Transporting Cryomodules from TRIUMF to Kolkata

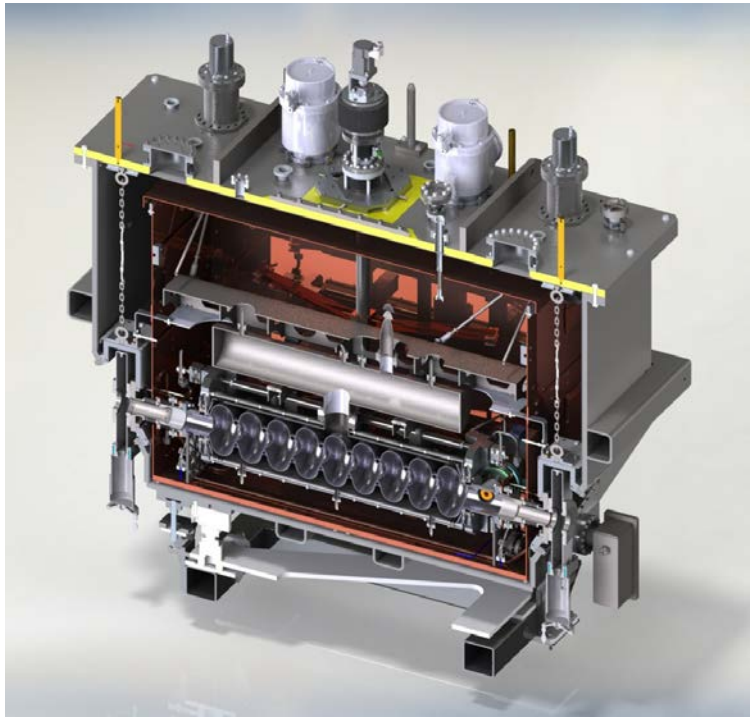
Documentation and Engineering

James Keir

TTC 2022

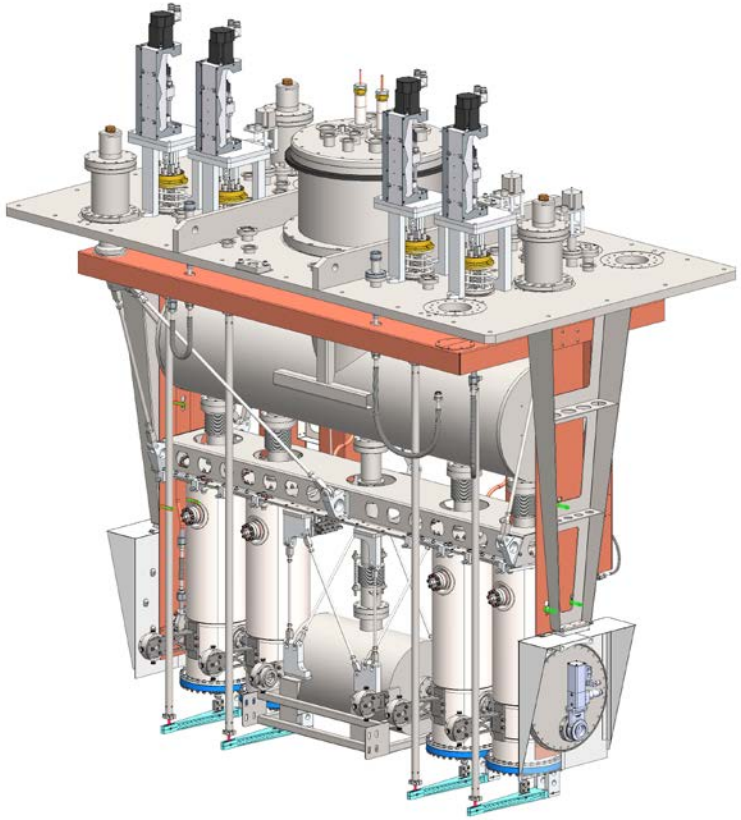
2022-01-24

Overview of VECC Cryomodules Produced by TRIUMF



VECC ICM

- Single 1.3GHz 9 Cell (Modified Tesla)
- 2 CPI (Cornell ERL Injector) Couplers
- Top Loaded
- Integral 4K/2K Heat exchanger and JT
- 2014-2018 (sent by air late 2019)

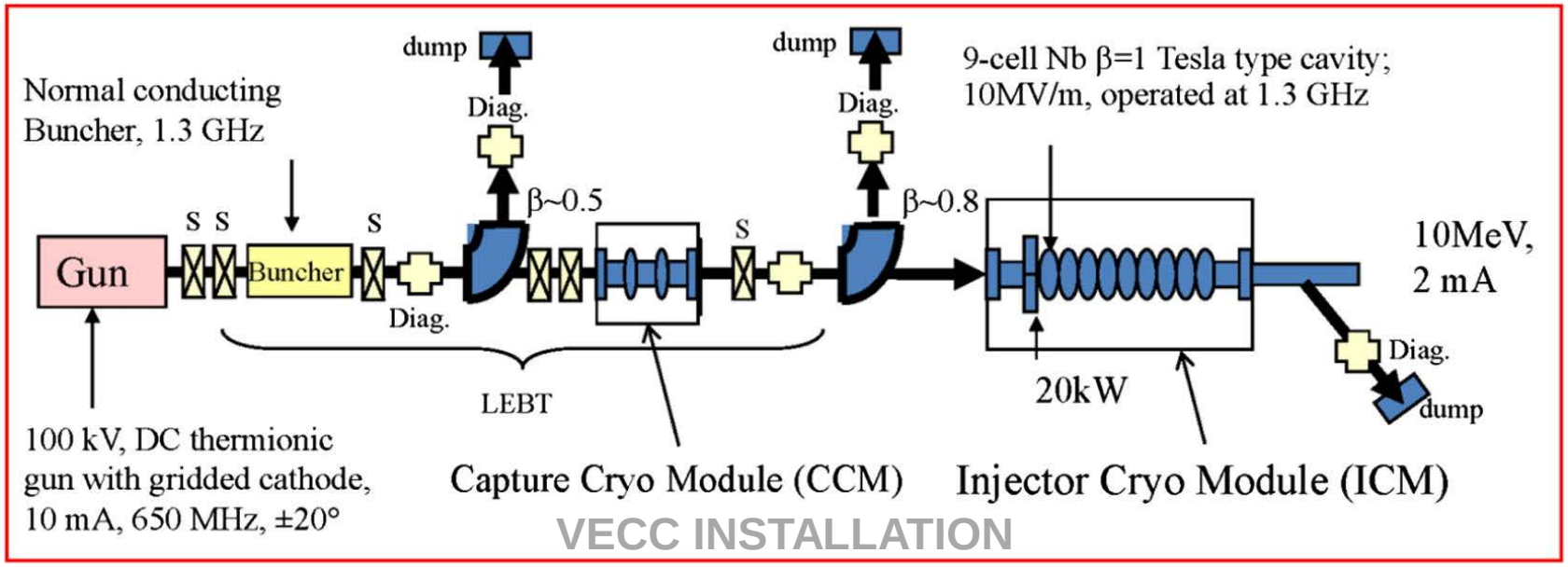


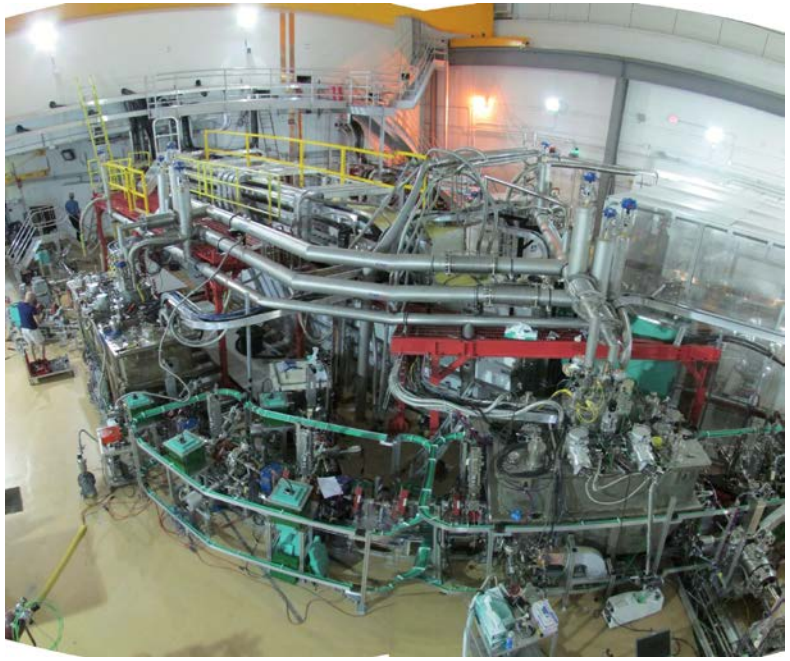
VECC QWR

- Four 113.6 MHz QWR with SC solenoid
- TRIUMF ISAC-II style with isolated vacuum
- Top Loaded
- 4K only
- 2018-present (currently being cold tested)

History of VECC Injector Cryo-Module (ICM)

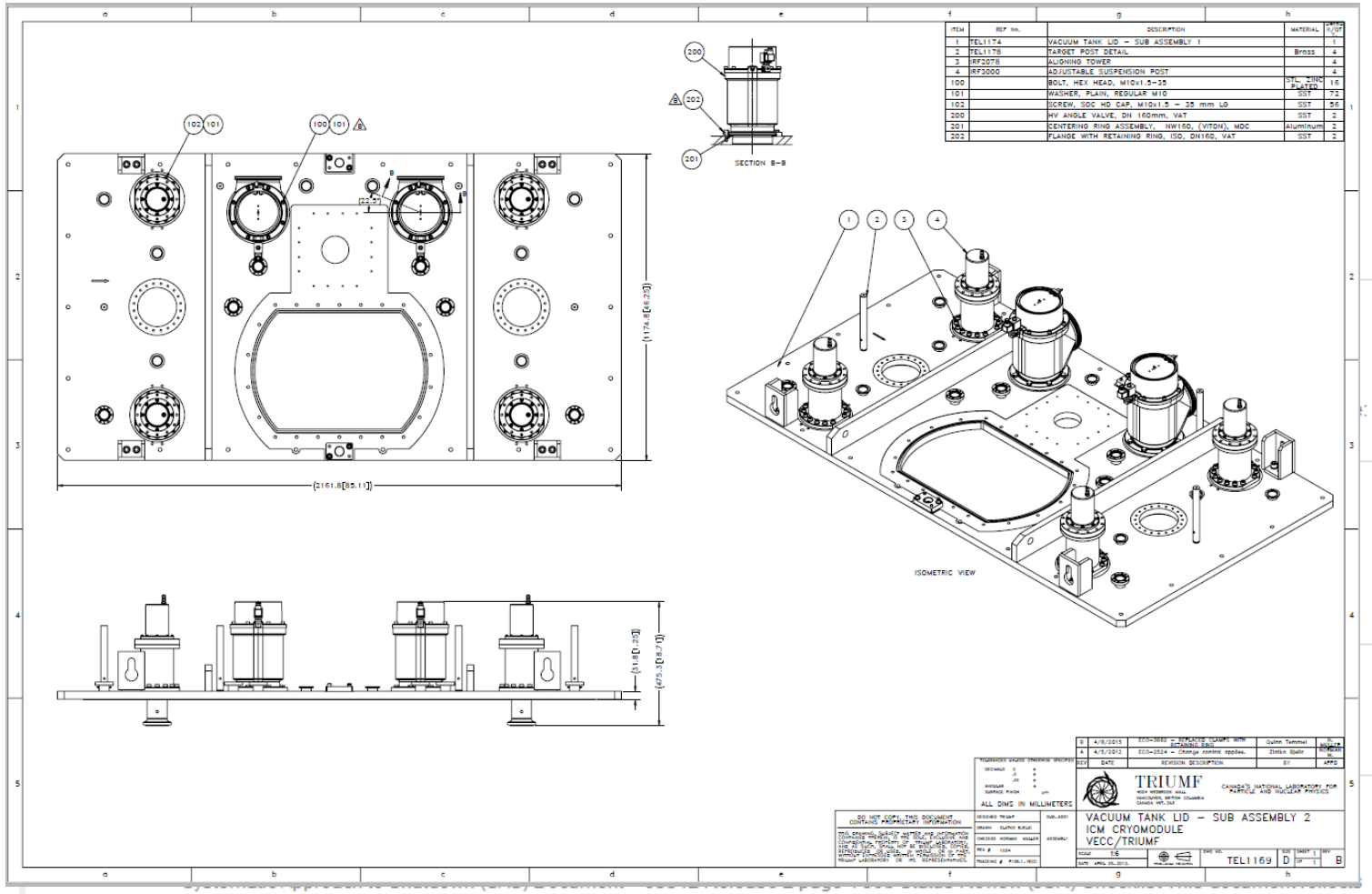
- In 2008 TRIUMF signed an MOU with VECC for a co-designed 1.3GHz cryomodule as part of the ARIEL (TRIUMF) and ANURIB (VECC) projects
- Two ICMs were built at TRIUMF with ICM2 sent to VECC. This module is a twin of ICM1 in the ARIEL e-Linac
- VECC is using ICM2 for a 10MeV test stand – see above figure





VECC Injector Cryo-Module (ICM) Engineering and Documentation Process

- Weekly meetings were held with 2-3, VECC engineers and scientists who were visiting TRIUMF
- At the time it was decided to focus the design on the operational requirements.
- Documentation was recorded in accordance with TRIUMF standards and VECC personnel were given access to our QMS and drawing servers.
- VECC was given a complete CAD model and manufacturing drawings



Injector Cryomodule Vacuum Vessel Engineering Analysis		
Document-77838	Release No.: 1	Release Date.: 2015-02-13

1 Summary

The ARIEL Injector Cryomodule (EINJ) Vacuum Vessel was analyzed for structural integrity and to determine the expected deflection under vacuum load. The current tank design meets a minimum safety factor of 2.5 with vacuum loads and mass from the lid assembly. Additionally, the lifting brackets were also analyzed to determine whether the Injector Cryomodule assembly could be lifted safely. The simulation results indicated that the lifting brackets can be used to safely lift the complete EINJ assembly (with lid).

2 Specifications

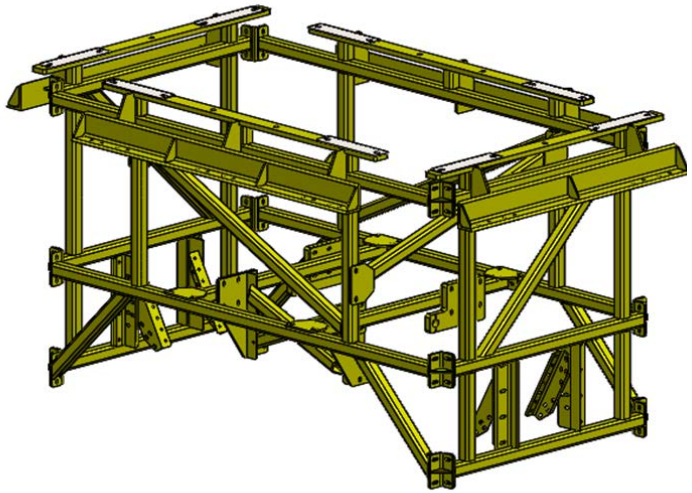
the information given by the proponent; it is not an assessment by the SAS Committee. (Instruct...

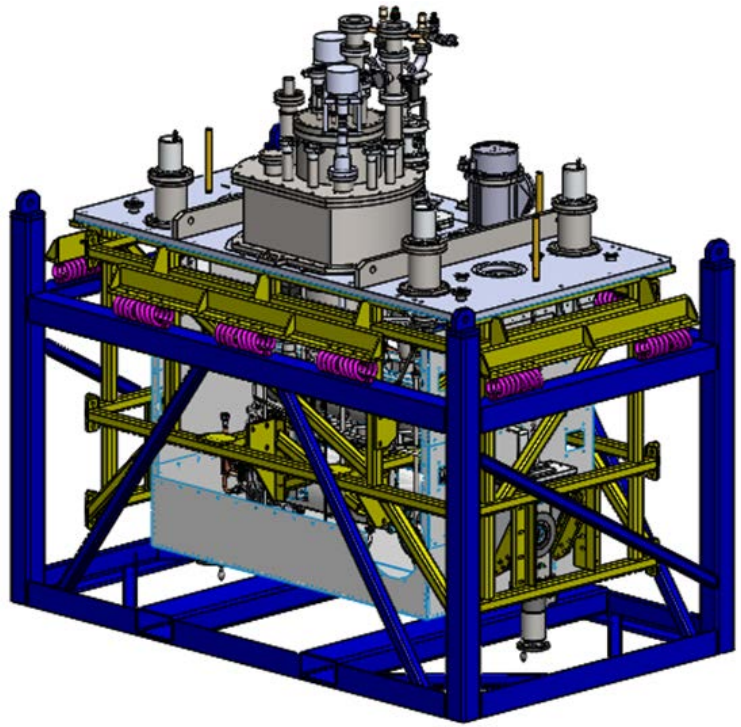
EINJ Vacuum Tank Lid Engineering Design and Analysis - Engineering Note
Release: 01 - Dated: 2012-03-29 - Document: 51012
Appears In: Engineering Notes - Released
Content Snippet:
20120329 095200 Template: Document-18187 Rel.3 Page 1 of 11 TRIUMF Document-51012 Engineering Note P0104, P0108 - EINJ Vacuum Tank Lid Engineering Design and Analysis Document Type: Engi...

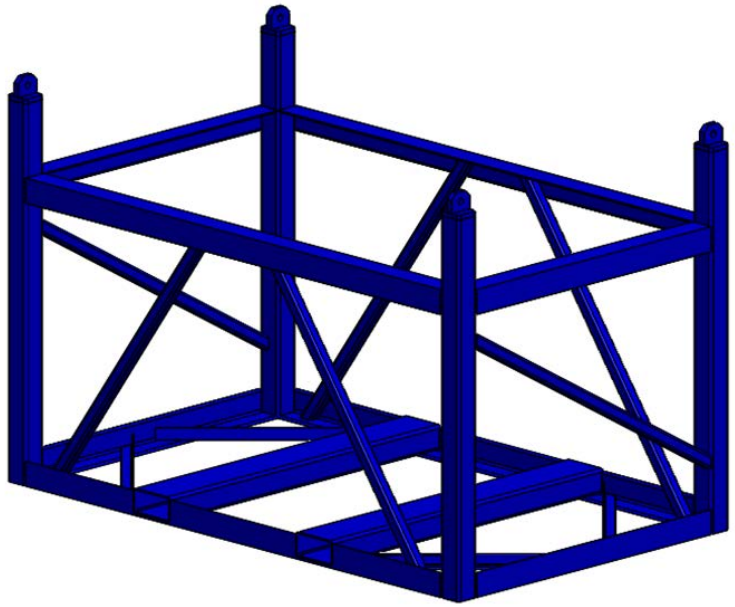
EINJ Valve and Warm-Cold Transition Assembly Procedure
Release:1 Release Date:2016-01-21 Document: 104574
Appears In: Manufacturing Procedures - Released
Content Snippet:
20160121 164900 Template: Document-18187 Rel.3 Page 1 of 14 TRIUMF Document-104574 EINJ Valve and Warm-Cold Transition Assembly Procedure Document Type: Procedure Release: 1 ...

ICM Transport Frame

- During the design stage, the plan was to;
  1. Online test and commission
  2. Package in simple crate
  3. Send to India via standard freight
- With the experience of LCLS-II, that plan was deemed inadequate.
- A skeleton support frame (yellow) was developed to host the top assembly and interface with the numerous components that were deemed “At Risk”.
- The skeleton frame was installed in a shipping frame with wire rope isolators to reduce the shock loads (10:1 as measured)







Due to lack of access the cold mass had to be removed from the vacuum tank to properly support everything

Disassembly and Packing of VECC ICM

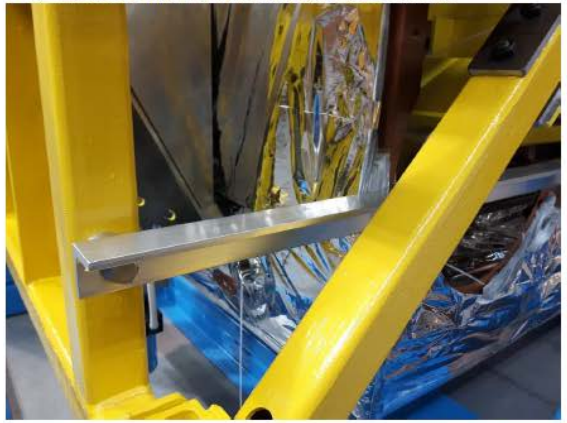
- The VECC ICM was disassembled over the course of several weeks
- Small components (under 30cm) not being shipped on the ICM were removed, packaged, documented and packed in boxes.
- The number of small components removed was so great that they had a combined weight of 275 kg (600 lb)
- The large components, such as flanges and 80K panels, were packed within the vacuum tank that was crated separately.
- The top assembly/cold mass was then lowered into the yellow frame and critical components were attached to it.

Creating Reassembly Instructions

- Using the photos taken during the disassembly, detailed and clear assembly instructions were created for the technicians at VECC

Proposed Procedure for VECC Injector Re-Assembly		
Document-174411	Release No. 1	Release Date.: 2019-09-12

5. Remove Aluminum Nitrogen shield supports (2 locations).



Proposed Procedure for VECC Injector Re-Assembly		
Document-174411	Release No. 1	Release Date.: 2019-09-12

6. Remove Tuner support plates (2 locations)

7. Remove Tuner Scissor support rod.

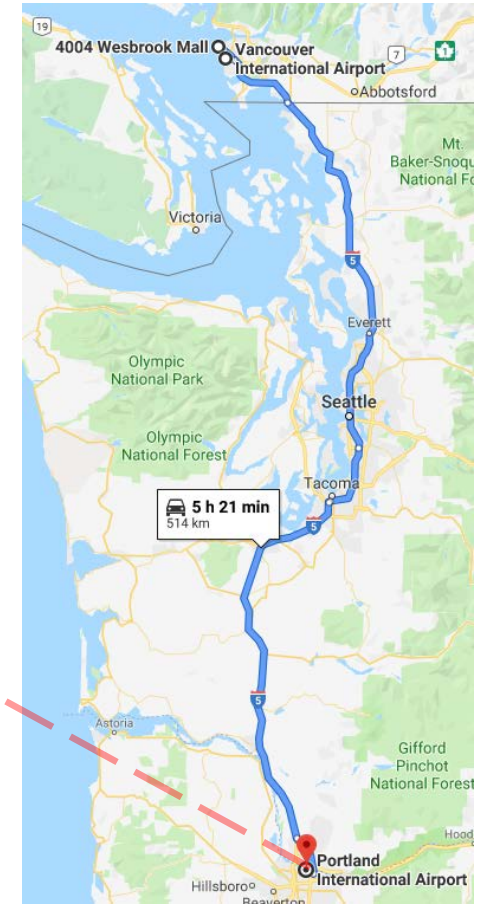
VECC Injector Wire Position Monitor Disassembly Procedure		
Document-174410	Release No. 1	Release Date.: 2019-09-11

4. Remove the wire support pulley assembly.

5. Remove the wire support disc.

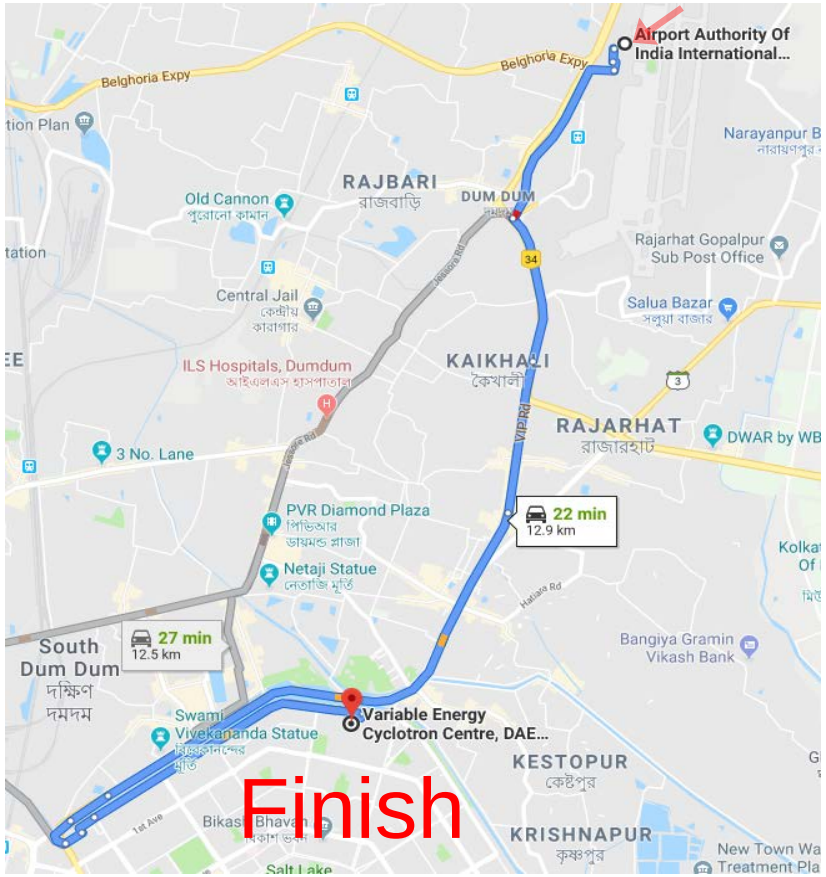
Planned Journey to Kolkata

Start

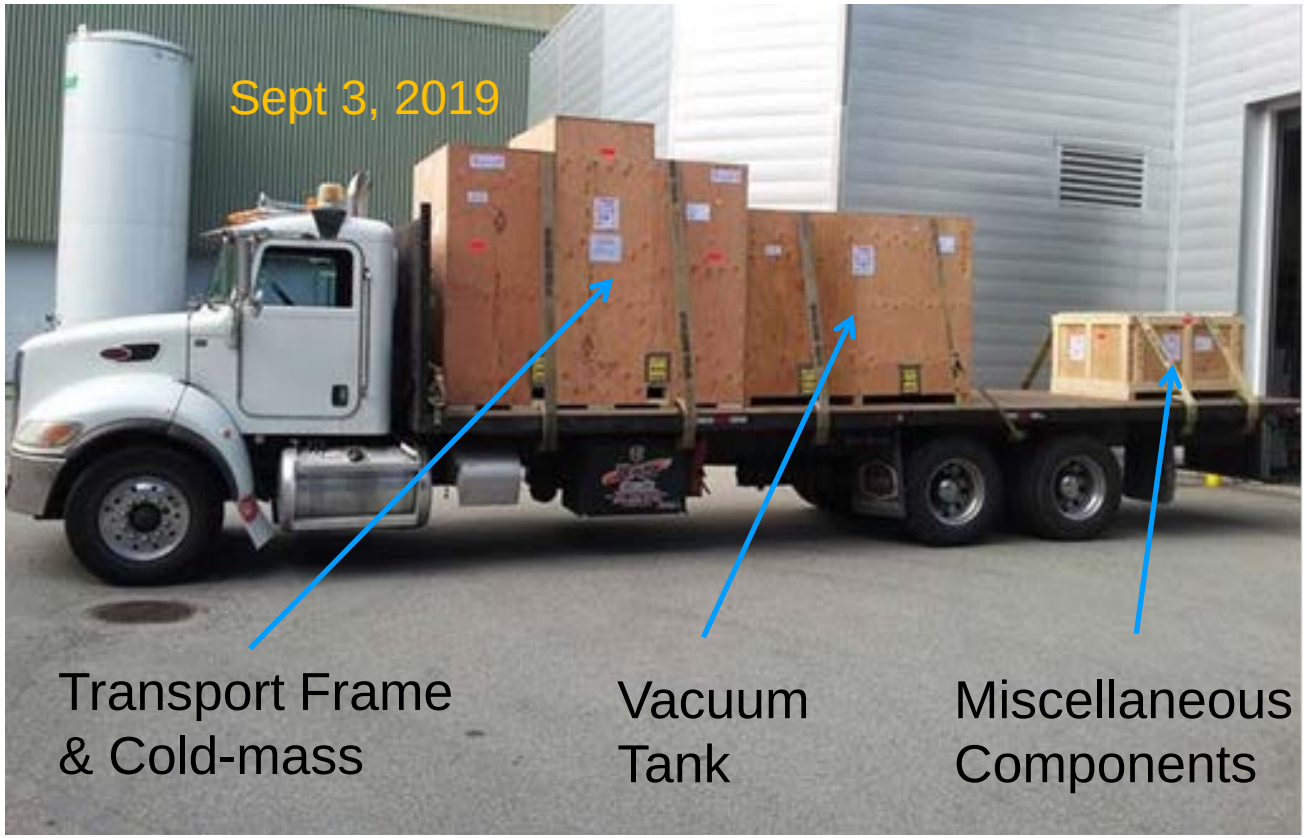


Total travel to VECC was to include:

- 530 km of road travel
- 20 hours of flight time
- 5 freight transfers
- Via YVR, PDX, HKD and CCU



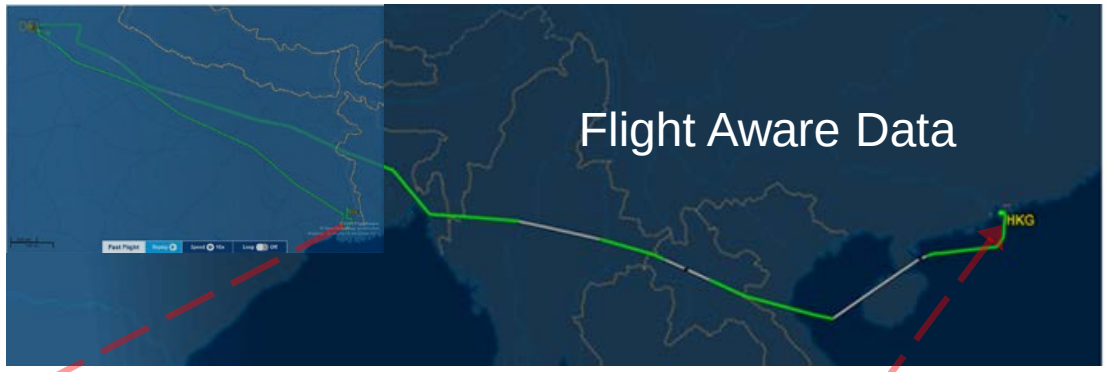
Leaving TRIUMF and Arriving at VECC



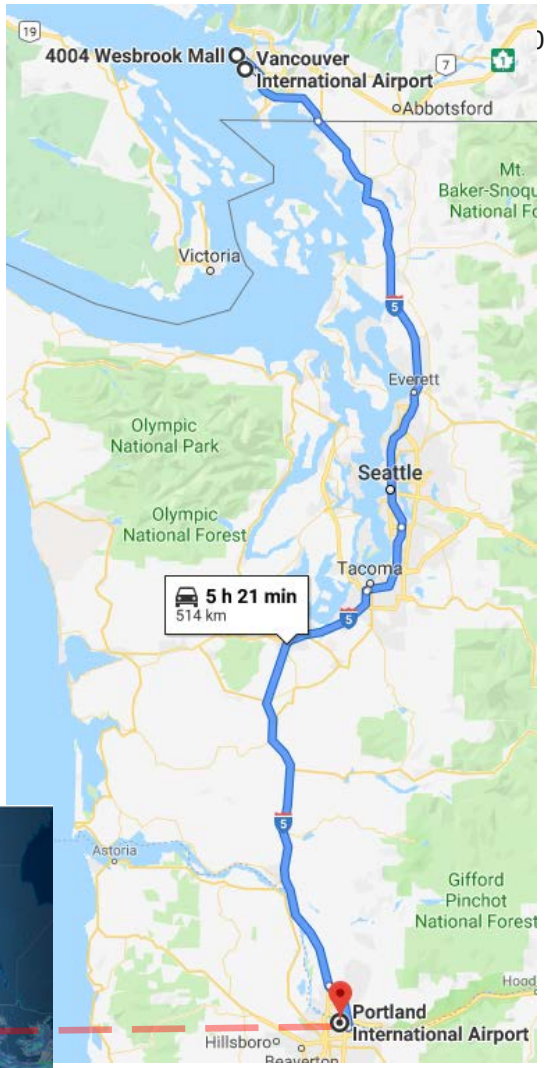
ICM loaded on an air-ride flat deck;
Beginning the long journey to VECC

Arriving at VECC
7 weeks later

Actual Journey to Kolkata

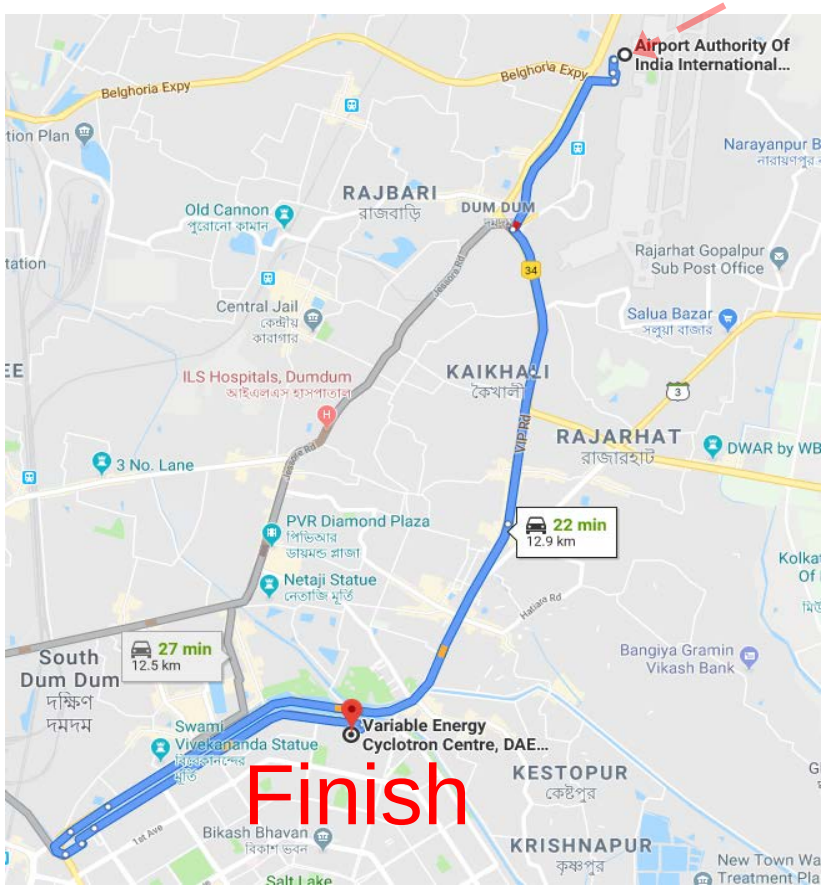


Start

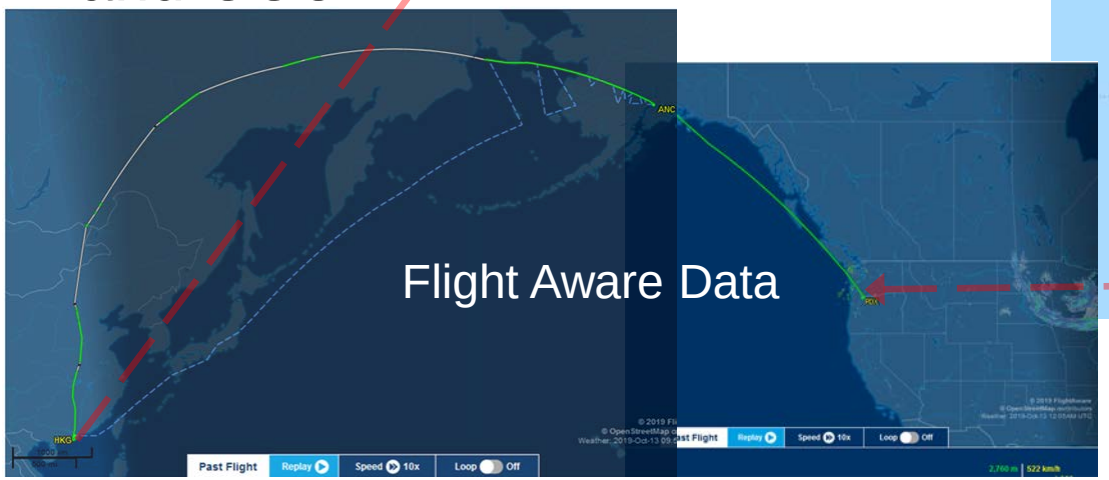


Total travel to VECC included:

- Held by CBSA for 6 weeks
- 530 km of road travel
- 20 hours of flight time
- Over 10 freight transfers
- Via YVR, PDX, ANK, HKD, DEL and CCU



Finish

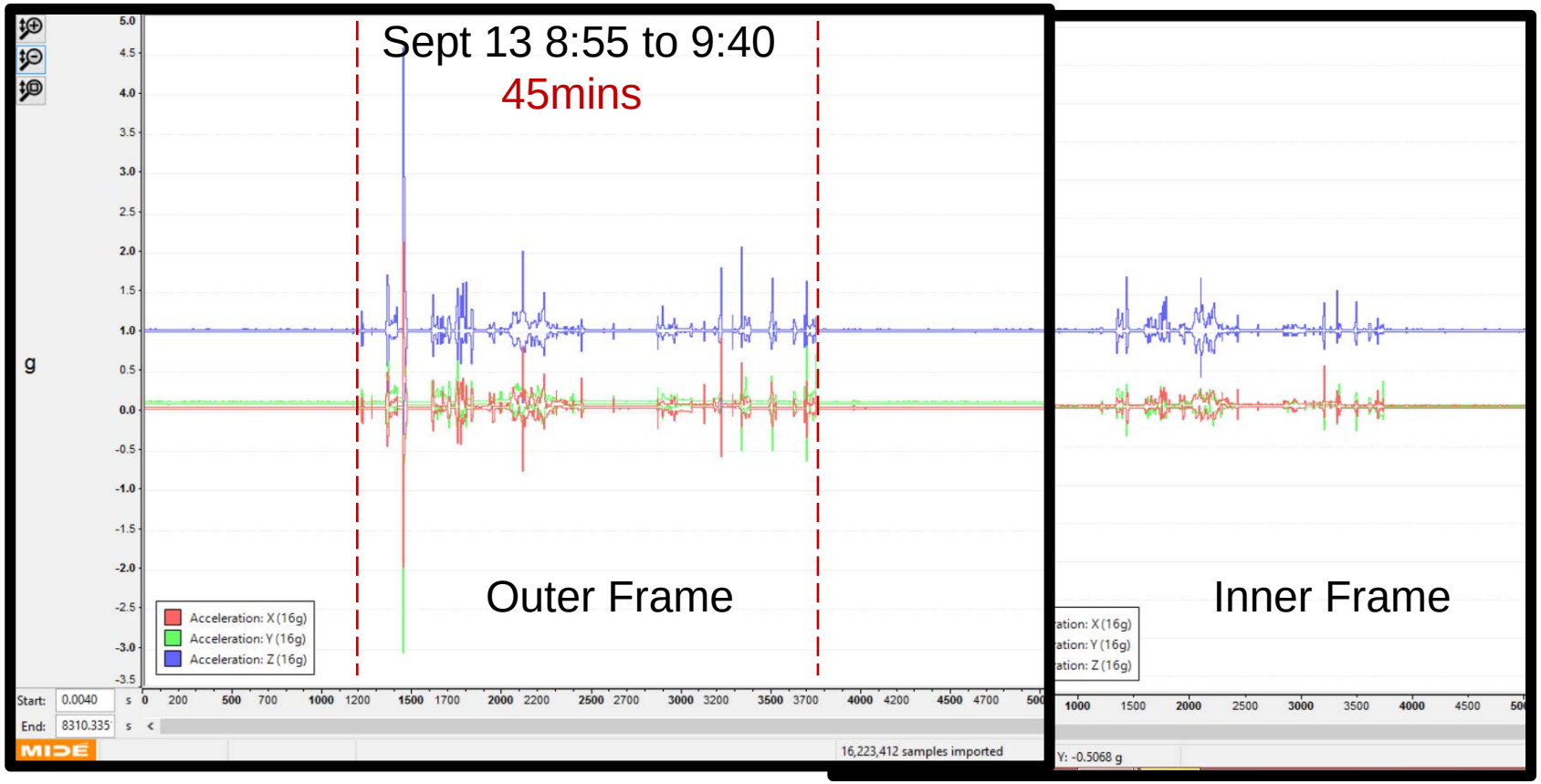


Vibration and Shock Monitoring

- Three SLAM STICK® sensors were installed
- 14.4 Ah AGM battery was installed to keep the sensors running for ~15 days.

MIDE – SLAM STICK

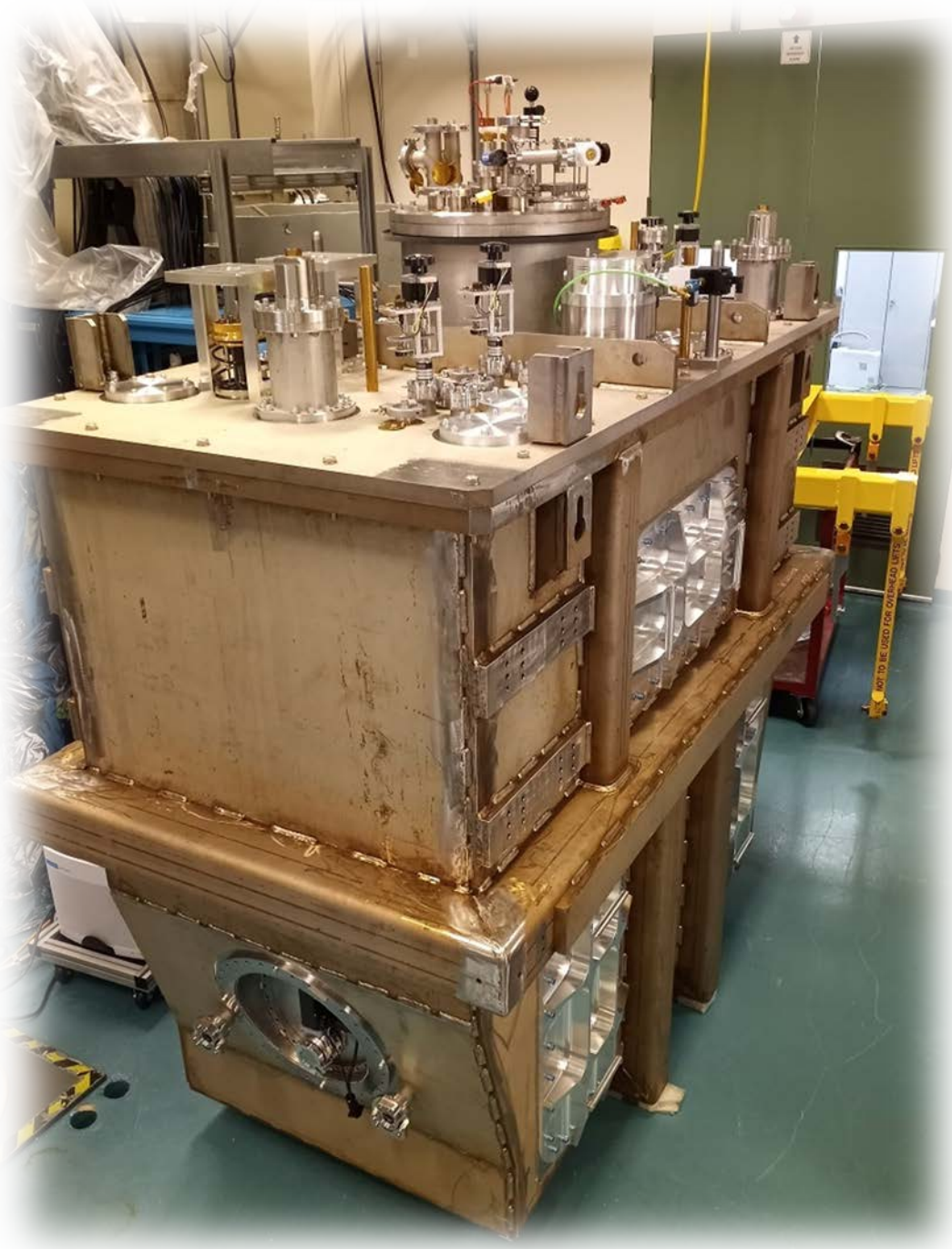
3 axis accelerometer
8 GB storage
12.5 to 3200 Hz sample rate
22 hour internal battery



Limited data due to the 6 weeks of idle time, which lead to the batteries dying mid-trip.

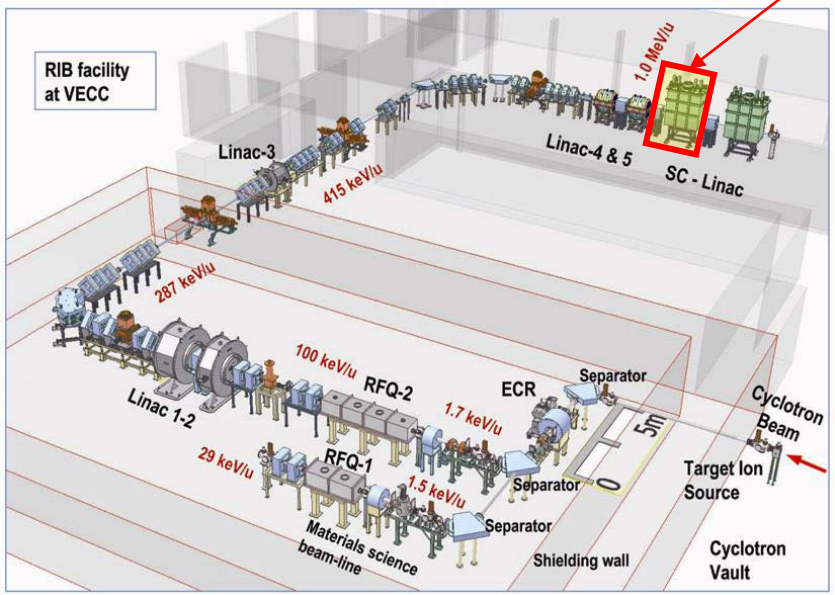
VECC 113.61MHz QWR, TRIUMF ISAC-II style with separated vacuum

July 2018 - Present



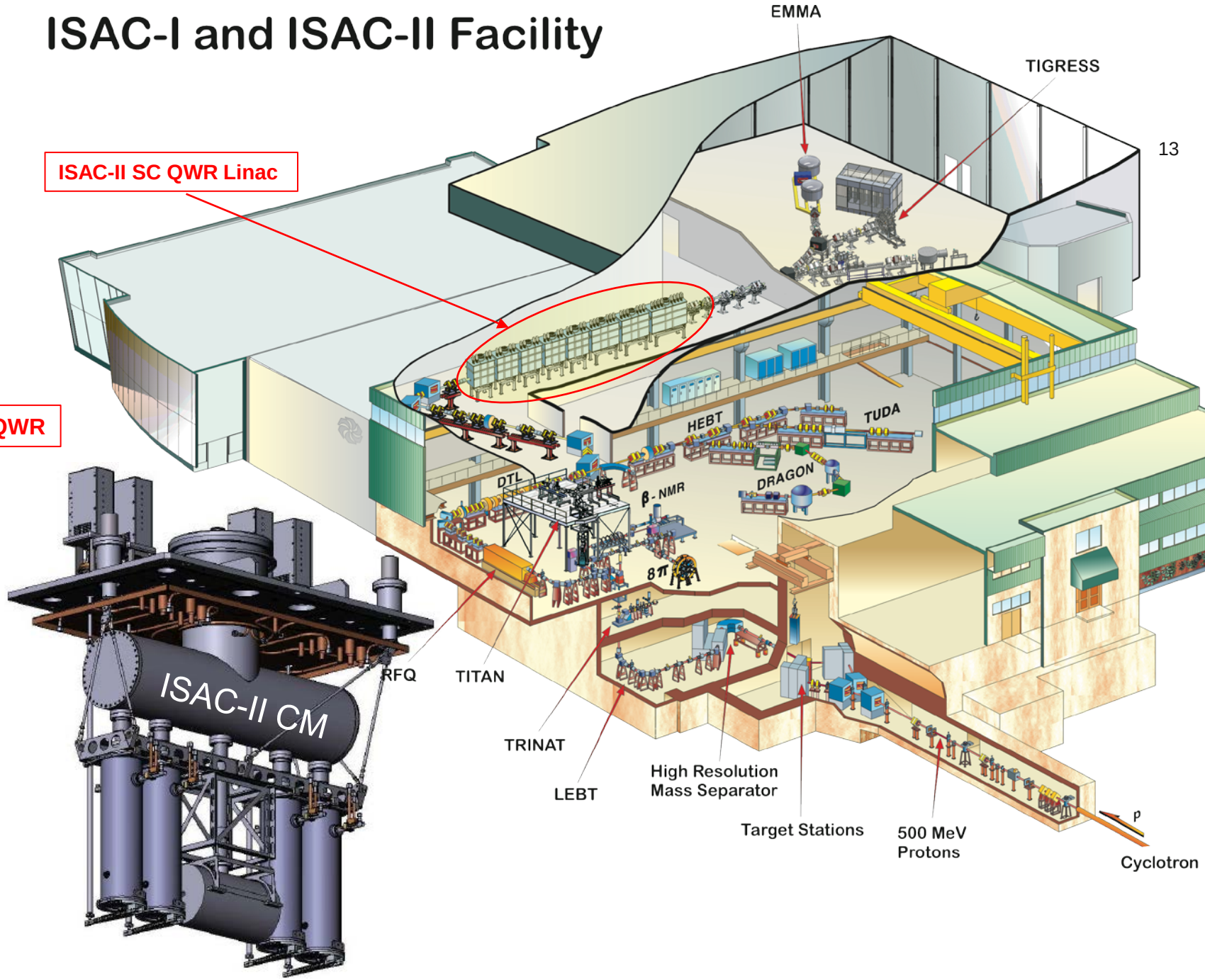
History of the VECC QWR

- In 2013 a subsequent MOU was signed for TRIUMF to produce RIB target modules and a heavy ion ISAC-II style cryomodule
- This module is to be used as a part of VECC's ANURIB Facility



VECC ANURIB Facility

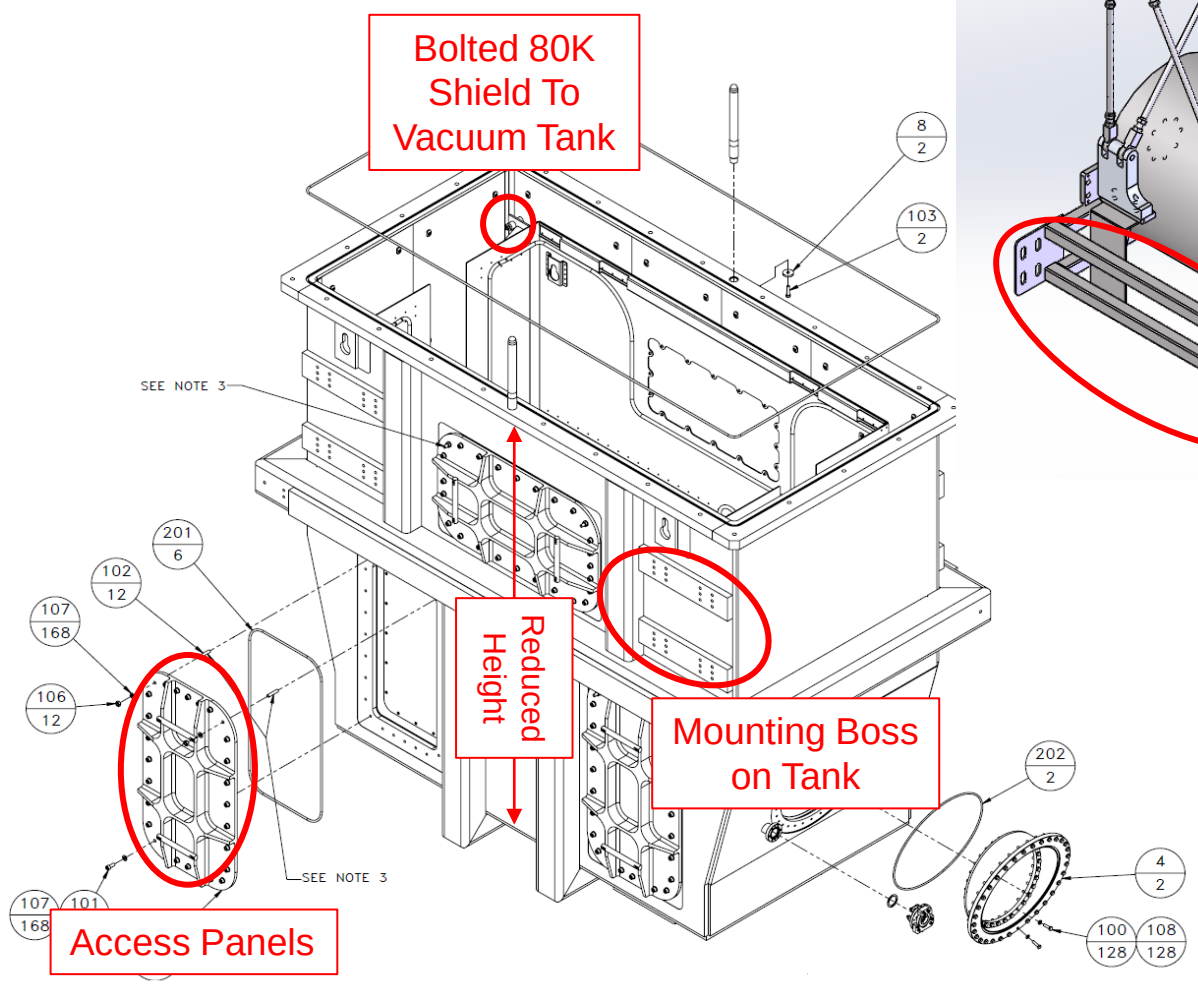
ISAC-I and ISAC-II Facility

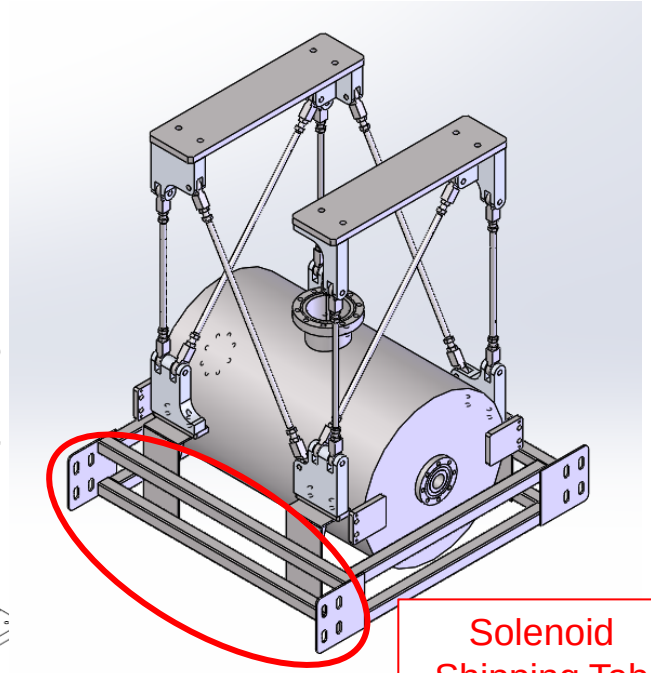


VECC QWR Engineering

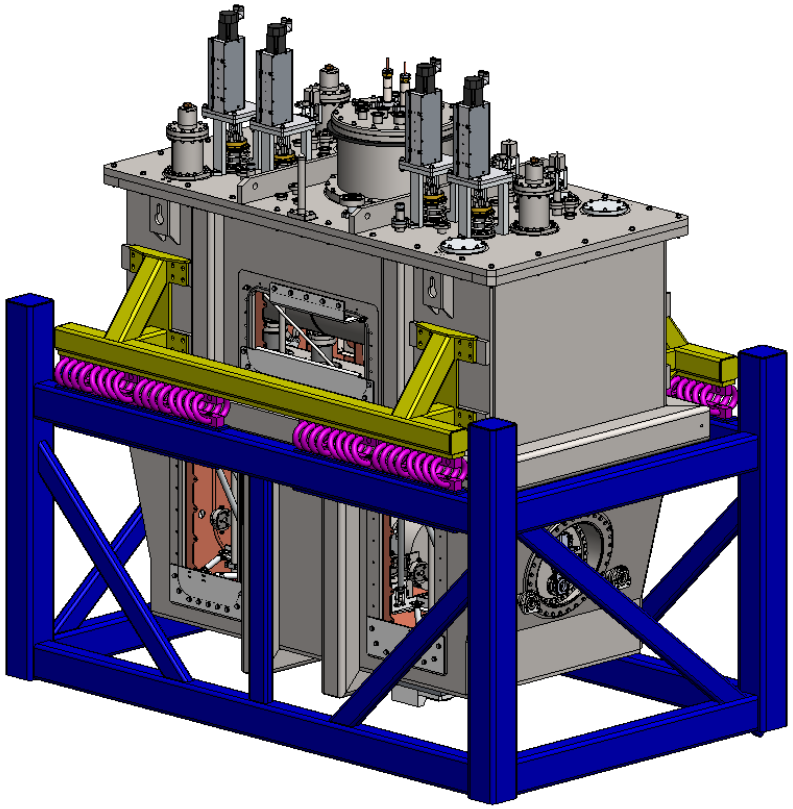
- We held weekly meetings with VECC as we did for the ICM
- We decided to use as much of the existing ISAC-II design as practical.
- This had its own issue as ISAC-II was designed in 2D AutoCAD
- VECC was given access to our PDM system and helped convert some ACAD drawings to SW models.
- Unlike the ICM, we considered the shipping of the cryomodule from the beginning with the intent to ship this CM within its vacuum tank.

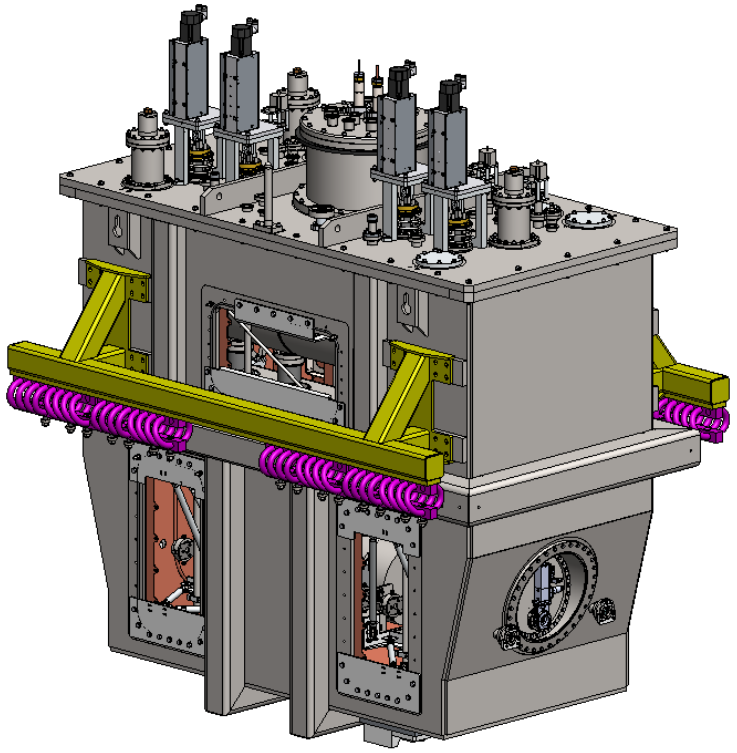
Shipping Specific Design Choices



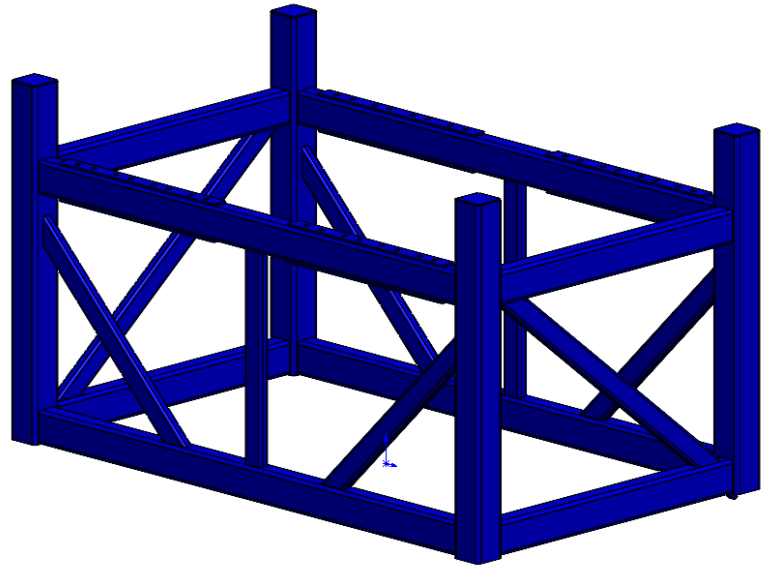


Transport Frame



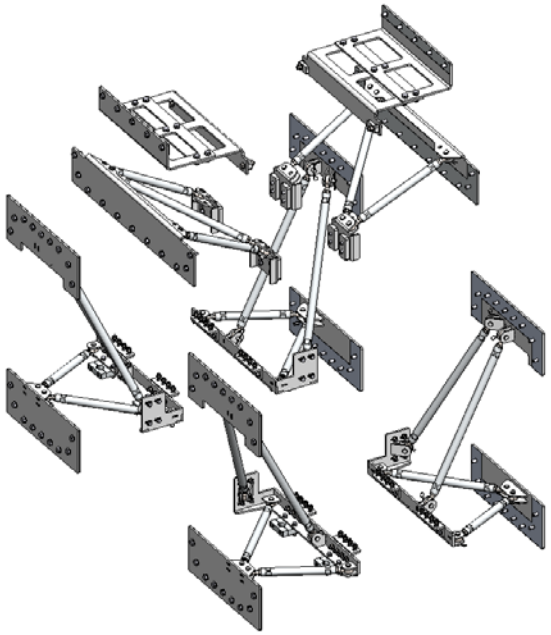


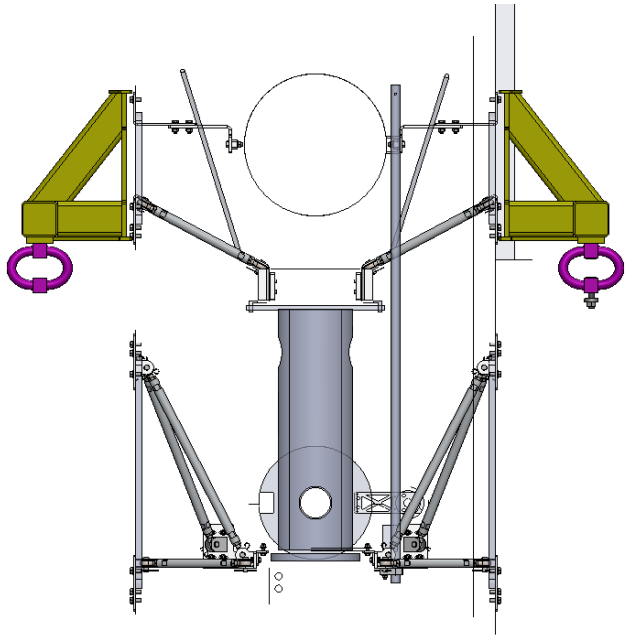
Sprung Mass~5000kg

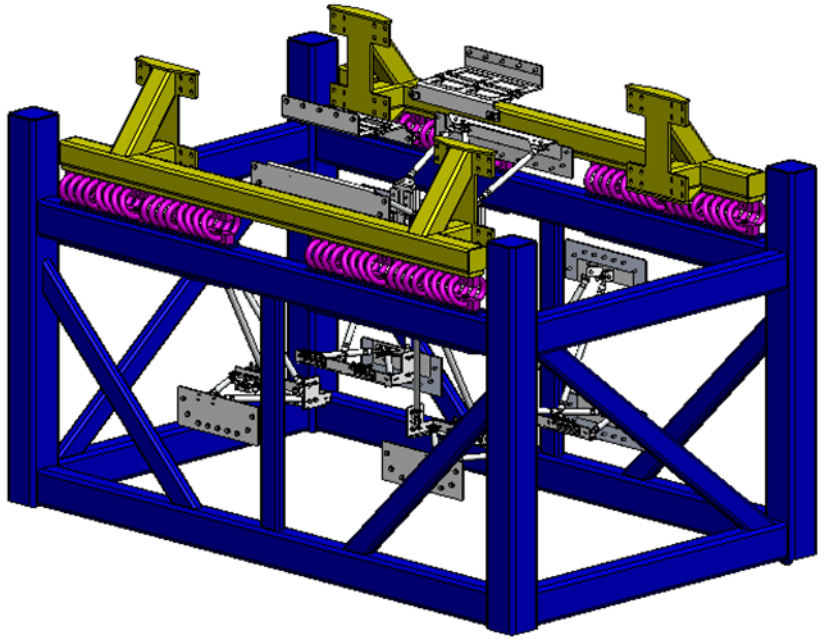


- After deciding to transport the QWR as a complete unit, attention was focused on the transport frame.
- The experience with ICM sold us on the need of attenuating shocks.
- The increase of sprung weight from ~1500kg to 5000kg increased the size of the frame and springs

Internal Transport Frame Design







Due to the lack to lateral rigidity in top loaded cryomodules, we have devised a system of linkages that can be installed through the access ports to provide the necessary support to all “At Risk” components.

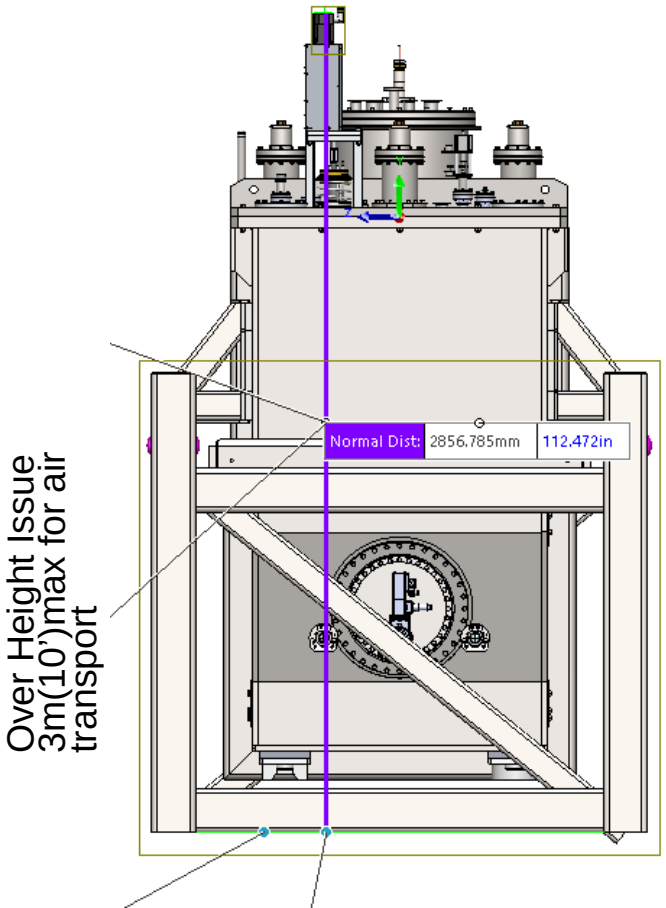
Due to the importance of the linkage system, it is designed to withstand shocks in excess of 20g

This stiff internal structure also gives us more confidence that it can handle rougher transport options (ie ocean transport)

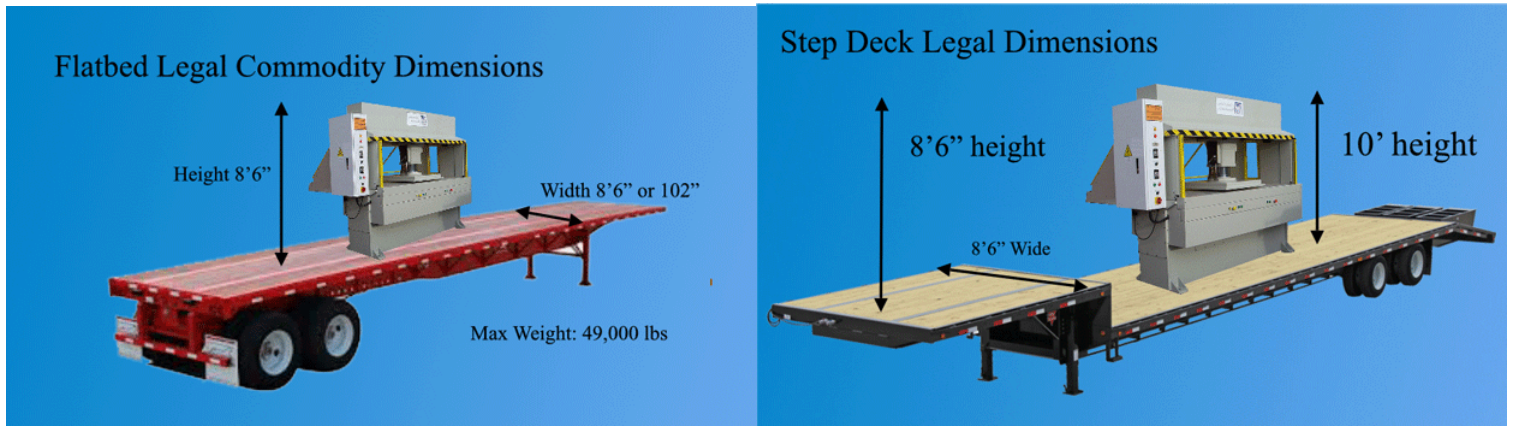
VECC QWR transportation issues and methods

To be transported by road without special permits in North America the overall height on a loaded trailer must be less than 4.15m (Canada) or 13’6” (USA)

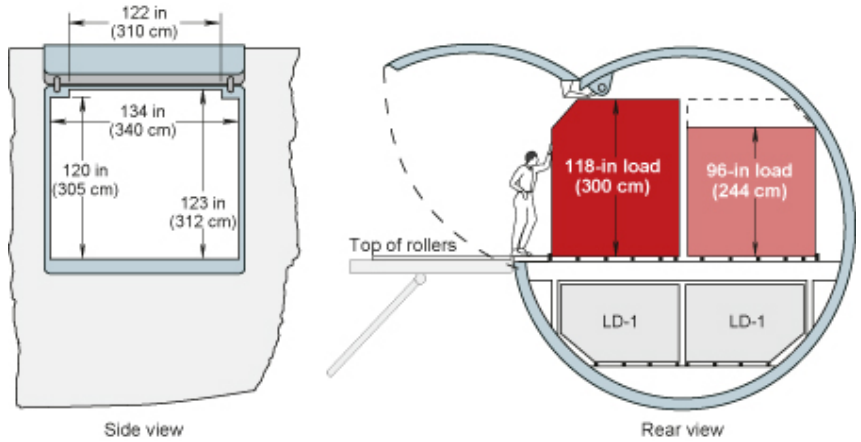
Total shipping weight 6000kg (13,200lb)



Over Height Issue 3m(10’)max for air transport



For a 3m (10’) tall cryo-module this will require a step-deck or low-boy trailer opposed to the more common flatbed or dry-van



The only commercial aircraft that can transport the VECC QWR are the B747F or B777F

Conclusion

Include shipping considerations into the CM design from the beginning

- Shipping method - Air/Road/Sea
- Complete/Partial/Components only

Early in the design think about transport mounts.

- Add tabs or flanges that can be used for securement of sensitive components.

Before you ship, work with your local customs agents to facilitate border clearance

- Both importing and exporting