

## **Satellite Imagery for Safeguards Purposes: Utility of Panchromatic and Multispectral Imagery for Verification of Remote Uranium Mines**

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### **Abstract**

The issue of a cost-effective means of obtaining information on uranium mining activities is of special relevance with the advent of strengthened safeguards measures. As part of a project under the Australian Safeguards Support Program, panchromatic images of three operating uranium mines in Australia were obtained. The three mines represent differing mining approaches—including one large scale open cut mine, one large scale underground mine and one small scale in-situ leach mine.

In collaboration with the Canadian Safeguards Support Program of the Canadian Nuclear Safety Commission (CNSC), multispectral (including hyperspectral) imagery will also be included in the analysis, to complement the results using panchromatic imagery.

The key objective is to determine whether satellite imagery can provide sufficient information to confirm the operational scheduling and other details that had been reported to the IAEA by the State and the operator. Key features examined include: signs of water, power and chemical usage; level of mining activity; level of milling activity; extent of onsite product storage; geographic extent of mining work; geographic extent of milling activities; and presence of other industrial activities associated with/in support of mining/milling activities. The paper examines the overall utility for safeguards purposes of satellite imagery of uranium mines, particularly in remote regions.

### **Discussion**

Australia and Canada are both strong supporters of the IAEA safeguards system. This paper has been produced as a joint project of the Australian Safeguards Support Program (ASSP) and the Canadian Safeguards Support Program (CSSP).

Under integrated safeguards the IAEA will routinely receive annual declarations of uranium production for States as a whole (Articles 2.a.(v) and 3.b. of INFCIRC/540). The Protocol provides that declarations of production by individual mines and concentration plants are to be provided only on request. The question arises, how will the IAEA be able to evaluate the data it receives. Seeking to comprehensively verify the absence of undeclared nuclear material and/or activities at uranium or thorium mining/milling operations with any State would absorb substantial IAEA and member State resources with little real improvement in the safeguards coverage of the State. Such efforts would be contrary to the spirit of Integrated Safeguards which is to arrive at an optimum system of safeguards

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measures where the cost of safeguards is one of the considerations affecting the evaluation of the optimum.

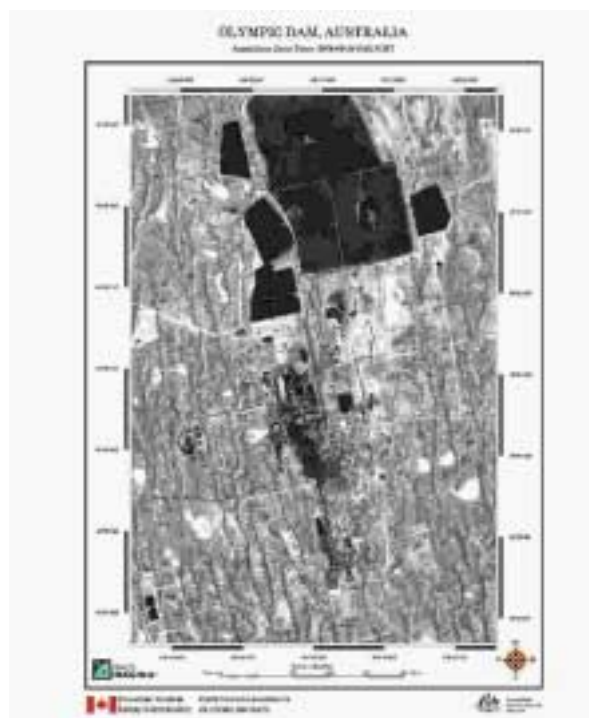
At the IAEA's request, Australian Safeguards and Non-Proliferation Office (ASNO) started a Support Program task to consider all the options that are available to the IAEA for deriving assurance that uranium mining/milling operations are consistent with the activities declared to the IAEA<sup>2</sup>. Originally this task sought to determine:

- (1) the circumstances under which the IAEA might undertake complementary access to a uranium mining/milling site,
- (2) what verification activities would be applicable, and
- (3) how open-source information (such as imagery and non-official sources) and official information (provided, for example, in a State's Declaration pursuant to the Additional Protocol) could be used in safeguards evaluation.

One of the reasons that the Australia Government considers this issue to be of major importance is that Australia has around 26% of the world's low cost uranium reserves, and is a major uranium exporter of uranium ore concentrates (UOC). As one part of the overall uranium mine project the ASSP funded the purchase of panchromatic images of the three operating uranium mines in Australia. The three mines represent differing mining approaches—including one large-scale open cut mine, one large-scale underground mine and one small-scale in-situ leach mine:



- The Ranger open-cut uranium mine and associated uranium mill with a current capacity



of about 4,500 tonnes U<sub>3</sub>O<sub>8</sub> per year are operated by Energy Resources of Australia Ltd (ERA), in the Northern Territory about 230km east of

<sup>2</sup> IAEA-SM-367/B/15/02/P, "Implementation of the Additional Protocol: Verification Activities At Uranium Mines and Mills", Carlson, Bragin and Leslie, IAEA Symposium 2001, Vienna



Darwin. It was proposed that mining operations would be moved from Ranger to a nearby (20km away) deposit known as Jabiluka, but the development of Jabiluka has been deferred indefinitely.

- The Olympic Dam copper and uranium mine is operated by the Western Mining Corporation Ltd (WMC) in South Australia 560km north of Adelaide. The deposit is some 350m underground, and is the largest known uranium ore body in the world. Last year (FY2000-01) the plant produced about 4,800 tonnes  $U_3O_8$ , essentially as a by-product of copper mining. Plans have been announced to expand production further to 5,600 tonnes  $U_3O_8$  per year.

- The Beverley *in situ* leach mine is operated by Heathgate Resources Pty Ltd in South Australia 520km north of Adelaide. Production, eventually reaching around 1,000 tonnes  $UO_4$  per year, began in November 2000, though no production was reported for FY2000-01.

Consideration is also being given to purchasing imagery of a new mine now approaching operational status – Honeymoon, South Australia – which will use *in situ* leaching to extract uranium. The Honeymoon Uranium Project of Southern Cross Resources Australia Pty Ltd is at the pilot plant stage. At the time of writing the project is awaiting final environmental approvals. Production is planned to be around 1,000 tonnes  $UO_4$  per year.

Eventually the project may be expanded to include an additional six uranium mines that have been closed: Radium Hill, Rum Jungle, Mary Kathleen, Moline, Rockhole, and Nabarlek – though such imagery is expected to confirm that the mines are non-operational and abandoned.

As Canada is another major uranium exporter with large reserves of uranium the Canadian Safeguards Support Program (CSSP) of the Canadian Nuclear Safety Commission (CNSC) was also interested in taking an active role in this project. In collaboration with the CSSP, multispectral (including hyperspectral) imagery has also been included in the analysis, to complement the results using panchromatic imagery. All of the imagery presented in this paper has been size limited to simplify distribution of the paper. Limiting the size of the images greatly reduces the detail that is visible within the images. All analysis has been done with full sized, detailed images.

At the first level of consideration, the analysis of satellite imagery provides the IAEA with the opportunity to confirm the gross details of the State's declaration of its uranium mining activities:

- is the declared location of the mine accurate;
- does the layout of the mine agree with the plans, maps and diagrams supplied by the State;
- is its scale consistent with the declared level of production; and
- is it currently in operation.

In order to achieve the full potential of the technique it is necessary to analyse the imagery in greater detail. One immediate result of the comparison between panchromatic (i.e. black and white) imagery and the pan-sharpened multispectral imagery was that experienced nuclear analysts that had not been trained in imagery analysis were able to find more detail to interpret within the colour images. Training in imagery analysis for experienced nuclear analysts would simplify this process to some extent.

The purpose of the analysis of information bearing on declared uranium mining/milling operations, and complementary access at such mines, is to derive some assurance that mines are not being misused. The forms of misuse of prime interest are the understatement of production and the presence of undeclared nuclear material or activities (ie the conduct of other fuel-cycle steps) at the location. Understatement of production would allow the State to acquire undeclared source material which could be used in clandestine nuclear activities. The use of commercial satellite imagery is simply one part of the information available to the Agency for consideration – others include import/export data, open source reports, and official and semi-official publications. Such sources would certainly have the capability to raise questions and reveal inconsistencies requiring Complementary Access for their resolution. They may also identify less serious uncertainties. Either situation could lead to an installation being selected for Complementary Access under Article 4.a.(i).



This paper is the first in a series of papers that will deal with each of Australian mines listed above.

### **The Ranger Mine**

The Ranger Mine is a clear example of a type of mine that is particularly well suited to imagery analysis. The mine itself is open cut, uranium is the only commercially significant product and there is no significant storage of inputs, process chemicals or product that is not clearly visible in the satellite imagery.

The image above is an example of sharpened multi-spectral partial image of the Ranger uranium mine. The inset letters will be used to describe some of the details that have to be understood in order to interpret the “ground truth” from a satellite image.

The Ranger project is an extremely large mine. One useful key that can be used to arrive at an understanding of the project size is the apparently small dots that can be seen at the point A on the photograph above. The small dots in this image are actually 15 meter long ore carriers (they only appear to be small in an image of this size - it is possible to see them in better detail in larger scale satellite images). The photo below shows a vehicle of the same type with a person in the shot to show the scale of these vehicles (these photos were not taken at the Ranger mine).



The two photos given above illustrate the types of details that must be understood if an analyst is to interpret satellite images. Both of the images detail activities that would appear to match the activities observed at point AB on the annotated image above (though neither image was taken from the Ranger mine). The first image is of an ore carrier refuelling station. The refuelling of trucks is an innocuous activity that will occur at any active mine. The second picture is of a “discriminator” station – this is a station for measuring the radiation level and hence the grade of the ore in the truck. High grade ore is sent straight to the mill for processing, lower grade ore is sent to the Coarse Ore Stockpile (point X on the annotated image above).

The use of a “discriminator station” is an activity that is unique to uranium mines – unfortunately it is difficult to distinguish between a discriminator and a refuelling station from a satellite image alone – even someone familiar with the type of site and its activities would need further information to distinguish the activities at point AB on the image with certainty.

Working our way through the image in detail:



- A - is a holding station for ore-carriers
- B - is two parked low loaders.
- C - is the sulphur stockpile (the stockpile is actually bright sulphur yellow rather than the white it appears in this image, the colour balance was chosen from other considerations)
- D - is the sulphur truck dumping station
- F - is the acid tanks
- G - is the acid plant



H - is the power station (with the cooling towers visible)

W - is the fine ore crushing station

X - is the coarse ore stockpile

Y - is the primary sewage pumping station with pond water tanks

Z - is the endpoint of the No.1 conveyor

AA - is the primary crusher

I - is the heavy equipment workshop

J - is the front gate

K - is the fuel storage tanks (diesel in the big ones, kerosene in the small ones)

L - is the ammonia storage tanks

M - is the emergency organic dump tank

N - is the mixer-settlers for the mill

O - is the product storage warehouse

P - is the main office/admin area

Q - is the sand filters

R - is the neutral thickeners

S - is the thickeners

T - is halfway between two retention ponds and

below the lime storage

U - is the pyrolusite stockpile

V - is the leaching pachucas (air agitated tanks)

Many of the features given in the images above are ambiguous (as in the example of trying to distinguish a refuelling station from a discriminator). Considerable familiarity with the form and function of the processes is necessary in order to adequately interpret the features in the image.

For the Ranger mine key features that are necessary to estimate the rate of uranium production over short periods of time (by which we mean 1-3 months, though there is no suggestion that the Agency would acquire imagery over this short a time period) at the facility are:

- the size and extent of the sulphur stockpile at point C on the image;
- the size and extent of the coarse ore stockpile at point X; and
- the indications of traffic through the discriminator at point AB

While the state of the process equipment is a true key determinant of the production rate of the mine it is very difficult to determine the state of the process equipment from satellite imagery alone. Bulk feedstocks provide the most readily interpretable information in the short term.

The tailings are stored underwater and the changes in the gross physical details of the tails storage over periods of six months or longer are a crucial indicator of the production rate of the mine. Changes in

the state of the tailings dams are difficult for the operator to conceal and relatively easy to determine from the multi-spectral imagery (though it is possible to note equivalent changes on panchromatic images).

### **Concluding remarks**

Satellite imagery does appear to be a valid tool for determining the state of operation of open cut uranium mines and to derive some indication of their rate of production. Key indicators in the short term are the stockpiles of bulk process input materials. In the longer term the key indicator is the rate of water usage and the state of the tailings stockpiles. While the considerations in this paper were restricted to a single, large, open-cut mine similar considerations should apply to large scale underground mining.

In a collaborative effort between the CNSC, Canada Centre for Remote Sensing has successfully acquired a hyperspectral image for Ranger mine from the Hyperion satellite. Initial processing and analysis are being carried out. The analytical methods used in this work have been applied on airborne hyperspectral survey data over Canadian mines and tailings. The analytical methods and some initial results of this work are described in the following Reference 1.

[ASNO and CNSC gratefully acknowledge the use of mine site images supplied by Minerals Council of Australia in producing this paper]

[Reference 1 - Q.S. Bob Truong et al., Chapters 6 and 10 of a Springer-Praxis book "Commercial Satellite Imagery - A tactic in nuclear weapon deterrence", edited by Bhupendra Jasani and Gotthard Stein, ISBN: 3-54042-643-4 Springer-Verlag Berlin Heidelberg New York.]