
CERN

CERN Tunnelling Workshop
26-27 October 2023

John Osborne
FICE

Email:
john.andrew.osborne@cern.ch

CERN, European Centre for Nuclear Research

Workshop Summary

Introduction to workshop and TAM activities at CERN

30m 160/1-009

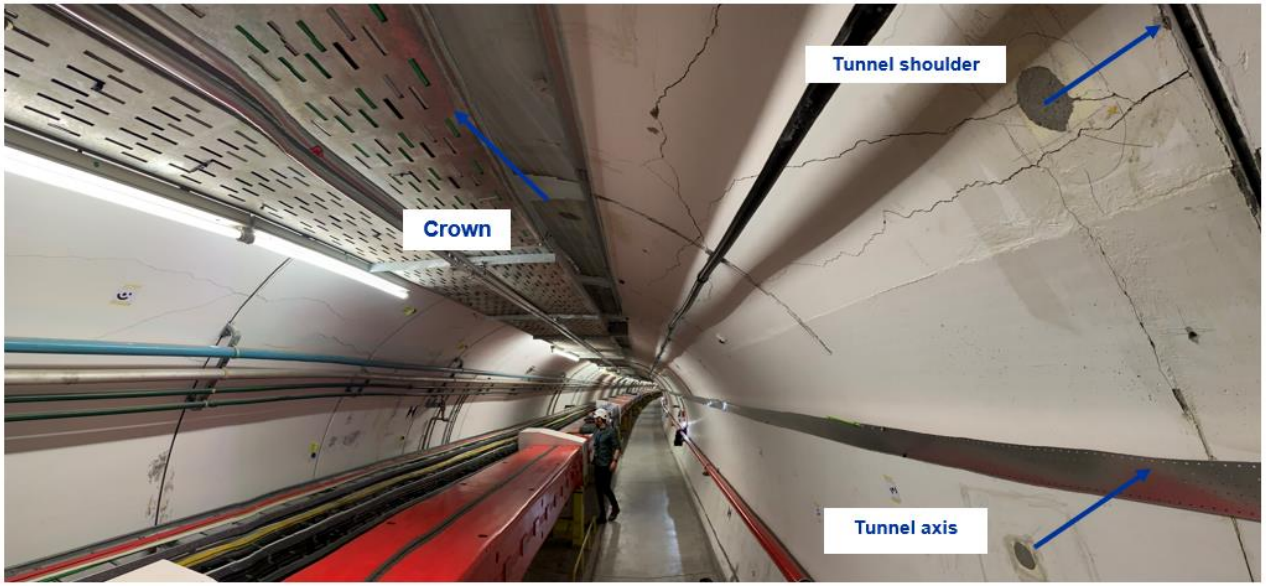
Maintenance strategy and routine inspections play a crucial role in the management of the large-scale infrastructures built at the European Centre for Nuclear Research (CERN), which owns more than 80km of tunnels. CERN laboratory, which sits astride the Franco-Swiss border, hosts a huge complex of particle accelerators, resulting in particles collisions which generate a radioactive underground environment that is not accessible during beam operation. Signs of ageing tunnel defects have been observed during tunnel inspections, particularly for tunnels constructed many decades ago. Aiming to increase the safety of CERN personnel and the operational performance of CERN tunnels, the implementation of smart monitoring tools is essential for data automation and remote inspections.
An overview of the advanced monitoring technologies that are implemented for the inspection of CERN underground infrastructures will be presented. This includes the state-of-the-art monitoring tools, robotic mounted imaging, unmanned aerial vehicle (UAV) and fibre optic sensors. The frontier analysis is conducted via artificial intelligence technology, machine learning, graphic based deep learning, and photogrammetry. The feasibility of the abovementioned methodologies has been tested in CERN undergrounds, providing instrumental data for the asset management of CERN tunnels.

Speakers: Dr Vanessa Di Murro (CERN), Aohui Ouyang (University College Cork)

SPS Crack behaviour

On-site investigation

- **3 core drilling** 80mm diameter



LBA (London Bridge Associates) - CIRIA Guideline on TAM

25m 160/1-009

The UK Industry organisation CIRIA* is preparing a new guide (intended to be published in Autumn 2023) on Tunnel Asset Management that reflects current industry advances in developed technological innovation and evolving tunnel asset owner requirements. This will enable asset owners to have a trusted practical guide that can support technical and commercial decision-making regarding legacy & future tunnel assets and aging infrastructure. It will also provide updated guidance for a spectrum of stakeholders including:

- Clients and Owners
- Consultants.
- Contractors.
- Planners, insurers.
- Academia.
- Government
- Funders, Insurers, Data and Technology and Monitoring companies, Concessionaires, Regulators etc.

Speaker: Mr Martin Knights (LBA)

What ?

New Guidance ciria

A systematic approach to tunnel asset management

Objective & standardised approach(process flow chart)

Technical and commercial decisions

Why?

Better planning & outcomes

Managing legacy assets

Mitigate disruption to operations and public

Data and quality management of assets

ciria is the UK Construction Industry Research and Information Association, a neutral, independent and not-for-profit body.

"Politicians often more interested in Shiny New Projects that TAM"

Epsimon - Fibre optic sensing for tunnel monitoring

25m 160/1-009

Fibre optic sensing (FOS) is a powerful technique that uses fibre optic cables attached to, or embedded in a structure to monitor temperature, strain and their derivatives such as displacement and crack opening. FOS can be used to monitor assets over very long distances (from a few meters up to several kilometers) and detect anomalies that would otherwise be impossible to identify using conventional point sensors.
In this presentation, I will first give a brief overview of the working principles of FOS and follow this up with some case studies where this technology has been used to monitor successfully different types of tunnel linings.

Speaker: Dr Nicky de Battista (Epsimon)

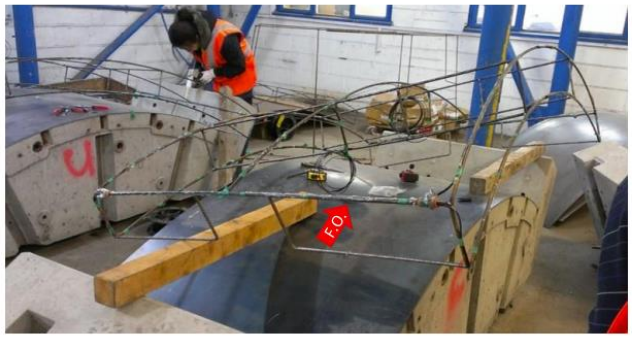
2023-10-26 - FO sen... 2023-10-26 - FO sen...

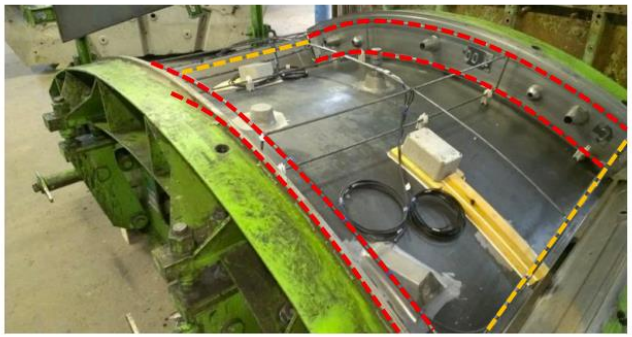
Monitoring of tunnels during construction

Segmental lining at National Grid power tunnels

- Instrumented 6 rings at 4 locations
- FO sensing cables embedded in lining segments at the precast plant

Images credit: Dr Matthew Wilcock





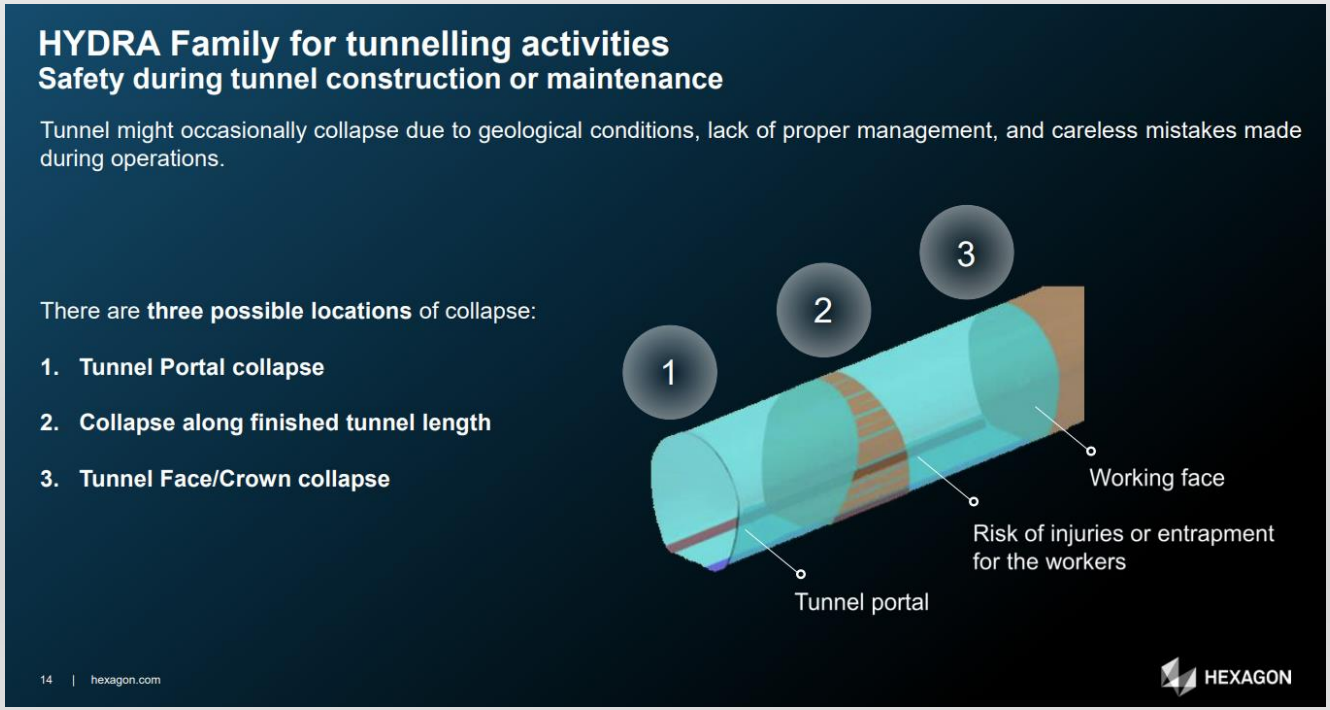
Complex systems.
Case study : Monitoring only during 1yr after construction

IDS Georadar - Ground based interferometric synthetic aperture radar (GB-InSAR) as innovative remote sensing technology for real time tunnel face safety monitoring

25m 160...

Tunnel face collapse represents a serious yet not improbable event for Tunnel construction industry, requiring the development of remote sensing systems to grant real-time deformation monitoring along with timely and automatic alarming capability. Unlike traditional contact technologies requiring installation of sensors on the target or optical systems which effectiveness is usually hindered by the environmental conditions typical of underground working sites, Interferometric Radars (InRa) allow to have a 24/7 monitoring of the tunnel face with sub-millimetric accuracy and a space resolution reaching tens of centimeters without any performance detriment derived from haze or dust. IDS GeoRadar, part of Hexagon, is leader in the remote sensing technology industry providing a wide portfolio covering any application from Critical Infrastructures to Natural Hazards monitoring; HYDRA-T, the Interferometric Radar system specifically developed for tunnel operations, represents the latest version of the renowned HYDRA (Hyper Definition Radar) family and is applicable to both drill and blast and partial-face mechanical excavation methods.
HYDRA-T is able to detect fall precursors, automatically triggering aural and visual alarms to increase safety during operations and allowing a timely evacuation of people and/or machinery at risk. Thanks to the advanced technology embedded, this system is capable of displaying displacement output data updated every 15 seconds with an accuracy up to 0.1 millimeter, working 24/7 in full autonomy without any intervention or control from the operators.

Speaker: Mr Alessandro Pettinari (IDS georadar)



Safety monitoring during tunnel construction

Arup - Loupe 360, automating the world of tunnel inspection

25m 160/1-009

Loupe 360, developed by Arup, is an innovative automated tunnel inspection service and digital platform that has disrupted conventional approaches to tunnel inspections and asset management. This workshop will showcase how Arup has combined expertise in civil engineering, data science, and product innovation to transform the entire asset lifecycle, from inception through to build and operations, helping Asset Manager identify changes before and after commissioning. Through compelling case studies from the Transport and Energy sectors, attendees will gain insights into the technical and business value, benefits, limitations, and key learnings for adopting or developing similar systems.

Attendees will also discover how cutting-edge hardware technology, including robotics and fixed vehicle-mounted systems, along with advanced computer vision sensors like 360-degree cameras, LiDAR, and thermal imaging, have revolutionised data capture, insights, and reporting. For instance, the possibility to integrate and geolocate multiple sensors in the same space, while continuously capturing high resolution images throughout a large infrastructure, is game-changing. The Loupe 360 online platform enables seamless visualisation and analytics of imagery, including change detection and severity rating, utilising machine learning for defect detection and inventorying. This enables Asset Managers to conduct virtual survey with timely and consistent data, improving health & safety by removing engineers from sites.

Speakers: Dr Fabio Panella (ARUP), Mr Yung Loo (ARUP)

TAM Workshop (1)....

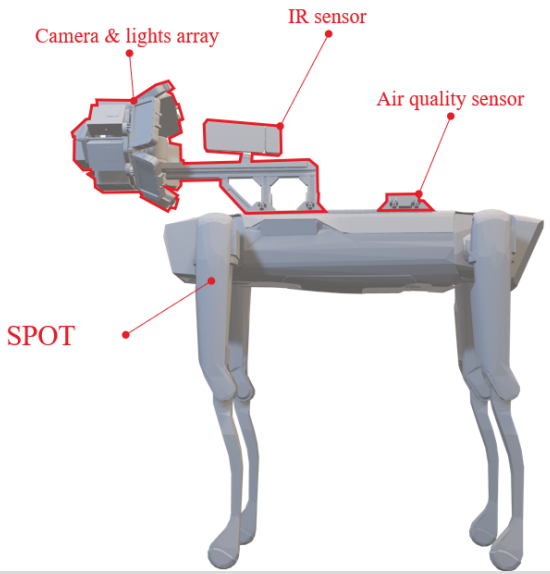
ARUP

Automation of tunnel inspection

Data Capture

In collaboration with multiple asset owners, Arup has developed a customized payload for capturing data from multiple sensors. These sensors have been carefully selected and arranged to ensure the collection of high-quality data in various tunnel environments. They are designed to work effectively in both large-diameter tunnels when mounted at the back of a maintenance train and in confined spaces when carried by a robotic dog.

By synchronizing the data gathered from these sensors, we can accurately assess the condition of tunnels, going beyond just visual inspections.



Automated Data Capture, ML, Data Visualization eg Robotic Dog

Arcadis - Aging tunnel networks, and ways to deal with them

25m 160/1-009

Sharing lessons learned from the Dutch tunnel refurbishment program.
Sharing lessons learned from activity group 2 of WG-06 tunnel maintenance and repair.

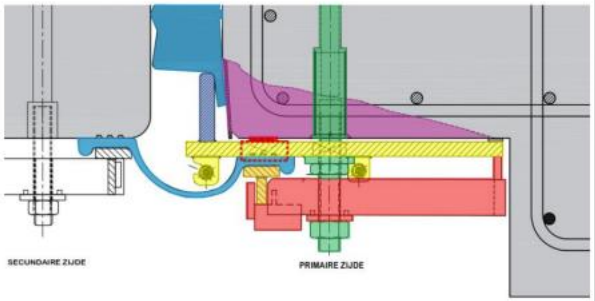
Speaker: Mr Sallo Van der Wounde (Arcadis)

Introduction

- Ir. Sallo van der Woude
  - Working with **Arcadis,**
  - Project manager tunnels at **the Blankenburg connection**.
  - Consultant in old (rail)road tunnels
  - Past President of the Royal Dutch Engineering Society for Tunnels and Underground works,
  - Animateur of ITA-WG-06.

- I started my career in bored tunnelling projects.
- In 2015 I became project manager of a renovation project of an immersed tunnel built in the ’60.
- My conclusion:

Renovation projects are interesting and often more challenging than green field tunnelling projects.



Renovation of ITT “often more challenging than green field projects”
ITA WG6 activities

Egis - A digital inspection methodology

25m 160/1-009

Egis has lengthy experience in asset management, including tunnels. We would like to describe a method which could be applied in CERN's underground structures, and which was successfully tried and tested in several tunnels in 2020 for Escota in France.
The principle is:
• A digital inspection phase (initial or periodic),
• A second phase with physical inspections.

The methodology was satisfactory for the State services.
After the successful demonstration of the method on a few tunnels using Amberg Technologie's robot, we were granted a framework contract with Lombardi for Escota's remaining 43 tunnels.

Details of the method:
Inspection technology: HD laser + infra red thermography
Advantages:
• Independent of lighting
• Very high definition (it is possible to read the equipment serial numbers)
• Fast: 1 to 3 km/h
• Can be carried out without interrupting access to other users (the high definition can cancel vehicles)
• Digital technology means that an exact comparison of cracks etc. really is possible
• Amberg's interface is very user friendly.

Speaker: Mr Patrick Garcin (Egis)

Survey history

Construction : 1976

Initial inspection : 1976 (« IDI »)

Periodic inspection :

- 1996 (traditional)

- 2003 (traditional)

- 2016 (semi digital)

- 2020 : Digital : here after presented

Technology : HS laser, thermography robot, 1 to 3 km/h

egis

History of inspections in France and Case Studies

Autostrade per l'Italia S. p. A - ARGO Tunnel Management System

25m 160/1-009

ARGO is the Tunneling Management System (TMS) developed by Autostrade per l'Italia in partnership with Movyon and IBM to manage a portfolio of about 600 tunnels. ARGO is a comprehensive software solution designed to streamline and enhance the inspection and maintenance processes through the assets digitalization. It collects and manages tunnels data in its digital inventory integrating smart inspection and analysis tools to optimize the planning and the execution phases raising up the quality of the entire process.

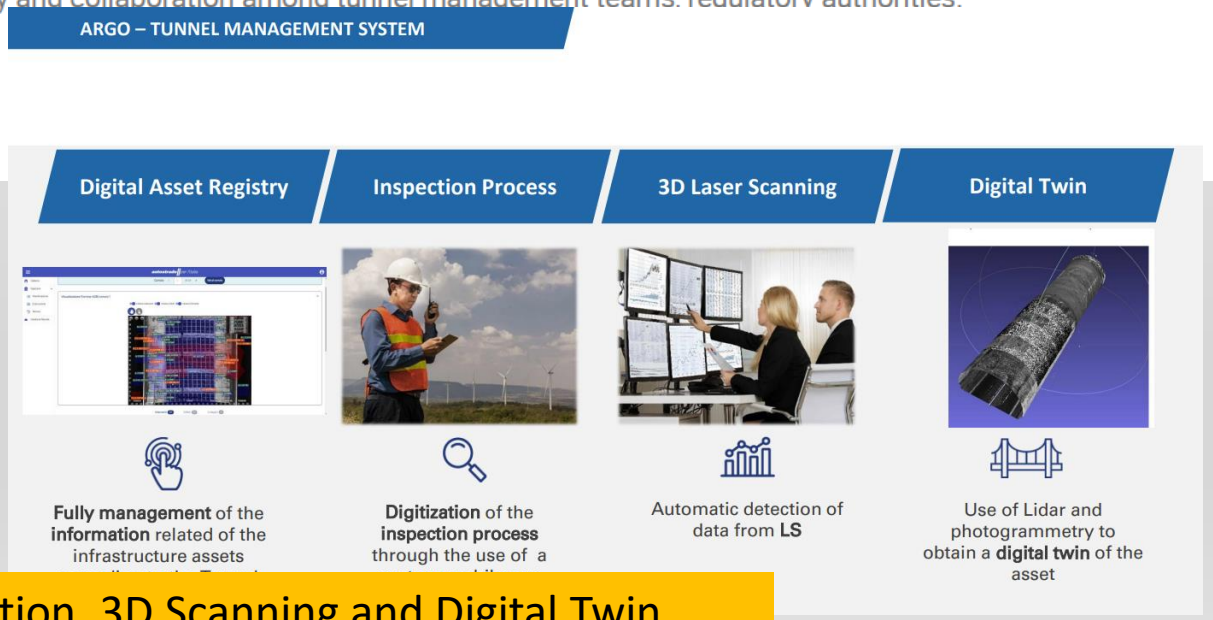
The core functionality of ARGO revolves around its advanced inspection scheduling and data management capabilities. The system allows users to create detailed inspection plans, allocate resources, and schedule inspections based on predefined criteria. The field inspection is performed by a Mobile App based on a three-dimensional digital twin of the tunnel which is converted to a two-dimensional surface representation that plays a crucial role to support the operator in the examination and mapping of the defects. Inspection data, including visual observations, measurements, and photos, are recorded using the system's user-friendly interface, ensuring consistency and accuracy in data collection.

The data collected during onsite phase are subjected to a postprocessing analysis referring to the examination, validation and interpretation, to extract meaningful insights and make informed decisions regarding the condition and maintenance of the tunnel. It involves the application of various analytical techniques and tools to summarize the inspection data and identify key findings, potential risks, and necessary remedial actions. Once the data is processed, algorithms such as advanced image processing, pattern recognition, and machine learning techniques could be used to detect and classify various types of defects, such as cracks, spalling, corrosion, and deformations. Furthermore, ARGO features a comprehensive reporting and documentation module.

It generates detailed inspection reports, highlighting critical findings and recommendations for remedial actions. These reports can be easily accessed and shared with stakeholders, promoting transparency and collaboration among tunnel management teams, regulatory authorities.

Speaker: Mr Antonio Sannino (Autostrade per l'Italia S.p.A.)

2023-10-25_TAM_e... 2023-10-25_TAM_e...



ARGO Platform : Data Collection, 3D Scanning and Digital Twin using Risk Based Classification System

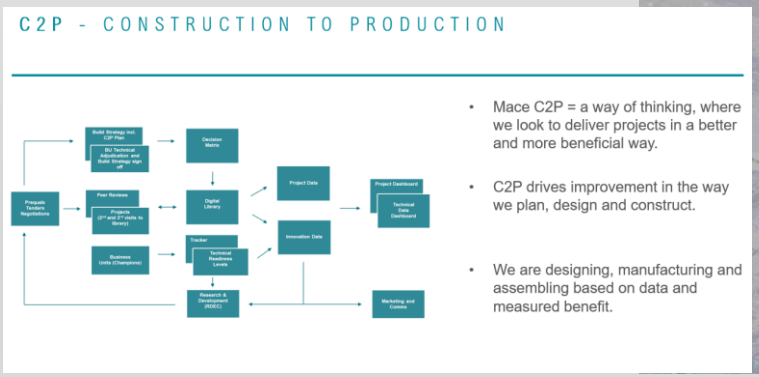
MACE - C2P (Construction to Production) Approach to Tunnel Infrastructure Works

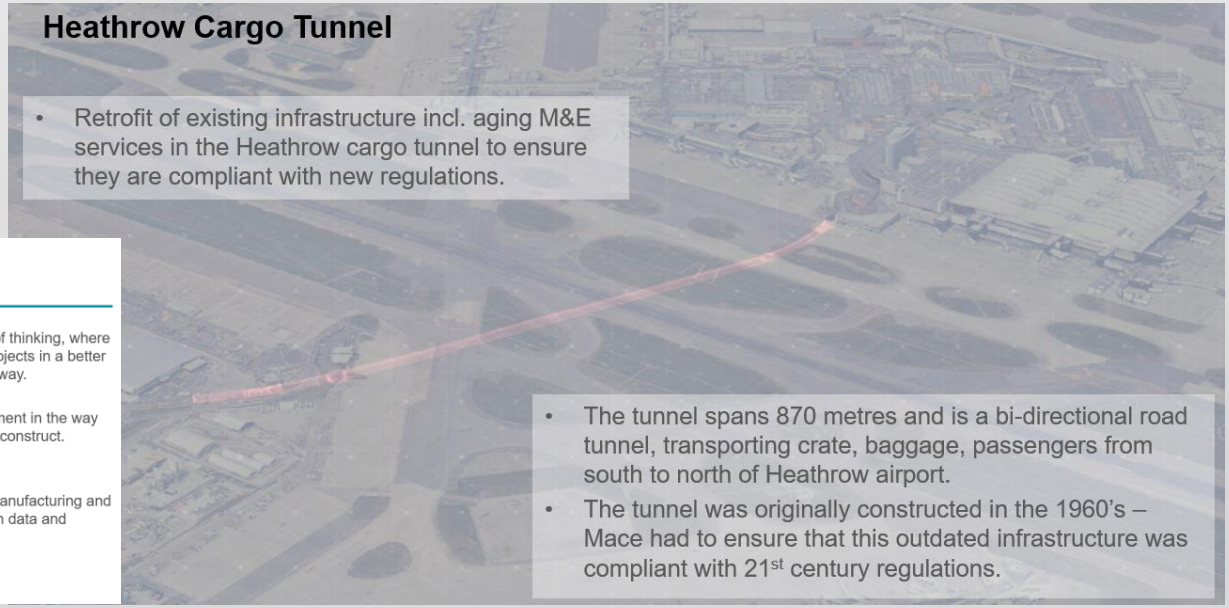
25m 160/1-009

Mace always look at ways to innovate in pursuit of streamlining construction processes. We specialise in prefabrication and off-site assembly to deliver better for our clients and communities. Our C2P Kit-of-Parts approach leads to the efficient, high quality, right first time construction reducing our programmes and carbon footprint. As part of workshop presentation we will introduce C2P concept, present our recent innovations and finish with a case study demonstrating application.

Mace MEP refurbished the tunnel connecting the Heathrow Airport Central Terminal area and the Terminal 4 Cargo facility. The original tunnel was constructed in the 1960s and upgraded in the 1990s. Mace MEP designed, coordinated, installed and commissioned a modern day, complaint MEP infrastructure system, incorporating full life safety and communication systems, within a live tunnel environment – requiring works to be undertaken at night. Using its MDFA expertise and the latest digital tools, Mace MEP successfully modelled and set out structurally complex prefabricated modules spanning over 12 metres in a circular tunnel, within a tolerance of +/- 5mm. Approximately 870m long, and comprising a central bored section, the tunnel features two system-supporting plant rooms at its North and South ends. This £57 million aviation and infrastructure project will provide a high-quality asset to the client, Heathrow Airports Limited, in early 2025.

Speaker: Dr Aleksandra Przydrozna (MACE)





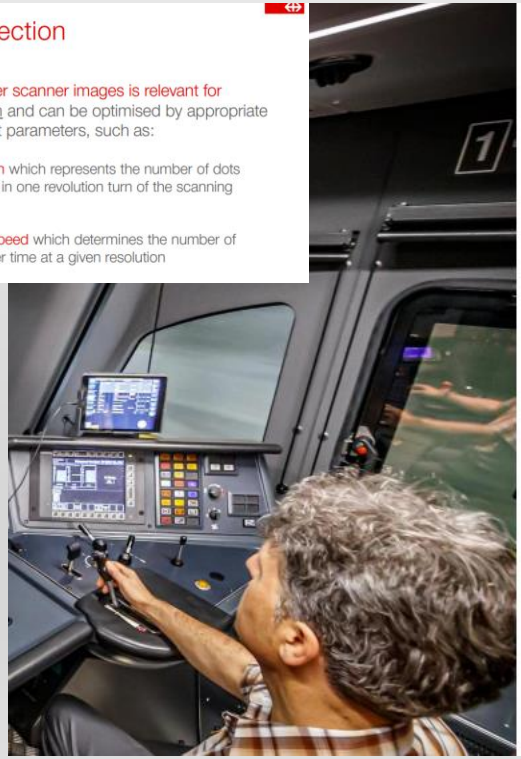
Approach to Tunnel Infrastructure Works : C2P

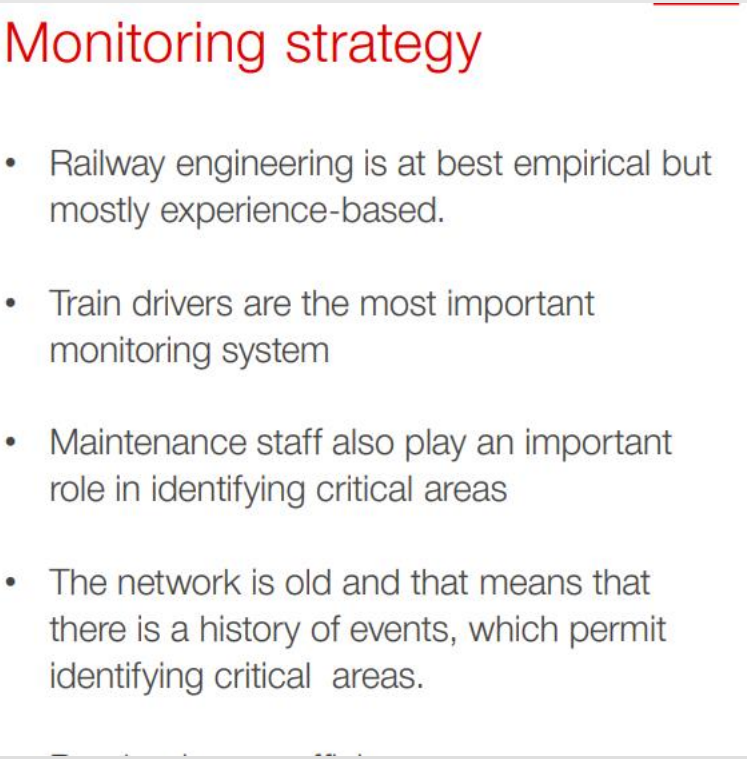
SBB - Assessment of railway tunnels

25m 160/1-009

The Swiss Federal Railways (SBB) operate a large railway network which includes some of the longest and deepest tunnels in the world. SBB Infrastructure has the duty to maintain the network, guarantee safety and ensure that the operational needs are at all times met. Although these tasks appear straightforward for recently built infrastructure, they become significantly more challenging in a large network with continuously changing operational demands, variability in the age of the infrastructure and increasing expectations on the performance of the network. To achieve these objectives, SBB uses computer-aided or image-based systems to document the state of the infrastructure network, assess its conditions, predict its evolution, and plan corrective maintenance. Such systems are only efficient if the input information can be gathered in time, with sufficient accuracy and reliability and with minimal disruption to the railway traffic. The different monitoring and assessment methods for tunnels and track will be presented in this short talk.

Speakers: Dr Federica Sandrone (SBB), Dr James Fern (SBB)





Inspection and monitoring methods for +400km tunnels : Insourced !

Jacobs - Inspecting a super sewer

25m 160/1-009

Jacobs team are taking their knowledge of working with the nuclear sector; performing inspection of very hazardous and complex plant and applying it into the civils major project market, working with Thames Tideway to develop an innovative robotic solution intended to enable the remote inspection of their tunnel and shaft infrastructure that has been constructed in London as part of a new sewerage system. The principal aim of the project is to develop an inspection solution that enables the assessment of the full asset without the need for humans to enter the structure, improving safety and maintaining availability of the asset as far as practical.

The Thames Tideway Tunnel is a major new project, urgently needed to protect the ti
approximately 31km of tunnels and pipelines ranging from 7.32m to 2.20m internal d m
internal diameter, and numerous secondary structures like connection culverts and n
The project faces many unique challenges to complete these inspections, which incl cation
underground (up to 7km), Unknown obstacles, Localisation as well as the volume of of
autonomy and require innovation in the system and the inspection process.

Our solution is developed from commercial platforms and sensors taken from multip ated
vehicle developed for rugged environments such as agriculture or nuclear decommis nclude
LIDAR camera systems and inertia measurement integrated into a complete inspection solution. Hear about the progress of this project and the findings to date including radio and imaging trials.

Speakers: Mr John Bortherhood (Jacobs). Dr Matt Willcock (Jacobs)

Data Capture - Jacobs Survey and Reality Capture (Geomatics)

- In-house survey team
- Supported by Leica Geosystems

Jacobs experience in Tunnel Monitoring. Example of using robotics for Thames Tideway

University College Cork - The impact of climate change on underground tunnel infrastructure

25m 160/1-009

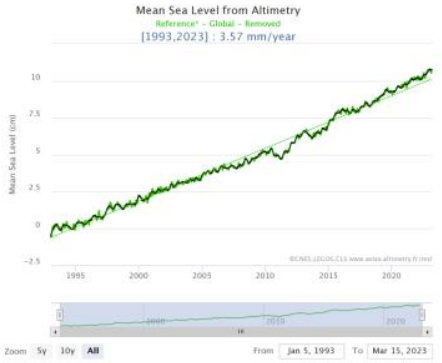
In many countries all over the world, large-scale underground tunnel infrastructure is inevitably susceptible to the impacts of climate change, including flooding, rising groundwater levels, and structural damage. This presentation conducts a comprehensive literature review on the crucial environmental factors, such as rainfall, sea level, and extreme temperature, in response to climate change. It focuses on their effects on underground transport infrastructure and provides valuable insights into this topic for one of the very first times.

Previous studies indicate that the rising sea levels resulting from climate change can intensify the vulnerability of underground coastal infrastructure due to flooding and saltwater intrusion. Moreover, extreme weather events like floods and heavy rainfall can erode the soil surrounding underground structures at the risk of structure safety and serviceability. Finally, the presentation introduces a case study that highlights the impact of extreme rainfall on an existing tunnel situated in karst terrain, along with the subsequent tunnel repair measures.

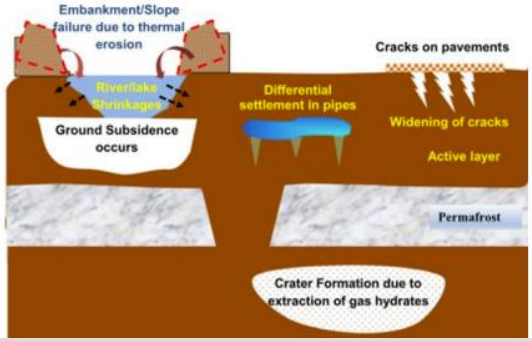
Speaker: Dr Zili Li (University College Cork)

Impact of Climate C... Impact of Climate C...

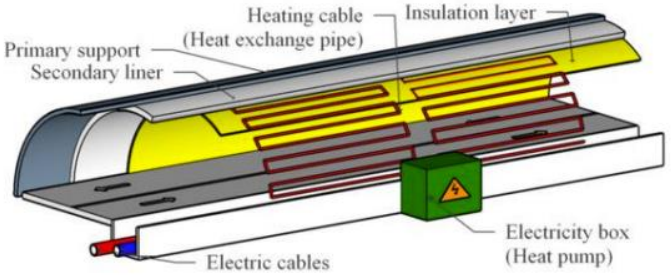
- Sea Level Rise



- The impact of temperature



Mitigation Strategies for Extreme Temperature Effects



Impact of climate change on tunnels, modeling, simulations and mitigation strategies. Case studies.

TECNE - Tunnel Renewal Strategy: the case of San Fermo right tunnel for sustainability achievement in lining reconstruction works

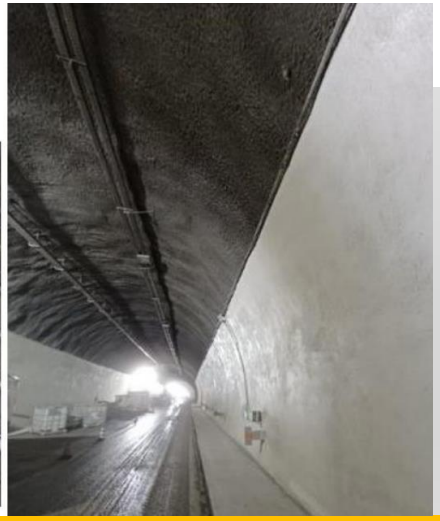
25m 160/1-...

The objective of ASPI Network's Tunnel Renewal Strategy (TRS) is the extension of tunnel linings' life cycle through the construction of new, internal and structurally autonomous shell structures ensuring suitable seismic performance. The need to limit the impact on highway-traffic requires innovative solutions by means of structures-optimization, automation and speeding up of construction processes, maximization of work productivity and flexibility in terms of sites and logistics in order to allow rapid job site start-up and dismantling. One of the most significant TRS pilot interventions implemented during 2022-2023 is San Fermo right tunnel renewal project, due to the special focus on the sustainability requirement of lining reconstruction works. The two-lanes tunnel, built in early '70s, 670 m long, is on the northbound carriageway of A09 Milano-Como-Chiasso highway. After detailed inspection and huge structural investigation campaign, concrete original structures resulted to be extensively interested by deep degradation mainly due to water permeation and ingress. Thus, for the entire bore-length, a new final lining has been designed, equipped with innovative waterproofing system consisting of light TPO sheet protected by a double layer of TNT, installed by mechanical-fixing strips tested for the first time in highway tunnel. Special attention was paid to the study of milling geometries to reduce time impact and transport costs of demolition activities. However, the most significant technical innovation is the adoption of high-performing shotcrete reinforced with PP micro and macro fibers as final lining structural material. Effective shotcrete application on 30 cm thickness, almost without time interruption, is made possible thanks to detailed procedures and special 3d anular skeleton consisting of GFRP modular cages. All these solutions strongly contributed to minimization of works environmental impact, considering both direct / indirect effects, from construction-materials quantity reduction and no steel adoption to traffic-safety issues met by reducing tunnel closure times.

Speakers: Mr Bruno Spigarelli (TECNE), Mr Roberto Pittalis (TECNE)

AUTOSTRADE PER L... AUTOSTRADE PER L...

PROJECT IMPLEMENTATION PHASE



365km of tunnels.
Case Study : Replacement of secondary lining with new high performance shotcrete lining.

Testia - Structural health monitoring (SHM) - A view from an SHM Enabler & Integrator

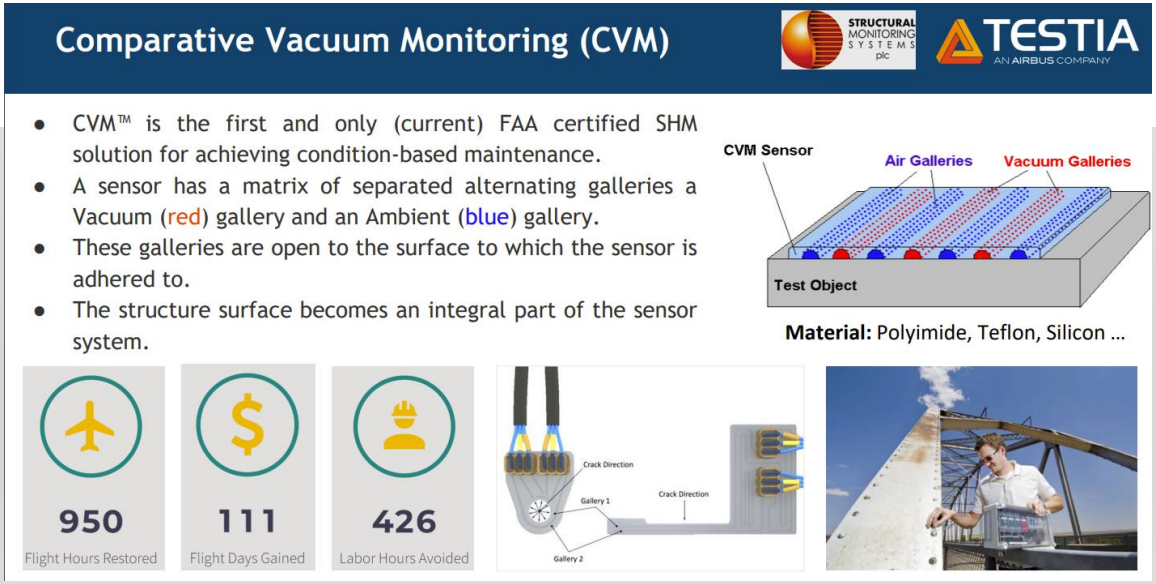
25m 160/1-009

Although Non-Destructive Testing (NDT) methods provide sufficient information about the state of the structure at the time of inspection, the need for continuously monitoring the health of the structure has asserted the use of Structural Health Monitoring (SHM) technologies to maintain the levels of safety and thereby reducing the overall costs for operation and maintenance. Although SHM has been an active discussion topic in different industries over the past few decades, only a few SHM technologies have been able to achieve the required readiness levels for implementation. The limited implementation can be associated with two critical factors, namely the lack of business cases and the lack of technological breakthroughs. These factors have constrained the use of SHM technologies to serve as an active, fully integrated on-line sensor network, which can increase the residual value of the structures.

As an Airbus company, Testia has always been on the forefront of aerospace inspection technologies. Our mission is however to play an important role in technology transfer from the aviation sector into various other sectors including infrastructure, automotive, wind energy, train and oil & gas. We apply a unique strategy aiming at enhancing cross-industry innovation. To generate innovative solutions and new business-cases for SHM, Testia utilizes the knowledge and experience gained in deploying solutions in different industries to drive innovation, maturation and technological advancements. This approach is envisaged to gather momentum in technological adaptation by leveraging the confidence gained in a successful use-case. At the workshop, we intend to discuss our cross-industry implementation approach with several relevant examples, including some of our key technologies & solutions. We strongly believe that our cross-industry innovation approach as an enabler & integrator of SHM solutions would result in relevant technological advancements that may lead to new use-cases & implementation strategies in the near future.

Speaker: Mr Aswin Haridas (Testia)

Testia at CERN 202... Testia at CERN 202...



Viewpoint from the Aviation Industry eg CVM : “Now scared of driving on the highway”

Flyability - Tunnel inspections and mapping using indoor drones

25m 160/1-009

Large infrastructures like tunnels or shafts can be extremely cumbersome to maintain, on a safety, efficiency and cost aspects.
The Flyability Elios 3 is a ground-breaking technology, as it enables to safely inspect and digitalize hard-to-reach areas in a matter of minutes, without exposing personnel to risk. Combined with a future digital twin platform, it provides the basis for thorough asset monitoring. Come and discover the future!

Speaker: Mr Francois Theil (Flyability)

Benefits of using drones for inspections in difficult area : Sewers, Shafts etc.

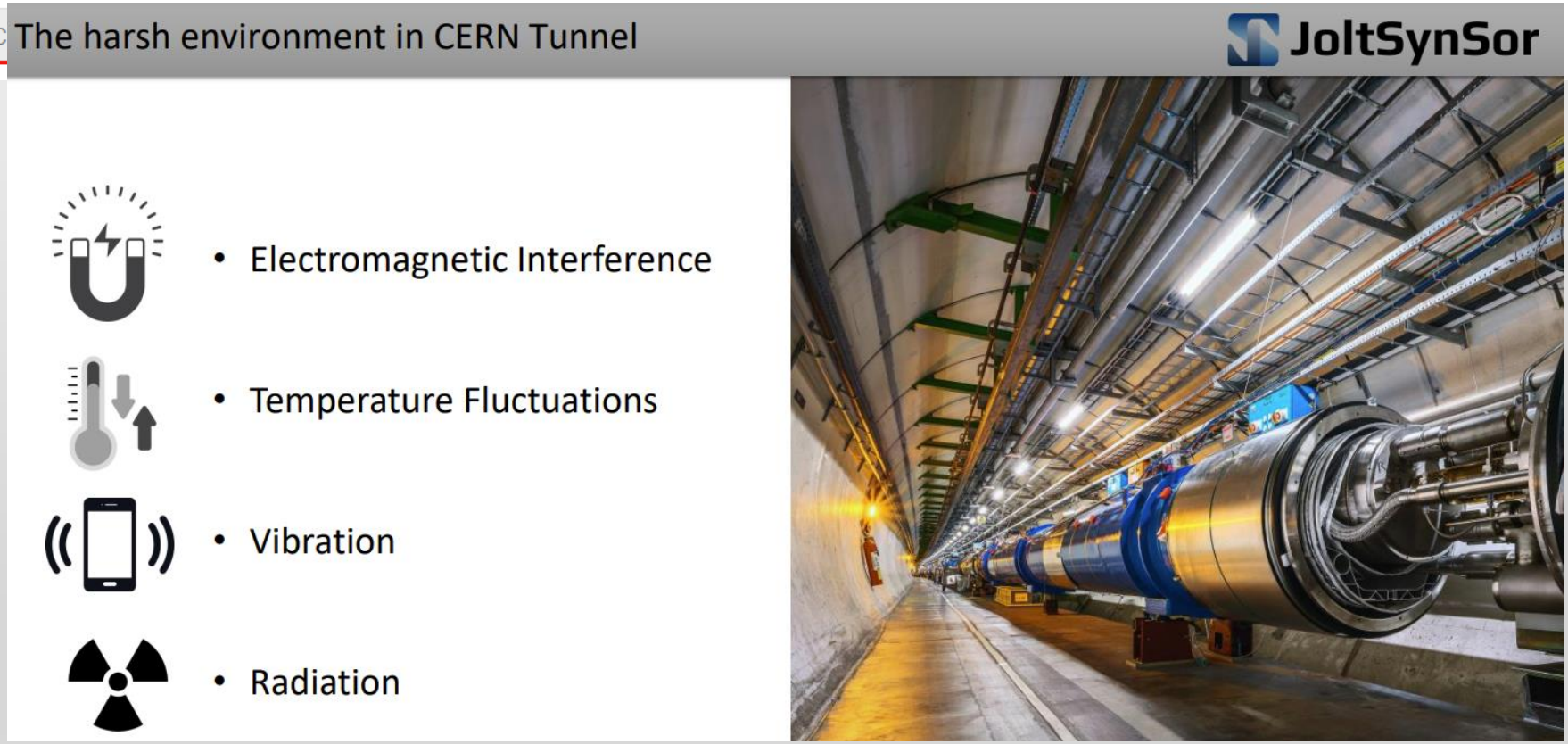
JoltSynSor (JS2) - The Development of a novel multi-axis force sensor and its application in underground construction

25m 160/1-0...

In our ongoing endeavours to advance sensor technology, our research team has formulated an innovative method, seamlessly integrating fibre optic (FO) strain sensing with artificial intelligence (AI) methodologies. Fibre optic sensors (FOS) present promising solutions to challenges often faced by conventional sensors, notably, their vulnerability to water damage and electromagnetic interference. During this presentation, we will shed light on the genesis and advancement of this pioneering sensor design. This will be followed by a comparative performance assessment against established force sensors. Concluding our talk, we will delve into a case study exemplifying the sensor's deployment in an underground civil engineering project for real-time field monitoring purposes.

Speaker: Dr Geyang Song (JoltSynSor (JS2))

C



Spin-Off company from Cambridge University : Sensor Technology in harsh underground environments

Main Goals of this workshop

- CERN to present what technology is being deployed for underground monitoring
- Understand what is industry best practice for tunnel monitoring and building of maintenance programs
- Knowledge sharing and Networking
- Build any new monitoring ideas into our future projects at concept stage
- Work with industry partners to implement any new monitoring
- CERN to promote opportunities for companies to contribute to Future Projects (eg FCC, Linear Colliders..)

- **FEEDBACK ?**

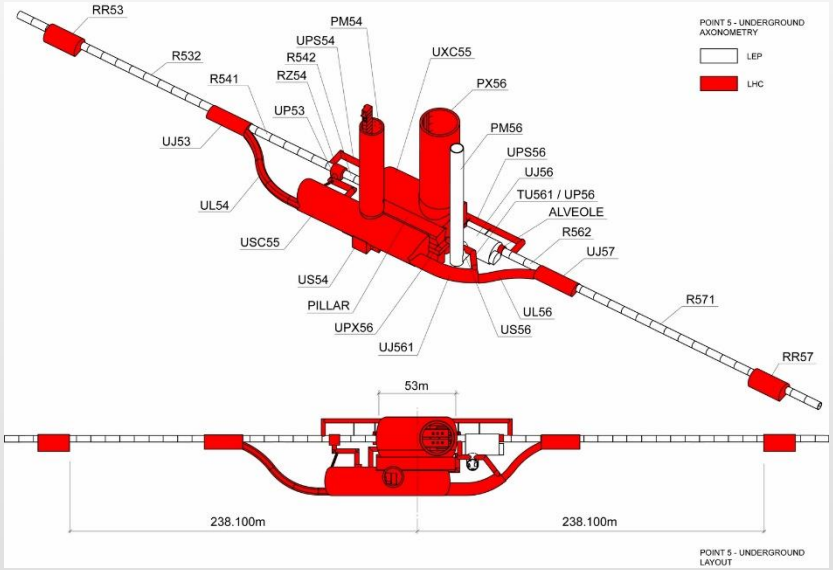
Workshop Photo

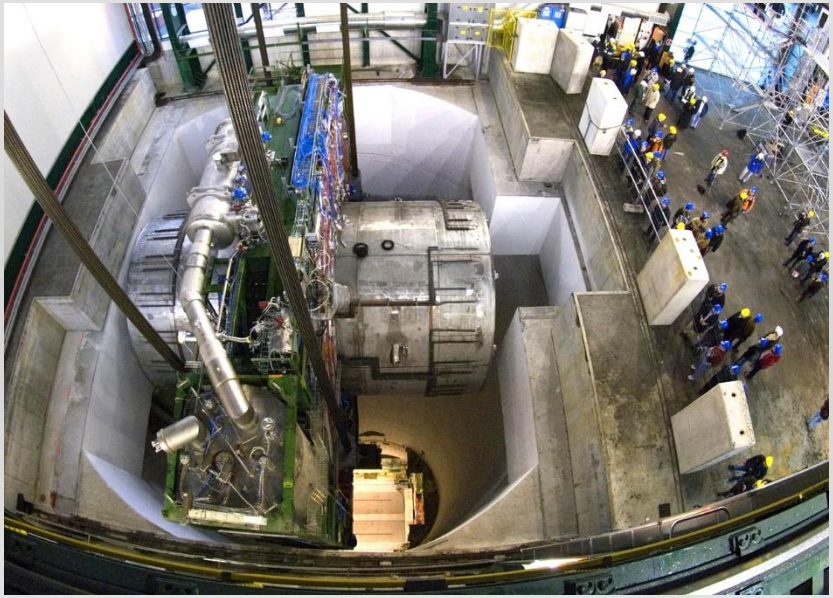
(Selection of Photos will be uploaded onto the INDICO meeting Page, Thanks to Vanessa Aidan !)

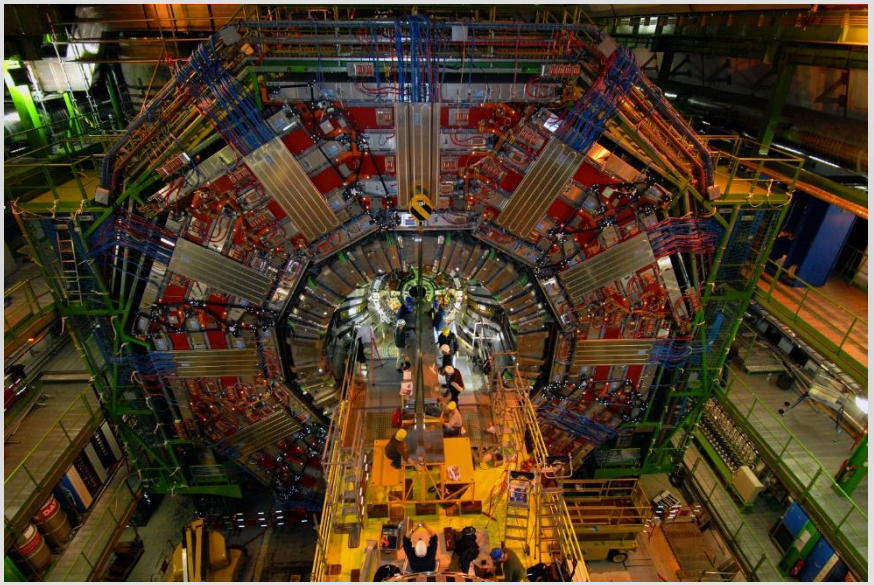
Site Visits : Science Gateway
Architect : Renzo Piano

Check out Tunnel Exhibit !

CMS Underground tour







Some logistics :

- Room will be locked now
- Go directly from lunch to Site Visits
- Meet at Coffee area after lunch at …..
- Back to this room around 5-5:30pm