CERN

Remote Handling Solutions for Inspecting CERN's General Infrastructure

Remote Handling Solutions for Inspecting CERN General Infrastructures

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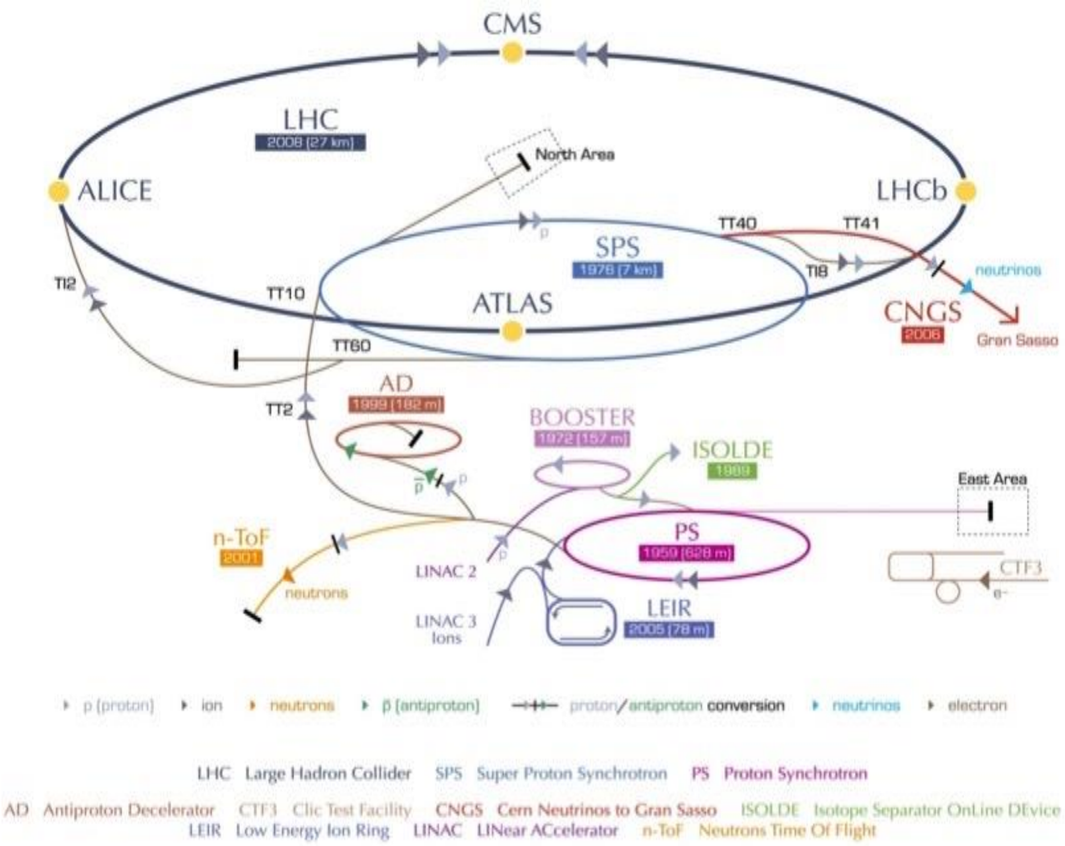
Introduction

- Objective of underground maintenance is to keep the existing infrastructure in a serviceable condition for the worlds largest (most expensive) particle physics experiment.
- The Challenge – a complex and ageing tunnel network consisting of tunnels, galleries, shafts and caverns.
- Difficult geotechnical conditions such as the LHC sector 3-4

CERN underground infrastructure



LHC Consists of:

- 4 main experimental areas
- 8 Satellite sites 7 – France, 1-Swiss
- 27 Km of tunnel

In addition we have the SPS, CNGS and injector tunnels which combine to give over 70km of underground tunnels

CERN underground infrastructure

Typical underground structures:

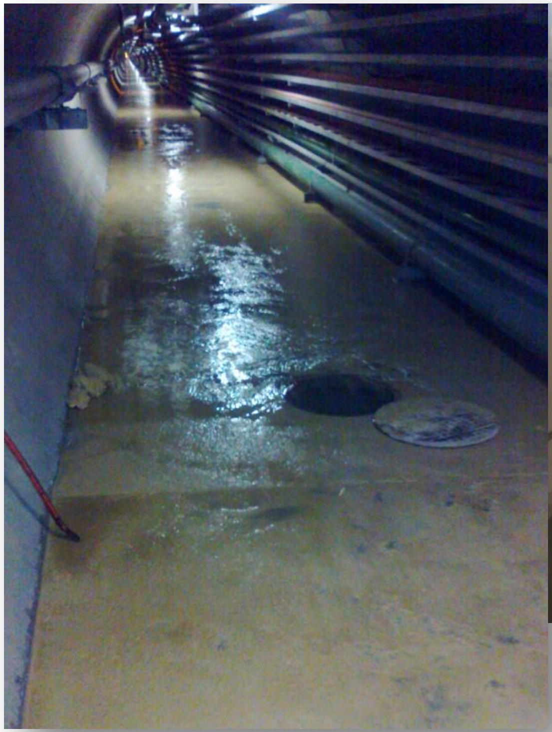
- Shafts
- Caverns
- Junction chambers
- Tunnels

Typical maintenance issues Infiltration

Treatment of Water ingress and damage is one of the most common Maintenance activities in the underground areas.

It is a direct threat to the machines serviceability.

Typical maintenance issues Drainage



Blocked drainage is a major risk to the tunnels serviceability

Mainly due to calcite deposits and a build up of sand exaggerated by construction quality issues

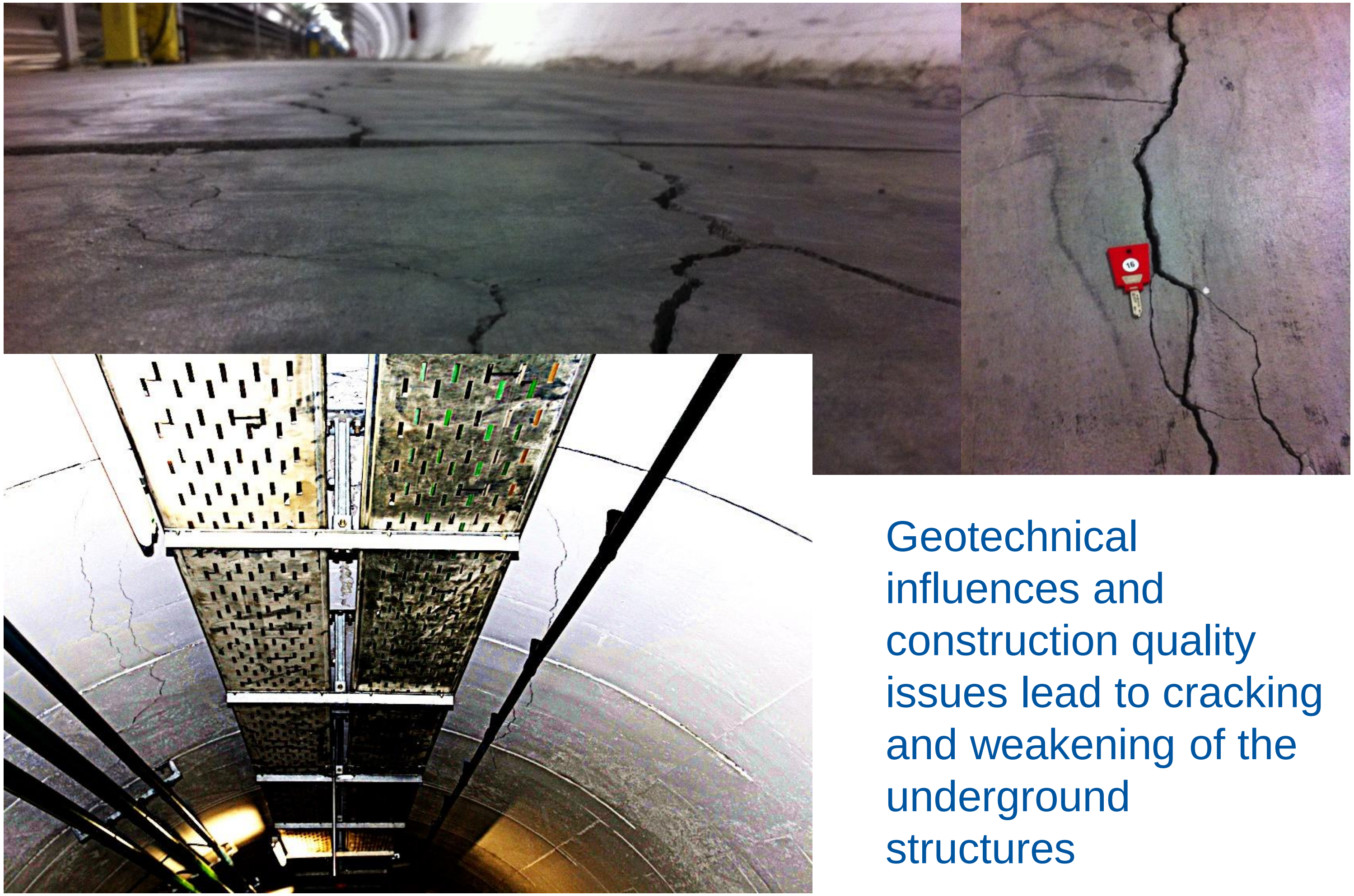
Typical maintenance issues Concrete wear and tear

Concrete repairs:

Repair of tunnel invert screed. Note typical SAS to protect existing CERN installations.

Typical concrete repair to tunnel lining and guttering system. The gutters are used to drain water away from sensitive equipment and require removal cleaning and refitting from time to time.

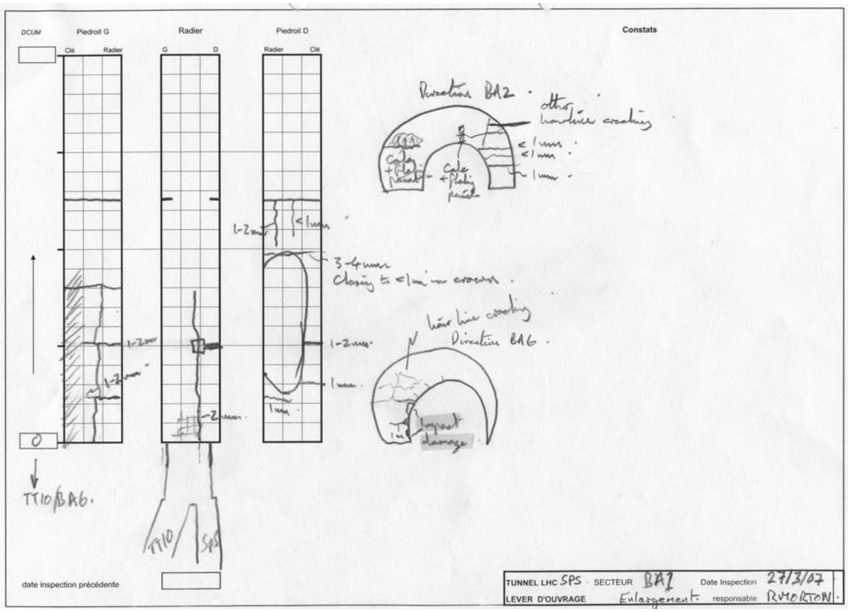
Typical maintenance issues Structural



Geotechnical influences and construction quality issues lead to cracking and weakening of the underground structures

Current inspection methods

Visual inspection by experts or trained staff



Reports consist of photos and hand drawn sketches with comments

Current inspection methods

In order to prepare campaigns of repair and maintenance a full survey of the infrastructure has to be carried out at the beginning of each technical stop. The current method has a number of significant drawbacks:

- Labour intensive
- Very slow process to inspect
- Long delays in analysing results
- Data is difficult to access and is not easy to compare
- Not always possible in hostile environments such as RP zones or structurally unsound areas
- Results are very subjective and dependent on the inspector
- Can only take place after the machine cools down
- Limited to areas easily accessible to humans

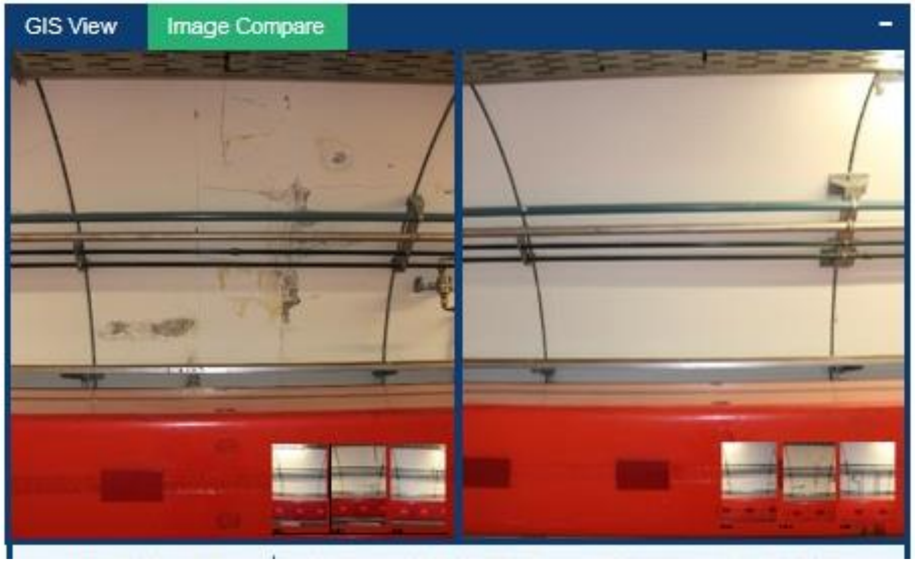
Future inspection objectives

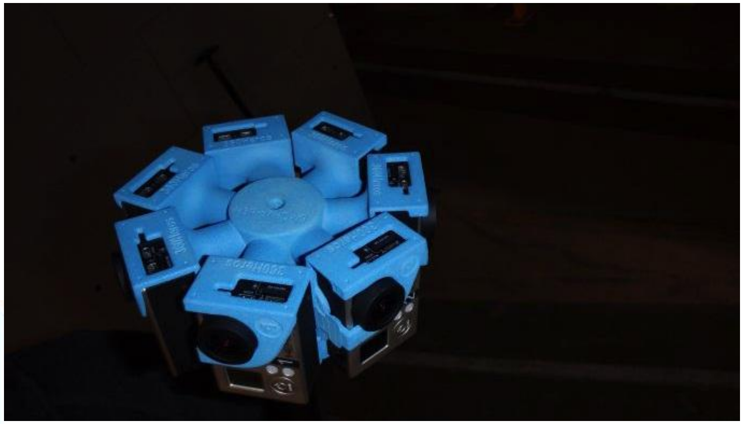
- Carry out data gathering during run and cool down periods via remote access to optimise time available for works.
- Gain access to previously difficult or dangerous areas without need for human intervention such as shafts and drainage channels
- Gather data in an objective way and identify change
- More frequent and faster inspections

Inspection methods being developed

Any remote access system must be capable of carrying any or all of the following systems:

Photogrammetry – change detection
Simple algorithm used to detect change between two consecutive photos taken from the same position on two consecutive inspections.

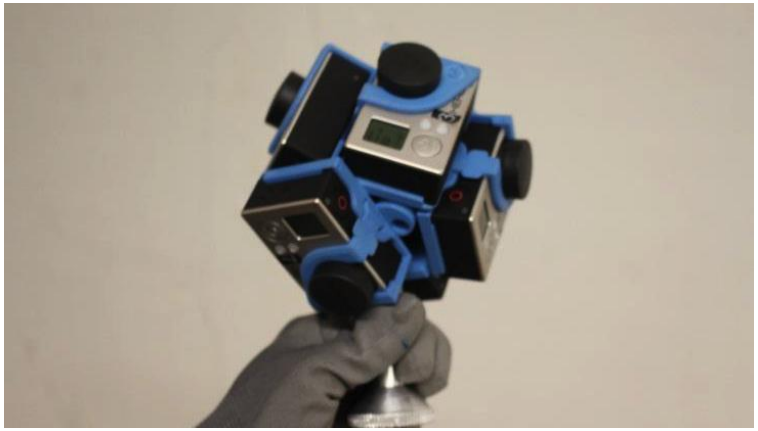




Above: Typical camera array used for radial 360 degree full circle photos and video

Inspection methods being developed

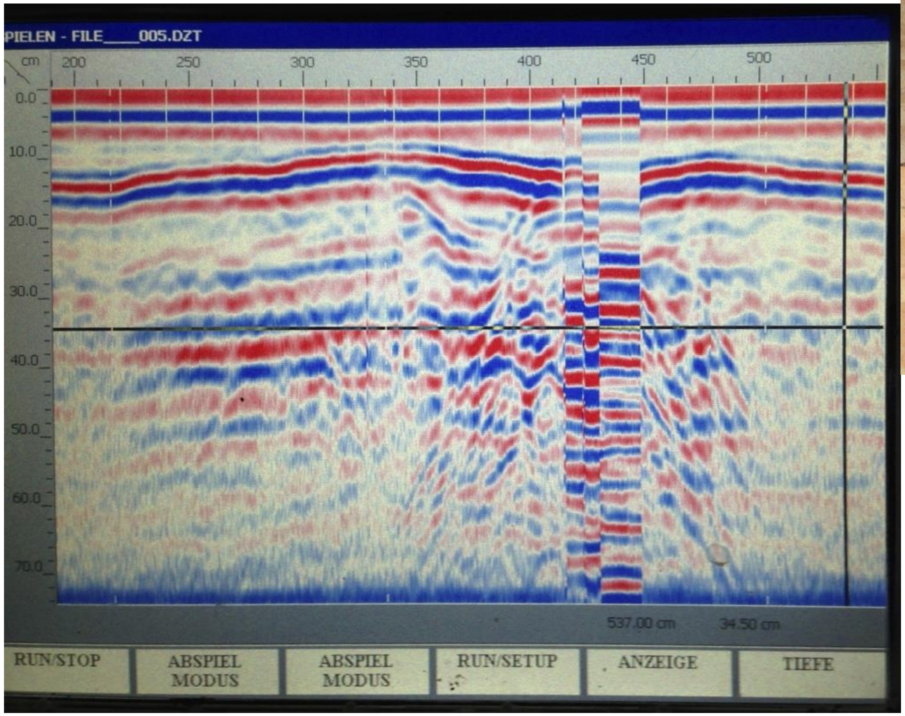
Video and still 360 degree surveillance
In future change detection algorithms may be possible.
Very useful for developing new works and allowing consultants or contractors to make virtual visits to future work sites.

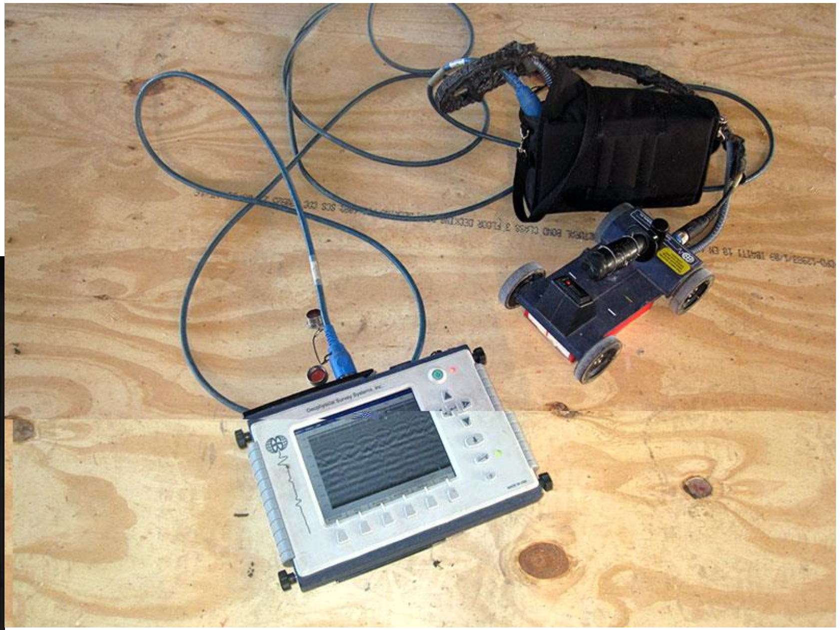


Above: Typical camera array for full 360 degree photo or video recording

Inspection methods being developed

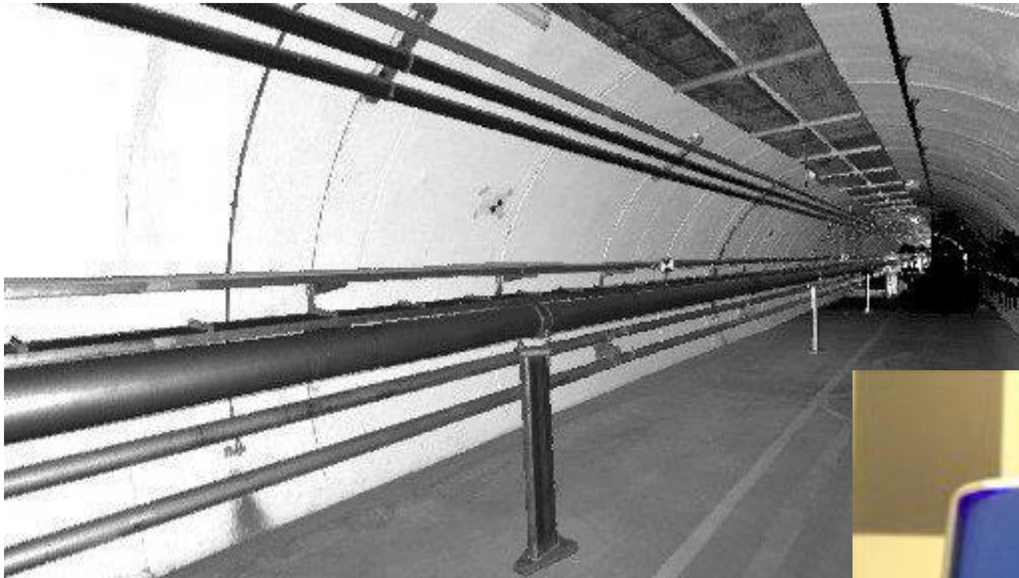
Geo-radar allows us to detect water, voids and other geotechnical anomalies behind the tunnel lining



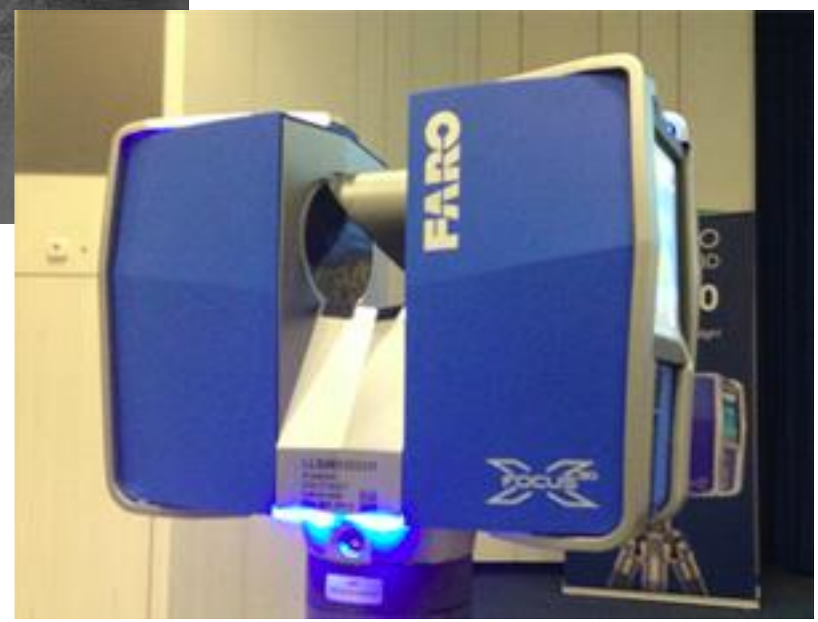


Above: Typical geo-radar type equipment

Inspection methods being developed



Laser scanning images and raw data can be used to measure movement, crack lengths and change detection

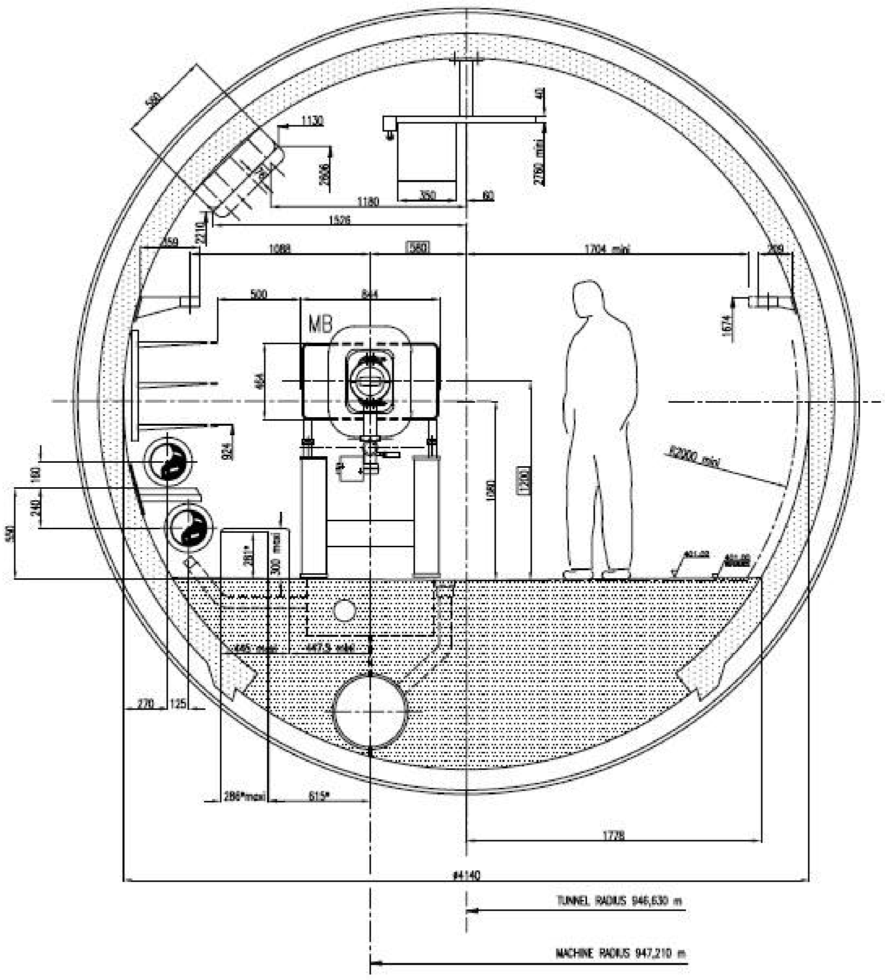


Right: Faro laser scanner is compact and may be suitable for mounting on a remote access platform

Basic requirements for a remote access platform

- Must be remotely controllable in real time
- Must be capable of autonomous operation for up to 3 km
- Provide a stable platform for high definition photography or laser scanning
- Provide a stable platform for video imagery during transit
- Be capable of carrying more than one surveillance system
- Be capable of self location and feeding coordinates in real time into the imaging system, accuracy depends on the imaging system
- Must be able to run two or more cameras simultaneously
- Capable of negotiating the MAD/PAD access control system
- Potential to negotiate fixed machine elements to “look behind” equipment

Basic requirements for a remote access platform



More than one point of view may be necessary to get maximum coverage of visible structure

LHC Solution

The LHC has an existing monorail and associated power supply. CERN has developed a Tunnel Inspection Machine (TIM) which will be used as a platform for civil engineering inspections in future.

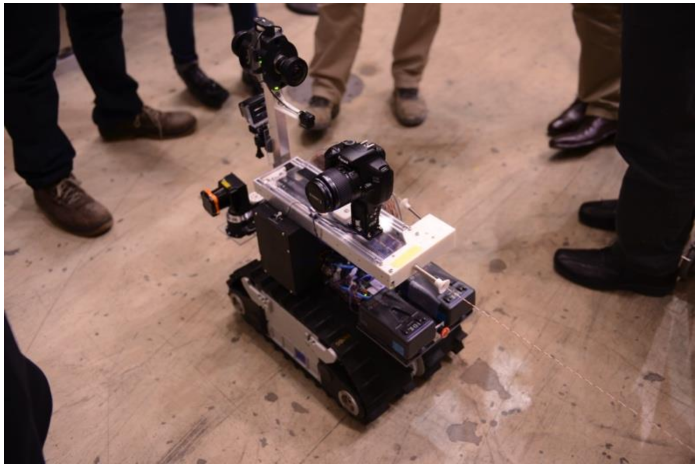
SPS and injection tunnel solutions

- All other tunnels at CERN will require an independant robotic access platform to carry out inspections. Some tunnels have civil engineering reference chainages and others do not, making localisation difficult.

- In the summer of 2014 we were lucky enough to host a demonstration of potential robot systems from Chiba Institute for Technology as part of our ongoing collaboration with Cambridge University. This was combined with some early tests of photographic methods for localisation and change detection.

SPS and injection tunnel solutions

- The trial was based on a modified Sakura1 robot
- Modifications included a number of cameras some with tilting support, a laser scanner and cable and wireless remote operation
- No autonomous system was trialed



SPS and injection tunnel solutions

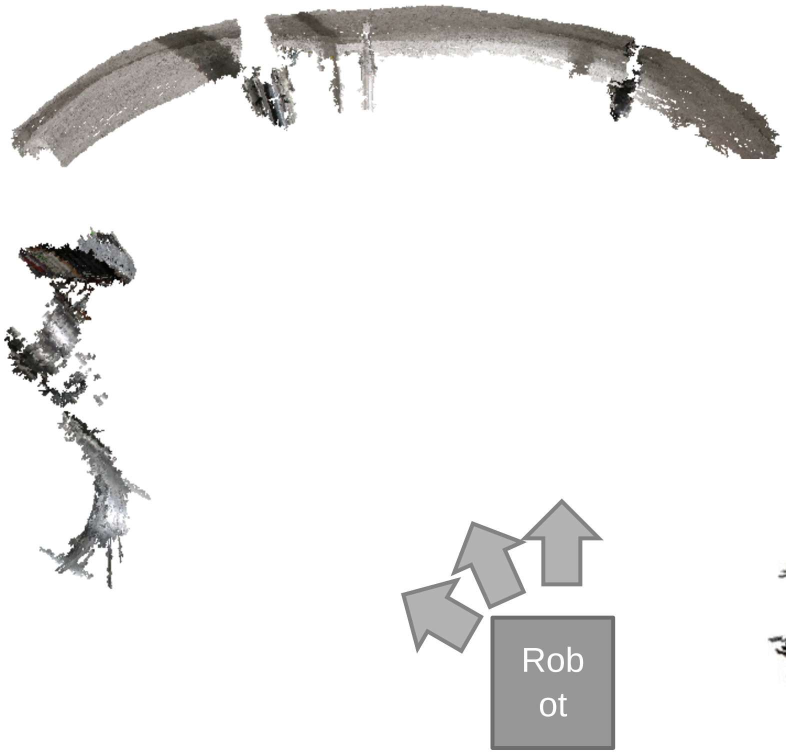


Figure 4. Side view of tunnel ceiling reconstructed from robot camera images

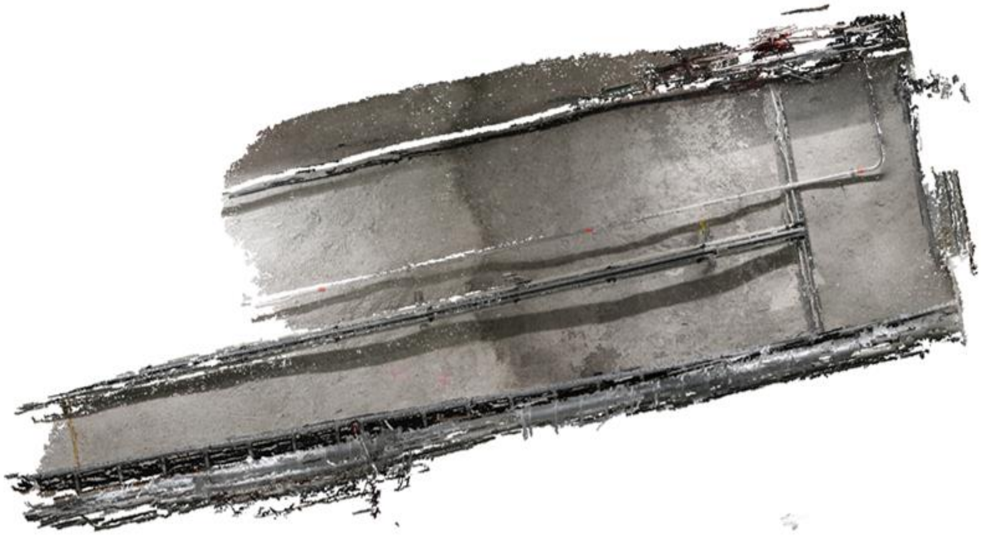


Figure 5. Below view of tunnel ceiling reconstructed from robot camera images

SPS and injection tunnel solutions

2. Localisation test

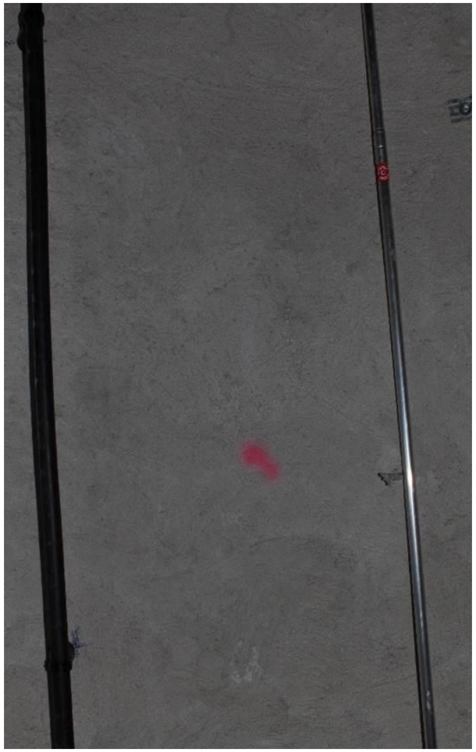


Figure 6. Query Image

Figure 7. Best matching image from database

Figure 8. Next best matching image showing a different region but with similar structure

Future developments

- Autonomous operation
- Onboard change detection and adaptive surveillance
- Speed up the operation and data gathering
- Develop a vertical version for shafts (quadcopter drone?)
- Drainage inspection – we have some parts of the network with more than 300m of pipe with no access manholes
- Access onto fragile roofs
- Remote access/control for civil engineering works, such as concrete cutting, drilling, repair, painting works, concrete works and general maintenance tasks