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Precision Information Environment (PIE) for International Nuclear Safeguards: Use Case and Technical Requirements

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February 2013



Pacific Northwest
NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The International Atomic Energy Agency (IAEA) is implementing an evolving approach to its international safeguards verification activities—one that is driven by the consideration of the State as a whole, and utilization of all safeguards relevant information available to the Agency. This approach has led to the need for IAEA inspectors to be kept abreast of all safeguards-relevant information, including new or emerging information, even while in the field (Gayne 2010; Zarucki and Norman 2010).

This document presents the use case for a proof-of-concept customization of Pacific Northwest National Laboratory's (PNNL's) Precision Information Environment (PIE) applied to an international safeguards problem space. PIE is an integrated user role-based environment for multi-source data sharing and analysis. PIE enables remote data acquisition, scalable storage, automated processing, analysis and machine learning, and collaborative interaction from a centralized location to both local and mobile users. The use cases described in this document reflect the following IAEA safeguards scenarios:

1. Creating an Inspection Plan and downloading information at IAEA headquarters
2. Syncing emerging or updated information between IAEA headquarters and remote users
3. Utilizing PIE to support Computerized Inspection Report (CIR) completion and access to supporting documents for Physical Inventory Verification activities
4. Utilizing PIE to support CIR completion and access to supporting documents for Design Information Verification activities.

This document also defines a series of technical requirements and performance metrics for the proof-of-concept customization. This project is intended to support the following high priority IAEA research and development objectives, as described in those documents (bullets are taken directly from the documents indicated):

IAEA Department of Safeguards Long-Term R&D Plan, 2012-2023¹:

- Milestone 2.1: Integrate information sources, including satellite imagery, electronic data (including images), technical and academic literature, trade data, etc., to detect inconsistencies in nuclear programmes and States' declarations (pg. 5).
- Milestone 2.4: Evaluate data analysis methods and computerized tools to aid the analysis of the large amount of all-source information in order to support the State evaluation process and assist in drawing soundly-based safeguards conclusions (pg. 6).
- Milestone 9.3: Deploy secure and authenticated communications between inspectors in the field and IAEA headquarters/regional offices (pg. 8).

Additional details are provided in Appendix A.

¹ International Atomic Energy Agency, "IAEA Department of Safeguards Long-Term R&D Plan, 2012-2023." STR-375, Vienna, January 2013.

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1.0 Introduction

The International Atomic Energy Agency’s (IAEA’s) approach to its safeguards verification mission has advanced over the years from being facility-focused, to being more State-focused (Nackaerts 2011). This State-Level Concept encompasses an evolution of the safeguards system to be more fully information-driven (Cooley 2011) and includes the requirement for the IAEA to “collect, analyze, and evaluate all information available on a State, with the IAEA’s inspection-related activities” (Moran et al. 2011). The information-driven system of safeguards incorporates more data than ever before (Table 1). As part of the State-Level Concept, safeguards inspectors are facing increasing responsibility at headquarters and in the field. Inspectors are expected to be familiar with, and able to act on, a wide variety of information related to a State that was previously not considered during in-field verification activities “in order to identify proliferation indicators and assess risks at an early stage” (Gayne 2010).

Table 1. Types of IAEA Safeguards Information

| Data | Analyses |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none">• State declarations• Nuclear material accountancy data• Design information• Images of a site/facility• Technical Cooperation information• Open source information (press releases, news, and scientific publications)• Trade data• Third party information | <ul style="list-style-type: none">• Material balance evaluations• Results from environmental sampling, destructive assay, and nondestructive assay• Inspection and complementary access visit reports• Historical State Evaluation Reports (SER)• Trade analyses• Annotated satellite images• Inspector notes from previous inspections at the facility• Meeting minutes from the Safeguards Implementation Committee |

1.1 Safeguards Information Collection and Analysis at IAEA Headquarters

The IAEA’s State Factor Analysis section archives approximately 150 news articles per day from general searches alone. This information, combined with scientific and technical literature, trade data, satellite images, data from State declarations, results from inspector activities at facilities, results in significant quantities of disparate information to be integrated during the State Evaluation process.

IAEA data at headquarters is not currently accessible to all those with a need to know, from a single access point. Open source information collected and analyzed by the Department of Safeguards’ Division of Information Management (SGIM) is not accessible to inspectors until it is copied into shared folders.

Trade data and satellite images are similarly inaccessible to inspectors, as well as to other SGIM analysts. State declarations must be accessed via a separate computer terminal with specific access privileges, and historic State Evaluation Reports (SERs) are available almost exclusively via hardcopy by signature.

There is a considerable amount of information for inspectors to process in order to understand what is relevant to their mission (that is, an information overload). Throughout the State Evaluation process, IAEA analysts and inspectors asynchronously assess heterogeneous types of information in different locations and from different sources.

1.2 Accessing IAEA Information in the Field

Despite the wide array of information and analysis being collected, created, stored, and analyzed at the IAEA, inspectors working in the field have limited access to this information. Currently there is an incomplete mechanism for IAEA inspectors in the field to access secure data stored at headquarters, in part because that information is stored on disparate, air-gapped servers. If inspectors take information from IAEA headquarters into the field, they do so via paper documents that they print before departing, or documents that they download to the laptops they will use in the field (Johnson et al. 2013). This means that inspectors in the field might not be aware of the emerging data or analysis from headquarters, and analysts at headquarters must wait for inspectors to return for debriefings on inspection activities.

To implement the IAEA's desired safeguards system that is fully information-driven, inspectors and analysts alike must have the same access to data, whether at headquarters or in the field, including emerging information. The development and implementation of a mobile-enabled information management platform (MIMP) would mitigate or eliminate many of these problems. A MIMP would allow inspectors to access data in the field, as well as allow analysts based at headquarters real-time access to inspector comments, questions, and observations. This would significantly improve IAEA information sharing and transparency between inspectors and analysts. The type of collaboration and situational awareness created through the use of a MIMP would allow inspectors to make timely and better informed decisions in the field, resulting in a more thorough, efficient, and accurate analysis of States' nuclear activities.

The current practice of printing paper documents or saving duplicate electronic files leads to a general lack of information control and integration. Inspectors may be missing critical real-time information to support their activities, such as news reports describing the type and scale of activities at a nuclear facility, government press releases about nuclear energy plans, or results from analytical activities completed at headquarters. An inspector who is kept informed with up-to-date information will be more cognizant while doing their inspection, potentially mitigating the need to return to a site to conduct follow-on activities.

1.3 Interacting with Information in the Field

In addition to completing planned sampling, measurement, and other verification activities while in the field, IAEA inspectors are required to document their work in a Computerized Inspection Report (CIR). The CIR documents which activities were performed during the inspection and can accommodate inspector notes, measurements, or observations (Johnson et al. 2013).

The CIRs are created at headquarters and include (at a minimum) information regarding the country and facility to be inspected, the inspectors that will go on inspection, and the planned activities for the inspection. The CIR consists of 13 modules related to activities that will be concluded in the field, and these modules can be automatically activated, depending on the type of inspection to be performed. The CIR has the ability to auto-populate follow-on activities identified in previous CIRs so that they appear for the next inspection at that facility (Diaz 2013).

Most inspectors are completing the CIR in the field, either at a facility, or at their hotel rooms afterwards. The CIR can be printed to PDF so that inspectors can fill it in manually in the field, or it can be completed electronically on a laptop (Johnson et al. 2013). Discussions with recent IAEA inspectors identified some technical issues related to the CIRs, including inspector-created strata for facilities (with minimal documentation), continuity issues related to inspections at a facility for which the previous CIR has not yet been finalized, and reconciliation of dates related to inspection periods and accounting records (Diaz 2013). Supporting the creation and completion of the CIR through a MIMP would promote standardization, and enable uploading of completed CIRs from the field.

This project is intended to support IAEA goals and objectives related to information integration and dissemination, collaborative analysis, and communication. Descriptions of the high-level IAEA research and development objectives that map to this project are described in Appendix A.

2.0 The Precision Information Environment (PIE) for Safeguards

The development of the integrated environment for secure safeguards information integration will utilize existing capabilities already present in PNNL's Precision Information Environment (PIE). PIE is a secure, Enterprise Service Bus-based, highly collaborative environment (Figure 1) used to support remote data acquisition, scalable storage, automated processing, analysis and machine learning, and collaborative interaction facilities from a centralized location to both local and mobile/remote clients.

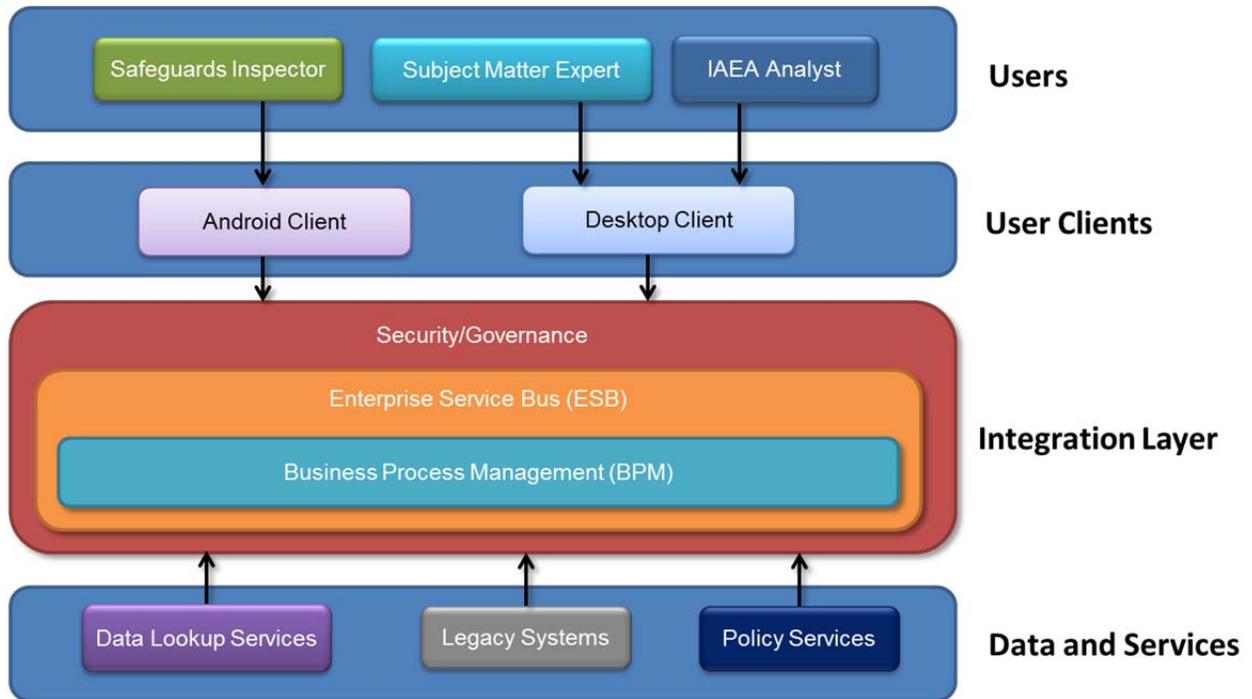


Figure 1. Proposed Service-Oriented Architecture for PIE-Safeguards

PIE has the capabilities to provide an intuitive and interactive interface for displaying and analyzing live data streams to personnel in the field. These data streams can be widely variable (such as text-based, images, audio, video, and sensor information). At the same time, all data collected in the field can be shared with headquarters. This could include notes and questions from inspectors, sensor data, geo-location and environmental data, photos, videos, audio, etc. The real-time capabilities of this type of information sharing works best when the in-field inspectors and people stationed at headquarters are connected via a high-bandwidth internet connection. However, PIE can also improve information sharing if one party is not online: upon reconnection to the internet PIE can upload and download appropriate content, indicate what is new, and analyze and group data by theme in order to minimize information overload and aid decision support. This data fusion approach, combining the most recent data streams from headquarters analysts with information from inspectors in the field, gives better situational awareness to all parties.

At headquarters, staff can interact with PIE in a number of different modes based on their roles or the activities they are performing, including a dashboard mode that is used to indicate current global statuses

of activities, display outstanding tasks and who they are assigned to, and any other information that is especially useful for knowledge transfer during staff changes. This capability has historically been implemented within PIE to assist emergency responders dealing with shift changes during an activation event but could be just as useful in the IAEA, given the nature of limited term staff assignments. This capability enables communication and knowledge management.

3.0 Use Case

User: The envisioned user for PIE-Safeguards is an IAEA safeguards inspector in the field. The inspector could use PIE-Safeguards as they prepare for, carry out, and analyze information from safeguards inspections in the field. Ideally an IAEA inspector would connect to the internet and secure a VPN connection while using PIE-Safeguards in order to have live updates with headquarters. However, access to stored information and analytic capabilities persist while PIE users are disconnected, and new or updated information can be synced between the mobile client and the PIE server at headquarters upon reestablishment of a VPN connection.

System: The use case is built around the PIE server. Connection to the server requires an internet connection, a mobile device (Android tablet) with PIE, and the data that can be streamed to the mobile device.

3.1 Base case: Creation of an Inspection Plan and Information Download

An inspector at headquarters is preparing for inspection in Ruritania.

He logs into PIE via his tablet, which is connected to the Internet at the IAEA headquarters, and creates an inspection plan including the country and facility he will be inspecting, the names of the inspectors performing the inspection, and the planned activities for the inspection. The inspector then uploads the inspection plan into Module 1 of the CIR (with the expectation that the CIR will eventually be incorporated into PIE).

The inspector then downloads the Ruritania country file with State declarations, previous CIRs, open source information, and any other pertinent information onto his Android tablet. This background information, along with the CIR he has just created, will allow access to these documents even when the PIE client is not connected to the PIE server.

Benefit: Supports the creation of the CIR by allowing the inspector to aggregate information. Information is easily downloaded to a PIE client, enabling integration with current systems.

3.2 Scenario 1: Information Sync

In transit to the facility, the inspector sees an interesting vantage point of the facility and snaps a photo. He annotates the photo, and uploads the photo and associated data to the PIE server for analysts to look at back at headquarters.

Benefit: Upon syncing with the PIE server, analysts in the State Evaluation Group with a need-to-know will have access to the new data.

On the way to the facility in Ruritania, the inspector launches the PIE Android client, authenticates with PIE server, and syncs with the firewalled PIE server. PIE identifies new and updated country information, such as a government statement on nuclear energy plans, a facility press release on annual

production, or the latest State declarations that have just arrived at the IAEA. The inspector browses for the latest information available for the country since he left headquarters.

Benefit: Enhances inspectors' situational awareness.

3.3 Scenario 2: Physical Inventory Verification

The inspector logs into PIE. He opens an existing CIR that was created with the inspection plan at headquarters. One of the activities identified in the inspection plan in Module 1 of the CIR is Physical Inventory Verification (PIV), which includes verification of operator accounting and book-keeping. The identification of that activity has led to the activation of Module 2 in the CIR. The inspector opens Module 2 of the CIR to examine the accounting and bookkeeping of the facility operator.

Via the packet of Ruritania information that he downloaded at headquarters, the inspector looks at the relevant information, including State-declared Inventory Change Reports (ICR), Material Balance Reports (MBR), and Physical Inventory Listings (PIL). In addition to the most current ICR, MBR and PIL documents, the inspector also has access to historical documents and other safeguards relevant information such as open source data. Based on activities defined in the Inspection Plan (in CIR Module 1), the necessary supporting documentation is queued and available for the inspector to view. The inspector views this information while comparing it to operator information, such as shipper and receiver documents.

According to the operator book-keeping, one item (for example, a barrel of material) has been shipped since the State last reported to the IAEA. The inspector compares the current operator inventory list and the warehouse. Upon inspection, the barrel appears to not be present, and there is shipping documentation to support its non-presence.

In the office space provided to the IAEA by the operator, the inspector accesses the internet, connects securely via VPN, and syncs data with PIE. There is a recent news article collected by an analyst at headquarters. The article, from an environmental watch group tracking shipments of nuclear material, says a shipment of nuclear material has left the facility in Ruritania and is headed to a neighboring country. The inspector has corroborating open source evidence to the operator's book keeping, and makes a notation in the CIR in PIE to check the next State declaration to verify that the transfer is declared.

Benefit: Allows for easy identification and access to relevant documents. Updates to latest open source and other IAEA data offer increased situational awareness for inspectors while in the field.

3.4 Scenario 3: Design Information Verification (DIV)

The inspector logs into PIE. He opens an existing CIR that was created with the Inspection Plan at headquarters, and downloads it to the local instance of PIE on his tablet.

One of the activities identified in the inspection plan is Design Information Verification (DIV). This has activated Module 10 of the CIR for completion. In Module 14.2 of the CIR, the inspector opens, reads, and comments on the State-provided Design Information Questionnaire (DIQ). Before the trip,

while the inspector was doing the Design Information Evaluation (DIE), he identified some items to ask about during the DIV. His notes are stored with the DIQ, and he can reference them during the visit.

Within the packet of information that the inspector uploaded onto his tablet at headquarters, the inspector uses keywords to search for a report on satellite imagery of the site he is reviewing. The inspector opens and views the satellite imagery report, and makes a note to follow up later on a new building under construction.

He also snaps a photo of the outside of one of the buildings, with operator permission, and uploads it to his packet of information residing on his local instance of PIE.

At lunch, the inspector has access to the Internet and establishes a secure VPN connection. He syncs with PIE located at IAEA headquarters. The inspector can see that new open source data has been collected that morning regarding the facility he is visiting, which includes some ground photos of several buildings on site as well as a press release from the public utility on operation production achieved in the last year. The inspector opens and reads the new documents, using this information to guide his questions and analysis for the DIV.

The inspector makes some notes concerning the DIQ related to what he has seen and completes that portion of the CIR within PIE.

Benefit: Access to relevant headquarters information. Analysts at headquarters receive updated information as it becomes available. PIE supports inspector workflow by facilitating the completion of the DIV.

4.0 Technical Requirements and Performance Metrics

1. Log in to system using secure credentials.
2. Open documents from folders authorized for use via role-based access controls. These documents could be in the format of:
 - Word documents
 - PDFs
 - MS Excel
 - Power point
 - HTML
 - Photo
 - Audio or video files.
3. Download selected information from headquarters server to an Android tablet.
4. On the tablet, see and open files that were downloaded through an intuitive interface.
5. On the tablet, edit documents available to the user/role.
6. On the tablet, upload new documents, photos, observations, annotations.
7. On the tablet, open and edit example CIR modules.
8. On the tablet, open documents. Provide users with capabilities to intuitively find, filter, and sort documents by content, document type and date modified.
9. When connected via VPN, provide ability to sync.
10. On the tablet, be able to identify newly acquired and updated documents.

5.0 Conclusion

While the evolution of the IAEA safeguards system to a more State-centric, information-driven approach will provide a more holistic view of States' nuclear activities, it demands a more informed inspectorate. The use case described in this document provides a proof-of-concept customization of PNNL's PIE information sharing environment. The use case seeks to illustrate mechanisms by which PIE could support IAEA inspectors in the field by providing information to IAEA information via remote devices, including emerging information as it becomes available.

The use case provided in this document represents work to be completed by PNNL in FY2013, for the proof-of-concept customization for international nuclear safeguards. Given PIE's aptitude for incorporating existing analytical tools and frameworks, there is a plethora of additional development that could potentially be completed in future years to provide additional information management, analysis, and documentation support to IAEA inspectors in the field.

5.1 Visions for Future PIE Development

The use case described in this document portrays a limited scope proof-of-concept customization of PIE for international nuclear safeguards. Given PIE's capability to integrate analytical capabilities and existing tools, we see two (not mutually exclusive or exhaustive) directions that future PIE development could take. The first is to further develop analytical capabilities for inspectors to use in the field to support their information collection, analysis, and verification activities. The other direction to focus PIE development would be to fully integrate with the IAEA's CIR, to provide start-to-finish inspection support (this could, of course, include the analytical capabilities proposed below).

5.1.1 Analytical and Logistical Support

PIE is designed to support the use of analytical tools to integrate and dispense highly relevant information to the people who need access to it in order to perform their jobs. As such, the integration of advanced analytical support would be an area to consider for future work. For PIE-Safeguards, this could likely include the following:

- **gamma spectroscopy support**—analyzing spectra, determining isotopes, ratios, mass of material, and whether or not measured values are within normal ranges
- **ingestion and digitization of paper records**—digitizing paper records in the field, with optical character recognition for searching, tagging, and storing data
- **advanced image comparison**—comparing historical images with vistas in front of a camera's lens (or recent photo) to identify changes or differences in the images. This could also be done with text-based files such as records or reports.
- **geo-location support**—assisting inspectors in getting to and from facilities and locations within country; for example, tracking routes to facilities (or within them) to determine routes taken from the guest house to the facility, or from the front door of the facility to the work station
- **inspector support and logistics**—supporting the inspector in the daily and emergency needs in-country, with information from IAEA resources, general information, or inspector input:

- language support
- information about medical facilities
- housing recommendations
- transport tips and other travel support provided form.

5.1.2 Start-to-Finish Inspection Support and Documentation

Another vision for the future is to incorporate PIE at every step of the IAEA inspection workflow, from planning, to filling out the CIR, to following up actions back at headquarters. This could include using PIE to enable inspector integration of IAEA information in the field, to provide updates for inspectors, and to provide updated information and tasking to analysts, managers, or other staff at IAEA headquarters.

Start-to-finish inspection support and documentation could fully incorporate the CIR, and could incorporate information management and analysis tools specifically relevant to each CIR module (as an expansion of the modules described in the uses cases for this year's work).

5.2 Sensitivities

While PIE-Safeguards could benefit many safeguards verification activities, some facilities or countries may have sensitivities that would limit inspectors' use of PIE. Sensitivities might include wireless internet transmission, photography capabilities, or the use electronic equipment in general. Some situations may be mitigated by disabling capabilities such as wireless internet connection or cameras. However, the use of equipment inside a facility is at the discretion of the state and the facility operator, and therefore might not be appropriate for all safeguards activities.

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Appendix A – Project Alignment with IAEA

The IAEA Department of Safeguards has recently published two documents outlining their research and development goals. This project is intended to support the following high priority IAEA research and development objectives, as described in those documents (bullets are taken directly from the documents indicated):

IAEA Department of Safeguards Long-Term R&D Plan, 2012-2023¹:

- Milestone 2.1: Integrate information sources, including satellite imagery, electronic data (including images), technical and academic literature, trade data, etc., to detect inconsistencies in nuclear programmes and States' declarations (pg. 5).
- Milestone 2.4: Evaluate data analysis methods and computerized tools to aid the analysis of the large amount of all-source information in order to support the State evaluation process and assist in drawing soundly-based safeguards conclusions (pg. 6).
- Milestone 9.3: Deploy secure and authenticated communications between inspectors in the field and IAEA headquarters/regional offices (pg. 8).

Development and Implementation Support Programme for Nuclear Verification, 2012-2013²:

- SGIM-03 (Open Source Analysis): Enhance the IAEA's ability to collect and analyse information in support of the IAEA's verification mission, in particular with respect to the State evaluation process and support of in-field verification activities (pg. xi).
 - Optimize information utilization.
- SGIS-01 (Integrated Analysis) Enhance information and system integration. Support information analysis (pg. xiii).
 - Deliver an integrated, service oriented, analysis friendly information architecture, as an effective base to collect, evaluate, analyse, structure, secure and disseminate safeguards-relevant information.
 - Continue to design and define enhanced information analysis architecture.
 - Support a collaborative analytic platform that enhances the Department's ability to draw sound safeguards conclusions.
 - Ensure information is appropriately classified and secure.

¹ International Atomic Energy Agency, "IAEA Department of Safeguards Long-Term R&D Plan, 2012-2023." STR-375, Vienna, January 2013.

² International Atomic Energy Agency, "Development and Implementation Support Programme for Nuclear Verification 2012-2013." STR-371.

- SGIS-02 (Information Security): Leverage information security to support a Safeguards system that is more objectives-based and information-driven, providing an appropriate balance between the need-to-know and the need-to-share (pg. xiv).
- SGTS-14 (Remote Monitoring and Data Processing Systems): Expand and upgrade Remote Monitoring (RM) software and hardware infrastructure to include new equipment, near real-time data processing, and advanced inspector communications world-wide (pg. xix).
 - Develop advanced communications for future inspector needs.
 - Develop enhanced software tools, especially for data acquisition, storage, and post-transfer analysis.



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