Consideration of Potential Impacts of Fusion Machine Features on Needs for Hazard Mitigation

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Plasma Physics and Technology Aspects of the Tritium Fuel Cycle for Fusion Energy

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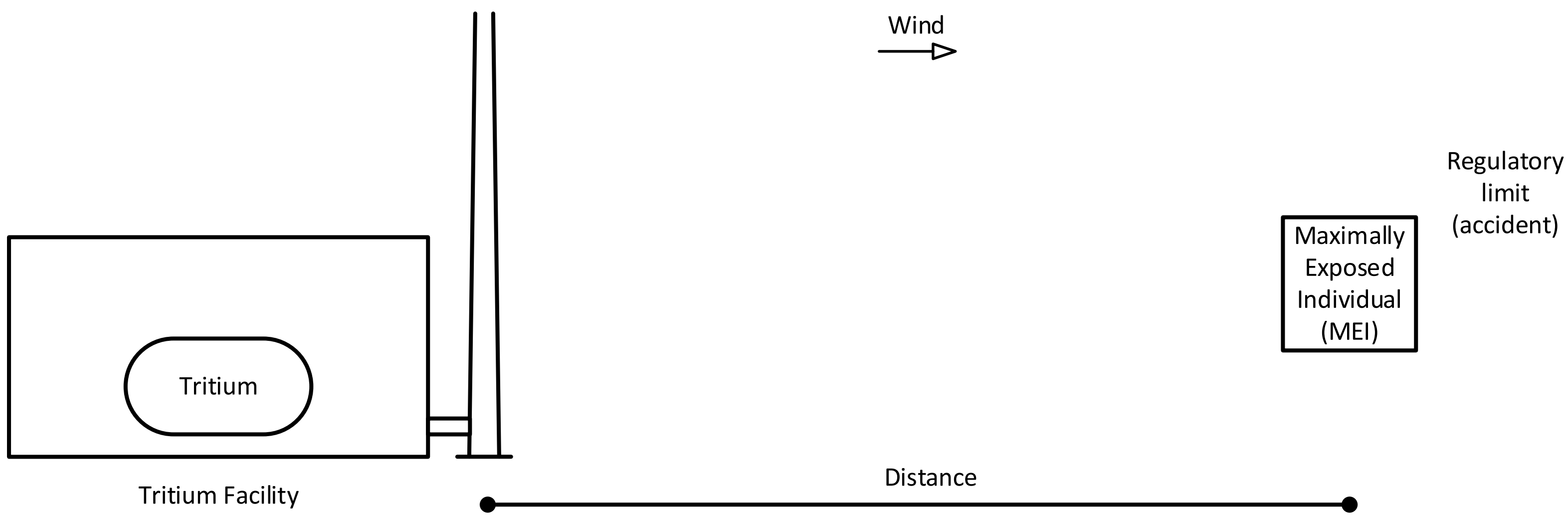
Purpose

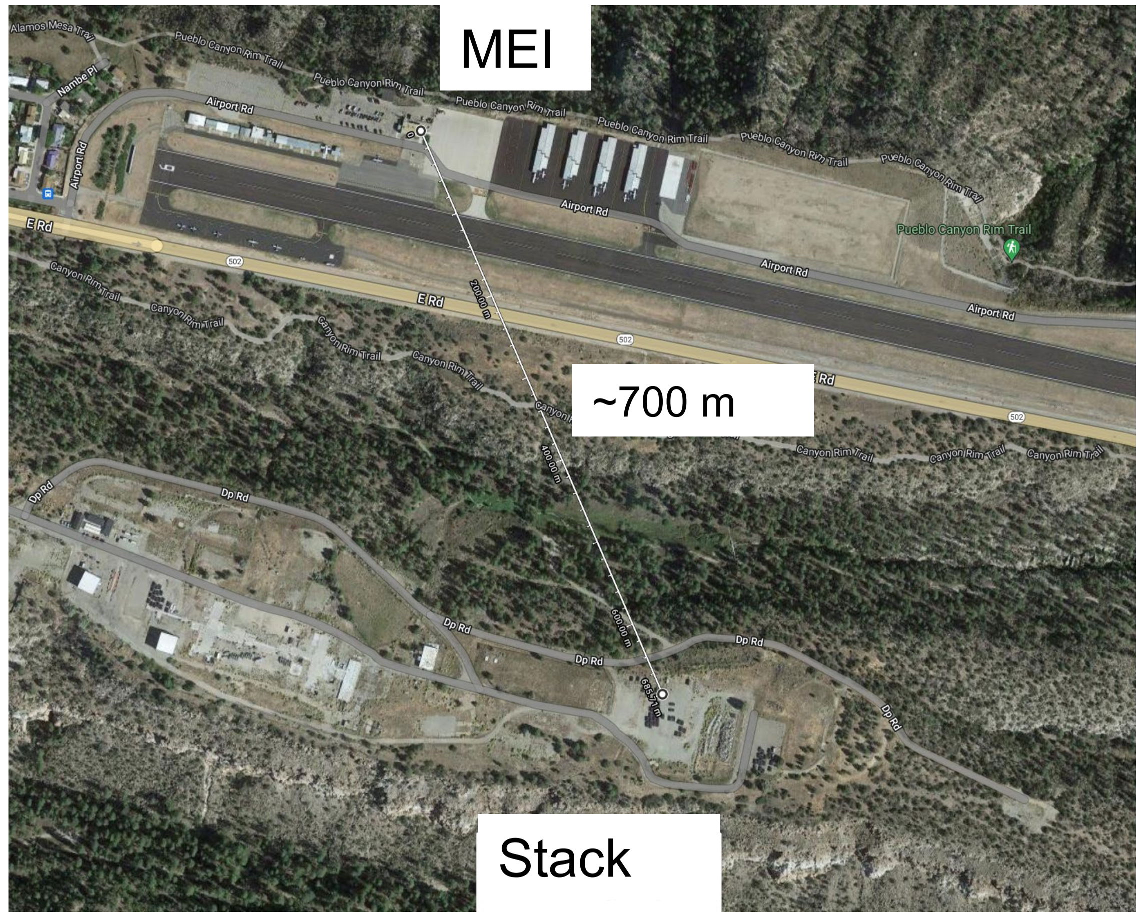
- Have been exploring relationships between physics decisions and fuel cycle consequences
- These have the potential knock-on effect of creating hazards
- This is a brief talk to just introduce this relationship

Key components for estimating potential for accidental public exposure



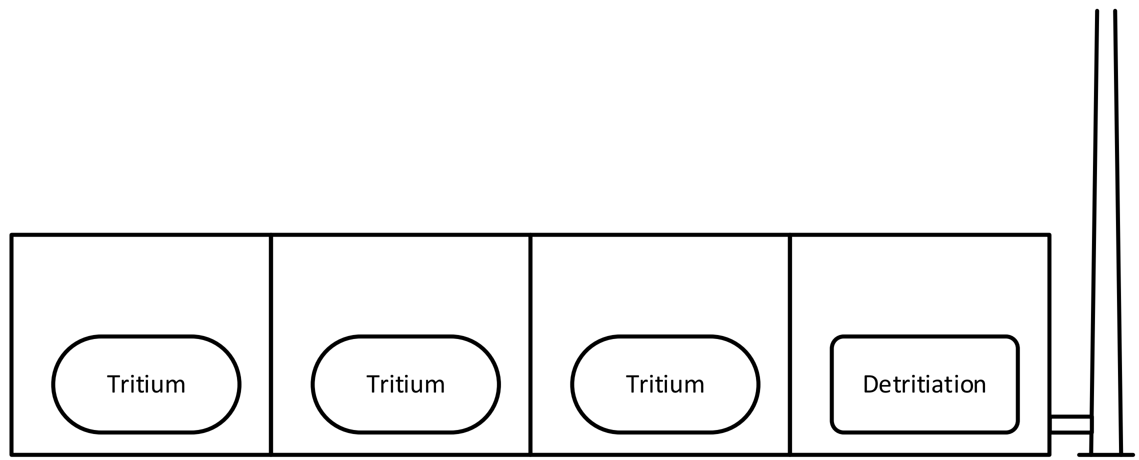
TSTA (Tritium Systems Test Assembly) example

- 200 g tritium necessary to reach regulatory limit
- Inventory was 140 g
- Therefore, no safety class equipment



However. . .

- DEMO-class machines may have tritium inventories which in accidents could result in greater than regulatory dose limits
- Mitigation requires
  - Safety class equipment such as
    - Inventory isolation
    - Detritiation system
  - Formality of operations
  - Greater regulatory scrutiny



Tritium Facility

First wall materials may be reactive in accidents

- Reactive first wall materials may require mitigation systems

- First wall materials may come in contact with steam and/or air through
  - Loss of Flow Accident (LOFA)
  - Loss of Vacuum Accident (LOVA)
  - Loss of Coolant Accident (LOCA)

- Helium-cooled vs. water-cooled
  - Helium-cooled runs hotter
  - Water-cooled runs cooler, but adds a reactant

- Loss of Vacuum and Coolant Accidents (LOVA, LOCA)
  - First wall material reactions following LOVA (air ingress) and LOCA must be considered, and, if necessary, mitigated

Future heat transfer systems

- Perspective
  - The entire fusion facility tritium working inventory can be permeated through palladium every hour

- Observations
  - Hydrogen permeability through Ni, Inconel and SS316 is only two to three orders of magnitude lower than Pd
  - Permeabilities for all these materials increase with temperature
    - Gas-cooled machines are hotter than water-cooled machines

- Hazards
  - Tritium permeation in reactor cooling and heat utilization systems will be an issue
  - Substantial amounts of tritium may migrate beyond the reactor and fuel cycle buildings
  - Issues will be worse for gas-cooled designs
  - The associated hazards will need to be identified and mitigated

Other physics decisions -> potential hazards

- Seeding gases
- Operation time
- Disruption mitigation
  - Frequency and severity
- Transmutation products
- Machine configuration
  - Tokamak, stellerator, spheromak, etc
  - Divertor(s) and first wall configuration
  - First wall tritium holdup and recovery
  - VV confinement strategy
- Others

Conclusions

- Fusion reactor design choices affect hazards and associated mitigations. Examples are:
  - Fuel processing rates -> tritium inventory -> segregation and detritiation systems
  - Cooling/heat utilization choices -> tritium migration -> more extensive confinement systems
- There is a strong relationship between physics/reactor design choices and fuel cycle choices. These choices also affect the facilities hazards and their potential need for mitigation.
- To date, solutions exist for all identified hazards
  - Though some are more complicated than others
- Consideration of hazards must continue as fusion develops