CERN Civil engineering developments

Ll. Miralles
CERN GS Dept. Head
The Mission of CERN

• Push forward the frontiers of knowledge
  E.g. the secrets of the Big Bang ...what was the matter like within the first moments of the Universe’s existence?

• Develop new technologies for accelerators and detectors
  Information technology - the Web and the GRID
  Medicine - diagnosis and therapy

• Train scientists and engineers of tomorrow

• Unite people from different countries and cultures
CERN was founded 1954: 12 European States

“Science for Peace”

Today: 21 Member States

~ 2300 staff
~ 1280 other paid personnel
~ 11000 users

Budget (2013) ~1000 MCHF

Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom

Candidate for Accession: Romania

Associate Members in Pre-Stage to Membership: Serbia

Applicant States for Membership or Associate Membership:
Brazil, Cyprus, Pakistan, Russia, Slovenia, Turkey, Ukraine

Observers to Council: India, Japan, Russia, Turkey, United States of America; European Commission and UNESCO
Science is getting more and more global
CERN accelerator complex

<table>
<thead>
<tr>
<th>Year</th>
<th>Top energy [GeV]</th>
<th>Length [m]</th>
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<tbody>
<tr>
<td>Linac 1979</td>
<td>0.05</td>
<td>30</td>
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<tr>
<td>PSB 1972</td>
<td>1.4</td>
<td>157</td>
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<tr>
<td>PS 1959</td>
<td>26.0</td>
<td>628</td>
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<td>SPS 1976</td>
<td>450.0</td>
<td>6’911</td>
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<td>LHC 2008</td>
<td>7000.0</td>
<td>26’657</td>
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</table>
LHC tunnel

Overall view of the LHC experiments.

Circumference = 26.7 km
Depth = 70-140 m
Slope = 1.4 %
<table>
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<tr>
<td>D. Mathieson (J. de Jonghe)</td>
<td>C. Delamare (P. Ninin)</td>
<td>G. Deroma (M. Galofre Vila)</td>
<td>G. Deroma (V. Sogno)</td>
<td>G. Deroma (M. Galofre Vila)</td>
<td>L. Marderosian (V. Sogno)</td>
<td>E. Raymond (V. Fassnacht)</td>
<td>L. Seible (N. Lopez)</td>
<td>J. de Jonghe</td>
<td>R. Mertens (G. van der Vossen)</td>
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<td>W. van Leersum</td>
<td>S. Grau</td>
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<tr>
<td>GS-AIS-GDI: General Development &amp; Infrastructure</td>
<td>GS-AE-EDS: Engineering Databases &amp; Systems</td>
<td>GS-DS-S: Site Services</td>
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<td>J. Janke</td>
<td>J. Janke</td>
<td>V. Sogno</td>
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<td>F. Briard</td>
<td>D. Widgren</td>
<td>M. Sanchez</td>
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</table>
2013 material budget

- Initial operation budget 34.2 MCHF
  - Carry forward (2012 budget) 2.0 MCHF
  - LS1 1.1 MCHF
  - Services + licences 0.6 MCHF
  - Revenues 0.1 MCHF
- Autumn operation budget 38.0 MCHF
- Projects budget 57.7 MCHF
2013 personnel

- Staff: 39.8 MCHF
- Fellows: 2.0 MCHF
  41.8 MCHF
• EDH:
  – 17’000 users
  – 360’000 document created
  – 760’000 electronic signatures

• HR:
  – 454’700 HRT reports run
  – 8’391 contracts created
  – 40’000 reminder emails sent
  – 28’500 job applications received
  – 39’439 SiR Trainings passed
  – 46’159 payslips calculated

• Finance & Purchasing:
  – 90’000 purchase orders
  – 100’000 payments made
  – 16’000 Imports/Exports
  – 700’000 transport documents prepared

• IMPACT:
  – 11’150 coordinated LS1 activities

• CERN Hostel:
  – 27’371 Online reservations

• OpenDays:
  – 20’000 tickets issues

• Public Outreach:
  – 3’453 visits organized
    (84’700 visitors)

• Phonebook:
  – 29’000 entries
  – 2.1 million searches

• Reporting Service:
  – 351’000 report executions
PS Access Project

• Major change in the PS Complex and in the LHC Injection Chain!
• 10/14 zones fully renovated
  – Buildings; buffer zones
  – Access points (21/22); doors
  – Interlocks
• Integration of new experimental areas
  – EAR2; EAR2
• Control system in CCC fully operational
Alarm Systems

• Fire Detection and Evacuation 2014
  – Bld 107, 774, HIE-Isolde, ISR Radiation Waste Project
  – PS Beam Imminent Warning/Evac - Commissioning
  – Numerous LS1 activities
    • R2E activities LHC4 & LHC5
    • PS Fire doors
    • Triggering of the LHC evacuation by the Fire detection
  – Technical galleries after the LS1
  – ...

• Flammable Gas and ODH Detection 2014
  – Centrals Point 1 & 5
  – HIE-Isolde
  – Flammable gas detection by air sampling in UX15
  – ODH sensors non accessible – solutions to be deployed
  – ...

MEDSI 2014. 20th-24th October, Melbourne  
Ll. Miralles. CERN
• Continuous and significant support effort
  – ~130 support requests per month
  – 16 design offices visited each week (>160 designers)
  – 94 new users (huge turnover!)
  – 65 people trained (45 new)
  – CATIA users forums & many FAQs

• Major CATIA/Smarteam upgrade (R23) Nov. 2013
  – Significant preparations and tests: ~12 man-months

• Piping solution provided for EN-CV with methodologies.
  – Improved efficiency.

• Prepare the succession of CATIA V5 (V6 or not ?)
  – Update of user requirements
  – Benchmark of CATIA V6
• EDMS 2013 in numbers
  – 7’000 new documents/drawings per month
  – 124’000 file downloads per month
  – 2’800 support tickets
  – 12 courses: 95 participants in total

• Joint effort launched with BE, TE & EN
  – Import/digitalize all maintenance documentation

• EDMS 6
  – New more intuitive and user-friendly interface
  – New search engine
  – Beta version now available on production
  – Full production Q2 2014
• Increased use and interest in Infor EAM
  – ~200k Work Orders registered in 2013 (~75k in 2012)
• EAM Light: Web interface for basic tasks
  – Mobile friendly version available for all platforms
• Continuous improvement of the Integration with Service Desk and CCC-TI
  – Computing tools and processes

• Pursue the efforts with the A&T sector (Maintenance Management Project)
  – Asset tracking, Documentation, Spare parts
  – New equipment groups
• Profit from this momentum for GS (SE, FB, IS, ASE)

• In the 2014 pipeline
  – Infor EAM upgrade to version 10.1.2 (or 10x)
  – IMPACT & planbook integration
  – Better access rights management
Third phase in the renovation of the Central Stores
(acquisition of two new storage towers)
Supply of equipment for open days
(264 000 items, Computers, Safety-Cloths, T-Shirts, Hoodies, Pens...)
Modernization of equipment in Row materiel store (Saw and hydraulic Shears)
Management of module for SRS project, developed at CERN and manufactured in Greece
### Evolution of turnover

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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<tbody>
<tr>
<td>Turnover (MCHF)</td>
<td>22.5</td>
<td>23.1</td>
<td>25.6</td>
<td>28.9</td>
<td>31</td>
</tr>
<tr>
<td>Direct Deliveries (MCHF)</td>
<td>6.9</td>
<td>7.4</td>
<td>8.4</td>
<td>8.3</td>
<td>10.5</td>
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<tr>
<td>Punch Out Direct Deliveries (MCHF)</td>
<td>2.2</td>
<td>2.5</td>
<td>3.0</td>
<td>3.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Stock Value (MCHF)</td>
<td>6.8</td>
<td>7.0</td>
<td>7.45</td>
<td>7.9</td>
<td>8.1</td>
</tr>
<tr>
<td>Number of Pickings (in Thousands)</td>
<td>100</td>
<td>135</td>
<td>152</td>
<td>165</td>
<td>226</td>
</tr>
</tbody>
</table>
GS-SE scope

From Design to construction
to large projects

COMPLEXITY

and Operation & Maintenance

From minor works

TIME

MEDSI 2014. 20th-24th October, Melbourne

Ll. Miralles, CERN
1 INTRODUCTION

1 TUNNEL MONITORING BY OPTICAL FIBER

1 TUNNEL INSPECTION BY REMOTE CONTROL VEHICLE

2 SELF SUPPORTED SLABS EXECUTION NOVEL TECHNIQUE
• Two sections of the tunnel were identified as at risk due to the presence of the saddle shaped cracking to the vault combined with significant heave of the floor.

• One section identified as requiring ongoing monitoring due to saddle crack and some floor heave

• Possible causes were identified:

  1. Geotechnical – long term stress relief (creep) of the rock, swelling due to water
  2. Quality issues – variations in concrete thickness and quality
  3. Concept – not the best design for our needs and ground conditions
Cracks in the floor were sealed to prevent possible infiltration by water leaking into the tunnel.
Defects and poor construction of the original drain allowed water to penetrate the rock under the floor causing swelling and floor heave.
Reinforcement of the existing tunnel Vault

Steel beams and spreader plates were designed to reinforce the structure

22 beams were installed in total
The adopted monitoring method makes use of innovative Distributed Fibre Optic Sensing (DFOS) systems.

A fibre optic (FO) cable is applied on the studied structure and a light is sent in the fibre using a Brillouin Optical Time Domain Analysis (BOTDA) analyser. The backscattered light is analysed in the frequency domain and the shift in the Brillouin frequency peak is related to a change in strain through a linear relationship. This calculated strain is then translated to other engineering quantities, such as displacements, forces and bending moments.

\[ v(\epsilon, T) = v(0, 0) + C_1 \epsilon + C_2 T \]

where \( \epsilon \) and \( T \) are strain and temperature, respectively; \( C_1 \) and \( C_2 \) are the strain and temperature coefficients, respectively, which are known to be about 0.05 MHz/micronstrain and 1.2 MHz/°C for conventional single mode optical fibers used at the 1500nm wavelength range of optical communication.
# Fiber Optic installation TT10

Table 1. Description of the different monitoring sections at tunnel TT10.

<table>
<thead>
<tr>
<th>Monitoring Section</th>
<th>Description</th>
<th>Installation</th>
<th>Readings</th>
</tr>
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<tbody>
<tr>
<td>CERN 1</td>
<td>8 circumferential + 1 longitudinal tunnel sections</td>
<td>First</td>
<td>Baseline, X, Progress</td>
</tr>
<tr>
<td>CERN 2a</td>
<td>12 I-beams (both top and bottom flanges)</td>
<td>Second</td>
<td>X, Baseline</td>
</tr>
<tr>
<td>CERN 2b</td>
<td>6 circumferential + 1 longitudinal tunnel sections</td>
<td>Second</td>
<td>X, Baseline</td>
</tr>
</tbody>
</table>
Figure 1. Arrangement of FO cables in CERN tunnel TT10 (as of July 2014).
Figure 9. Brillouin Frequency data for CERN2b (July 2014)
Figure 7. Brillouin Frequency data for CERN2a (July 2014)
Figure 5. Brillouin Frequency data for CERN1 (July 2014)
Two installations have been deployed: (a) 8 circumferential tunnel loops with a longitudinal section and (b) 6 circumferential tunnel loops with a longitudinal section and 12 sets of horizontal I-beams within the tunnel.

Three readings were taken so far: March 2014, May 2014, July 2014. However, due to some instrument malfunction the readings of May 2014 are not considered reliable and therefore are not included in the analysis. Hence, the readings of July 2014 are used as baseline readings for the second installation. Consequently, we present strain results for the first installation and base readings for the second installation.

Regarding the readings taken for the first installation the longitudinal section showed some compressive strains, generally less than 200με, with an average of around 120με. The circumferential tunnel loops showed some larger values of axial strains in the FO cable (the peaks showing an average of around 300με) and a somewhat consistent profile of the strains for all 8 circumferential loops with positive tensile strains at the sides and negative-compressive strains at the crown of the tunnel. Data consistent with the observations.
The test aims to crosscheck the following aspects:

1. Manoeuvrability.
2. Wired/wireless communication system distance range.
3. Photos quality
4. Autonomous functions

Tests conducted:

A. Trial run in the tunnel (for Q-1, Q-2)
B. Capturing photos of the tunnel (for Q-3)
C. Capturing 3D point cloud using a laser scanner (Q-4)
D. Test some miscellaneous cameras.
Tilting table
Extra camera mount
Laser scanner
External battery port
Main camera for remote operation
Cable handling device and cable reel
Wireless system: Run 40m, and switched to wired system
Wired system: Run 220m and returned back because the battery voltage seemed low
Moved through chicane to ECX4 and explored there
Accessed Ti81
• The robot capture comprised ~180 images of a small section of the tunnel, half taken before and half taken after some changes were made
• Images were lit with ambient tunnel light, 18mm focal length
• Detail & lighting were sufficient to reconstruct the concrete surface from images
• Three changes: 1. White marks on wall from hammer, 2. Pink spray, 3. Water splashes
• First two are clearly visible to human eye so should be detectable
• Water did not cause much surface discolouration so probably won’t be detected
• Yet to process data for change detection but the images can be reconstructed, suggesting it is feasible

Sample image captured by robot

Close up of previous image showing crack detail
Side view of tunnel ceiling reconstructed from robot camera images

Below view of tunnel ceiling reconstructed from robot camera images

Laser scan
1. **Maneuverability**. In the case of stair steps, the robot needs sub-tracks.

2. **Range**. 220m tested. Reel capacity 500m of cable. Main limitation the battery.

3. **Photo quality** OK. Interval shooting mode. (No remote control)
   A remote controlled tilting table was used to move a camera along a diameter

4. **Autonomous functions**. Obstacle avoidance. Path following, line/wall. Localization based on laser scan.
Reinforcement of the PS shielding at PS septum zone, between 2 to 3 m of soil, requires independent supporting slab to protect the existing tunnel and services.
<table>
<thead>
<tr>
<th>Description de la variante</th>
<th>Illustrations</th>
<th>Avantages</th>
<th>Inconvénients</th>
<th>Estimatifs coûts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Poutres en béton armé et précontrainte coulées en place avec préfaisettes intermédiaires</td>
<td><img src="image1.png" alt="Illustration" /></td>
<td>1. Pas d’efforts latéraux sur les murs existants induits par le nouveau blindage 2. Pas d’efforts sur les dalles existantes</td>
<td>1. Mouvement de terre (contact avec structure existant nécessaire) 2. Charge verticale supplémentaire sur les murs existants 3. Risque de coinage des drains lors de l’installation des préfaisettes 4. Rigidité des préfaisettes vis-à-vis des appuis sur la structure faible 5. Étanchéité des appuis sur existant</td>
<td>1.87 Mio. CHF HT (Hors traitement de l’étanchéité) Selon devis GEO (20%)</td>
</tr>
<tr>
<td>2. dalle continue en béton armé ép. env. 10 m. avec sommiers décalés pour les grandes portées</td>
<td><img src="image2.png" alt="Illustration" /></td>
<td>1. Aucun contact avec les structures existantes (pas d’efforts sur la dalle ou les murs) 2. Structure existante soulignée par excavation du terrain en place (mise en conformité des ouvrages) 3. Pérennité des drains et de l’étanchéité 4. Dalle portant dans 2 directions → adaptation à géométrie complexe</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td>1.78 Mio. CHF (10%)</td>
</tr>
</tbody>
</table>
Reinforced concrete slab 1.1 m thickness

Bio degradable shutter
Rain water penetrates inducing the collapse of the shutter.
TEST

• Replace the biodegradable shutter by a layer of sand. A test on 15 x 3 m slab is executed.
• Pumping by aspiration not efficient.
• Injection of high pressure water allows the extraction of the sand, slope of 2% allows to channel the sand to a gutter.
• No geotextile between concrete and sand!! Avoids water flow.
SOLUTION

- Protection concrete with an slope of 2%.
- Layer of 20 cm of sand with the top surface correcting the slope.
- Preslab of 7cm, top surface correcting slab. Leave access for nozzle.
- Access for persons on the slab for pressure water hose.
- Lateral gutter for sand collection.
Thank You for your attention