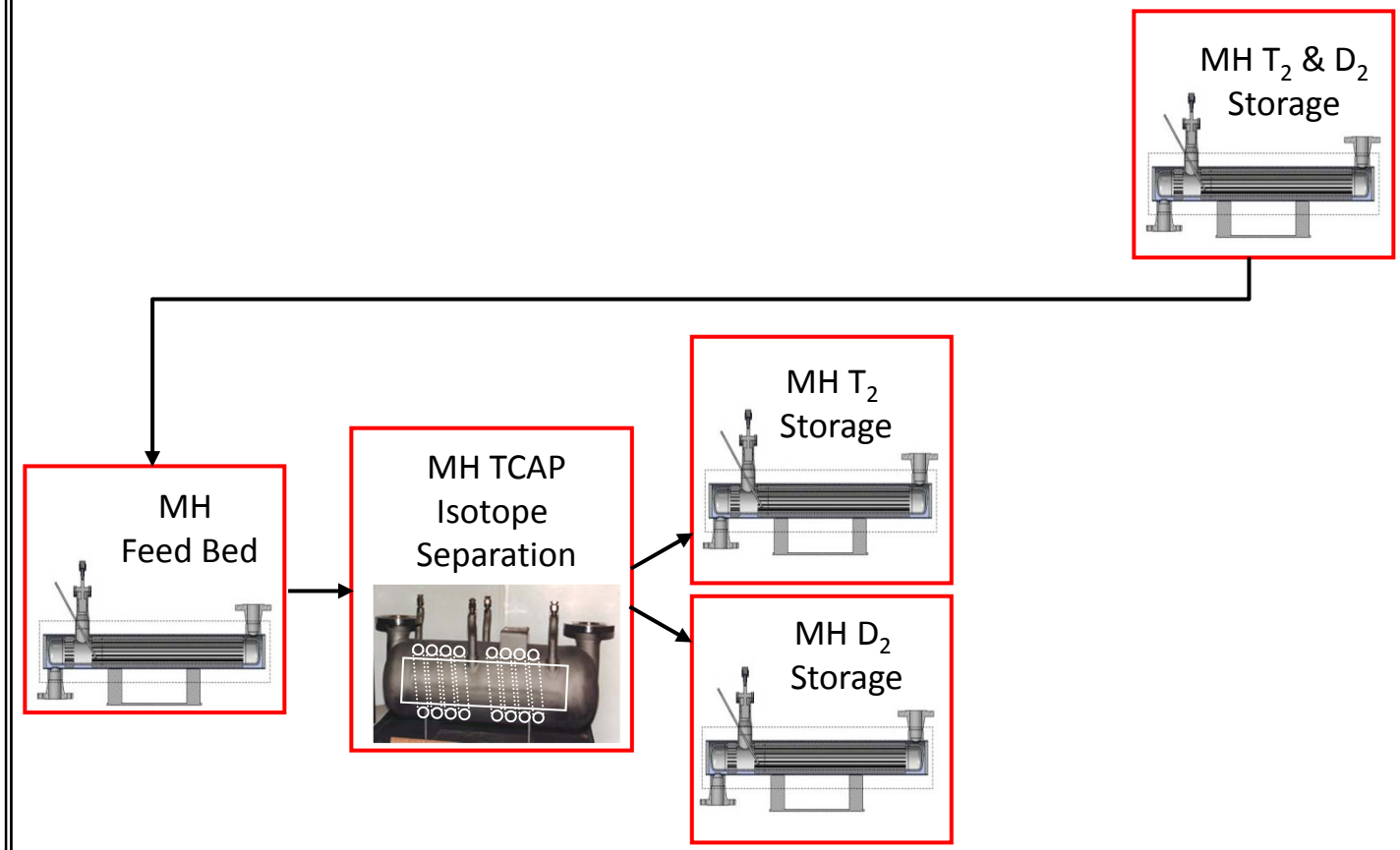
New Development Path: New Requirements, Improved Processes

- **Replace <u>system</u>, not just <u>components</u>: "Right-Size" System**

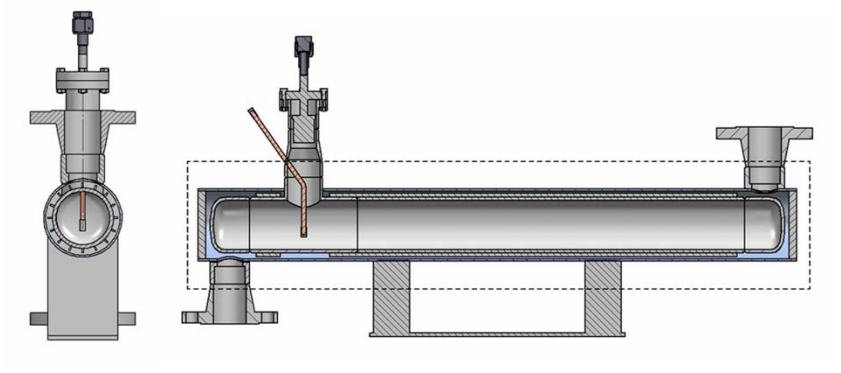


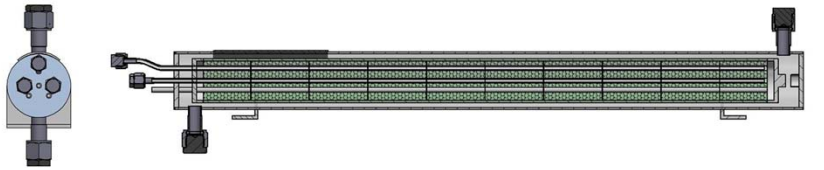
Storage and Isotope Separations

Gloveboxes



Storage and Isotope Separations: Current Hydride Storage Beds

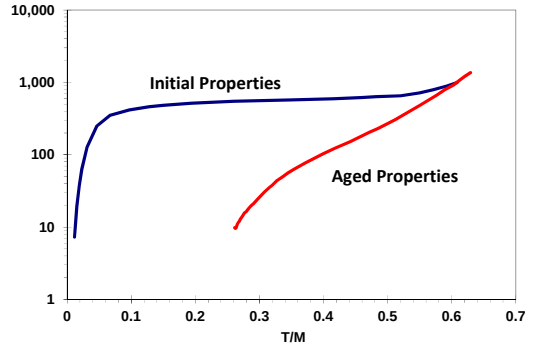




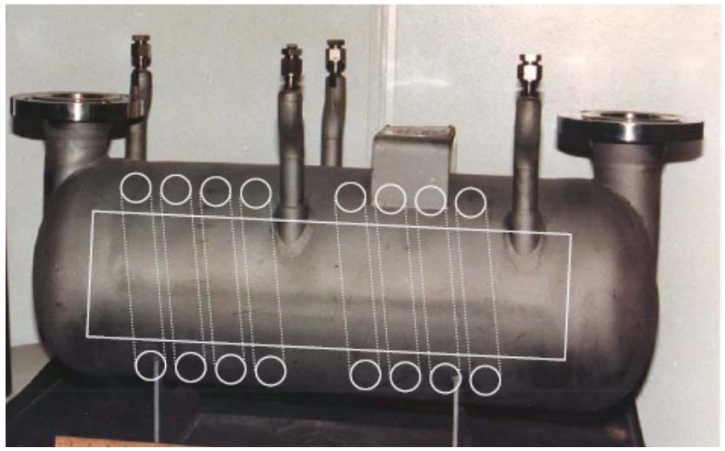
Three Generations of Metal Hydride Storage Beds

Previous Development Pathway

- **Stay with existing hydride storage material (e.g. $LaNi_{4.25}Al_{0.75}$ or "$LANA_{0.75}$")**
- **Develop Improved hydride beds**
- **Rev. 0: Used Hot and Cold Nitrogen System**
- **Rev. 1: Forced-Atmosphere Cooling, Electric Heaters (PACE/FACE Beds)**
- **Rev. 2: More Efficient PACE Bed**
  - **Four Inch Short Hydride (FISH) Bed**
- **Some Beds Still Rely on LANA Alloys**
  - **Retain He-3**
  - **P-C-T Altered by Retained He-3**



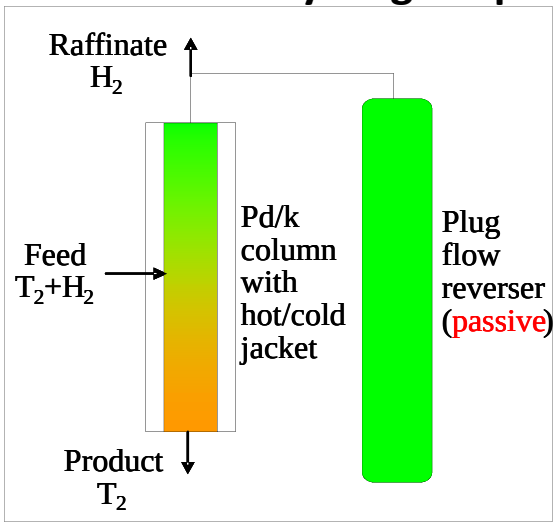
Storage and Isotope Separations: Current Isotope Separations



Two Generations of Isotope Separation Columns

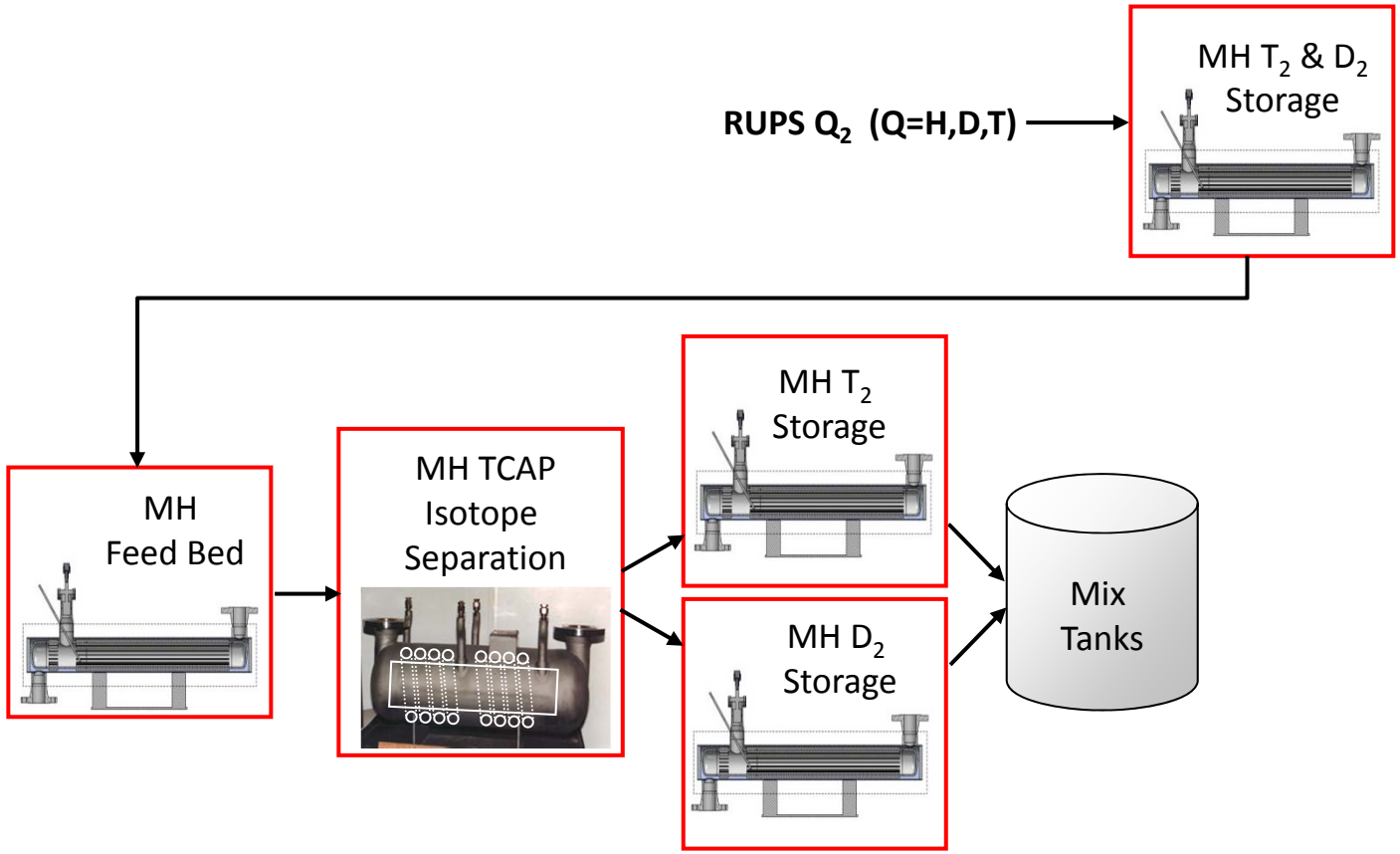
Previous Development Pathway

- **Stay with known metal hydride**
  - **Pd on kieselguhr (Pd/k)**
- **Stay with Current Process**
  - **Inert, Passive Plug-Flow Reverser to Preserve Concentration Profile**
- **Close-Couple Column with Heating and Cooling Systems to Reduce Cycle Times**
- **Use Internal Heat Transfer Foam to Improve Thermal Cycling Response**



Optimized, Advanced Storage and Isotope Separation (OASIS): New Boundary

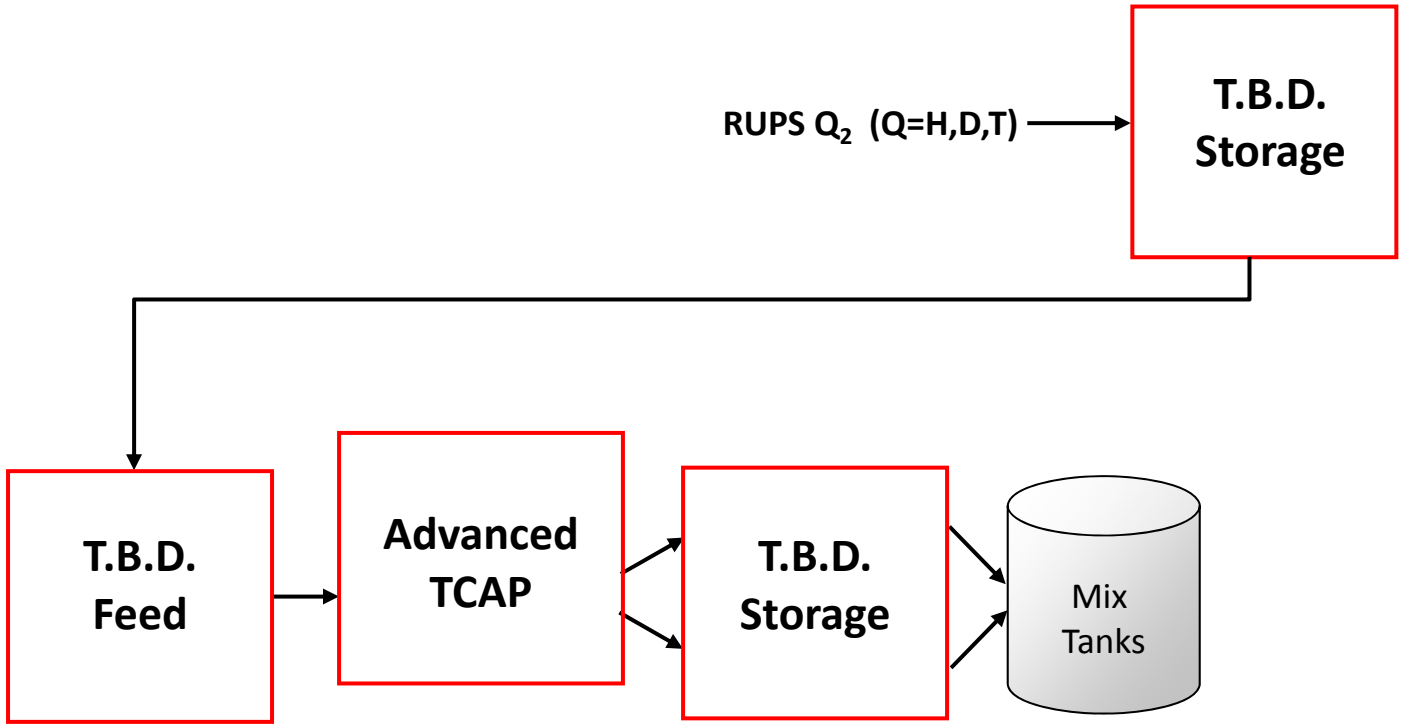
Gloveboxes



Include Mix Tanks In Scope of System Redesign

Optimized, Advanced Storage and Isotope Separation (OASIS)

Gloveboxes

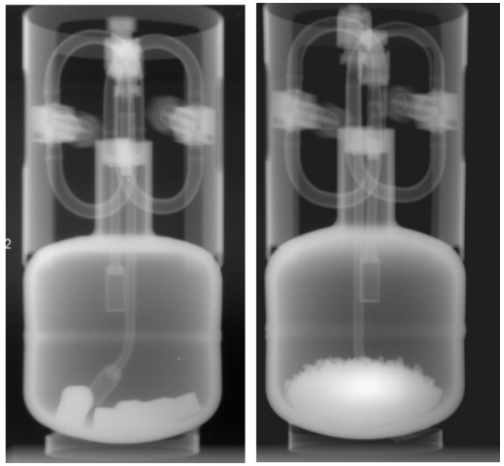


Include Mix Tanks In Scope of System Redesign

OASIS Tritium Storage and Pumping: New Focus

New Development Pathway

- **Expand role of other metal hydride storage materials (e.g. Depleted Uranium: DU)**
- **New Storage Bed Concepts**
  - **Storage and Separations**
- **Evaluate Merit of Pumps vs Hydride Beds**
  - **Gas Transfers**
  - **Gas Supplies**
  - **Gas Compression**
- **Evaluate System with Mixed Hydride Storage Beds**
  - **DU for Storage?**
  - **LANA Beds for Supplying/Compressing?**
- **Incorporate He-3 into Bed Design**



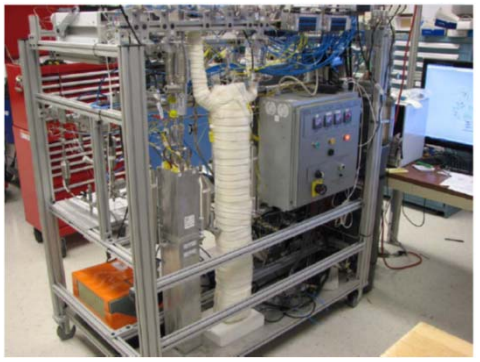
OASIS Advanced TCAP Process: New Focus

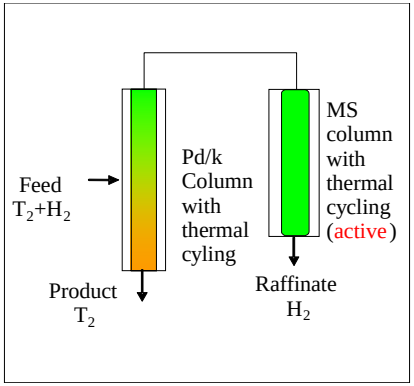
New Development Pathway

- **Eliminate Use of Hot and Cold Nitrogen**
  - **Liquid Nitrogen Cooling**
  - **Electric Heaters**
- **Advanced Column Designs**
  - **Business Proprietary**
- **Develop Active (Inverse Separation) Column**
  - **Molecular Sieve Selected**
- **Advanced Process Control Logic**
- **Close Integration with Feed and Discharge Systems**

Possible Development Pathway

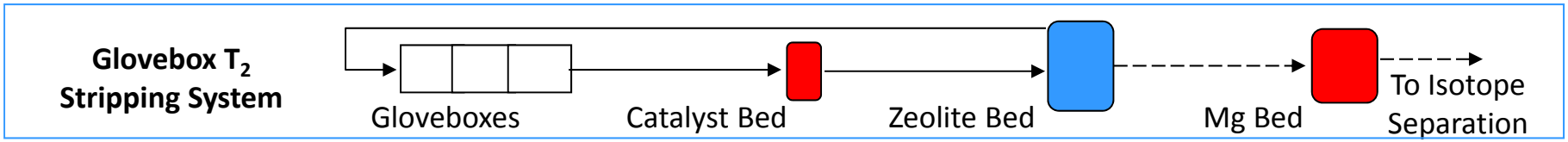
- **Re-examine Cryogenic Distillation**





Tritium Confinement at SRS

Gloveboxes



Current Confinement

- **Large gloveboxes with many thousands of gloves**
  - **Large glass panels**
  - **Many gloves per panel**
  - **Recirculating strippers with purge**

Current Water Processing

- **All water entering or created in glovebox is processed**
  - **Large amounts of protiated water**
- **Use of Hot Magnesium Beds for Water Reduction**
  - **Expensive, consumable waste vessels**

New Development Pathway: Topic of Future Presentations

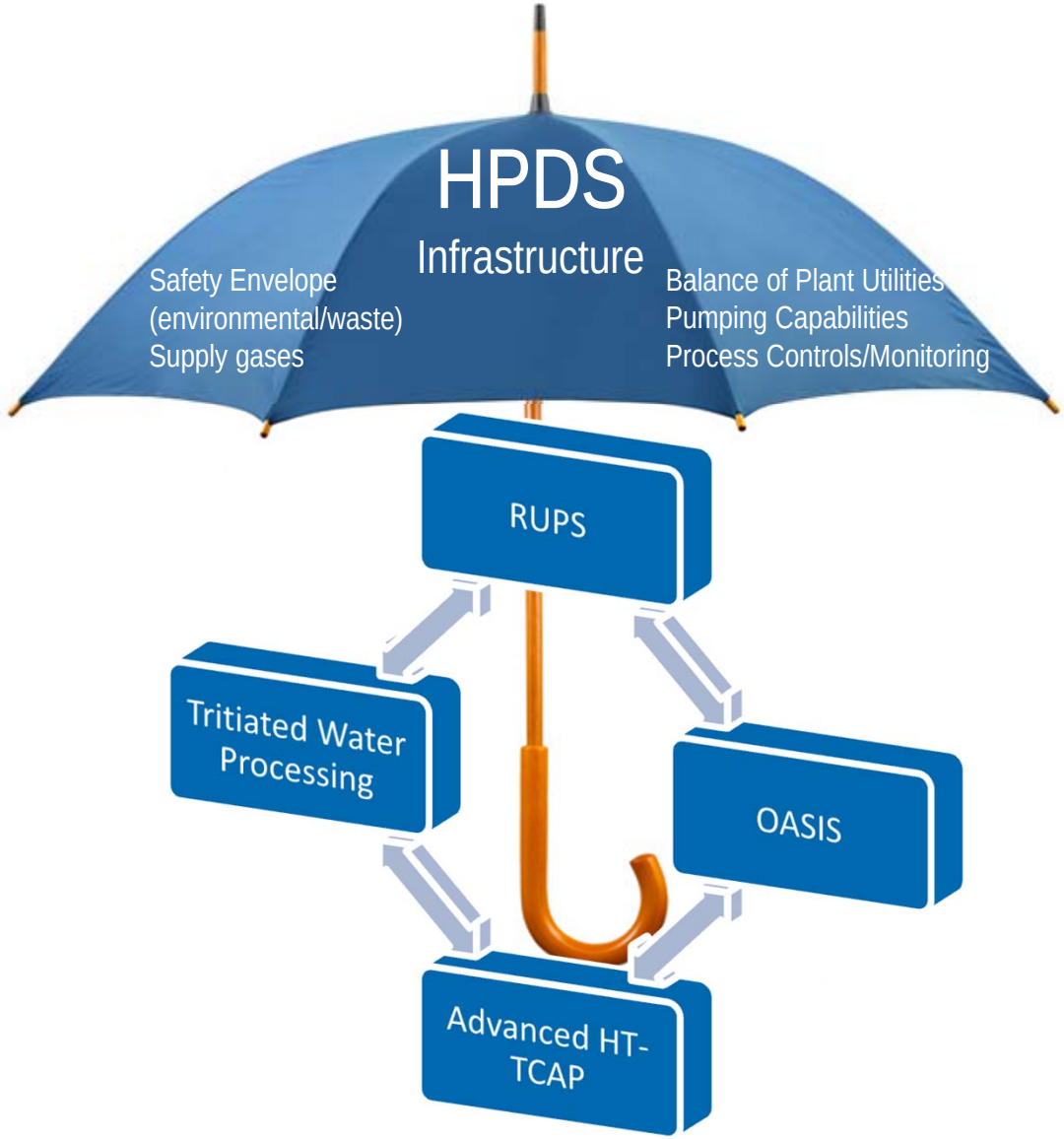
- **Reduced Area Confinement and Water Processing (RACWAP) System**
- **Includes Advanced H-T Separation Capacity TCAP Systems**

Hydrogen Processing Demonstration System (HPDS)

Construct Cold (e.g. non-rad) Hydrogen Processing Demonstration System

- **Develop Components for Tritium Processing**
- **Test Integrated Processing Sub-Systems**
- **Develop and Deploy Analytical Measurement Systems**
  - **Integrate measurements into component or system designs**
- **Training Facility for New Employees**
- **"Cold" Operator Training for New Tritium Processes**
- **Component Evaluation Before Process Installation**
- **Institutional Knowledge Transfer**
  - **Program Based**
  - **Not Succession Plan of Individuals**
- **Based on Success of Test Facility for Current Tritium Process**
  - **"Advanced Hydride Laboratory" (AHL)**
- **Support Development of "Short Course" on Tritium Technology**
  - **Training Class for Fusion Researchers**
- **Work-For-Others (WFOs) Test Capabilities**
  - **Conduct cold testing for outside users??**

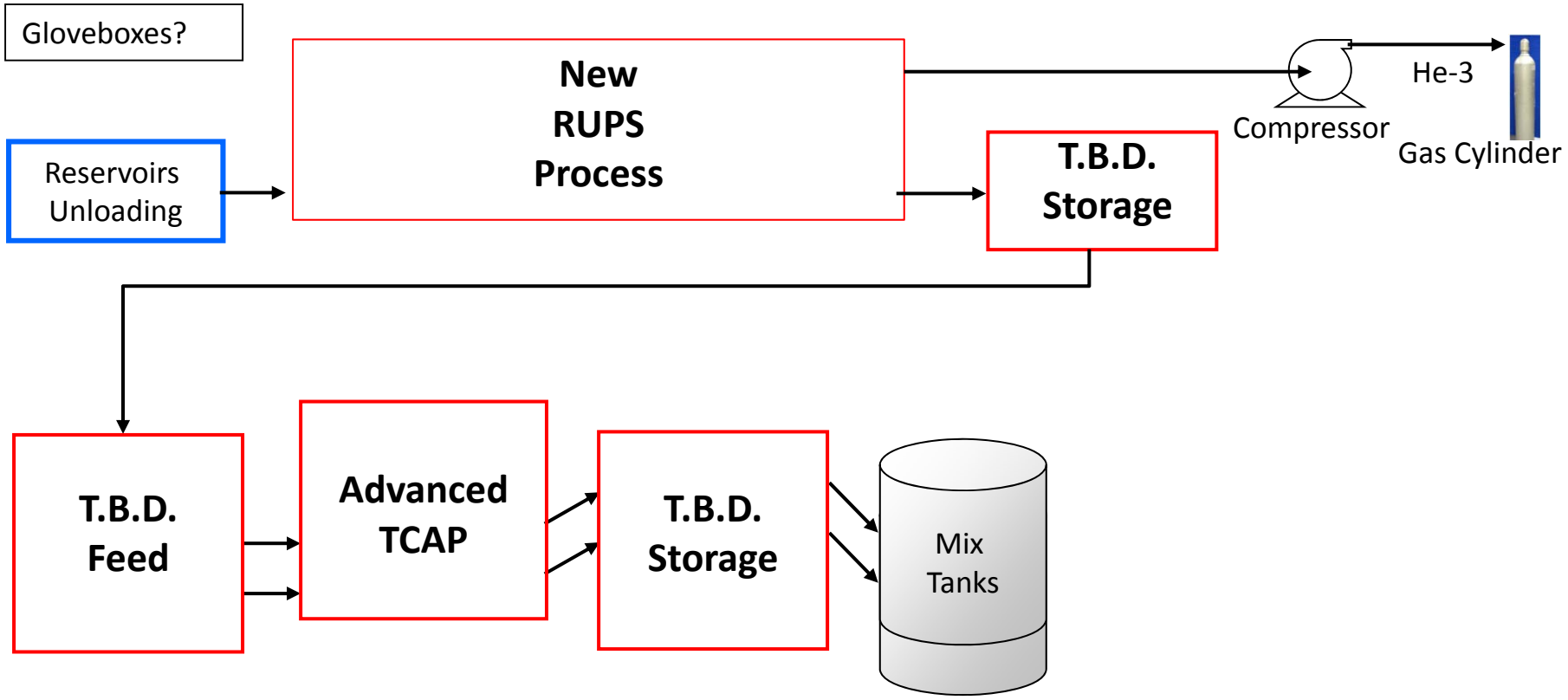
HPDS provides a FRAMEWORK for increasing MRL by integrating unit operations



HPDS provides a space where technologies can be inserted for integrated and/or stand alone testing. Proof of concept or prototype units are tested prior to insertion into a production operation.

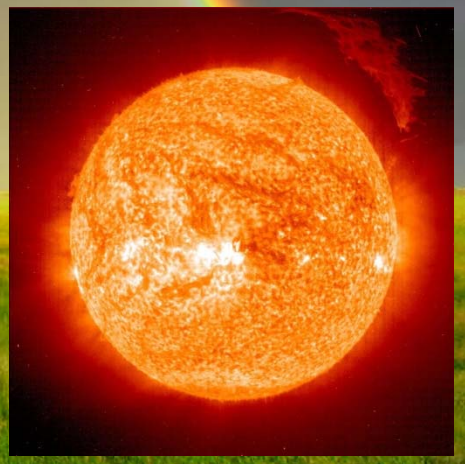
Hydrogen Processing Demonstration System (HPDS)

- **Early In Planning Stages**
- **New Process Design Bases Under Development**
- **Flowsheet/Technology Selection in 2015**
- **Process Design and Technology Testing Starting in 2016**



Conclusions

- Synergy Exists Between the Needs for the Use of Tritium
  - Improved Systems Benefit Everyone to Create Safer Systems
- "Right-Sizing" Requires System Replacement (not just components)



Tritium 2016

Charleston, SC, USA

April 17-22, 2016

11th International Conference on
Tritium Science & Technology

Call for Papers – April 17, 2015

Call for Papers

11th International Conference on Tritium Science & Technology

April 17-22, 2016 • Charleston Marriott • Charleston, SC, USA

Summaries Due:	October 16, 2015
Author Notification:	December 11, 2015
Full Papers Due:	April 12, 2016
Final Papers Due:	August 2016

Authors should submit 300 word (min.) summaries in English via the conference website http://epsr.ans.org/meeting/?m=213). The summary should clearly state objectives, methods, results and conclusions of the work. MS Word format (use template).

http://tritium2016.org

ANS

Suggested Paper Topics

- Biological Effects
- Containment and Decontamination
- Environmental impacts
- Fusion and fission concepts
- Groundwater issue resolution
- Measurement, monitoring and accountancy
- Safety and waste management
- Standards and Implementation
- Tritium processing (purification, isotopic separation, recovery, etc.)
- Tritium facilities and operation
- Interactions with materials
- Tracer techniques and isotopic effects
- Tritium supply, transport and storage
- Tritium breeding and extraction
- Water and air detritiation

General Chair:
Dr. Robert P. Addis
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Technical Program Chair:
Dr. James E. Klein
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TRITIUM 2016

The objective of the conference is to provide a forum for an exchange of information on science, technology, engineering, and general experience in safe tritium handling for fusion, fission, pharmaceuticals, and other unclassified isotopic applications. The 11th edition of this triennial Conference is sponsored by the Fusion Energy Division and cosponsored by Decommissioning and Environmental Sciences and Nuclear Installation Safety Divisions of ANS, and is hosted by the ANS Savannah River Section. *Full papers will be published in* **Fusion Science and Technology**.

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Charleston, SC, USA April 17-22, 2016