Information Modeling of an Underground Laboratory for the R&D of mining automation and tunnel construction robotics

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Abstract –

We discuss the idea of developing Information Modeling (IM) for an existing underground facility so that it can be efficiently utilized as a laboratory for testing automated machinery in tunnel construction and mining.

The currently existing underground laboratories are located in old mines or underground storage facilities of which there exists usually only rough 3D CAD drawings, often done with geological modeling software. We discuss the relevant information content to create a useful IM for the purpose of the R&D of tunnel construction and mining equipment. We also present the current status of the IM, created in Lab 3 at 990 m depth in Callio Lab, the new underground laboratory in Pyhäsalmi mine in Finland.

Keywords –

Information modeling, IM, BIM, Underground facility, Underground laboratory, automation, robotics, mining, tunneling**.**

1 Introduction

Several underground facilities of old mines, nuclear waste storage facilities or extensions of road tunnels have been utilized as a laboratory for the research or development of activities, which specifically require underground conditions. Such activities include for example basic research of physics [1], geophysics [2] mining and tunneling equipment automation as well as education of mining engineering (for example in [2] and [3]) or even experimental food production [4]. Some of the major manufacturers, such as Sandvik or Atlas Copco, have excavated their own underground facilities for the testing of tunneling equipment and robotics [5].

When converted to laboratory use, an underground space is essentially turned into a building, where people work and spend substantial amounts of time in environments, which should be characterized similarly to office buildings or normal laboratory facilities. However, there are no standards for the conversion of an underground facility into a work place. The purpose of this study is to test the idea of creating an Information Model (IM), similarly to normal Building Information Modeling (BIM). We discuss specifically the case of creating a test laboratory for the research of tunneling automation and robotics and the benefits of the approach both from the user's point of view and the infrastructure provider's (the operator of the underground laboratory) point of view. We also present the results of a proof-of-concept experiment to make an IM, using the Industry Foundation Class (IFC) [6] data format, for the creation of an office in the Lab3 facility of Callio Lab at the 990 m depth in Pyhäsalmi mine.

2 Callio Lab

The tunnel network of Pyhäsalmi mine extends down to 1430 m depth, making it the deepest metal mine in Europe. The main ores, excavated since 1962, have been copper, zinc and pyrite. However, the current forecast is that the ore reserves are going to be exhausted by the end of 2019 and the mine is due to a closure.

Because of its depth and the extraordinarily large tunnel network, created during the 66 years of underground operations, the mine has hosted a variety of research activities since 1995. The modern and extensive support infrastructures both on the main service level, at +1400 m depth, and on the surface, provide a great platform for developing the mine into a versatile underground laboratory.

In 2015, the municipality of Pyhäjärvi started the project Callio (the name Callio is derived from Finnish word *kallio* meaning *bedrock*) to co-ordinate and develop the underground laboratory activities in the mine under the brand name Callio Lab [7]. During 2015-2017, the non-mining activities included the research of mining vehicles, radiation shielding systems, particle physics detectors and an observatory for cosmic rays and even an experimental farm for growing green vegetables and potatoes in underground conditions [8][9].

In 2017, Callio Lab had four dedicated Lab facilities on the levels +75 m (Lab 1), +660 m (Lab 4), +990 m (Lab 3) and +1430 m (Lab 2) depths of the mine .(Fig 1.).

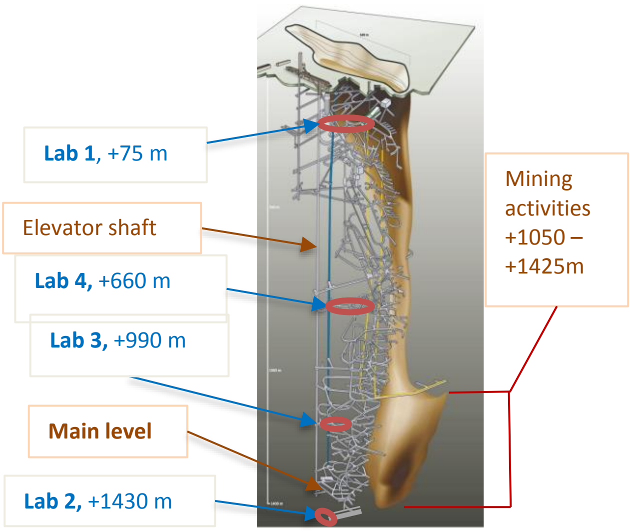

Figure 1. Cross section of the Pyhäsalmi mine. The brown column represents the ore deposits.

The main level is accessible with a mine elevator, hoisting people at 12 m/s and reaching the surface in 3 minutes. All levels are accessible with an 11 km long, truck-sized incline, which takes about 30 minutes to drive from the surface to the 1400m level. The rock conditions are uniquely stable and the rock mechanical tensions thoroughly investigated for the laboratory use, especially in the bottom part of the mine [10].

3 Testing of mining equipment, tunnel construction machinery and robotics in an UL

The creation of a possible standard IFC data model for underground laboratories requires a combination of different approaches:

- A mine model, mainly as a tool for the transportation and excavation of ore, described in the terms of geoscientific modeling, such as Geospatial Information Systems (GIS) [11][12]
- Underground tunnels, modeled as infrastructures for the transportation of people, machinery, mining and tunneling equipment (Infra IM) [13]
- Underground laboratory as a working space, with a BIM comparable to facilities in normal buildings.

For example, Fraser [14] has pointed out that the broader adoption of the IM in the mine environment is still an unchartered area of opportunity for interoperability and equipment standards for testing of both mining and tunnel construction automation. Tunnel construction and mining industry should see similar benefits as do building construction in general by adopting the use of BIM. In Europe this can be seen as an extension to open data concept of BIM, in Australia it's part of the "*Common Mine Model"* [15]. Automation and robotics can be linked via this concept as well. Mine geoscience and geophysics applications would be eventually natural additions to these studies.

Based on the discussion with the representatives of mining and tunnel industries, we propose that an IM of a tunnel construction or mining technology test facility could provide at least (but not limited to) the following types of information:

Objects

- Tunnels, which are available as test areas for mining or tunneling vehicles
- Electrical outlets, WiFi or cable connection to the internet, water supply, compressed air
- Location of rescue services with rescue chambers or other emergency services
- Offices, control rooms for operators and service areas, such as cafeteria, conference room, rest room, etc.
- Material handling spaces, for example concrete mixing
- Vehicle maintenance spaces
- Storage rooms
- Doors
- Roads and parking areas
- Elevator station or other transportation

Information tagged to the 3D model or the objects

- Mine driveway inclines
- Characteristics of the rock and surfaces
- Special areas available for blasting, drilling, installations
- Average ambient temperature
- Moisture, dust
- Other sensory information
- Specific rock mechanical considerations, such as tensions or fracture

The goal is that the comprehensive information modeling makes it easier for users to plan their test programs: How to make the automated tunnel construction or mining machinery to navigate better in tunnel networks, how to plan the testing and how to arrange the safety and facility maintenance procedures for the personnel.

Also from the underground laboratory operator's point of view, the Information model provides clear benefits:

- Better service to the customers, which helps to make the underground laboratory more competitive
- A methodology to take new tunnels into use more rapidly
- A tool for Facility Management (FM) of the underground facilities.

4 Information Modeling of Lab 3 of Callio Lab

As a proof of concept to study the viability of making an IM into an existing underground facility, we created and IFC model based on the existing 3D mine model provided by the Pyhäsalmi mine's surveying department and using existing software tools.

The Information Modeling for Callio Lab was started on the level +990 m in the Lab 3 tunnel (Fig. 2) by designating it as "office".

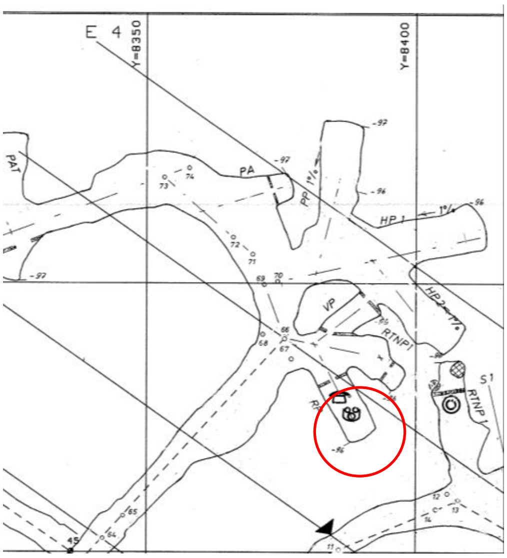

Fig 2. The location of Lab 3 in +990 level shown inside the red circle.

The IFC file for the "office" in Lab 3 was created with Autodesk Revit (Fig 3), so that it relates each object type from the building information model to the corresponding IFC entity (*e.g.* ifcWifi, ifcDoor, ifcElectricalOutlet, [16]). The IFC file can then be saved and edited as an external text file and it is possible to add simple meta-data to an IFC file.

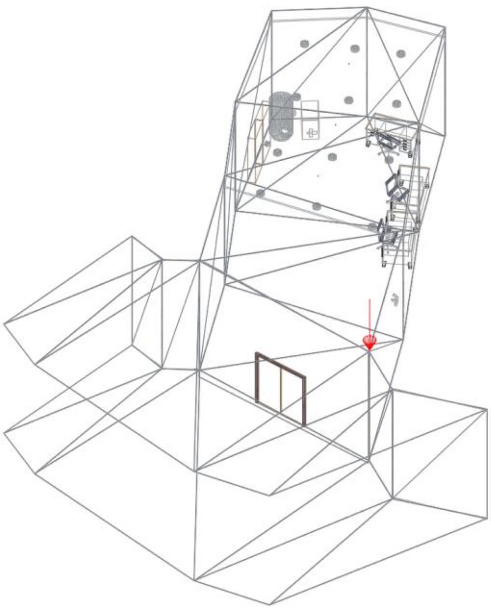

Fig 3. The Lab3 office model in co-ordination view of Revit.

However, the creation of the office based on the existing data was not straightforward. The mine's structures are modeled with Surpac geological surveying modeling software (Fig 4.) and importing the point mass information into Revit required and intermediate step of creating a tool for the conversion of data with Autodesk Dynamo.

An even bigger problem was that the resolution of the mesh in the mine model was at best of the order of 1 m, which may turn out to be insufficient for some users. The way to achieve a better resolution would then be to make laser scanning in the location (see for example Makkonen [17] and [18].

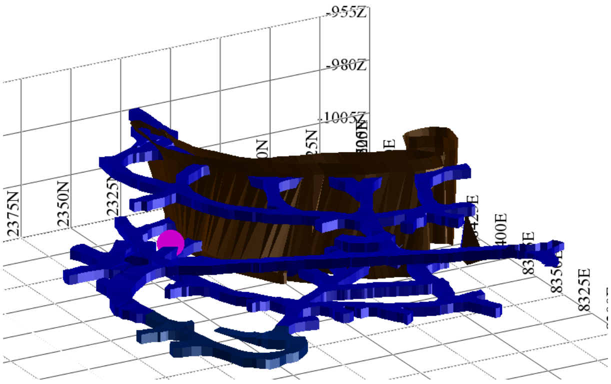

Fig. 3. The Surpac 3D plot from level +955 m to +1030 m. The location of Lab 3 is indicated with the pink ball. The black area in the background represents the ore reserves.

The work is continuing by developing the IM further. The next steps could include the creation of more objects and by tagging more information also to the adjoining service roads and tunnels. The new objects can include warning lights, valves related to plumbing location of escape pots (locations with reserve air) and available sensory information. Eventually the information shall include information about the inclination of tunnels and characteristics of wall surfaces for tunnel construction robotics.

5 Conclusions and future work

The information modeling of Callio Lab, based on the existing Surpac models of the Pyhäsalmi mine was demonstrated to be a viable possibility, although not straightforward. Based on the discussions with a tunnel construction company and a mining company we also reviewed the information, which would be useful for an IM of a testing platform of underground construction and mining automation.

The work shall continue by developing the underground laboratory IM further and implement especially the information, which is relevant for the testing of automated tunneling and mining machinery. Then we plan to collect feedback from the current users of Callio Lab and other companies in the industry. The work shall be conducted partly within the framework of the project BSUIN - Baltic Sea Underground Innovation Network, an ERDF funded Baltic Sea Region INTERREG program for developing services and technical characterization of six underground laboratories in the Baltic Sea Region in EU and Russia [19].

For the parties interested in utilizing Callio Lab's facilities, there is an open call for expressions-of-interest, accessible at Callio Lab's web page [20].

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