Modes of Social Science Engagement in Community Infrastructure Design

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1. Introduction

A new space for social science is opening within information infrastructure design projects. These are large-scale, distributed scientific collaborations with the dual goal of building community and technical resources for that community. These endeavors are complex and ambitious combinations of research, information technology deployment, and bringing together of heterogeneous communities (Finholt 2004). It is becoming increasingly common for such projects to seek out the 'services' of social scientists not only as researchers but also as project participants in building community, organizing collaboration or assisting in the implementation of novel technologies. These are opportunities for social science. In this paper we ask 'how best to make use of these opportunities?'

In her studies of multidisciplinary collaborations anthropologist Marilyn Strathern has noted that social scientists are often acting in a 'response mode' (2004). Rather than initiating studies, social scientists are called upon to participate in these projects; inquiry is guided by requests for service rather than a systematic research program. Strathern argues that social scientists do not participate to further a specific research agenda but 'in response' to the identification of a problem that is to be solved by social science. We believe Strathern is correct.

How can social scientists understand the projects in which they participate beyond a 'response mode' to research opportunities? It is far too early

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to propose a programmatic answer to this question. Instead, in this paper we seek to render the question researchable. Our research seeks to produce the resources by which i) fruitful engagements may be designed and will then in turn be capable of addressing local needs within infrastructure and technology projects, ii) while also contributing to a budding research program. In order to move beyond a response mode we must first foster an analysis of the modes of engagement: *how* do we engage? How are social science modes of engagement shaped by the structure of a project? As opportunities open for social scientists to participate in large-scale technology development endeavors we ask: in what situations can our contributions be rendered valuable?

This paper will explore these questions by providing conceptual tools for understanding how social science is involved in infrastructure design. We argue that there are *elements* influencing the mode of engagement beyond the control of the social researcher. Studies of 'intervention,' 'collaboration' and 'participation' have focused on how the social science researcher can shape the engagement[1]. For example, one common model for contribution in a technology project is by conducting 'requirements solicitation' about future users (Jirotka and Goguen 1994). Here the social researcher is making visible a set of future users and articulating their needs. An emerging set of criticisms takes this to be a limited understanding of the social science contribution (Dourish 2006). Dourish argues that social science, and particularly ethnography, has more to offer in the way of perspectives and concepts than 'facts' about a user community. We agree with Dourish but argue that there is more to this question. It is only occasionally that the concepts and perspectives of social science can be heard within technology projects: what influences the possibility of contributing to these projects?

What has not been explored is how the organization of a technology project comes to structure the contribution of social science. Past approaches have all assumed that it is social scientists who play the largest role in shaping the collaboration. In this paper we seek to show how social scientists are only one element in constituting the mode of engagement.

[1] In this paper we use the terms 'intervention,' 'collaboration,' 'engagement,' 'participation' and 'contribution' somewhat interchangeably. This said, these terms have more specific connotations which we attempt to follow in usage: intervention refers to a bounded event or act (i.e. 'an intervention'), collaboration and participation characterize a model of work relations across disciplinary boundaries, contribution has the positive connotation of an effective intervention, and engagement wraps together the entirety of a structured interaction (i.e. 'our engagement with GEON').

The mode of engagement is shaped by the various elements of the project. In a large project no actor, including social scientists, is free to completely determine their role in the organization.

By making visible the structuring of the engagement it becomes possible for the social scientist to make choices, within constraints, about how to intervene. To address these questions we reflexively analyze our own engagements within three scientific information infrastructure projects (today dubbed 'cyberinfrastructure' or 'e-science').

We outline four elements that contribute to the mode of engagement: (i) the state of the project relative to its development timeline; (ii) the time of initiation with social science, (iii) the participation type for social science; and (iv) the details of involvement for social scientists. These elements are exemplary, but certainly not exhaustive. Our cases do not represent a full spectrum of modes of engagement. Rather than a closed typology, the elements are analytic tools for understanding the construction of a particular social science engagement within a project.

Our goal is to begin identifying properties of structured relationships between infrastructure projects and social science collaborators. By mapping avenues for intervention, we begin understanding how the organization of technology building projects impacts social science modes of engagement. In turn, we intend this research to guide the planning of future infrastructure building endeavors and to inform the decisions of social scientists to engage as participants.

2. Cases, Methods and Intervention

This research is part of a larger comparative study of strategies for achieving interoperability across heterogeneous communities (Ribes, Baker et al. 2005). Our research team is composed of social and information scientists from diverse backgrounds: history, sociology, communication, and information management. Findings are based on extended ethnography, document analysis, and grounded comparisons of three information infrastructure building projects for the environmental sciences: GEON, the geosciences network; the Long Term Ecological Research Program (LTER); and Ocean Informatics (OI) at the Scripps Institution for Oceanography. Our goal in engaging in these projects is to foster a vision of infrastructure development that carefully considers the enactment of technology (Fountain 2001), social organization and the consequences of technical investment for inclusion and exclusion of participants (Bowker and Star 1999).

All three projects have the goal of developing 'umbrella infrastructures' bringing together multiple scientific disciplines. In each we are investigators and participants: our research agenda is strongly coupled to a goal of contributing back to these projects. Our engagement in each, shaped by the organization of the project itself, differs in terms of access to the research site, venues for communicating findings, and means to collaborate in design. From this duality of research and intervention we have developed the findings in this paper.

While we call our research 'comparative' it is more accurately described as 'cross-case analyses.' We do not seek to execute a formal comparison using the method of difference or similarity (Mill 1843). Instead, we seek to conduct the 'constant comparisons' of grounded theory (Glaser and Strauss 1973; Clarke 2005). These comparisons engender insight into the phenomenon and assist in the generation of substantive theory.

Constant comparison allows us to see how a technical project 'could have been otherwise' rather than naturalizing a single model of technological implementation. When seen from the gaze of a single technical logic, implementation approaches may appear as though they are 'necessarily so.' During our ethnographic research we have found it invaluable to be able to contrast varying strategies of technical implementation, social organization and community enactment across multiple infrastructure development projects. It is by contrasting practical work (Star 1991) that the human choices, emerging contingencies and possible technical trajectories are rendered visible to the analyst.

Similarly, by comparing our own roles as social scientists in each project we have generated an understanding of how modes of engagement may vary. The means by which we became participants in each project varies across the cases and we consider these important factors informing the mode of engagement. Each mode of engagement is specific; how and when social scientists join a project can affect their ability to contribute. This said, we can make several generalizations about method and site. First, our research is primarily qualitative. We draw on ethnographic data, document analysis and interviews. Second, our access to the research sites, participants and related materials has been generous and unconditional in all cases. Third, with each project there have been some opportunities for feedback of findings or participation in design. Within large scientific programs and cyberinfrastructure circles there is a growing understanding of the importance of 'social and organizational issues.' Project participants in GEON, LTER and OI are aware of the nature of our social research and have discussed its development with our team.

We have adopted the view that interventions are not simply acts upon the subjects of research but are also, in turn, sources for the development of new knowledge (Hacking 1983). Within the field of Science and Technology Studies (STS) 'intervention' has come to have a particular meaning: a social researcher who partakes in the unfolding of the research object.

From this perspective intervention becomes important as a consequential act. What is it to contribute to, assist even, the site of investigation? STS often takes on questions such as the relationship of science to the state (Shapin and Schaffer 1985); the work that categories do (Bowker and Star 1999); and the epistemic and moral consequences of information organization (Vaughan 1999). Because investigations of large-scale information infrastructure building, such as cyberinfrastructure, inevitably raise such questions for the STS oriented scholar, it becomes important to consider the consequences of engagement.

This is to say, for example, that if categorization work has epistemic effects then intervening on the production of categories has broader ramifications than local transformations of organization. The cases of intervention described in this paper are the 'stuff' of politicized STS questions writ small. Interventions are experimentalist actions, resulting in further elaborations of meaning but also unintended outcomes.

The majority of the discussion in STS has been around the question 'to intervene or not to intervene.'[2] Most responses can be placed on a spectrum from thinly veiled objectivism to arguments about the inevitability of intervention in any research (Ashmore and Richards 1996; Haraway 1998; Collins 2002). We would like to move beyond this conversation. In our research projects we are already participants. It is *how* we are participants that interests us. As a community of researchers we know next to nothing about a practice of intervention, a topic which should be at the heart of STS research.

3. Four Elements Influencing the Mode of Engagement

In each of the three infrastructure building projects we are researchers and participants. The configuration of each engagement, however, is project specific. In each we play different roles and have varying responsibilities.

[2] A notable exception is the recent work of Lynch and Cole (2005) on the status of STS expertise. They address an instance of intervention rather than the question writ large.

We call the totality of the character of the collaboration the *mode of engagement*.

We define four *elements* which substantially influence the mode of engagement. We do not develop a typology of modes of engagement. Modes are specific, emerging at the intersection of elements. The elements are: i) the *development timeline* of the infrastructure project, ii) the *initiation* of social science collaboration relative to the state of the project, iii) the *participation type* for social science, and iv) the *details of involvement*.

Rather than a causal chain from elements to modes, the elements serve as analytic tools for rendering comprehensible the composition of social science engagements. Through an articulation of the elements we are developing substantive theory for understanding the possibilities of social science collaboration.

It is at the intersection of elements that a mode of engagement emerges. The mode is partly shaped by the social researcher, but even more so, it is shaped by other actors in the infrastructure project. We have subdivided the four elements into two categories: the *state of the project* and the *organization of social science*. Modes emerge both from within i) the nature of the infrastructure projects themselves and ii) from the ways in which the engagement with social science researchers is organized.

3.1 State of the Infrastructure Project

Over time infrastructure building projects gain a form of conceptual and technical 'trajectory' (Strauss 1993). We attempt to capture this in the notion of the *state of the project*. The development timeline is the extent of organizational and technical development when social scientists join the project. The state of the project impacts the kind of contribution that can be made by social scientists.

For example, we joined the GEON project immediately after awarding of funding. This means that GEON did not yet have a formal organization or a technical infrastructure. In this sense it was relatively malleable and open to future change. However, it also means that participants had undergone a series of proposal writing iterations before receiving funding: a vision of GEON was already established amongst participants. This is what we call a conceptual trajectory.

Conceptual trajectory can include planned users – such as GEON "providing an infrastructure for the geoscience community" – or it can include an organizational mandate, such as LTER's commitment to "maintaining long-term accessible databases". What will be the purposes of the infrastructure? How will it be enacted from vision to infrastructure?

In infrastructure building, a conceptual trajectory is always coupled to a technical trajectory. Technical trajectories include choices amongst technologies, but also understandings of those choices. For example, when we joined the GEON team, 'ontologies' (see section 4.3) were the clear choice for the integration of data. This 'choice' was written into the proposal and part of the shared technical trajectory amongst GEON participants. Joining the project after these decisions had been made left social science out of the discussion about technical trajectory. Furthermore, this also made it difficult to generate discussion about the consequences of particular technologies. We joined the OI team when the state of project was 'nascent.' No proposal had been written and no technical trajectories had been fixed. This left a great deal of room for us, as social scientists, to participate in fostering discussion about technical choice.

The *temporal initiation* of the social science participation relative to the state of the project has a great impact on the mode of engagement; when social scientists join the team matters. As noted, in GEON we did not participate in the proposal writing activity; we did not contribute to the conceptual or technical trajectories. In contrast, with OI we were intimately involved in the writing of proposals, in the articulation of goals and in planning technical deployment. Joining earlier or later defines a set of possible interventions.

To be clear, we are not simply claiming that social scientists should join projects early. Rather, we are pointing to the significance of the initiation of engagement. Joining a project early can mean an opportunity to assist in composing the vision and shaping the *type* of social science participation (see below). However, there can also be advantages to joining a project at maturity. For example LTER is more than 20 years old; it has a mature technical infrastructure for communication amongst participants and a strong culture of disciplinary diversity. The members of this research community are familiar and comfortable with exchanges across traditional disciplinary boundaries. Because of this we have been able to leverage the existing infrastructure to communicate with the entire network. The maturity of this infrastructure has shaped our participation. By joining an institution with a strong communicative infrastructure our social science contributions could be made to *propagate* across the network. This has shaped the mode of engagement within LTER.

3.2 Organization of Social Science Engagement

The phrase 'social science' is a short-hand that has become a popular umbrella term in scientific cyberinfrastructure programs. It occludes the multiplicity of disciplines that come under its heading. As noted, our research team is composed of a sociologist, a historian, a communications researcher and an information scientist. However, with any subset of the social sciences, there are many ways to organize collaboration. These arrangements are what we call the *participation type*.

The participation type is partially shaped by the social scientists involved in the project itself (Schon 1983), but it is also a matter of the design, planning, and organization. What are the expected forms of collaboration for social scientists? How will social science contribute in the everyday and in the long-term?

For example, the OI project has been developed under a type we describe as *participatory design* (Schuler and Namioka 1993). Teams across disciplinary boundaries are brought together to participate in the design of an infrastructure. Participatory design can be contrasted with methods that partition the designers, users, and social scientists into discrete sets of responsibilities. In participatory design these roles blur as, for instance, social scientists are invited to comment on technical design. In this type social scientists have a broader range of sites for engagement.

In contrast, our work with GEON is of the type 'social dimensions feedback.' Here the social scientist is primarily an observer, occasionally requested to participate by providing feedback about 'social aspects' of the project (such as culture or communication). In GEON this role was primarily ascribed to us by the project organizers.

A final element is the *details of involvement* of social scientists with the project. Participation type defines a general philosophy of intervention, while the involvement refers to the specific activities in which social scientists partake. In the practice of social science research, strategic choices must be made as to when and where to intervene. The details of involvement include research methods, techniques for presenting findings, or particular sites of investigation.

In summary the participation type captures a general orientation of the social researcher to engagement, and the details of involvement are the particular events or sites of intervention. Both of these elements may initially appear to be 'up to the researcher,' however, as participants in a larger project such aspects are deeply structured. Below we explore this argument through a more detailed examination of the cases and brief vignettes that illustrate the modes of engagement.

4. Three Distinct Cases – Three Distinct Modes of Engagement

In each of the three infrastructure projects, a different position has emerged for the social scientist as contributor. Each structured relationship has distinct initial organizational conditions, moments of social science inclusion, and envisioned social science participation that influence the themes of study, tone of dialogue, and dynamics of mutual interaction.

4.1 GEON – The Geosciences Network

GEON is a five year cyberinfrastructure development project for the broader geosciences (Keller 2003). It is a collaborative project between information technologists and earth scientists to build and deploy high-end information technology tools for everyday earth science research: computing, visualization and knowledge mediation. The project draws together principal investigators (PIs) from multiple universities and disciplines.

Our participation began as an invitation into the project as 'social informatics researchers' immediately following the awarding of the GEON grant. At formal project inception GEON participants had already written a successfully funded grant proposal. This included two rounds of grant-writing but as of yet no organizational or technical enactment. GEON existed on paper, but not yet in practice.

Although the original GEON proposal did not include social science participation, it did identify expected difficulties of a communicational nature. We were asked on-board with the explicit goal of facilitating relations between earth scientists and information technologists. GEON draws together a very wide swath of earth scientists from disciplines as diverse as geophysics and paleobotany. Many of the earth science participants in GEON were in completely different academic arenas and relatively unfamiliar with the research topics, methods or agendas of their collaborators. This diversity and unfamiliarity prompted a concern from administrators within the GEON project and led to an invitation for us to join as social science participant observers.

Lack of formal planning for social science participation has had significant repercussions in terms of an ambiguous status within the GEON project. From the initial invitation to join, the model of social science participation was understood as assisting with communication practices. We characterize the position of social science as primarily observational and responsive to calls for feedback presentations. We call this participation type *social dimensions feedback*. In this type a subset of concerns in the

project are demarcated as 'social,' such as communication and culture, and are considered the domain of expertise for 'social science' (Woolgar and Pawluch 1985).

Interventions within GEON have been conducted as formal and informal activities. Informal interventions include the continuous presence and occasional commentaries of a social scientist at GEON activities. Here, ethnographic research is also a form of vernacular participation and casual conversation. Formal interventions have taken the form of presentations of findings at GEON forums, publication and presentation of papers. For example, we have conducted presentations at the annual meetings of GEON and for the director's team at the San Diego Supercomputer Center. The content of these presentations has included identifying diverging understandings of infrastructure building within GEON; introducing theoretical concepts such as shared local language for communicating across disciplinary boundaries, and connecting seemingly local GEON problems to historical issues within infrastructure building.

GEON Vignette

GEON is funded by the National Science Foundation (NSF), the federal funding body for science in the US. As part of the funding agreement NSF conducted a 'site review' two years into the five-year project. The GEON PIs asked our social science team to present findings during this daylong evaluation. In this presentation we discussed the formation of communication and coordination practices across computer and earth sciences. We also identified how geoscientists had come to gain stronger technical understandings of data sharing and interoperability. Drawing from STS research, we presented concepts relevant to multidisciplinary collaboration such as boundary objects (Star 1988) and pidgin languages (Galison 1997). Put briefly, we outlined the slow development of a 'culture' and skill-set for working across disciplinary lines.

Our presentation sought to broaden the criteria NSF would use to evaluate the infrastructure project. The original standards for GEON's evaluation (as codified in the proposal) did not include categories such as 'social,' 'culture,' 'community' and 'organization.' Our presentation showed these kinds of activities to be crucial in any multidisciplinary endeavor, and furthermore that they required 'work' on the part of GEON participants. We argued to the NSF site-visit team that activities such as community building and language formation should be part of the evaluation repertoire for this kind of technology project.

We believe our interventions aided in shaping the evaluation of GEON. The written report of the evaluation team placed centrally many 'social' is-

sues. It recognized the difficulty and work of operating with diverse communities, and characterized GEON's efforts as effective:

> Successful coordination of a large group of multi-disciplinary PI's, who had never worked together as a team before, but came together for the first time in this project. [...] On-going graduate student research in cyberinfrastructure topics at PI institutions involving partnerships with computer science departments is further demonstration of the change in culture taking place through GEON (NSF Site-Review Report 2004)

Within GEON, a space was opened for consideration of 'social dimensions' in infrastructure design. This intervention was substantially structured by the understanding that social science in GEON was concerned with culture and communication. Building lines of communication, culture formation, sharing technical understandings and forming organizational routines have become criteria for measuring GEON's success.

We characterize this participation type as 'social dimensions feedback.' In this type of participation, social science is ascribed a tidy role as experts of the social sphere. In GEON this was formulated as a concern with communication and culture across disciplinary difference; the goal of social science interventions was to facilitate working across these boundaries.

4.2 LTER – Long Term Ecological Research

LTER is a federation of American ecologists with the goal of understanding biomes and creating datasets that match time spans operational within ecosystems (Hobbie, Carpenter et al. 2003). Their research network includes 26 diverse sites, distributed across the nation, and drawing together many disciplines related to ecological research. The project was initiated in 1980, and has gone through several iterations of funding renewal, identity adjustments, and growth.

LTER is primarily dedicated to natural scientific research; however, social scientists have become involved as participants and PIs at a number of sites. Unlike our own research team which focuses on information practices (Baker, Benson et al. 2000), these social scientists focus on the relations of humans and the natural environment. The combination of the diverse natural and social sciences has, over the years, tempered the network to be aware and accepting of heterogeneous forms of research.

Over time members of LTER have established a series of mechanisms and traditions for communication across disciplinary boundaries. Within LTER these mechanisms for communication are continuously reinforced by the vision of LTER as a *network:* a setting for prototyping new types of

scientific collaborations and by ecological frames that emphasize diversity and emergence. It is these established means of communication that interest us in this paper. They permit the transmission of social science findings to the heterogeneous scientists in the network through publication, newsletters, email list-serves, and at the various face-to-face meetings.

LTER Vignette

Our activities within LTER were enabled by established network mechanisms for communication. For instance, the Information Manager's Newsletter provides a community mechanism for reporting findings on technologically related activities. Over the years these forums have served to introduce concepts and methods from many scientific fields; it has allowed us to communicate our own research. Here, we briefly describe two instances that illustrate the introduction of concepts from STS that emphasize the importance of language.

In 2002 members of our research team presented a talk focusing on concepts involved in building information systems. The goal of this presentation was to introduce and open up the vocabulary of STS to the broader community of LTER information managers. Concepts presented included *articulation, ethnography, participatory design, tacit knowledge, and practice*.

This first presentation prepared a way for a second, almost two years later, focused on data sharing. This article emphasized *concept sharing* as part of the practice of data exchange: "the vocabulary and language used to frame the discussion brings valuable definition to some frequently unarticulated thoughts regarding data at work." (Baker 2004). Such presentations and their accompanying publications, contribute to understandings of knowledge, data sharing and concept formation. This work informs the LTER community about the importance of language and provides examples of theory-practice bridges (Brunt 2005).

The focus on language development culminated into an effort to work jointly on a 'community unit and attribute dictionary.' These are repositories for the diversity of data and language used within LTER. Within a heterogenous community of scholars scientific terminologies or methods of classification can vary substantially across the network. Prototyping a community dictionary has come to reflect concerns for articulation, inclusion and bringing forth tacit knowledge.

In putting together this dictionary, our research team placed emphasis on the process of its creation. The dictionary is to be a 'living resource' mirroring emerging language use, and encouraging grass-roots contributions. An article published in a community forum by members of our re-

search team stated: "Although names and their definitions are seemingly mundane and even trivial concepts, this does not mean that the articulation, exchange, and blending of unit and attribute names are simple matters. Names go to the heart of local work practices and of data interoperability" (Baker, Yarmey et al. 2005).

This narrative reminds us that conceptual innovation is an extended process: one cannot simply make claims about the importance of, for example, language, and expect immediate meaningful community uptake. Concepts must be repeatedly articulated and integrated within existing practices in order to establish a shared meaning across a community.

Within LTER introduction of concepts and language is facilitated by the existence of diverse, robust networks for communication and coordination. Here we can only outline a small portion of the work which went into establishing the dictionary creation process; the reader should imagine regular meetings and exchanges over often extended time periods between information managers in order to facilitate the collaborative work of developing novel conceptual resources and eventually a community dictionary coupled to a participatory process for its creation.

We describe this participation type as *network propagation*. In this type it is possible to communicate research findings to heterogeneous experts by relying on an already existing communication infrastructure. However, effective propagation requires significant tailoring to the communicative standards of the existing network.

4.3 OI - Ocean Informatics

OI is a loose collection of information managers and ocean scientists largely located at Scripps Institution of Oceanography. Named in 2003, the endeavor is relatively new, and has yet to achieve formal recognition. The nascent state of the project and early temporal initiation of our engagements has opened many possibilities for shaping the nature of the social science interventions.

Participation in the group is relatively informal. Over time planning has been carried out collaboratively by a small team with backgrounds in technology, information management, and STS. Broadly stated, the intention in OI is to strengthen the information infrastructure for scientific research and training. Our participation in this project comes close to transcending the 'investigator' role to that of collaborator at multiple levels of engagement, including planning events, reading groups, and continuous developmental feedback.

OI Vignette

An OI intervention has been the formation of a monthly reading group that brings together information managers, scientists and social scientists. Readings are selected to broaden participants' understanding of the practice of science as represented in the literatures of STS, the history of science or technology adoption. In turn the reading group has included 'technical' articles drawn from information science such as methods for producing interoperable datasets. The value of the resulting conversations for participants cannot be overemphasized, creating a space in which concepts from many disciplines can be discussed at a single table. Conversations flowed smoothly across technical, organizational and communicational themes.

On one occasion our research team shared an article with the reading group that described the process for developing software technologies known as 'ontology'(Ribes and Bowker forthcoming). Ontologies are a relatively novel solution for data sharing and interoperability. The article focused on how these technologies are built and deployed over time.

The discussion that ensued made it apparent that the broader group of ocean and information scientists had misinterpreted our intentions for sharing the article. They had read the article as an argument *in favor* of adopting ontologies in their technical trajectory. For social scientists the article was an analysis of deploying technologies. Our assigning of the article was an endorsement of that technical approach. Within information science circles reading an article *about a technology* occurs in the context of considering its adoption. In contrast, within social science circles *a case study of a technology* serves to illustrate more general *themes*, such as enactment, resistance, or process.

Social, information and natural scientists spent a great deal of time in that reading group discussing the varying disciplinary conventions in reading scholarly material. In order to properly collaborate across disciplinary boundaries, it is necessary to dedicate significant time to aligning approaches in activities. Through such work all groups learned about each other's research conventions and the typical forms and purposes of a reading group. Later reading groups could then begin from a stronger base of shared understandings.

We describe this type as *participatory design*. This type enables complex collaborations across disciplinary boundaries. The design of a technology, or in this case of a community infrastructure, becomes the domain of all participants. The exchange of expertise is one of the most fruitful outcomes of such an endeavor. However, it also requires investment of time and effort to properly coordinate across disciplinary boundaries.

5. Discussion: Modes of Engagement

We have thus far outlined three particular social science engagements with infrastructure building efforts and provided three vignettes as examples within these engagements. In making a structural analysis of the positions of the social scientist within engagements we have considered four elements:

- the project development *timeline* at social science engagement;
- the *initiation* of social science engagement with the project
- the *participation* type for social science in the project; and
- *the details of involvement* for social scientists in the project.

Ours is not a causal argument: modes of engagement emerge at the unique intersection of elements. We have divided these elements for heuristic purposes; the elements are analytic tools. To understand the mode of the engagement, these elements must be understood in combination. In the descriptions and narrative vignettes of the previous section we demonstrated the interactions of the elements in shaping a mode of engagement.

Here we do not offer a typology of modes, but rather the analytic means to render a particular mode comprehensible. Table 1 summarizes the ties between the four elements in three infrastructure projects we cover in this paper. It suggests the kinds of possible interventions that emerge at the intersection of elements.

The timeline and initiation of an engagement are linked to the malleability of the mode of engagement. For example, within GEON the social science relationship began at formal inception. At this point the level of development of the infrastructure was 'made of' conceptual and technical

Table 1. Elements in the Mode of Engagement

	ELEMENTS	GEON	LTER	OI
State of Project	***Development Timeline***	**Proposal**: no organization or infrastructure	**Mature**: organization and infrastructure	**Nascent:** no funded proposal or technical infrastructure
	Social Science Initiation	**After Funding**	**At Maturity**	**In Planning**
Organization of Social Science	***Participation Type***	**Social Dimensions Feedback**	**Network Propagation**	**Participatory Design**
	Details of Involvement	**Observation; Feedback Presentations**	**Colleagues, Research Findings**	**Member, Participants**

plans as outlined in the written proposal and shared by project PI's. At social science initiation, then, GEON already had a certain conceptual and technical trajectory. These were not up for negotiation in the participation of social science. The mode of engagement was partially structured – that is, out of the hands of social scientists -- by the state of the project.

In contrast, the social science engagement with OI is most accurately described as beginning *before* OI – social scientists were participants in creating the notion of the OI infrastructure. At this point the level of the development of the infrastructure is 'made of' informal social networks from which, over time, proposal writing and other collaborative activities began to produce a vision for OI. As such, the mode of engagement in OI could be heavily shaped by social science participation. We were able to assist in formulating an understanding of the project as participatory design, and foster sensitivities towards language and shared meaning.

Within LTER the engagement began with an already mature and highly structured organization. LTER sustains a complex vision, technical infrastructure and multiple means of communication and organization. At initiation of our research, we could not easily shape the engagement as it was deeply embedded in extant organization and infrastructure. However, LTER did provide many resources for communicating within the existing network which we call propagation.

The participation type and the details of involvement are the practical relationships of social scientists to the technology building project. The participation type defines a philosophy of intervention: will we be interacting daily in various aspects, as in participatory design? Will our role be primarily observational with occasional sessions to describe findings as in social dimensions feedback? Or, will we be propagating our findings in a large association of experts in a network?

A general orientation towards participation is coupled with the details of activity. The details of involvement are informed by training in particular social sciences. For example, our research methods are primarily qualitative and drawn from the (disciplinary) traditions of history, sociology, communication and information science. Thus our interventions have been in form of, for instance, insights about infrastructure development drawn from history and findings from ethnographic studies. The details of involvement can vary substantially by field. The types and details of involvement in this paper are based on our own empirical research; there are many more possible participation types than those we have identified.

In summary, we offer two key points. First, the mode of engagement of social scientists in technology projects is particular; it is shaped at the intersection of elements. Second, modes of engagement are a function of fac-

tors such as project state and social science organization rather than determined independently by a social science study plan. This should not be confused with the converse statement that the mode of engagement determines the activity of social sciences. By taking into account structured constraints such as the conceptual and technical trajectories of a technology project, we can begin systematically understand the possibilities for action. The mode circumscribes a space for social science intervention, outlining constraints and opening possibilities.

5.1 Examples of Participation Types

Below we include a more extensive account of the three participation types we have described: these are 'social dimensions feedback,' 'network propagation,' and 'participatory design.' Each of these types leaves open the details of involvement within them. They are ideal types, analytic categories generated through grounded research. In practice the participation types are much more fluid, often shifting within individual projects. We provide the types as tools for understanding what *in action* is always a much messier set of roles. Each type is articulated relative to the dangers of entering a reactive or 'response mode'(Strathern 2004) of social science research.

Social Dimensions Feedback

In this participation type social science becomes the mouthpiece for 'the social.' A social sphere is demarcated as the realm of expertise for social science. In the case of GEON this was understood as communication, culture and community formation. In this type the responsibility falls to social scientists to render the social sphere visible to other participants in the technology project. Social scientists must come to know a community, or its culture and future users, and to communicate this formally in the form of presentations or publications and informally in hallways and during coffee breaks. The dangers of this approach include a poor integration in the larger organization and a mismatch between expectations for social science and what can be delivered. The advantages include broadening attention in the project beyond a narrow definition of the technical as well as a smaller investment in time for the researcher in the form of daily 'contributions.'

Social science is a very broad umbrella term. Under this heading we find a plethora of competing definitions of 'the social.' The maximizing homo-economicus is an altogether different construct from the socialized and normative subject of structuralist anthropology. Within STS there are

several traditions which altogether disavow an autonomous or pre-existing 'social sphere' e.g. arguments for sociotechnical systems (Hughes 1983) or the shifting boundaries between the social and technical in actor-network theory (Latour 2005). In other words, the definition of a social sphere within a technology project may differ from the research tradition of the social scientist.

This participation type has the disadvantage of being shaped by parties other than social scientists themselves. To the extent that a conceptual and technical trajectory has already been articulated amongst participants a clear role for social science may be difficult to define. In the worst case scenario the situation can be described as 'add social science and stir.' Here the participation of social scientists is poorly entrenched in the larger trajectory of technology project. Research findings may be communicated, and even be well-received, but without organizational mechanisms to act upon these there will be no results.

For example, in the late-1980's US industrial researchers looked towards the innovations of Japanese car manufacturers and discovered 'quality circles.' Quality circles quickly sprang up within American firms. However, unlike in Japan, in the US no mechanisms were instituted to incorporate the findings of quality circles into the larger production process (Kenney and Florida 1993). The result was a great deal of data on quality, but no means to act upon these. Similarly, if social science research is not well entrenched in the organization of the infrastructure development project it will remain simply 'data and findings' rather than serving future design and implementation.

On the other hand, if there are strong venues for communicating 'social feedback' the results can be beneficial. As we saw in the GEON vignette, the social science presentations to NSF evaluation team opened a space for considering communication and culture as positive achievements in the GEON project. There is no doubt that working across disciplinary boundaries is difficult. In this case social science findings served to validate work in GEON that pushed beyond a narrow definition of technical infrastructure building.

In Strathern's terms, social dimensions feedback fits most neatly as a 'response mode' of research. In our experience it is also one of the most common forms of participation for social scientists in technology projects. Here the communication of findings is instrumental, serving to address particular problems in a project. This form of research can still contribute to a larger scientific program but there is a danger that findings will be atomistic (as in the case of 'best practices'). Response mode interventions

have not tended to contribute to a general body of knowledge about *how* to intervene.

Network Propagation

In this participatory model what is communicated is a form of expertise, but the definition of that expertise is more broadly defined than in social dimensions feedback. Because, as in the case of LTER, a network is composed of heterogeneous experts it is expected that each participant will define their field and their contribution to that network. This applies equally to ecological scientists and social scientists; it is the responsibility of members to carve out a research domain and articulate findings to the broader community. The *possibility* of communication is the advantage of this type, while the *work* of communicating is its veiled disadvantage.

The existence of a robust network for sharing research makes the communication of findings 'easier,' but not 'easy.' Propagation across a distributed network is by no means automatic or unidirectional. Each act of propagation – such as the publication of an article in a newsletter – requires substantial articulation work for effectively communicating across disciplinary boundaries, for example: dropping excessive theoretical detail, framing examples in accessible language, or tying findings to relevant domain cases.

As we have seen in the LTER vignette above, propagation is also iterative and dialectic. Baker and Karasti's presentation on 'tacit knowledge' required substantial translation work from the fields of STS and Participatory Design into conceptual languages accessible to the broader LTER community. This work was followed later by publishing similar concepts in a newsletter, presenting again in later years, and through informal 'hallway' conversation. In sum, the propagation of social science findings was heavily facilitated by an existing network conditioned for interdisciplinary communication, but involved multiple iterations of articulation work before gaining a foothold in the communities' conceptual repertoire.

Network propagation, as a participation type, has great advantages for communicating social science research with large and heterogeneous body of experts. We consider this a valuable form of intervention. But it also has the disadvantages of both other types. That is, as with participatory design (see below), a great deal of effort must be invested into the proper framing of contributions. Research results must be coded in languages familiar to the existing network of communication. As with social dimensions feedback, the interventions themselves are deeply shaped by an established conceptual and technical trajectory of the network. Findings must be

framed in accessible communicative forms and draw from relevant domain examples.

In terms of pushing social science out of a response mode, network propagation is a very promising participation type. Within an interdisciplinary research network participants delimit a form of expertise ('a science') and contribute to the general goals of the network. In LTER this type has encouraged us to foster a scientific research program while simultaneously pushing us towards making our research relevant to practical work of LTER members. Social science is free to craft its research object, so long as findings are worked over in ways that are accessible to the network.

Participatory Design

In participatory design social scientists are involved, at multiple scales, in contributing to planning and design decisions ranging from 'small scale' activities (such as organizing reading groups) to 'large scale' activities (such as proposal writing). Furthermore the boundaries for intervention which seem naturalized in 'social dimensions feedback' – culture, community, organization, communication – are considerably more fluid in participatory design. Here social scientists may contribute to activities traditionally defined as technical, such as writing metadata standards or creating dictionary. The advantages of this type include a deep ability for social scientists to shape the engagement, however this is coupled to the disadvantage of the responsibility and work required in fostering an effective engagement.

In the participatory design model the lines between technical and social dimensions of an infrastructure building project can become a hindrance. At a fine scale of granularity (e.g. participating in a reading group) social and technical boundaries dissolve: information managers regularly speak to organizational issues or strategies for receiving funding; and, social scientists evaluate technical commitments in terms of human resource allocation or long-term feasibility. Social science participation in this type is significantly more 'everyday.' By leaving aside clean-cut social/technical divisions the problem space of infrastructure design is opened, permitting a definition of 'social science' or 'technical' expertise in relation to emergent concerns. For example, in the OI vignette of intervention our contribution as social scientists was to provide findings on the process of ontology development, and to attempt to provide an alternative frame for comparing available technologies of interoperability.

As we have noted, the disadvantage of participatory design for social scientists is in the commitment and investment in time. Communicating the theoretical or methodological frameworks of social science can be an

arduous task. Similarly, coming to understand the communicative conventions and methods of another discipline is no small task. STS scholars place a great deal of pride in understanding the 'content' of science, however, participating in design reveals a considerable gap between 'understanding content' and being able to engage at the level of practice.

Within OI, collaboration with social scientists has been developed strategically for several years**.** Proposal writing (and thus, conceptual and technical trajectories) occurred as a highly collaborative experience. OI proposals to NSF have included not only funding for social science research activities, but also outlined particular tasks, sites of research and expected outcomes. Social science becomes deeply entrenched in conceptual and technical trajectories.

This detailed participation in the 'everyday' of design and implementation could be venue for moving beyond a response mode. The initiation point of the social science team during the envisioning and planning process enables an organizational arrangement of a qualitatively different nature from social dimensions feedback. The extended interactions amongst members in participatory design enable a clearer understanding of just what social science can contribute, what resources might be required, and what sort of organizational structure may facilitate this. This vision can in turn be represented and codified within the writing of a funding proposal. To the extent that social scientists are 'stakeholders' in the success of a project they are no longer in 'response mode' but are instead responsible.

6. Conclusion

There is an emergent quality to the interventionist activities we have described. In each case it has been a somewhat surprising set of circumstances that have constituted interventions, and in turn a surprising outcome. To pose outcomes of interventions as surprising is not an excuse for recklessness, but rather a call to careful reflection, before and after the fact. This paper is a study in just such an activity of reflexivity.

In this paper we have asked, how are the modes of social science engagement shaped in collaborative technology building projects? We have identified four elements of engagement that significantly structure the ways in which social scientists participate. These are project development *timeline* of the infrastructure project at the *initiation* of social science engagement, the *participation type* organizing activity in the engagement and the *details of involvement* of social scientists in the technology project. These are not 'causal factors' determining a mode of social science en-

gagement. Rather, the elements are tools for understanding the makeup of a collaboration.

We argue that the specific configuration of the elements inform how social scientists can participate in technology projects, and hope that in the future this will serve to model new collaborations. Within technology development projects there is no predetermined set of 'social problems' to which social scientists must set themselves the task of resolving (Woolgar and Pawluch 1985; Vinck 2003). Infrastructure development issues emerge relative to the mode of engagement. Our analysis of configurations of social science participation is not intended to gauge the extent of 'successfully managing the social aspects of a technology project.' Instead we take configurations of social science engagements within infrastructure projects as themselves constitutive of varying spaces for purposeful action.

This approach allows us to stretch further the analysis of social science contribution from a 'response mode.' What we have called the participation type can be understood as the philosophical core of the mode of engagement. However, our argument is not in support of one or another type e.g. social dimensions feedback, propagation or participatory design. A participation type, and then its details, must be assembled relative to existing organizational and material arrangements within a particular technology project.

The elements we have identified in this paper speak to the diversity of kinds of engagements and contributions a social scientist can make within infrastructure projects. The correct question is not 'which participation type or mode of engagement is best?' Rather, it is critical to take into account the state of the project and organization of social science within it in order to organize an effective mode of engagement. The possibilities for intervention emerge at the spaces within the structured constraints of the elements.

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