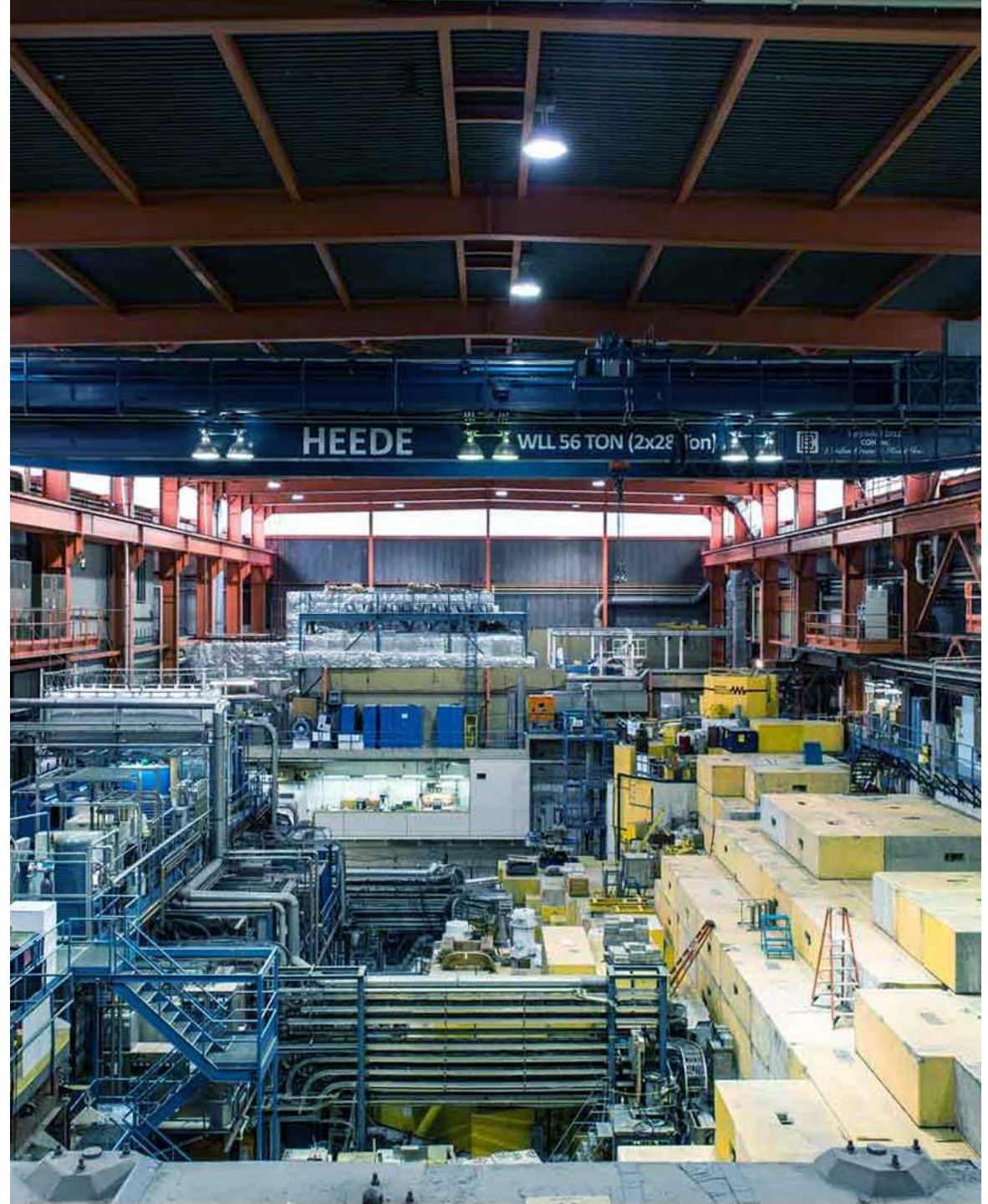


Cryogenic Supply Chain Disruptions Effect on Accelerator Operations

David Kishi

Accelerator Division

2022-10-16



TRIUMF: Canada's Particle Accelerator Center

- TRIUMF (Tri-University Meson Facility) was founded in 1968
 - Now 20 full and associate members across Canada
- Research areas include nuclear and particle physics, material science, and medical isotope science
- Main cyclotron is the primary driver accelerator
 - 500 MeV proton beam
 - Capable of sending proton beam to several beam lines simultaneously
- Future driver accelerator is the ARIEL electron Linac
 - E-linac is operational
 - Now working on Target stations
- Isotope Separation and Acceleration (ISAC)
 - ISAC I experiments at lower energies
 - ISAC II Superconducting Linac for experiments at higher energies



Liquid Helium Supply Challenges

Helium Shortage 4.0



Liquid Helium Supply Challenges

Accelerator Facilities at TRIUMF that use Helium

- Cyclotron 4K cryopanel
- Cooled to 4K with Linde 1630 helium refrigeration system
- Does the bulk of the vacuum pumping in the cyclotron
 - Cyclotron will not run without the Linde 1630



- ARIEL Electron Linac
- 2 cryomodules cooled to 2K
 - 3 x 9-cell elliptical cavities
- Air Liquide Helial LL cold box

Liquid Helium Supply Challenges

Accelerator Facilities at TRIUMF that use Helium

- ISAC II SC Linac
 - 8 Cryomodules cooled to 4K
 - 40 quarter wave resonators
 - 2 Linde TCF50 cold boxes



Liquid Helium Supply Challenges

Helium Recovery Facility at TRIUMF



- Dedicated to recover helium from various experiments across the lab
- Re-liquefies helium where we can put it into transport dewars
- 90 – 95% recovery efficiency

Experimental Facilities that use Helium at TRIUMF



- There are several experiments that use LHe
 - bNMR, M20, TITAN
- Two new installations in the near future
 - M9B superconducting solenoid
 - TUCAN

Liquid Helium Supply Challenges

Helium Shortage Affect on TRIUMF

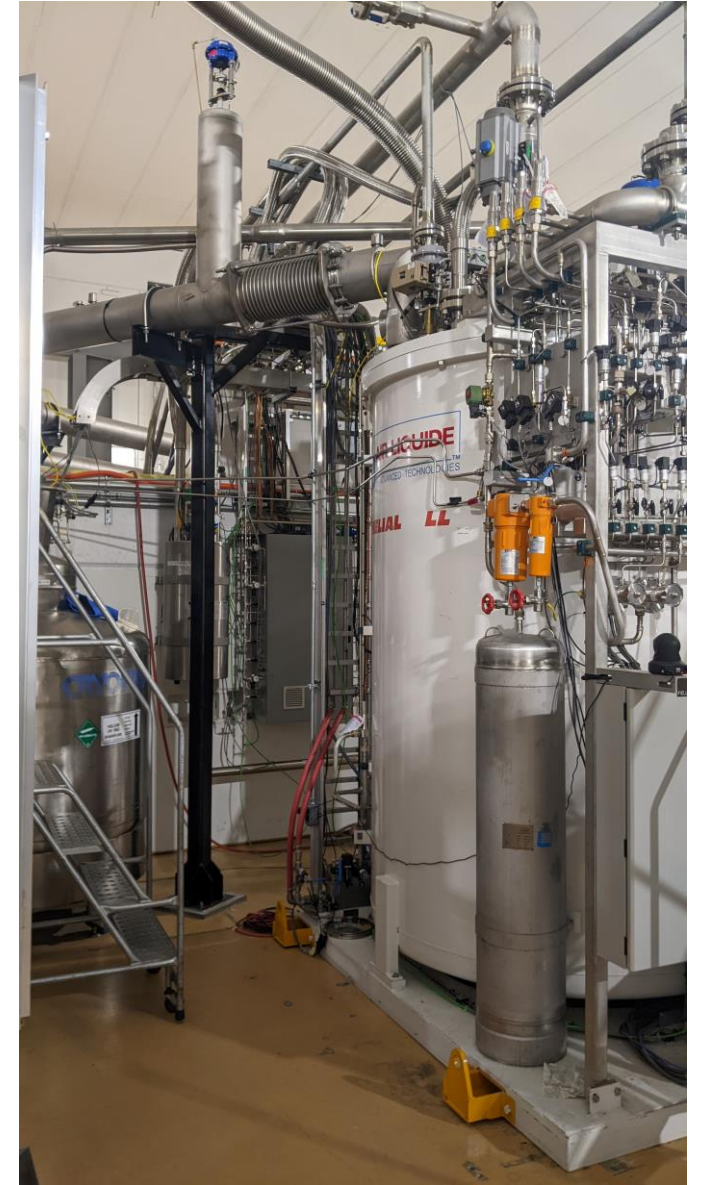
- In 2022, TRIUMF was restricted to 75% of what we ordered in 2021
 - 250 L of LHe per month
- The Accelerator Division worked even more closely with Science Division to distribute this helium to keep the various experiments running as well as our accelerator facilities
- However, in October we received our last 350 liters of LHe for 2022
 - Helium in gas cylinders also became more difficult to purchase
- For the most part, the accelerator facilities have enough to keep running
- We will be in trouble if there are electrical power interruptions, and the cryogenic systems trip off
 - E-Linac is the lowest on inventory right now
 - This will be difficult to re-start
 - Cyclotron cryogenics can survive 1 more power outage
 - ISAC II is OK for now



Liquid Helium Supply Challenges

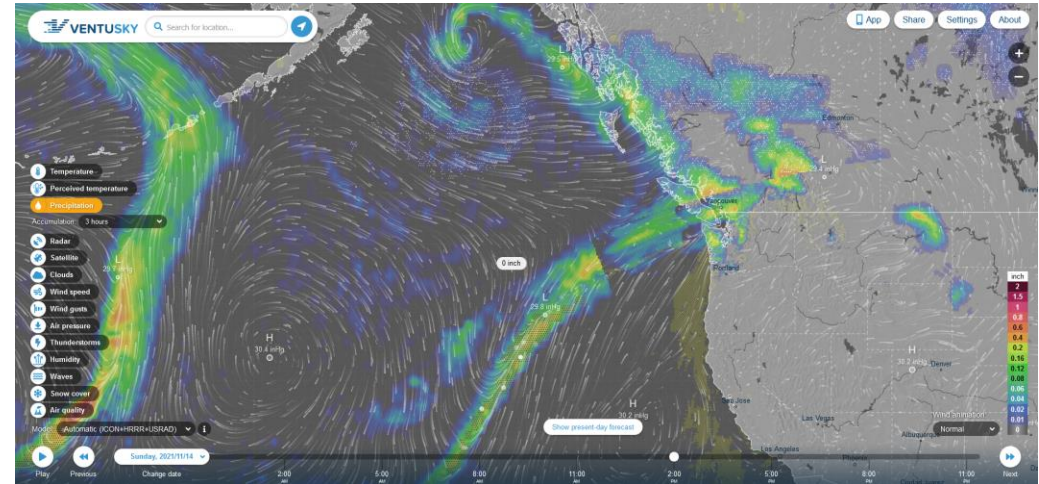
Plans on how to work with the Helium Shortage

- Change the way TRIUMF orders Helium to more efficiently distribute to all the users
- Previously, each facility would order their own supplies of LHe
- Now we are working towards have a single facility order LHe and distribute based on priorities
- The Helium Recovery Facility appears to be best situated to accomplish this
 - They have the most experience in managing limited helium supplies
- Will look into doing the same with helium gas cylinders, but there are more users here
- Look into adding more recovery piping to parts of the lab that do not currently recover helium
- If the current helium restrictions run into 2023, we will have some difficult decisions to make



Liquid Nitrogen Supply Challenges

Natural Disaster: Floods from
Atmospheric River November 16, 2021



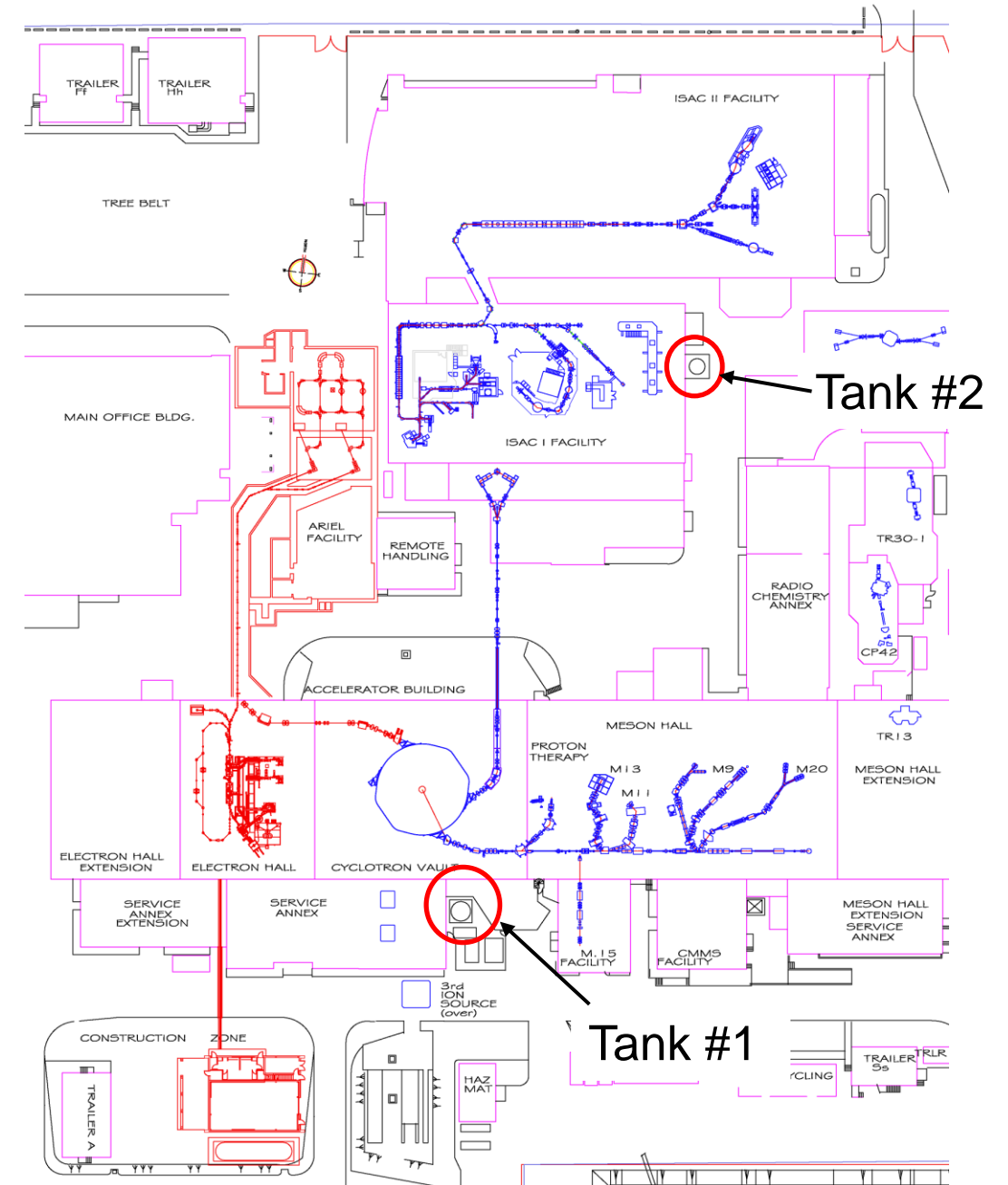
Covid 19 Pandemic



Liquid Nitrogen Supply Challenges

Liquid Nitrogen Infrastructure

- 2 x 9,000 gallon LN₂ tanks at TRIUMF
- No piping between tanks
- Vacuum jacketed manifolds, hoses and piping to carry LN₂ to various points of use



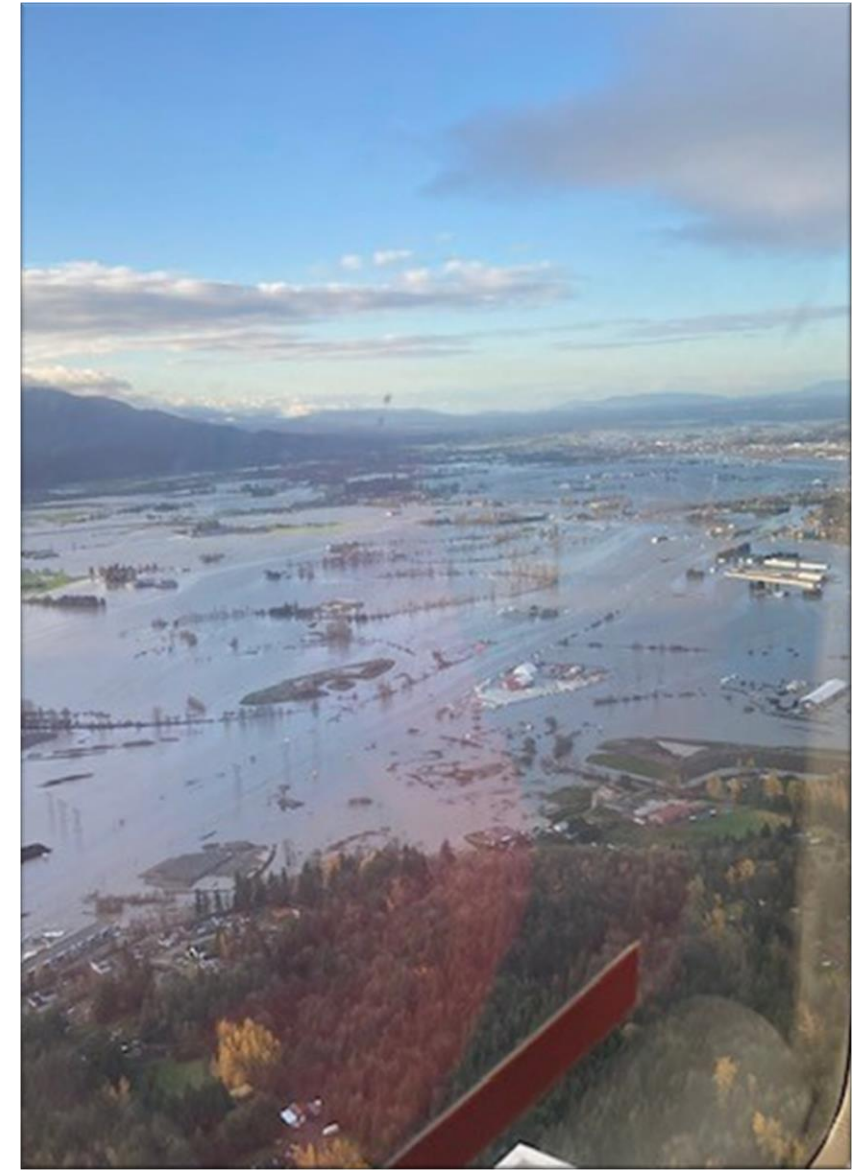
Liquid Nitrogen Supply Challenges

Natural Disaster: Flooding during November 2021
Atmospheric River



Source: BC Ministry of Transport

<https://www.flickr.com/photos/tranbc/51696731994/in/album-72177720296359549/>



Source: BC Ministry of Transport

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Liquid Nitrogen Supply Challenges

Natural Disaster: Flooding during November 2021 Atmospheric River

- What happened
 - Floods and mudslides washed out several highways through BC and Washington State
 - Supplier called me to inform us that there they would be unable to send tankers to Canada until Interstate 5 was re-opened
- What we did initially
 - Immediately contact Accelerator Div. Head (and many others) to determine operational priority
 - Notify users
 - While waiting for reply, calculate how long we can run at our current LN₂ tank levels



Source: BC Ministry of Transport

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Liquid Nitrogen Supply Challenges

Natural Disaster: Flooding during November 2021 Atmospheric River

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- Priorities set
 - Cyclotron top priority
 - ISAC II SC Linac second
 - Everything else



Source: BC Ministry of Transport

<https://www.flickr.com/photos/tranbc/51684852986/in/album-72157720143417483/>

- What we did
 - Shut down e-Linac cryogenic systems and begin warm-up of cryomodules and cold box
 - Determine how much dynamic heat load on ISAC II SC Linac to see if we can support with only 1 cold box
 - Yes
 - Shutdown Phase II cold box and have SC Linac cooled by only the Phase I cold box
 - Decide on minimum LN₂ tank levels
 - Begin preparations for full shutdown and notify affected parties if tanks cannot be refilled in time

Liquid Nitrogen Supply Challenges

Natural Disaster: Flooding during November 2021 Atmospheric River

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- Interstate 5 repaired enough to be re-opened the next day
 - Supplier informs us that they are sending tankers
 - We begin preparations to re-start, but wait until a tanker arrives just to be sure
- Start recovery of cryogenic systems that were shutdown
 - Notify everyone
 - ISAC II Phase II cryoplant restarted
 - Wait until the experiment was completed before reconnecting to the SC Linac
 - E-Linac cold box re-cooled
 - Re-cool cryomodules to 4K and then eventually 2K
 - This took 2 weeks to complete



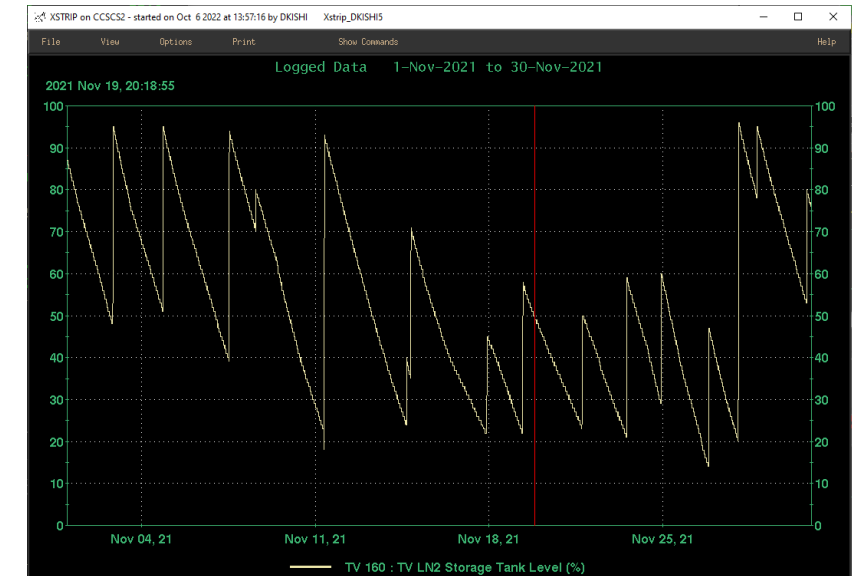
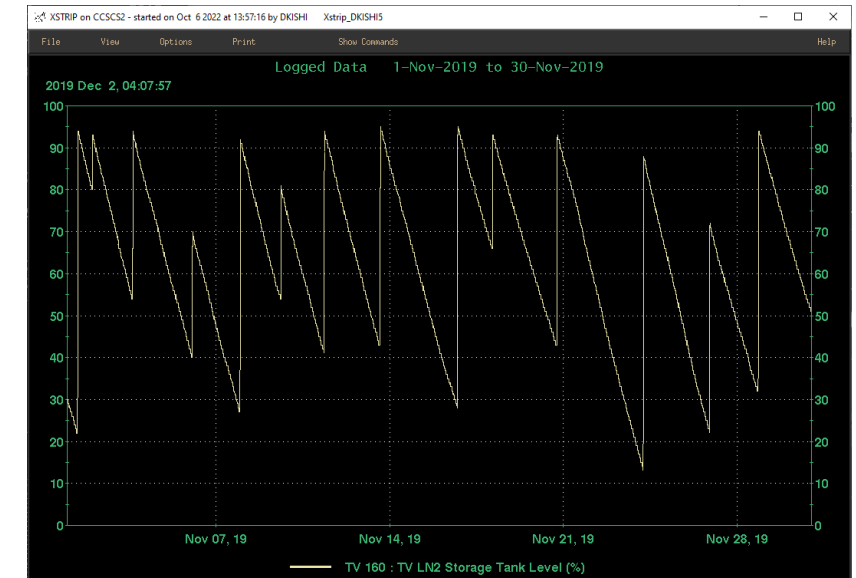
Source: BC Ministry of Transport

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Liquid Nitrogen Supply Challenges

Covid 19 Pandemic

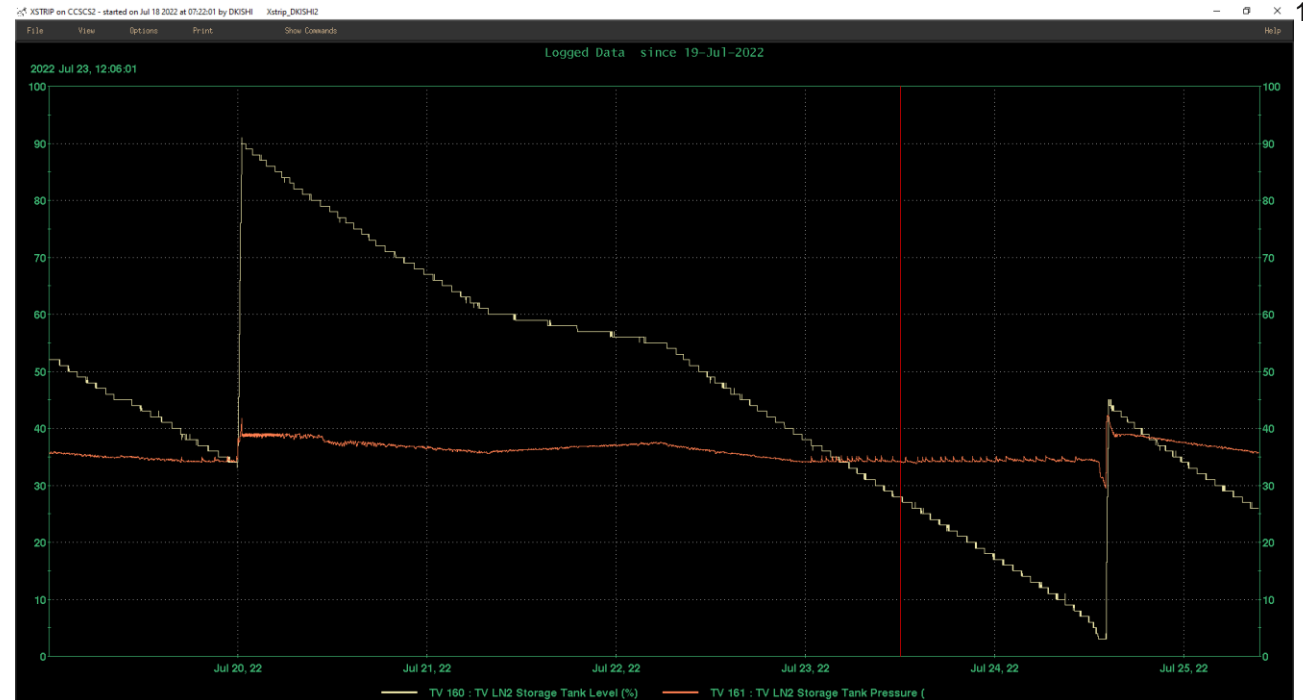
- Tanker driver shortages
- Vaccine restrictions at border crossing limiting the number of tanker drivers who could enter Canada
- Before the pandemic, LN₂ tank levels would rarely drop below 30%
- During the pandemic, LN₂ tank levels would frequently drop below 30%
 - We use about 18% per day



Liquid Nitrogen Supply Challenges

Covid 19 Pandemic

- Tanker driver shortages
 - Twice this summer the LN₂ tank that supplies the Cyclotron and e-Linac ran dry
 - July 24, the low levels were noticed
 - Contact Supplier to find out when the tank will be refilled
 - It will be tight
 - Inform all affected parties
 - Shut down e-Linac to run the Cyclotron longer
 - Began shutdown of Cyclotron Operations, but tanker arrived just in time so restart was quick

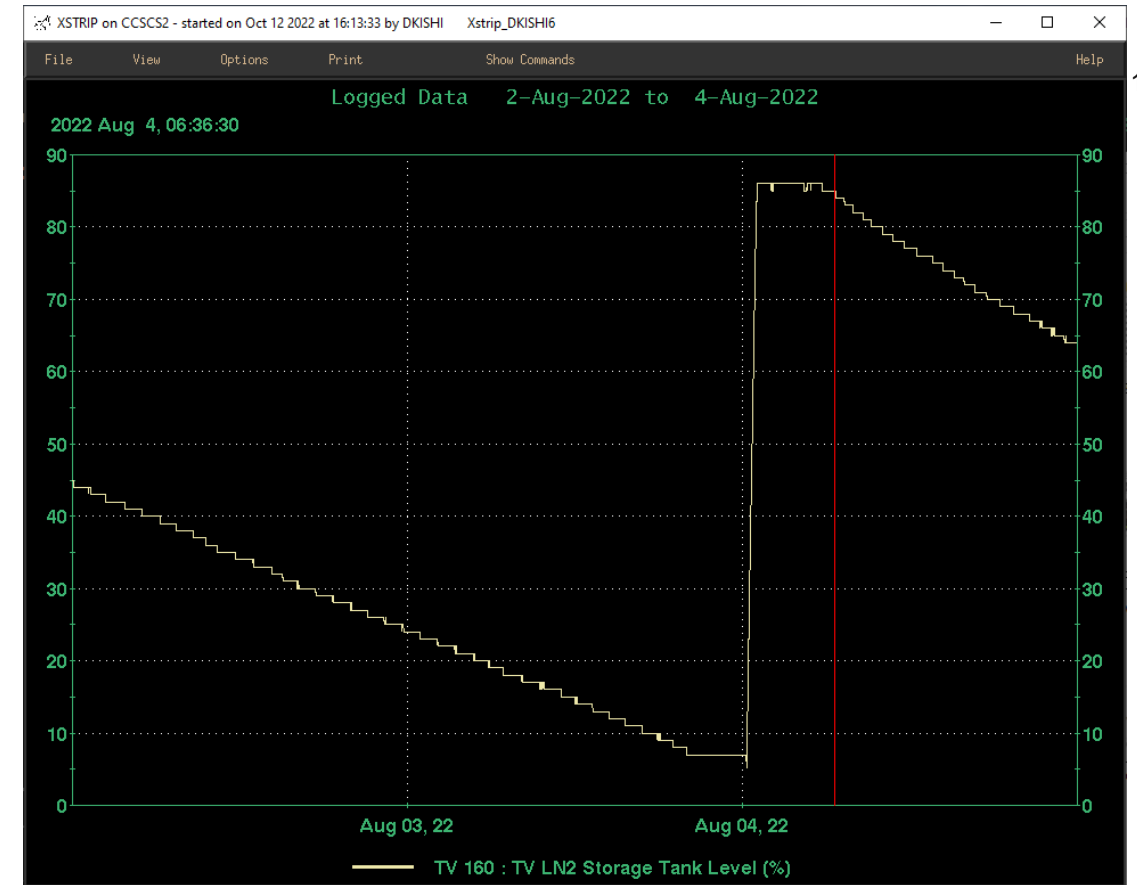


- Only incurred 5 hours of cyclotron downtime
- No downtime on e-linac as we were able to restart and re-cool before it was needed

Liquid Nitrogen Supply Challenges

Covid 19 Pandemic

- Tanker driver shortages
- August 3, tank level is low again
 - Calls to supplier and we knew the tanker would not arrive in time
 - Notify all affected users
- Again shut down e-linac cryomodule cryogen supply
 - Keep cold box running but turn off LN₂ pre-cooling
- Ran cyclotron until tank is at 5%
 - Shutdown at 8:00 PM
- Tanker arrives 4 hours later (just after midnight)



- Recovery begins first thing in the morning
- Total Cyclotron downtime 20 hrs
- E-linac downtime 8 hrs

Liquid Nitrogen Supply Challenges

What did we need to maintain operations?

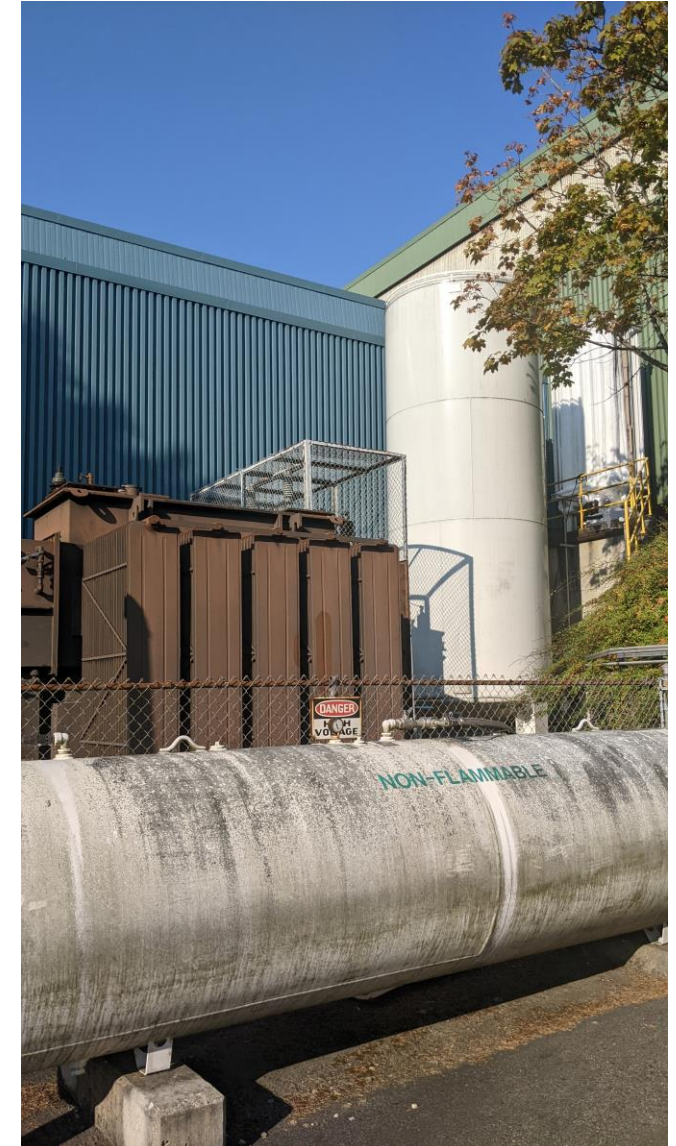
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- Know what are the lab priorities
 - What needs to keep running and what can be sacrificed
- System expert flexibility
 - People who are willing to come in at odd times to get stop and start systems at odd hours or days
 - Cross trained staff so that you are not relying on one individual to do certain tasks
 - We are a small lab so this is cannot always be taken for granted
- Maintain communication with affected users
 - This is where Ops is especially helpful

Liquid Nitrogen Supply Challenges

Possible Future Upgrades

- Upgrade LN₂ tanks from 9,000 to 13,000 gallons
 - We would need to upgrade the support pads they sit on
- Install interconnection piping between the 2 sides of the lab
 - Would increase our flexibility
 - Long vacuum jacketed piping runs
 - Cyclotron 80K cryopanels are sensitive to LN₂ quality
- Install a third tank somewhere between that can share to both tanks
 - Where to install
- Install LN₂ production facility
 - We would be much less reliant on our supplier
 - Costs to procure and operate?
 - Where to install?



Thank you
Merci

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