Conceptualizing Common Information Spaces Across Heterogeneous Contexts: Mutable Mobiles and Side-effects of Integration

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ABSTRACT
The design and conceptualization of Common Information Spaces (CIS) has long been recognized as an important research topic within CSCW. Informed by recent developments in Actor-Network Theory (ANT), this paper contributes to the conceptualization of CIS across heterogeneous contexts. In particular, the paper develops a dynamic perspective on CIS emphasizing how CIS is malleable, open and *achieved in practice*. Furthermore, we argue that large-scale CIS efforts inherently tend to *re-produce fragmentation* as an unintended consequence of integrating heterogeneous sources of information. Empirically, the research is grounded in extensive field work in a major international oil and gas company.

Categories and Subject Descriptors
K.4.3 [**Organizational Impacts**]: Computer-supported collaborative work

General Terms
Management, Design, Human Factors, Theory.

Keywords
Common Information Spaces, Actor-Network Theory, Implementation of large-scale collaborative systems, Global organizations, Oil and gas industry.

1. INTRODUCTION
In the CSCW literature, the notion of a Common Information Space (CIS) has been proposed as an attractive explanation and theoretical perspective on the dynamics of collaborative technologies. The concept of CIS provides valuable insights on why simply providing a common technology platform or shared access to informational resources, as for instance in terms of a corporate Portal, does not necessarily imply fruitful collaboration and sharing of information. In more detail, this – as explained by Schmidt and Bannon, "requires the active construction by the participants of a common information space where the meanings of the shared objects are debated and resolved, at least locally and temporarily [29: p. 27].

Taking the concept of CIS further, contributions in the CSCW literature have focused on different types of CIS in different contexts, issues of heterogeneity, the degree of work distribution, and the varying need for articulation work – to mention a few aspects [1, 2, 4, 7, 11, 12, 15, 27]. A recent contribution in this regard is a paper by Bossen [7] who based on empirical observations, defines seven parameters and dimensions that can be used to position a CIS. Bossen's parameters allow a CIS to be classified in terms of distribution between employees that need to collaborate, the extent to which tasks need to be articulated and the diversity of frames of meaning that exist for articulating activities, and the means of communication that exist and the immaterial and material mechanism of interaction that support coordination.

Furthermore, in a different paper, Erickson and Kellog [12] take the work on coordination mechanisms and qualities of artifacts in CIS further by developing the notion of social proxies. These are artifacts that support work tasks but at the same time makes visible the status of professional's activities. They use the term social translucence to describe the abilities that artifacts used in work to render visible, the activities of one professional to other professionals.

Another interesting paper adding to the understanding of CIS is Bertelsen and Bødker [4] who address the development of a CIS in an especially geographically and temporally dispersed setting. The authors describe a large distributed space, a wastewater treatment plant, where workers move around and access information as they go. Thus, coordination in this case comprises informal encounters between works as they move from place to place.

Thus recent contributions in the CSCW literature show that the 'shared' aspect of CIS (or the 'C') has, of course, proved notoriously slippery and remained a source of debate. Key contributions [1, 2] within CSCW draw on the notions of 'immutable mobile' from actor-network theory (ANT)-inspired work within Science Studies to underscore differences in perspectives and meaning when objects cross communities [8, 20, 31]. Latour [20] refers to objects that are shared across heterogeneous context (i.e. a common and standardized object), but have a relatively stable meaning as manner across contexts as 'immutable mobiles'. Based on these theoretical insights, Bannon and Bødker argue that CIS display a dialectical nature, where on the one hand, they are open and malleable, and on the other hand they are "packaged and being turned into immutables to allow for sharing across contexts and communities of practice" [2]. The same authors also utilize the well-known concept of 'boundary objects'. Boundary objects are especially plastic objects interpreted differently in different communities that simultaneously appear stable enough to maintain their integrity as 'common' objects across different communities. The mutability of objects often as a consequence of negotiations on working orders between social worlds have been of interest to qualitative American sociology for decades and the term boundary object not originally developed in ANT/STS has increasingly been domesticated by this latter tradition.

In this paper, we critically explore and elaborate on this conceptualization by empirically looking at the heterogeneous practices and collaborative technologies involved in integrating and achieving CIS across a major international Oil and Gas Company (dubbed OGC)[1]. The nature of common information spaces in the OGC is part of a larger context characterized by the development in most major oil companies and globally operating service companies coined *integrated operations* (or e-fields). Even though the scope varies among actors in the industry, most of the initiatives evolve around planning and implementation of new work processes/practices in parallel with real-time information and communication technologies [16, 17, 24, 26]. Common to these initiatives, is that they although in different ways, focus on integration. Integrated operations typically imply larger integration of technical disciplines and closer collaboration across geographical distance. The subsurface domain of most oil and gas companies today represents numerous proprietary software and hardware platforms. With the growth of increased cross-disciplinary collaboration there is a trend towards increased integration of seamless applications that make use of central data repositories. For example, increased focus has also been on developing XML-based standards to ease data-exchange between oil companies and vendors. In the drilling domain WITSML (wellsite information and transfer standard mark up language) has been developed as an important data exchange standard in easing integration between proprietary systems. In such contexts we argue, it is particularity challenging to establish a CIS because of the '*extreme heterogeneity'* in terms of involved disciplines, number of actors and geographical sites, and a heterogeneous collection of partly incompatible collaborative technologies and infrastructures. Thus, we ask what is the nature and dynamics of a CIS across such heterogeneous contexts?

In zooming in on two recent initiatives in OGC, both linked to the overall emphasis on integrated operations, though also very different, we demonstrate key characteristics of establishing CIS across particularly heterogeneous contexts.

Firstly, we look at a local initiative for achieving multidisciplinary and virtual collaboration in well planning and drilling through so-called 'Collaboration Rooms'. Collaboration Rooms comprise a flexible arrangement of collaborative technologies were participants can draw on, filter, and integrate information from different sources as well as displaying the information in different 2D and 3D views. We identify how the Collaboration Room tends to remain an open-ended, malleable, and heterogeneous arrangement that *only occasionally and temporarily* through the situated improvisations of the participants appears as a CIS.

A second major initiative within OGC was an attempt to integrate numerous local databases in order to establish one common database for experience transfer on drilling operations across the international organization. Technically this was relatively unproblematic, but to some extent the initiative failed to be established as a large-scale CIS. However, the Experience Database can be perceived as a working CIS in some communities, the initiative – highly unintentionally, tended to re-introduce several locally fragmented systems for sharing information on drilling operations.

Analytically, we also draw on ANT, but with a particular attention to more recent developments [3, 19, 21, 22, 23, 25] that act as occasions for looking at CIS from a different angle. In so doing, we aim at developing a theoretical lens focusing on how CIS is *achieved in practice* involving heterogeneous collections of practices and technologies. Drawing on Law and Singleton [23] we argue that a primary characteristic of achieving a CIS across heterogeneous context is through establishing *mutable*, rather than immutable objects. Furthermore, this also extends into the debate whether or not sharing through a CIS should be conceptualized as a 'boundary object'. In this paper we show that especially when introducing CIS across heterogeneous contexts, sharing and negotiating common understanding are much more temporary and fluid than the term boundary object suggests. In other words, a CIS is not simply a boundary object for different communities of practice, but a socio-technical arrangement that only temporarily on specific occasions are practiced in such ways that give a momentary common understanding.

Secondly, in light of the establishment of collaborative technologies as generic platforms in global corporations [e.g. 10] we stress the dilemmas of extending CIS beyond smaller communities and functions. In particular, establishment and implementation of CIS across heterogeneous contexts *inherently produce unintended side effects* that potentially undermine its very construction. Here we draw on a body of work [3, 14, 22] that inspires us to focus on how the very efforts of integrating heterogeneous information sources, in themselves, re-produce non-integration (typically in the form of local, non-consistent variants).

The paper is structured in the following way. In the next section we outline some detailed examples of achieving a CIS in the context of the Collaboration Room. Then, we flesh out the dynamics of the Experience Database focusing on exemplifying how it tends to re-introduce fragmentation. Thereafter, we discuss the theoretical implications of CIS as identified in OGC. Finally, the paper concludes by giving some suggestions for further research.

2. ACHIEVING COMMON INFORMATION SPACES IN WELL PLANNING

2.1 Research methodology and sites

Empirically, we draw on several examples from initiatives on establishing CIS across the major international oil and gas company, OGC. OGC is an integrated oil and gas company with substantial international activities. During the last decade, OGC

[1] The name of the company, all its products, departments, and services described in this paper are pseudonyms.

has transformed itself from a company operating nationally, to a globally working company located in 28 different countries. At the time of writing, the company has about 24 000 employees of which a significant and increasing part of the production is in international operations. However, this expansion is challenging both due to increased international competition, but also due to the fact that a more geographically distributed organization makes coordination and collaboration more complex.

The research reported in this paper is part of a larger research project where extensive field work has been undertaken in order to understand the work practices and the use of different technologies involved in well planning. Accordingly, we frame our research an interpretive field study [18]. Our primary leitmotif here is to unpack the *technologies-as-practiced* aiming at establishing an understanding of the role of information technologies in collaborative practices crucial for improving the way oil and gas is produced in OGC.

To this end, data collection involved observations, in-depth interviews, as well as reading various documents. Observations of the practice of well planning were conducted on four different occasions lasting for about 2 hours each. In addition, observations of individuals' use of various specialized IT-tools used during well planning for geological interpretation and visualization (e.g.: Landmark's: DecisionSpace, SeisWorks, and StratWorks, COMPASS) as well as other collaborative tools (NetMeeting, Lotus Notes, and SharePoint) was conducted during interviews. A total of 18 interviews of geologists, reservoir engineers, drilling engineers, completition engineers, IT experts, and managers have been conducted. Numerous volumes of documents including formal and more informal documents produced during well planning, standard operating procedures, and various project plans have been thoroughly studied and discussed with informants. In addition, the authors have for over a decade been involved with the company in terms of conducting research, consulting, and/or as employees.

2.2 Well planning in the 'Collaboration Room'

Well planning is a complex and knowledge-intensive undertaking involving participants from different disciplines, external experts and a wide range of different collaborative IT systems. In well planning projects, geologists and geophysicists are mainly responsible for identify targets for well paths and producing optimization analysis. This implies interpreting seismic data through plotting of the geological formations in a specialized IT-system. On the other hand, drilling engineers typically focus on the more tangible aspects as specifying of equipment, writing more detailed procedures for drilling and completion, and in general having a more operative focus in terms of coordinating activities with external service companies.

The well planning process is the result of a 'Target Remaining Oil' process (TRO), where the asset conducts a maturing of potential drilling locations, drilling projects and prioritizes drilling schedules. Consequently, well planning occurs on prospects defined during the TRO-process. Involving a multidisciplinary team of experts – including geologists, completition engineers, reservoir engineers, and drilling engineers, a common goal, through an iterative process, is to produce a "Recommendation to Drill" (RTD) document. This document RTD describes well paths, well target, geological prognosis, reservoir technology elements like pressure and production prognosis, and well productivity completion. It also has an appendix with seismic profiles, preliminary drainage strategy and field maps. Perhaps just as important, it serves as an important coordinating mechanism [30] for the multidisciplinary team.

The recommendations in the documents is based on interpretations of seismological data, experience with previous wells, as well as more practical issues concerning the operation and equipment to be used. A challenging aspect of this process is that it involves participants from different disciplines, departments, and people whose work are mostly offshore or more related to the actual activates on rigs. The differences between disciplines are to a large extent embedded in the practices of different disciplines. In this regard, it is important to remark that whereas some of the disciplines work with a tangible product (e.g. drilling engineers), others (e.g. geologists) because of sub-surface structures well paths are obviously not accessible to the experts. Their work is purely based on conceptualizations in the form of geological models, well paths and analogies (For example, some geological formations on Greenland where similar terrains and reservoirs to the formations on the Norwegian continental shelf, can be spotted and analyzed in the daylight).

This heterogeneity has several more practical implications for collaboration in well planning in general, and hence for the prospect of designing CIS in particular. First, the different disciplines tend to be geared towards slightly different goals. For example, it is a difference between finding the optimal well path in terms of producing as much oil and gas as possible, and the more practical aspects of the drilling operations itself. Whereas the geologists typically are concerned about the former, drilling engineers typically emphasize the latter. Secondly, since geologists and drilling engineers have different practices, ways of organizing, and technological arrangements, this sometimes makes their knowledge views incompatible – or at least it is difficult to make sense of information across the different communities. Thirdly, since members of a planning team to an increasing extent involve participants working at different geographical locations, there is the challenge of moving information across different contexts. Fourthly, an additional issue is that the number of remaining reservoirs consists of small oil and gas pockets not so easily discovered, making the collaboration to find these pockets more difficult, which again, generates a (perceived) need for increased collaboration between disciplines.

As one of numerous initiatives ranging from technical projects for standardizing well data to organizational change projects, aimed at improving collaboration in multidisciplinary well planning teams, so-called 'Collaboration Rooms' have been developed at local sites. A Collaboration Room generally consists of three *smartboard* screens operated by a coordinator. Each participant in the meeting (either co-present or virtual) has their own computer where they can run their specialized applications in the same way as in their individual offices. A participant can easily render information on her screen visible on the other participants' screen, or on the common smartboards. The coordinator can decide what screen that should be visible on the smartboard. Additionally, the smartboard is also be used as a screen in a videoconference showing participants on other sites or live pictures from an offshore oilrig. Furthermore, an important part of this arrangement is the traditional boards on the side walls of the room (not visible in the picture below) that make it possible for participants to improvise small drawings or sketches of a particular problem. Thus, the Collaboration Room is a rich arrangement of heterogeneous technologies that support different kinds of collaborative work among both co-located and virtual participants. In this way, then, a Collaboration Room can be perceived as a flexible technology for achieving a CIS for supporting well planning teams.

In the following paragraphs we highlight the hybrid collective [21] of technologies and practices through which a momentary Common Information Space is achieved.

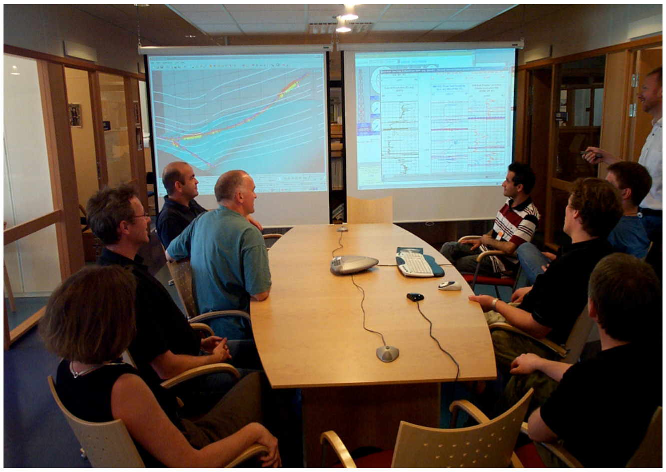

Figure 1: Example of a Collaboration Room

2.3 Achieving a working CIS

In contrast to previous conceptualizations of CIS, the Collaboration Room can be perceived as an example of a particularly mutable mobile enabling different temporary forms of collaboration and sharing. Thus, instead of perceiving CIS as a relatively stable collection of boundary objects, a CIS is here a short-lived arrangement that constantly needs to be re-negotiated.

The Collaboration Room through improvisations constitutes a common context in which a wide range of heterogeneous information can be interpreted:

> The computers make it possible to work during the meeting. In addition we can switch between different applications to be shown on the big screens. In this way, we can discuss whether seismological data is interpreted in the right way or not (Geologist-1)

Thus, since the Collaboration Room makes it practical to switch between different alternatives and types of information, representing the same phenomena or aspect of geological formations, interpretations of seismic, and the entire reservoir, it becomes a mechanism that allows complex knowledge representations to be negotiated among participants. This is of profound importance, since geologists and drilling engineers typically use different specialized and partly incompatible IT-systems for presenting information. The gap between the different processes of knowing is bridged through a possibility of modifying existing representations and displaying alternative representations in-situ. Through this practice a shared understanding of a particular problem can be negotiated. However, on the same time it is important to note that a particular arrangement of the Collaboration Room must be established *before* any degree of a common information space is established. Thus, a CIS is always performed through the practices of the participants. It can never achieve a closure in the sense that it establishes a common understanding once and for all.

For example, rather than aiming for a technological fix of the inherent ambiguities of representations, the Collaboration Room provides a platform for discussing and marking out where information is ambiguous or uncertain. Drawing on individual experience and the functionality of their IT-systems, geologists need to simplify and exclude what they perceive as irrelevant information in order to reduce complexity of large amounts of data from the OpenWorks database:

> [...] my simplification of the seismological data means that there is a lot of information that is taken away when transferring information [from seismological data to the cross section description] to the drilling engineers. One example of such information, can be that often there is sometimes a built in flexibility in the well path description, but other times one have to follow the exact well path as described (Geologist-2)

Thus, when transforming geological representations referred to as cross sections less complex, potentially important information is lost in the process. While this is unproblematic for other geologists, for drilling engineers' part of a different community of practice, as pointed out by the geologist, this can turn out problematic. In such cases where information and representations are highly ambiguous, the Collaboration Room provided a common arena for discussion and providing additional context to representation that made them easier to interpret by individuals outside the community they were designed by. Especially in well planning this is important since reservoirs often have an inherent complexity, there operations in one well has effects on other wells in the same reservoir.

Again, the Collaboration Room as a CIS is only shared for a short period of time; when a particular configuration of the Collaboration Room has been negotiated. Important here, is that this work has to be undertaken *each time*. Ambiguities are seldom sorted out once and for all. The problems experienced whenever participants do not participate underscore this:

> It is very hard to get into a meeting after having been away for a couple of times…[]… [Searching] for and getting hold of information after a meeting is very difficult – if I am not present I have a hard time understanding the different models. (Completion engineer)

The problem of not participating also underscores the important role of the technological artifacts. Without having access to a particular *configuration* of views of geological models on smartboards in addition to the discussions among participants – a crucial part of the context of a particular model disappears.

A second example illuminating the performed nature of CIS in well planning is how information from different heterogeneous sources is integrated in situated practices of use. During discussions, the engineers often draw on information from very different sources in order to explore different alternative solutions to a particular complex problem. For example, on one occasion during planning of a particular well path it was necessary to illustrate the consequences of different alternative well paths for other wells in the same reservoir. In order to make this possible, the team had to combine information in different Lotus Notes databases and specialized IT-tools. This information was through collective act of improvisation assembled in an excel sheet listing the different well in vertical column and an overview of the historical production of the different wells horizontally along the x-axis. Drawing on the distributed knowledge of individuals and encoded knowledge in databases a CIS was achieved in practice.

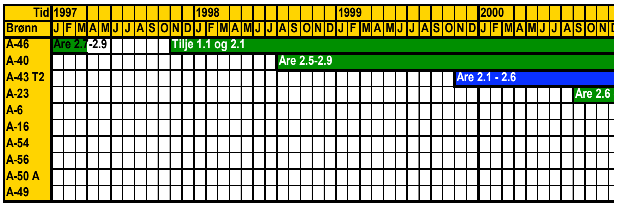

Figure 2: Parts of the improvised excel sheet.

However, the particular excel sheet as shown on the figure was not an immutable mobile used across different meetings and projects. Rather, it was a description developed in a specific situation creating a short-lived common ground for decision making in the cross disciplinary team of engineers. Although the social and technical components of the arrangement persist beyond the meeting or project, the actual CIS only exists during a momentary and specific use of the heterogeneous collection of components. Likewise, our fieldwork also uncovered similar practices using paper-based flip charts or other IT tools as for example MS. POWERPOINT. In particular, this happened whenever the different actors needed a shared understanding in order to negotiate and decide upon different alternative solutions. Arguably then, it is not boundary objects that make the Collaboration Room work as a CIS, but rather the inherent fluidity of the socio-technical arrangement [cf. 19].

3. Inherent side effects in implementation: cycles of integration and fragmentation of CIS

The practices exemplified in the previous chapter comprise only a small fraction of well planning and the involved collaborative technologies. What remains invisible, is that the functioning and development of a CIS will often depend upon integration with strategic decisions, collaborative technologies and work practices outside the domain of the well planning team and their CIS. As our research also have included implementation of large-scale collaborative suits like Lotus Notes, and more recently MS. SHAREPOINT and a corporate-wide database for experience transfer, we have been able to observe how these initiatives often try to extend the durability, expand the reach, and to homogenize local CIS like the Collaboration Rooms in order to establish globally integrated infrastructures [10, 28]. Accordingly, based on our research in OGC, we identify *a different type of heterogeneity* often stumbled up on when aiming at establishing more durable and more comprehensive CIS involving a larger number of more geographically distributed participants and large-scale collaborative technologies. In recent times, several initiatives have been launched in order to tidy up the perceived mess of information and IT tools used.

One of these envisioned as a CIS for sharing drilling information across different parts of OGC is the Experience Database. Previously, there existed over 20 local databases running on different platforms (e.g. MS ACCESS databases and LOTUS NOTES databases) having very different ways of structuring information. The unfortunate consequence of such fragmentation was that potentially valuable information stored in one license's database was not spread out to other licenses. This situation led the management of the central Drilling and Well department to integrate the information in one common system, the Experience Database. The Experience Database aims at capturing local experiences in drilling operations by providing experience records for describing a particular event during the drilling process. For example, this can be experiences regarding particular equipment used in drilling, particular methods for completion, safety issues, how a particular critical operation was conducted, and so on. The experiences can then be classified according to a pre-defined set of keywords. The keywords are supposed to describe the meaning of the experience and make searching for particular information, for example, regarding specific types of equipment more convenient. In this way the Experience Database can be perceived as a large-scale CIS aiming at sharing knowledge across different heterogeneous contexts. At the time of writing the system has nearly 9000 experiences categorized and over 1000 engineers worldwide involved in well planning and drilling are using the system.

Despite the good intentions, however, the use of the Experience Database varies greatly from license to license and from person to person. The reasons for this are for sure multifaceted. For example, a common problem with the Experience Database as perceived by both engineers working in licenses as well as engineers working at HQ, is that although the information in the system is extensive, the engineers are rather uncomfortable with using it:

> The problem is the quality of the information…[…]…People put lots of things into the system, but since they are not frequently using anything [of the information] this becomes a job that is less interesting and motivating. It is also a fact that one part of a very complex operation can have a very specific focus, and at the same time, a different part of the operation can have a very different focus. (Manager, HQ)

Not surprisingly then, the engineers find it difficult to make sense of the bits and pieces of information since they do not have access to the particular focus in which the information was entered into the system. This illustrates as aptly pointed out in the CSCW literature on CIS that simply establishing a shared platform in terms of an IT-system is in most cases far from sufficient, and in many cases completely naïve way of implementing a CIS.

However, there are small pockets to be found in the organization were the Experience Database is actually working as a CIS. There are for example, cases were a group of engineers involved in well planning are using it for sharing information on particular kinds of situations and equipment that is specific to that local site or oil field. Additionally, the Experience Database is part of a larger information system for daily reporting on drilling activities.

Although imperfect, some engineers do use the information in the Experience Database. In order to do this, however, it takes *additional work* in terms of calling up trusted colleagues and triangulating the information with information from other sources. For example, a drilling engineer stated the following recipe for how to survive in a complex maze of information:

> [In addition] to using the [Experience Database], when I have to conduct operations I have never done before, I usually contact people I know at [HQ] and the R&D centre ... And finally, I let my stomach decide what I eventually do...

There are also local offices and departments were the Experience Database is substituted for local experience databases locally developed in LOTUS NOTES, MS. ACCESS, or existing as large EXCEL sheets. For example, we interviewed an engineer who in frustration of the slow development and re-design of the common Experience Database has designed his own. This illustrates how an initial aim at *integrating* all experience information has resulted in *new forms of fragmentation*. This, we argue is a key characteristic of CIS implementation that is not often focused on in existing literature.

Other examples of similar large information and communication infrastructure developments are the company-wide implementation of SAP that was undertaken in the latter part of the 1990's and the full-scale implementation of Halliburton-Landmarks integrated software solutions in the subsurface disciplines in the same period. In these cases, much like the Experience Database we see repeating cycles of integration and fragmentation when it comes to developing flexible CIS in large companies.

Currently the company put great efforts in implementing an integrated information and communication infrastructure based on MS SHAREPOINT. The ambition concerning integration is large and XML-based meta-tagging has an important role in integrating information and data from various knowledge domains. However, it is our hypothesis that these integrated solutions will not endure and that fragmentation will pop up again mainly because the articulation work and the situated character of work practices in the domains that use the common information space have to respond to the contingencies that develop in their work.

4. DISCUSSION: IMPLICATIONS FOR CONCEPTUALIZING CIS

Recently, CSCW research on the concept of CIS has drawn upon theoretical insights in science studies and ANT in particular [2]. The findings from our research reported in the previous sections, indicate some key characteristics of CIS across heterogeneous settings that we argue differs from existing conceptualizations in important ways. Our analysis also draws on ANT, but with a particular attention to more recent developments that act as occasions for conceptualizing the more dynamic aspects of CIS. Consequently we discuss three issues: (i) im/mutable mobiles, (ii) perspectives and boundary objects and (iii) inherent imperfection in implementation.

4.1 Immutable or mutable?

Firstly, we argue that key characteristics of CIS in heterogeneous settings are their malleability and momentary character. Thus, in contrast to what argued previously by Bannon and Bødker [2], we submit that a CIS only seldom and momentary arrives at a *closure*. Interestingly, the inspiration for the notion of closure in CIS stems from science studies and social construction of technology where it was coined to capture the black-boxing or finalizing of technological design process culminating in an accepted solution [5]. In science studies, but apparently not in relation to CIS, there has since been a lively debate around the notion of closure. The problem, as succinctly formulated by Bijker [6], is that from an analytical but also empirical point of view, the notion of closure fails to accommodate instances (not rare in practice!) where black-boxed solutions and decisions are reconsidered and possibly redone. To this end, Bijker [6] proposes the notion of *stabilization* as a time-dependent form of closure. Remain stable for some time but are often re-opened again later. This is, we argue exactly what happens in the Collaboration Room case: a common understanding (or 'closure') is achieved in relation to a particular configuration of the technologies, but this only last for a short time. The issue, or issues are in this case soon re-opened, and discussed again.

An essential aspect of CIS, we argue, is that CIS like the Collaboration Room in OGC tend to *remain* open and malleable, and only provide a shared understanding between actors at the spur of the moment when information is practiced and thereby made sense of in a specific temporarily arrangement.

Rather than focusing on immutable mobiles then, we submit a conceptualization building on Law (among others) who underscores the *mutability* of objects. Objects are changing – in content, but also in its surrounding network of relationships – constantly. In the compact formulation of Laet and Mol [19], "objects must change to remain the same". Emphasizing out the mutability, as opposed to stability or immutability, of objects, mirrors the broader shift in social sciences that could be coined the performative turn: the systematic substitution of nouns for verbs as in organization/organizing, strategy/ strategizing, work/ performing, and so on. An CIS is always in the making – it can flux between the different characteristics or parameters as described by Boosen [7].

4.2 Boundary objects revisited

As shown in the case of the Collaboration Room, the shifting artifacts, practices, and boundaries used in achieving a shared understanding also challenge the notion of a boundary object. In the science studies literature Mol [25] challenges key assumptions underpinning the also in CSCW widely employed notion of boundary object. Mol more radically suggests that communities quite routinely are capable of working quite independently around a given object. Their differences in how they ascribe meaning to objects go well beyond the notion of 'perspectives' embedded in boundary objects. The different work practices "exclude one another… It is not a question of looking from different perspectives either" [25: p. 35]. The differences are incompatible; there is not one object but multiple; objects are multiple and "make a patchwork" [p. 72]. Yet, and this is the vital aspect of Mol's analysis, *when required* in given circumstances, *compatibility is produced* as a practical task.

In the context of CIS, this insight implies bracketing foundational concerns regarding exactly how much need to be common for information to be shared, and instead tracing out the ongoing, fragile and contingent performances that make up instances of collaboration. In such settings, we argue that the dynamics of establishing CIS are – to some extent – different form current conceptualizations. However, we do find of course aspects that are more stable than others also in our Collaboration Room. For example in our study we find obvious candidates for boundary objects that are less plastic. A shared boundary object in this sense can be an IT artifact like DecisionSpace. This is a software tool from Halliburton-Landmark that has the capability to display and manipulate (rotate, translate, zoom) geo-science earth model data objects together with drilling engineering and operations data for integrated knowledge management and real-time decision-making. This tool can dynamically display in 3D the real-time updates of well trajectories and log curves. Boundary objects in this setting can also be documents and flowcharts that describe procedures, goals, and best practices concerning work processes in well-planning.

4.3 Inherent side-effects producing new forms of fragmentation

Another key characteristics of CIS, we argue is related to its inherent imperfection in producing fragmentation, as well as integration. As shown in the case of the Experience Database, there are inherent limitations and barriers for achieving a perfect CIS across heterogeneous settings. In particular, this illuminates the focus in CIS of identifying micro-practices of (overcoming) heterogeneity embedded in achieving cooperation, there is the in CSCW much less pronounced issue of heterogeneity in implementation. By this we mean processes of implementing collaborative technology typically aim for complete solutions in the sense of comprising the full set of information sources. Responding to a situation where information sources are fragmented, collaborative efforts typically aim at integrating and aligning these different sources. Understandably as it may be, this ambition is empirically as well as analytically problematic.

Empirically, especially clear in largish project, these efforts tend to fail in achieving the aspired level of integration and reproduce the initial fragmentation. On a conceptual level, this is similar to what Hanseth and Braa [13] have recognized in relation to large-scale IT infrastructures. Metaphorically, they describe the process of standardizing and integrating a corporate-wide infrastructure as "hunting for the treasure at the end of the rainbow". Hence, such thing as a fully integrated and standardized IT infrastructure incorporating all required features can practically never exist. Likewise, striving for a perfect CIS – in terms of flawlessly and seamlessly integrating all thinkable information is very unlikely to happen in organizations like OGC. Ultimately, we argue, as CIS they are bound to produce some abnormalities.

Thus, although local initiatives like the Collaboration Room in OGC is relatively successful as a CIS they can also be deceiving, especially when trying to expand such CIS to a larger community. Rather than order, there will inherently be surprises, risks, and thus imperfection in establishing such CIS. Analytically, such efforts correspond to striving for a level of perfection in integrated solutions that, Law [22: p. 11] warns us, neither attainable nor ultimately desirable:

> There are always many imperfections. And to make perfection in one place (assuming such a thing was possible) would be to risk much greater imperfection in other locations…The argument is that entropy is chronic. Some parts of the system will dissolve…For a manager accepting imperfection is not a failing. It is an advantage. Indeed a necessity. Perfectionism would be dangerous.

Similarly, this point also evokes recent focus on the potential harms with erasing all kinds of redundancy in recent CSCW literature [9, 32]

5. CONCLUDING REMARKS

The CSCW literature has recently provided some valuable insights on CIS, expanding the original ideas of Schmidt and Bannon [29]. In particular these contributions have emphasized different types of CIS along different dimensions as for example heterogeneity and the distributed and mobile character of the embedded work practices [e.g. 4, 7]. In this paper, we have also aimed at furthering the conceptualization of CIS by drawing on an interpretive field study of different CIS in a major international oil and gas company. We contribute by suggesting that some CIS, especially those in extremely heterogeneous contexts in terms of multidisciplinary participants involving a patchwork of different collaborative technologies, CIS appears as much more situated, momentary, and malleable. Secondly, our research strongly indicates that CIS that attempt to integrate and cut across geographically dispersed communities of practice and heterogeneous collections of information are likely to produce new instances of fragmentation.

Following these tendencies, there is a need for more research on large-scale collaborative systems in order to improve current conceptualizations of CIS. As most studies within CSCW have been focusing on relatively small-scale systems involving a limited group of users collaborating over small distances, there is a need for shifting focus to larger, more complex fluids of collaboration involving patchworks of systems and actors.

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