PNNL-26107

Stack Release Data Requirements for the STAX (Source Term Analysis of Xenon) Experiment

October 2016

Purpose

This document describes the data required to be collected from a medical isotope production (MIP) stack detector network to meet the goals of the STAX (Source Term Analysis of Xenon) experiment. These data requirements were compiled from input from multiple National Data Centers (NDCs) and the International Data Center (IDC) supporting the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The data requirements outlined in this document will ultimately determine the hardware and software specifications needed for this experiment.

Background

Radioxenon released from MIP is detected every day by the CTBT IMS and can complicate nuclear explosion detection activities. The STAX project is an experiment focused on the development of a worldwide MIP stack detector network to help improve discrimination between industrial activities and nuclear explosions. The experiment will be conducted by a large team of people from the Workshop on the Signatures of Man-Made Isotope Production (WOSMIP) technical community. This workshop has been bringing the monitoring and medical isotope production communities together for several years with stack data sharing being one of its primary objectives. This experiment will continue the progress made in the WOSMIP community by establishing a detector network specifically designed to collect data that can help differentiate civil nuclear activities from weapons-related activities.

The STAX experiment is planned to be a five year effort to install up to 18 detector systems at MIP facilities, transmit the collected data to a central repository and develop algorithms to analyze this data. Medical isotope facilities already deploy a facility stack monitor for regulatory purposes, but these stack monitors typically measure for large releases relevant to health and safety regulations and are not sufficient for the interests of the nuclear explosion monitoring community. This project will provide a high-energy resolution stack detection system (not intended to replace the existing regulatory monitor) to producers willing to participate in this experiment. If a producer has sufficient technology already deployed, or prefers to deploy in-house equipment, existing stack release data can be collected and utilized. To improve deployment time, the project will be based on current commercial off-the-shelf (COTS) detector technologies.

The long-term goal of this effort is integration of the STAX Network data with the current IDC data flow in support of the CTBT. During this experiment, the data collected from the network of stack detectors will be transmitted to an experimental data repository (separate from the current IDC database and separate from the operational processing system) for compilation and analysis. The data may also be simultaneously transmitted to the CTBTO's Virtual Data Exploitation Centre (vDEC) to develop data accessibility methods. Figures 1 and 2 below provide a high-level logistical view of the planned data stream proposed in the experiment. Although this experimental database will be set up separately, the project team will work to use identical or similar methods to what the IDC currently uses to allow for smooth data integration into the IDC data flow at the end of the project. The experiment will include confidential data transfer and storage that will meet the medical isotope producer's and the CTBTO's requirements of data confidentiality standards.

The initial steps in executing this experiment are communicating the goals and getting various participants on-board, developing an experimental work plan and schedule, and listing the specific

data/technical results needed to achieve these goals. The first step has been initiated and will be ongoing throughout the project. The second step can be found in Doll et al.[1], and the third step is being captured in this document. To meet the data requirements outlined in this document, specific detector technologies and equipment will be identified and investigated throughout the project. Software specifications will be guided by the data requirements listed in this document and will include data input, data processing, data storage, data viewing/reporting, and outputs from the experimental database. Input provided by the CTBTO in the software specifications document will be incorporated in the software development for this STAX experiment[2].

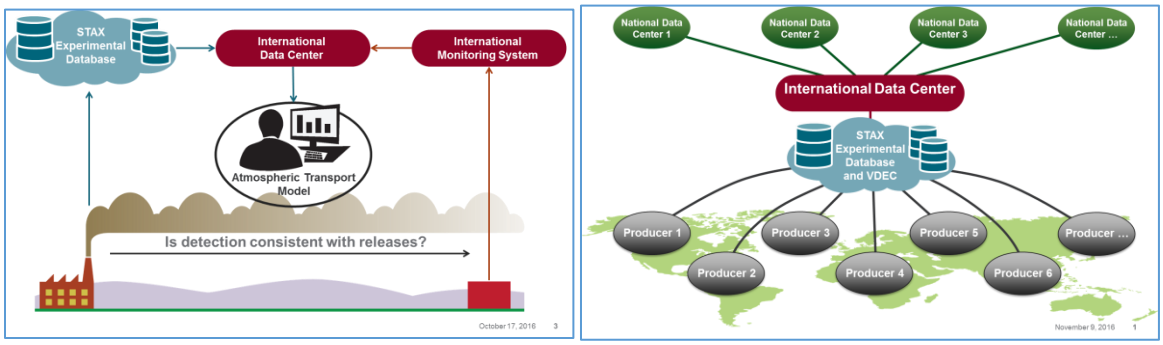

Figure 1. Images suggesting how the medical isotope production stack release data may flow in the STAX experiment.

Data Requirements

Data Types and Quality

This project will employ a high-energy resolution stack detection system. The main components of this system will be a radiation detector and a mechanism to indicate the measured gas flux from the stack. The latter will consist of air flux measurement through the detector chamber as well as the amount of air flux through the stack. The primary data that will need to be collected for this experiment is the gamma energy spectrum from the detector system. The illustration in Figure 2 below shows examples of data required to meet the goals of this experiment. The raw/unanalyzed gamma energy spectrum can just be stored at the MIP facility if needed, though it is preferred that the spectra are sent and stored in the STAX experimental database. After a gamma spectrum is collected, analysis can be executed by software at the MIP facility and/or within the STAX database. Other metadata will also need to be sent to the STAX database to analyze the data. QA/QC (periodic calibration data) will be incorporated and is necessary to calculate accurate isotopic concentrations. Detector State of Health (SOH) report will need to be sent periodically to ensure the system is functioning properly. Stack and detector sample cell air flow rates are needed to understand the fraction of total stack emissions being measured by the detector. Ancillary metadata like isotope production information and meteorological data from a nearby weather station could be helpful, but are not required.

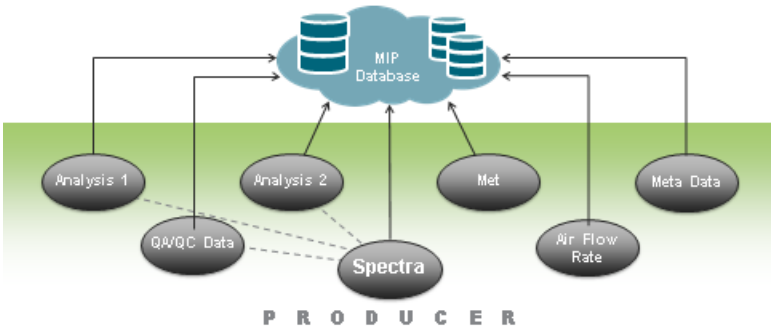

Figure 2. Data Types for the STAX Experimental Database

Gamma Spectra

Gamma spectra will need to be collected by the stack detector that will allow measurement of relevant radionuclides including the radioxenon isotopes needed for nuclear explosion monitoring, i.e., ^{131m} Xe, ^{133m} Xe, ^{133}Xe, and ^{135}Xe. The goal for this experiment is to collect energy spectra with resolution and efficiency needed to measure the activity of ^{133}Xe. In addition, the gas flow through the detector chamber and in the stack itself must be measured. The gamma spectrum analysis together with the determined gas flow will allow the xenon activity released to be determined. Therefore, the overall uncertainty accounting for the measured activity and the uncertainty in the gas flow (and other contributing parameters) should be about ±10% relative standard deviation (RSD). Additionally, the detector resolution must allow discrimination between various interferences from isotopes of krypton, iodine and any other species present for a ^{133}Xe activity range of 1E9 Bq d^{-1} to 1E13 Bq d^{-1}. The detector will actually measure some fraction of this activity as only a portion of the gas released from the facility stack will be measured by the detector. The detector will likely need to be shielded to ensure that spectra include only the measured activity from the sampled stack gas flow and not from the activity that may be elsewhere in the facility. As stated above, depending on the producer's requirements, the raw gamma spectra can be held only at the medical isotope production facility or be sent to the secure STAX experimental database for storage (with the latter being preferred).

Spectral Analysis Reports

Analysis reports will need to be generated at the MIP facility and/or at the STAX database that provide activities of detected isotopes. All relevant radionuclide isotopes and their precursors should be reported which includes the 4 radioxenon isotopes listed above.

A time series report should be generated that provides the total activity of each radioxenon isotope that is being released from the stack. These time series reports could be generated with activities reported at shorter and longer time intervals as needed or is available. A time series report is simply the activity (or activity concentration) per unit time from the interpretation of the spectra during that unit time.

QA/QC Data

A detector calibration plan will be established that ensures accurate reporting of measured isotope activity and requires minimal support from the medical isotope producer. Part of this plan will include the frequency at which the calibration data will need to be sent and stored in the STAX database. This could consist of a Canberra LABSOCS calibrated detector that would be calibrated yearly with a standard source check. A suggestion was made by one NDC to add a pulser to the detector system for QA/QC purposes. Also the data from the actual stack release measurements can be utilized for QA/QC purposes, e.g. for checking energy and resolution calibration. Detector SOH reports will need to be sent and stored in the STAX database in an automated method. This will need to be reported in real time at some frequency but likely not every 15 minutes.

Facility and Equipment Information

A measurement of the gas flow rate through the stack and the sample cell must accompany each gamma spectrum so an analysis report can be generated. The volume and geometry in the sample cell that the stack gases occupy during counting will be precisely determined to ensure accurate calculations. Also the location and design of the inlet, from where the air from the stack is collected, shall be documented. Other metadata like accompanying MIP processing information is requested but not required and can be sent to the STAX database at a frequency acceptable by the producer.

Meteorological Data

This project will not make a significant investment in setting up equipment to collect or send meteorological data because it was determined to be low priority when discussing this with various NDC's. If meteorological data is easily available, it could be sent and stored in the STAX database in a separate data file from the spectral and data analysis files.

Data Format

Where possible, the data types should be sent in the same or similar formats as currently used by the IDC. For example, the gamma spectra should be submitted similar to PHD file and stored in the database with a schema similar to the IDC's. Similarly, the spectral analysis report should be in the typical automated report. If alterations to the formats or schemas are deemed necessary or an improvement, then they will be made for the experiment with possible recommendations for broader adoption at the IDC.

Data Frequency

During discussions at previous WOSMIP's, the monitoring community requested data in 3 hour time intervals based on current atmospheric transport modelling techniques. For this experiment, we are considering possible future data needs and will target 15 minute time intervals for data collection (with 1 hour being the maximum target interval). Another option that was discussed with the NDC's is to measure until there are 10,000 counts in a spectrum/peak (or some other appropriate total number of counts) or 15 minutes have elapsed, whichever comes first and then report the spectrum. Another option is to have a parallel data flow from the detector system that collects time-stamped list mode data. This data could be binned in the future and could help evaluate different options/methods to support data confidentially. These are options that can be considered but are not required.

Various delay times have also been discussed previously at WOSMIP. Real time data sharing is the most ideal, but a lag time of up to a week or more could also be acceptable if real time data was

made available upon request during nuclear events scenarios. Data transmission in real time every 15 minutes is ideal and is what the project will initially request from each producer although an agreed upon alternate data frequency plan could be acceptable in some cases.

Data Integrity

The data will be sent from the detector system at the facility by email (although a comment from the IMS stated that this might not be the preferred method) or via secure VPN (where the router encrypts the emails). There is also the possibility of a data integrity stamp as part of a data certification process. Other data integrity indicators may also be used.

Data Accessibility

The data collected and stored in the STAX database will be used only for scientific studies to determine how such data can be fully utilized to support treaty verification purposes. When the STAX network is fully implemented, this data will be available to all signatory NDC's. During the initial setup experimental stage, the data will be available to NDC research partners to aid in the development in the functionality of the network. The data can be requested by an NDC. Research NDC's will access the data via secure VPN. The goal is to make the data access compatible with existing software used for similar data access to the NDCs.

Conclusion

This document summarizes the data requirements needed to best meet the goals of the STAX experiment with information gathered at the start of the project, but as mentioned several times throughout this document, there will be slight variations made to these listed requirements depending on what each medical isotope producer is willing to share. The list below is a summary of what this project will initially target to best meet the experimental goals. In some cases, the data accepted will not completely meet these requirements, but will still be beneficial to the experiment as it will allow the further development of data sharing methods. In other cases, a stack detection system will not be purchased and a support contract will not be set up with a medical isotopes producer if it is determined that the data they are willing to share does not sufficiently meet these requirements. Data sharing plans will likely vary between producers as they each will have different data confidentially concerns.

Summary of initial data requirements:

- Project purchased detector system installed or an almost identical system (meeting targeted data quality requirements listed above)
- Gamma spectra (with accompanying metadata) collected every 15 minutes and sent to the STAX database in real time
- Detector calibration plan developed and implemented
- Spectral analysis reports of the released activity for the relevant radionuclides and time series of selected radionuclides

References

1. Doll et al., "STAX (Source Term Analysis of Xenon) Experiment Project Work Plan – Year 1", October 2016.

2. CTBTO, “Stack Release Data Software Requirements Specification DRAFT”, January 2016.