SPACE-BORNE REMOTE SENSING DATA CAPABILITIES TO SUPPORT SAFEGUARDS NEEDS

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ABSTRACT

Over the past two decades, experience gained from the analysis of space-borne remote sensing data and new capabilities and technologies has significantly benefited the enhanced safeguards system. Space-borne remote sensing data (a.k.a., satellite imagery) has become a key source of "other relevant information", contributing to the ability of the IAEA to increase effectiveness of safeguards implementation, increase confidence in safeguards conclusions, and has led to improved decision making.

Hundreds of earth observation sensors currently in orbit are capable of measuring electromagnetic energy that is emitted or reflected from the Earth's surface or its atmosphere. Such measurement enables the IAEA to detect and assess ongoing activity, to characterize different types of materials or soils, to recognize or identify specific features, to count items, etc.

Space-based earth observation is undergoing a revolution, with an unprecedented fleet of sensors recently put into orbit or ready to be launched and covering ever more of the electro-magnetic spectrum. This revolution opens up new perspectives to enhance safeguards implementation at the IAEA, and will subsequently unveil new challenges regarding data (geospatial) management.

INTRODUCTION

The Department of Safeguards of the IAEA is responsible for verifying that States are complying with their safeguards agreements. The Division of Information Management is responsible for providing the relevant information services to the Department of Safeguards in support of its mandate.

Over the past two decades, the use of satellite imagery analysis to increase the effectiveness of safeguards implementation and increase confidence in safeguards conclusions has been widely demonstrated. The experience gained from the analysis of remote sensing data (a.k.a., satellite imagery) and new capabilities and technologies have opened up new perspectives for the information analysis component of the strengthened safeguards system. Space-borne remote sensing data has become an essential enabler of "other relevant information", contributing to the ability of the IAEA to increase the effectiveness of safeguards implementation, increase confidence in safeguards conclusions, and led to even better based decision making while assessing the correctness and completeness of a State's declaration.

The miniaturization of satellites (SmallSats) together with affordable space launch capabilities (e.g. Space Exploration Technologies Corp. – SpaceX) have boosted space-borne earth observation capabilities. This paper aims to review potential techniques and perspectives triggered by new systems of space-borne sensors recently launched through the prism of the fundamentals of remote sensing and in particular the technological boost on three key aspects of resolution: spatial, spectral, and temporal.

Spatial Resolution

The definition of spatial resolution is not unique. For the purpose of this document, the spatial resolution is the capability of the sensor to discriminate two features in an image. The ground sample distance (GSD) is the geometrical separation of consecutive picture elements (pixels) measured on the Earth's surface. Despite being the most popular quality performance parameter advocated by earth observation providers, other parameters, e.g., modulation transfer frequency (MTF) or the bit depth or bits per pixel (bpp) should also be considered for the characterisation of a sensor.

Landsat-1, the first commercial earth-observation satellite, was launched on 23 Jul 1973. was able to deliver imagery with a ground sample distance of 60 m. The initial objective Landsat-4 and Landsat-5 launched on 16 July 1982 and 01 March 1984 respectively, delivered 30 m resolution and permitted the detection of large industrial areas, roads, rivers, railway, etc.

The 10 m ground sample distance was reached by SPOT-1, launched on 22 February 1986. Such a resolution allowed the detection of mining exploration, construction of large nuclear complexes, detection of unusual large activity (trains, large containers, ships or cargo aircraft), etc.

Ikonos, launched on 24 September 1999, was the first commercial Satellite able to deliver sub-metrical imagery and was therefore deemed suitable for the use in support of Safeguards activity.

The advent of satellites capable to image the Earth and to deliver sub-metrical imagery has provided the IAEA and the image analysts with unprecedented ability for assessment of most of the nuclear-fuel-cycle related facilities throughout their entire life cycle.

The high-resolution and very-high resolution imagery provide the Department of Safeguards with enhanced capabilities for in-depth analysis of nuclear-related industrial sites/facilities status through a range of specific features (e.g. inlets/outlets, stacks, plumes, cooling systems, switch yards) but also the ability to assess activity at these sites/facilities via the analysis of key indicators (containers, shipments, casks/cylinders, construction materials, extension of buildings, refurbishment).

Spatial resolution better than one-half meter (0.5 m) enables technical analysis, height and volume measurement, as well as the differentiation of different type of features within the same class/category: cars, containers, casks, cylinders, etc (*Fig. 1*).

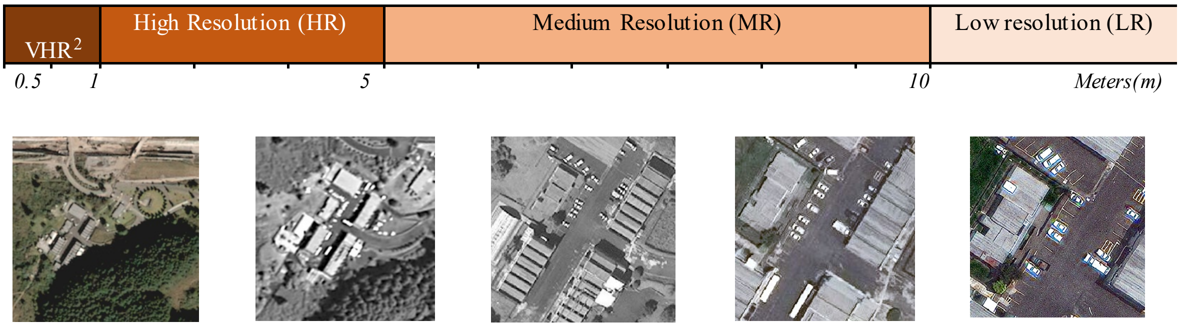
Water discharge, pumping | *Plume from cooling tower[1], activity at ponds* | *Private car on parking or buses* | *Presence of containers* | *Fluctuation in cask or cylinders numbers* | *Unattended delivery or shipment (train)*

Fig. 1 (Credit: MAXAR/Airbus)

Due to diffraction due to water particles in the atmosphere, 15 cm resolution imagery appears to be the limit for space-platforms in Low Earth orbit (LEO) at an altitude higher than 100 km above sea-level (Kármán line).

International community has difficulties in adopting standards in spatial resolution subdivision.
For the purpose of this paper, resolutions (for electro—optical imagery) have been divided as follows (*Fig 2*):

[1] *Subjected to specific weather condition to be observed*



SPOT6 (1.5m) 21 Dec 2018 (Credit: Airbus) | *KOMPSAT-2 (1m) 12 Apr 2008 (Credit: SSIS)* | *WorldView-1 (50 cm) 02 Oct 2020 (Credit: MAXAR)* | *WorldView-3 (30 cm) 06 May 2021 (Credit: MAXAR)* | *Legion Simulation (15 cm) (Credit: MAXAR)*

Fig 2

Super-Mode, Super-Resolution, Enhanced Resolution

Super-resolution is the process of increasing the perceived spatial resolution of images using algorithms to enhance object detection.

Spot-5, launched in April 2002, is likely one of the precursors of enhanced resolution ("Super-Mode"). The technique relies on "information theory" by Shannon, ($f e \geq$ fmax/2), to enhance the resolution of the satellite. The system consists of two-line sensors (push-broom), shifted by half-pixel size (in-track direction) and 3.5 pixels (left/right). Images acquired by both sensor lines having half redundant information are interlaced, interpolated, and restored to form a new super-mode image.

Maxar has recently developed a proprietary high definition (HD) imagery product to enhance the spatial resolution of their imagery from 30 cm to 15 cm. Investigation of resolution enhancement algorithms continues today, primarily based on deep learning algorithms and architectures [1].

HD Mode (Credit: MAXAR)

Spectral Resolution

Spectral resolution is commonly defined as the ability of a sensor to measure energy emitted or reflected from the Earth's surface over different wavelength intervals [2].

Since the 1970s, most space-borne remote sensing sensors have been designed to measure energy either emitted or reflected from the Earth's surface or its atmosphere over different parts of the electromagnetic spectrum (EM). The collection of digital imagery in a multitude of narrow and contiguous spectral bands enables the modelling of a continuous spectral behaviour for each of the pixels of the image.

Surface materials have a specific and unique electromagnetic behaviour. Their intrinsic characteristics, density, water content, roughness, porosity, shape, material or chemical composition, influences the emission, absorption, diffraction or reflection of energy over different wavelengths.

Where multispectral (MS) sensors such as WorldView3 or Landsat are capable of simultaneously acquiring tens (~5 to 10) of discrete spectral broader bands, hyperspectral (HSI) sensors like Earth Observing One (Hyperion) or PRISMA collect hundreds of narrow spectral bands.

Such unique electromagnetic signatures of different materials allow the classification of some materials into different land use categories, and in the case of hyperspectral sensing, allows the differentiation of

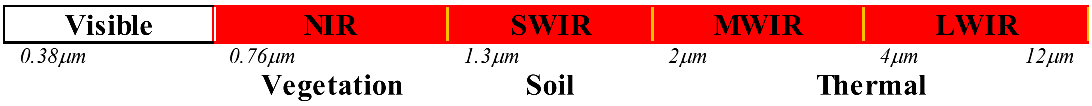
[2] *Very High Resolution*

some specific materials. Nevertheless, measurement over narrow spectral bands meaningfully limits the quantity of energy collected by the sensor, leading to a loss of spatial resolution.

Combining several images acquired at different wavelengths makes possible the calculation of spectral indices for visualization or further scene classification (vegetation health, water indices, urban indices), and comparison of the measured spectral signatures to reliable spectral libraries of material samples enables the potential characterisation or identification of materials (water, soil, geological features, minerals, plastics, algae). Cloud-free and corrected reflectance are required for multispectral or hyperspectral advanced processing.

INFRARED

Infrared radiation emitted from the Earth's surface can be measured by space-borne remote sensing platforms. The infrared portion of the electromagnetic spectrum is commonly split into four main regions: near-infrared (NIR), short-wave infrared (SWIR), and then medium- (MWIR) and long-wave infrared (LWIR).



NIR

Near-infrared band are natively collected by a large number of space-borne remote sensing sensors including VHR sensors. Near-infrared is mainly used for its high sensitivity to vegetation.

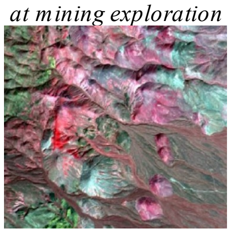
Most of the vegetation indexes such as Normalized Difference Vegetation Index (NDVI) are based on the NIR band.

The NIR bands of satellite imagery provide the Department of Safeguards with the capabilities to measure the stress of vegetation caused by moisture levels, pollution, gas release, fire, blast or natural hazards (flooding, earthquake, etc) or even to measure moisture on the roof of a disused workshop.

SWIR

Although space-borne remote sensing platforms have been capable since the 1970s of measuring energy in the short-wave infrared, the delivery of very high-resolution SWIR data in eight bands by WorldView-3 significantly enhanced the ability to differentiate among materials, reveal the mineral content of rocks, the moisture of soil, the health and species of vegetation, the physical composition of buildings and other previously undetectable details [3].
Since 13 August 2014, WorldView-3 expanded deeper into the infrared spectrum and provides 3.7 m short wave infrared (SWIR) imagery.

Characterization of soils at mining exploration



WorldView-3 (Credit: DigitalGlobe)

SWIR 1	SWIR 2	SWIR 3	SWIR 4	SWIR 5	SWIR 6	SWIR 7	SWIR 8
1195 - 1225	1550 - 1590	1640 - 1680	1710 - 1750	2145 - 2185	2185 - 2225	2235 - 2285	2295 - 2365

SWIR bands delivered by WorldView-3 (nm)

The eight SWIR bands delivered by WorldView-3, measure the electronic absorptions in the SWIR wavelengths and may be used for detecting materials containing anion groups such as Al-OH, Mg-OH, Fe-OH, Si-OH, carbonates, ammonium, and sulphates - many of which are indicator minerals in the mining industry [4].

Space-borne platforms such as Landsat -8 (*3 Feb 2013*) or Sentinel-2 (2A: *23 Jun 2015*, 2B: *7 March 2017*) are also able to deliver, at lesser ground resolution, free and open data for applications. With two satellites, the Sentinel-2 constellation revisit is 5 days.

Landsat-8 Bands 6 and 7 cover different narrow parts of the shortwave infrared, or SWIR. They are particularly useful to distinguish wet earth from dry earth, and for geology: rocks and soils that look similar in other bands often have strong contrasts in SWIR (Fig. 3).

Landsat-8
Bands 6 and 7 (SWIR)

Detection of moisture and water in ponds — *Fires and smoke penetration*

WorldView-3 (Credit: DigitalGlobe) | *WorldView-3 (Credit: DigitalGlobe)* | *Sentinel-2 (Credit: ESA)* | *Landsat-8 (Credit: USGS)*

Fig. 3

The SWIR bands of satellite imagery provide the Department of Safeguards with the capabilities to analyse water in ponds, turbidity, possible algae, but also to gain insight into geological component of soils, exploration areas, tailings or waste deposits.

TIR (MWIR-LWIR)

Thermal imaging is the process of measuring radiant energy emitted from the Earth's surface, and to convert it (heat) into data that portrays the spatial distribution of temperature differences throughout the Earth-surface area captured by the TIR sensor [5].

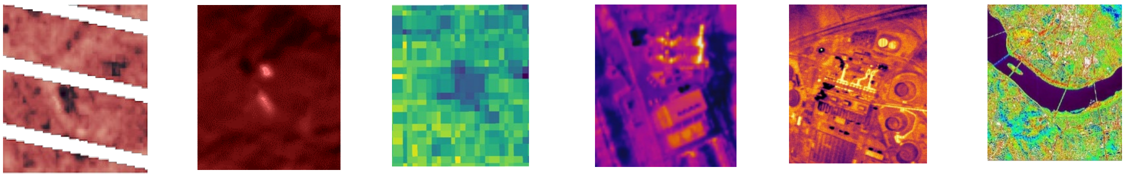
The energy emitted from the Earth's surface is mainly due to absorbed energy from the Sun or results from thermodynamic human processes (emitted). Heat (a.k.a., waste heat) is routinely emitted as a by-product of doing work during industrial processes, and may be considered as one of the main indicators to characterize ongoing processing.

Thermal infrared (TIR) remote sensing primarily is used to characterize land surface temperature (LST) of natural or manmade objects. In order to calculate LST from remote sensing missions such as Landsat, retrieval algorithms convert the detected digital numbers (DN) to radiance, then brightness temperature, and finally to LST. Input parameters for the collection conditions are required for the computation including parameters such as the normalized difference vegetation index (NDVI) and atmospheric water vapor content. The complexity of estimating parameters and collecting timely data as inputs for LST algorithms may be simplified using open source tools and data such as Google Earth Engine (GEE) (Ermida, 2020) [7].

The spatial resolution of TIR bands historically has been low, 100's of meters, but is improving with new sensors, which will enable better usability of this information for smaller observables for Safeguards analysis. Although the few commercial TIR space-borne commercial sensors currently available have very limited spatial resolution, the development of SmallSats and advances in sensor design has enabled some companies to advertise a new era of TIR imagery.

Such a breakthrough in high-spatial-resolution thermal imaging will provide the IAEA with significant capabilities regarding the assessment of activity and status of a facility, and quantitative and qualitative information regarding soil sciences, hydrology, geology, biology, oceans, and atmosphere.

Low resolution of commercially available TIR imagery significantly limits the applications related to safeguards to large industrial facilities. Nevertheless, the detection of heat remains the most relevant indicator for industrial activity (Fig. 4).



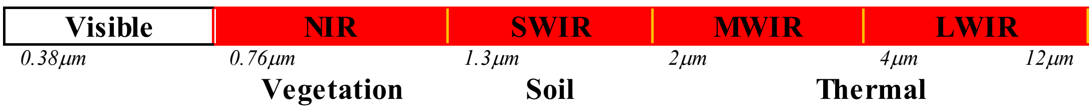
Landsat-7 (Credit: USGS) | Landsat-8 (Credit: USGS) | Aster | Albedo (Credit: ALBEDO) | Satellite Vu (Credit: satellitevu.com) | Kompsat-3A (Credit: KARI, SIIS)

Fig. 4

HYPERSPECTRAL

Hyperspectral (HSI) sensors (a.k.a., imaging spectrometers) measure radiant energy over hundreds of narrow contiguous spectral bands.

Surface materials have a specific and unique electromagnetic behaviour. Their intrinsic constitution, roughness, porosity, shape, composition, influences the emission, absorption, diffraction or reflection of energy over the wavelength. Unique electromagnetic signatures empower the classification of some material and in particular the differentiation of some specific ones. Nevertheless, measurement over narrow spectral bands meaningfully limit the quantity of energy collected by the sensor, leading to a loss of spatial resolution.



Due to the recent availability of Space-borne Hyperspectral sensors, the Department of Safeguards continue to evaluate application for hyperspectral imagery. In-depth analysis of soil components and in particular the discrimination of some materials and components is one of the main applications related to safeguards matter.

SYNTHETIC APERTURE RADAR IMAGERY (SAR),

In contrast to Electro-Optical (EO), a SAR actively illuminates the scene with coherent electromagnetic (EM) waves. SAR images are formed by processing the measured back-scattered signal from a multitude of spatial locations as the sensor moves along its track. On the one hand, active illumination allows a SAR to operate at night, on the other hand, using EM radiation in the microwave region permits imaging through clouds and fog.

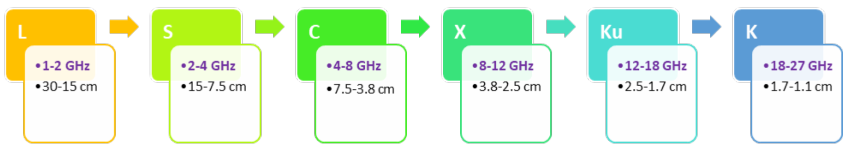


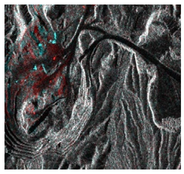
Fig. 5 - Microwave Bands

Current space-borne SAR sensors operate in L, C or X-band (Fig. 5), and most of them are able to utilise various polarizations. These bands offer different spatial resolutions (due to bandwidth availability) and a range of capabilities for foliage penetration. A SAR sensor can generate imagery in a variety of modes. In a high-resolution, small-area spotlight mode (25 cm resolution, 3 x 3 Km), the SAR beam is rotated as it operates. In a stripmap mode, the beam is not rotated yielding medium-resolution, medium-area imagery (3 – 10 m resolution, 50 x 50 Km). Finally, some SARs can image in scansar or topsar modes where a combination of different beams yields low-resolution, wide-area imagery (20 – 50m resolution, 400 x 400 Km).

Interferometry with a SAR exploits the wave properties of the illumination and requires at least two time-separated images collected under interferometric acquisition conditions, that is, from almost identical positions in space with similar beams. This can be achieved by using two different satellites in a constellation where one satellite trails another (Cosmo-SkyMed, TerraSAR-X/TanDEM, ICEYE), and/or it can be done by using a single SAR on a repeat-cycle[3] (RADARSAT-2, PALSAR-II). Missions with multiple satellites on the same orbit have significantly greater capabilities for interferometry than single satellite missions.

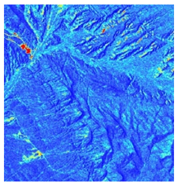
The analysis of SAR imagery requires experience coupled with a good understanding of effects arising from the SAR imaging geometry, such as layover, foreshortening, shadowing and texture. The following techniques aid with the analysis of SAR imagery:

- Amplitude Change Detection (ACD) compares the intensity of backscatter of at least two time-separated SAR images, typically acquired using similar orbit and frequency parameters. ACD analysis often only provides indications of activity that require clarification with EO imagery.



Credit: E-GEOS

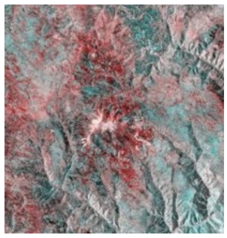
- Coherent Change Detection (CCD) exemplifies a unique benefit of SAR images collected under interferometric acquisition conditions. A CCD image provides a highly sensitive statistical measure of the similarity between pairs of images where the high sensitivity is a property provided by the interferometric phase.



Credit: E-GEOS

- The Multi-Temporal Coherence (MTC) product combines ACD and CCD by mapping the two amplitude images, to red and green, and the corresponding CCD image to blue. MTC images can highlight changes not apparent through ACD analysis. This technique is particularly relevant when surveying large storage areas (UO2 or UF6 casks) and often used to complement the CCD technique.

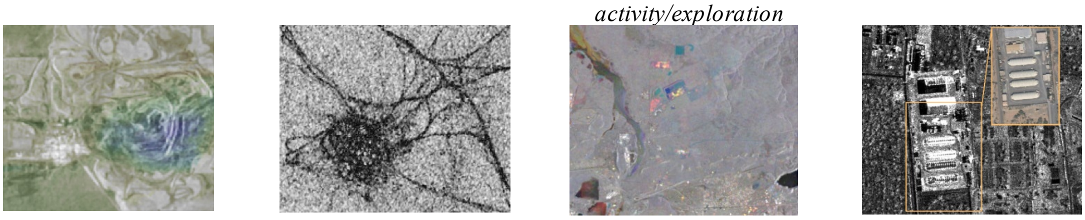
- Differential Interferometric SAR (DINSAR) can detect centimetre-scale surface deformation. The technique generates a subsidence/uplift map by isolating the component of the phase that is related to displacement, and transforming this into either a line-of-sight or a vertical displacement. Under ideal conditions, it is possible to resolve deformations of a few millimetres. Further, a stack (or series) of deformation maps can reveal important trends related to ongoing underground activity.



Credit E-GEOS

The number of space-borne SAR sensors has dramatically increased over the last decade. The advent of small SAR satellites has economised space launches, thereby empowering new actors. Companies such as ICEYE and Capella Space already orbit a large number of small SAR satellites, and have ambitious plans to add to their fleets in the coming years.

Detection of subsidence for underground facilities	*Detection of loss of coherences*	*Tipping & cueing Detection of mining activity/exploration*	*Monitoring of activity*



	(Credit: E-Geos)	*(Credit: ESA)*	*(Credit: ICEYE)*

Figure 6

Over the past years the use of SAR imagery in support to the Department of Safeguards has significantly increased. Its main applications are tipping and queuing over large areas, in particular mining exploration, detection of subsidence for underground deposits or facilities, but also detection and assessment of activities at nuclear-related facilities (Fig. 6).

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[3] *A satellite returns to its former spatial position after a certain period of time*

TEMPORAL RESOLUTION

The temporal resolution is determined by the frequency of revisit of a local point on the earth. The temporal resolution depends on the platform orbit.

Temporal resolution can be significantly reduced by the agility *[8]* of space-borne platform or imaging systems. With the advent of new generations of control moment gyros, satellites and/or imaging system are able to off-point rapidly around its axis (yaw, pitch, roll). Current Earth observation systems allows off-nadir viewing angles up to 45°.

The recent strategy used by most of the satellite operators to further increase revisit frequency is to propose a constellation of satellites. The assignment of each space-based platform on a different orbit plane, enables the delivery of imagery at different local time.

With more than 180 satellites in LEO orbit, Planet's constellation is able "to capture imagery of a single location on Earth up to 12 times per day" with "an average of 7 revisit per day." [9]

Despite limited resolution (HR) and weather dependency, PlanetScope daily acquisition provides the IAEA with the capabilities to monitor the activity at selected location (Fig. 7) in particular to mitigate access restriction like pandemic period. Analysis of HR imagery is supported through reference to VHR imagery to avoid any biases.

24 Mar	*25 Mar*	*26 Mar*	*29 Mar*	*30 Mar*	*31 Mar*	*01 Apr*	*03 Apr*
6	2	1	6	1	8	5	4

Number of PlanetScope imagery acquired on that day

Fig. 7 - Credits: PlanetLabs – PlanetScope 2021

Agile satellites and constellations allow acquisition of imagery through different line of sight/viewing angle which significantly improve the understanding of the infrastructure, but also provide the department of Safeguards with the capability the build 3D modelling (Fig. 8).

Credit: MAXAR *Credit: Airbus* *Credit: Airbus* *Credit: MAXAR* *Sketchup*

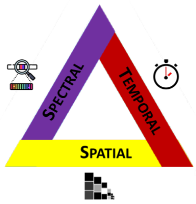
Fig. 8

COMPLEMENTARITY OF SENSORS AND DATA INTEGRATION

Commercial satellite imagery as part of "other relevant data" has been routinely used to increase the effectiveness of safeguards implementation, increase confidence in safeguards conclusions, and leads to more sound-based decision making.

Although the number of satellites significantly increased the availability of imagery of safeguards areas of interest, the complementarity of the different systems provides an unprecedented understanding of a facility or situation and enables in-depth analysis.

The image analyst, in cooperation with experts from the Department of Safeguards, determines the most effective and relevant dataset. The selection of the best dataset to fit-the-purpose requires awareness of the different sensors available as well as a deep understanding of their technical capabilities. It is essential to benefit from the complementarity of the images to enable in-depth analysis.



The analysis primarily focuses on facts or evidence derived from satellite imagery, but the integration of pertinent SG-relevant information within the analytics ensures the most comprehensive assessment to support state evaluation process or decision making.

Integration of data collected through multiple sensors is challenging. As shown in this paper, satellite imagery is acquired: from different orbits, various spatial resolutions, assorted geometry, and through heterogeneous spectral bands.

Prior to the analysis, satellite images have to be corrected for a number of radiometric and geometric distortions and pre-processed to enhance geospatial homogeneity and produce seamless orthorectified images.

Then the image analyst can use a series of techniques to manipulate, compare, combine, merge, blend and enhance satellite imagery.

OPPORTUNITIES AND CHALLENGES

This paper demonstrated the trend of an increasing number of satellites mainly triggered by the advent of reduced costs for commercial SmallSat satellites. This increase of available imagery will generate a flow of imagery which is not affordable or manageable for the IAEA with the current resources and IT infrastructure. To successfully turn this unprecedented volume of satellite imagery data into meaning, insights and analytics, the IAEA will need to consider a number of challenges:

The storage of such an incredible volume of imagery has become a crucial issue. Several-trillion-pixels of imagery of the earth are collected daily by space-based remote-sensing sensors. The foreseen volume of data requires significant augmented capacity in terms of servers, networks, but also the adaptation of security measures and data verification efforts.

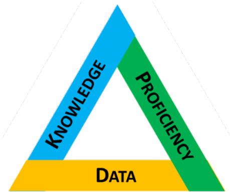
Data visualisation has become crucial when dealing with a large volume of data to be displayed. Highlighting facts for non-experts may be challenging in particular when using advanced image processing of data which are not natively perceived by human eyes. Cosmetic quality of the images must also be considered since analysis is delivered in published reports. The development of dashboards and other data visualisation methods, built on structured data derived from remote sensing data, can raise the Department of Safeguards' awareness and enable preventive, descriptive, or prescriptive analysis.

The increasing availability of remote sensing data, the growing demand for satellite imagery and geospatial analysis without a commensurate increase in analytical resources and technological developments in machine learning, will force the transition away from eyes-on every pixel towards "focused analysis". Historically, an imagery analyst assessed each available image, encompassing a much larger area than the designated location. This larger area search was undertaken to understand the context of the location, and often identified activities of interest associated with the target location; these opportune discoveries are a key benefit of traditional imagery analysis. In an environment of focused analysis, a system to ensure this opportune analysis continues will need to be developed.

To efficiently cope with the vast and rapidly growing volumes of data, the IAEA would benefit from an investigation of machine learning, deep learning and computer vision tools to propose to the analyst the most relevant image to be analysed, to detect anomalies, and to ease and support the analytical process. Machine learning may assist analyst workflows via predictive analysis, creation of indexes to find insights and value from big data, or to identify trends and specific patterns. Routine automatic "change-detection" algorithms can support the analyst to spot and correct discrepancies in State declared information and also can enable the detection of potential undeclared nuclear related activity. To enable the deployment of new technologies such as machine learning and deep learning, the IAEA has to consider the access to cloud data and also investigate cloud computing capabilities.

The delivery of reliable analytics does not only reside on data quality. The IAEA has always sought for highly skilled and experienced image and geospatial analysts to advance the use of safeguards-relevant information and enable the most comprehensive assessments. The technical skillsets needed to achieve these goals encompass a wide extent of capabilities such as Remote Sensing (RS) techniques, understanding of Nuclear Fuel Cycle (NFC) processes, infrastructure analysis, Safeguards (SG) matters, geospatial information (GIS) analysis techniques, chemical basic knowledge, integration of open-source data, etc. In order to tackle the opportunities triggered by the advents in computing science and data visualization techniques, the IAEA will need to gain insights into additional advanced technical skills in particular the ones related to data science.

The quality and resolution of satellite imagery analysis products are highly dependent upon image collection parameters such as the type of sensor, the time of day, and the weather conditions, but also rely on the imagery analyst's ability to identify specific items, infrastructure, equipment or vehicles within the images. Machine learning, deep-learning or computer vision algorithm may significantly support the image analyst in this task.



It is noteworthy to mention that maintenance and enhancement of imagery analyst's skills and knowledge is essential for the Department of Safeguards.

Finally, in order to allow the Department of Safeguards to benefit the new opportunities identified in this paper, and in order to ensure that all Department of Safeguards' geospatial data, and analysis based upon these data, are searchable, discoverable, exploitable and interoperable, the effective synergy of geospatial information within the Department shall be enhanced through the establishment of an enterprise-level geospatial information system. This system will be based upon a set of safeguards-wide geospatial data standards to which all safeguards-generated geospatial data will comply.

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