Have you ever heard about the Higgs Boson Blues?  
I'm going down to Geneva, baby  
Gonna teach it to you  
Who cares?  
Who cares what the future brings?

Nick Cave

**Science’s global icon: CERN**

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**High modernity in Geneva**

It is not an architectural marvel by any stretch of the imagination. Built largely in the fifties through the seventies, the campus of the European Organization for Nuclear Research, known the world over as CERN, does not immediately light a spark in those who visit it. That is, until one gets in deeper and deeper and begins to see and feel the story of the imaginative, disciplined and relentless collaborative endeavour that continues to be made there. The visitor centre suitably impresses with the kind of dynamic visual displays of space, matter, movement and energy that one would expect there.

But it is not until one is taken underground deep below the Geneva countryside and into the organisation’s current crown jewel, the Large Hadron Collider, that the lure of the endeavour becomes irresistible. It is like that moment about two thirds into any James Bond movie, when Bond is being led – often at gunpoint - into the villain’s subterranean headquarters and encounters a hidden world of shafts, staircases, miles and miles of electrical cables, gigantic machines, control panels, busy technicians in overalls and focused scientists donning hardhats.

It is a captivating spectacle. Indeed, as one observer put it, ‘[t]he idea of accelerating sub-atomic particles to almost the speed of light, and smashing them into each other deep under the French and Swiss countryside, has a Bond-villain grandeur that has manifestly caught the public imagination’ (O’Neill 2008). It is in these bowels of the Large Hardon Collider that one sees CERN epitomised as the materialisation of high modernity: high science being put to work so the knowledge thus generated allows man to continue to comprehend and conquer the planet and the universe.

Ironically, CERN has ended up with a name that does not reflect what it does. No nuclear fusion or fission is attempted there. It is not in the business of generating new forms of consumable energy, let alone building weapons of mass destruction. It is, however, the world’s most formidable and enduring centre for particle physics. Its mission is targeted to nothing less than uncovering what the universe is made of and how it works, by providing particle accelerator facilities that enable research at the forefront of human knowledge, performing world-class research in fundamental physics, and uniting people from all over the world to push the frontiers of science and technology, for the benefit of all. It is widely recognised as one of the most successful and certainly the noblest, loftiest and in effect truly global research institutions in the history of mankind.

How good is CERN, really? A quick benchmark with the American space organization NASA, whose annual budget is well over 15 times the size of CERN’s is helpful. NASA held the world spellbound for a decade or so during its golden era of the Apollo program, but soon after found itself fighting for budget to keep its fledgling Space Shuttle program afloat, then faced disasters of its own making which produced a reputational setback that it has never fully recovered from. CERN on other hand has managed to effectively resolve the existential political conundrum of any large- scale public endeavour (see Schulman, 1980). For more than six decades it has managed to straddle the inevitable gap between the requisite multi-year up-front investment of money, infrastructure and human effort, and the eventual accomplishments that make everyone feel it has all been worthwhile – in its case scientific breakthroughs in the world of particle physics.

With its very existence rooted in Cold War rivalry (the ‘space race’), NASA was and remains a fundamentally American enterprise that forever faces a delicate balancing act between its scientific and military drivers and constituencies. CERN in contrast is a European organisation with permeable boundaries that has developed into the undisputable hub of a global network of scientists without peer. Where NASA is closed to outsiders, CERN’s ethos is one of transparency and knowledge-sharing. NASA’s efforts have spawned an impressive array of spinoff technologies that have made it into tech company product lines around the world, yet CERN has gifted its key spinoff technology - the World Wide Web - to the world for all to use (the deed by which it does so is on public display, yet oddly tucked away in an obscure pocket of its visitors centre, Gillies and Cailliau 2000).

CERN is without a doubt to be considered an institution as defined in this volume. And yet it is an unlikely venture to have achieved this lofty status. It pursues a mission that can only be described as elusive. It has no set path to achieve its main goals, in fact the whole point of the exercise is to discover such pathways – which requires incessant, vast, costly and failure-prone experimentation. It is a multinational endeavour that requires theoretical physicists – who by nature are competitive animals that are seldom short on professional self-esteem – to collaborate on an even keel with engineers and, even more challenging, with science administrators. As an intergovernmental organisation it has to navigate geo-political complexities, diplomatic challenges and misalignment between the organization’s needs and the political and budgetary realities of its member state funders.

Overcoming such centrifugal forces, CERN has evolved into a paragon of cooperation, driven by a sense of interdependence, moved along by entrenched norms of mutual respect, trust, empathy and consensus, and governed by far-sighted leaders. Enabled by these propitious conditions it has delivered the goods: scientific advances, technological breakthroughs, spinoff technologies, a thriving global scientific community, contented member states, compliant media, and captivated publics.

This chapter tells the story of how CERN got to where it is today. We will not delve into the substance of the science it pursues but instead explore what constellation of circumstances, choices and practices has allowed it to become and remain a global science institution. We conclude by examining CERN’s future in view of the growing tension between the size and duration of requisite investments and the uncertainty about if and when it will deliver its next piece of magic.

**Working on a dream: Building CERN**

CERN was founded in September 1954. Its roots lie in the coming together of scientific aspirations grounded in the state of the art of mid-20th century physics and the cooperative aspirations of the European Movement that rose from the ashes of the Second World War. Acting against the gloomy backdrop of the escalating Cold War which was once again dividing the continent, the Movement sought to unite Europeans, and its founders saw that science had a crucial role to play in doing so. At their instigation, leading French quantum physicist Louis de Broglie had an address delivered in his name to the first European Conference in Lausanne in December 1949. He told the delegates that

[A]t a time when we are talking about the peoples of Europe, the question now arises of developing [a] new international unit, a laboratory or institution where it would be possible to work scientifically in a manner outside and above the framework of the different participating nations. As a result of the cooperation of a large number of European States, this body could be endowed with more resources than those available to national laboratories and could subsequently undertake task which by virtue of their size and costs remain prohibitive to these’ (quoted in Gillies 2018: 12).

Emphasizing the urgency of resource-pooling proved a powerful rhetorical tool for the advocates of a European advanced physics laboratory. Robinson (2019: 43) notes that eventually:

Consensus to form CERN was reached through the timely and powerful combination of … European-minded politicians and single-minded European particle physicists. The politicians were looking for practical ways of reorienting Europe and the physicists were looking for their facility.

It was a case of scientific idealism meeting scientific realism. Unmentioned in his speech, but the Manhattan Project and its Cold War successors were the palpable counterpoints from which De Broglie and the core group of his academic colleagues from around Europe wanted to distinguish the new European scientific collaboration. It was to be a purely scientific venture, not military R&D. It was to be genuinely European and thus not dependent upon collaboration with the United States (where influential fellow physicists such as Isidor Rabi helpfully lobbied for throwing a bone to the European scientists to which the U.S. as the now dominant global science player owed so much). And it was rooted in the recognition that the cash-strapped impoverished nations of Europe could only hope to do something worthwhile in this high-investment area of scientific research if they were going to pool their resources.

It took another five years of science advocacy and maneuvering the geopolitics of knowledge – particularly in a sensitive field such as ‘nuclear’ research - before there were enough signatures on the Convention to allow the new institute to be founded. The early decades that followed were not easy. CERN was a ‘shell organization’, with a name, a site, a budget, a formal governance structure, a dedicated group of foundational leaders and a rump staff, but it was many years away from being in a position to deliver on its potential. Pestre’s (1988) study of the early years of CERN’s institutional development shows how during its first decade and beyond, the organization was struggling to find its feet. The scientists and non-scientists (science administrators from the member states) that co-governed it had to learn to get along. Trawling through the paper trail of memos, minutes and reports from the early decade, Pestre (1988) notes that despite the overall atmosphere of goodwill and mutual respect, ‘various forms of ‘incomprehension or of denigration’ lurked in the background, ready to surface when there were tensions about budgets, priorities and allocation of contracts for the construction of facilities and equipment. He observes:

Th[e] esteem which the scientist have [for the non-scientists on the CERN Council and in key committees, see further below] is never blind, is never as total as it appears to be between the members of the physics clan themselves. It is limited precisely because the ‘politicians’ are not, after all, high-energy physicists… [T]his is sometimes expressed in … a measure of condescension towards the non-scientists – and notably he ‘politicians’, those who stop them from doing their job properly, who always introduce unnecessary complications, who never grant even the budgetary minimum without looking sur, without bickering – and who want to control.

He notes that the scientists regularly resorted to ‘offensive selling’ of their projects and their budgetary claims:

Since CERN always had to act *quickly* – CERN was to be the first in the world – and since CERN had to have the *best* men and the *best* equipment, it was always easy and tempting to present the ‘politicians’ with a *fait accompli*, … [making] abundant use of the argument that things were ‘urgent’ and top priority.

The threat of losing out to the Americans with their massive science community and post-World War 2 opulence and momentum, was regularly invoked to obtain decisions. It was hard for the civil servants serving on the Council and in particular the Finance Committee, who had to straddle the mandates provided to them by their national government superiors and the desire to be seen to be a constructive partner in the great cooperative venture envisaged by the scientists. Likewise, not all European physicists were self-evident internationalists. While subscribing to the general idea of a joint facility, they also kept in mind and promoted the interests of their own research programs, their own teams, their own labs back home.

This guarded posturing was prevalent in the early years when CERN had not yet proven its worth and had not yet delivered on its claim to be the apex of the European high-energy accelerator pyramid. And there were the British, who were fundamentally ambiguous about what really was in it for them, given that they had made significant advances on their own during and following World War 2. As a result of these underlying drivers, the emerging balance of power between the (supranational and scientifically driven) Director-General and the elite scientists whispering in the DG’s ear and the (intergovernmental and policy-driven) Council was carefully monitored and much discussed by all the principal actors. The CERN-based actors sought, and by and large managed, to keep national bureaucracies at arms length and gain a measure of autonomy in setting directions for the institution. Pestre (1988) characterizes in terms of ‘the jealously guarded autonomy of the Council’ and the machinations of a ‘pro-CERN lobby at its heart’ designed to ‘neutralize’ any initiative from any of the domestic authorities that aimed to bypass the Council.

At the same time there were protracted and heated discussions about CERN’s internal governance. The early Directors-General, particularly Cornelis Bakker (1955-1960) and Victor Weisskopf (1961-1965) faced the challenge of herding cats, with powerful divisional directors such as the head of the synchrotron division (and future director) John Adams looking to build their baronies and fighting their corners for their autonomy. There were constant proposals and debates about internal organization, which were essentially about where the power of policy initiative and investment decision making would come to lie in the organization, and how accountability for policies and expenditures was to be organized.

It was not until the early to mid-1960s, when CERN’s first major common pool resource, the proton synchrotron, then the world’s highest energy particle accelerator, became available and was being used by many high-profile experimentalists that perceptions started to change. It served to cement commitment to CERN among key players beyond its close-knit founding community – first on the Continent and some years later in Great Britain. It proved to be a watershed, laying the foundation for what became the formidable, politically impenetrable fortress of high-minded scientific collaboration that CERN has since become. Pestre (1988) concludes:

Not constituted from above, by a juxtaposition of delegates nominated administratively by the states…, the central core of the Council built itself up in the course of a battle which lasted several years. From these beginnings an unusual degree was born, along with a determination to succeed, which bore fruit thanks to the favourable context in which it emerged, the context of a Europe looking for ways to unite, and fascinated by all that was nuclear… Once the leaders of European nuclear physics realized, early in the 1960s, that there was no alternative to building a central installation for the ever-heavier equipment their science demanded, and once they accepted that this installation would be CERN, they no longer submitted their national authorities to conflicting pressures… Speaking with a single voice to the exterior, they ensured the continued good health and the success of the organization and left the member states watching developments from afar.

Fast forward fifty years and a picture of a settled institution and a cohesive community emerges. It is cemented by a series of landmark achievements that demonstrate the value-add of the collaborating across disciplinary and national boundaries, but also by decades of identity work to ensure that the constant flow of new-blood eager scientists come to regard CERN as not just a tool to be used but as a place that confers identity and respect on them. (Robinson (2019: 48), who studied its governance up close, observes that

CERN has an unchallenged standing of legitimacy and enjoys a shared set of normative and principled beliefs, shared causal beliefs, shared notions of validity and a common policy enterprise throughout its epistemic community.

The OECD (2014: 64) notes how this then feeds into a self-reinforcing cycle of high legitimacy and high performance by virtue of the ability to continuously attract top staff and make them work together to achieve both scientific advances and tangible, brand-enhancing outcomes:

The combination of … high scientific and political standing, ambitious forward-looking research programme, independence as a supra-national organisation [and] cash-based finances results in an ability to recruit and retain very competent staff. As an established international organisation… CERN is able to offer attractive employment conditions (salaries, pensions, etc.). The staff form an interacting community characterised by a vigorous exchange of ideas. At times, ideas emerge that can be transformed into innovative new technologies, even commercial products.

**Making CERN work**

One example of CERN’s record of high performance lies outside the realm of the physics itself and concerns one of its crucial supporting processes: sifting through many billions of particle collisions and detecting promising patterns among them. The CERN Community, both at its Geneva campus and its many tentacles in research institutes around the world, has invented and built the capacity to do so. Today CERN’s Data Centre is widely regarded as pioneering the future of computing, with very large quantities of data - about1% of daily global data traffic - being continuously analysed through seamless connectivity to 170 other data centres in 36 countries (Cogen, 2015).

This analytical capability has enabled CERN’s scientists to achieve its greatest deliverable so far: the 2012 detection of the Higgs Boson particle - the jewel in the crown of the Standard Model of particle physics, which itself has become ‘the most accurate scientific theory known to human beings’ (Starkman 2018). CERN got to get so good, we argue, by evolving a particular mode of harnessing human ingenuity: self-organization backed up by robust governance. Let’s consider how this operated in practice.

*How CERN is run*

The CERN Council is the supreme authority of the organization. **Appointed by the Council for a single 5-year term, the Director-General leads the CERN Laboratory on a day-to-day basis**, supported by a senior management team called the Directorate. Below them operate a series of departments. All major policy and funding decisions require Council approval. It controls CERN’s activities in both scientific and technical as well administrative matters. It **approves programmes of activity, adopts the budgets and reviews expenditure**. Each of the 23 member states has two delegates on the Council: one science administrator and one leading scientist. **Each Member State has a single vote.**

**Most Council decisions require a simple majority,** but some, such as the appointment and dismissal of a new Director-General, require two-thirds majorities. In practice the Council reaches decisions by consensus and strives for genuine unanimity. The Council is supported by two pivotal advisory committees: the Scientific Policy Committee and the Finance Committee. The Science committee is composed of top scientists regardless of nationality who are elected into membership by their peers on the committee. The Finance Committee comprises of technical experts from the member states and mainly focuses on matters related to financial contributions.

That all seems straightforward and in the mould of any other international bureaucracy. But, as we have already seen in our account of CERN’s early years, the big difference is that CERN is a working science laboratory embedded within an intergovernmental treaty framework. It cannot work effectively if it is run as if it were any other public agency. The science that is at the very heart of its mission would lose out. And yet its sheer size, complexity and international membership structure make it impossible for it to be run in the manner of the average university lab - as the personal fiefdom of a single chief scientist. Another reality that CERN deals with is money. Vast amounts of it are required to build and operate its infrastructure, pay its staff of thousands, and run its complex multi-year experiments (its annual budgets run well upward of 1 billion Swiss Francs;

The institutional logic of scientific endeavour somehow must in other words be reconciled with that of an intergovernmental organization. A research lab such as CERN needs the allure of great scientific minds being enabled to follow their joint instincts through trial and error and subject to rigorous peer scrutiny. Ànd it needs the continued support of its institutional funders, the member states, each of which brings a distinctive set of policy settings and administrative requirements to the table. How does one align these two logics of organizing in a way that harnesses the science organization’s ability to deliver on its mission? To understand how this is accomplished at CERN, we need to look at how the edifice of its governance operates in practice.

*A case in point: the Large Hadron Collider project*

Gillies’ (2018) assessment of CERN’s crowning achievement reflects the contemporary consensus within and far beyond its global community of contributors and users:

CERN’s Large Hadron Collider is a triumph of human ingenuity. It has pushed technology to new and hitherto unimaginable limits. Far from struggling more than one particle collision per bunch crossing – a scenario feared when the LHC was first proposed, the experiments are dealing with dozens. The LHC produces close to a billion collision in each detector per second, and processes have been perfected to sort out those that might contain interesting physics.

Key to the success of the LHC accelerator and detectors were and are the organization and quality reference provided by CERN. The high-energy physics community ‘self-organized’ in a remarkable way from the early days of the LHC project. In the years leading up to the decision to go for the LHC, the CERN community faced a stark choice: the next step for high-energy physics after the Large Electron Positron collider (that was in operation between 1989-2000) would ideally be a linear electron–positron collider, but nobody knew how build it. The alternative was to build a hadron collider, but nobody could build the requisite detector for catching the data it would generate. From these two ‘impossible’ option, the community chose the second. It got the go ahead from Council and after years of ground-breaking R&D-work, it succeeded.

The LHC Committee (LHCC), a peer-review committee consisting of independent scientists, was set up in 1992 and continues to shape the experimental LHC program and provide stewardship of its quality and legitimacy. It advises on directions, monitors progress of the experiments, and assesses the credibility of their schedules. It reports to the Directorate and Council. Although the LHCC reports ‘up’, it also interacts closely with the four multinational experimental collaborations that have formed around the LHC. In general, its advice is accepted by the collaborations, precisely because in case of disagreements it offers an arena for open and robust debate. Trust in the integrity of its processes thus mitigates conflicts that could otherwise disrupt and delay the joint efforts (Engelen 2012).

The large collaborations, consisting of more than a thousand members, coming from dozens of different institutes, supported by dozens of funding agencies, organize themselves but adhere to a generic structure agreed with CERN. It consisted of a Spokesperson, a Technical Coordinator, a Resources Coordinator and a Collaboration Board at which each collaborating group was represented. The Spokesperson is elected by the Collaboration Board on the basis of qualities of scientific leadership and managerial competence. The collaborations were underpinned memoranda of understanding (MoUs). Although not legally binding, these documents were signed between CERN and the collaborating institutes and were essential in agreeing on the contributions and long-term commitments from each of the institutes, including CERN, and then for monitoring that the various partners delivered on these commitments.

The MOUs formed the bedrock upon which the worldwide LHC Computing Grid (wLCG) was founded. It was not until relatively late after LHC approval that it was realized that the computing effort required for processing the LHC data would need a highly innovative approach and would also require very substantial investment, both at CERN and worldwide. The MoUs, drafted at CERN’s legal department and signed by delegates from the participating institutions with appropriate mandates, were particularly important as a way of communicating with the national funding agencies providing the all-important financial footing of the collaborating partner institutes and institutions.

Resources review boards (RRBs) were set up for each experiment and continue to shadow them throughout their lifetime. Their membership consists of one representative from each funding agency with the experiment's management in attendance. They are chaired by CERN’s Director of Research and provide the interface between the experiments, the national funding agencies and CERN. During the long years of construction of the experiments, the RRBs were particularly crucial in securing adequate and continuing funding.

The RRBs monitored progress in the light of available (or pledged) resources. For the large general-purpose experiments in the LHC, ATLAS and CMS, a ceiling of 475 million swiss francs for each was set by the CERN Directorate as the maximum investment costs. Capping investment in this fashion proved to be a great incentive for the experimental collaborations to be as resourceful and realistic as possible. The term ‘descoping’ was invented to denote the process of giving up some (redundant) functionality in order to save costs. In case of unavoidable additional expenditure, the RRBs provided the platforms for assessment and for reaching agreements on additional pledges from the funding agencies and from CERN and for postponing certain investments that were less urgent than others.

This process was – not surprisingly - not always devoid of conflict. For example, the considerable continuing management and operating costs for the experiments were not readily accepted or even understood by some of the funding agencies. In order to make the cases as convincing as possible, a Scrutiny Group reporting to the RRBs was formed. The experiments provided detailed information on the costs incurred (retrospectively) and made estimates for the next year. After scrutiny, these costs were then shared between the participants. The discussions were often emotional. ‘Users’ are not used to paying for things at CERN, and yet CERN could not and would not provide financial carriage of the entire experimental programme in addition to the investments (and running costs) for its accelerator complex. The RRBs provided crucial platforms buffeted by clear rules of engagement for working through these tensions and laying the foundations for cost-sharing agreements between funding agencies (Engelen 2012).

**The anatomy of ingenious perseverance**

What has enabled CERN to be birthed, survive and thrive for over 65 years is best described as a combination of a smart institutional design, good governance, resourceful leadership and resilient collaboration. This powerful mix provides the spring board for the astute adaptation and dogged determination that allow CERN to sustain its performance.

Robinson (2019) provides a useful starting point for the discussion. His argument is couched in terms of what he calls ‘mechanisms’ that are embedded in CERN modus operandi that allow it to overcome the threat of gridlock that besets any multilateral collaborative endeavour. The pathways in the left-hand column of Table 1 refer to Hale et al. (2017)’s theory of gridlock-busting factors. The right-hand column then details the extent to and forms in which these factors are present in the case of CERN.

Table 1 Pathways to effective international collaboration: the case of CERN



Let us now take a closer look at what lies behind these mechanisms.

*Smart institutional design*

The 1953 Convention in which CERN’s mission and institutional design were articulated is widely credited with inculcating a sense of purpose and ground rules for governance that have stood the organization in good stead. It is crystal clear about what CERN is to be and not to be, delimiting its activities to scientific collaborative research on high energy particles and laying down clear boundaries and norms for how it is to pursue its activities: ‘The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available’ (Convention 1953, Article II,1). This clear scoping of the organization’s mission in the Convention provides the Council with a key lever to act as a check on mission creep and ensure the coherence of resource allocations without stifling innovation in how CERN researchers pursue the mandate.

The Convention also provides for a one member, one vote decision-making mechanism within the Council, thus steering CERN’s governance away from the politics of (financial) weight that plague so many other intergovernmental organizations (Goetz and Patz 2017). It creates a stable level playing field and it has survived the growth of the organization from 12 to (as at late 2019) 23 member states and the attendant differentiation of member state resources and capabilities. Meanwhile, the Convention also explicitly instructs all staff from the DG down to work without fear or favour for the benefit of the international, collaborative entity that is CERN and not to be influenced by preferences, demands and hints from any of the member states or other research institutes.

A former Director General notes: ‘The spirit from the beginning, was that we are not at CERN to profit we are there to help to achieve the common objective. A principle introduced by the founding fathers that still exists today’ (quoted in Robinson 2019: 43). In Robinson’s (2019) fieldwork at CERN, many long-serving staff voiced how proud they were of ‘their’ Convention as a document that sets the scene for fostering international collaboration and provides a healthy balance between top-down and bottom-up management approaches.

The spirit of the Convention pushed those who ran CERN to embrace norms of collaboration, trust, transparency early on. This in turn helped the DERN community deal with conflict, navigate adversity and maintain support among its critical constituencies. Well over sixty years from its adoption, staff sentiment was one of continued appreciation for CERN’s institutional architects who produced it. As one interviewee granted: ‘we owe a lot to our founding fathers both on the scientific side and wise people in the ministries and governments at that time who made that happen’ (Robinson 2019: 43).

*A conducive governance culture*

A key operative principle in CERN’s governance and operations is that of balance-seeking. Balance between funding member states and the spending CERN administrators. Balance between small and large contributors. Balance between centralised lab and infrastructure funding and bottom-up funding of the experiments. Balance between getting on with current work and preparing the ground for taking on new challenges and realizing future ambitions that are decades away. Balance between the scientists’ advances in theoretical physics and the engineers’ development of the technological tools required to test them. Balance between running a tight ship financially and maintaining the ability to respond flexibly to financial setbacks or emerging expenditures. Balance between the patience required to do the work necessary to achieve major scientific breakthroughs and the need to be seen to be active, relevant and impactful in the present vital to maintain the institution’s global public and political support base. Balance between banking on the authority of established scientific leaders and on empowering the innovative irreverence of emerging research talents.

Such balancing does not simply happen. The conditions for it to occur must be created in its organizational structure and nourished in its organizational culture. Take the ‘power distance’ (Hofstede 1992) between the established ‘God-professors’ and next-generation budding talents. In its examination of the economic and societal impact of large research infrastructures, the OECD’s (2014: 65) case study report about CERN paints a picture that epitomizes what Goodsell’s (2011) mission mystique matrix considers a ‘prime quality’ of public institutions – that its official truths are open to contestation because this power distance is actively kept within bounds:

All large research institutions are necessarily hierarchical organisations, with well-defined structures and procedures for ensuring responsibility, accountability and reporting. CERN’s version of the hierarchy is relatively “flat”, especially where it concerns communication and interaction across the vertical dimension of the hierarchy. It is not unusual for junior members of the staff, or researchers from collaborating institutions (even graduate students) to “buttonhole” the senior laboratory leaders in order to present original ideas or opinions. In part, this is a consequence of the inherently meritocratic nature of scientific research but, at CERN, it is reinforced by the special status of the laboratory that sets it apart from traditional institutions.

Another good example is the funding regime. Its ingenuous architecture is a key source of CERN’s strength. It provides a solid central base funding but allows no one to get fat and careless. In fact, it incentivizes entrepreneurship and coalition-building among staff members, research institutes and nation states whilst at the same time hedging against risk by allowing for loose coupling:

Countries contribute to a central fund for the infrastructure of the lab as a whole. However, while the infrastructure of the lab comes from the pooled fund, the experiments do not. This means that while the Large Hadron Collider (LHC) was built by CERN using the money contributed to the central fund, the four giant detector experiments were funded, designed, and built by independent collaborations of nations. This way, if one falls behind, it doesn’t necessarily mean the entire project will suffer (Lucibella 2014).

Also, it spreads the load fairly in that member state contributions are pegged to (developments in) their GDP. If times are lean in a particular member state, its representatives in the Council do not face pressure to go home and fight unwinnable budgetary battles with their science and treasury departments in order to maintain a set contribution amount. Moreover, as critical episodes involving budgetary and political turbulence in the UK and hen Germany in the 1980s and 1990s have shown, there is a collective norm of empathy and a propensity for pragmatic long-term thinking within the Council and in CERN’s Directorate and Finance Committee. This leads them to respond flexibly to the budgetary and political exigencies of the moment by accommodating the predicaments of certain member states through collective burden-sharing. Fairness, empathy and adaptability are thus built into the fabric of CERN’s decision-making structures and the rules by which they operate.

*Effective leadership processes*

Several forms and loci of leadership have shaped CERN. Firstly, it would never have existed but for the *visionary* leadership of its founding elites in the late 1940s and early 1950s. Scientists like De Broglie, Rabi and colleagues gelled with diplomats and other promotors of European cooperation to make and sell the case for this form of science collaboration. Soft-power leadership through relentless advocacy, smart appeals to the prevailing international climate, a well-framed moral compass and the use of targeted and well-timed convening all helped to build a founding coalition. To persuade not just get small states (who had nowhere else to go anyhow) but also Europe’s major powers France and Great Britain (in which geostrategic preferences and academic chauvinism may well have combined to turn against participation in a joint enterprise) and their World War 2 opponents Germany and Italy to sign up to the proposal and take part in this coalition was a major coup of academic entrepreneurship and diplomatic ingenuity.

Secondly, the *stability* of its scientific and administrative leadership cadres in the critical early years of the organization has been an important factor. Pestre (1988) reports that during the first fifteen years of its life-span the Council was dominated by a core group of men – they were all men – of the first hour who had held key positions in CERN and/or were representatives of countries that carried weight. The same goes to a large extent for the Scientific Policy Committee. This stability at the core of the nascent enabled interpersonal trust between key players to develop, smoothen the functioning of nascent formal structures and to act as a buffer to contain centrifugal forces and deal with emerging conflicts pragmatically. The members of these informal inner circles took up their roles in a particular way: they are not acting as national gate-keepers but increasingly as ambassadors for the organization within their respective constituencies.

Thirdly, with multiple power centres and multiple balancing acts between constituencies, values and interests to be conducted continuously, an organization like CERN can only be steered and adapted through a form of *dispersed l*eadership (Verbeek 2009). Over the decades, a now entrenched form of power-sharing has developed between Directorate, Council, the committees, the divisions the experimental collaborations. The rules of engagement provide a holding environment in which individual and teams of scientists wanting to ‘do their thing’ can get on with it, within parameters and levels of resourcing and accountability that are negotiated and determined in the interplay between the key institutional nodes in the governance structure. The Director-General is the face of the organization in the world outside CERN, and an influential authority figure within it, but cannot and will not impose major policy decisions on the system. Smooth relationships between DGs and Council presidents ae essential for greasing the wheels of the relationship between the core executive team (the Directorate) and its ‘board of directors’ (the Council).

Finally, in a science organization such as CERN it is pivotal that a significant share of the leadership structures and processes are animated by *professional* authority figures, whose leadership claims are rooted in substantive expertise and peer esteem rather than managerial qualities or political networks. CERN is not run simply and solely by ‘administrators’, far from it. There is a large and vocal community of scientists that jealously ensures that Parkinson’s law – ‘(administrative) work expands so as to fill the time available for its completion’ - will not creep up on them. DGs need to felt to be ‘one of us’ by the scientific community, and the very few that did not have a stellar scientific cv have had to work hard to earn its respect.

*A path-dependent collaborative regime*

In many ways an analytical apparatus that conceives of CERN as a ‘an organization’ (as does the foundational work on institutions and mission mystique by Selznick and Goodsell on which this volume’s conceptual framework relies) cannot capture its institutional essence. CERN began as a collaboration, and collaboration remains at its heart today. The language of collaboration is deeply entrenched in CERN’s structures and semantics. CERN’s entire modus operandi belies notion that science is essentially or even predominantly a competitive enterprise. The genius of CERN’s formula is that it does not deny the existence and propulsion power of competition between scientists, but that is has found a way of harnessing these competitive instincts within an overall framework of collaboration. Therefore the tools of contemporary collaborative governance studies (e.g. Ansell and Gash 2008; Emerson and Nabatchi 2015) are equally if not more suited to understand what makes CERN tick than those of institutional analysis. In models of collaborative governance, the essential fuel that makes collaborations happen and succeed is a composite of felt interdependence around a task or ambition that is salient to all the parties involved; the growth of trust and alignment of motivations between participants that may have widely varying perspectives, responsibilities and values and are subject to their own governance structures and accountabilities; commitment to a process of joint deliberation that they consider fair, safe and effective in forging paths towards concerted action; and eventually a generative cycle of trust-building begetting joint action that produces tangible benefits to all which in turn increases the appetite for continued collaboration.

The story of CERN that we have told in this chapter contains each of these elements. We shall not repeat them here. What we will add, however, is the important role of feedback loops and path dependencies that started to happen from the early 1960s on and were brought to a new level once the LHC was embarked upon and produced the results that it did. The

OECD’s (2014: 63) analysis of CERN’s impacts on innovation picks up on this point:

CERN’s network of institutional and personal contacts played a critical role in catalysing R&D, and in overcoming difficulties in meeting cost and schedule goals. To some extent, the network is there simply because of the passage of time (the institutions concerned have been interacting for sixty years). It is true, as well, that national research organisations receive their funds from the same agencies that finance CERN, so that the linkages emerge naturally during the elaboration of national science policies.

But the import of collaboration-induced feedback dynamics is much broader. Once the participating nations decided to pool their resources in this domain of science and kept at it for over a decade, this changed the incentive structures of the next generations of high energy physicists and institutions. There was now this unique common pool resource without which the experiments that needed to be done could not be performed. As similar accelerators in the US and Japan closed down in the 1960s-80s or were never built, there were no alternatives left, thus raising the costs of exiting from the collaboration (or of not entering it in the first place). Once thought of as a mere resource, CERN furthermore became an intellectual ‘hub’ and a source of professional identity, further increasing its professional centrality, the attractiveness of membership, and thus the centripetal pull of its resource claims.

**Sustaining the mystique: Challenges of consolidation**

If iconic organizations (Bekaert et al. 2016) are to retain their status as institutions, they need to be able to continuously challenge the very ‘way we do things around here’ that has produced their past successes. Indeed, Selznick (2000) reminds us that to maintain viable, an institution will have to adapt to maintain its fruitful relation with its ever-changing environment without changing direction, shedding competitive advantage or effectiveness, without identity damage and while maintaining its moral integrity. But how to accomplish this when their past and present are regularly glorified both externally and internally? As organisations institutionalize their character and modus operandi become imbued with value. This begets stability but loses flexibility (Selznick 1957: 7).

How then, in this era of the ‘Fourth Industrial Revolution’ and the ‘Asian Century’, do today’s ‘institutions’ overcome the twin threat of complacence and rigidity that perennially beset them? Ansell et al (2015) propose that institutional leaders should pursue a strategy of dynamic conservatism in which the organization engages in ‘pre-emptive adaptation’ to foreseeable and consequential changes in its operating as well as its political environment.

This is highly apposite to CERN. As Hörne and Kurbalija (2018: 70) note, CERN’s governance structures and practices allow for its projects to originate from and be driven by the needs and ambitions of science, while also allowing for compromise on the basis of political and resource considerations. This track record of achieving workable balances will be put to the test in the coming decades, in a European and global environment that is much more turbulent and less favourable than it was in the decades when the LHC came to fruition. Womersley (2019) reflects the ambivalence, noting that as ‘the archetype of intergovernmental organisation in science’, [CERN] offers great stability in the face of political upheavals such as Brexit, but at the same time admonishing the CERN community on the other hand that ‘its challenge today is to think outside the box.’

CERN’s current DG, Fabiola Gianotti echoes the sentiment and envisages a post-LHC world in which CERN is no longer the only game in town, with both Japan and China preparing their own collider megaprojects. She realizes that CERN cannot afford to drag its feet in pushing for the next frontier: complacency: ‘With CERN, Europe has regained leadership in fundamental physics at the energy frontier and also in the advanced technologies that are needed to do these experiments… [I]t would be a real pity if that leadership were to go elsewhere in the world.’ Moreover, in today’s era of ‘monitory democracy’ (Keane 2018) and public disenchantment with many public institutions, the benign opinion climate about CERN cannot be taken for granted. Media and other watchdogs may ‘wake up’ and change their tune on CERN at any time. One pre-Higgs Boson critic (O’Neill 2008) observed astutely that

The media would rather talk excited gibberish about the LHC than ask hard questions about support for science in a democratic society, or the proper priorities for research in physics. The CERN scientists are happy to meet the media’s demand for hyperbole, as it obscures the most important questions about funding for CERN. This should not sound too negative. The LHC is a magnificent human achievement, a great feat of collaboration and logistics, and it will surely bring fascinating scientific advances. But, in a sane democratic society, the media and the scientists themselves need to do a better job about talking sensibly about its purpose, goals and justification.

For the time being, the history of CERN buffets Mazzucato’s (2018)’s celebrated thesis that only the state – in CERN’s case a growing coalition of states represented in its Council and Finance Committee - has the patient capital and persistence to fund the kind of fundamental research that produces the knowledge infrastructure for highly impactful and commercially viable innovations. If it is to continue to do so, CERN will need to produce new quantum leaps in physics and technology in order to stay ahead of the pack and sustain its position as an icon of global science. For that to happen, it needs to once again make strategic choices about its future research directions, bring its stakeholders along on that journey, and secure very large amounts of money for very long periods of time to pay for it. In short: what will CERN need to keep doing, what will it need to stop doing, and what will it need to learn doing that it has not done before?

Given how many resources, careers and reputations are invested in its path leading up to the present, asking and answering these questions will require strategic leadership of the highest order. It will come down to the interplay between Directorate, Council, the CERN Community and its member states and stakeholders to rethink, retain and renew CERN’s way of operating without compromising its core mission and values which have served it so well in its first six decades.

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