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Artifacts that organize: Delegation in the distributed organization

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ABSTRACT

A great deal of research on geographically distributed organizing focuses on communication among members; however, in the face of increasingly large, complex and interdependent infrastructure, scholars must also examine instances of technology-supported coordination that function by replacing rather than enhancing human communication among organizational members. Central to this are complex processes of *delegation* – in which organizational work and agency are passed back and forth across the shifting line between “social” and “technical” elements. Building on work in the sociology of science, this paper extends the concept of delegation and applies it to thorny questions around the work of sustaining organization over time. We explore two examples from the Open Science Grid (OSG), an initiative that distributes computational resources to geographically dispersed and otherwise loosely coordinated research teams. Our first case is one of successful delegation, as automated access to resources is extended to a new group of distributed scientists. We then turn our attention to a case where the process of delegation breaks down, revealing the usually invisible work needed to sustain “seamless” integration. As these cases show, delegation is complex, fragile, and central to the nature of contemporary organizing. Specifically, delegation: 1) reconfigures the organization of work; 2) transforms how outcomes are accomplished; 3) redistributes responsibility for organizational decision-making; and 4) shifts the visibility and invisibility of both actors and their work.

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1. Introduction

To date, the vast majority of research on distributed organizing focuses on the facilitation of human communication across geographic and institutional divides. While many important findings have been developed from this research area, such a view of organizing is incomplete, as it fails to account for a key emerging tendency: the increasing development and deployment of collaboration technologies *not* for the purpose of facilitating richer and more effective communication between individuals, but rather to lighten the amount of social interaction necessary to sustain organization. In the development of these highly automated information technology (IT) systems, person-to-person or team-to-team contact is seen as an unnecessary hindrance. Instead of fostering human interaction, tools and systems are explicitly built to minimize commitments to coordination through communication, nominally freeing time for other tasks.

The introduction of such information technologies challenges our understanding of organizing at a fundamental level. Organizations in this context can no longer – if they ever could – be examined solely or even primarily as social networks sustained by communication in the traditional sense. In the analysis offered here, rather than viewing IT as a prop or corrective tool to special problems of distance, we place tools and technologies themselves as the central sites and carriers of key organizational properties and functions such as trust, access, and resource distribution. We start from the concept of *delegation* drawn from Actor–Network Theory (ANT), principally from the work of Bruno Latour and Madeleine Akrich (Akrich & Latour, 1992). Broader than the common usage of delegation in organizational theory (referring usually to the allocation of authority and responsibility downwards in the organizational chain), the ANT conceptualization of delegation starts from the premise that human and technological work are interchangeable—and that choices across this “divide” carry deep and often overlooked consequences for organizational life and performance, establishing new configurations of technology and human work. As such, technical decisions are rarely purely so nor are “social” moves, in these contexts, devoid of technical content or consequence. The language of delegation calls these choices and their consequences to the fore, and marks a contribution to ongoing organizational and social scientific efforts to think the “technical and the social together” (Leonardi & Barley, 2008; Orlikowski, 2007), including around such key organizational questions as trust (Knights, Noble, Vurdubakis, & Willmott, 2001), resource distribution (Lanzara & Patriotta, 2007) and coordination (Pollock & Williams, 2007). Such trends not only raise new research questions and require us to shift our empirical focus; they also demand that we rethink the relationship between organizations and technology.

1.1. Delegation, technology and the infrastructures of science

Delegation draws on a seemingly obvious insight regarding the interchangeability of human and technical work: put simply, that actors pursuing goals in the world may do so through technical or social means – or both. For instance, hotel managers seeking the return of room keys may remind, cajole, and threaten their patrons, or they may simply attach a weight that makes the key hard to forget and unpleasant to carry. Similarly, building owners seeking to ensure that doors are properly closed may install a doorman or an automatic door closer—both entities working to close the door after forgetful patrons have left the building (Latour, 1988). Acts of ‘technical’ delegation function by altering the material world—guiding and constraining future action through the shaping effects of the built environment. Acts of ‘social’ delegation seek to constrain future choice by more traditionally human means—introducing or maintaining human intermediaries at the heart of ongoing choice and interaction. In practice the distinctions social and technical fade in the face of complex assemblages. The half-life of such material rearrangements may prove to be surprisingly long: individual acts of delegation often initiate chains of development that cascade forward in time, often outliving any initial and short-term rationales. Bruno Latour uses this feature to explain durability of “the social” through time, locating its stability in the “missing masses” of artifacts, equipment, and material resources that most social (and we would add, organizational) scientists have historically neglected (Latour, 1992).

Our immediate concern is a particular kind of large-scale virtual organization (VO),¹ becoming increasingly common in corporate, governmental, and academic sectors. Specifically, we examine examples from the Open

¹ We do not wish to overburden the term virtual organization. In fact, we have a great deal of trouble with how it has been conceptualized in the literature (see the next section and the Discussion). However, VO is now also an actors’ category: the people we investigate in this paper self-identify as members of a virtual organization. For the purposes of this paper we use the term as a short hand for geographically distributed organizing activities.

Science Grid (OSG), a scientific research network built with the goal of facilitating resource and information sharing among thousands of scientists from dozens of academic institutions and national laboratories. Organizational scholars often study geographically distributed research teams in sectors, such as biotechnology (Owen-Smith & Powell, 2004) or global finance (Knorr-Cetina & Bruegger, 2002). Yet, there is also much to be learned from the multi-billion dollar scientific VOs assembled to study topics like global climate change, the Human Genome Project, or particle physics' Large Hadron Collider. Just as scientists at the European Organization for Nuclear Research (CERN) created the basis for the World Wide Web (WWW) in order to share their research, today's 'big science' projects are actively developing and deploying what may become tomorrow's commonplace collaboration platforms. Scientific VOs provide insight into one possible future of organization in our increasingly networked and globalized world – one in which interpersonal communication is seen as a hindrance that can be successfully delegated to automated technologies.

Networks like the OSG are simultaneously technologically rich computational systems and organizationally laden social networks, presenting a robust and generative site for scholars seeking to understand emerging organizational forms. Furthermore, the OSG is especially valuable for those wishing to study novel IT, as scientists have developed many now commonplace breakthroughs (i.e. the WWW) in the course of performing their research. Historically, science has always been a pioneer of the virtual: from early modern times, science has worked as a highly distributed enterprise dependent upon concrete places, institutions, and people as well as material sets such as equipment, samples, and textbook figures. The sociotechnical qualities of science have been linked through various forms of information infrastructure—ranging from 18th century networks of post, print, and transport to today's advanced computational forms. As a number of sociologists and philosophers of science argue, it is these information infrastructures – not illusory accounts of a “unified scientific method” – that have set the sciences apart from other ways of producing and organizing knowledge (Bowker, Baker, Millerand, & Ribes, 2010).

Moreover, under the language of 'cyberinfrastructure' and 'eScience,' networks like the OSG represent an ongoing shift in the organization of science, spurred by science funders and planners nationally and internationally. Those individuals in favor of 'eResearch' efforts seek to leverage computational resources to advance the scale, nature, practice, and efficiency of science (Atkins, 2003; Jackson, Edwards, Bowker, & Knobel, 2007; Lawrence, 2006; Lee, Dourish, & Mark, 2006; NSF, 2007; Ribes & Lee, 2010). Similar in spirit to large-scale enterprise resource planning (ERP) systems in the corporate world (Boudreau & Robey, 2005; Volkoff, Strong, & Elmes, 2007), high performance eScience networks connect geographically and institutionally disparate researchers into a single networked computer 'Grid' (Foster, Kesselman, & Tuecke, 2001). Orders of magnitude larger and more complex than most collaboration platforms, they utilize dozens of storage centers, whereby thousands of terabytes of data are collected, held, analyzed, and shared across research sites, institutions, and disciplinary fields.

In the sections that follow, we elaborate the notion of delegation sketched above. Additionally, we highlight both successful and failed instances of delegation by analyzing two ethnographic and archival case studies. Together, these cases showcase the consequences of delegation in large-scale distributed organizations, and in turn, the important and critical role this concept plays in understanding how technology is redefining what it means to collaborate and organize.

2. Organizing as communication (and then technology)

Viewed broadly, in the most prominent approaches to distributed organizing, the carriers and connection points of organizational life are assumed to be primarily human—augmented but not supplanted by tools and technologies. For example, as DeSanctis and Monge state: “The virtual organization provides a metaphor for considering an organization design that is held together, literally, by communication” (DeSanctis & Monge, 1999, p. 694). This scholarship also includes many canonical studies of collaboration technologies, for example, around efforts to understand and enhance remote collaboration through tools and applications ranging from video conferencing, to email and listservs, or from shared scheduling systems to an array of project management tools. Olson and Olson (2000) offer a widely cited synthesis of this work, emphasizing the negative effects of distance on organizing, including reduced awareness of co-workers (Dourish & Bellotti, 1992; Fussell, Kraut, & Siegel, 2000; Kraut, Egido, & Galegher, 1988; Nardi, Whittaker, & Bradner, 2000), diminished trust (Jarvenpaa, Knoll, & Leidner, 1998; Jarvenpaa & Leidner, 1999; Nardi, Whittaker, & Schwarz, 2002), and extra delay in performing tasks (Herbsleb, Mockus, Finholt, & Grinter, 2000, 2001). Research topics in this formulation emphasize

communication content, structure and effectiveness, tradeoffs between electronic and face-to-face relationships, as well as the use of communication in the formation of organizational identity (DeSanctis & Monge, 1999). Tools that support the distribution of collaborative work may therefore make direct and important contributions to organizational innovation and effectiveness, without supplanting or reformulating the nature of social ties.

In such approaches technologies function as props or assists to the sociality of distributed groups, supporting or restoring (rather than replacing) the essentially social ties binding individuals and groups within formal and informal organizational structures. This scholarship places geographic and institutional distribution as the primary threat to the continued viability of the organization, and enhanced communication flows in support of formal and informal modes of sociality as the solution. Sustaining the organization looms as an ever-present difficulty—a challenge that can be mitigated but never fully overcome through the design and use of communication enhancing collaborative technologies. However, this research trajectory has yet to take into account the emerging trend for technologies themselves to actively sustain a geographically and institutionally distributed organization. We wish to challenge this implicit hierarchy, and open the possibilities for a more flexible understanding of the simultaneous roles people and technology play in sustaining organization.

Organizations seek to do more than facilitate interpersonal or intra-organizational communication: they have taken to heart the motto expressed by Hollan and Stornetta (1992) to develop organizations that support activity 'beyond being there'. In fact, we have found that many of the cyberinfrastructure and eScience projects we focus on take the next step and are specifically designed to minimize the need for human communication, whether face-to-face or computer-mediated: for example, by granting scientists access to federated data-sets or distributed computing centers without going through a human gatekeeper or administrative process. Such approaches have sought to improve the effectiveness of distributed organizing through the design of tools and systems that work to *encode* the sociality of groups by shifting key organizational processes and functions into the technological infrastructure itself. In this respect, delegation is similar to studies of organizational routines that take artifacts into consideration (Barley, 1990; Feldman, 2000; Nyberg, 2009), but shifts the analytic focus to how technologies can actively sustain patterns of interaction. Under this model, missing or weak affective ties may be made up in code by automating the workflows, models of trust, and norms of cross-organizational collaboration (Pickering & King, 1995).

In this vein, scholars of infrastructure have drawn our attention to the myriad ways in which technological systems are transformative of their work environments (i.e. shared data repositories, distributed computing, and digital visual representational tools). As Susan Leigh Star and Karen Ruhleder remind us, infrastructure is not simply a “substrate” upon which something “runs”; rather, it establishes and sustains particular types of relations and actions, while disabling others (Star & Ruhleder, 1996). Transformations in one facet of infrastructure percolate throughout an organization and must be locally managed and ‘tailored’ (Barley, 1990; Feldman & Pentland, 2003). At the same time, sinking organizational functions into infrastructures introduces new sets of technical actors with responsibilities for enacting (Fountain, 2001), maintaining (Ribes & Finholt, 2009) and repairing (Goodall & Roberts, 2003; Graham & Thrift, 2007) these organizational systems. Surprisingly, such findings have not been well incorporated into studies of distributed organizing to date.

We seek to draw attention to and to render researchable these very activities and technologies through the introduction of what we call delegation: defined here as the in-principle interchangeability between “technical” and “social” means for the accomplishment of organizational ends. Scholars must turn their attention to coordinated collaboration with alternate kinds of technologies and the (human) staff and technicians that support them.

2.1. Technology and technical work as actors in sustaining organization

This paper is not a call to ignore or diminish the importance of studying human communication or practice. Far from it, our own fieldwork takes such activities as the primary source of insight, as our two case studies will illustrate. The study of materiality and discourse should be considered together (Taylor & Van Every, 2000), and we do so with an eye on understanding how technologies act to sustain organization in conjunction with human activities of technological deployment and maintenance. As such, our research is neither techno-centric nor human-centric, but instead focuses on what Wanda Orlikowski has called *sociomaterial practices* (Orlikowski, 2007). We seek neither to tilt in the direction of a social explanation that elevates action to voluntarism nor a material explanation that reduces to determinacy (Leonardi & Barley,

2008). Instead, we trace agency as it is “handed off” across distinct kinds of actors: scientists, technicians, computers, or ticketing systems.

Delegation should be thought of as a *redistribution* of human work and social ties rather than a complete supplanting of them. A delegation approach draws particular attention to:

- *The reconfiguration of who or what does the organizational work, highlighting, for instance, the introduction of new (human and non-human) actors for purposes of sustaining collaboration;*
- *A practical shift in how organizational outcomes are accomplished; namely,*
- *The redistribution of responsibilities and authority for everyday decision-making and upkeep; and,*
- *The subsequent change in the visibility and invisibility of actors and their work.*

As an initial heuristic to explore the concept of delegation, we will draw on a revealingly banal case: the speed bump. As Latour (1992) As Latour notes, in French a speed bump is called a ‘sleeping police officer’. On the surface, the consequences of a speed bump are comparable to those of the police officer: slowing traffic. We can thus say that we have delegated to the speed bump the responsibility of regulating the speed of automobiles in, for example, residential areas. However, at a more nuanced level this delegation has changed four features of the activities associated with the speed bump.

First, we observe a change in who and what accomplishes the work of slowing down traffic: we have shifted from a human to a non-human technological actor. The speed bump does not need to be paid or fed, it does not take breaks, it does not have an eight hour-workday and it does not accumulate vacation time. It is also, in Latour’s vivid language, “relentlessly moral”: whether the driver is a tense employee late for work or an ambulance speeding toward the hospital, the speed bump remains indifferent to their purposes, indiscriminately slowing all automobiles.

This draws our attention to how slowing is accomplished. A police officer slows traffic by his or her presence and actions (a wave to a driver, or a ‘slow’ sign) and also by the implicit deployment of legal force: the threat of a speeding ticket. While still achieving a similar outcome, a speed bump operates differently. It slows drivers by an implicit deployment of physical force: the threat of damage to one’s car, an effect achieved by constructing speed bumps from harder stuff than police officers. In broad stroke, the consequences of the speed bump are comparably similar to the police officer, but the shift in the responsibilities for sustaining those effects is markedly different.

Turning our attention to the organizational and technical work behind the speed bump, we can observe how the network of actors is radically transformed. No longer is the police force, with its legal administrative apparatus, directly engaged in regulating speed on residential backstreets. Instead, the speed bump’s infrastructure is populated with technical actors: engineers, traffic planners, road-crews and their associated institutions of urban planning and maintenance. Sinking responsibility into infrastructure shifts work to new groups of technical workers. Delegation, then, is not elimination or a simple reduction of human work; it is a reconfiguration of the kinds of work and the time frames of their action.

Finally, this human and technological infrastructure is rendered less visible than that of the police officer: what remains is literally a bump in the road, becoming notable only upon breakdown when road crews interrupt the flow of traffic. Conveyed by this example – and in contrast to the focus of the communicational perspective – technology is more persistent, obdurate and unrelenting than human communicational work. Technology helps hold together an interactional order.

3. Delegation in action: the Open Science Grid

In the accounts that follow, we trace an act of delegation followed by a breakdown that reveals its organizational consequences (Geiger & Ribes, 2010, 2011). We first follow a team of scientists in initially joining the Open Science Grid (OSG). This initial moment of delegation is analogous to the construction of the speed bump: as these scientists developed new tools in order to get their existing software to run on the grid, traditional organizational issues of trust, accountability, and resource management were incorporated into the ‘middleware’. The case illustrates the ideal promises of delegation: reducing the communication and coordination work of scientists as they seek to go about their research while also highlighting up-front and often-forgotten forms of technical and organizational work. These are the sunken costs of delegation that all too often disappear in celebratory, idealized, or retrospective accounts of now-functioning systems.

The OSG (opensciencegrid.org) is a distributed scientific infrastructure supporting the computational activities of scientists. The goal of OSG is to bring together computing and storage resources from multiple campuses and research communities into one common, shared Grid infrastructure. Jobs on the Grid run on computing nodes distributed across the globe, and housed within heterogeneous institutions. For example, some minor sites only contribute a handful of computers to OSG, while others – like Fermilab in Chicago – have over ten thousand CPUs connected to the grid (Chadwick et al., 2008).

Sharing scientific data and computational resources is an organizational task that inevitably involves institutional negotiations and localized arrangements (Kellogg, Orlikowski, & Yates, 2006). However, the Grid-based approach aims to make such organizational work obsolete through its automated mechanisms. As developers of these networks argue, before the Grid, technologically-mediated distribution of resources operated on an ad-hoc model of authorization: each entity (a single user, a group, or an institution) had to make contact with another, convince them to share resources, establish an agreement on how the sharing would be done, and then find means to enforce the agreement. That is, while the Internet linked many research sites, collaboration was only possible *after* individuals had made contact and established idiosyncratic agreements for sharing resources:

with [pre-Grid] technology, not only must the data manager spend considerable time managing the process of data creation, but any user who wishes to access this data must engage in a difficult and tedious process that requires considerable knowledge of all the services and resources necessary (Bernholdt et al., 2005: 486).

What differentiates the Grid from its predecessors is the support for “seamless” and automated authorization that occurs before sharing can proceed.

Our second case highlights a later moment in the trajectory of delegation—following another scientific team *trying and failing* to submit a computational ‘job’ to OSG. These scientists already joined the Grid and invested the up-front organizational and technical work of delegation. Nominally, and normally, submitting a job is seamless, managed, scheduled and monitored by the Grid itself; however, in our second case, the submission process breaks down—revealing the human infrastructure of system administrators and technicians involved in ensuring that the Grid functions smoothly. In exploring an incident of breakdown, we reveal the required maintenance work, and the consequences for the shape and operation of delegated organizational work.

3.1. Delegating to technology

Much organizational negotiation and work must be performed in order for a new scientific team to join OSG. However, what makes delegation within OSG interesting is that the outcomes of agreements are subsequently incorporated into the software. This integration ensures that the next time a user accesses an OSG site, middleware software negotiates with the server’s access and authentication mechanisms instead of requiring scientists to wrangle with computer administrators.

Ana Damjanovic and her team of biomolecular researchers at the National Institutes of Health (NIH) and Johns Hopkins University are seeking to more accurately model protein folding in a water solution. But, such computer models introduce more variables, which require an exponential leap in processing power far exceeding what is available in-house. In 2007, they decide to address this problem by joining and drawing on the resources of the OSG.

The program Damjanovic’s team uses to simulate molecular dynamics is called CHARMM (Chemistry at Harvard Molecular Mechanics). CHARMM, is designed to run one simulation at a time on a single local workstation or mainframe. By interoperating CHARMM with the OSG “middleware,” CHARMM could run on dozens of different Grid servers at the same time. While this seems like a purely logistical issue, getting CHARMM to run on OSG required interacting with a number of protocols involving security access and resource provisioning. As each local OSG site maintains ownership over the resources they contribute, there is a complex web of authorization, configuration, and resource distribution mechanisms that must be negotiated. As Damjanovic’s team explains:

Achieving this was challenging because of issues with different hardware environments at the remote sites as well as with data locality and program control. A control mechanism had to be devised that would allow a researcher without direct access to Grid storage and staging resources to describe the

work that needs to be performed, define where the output data should be stored, and have that work be completed with minimal further human interaction... With such a large number of simulations that needed to be managed, automatic submission, monitoring, and resubmission featured by the grid executor became indispensable, not only to minimize the possibility of errors, but also to save the time that the researcher spends performing the simulations (Damjanovic et al., 2008).

Beyond maintaining local resource control, this decentralized permission system performs important Grid-level security functions, most notably, by vetting persons who want permission to use the Grid. Damjanovic's team negotiates access to the individual sites for CHARMM computations — one by one. As with resource sharing in any organization, this first request for access requires human-to-human negotiation; that is, each site of OSG makes decisions as to whether or not to support another site based on the hardware and software they are willing to provide and maintain. However, the goal of the OSG is thereafter to use standard protocols and certificate systems to automate all subsequent negotiations. This is an organizational act, as well as a technical one: once Damjanovic's certificate is on file she will (or rather, should) gain access to the resources she seeks. In the smooth operation of this system, neither the scientists nor the systems administrators have to act each time a piece of the simulation is to be submitted or approved.

As a now certified member of OSG, CHARMM's future requests for access to the distributed computational resources in OSG are largely delegated to technological components of the Grid itself. Jobs are submitted, broken down, distributed to multiple available sites, reassembled and returned in finished form without any overt or additional "human" negotiations. For Damjanovic and her group, the net result is a notably efficient and largely invisible process that "mask[s] the complexity involved in running on machines with different operating systems and architectures, managed by different software systems, owned by different organizations and located at multiple sites" (Natrajan et al., 2004, p. 386).

Joining the virtual organization turns out to be just as much an organizational task as it is a technical endeavor. However, once this barrier is passed, the trajectory and mechanisms of everyday work shifts. As this example shows, researchers on the "sending" end of an OSG job may have little to no relationship with (or even know) the facilities currently processing their data; conversely, local site managers have little knowledge or investment in the content of the computational jobs being processed by their servers. This ongoing circulation of jobs and sites occurs more or less "under the hood," attracting no more than the passive attention of human actors on both ends.

There is thus little recognizably "social" or "communicational" going on. More precisely, human-machine and machine-machine communications are ubiquitous, but not human-human communication. In this particular style or modality of collaborative science, human relationships are not the point. Jobs are submitted, and after some expected time period, returned complete. Computational resources are allocated and shared without any additional relationship or interaction between the providers and users of these resources. Jobs, such as Damjanovic's, flow into and out of sites leaving little discernible local trace.

While occurring largely beneath the radar of the human actors involved, science has been conducted and a collaboration of sorts *has* ensued. In line with the network's expressed principles, researchers have been "able to focus on the science, not on the Grid infrastructure" (unpublished, slide presentation on CHARMM/OSG). True to findings of scholars like Star and Ruhleder, infrastructural invisibility produces certain kinds of collaborative efficiency. For Damjanovic and the CHARMM researchers, the OSG has indeed "worked like a charm. All I had to do is initially submit my simulations... A month later, I had statistical analysis of lots and lots of simulation. No pain, and no babysitting" (Nahn, 2007).

The problem with this idealized vision of the Grid is not that it is a myth; in fact, these mechanisms increasingly work successfully—facilitating a kind of distributed scientific collaboration that was previously harder and more costly to sustain. Nonetheless, while explicit communication among scientists is reduced, any belief that the Grid's automated resource distribution makes social ties altogether obsolete is far too simplistic, and renders invisible the very activities that make the Grid possible. Within delegated collaboration, the human-to-human relationships re-emerge in those practices that *sustain* distributed organization.

3.2. Breakdown and maintenance: tracing the trajectory of a job

In order to make these humans-at-work visible, we trace a computational job that encounters technical difficulties with the authentication mechanisms that, when operating properly, automatically ensure that only

authorized users can run jobs to OSG sites. The fact that an information infrastructure regularly breaks down and requires maintenance workers is not surprising. However, from our delegation-based approach, we see that automated IT systems have a number of consequences, the most common being the introduction of new kinds of organizational actors, their new forms of authority and the changing levels of visibility for them.

Our second case follows scientists from the NanoHUB project, a virtual organization supporting nanotechnology researchers, in our case by providing computational cycles. NanoHUB is part of the OSG and, as with Damjanovic's team previously described, has gone through the process of integrating its scientific software with the OSG middleware and negotiated access to a number of sites via the certificate-based system. We join them farther along the delegation trajectory (they have already gone through the steps described in our first step): November 2008 to be precise, when the NanoHUB scientists submit a molecular simulation for OSG processing. The request goes directly to the University of Wisconsin–Madison's GLOW-ATLAS (site 4 in Fig. 1): a computing center built primarily to handle data from the particle physics experiments at the Large Hadron Collider in Geneva. According to the OSG's automated diagnostic platform, the UW–Madison GLOW-ATLAS site is fully NanoHUB compatible—able to run any NanoHUB simulations when the servers are not otherwise occupied with core particle physics local work.

Despite this fact (and as will only become apparent later), NanoHUB jobs sent to UW GLOW-ATLAS are routinely failing to run: there seems to be some sort of error with the authentication mechanisms designed to act as gatekeepers to the site's computational resources. In consequence, the automated authentication system at GLOW-ATLAS does not trust that the submitted jobs have originated from authorized NanoHUB scientists. The first indication of this problem comes in the form of an automated message sent to “Alex”—the primary application engineer and administrator of NanoHUB (site 2)—indicating that GLOW-ATLAS is not processing some of the NanoHUB jobs.

While trained in nanoscience, Alex is not a researcher, but rather, part of NanoHUB's technical support staff. It is his task to ensure that all of the eleven hundred NanoHUB scientists can seamlessly run their jobs on any of the compatible OSG computing facilities available. While the initial task of managing the computation of the job is the responsibility of the Grid itself, a cascade of further delegations is revealed in the face of a breakdown.

Here, as the distributed resources of OSG fail to compute the job, Alex is tasked with restoring the smooth functioning of the Grid. Alex attempts to troubleshoot on his end, but determines that the problem resides at GLOW-ATLAS. Instead of communicating with the GLOW-ATLAS site directly (site 4), he forwards the issue to

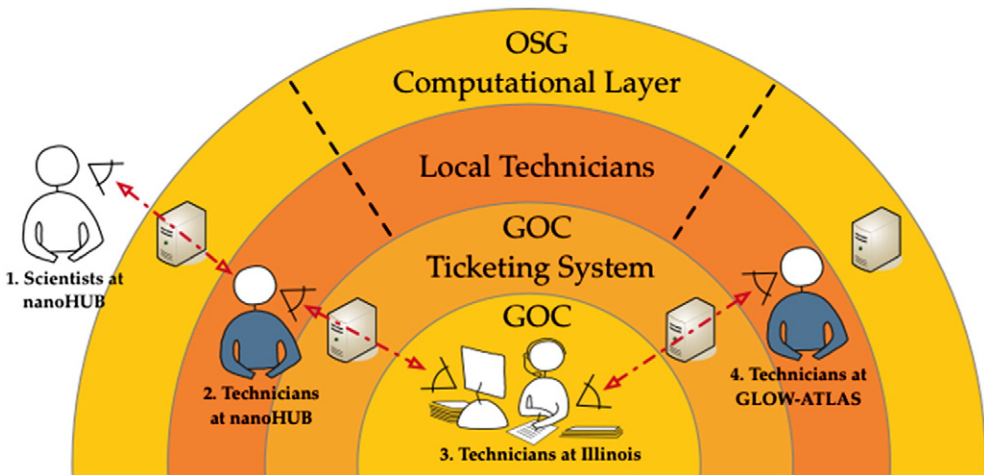


Fig. 1. The trajectory of the job begins with scientists at NanoHUB (1). The processing of the job across the Grid has been delegated to OSG's computational layer, but an authentication failure reveals a cascade of human and technological delegations: a local system administrator (2); a ticketing system for coordinating repairs; a team of technicians that manage errors at the global Grid level (3); and a local technician at GLOW-ATLAS (4). Arrows indicate the trajectory of the job, and also demarcate the bounded visibility of the heterogeneous actors.

the Grid Operation Center (GOC – site 3). Run out of Indiana University, GOC is the support center for the entire OSG network. Alex logs the error in an email, stating: “NanoHUB submissions repeatedly fail authentication at the GLOW-ATLAS site even though it is reported the NanoHUB VO is supported.”

Upon receiving his email, a GOC staff member creates a new ticket in the OSG-wide ticketing system, appending metadata concerning the individuals and sites involved with the issue. This information includes routing metadata for the ticket, as well as the name, email, and phone address for the GLOW-ATLAS administrator; because this issue occurs at GLOW-ATLAS, the ticket is sent to the primary administrator of that OSG site.

While Alex is ‘local’ to NanoHUB, GOC staff is geographically distributed. Alex’s work with the GOC is invisible to the NanoHUB scientist—interactions between Alex and GOC occur in the technical substratum of OSG as activities that remain blackboxed to the initial submitters of the job (the NanoHUB scientists).

Following no response from the systems administrator at GLOW-ATLAS, a GOC staffer responds to the ticket 3 hours later by succinctly stating: “US ATLAS, please respond to the following issue.” Nominally, this action escalates the issue to the level of the national ATLAS project – of which GLOW-ATLAS is a member – yet there is no response for over a month. Consequentially, another GOC staffer updates the ticket by writing that the “ticket seems to have stalled” and then asking the NanoHUB system administrator if “the issue still persist[s]?” Alex responds within an hour, confirming that it does.

These sorts of interchanges continue for several months in a similar fashion. Occasionally, the ticket is dropped for a month at a time; at other times, the ticket initiates short-term flurries of activity when a technician or GOC staffer checks in on it. Meanwhile, scientific work and computational modeling continue (1 in Fig. 1). Scientists are not complaining; their computational jobs are still being processed, only without drawing on particular cycles located at GLOW-ATLAS. Such problems are fully infrastructural; they do not (visibly) affect the ongoing activity of the scientists. The ticket is merely an itch, an unresolved issue, for the various OSG technicians to scratch.

Eventually, a GOC staffer takes it upon himself to seek outside help and requests that a software development specialist from an affiliate operations center enter the ticket. The staffer confirms that the automated authentication system is running correctly. He also suggests that the GLOW-ATLAS sites are “heavily skewed towards running CMS jobs” (another particle physics experiment at the Large Hadron Collider), which take precedence over jobs from other projects like NanoHUB. While they work out the technical details involved with running NanoHUB jobs on sites, the NanoHUB administrator points out that the initial problem, an authentication issue, has been identified and resolved. At 5:15 pm on May 22nd 2009 the ticket is closed, the GOC staffer thanks the NanoHUB administrator for informing the GOC of the issue, and our story ends – a full 6 months after it began.

This story showcases the complex nature and dynamics of delegation in practice. Even in the brief and simple example offered above, a number of nested delegations occur: 1) the NanoHUB scientists delegating the routing and management of their job to the Grid; 2) the delegation of trouble-shooting through the automated ticketing system; and 3) the multiple delegation hand-offs between NanoHUB, GLOW-ATLAS, and GOC staffers when the ‘seamless’ system fails. Some of these deepen or extend strategies of delegation along a common track or trajectory – for instance, automated systems delegated to other automated systems. Other strategies – such as calling in the (human) staffers to sort out the failures of the OSG’s routing mechanisms – amount to switching acts, shifting the modalities of delegation from objects to humans, and vice versa.

The NanoHUB case also illustrates the deep relationship between delegation strategies and levels of visibility that shape organizational activity. Within a virtual organization the size of OSG, even the technicians are heterogeneous and only partially visible to each other. The two local site administrators (sites 2 and 4) never communicate directly. Activities of repair are coordinated through the GOC, and their automated ticketing system. Sites 2 and 4 are also beyond the horizon of each other’s visibility. Invisible work is a relative phenomenon; as Star and Ruhleder remind us, one person’s infrastructure is another person’s daily routine of upkeep (Star & Ruhleder, 1996). The invisibility of the ongoing technical work needed to process a job is largely a benefit for the NanoHUB scientists, freeing their time to work on their science.

What one may view as a Grid breakdown, another views as routine activity: for the GOC technicians this is just another event or task in the queue (hence, the very existence of a ticketing system). This is synonymous to what Pollock, Grimm, and Williams (2008) refer to as a ‘passing regime’: “an organizational form that routinely and prodigiously uproots problems from their context, packages them up so that they are mobile,

and then shifts them around its geographically distributed sites in search of expertise that can provide a solution” (p.248). Thus, the invisibility of these tasks is a benefit for scientists who are concerned with their work, rather than the functioning of infrastructure.

4. Discussion

In an article coauthored with primatologist Shirley Strum, Bruno Latour uses an ethnological case study of primate interactions to make the case for the role of non-human agents in sustaining social order (Strum & Latour, 1987). For Strum, the paper is an argument directed at primatology. She critiques the long-standing structuralist assumption that there is a *given role hierarchy* among baboons comprising, for example, beta and alpha males. Instead, she demonstrates that such roles are a unique tenuous achievement that is agonistically regenerated in every interaction with another baboon through, for instance, posturing, demurral or aggression. Baboons “have a hierarchy,” only to the extent that they actively sustain and recreate it, and with every interaction there is a possibility of remaking it. Nothing holds their social order together except these ongoing interactions.

Latour likens this to the core ethnomethodological insight that members of social orders enact that social order through interaction (put differently, that order is something we *do* as well as *have*). Order is an outcome rather than a precondition or inherent property of society (as with a structural–functionalist formulation). Latour is sympathetic to this worldview, and early formulations of ANT were replete with nods to ethnomethodology. But his paper with Strum is a critique, an advancement, on ethnomethodology. Latour argues that humans are different than baboons. Not because of our ability to ‘use technology’ which has so often been used to distinguish humans from animals, but because of our capacity to delegate the work of sustaining social order to objects, such as heavy keychains, or speedbumps. These objects act with greater obduracy than humans, helping us to produce and reproduce order in the world: e.g., keys that return with the concierge or residential zones with slow driving. It is not that ANT is against ethnomethodology’s insistence on interactionism, ANT simply provides an analytic handhold for making sense of those human–nonhuman and nonhuman–nonhuman interactions that also help sustain an interactional order.

The argument in this paper has followed a similar arc. Early investigations of distributed collaboration noted that organizational studies had largely ignored the difficulties of distance and the specific mediating roles of technology. In response, studies of virtual organization drew attention to the seminal role of communication in organizing: “an organization design that is held together, literally, by communication” (DeSanctis & Monge, 1999, p. 694). In this approach, spatial distribution became a threat to organizing, impoverishing lines of communication and weakening social ties. At its best, technology provided assistance, making communication easier, faster or richer but never supplanting the fundamentally human nature of collaborative work.

In contrast, we have sought to demonstrate the participatory role of technological agents that themselves play a distinct role in enacting organization. We have shown technologies that are *not a mediator of communication* between distant humans, but which instead work to sustain a particular social order. Specifically, we have analytically populated a virtual organization with technological actors that eliminate or minimize human–human communication from the act of resource distribution. Thus while social studies of distributed organizing have raised concerns around the need for continuous communication and the dangers of attrition, the developers of tools such as Grid computing have set out to reduce or even supplant explicit human communication across a range of key organizational functions. As conveyed in our first example, technology appears as more reliable, persistent, and unrelenting when compared to human communicational work. In the delegation of both technical interoperability and institutional access provided by OSG, technology helps hold together a geographically distributed organization of collaborative resource sharing. Once back-end computational and institutional handshaking is complete, the work of securing distant computing cycles becomes markedly easier for the molecular scientist. Organizing is sustained by technical actors.

On the other hand, and in contrast to any naïve view of *automation*, delegation to artifacts results not in the wholesale transfer of human work across a sociotechnical divide, but rather a *reconfiguration* of that work—bringing new technological and human actors into the mix. Any technological system must be maintained or it degrades over time; maintenance requires maintainers, and thus, a new (or revised) organizational role is born. The first vignette introduced a set of technical actors: the developers, programmers and implementers of the Grid itself; and as the second vignette illustrates, the delegation of organizational work to Grid tools

introduces a new set of administrative and technical personnel onto the scene. Both programmers on the front-end, and technicians on the back-end, became participants in sustaining the activities of this distributed scientific organization. Such roles are not always immediately recognizable from the outside, but they are crucial for constituting and then sustaining smooth organizational activity. In such activities we see novel relations of power and of sustaining a moral order.

Part of social order is moral order; correspondingly, delegation of organization to artifacts also has moral consequences. Latour makes this explicit in his discussions of delegation: “In spite of the constant weeping of moralists, no human is as relentlessly moral as a machine, especially if it is as “user friendly” as my computer” (p.301). A speed bump continues to slow traffic regardless of whether the automobile is expensive or if it is speeding a woman in labor to the hospital.

The Grid too has a moral idiom, one that is made explicit by its developers. For instance, the Grid is intended to provide access to non-traditional and non-elite scientific groups, such as those at universities not producing data. Grid developers have noted that pre-Grid systems tended to be fantastically complex in terms of the technological and institutional knowledge required to use them, and that such complexity increased barriers of entry for non-technical or non-elite groups. Grid developers Berthold et al. comment on these inequalities, arguing: “Because of this complexity, data access tends to be restricted to privileged specialists” (Bernholdt et al., 2005: 486), and argue that the Grid will open access to “many researchers, policy makers, educators and others,” (Bernholdt et al., 2005: 486). Part of the goal of the Grid is to remake the hierarchies of alpha and beta scientists. The unwashed data poor will now have seamless interoperated access to the archives of the data rich; no cycle will go wasted, all will be free to render the most complex of visualizations.

The traditional questions of resource distribution remain the same: who can use whose resources? Who has priority over whom? But the means and forms of enactment changed, resulting in organizational consequences that are difficult to decode, buried as they are within a sociotechnical infrastructure.

Key human actors in enacting and sustaining these relations have been transformed. While scientific work has always relied upon a technical staff, with the increased size, complexity and technological interdependence of contemporary organizations, technical staff and their support technologies are proliferating and becoming increasingly tied to the smooth functioning of everyday science. These actors evidence surprising reversals of authority and responsibility, most often rooted in the technical demands of computational systems (e.g., authentication or interoperability). Decision making that we usually consider managerial is partially shifted into the technical domain. In our case it is computer scientists and software engineers that develop and implement the Grid, which thereafter redistributes access to resources. It is data managers and systems managers that sustain and modify the routines that thereafter prioritize one computing job over another. Such decisions are made in collaboration with traditional project managers and lead scientists, but they are ultimately (and literally) hardwired and encoded into algorithms by human technical actors, and thereafter sustained by such technologies themselves.

5. Conclusion and future research

Just as organizational researchers have noted with enterprise resource planning systems (Boudreau & Robey, 2005; Pollock & Williams, 2008; Volkoff et al., 2007), these highly automated infrastructures transform organizing in ways that go far beyond efficiency-based metrics. In the course of being delegated – the traditionally communicative work of sustaining and reproducing organizations – IT is changing the very fabric of organization. Scientific organizations are an excellent example of the phenomenon identified by Zammuto and colleagues, whereby “IT takes over many coordination and control responsibilities from hierarchy” to such an extent that “traditional hierarchical views of organizational form become incomplete” (Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007, p. 752). In this context, delegation is not a theory of organizations, but an analytic framework that can be used to unpack the complex relationship between forms of organizing and information technology.

Research that takes as its object distributed collaborative work and infrastructure development must take account of many things at once: technology design and implementation; tool use in practice; the nature and rhythms of existing organizational relations; and the ever-present work of maintenance. Principles of delegation open up these questions in new and promising ways. They draw our attention to the reconfiguration of who (and what) does organizational work. They alert us to practical shifts in how

outcomes are accomplished — shifts which may be strategic and more or less accidental in nature. They emphasize relocations in the sites and forms of organizational decision-making, whereby actions are enabled, constrained, or redistributed. And they cast explanatory light on differing levels of visibility and invisibility of actors and their work — dynamics that impact both the efficacy and reward structures shaping collaboration.

Methodologically, such shifts are difficult to track for organizational scholars without delving into the technical infrastructure to inspect the work of design, implementation and maintenance. Our paper has opened up the analysis of delegation in scientific and other organizations by telling two simple, but important stories. First, we traced *acts of delegation* as human agents developed and enacted the tools and technologies that facilitated distributed organizing. In these situations, design and procurement choices were made and primarily human actors within the organization took actions. An important part of this activity included operations on what we might think of as local material sets: i.e., the assemblage of artifacts, systems, and other elements of the built environment that structure and support collaborative and indeed all other forms of work. Second, we showed how delegation cedes important elements of *sustaining* social order to the material sets themselves; key actions were constrained *and* enabled by the affordances of the material infrastructure. We observed patterns of routinized activity (such as repair) and technological accumulation that came to shape and condition subsequent acts and choices. Through such patterns of accumulation, successive acts of delegation come to exercise a distinctive kind of durability through time: in principle, reversible, acts of delegation are in practice prone to all sorts of path dependencies that make going back to prior states costly and/or impossible. This feature gives delegation its notably sticky quality, and enables organizational forms that are less (or differently) dependent on continuous human work. At a very basic level, delegation therefore establishes the conditions of possibility upon which organizations ultimately rest.

While we have focused on a highly geographically distributed organization that has delegated an unusually large amount of organizational communication to automated IT systems, our delegation-based approach can be used to study technology use in a wide range of organizations. In particular, cloud computing is becoming an increasingly prevalent business model that is comparable to grid computing in the sciences. The consequences of delegation are assuredly far more numerous and complex than those we described, and such effects can be examined using a number of research methodologies and frameworks. Another topic for further research is how delegation functions in the lifecycles of virtual organizations, especially the activities that surround the decision (conscious or otherwise) to delegate organizational responsibilities.

The lifecycle of delegation itself is also worthy of investigation, which may reveal a staged process in, for example, the introduction, ascendancy, and obsolescence of such systems. There remain, for example, important questions of scale that go relatively underexplored above (but are the subject of ongoing research). One of these has to do with the relationship between individual acts of delegation and the larger 'delegation regimes' within which they reside—systematically reflecting, and in turn, influencing individual and organizational choices over time. The recent exuberance for infrastructure development that has accompanied efforts to delegate organizational work has not been matched by a critical examination of the differences between traditional human gatekeepers and these new technical intermediaries. A final research trajectory concerns the inherent timeliness of success and failure, built on the recognition that individuals, groups and projects may enter and leave virtual organizations with a good deal more fluidity than is commonly acknowledged. Seeming tendencies towards increasing distribution or technological interdependence may be unexpectedly reversed in favor of local, low-tech or human work. These and other questions constitute important aspects of studying delegation in organizational activity, within and beyond the worlds of science.

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