GEOSPATIAL DATA CAPABILITIES TO SUPPORT SAFEGUARDS UNDERSTANDING AND AWARENESS

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ABSTRACT

With the advent of earth observation, geospatial data has become a key component for a better understanding of contextual information. Geospatial information and Geospatial Information Systems (GIS) support management, improve decision-making, enable collaboration within a community, and boost the synergy of data at an enterprise level.

Geospatial data (also known as 'spatial data') is used to describe data that has an implicit or explicit association with a location relative to the Earth [ISO 211]. Whether it's man-made or natural, if it has to do with a specific location on the globe, it's geospatial. Geospatial data is gathered, stored, managed, and analysed within a GIS.

Within the IAEA, geospatial capabilities include the gathering, storage, management, and dissemination of satellite imagery, other raster data, and vectorized representations of NFC-related infrastructure. These data form a foundation upon which a diverse range of other data sources can be integrated. In this sense, the geospatial foundation data provides the spatial context for the other data sources that together enable the detection of patterns and improved conclusion-making.

Structured geospatial databases and geospatial analysis also provide the IAEA with a unique capability to gain deeper insights into areas of interest, to analyse spatial locations and relationships, to conduct classification or network analysis, to detect patterns of life, and to turn layers of information into geo-visualizations. Geospatial analysis is commonly delivered through an interactive format which enables further customization, or additional ad-hoc processing by the user.

This paper will discuss geospatial data governance and management to ensure the best use of geospatial data across the Department of Safeguards. This paper focuses on geospatial data and products derived from satellite imagery and therefore, it approaches commercial satellite primarily as a baseline source for other geospatial data and geospatial products.

KEYWORDS: geospatial data, data governance, data as a service (DaaS), 'delivering as one' approach

INTRODUCTION

In May 1997, the IAEA Board of Governors adopted the Additional Protocol [1] to increase the IAEA's ability to verify the peaceful use of all nuclear material in States with comprehensive safeguards agreements. The IAEA Board of Governors confirmed that the Agency has the authority to consider all available safeguards-relevant information, specifically, information derived from open sources. This new strengthened Safeguards system

opened the door for the IAEA to make use of all types of information (safeguards-relevant information), including geospatial information.

The IAEA Department of Safeguards is responsible for verifying that Member States are complying with their Safeguards agreements. Satellite imagery-derived geospatial information identifies geographic locations and characteristics of natural or man-made features on the earth. As such, the geospatial information assists the mission of the Division of Information Management (SGIM) in the provision of relevant information services to the Department of Safeguards in support of its mandate.

The State Infrastructure Analysis Section (ISI) which is dedicated to the analysis of commercial satellite imagery and management of geospatial data, was created in 2002. Since this time, geospatial information as commercial satellite imagery derived information has become one of the key sources of information contributing to the ability of the IAEA to improve the effectiveness of Safeguards implementation, confidence in Safeguards conclusions, and the decision-making process.

From the data lifecycle management perspective, ISI has the leading role and responsibility in the collection, processing and creation, storage, dissemination and maintenance of geospatial data and products. Data custody, integrity, security and data integration are also an important part of ISI's role. The original data and interpreted geospatial information derived from commercial satellite imagery, other open sources and data provided by States generate the foundation geospatial data and structured observation management (SOM) data as baseline geospatial datasets. Geospatial products such as Site Plans, Image Plans, Thematic Maps, Georeferenced Site Maps, Geoportals/Story Maps, Web Maps and other GIS Applications are products that rely on the baseline geospatial datasets.

BASELINE GEOSPATIAL DATASETS AND GEOSPATIAL PRODUCTS

FOUNDATION GEOSPATIAL DATASET

Foundation geospatial dataset is a base or fundamental geospatial dataset that contains relevant information about nuclear fuel cycle infrastructure locations including the area of interest, site, facilities and supporting infrastructure.

The following layers comprise the foundation geospatial data as currently managed by ISI:

1. Reference points
2. Boundaries/Areas of interest
3. Buildings/Structures
4. Facilities
5. Fences/Walls
6. Transportation networks
7. Utilities

and optionally:

8. Water streams
9. Water polygons or water features
10. Landcover

Vector layers of the foundation geospatial dataset are attributed with information from satellite imagery analysis and State Declarations under the Additional Protocol. Therefore, the pure geometry dataset is enriched with information such as building functions and functions sources, names, descriptions, heights and other relevant attributes.

STRUCTURED OBSERVATION MANAGEMENT DATA

Structured Observation Management data (SOM) [1] is another baseline geospatial dataset containing additional, often transient, observations derived from Satellite Imagery. SOM represents an organized system for storing, managing and retrieving the observations collected through the analysis of Satellite imagery.

Together with Foundation geospatial dataset, SOM data are used as sources for geospatial products mentioned hereinafter in this section.

SITE PLAN

A Site Plan is a cartographic representation of the foundation geospatial dataset for a particular site/area of interest, showing all relevant features and supporting infrastructure. The Site Plan is created as a geoPDF document including the main cartographic elements, such as title and description, inset map, north arrow, legend, date and source and classification designation. An image plan is a type of site plan with satellite imagery as a base layer.

SITE MAP

A Site Map [3] is a cartographic interpretation of a site provided by the States and available within the Additional Protocol System, primarily in either .pdf or .doc format. In order to extract the highest value from those State-provided documents, ISI transforms Site maps by enabling the geospatial component and having it positioned in space. Georeferenced Site Maps are stored as a mosaic dataset, together with relevant metadata and shared as an image service. The Site Map georeferencing process is done within the AP verification process.

GEOPORTAL

A Geoportal is an interactive web-based document which integrates a wide range of geospatial data (commercial satellite imagery, ground photos, video, open-source information, and text) to provide users with a comprehensive and graphical compilation of resources regarding nuclear-related activities or infrastructure at a known or suspect location, site or facility. The analysis is derived from the most recent and relevant satellite imagery available, supported by all safeguards-relevant information. A Geoportal may also support long-term tasking, providing a graphical and interactive view/summary of information recorded in other ISI products.

WEB MAPS AND GIS APPLICATIONS

Web Maps and GIS Applications are web-based tools that rely on geospatial data and allow content to be accessed, used and shared via the web. The key concept behind web GIS is that all authorized members of an organization can easily and securely access and use geographic information within their own collaborative environment. To support this concept and as part of the GES project, ISI established and maintain Enterprise web GIS within both environments, integrated safeguards environment (ISE) and safeguards local area network (SGLAN).

The following figure presents the structure and relationships of Safeguards geospatial information under the responsibility of SGIM/ISI:

[1] Structure observation management is defined as 'An organized method to capture, store, standardize, and provide data and information from GEOINT sources (sensors).' *National System for Geospatial Intelligence, Geospatial Intelligence (GEOINT) Basic Doctrine, April 2018*

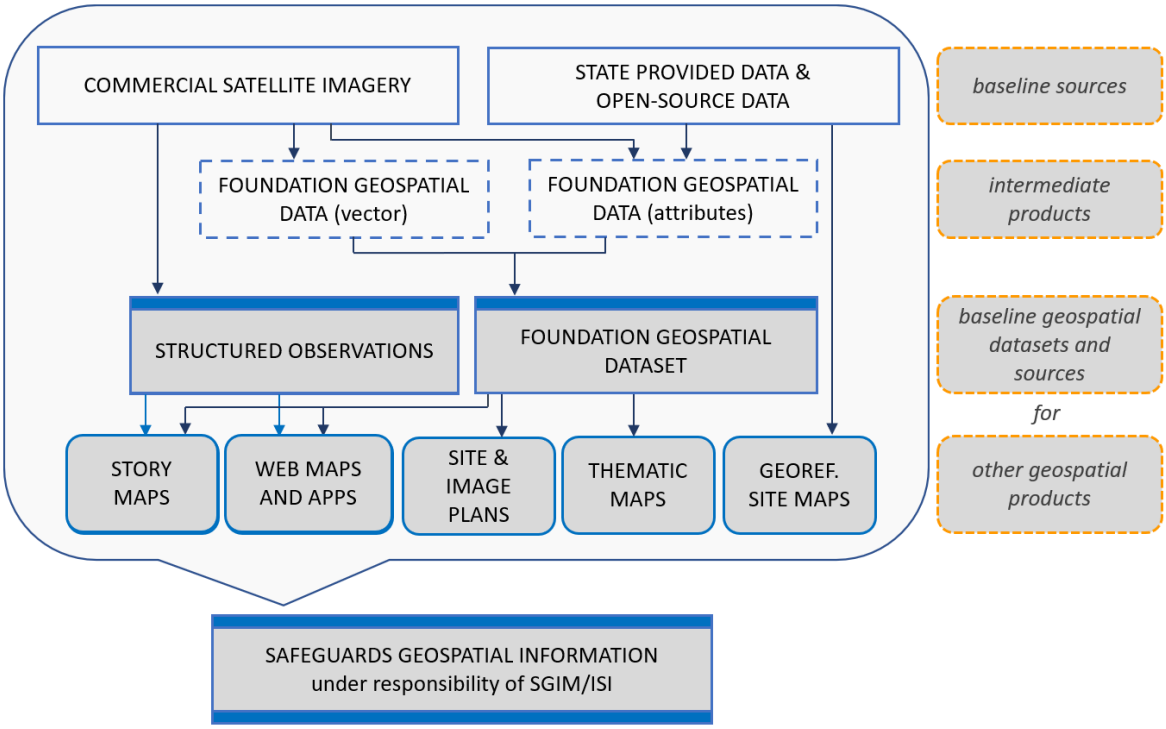

Figure 1: Safeguards geospatial information

APPLICATION OF SAFEGUARDS GEOSPATIAL INFORMATION

The foundation geospatial data and other geospatial information are routinely used to support the imagery analysis process, to evaluate the information provided by states on their nuclear activities, to support planning in-field activities (to verify design information and conduct complementary access activities) and as a baseline for integration of others safeguards-relevant information.

The applications of foundation geospatial data and geospatial products, geospatial analysis and geostatistical methodologies that are most relevant to the nuclear verification process include, but are not limited to the following:

- support the process of imagery analysis by providing authoritative geospatial information about sites and facilities;
- support the process of verifying the correctness and completeness of safeguards-relevant information available to the IAEA, e.g., as provided by States under their Safeguards Agreements and Additional Protocols;
- provision of a tool for the detection of changes in nuclear sites over time; maintaining historical information and comparing it to current information helps to monitor the construction or the dismantlement of nuclear facilities, monitoring and assessing the general status of nuclear facilities during a specific time frame;
- provision of a tool to assist in the verification of design information of facilities that are subject to Safeguards, and evaluate compliance during the different stages of construction when compared to submitted declarations;

- support for the investigation of undeclared nuclear activities;
- provision of an additional source of information to support the State Evaluation process;
- provision of a complementary source of information that can support or corroborate other types of open-source information;
- provision of reference information for planning, logistics and reporting of in-field activities;
- provision of map-based Safeguards information
- support machine learning and artificial intelligence initiatives.

SGIM/ISI roots its mandate on satellite imagery as base geospatial data. Added value is the transformation of reliable, up-to-date, raster satellite imagery to vector data [5]. Raster data open a possibility to take the information beyond the visible, and it is more suited to pixel-based mathematical modelling and analyses. Due to the fact that raster surfaces represent one attribute or value, calculations, algorithms and quantitative processing can be very quick and simple to run. On the other side, vectors are structured data that deliver a representation that is sharp, clean and scalable. Data is stored without any loss or generalization and accurate geolocation information is preserved. Multiple attributes and data fields can be stored in vector features. Through having and managing both types of data on nuclear sites and facilities, SGIM boosts its analytical capabilities by applying different analytical techniques and methods, rendering 3D models and providing adequate data sets for machine learning and other techniques for automation.

Geospatial data extracted from satellite imagery provides additional value and more possibilities for the analysis of a particular location. Various applications, flexible management and easy communication with other relevant systems make the foundation geospatial dataset and SOM data significant for the process of Safeguards implementation and drawing of Safeguards conclusions. It contributes to the strengthening of the Safeguards assessments by supporting the satellite imagery analysis process and making it more efficient and effective. These data also provide a system of corporate knowledge management. Temporal attribution of geospatial data allows both the collection time of the satellite image on which the observation was made, as well as the time at which the feature was entered into the database, allowing the analysis of not only what happened on the ground, but also a history of what geospatial information was available to the Agency at a particular point in time.

Nuclear sites, facilities and infrastructure are spatially located assets, geometrically represented by points, lines or polygons. This dataset can be symbolized and annotated based on intrinsic characteristics described by attributes. Change-tracking of a particular site or facility provides an additional value in following the history timeline or the life span of the feature. Analysis of the geometrical shapes, attributes and properties of facilities and their status during a specific period of time is of crucial importance to the analytical conclusions drawn by ISI analysts.

The foundation geospatial data enables connectivity to the Additional Protocol System (APS) and an assessment of the completeness and correctness of a State's declarations, which contributes to the State Evaluation process.

Web maps and web applications together with Site Plans and Thematic Map products are one more area where geospatial information plays a crucial role and creates a base for planning in-field activities.

COLLECTION AND UPDATE OF FOUNDATION GEOSPATIAL DATASET AND AP VERIFICATION PROCESS

The foundation geospatial vector dataset is collected and updated based on commercial satellite imagery, while attributes are collected and updated through the process of Additional Protocol declaration review, satellite imagery observations and other open-source information. Initial collection and editing or update of the foundation geospatial dataset are performed at the site level.

Editing and updating of data are enabled by the framework that enables multiple editors to work simultaneously in a highly isolated fashion, without creating copies of data [4]. This framework tracks changes made to a database, brings the ability to work internally without affecting published data and the capability to monitor data evolution over time. An important component of this system is vector archiving which offers the ability to track changes to a site, building, or other structure over time. The most recent and historical edits of data are time-stamped and user-stamped, and once the revision and QA process are completed, stored in the system. This authoritative dataset is available for further exploitation and analysis including spatial and temporal analysis.

Collection and updating of foundation geospatial data are performed by ISI Analysts. Data collection and/or updating and quality assurance processes have to comply with requirements for vector geospatial data as defined by SGIM/ISI which include basic topology rules.

The Additional Protocol verification process is done in parallel with the collection/updating of foundation geospatial vector data. This process comprises the verification of foundation geospatial vector data (mainly sites, buildings and facilities) collected from relevant imagery, against the data about sites, buildings and facilities provided by the State. For many States, the declarations under article 2.a.(iii) of the Additional Protocol, represent the most comprehensive part of their AP declarations. Based on INFCIRC/540 (Corr.), States are required to provide in a 2.a.(iii) declaration a general description of each building of a site (Art. 18.b, INFCIRC/540 (Corr.)) including its function, approximate size in terms of a number of floors, total square meters of floor space as well as the main content. The detailed description of each building on a site should be complemented by a map comprising all facilities or LOFs defined in the relevant design information and all co-located installations or buildings associated with these facilities or LOFs, surrounded by a distinct boundary. However, most emphasis regarding details should be given to buildings where nuclear activities take place. Annual updates to each initial site declaration covering the previous calendar year have to be submitted once a year by 15 May even if no new information relating to a site is available. If new activities or changes occur on a site, especially when a location is an ongoing construction site, not only the description but also the relevant map of a site shall be updated and sent to the IAEA as part of the annual updates. These declarations are then verified against satellite imagery covering the same period.

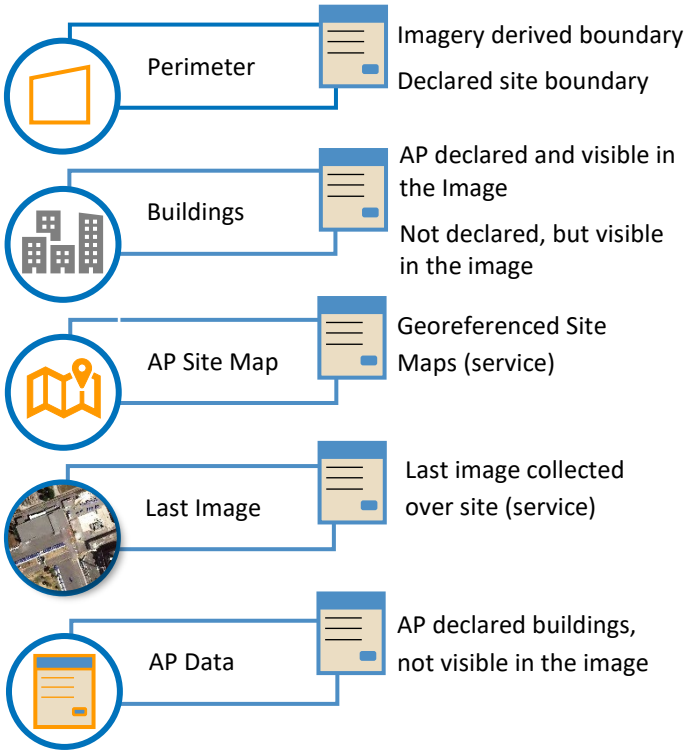

Figure 2: Geospatial information-based AP declaration review

As part of the GES project, web services were identified as the primary method for accessing and sharing foundation geospatial data. Web services organize geospatial data into functional resources to run on a web server. In this way, services allow many users to simultaneously access and explore data via central servers and to include this data in their geospatial products. This technology keeps data security at the highest level by disabling direct access to the data in the enterprise database and by enabling predefined SGIS security based on need-to-know and need-to-share protocols. ISI continue to work to enhance the capacity, capability, and range of authoritative geospatial web services within the department.

STRUCTURED OBSERVATION MANAGEMENT

Structured observation management supplements the foundation geospatial dataset and provides a system to allow additional observations made on satellite imagery to be collected within a structured framework. SOM features are collected as part of the imagery analysis process and generally pertain to ephemeral features, or attributes of features, for example the movement of construction support equipment. These do not form part of the foundation geospatial data; however, their identification and capture support the wider analysis of the site.

POLICY ON GEOSPATIAL INFORMATION WITHIN THE DEPARTMENT OF SAFEGUARDS

The Geospatial Strategy for the United Nations [2] was published in 2021 with the main intent to design, foster and build synergies for activities and investments in geospatial information management within the United Nations, in coordination with the wider geospatial and data community of the United Nations system 'Delivering as One'. The mission of the Geospatial Strategy is to mainstream the use of geospatial information across the United Nations system for unified, integrated and accessible information; analysis and visualization for evidence-based decision-making; and data action in support of peace and security, human rights, international law, development, and humanitarian aid. This strategy recommends key objectives and related strategic pathways.

Figure 3: UN Geospatial strategy - strategic pathways

With the aim of establishing a uniform, interoperable system for the management of geospatial datasets within the Department of Safeguards, and to follow the strategic pathways established by the UN geospatial community as proposed by UN Geospatial strategy, the IAEA/SGIM/ISI proposed the Policy on Geospatial Data within the Department of Safeguards. This policy addresses geospatial data within the department and defines standards for the collection, management and dissemination of geospatial data as well as governance roles and responsibilities. Having a geodata ecosystem that supports global standards and provides accessible and authoritative knowledge and added value to support the mandate and operational decision-making through information, innovation, technological solutions, and services, SGIM is constantly working on capacity and talent development, system and policy improvements and establishment of supportive communication and firm partnership with all relevant actors.

RELATIONSHIP WITH OTHER SAFEGUARDS (SG) DATA ECOSYSTEMS

SGIM/ISI is committed to the collection, management and sharing of geospatial datasets that are interoperable and accessible, using recognized methods and standards. Therefore, the importance of a relationship with other SG data ecosystems is highly recognized.

The integration of the Foundation geospatial dataset with Safeguards master data and Additional Protocol Systems for State declared sites and facilities is established through unique identifiers (IAEA site codes and facility codes). One of the main goals for the near future and a big component of ongoing activities is the geolocation of all nuclear-related sites and facilities that are under the responsibility of IAEA Safeguards, and therefore full integration of the mentioned system.

Foundation geospatial dataset plays an important role in Geo-based Data Integration (GDI) the application used by IAEA inspectors, as geospatial vector data represent a base for integration of other information and applications used in SG. Those data are shared as web services, together with imagery and georeferenced site maps and provide a full availability of raster data, geometry and related attributes.

Currently, foundation geospatial data covers the level of detail of the nuclear site or facility. The idea for future enhancement is to go to the in-depth level, by having georeferenced plans of buildings and infrastructure objects inside the site/facility. This in-depth level would bring a more detailed overview of the nuclear site-related infrastructure and open the possibility of having a 3D model and precisely located environmental samplings and other data of relevance on the building/structure level.

CONCLUSION

Good, authoritative data is vital. Today more than ever, creating and sharing authoritative data is of high importance. Satellite imagery, foundation geospatial vector and structured observation management data are authoritative geospatial SG data. The framework that is designed around geospatial data management makes data secure, and easily accessible by multiple users and enabled multi-user editing workflows in a simpler way. The capabilities introduced through integration with web GIS expand our reach, making the sharing of data easier and more reliable, while helping to ground the flashy pictures of web apps and visualizations in the reality of data.

The main goal is to enable integration with other Safeguards ecosystems and the new trends in GIS towards service-based models, opening the door for data integration into web maps, applications, and custom cloud service solutions.

In recent years, SGIM/ISI has placed a large focus on reengineering geodata management, and on introducing a services-based accessing and editing framework to support Safeguards activities. Development of new methodologies and products, and innovation on the cutting-edge of GIS science are nearly all focused on the services model. This helps to balance the needs for continuity and consistency for current users and their work, all while presenting new functionalities for smooth data synergy and a one-house approach. This is an exciting development in the SG geodata management environment.

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