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JÜLICH FORSCHUNGSZENTRUM

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IAA and ISPRS: Earth Observation Forum-3: Non Commercial and Legal Issues Session

Advances in the Use of Remote Sensing and Geoinformation Technologies in Nuclear Non-proliferation and Arms Control Verification Regimes

August 28, 2012 |

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The Telegraph

Satellite shows North Korea's progress on nuclear reactor

North Korea has put a dome on a light-water reactor it is building, a key step towards completing a plant that could be used to support its nuclear weapons programme, a leading defence journal said.

Three satellite images taken (from left) on March 20, June 24 and August 6, 2012 of the Yongbyon Nuclear Scientific Research Centre in North Korea Photo: AP Photo/GeoEye and IHS Jane's Defence Weekly

8:19AM BST 22 Aug 2012

Jane's Defence Weekly, examining images taken on August 6 by the GeoEye-1 satellite, said the dome, which had been lying on the ground at the Yongbyon complex, has now been put in place.

"North Korea has taken a major step in its mission to build a modern, indigenous nuclear reactor with a 21-metre diameter dome now having been emplaced over the reactor building," said image analyst Allison

August 24, 2012

Institute for Science and International Security

ISIS Imagery Brief

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New Phase of Suspect Activity at Parchin Site

By David Albright and Robert Avagyan

Figure 2. Satellite image from July 25, 2012 showing the results of extensive alterations undertaken at the suspected high explosives testing site, including the demolition of two buildings and major earth displacement activities.

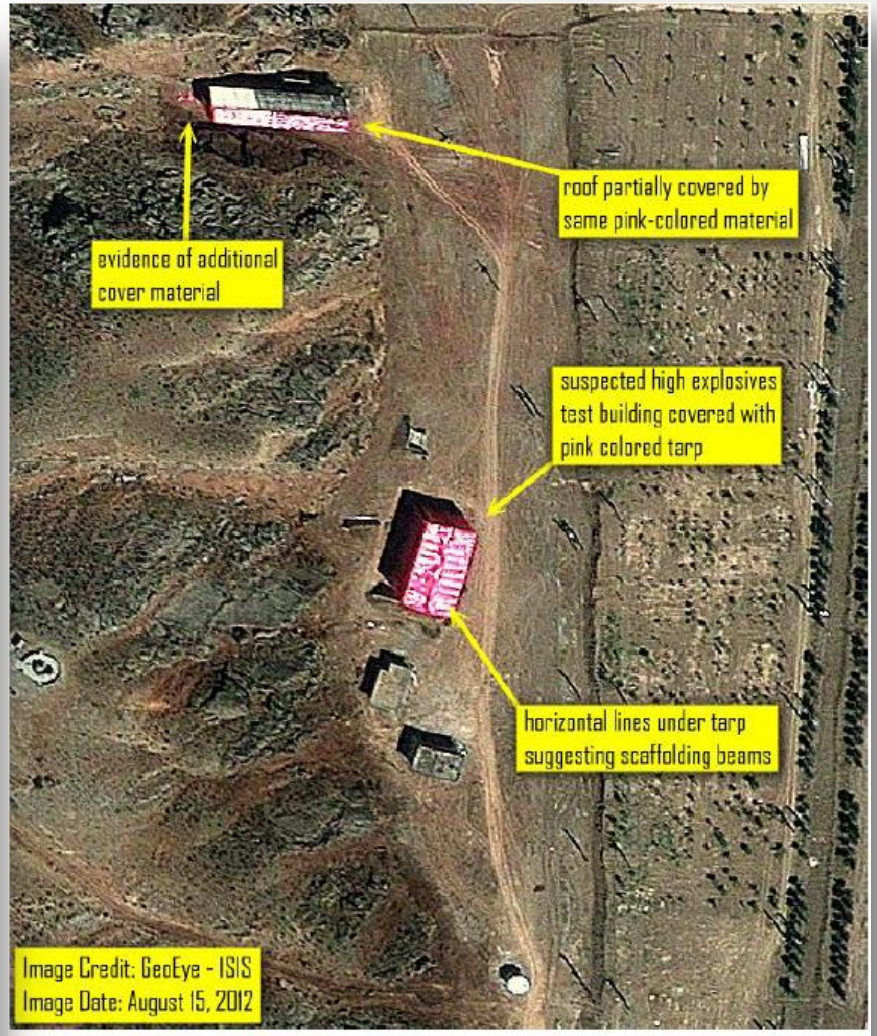

Figure 1. GeoEye satellite image from August 15, 2012 showing the suspected high explosives test building covered with a tent like material most likely supported by scaffolding. An adjacent building to the north also appears partially covered with the same material.

Non-Proliferation & Arms Control Treaties

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Multilateral and intended to cover all States:

- Treaty on the Non-Proliferation of Nuclear Weapons (NPT)
- Convention on Biological Weapons (BWC)
- Convention on Chemical Weapons (CWC)
- *Comprehensive Nuclear Test Ban Treaty (CTBT)*
- *Fissile Material Cut-Off Treaty (FMCT)*

Applicable to a particular region:

- Conventional Forces in Europe Treaty (CFE)
- Open Skies Treaty
- Antarctic Treaty
- Treaty of Tlatelolco
- Other (nuclear) weapon-free zone Treaties

Bilateral at origin:

- Intermediate Nuclear Forces Treaty (INF)
- (New) Strategic Arms Reduction Treaty (nSTART)

Objectives

- to reduce or eliminate of arms, particularly weapons of mass destruction,
- to curb or stop the proliferation of weapons and of sensitive, dual-use technologies, or
- to increase security and build confidence in other ways.

Verifying Treaty Compliance

- Most of the treaties/agreements include verification provisions.
- Verification regimes contain technical, institutional and/or administrative procedures and generally intend to prevent State Parties from non-compliance or to detect non-compliance, should the situation arise.

Verification measures

- Cooperative measures (e.g. exchange of information);
- national technical means (e.g. national/military satellites);
- technical monitoring/measurement devices placed at/near sites;
- on-site inspections;
- intelligence information;
- open-source information (internet data, **satellite imagery**,…)

Treaty Monitoring using Satellite Imagery

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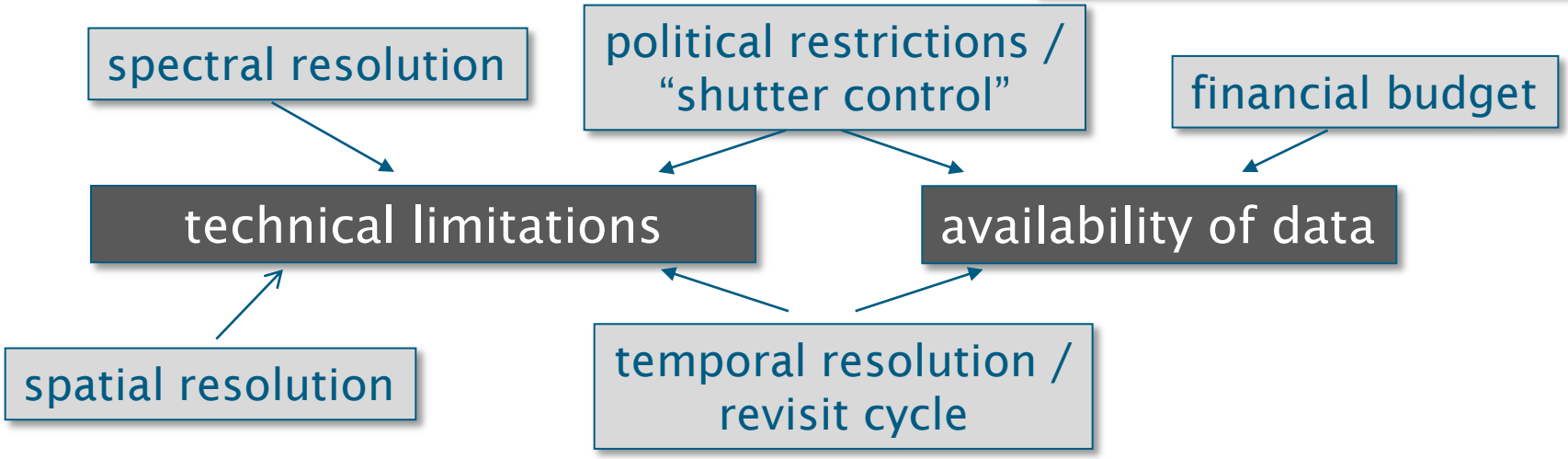
In the absence of "ground truth", commercial satellite imagery provides one of the few opportunities to gather "real" information.



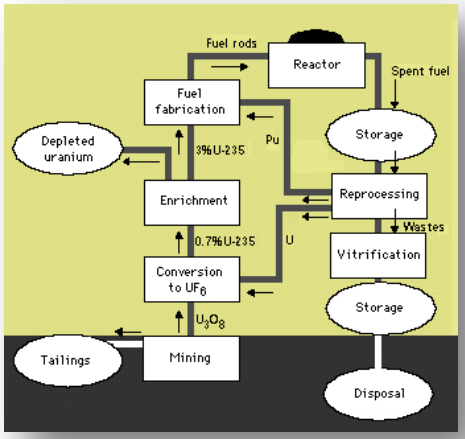
Verifying NPT Compliance Using Satellite Imagery

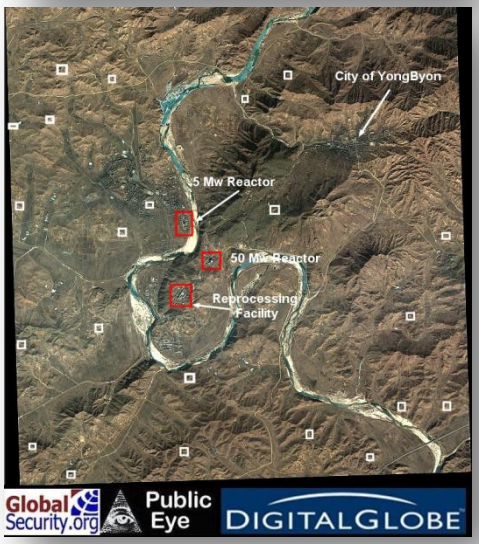
- Under the nuclear Non-Proliferation Treaty (NPT, 1970), non-nuclear weapon States are prohibited from, inter alia, possessing, manufacturing or acquiring nuclear weapons or other nuclear explosive devices.
- The Treaty establishes a Safeguards System under the responsibility of the International Atomic Energy Agency (IAEA), Vienna.
- Safeguards are used to verify compliance with the Treaty through inspections conducted by the IAEA.
- Safeguards are intended to prevent the diversion of fissile material for weapons use.

IAEA
International Atomic Energy Agency

Verifying NPT Compliance Using Satellite Imagery

IAEA
International Atomic Energy Agency





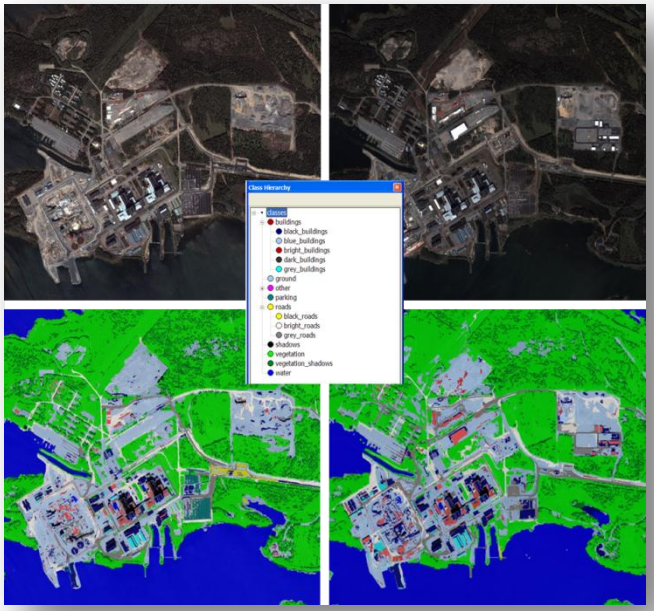
Application of satellite imagery within IAEA safeguards

1. Verification of Member States declarations
   → *Correctness?*

2. Verification of Member States declarations
   → *Completeness?*
   - Identification of undeclared facilities / activities

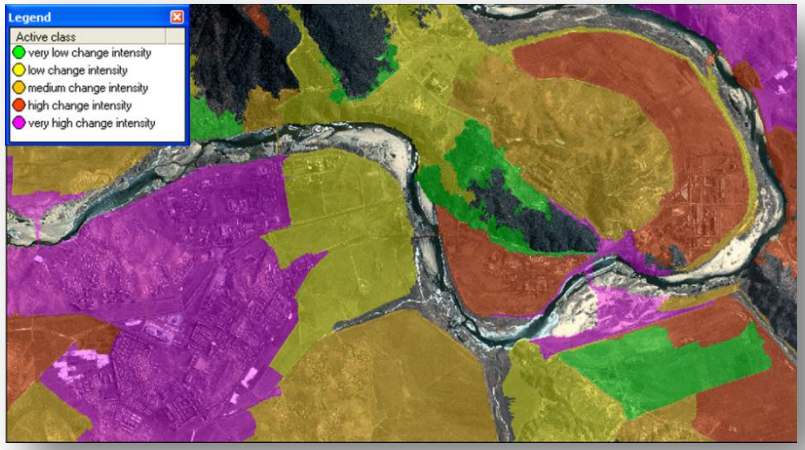
3. Preparatory information for
   - Inspections
   - Other technical visits

R&D Supporting IAEA Safeguards:
Automated processing of VHR optical imagery



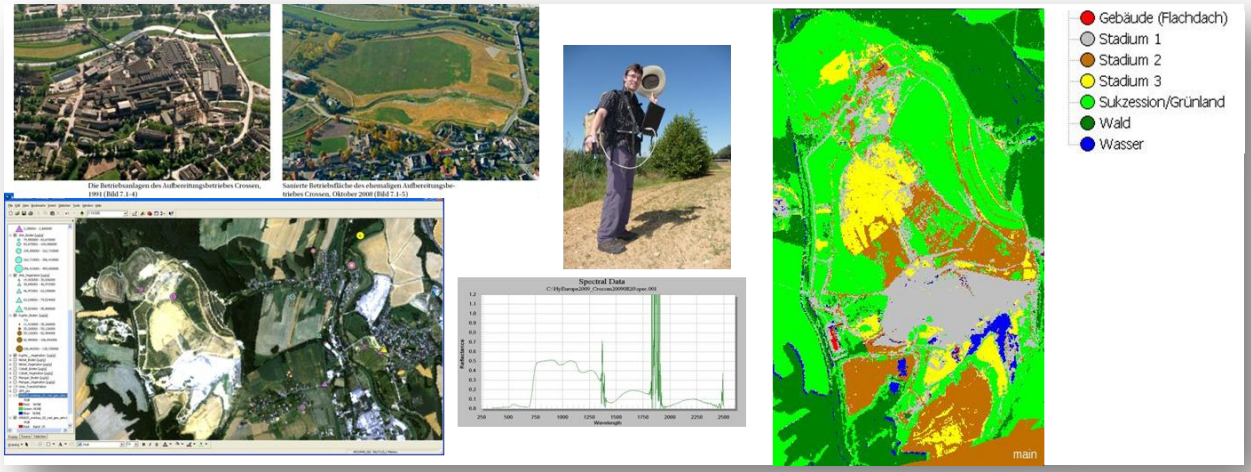
Classification

Change detection

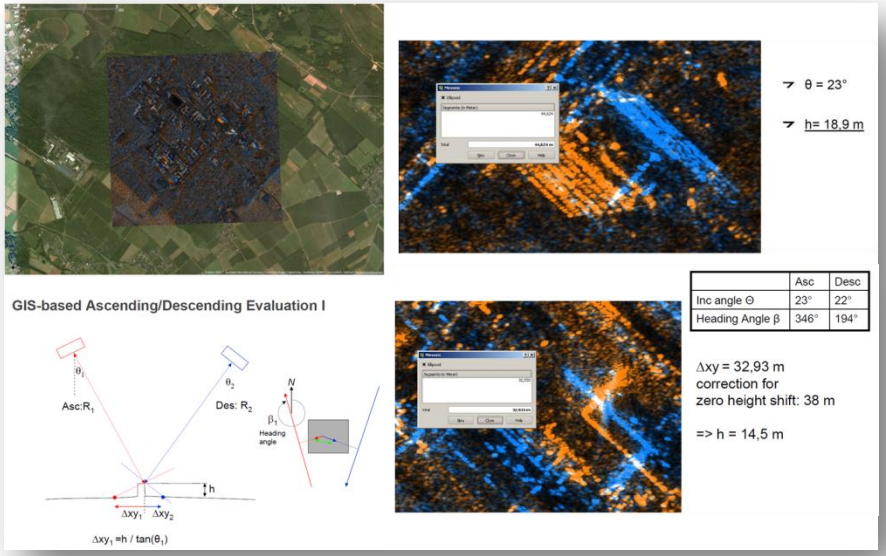


Rapid change mapping

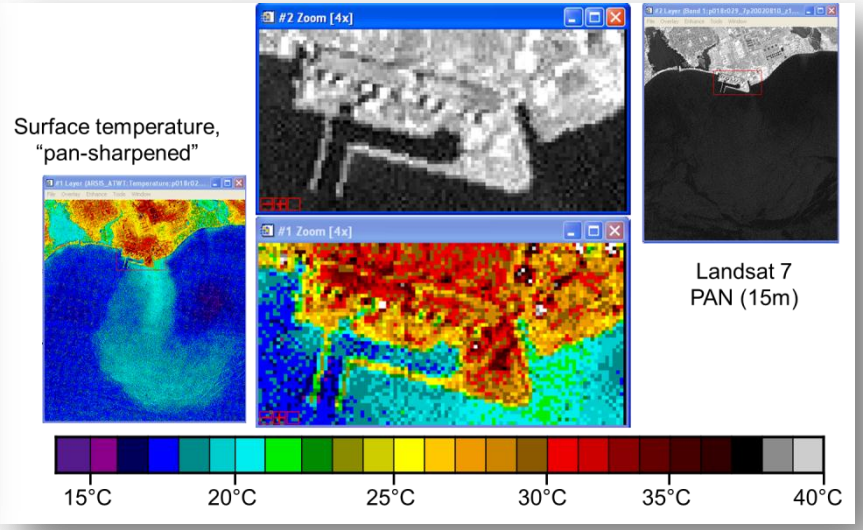
R&D supporting IAEA Safeguards:
Potential of SAR, hyperspectral and TIR imagery



Hyperspectral Signatures of Uranium Mining and Processing Sites



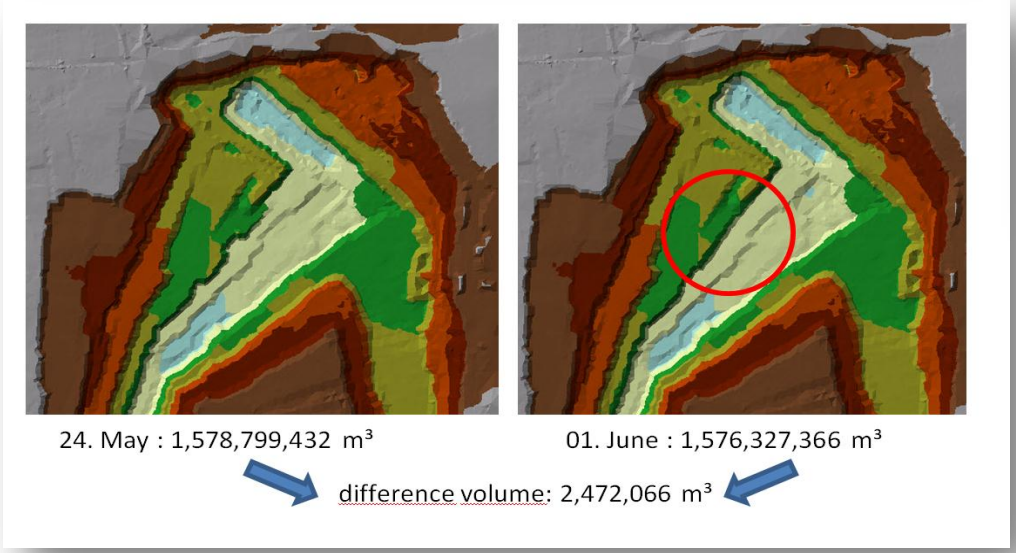
3D SAR Signatures of Nuclear Sites © DLR



Thermal Signatures of Nuclear Sites

R&D supporting IAEA Safeguards:
Geoprocessing

Visibility analysis using ArcGIS 3D Analyst



Volume calculation using ArcGIS Spatial Analyst

Geoinformation from the web using e.g. Geohack and Wikimapia

NPT Monitoring under GMES

G-mosaic
GMES Pilot Services for Security

Home | Project Overview | Publications | Team | Press & News | Calendar | Links

Nuclear and Treaties Monitoring

Home » Project Overview

Project overview

- G-MOSAIC in a Nutshell
- Intelligence & Early Warning
  - Nuclear and Treaties Monitoring
    - Monitoring of Nuclear Decommissioning Sites
    - Continuous Surveillance of Nuclear Facilities
  - Natural Resources and Conflicts
  - Migration and Border Monitoring
  - Critical Assets
- Crisis Management & Operations
- Project Users
- Service Cases

Nuclear and Treaties Monitoring

Services in the Nuclear and Treaties domain are focused on regularly monitoring specific sites in order to verify that decommissioning activities are taking place as per nuclear non-proliferation treaties. The services support the image analyst in verifying treaty compliance. Test sites in different areas of the world were selected based on the presence of nuclear facilities, such as the storage of nuclear armaments or the decommissioning of nuclear material.

The main activities are the regular assessment, identification and monitoring of nuclear capabilities, infrastructures and decommissioning sites. A complete set of geo-spatial products derived from Very High Resolution (VHR) Synthetic Aperture Radar (SAR) data and optical data are produced in both service chains. Products are based on a change detection analysis, which is carried out between different dates and over a long time span (9 months in the first G-MOSAIC operational phase and 6 months in the second one).

Aerial view of four decommissioned nuclear-powered attack submarines in the late stages of being scrapped out in a graving dock

Services

Two pilot services are developed in the domain of Nuclear and Treaties Monitoring:

- Monitoring of Nuclear Decommissioning Sites
- Continuous Surveillance of Nuclear Facilities

NPT Monitoring under GMES

Continuous Surveillance of Nuclear Facilities

The interest of this service chain is the **verification** that nuclear material and facilities in the selected sites are used for civil purposes, and the **assessment** of whether the initial declaration of material and facilities was complete and correct. The focus here is on operational nuclear facilities (as opposed to decommissioned sites).

The activity on such facilities is analysed using Very High Resolution (VHR) optical and Synthetic Aperture Radar (SAR) data. These products are integrated using a system which is able to manage multitemporal and multi-type information.

Nuclear areas are monitored to ensure treaty compliance

Core products

Volumetric Change Detection Map showing changes to the heights of objects

Multi-temporal Coherence Map showing the removal (or addition) of material to a site

Optical 2D Change Detection Map showing changes between two points in time

Monitoring of Nuclear Decommissioning Sites

The focus of this service chain is **monitoring the decommissioning** of nuclear sites in order to **verify compliance** with nuclear non-proliferation treaties.

This service chain provides geo-spatial products based on Very High Resolution (VHR) Synthetic Aperture Radar (SAR) images (in contrast to the service chain Continuous Surveillance of Nuclear Facilities, which also uses optical data).

Russian nuclear submarines (Credit: Grigory Pasko)

Core products

Radiometric Improved SAR products providing an improved radiometric resolution for better imagery analysis.

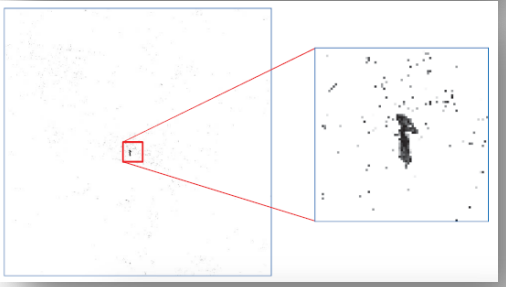
Multi-temporal Coherence Map showing changes between two points in time

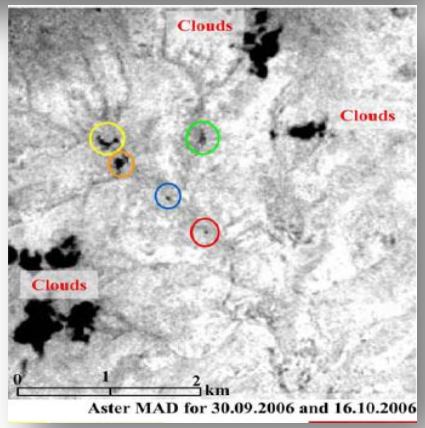
Verifying CTBT Compliance Using Satellite Imagery

- The Comprehensive Nuclear-Test-Ban Treaty (CTBT) bans nuclear explosions by everyone & everywhere.
- The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (PrepCom) has been founded in order to promote the Treaty and to build-up the verification regime
- Verification regime to make sure that no nuclear explosion goes undetected:
  - International Monitoring System (IMS), including seismic, hydroacoustic, infrasound and radionuclide monitoring
  - International Data Centre (IDC)
  - On-site Inspections

Verifying CTBT Compliance Using Satellite Imagery

- Presently, satellite imagery analysis is not included in the CTBTO verification regime.
- However, the CTBT considers satellite monitoring as an additional technology whose verification potential should be examined (Article IV, paragraph 11).
- Application of satellite imagery in the preparation of on-site inspections with regard to the specification of inspection area and point of entry, and for focusing activities during inspections.
- Complementary for confirming information gathered from the IMS.





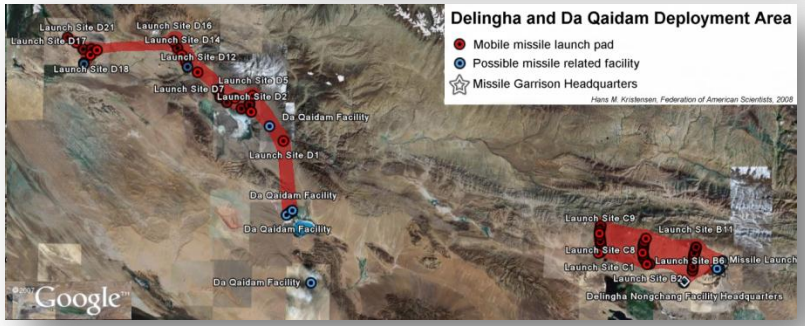
Sources: CTBTO (top), Henderson 2010 (mid), Schlittenhardt et al. 2010 (bottom)

Consultancy as to other Treaties

- Open Skies Treaty

[http://www.globalsecurity.org/wmd/world/syria/images/al-safir-dg-1b.jpg]

- Fissile Materials Cut-off Treaty (FMCT)



[http://www.fas.org/programs/ssp/nukes/_images/deployment.jpg]

- Nuclear Weapons Free Zones (NWFC)

- Missile Free Zones (MFZ)

[http://www.timesonline.co.uk/tol/news/world/middle_east/article3724048.ece]

Remote Sensing and Geoinformation Technologies for Treaty Monitoring

- EO generally represents a key source of information for the different national and international bodies involved in the implementation of treaties.
- EO has a lot of potential in verifying Treaties compliance by
  - Supporting the efficient management of arms control and non-proliferation issues;
  - Contributing to improve the performance of the Treaty.
- However, the potential of EO data and digital image processing still has to be investigated and utilised for a number Treaties.
- The use of satellite data under the NPT Safeguards System could serve as an example.
- ISPRS could play an important role.

Future directions for R&D

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Imaging satellite sensors

- Thermal infrared and hyperspectral sensors with improved spatial and temporal resolution
- Very high resolution optical sensors with enhanced spectral resolution
- High spatial resolution SAR sensors offering polarimetric data in L-/P-band

Information extraction and management

- Processing of satellite images as to Treaty-relevant physical or chemical parameters
- Modeling of Treaty-relevant features
- Computer-aided image understanding (computer vision)
- Integrated analysis of multi-source data
- Development of user-friendly geoinformation management and geoprocessing tools

Thank you for your attention.

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