Maintaining the Balance between Unity and Disunity in the era of Big Science: The case of the "Sister Experiments" UA1 and UA2 at CERN

The laboratory structure of CERN represents perhaps the most emblematic version of postwar Big Science, being an extremely complex institution, composed of hundreds of laboratory teams dispersed across the entire globe. Furthermore, it is an organization where diverse groups (experimentalists, theorists, engineers, and technicians) are called upon to cooperate through "trading zones" that are formed within the modern laboratory. This lack of singleness confers upon CERN a diverse dynamic of multiple goals, perspectives and ideas. Nevertheless, if this diversified landscape were not counterbalanced by specific mechanisms of integration (particular hierarchies, structured collaborations, shared modes of communication, cohesive publication policies, uniform research policies, strategies and organizational charts), CERN could not retain its standing as a unified organization and would deteriorate into a formless sum of diverse groups. Unity is, in essence, CERN's cell wall, allowing it to be seen as a cohesive whole by people both outside the laboratory and within it. This unity that should not be conceived of as a singleness but instead as something akin to a harmonious integration.

We will attempt to examine CERN's peculiar balance between unity and disunity by tracing back the history of the emblematic UA1 and UA2 experiments, which led to the discoveries of the W and Z boson, lending the organization the prestige of a physics Nobel award. This case study is exceptionally illuminating since these particular experiments formed the template for the management of the various massive multi-institutional collaborations that followed. They were, after all, the first "sister experiments", a strategy that was followed on all later colliders: both with the LEP (Aleph, Delphi, Opal, and L3 experiments), as well as with the LHC's ATLAS and CMS experiments.

The birth of the "sister experiments"

A series of experimental results and theoretical developments that took place during late 60s and early 70s gave strong support to the so-called unified gauge theory proposed by Steven Weinberg, Abdus Salam and Sheldon Glashow, a theory that later came to be known as the *Standard Model*. As a result, by the mid-1970s, the discovery of the W and Z bosons which were predicted by the *Standard Model* had become the holy grail of experimental physics. The expected masses of the bosons ranged from 60 to 80 GeV for the W and from 75 to 92GeV for the Z, energy levels far too high to be accessible by any accelerator in operation at the time. As the protagonists of the experiments, Carlo Rubbia and Luigi Di Lella, admit "the ideal machine to produce the weak bosons and to measure their properties in the most convenient experimental conditions was an e+e− collider, as beautifully demonstrated by the success of the LEP program" (Rubbia& Di Lella 2015). However, the Nobel prize fever and the competition with the laboratories on the other side of the Atlantic demanded swift initiatives. In this context, Carlo Rubbia suggested an experimental structure that could allow the discovery of the W and Z bosons with only certain modifications to the existing SPS accelerator, thereby avoiding any lost time until construction of the LEP was complete. After all, such a delay may have proven to be fatal for CERN's attempt at climbing out of the shadow cast by the American laboratories, since the discovery of the W and Z could, in the meantime, take place at the Tevantron accelerator which was under construction at Fermilab. More specifically, Rubbia proposed the transformation of the existing high-energy proton accelerator (SPS) into a proton– antiproton collider (SppS) as a quick and relatively cheap way to achieve collisions above the threshold required for W and Z production. Despite the fact that the project was exceptionally clever, it nonetheless remained an 'exigent circumstances' option, a "quick and dirty" experimental scheme, as it was unofficially referred to in the corridors of CERN.

What was, then, the reason to create, in tandem, two identical experiments with similar experimental goals? First of all, it was an answer to the nagging problem of the inability of replication of an experiment in the era of Big Science and more specifically in the field of High Energy Physics. Under circumstances where it takes many years, hundreds or thousands of people, and millions of euros to build a new collider, an attempt was made to mitigate the objective difficulty in replicating experiments, which had been one of the cornerstones of the scientific method for centuries, through the strategy of "sister experiments", for which UA1 and UA2 paved the way. However, besides the wider issue of replication, the undertaking of these experiments was given the go-ahead for two more specific reasons. Firstly, as we mentioned before, this was an 'exigent circumstances' experiment, which carried a sizeable risk. Secondly, CERN's management and more specifically the Director-General John Adams were skeptical regarding the personality of Carlo Rubbia, around which the UA1 collaboration had been set up. As the historian of science John Krige (2001, 527) notes, "Rubbia was an almost mythical figure in the international high-energy physics community, revered for his intelligence, feared for his temper, despised for his arrogance, and notorious for jumping to premature conclusions". Rubbia's reputation led the management of CERN to attempt to ensure the credibility of experimental results by giving UA2 the green light to proceed with construction, six months after UA1 had got under way.

However, it would be a mistake to consider each of these two experiments as a replication of the other, since their roles remained distinct and ancillary. UA1, with its director, Rubbia, having an immense influence across the entirety of CERN, seemed to have led the way, whereas UA2 appeared to have played the role of a control experiment, an invaluable cross-check. The complementarity of the two experiments was crystallized both in the different experimental mentalities of the two groups, as well as in the detectors themselves. In contrast with Rubbia, the director of UA2, Pierre Darriulat, was known as a consistent, cautious and patient researcher. Moreover, UA1 's detector could be seen as a projection of Rubbia's personality. It was designed to be a "multipurpose" machine suited not only to the search for the weak bosons, but also to studies of high transverse momentum jets and also possibly to the production of free quarks. It was a very ambitious, complex and sophisticated piece of equipment in a context of "dirty" proton-antiproton collisions, a truly high-risk choice. On the other hand, UA2 's detector was much more simple, using conventional, tested technology: a single-purpose detector specifically dedicated to the search for the W and Z. Thus, two experiments were set up in parallel with the purpose of comparing each other's results. For this reason, apart from some informal channels, they didn't exchange data, methods, and detector designs. This was a clever way to reinforce the credibility and the robustness of the experimental procedure within the context of Big Science and specifically in a "quick and dirty" experiment such as this.

Collective publication as a homeostatic mechanism of unity

Over the last century, fundamental physics has undergone a change of scale, as hundreds of physicists were required for the carrying out of new experiments of enormous complexity, each with their own unique expertise. In turn, the experimental procedure, as noted by quite a few physicists, started resembling a giant 'assembly line', where each physicist fulfilled just a small part of the whole, while only a few were afforded with a holistic view of the complete experimental process. But how does an organization like CERN manage to avoid coming apart at the seams by these opposing forces which arise from a structural disunity? For the most part, this comes down to one of the major homeostatic mechanisms of unity, which is none other than the collective publication of the experimental results. After all, the co-signing by hundreds - and today even thousands – of scientists of an experimental result not only imbues the publication with an added credibility but also with a symbolic sense of unity for an organization like CERN, that, despite the diversities inside it, acts as a uniform community to the outside world, one that stands united to defend its results. As Galison (2003, 336) puts it "pulling towards inclusiveness is the desire to make the collaboration as complete and unified as possible; anyone left out might undermine the authority of the claim".

The experimental output of the laboratory should therefore be uniform, persuasive and specific, while the decisions regarding the official announcements would be relegated to a very concrete hierarchy. It wasn't by chance, then, that as CERN was in upheaval during January of 1983, due to the intense dispute between the UA1 and UA2 experiments with regards to whether the experimental results that they had at their disposal constituted the discovery of the infamous W boson or not, a press conference was called by Director General H. Schopper on January the 25th. This press conference, which would conclude with the announcement of the discovery of the W, was construed in a way that presented the organization as a uniform, indivisible whole. Seated to the left and right of Schopper, were the two representatives from UA1 and UA2, Carlo Rubbia and Pierre Darriulat. As Krige notes, Schopper put Darriulat on the stage at the press conference along with Rubbia "to legitimatize that decision, and to dispel doubts about the credibility of UA1's findings. In doing so, he traded on Darriulat's sound reputation, forcing the UA2 spokesman, out of loyalty to CERN, to collude in the marketing of a claim that he was not fully convinced of himself […] Darriulat's primary role was to reassure, not to celebrate, to give credit to UA1, not to seek accolades for UA2" (Krige 2001, 536). Thus, despite it being known that there existed differing opinions both within the experiments as well as between UA1 and UA2 (Krige 2001, Taubes 1987), through specific mechanisms of consensus and unity, this pluralism and antagonism of ideas was transformed into conviction towards the outside world and the discovery of the W boson had become now a concrete fact. This complementarity of the two distinct experimental mentalities and the balance that CERN's management attempted to retain between them is what gave the experimental result its required credibility, by setting aside the various critical voices from both within and outside CERN.

The Multinational Construction of the Detectors

The construction of the UA1 and UA2 detectors itself is another characteristic example of the inseparable relationship between unity and disunity, since they were built piece by piece with components made by a multitude of research institutes, all of them spread geographically across the globe. Construction of the various components of the detectors was assigned on the basis of the interests, past experience, and resources of each participating institute. For example, the different parts of UA1 detector were constructed by 8 different institutes in 6 countries. In this case, disunity imbued the process of building the detector with a distinct dynamic. The autonomous construction of the various different parts allowed each institute to focus on developing specific expertise and to delve more deeply with their R&D into very specialized fields.

On the other hand, this decentralization and division of labor had to be counterbalanced by certain unification and composition processes that would transform all of the pieces into a common, indivisible detector and would give to this de-spatialized experiment a central point around which it could revolve. The coordination of the building, assembly and installation of the UA1 detector was entrusted to a Technical Committee chaired by Hans Hoffmann. This committee met every week throughout the construction period while there were other, more specialized interinstitutional meetings that took place periodically as well, such as the Calorimeter Meetings, the Trigger Meetings etc. (Krige 1993, 246-7). Finally, the process for assembling the various distinct building blocks of the detector, a process that took place in stages, collaboratively and with extreme care, was also of pivotal importance. After all, the new detector, representing a cohesive materiality, was the most powerful symbol of unity, one that gave both the collaboration and the aspect of "belonging" in the experimental group a material substance.

Conclusion

The above examples can help us realize how disunity does not necessarily constitute a problem but, oftentimes, is a factor that lends pluralism and momentum to the experimental process. Of course, attention should be paid so that these particular aspects of disunity don't become a centrifugal force capable of unraveling the endeavor; instead, they should be counterbalanced by extremely delicate mechanisms of unity, without numbing the various forms of diversities that we can find within a modern laboratory. We should conceive of these particular mechanisms as a complex epistemic, technical, social and political achievement, one who's importance for the modern laboratory cannot be overstated and which deserves further historical research.

References

Di Lella L. and Rubbia C. (2015) "The Discovery of the W and Z Particles", in Herwig Schopper and Luigi Di Lella (eds.) *60 Years of CERN Experiments and Discoveries* (World Scientific)

Galison, P. (2003), "The Collective Author," in P. Galison & M. Biagioli (eds.), *Scientific Authorship: Credit and Intellectual Property in Science* (Routledge).

Krige, J. (1993). "Some Socio-historical Aspects of Multinational Collaborations in High-Energy Physics at Cern Between 1975 and 1985," in E. Crawford, T. Shinn, T., S. Sörlin (eds.), *Denationalizing Science: The Contexts of International Scientific Practice* (Springer).

Krige, J. (2001) "Distrust and Discovery: The Case of the Heavy Bosons at CERN", *Isis*, Vol. 92, No. 3, pp. 517-540

Taubes G. (1987) *Nobel Dreams: Power, Deceit, and the Ultimate Experiment* (Random House)