INL/MIS-21-62836-Revision-0

FY2021 Information Exchange for MINOS: Multi-Informatics for Nuclear Operations Scenarios - Acoustics

June 2021

David L Chichester, Edna S Cardenas, Scott M Watson, Jay D Hix, James T Johnson, Kei Takazawa, Jonathan Tobin, Brain Williams, Tyler Yoshiyama

Changing the World's Energy Future

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration
Defense Nuclear Nonproliferation

FY2021 Information Exchange for MINOS:
Multi-Informatics for Nuclear Operations Scenarios

Task 2.5: ATR – Collections Support
Task 4.4: Transfer of Nuclear Materials - Acoustics

Presenter: David Chichester, INL

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U. Hawai'i
Milton Garcés, Kei Takazawa, Jonathan Tobin,
Brian Williams, and Tyler Yoshiyama

May 2021

Idaho National Laboratory

Overview

- This task area is a collaboration between INL and the University of Hawai'i
  - Building on a 5+ year effort to explore how real-time acoustic monitoring can be expanded to support nuclear nonproliferation and nuclear security
  - INL: nuclear facility operations, nuclear nonproliferation, data analytics, field operations and test support
  - UH: infrasound and acoustic signal generation and propagation, acoustic data collection and field support, smartphone platforms, cloud data warehousing and analytics

- This project is now benefiting (and benefiting from) two NA22 university consortia
  - Consortium for Enabling Technologies and Innovation (ETI)
    Data analytics, advanced method development (nonproliferation), signature collection (e.g., unmanned aerial systems)
  - Consortium for Monitoring Technologies for Verification (MTV)
    Scenario analysis, advanced method development, signature collection (e.g., high explosive detonations)

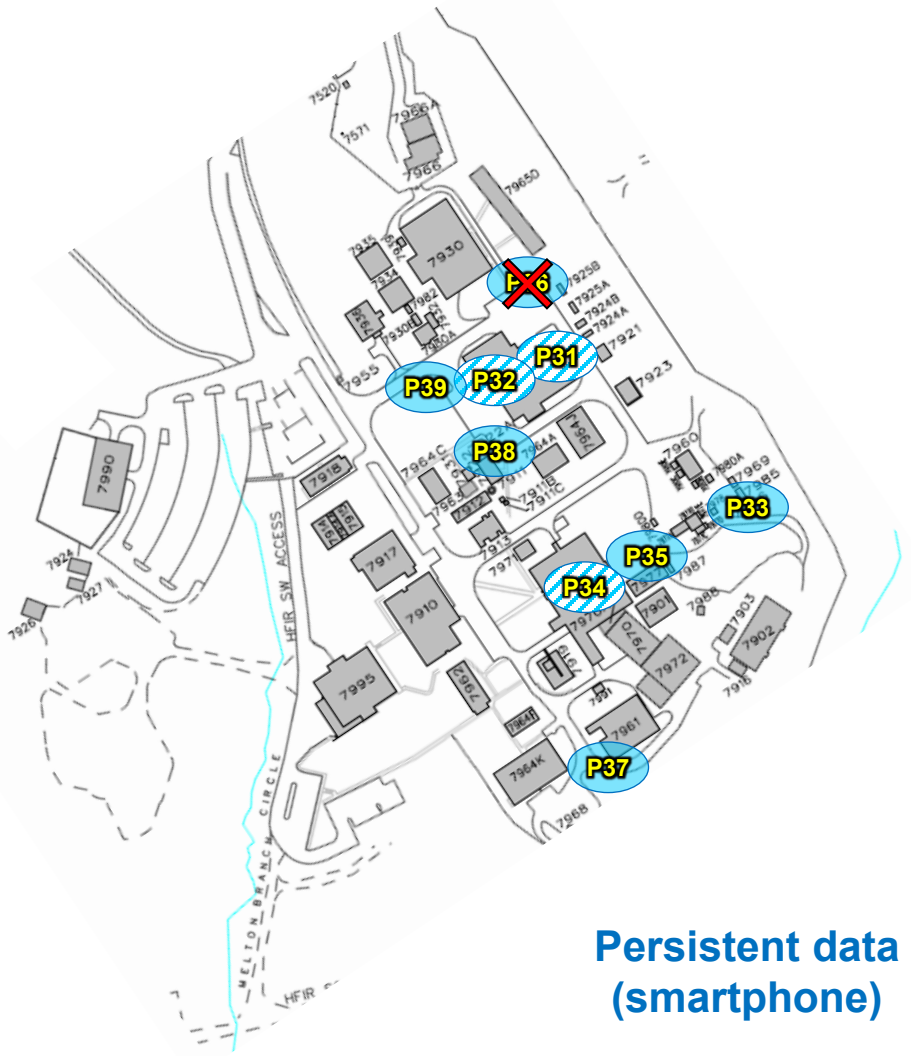
Thank You

- To our program sponsor: NNSA's Office of Proliferation Detection and Angie Sheffield our Program Manager
- To the MINOS Leadership Team: Jared Johnson, Paula Cable-Dunlap, Jessie Gaylord, Kary Myers
- To the other labs that help with collections support:
  - Oak Ridge National Laboratory (Chris Young and Riley Hunley) for onsite logistics support
  - Lawrence Livermore National Laboratory (Steven Magana-Zook) for data formatting and transfers from AWS to LBNL)
  - Lawrence Berkeley National Laboratory (Brian Quiter) for data transfers, data warehousing and access
  - Argonne National Laboratory (John Krebs) for data curation and validation; thrust leadership
- To the data analytics teams that use our data and collaborate with us, including:
  - Sandia National Laboratories (Tom Reichardt and Sam Eaton)
  - Oak Ridge National Laboratory (Ken Dayman and Jason Hite)
  - Los Alamos National Laboratory (Emily Casleton)

Thank You

Activity in FY2021

- Task 2.5: ATR - Collections Support, Work Control, and Hosting
  - Finalize deployment plan with approvals (done)
  - Complete temporary deployment (done)
  - Supply relevant ground truth from collection (due: 30MAY2021)
- Task 4.4: Infrasound Data Collection and Analysis
  - Maintain deployed array of smartphone-based acoustic sensors, including deployed hardware and data streaming service (underway)
  - Complete analysis of 2020 data from smartphones with focus on targeted transfer event detection and ancillary equipment operations (done: MEMO INL-MIS-20-61158)
  - Support revised signal collection plan (due: 30SEP2021)
  - Post analysis products to data portal (underway)

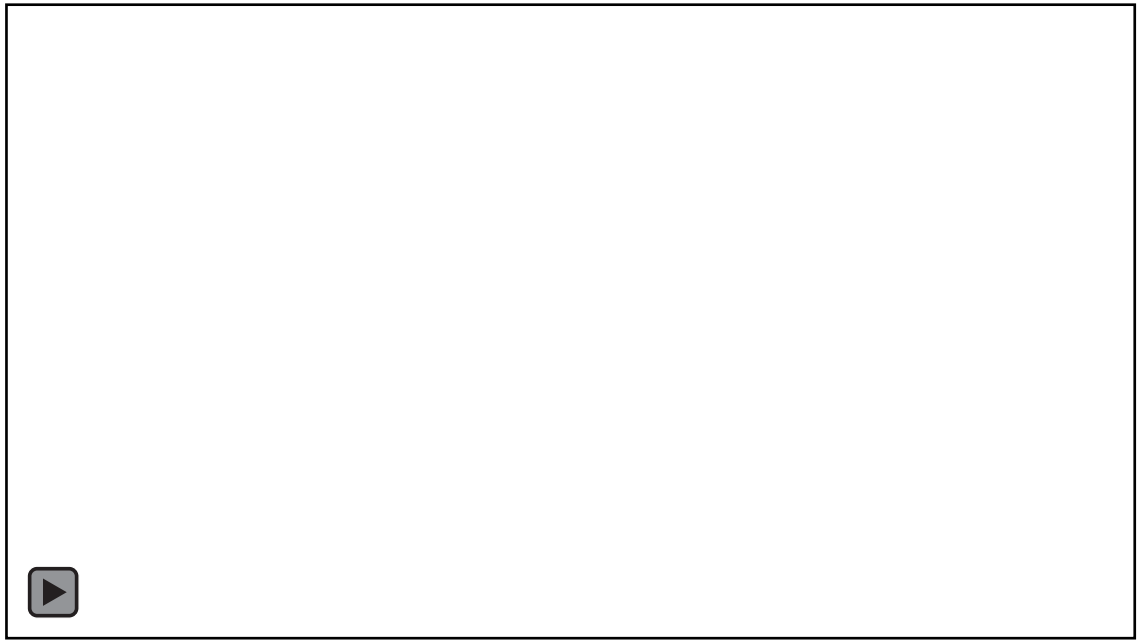


Persistent data (smartphone)

P40 *on top of ridge overlooking HFIR/REDC*

Notable Outcomes So Far in FY2021

- ICE LABYRINTH measurement campaign at ATR
  - Planning, work controls, set-up, execution, monitoring, take down and removal
  - High operational availability of all equipment (daily inspection and data transfers for the first month, bi-weekly visit for second and third months)
  - No injuries or other problems, despite a) adverse weather conditions and b) COVID and restrictions
- Continued maintenance of the deployed smartphones at HFIR
  - Q1: Operational availability was 95.1%
  - Q2: Operational availability was 98.5%
    - New metric: Data was cloud accessible within 2-minutes of acquisition 90.4% of the time

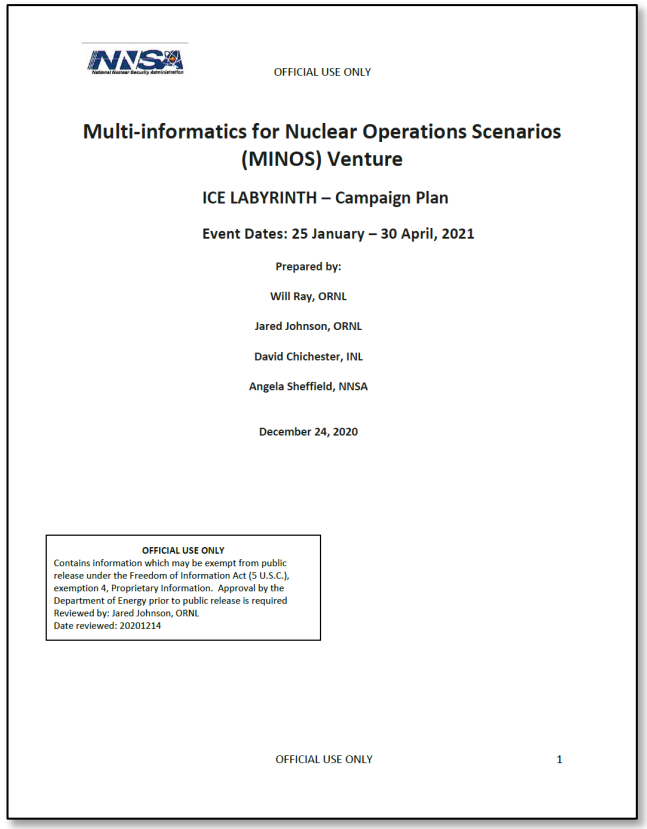


Water vapor rising from the ATR cooling tower, 10 March 2021

- Completed analysis examining infrasound and low-frequency acoustic data signals recorded during a Np dissolution at REDC and during fuel transfers at HFIR, INL-MIS-20-61158
- Support to MINOS data analytics teams

ICE LABYRINTH

- ICE LABYRINTH (IL) purpose: to provide a unique set of measurements to enable a quantitative assessment of whether data analysis methods developed at HFIR, for estimating reactor power levels, are applicable at another DOE research reactor
- Location: INL's Advance Test Reactor (ATR), a pressurized light water reactor
  - Temp: ~71 °C (160 °F)
  - Pressure: 2.69 MPa (390 psi)



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Multi-informatics for Nuclear Operations Scenarios (MINOS) Venture

ICE LABYRINTH – Campaign Plan

Event Dates: 25 January – 30 April, 2021

Prepared by:

Will Ray, ORNL

Jared Johnson, ORNL

David Chichester, INL

Angela Sheffield, NNSA

December 24, 2020

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Reviewed by: Jared Johnson, ORNL
Date reviewed: 20201214

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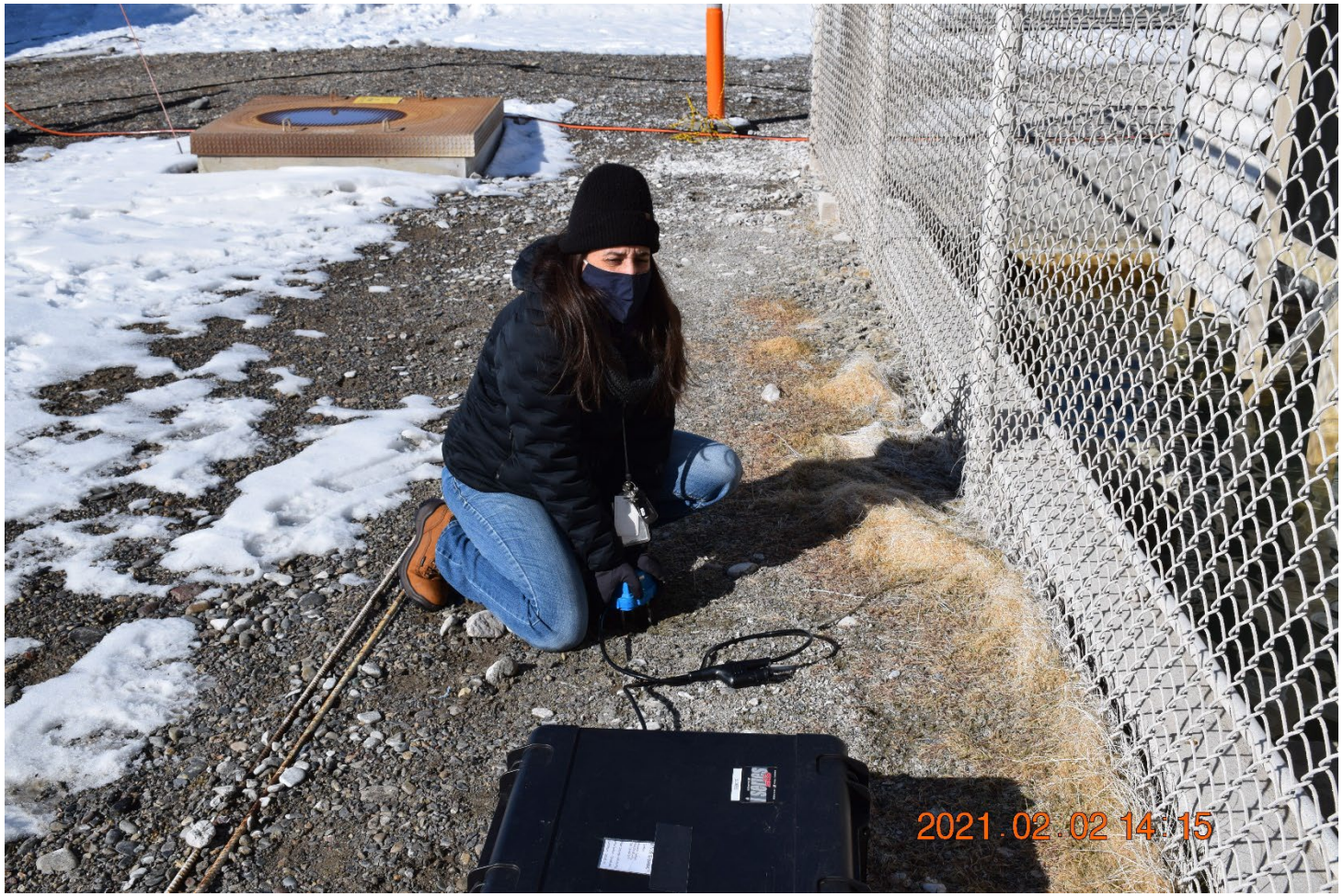
ICE LABRYRINTH campaign plan

Last day of installation, 5 FEB 2021

IL Photos

Installing smartphones near the cooling tower



Installing a seismic sensor near the cooling tower

IL Photos

Staging ORNL equipment at Trailer 1

Installing an EM sensor near the motor for fan two

IL Photos

A sensor tree with a weather station, a thermal imager, and a MERYLN

Smartphones installed on the cooling tower deck

IL Photos

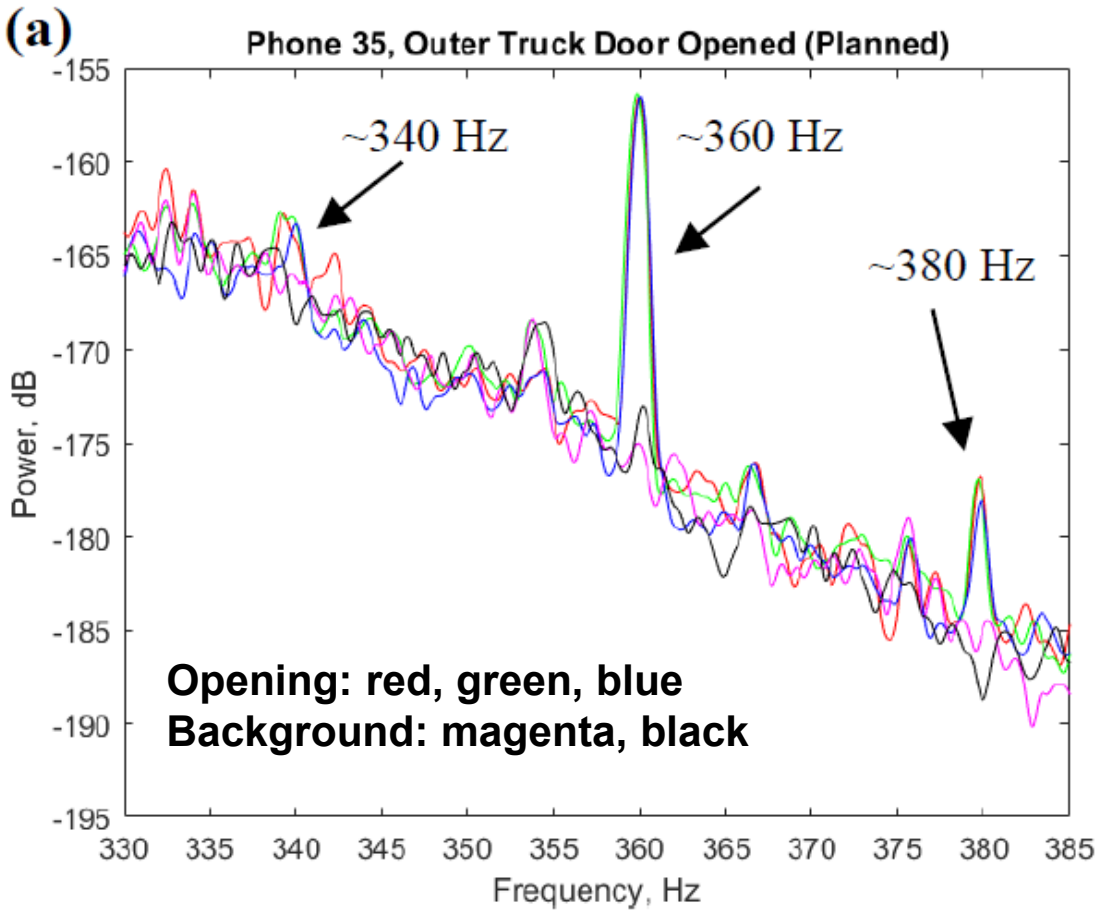
Installing a seismic sensor outside the ATR fence line

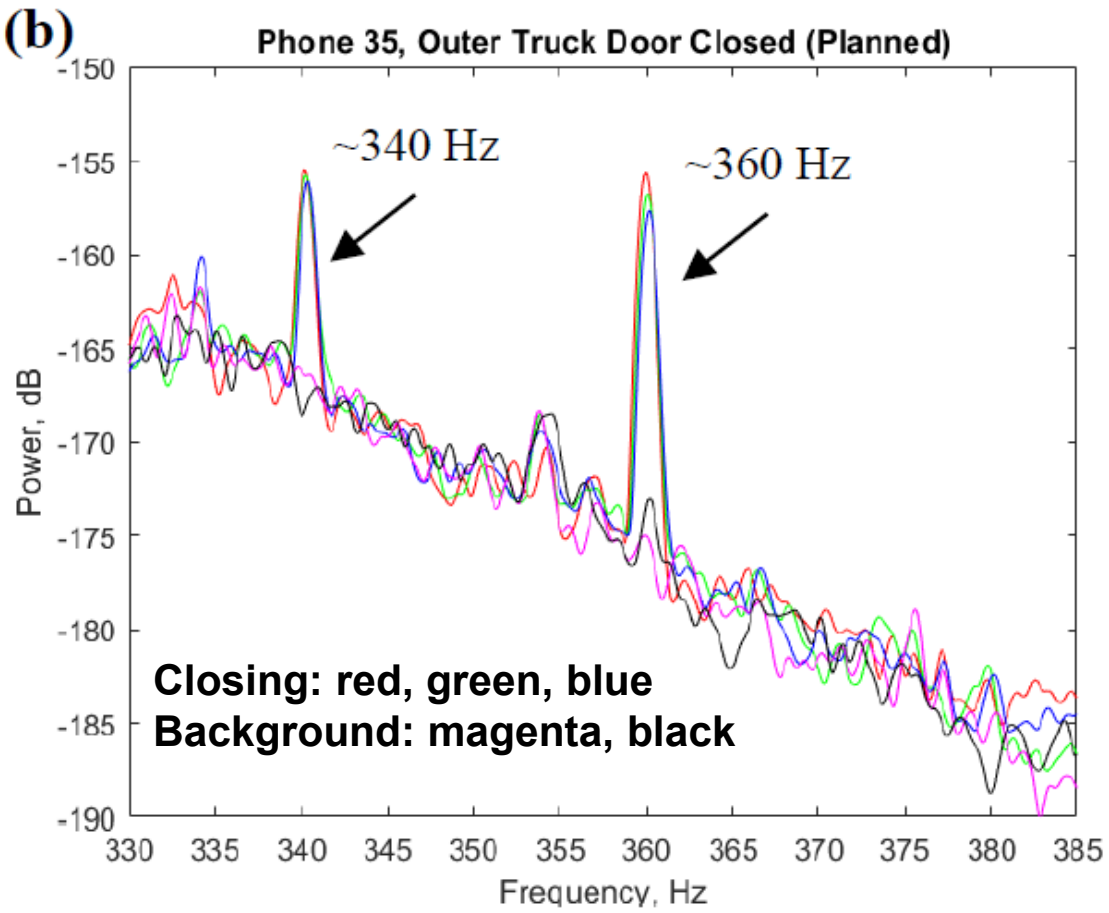
IL Photos

A visit to the deck on the cooling tower

Acoustics – Data Analysis
HFIR Tuck Lock Door - Planned

- Compendium Vol. 3
  - HFIR truck lock door opening and closing planned event

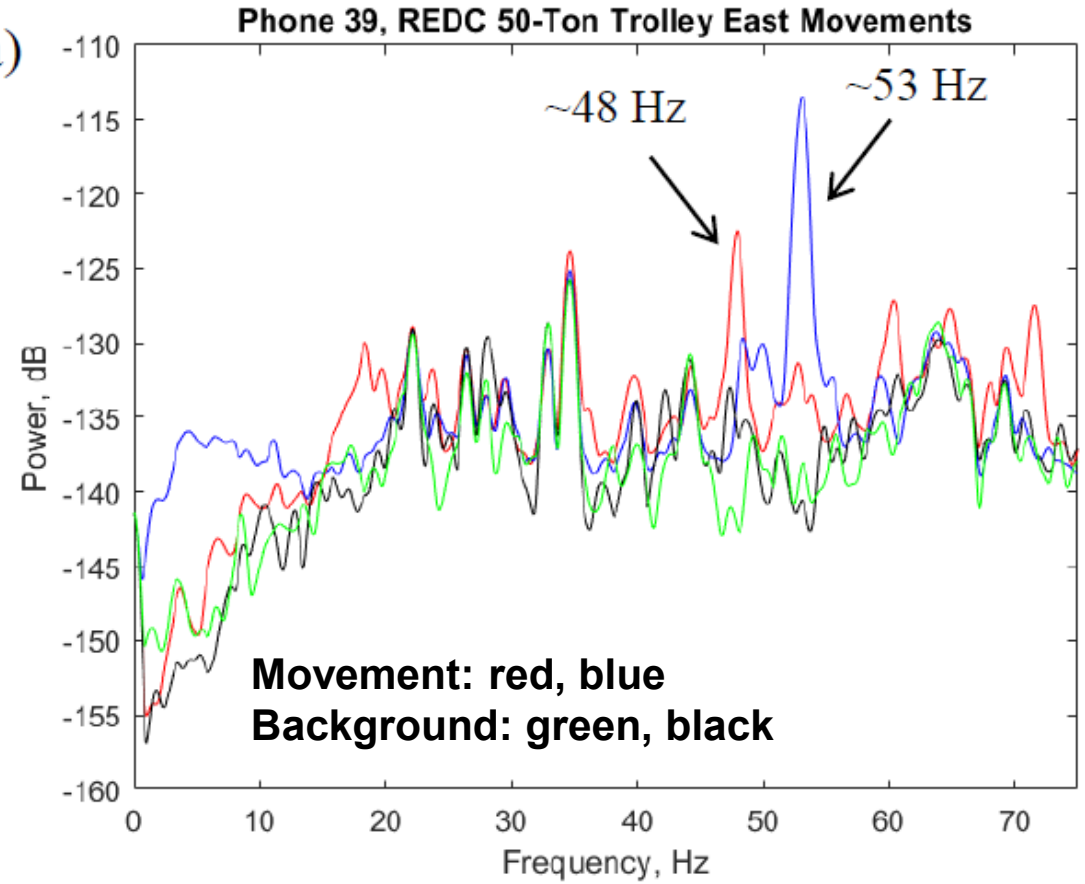




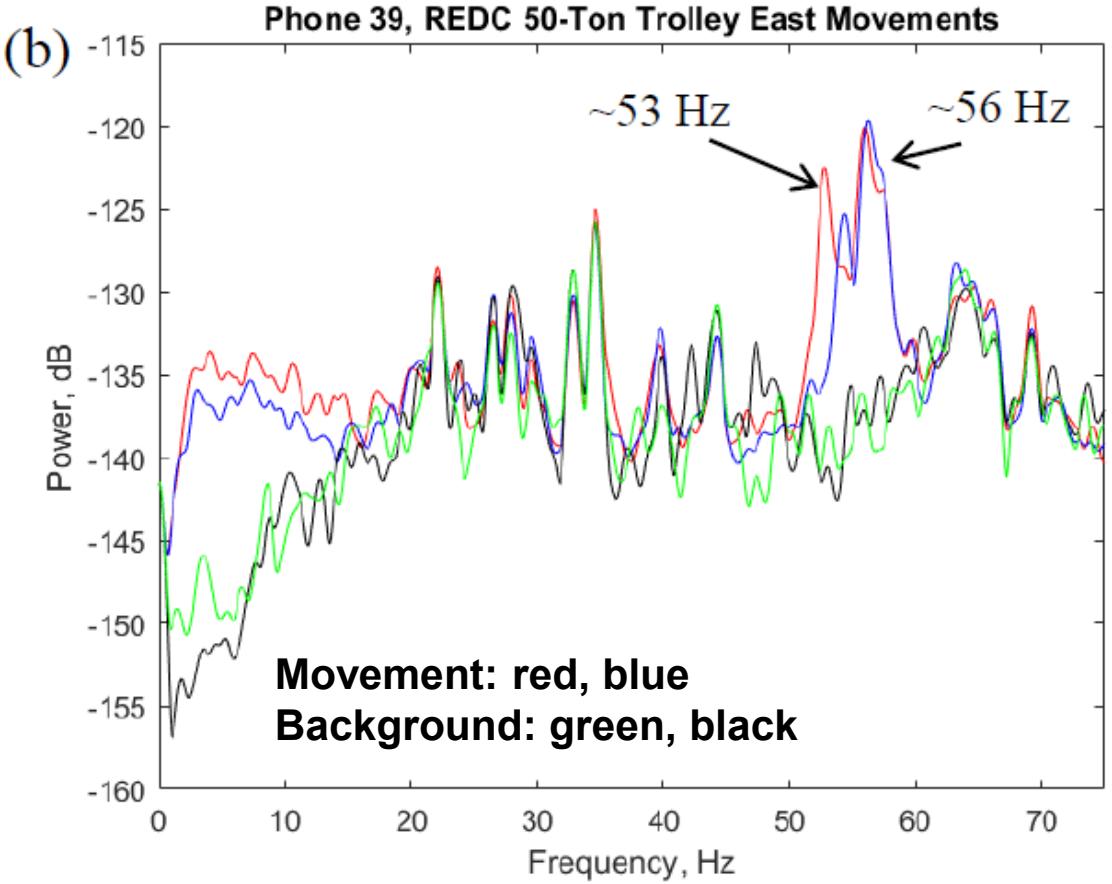
Acoustics – Data Analysis
REDC Outdoor Crane - Planned

- Compendium Vol. 3
  - REDC outdoor crane – trolley movements

(a)

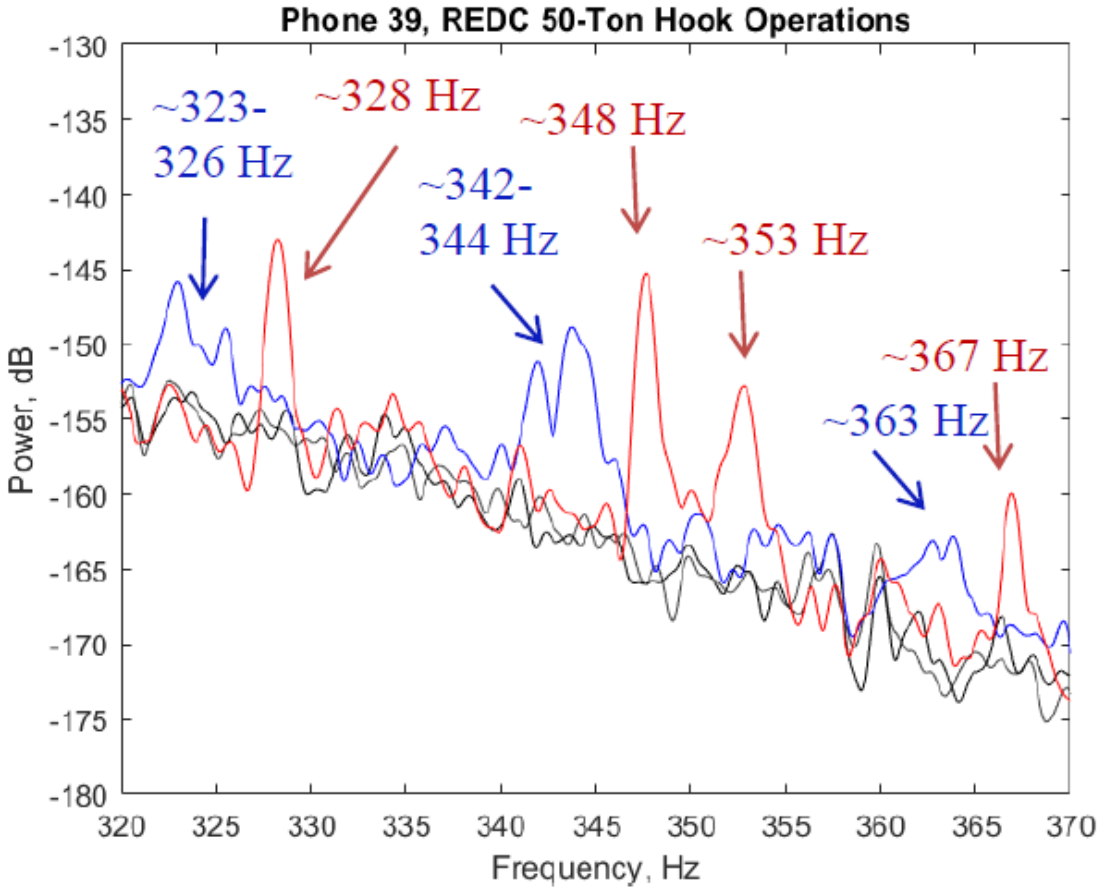


(b)



Acoustics – Data Analysis
REDC Outdoor Crane - Planned

- Compendium Vol. 3
  - REDC outdoor crane – 50-ton hook raising and lowering

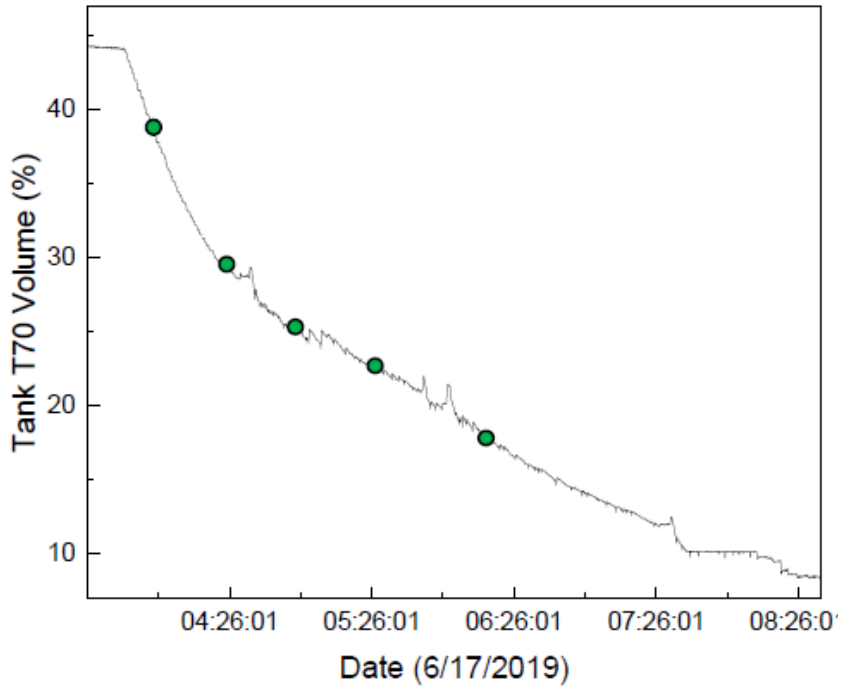


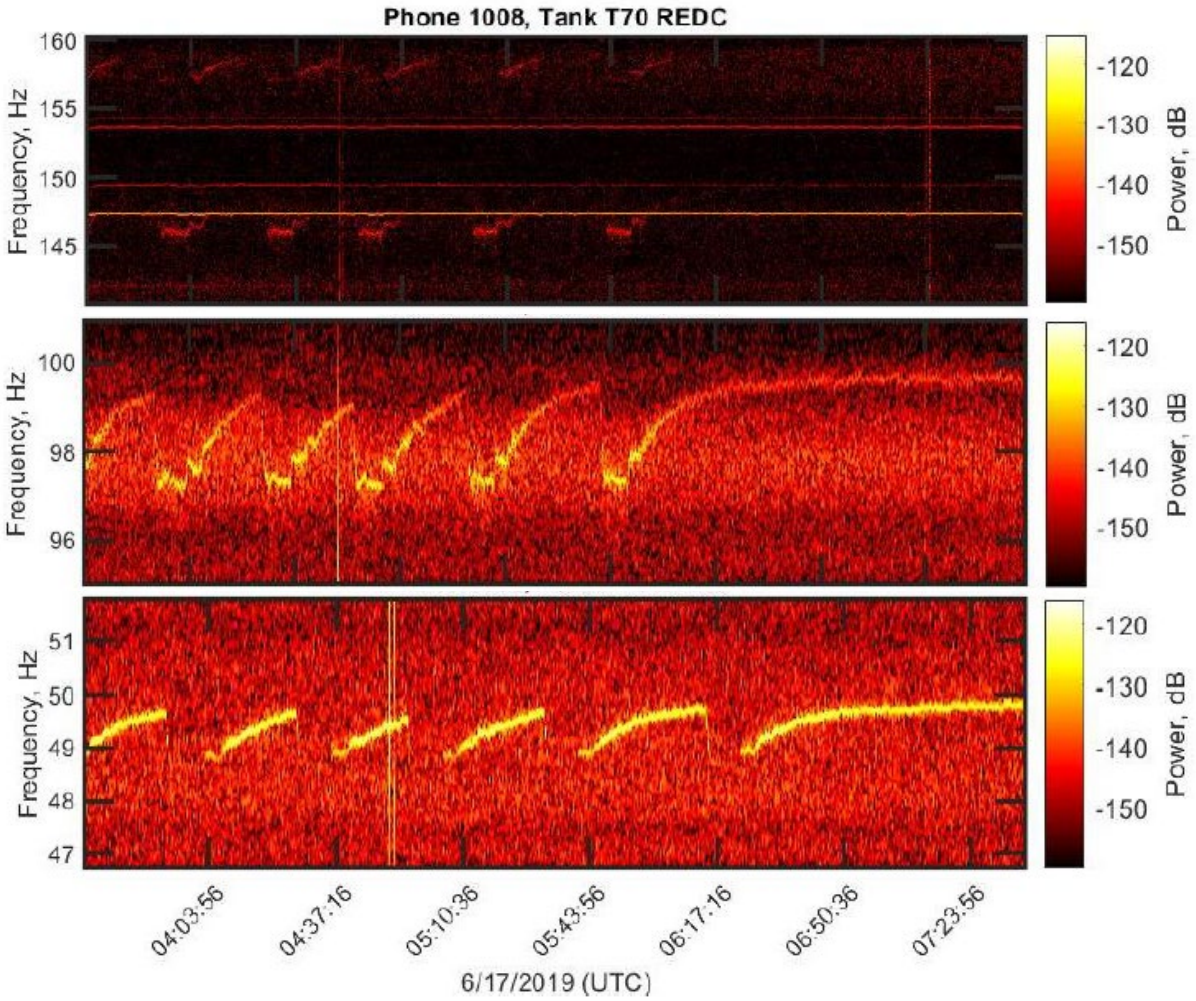
Raising: red
Lowering: blue

Acoustics – Data Analysis
Np Dissolution

- INL-MIS-20-61158
  - Np dissolutions
  - Clear, unique signals observed in frequency spectrum from sensor in REDC during tank transfers but insufficient ground truth to attribute observation to distinct activities

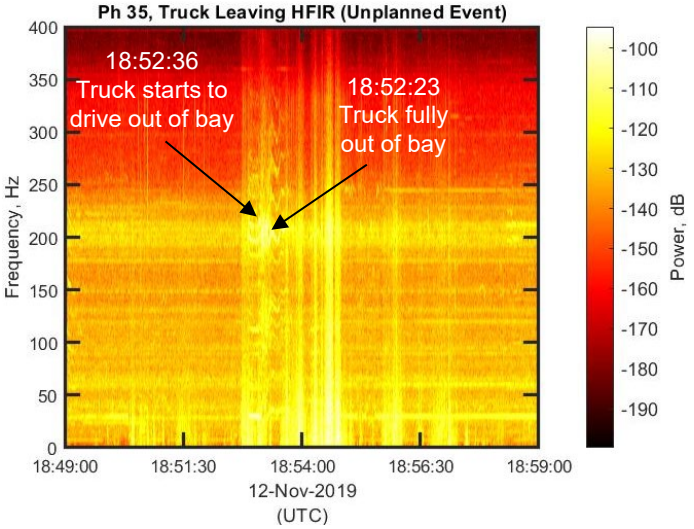
Tank volume change during Np dissolution: green dots correspond to peaks in spectrogram

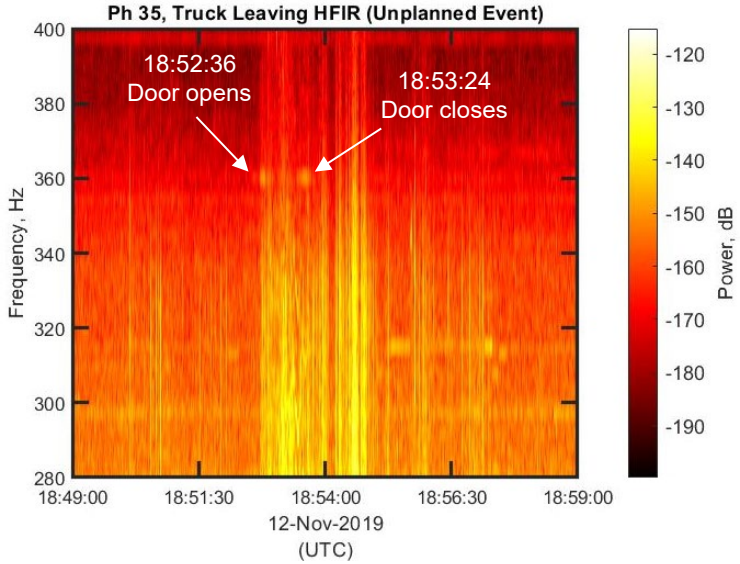




Acoustics – Data Analysis
Fuel Departure at HFIR - Unplanned

- INL-MIS-20-61158
  - Fuel departure at HFIR (unplanned event)
  - Acoustic data suggests a two-part time-sequence can be used to detect the truck exiting the HFIR high bay. The door opening/closing (18:52:36/18:53:24) and then the truck exiting the bay (18:52:36).
  - A tonal time-picker could used to alarm on this signal.





Truck leaving HFIR, hauling spent fuel container

Acoustic data associated with a tuck exiting the HFIR truck lock

Acoustics – Data Analysis
Fuel Departure at HFIR - Unplanned

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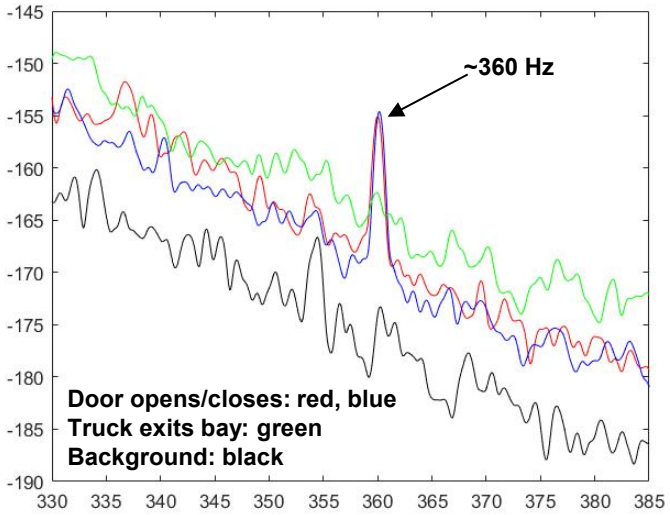
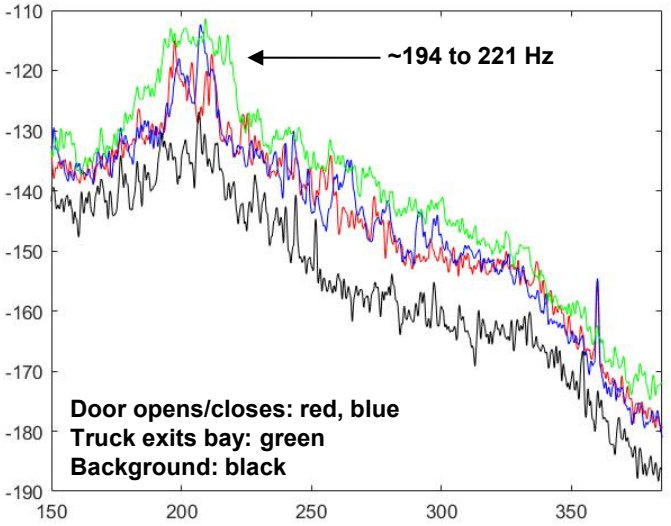


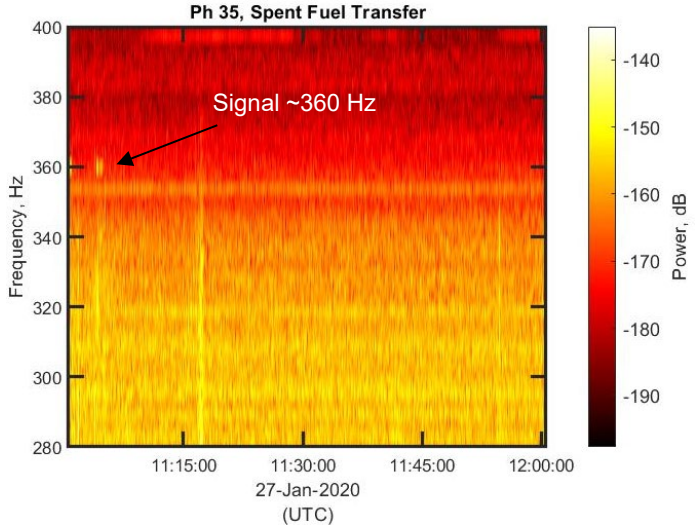


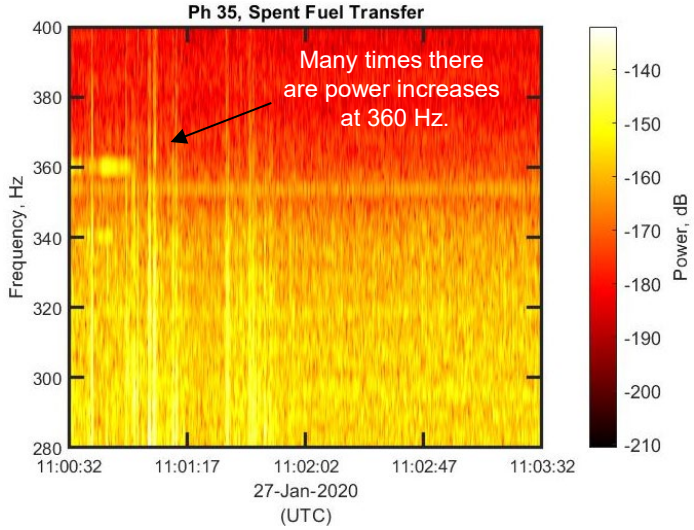
Truck leaving HFIR, hauling spent fuel container

Acoustic data associated with a tuck exiting the HFIR truck lock

Acoustics – Data Analysis Searching for 360 Hz Signal

- Can we find the HFIR bay door opening/closing using the 360 Hz signal?
  - Implement z-test (inspired by Emily Casleton's work)
  - Use background signals at frequencies just below and above 360 Hz signal
  - Employ algorithm on spent fuel dates indicated in spreadsheet provided by John Krebs
  - 360 Hz signals discovered on 1/27/2020 at 11:00 am UTC
  - Use multiple methods to pinpoint bay door opening/closing
    - Track time power is increased at 360 Hz
    - It takes ~23 s for the door to fully open/close





Zoom in to 360 Hz signal

Summary

- Major focus of our effort so far for this FY was preparing for deployment at ATR, and then doing it
- We are continuing to maintain the installed smartphones at HFIR
- We are now exploring more detailed analyses of data from HFIR
  - Other teams have focused on using the acoustic data to assess long-term status (e.g., reactor power)
  - We are focusing on transient signatures to pinpoint activities – HFIR truck lock, REDC crane

View of the gear reduction box for ATR fan #2