A Study on the Use of Commercial Satellite Imagery for Monitoring of Yongbyon Nuclear Activities

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1. Introduction

Satellite imagery has been utilized to detect clandestine nuclear activities in target countries for intelligence purpose [1,2]. IAEA have applied satellite imagery analysis in their safeguards monitoring program [3]. It is particularly useful for the areas that are hard to access, such as the DPRK. On April 2009, North Korea expelled IAEA inspectors and USA disabling team at Yongbyon. Since then,.There is not much left except for satellite imagery analysis.

In this paper, we focused on the growing role and importance of commercial satellite imagery analysis for detecting and identifying nuclear activities at Yongbyon. For this, we examined (i) monitoring capability of commercial satellite imagery (ii) status of commercial satellite imagery analysis to monitor the Yongbyon nuclear site. And we suggested several recommendations for enhancing the monitoring and analyzing capability.

2. Analysis

2.1 Monitoring Capability of Commercial Satellite Imagery [4]

There are four types of Satellite Imagery. **Optical Imagery** has very high resolution as shown in Table I. However, acquisition is restricted by cloud and limited to daylight hours.

Table I: High Resolution Satellite Imagery of USA (as of AUG 2014)

Satellite Imagery	WorldView-1	GeoEye-1	WorldView-2	WorldView-3	WorldView-4 (GeoEye-2)
Launch	2007.9	2008.9	2009.10	2014.8	2016-mid
Sensor*	Pan	Pan/Multi	Pan/Multi	Pan/Multi	Pan/Multi
Resolution	0.5 m	0.41 m(Pan) 1.64m(Multi)	0.46 m(Pan) 1.84m(Multi)	0.31m(Pan) 1.24m(Multi)	0.34m(Pan) 1.45m(Multi)
Swath Width	17.6 km	15.2 km	16.4 km	13.1 km	14.5 km

* Pan : Panchromatic, Multi : Multispectral

Radar Imagery provides 24-hour monitoring capability because it can penetrate clouds. But it has slightly lower resolution (about 1 m) and processing and interpretation of imagery is much more difficult. So, it is useful complement to optical imagery. **Multi-spectral Imagery** can provide the means to view sites in a more natural, true color setting. And It may also provide a means for determining material/chemical composition and material transfer, for detecting camouflage and concealment activities. But its resolution is very low (about 2.5 m). **Thermal infrared Imagery** provides a quantifiable measure of heat transfer as a basis for determining site status such as reactor power operations. When correlated with optical could determine heat flow, both qualitatively and quantitatively, from waste ponds, steam lines, vents, stacks, cooling towers, etc.

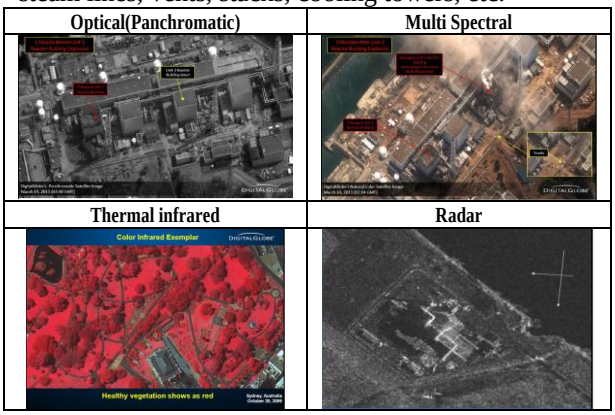

Fig. 1. Example Scenes of various types of Satellite Imageries

By using the satellite imagery, we can detect and/or identify the nuclear activities, as shown in Table II. As with all technology, satellite imagery is getting better all the time. As of Aug 2014, the highest resolution is about 0.3m. So far, DigitalGlobe, the only one satellite operator of USA, were prevented by law from selling images to foreign or commercial organizations in which features smaller than 0.5 m were prohibited. However, lately U.S. government had approved its longstanding restrictions and DigitalGlobe can sell high-resolution images from that satellite six months after it enters operation, which would make them available sometime in the first half of 2015. Therefore, except for the detection of undeclared gas centrifuge plant, and technical analysis and O&M verification of the yongbyon gas centrifuge enrichment plant and 5 MWe reactor, detection and identification are possible in theoretically.

Table II: Minimum Overhead Imagery Resolution Necessary for Analysis of Nuclear Fuel Cycle Related Facilities [4]

Facility	Detection	General Facility Identification & Site Layout	General Functional Building Description	Precise Building Identification	Technical Analysis & OMV
Gas Centrifuge Enrichment Facilities	**N/A**	1-3	0.5	**0.2**	**Limited to none at any resolution**
Research Reactor	2-5	1-3	1	0.5	**Limited to none at any resolution**
Pu Production Reactors	2-10	1-5	1	0.5-1	0.5-1

2.2 Status for Monitoring of Yongbyon Nuclear Activities

Since IAEA inspectors were expelled from the

Yongbyon complex in 2009, North Korea has embarked on a modernization program for its aging nuclear facilities. In November 2010, the North unveiled a new uranium enrichment plant. The construction of an Experimental Light Water Reactor in the early stage with a target operation date of 2010, also revealed at the same time, is now externally complete [5]. Also, after announcing its intention to restart its old 5 MW plutonium production reactor in April 2013, and its operation was restarted by late summer. Now, the identification of a probable fuel fabrication plant for the 5 MW reactor as well as a large new building that may be related to the production of ELWR fuel assemblies reinforces the conclusion that this effort is more wide-ranging and extensive than previously understood [6-9].

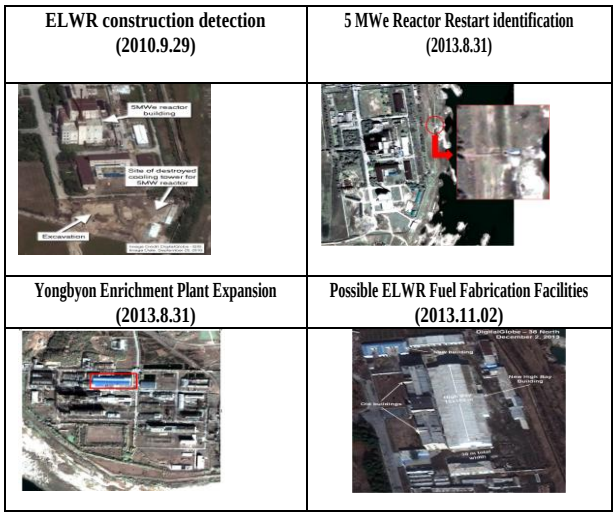

Fig. 2. Example Scenes of Detection or Identification for Yongbyon nuclear activities [6-9]

2.3 Limitation of its monitoring capacities

A famous Think tank organization on North Korea Issues, "38 North", has concluded that recent commercial satellite imagery indicates that North Korea continues to experience difficulties in operating its 5 MWe reactor. This assessment is based on the absence of white foam discharge caused by hot steam from the turbines after powering the reactor's electric generators [6]. Contrary to "38 North", another Think-tank, "ISIS", assesses that the discharge of water from the 5 MWe reactor's secondary cooling system between August 2013 and June 2014 could signify on-going operation of the 5 MWe reactor. However, without more data, such as regular steam production, it is hard to determine the operational status of the reactor and thus to estimate the amount of plutonium produced by the reactor. However, it is reasonable to assume that North Korea is renovating this reactor so as to achieve the reactor's previous level of plutonium production [8].

The presence of a steam plume provides a much better indication of the 5 MWe reactor's operational status than thermal imagery can give. However, the visibility of steam plumes on satellite images can be reduced by certain atmospheric conditions such as strong winds or high temperatures. It is likely that it is only because of this reason that its operational status can be monitored with thermal satellite imagery. Since January 2009, all scenes dating back to 1972 and new acquisitions by the Landsat 5 and Landsat 7 satellites can be downloaded from the US Geological Survey (USGS) website [10].

3. Conclusions

Current commercial satellite imagery has proven effective in monitoring for Yongbyon nuclear activities, especially change detection including the new construction activities. But identification and technical analysis of the operation status is still limited. In case of North Korea, operation status of 5 MWe reactor should be clearly identified to assess its plutonium production capability and to set up the negotiation strategy. To enhance the monitoring capability, we need much more thermal infrared imagery and radar imagery.

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