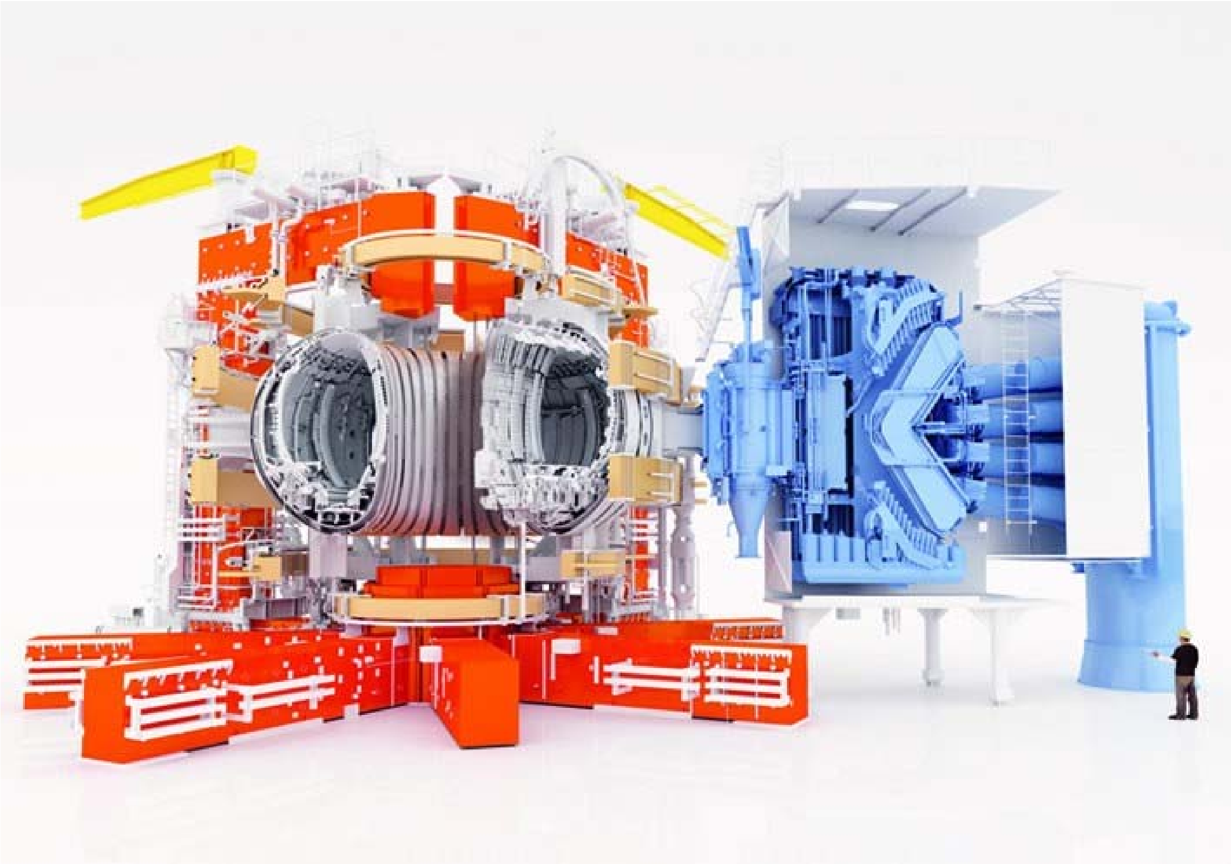
MELCOR-Fusion: Loss of Vacuum Accidents on JET

Presented by
Samuel Ha
Based on work by
Simon McIntosh and Jenny Cane

JET



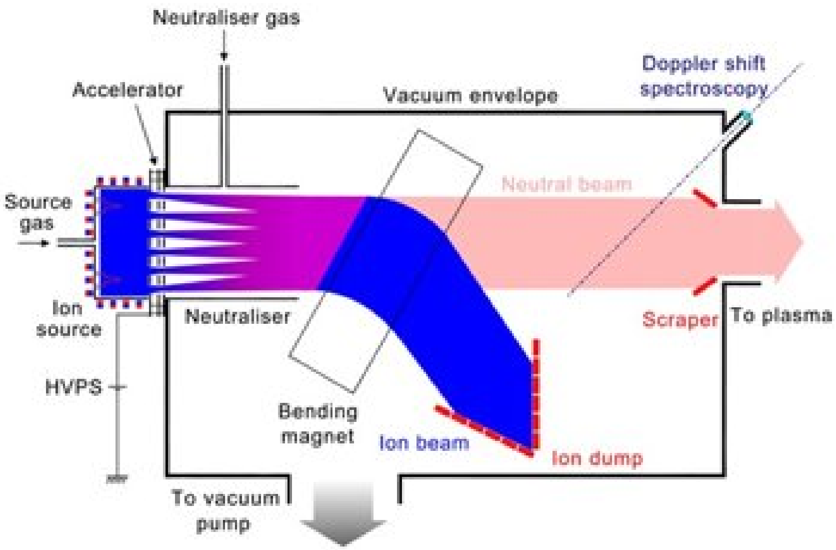
JET Operations

- Plasma operations begin with initial pressure <10^{-7}mbar, achieved by:
  - Turbo-molecular pumps
  - Cryogen pumps
  - Boiling impurities by heating vacuum vessel to 320ºC
- Plasma typically at 150MK, with divertor exhaust
- Fuelled with two isotopes of hydrogen – Deuterium and Tritium

UK Atomic Energy Authority

JET Operations

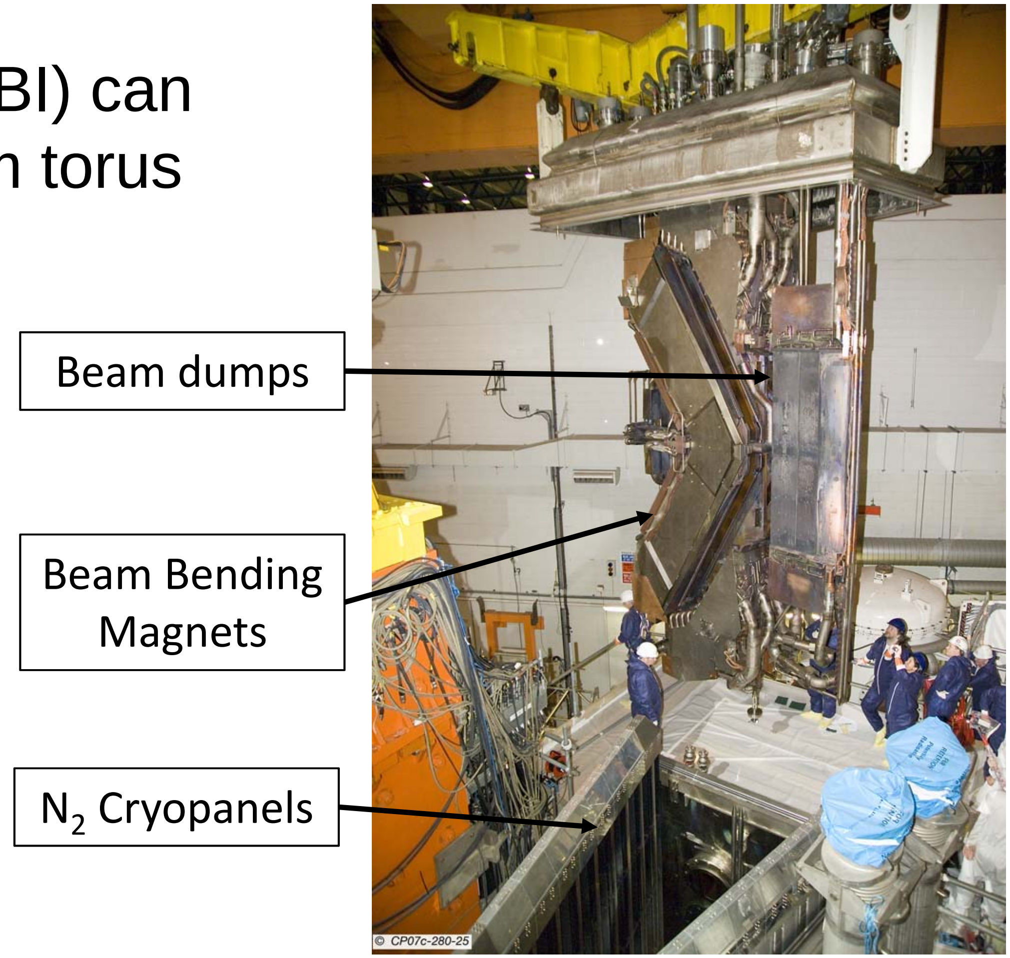
- High energy particle beam used to heat plasma
- Ion beam neutralised
- Stray beams diverted to *beam dumps* by *bending magnets*



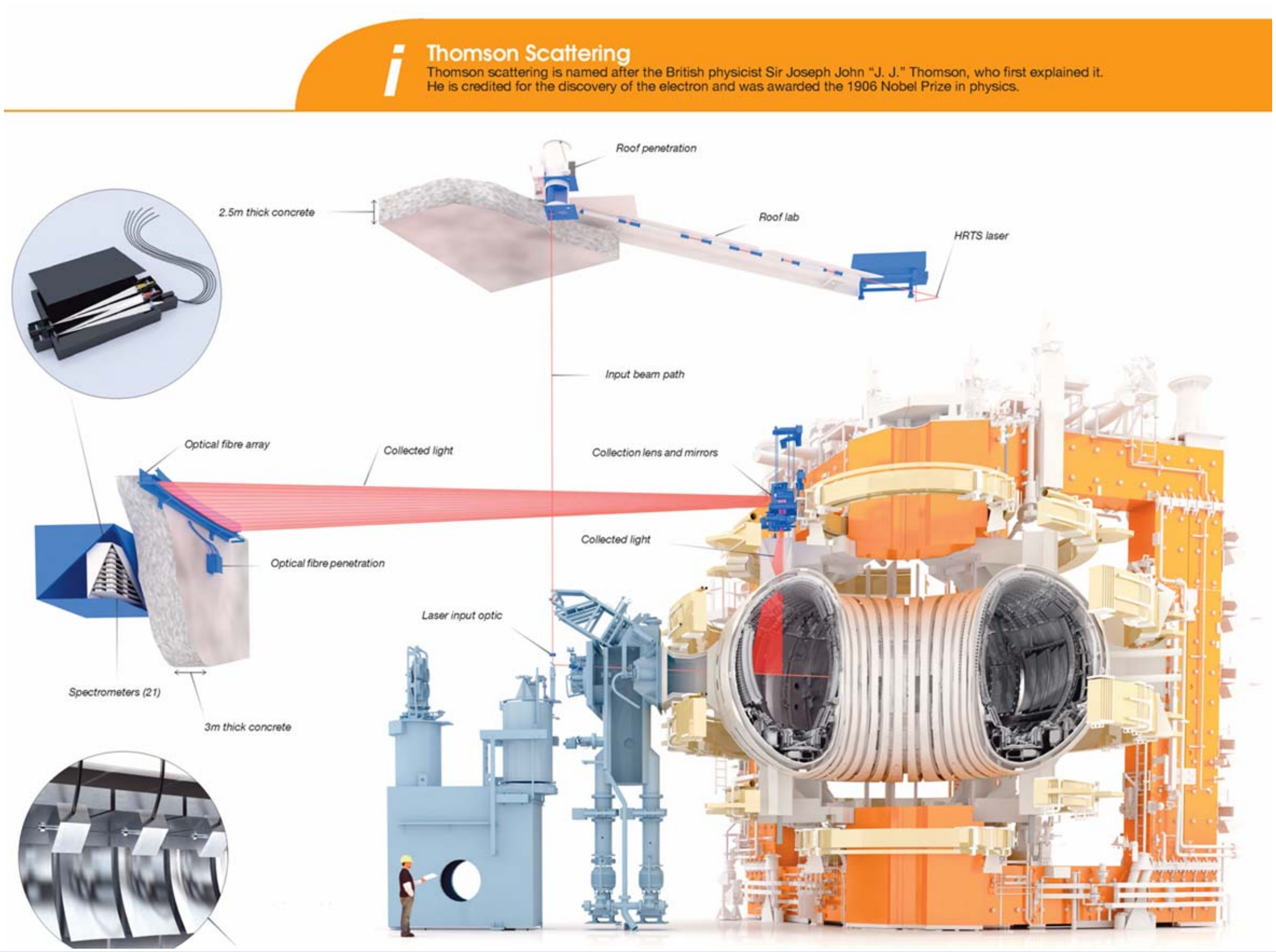
UK Atomic Energy Authority

JET Operations

- Neutral Beam Injectors (NBI) can be connected/isolated from torus via large rotary valves
- NBI requires low pressure
- Major pumping system (cryopanels) works by condensation

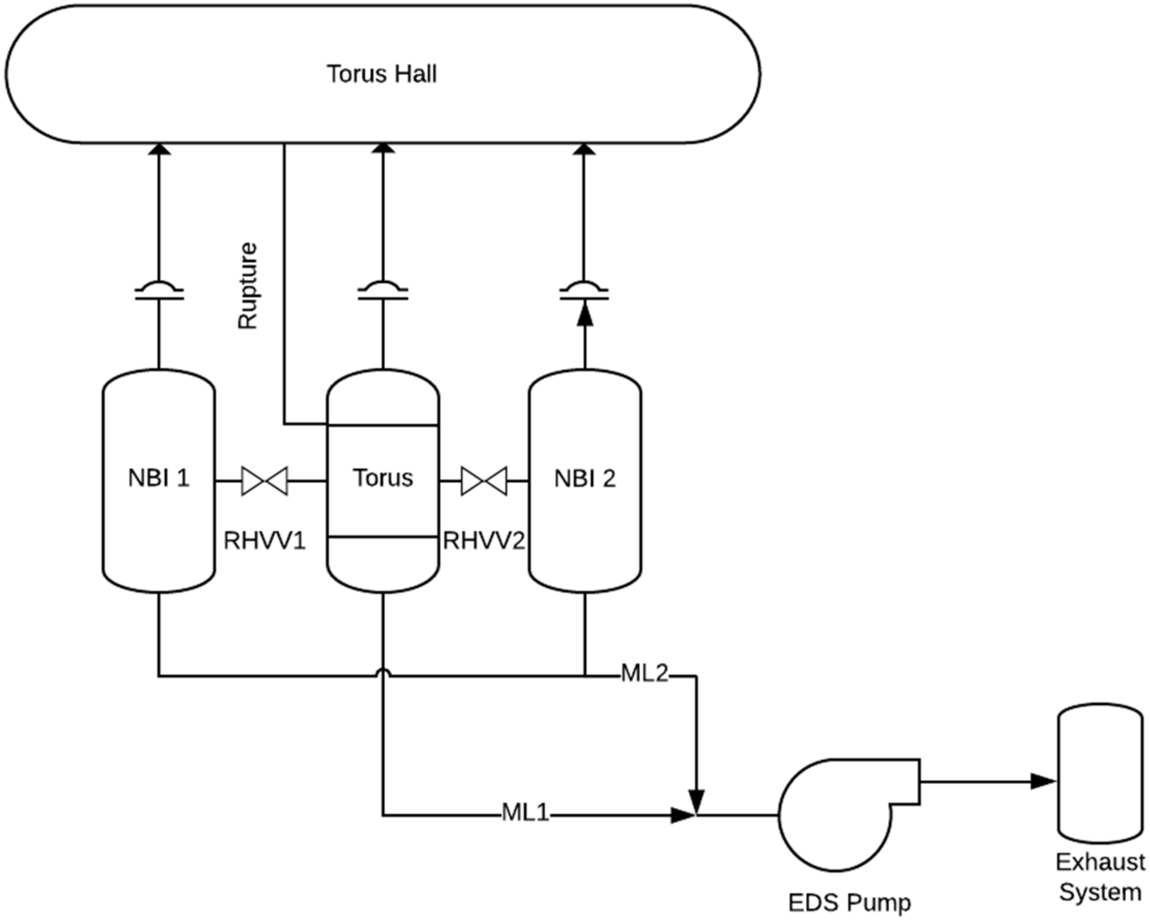


JET Operations



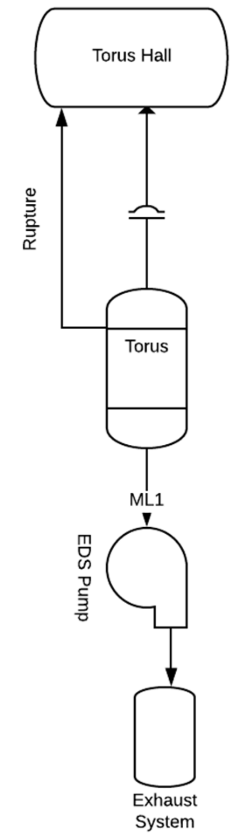
UK Atomic
Energy
Authority

LOVA scenario



LOVA scenario

- Postulated scenario:
  - Flow path opened from Torus Hall to Torus
  - Air flows into Torus and mixes with deuterium/tritium
  - Air heats up within torus and expands
  - Expansion causes pressure increase in torus
  - Flow reverses from increased pressure
  - **Tritium released to the torus hall**

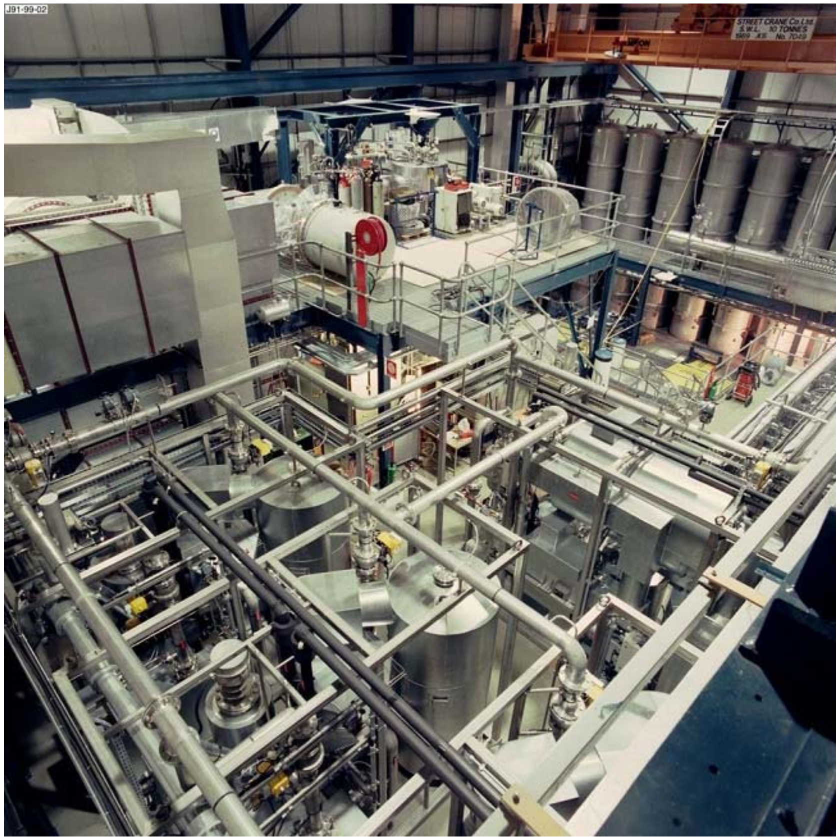


LOVA scenario

- Active pumping from vacuum vessels via Exhaust Detritiation System (EDS)
  - Peak flow rate of 0.29m^3/s
- Diagnostics connected to JET via windows from Ø37mm to Ø170mm
- Torus protected from overpressure by burst disc (set to 3kPa overpressure)
- Neutral Beam Injectors protected from overpressure by burst disc (set to 50kPa overpressure)
- Neutral Beam Injectors and Torus connected to EDS by separate lines

MELCOR Model

- EDS (Exhaust Detritiation System):
  - Removes tritium from torus exhaust gases
  - Provides pumping to reduce torus pressure
  - Multi-staged exhaust processing
  - Modelled as a pressure-dependent pump



MELCOR Model

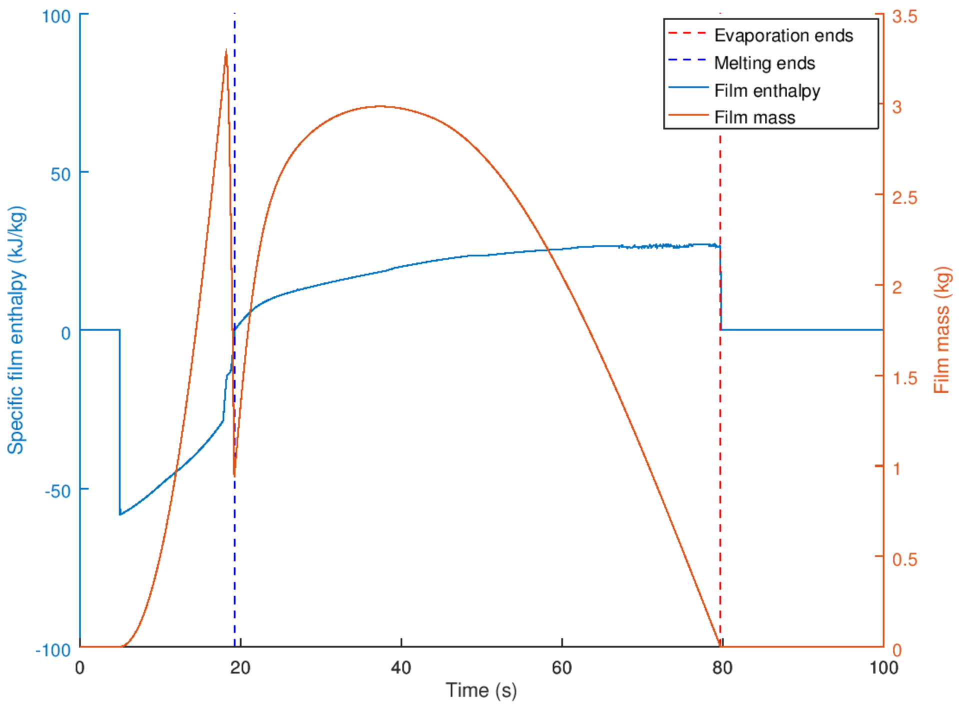
- Nitrogen working fluid at 99.9% composition, 0.1% oxygen NCG
- JET Vacuum Vessel (VV):
  - Held at 320ºC;
  - 120t of stainless steel
  - Holds a 8.2m^2 L-He Cryopanel, a 24.7m^2 L-N_2 Cryopanel, ~80t of heated components
- One Neutral Beam Injector:
  - 50m^3 free space
  - Connected to VV via a large Rotary High Vacuum Valve (RHVV)
  - Holds various heated magnet components
  - Holds a 62m^2 L-He Cryopanel, Holds a 171m^2 L-N_2 Cryopanel, >10t magnets

MELCOR Model

- Several run variations:
  - Up to 2 NBIs connected to torus
  - NBIs close during accident sequence
  - EDS operational or in failed state
  - Torus temperature
- 26 runs total
  - 11 single failure scenario
  - EDS failure constitutes dual failure scenario

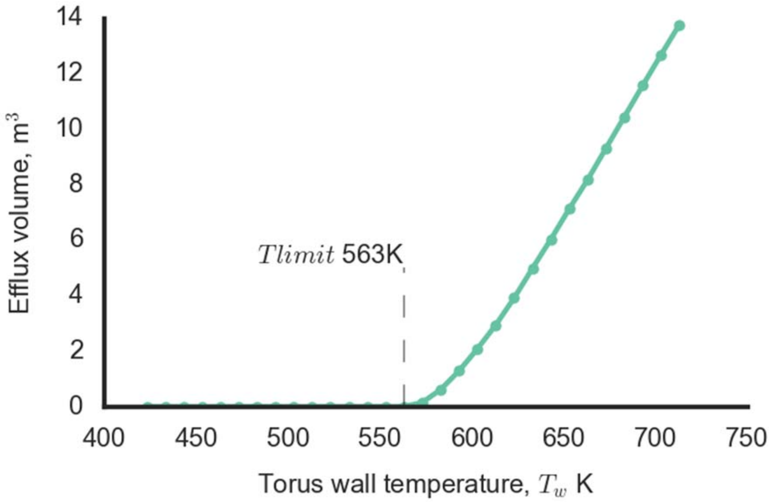
Outcomes

- MELCOR-Fusion allows nitrogen to form frozen films on Helium cryopanels
- Results plotted for NBI cryopanels
- N_2 Film melts at ~20s
- N_2 Film boils at ~80s



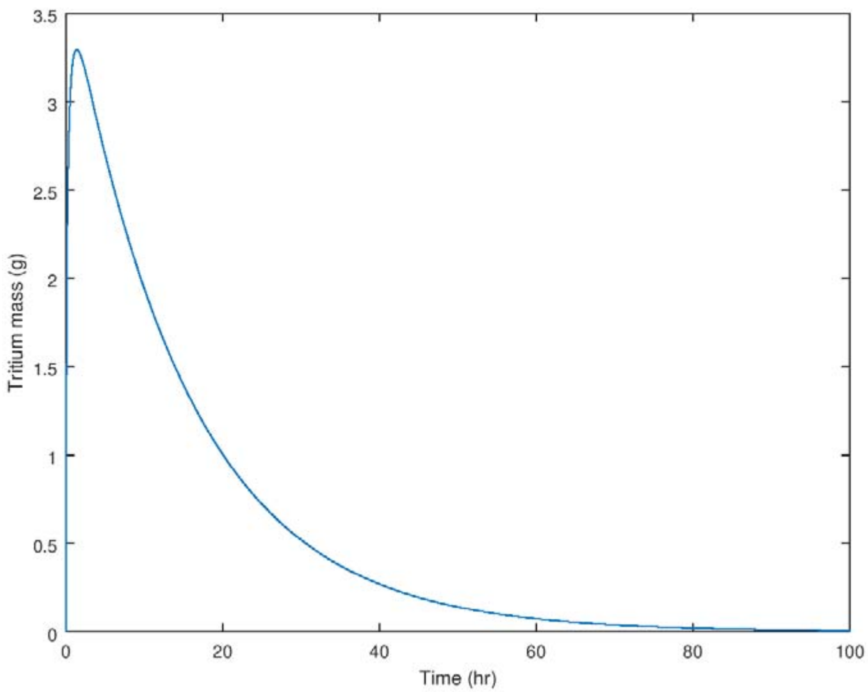
Outcomes

- Release dependent on torus wall temperature
- Study conditions:
  - No NBIs connected to torus
  - EDS operational



Outcomes

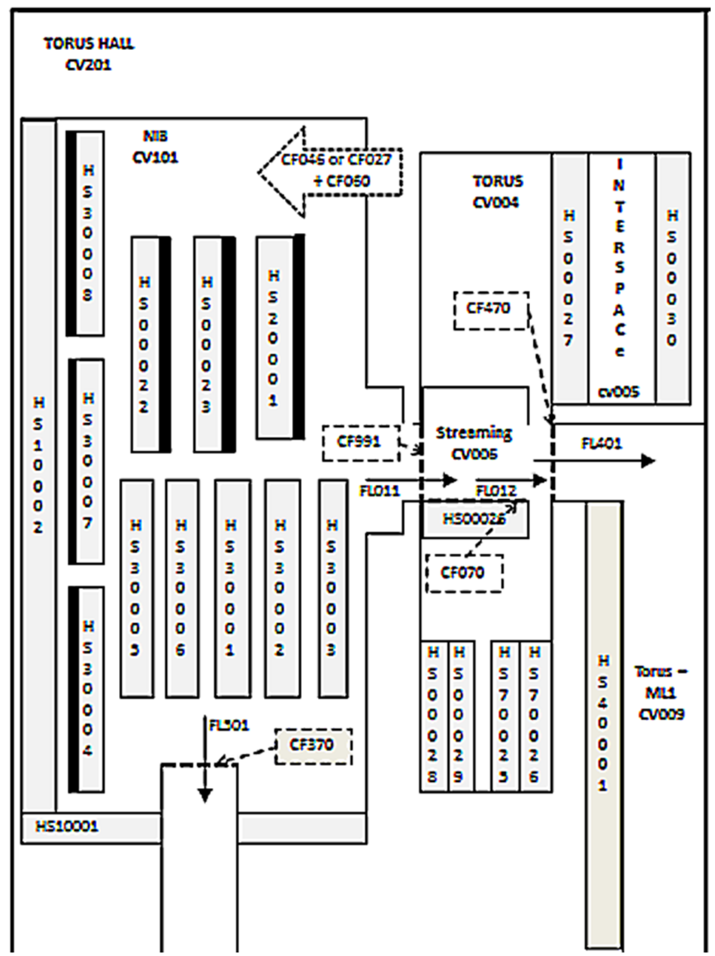
- No tritium released in 10 single failure scenarios
  - Release occurs when no NBIs connected and torus temperature at 320ºC (higher than operation temperature)
- 10 of 15 dual failures lead to tritium release
- Tritium source terms used for dose rates to on-site workers and public



UK Atomic Energy Authority

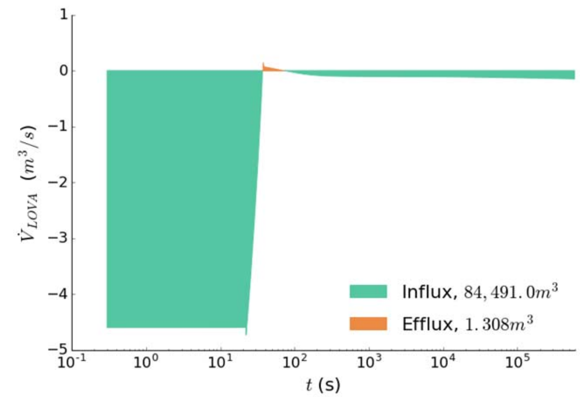
Model notes

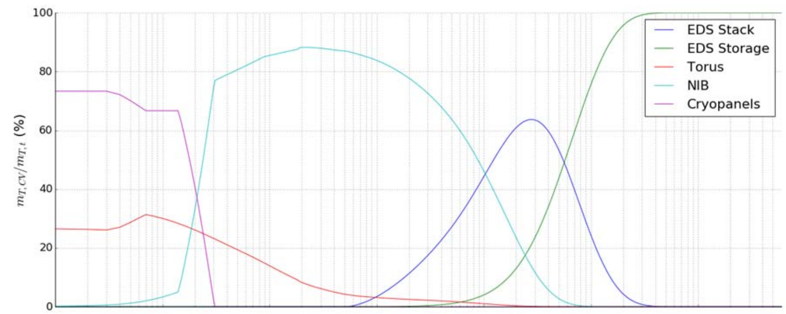
- Liquids only exist as fluid films in all models
- Simple altitude maps and volumes used throughout
- Further model improvements:
  - Subdivided volumes
  - More representative exhaust models
  - Add model to represent heated structures in torus hall

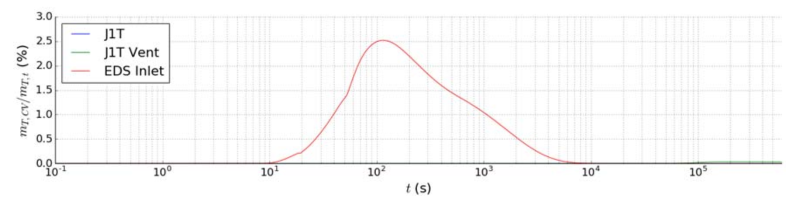


Summary

- MELCOR-Fusion used to evaluate multiple Loss of Vacuum Accidents
- Risks of tritium release quantified
- Key Safety Related Equipment (KSRE) identified to prevent radiation exposure, e.g.:
  – EDS
  – Personnel Safety Access Control System
  – Pressure operated interlocks







UK Atomic Energy Authority

Thanks for Listening

Questions?

CULHAM CENTRE FOR FUSION ENERGY

UK Atomic Energy Authority