Agility, Improvisation, or Enacted Emergence

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AGILITY, IMPROVISATION, OR ENACTED EMERGENCE?

DISTRIBUTED DEVELOPMENT OF

A PARTICLE PHYSICS GRID

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Abstract

There has long been a debate in system development centered on the dichotomy between control and innovation. In recent years this has been exemplified by the movement for agile methods. This paper seeks to bring some theoretical underpinning to this discourse by drawing upon the literature of “improvisation”, extensively explored in organization science. We relate this discussion to an example of a large scale system development effort undertaken “in the wild” – the ongoing construction of a particle physics grid in the UK (GridPP), itself part of the world’s largest grid, the LHC (Large Hadron Collider) Computing Grid. Our findings show that a combination of top-down coordination and bottom-up innovation is at work in this domain. Limited defined system development methodology is explicitly employed in the project, and home-grown methods and ad hoc activities seem to dominate the day-to-day practices of system development. We also find that this way of working is embedded in, and draws from, the conventional practices of the community: for example, the way particle physics experiments are organized and constructed. We conclude by formulating a framework of “enacted emergence” which characterizes system development practices in an environment with a high level of complexity and uncertainties.

Key words: agile system development, improvisation, grid computing, particle physics.
Introduction

This paper reports on a large scale systems development effort “in the wild” – the ongoing construction of the UK particle physics grid (GridPP – www.gridpp.ac.uk/). GridPP is itself part of the world’s largest grid endeavor, the Large Hadron Collider Computing Grid (LCG – lcg.web.cern.ch/LCG/) (Venters and Cornford, 2006). This initiative aims to produce not just an infrastructure for particle physicists worldwide but a new generation of computing technology that will potentially have significant consequence for scientific research and may foreshadow the “next generation Internet” (Abbas, 2004, Carr, 2005). Collaborative and distributed working are predominant characteristics of GridPP and the LCG – with diverse collaborators bound by no legal obligations but mere Memorandums of Understanding – a very different kind of organization from most who construct complex technical systems (for example NASA or a national power distribution system). Working at the cutting-edge of computing this Grid project progresses without a well-defined and rigid “master plan” or much reliance on sophisticated system development methodologies. It more or less grows by trial-and-error. The emerging Grid infrastructure is not perfect and can be improved in many aspects, yet it appears to be working and is on track to provide the data storage and analysis service needed in time for the Large Hadron Collider experiments due to start at CERN in 2008. How do the particle physicists organize themselves to manage such a complicated distributed project and a working system? If there is no powerful management hierarchy to make decisions or to tell people what to do, what is driving the project forward? What implications can be generated from their experience to shed light on system development practices in other environments with a high level of distribution, complexity and uncertainty? This paper explores these questions by drawing upon the discourses on agile methods and organizational improvisation to propose a new theoretical framework of enacted emergence.

The primacy of control in systems development work has long been under suspicion with suggestions that methodologies have not been effectively or extensively used (Agerour and Cornford, 1993; Bansler and Bodker, 1993; Dobing and Parsons, 2006; Whitley, 1998), are often justifiably “faked” (Parnas and Clements, 1986), or used as a “fiction” to create some sense of coherence in day-to-day activities (Nandhakumar and Avison, 1999). Such observations have caused many to rethink the status of methods and methodology in systems development. Ciborra (2002; 1998), for example, speaks of the crisis generated by an overdose of method and planning and the ontological assumptions it promotes, and asks us to “suspend the belief that behind the messy everyday reality there is a geometric universe” and substitute this with new concerns for care, hospitality and cultivation (Ciborra, 2002).

Challenges to the belief in method, together with evidence from empirical studies of development work, have given rise to the idea of so-called “amethodical” development (Baskerville, 2004) that can better appreciate and support innovation and organizational change, adaptation and experimentation, as well as accidents and opportunism (Truex, et al., 2000). But, as Truex et al. (2000) suggest, amethodical practices, despite enduring for decades, have usually been placed at the margins of the discourse of system development. Recently, though, the rise of agile methods (Fowler and Highsmith, 2001) and the associated conceptual apparatus have served to bring such ideas closer to the mainstream (though they may be better described as ‘methodical-lite’ rather than amethodical). Still, the existing literature on agility is predominantly written by practitioners, and occupied with extracting “abstract principles” from individual experience, rather than building on significant studies (Abrahamsson, et al., 2003), and shows a lack of theorization and conceptualization of agile methods (Conboy and Fitzgerald, 2004). Moreover, the concept of agility as presented by its advocates does not seem to address the challenge of distributed systems development activity so prevalent today when system development is re-scaled as a virtualized effort undertaken by loosely coupled alliances and collectives, distributed in time and space.

In any case, agility is not just a case of substituting a new set of controlling ideas for an old set; the challenge is to blend a capacity for agile performance, innovation and surprises, with a means and context that sustains the focus and momentum of a development effort (Williams and Cockburn, 2003). Although some recent attention has been paid to organizational cultures which sustain agility (Adolph, 2006), the concept of agility or agile processes for systems development has not been substantially studied as an organizational phenomenon or linked to organization theory. If organizational landscapes are emergent or enacted (Weick, 1993b; Weick, 2001), and equally technology (Oriewk, 2000), so theorizations of IS development practices, as their offspring, need to support a strong contextual contingency and allow for “improvisational action and bricolage” (Bansler and Havn, 2003).

Here we address this new style of systems development by bringing theoretical underpinning from the literature of ‘organizational improvisation’ (Weick 1998, Cunha et al 2000) and frame the complicated and at times contradictory ideas underlying agility in terms of paradoxes; for example, learning to “plan not to plan” (Baskerville, 2006) or to
achieve a “disciplined messiness” (Highsmith, 2002). Serious consideration of agility requires a rejection of any bipolar distinctions between concepts like planning and serendipity (Baskerville, 2006), discipline and creativity, nor to deny or negate the value of concepts of structure, design or order in systems development. Rather we suggest that it is in the tension between these, structure and change, order and chaos, control and innovation, that creative attitudes, innovative outcomes, and productive practices may be found. The tradition of using the paradox as a dialectical device to dig deeper has a long tradition in IS, for example see Poole and van de Ven (1989).

The rest of this paper is laid out as follows. Section 2 develops the conceptual framework which we use to analyze the empirical material. Section 3 briefly introduces Grid technology and presents the research data on the development of the UK particle physics grid. This is followed by our analysis in section 4. Section 5 reflects on contributions and limitations of the research and concludes the paper.

**Conceptual Basis: Organizational Improvisation**

Writings on improvisation have drawn heavily upon various metaphors, e.g. jazz (Barrett, 1998; Hatch, 1999), improvisational theatre (Crossan, 1998), etc. Cunha et al (1999) defined improvisation as “the conception of action as it unfolds, by an organization and/or its members, drawing on available material, cognitive, affective and social resources” (Cunha, et al., 1999). This definition emphasizes two aspects. Firstly, the temporal order of improvisations, namely, the convergence in time of conception and execution (Moorman and Miner, 1998), or “real-time planning” (Miner, et al., 2001). Secondly, *bricolage* – the aspect of finding solutions from available rather than optimal resources – which is often implied or used interchangeably with improvisation by authors (e.g. Weick, 1993a; Weick, 1993b), and which is considered to be inseparable from the action of improvisation (Cunha, et al., 1999). Improvisation and *bricolage* have been introduced into the field of information systems (e.g. Ciborra, 1999; Ciborra, 2002; Lanzara, 1999) in order to critique the dominant structured analysis and methodology in information systems design, yet have not before been linked with agility and agile methods.

Inspired by the paradoxes of improvisation suggested by Mirvis (1998) and Ciborra’s (1999) work, we present here a set of conceptual constructs, what we call improvisation-paradoxes, which draw upon and synthesize the literature on organizational improvisation. These serve as the conceptual vocabulary for the research findings presented in the following section.

*Situated improvisation:* Improvisation does not arise out of the blue. It is either a reaction to circumstantial (possibly un-predicted) changes, or a pro-action to obtain a future state via unknown paths. Improvisation is situated, and can be deliberate activities. Factors that induce improvisation could come from several sources; the most common one is uncertainty, or environmental turbulence (Moorman and Miner, 1998). But unexpected and “unplanned-for” (Miner, et al., 2001) occurrences can take place both outside and inside the organization (Cunha, et al., 1999). A second reason may be if the complexity of the task is beyond the scope of any rational planning or predetermined method at a micro level. For example, Hutchins (1991) provides a case of collective improvisation. He describes how the crew of a ship whose navigation system broke down managed to bring the ship into the harbor by working out a set of routines among themselves while none of them had a high level view of how the complete system works. Finally, new visions which articulate the gap between reality and a possibility can also induce actions which are partly planned yet significantly emergent (Mintzberg and McHugh, 1985) and improvised (Crossan, et al., 1996).

*Structured Chaos:* It is recognized that improvisation and *bricolage* often occur within persistent structures which display order and stability, and some inertia and resilience, while also being in a constant state of flux, and embodying local disorder and incoherence (Lanzara, 1999). Cohen et al. (1972) characterized “organized anarchy” with three properties: problematic preferences, unclear technology, and fluid participation. An organization with a “collateral structure” (Cunha et al, 1999) fosters improvisation by relieving members from the impositions of formal and prescribed practices, thus allowing members to build a repertoire of improvisational ideas. Other organizational configuration that support innovative activities may include what an “aesthetic of imperfection” (Weick, 1999), a strong pro-innovation culture (e.g. Miner, et al., 2001; Mirvis, 1998; Weick, 1998), and a sense of urgency (e.g. Crossan, 1998; Hutchins, 1991; Mirvis, 1998).

*Planned agility:* While improvisation can be seen as an activity with “no split between design and production” (Weick, 1993a), it is not the opposite to planning. As Weick (1998) comments, “improvisation is a mixture of the pre-composed and the spontaneous, just as organizational action mixes together some proportion of control with innovation, exploitation with exploration, routine with non-routine, automatic with controlled.” Miner et al (2001) also suggest that organizations can plan to improvise, routinize processes to stimulate improvisation, and routinize...
the observation of their own improvisational activities, without planning the content of improvisation in advance. Moreover, clearly articulated goals provide a sense of direction in terms of organizational objectives, and serve as a magnetic field which, without prescribing individual action, is strongly normative as it concerns the results of such action (Weick, 1993b). In other words, improvisation is not a totally random and non-directional activity. It can be embedded in a certain organizational context which exercises a certain degree of planning, control, and pre-conception.

Reflective Spontaneity: Retrospective sensemaking (Weick, 1993a) can provide order, purpose, and coherence (Barrett, 1998) to improvised activities which may seem chaotic on the surface or at the time; “Whether treated as a noun or a verb, improvisation is guided activity whose guidance comes from elapsed patterns discovered retrospectively” (Weick, 1998). Similarly, Lanzara (1999) comments that meaning often arises from ex post interpretation and sensemaking by a large number of dispersed agents, rather than from ex ante planning and implementation by a central designer. A project’s milestones and deadlines may serve as devices for such retrospection (ibid.). Lanzara (1999) also offers the concepts of “transient constructs”, such as “makeshift artifacts, recombinant routines, … ephemeral organizations, disposable symbols, fugitive meanings”, used as a way to embody experience and what is known so far, working like “arches of a bridge thrown across time” to sustain some continuity and stability. Thus, at the macro-level, an unfolding improvisational performance and reflections on it, give rise to (or jointly enact) an “emergent order” (Miner, et al., 2001), or “persistent structures” (Lanzara, 1999) which in turn can be drawn upon by others (Orlikowski, 2000).

Collective individuality (Mirvis, 1998): Creativity and improvisation may be encouraged and supported, but individual freedom has invariably to be bound by a level of group cohesion in order to achieve any collective goal, especially when, as in distributed systems development, task complexity is beyond the cognitive capacity of any individual (Hutchins, 1995; Weick and Roberts, 1993). As Weick (1998) puts it, “discussions of improvisation in groups are built on images of call and response, give and take, transitions, exchange, complementing, negotiating a shared sense of the beat, offering harmonic possibilities to someone else, preserving continuity of mood, and cross-fertilization”. Facilitative leadership (Barrett, 1998; Crossan, 1998), trust (Crossan, 1998; Weick, 1993a), and fluid communication (Miner, et al., 2001; Orlikowski, 1996) nurture such group performance. These characteristics express what Hatch (1999) refers to as a replacement of dependence on rationality with emotional communication, “as influence and persuasion replace authority as avenues for getting things done in de-layered organizations”. Such emotional ties do not have to stem from self-disclosed intimacy but from shared actions, “hanging out” and a sense of membership in the collective (Barrett, 1998).

Anxious confidence (Mirvis, 1998): Emotional ties also serve to provide a “safety-net” for members of a collective to cope with anxiety, or to “deal with [the] affective element” in their performance (Cunha, et al., 1999). As Ciborra (2002) points out, our moods change the way we encounter the world and make sense of situations. He considers improvisation as a mood and contrasts it with conventional moods of the development context such as panic or boredom, both of which fog vision and conceal possibilities for action. Mirvis (1998) suggests “anxious confidence” as the means to live with the ambiguity, complexity, and challenges of working in an improvisational collective. While Mirvis focuses mostly on individual capability and confidence, confidence is not only, even primarily, experienced through individual knowledge and skills (Hutchins, 1991; Moorman and Miner, 1998; Orlikowski, 1996) but also in organizational cultures and as “learned ways of thinking and behaving” (Moorman and Miner, 1998) which all can draw upon. Memory, practices and shared forms are requirements of improvisational success (Weick, 1998).

Research Context and Methodology

In this section, we first introduce Grid technology, and then describe GridPP in more detail. We also explain the methodology employed in our research.

What is a Grid?

The name “Grid” comes from the metaphor of an electricity grid, the idea of accessing remotely located resources by plugging in locally. A Grid may be seen as a platform for coordinated resource sharing and problem solving on a global scale suitable for data-intensive and compute-intensive applications (Foster, et al., 2001). A Grid connects and coordinates computing resources around the globe and across different domains, presenting itself to the users as though it was a single computer. A central concept for Grid is that of the virtual organization (VO), which sets
permissions on shared resources that members of the VO can make use of, disregarding actual hardware locations. Grids are distinguished from existing distributed computing in that scientists/users don’t have to negotiate their use of different sites or resources separately and deal with security restrictions of individual sites, nor have to find out the precise location of their data. They need only one user-account to access a wide range of resources – processing and data – as permitted by being a member of a VO.

Grid technology is currently being developed and constructed simultaneously in many different countries, using different technologies, involving various stakeholders across disciplines and industrial boundaries. Collaborative sciences have been the major driving force behind the development of Grid technology, with their desire to share and process increasing amount of data, and the desire to foster collaborations between scientific institutes scattered in different locations around the country or the world. Apart from the particle physics Grids studied here, examples of scientific grids include the European biomedical grid, and medical grids, such as the MammoGrid which federates mammography databases to assist cancer diagnosis (Kyriakidou and Venters, 2007).

What is GridPP?

GridPP is the largest contributor of computing resources to the LCG which is preparing for the challenge of the imminent “data deluge” from the launch of the Large Hadron Collider (LHC) experiment at CERN, the European Laboratory for Particle Physics (Lloyd, 2003). The LCG is in turn part of an even larger European project - Enabling Grids for E-sciencE (EGEE - www.eu-egee.org/). The LHC, to be launched in 2008, will collide particles at energies close to those experienced moments after the Big Bang in order to search for the Higgs boson – a particle, it is hoped, that will answer the question of why matter has mass. Searching for the Higgs signature among the vast amounts of data generated has been likened to the task of searching for one person in a thousand world populations, or for a needle in twenty million haystacks. The LHC will produce a deluge of data, some 15 million gigabytes a year, equivalent to a DVD’s worth of data every 15 seconds or another 1% added to the global information production (The Economist, 2005). To process this data the LHC experiments require 100,000 computers spread across the globe working as a Grid (Faulkner, et al., 2006).

GridPP currently contributes around 5,000 computer processors and 0.5 petabyte of storage for the LHC experiments (GridPP, 2006), increasing to 10,000 CPUs by 2010. GridPP is a collaboration of 19 UK universities, the Rutherford Appleton Laboratory, and CERN. It is funded by the UK Science and Technology Facilities Council (STFC), and employs about one hundred people within the UK on the basis of between 10% and 100% FTE. There are many other people who directly or indirectly work with GridPP, e.g. people at the collaborating institutes or the experiments, but who are not on the payroll. Work started in 2001 as two main activities: developing software to allow users to submit computing jobs to the LCG, and developing and operating the UK’s component of LCG. The national Rutherford-Appleton Laboratories (RAL) is the UK’s Tier 1 centre, with four Tier 2 centers: London, ScotGrid, NorthGrid and SouthGrid, each coordinating a number of institutes in their region (Figure 1).

GridPP’s constitution is as a collaboration in which decisions are made on a democratic and consensual basis, and are implemented by influence and persuasion. GridPP’s management structure is best described as a network rather than a hierarchy (Figure 2). As a collaboration or collective any attempt to describe GridPP as an organization (with an organization chart) inevitably underplays its virtual, federated, overlapping and inter-connected nature. At its
heart is the “Project Management Board” (PMB) coordinating the whole project and interfaces with the LCG. The PMB provides quarterly reports to the Collaboration Board representing the 19 participating institutes. These institutes enter the collaboration bound by a Memorandum of Understanding, which specifies the amount of resources and the level of service that each site is committed to provide, and the funding and support they will receive from GridPP in return. This serves more as a “gentlemen’s agreement” than a contract.

The PMB, in addition to three ‘leaders’ who chair and coordinate, consists of representatives from internal and external committees, boards and functions. Since GridPP overlaps with other projects and organizations the PMB includes representatives of the wider LCG project, the UK’s e-science projects, funding bodies and the middleware producers (EGEE). The Deployment Board monitors resources deployment (which is undertaken by the Deployment Team), and the User Board represents the LHC experiments and physicists. Many people straddle multiple boards and key members of the project are constantly traveling between these boards’ meetings. The “practicing” particle physicists involved in GridPP are all members of one of the four experiments on the LHC and attend the associated meetings. Almost all the PMB, and around half of GridPP’s members in general, have a particle physics background. Others are from computer science, engineering or other advanced sciences.

It should be noted that the above general description and diagrams entail immense simplification. As one senior member of GridPP reminded us, “Reality is much more complicated than that.”

Methodology

This research is one output from a project conducting ethnographic informed research on the GridPP collaboration and the Grid they are building (Venters and Cornford, 2006). GridPP’s unique nature precludes comparative studies, but provides a revelatory case of distributed systems development practice. From the start we have understood that within particle physics it is intensive ongoing communication that shapes the work. As Knorr-Cetina (1999, p173) describes: “Discourse runs through HEP experiments; it provides experiments with a massive spectacle of object features, of their story lines, and technical dramas, which are held by and spill from computer displays and printouts, transparencies, internal notes “documents”, and together with all these, talk […] Discourse channels individual knowledge into the experiment, providing it with a sort of distributed cognition or stream of (collective) self-knowledge which flows from the astonishingly intricate webs of communication pathways”. This highlights the need for research methods which can follow the ongoing activities and discourse of participants. Hence our choice of an ethnographic approach allowing direct observations by researchers embedded within the context over an extended time period (Agar, 1996; Czarniawska, 1997; Hammersley and Atkinson, 1995). The team includes a senior experimental particle physicist to ensure that the research is not undermined by a lack of understanding of physics. Drawing from the interpretive research tradition in information systems the focus of this ethnography is on sensemaking and the symbolic world of those studied (Walsham, 1995).

Data collection began in August 2006, following earlier pilot work, and has included participant observations of weekly project management board meetings and deployment team meetings, quarterly GridPP collaboration meetings in the UK, international meetings of the LCG, site reviews carried out by GridPP, observation of various forums and conferences in which GridPP participates. The research team has had full access to the GridPP main documentation, and subscribe to its main mailing list and the deployment team mailing list. At the core of this research are 41 semi-structured qualitative interviews of between one and one and a half hours, undertaken at various universities across the UK and during two week-long periods at CERN in Geneva. Table 1 provides details of the research activities undertaken. Interviews were audio-recorded, transcribed and some then free-coded using Atlas.Ti software to derive themes and concepts, generally underlined by ideas of improvisation and agility discussed above, as well as ideas derived from previous studies of particle physics communities (e.g. Knorr-Cetina 1999 and Traweek 1988). For the most part the analysis reported here is the result of the iterative reflections and ongoing discussions within the research team and with GridPP members, rather than a narrow machine-derived account. While all the quotes given here are taken from interview transcripts, they have also been reinforced by informal conversations and participant observations. This is not to say that the community is unified in their opinions. Tensions, conflicts and different views exist and are inevitable in any collaboration of this scale. Nevertheless, the research attempts to capture the distinctive features of GridPP, which are broadly supported by three GridPP PMB members who were presented with the key findings of this paper.
Research Findings

In this section we present the findings of the study using the conceptual framework developed above. Most of what is described here also applies to the LCG as a whole. But as our focus is on GridPP, we will use GridPP as the unit of analysis. The space limit only allows a few selected quotes to be presented. Table 2 lists the codes of the anonymous contributors.

<table>
<thead>
<tr>
<th>Research Methods</th>
<th>Examples</th>
<th>Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-structured interviews</td>
<td>Members of GridPP, middleware developers at CERN, members of CMS experiment…</td>
<td>Audio-recorded, transcribed, coded</td>
</tr>
<tr>
<td>Virtual meetings</td>
<td>weekly PMB meetings, weekly deployment team meetings</td>
<td>Audio-recorded, notes taken, not transcribed</td>
</tr>
<tr>
<td>Participant observations</td>
<td>GridPP collaboration meetings, PMB face-to-face meetings, deployment team face-to-face meetings,</td>
<td>Many audio-recorded, notes taken, not transcribed</td>
</tr>
<tr>
<td>Site visits</td>
<td>GridPP site readiness review</td>
<td>Notes taken</td>
</tr>
<tr>
<td>Secondary data</td>
<td>GridPP publications, GridPP documents, GridPP website, wiki, blogs, mailing lists</td>
<td>Frequent consultation</td>
</tr>
</tbody>
</table>

Table 1. Details of research activities.

<table>
<thead>
<tr>
<th>Code</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Senior particle physicist, GridPP PMB member A</td>
</tr>
<tr>
<td>P2</td>
<td>Technical expert at one of the Tier 2s</td>
</tr>
<tr>
<td>P3</td>
<td>Senior particle physicist, GridPP PMB member B</td>
</tr>
<tr>
<td>P4</td>
<td>Senior particle physicist at CERN, member of LCG</td>
</tr>
<tr>
<td>P5</td>
<td>CERN liaison, GridPP PMB member</td>
</tr>
<tr>
<td>P6</td>
<td>Senior technical expert of LCG</td>
</tr>
<tr>
<td>P7</td>
<td>Senior particle physicist, GridPP PMB member C</td>
</tr>
<tr>
<td>P8</td>
<td>Senior technical expert in GridPP</td>
</tr>
</tbody>
</table>

Table 2 Keys to codes of attributed quotes.

Situated Improvisation

In GridPP we observe development practices that are “amethodical” from any conventional systems development perspective. They are largely improvised, and one can ascribe three major reasons for the need to improvise. First, the GridPP project contributes towards a vision of building a grid infrastructure for the whole particle physics community, which constitutes an innovative effort towards constructing a new information technology. The process of filling the gap between the current status and that vision has to be trial-and-error, since nobody knows what exactly the end product will look like. Second, the complexity of the project means no one person can have a clear idea of the whole system (Hutchins, 1991); requirements cannot be pre-specified in detail; architectures are conjectures, and even the only centrally designed piece of technology, the middleware, has to be modularized and released gradually rather than in a big-bang manner. Third, the project faces great uncertainties ranging from funding, human resources, external and internal technological changes, hardware and software configuration, user requirements from the experiments, computer market conditions, and other institutional and political factors including EGEE and LCG. The GridPP project is funded on a rolling basis by UK’s STFC, and has to justify its
funding by going through complex and painstaking application processes. Only recently they were approved of only 70% of the required funding for the third phase of the project – GridPP3 to run from 2008 to 2011. GridPP3 was not anticipated when the project started and before the funding was approved it was uncertain whether there would be a GridPP3 at all. Not getting 100% of the resources required means that some support posts will have to be cut, and GridPP will have to come up with solutions to reduce the impact of the lack of human support.

Being dependant on open source software and as part of a wider grid program, GridPP is also subject to external technological perturbations. They rely on the EGEE to provide the middleware as it is developed and released. They then face an ongoing process of learning and adapting to immature software, and making it work at each individual sites. For example, Science Linux (SL) is the common operating system used in High Energy Physics (HEP) communities. The latest version, SL5, is now released and SL3 will soon stop being supported, but the EGEE middleware is still not upgraded to support SL4. As a result, GridPP is not able to upgrade to the up-to-date operating systems requested by local sites.

**Structured Chaos**

GridPP is a collaboration of institutes who work together under the informal binding of a Memorandum of Understanding. Thus there is no top authority within this community. Management in GridPP does not rely on vertical lines of command, and while there is an extensive structure of management boards, committees, and technical groups, they serve more as communication channels than hierarchies of authority. Managerial roles in the collaboration serve most of the time as representatives, spokesperson, or coordinating facilitators, and when decisions (e.g. financial planning) have to be made centrally at the PMB, such decisions are open to scrutiny by the full collaboration.

Most importantly, there is enormous respect to the technical knowledge at the grass-root level. As one previous group leader stated: “there’s no strict hierarchy (...) the group leader doesn’t get to say what to do. In fact, I was extremely socialist at (in my role as a group leader) ‘cause we recognize it’s the younger people that are much smarter and they’re going to be making the papers … So it’s kind of a federation, club… of smart academics who all want to do it and everyone trusts each other to do the best they can for the experiment. And that fundamental trust drives our particle physics group. [P1]” This means that technical decision-making in this environment does not stem from social arbitrariness or political power. Different solutions often compete with each other within the collaboration for a while until one of them wins by forming more alliances or others die in a natural course e.g. due to technical failures, low up-take, lack of funding or other circumstances. The technical systems then emerge from “contests of unfolding” (Knorr-Cetina, 1999), so that the winning technology emerges as a fact of nature. “The cream comes to the top. Things that work win out and that’s how we worked it. (...) Nobody knew what the right approach was so you try several approaches and some win, some lose [P3].”

This is not to say that politics does not exist, but that they are dispersed, sidelined, and the influence of powerful actors often dissipated, or contingent on technical judgement. For example, an interviewee commented that “nobody, no matter, even if they were the most politically powerful person in EGEE, cannot force a broken piece of software to be deployed, because they will lose their political influence if they do that. [P2]”. The emerging system is often compared to a combination of “ecosystems” of different technical components, and the process for certain technical solutions to win out among parallels is considered a “natural selection”, in which multiple vested interests and technical alliances compete.

**Planned Agility**

While improvisation is one way of coping with complexity and uncertainty, planning is certainly not absent. Gantt charts and schedules are produced for bureaucratic reasons, considered no more than “fictions” since particle physicists understand too well that things don’t normally happen according to a plan. This does not however mean that they do not believe in planning. Indeed, GridPP has a set of milestones that are set against the milestones of the LCG, and they constantly measure their performance against the short, medium and long term goals. Considering GridPP as in its essence “experimental” and undertaking “green-field research”, the PMB focused on supporting (and justifying) change as their minimal planning process. “We wanted to establish the fact that we had the right to change our deliverables. So we set up this project map and we set up the formality of change forms. So this was to formalise our freedom to change the project … yes, we had a set of milestones but you know, we had a mechanism to change them because we have to be responsive. [P3]”
Although schedules are constantly moving in a flux, the project seeks never to lose sight of where they are and where they are heading. While there is not a detailed pre-established plan so that everybody knows what to do at any one time, there is always some form of plan to carry the project forward, even though such a plan is emergent and has to be laid out in their day-to-day sensemaking and actions. In other words, there is a plan to improvise, routinized processes to stimulate improvisation, and routinized observation of their own improvisational activities, without planning the content of improvisation in advance (Miner, et al., 2001). As one of the technical coordinators described, with an extended metaphor “We are in a foggy valley with a goal that we are roughly marching towards and sometimes frankly you go forward and discover, oh, there is a big blooming river there I can’t get over, I have to go round a bit and find the bridge….I think you… need to keep enough of an idea of the general direction which represents progress, and the very specific goals which advance you… You need your head in the clouds to see the big picture, but you very much need your feet on the ground because you have to put one foot in front of the other, and day to day we keep putting one foot in front of the other … and different people, depending on their role in the project are more oriented towards the ultimate goal or more oriented towards the little concrete footsteps that need to be taken...[P2]”

Reflective Spontaneity

The way particle physicists do computing can be said to be “amethodical”, highly pragmatic and improvisational. “I think the people who come from a physics background are ultimately more pragmatic in computing. They see the computing as a tool to get a job done. And if it requires you to wrap sellotape around it to get it to work, then they will wrap sellotape around it… the physicists are happier with an ad hoc solution just to get the job done and push them through. [P2]” Another senior member in LCG comments, “computer scientists will put together the most elegant thing in the universe, but it will never work… Physicists will come up with the most hacked solution in the world... but it will work [P4]”.

On the other hand, seemingly spontaneous practices at the low level are balanced by a level of reflexivity maintained by continuous and extensive communication flows. Particle physics collaborations are managed by what Knorr-Cetina (1999) refers to as “a fine grid of discourse”, channeling individual knowledge into the collaboration and providing it with a sort of “distributed cognition”. This web of communication includes a complex structure of boards, committees, and working groups which are regularly holding meetings. One of the most important methods is the online virtual meeting. For example, the Project Management Board meeting takes place every Monday online where they discuss the status quo of the project and make action plans. The Deployment Team meets online on Tuesdays where they discuss technical issues. There are also many other meetings taking place virtually or face-to-face during the week. Wikis, webpages and blogs are consultation points in the meetings. More importantly, members of GridPP subscribe to various mailing lists which carry constant exchanges of up-to-date information and emerging solutions.

Such extensive communications embody mutual monitoring and proactive sensemaking. A significant part of GridPP’s activity lies with monitoring, accounting, and making sense of the behavior and performance of the system. Targets of service levels and regular data transfer exercises are used to test the reliability and robustness of the system, in terms of both hardware and software. Indeed, much GridPP debate revolves around the results of tests and monitoring statistics. And interpreting the statistics is not straightforward or free of controversy. It is common to hear comments like “we have to understand what is causing this phenomenon” or “find out what is behind the data”.

In other words, retrospective sensemaking is an inherent and natural component in the process of system development. There is a “humming” of the collaboration “with itself, about itself” (Knorr-Cetina, 1999), which maintains a constant collective reflexivity, as “the monitored character of the ongoing flow of social life” (Giddens, 1984). Nevertheless, even though the project is highly transparent (e.g. all minutes of PMB meetings are published on the website), there is insufficient documentation due to fast changes in the technical system, rendering knowledge and expertise embodied in key experts rather than explicitly available. Thus personal contacts are crucial in this environment, making it difficult for new comers to obtain information or to navigate themselves in the project easily.

Collective Individuality

The improvisational practices in GridPP are partly required by the innovativeness of the project, and partly arise from the nature of this community. Most members in GridPP are particle physicists or have a particle physics background. The particle physicists are a group of highly intelligent and independent thinking people (Traweek,
With the high level of trust, people generally enjoy a high level of autonomy at work, usually without clear instructions or strict supervision. “This environment is based on, if you want, charismatic leadership and people doing things relatively independent but also having the freedom to do them, and not having to report every two minutes on what they are doing” [P6]. Individuals in the project will try to solve a certain problem, develop a certain package, write a certain document, not because their line manager told them to, but because they felt that it was something useful to do for the whole project. “If you get someone who is very good, you don’t over-manage them. You let them get on with it. And I think people feel that the management involved in software, formal software engineering end up hampering the developers rather than really helping them” [P7].

On the other hand, with members of the collaboration based in disparate institutes, it is important to develop an emotional bond among individuals for the project to function collectively. The deployment team provides a very good example. “We have to work very well together as a team, in order for GridPP to be successful. And ... it’s quite a complicated structure - there are multiple channels of communication, some of which are duplicated some of which are contradictory, and there are all sorts of ways in which information flows. And anything that you can do to oil the cogs of the machine is going to help. And one of the things that is going on very well in GridPP is the cohesiveness of the deployment team. And I think for us to socialize together is a very important thing” [P2]. “Going to the pub” together when they meet, for example, is one aspect of it. “It fosters a bond between people... it helps a lot I think because many aspects of working in this project are frustrating because it's so large. And so if you can go out together and you can identify the problems and let out steam about them, I think that's actually a very important social function of these meetings” [P2].

**Anxious Confidence**

GridPP is under great pressure to be ready for the LHC switch-on in the near future, as well as the pressure of showing the UK in a good light among the worldwide particle physics communities. The collaboration is committed, engaged, and is always “just about” on top of things. They seem to be constantly fire-fighting, discovering problems, managing crises, and negotiating solutions. Nevertheless, almost everybody we asked in GridPP showed a firm belief that the Grid will work; it may not work perfectly, but it will work. There is a high level of confidence despite the sense of urgency and disorder on the surface. Where does this confidence come from? We think this is in part because of the high level of intelligence and experience prevalent in the community, namely, confidence in individual and collective competence, and in part in the history of computing success in particle physics. CERN for example accepted the problems of working with pre-production supercomputers from the days of the CDC 6600 through to the CRAY X-MP (Jones, 2004). Later they pioneered work on the Web (Berners-Lee and Fischetti, 1997), shifted early to use Open-source (Linux) server-farms. Grid computing, it seems, is only another computing waypoint on the route to the truth about the universe.

Another source of confidence resides perhaps in physics’ formative context of “democratic meritocracy”. While GridPP employs people from other fields, the majority are from this “elite science” (Traweek, 1988) which is highly competitive to enter. Indeed, the nature of experimental particle physics work is quite distinctive. The experiments that underlie the field require very large capital investment beyond the possible budgets of most individual national science programs, or their human resources (Traweek, 1988). Intriguingly, such experiments are achieved within organizational structures which have very few formal lines of authority, working as collaborations of members of various institutes with different (though broadly aligned) aims. With established traditions and accumulated
experience, working in large scale, globally distributed collaboration is almost “second nature” to particle physicists. Therefore, when asked how likely LCG will succeed a technical coordinator stated firmly, “I am very confident in the abilities of the people in the project, of the focus of the project...on the goal, of our ability to work, together as a team in the places where that’s necessary... and we will do it!” [P2] Or more simply, “I have seen it (this kind of project) worked before... and I know where we are now... It (the Grid) may not be all singing and dancing on the first day, but it will more or less work...[P8]”

Analysis: Agility, Improvisation, or Enacted Emergence?

To recap, we started by examining the debates over system development methodology and between methodology-led development and the “amethodical” movement including agile methods. Then we derived a set of conceptual constructs from the literature of organizational improvisation, and used them to make sense of how Grid technology, a new type of computing system, is being developed in the particle physics community. In this section, we will reflect on the case material and draw some implications for the discourse of systems development.

The diverse dimensions and subtle implications revealed in our investigation of organization improvisation and the analysis of the GridPP study seem to stretch far beyond the concept of agility. Rather than stressing on just flexibility, creativity, and ad hoc activities, the literature of organizational improvisation provides a lens of seeing systems development practices in paradoxes, namely, in the form of dynamic tensions. To capture the sense of dynamic duality between the paradoxes, we propose to use “enacted emergence” to portray systems development practices that are both constructive and emergent. This concept is distinct from the “linguistic view of emergence” which Truex and Baskerville (1998) adopted to highlight the “emergent nature of IS requirements”. In contrast to their argument that emergence has no connection to “deep structures”, we do believe that there is a connection in the sense that ‘structure’ itself is emergent which displays characteristics of stability and continuity over time and space. This is not necessarily to say that such structures can be captured and modeled as traditional systems methodology attempts, exactly because it is emergent. Nevertheless, emergence can be enacted and supported.

The “enactment” perspective proposed by Weick (1977) suggests that organizations “construct” the environment before they “respond” to it or try to control it, and this is a process of interacting and sensemaking. Enactment embodies the sense of action and creation. Indeed, Weick believes that “people invent organizations and their environments and these inventions reside in ideas that participants have superimposed on any stream of experience (ibid. p. 196)”. On the other hand, “emergence” has a much more evolutionary connotation, implying that new properties arise from the interactions of existing elements. We will further examine this concept below.

First of all, enacted emergence entails evolutionary elements. Agile methods can be considered as stemming from the tradition of an evolutionary approach (Dahlbom and Mathiassen, 1993) to systems development in which developers “have to interact with the environment, accept the openness of the problem and the system to be developed, take into account the preferences and beliefs of problem owners and users, deal with the economical and political climate of the project, and keep in step with the changes in the kind of technologies on which the project is dependent” (ibid.). These seem to be fairly accurate descriptions of what has been observed in our study. Indeed Dahlbom and Mathiassen (1993) argue that in such approaches systems developers act like scientific investigators who make interpretations and decisions of a “hypothetical” nature, without knowing for sure whether they will prove useful or not. Moreover, being technical experts, system developers also have to be teachers and facilitators, emphasizing the communication and interaction with problem owners and users. In other words, the evolutionary approach is largely about enacting sensemaking processes, especially to develop an understanding of the environment – this is typically crucial when the organization is faced with great complexity and uncertainty. Weick describes it as an enactment process which encompasses generating “raw data”, bracketing and labeling them into “information” to serve as basis for future actions. The understanding or “construction” of the environment emerges from active interactions with the environment – although Weick would argue that the boundary between the organizations and the environment is blurred. Therefore, while emergence indicates unpredictability, it also implies connection to history and past experience.

Expanding from this notion, enacted emergence presents an unfolding lens on the organizing and practices of systems development, as illustrated in Table 3. The improvisation-paradoxes juxtapose seemingly bipolar elements of improvisation, which can be explicaded as between chaos and order, practices and structure, agility and planning, individual and collective, anxiety and confidence, constraints and creativity, and present and the past. Table 3 reassembles these elements to illuminate the concept of enacted emergence. The arrows in between the paired
concepts represent mutual constitution rather than exclusive oppositions. If we define enactment as “active engagement”, it can be argued that enacting elements in one side of the table may contribute to the emergence of those on the other side, and vice versa. For example, order can emerge from seemingly chaotic processes. Lanzara (1999) suggests that system design is emergent, and that because systems built by bricolage are loosely connected and incoherently assembled, the constituent components can be partially reworked without causing too much disruptions to the whole system, hence maintaining stability and continuity. On the other hand, enacted stability at a certain level also provides the safety-net for individuals to improvise. The similar dynamic applies to the rest of the paired concepts in Table 3. This reciprocity and mutual reinforcement can be understood as embedded in the duality of structure and agency (Giddens, 1984), where structure is both the medium and outcome of agency.

Our study of system development “in the wild” of this large scale, distributed, collaborative project, and its analysis through the concept of improvisation has suggested that systems development is a form of enacted emergence. For example, the Grid project arise from the need for a tool to analyze data from the LHC; the organizational memories of the particle physicists who have successfully undertaken innovative projects such as the large scale experiments they have built; and from a history of doing cutting-edge computing, especially in the last few decades as it is required to do data analysis. Moreover, it also emerges from an enacted tradition and culture of

<table>
<thead>
<tr>
<th>Enacted Emergence</th>
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<tbody>
<tr>
<td><strong>Environment</strong></td>
</tr>
<tr>
<td>complexity, uncertainties, visions, pressure, risks</td>
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<tr>
<td><strong>History</strong></td>
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<tr>
<td>organizational memory of improvisation, history of innovation,</td>
</tr>
<tr>
<td><strong>Chaos</strong></td>
</tr>
<tr>
<td>trial and error, improvisation, <em>bricolage</em></td>
</tr>
<tr>
<td><strong>Order</strong></td>
</tr>
<tr>
<td>continuity, stability, resilience</td>
</tr>
<tr>
<td><strong>Individuals</strong></td>
</tr>
<tr>
<td>competent, confident, creative, committed, pragmatic</td>
</tr>
<tr>
<td><strong>Collective</strong></td>
</tr>
<tr>
<td>shared goal, trust, hanging out, emotional bond, facilitative leadership, aesthetic of imperfection</td>
</tr>
<tr>
<td><strong>Planning</strong></td>
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<tr>
<td>broad direction, retrospective sensemaking</td>
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<tr>
<td><strong>Unfolding</strong></td>
</tr>
<tr>
<td>democratic debates, spontaneous actions, natural selection</td>
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<tr>
<td><strong>Practices</strong></td>
</tr>
<tr>
<td>tinkering, innovation, invention</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
</tr>
<tr>
<td>collateral, de-layered, democratic, communicative</td>
</tr>
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Table 3. Systems Development as Enacted Emergence

strong commitment with a long term vision, pragmatic problem-solving and tool developing via improvisation and *bricolage*, as well as respect for individual creativity and technical expertise. As one of the interviewees explained, “I think we have somehow learned how to organize things, at project management level and how to get things, to take the pragmatic view and to, faced with a problem, how to get from here to the solution... not just in GridPP but in building hardware and building detectors. All sorts of setbacks occur and you have to find solutions. Certain technology doesn’t work, the company cannot provide what you want. So I think there’s this background in problem solving and project management and the sort of pragmatic approach. [P5]”

Such enactment of past experience is clearly demonstrated in that the GridPP collaboration is designed to model onto a particle physics experiment. “I mean the original proposal for GridPP was set up deliberately to make it look like an experiment. This whole idea of a collaboration board for instance, comes out of the idea of what an experiment does... And again, in an experiment you would have somebody in charge of resources, probably at CERN in the case of the LHC experiments. You’d have … [a] project manager and you’d have a spokesman for the experiment ... [P5]” The tradition of large scale collaborations (e.g. the Atlas experiment, one of four at the LHC, has over two thousand members across the globe) working on a distributed basis is well established and provides a solid basis for the organization of the Grid development project. “…in a sense I’m not sure there is anything special. I think it’s the way we work is probably, it’s the thing that makes it work, makes GridPP work... that’s somehow related to the fact
that we have a background in working in large teams and working with different sorts of people, different nationalities, different categories of people, students, technicians, engineers, physicists. [P5]"

The existing respect for technical knowledge and individual freedom to improvise and innovate are sustained, coordinated and protected by drawing upon, or enacting certain organizational configurations in the particle physics community. These independent thinking, geographically distributed individuals are capable of working well together partly because they share the same long term goal at work, and partly because they see it important to “hang out”, whether in the cafeteria at CERN or going to pubs in the UK, which inspires trust and cooperation. Moreover, “clusters of expertise” are circulated by an extensive – almost inefficient and redundant from a corporate perspective - structure of management, which serve as communication channels rather than authoritative centers. Management serves to facilitate and coordinate, not to dictate and impose. Therefore persuasion and influence are usually the only effective means to achieve results. In other words, rather than having a “super mind” behind the scene making a master plan, the project almost works as a “collective mind” (Weick and Roberts, 1993), collecting and circulating information from different lines of work, performing sensemaking and decision-making collectively. Thus distributed cognition emerges from interactions of the components.

The selection of technical solutions serves as another good example of enacted emergence in this case. Although the central piece of Grid technology, the middleware, is developed centrally by the EGEE project, it is modularized and each of the components are prototyped, released, deployed, tested, and improved in an evolutionary manner. There are often parallel technical solutions in the project, such as some components of the middleware, or other software packages developed locally to help deploy, monitor, or manage aspects of the system. The Grid environment in this project consists of a mixture of “ecosystems”, in which multiple technical solutions compete until one of them win out and the others “die a natural death”. Political influence and vested interests are also involved in the competition, but do not dictate the individual ecosystems. While such natural selection might be seen as a waste of resources, in this community it is believed to be the appropriate way to find the best solution, and indeed also a way to offset risks of technical failures. In other words, decision making is not centralized or top-down, but an unfolding process, emerging from the activities of trial-and-error, prototyping, and continuous improvement, which are actively enacted processes.

Conclusion

In this paper we make three contributions.

First, we have summarized and introduced the concept of improvisation from organizational science to system development. The majority of studies on agile methods are prescriptive, in other words, giving advice on what to do. There is, however, little effort on trying to contextualize such advice. Without a sound conceptual basis it is very hard to justify the generalizability of those principles that are proposed as methods to be applicable to the heterogeneous environments. System development methodologies, as a set of distilled principles, are only relevant when developers, as knowledgeable actors, draw upon them in their day-to-day practices. They are the medium and outcome of situated system development practices, which are embedded within organizational cultures, institutional conditions, and environmental constraints. Therefore, systems development methodologies cannot be discussed in a vacuum, but should be evaluated in terms of their applicability within a specific context.

The literature on organizational improvisation provides an appropriate conceptual basis for this paper as the concept of improvisation has been thoroughly investigated, explored, and applied against a multiplicity of contexts and along a variety of dimensions in the literature. The conceptual framework that we derive from the literature on organizational improvisation consists of six paradoxes, which clearly manifest themselves in the case material. This is because, like most other things in life, it is not a choice of either/or, but a balance between the opposites. Agility does not mean a total abandonment of planning, order, or design. Rather, it should embody a deliberate or natural mixture of structure and improvisation, order and changes, intentionality and flexibility, spontaneity and reflexivity. Moreover, for agile group performance, there should also be balance between collectivity and individuality, between ‘pushing the envelope’ and providing ‘the safety net’ for mistakes. It is essential to have the right mixture of individual propensity and competence for improvisation, and the trust, support, and shared goal within the group to maintain the cohesiveness and direction of system development.

Second, we have presented a case of system development “in the wild”, demonstrating how improvisation is practiced in a large scale, collaborative, and distributed Grid initiative. We have observed that the Grid system unfolds in a constant negotiation and mediation between methodical and amethodical, planning and improvisation,
success and failure. The framework of paradoxes of improvisation allows us to examine system development practices in the project regarding aspects that are often pushed to the background in discussions of system development methodologies, such as environmental conditions, individual skills, organizational structure, communication pattern, and interpersonal relationship. While science itself is often seen as consisting of hard and cold methods and facts, the way science is organized, including the way tools such as the computing infrastructure are developed, is more like an “art” of improvisation – visionary, passionate, innovative, agile, and emergent. More importantly, the case demonstrates that in real life, improvisation can not only be seen as skilled individual performance, but coordinated group performance. Most studies of improvisation have stated that it is easier performed in a small group, such as a jazz band. Our case shows that it is possible in a large group, when the “ambience” is right. This style of distributed collaboration has been developed in the experimental particle physics communities over the last few decades as experiments have grown to be multinational collaborations with thousands of members. On this basis, the management of GridPP, being mostly particle physicists themselves with a deep understanding of this culture and community, coordinate the Grid collaboration in a similar style.

Third, drawing upon the conceptual framework of improvisation and the case material, we propose enacted emergence as a type of systems development, which is observed in the particle physics Grid project. Words like “agility” or “improvisation” seem to highlight only one end of the opposites. They remind us of elements of flexibility, spontaneity, creativity, murkiness, but disguise the other end which provides discipline, order, cohesiveness and direction or history. We suggest that the key of successful improvisation in systems development is in fact the duality between structure and agency, namely, the enactment of certain structuring properties may actually enable a wider space for creative agency, while reflexive monitoring of the agents and the emotional ties formed by trust and shared goals give rise to order, continuity, and stability.

To conclude, the paper has revisited “amethodical” or agile system development, and provided it with a conceptual basis from organizational improvisation. The analysis on the empirical study of a complex project of systems development allows us to reflect and further develop the improvisation-paradoxes to an enacted emergence process to characterize agile systems development. In a sense, the case material presented in this paper is quite unique and very different from system development projects that we normally observe in most organizational settings. GridPP is part of a multinational project which constitutes a big science initiative, with multiple stakeholders ranging from the EU to national research councils. It does not take place in a business setting but in a scientific community. Commercial interests and influence are present but by no means the driving force. GridPP has a relatively well-defined goal, which points towards not only potential breakthrough in physics science, but also a global innovation in computing infrastructure. The scale of the global project, the amount of financial and human resources invested, and the potential impact on the outside world, especially on the scientific communities, are all quite exceptional compared to other systems development projects. This means the implications that we draw from this study may not be directly applicable to projects that we usually encounter, especially those in the business environment. Nevertheless, this does not undermine the value of our research. Sunzi’s Art of War, written almost two thousand five hundred years ago on military tactics and strategies, is found to give excellent guidance in the modern day commercial world; so in-depth study of extreme, ancient or unusual circumstances can often shed lights on our daily practices. This paper is also part of a hermeneutic process to explore and unpack some of the interesting themes in Grid development. As mentioned earlier our research is ongoing and there will likely be further findings and further interpretations of the project under study, which may supplement and expand our current understanding. We believe there is much to be learned in the case of the construction of the particle physics Grid, and this paper is an effort to interpret and communicate what can be learned.

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