# Satellite Imagery Analysis of Yongbyon Experimental Light Water Reactor (ELWR)

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## 1. Introduction

In December 2022, Kim Jong Un called for an 'exponential increase in the number of nuclear warheads', and in September 2023, he demanded that the 'strengthening of the nuclear arsenal' to be included in North Korea's socialist constitution. Since then, significant and minor activities were observed at the Yongbyon nuclear complex, including the construction of new buildings. Most notably, the International Atomic Energy Agency (IAEA) announced in November that the Yongbyon Experimental Light Water Reactor (ELWR), which North Korea had previously claimed was for power generation, may have started operating in October. According to Dr. Siegfried S. Hecker, who visited North Korea in 2010, the reactor is a small prototype LWR with a thermal output of 100 MWth and an electrical output of 25-30 MWe that North Korea has developed on its own in imitation of the Soviet-designed Water-cooled and Water-moderated Energy Reactor (VVER) [1]. At the time, an engineer there noted that the ELWR had broken ground on 31 July 2010 and was scheduled for completion in 2012. However, it has been difficult to identify any clear evidence of operations until recently, following the supposed completion of the facility's exterior in 2013. Given the concerns from a nuclear non-proliferation perspective that this reactor could be used to produce plutonium from low-enriched uranium nuclear fuel, there is a need to verify whether the facility is operational or not [2]. However, there are significant restrictions on physical access to the site, as well as limited technical specifications associated with the ELWR. Therefore, understanding North Korea's intentions requires relying on a variety of publicly available information.

Therefore, this paper presents a comprehensive assessment of the current status of the ELWR by understanding the configuration of the reactor and its infrastructure through time series analysis of satellite imagery, which is effective for monitoring in restricted access areas, and by linking direct and indirect evidence of operations such as warm water discharges.

## 2. Satellite Imagery Analysis

In a 2022 study, the Korea Institute of Nuclear Nonproliferation and Control (KINAC) derived several direct and indirect evidence, or signatures, discernible from satellite imagery to monitor North Korea's nuclear activities [3]. In this section, we analyzed over 318 available satellite images from 2010 to February 2024 based on them [4].

### *2.1 Configuration of the Buildings*

Located on the northern side of the Yongbyon Nuclear Complex, the ELWR is located south of the 5 MWe reactor along the banks of the Kuryong River. Construction began in 2010, and the reactor, auxiliary buildings, and external substations appear to have been externally completed around 2013. The surrounding roads, pipelines, and south (2011-2012) and west (2018) support buildings were then constructed at a slow pace until late 2019. However, as shown in Figure 1, since 2020, there has been a short period of construction to repurpose or expand facilities. Between August 2021 and December 2022, they removed the existing southern support buildings and constructed new ones. Given the pipeline connections (see section 2.2), they may perform reactor-related water treatment or spent fuel pre-treatment and cooling. Subsequently, in 2023, a building of approximately the same size was constructed or extended to the north of the western support building. This building is likely an office building, as people and vehicles are often seen in front of it.

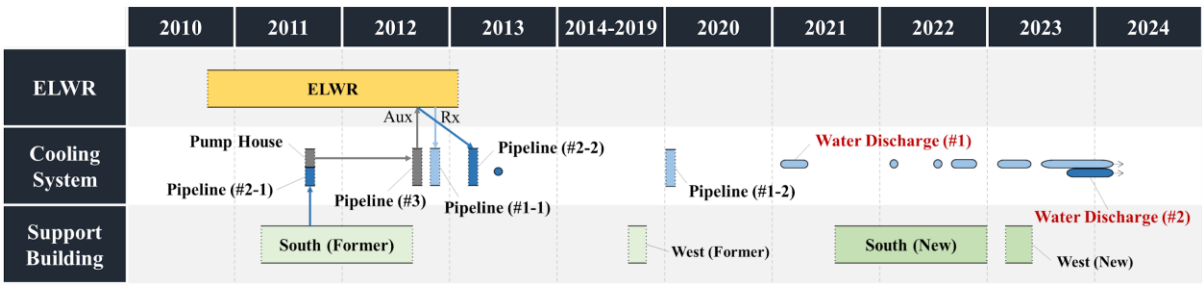


Fig. 1. Construction and water discharge history of Yongbyon ELWR based on satellite imagery.

### *2.2 Water Discharge*

Through time-series analysis of a large number of satellite images, we have mapped out the pump house and intake and outflow pipelines for the ELWR cooling system, as shown in Figure 2. Typically, heat from the reactor is used to produce steam to turn the turbine, and cooling water (river or seawater) cools the steam in a condenser, which is then released as warm. Therefore, liquid discharges from pipelines connected to the reactor can be an indicator to assess the reactor's operational status. Based on historical imagery, two outlets can be identified by following the pipeline southward, connected to the reactor building and auxiliary building, respectively. Prior to 2020, little drainage was observed, but intermittent discharges from Point 1 began in early 2021, coinciding with active construction within the complex. Also, as mentioned earlier, a very large amount of water has been discharged from Point 2 since early October, and a relatively small but steady amount from Point 1. Because we do not know the internal structure of the ELWR, it is difficult to determine exactly what process this effluent is the result of. However, we can make some assumptions about its origin based on the layout of the building and pipeline connections analyzed using satellite imagery. Pipeline 1 is connected to the reactor building, and drainage at Point 1 may be associated with reactor auxiliary or emergency system testing or spent fuel cooling. In addition, the water discharged from Point 2 could be cooling water that absorbs heat from the reactor secondary cooling system in the auxiliary building and is then discharged to the river via Pipeline 2. If so, Pipeline 3 serves to pump river water from the pump house and supply it to the auxiliary building.

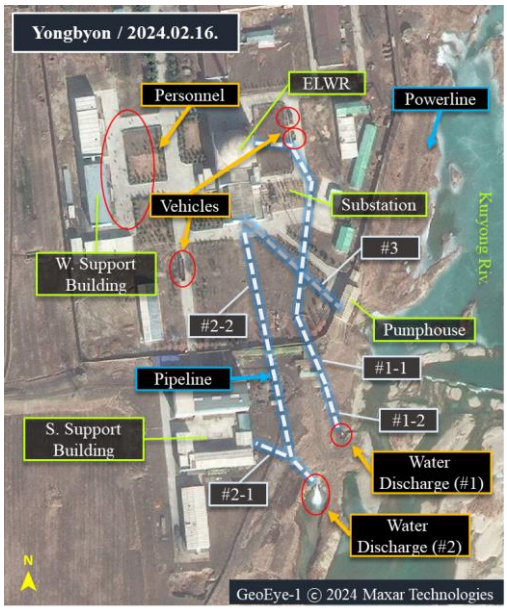


Fig. 2. Analysis of the latest satellite imagery of ELWR (February 16, 2024)

### *2.3 Thermal Patterns*

Thermal infrared (TIR) imagery can be used to provide additional evidence, such as thermal patterns within the complex. Figure 3 shows TIR imagery from December 24, 2023, converted to surface temperature, visualized as a temperature bin, and compared to optical imagery from a similar period [5]. The optical image shows that the snow on the roofs of the reactor building, auxiliary building, and south support building has melted compared to the surrounding ones. TIR imagery shows that the high temperatures of the Kuryong River make it difficult to identify distinct thermal patterns in the ELWR visually, but they are about 1 degree higher than the surrounding area. 38 North also noted that high-resolution thermal imagery taken from October to December 2023 confirmed slightly higher temperatures in the reactor switchyard [2]. In addition, the thermal pattern was evident in the Kuryong River, where a large amount of water was being released. The surface temperature of the river near the discharge point is about 6 degrees Celsius higher than upstream. Optical imagery also shows snow and ice melting and water vapor near the point, suggesting that the outfall is discharging relatively high-temperature water.

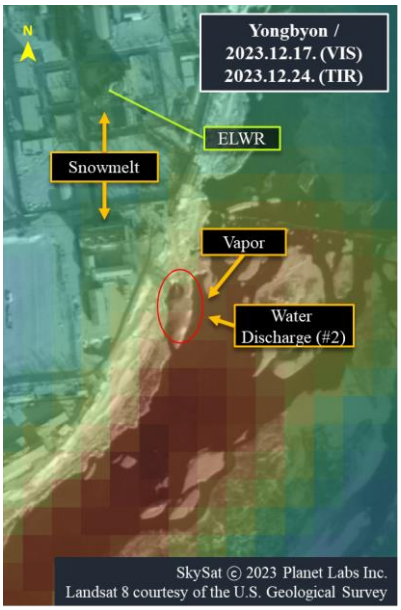


Fig. 3. Thermal pattern of Kuryong River near ELWR (December 24, 2023)

### *2.4 Personnel and Vehicles*

Observations of personnel and vehicles in the vicinity of nuclear facilities can be used as indirect evidence of nuclear activity. In the past, North Korea has seen an increase in vehicle activity during major nuclear activities, such as the Punggye-ri nuclear test, with process-related and VIP-related vehicles observed near the facility. Satellite imagery from October 2023

(when large amounts of effluent began to be released) to February 2024 was used to examine the number of vehicles identified around the ELWR. As shown in Figure 4, at least one vehicle was consistently captured in most of the available images, with at least three vehicles observed on the day the discharge of Point 2 was first identified. Recently, there appears to have been an increase in activity at the facility, with three or more vehicles consistently observed since mid-January 2024. Notably, despite the winter season, we have captured a large number of personnel near the support building, and the removal of snow on the connecting roads due to the movement of personnel or vehicles indirectly suggests that some activity is taking place here.

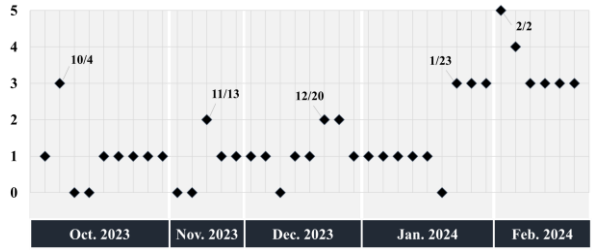


Fig. 4. Number of vehicles near the ELWR captured in recent satellite imagery

## 3. Conclusions

North Korea has officially touted the completion of significant infrastructure, such as hydroelectric and thermal power plants, but has not yet mentioned the ELWR. Based on the evidence discussed above, it cannot be denied that "something" is happening at ELWR. The relatively weak thermal pattern of the ELWR suggests that the reactor is still in the testing phase or possibly in the early stages of operation. Accordingly, the warm discharge water may be the result of a hot functional test of the reactor. Going forward, we will continue to monitor the increasing thermal patterns at ELWR and Kuryong River.

Activities at ELWR have increased amid North Korea's stated intentions to build up its nuclear arsenal. The lack of physical access to or verification of North Korea limits our ability to determine exactly what they are doing, what their intentions are, and what stage it is at. Nevertheless, satellite imagery can provide some inference of activity in areas that are physically inaccessible, so we are keeping our options open and will continue to monitor the ELWR.

## REFERENCES

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