



Science and
Technology
Facilities Council

HB650 Transport Frame FDR Design Overview

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22/09/20

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Requirements

Requirements

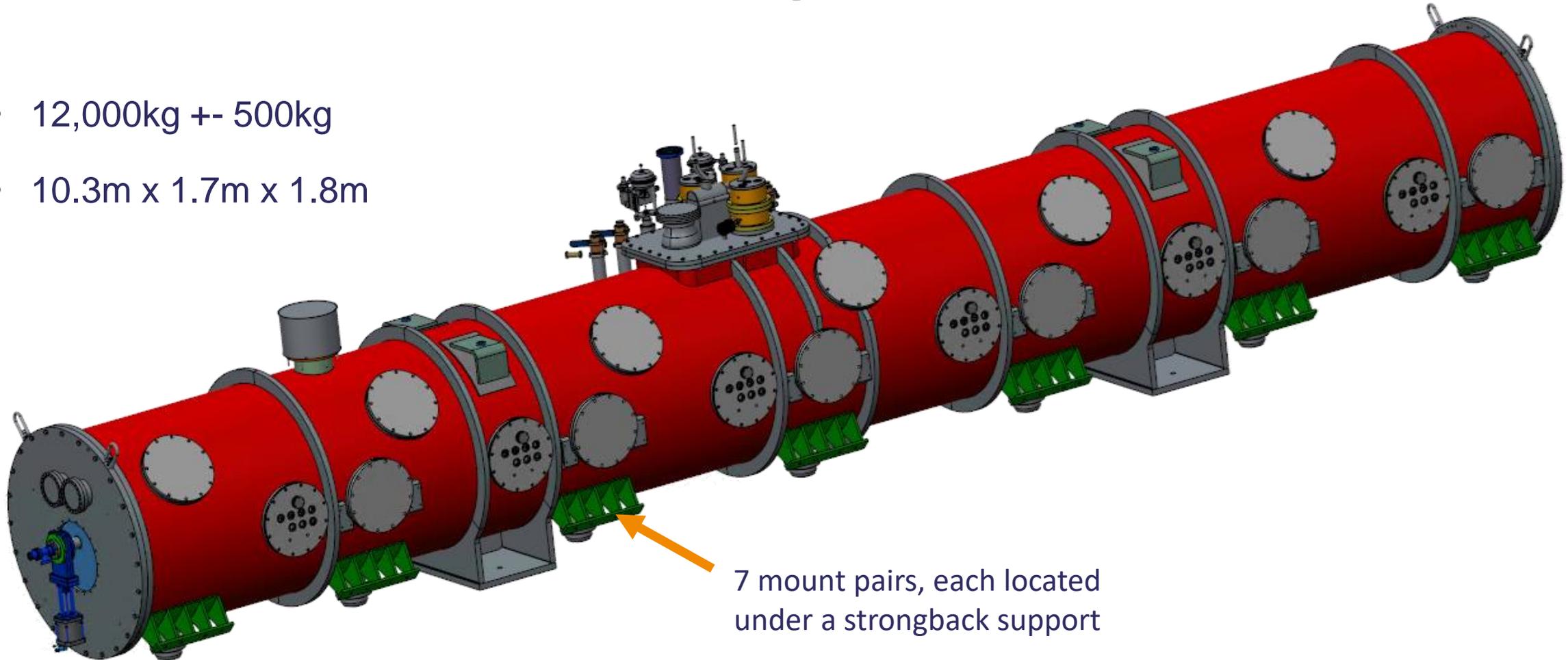
- Transport the HB650 cryomodule in its transport configuration from FNAL, USA to Daresbury Laboratory, UK
 - Transportable by road and air
- Mitigate logistical drops up to 200mm
- Reduce shocks to the HB650 to:
 - 2.5g vertically
 - 1.5g transverse
 - 3.5g longitudinally
- Isolate input vibrations by at least 80% above 10Hz

Requirements

- Act as cryomodule lifting system
- Resist transportation loads, e.g., braking, cornering, accelerating
- Provide mounting points and platforms for instrumentation and electronics
- Ensure adequate clearance between module and frame
- Protect from environmental effects and restrict access

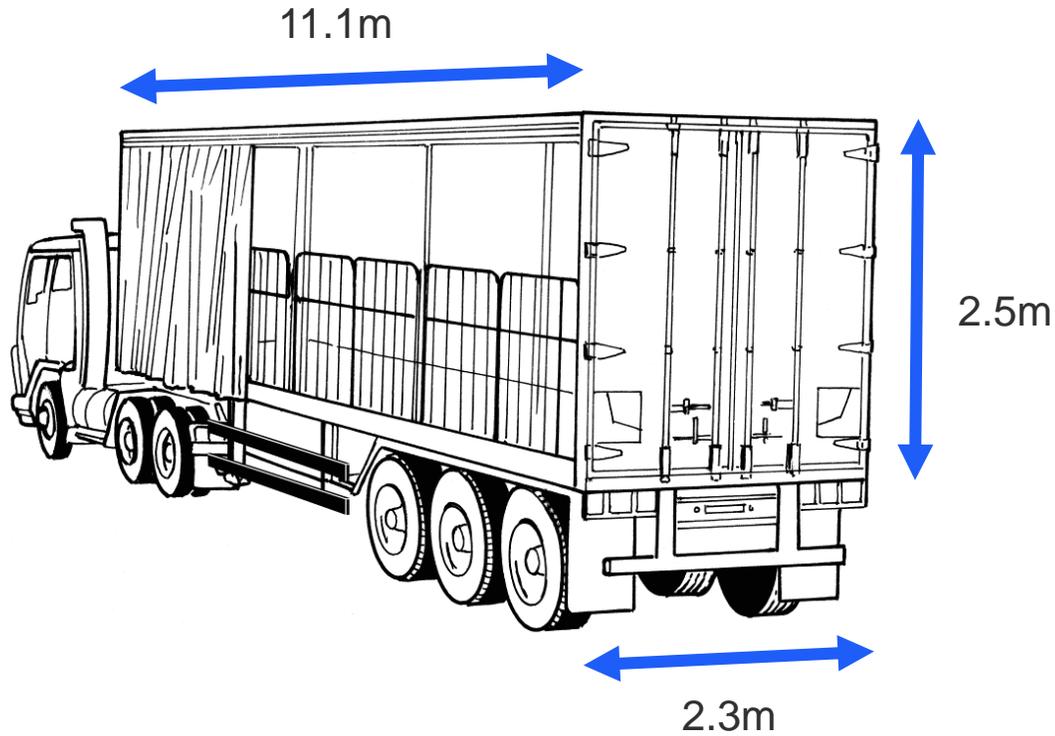
HB650 – Transport Configuration

- 12,000kg +/- 500kg
- 10.3m x 1.7m x 1.8m

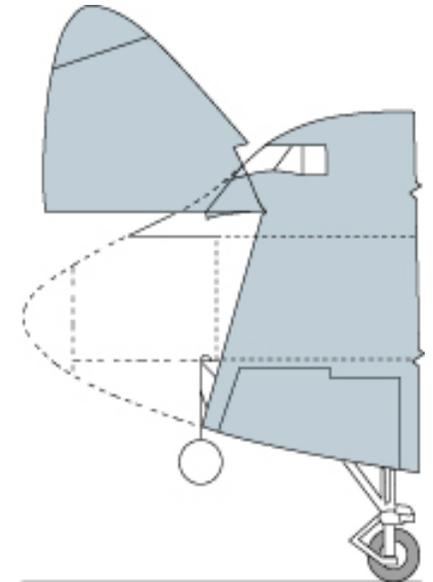
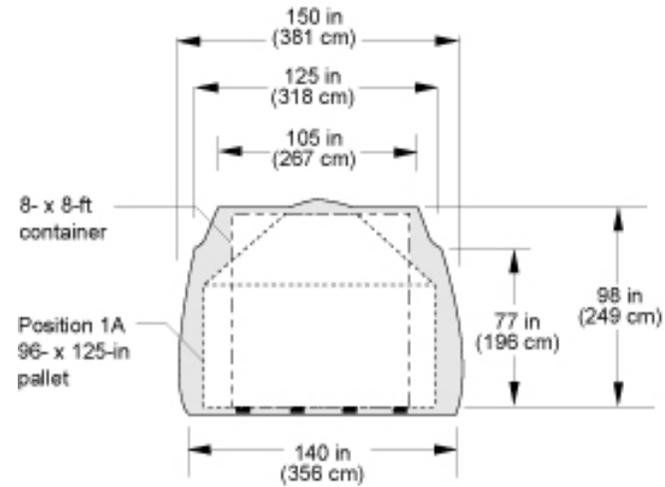


7 mount pairs, each located under a strongback support

Envelope

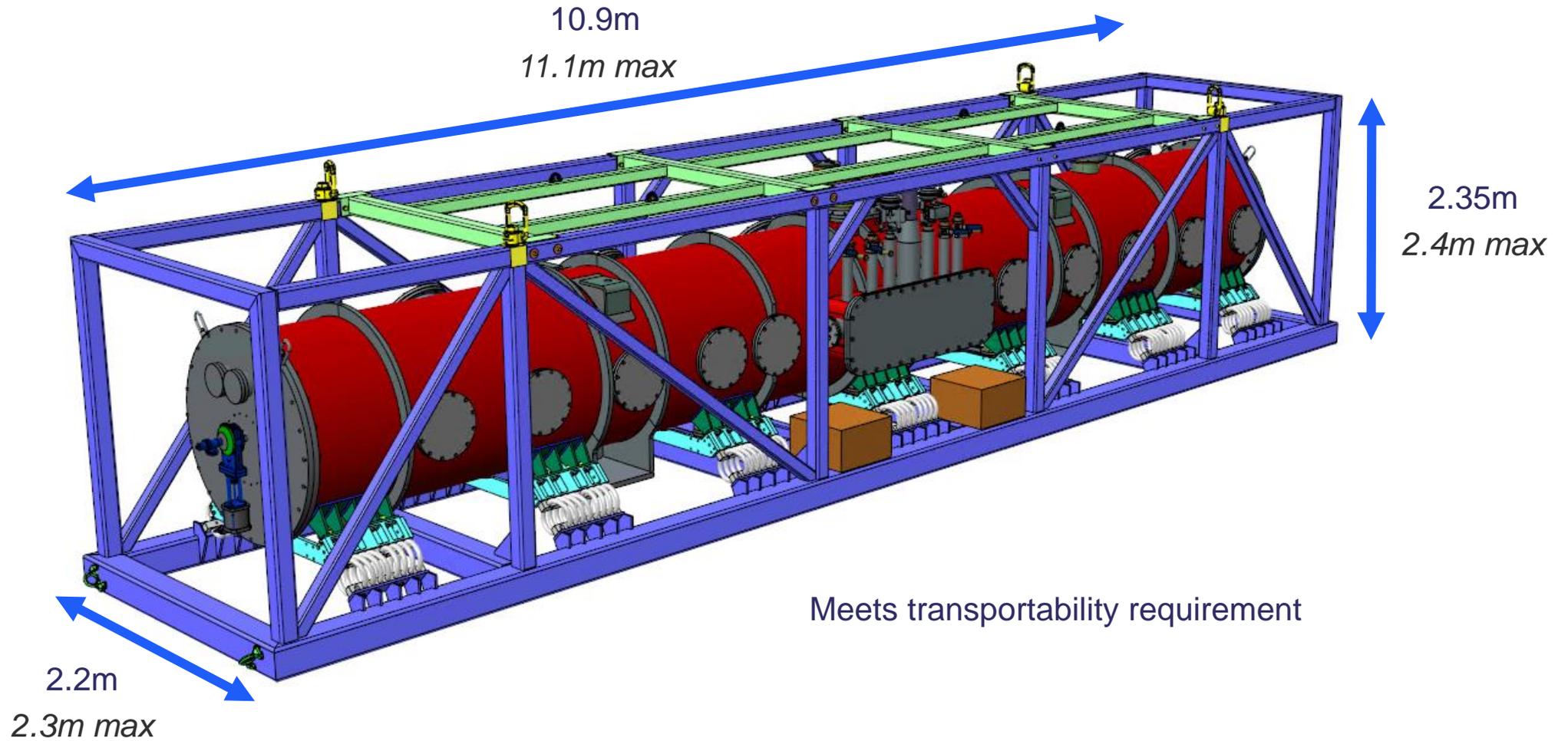


Curtain-sided Truck



Boeing 747-400F
2.4m x 2.4m x >20m

Envelope - Actual

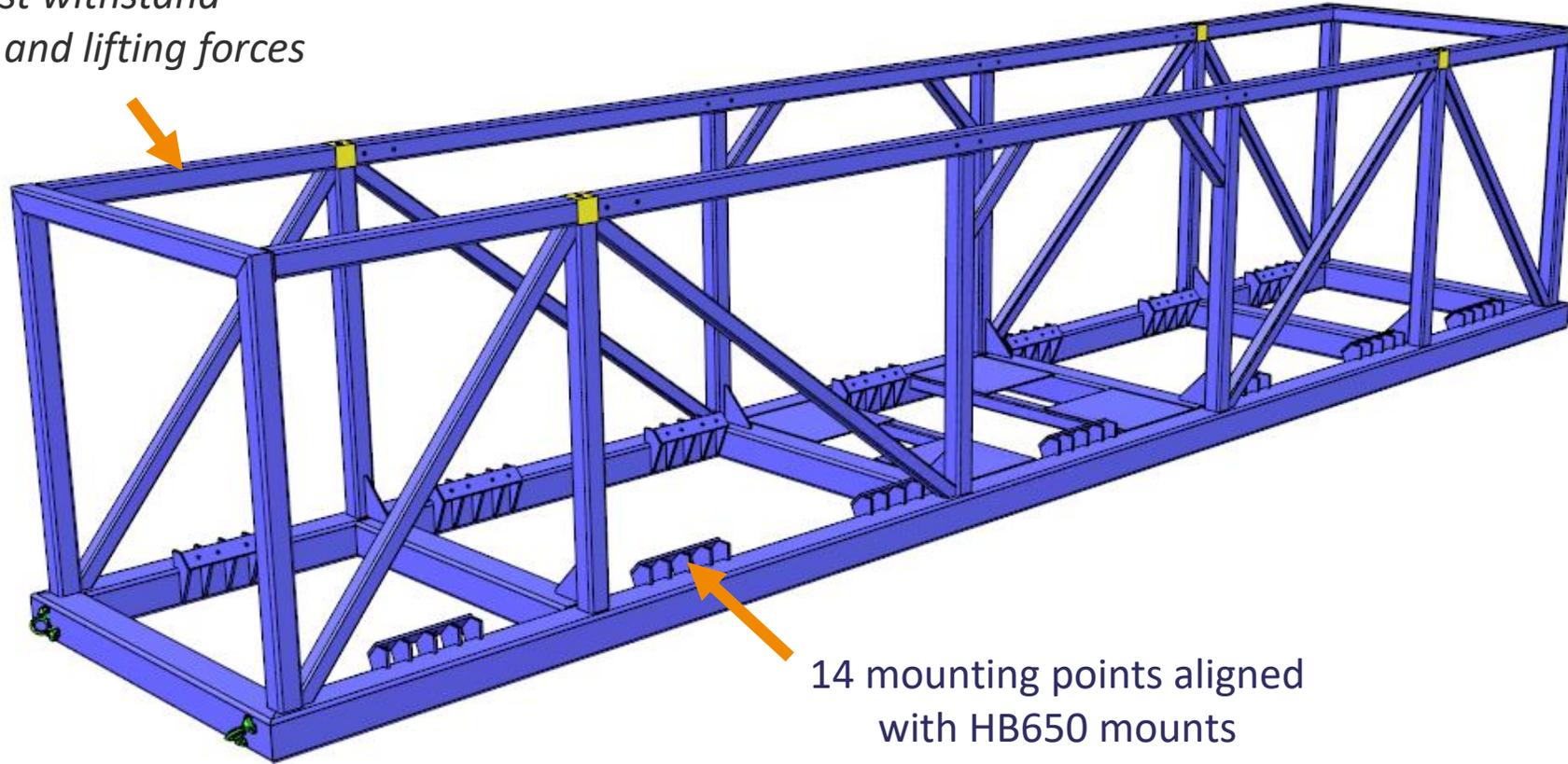


Design

Frame

S355 structural steel frame

*Frame must withstand
transportation and lifting forces*

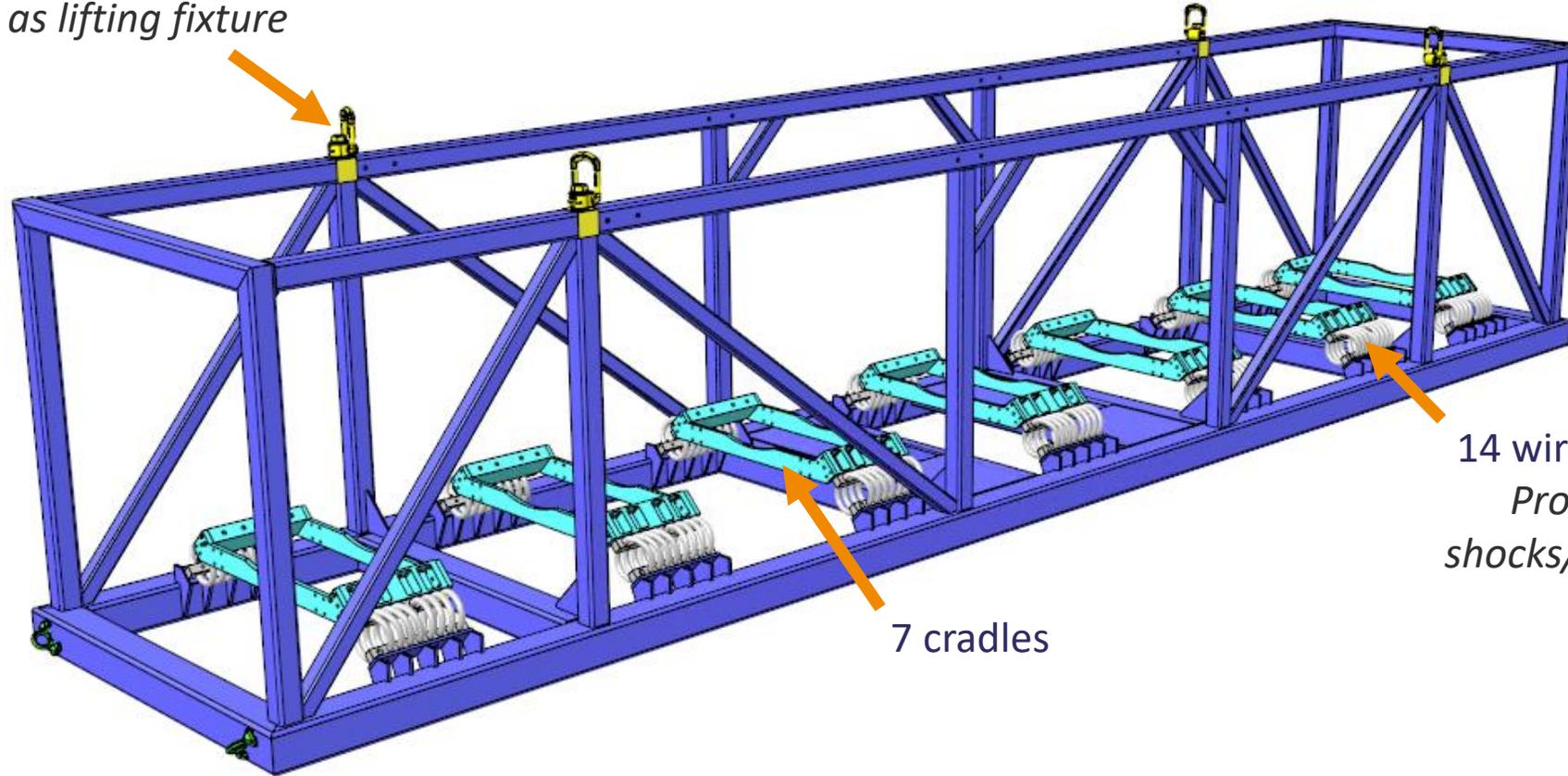


14 mounting points aligned
with HB650 mounts

Lifting and Isolation

4 lifting points

Frame must act as lifting fixture

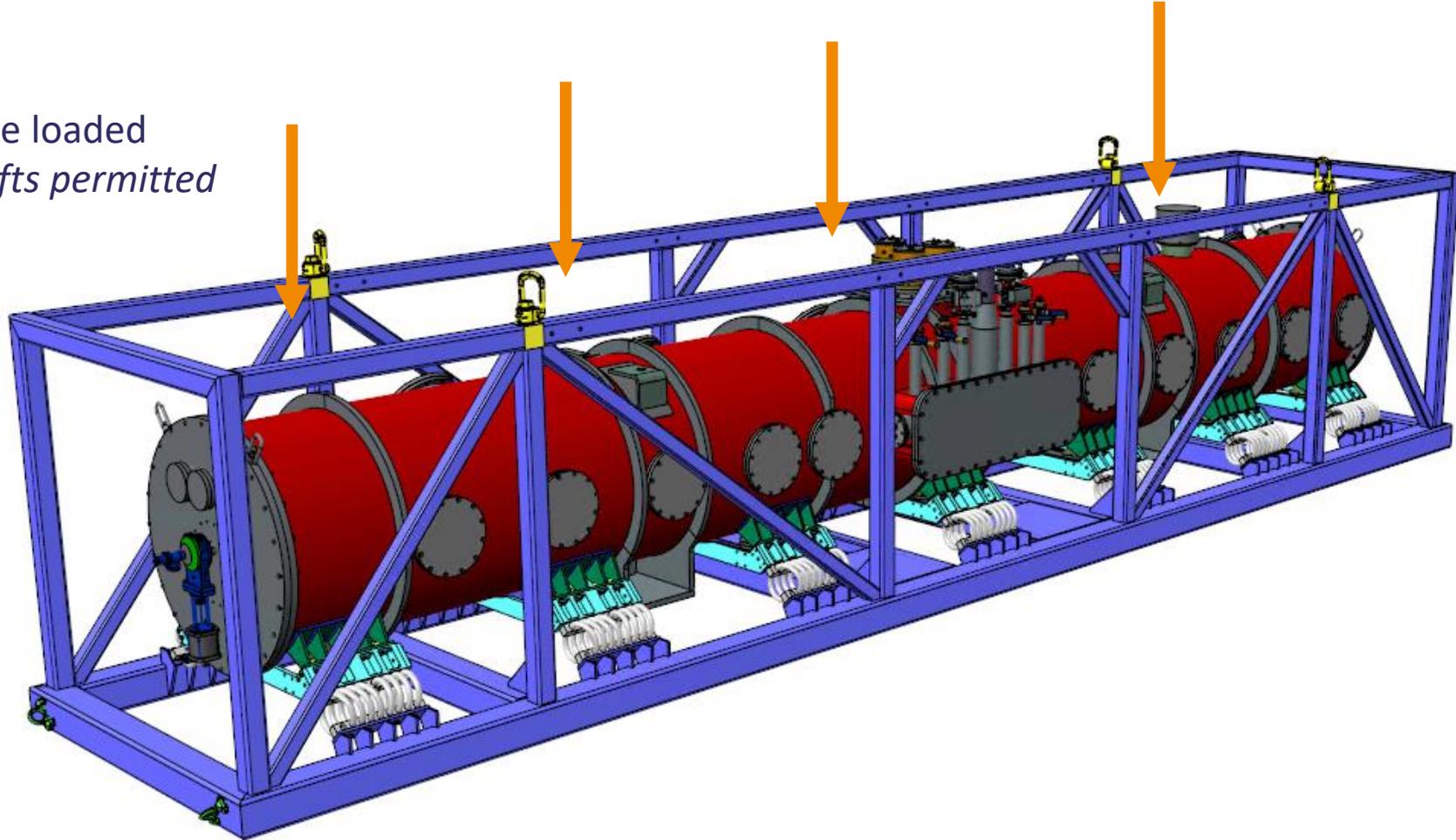


14 wire rope isolators
*Protection from
shocks/drops/vibration*

7 cradles

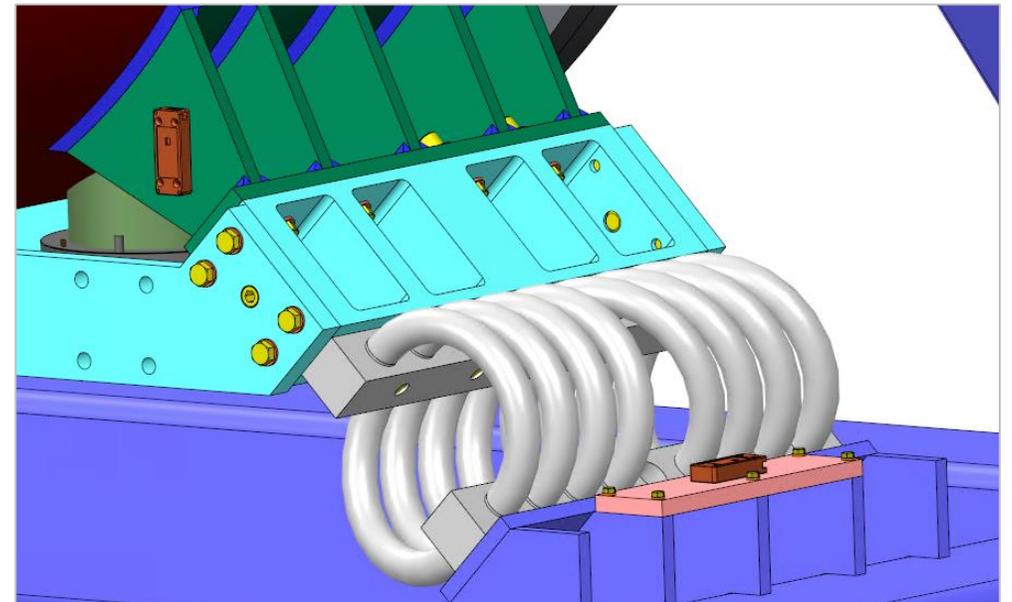
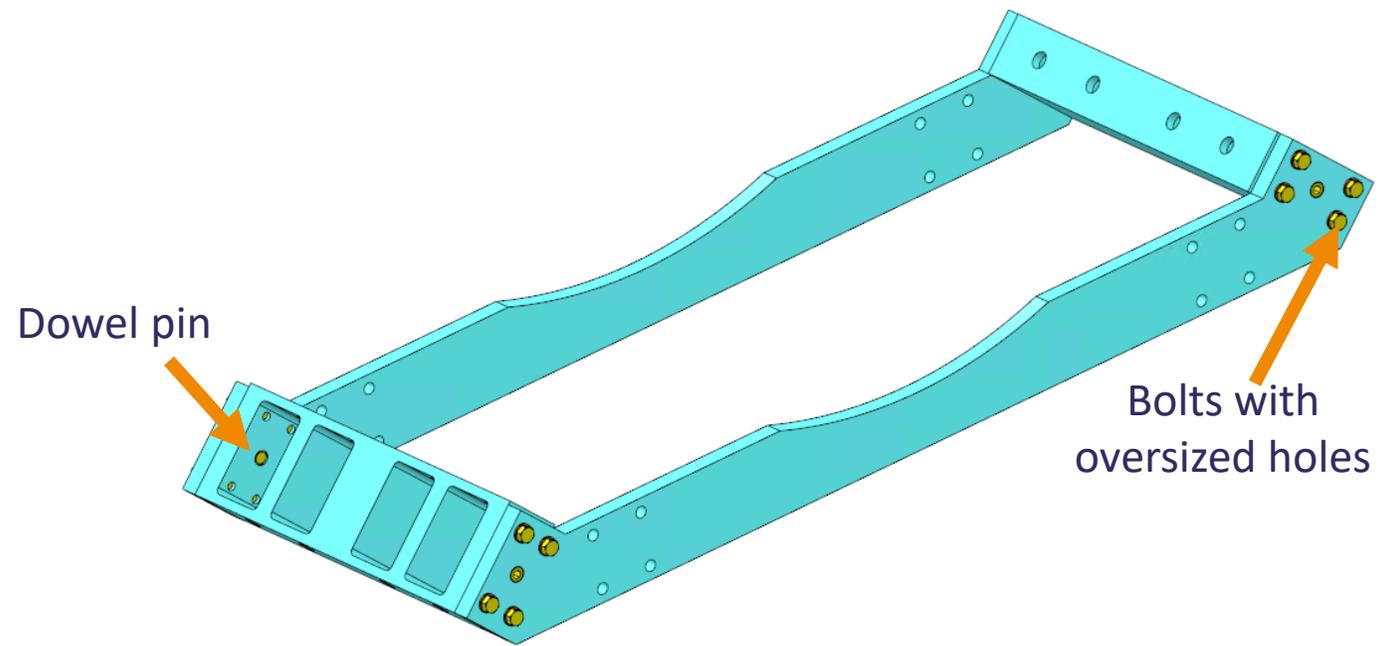
Loading

Crane loaded
No forklifts permitted

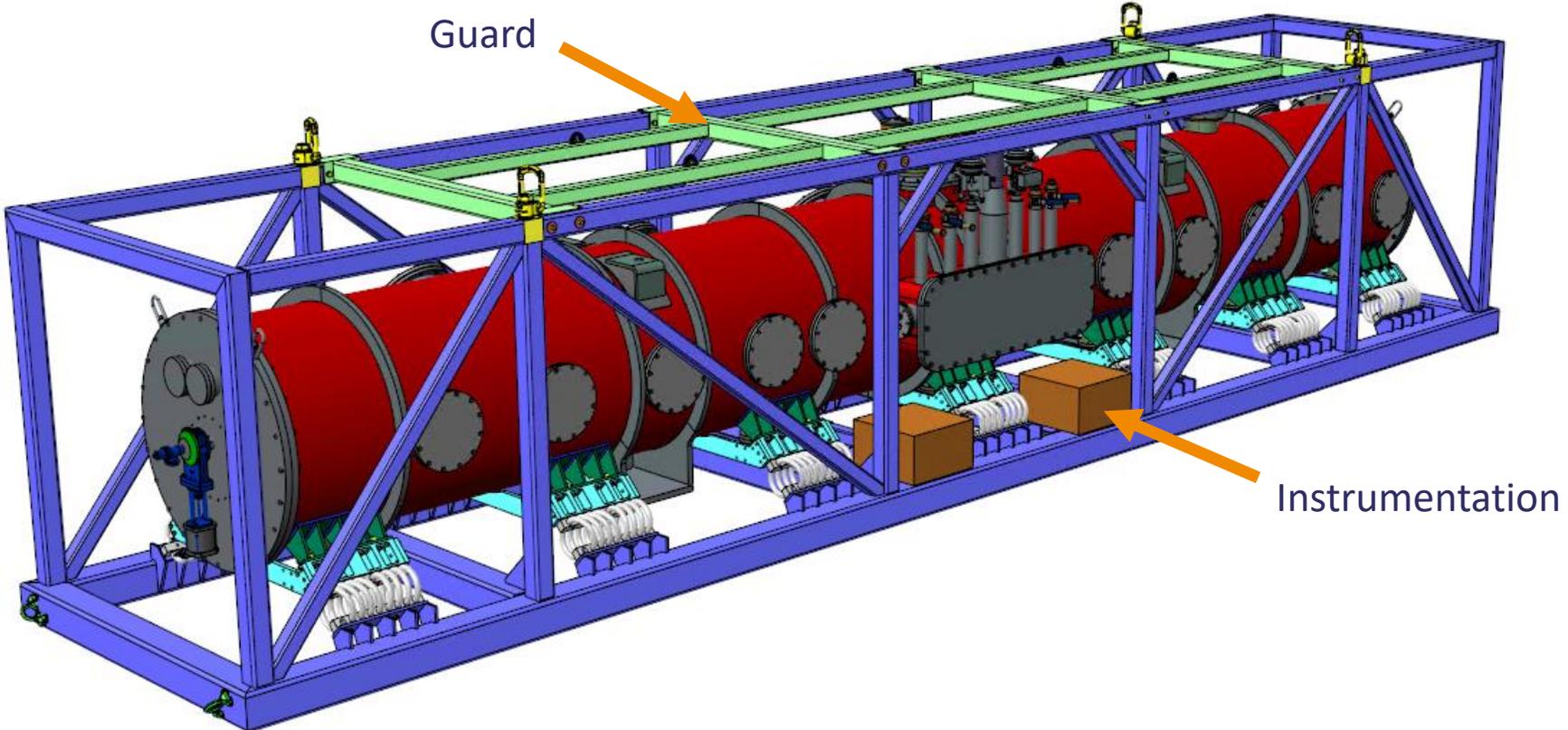


Cradle Interface

- Intended to ease assembly
- Constrains isolator pair separation to that of the module mounts
- Mitigates load cycling deformation, lesson learnt from LCLS-II
- Compensates for rotational tolerances by permitting movement about dowel pin
 - Locked in position by bolts

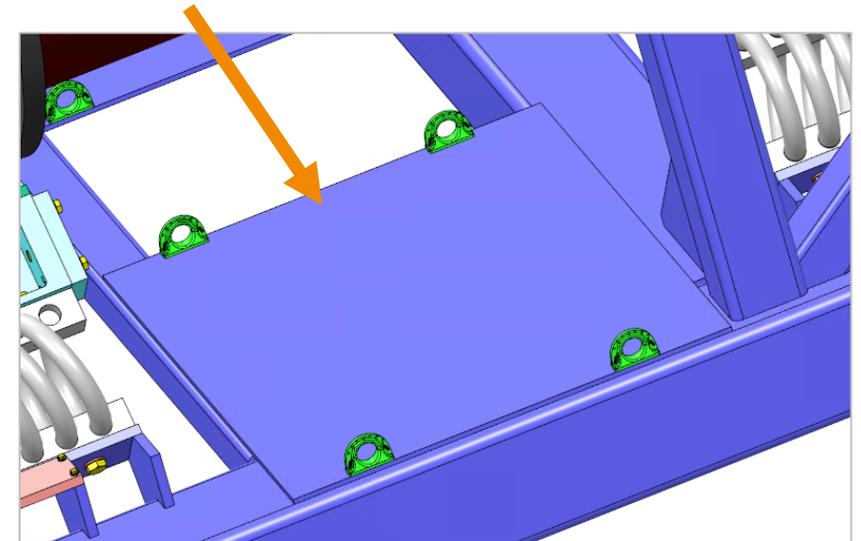
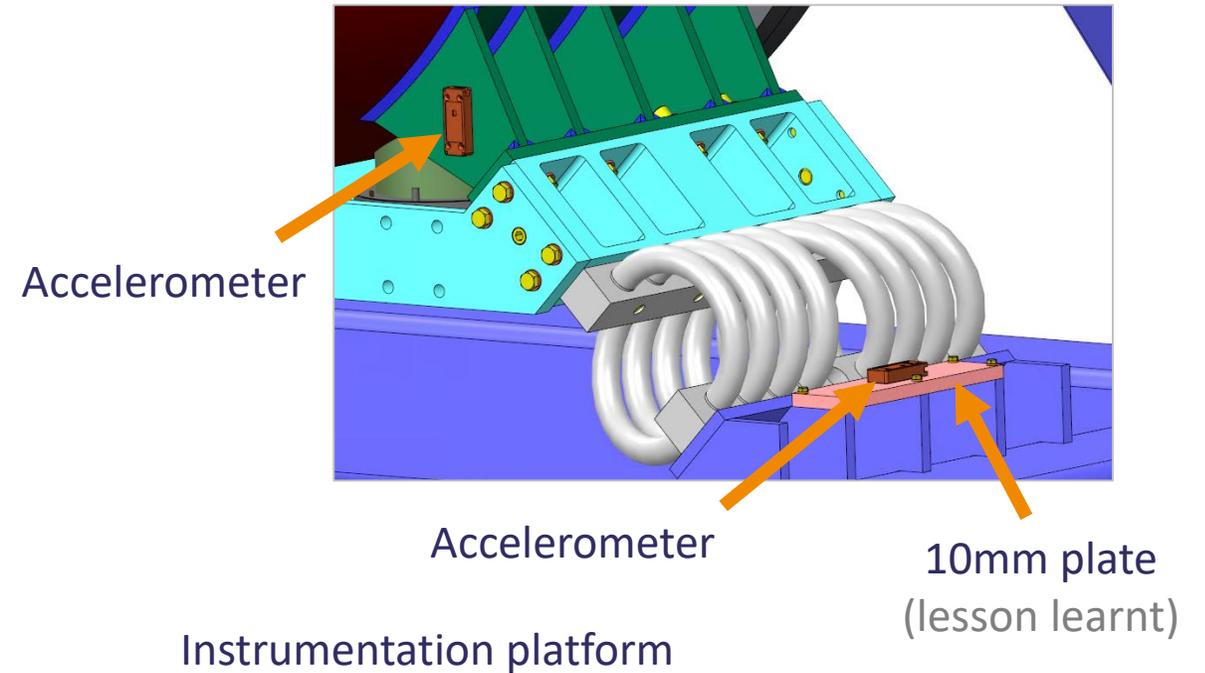


Guarding



Instrumentation

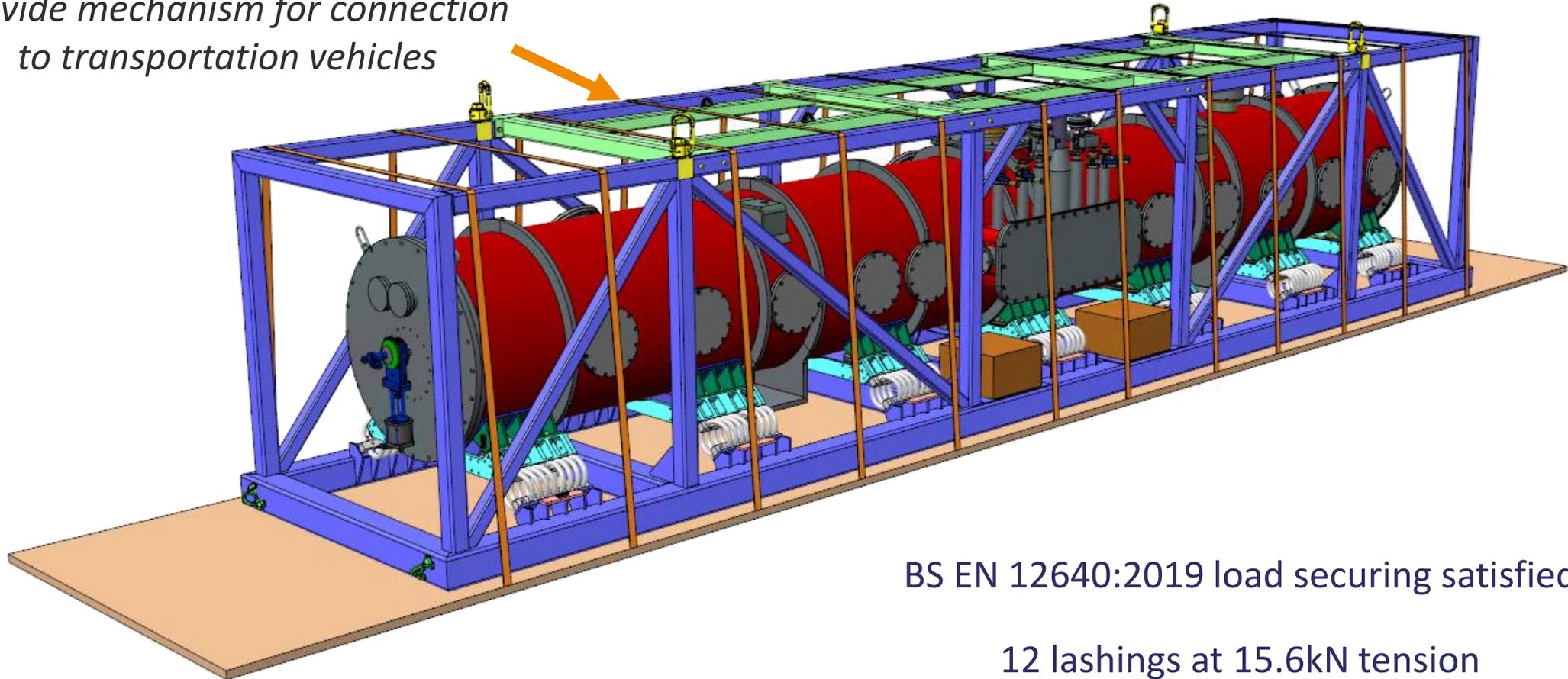
- *Requirements:*
 - *Measurement of acceleration on outer frame and cryomodule*
 - *Space for 2 x battery assembly case – 510mm L x 510mm W x 310mm H*
 - *Space for 2 x electronics rack case – 510mm L x 410mm W x 410mm H*
- Accelerometer mounting points located on cryomodule mounts and isolator frame interface
- 4 x platforms for equipment exceeding required dimensions



Securing

Lashing system

*Provide mechanism for connection
to transportation vehicles*



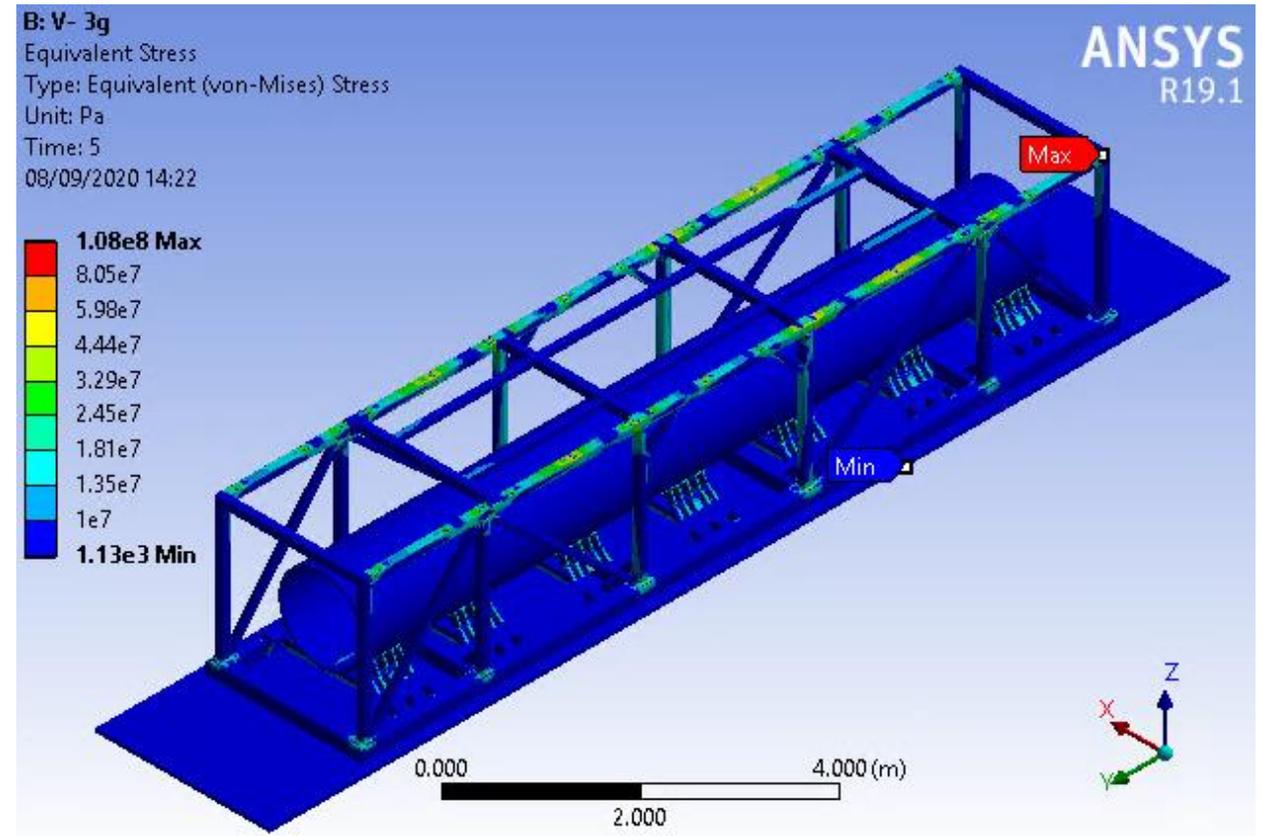
BS EN 12640:2019 load securing satisfied

12 lashings at 15.6kN tension

Analysis

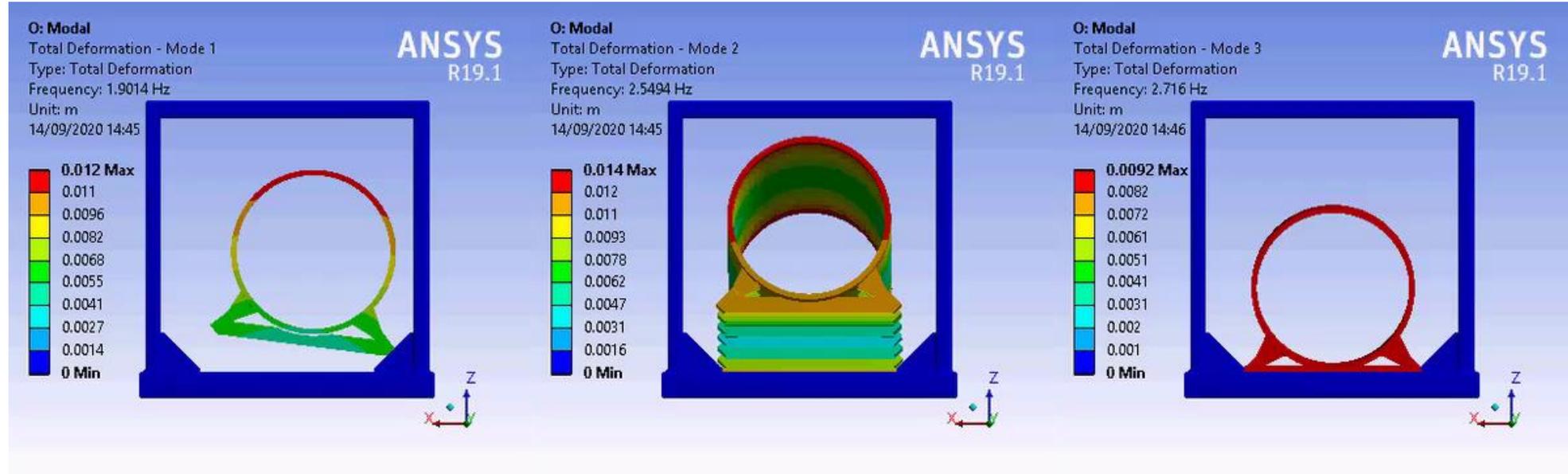
Drop

- *Requirements:*
 - *Isolator capacity for 200mm drop*
 - *HB650 shocks limited to 2.5g vertically*
- 0.24m achievable at 1.9g with chosen isolators
- 0.31m achievable at 4.3g with alternative isolators
- Frame yield stress safety factor of 3.1



Modal Analysis 1-3

Requirement: Isolation of external vibration by at least 80% above 10Hz

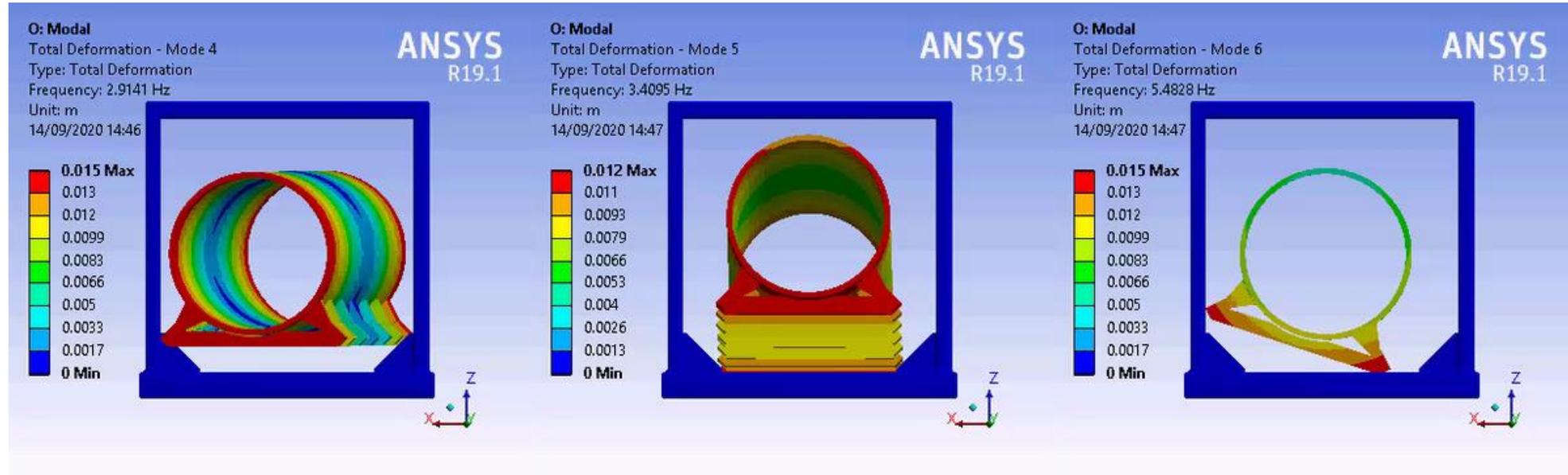


1.9Hz
Transverse

2.5Hz
Transverse axis
rolling

2.7Hz
Vertical

Modal Analysis 4-6



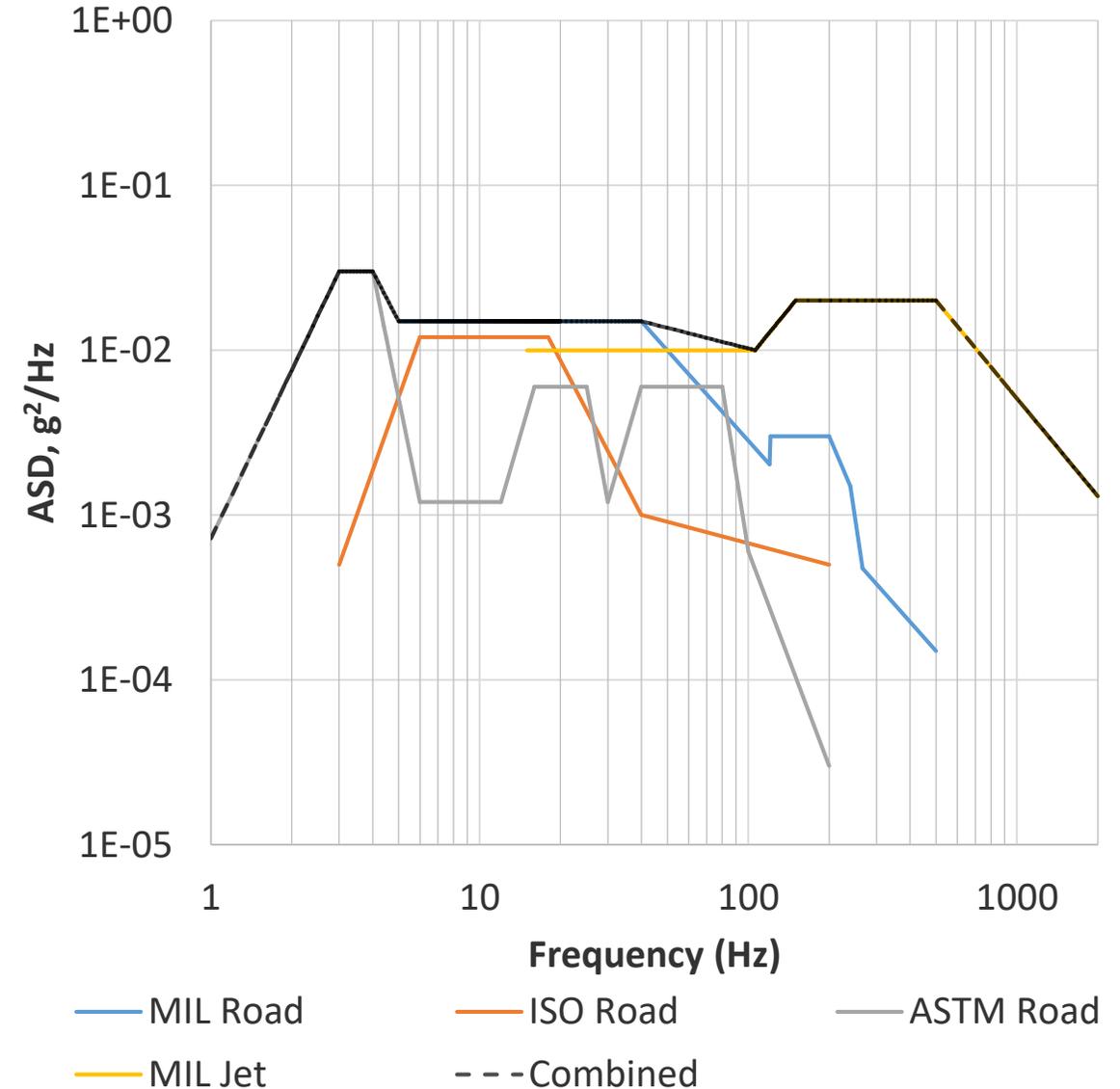
2.9Hz
Vertical axis
rotation

3.4Hz
Transverse axis
swinging

5.5Hz
Longitudinal axis
rotation

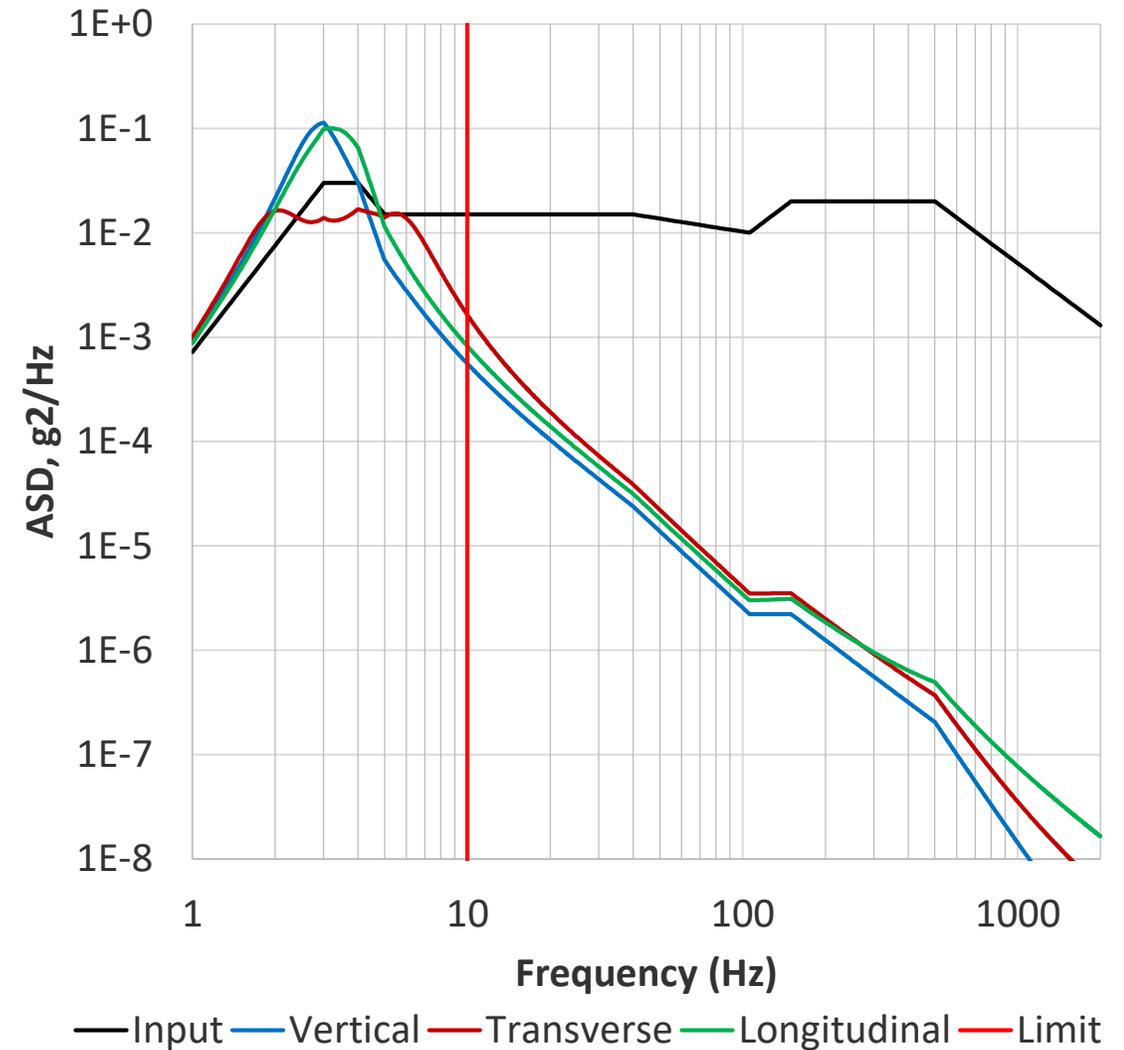
Vibration - Envelopes

- *Specification requires isolation of transport-induced vibration*
- Input vibration envelope created from peaks of:
 - MIL-STD-810H, road and air
 - ISO 13355:2016, road
 - ASTM D4169 – 16, road
- Encompasses both US and European roads, and air travel



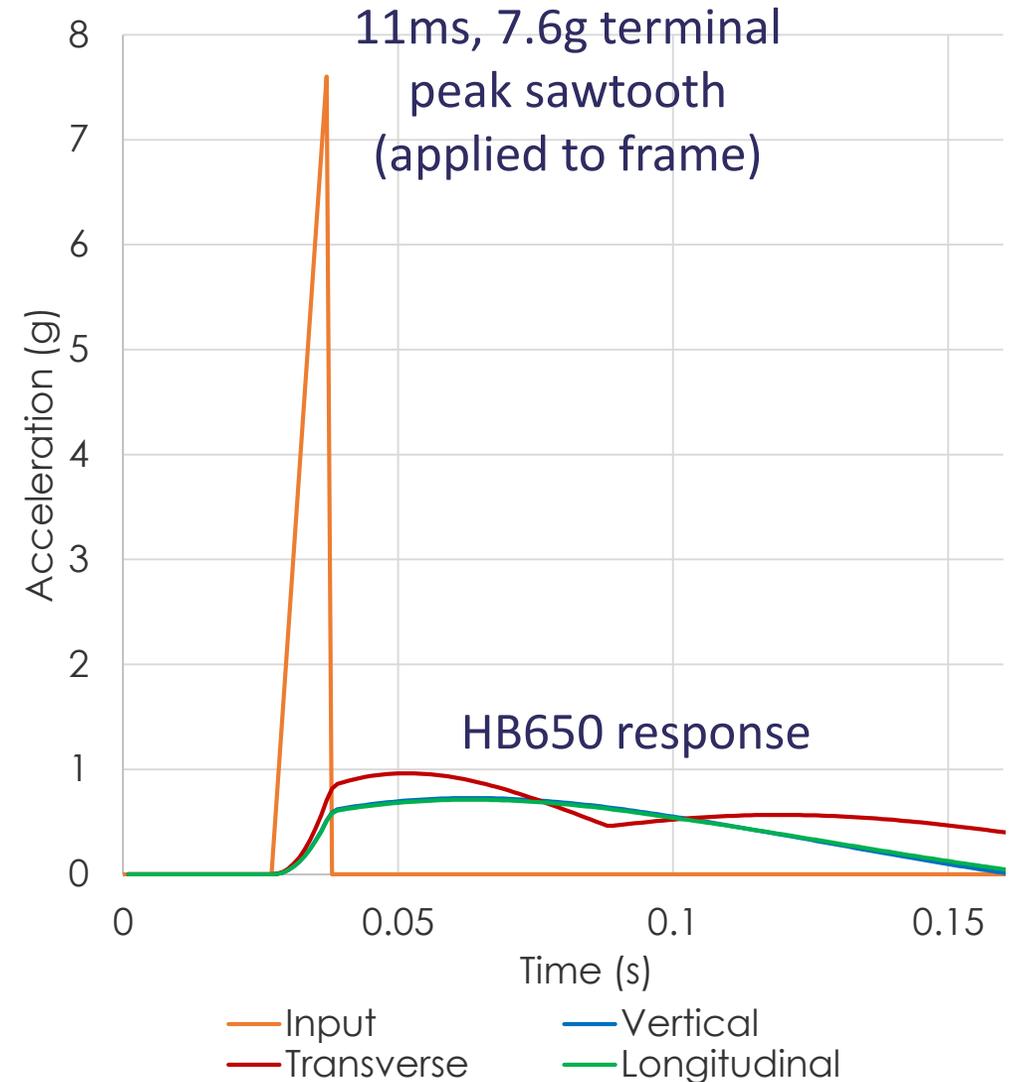
Vibration

- Simulation conducted using calculated modes
- Combined profile applied in all 3 directions
- Isolation at 10Hz achieved:
 - 95% vertical
 - 90% transverse
 - 95% longitudinal
- Meets requirement of 80% isolation above 10Hz



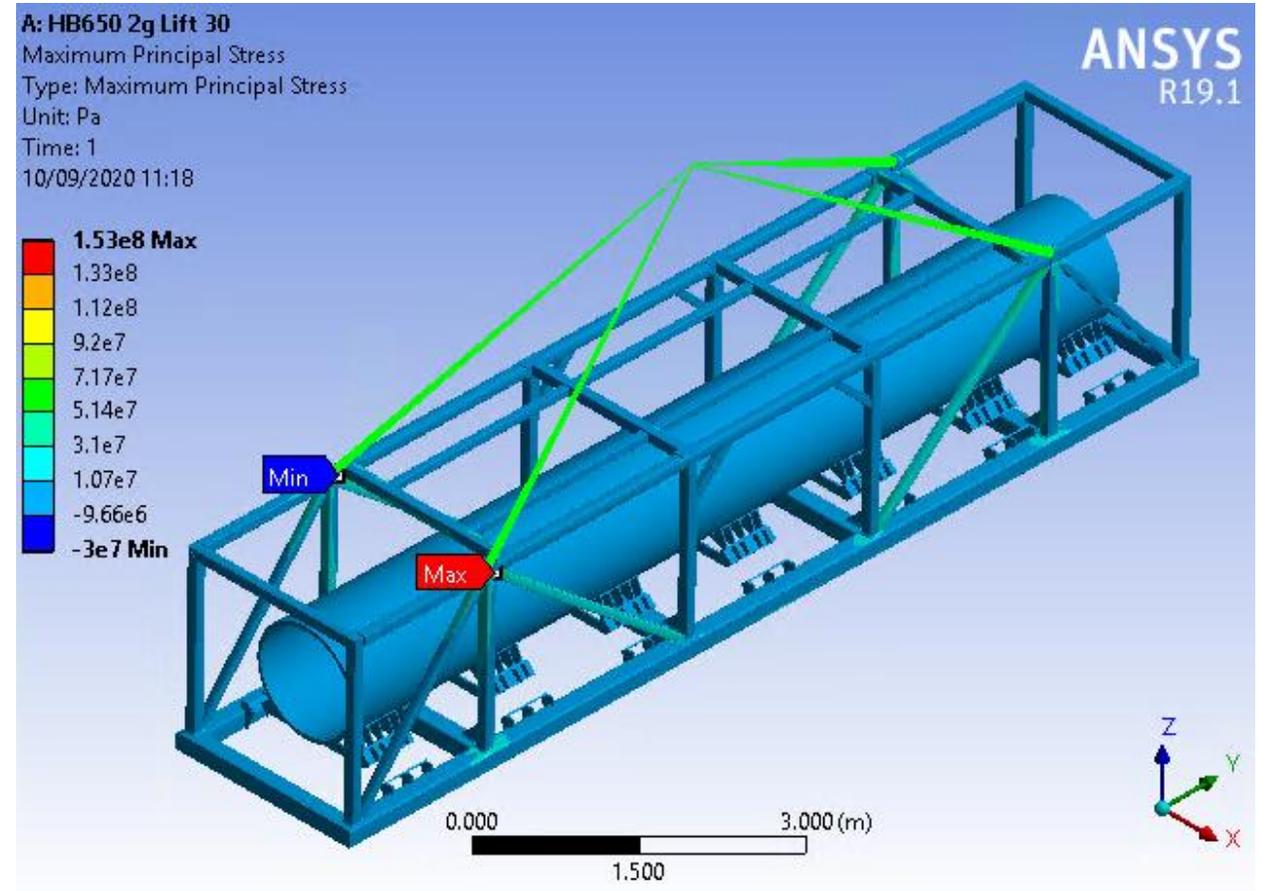
Shock

- Requirement: reduce HB650 shocks to
 - 2.5g vertical
 - 1.5g transverse
 - 3.5g longitudinal
- Frame shock input defined by MIL-STD-810H worst case on-road transport shock
- HB650 shock response achieved:
 - 0.8g vertical
 - 1.0g transverse
 - 0.7g longitudinal



Lifting

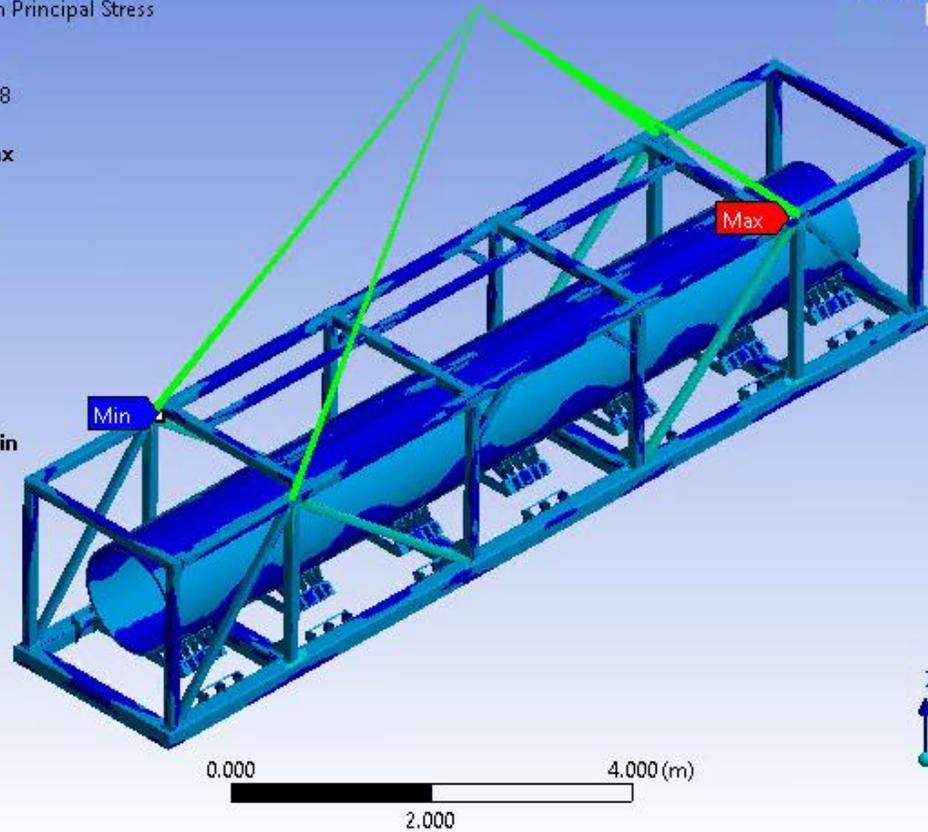
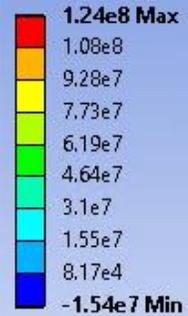
- *Lifting via frame required*
- BS EN 13155:2003 used as design standard
- Specifies maximum admissible design stresses under twice lifting load
- 225MPa weld principle stress limit
 - Maximum of 153MPa
- 186MPa weld shear stress limit
 - Maximum of 100MPa



Lifting – 45° and 60°

B: HB650 2g Lift 45

Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
14/09/2020 15:18



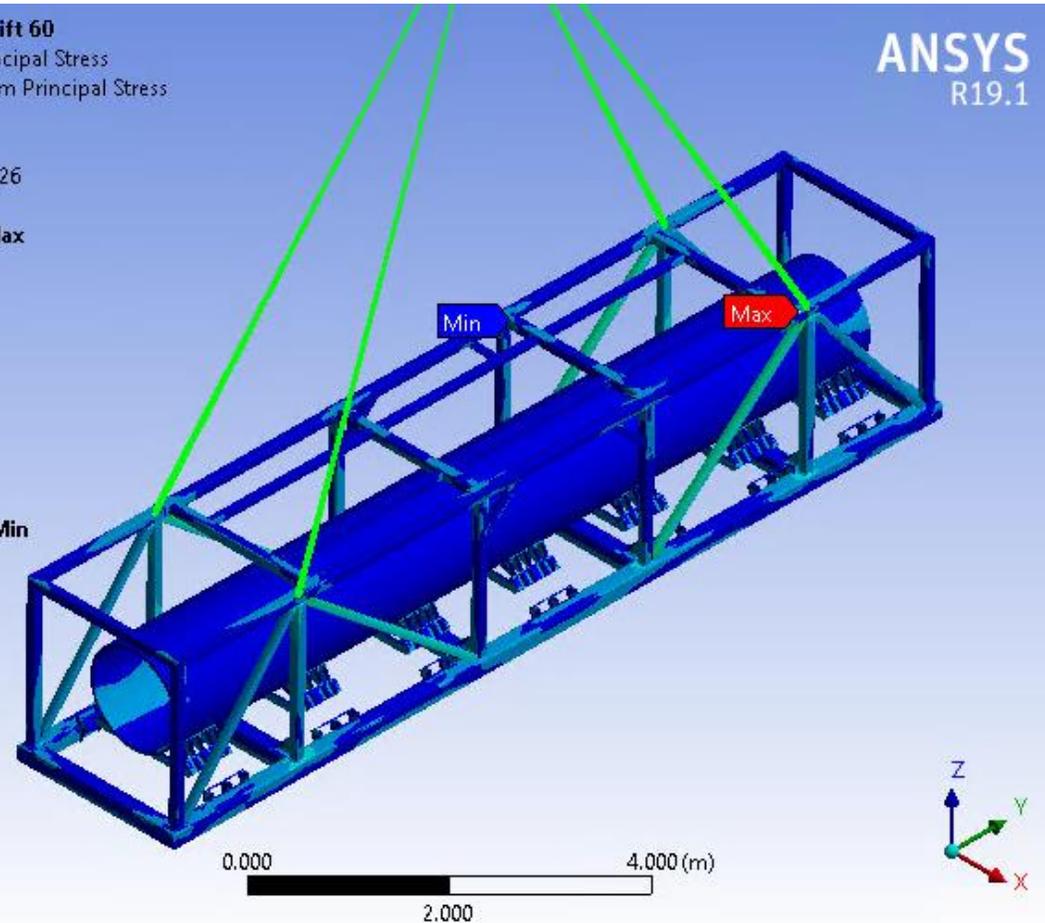
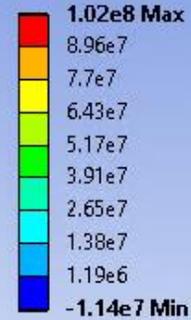
45° lift, 3.7m

124MPa principle / 69MPa shear

ANSYS
R19.1

C: HB650 2g Lift 60

Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
14/09/2020 15:26

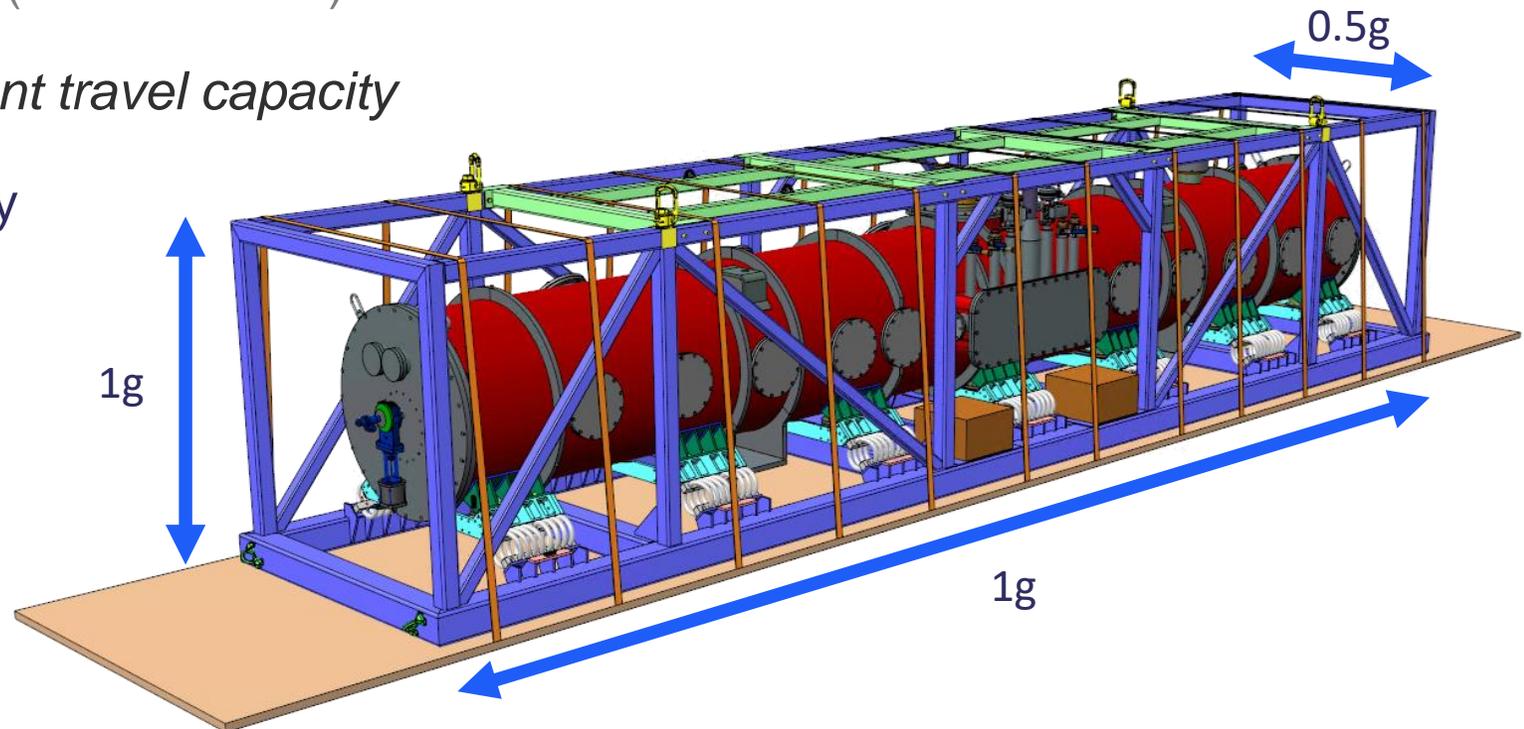


60° lift, 6.4m

102MPa principle / 53MPa shear

Transportation Loads

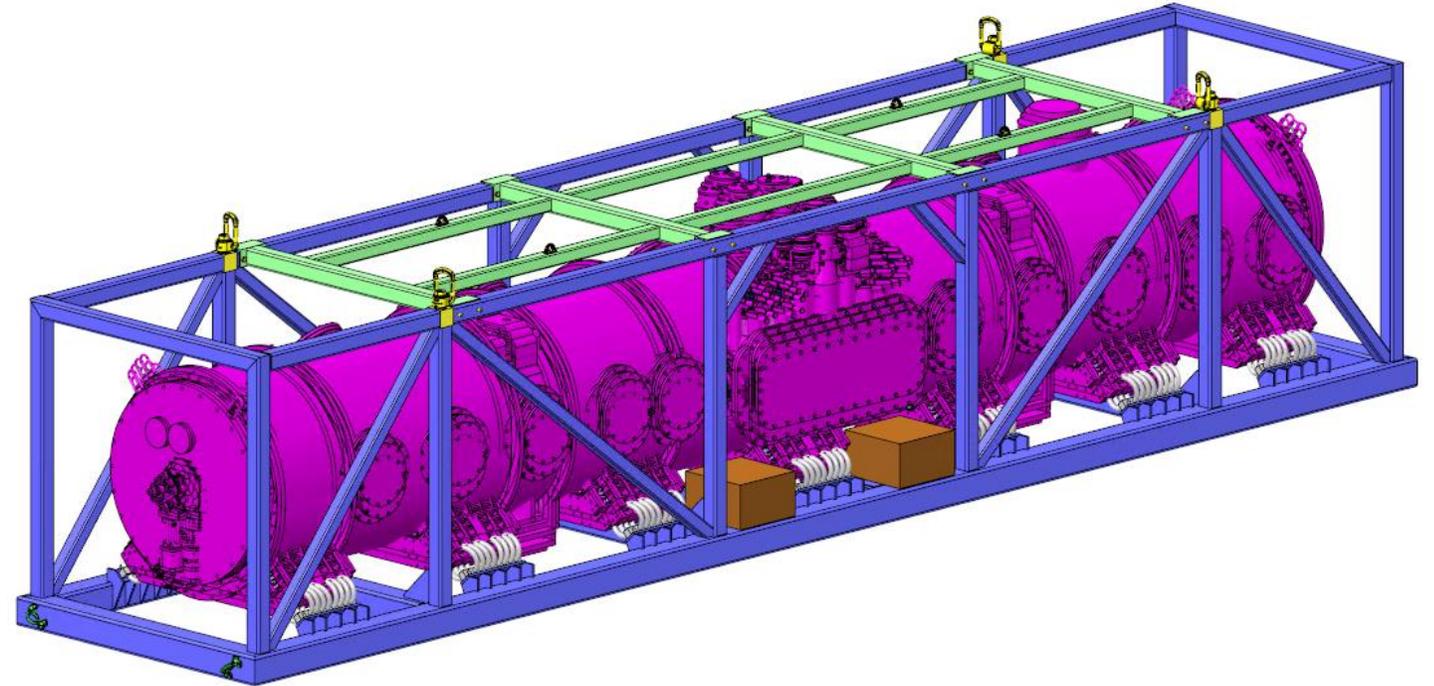
- *Frame required to resist transport loads*
 - BS EN 12195-1:2010 loads applied (combined)
 - Maximum principle stress 147MPa (225MPa limit)
 - Maximum shear stress 99MPa (186MPa limit)
- *Isolation system must have sufficient travel capacity*
 - Travel is within isolator capacity



Clearances

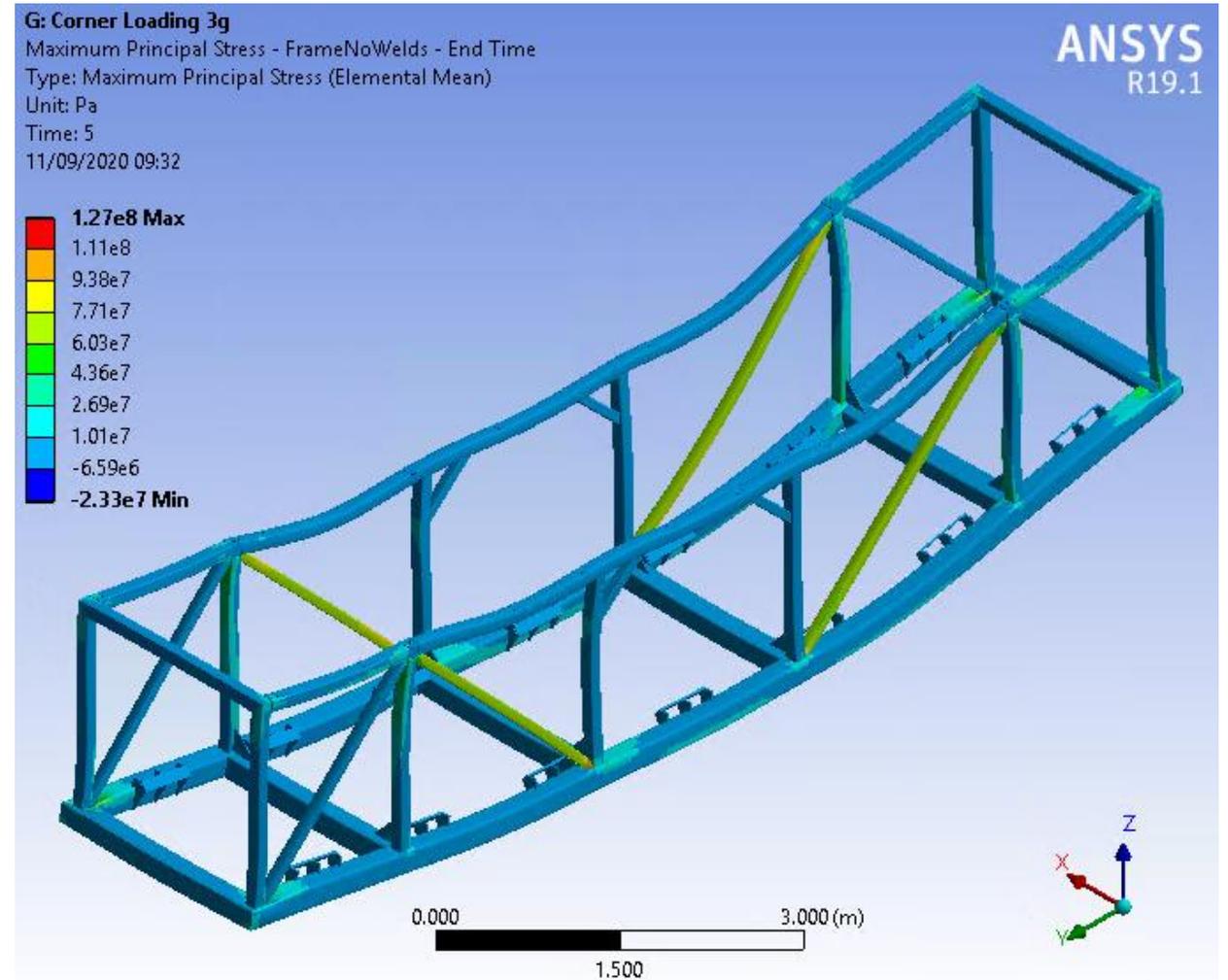
Requirement: clearance for full isolator stroke in all directions

Direction	Nominal clearance (mm)	Clearance at maximum travel (mm)
Longitudinal	125	14
Transverse	114	32
Vertical (top)	95	13
Vertical (base)	194	65



Poorly Supported Frame

- Simulation ran with frame only supported by corners
- Conducted to ensure that an uneven transport bed would not cause a failure
- Maximum principle stress: 127MPa
- Maximum shear stress: 118MPa
- Stresses increased, though within limits
- Maximum 5.1mm deflection, within isolator clearance margin (13mm)



Deformation exaggerated x100

Access

- *Specification requires:*
 - *Restricting access*
 - *Protection to IP21*
 - *Objects > 12.5mm*
 - *Vertically falling water*
 - *Mitigation of thermal changes*
- **Curtain sided trailer as first layer**
- **Bespoke weatherproof, insulated covers for transport frame and cryomodule**



Drawing Status

Summary

Summary

- Frame 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, exceeding 200mm requirement
- Maintains clearance in all directions at isolator maximum travel
- Protected by an insulated, weatherproof cover and transported on a curtain-side trailer for IP21 compliance
- Draft design drawings complete

Charges Addressed

2. Is the Transport Frame design, as presented, likely to successfully meet the specified performance?

- The design meets or exceeds the specification in all aspects and includes appropriate factors of safety*

3. Is the Transport Frame design, as presented, at the final design level (90%)?

- The design and analysis are complete other than the incorporation of any recommendations from this review*
- A design drawing pack has been drafted and will be finalised upon design conclusion*

Questions?