



Transport Frame

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650 MHz High Beta CM Prototype FDR

29 – 31 July 2020

A Partnership of:

US/DOE

India/DAE

Italy/INFN

UK/STFC-UKRI

France/CEA, CNRS/IN2P3

Poland/WUST



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Requirements

Requirements

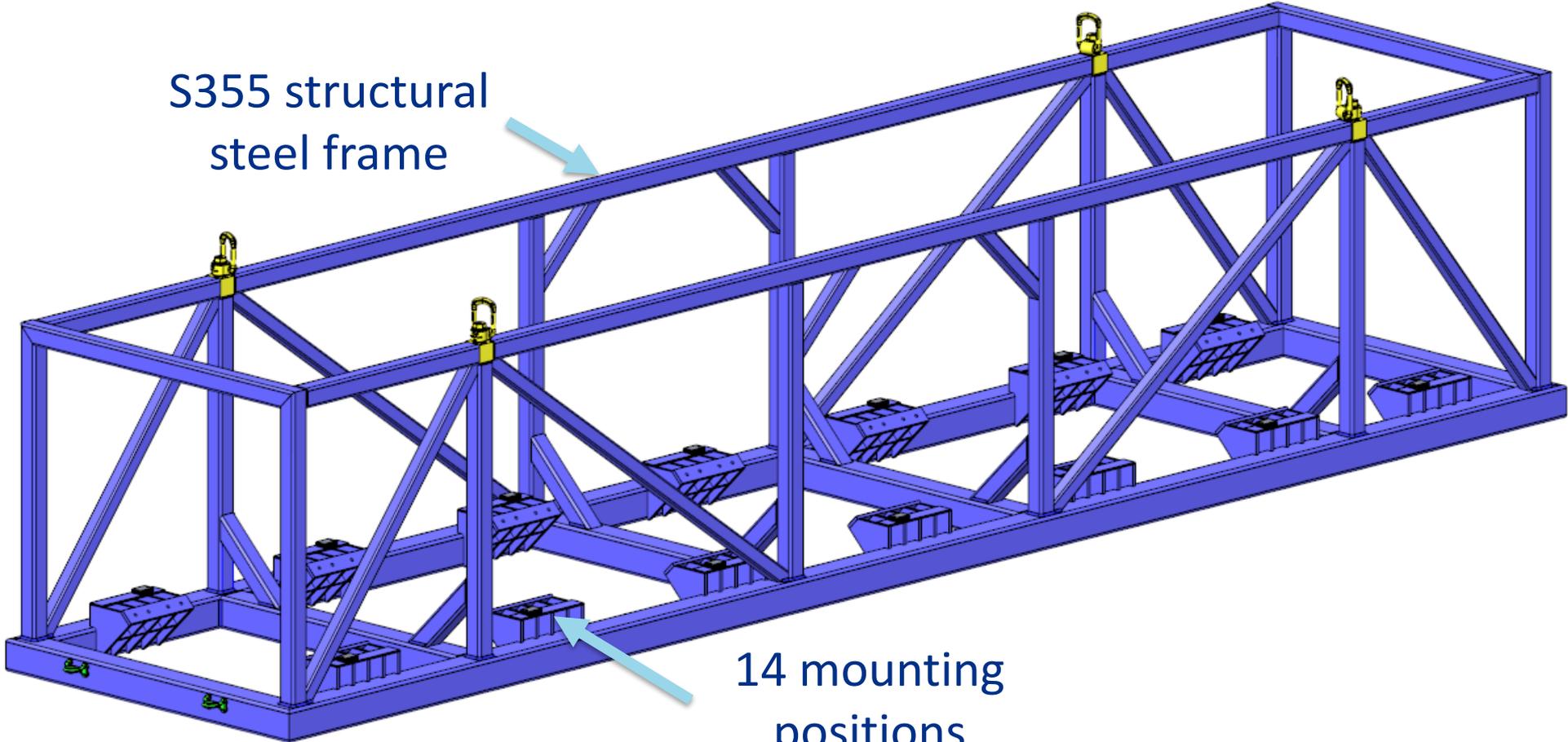
- Transport the HB650 cryomodule in its transport configuration from Daresbury Laboratory, UK to FNAL, USA
- Mitigate logistical drops, shocks, and vibrations
- Enable the cryomodule to be lifted through the frame
- Resist transportation loads, e.g., braking, cornering, accelerating
- Ensure adequate clearance between module and frame
- Protection from environmental effects and restricting access

Design

Design - Frame

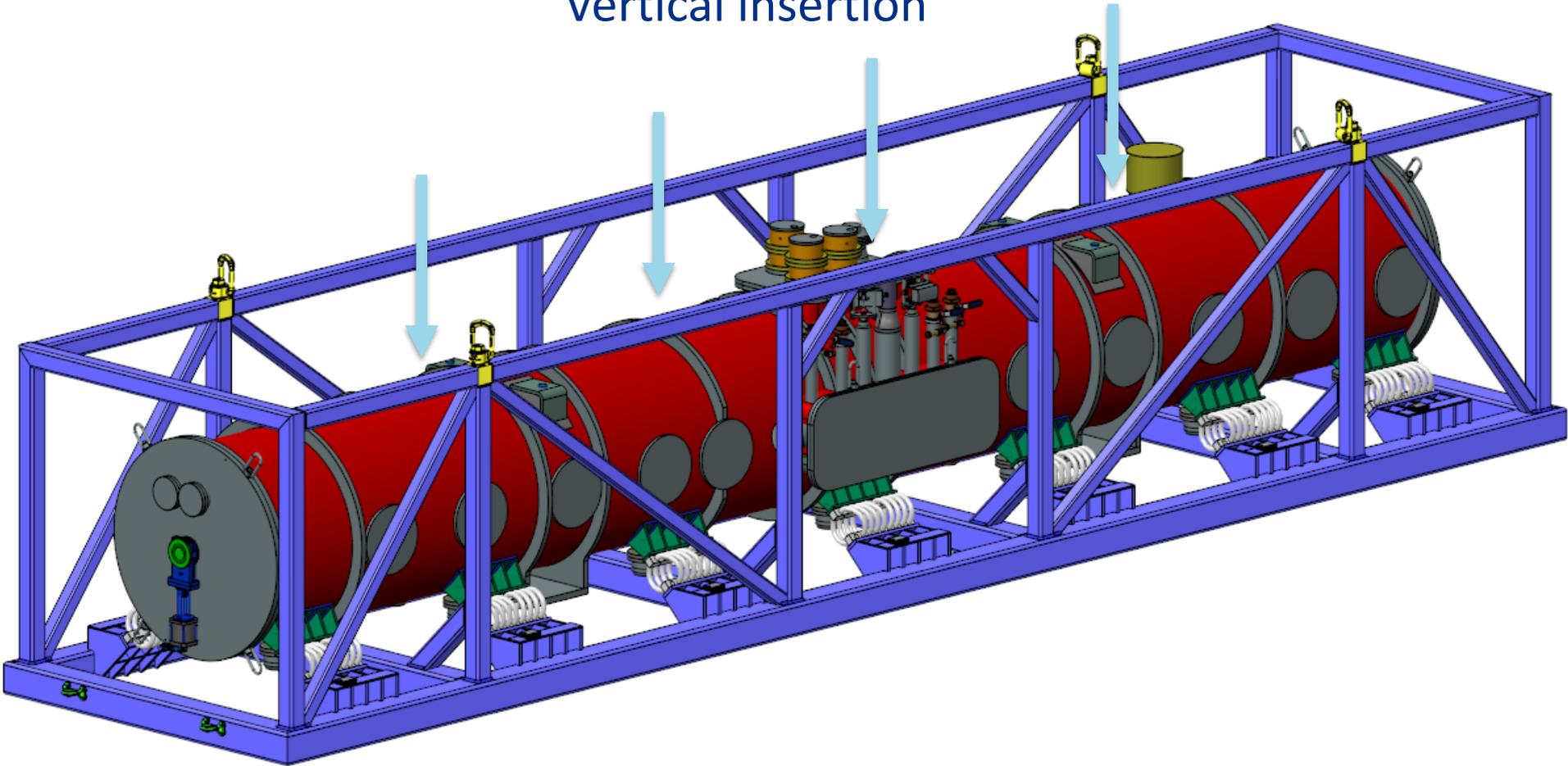
S355 structural steel frame

14 mounting positions



Design - Loading

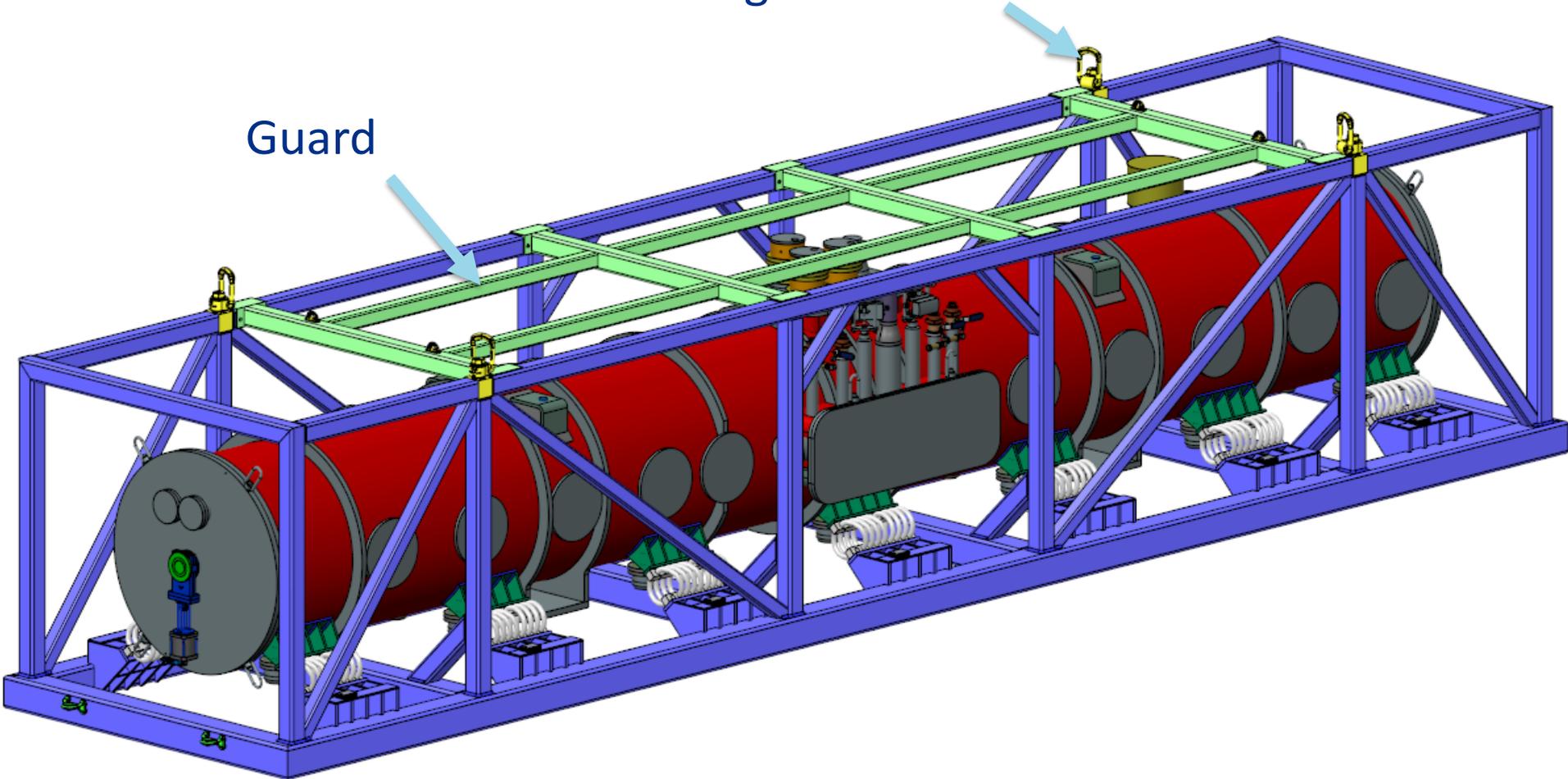
Vertical insertion



Design - Lifting

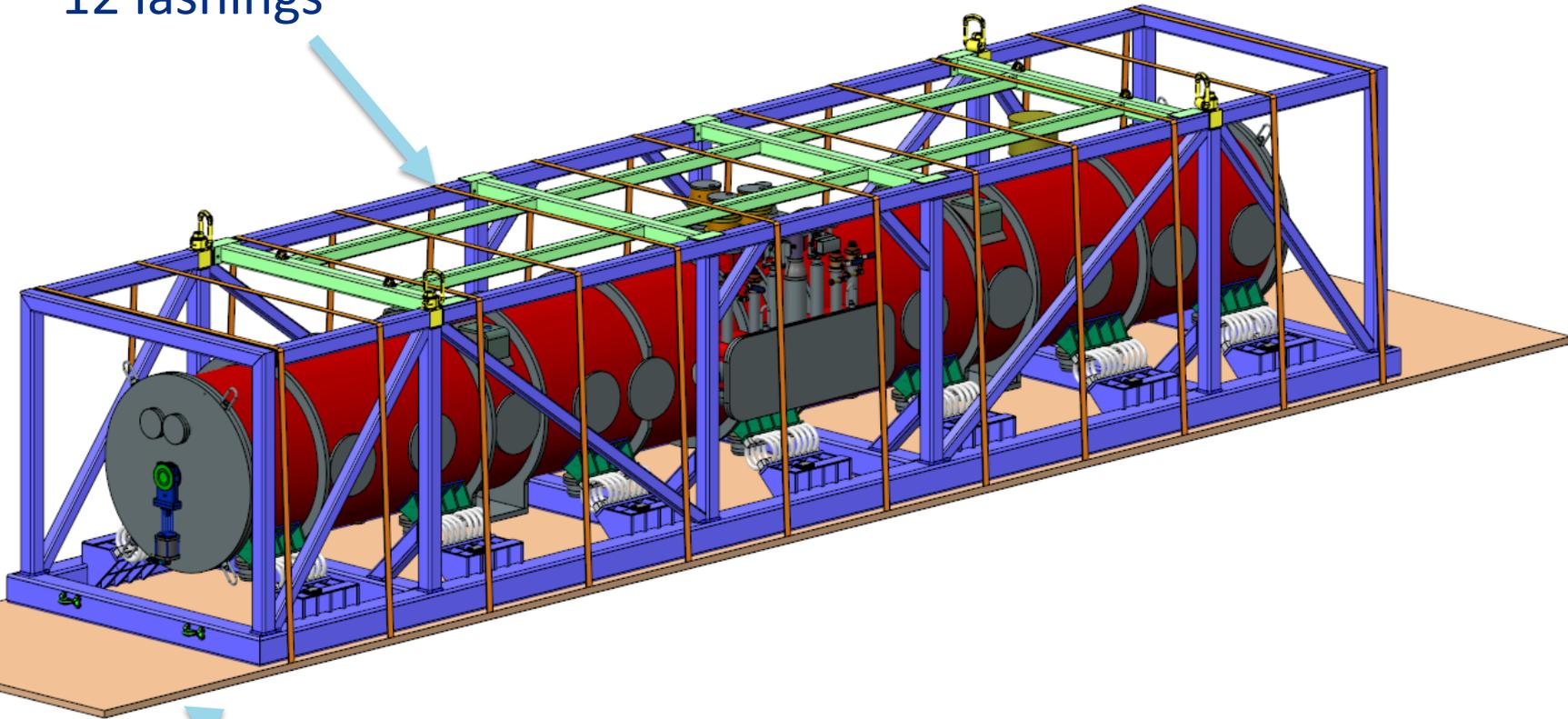
4 lifting interfaces

Guard



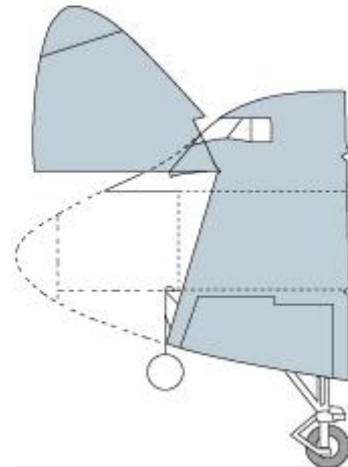
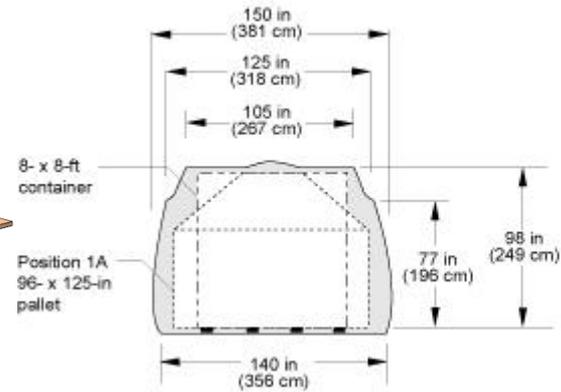
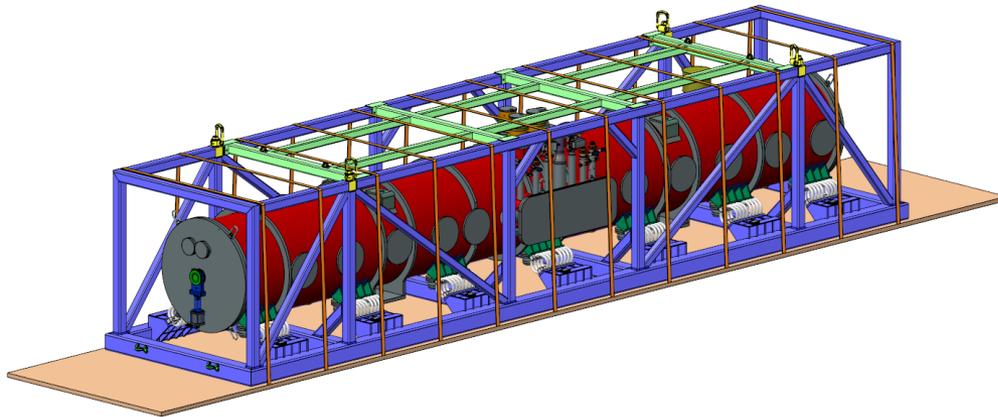
Design – Road Transport

12 lashings



13.6m x 2.5m x 2.7m
road transport envelope

Design - Flight

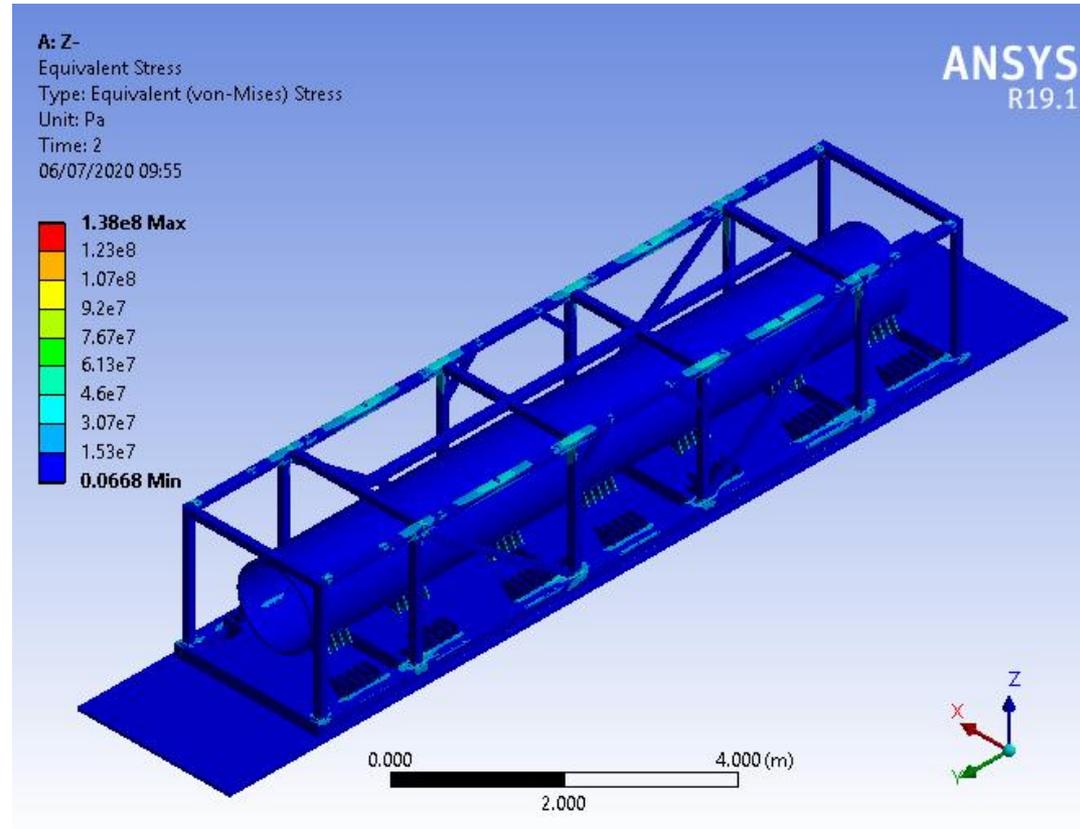


2.4m x 2.4m air cargo
transport envelope

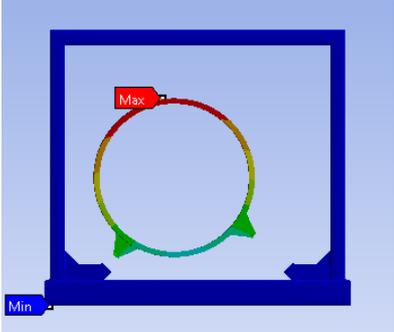
Analysis

Drop

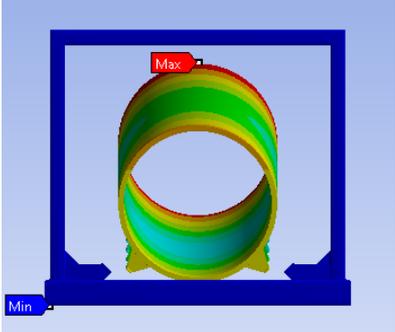
- MIL-STD-810H specifies a 0.46m drop height for general items
 - Exceptions permitted for large, complex items
- Specification limits pCM shocks to 2.5g vertically
- 0.24m achievable at 1.9g with chosen isolators
- 0.31m achievable at 4.4g with alternative isolators



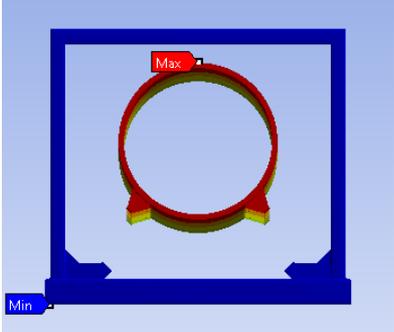
Modal Analysis



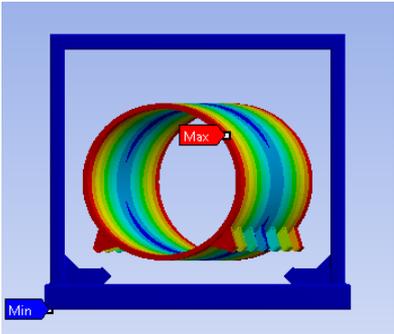
1.8Hz
Transverse rolling



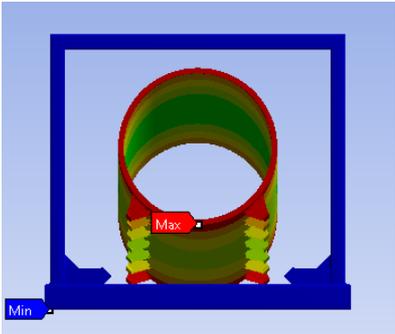
2.7Hz
Longitudinal rolling



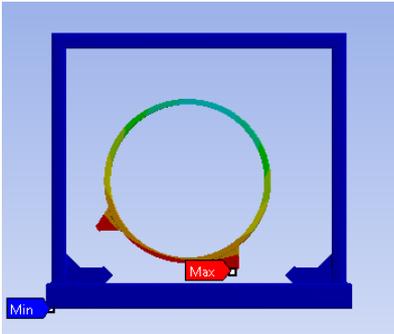
2.8Hz
Vertical



3.1Hz
Vertical axis
rotation



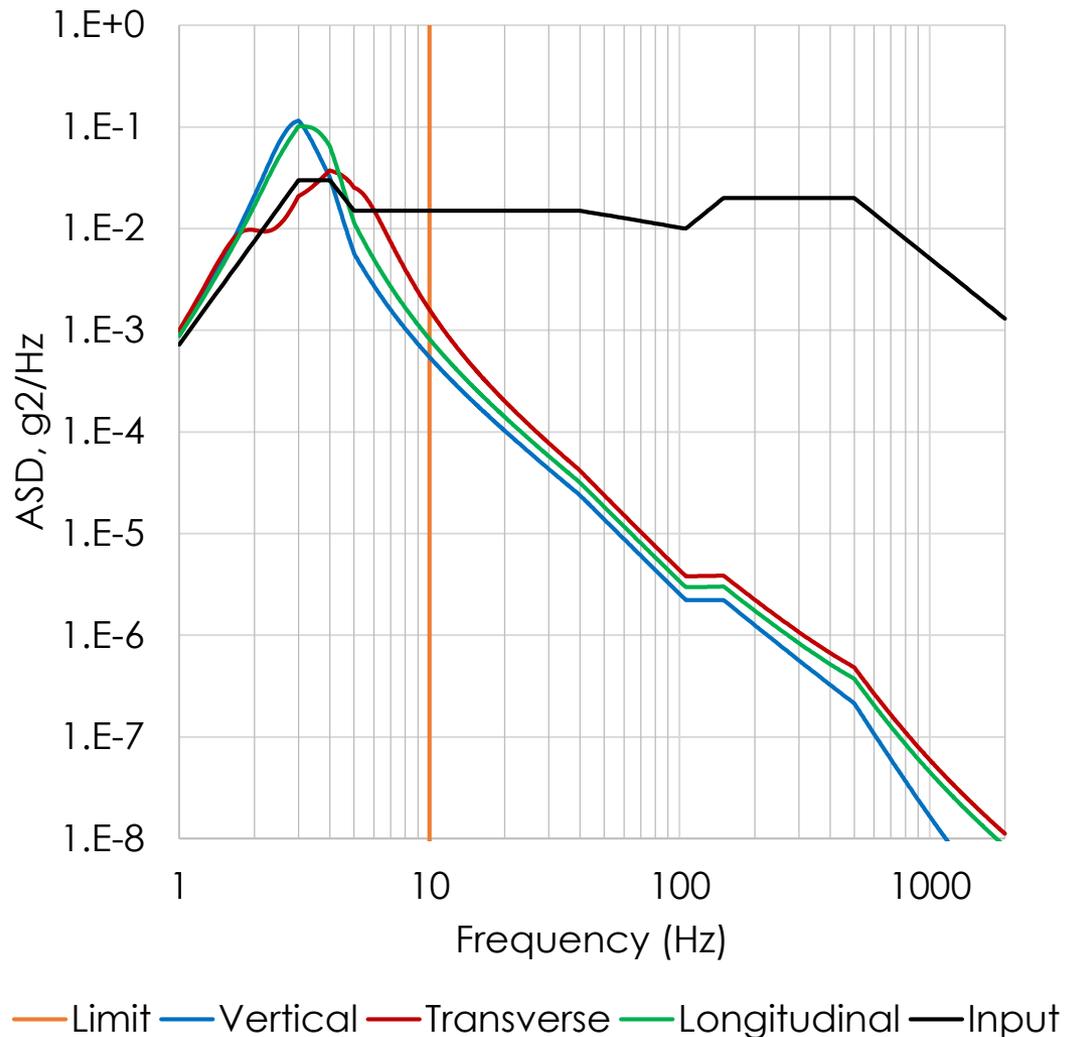
3.6Hz
Transverse axis
rotation



5.1Hz
Longitudinal axis
rotation

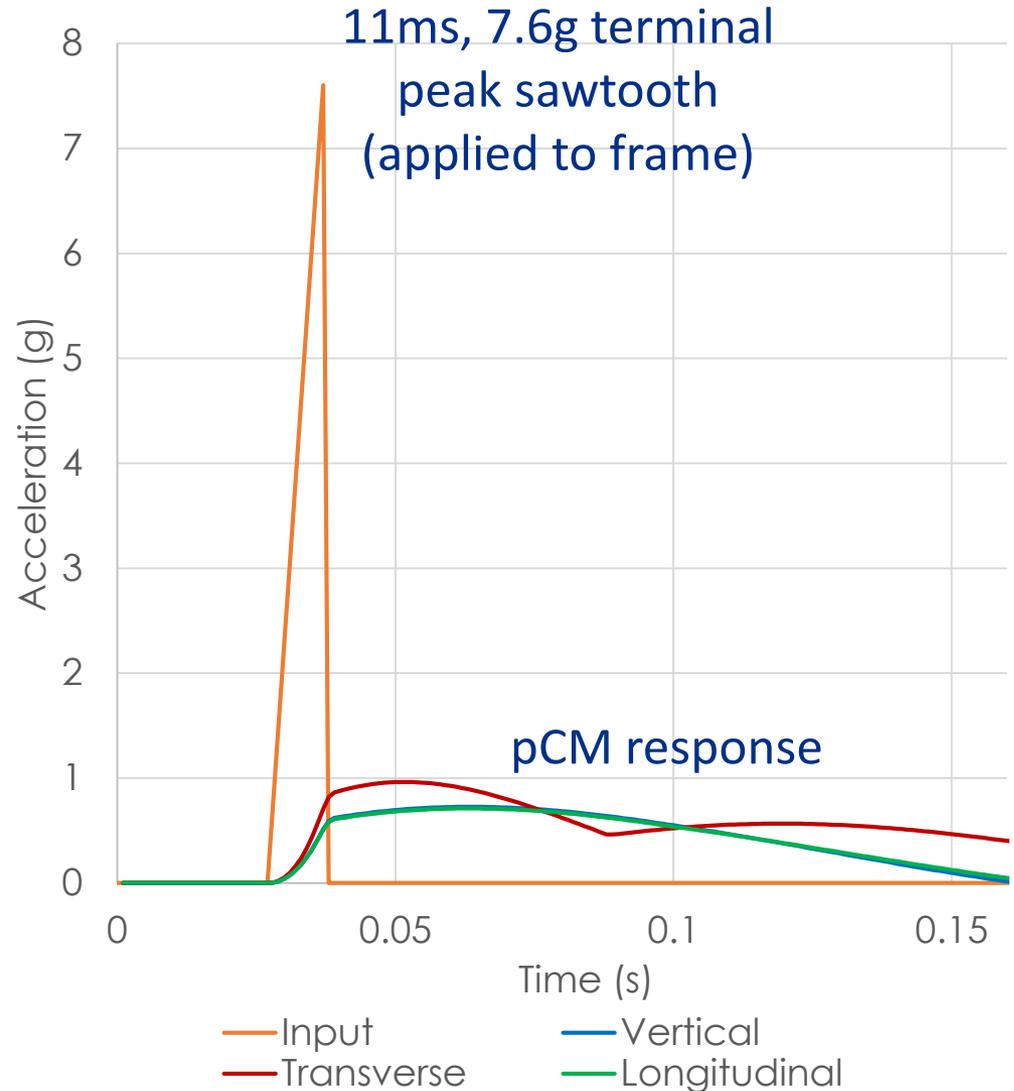
Vibration

- Specification requires vibration isolation above 10Hz
- Input ASD created from peaks of MIL-STD-810H, ISO 13355:2016, and ASTM D4169 - 16 (high level) profiles
- Isolation at 10Hz achieved:
 - 96% vertical
 - 89% transverse
 - 95% longitudinal



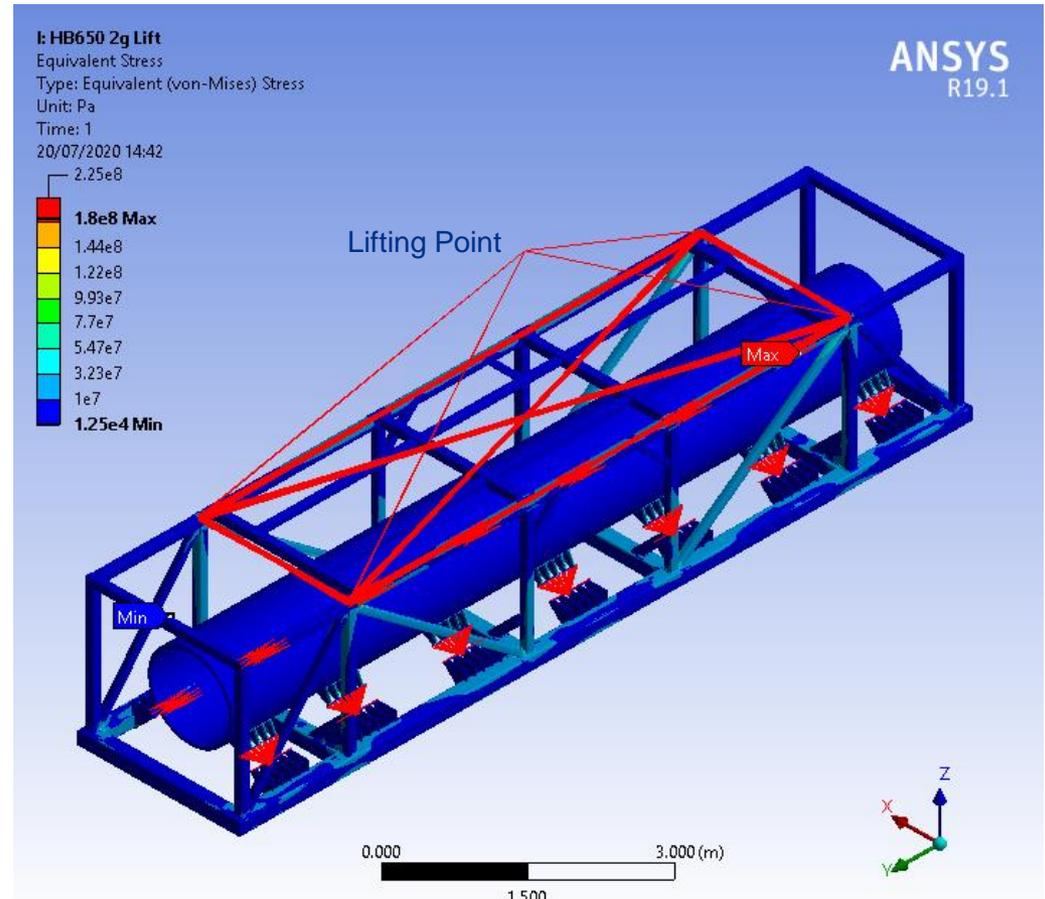
Shock

- Frame must reduce pCM shocks to 2.5g vertically, 3.5g longitudinal, and 1.5g transverse
- Shock defined by MIL-STD-810H worst case on-road transport shock
- pCM shock response achieved:
 - 0.7g vertical
 - 1.0g transverse
 - 0.7g longitudinal



Lifting

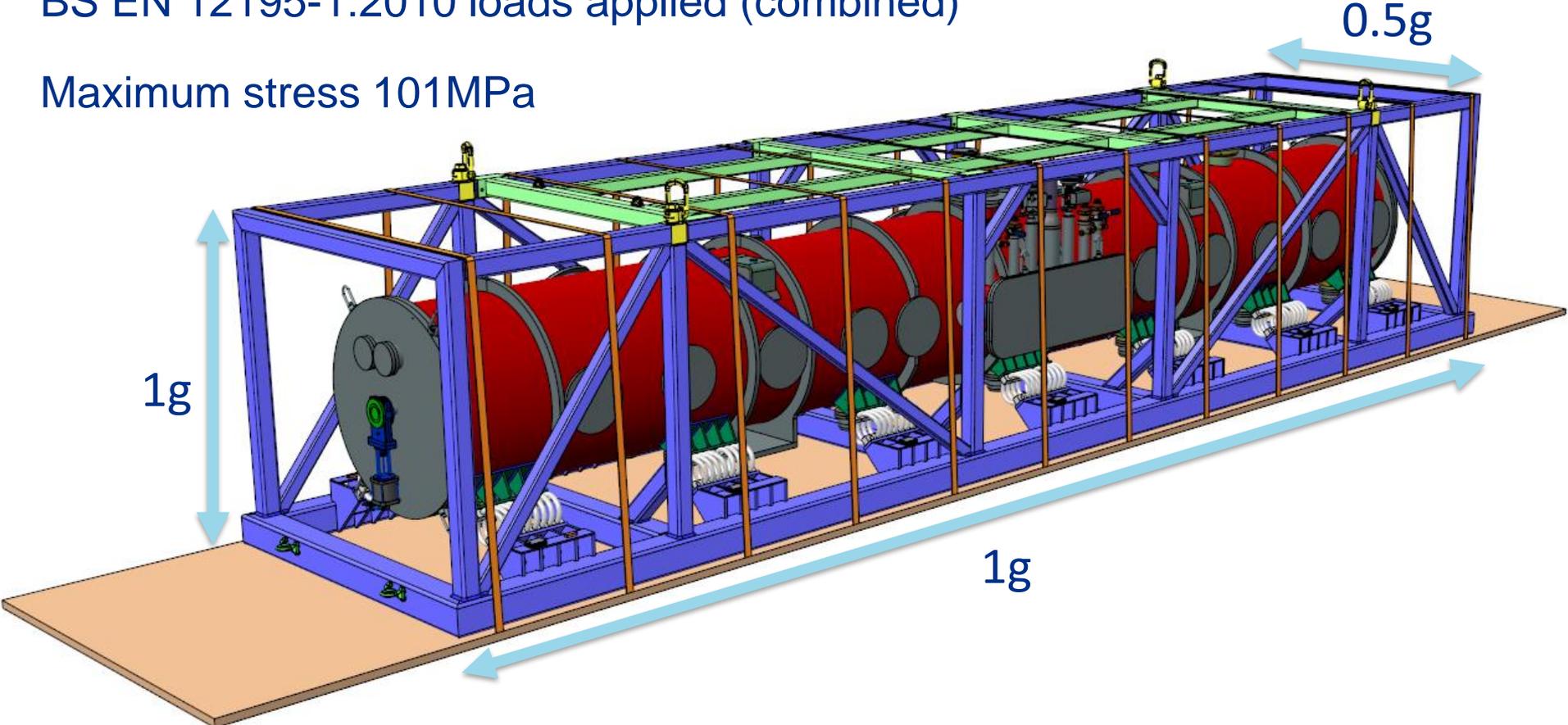
- Lifting via frame required
- BS EN 13155:2003 used as design standard
- Specifies maximum admissible stresses at twice lifting load limit
- 225MPa principle stress
 - Maximum of 186MPa
- 186MPa shear stress
 - Maximum of 97MPa



Transportation Loads

BS EN 12195-1:2010 loads applied (combined)

Maximum stress 101MPa



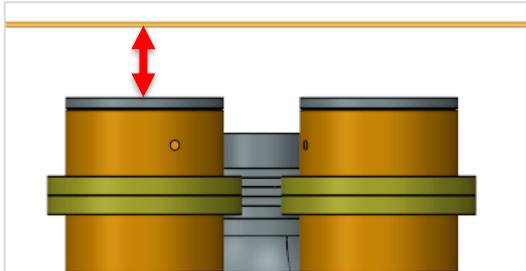
BS EN 12640:2019 load securing satisfied

12 lashings at 25.3kN tension

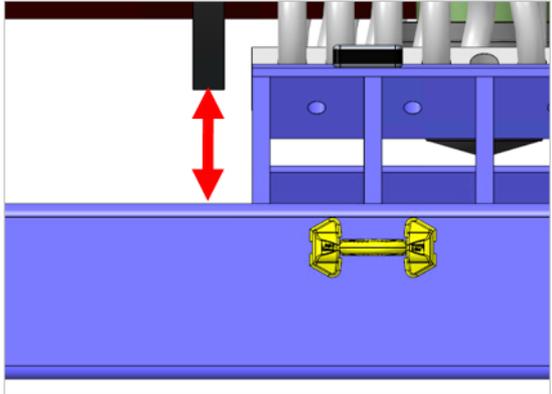


Clearances

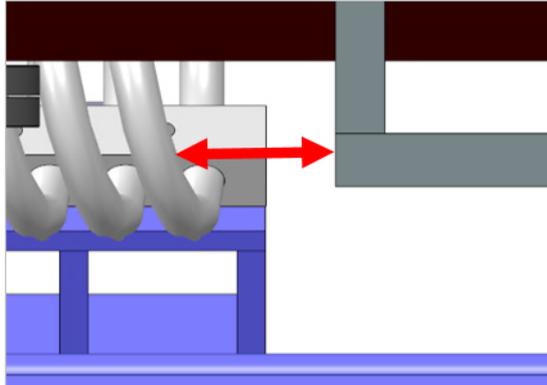
Direction	Clearance, No Load (mm)	Clearance Used Under Load
Longitudinal	78	50%
Transverse	215	16%
Vertical (top)	93	19%
Vertical (base, static)	145	12%
Vertical (base, drop, peak)	145	88%



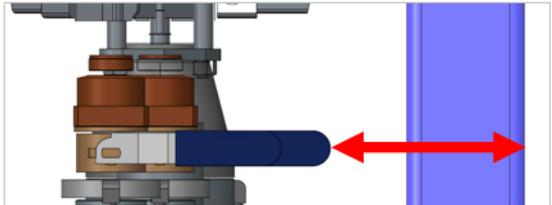
Vertical clearance (top)



Vertical clearance (base)



Longitudinal clearance



Transverse clearance

Access

- Specification requires:
 - Restricting access
 - Protection from precipitation, debris, and thermal changes
- Curtain sided trailer as first layer
- Bespoke weatherproof, insulated cover for transport frame and cryomodule



Summary

Summary

- Designed to be compatible with road and aircraft cargo envelopes.
- Meets the requirements for shock, vibration, lifting, and transport loads
- 240mm maximum drop height is achievable
- A maximum of 50% of clearance is utilized under maximum transport forces, and 88% during a 240mm drop
- Protected by an insulated, weatherproof cover and transported on a curtain-side trailer during road phases

Specifications & Charges Addressed

- Specifications
 - FNAL HB650 transport specification
- Charges
 - 1.e. Are the design and testing plan appropriate to meet transportation requirements?
 - Design adequately protects HB650 according to specification
 - 1.c. Are items that could affect safety, quality, cost, schedule, or performance mitigated or managed?
 - Mitigates transport risks that could affect cost and schedule