OAK RIDGE National Laboratory

Gas Injection at SNS

Accelerator Safety Workshop 2018

Jake Platfoot

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

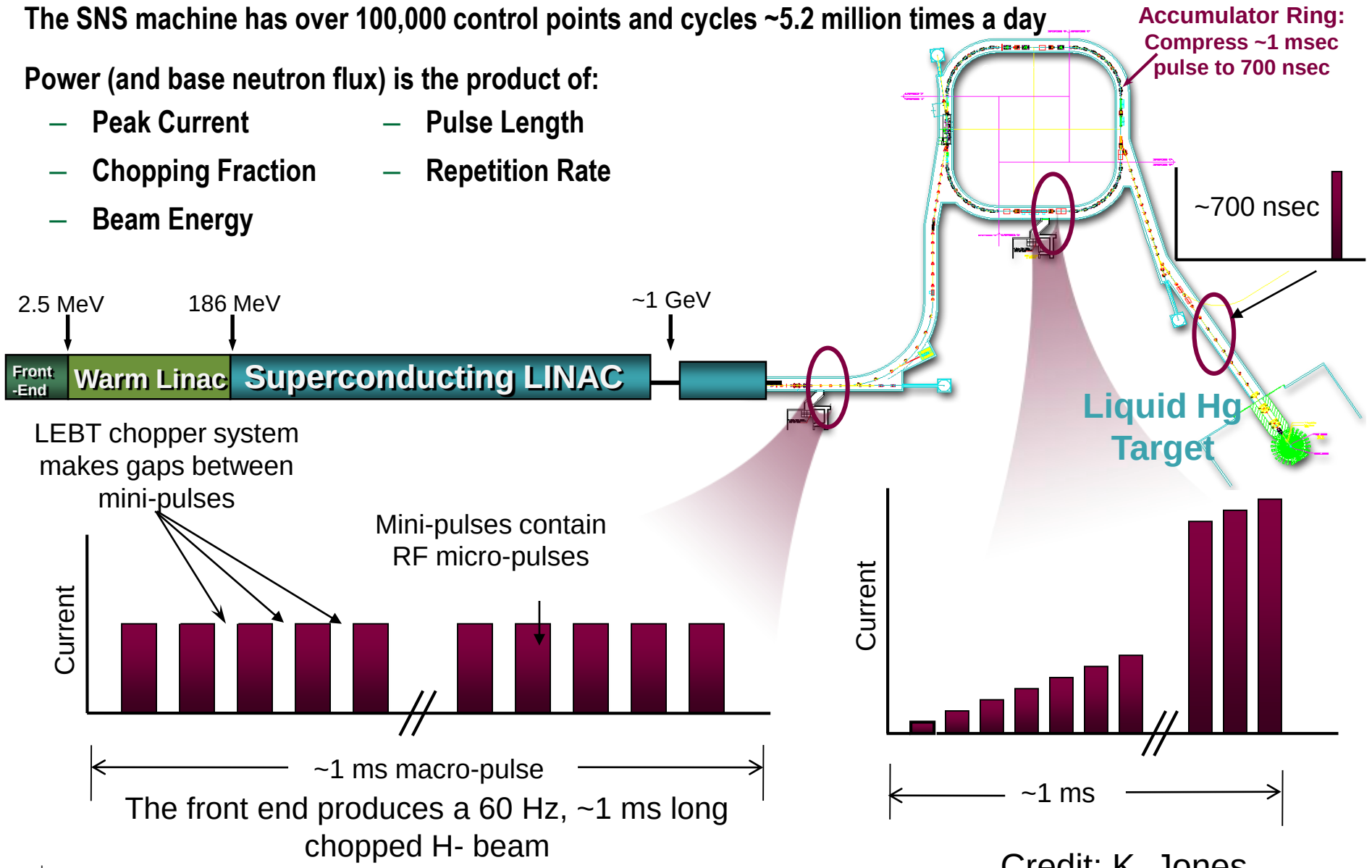
U.S. DEPARTMENT OF ENERGY

Outline

- Introduction to SNS and its Target
- Background – Need for gas injection
- Safety Analysis
- Regulatory Path
- Summary

The SNS is a complex machine that performs well – overall system reliabilities (excluding targets) > 90%

- **The SNS machine has over 100,000 control points and cycles ~5.2 million times a day**
- **Power (and base neutron flux) is the product of:**
  - **Peak Current**
  - **Chopping Fraction**
  - **Beam Energy**
  - **Pulse Length**
  - **Repetition Rate**



Credit: K. Jones

The target provides neutrons to 24 beam lines

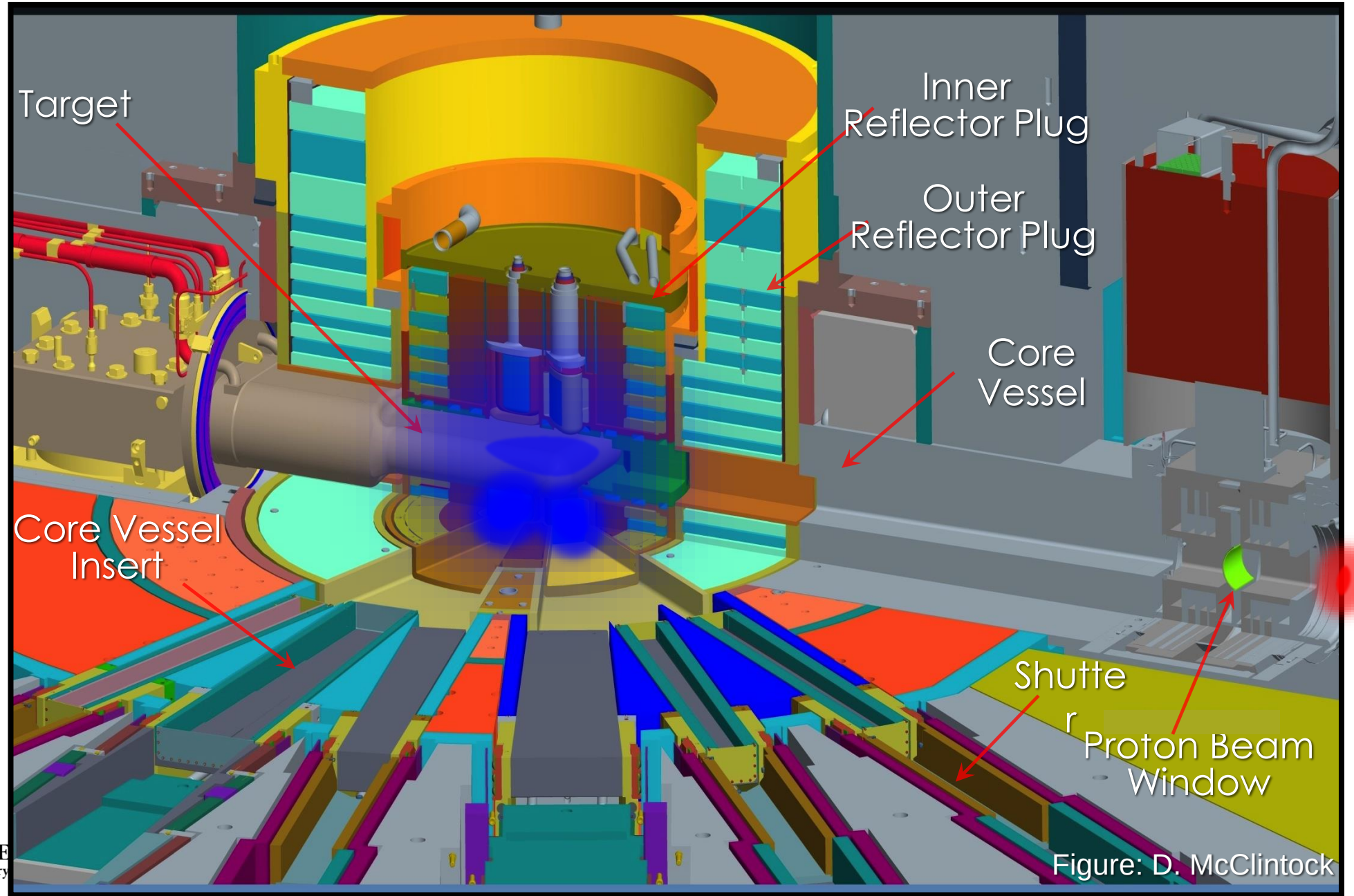
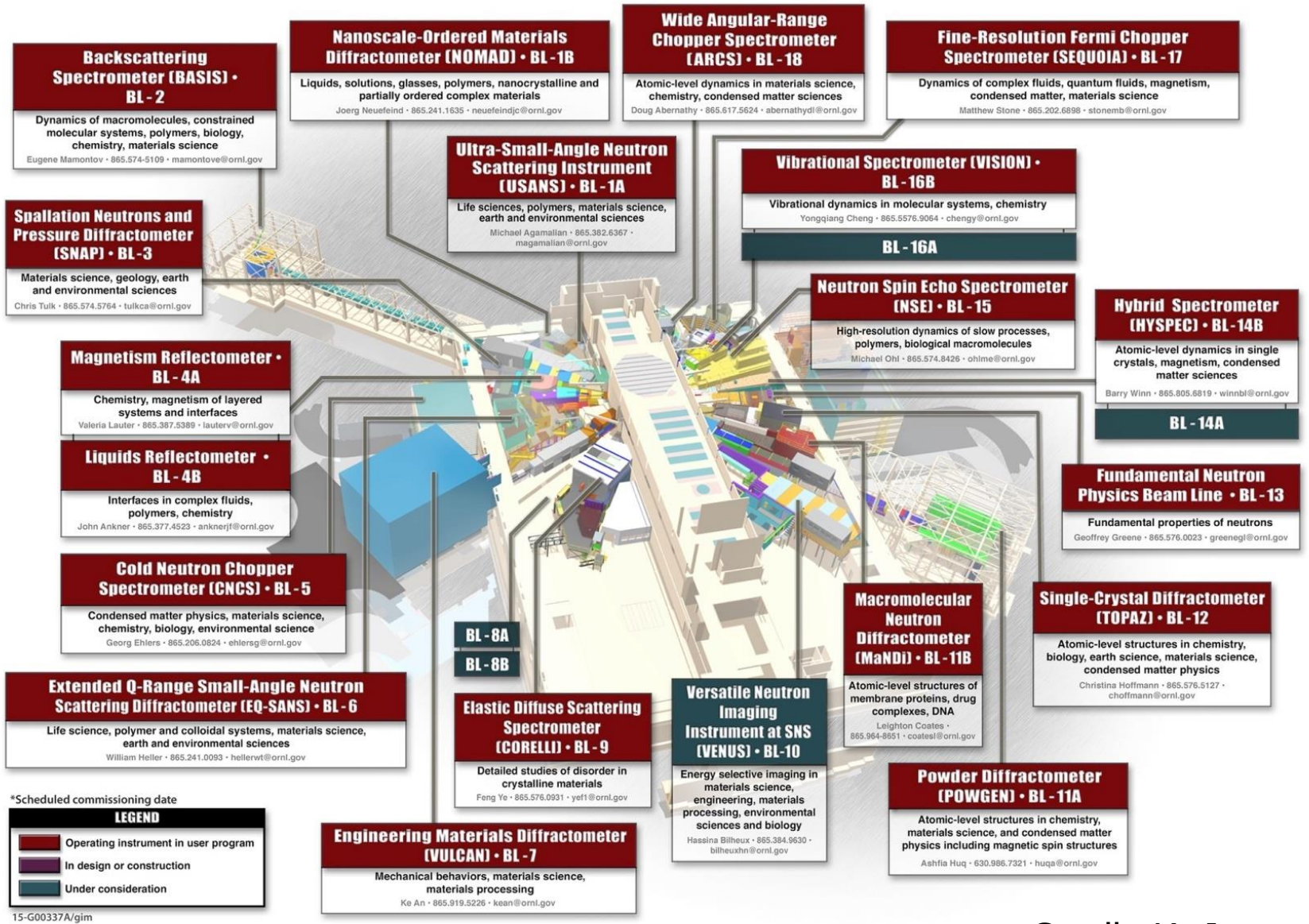


Figure: D. McClintock

There are now 18 instruments in the user program along with one operated by Office of Nuclear Physics



Credit: K. Jones

Mercury enters through side supply passages and returns through the center return passage

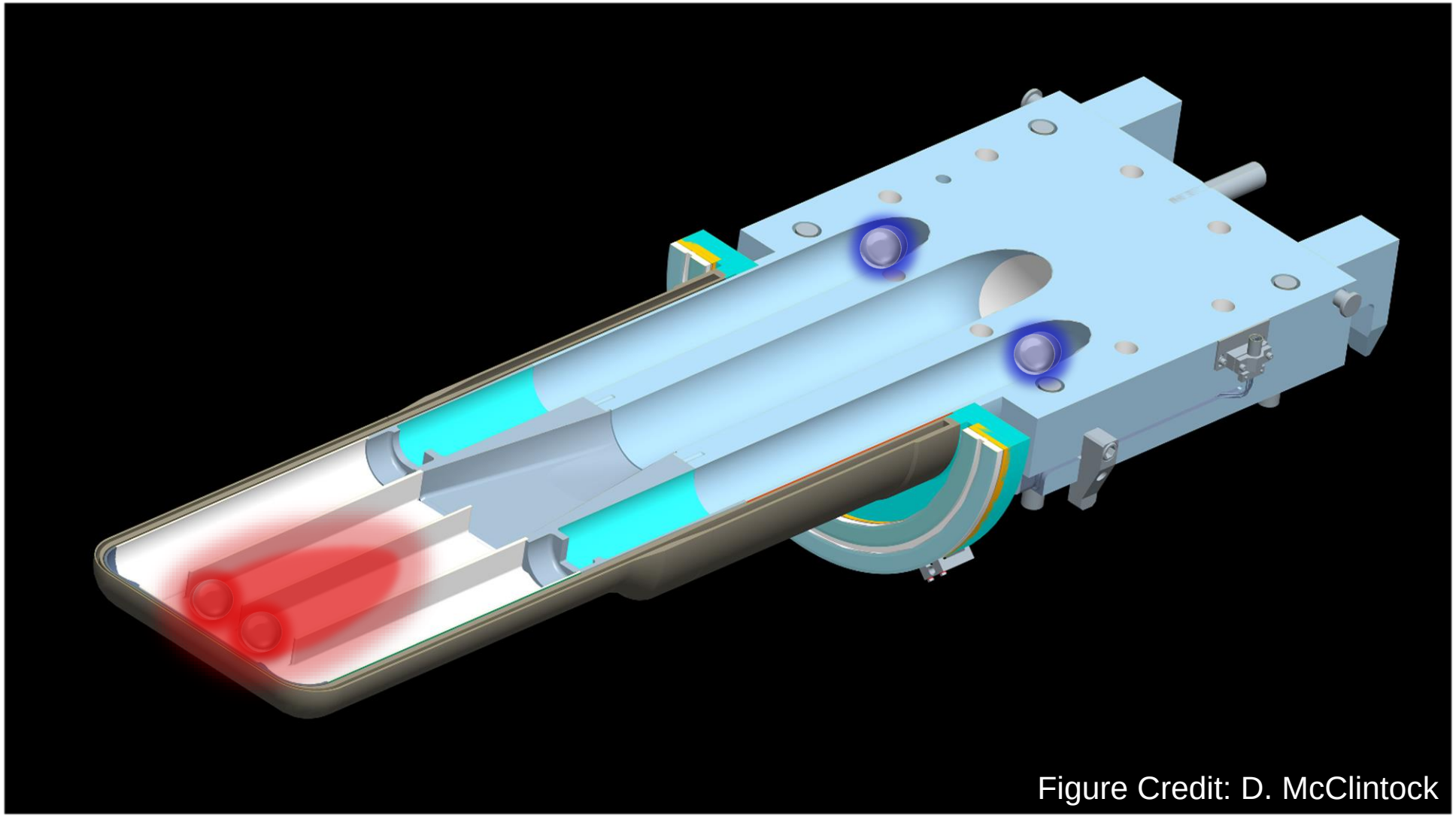
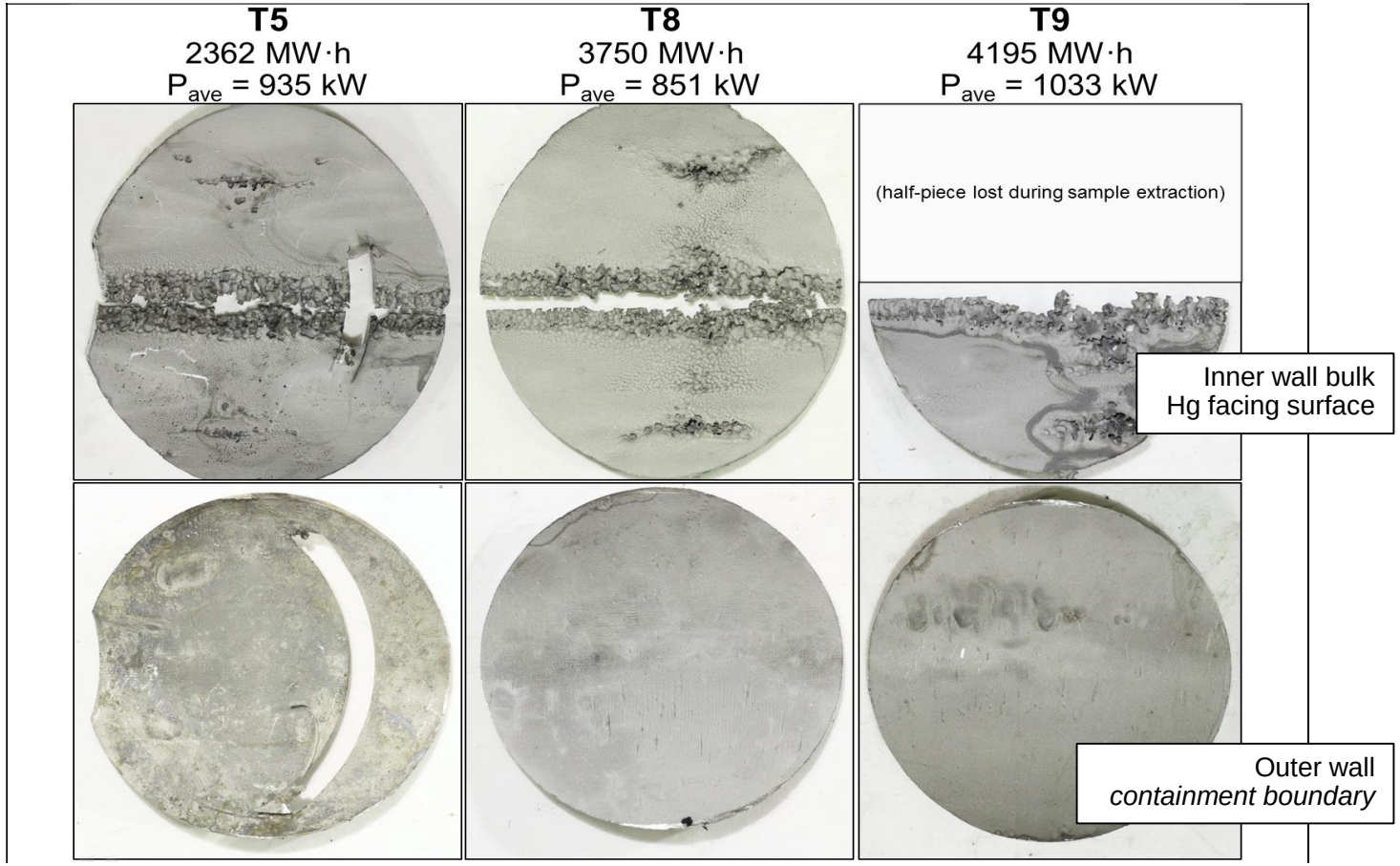


Figure Credit: D. McClintock

Fatigue Stress and Cavitation Cause Target Failures

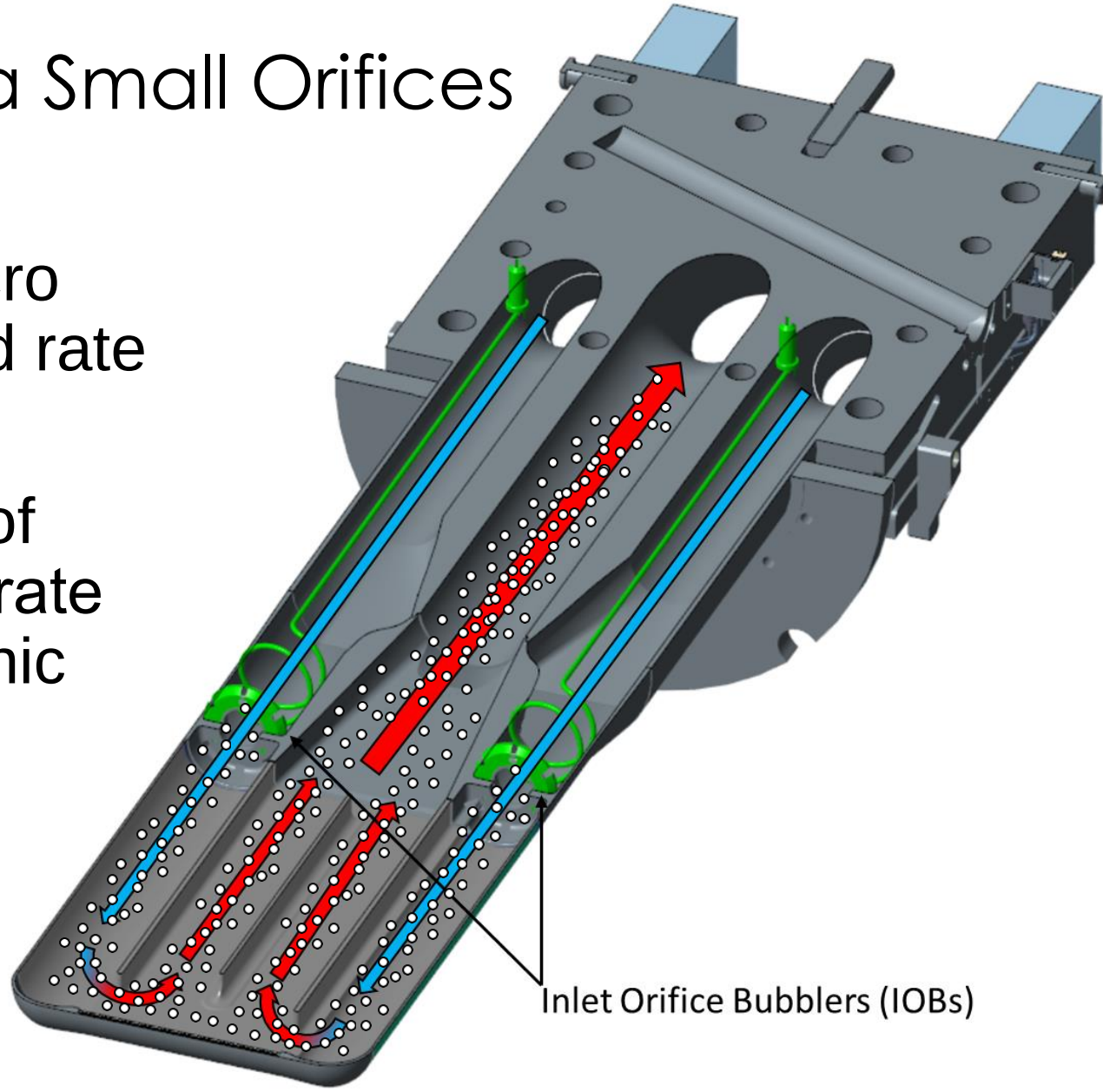
- Giga-cycles of fatigue stress in the mercury vessel over desired target lifetime.
- Pitting & erosion damage to the vessel caused by mercury cavitation.
- Pulse stresses and erosion rate increase with higher power.



Credit: B. Riemer

Target Module Injects Gas via Small Orifices

- The gas injection system uses micro orifices to inject gas at a measured rate into the mercury loop.
- The orifices work on the principle of “choked flow,” where the gas flow rate levels off after the gas reaches sonic velocity going through the hole.
  - This provides a stable flow to multiple gas injection sites to help generate many small bubbles in the mercury flow.



Integration of Safety in Design

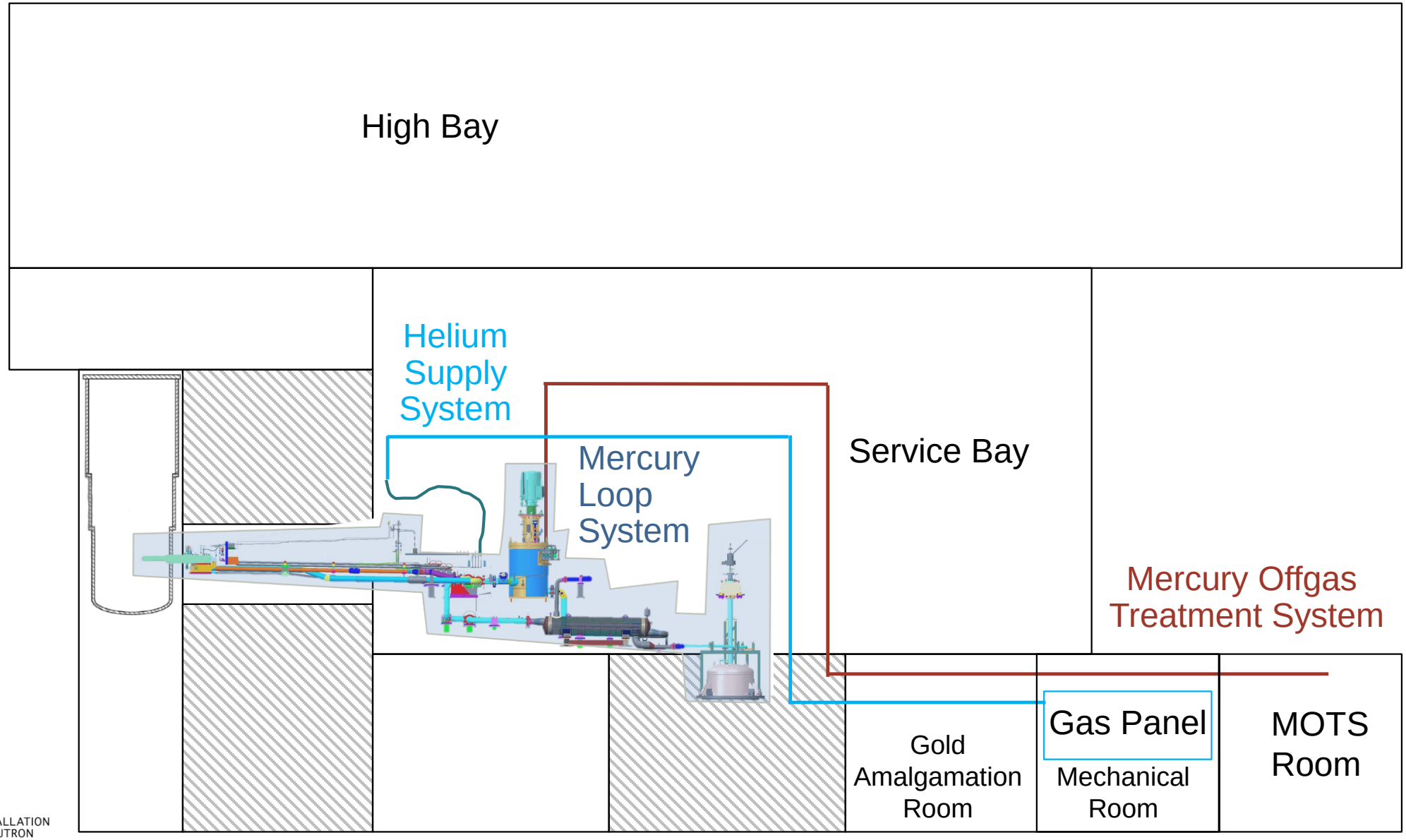
- Facility safety became involved during preliminary design phase.
  - Conceptual design chosen – orifice bubblers in target module inlets.
- Weekly coordination meetings provided frequent opportunities to provide feedback to design team from a facility safety perspective.
- Safety Analysts co-located with Engineering.
- Testing could be developed to evaluate the physical credibility of phenomena.

Helium venting through Hg

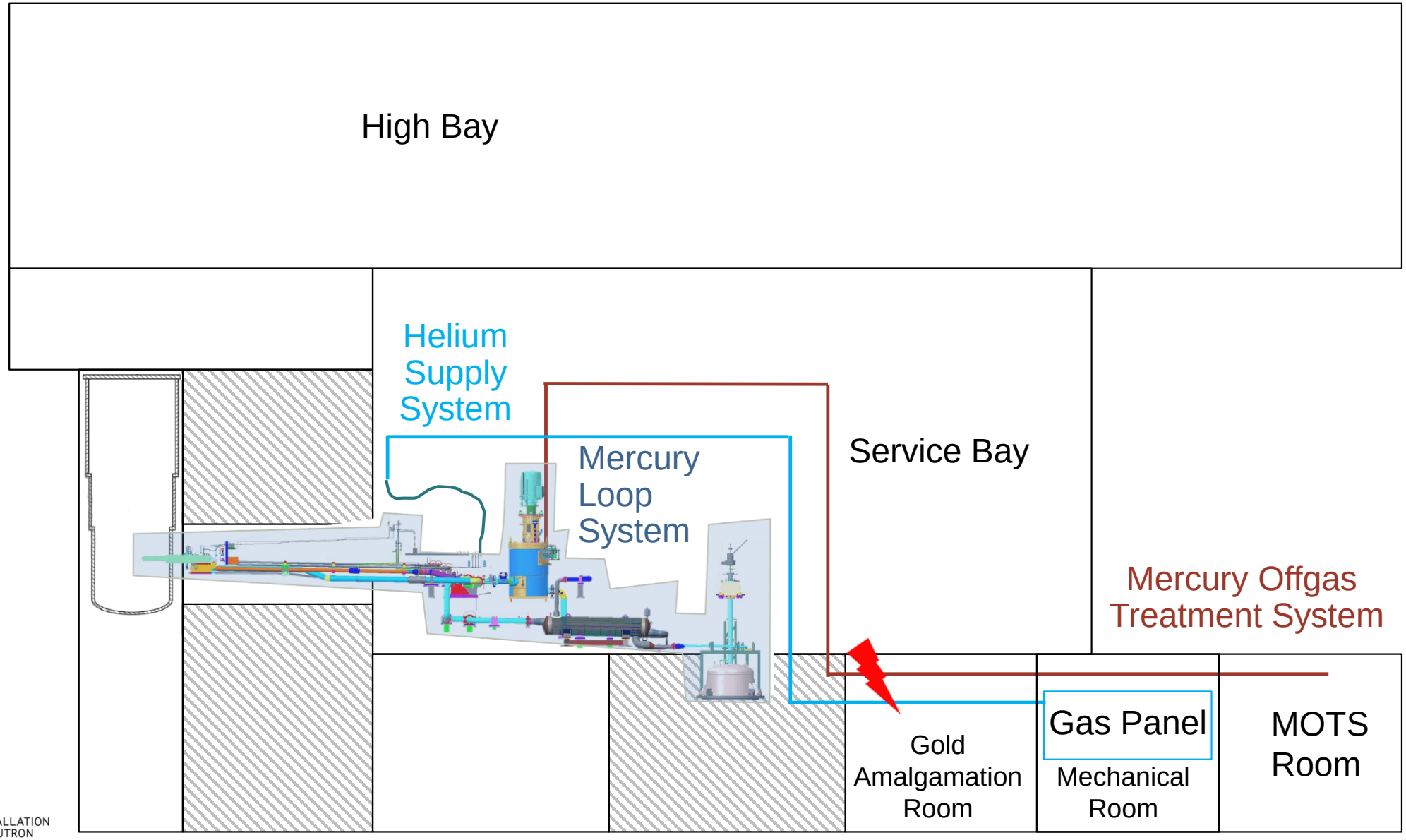
Target Mercury - Radiation Hazard

- ~300 gallons (16T) target mercury used throughout life of facility.
- Spallation/activation produces radioactive nuclei that accumulate in target mercury.
  - ~42.5 GW-hrs total power history ≈ 318g Hg converted
- Most of the ASE controls are focused on preventing the release of target mercury.

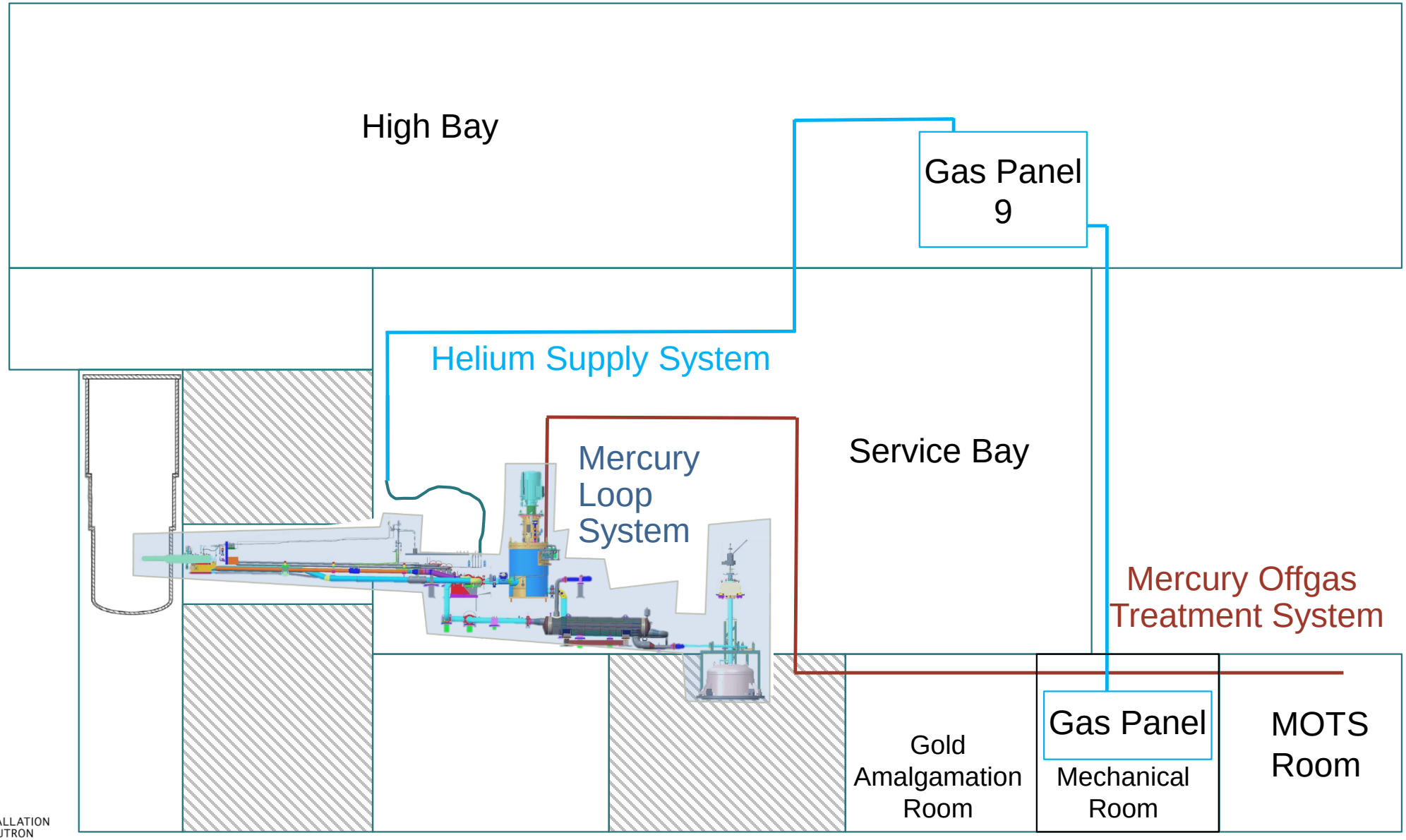
Helium Supply Design



Helium Supply Design

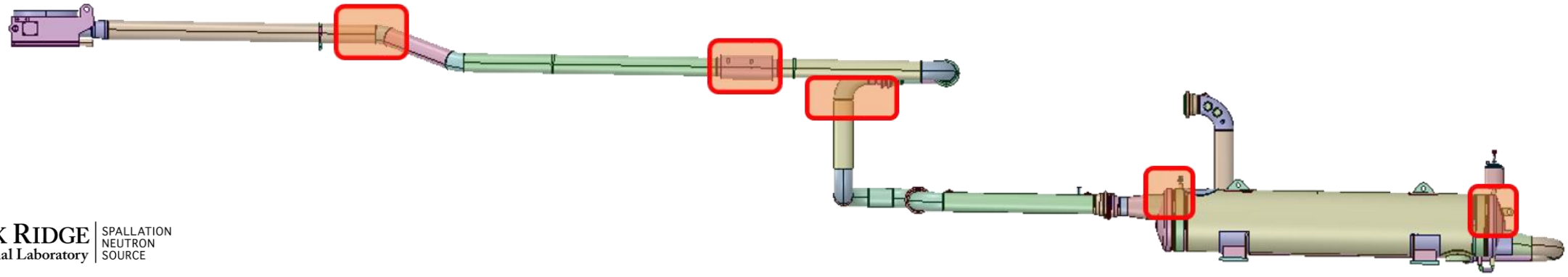


Helium Supply Design

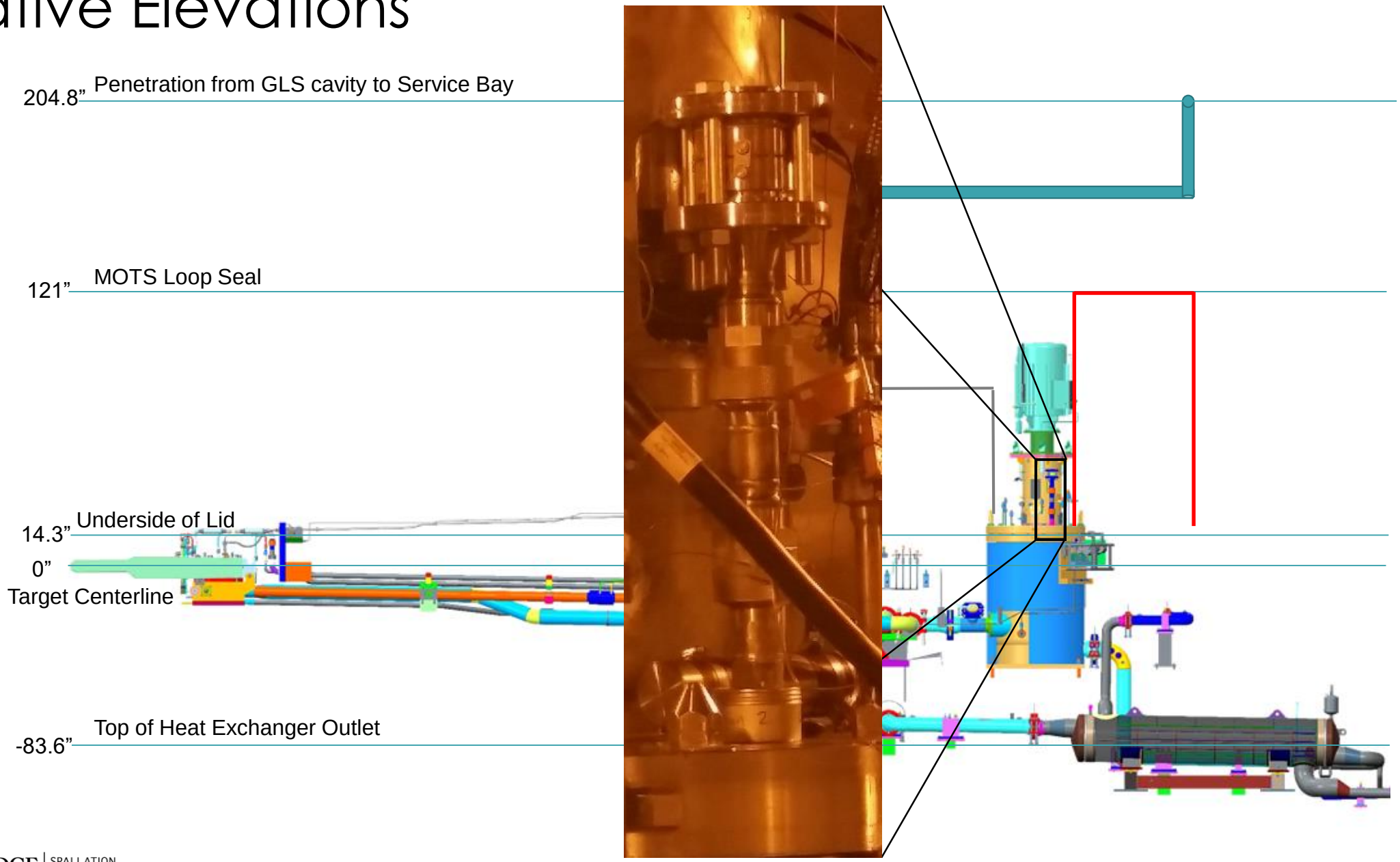


Gas Accumulation Analysis

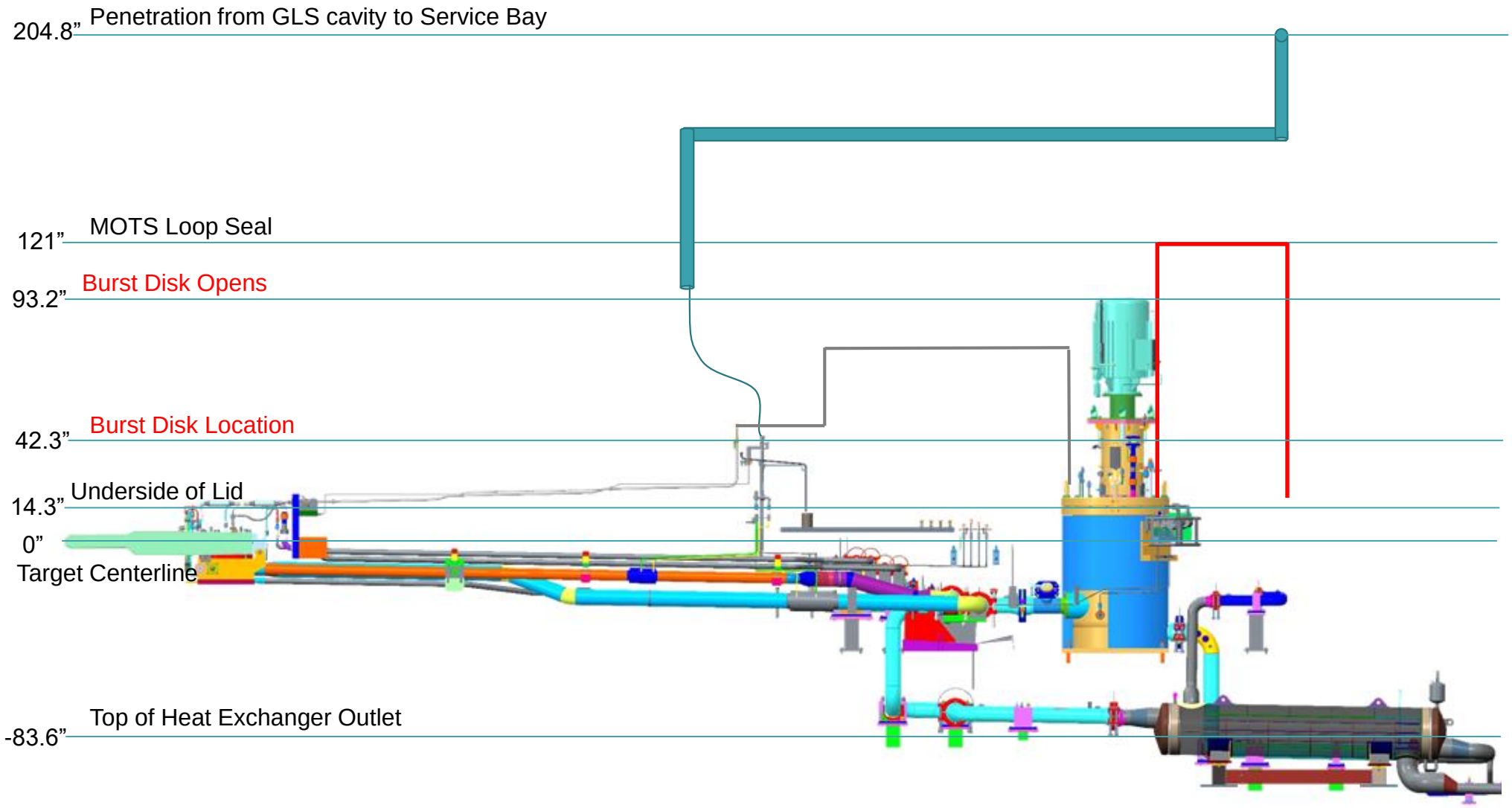
- Testing in a prototypic loop indicated that apparent mercury level rises in the pump tank due to gas displacement.
  - Geometric differences between the prototypic and actual loop made the degree of accumulation in the actual loop uncertain.
- Excessive rise in mercury level could result in mercury leaving the Service Bay via the off-gas system.
- An existing control prevented this condition during loop fill operations by establishing a high point in the off-gas connection.



Relative Elevations

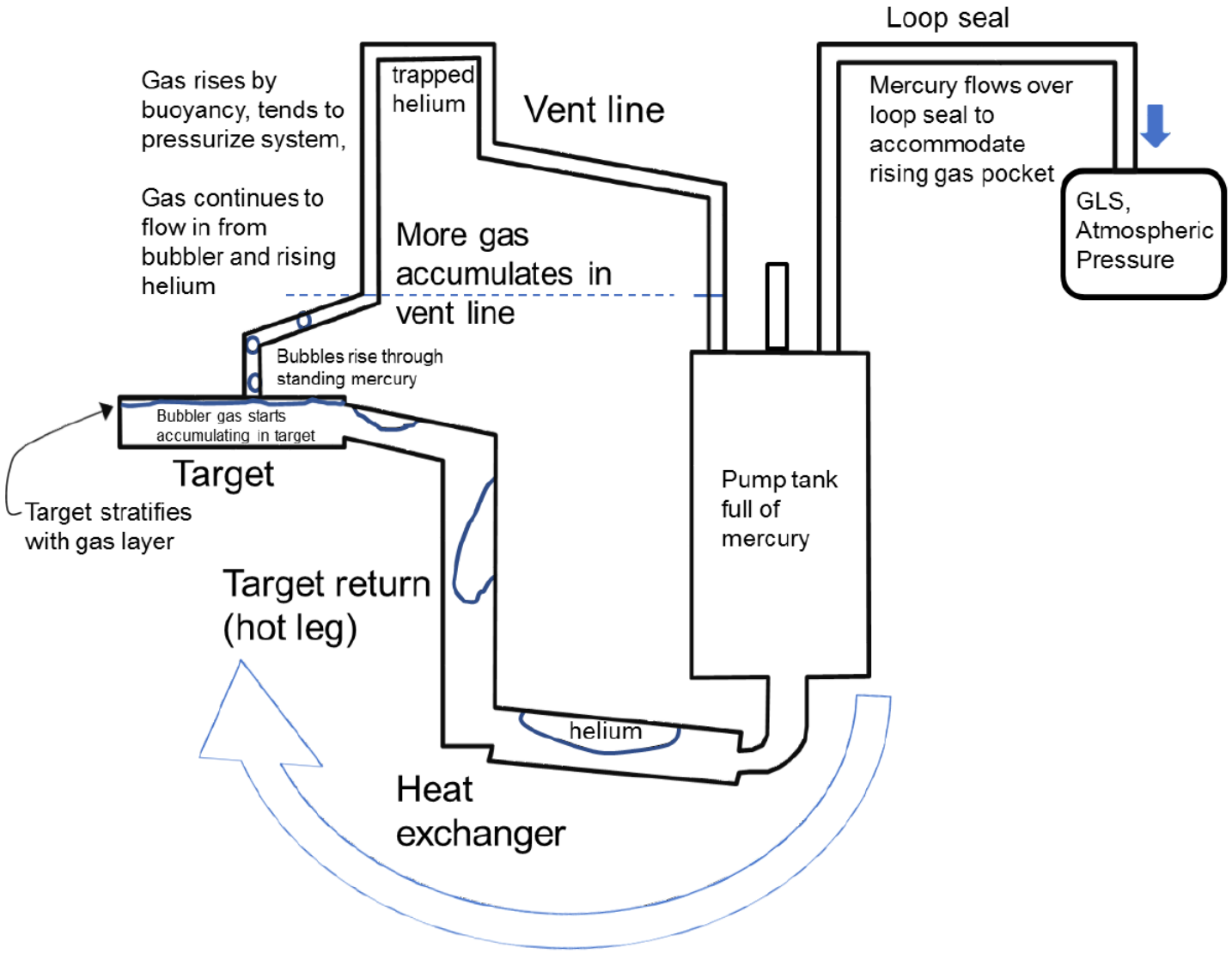


Relative Elevations



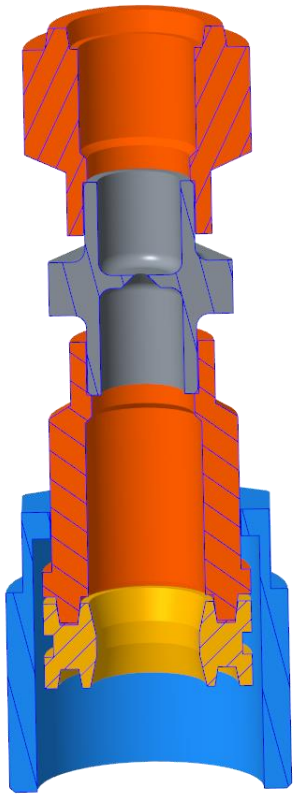
Transient Bubble Expansion

- Bubble accumulates low in the loop, thus expands as it rises.
- Potential to displace mercury more rapidly than burst disc can remove it.
- Transient analysis necessary to ensure no overflow.

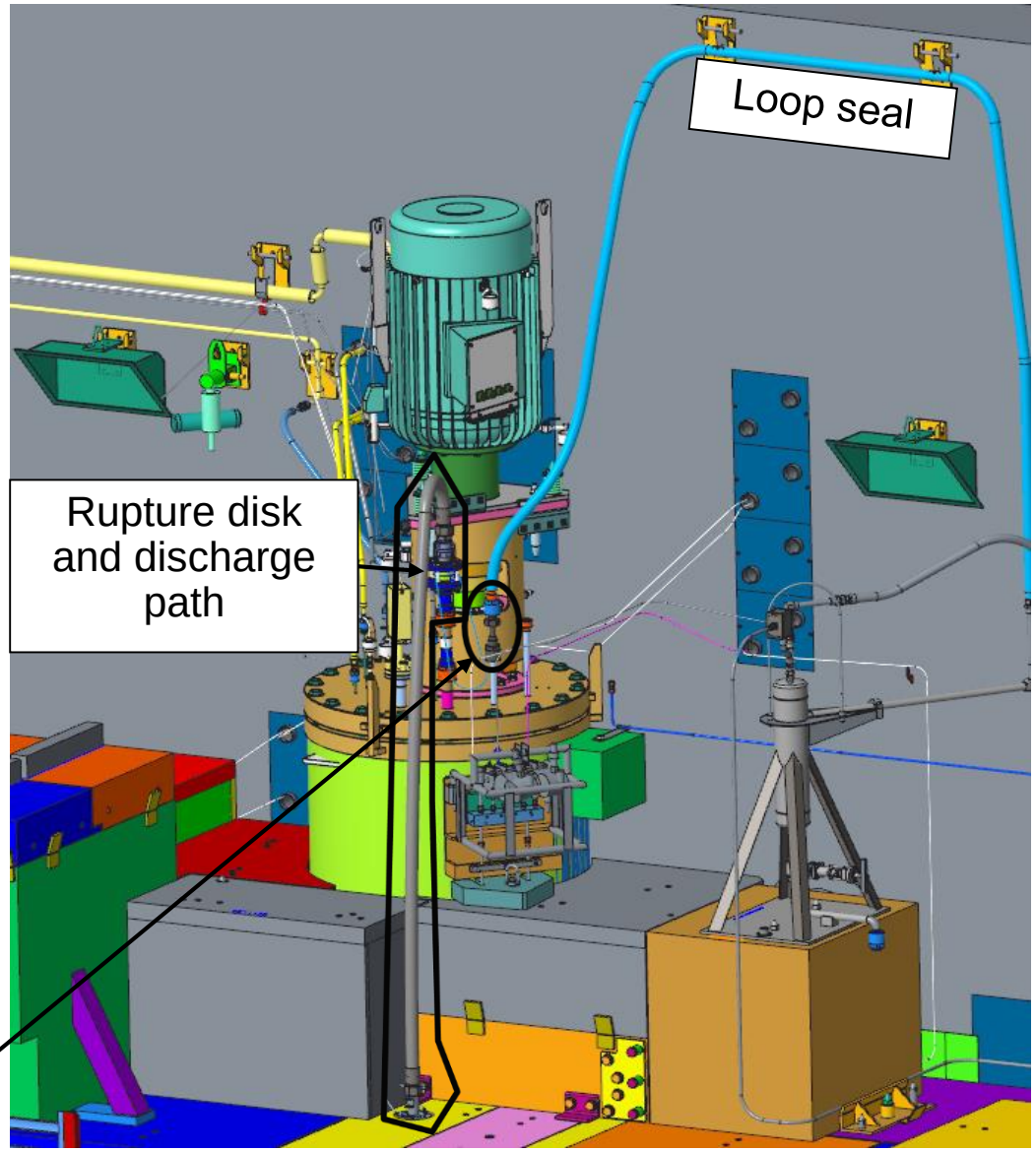


Transient Bubble Expansion

- Analysis showed that a restriction in the vent path was necessary.
- Orifice sized to ensure no mercury escapes Service Bay for bounding case.
- Credited Controls
  - Rupture disk
  - Orifice
  - Loop seal



Orifice weldment

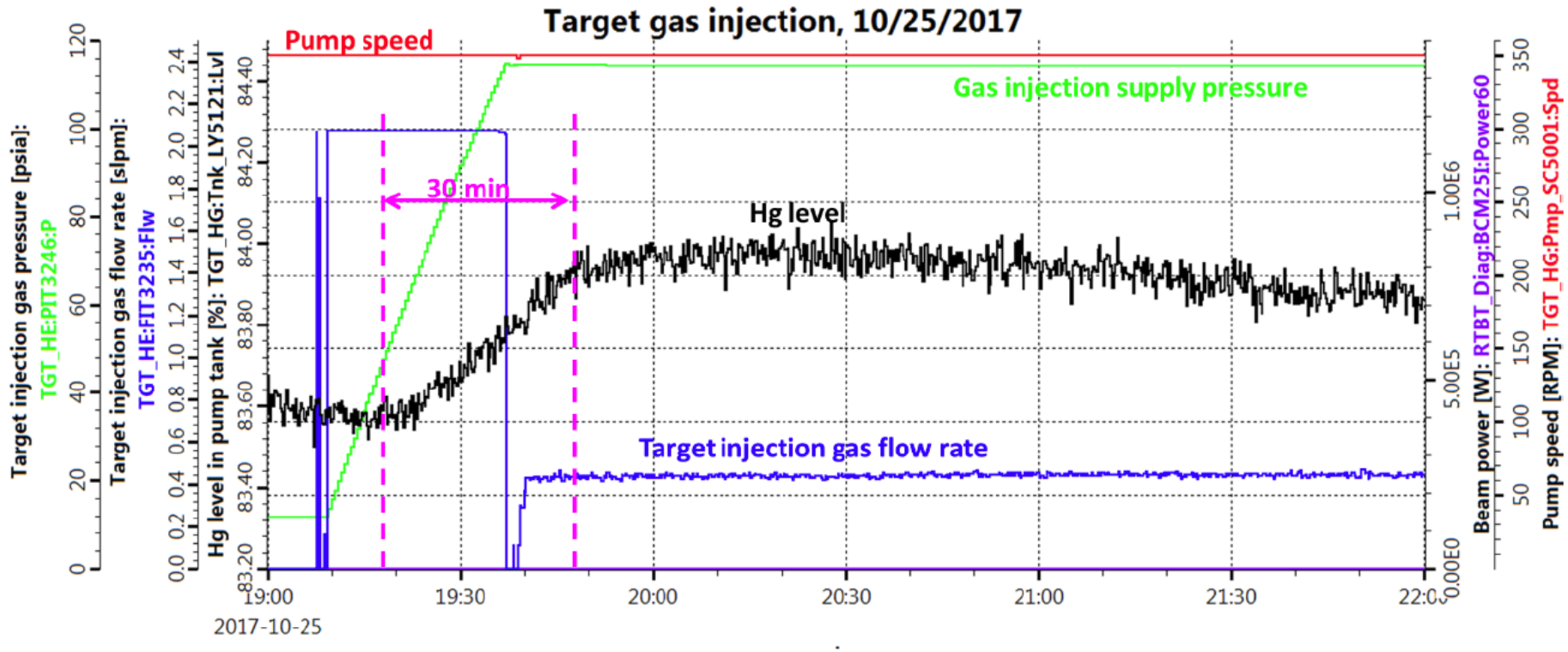


Regulatory Path

- Positive USI
- Safety Assessment Supplement
- Supplemental ASE – DOE Approved
- ARR
- DOE Authorizes Commissioning

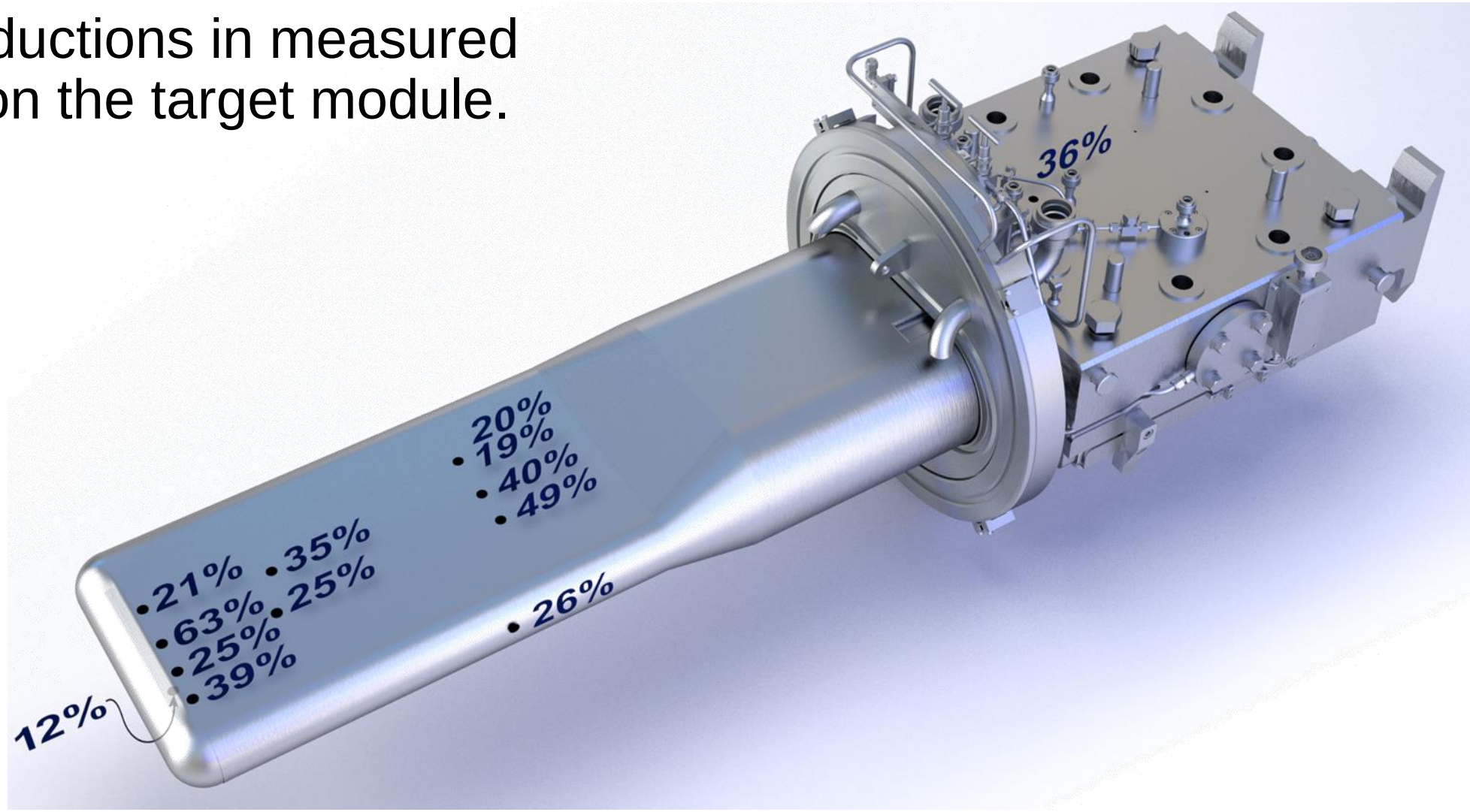
Outcome

- In October 2017, SNS successfully commissioned gas injection into the mercury process loop.
- System response was very favorable.



Outcome

- Significant reductions in measured stress/strain on the target module.



Summary

- Integration of Safety and Design
- Safety analysis identified credited controls
- Successful ARR, DOE authorizes commissioning
- Successful commissioning
- Significant strain reduction - success