Conducting Research on North Korea using Commercial Satellite Imagery, Map and Other Geographic Data

Matthew G. McKinzie, Ph.D. and Thomas B. Cochran, Ph.D.
Natural Resources Defense Council

In 2003 the Nuclear Program at the Natural Resources Defense Council (NRDC) undertook a project to create a geo-spatial database of North Korea, drawing on information from U.S. and South Korean military maps, 10-meter resolution black and white and 15-meter resolution color satellite imagery covering the entire Korean peninsula and—most importantly—NRDC's extensive collection of higher-resolution commercial satellite imagery of North Korean cities and other specific areas. Currently the NRDC database contains over 3,500 data records, including sites relating to the North Korean economic and power-generating infrastructure, political leadership and military. Each data record is comprised of data fields that identify the point of interest by name, its coordinates and function, the source of the coordinates, reference data and other characteristics of interest. A general description of the database format, including a simplified record classification scheme to facilitate sorting the data records and constricting database queries and graphic themes, can be found in *The U.S. Nuclear War Plan: A Time for Change*, Chapter 3 and Appendix C (See, http://www.nrdc.org/nuclear/warplan/warplan_ch3.pdf. Fig. 1 shows a map of the current NRDC database.
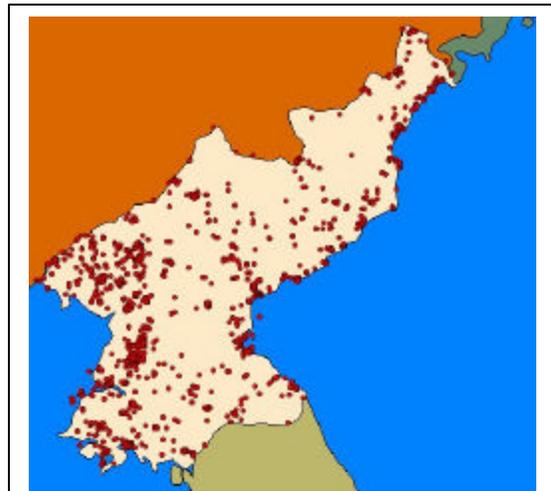

Fig. 1: The NRDC North Korea database as of September 2004.

The goal of the project is to develop a research tool—a window into this closed society—that can be used to for projects relating to both security and human rights issues.

Today the computing power available in commercially available laptops is comparable to the Cray II that went into Lawrence Livermore National Laboratory in 1985. The commercially available imagery is comparable to state-of-the-art imagery of the U.S. intelligence community in the early 1970's. Thus, the imagery and computational capabilities available to the non-government community, while constrained by budgetary considerations, are roughly comparable to U.S. government capabilities some 20-30 years ago.

Basic geographic information related to North Korea's military and economy are considered a sensitive topic, much like the geography of the Soviet Union was during the Cold War. By organizing information geographically one can gain a far greater understand how this closed society works: the sum of the data is greater than its parts. From an arms control point of view, this geographic information can serve to refine open estimates of military assets, such as published in the <u>Military Balance</u>. It can be used to assess the implications of regional military conflict, such as occurred in Iraq, including the use of chemical, biological and nuclear weapons. It has demonstrated utility in human rights and environmental assessments.

COMMERCIAL SATELLITE IMAGERY OF THE DPRK

High-resolution (one meter resolution) satellite imagery was first made available to non-governmental researchers in 1999, with the launch of the Ikonos satellite by the Space Imaging Corporation, based in Thornton, Colorado. The Ikonos satellite circles the earth in a sun-synchronous orbit every 98 minutes, photographing scenes in strips approximately 12 kilometers wide. The sensors on the Ikonos satellite photograph objects on the earth's surface in black and white at one-meter resolution and in four spectral bands (near-infrared, red, green and blue) at four-meter resolution. A composite image, called pan-sharpened, is produced which provides a color photo at one meter resolution.

In 2000 the DigitalGlobe Corporation, also based in Thornton, Colorado, launched the QuickBird satellite which can achieve a 61-centimeter resolution under some conditions.

The business model of the Space Imaging Corporation involves regional affiliates who task the satellite, download data from the satellite's computer and have proprietary ownership over images photographed in the affiliate's Communication Cone or CommCone. Space Imaging Korea is a Space Imaging affiliate whose CommCone extends over the Korean peninsula and also covers Taiwan, Japan and portions of China and Russia (see Fig. 2). The Space Imaging Corporation, whose parent company is the U.S. defense and
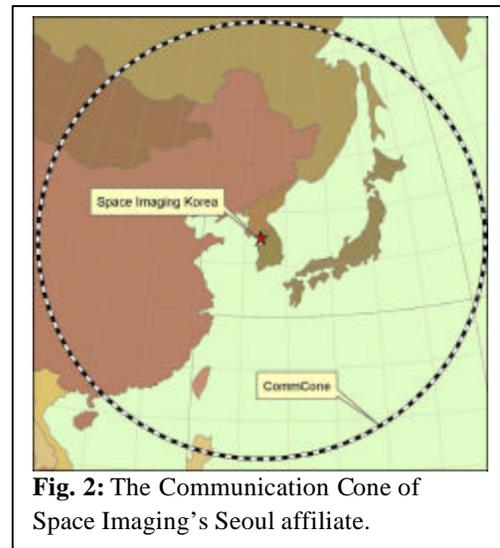

Fig. 2: The Communication Cone of Space Imaging's Seoul affiliate.

space contractor Lockheed-Martin, builds satellite ground stations for its affiliates who then often task the satellite in their region in support of intelligence collection.
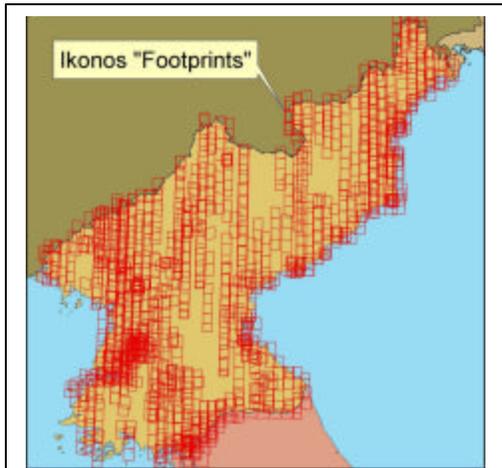

Fig. 3: Commercially-available satellite images of North Korea in the Space Imaging on-line archive.

Commercially available images from both the Ikonos and QuickBird satellites are accessible in internet-searchable archives from which customers order specific scenes (www.spaceimaging.com and www.digitalglobe.com, respectively). To date Space Imaging has more than 1,600 satellite scenes of North Korea in their archives for sale to the public, as shown in Fig. 3. DigitalGlobe's coverage of North Korea is sizable but not yet as extensive.

Purchasing satellite imagery out of the archives of the DigitalGlobe or Space Imaging corporation is much less expensive than ordering new imagery. It should be noted that most of the commercial high-resolution satellite image coverage of North Korea is currently in the form of one or at most a few images of any given site. Time sequences of satellite images, from which more information can be derived, are generally not now available to the NGO research community because of the prohibitive cost.

Therefore existing archives of commercial satellite images are most useful for understanding infrastructure and analyzing snapshots of military deployments, such as navy vessels in port, parked aircraft or vehicles stored in the open at military depots.

Under some circumstances the Ikonos satellite may be tasked to image a specific area of the earth within a short time frame. Such rapid turn-around was done in response to the Space Shuttle disaster and

Fig. 4: Ikonos satellite image of down-town Baghdad taken on 1 April 2003.

the wars in Afghanistan and Iraq. Fig. 4 illustrates this capability with an Ikonos image of Baghdad taken on 1 April 2003. The most prominent features in this image are the smoke plumes from oil fires set by the Iraqis to interfere with U.S. precision bombing.

There also now exists a wealth of publicly available, lower-resolution satellite images that can assist in defining sites of interest in North Korea and provide information about larger-scale features such as urban areas, airfields and ports. For example, the U.S. National Imagery and Mapping Agency (NIMA: an agency of the U.S. Department of Defense) provides 10-meter resolution, black-and-white satellite coverage of the entire Korean peninsula for internet download, accessible at geoengine.nima.mil. This data set is referred to by the U.S. government as Digital Orthorectified Imagery – 10 meters (DOI-10) and is comprised of SPOT imagery dating from the 1990s. DOI-10m coverage of the Korean peninsula fits on about 10 CD-ROMs and NRDC has created an "image catalog" on our hard drives whereby any location in North or South Korea can be zoomed to and the DOI-10m imagery immediately displayed. DOI-10m imagery is useful for identifying the location of densely populated areas, airfields, dams, bridges, and large ship piers. We found DOI-10m particularly useful in identifying and locating airfields with associated underground hangers and selected navy bases and commercial harbors and often used it in prioritizing which areas to examine in more detail by purchasing Ikonos and QuickBird images. Fig. 5 shows DOI-10M coverage of Seoul acquired on 24 January 1995.

Fig. 5: DOI-10m (SPOT) satellite image of Seoul taken on 24 January 1995 showing the many bridges across the Han Gang River.

Similarly, NaturalVue—a global dataset derived from the LandSat-7 satellite—provides 15 m resolution full color imagery of North Korea (see http://www.earthsat.com/HTML/naturalvue/). As one might expect, the color imagery is particularly useful in distinguishing undeveloped areas, e.g., forests, agricultural features, rivers, reservoirs, urban areas, sharp differences in elevation, e.g., mountains and valleys, and even shallow areas along the seacoast. Figure 6 shows a NaturalVue image of the DPRK capitol city Pyongyang. The individual LandSat-7 satellite photographs which make up the NaturalVue data were acquired between 1998 and 2002.

Fig. 6: NaturalVue image of P'yongyang, DPRK, built along the shores of the Taedong River.

We also use digital elevation data collected during the February 11, 2000 Space Shuttle Radar Topography Mission (see http://www2.jpl.nasa.gov/srtm/mission.htm). These data, which have a horizontal special resolution of about 50 meters, can be integrated with the higher resolution NaturalVue, Ikonos and QuickBird imagery to create 3-D images. Accurate, detailed elevation data is also useful in plume model calculations of the effects of chemical, biological, radiological and nuclear weapon use in this mountainous terrain. Figure 7 shows a 3-D rendering of a DigitalGlobe satellite image of the DPRK auxiliary airfield at On'chon. Note the runway terminating in the hill near the airfield. In the distance the NaturalVue background can be seen over which the DigitalGlobe photo has been displayed. Military sites constructed partially within hills and mountains are a unique feature of the DPRK and more easily analyzed using the Radar Topography data.

Fig. 7: A 3-D rendering of a DigitalGlobe satellite image of the DPRK auxiliary airfield at On'chon. Note the segment of runway which continues through the hill.
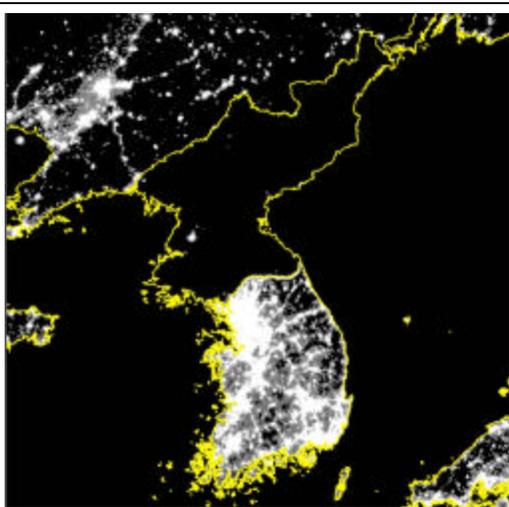

Fig. 8: Defense U.S. Defense Meteorological Satellite Program (DMSP) satellite data of stable nighttime lights on the Korean peninsula, 2000.

Another, even lower-resolution satellite imagery resource on North Korea is from the U.S. Defense Meteorological Satellite Program (DMSP). The break-up of the Soviet Union in 1991 hastened the severe economic decline of North Korea. High-resolution satellite images of North Korean cities show many industrial facilities, but it is hard to judge from one image alone what the level of activity is at these facilities. In images of stable nighttime lights on the Korean peninsula taken by DMSP satellites, North Korea appears very dark compared with South Korea (Fig. 8). Indeed, comparisons of 1992-1993 and 2002 DMSP images of Seoul and P'yongyang show that the area of persistent nighttime lights in the North Korean capital appears to have decreased a

decade after the collapse of the Soviet Union, in contrast to the growth of Seoul (Fig. 9 – note the differences in scale between images of P'yongyang and Seoul). Economic hardships suffered by North Korea and widespread famine in the 1990's caused an unprecedented exodus of refugees, whose accounts have provided more insight into this closed society.
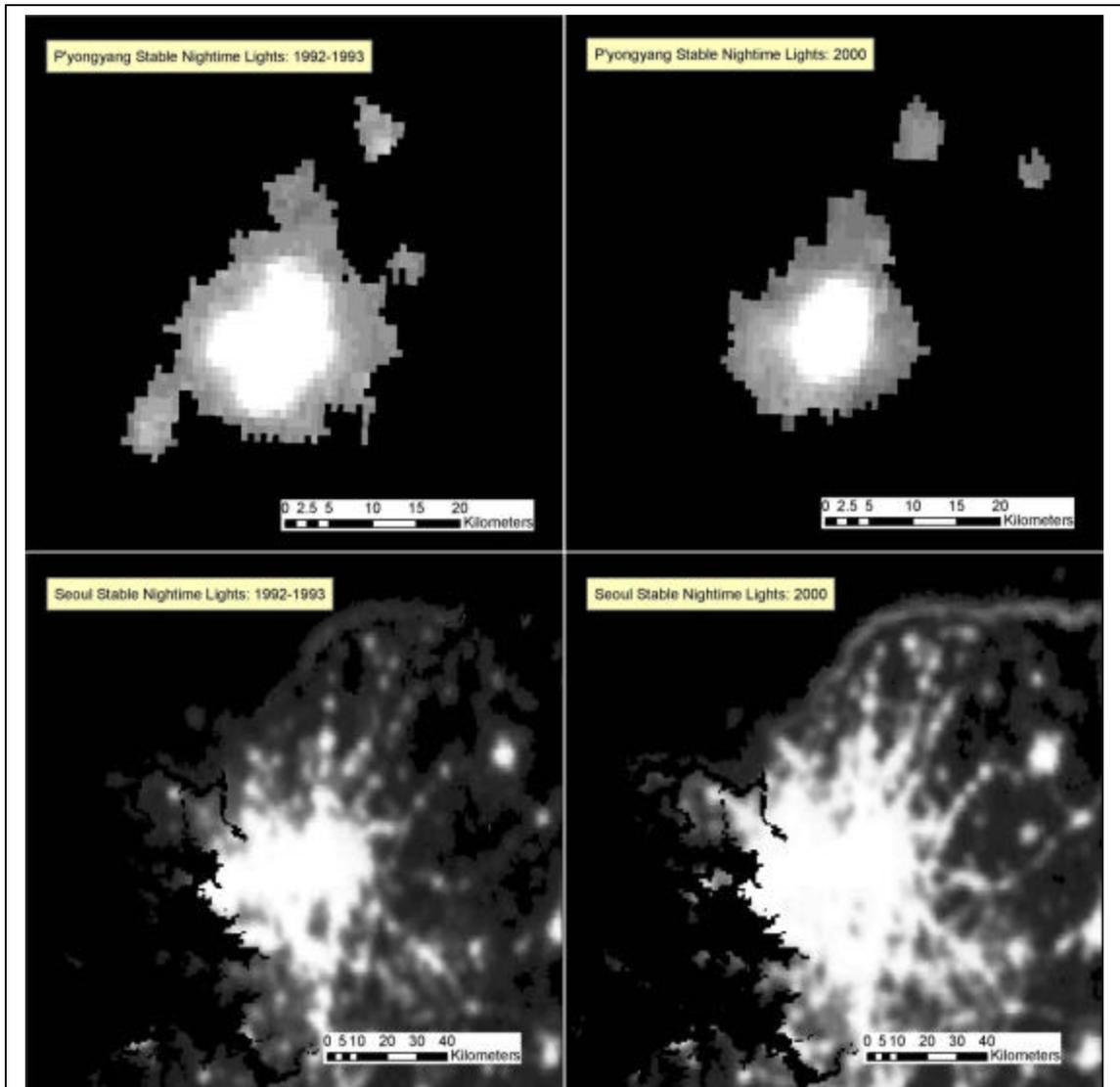

Fig. 9: Comparison of 1992-1993 and 2000 stable nighttime lights data for P'yongyang (above) and Seoul (below). Note the differences in scale between images of P'yongyang and Seoul
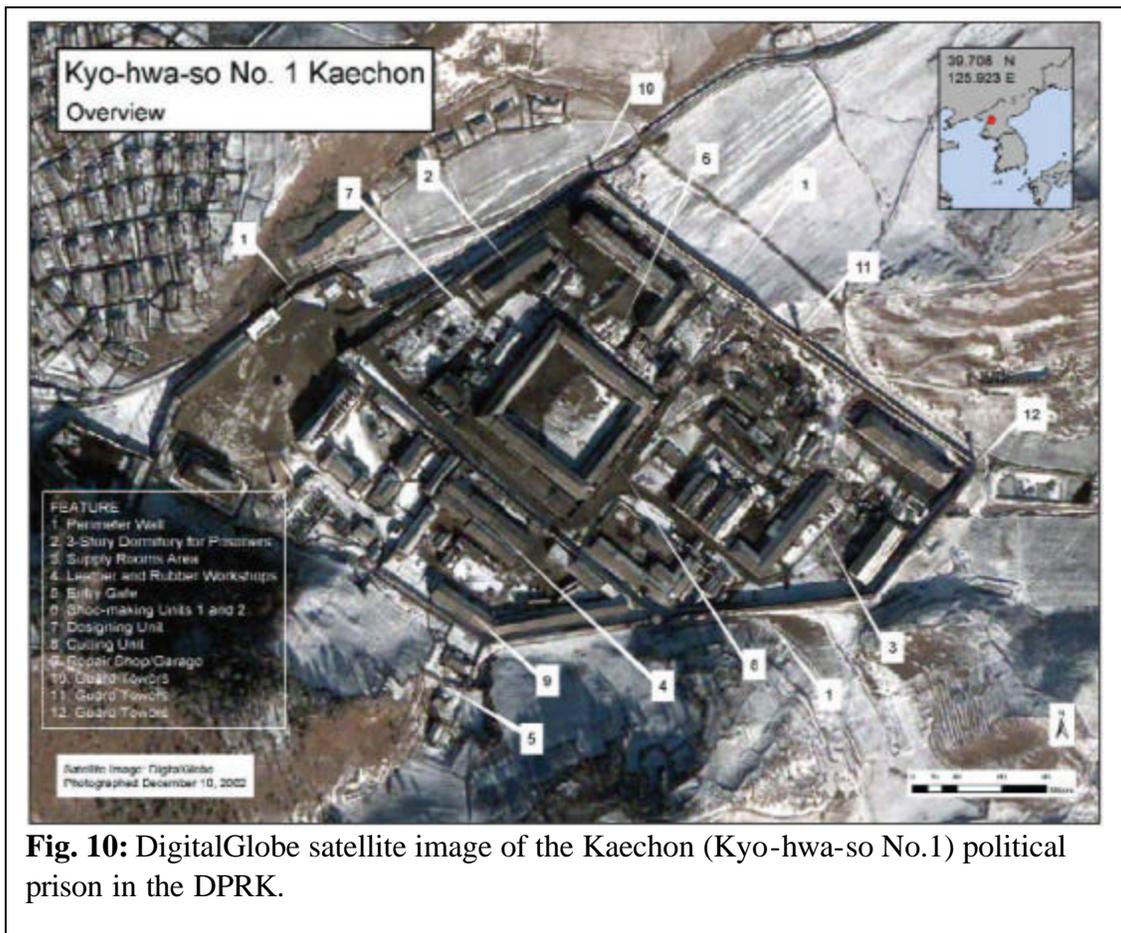
APPLICATIONS OF THE NRDC DATABASE: THE DPRK GULAG

Beginning in the mid-1990's, several thousand North Koreans have made the difficult journey to South Korea to escape famine and political repression. A small fraction of these refugees have had experience with the extensive political prison camp system in the DPRK. In collaboration with the NRDC, the U.S. Committee for Human Rights in North Korea, a Washington, DC based NGO, recently published an unprecedented, systemic study of the North Korean political prison camp system, supplementing defector interviews with satellite imagery (The Hidden Gulag: Exposing North Korea's Prison Camps; Prisoners' Testimonies and Satellite Photographs at www.hrnk.org/hiddengulag).

With meter and sub-meter resolution satellite imagery, objects such as buildings, forests, orchards, fields, fences, rivers, railways, trails, and roads are easily recognizable. Indeed, satellite photographs were shown to former North Koreans who were imprisoned in these places, and who were able to identify specific features in the photographs and to describe their purposes. Using the satellite imagery, interviews with former prisoners were conducted in Seoul, Washington, DC, and Los Angeles, and the derived annotations have been overlaid on the photographs reproduced in this section of the report. NRDC's database and map collection further served to understand the geography and organization of the DPRK's political prison camp system.

Commercial, high-resolution satellite imagery, and the testimony of North Korean defectors who were exposed to the gulag, are revealing windows into this closed society. Annotated satellite images of five sites in the North Korean gulag offers a glimpse into the different sorts of work that prisoners are forced to perform: food production and mining camps for example, very large sites consisting of several villages spread over more than a hundred square kilometers. Smaller prison sites have factories or workshops where prison laborers are forced to produce bricks, clothing, shoes, or other goods.

Figure 10 shows a DigitalGlobe satellite image of the Kaechon (Kyo-hwa-so No.1) political prison. The prison is located in the corner of a valley surrounded by mountains and has held up to 6,000 prisoners. A high wall with an electrified-wire fence surrounds the complex, which includes prisoner dormitories, a large two-story factory, and office buildings for guards and prison officials. According to the testimony of former prisoners, the primary prison-labor occupations at Keachon during the 1990's were garment and shoe manufacturing. A table-sized printout of the satellite image encompassing a much larger area was presented to two former prisoners, who traced with their fingers the road from the nearby city of Kaechon which they traveled to the prison site.

Fig. 10: DigitalGlobe satellite image of the Kaechon (Kyo-hwa-so No.1) political prison in the DPRK.

APPLICATIONS OF THE NRDC DATABASE: HARDENED AND DEEPLY BURIED FACILITIES IN THE DPRK

Most airfields in North Korea are identified on unclassified 1:250,000-scale Joint Operations Graphic (JOG) military maps. We used DOI-10m black and white and 15m NaturalVue color imagery to identify airfield with taxiways to nearby mountains. We then ordered QuickBird 0.6m-resolution images of these candidate airfields to verify and analyze the associated underground hangers and to analyze identify aircraft in open parking areas. The elevation data from the Shuttle radar were integrated with the NaturalVue and QuickBird images to create 30D images of the airfields.

We are also using the underground hangers and other identified underground facilities to analyze the consequences of using earth penetrating nuclear weapons against these targets. The results of this analysis will be presented in a forthcoming report.

FUTURE APPLICATIONS

The NRDC database of features in the DPRK and satellite imagery is a rich resource to better understand many aspects of the "Hermit Kingdom." The NRDC would welcome the opportunity to work collaboratively with this resource.