Risk Management Considerations of the SOFIA Aircraft

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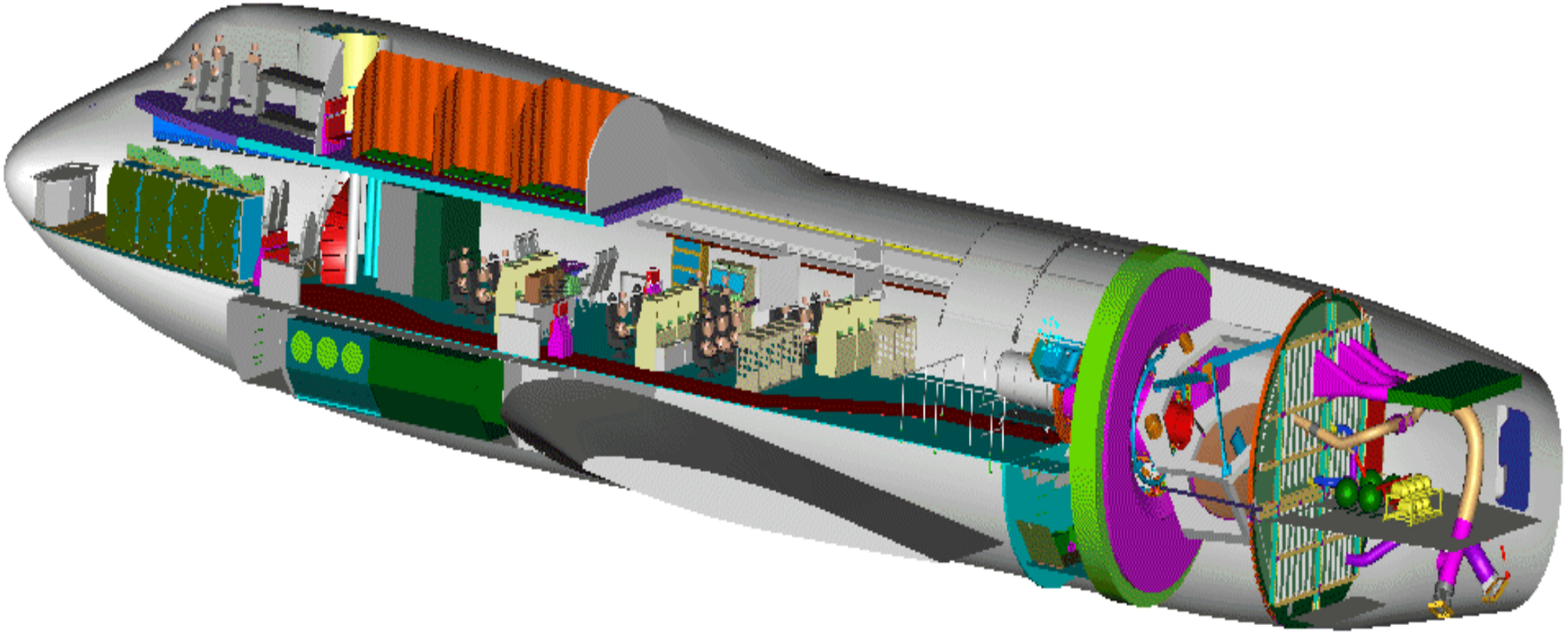
SFA Safe, Reliable, Affordable Technology

SOFIA Project Overview

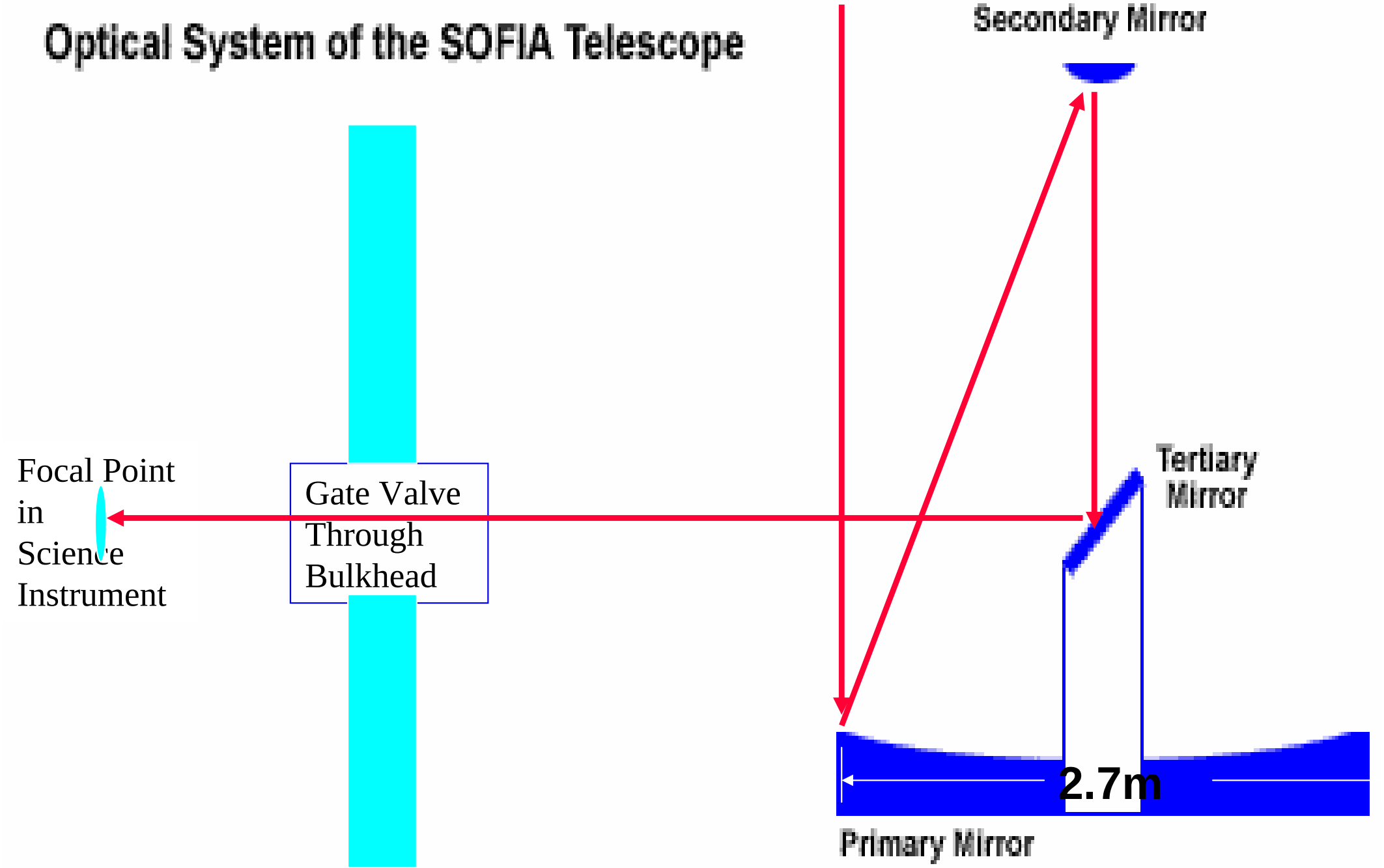
- Create a Stratospheric Observatory for Infrared Astronomy (SOFIA) from a Boeing 747SP
- Cooperation between National Aeronautics and Space Administration (NASA) and Deutsches Zentrum Für Luft- und Raumfahrt (DLR)
- 41,000 feet and above, excellent access to infrared wavelengths
  - Only 1% of atmospheric water vapor remains; unrestricted access to infrared wavelengths.
  - Less expensive, easier to maintain, update and modify than orbiting spacecraft
- First test flight 2006
- 20 year flight program

SOFIA Aircraft

SOFIA Interior

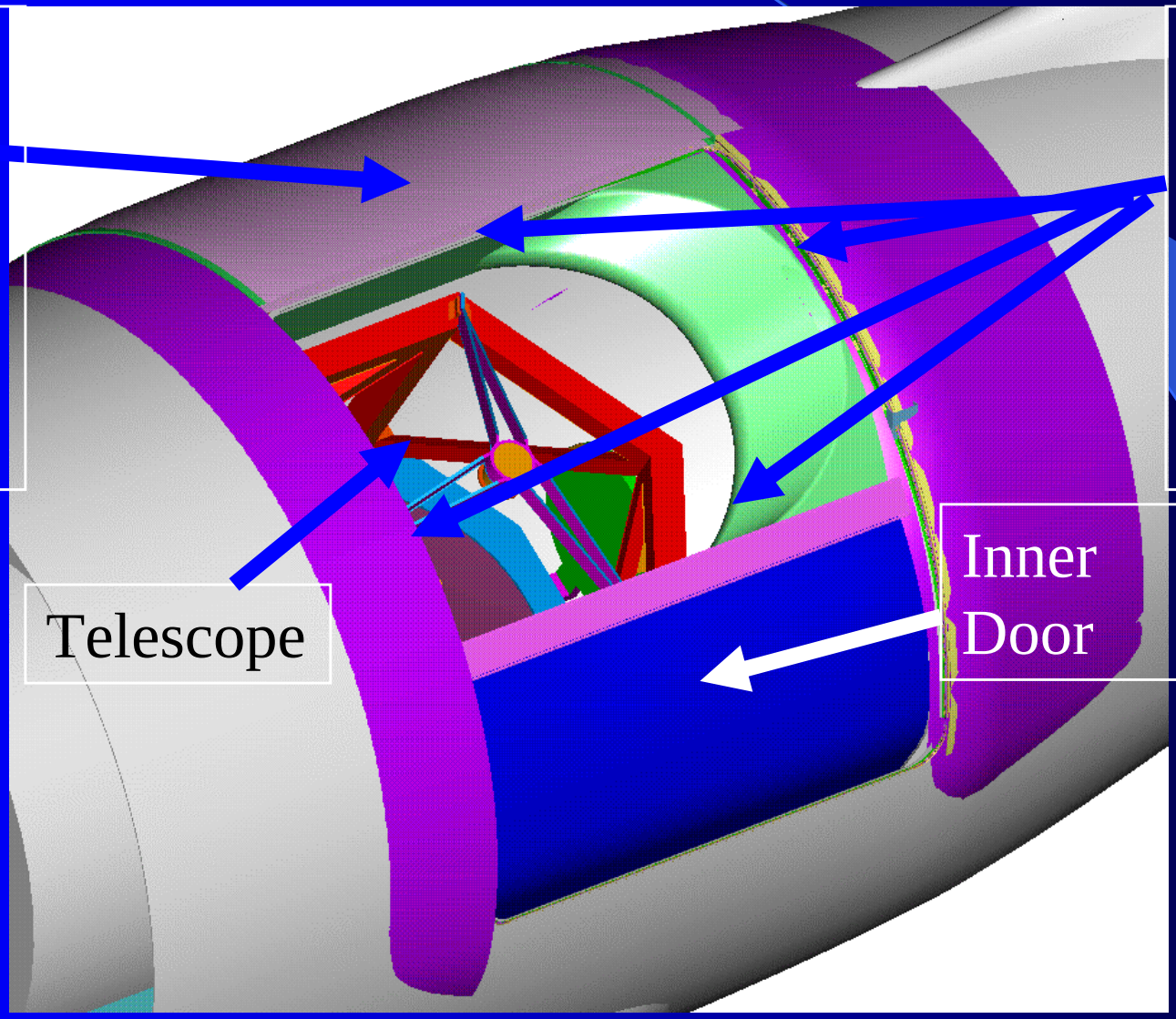


Infrared Pathway



Cavity Doors

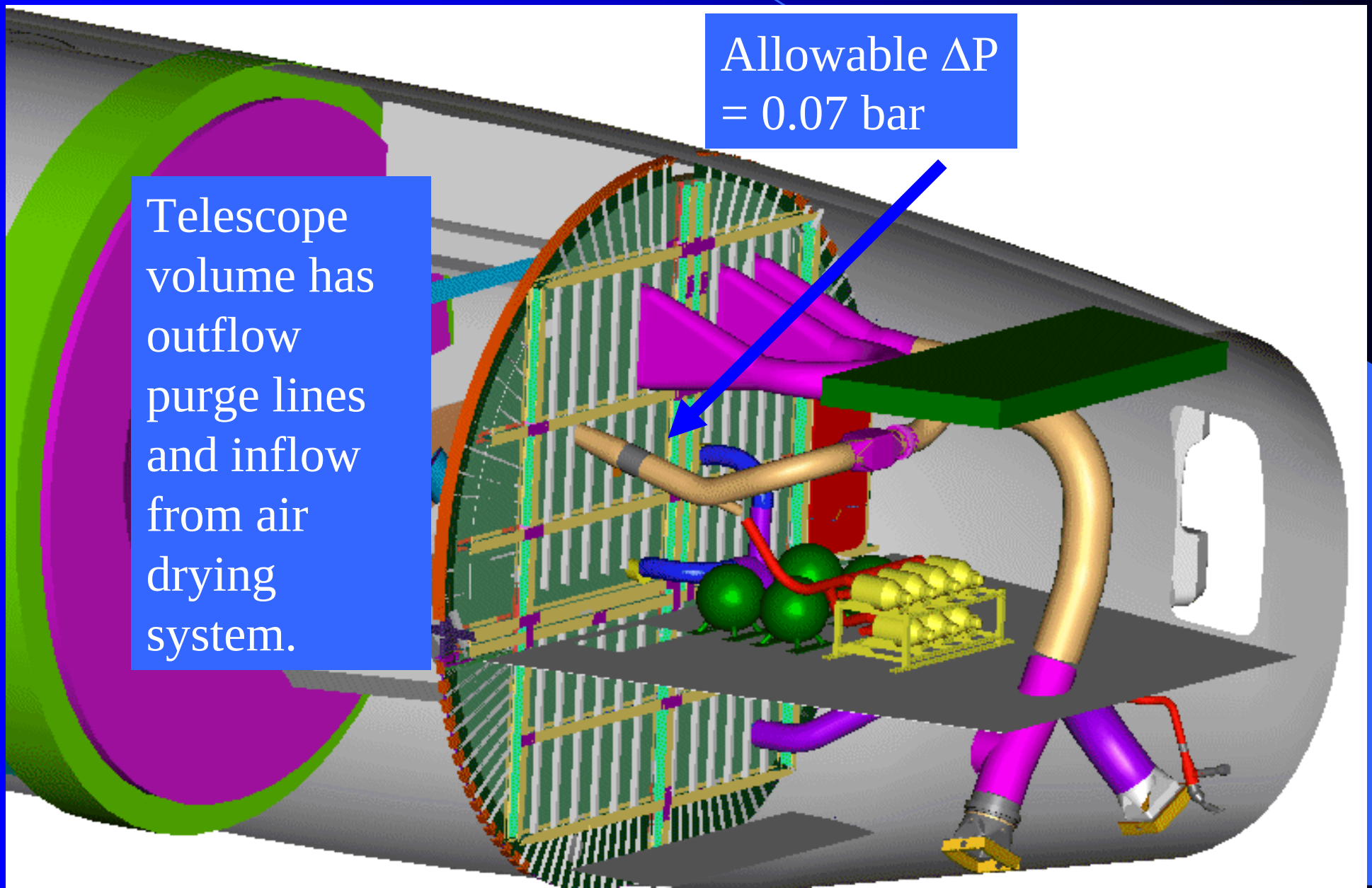
External Door closed during ascent, descent.



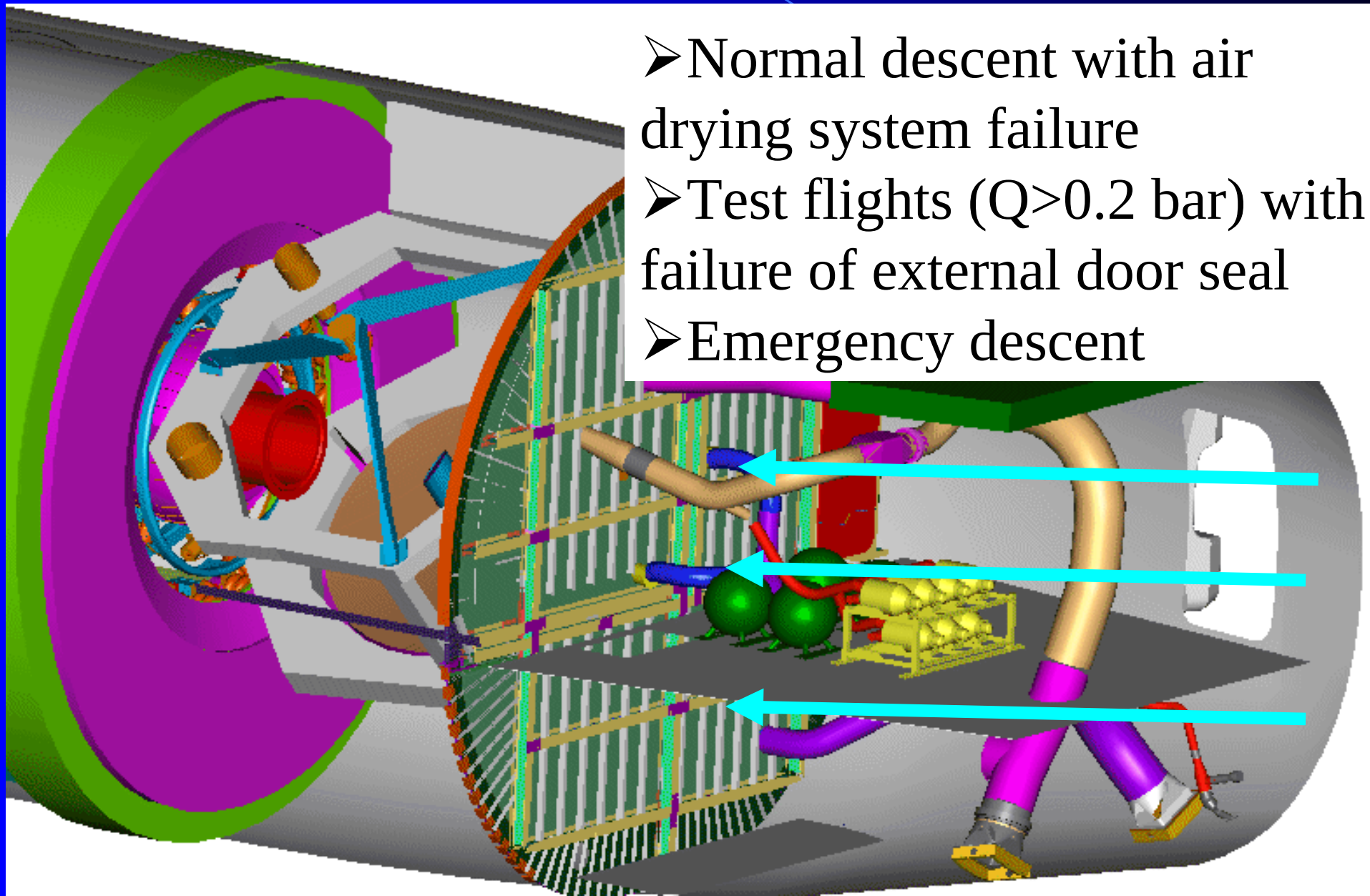
Inflatable silicone seal around inside of opening

Example Risk Management for Inter-compartment Pressure Differential

Aft Bulkhead Pressurization



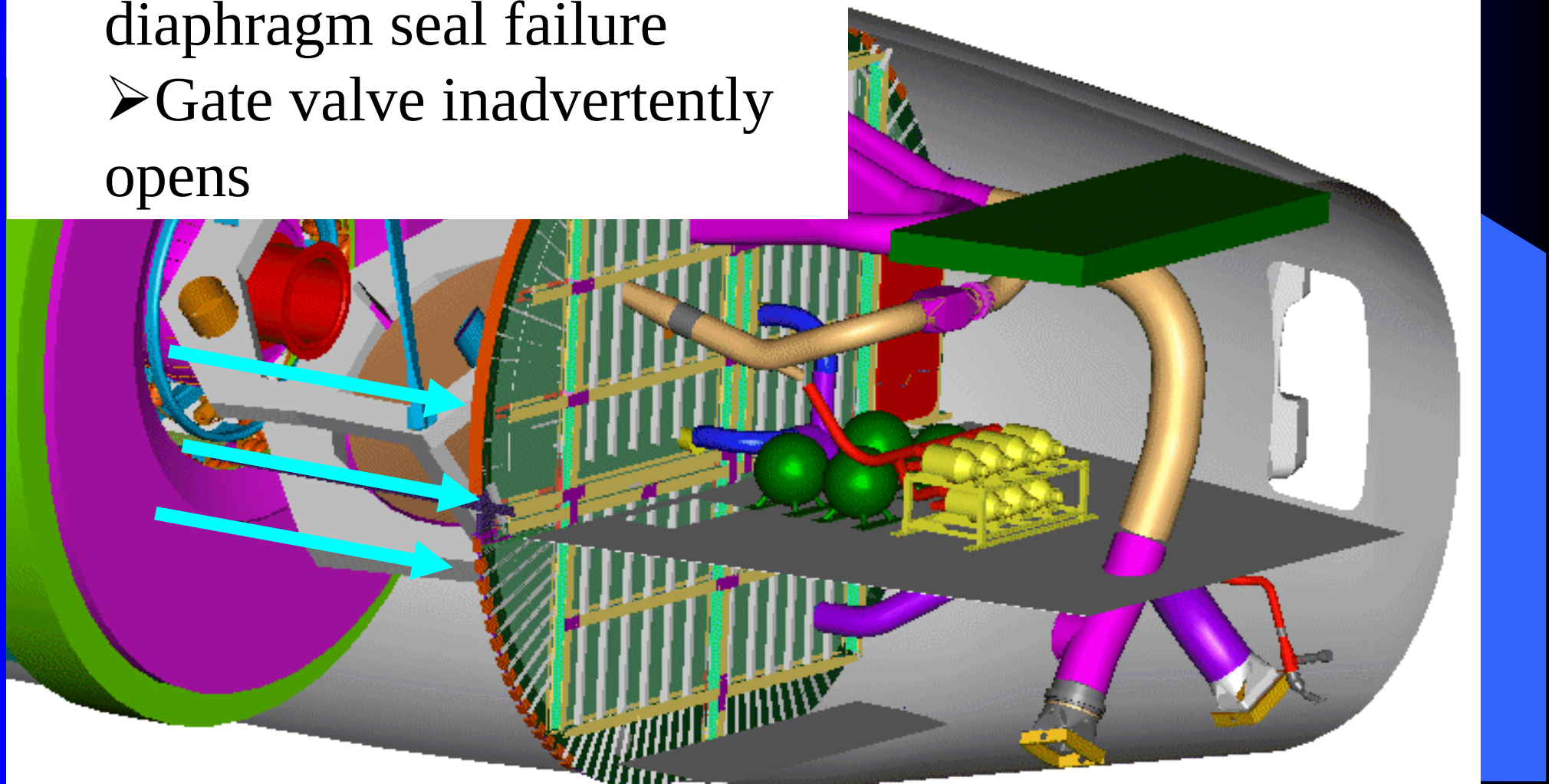
Causes of Exceeding Allowable ΔP (Forward Pushing Pressure)



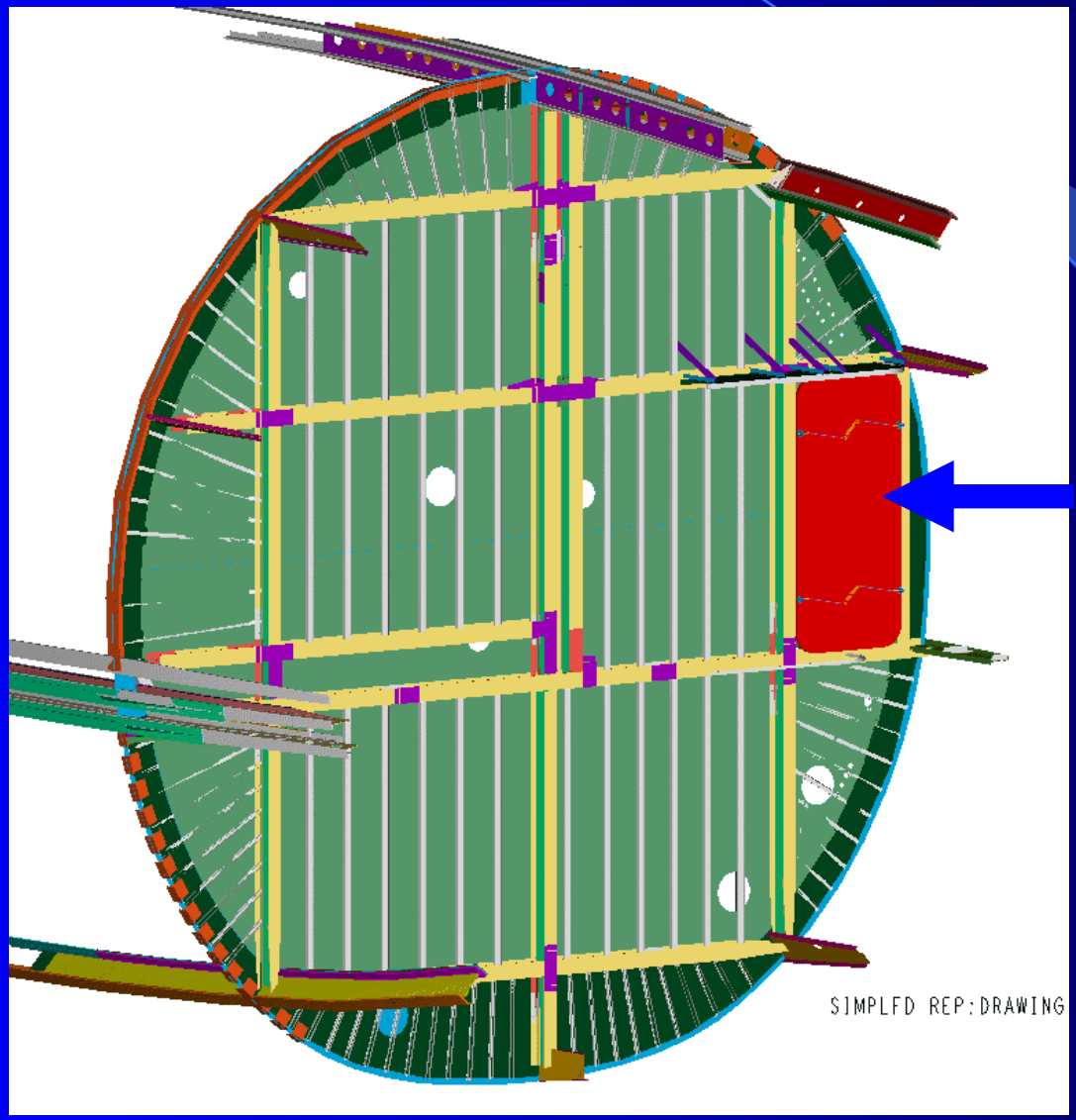
- Normal descent with air drying system failure
- Test flights (Q>0.2 bar) with failure of external door seal
- Emergency descent

Causes of Exceeding Allowable DP (Aft Pushing Pressure)

- Cabin depressurization
  - ➢Main bulkhead silicone diaphragm seal failure
  - ➢Gate valve inadvertently opens



Aft Bulkhead with Access Door

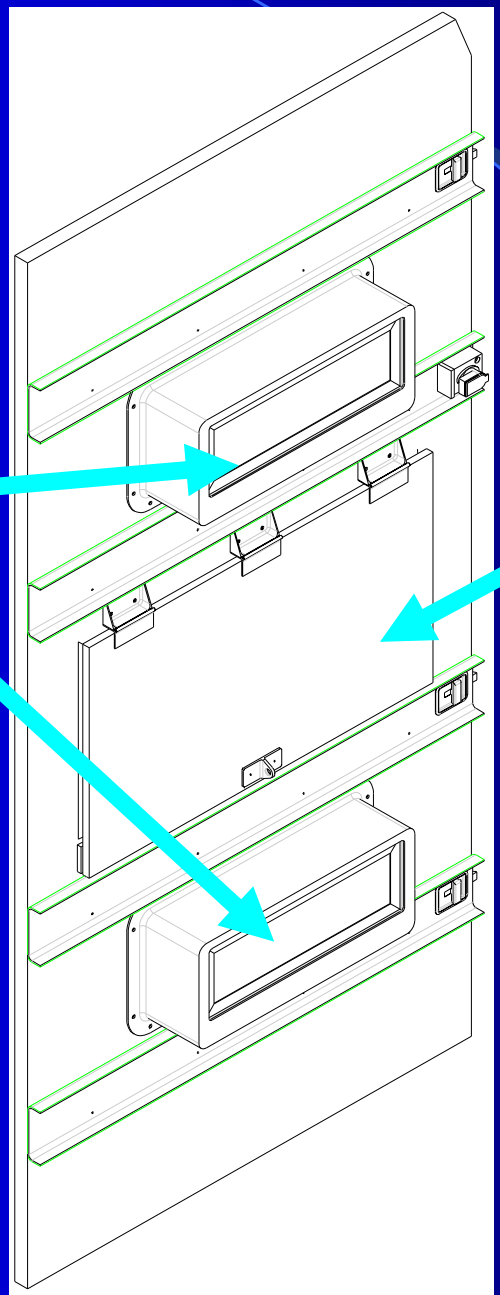


Access Door

Access Door with Relief Vents

Relieves pressurization of aft compartment

Each one sized for flight conditions Q< 0.24 bar



Relieves pressurization of Cavity due to Cabin Depressurization

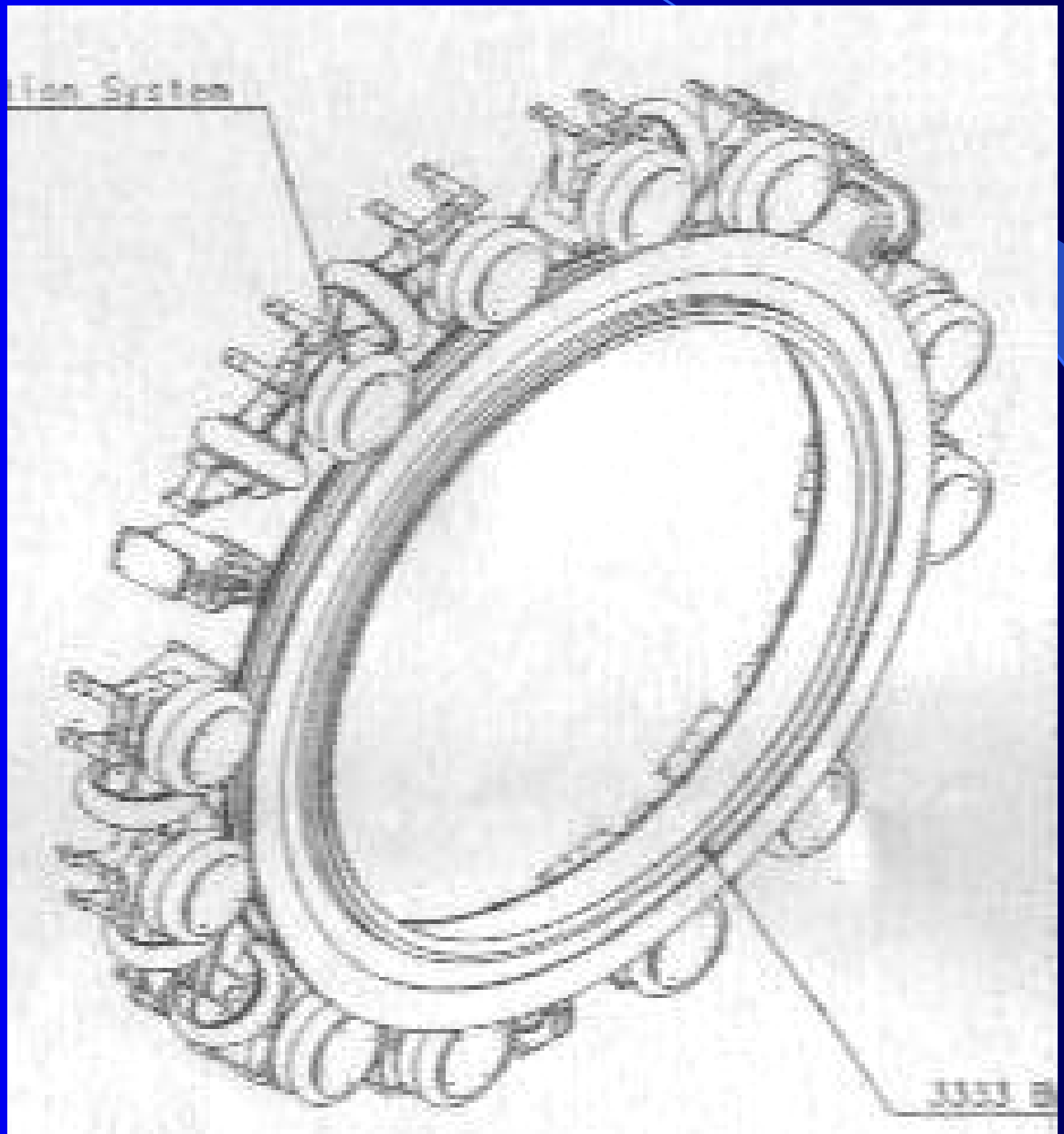
Sized for Gate Valve Opening

Other Risk Reduction Strategies

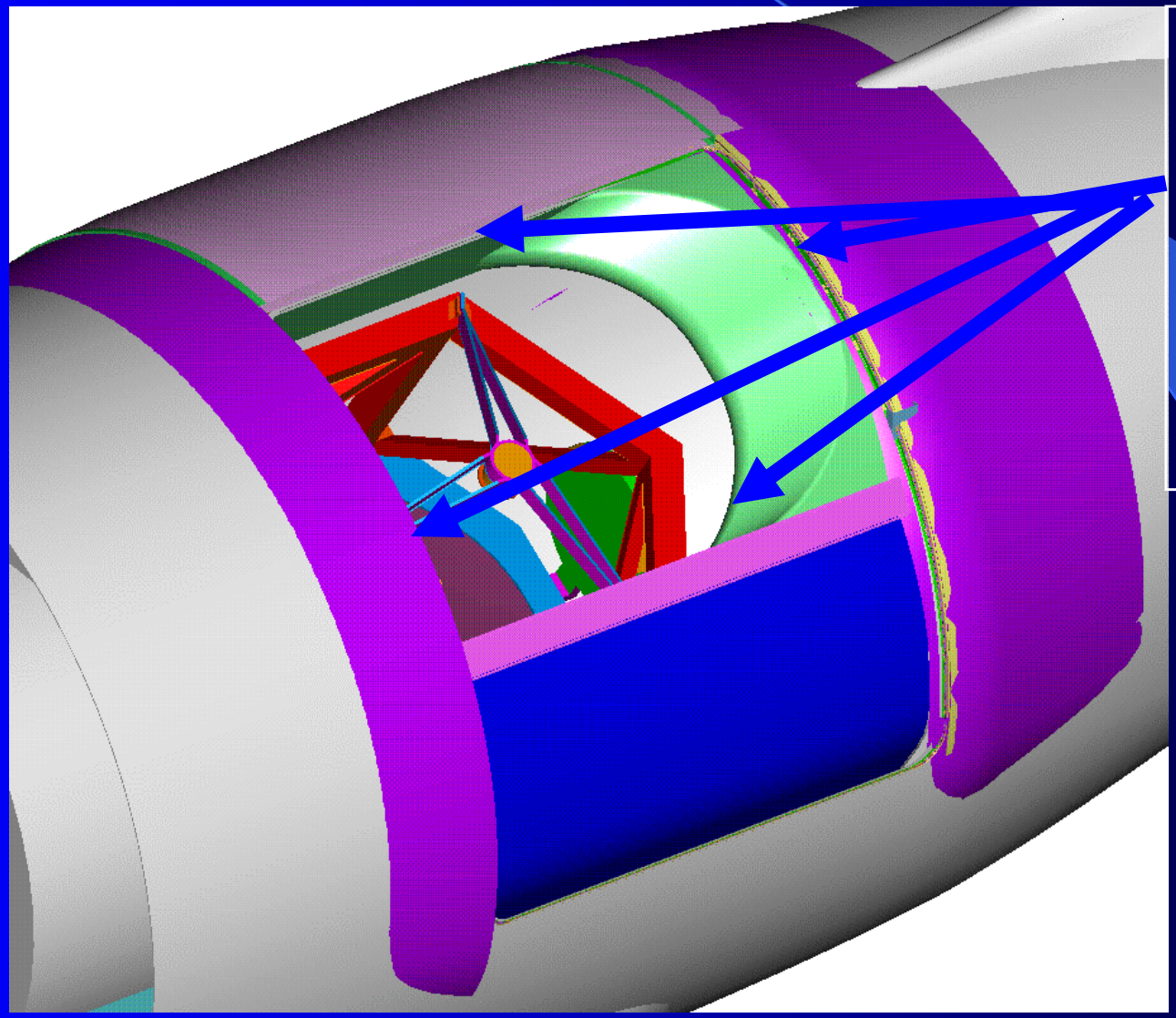
- Cabin Depressurization
  - Gate valve rarely primary pressure barrier
    - When it is, power interlocked out
    - Normally Science Instrument in place
  - Flow limiter after bulkhead diaphragm seal limits flow to equivalent of gate valve flow
- Oxygen masks on-board
- Emergency descent procedures established
- Decompression switch at cabin altitude of 4268 m turns off all non-essential aircraft electrical power to prevent arcing
- Inspection program for seals at manufacturer recommended intervals

Example Risk Management for 156 bar Air Cylinders

Vibration Isolation System (Showing Air Springs)

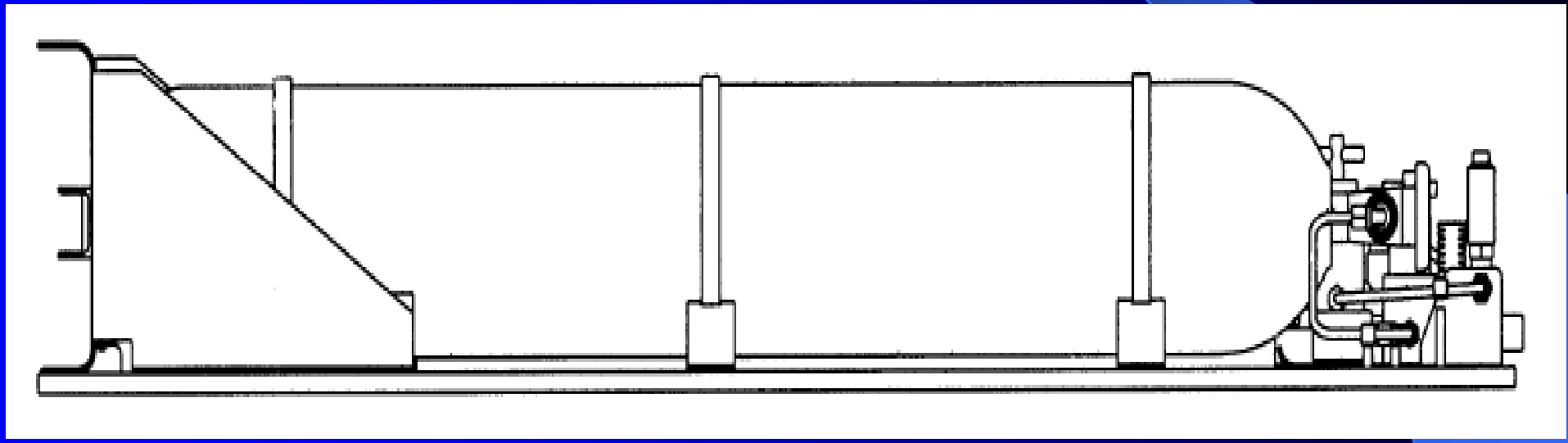


Cavity Door Inflatable Seal



Inflatable silicone seal around inside of opening

High Pressure Air Cylinder on Pallet (3 cylinders)



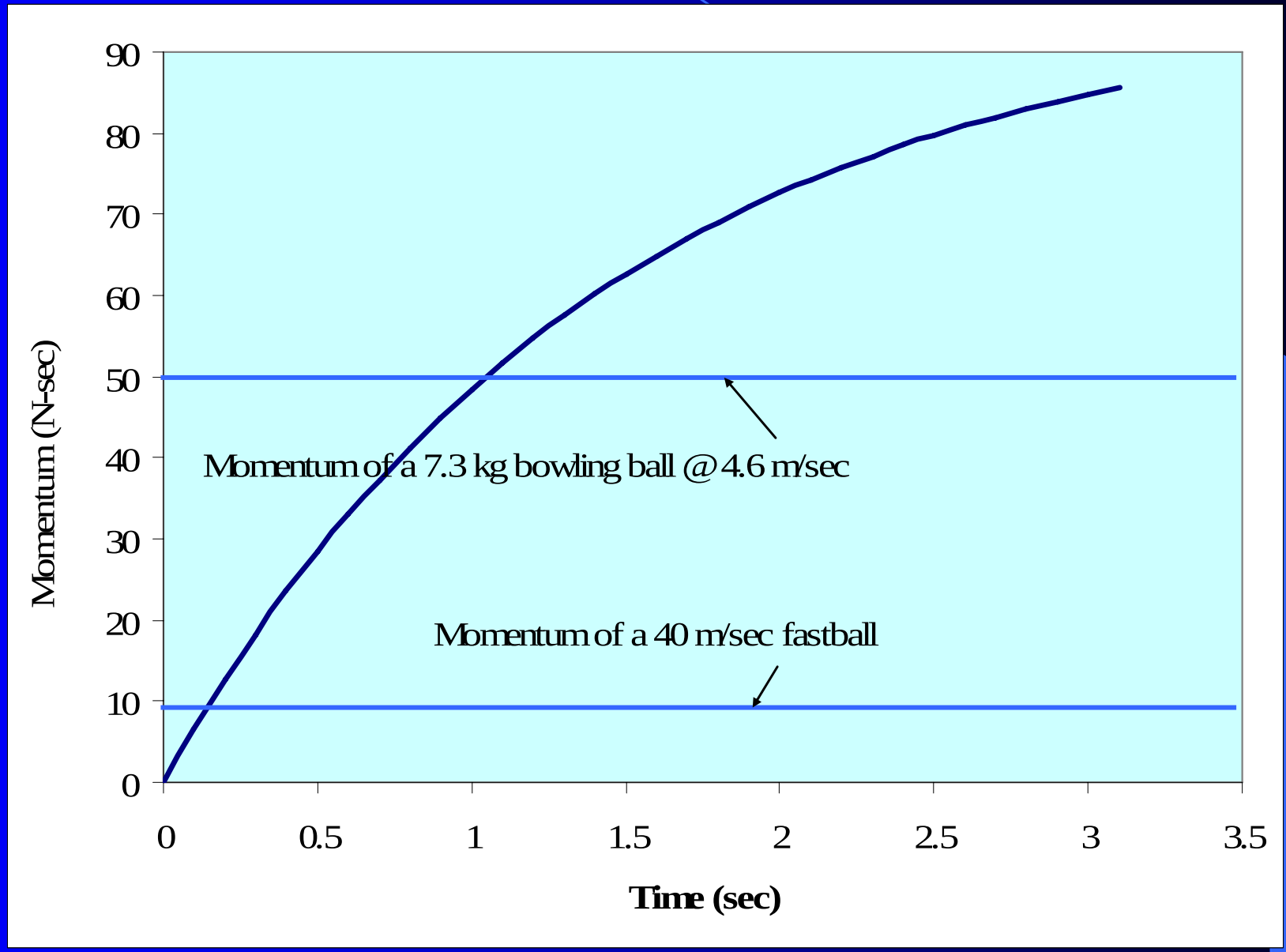
23 liters; 156 bar;
34 kg

Four Risks

1. Missile from breaking off valve stem (e.g. dropped cylinder-human error).
2. Leak causes loss of cavity external door seal (contribution to aft bulkhead overpressurization).
3. Fire causes rupture or explosion (large fire on aircraft extremely rare).
4. Spontaneous rupture/explosion from aging effects such as fatigue and corrosion (extremely rare).

Note: Unlike other high pressure bottles on aircraft, these are discharged, removed, refilled and reinstalled 20 times per year.

Cylinder Momentum from Broken Valve Stem (Nozzle diameter = throat diameter)



Risk Management Strategies

- Fill line through the aircraft for in-situ refill
- Protective hard cover over the valve stem or place the entire cylinder in a carrying case (selected strategy)
- Remove all cylinders in favor of an on-board compressor that does not operate at high pressure.

Summary

- Many risk management challenges
  - Only two examples given here.
- Project tends toward simple risk reduction strategies that are well within state-of-art.
- SOFIA aircraft must meet all FAA certification requirements and all NASA safety standards.
- Risks identified by hazard analysis, FMEAs and a limited number of small focused probabilistic risk assessments.