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Managing Context: Lessons from a Large-Scale Science Project

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Context of a Research Collaboration

This chapter describes a study of relationships within the ATLAS experiment at CERN, Geneva, and the narratives deployed by the individuals charged with the management and development of a unique organisation. These managers are scientists elected to their post by their peers in order to sustain the organisation in conditions of uncertainty and complexity derived from the heterogeneity of members and stakeholders and the uncertainty inherent in the core scientific endeavour.

The MODE research collaboration was an international interdisciplinary team of researchers from universities and business schools in Birmingham, Dublin, Lyon, Geneva and the Open University in the UK. The Resources Coordinator for the ATLAS project at CERN, the European Organisation for Nuclear Research, was an active partner. The collaboration investigated the processes of knowledge creation and dissemination within a network of some 3000 researchers who constitute

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G. Bell et al. (eds.), *Problem Structuring Approaches for the Management of Projects*,
https://doi.org/10.1007/978-3-319-93263-7_7

one of four major experiments at CERN and are responsible for the design, construction and operation of a unique scientific instrument weighing 7000 tonnes and occupying half the volume of Notre Dame Cathedral. The present author examined the mechanisms by which successful technological innovations resulting from this task are transferred from CERN to member organisations and other stakeholders.

Sauer (1993) and Flyvbjerg et al. (2003) show that large-scale project management involves the definition and redefinition of success and failure, and the maintenance of financial and political support. Perrow (1984) and Collingridge (1982) offer frameworks of analysis of complexity and coupling and of the dynamics of large-scale commitment. Here it is argued that an overarching meta-technical perspective (Little 2004) is necessary to capture the full range of technical and institutional considerations of such a project.

Discrepancies between time-frames operating at, institutional, organisational and technical levels are an additional source of complexity. At CERN, the time-span from the inception of an experiment as a technical proposal to the delivery of data for analysis and argumentation is measured in decades and commonly exceeds that of an individual's career.

Organisational narratives play a key role in sustaining the collectivist ethos which underpins the collaboration and which substitutes for formal managerial structures (see Knorr-Cetina 1999). However, this collectivism is itself an obstacle to effective performance in certain contexts. For example, technology transfer represents significant additional value from the core research at CERN. The ethos of transparency conflicts with the commercial confidentiality essential to the marketability of intellectual property.

The founding principles of CERN excluded military and commercial (e.g. power-generation) related research and restricted the remit of the centre to fundamental physics research. Nevertheless, technology transfer is an important component of the argument for funding for research which in investigating fundamental question of the nature of the universe, has little prospect of short-term economic benefit. The technologies developed for the infrastructure and instrumentation at CERN represent significant innovations in a number of fields including detection and monitoring which have been transferred to medical and safety applications. The data processing requirements of the experiments has led to strong support from CERN for the development of grid computing. The most significant transfer of technology so far, however, has been the World Wide Web protocols developed to facilitate communication between the distributed members of the large experimental collaborations. In 2009, CERN staged a high-profile celebration of the 20th anniversary of the internal memorandum, written by Sir Tim Berners-Lee, which proposed this initiative.[1]

CERN dates from an international council established in 1952 by eleven European states. The organisation was inaugurated in 1954. Following on from the creation of the European Iron and Steel community, the precursor of the EEC and EU, it represented a significant international collaboration in the context of a recovering postwar Europe. As a counter to the Americanisation of nuclear physics via the Manhattan project, it sought both peaceful research and the means to retain scientific capability within Europe. The established criterion of scientific success is the award of the Nobel Prize. It was not until 1984 that the Nobel Prize in physics was awarded to CERN scientists. Carlo Rubbia and Simon van der Meer were awarded their prize for the developments that led to the discoveries of the W and Z bosons. Taubes (1986) gives a detailed account of the pathway to this breakthrough and Knorr-Cetina (1999) provides a comparison between knowledge creation in particle physics and molecular biology, drawing on subsequent work at CERN.

The 1992 Nobel Prize in physics was awarded to a CERN researcher, Georges Charpak, for work on particle detectors and the collaborative experiment described in this chapter contributed to the award of the 2013 the Nobel Prize in physics jointly to François Englert and Peter Higgs

> for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider. (https://home.cern/topics/higgs-boson)

The rules of the Nobel Prize committee were drawn up at the end of the nineteenth century and modern science is conducted in a far more complex environment. The scale and nature of collaboration at CERN makes the award of a prize which is limited to a maximum of three recipients highly problematic. CERN practice is to credit all members of an experimental collaboration as authors on all CERN publications of findings. With teams numbering thousands, however, this practice is becoming increasingly unwieldy and has become the subject of discussion and re-evaluation (Birnholz 2008).

Since its inception. the membership of CERN has expanded from 12 to 22 core members. Three states plus the EU, UNESCO and the JINR now have observer status and a further 58 non-member states have entered into co-operation agreements. Decisions are made though votes by national representatives at Council level and by the partner institutions from these countries at project level, one institution one vote. ATLAS, one of four major experiments located in 100 m deep caverns along the 27 km underground circuit of the Large Hadron Collider (LHC),[2] currently involves around 3000 physicists, only 100 of whom are employed directly by CERN. A quarter of this total are research students who are crucial to the running of the experiment. Key decisions on the experiment are made through the votes of the 182 member institutions from 38 countries following open discussions at face-to-face and online meetings. This practice is common to all of the experiments.

The MODE team included the Resource Coordinator for the ATLAS experiment and met regularly at CERN. In July 2009, members attended the ATLAS Week. This is an annual programme of on-site meetings and technical seminars, streamed via the internet to the majority of members who could not be physically present. The plenary discussions focused on the re-commissioning of the LHC after the completion of repairs and modifications following the September 2008 accident which damaged four km of the collider circuit and led to the comprehensive re-engineering of protection systems to prevent future damage. This had taken place just ten days after the high-profile commissioning event and produced widespread adverse media coverage.

Following presentations on the status of both the collider and the ATLAS detector, the main issue of discussion was the energy level at which the machine should be operated versus the timing of "first collisions". A prominent factor in this debate was the requirement for live data to allow a significant number of doctoral students to complete their degrees. These meetings also marked the handover from the previous Spokesperson for the experiment, Peter Jenni, to his successor, Fabiola Gianotti, chosen by a ballot of members. The internal role is one of convener and the external that of a public face for the experiment. These and other posts are held for a limited period by active scientists so that there is effectively no managerial class at CERN. The tenor of the meeting typified the collaborative work practices of the ATLAS collaboration and emphasised the importance of the support for and socialisation of future generations of physicists.

Leveraging Cultures

There is a cultural dimension to the established practice and expectations within organisations, which will impart its own dynamic to the process of change and development. Selznick (1957) invoked notions of culture in his explanation of the emergence of institutionalised organisations. Some writers refer to culture in terms of national differences in social and economic organisation. Latin and Anglo-Saxon and traditional cultures are reflected in distinctive organisational types identified in studies examined by Lammers and Hickson (1979). Turner (1971) describes industrial sub-cultures which can be identified across individual organisations, and are distinctive from the larger society. Eldridge and Crombie (1974) define organisational culture as characteristic for individual organisations, while Strauss et al. (1973) describe a range of cultures within a single organisation. As a wide-reaching international organization, CERN must bridge multiple national cultures but is itself instrumental in the development and maintenance of a global culture of high energy physics.

Thompson (1967) utilised the concept of an organisational constituency capable of entering into coalition with other constituencies in order to promote its interest. Such a conception allows the formal elements of an organisation, such as the separate experiment groups, to be related to the informal communication and negotiation which often modifies, or in extreme cases frustrates, the intention of management. Thompson's approach also allows consideration of intra-organisational variations in culture, arising from these differences of interest and experience. However, the underlying consensus around the investigation of the standard model of physics acts as a constraining framework at CERN. One major cultural division is between the theoretical physicists whose models run ahead of the capability of the experimental physicists to test them by decades, another is between the core of support staff responsible for the maintenance and care of the Meyrin site and the ever-changing population of researchers.

The main CERN site at Meyrin outside Geneva now spans the Franco-Swiss border, though there is little evidence of this within the site, and since 2008, Switzerland as part of the Schengen area has opened fully its land borders. The site itself reveals the history and origins of the organisation and its established practices. Many of the older buildings reveal their origin in a straightened period of post-war reconstruction. Only the most public spaces reveal a moderate level of aesthetic sensibility and only the most recent construction, including Building 40, the main centre for the LHC experiments, represents state of the art architectural practice. In the buildings used by the MODE group for meetings, the wear and tear of 30 years was evident, with worn (but safe) flooring, and only the IT infrastructure reflecting current standards. Expenditure was clearly focused on the scientific infrastructure.

The majority of participants in CERN experiments are based at their own institutions and visit the Meyrin site for days or months at a time. The on-site hostels are modern but functional with rules against noise at any time of day or night. The atmosphere is positively monastic.

The most prominent (and sinister looking) building on the site is the Globe. While it resembles a fast breeder reactor building, it is in fact a public exhibition and meeting space constructed entirely of timber and re-located from the Expo.02 site at Neuchatel. The Globe is used for high-profile presentations of progress and results and for outreach to the general public, from secondary school onwards. CERN is focused on the science and the dissemination of experimental data to its members and the wider scientific community and this is where resources are concentrated. Successive forms of social media have been harnessed, from websites to blogs and Twitter feeds, both to report findings as they emerge, and to host and publicise events to promote science to the wider public and to youth.

Maintaining Commitment Though Narratives

The purpose of the successive experiments at CERN is to get progressively closer to conditions at the moment of the creation of the universe. Close (2007) provides a (relatively) accessible account of the development of particle physics up to the current concerns with the Higgs boson. To achieve its goal, however, the organisation has to maintain support from national governments, the member and partner institutions from within those countries, the wider scientific community, individual scientists and members of the general public.

The cancellation of the US super-collider project (SSC) in 1993 made CERN "the only game in town" and greatly aided its aim to become the world centre for particle physics. Since no other venue could replicate the experimental conditions achieved at CERN, however, complementary experiments, ATLAS and CMS, had to be built, using alternative designs to investigate the same phenomena. This ensured that results could not be influenced by data artefacts originating in the apparatus.

The SSC cancellation also highlighted the vulnerability of pure research to political priorities and pressures. SSC was abandoned following lobbying from competing scientists including solid state physicists arguing that a greater and more immediate economic impact would result from research into the physics of electronics and microprocessors. As a consequence, a complex of internal and external narrative presentations has developed around the activities and priorities within CERN.

The role of story and narrative in organisations has been discussed extensively and has become a key component of knowledge management (Denning 2000; Gabriel 2000; Seely Brown et al. 2005). To maintain cohesion and commitment among participants, and to sustain support from member countries, CERN deploys a narrative of its 50-year history as a pioneering transnational institution emphasising its historical continuity with earlier revolutionary developments in physics alongside a parallel meta-narrative which runs 13.7 billion years into the past to the Big Bang although the limitations on reaching this objective are less well understood by the public.

The time-span from the inception of an experiment as a technical proposal to the delivery of data for analysis and argumentation is measured in decades and commonly exceeds that of an individual's career. Within the experiments, the management baton must pass between incumbents who are committed to the role of "coordinator" for overlapping three-year terms. The Higgs mechanism was theorised in 1964, the LEP (Large Electron-Positron collider), precursor to the LHC (Large Hadron Collider), was proposed in 1977 and construction of the 27 km tunnel for it was approved in 1981. The concept of hadron collision was mooted in 1984, but the LHC commissioning date slipped from 2002 to 2008. The first low energy collisions were achieved on December 6 and, experimental data was obtained from collisions at 3.5TeV during 2010. This was the first new data since the decommissioning of the LEP installation in 2001 in order to reuse the tunnel for the LHC. The identification of the Higgs boson was announced on July 4, 2012, 48 years after its prediction by Peter Higgs.

Once the novel equipment necessary to the detection of new particles has been designed, constructed and commissioned, the management of CERN experiments involves decisions on upgrades, negotiation over priorities and access to the beams delivered by the collider. The extended project time-frames require the continuing motivation and recruitment of participants and there is evidence that the complex career trajectories of individual participants are sustained by organisational narratives. For example, the manager responsible for the day-to-day running of the ATLAS detector, a physicist who has spent the previous decade on a major construction project felt "closer to the physics" running the detector because useable data was about to be produced.

More recently CERN's narratives have been extended to address the general public, giving the Spokesperson for each experiment a higher public profile. However, the publicity surrounding the initial operation of the LHC in autumn 2008 led to court cases seeking to shut down the experiments lest they create a black hole capable of consuming the entire planet (Gray 2008). The failure of the collider beam on September 19, 2008 after ten days of operation gave the widespread external impression of a major problem, very different from the perception within the organisation, signalling a new layer of complexity in the environment of CERN. It became clear that the combination of popular speculation and the policy of outreach through popular media had led to some problematic effects. While the profile of particle physics has been raised, the expectations of the general public are some distance from the reality of the work in hand. Collaboration with production of the film based on Dan Brown's "Angels and Demons" has allowed a companion website to draw interested individuals in to the reality of anti-matter production and way from Brown's fictional anti-matter "bomb".[3] However, a BBC radio drama broadcast on the eve of the initial LHC operation in September 2008 implied that results would be instant. Instead, the initial operation of the new detectors will be concerned with replicating the results obtained with the previous generation of technology, to demonstrate their compatibility and accuracy, before moving on to the search for new phenomena. Such conflicting expectation of the time-frames of technical and scientific progress is potentially damaging to a project (Little 1987).

Speculation on the nature of the delays in decommissioning the LHC reached a nadir with the argument aired in the British *Sunday Times* newspaper on October 18, 2009 (Leake 2009). This was based on speculation that the LHC was sabotaging itself from the future on the grounds that the Higgs boson is "abhorrent to nature". In the 2012 joint announcement from the ATLAS and CMS experiments at CERN's LHC stating that each had observed a new particle in the mass region around 126 GeV consistent with the Higgs boson predicted by the Standard Model of physics, ending such speculation. Work continues at higher energy levels in search of particles predicted by variants of the theory.

Managing the Project Environment

As an international organisation engaged in cutting edge research and the development of new technologies to support this CERN must manage both its *task* environment of organisations and its *institutional* environment as set out by Scott (2003). The two principal concerns of task environment management are the protection of the central work processes, mainly through "buffering" strategies and the management of the relationship with the task environment as a social and political system, dealt with through "bridging" strategies. The task oriented view sees the environment as a source of inputs, markets for outputs, competition and regulation.

However, the demands of institutional environments require a different mechanism for transactions from those demanded by task environments. The institutional orientation seeks to build bridges into the environment by conforming to expected categories of staff and structure. Scott argues that organisations *exchange* elements with their technical environments, but are *constituted by* elements from their institutional environments. These elements are not transformed by the organisation as are technical elements and inputs. Instead they are made visible to outsiders with their distinctive features remaining intact. The purpose is to legitimise the organisation and to reassure clients. Bridging, not buffering, is the key strategy with regard to the institutional environment.

CERN demonstrates the importance of the management of the institutional environment, even in a highly focussed technical undertaking. Organisational culture can be seen to be as closely associated with institutional choice as with technical choice and task environment.

Scott describes the mechanisms for bridging into the institutional environment in terms of conformity:

- *Categorical* conformity in which institutional rules provide guidelines which can pattern structures.
- *Structural* conformity in which environmental actors may impose very specific structural requirements upon organisations as a condition for acceptance and support.
- *Procedural* conformity resulting from the pressures from institutional environments to carry out procedures in a particular way.
- *Personnel* conformity arising within the complex, differentiated organisations likely to contain large numbers of educated, certified workers who assume specialised roles within them.

Within CERN, procedural and personnel conformity can be related to the strict implementation of accepted scientific method and the academic qualifications of the research personnel. Categorical and structural conformity relate to the foundational framework of the organisation.

Influences from different levels encompassing institutional and task environments co-exist in the decision-space of project managers and designers, in the form of conflicting time-frames imposed upon their decision-making (Little 1987). Equally significantly, interaction with the two different types of environment also makes very different demands on the skills and attention of actors.

Parsons (1960) identifies three level of organisational structure: the bottom level is the technical system, above this is the managerial system which mediates between the organisation and the task environment. At the top is the institutional system which relates the organisation to its function in the larger society. Parsons sees a clear analytical distinction between technical, managerial and institutional levels, arguing that there is a qualitative break at the interfaces of the three. The systems views of organisations described by Scott (2003) can easily be related to these levels. However, it can be argued that although task and institutional environments require the different strategies enumerated by Scott, these overlap in some cases, and the two areas are less easily separated than is implied by Parsons.

At CERN, the overall organisational mission can be seen to take precedence over the career trajectory of individuals. At the same time, the circulation of high-energy physicists from CERN itself is an institutional device for the creation and maintenance of the global high-energy physics community. CERN's organisational "flatness" creates a common engagement across a range of roles and levels.

According to Thompson (1967), the technical core strives for technical rationality, even though it exists in an open, natural system requiring environmental transactions. Managers and departments in an organisation exist to buffer the technical core and work at the managerial level requires an appreciation of conflict and motivation given by a natural systems approach. This involves an appreciation of the variety of human resources as an essential ingredient. The institutional level of the organisation must deal with external relationships with other organisations in the environment, so it must embrace an open systems view. In this respect, CERN is an exemplar of such an open approach.

Learning from CERN

There is a conflict between CERN's collectivist and open ethos and the requirements for the successful formation and management of intellectual property. However, in addition to the identification and formal protection of intellectual property created by the members of CERN, value is created through the collaboration between CERN members and technology providers in the form of intellectual capital and increased capacity generated through the development of the infrastructure supporting ATLAS and other experiments.

Other founding principles and practices have proved problematic in some areas. The tendering requirements of CERN require acceptance of the lowest bidder. Some contractors have achieved a lengthy relationship with CERN, but this requirement results in the production of highly detailed specifications which can in turn be problematic. It discourages larger integrated engineering companies from tendering. They judge that they will achieve little learning from following rigidly a pre-prepared specification. This is in marked contrast to relationships between the European Space Agency and aerospace contractors, where longer term and more integrated contributions are negotiated (Harvey 2003). At CERN, small and medium high technology companies are left to fill the gap, these in turn may win one bid, only to bid too high on a repeat tenders as a result of the lessons learn in their first contract. This leads to limited relationships with some tenderers. In the worst case, the contractor for the super-conducting magnets for the ATLAS detector defaulted on their contract following a change in ownership of the company. The new owners quickly concluded that the contract was costing them money and opportunities and simply delivered the incomplete components to CERN who were then forced to complete the work as their own contractor.

The interaction between internally and externally directed narratives will be an important aspect of understanding the dynamics of technology transfer from ATLAS and CERN, both through the spinout by members of the collaborations and through the recruitment of external stakeholders.

The power and efficacy of CERN's efforts to communicate its mission were demonstrated in May 2009 when an announcement was made by the Austrian minister of science that his country would terminate its membership of CERN as this was consuming too high a proportion of the national budget for international research. Within ten days, and following a global round of protests from the scientific community, the decision was reversed.[4]

The short-lived "withdrawal" of Austria from CERN membership in May 2009 demonstrates the power of the interwoven narratives for CERN. However, the very high profile of the LHC start-up produced expectations of "instant" results and resultant negative publicity. Worse, the policy of outreach through entertainment media can be problematic. *The Sunday Times* newspaper's proposal of divine intervention from the future contrasts with the discussions at the ATLAS Week which revealed a far more prosaic narrative involving calculated risks around a cost-related simplification in the fabrication of welded stainless steel joints intended to function below 4 degrees Kelvin.

While CERN and its component experimental groups benefit from the support of a strong and focused scientific community in pursuit of a clearly agreed objective, the complexity of cross-boundary relationships and the need for continual monitoring and management of that support hold lessons for many other contexts in which sustained commitment to complex projects throughout their lifecycle is essential to their success.

Notes

1. Tim Berners-Lee celebrating 20 years of WWW at http://info.cern.ch/www20/.
2. The LHC is a collider in which two opposing beams of electrons (hadrons) are brought together within detectors in order to produce collisions which create short lived sub-atomic particles. Four major experimental detectors are located around the 27 km circumference of the LHC.

3. See http://angelsanddemons.cern.ch/.
4. Austria to quit CERN particle physics laboratory

   Fri, May 8 2009, 7:11 AM EDTVIENNA (Reuters) – Austria plans to pull out of the international particle physics laboratory CERN because its share of the high cost is eating up too much of the country's budget for international research.

   See the response to this statement at
   http://user.web.cern.ch/user/news/2009/090508.html.
   http://www.math.columbia.edu/~woit/wordpress/?p=1978.
   http://www.teilchen.at:8080/teilchen/laufend/OneArticle?updatelogo=1;id=208;e=0.

   Austria to stay in particle physics lab after all.

   Mon, May 18 2009, 11:30 AM EDTVIENNA (Reuters) – Austria has changed its mind and will now not pull out of the international particle physics laboratory CERN over the cost, Chancellor Werner Faymann said in a statement on Monday, overruling his science minister.

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