Cabling the ATLAS experiment.

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Abstract

In 1994 the first provisions for the cabling of the experiment were made: two hundred and fifty racks in an undergound cavern with linking galleries housing 44 cable trays to the experimental cavern.

The civil engineering design drawings of the surface and underground areas were approved in August 1996.

The installation of the ATLAS experiment started in September 2003.

This paper covers the range of tasks involved in the cabling of ATLAS from 1994 until the present

I. DEFINITION OF THE INFRASTRUCTURE

In general, the LHC project makes use of the existing civil engineering infrastructure and facilities at CERN that were used for the previous LEP project.

The unprecedented size of the two largest experiments, ATLAS and CMS, required, however, new underground caverns to accommodate them and their associated technical services (electronics, power supplies, cryogenics and cooling plant).

In order for these new caverns to be excavated and built in time for the start of the assembly of the experiment, the technical service caverns needed to be defined at an early stage – 1996. At this time, details of the cabling – dependent on the definition of the electronics and power supplies – were not known.

This was the situation when the conceptual studies for the cabling of the experiment had to be made.

In June 1994 the first meeting “coordination of the ATLAS experimental zone and its infrastructure” took place. This regular, fortnightly, meeting still takes place and serves as a forum to discuss, and decide, on matters related to the infrastructure of the experiment.

A. The underground areas

The larger size of the ATLAS experiment led to it being positioned at point 1 of the LHC ring where the soil conditions were more favourable than the alternative location at point 5.

Budgetary concerns were also prevalent at this time – the LHC project was to be built on the back of the LEP project with “minimal” additional costs.

Point 1, at the time of LEP, already had two shafts (PM15 and PX15) and a small underground cavern (US15) with link galleries (UL’s) to the main accelerator tunnel.

The new underground areas for ATLAS were to exploit this existing configuration. Importantly, the existing areas were not to be touched so that costs could be kept down.

With the above in mind, the layout of the underground areas was fixed, as shown in figure 1 and 2.

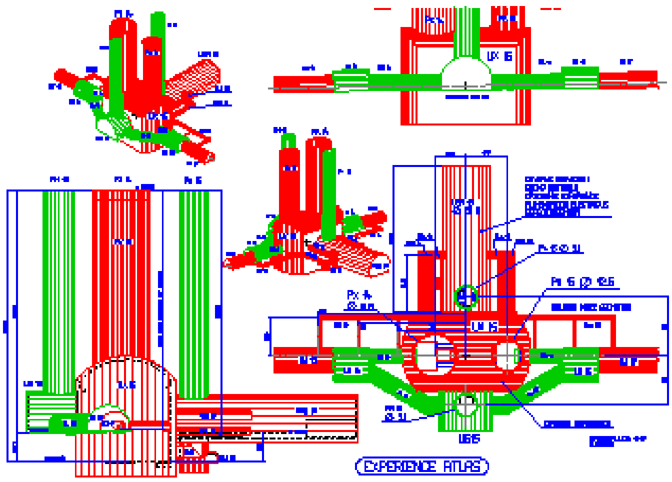

Figure 1: The underground structures:new and existing

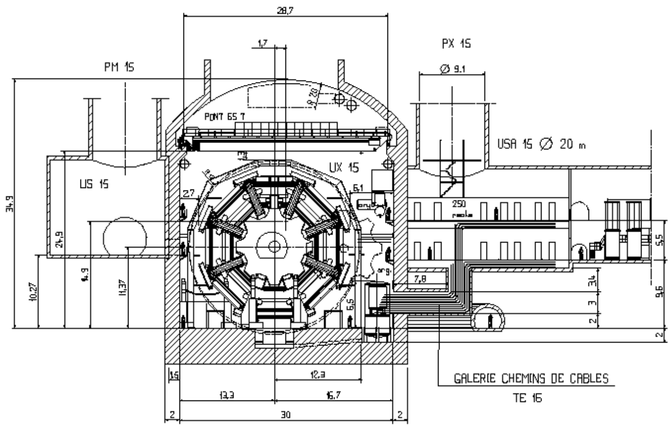

Figure 2: The ATLAS experimental cavern sandwiched between the existing PM15 and PX15 access shafts.

B. Provision for racks and the distribution of cables

In defining the layout of the underground areas, thought had to be given to the provision of space for racks and for the distribution of cables from these racks, through service galleries, and around the experiment – see figure 3. .

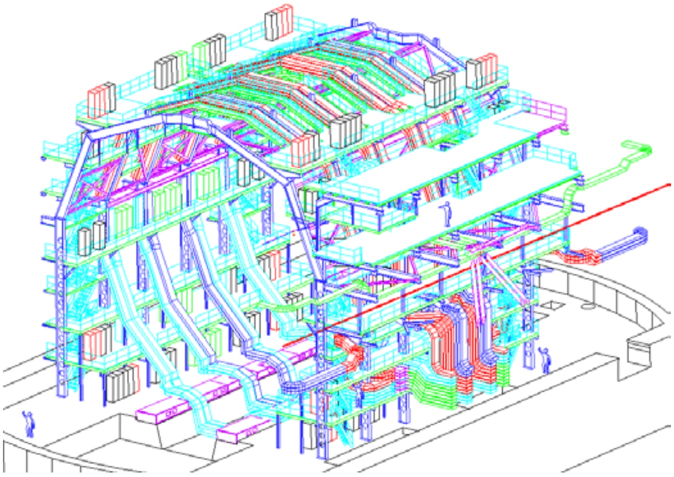

Figure 3: Cable trays around the experiment

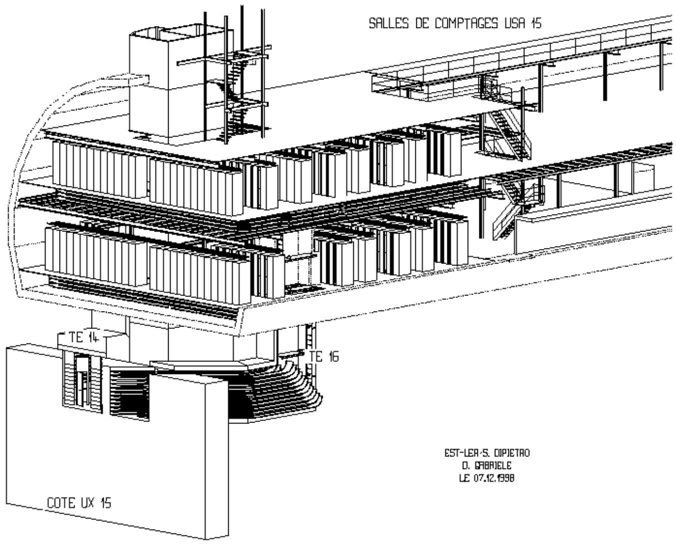

Figure 4: 250 racks on two levels in USA15 with the two linking service galleries housing 44 cable trays.

At the time of this definition an allowance for 250 racks was made for all the underground areas. The racks were split on two levels of the technical cavern (USA15) and positioned closest to the experiment to minimse the cable lengths. See figure 4.

There are two main cable galleries, arranged in chicanes for radiation protection reasons. Each gallery houses 22 cable trays, each tray is nominally 600mm x 100mm.

In addition, there were initially 4 holes foreseen in the wall separating the two caverns to allow for the passage of level 1 trigger cables. These holes, arranged at angles for radiation protection reasons, are of 300mm nominal diameter. The number of holes has increased over the years and there are now nine holes set into the concrete wall.

Since the definition of the infrastructure we now have 66 racks for ATLAS that are to be housed in the existing US15 cavern. In addition, more than 20 holes have been set into the wall of the US/UX to allow for the passage of cables.

With the benefit of hindsight we can now see that the intitial provision for 250 racks was insufficient. However, by placing them in the existing US15 cavern we not only economise on civil engineering costs but also, with the improved cable distribution possibilities, we economise on cable lengths and costs.

II. OBTAINING DETAILS OF CABLES

C. The technical design report (TDR) of the technical coordination

At the time of the TDR, information was collected from the various representatives of the sub-detectors that comprise ATLAS. This was in the period 1998/1999. At this stage many decisions on the choice and number of cables were still outstanding. The data was, therefore, typically an estimate of the cross-sectional areas of cables. From this information – usually obtained by emails – tables and schematic diagrams were created that included an allowance for the "packing factor" of cables – see figure 5. With this information the space needed for the routing of the cables, and other services, was sought. Where this involved the routing of the services through the experiment itself the negotiations were often long and difficult, since, invariably, the space requirements often increase with time as more details become available.

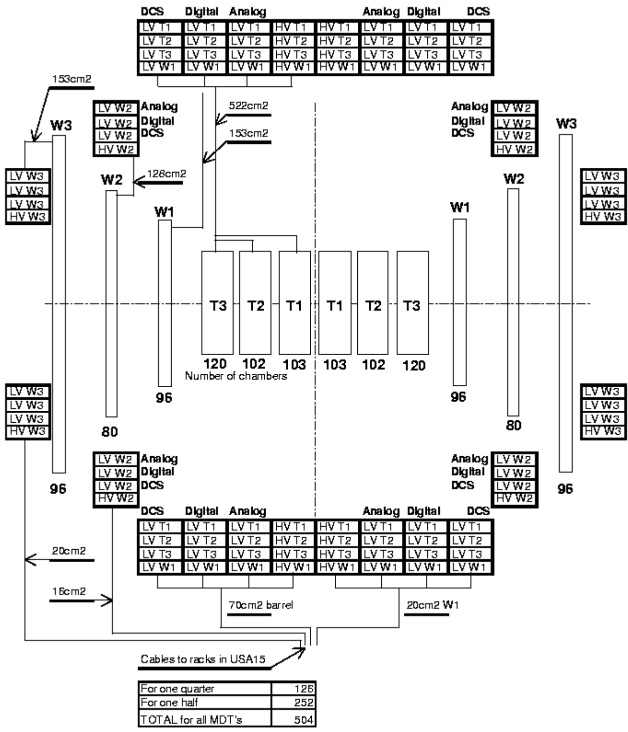

Figure 5: Schematic arrangement of the cable distribution for the MDT muon chambers at the time of the TDR (no longer valid).

D. The web accessible database of cables and racks

In August 2000, Chris Parkman joined the team. In addition to his other tasks, his role soon expanded to become responsible for the allocation of racks. He developed what was to become an invaluable tool for obtaining the information that we needed on racks and cables. By creating a web accessible database, individuals working on ATLAS could themselves complete a questionnaire that would enable their data to be stored and visualised in a tabular form. The advantages of this scheme were as follows:

- Instead of sub-system coordinators trying to chase up the information from their international colleagues in different labs around the world those same colleagues could complete the questionnaires themselves.
- The information is presented in a standard comprehensive way
- The persons responsible for their cables can easily check the data on the web for accuracy
- The information is transparent enabling their colleagues, coordinators, and other sub-detectors to see who is using what cable.
- Technical coordination has a means of obtaining all the relevant data on cables and easily identifying to management those systems who are late in providing the necessary information.

The web address for the cable and rack information is: http://atlas.web.cern.ch/Atlas/GROUPS/FRONTEND/index.html

Please note, however, that the link to the rack and cable data is currently dis-connected for reasons that are explained later.

E. Analysis of the web accessible cable database

September 2002 saw the arrival of Sergei Malyukov into the team with the role of “cable manager”.

His first task was to analyse the web database. Up until this point we had no accurate estimation of the total cable quantities and lengths. We needed these for a number of reasons. One of them being to estimate the installation costs for which technical coordination had assumed the responsibility. A comprehensive analysis was made summarised by a number of charts:

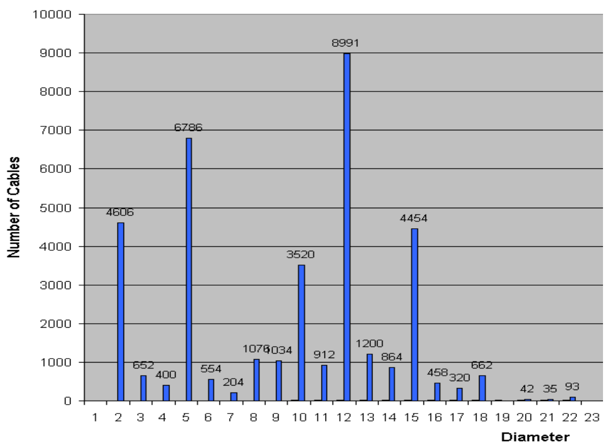

Figure 6: Total number of cables by diameter

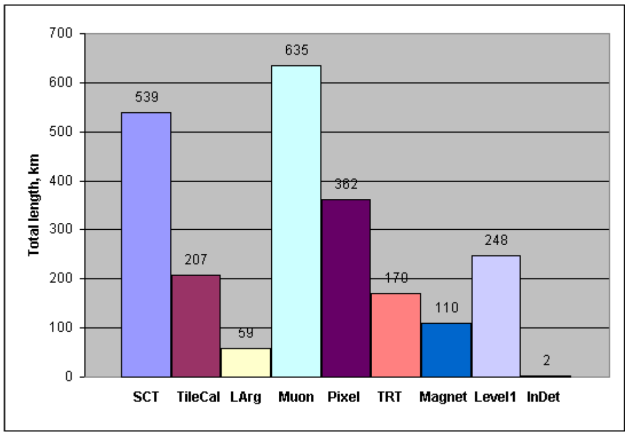

Figure 7: Total length of cables by sub-detector

F. Most recent data on cables for ATLAS

The most recent data on cables and racks for ATLAS is now managed by Malyukov. Documents are uploaded onto the CERN engineering data management system (EDMS).

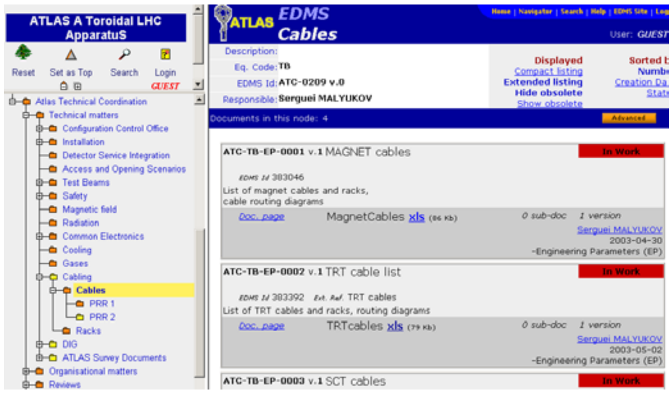

Figure 8: Latest data on cables on EDMS web

III. FIXING THE POSITIONS OF RACKS

To plan for the cable distribution scheme in a project one needs to know the start and end points of all cables. When this is known, schematic diagrams can be made of the cable distribution from which the number and arrangement of cable trays can be determined.

For an experiment, the end points of the cables are on-detector connections, patch panels and racks. In the case of ATLAS, these positions have only just been fixed (July 2003).

G. The web rack database

A web accessible rack position tool was established by Chris Parkman. The allocation of the racks is made by technical coordination after consulation with the system representatives and in consideration of the constraints –normally technical.

From the web anyone can consult either layout drawings showing the position of the racks or listings of the racks.

More recently the web link has been disconnected whilst the cable manager completes the final layout. It will be re-activated when the situation is stable.

1) USA15 racks

USA15 Has two floors with a total use of 238 racks as shown in the following figures:

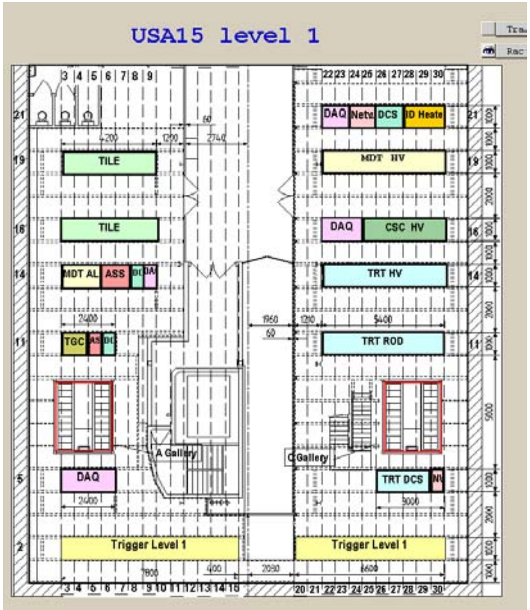

Figure 9: USA15 level 1: 103 racks

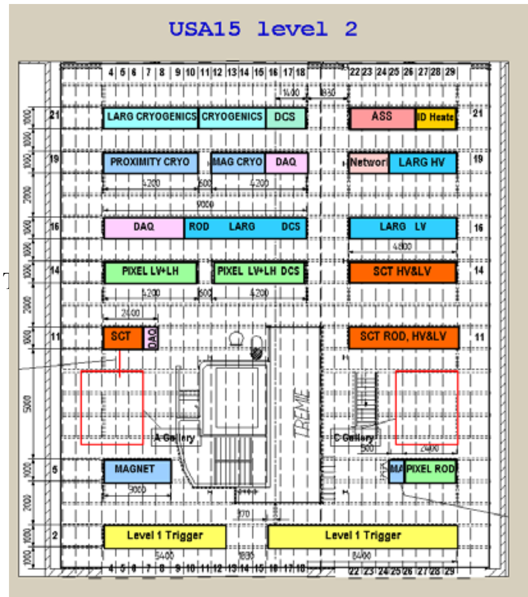

Figure 10: USA15 level 2: 135 racks

2) Main cavern racks

The main cavern currently has 154 racks arranged on the access platforms of the HS structure. These racks are used for gas and cooling systems as well as for power supplies, patch panels and electronics for the sub-detectors.
The latest arrangement for the side US

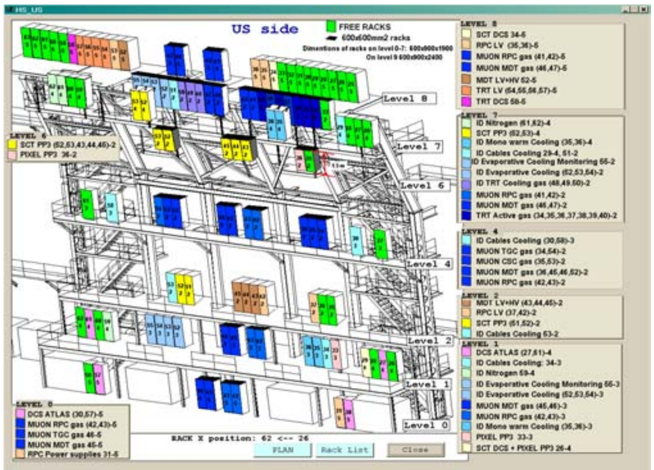

Figure 11: UX racks: US side

3) US15 racks

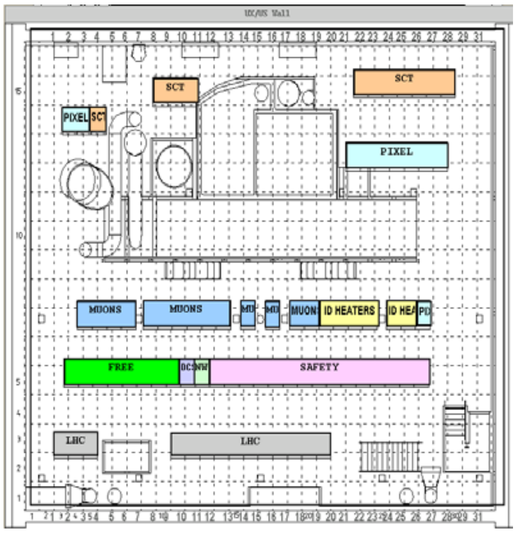

Figure 12: US15 racks

There are 66 racks currently planned for the existing cavern US15 on the second floor and in excess of 20 holes of 300mm diameter in the wall of the experiment cavern to allow for the passage of the cables.

IV. SCHEMATIC DIAGRAMS OF CABLE ROUTES

When the position of the racks and patch panels are fixed the schematic diagrams of the cable routes can be made. From this data the assessment of the arrangement and number of cable trays can then be made and compared to the initial provisions made back in 1994.
In practice, however, work on the schematic diagrams usually starts before the rack positions are frozen so that the whole project can make some progress. This requires that the diagrams are modified if rack positions change.
Although we organised a rack review in February 2002 it has not been possible to finally freeze the positions until July 2003. In some cases, the sub-detectors run parallel solutions for their electronic and power supply problems and do not

make a decision on which path to take until pressured to do so by the ATLAS management.

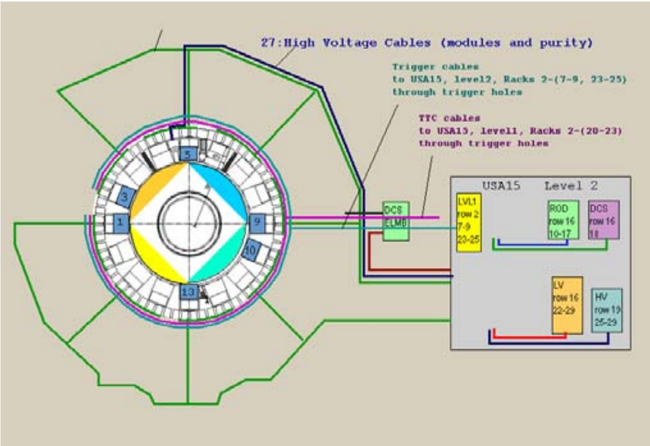

Figure 13: A schematic cable arrangement for the Lar barrel

V. DESIGN STUDIES

H. CAD Models and drawings

Armed with the schematic diagrams of the cable routes the cable manager is then in a position to work with the CAD designers for the detailed arrangement of the services.

Where space is tight, inside the experiment, the drawings usually include details of the cable bunches to demonstrate the feasibilty, or otherwise, of the arrangement.

For the main cable tray distribution from the experiment to the racks in USA15 & US15 only the cable trays are indicated on the CAD models – see fig14. Details of the contents of the cable trays are maintained by the cable manager in his database (web accessible) including the schematic arrangements.

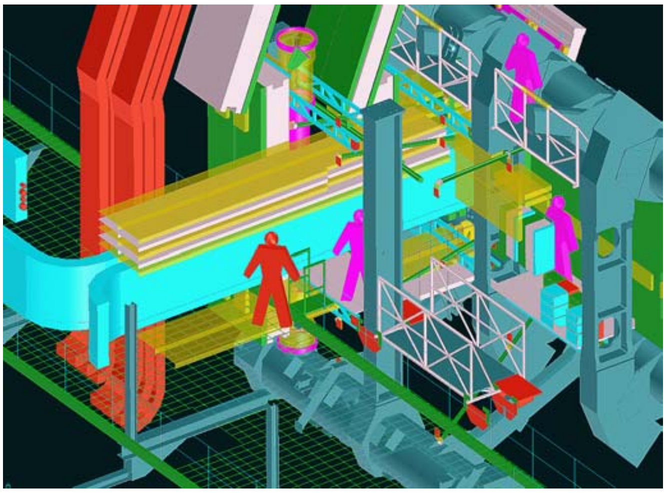

Figure 14: CAD modelling of cable trays entering the central region of the ATLAS experiment in sector 9.

I. Full scale modelling

Figure 15: Full scale model of the inner detector services

A full scale model of part of the barrel calorimeter assembly has been made – see figure 15. This model has served to test the inner detector evaporative cooling system and to demonstrate the space raquirements for the services of the inner detector. These services need to exit the gap regions between the barrel and end-cap calorimeters and space to do so was very restricted. Based on this modelling work, and detailed CAD studies, ATLAS decided to increase the gap between the calorimeters to allow for the passage of the services.

J. Testing of cable behaviour in chains

To allow access inside ATLAS, the sub-detectors in the forward regions, end-caps, will move on a rail support via air pads. For these sub-detectors to remain cold and operational the services need to remain connected. This will be done by routing them through flexible chains. We have already tested the mechanical and optical performance of optical cables in a flexible chain. The test was arranged, full scale, to replicate the eventual arrangement. The test was successful.

Figure 16: Testing optical cables in a chain

K. Identification and labeling of cables

In order to faciltate the installation and connecting of cables a labeling scheme is typically employed.

For ATLAS this scheme has been deveopled by K.Pommes and it has been presented at our technical management board meetings.

Each cable will be identified by a unique code of the form 2711001 where:

2	:	ATLAS
71	:	Muon MDT (From PBS)
XXXX	:	Number

2711001 **MMBOL.3A12** / L / **Y.22-19.USA1**

MM: MDT Chambers
BOL: Barrel Outer Large
3A12: Third Chamber on A side sector 12

Y: Rack
22-19: X-Y position on floor
USA1: first floor of USA15

Names of Functional Positions follow conventions outlined by Technical Coordination

Figure 17: Typical cable lable

Cables should be labeled with this identifier on each end in both human readable text and as a barcode.

With the cable identifier, one can retrieve all cable information from a web-accessible cable database.

To reduce the database interaction during the installation, additional information can be printed on cables:

Cable endpoints : The laying and connection of the cable can be facilitated by specifying the places the cable will connect to on each end (e.g. the name of a muon chamber and a rack).

F	Gas In
R	Gas out
E	Extra Low Voltage power Cable (U<50 VAC, U<120 VDC)
L	Low Voltage Power Cable (50<U<1000 VAC, 120<U<1500 VDC)
H	High Voltage Power Cable (U>1000 VAC, U>1500 VDC)
D	Data – electrical cable
O	Data – optical cable
C	Control – electrical cable
T	Control – optical cable
N	Network – electrical cable
W	Network – optical cable
S	Safety
M	Multipurpose
..	…

Figure 18: Functionality of a cable

Cable functionality : It is useful to label a cable with its functionality (e.g. High Voltage) for both identification and safety reasons.

Connection Point Labels : The place a cable connects to should also have a label containing the ID number of the cable that will connect to it : this makes the association between the two straightforward. Figure 17 illustrates a typical cable label.

VI. ORDERING OF CABLES

L. Monitoring the cables supplied to CERN

Technical coordination (TC) is concerned that the cables will arrive at CERN in time for them to be installed in accordance with the installation schedule. To assist with the monitoring of the cables we track the progress according to a typical model we use for the planning, see figure

The individual systems require from TC an estimation of the length and confirmation that the CERN safety codes are complied with. This is handled by the so called PRR1 and PRR2 documents.

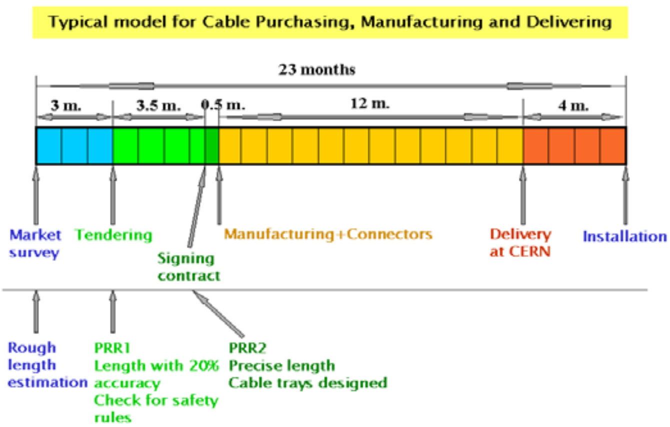

Figure 19: The cable procurement model

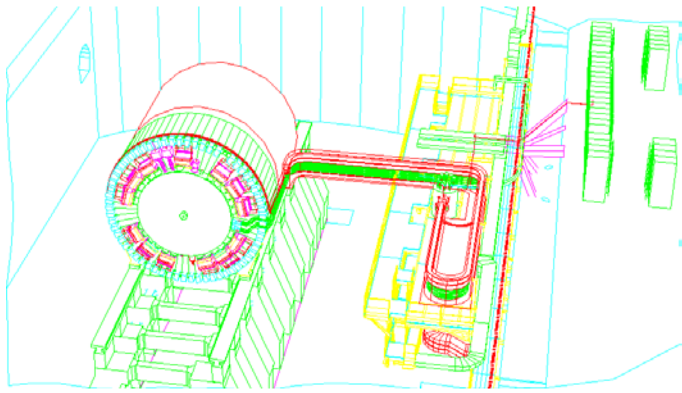

Figure 20: Using CAD models to estimate cable lengths

M. PRR1 Document

We have developed a procedure for the checking of cable data before the call for tenders are released.

This procedure includes for the writing and approval of a document, PRR1. This document is prepared jointly by the systems responsible for the purchase and by the cable manager of technical coordination. The latter provides details of the cable lengths, accuracy +/-20%, and confirms that the cable meets with the CERN safety criteria. The system representative completes all other technical details and characteristics of the cable and the connector.

N. PRR2 Document

A similar document is produced at the time of the cable order where cables may need to be cut to length. The cable estimates are then to be made using the CAD models of the cable tray network.

VII. OUTSTANDING WORK

At the time of writing we are at the stage of completing the schematic diagrams and starting the assessment of the cable tray distribution around the main experiment.

Inside the experiment we are producing detailed CAD layouts of the access platforms, cable trays and support structures.

We have installed cable trays in the floor of USA15 and soon the cable trays in the linking galleries will be installed.

The order for the rack structures is placed and we have teams identified to install them at the approriate time.

The main list of outsanding work is as follows:

- Complete the schematic layouts of cables
- Complete the detailed design of cable trays in and around the experiment
- Complete a market survey and tender for the remaining cable trays
- Obtain a building at CERN that can be used for the reception, storage and preparation of cables
- Plan the resources for the installation
- Instal the cables to the limits agreed with the systems.

VIII. CONCLUSIONS

- The cabling studies for the ATLAS experiment started years before any details were known about the electronics.
- The ultimate success, or failure, of the cabling scheme is largely dependent on the provisions that are made at the time of the definition of the infrastructure.
- The service galleries need to be large enough to accommodate a sufficient number of cable trays that can be accessed in a satisfactory way.
- The space, underground and on the surface, needs to be large enough to accommodate a sufficient number of racks – difficult when the focus is on budget restrictions.
- When provisions are insufficient the design team need to interact quickly with CERN infrastructure groups to implement the necessary changes. Additional costs are usually involved.
- The infrastructure for ATLAS needed to be fixed in 1996. The number and position of the racks have just been fixed in 2003.
- It is difficult to obtain the information on cables largely because the electronics and power supplies are ill defined up until the moment the experiment starts to be installed.
- The above constraints require that much activity, and resources, are needed to complete the detailed designs at a "later than normal" stage in a project.
- The range of tasks involved in the cabling of ATLAS has been shown. The list is incomplete, we still need to manage the storage, transport and installation at CERN.

IX. ACKNOWLDEGEMENTS

Many people have been involved in the work described in this paper. I mention their names below and apologise in advance for any, unintentional, omissions.

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Advice on working methods:
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C.Parkman
Present CAD designers
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Installation data base and cable labelling
K.Pommes, M.Sharp
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