

# TECNOSCIENZA

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**SPECIAL ISSUE**

**Maintenance and Repair in STS**

### **Dispatchwork** by Jan Vormann (Germany)

I do not enjoy living in dull and grey cities. Do you? Have you noticed that toys for kids are generally very shiny and colourful? I wonder why that is, given that they are to be brought up to live in mostly dull and grey cities as adults. Since I lived in many of such cities, I am seeking to improve the appearance of public spaces in different ways, in terms of what I consider improvement. Dispatchwork aims to seal fissures in broken walls worldwide, completing the material compilation in urban constructing and adding colour to the urban greyscales, by inserting a very basic construction material: Plastic Construction Bricks (PCBs). In fact, PCBs are one of the first materials with which we conceive architecture. PCBs are solid and stiff and shape up perfectly rectangular yet, concerning the essential structure, they contradict the purpose, given that the repair is just so very temporary, with the patches crumbling out of the walls in a matter of no time, being taken or washed away.

Dispatchwork does not defy deterioration. Rather, it aims to emphasize transitoriness as a chance for the construction and reconstruction of our environments. Adapting to various cities, the project infiltrates walls of cultural heritage, historic facades, fortifications and yet many more less spectacular corners as a colourful repair of shabby walls within our shared spaces.

Dispatchwork contradicts and satirizes the superimposed seriosity of constructions in the cityscape. Within all that rigidity and stiffness there are plenty of chances for your own creativity. The project also aims to put the focus on the playful, hands-on aspects of creation in our daily lives, and further, on the possibilities for participation to construe and design our own reality.

[www.dispatchwork.info](http://www.dispatchwork.info)  
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# TECNOSCIENZA

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# Maintenance & Repair in Science and Technology Studies

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**Abstract** Notably taking root in the first laboratory ethnography studies and in the interactionist sociology of work, several studies have recently provided an in-depth account of maintenance and repair work in very different sites (workplaces, urban settings, homes). They have provided great insights to not only reconsider largely invisible operations, but also to pursue the discussion of issues such as innovation, ordering processes and materiality in Science and Technology Studies. In this introduction, we focus on two topics of discussion. First, we show how maintenance and repair studies expand our understanding of sociomaterial work and object agency. Second, we highlight reasons for exploring maintenance and repair practices to challenge and decenter innovation studies.

**Keywords:** maintenance & repair; vulnerability; innovation; materiality; modes of ordering.

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For several years, interest in maintenance and repair practices have been growing in science and technology studies (STS), and numerous investigations have been conducted on the expansion of the seminal works of Akrich (1993) and de Laet and Mol (2000). The emerging stream of research explores overlooked sites and practices and contributes to various issues such as “ontological politics” (Mol 1999), “new materialism” (Coole and Frost 2010), and “knowing capitalism” (Thrift 2005). Considering papers from different European countries, this special issue of *Tecnoscienza* offers ethnographic insight on specific political, economic and technical configurations. The current work examines the enactment of material vulnerability in e-waste practices (Blanca Cállen and Tomás Sánchez Criado), the “distributed correction process” in the design of

advanced driver assistance systems (Oana Stefana Mitrea), the mundane interventions of building caretakers (Philippe Sormani, Ignaz Strebel and Alain Bovet), and a major breakdown in an industrial pharmaceutical plant (Cynthia Colmellere).

Before describing the analytical contributions of the articles in more detail, we outline a brief genealogy of maintenance and repair in STS and highlight two main topics of discussion that are particularly worthwhile: 1) sociomaterial work and agency and 2) innovation and concrete conditions

## **I. Work and Material Agency: Living in a Vulnerable World**

For a long time, laboratory studies have stressed the material side of work involved in the daily production of scientific facts, relying on a diverse range of documents, machines, instruments, inscriptions, chemical and physical substances, etc. (Latour and Woolgar 1979). Consequently, studies have emphasized the role of technicians in the maintenance of places, instruments, and experimental materials (Mukerji 1989; Barley and Bechky 1994).

In a well-known article, Shapin (1989) investigated the work of lab technicians (“servants,” as they were called in those times) in the 17th century, showing the crucial role they played in experimental arrangements. Remaining largely invisible in scientific reports, lab technicians used to regularly prepare and build machines, calibrate and repair instruments, and fix damages directly caused by unsuccessful experiments, sometimes leading to fire or explosions. As Shapin emphasized, technicians not only performed experiments and maintained the different devices assembled in experimental settings, but they also assumed the corporal risks of dangerous experimental trials.

More recently, Knorr-Cetina (1999) showed that researchers in molecular biology are also caretakers of the living organisms prepared for experimental manipulation in laboratories. Animals are bred and nourished, plants are warmed and observed, and other materials (bacteria, plasmids, cell lines, viruses, etc.) need careful attention on a daily basis. As she clearly demonstrated, caretaking also encompasses technical devices such as glassware, flasks, pipette tips, and test tubes that must be cleaned, sterilized, and stored to prevent degradation.

Laboratory studies investigate maintenance and caretaking practices from the angle of work organization, indicating the boundary between the scientist that thinks and produces original ideas and the technical workers that manipulate instruments and remain in the background. Criticizing the disembodied figures of the scientific genius stressed out by some historians and philosophers of science (such as the superior mind of scientists) is related to what Hughes (1962) has shown regarding the na-



ture of the tasks carried out in workplaces, which are barely considered honorable or respectful. He emphasized that professions are not just organized by the technical distribution of tasks, but they are also affected by a moral division of labor. Every profession, even the most prestigious, involves some “dirty work,” generally conducted by those considered outside of the “real” or “core” professional circle. Such a monopoly defines “what counts” as a job, particularly in the professional world (Strauss 1985; Star and Strauss 1999). At the crossing of laboratory studies and the interactionist sociology of work, a new domain of research has emerged, making room for an explicit interest in how “work is the link between the visible and the invisible” (Star 1991, 265). It has notably laid the basis for the study of infrastructures and the distribution of work enacted through daily functioning, and it has invited us to reconsider the role of mundane operations, including maintenance and repair, in their “taken-for-grantedness” (Star 1999).

On the margins of STS, some scholars have investigated maintenance and repair practices (Orr 1996; Henke 2000). They notably insisted on the dynamics of knowledge within occupational communities and highlighted the irreducibility of repair work, which inherently resists attempts of rationalization and planning (Orr 1996). Through in-depth ethnographic investigations, scholars have dramatically enriched previous studies concerning what Shapin (1989) has termed “invisible technicians”, foregrounding the crucial role of improvisation in maintenance work (Orr 1996) and the kind of material and bodily commitment required (Henke 2000; Dant 2008).

More generally, these works aim at expanding one of the main assumptions of interactionist sociology and ethnomethodology, i.e., that social order is not a given, but the vulnerable outcome of a ceaseless process which draws on mundane “remedial interchanges” (Goffman 1971) and on conversation repair (Garfinkel 1967; Schegloff 1992; Schegloff et al. 1977). Taking inspiration from these crucial theoretical claims, maintenance and repair studies strive to broaden the focus from conversational exchanges and face-to-face interactions to the material features of our daily lives and environment. Social order, then, can be conceived not only as sociomaterial order, but also as the concrete result of the everyday practices of material maintenance and repair. Insisting on the perpetual production of social and material order, these studies stress the instability and potential failures and fragility beyond a definition of sociomateriality that only focuses on “affordances” and “scripts” (Jarzabkowski and Pinch 2013).

A particularly promising set of studies regarding architecture preservation (Edensor 2011; Jones and Yarrow 2013) and art conservation (Dominguez Rubio, forthcoming) pushes the discussion further, questioning the status of the “order” maintenance and repair are supposed to create. These studies notably show that authenticity, for which preservation practices strive, is distributed amongst heterogeneous arrays of agencies

and, above all, is always negotiated. Hence, sociomaterial order would be, by no means, a shared and univocal horizon toward which all repair work would be oriented; on the contrary, investigations of maintenance and repair foreground the relationality of sociomaterial order. Maintenance and repair practices are embedded in social worlds that bear specific normativities (Gregson et al. 2009) and enact various, and sometimes opposite, orders.

Similarly, following Mol (2008) and Puig de la Bellacasa (2011), scholars recently discussed maintenance and repair as deeply inscribed in a logic of care (Jackson 2014; Denis and Pontille 2015) that starts from decay and vulnerability instead of denying them (Tronto 1993). Because they concentrate on the material fragility of things (Connolly 2013) and the constant necessity of taking care of them, maintenance and repair actually offer an opportunity to reconsider the traditional view of the role of artifacts in society and, more generally, of object agency (Law and Singleton 2005), pursuing feminist reflections on human and nonhuman relationships (Haraway 1991). Studying the ways in which maintenance workers or mundane users explore matter and its various modes of existence is thus a particularly efficient means to think materially, beyond inertia (Barad 2003; Ingold 2007) and sturdiness (Denis and Pontille 2014).

## 2. Maintenance, Repair and Innovation

Within STS, maintenance and repair, as a matter of concern and as a field of inquiry, challenge the more widespread images of innovation. Innovation is “a highly politicized construct taken up by specific actors and made to work in particular ways” (Suchman and Bishop 1999, 7).

We can clearly distinguish two ideas of innovation: a more widespread series of representations focused on the relation between designers and users or a series of analyses focused on the overall articulation process. The spectrum can be characterized following the roles played by things and matter (Barad 2003; Puig de la Bellacasa 2011).

Innovation has been mostly defined as a successful two-step process consisting of relevant actors articulated in invention and diffusion. Innovation in public space and discourse is accepted without specifying consistency or characteristics (Godin 2013). However, if we consider every change in processes and products, in use and configurations, and in tasks (touching the sociotechnical or hybrid sets as an element of process innovation), we must admit that heterogeneous actors in common settings of maintenance and repair continuously produce a large amount of innovations (Jackson 2014). Unfortunately, these innovations are not easily acknowledged as such (Mongili 2015).

Largely drawing on feminist studies, maintenance and repair studies is concerned with “decentering” sites of innovation (Suchman 2009) and

widening the interest in design, use, organizations, corporations, and markets (Graham and Thrift 2007; Graham 2010). Because maintenance and repair studies take the fragility of technology as a starting point (Denis and Pontille 2014) and focus on object breakdown rather than closure (Jackson 2014), maintenance and repair studies explore overlooked innovation practices. Graham and Thrift (2007, 5) state:

But when things break down, new solutions may be invented. Indeed, there is some evidence to suggest that this kind of piece-by-piece adaptation is a leading cause of innovation, acting as a continuous feedback loop of experimentation which, through many small increments in practical knowledge, can produce large changes.

Most designers limit themselves to assembling elements that already exist, rarely introducing new elements. They verify or produce interoperability among the elements driven to converge in a new device, and their job is characterized by an extended use of the tools, infrastructures, and materials at hand (Oudshoorn and Pinch 2003; Mongili 2014; Sefyrin 2012; Suchman 2002). Therefore, repair is at the heart of a continuous process that includes patching up, reconfiguring, interpolating, and reassembling settings from previous forms of existence.

Repair practices show that the “articulation” of a device is as relevant as its design. The concept of articulation is derived from interactionist matrices. Geoffrey Bowker and Leigh Star (1999, 310) defined “articulation” as a “work done in real time to manage contingencies: work that gets things back on track in the face of the unexpected, that modifies action to accommodate unanticipated contingencies.” Decentering our interest from design, conception, projects, and stabilization and moving toward the big domain of articulation, we have found a junction element between innovation and maintenance and repair studies because changes and innovation occur during articulation. In studying maintenance and repair, we shift toward more ordinary technical devices (Denis and Pontille 2014) and their fluidity and fragility (de Laet and Mol 2000). Outside and beyond representational understandings of innovation, we consider innovation as occurring every day, but we consider it often invisible. Shifting to the ordinary has important consequences. First, the changing processes of devices and their assemblages must be studied in unexpected places and temporalities. In particular, the extension of sociotechnical networks to the countries of the South, transformations endured during those processes, and the changes they enact all seem particularly interesting. Second, the changing processes should be investigated in studying design and use, maintenance and repair, and their convergence, specifically, the convergence between these aspects digitally. As Suchman recently asserted, the digital “undoes professional boundaries historically drawn between making and using” (Suchman 2014, 129) and, we can add, between making, using, and repairing.

STS have insisted on the role of crises and breakdowns in innovation processes for years. Research in the social construction of technology notably highlighted how innovation occurs far after its last official steps and how technologies constantly oscillate from open states to closed ones. However, considering the many possibilities of innovation, maintenance and repair practices show differences in foundational studies. Indeed, the constant ordering processes that maintenance and repair studies have foregrounded (Orr 1996; Henke 2000; Denis and Pontille 2014) have little to do with closure or the dynamics between the moments of crisis and stabilization. Through dismantling, disassembling, and reassembling activities, maintenance and repair practices are grounded in a disordered ground, not in an immanent order to be reproduced or defended. They enact multiple realities (Mol 2002; Law 2004) and multiple “vulnerabilities” (Callén and Sánchez Criado, in this issue) that are the grounds for innovation.

### 3. The Papers in this Issue

The papers gathered in this special issue emphasize, revisit, or pursue the aforementioned topics, investigating distinct empirical cases.

We saw that maintenance and repair studies highlight the material vulnerability of our world. In “Vulnerability tests. Matters of ‘care for matter’ in e-waste practices”, Blanca Callén and Tomás Sánchez Criado try expand on this stance, exploring the diversity of the ways in which vulnerability is experienced in practice. Studying the case of electronic waste, they show that mending, fixing, and maintaining obsolete computers involves at least three kinds of, what they term, “vulnerability tests:” sensing matter, setting up informal experiments, and intervening in obsolescence. These tests bear witness to very different ways of enacting vulnerability through specific and situated “care for matter” practices. Moreover, they each participate in sustaining a particular ethical and political alternative order that resists the current e-waste regimes and their focus on obsolescence. Using these vulnerability tests, the authors, following Puig de la Bellacasa (2011), ask us to think about how we, as STS researchers, can approach fragility with care, and they ask us to not quickly see maintenance and repair processes as mere restorations of a preexisting sociomaterial order.

In “Instances of Failures, Maintenance, and Repair in Smart Driving”, Oana Stefana Mitrea questions the designers’ point of view on maintenance and repair in investigating the ways that failures are envisioned in advanced driver assistance systems. In autonomous car experiments, which actually appear semi-autonomous, repair is not perceived as a mainly human practice to help objects or technologies retrieve their full functionalities; conversely, they are perceived as complex technological

activities aimed at surveilling humans, which are considered major, if not unique, causes of failure. Such a specific case invites a more symmetrical view on maintenance and repair, sometimes made of “distributed reciprocal monitoring.” Moreover, it shows the importance of considering the broad ecology of maintenance and repair and questioning, beyond the situated practices, the ways that failures or weaknesses are attributed in sociotechnical structures.

The ethnomethodological roots of maintenance and repair studies have been stressed many times. Garfinkel (1967) and Schegloff and his colleagues (1977) have been crucial in studying the vulnerability of social order and the continuous role of repair in its daily accomplishment. In “Reassembling Repair: Of Maintenance Routine, Botched Jobs, and Situated Inquiry”, Philippe Sormani, Ignaz Strebel, and Alain Bovet return to these early questions, investigating the daily maintenance of a building. Drawing on video ethnography, they investigate maintenance and repair as a practical issue instead of a theoretical topic. The authors examine the methods of situated inquiry conducted by professionals (plumbers) and laypersons (tenants) to recognize and fix particular housing problems (such as sink and bathtub aerators). At the core of these situated inquiries, the practices of reassembly emerge as crucially at stake. Repair operations draw upon the coordination of different participants who, as Sormani, Strebel and Bovet put it, “configure the very site and situation of their (inter-)action *in vivo*.” Thus, the participants evolve during the course of their actions (for instance, switching from a maintenance routine to an urgent repair) and are defined in their own terms, concepts and distinctions, which do not necessarily fit with the researcher’s preconceptions.

In “Repair in socio-technical systems: The repair of a machine breakdown that turned into the repair of a shop”, Cynthia Colmellere addresses the issue of crisis in repair, analyzing the implications of a major breakdown occurring in a large sociotechnical network; namely, in an industrial plant. In particular, she focuses on negotiations that emerge between different actors trying to identify the needs for repair, produce a reliable diagnosis, and designate the actors entitled to repair. The author points out the specificities of repair, and she identifies how repair intertwines with power, social relations, and technological issues as activities characterized by contingency management and *bricolage*. Maintenance and repair are here characterized as a distributed activity within an organizational framework, and they raise important organizational questions in terms of their visibility as a recognized activity and their relevance in the workplace and in organizations.

This collection of articles does not cover the range of topics falling under the extensive scope of maintenance and repair studies. Based on an in-depth case study, these articles investigate maintenance and repair practices in contrasting sites and workplaces that involve distinct occupational communities. By doing so, the articles do not exclusively focus on

the singularities at play. Rather, they simultaneously examine the ways in which the peculiar issues addressed are related to larger topics such as planned obsolescence and tinkering, the distribution of action and the ascription of responsibilities in innovative sociotechnical networks, and the ongoing process of reassembling people and things in particular settings.

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# Vulnerability Tests

## Matters of “Care for Matter” in E-waste Practices

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**Abstract:** In this paper we will think ethnographically about how material vulnerability is dealt with and conceived of in the practice of informal menders. We explore different practices to “care for matter”, mobilized in dealing with obsolete computers, categorized as electronic waste, and will analyse the epistemic repertoires to acknowledge and intervene in such computers vulnerabilities. In dialogue with STS and Repair and Maintenance Studies literature, we will move from vulnerability as an ontological quality of the world to the enacted properties and epistemic repertoires emerging from concrete “tests”, through which we might learn how vulnerability matters. In particular, we pay attention to three specific vulnerability tests performed by these informal menders, underpinning particular distributions of labour as well as concrete enactments of vulnerability, and how to make it matter. Namely, *sensing matter*: manipulative practices of electronic waste whereby vulnerability is enacted as a property of materials; *setting up informal experiments*: informal practices of trial and error whereby vulnerability appears as a result of dis/functioning technical systems; and *intervening in obsolescence*: whereby sociomaterial orders regulate how material vulnerabilities are redistributed and put to the test.

**Keywords:** maintenance & repair; matters of care; vulnerability; test; electronic waste.

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### I. Introduction: Dealing with E-waste

Observing the world around us, we might realise that material vulnerability is probably inevitable, a kind of ontological condition affecting all matter and bodies. Something we might take for granted, be it because of the passage of time or because of the wear and misuse of our everyday

things. However, in this paper we would like to reflect on how such vulnerability is dealt with and conceived of, or as we will say ‘enacted’ or made to matter, in maintenance and repair practices. Through different empirical vignettes drawn from ethnographic fieldwork on informal practices of mending, reusing, repairing and hacking of electronic waste in Spain, we will try to explore how such material care – or “care for matter” – practices mobilized to deal with obsolete computers could also be thought of as powerful epistemic repertoires to acknowledge, make perceptible and intervene in particular vulnerable matters. More specifically, we would like to consider these practices as working experimental trials or vulnerability “tests”, similar to the ones occurring in the implementation, repair and maintenance of other diverse matters, objects and infrastructures. We would like to put forward that these vulnerability tests also underpin the ethical and political orders and ecologies that are being sustained, maintained and produced alongside.

Hence, this paper seeks to develop a twofold argument: On the one hand, we seek to foreground the importance of material care or “care for matter,” and the recognition of vulnerability occurring there, paying attention to the situated knowledge methods mobilized to tackle it, to understand it and, eventually, to intervene in it. On the other hand, and as an effect of the previous point, we would like to suggest “mending” as a particular form of maintenance and repair practice, whereby conservation is exerted in a more interventional and politically nuanced register.

The ethnographic material we would like to think about stems from a research project<sup>1</sup> on informal but innovative responses to e-waste problems carried out in Spain between 2012 and 2014 by Blanca. Considering the limited results of public policies on e-waste and the relative novelty of this emerging ecological problem, the aim was to explore the material and epistemic informal practices arising at the margins of institutionalized managerial circuits, in the space that seems to appear between a mainstream consumerist conception of electronics and the e-waste treatment solutions, focused on recycling. The idea was to understand how these informal experiences might be practically altering (be it resisting, avoiding, slowing, hacking or transforming) the managerial processing sequence that goes from “computers” to “e-waste”, but also offering alternative models on how to make electronic waste matter. Hence, Blanca observed three different experiences.

The first one was a group of informal migrant waste pickers who look for metal pieces and components in the streets of Barcelona<sup>2</sup>. Living and

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<sup>1</sup> To know more about the “Politics of scrapping” research project, see <http://politicadechatarra.wordpress.com/>.

<sup>2</sup> From November to December 2012, Blanca visited their warehouse three or four times a week and used to accompany one of them in his daily activities. Besides fieldwork direct observation and informal interviewing, several individual

trading, at that time, in an impoverished neighbourhood's huge squatted warehouse, they wandered around the city every day picking up scrap metal and precious objects to sell them to bigger scrap-traders. In the case of still "useful" computers and electronic devices, they were sent – either directly or through middlemen traders – to second-hand markets in Africa through informal but trustworthy networks of contacts in order to have them repaired and sold again.

The second and third were located in Madrid<sup>3</sup>: *Obsoletos*, a small hacker research project in Madrid, composed of four friends trained in different scientific and technical disciplines. Thanks to a grant from the Spanish Ministry of Culture they organized several workshops and meetings to teach how to rebuild obsolete computers and to create other "hacks" from discarded components and devices. They also published a blog<sup>4</sup> dedicated to the analysis of different aspects of technological obsolescence and to document their creations, such as a soap bubble-maker, a hard drive speaker or a laser oscilloscope. Despite the fact that their educational project finished a few years ago, they still blog, collaborate with other groups and develop some hacks and creations just for fun or the pleasure of learning.

And *Cyclicka*, a self-managed computer repair collective workshop<sup>5</sup> that operated, at that time, as an informal learning hub inside a huge social centre in Madrid. They were hosted there and, as an exchange, they offered help with maintenance and repair services. Old computers were donated (mostly by neighbours) and volunteers gave lessons on computer refurbishment. There was also a weekly repair workshop open to the public. The repaired and refurbished computers could either be sold by repairers – who then earned two thirds of the money – or given for free to social and activist local projects. They could also be given to schools and educational projects all over the world, thanks to a self-managed social network called *Labdoo*<sup>6</sup>, which puts laptop' donors, repairers, carriers, petitioners and receivers in touch.

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interviews were also made with different waste-pickers, a "middle-man" trader and a local seller who used to make deals with scrap-traders in the warehouse.

<sup>3</sup> From October to November 2012, Blanca hired a place in the co-working space of the *Obsoletos*' warehouse. However, considering the decrease in their activities as a group, what was to be observational fieldwork turned into an ethnographic research carried out through individual and collective interviews and a documentary analysis of their blog, which operated as an archive of their past activities and publications about e-waste, hacking and repair of electronic products. In the case of *Cyclicka*, Blanca made a participatory observation of their activities and interviewed different participants of *Cyclicka* and *Labdoo*. Also, a public presentation of the research project operated as a debate and collective interview with *Cyclicka*'s crew.

<sup>4</sup> See <http://obsoletos.org/>

<sup>5</sup> See <http://blogs.latabacalera.net/cyclicka/>

<sup>6</sup> See <http://www.labdoo.org/es>

## 2. Re-enlivening Mending, Tackling Vulnerable Matter

These practices indeed bear witness to how, since the 1970s, in different countries of both the so-called developed North and the Global South, different collectives have begun to explore other models of design and production, different habits and everyday routine practices (be it in communes or in self-organized groups and institutions; see Turner 2006), building different narratives and manifestos on what it would be like to inhabit a finite world, thinking of alternative distributions of goods and community economies (Roelvink, St. Martin and Gibson-Graham, 2015), talking about other kinds of relationships with the immediate environment, personal and collective resources and the things around us.

We use the word “menders” to describe those diverse collectives engaged in different sorts of mending and repair practices, be it through professional practice or through the revival of traditional crafts and the articulation of new technological hopes via open-access technologies – such as “do it yourself” (DIY) and “do it with others” (DIWO) philosophies and other sorts of participatory design projects (e.g. hacker or maker cultures studied by Kelty 2008). Indeed, many of these collectives have articulated a critique of innovation (Suchman and Bishop 2000) – re-analysing Schumpeter’s works on capitalistic “destructive creation” – by focusing not only on the sheer ingenuity of designers and engineers in materializing their ideas but also, and more fundamentally, on the practical issues related to the user adoption together with the work of technical implementation and the practicalities of maintenance and material wear affecting the objects and technical systems conceived of by them (Akrich et al. 2002; de Laet and Mol 2000). To use Ingold’s (2013) vocabulary these collectives warn us against focusing exclusively on practices of “form-giving” and direct our attention towards the crucial practicalities of “form-keeping” in our life with materials.

Following this interest in maintenance and repair, some research and social projects, such as the ones observed by Blanca, have already started to explore the reach and effects, as well as the limits and scope of what could be called, in line with the recent re-enlivening of craftsmanship and workshop cultures, “mending cultures” – see also Dant (2010), Oroza (2009) and Sennett (2008). Many activist projects and experiences that critique design’s logic of conception and its grandeur are also claiming mending and repair practices as vibrant social and innovative acts, far removed from the tedious, and domestic attributes usually ascribed to them (being considered by some as “chores”). From this perspective, mending means establishing direct, caring and lasting relationships with our surrounding material world. For some, these new “craft consumers” (Campbell 2005), “lead users” (von Hippel 2005) or “creative communities” (Meroni 2007) are defining a sort of open-source “new DIY age” (Hoftijzer 2009) or “Post-Professional Era” (Atkinson 2010) where

mending and repair result in opportunities for social, economic and technological innovation. Without any doubt, the everyday practices of such menders constitute particular cultures that could maybe challenge and redefine, in more creative and sustainable terms, our economies and environments as well as our role as active citizens or the way we approach our daily infrastructure and socio-technical systems, or more generally how we approach design (Papanek 1971).

These movements signal, indeed, the emergence of more conscious and sustainable growth ideals in which the meanings attributed to values, the definition of matter and design, as well as the concepts of time and the economy are affected. For instance, Graham and Thrift (2007) note that perhaps the main imperative in more responsible forms of object design should be to address “repairability,” hence stressing their potential for a renewal of economic and industrial practices. Such potential is also put forward by Gregson et al. (2009) who analyse different practices of object maintenance at home, thus showing their importance, in terms of competence, purchasing power or parenthood, for the social lives of consumers. Recent research has also put under a critical lens key aspects of unsustainable practices of consumption, such as the “planned obsolescence” of technological devices (Huisman et al. 2008; Maycroft 2009).

What remains clear for many of these projects is that, sooner or later, more or less intensively, everybody experiences material vulnerability at some point, revealing the neglected, denied, bracketed or forgotten counterparts of common modern assumptions regarding subjects and objects (Jackson 2014). Or, “thinking big”: the risks to economic, social and environmental well-being posed by, amongst other issues, environmental damage and climate change, the shortage of natural resources, the global financial crisis, or the increase in impoverished, vulnerable and marginalized populations both in the North and in the Global South, are just some of the current problematic expressions of widespread social obliviousness to the conditions of finitude and fragility affecting not only our organic and social bodies but also the “bodies” of those objects we live by.

Many of these themes have also been present in recent STS literature, such as Bijker’s (2006) reflections on how our contemporary technological cultures are underwritten by variegated and polysemic forms of vulnerability having both positive and negative aspects: ranging from the negative vulnerability appearing in the presence of increasing technoscientific risks requiring us to develop precautionary principles to the positive discovery of many forms of grassroots resilience and coping practices in relation to such risks (Hommels, Mesman and Bijker 2014). Indeed, many STS works related to feminist literature have been stressing the importance of paying attention to what some philosophers name “ontological vulnerability” (Connolly 2013). When talking about subjects, the use of vulnerability has become central to many feminist students of technoscience, for it summons an ethical repertoire different to the liberal and

modern conception of subjects as autonomous and free individuals. These scholars rather talk of bodies as fragmentary entities in need of constant careful practices to be “held together”, as Mol (2002) puts it. But this could also affect how we think about matter: an attention to brokenness and decay mobilizes other theoretical and practical engagements different from the ones available when using the concept of “object,” as a closed-down and ready-made commodity – an object “at hand”, part of the “furniture of the world” to use the vocabulary of analytical philosophy –. Indeed, we could follow Maria Puig de la Bellacasa’s reflections (2011) to foreground how repair, maintenance or other “care for matter” practices might be taken as epistemic repertoires addressing matters that, despite usually remaining hidden or not easily visible, are still crucial and necessary for the fragile continuity of our common but uneven socio-material worlds.

Hence, despite the fact that vulnerability is in many practical situations easy to identify – such as when a clear breakage happens while using something, after an accident or as a result of a disaster – it usually emerges out as part of an ongoing process of sensing and practical manipulation, hardly ever recognised at first glance. Hence, although vulnerability and wear are constitutive of any entity or matter, as many feminists writers working on ethics of care have long argued (Tronto 1993; Pérez Orozco 2014; Mol 2008), they are not so evident and perceptible if we do not pay enough attention. And this is, precisely, what the observed mending practices around e-waste do: to experiment and identify material vulnerability through attentive and careful “tests” on matter. In clear analogy with what Latour stated in *Irreductions*:

[...] There are only trials of strength, of weakness. Or more simply, there are only trials. This is my point of departure: a verb, “to try.” [...] It is because nothing is, by itself, reducible or irreducible to anything else that there are only trials (of strength, of weakness). What is neither reducible nor irreducible has to be tested, counted, and measured (Latour 1988, 158).

Building from this, our aim in the following section would be to describe and read such practices of handling, treatment, repair or maintenance of e-waste as “vulnerability tests”: that is, situated and overlapping informal experimental settings allowing practitioners to sense and discuss different meanings, expressions, values and distributions of electronic waste, enacting particular versions of their vulnerability and how it might matter. More specifically, the first test on sensing matter focuses on how matter or functional vulnerabilities are sensed through manipulation. We also refer to a second type of test, consisting of setting up informal experiments whereby epistemic repertoires and methodical knowledge about vulnerability are produced. At a third moment, by intervening in socio-material orders, these collectives can “put to a test” the policy regulations



and governmental dispositions that rule, order and distribute our daily and unequal vulnerabilities. That is, the ontologies and boundaries of waste appear as multiple and unstable situated effects of performance (Mol 2002) through explorations, and interventions, very much in line with what Maintenance and Repair Studies have shown (Denis and Pontille 2014a, 2014b; Henke 1999; López and Sánchez Criado, 2015; Orr 1996; Sanne 2009, 2014).

Hence, versions of vulnerability are enacted in these experimental testing activities that produce particular forms of both informal and formal knowledge on matter that might help us think “more carefully” – or care “better” – about the ecological dimension of e-waste. To conclude, we will suggest that such vulnerability tests could be extremely important beyond a concrete analysis of e-waste practices to devise “more caring” analytical tools, especially in STS, allowing us to think more responsibly and carefully about how, under which conditions and effects vulnerability is collectively enacted but, also, how it might be intervened in.

### **3. Tests: Enacting Versions of Material Vulnerability by Scrapping Metals and Repairing Computers**

In this section we would like to delineate empirically three “vulnerability tests” taking place in the observed practices. A first test involving *sensing matter* where vulnerability emerges as a property of materials sensed through manipulation. Second, a form of testing that entails *setting up informal experiments* where vulnerability is enacted as a property of dis/functioning technical systems. And third, a testing regime *intervening in obsolescence*, whereby vulnerability is highlighted as a sociomaterial order related to policy instruments that rule, order and differently distribute our daily vulnerabilities.

#### **3.1. Sensing Matter: Vulnerability as a Property of Materials**

When doing fieldwork with waste-pickers in Barcelona learning how they weighed the value of their findings, Blanca accompanied Marcel along his daily work of searching for and manipulating scrap:

In most of the cases, it requires them both to recognize different kinds of materials at hand – especially metals – and to know if the electronic devices found are still functional. These variables help them to mark the right price in negotiating with others. The magnet, as I learnt, is a key tool in all these processes: if the piece attracts some materials, it is ferrous. If not, you just need to scratch a bit to distinguish brass from aluminium. But the best paid is copper, known by its reddish colour. Marcel, the closer informant who has taught me the trade and with whom I have walked most, tells me that it was also very important to know how to “crack open” the

things you have found: “You never know what you can find inside”. A wrong blow on the incorrect part can make the opening and access much more difficult, in terms of effort and time. The most difficult task is to crack open motors. Whether they come from fridges, washing-machines or any other small device, the motor is where the biggest quantity of copper can be found. Today he recalled his first day as a waste-picker, when he found a motor but he had to sell it as a whole: “At the beginning it was very difficult: as I didn’t know what to do to extract the motor. Sometimes, it took me a week” (Excerpt from Blanca’s fieldnotes).

But how do they face the unknown? How do they tackle and deal with strange “new” devices? The weight is the clue:

Marcel also explains: “Until now, I didn’t know what it was, but if it weighs, you have to break it. Because if it is heavy, it may have a big motor inside. Because the most important [material] is copper. Then, you break it and you can get 2 or 3 kilos of copper from just the motor”. And after this, he mutters very quick calculations about how much money he can make if he extracts the motor. “[...] But if you don’t even know that this is a motor, how can you know that there is copper inside!?” he concludes” (Excerpt from Blanca’s fieldnotes).

Another day, there was a case of a lamp that turned out to be hiding a very big piece of copper inside, and of a CPU (see Fig. 1).

Marcel suspected there was copper inside because of the sound and the weight when manipulating it. I had asked him before if it might not be better to sell it as a whole. That is, as a lamp. But he shook his head saying it would not sell “because it doesn’t “look” like an antique”. If it were an antique, it would have some value. In the case of computers, he seemed to know much better what to do with them because of the standardization of their assembly, components or materials. One of the CPUs he found was completely taken apart. The owner told him that it was very old and this was evident because of the external “appearance”. The most precious part, he told me, was the electricity supplier – because there was most copper inside – then the hard disk – either because of its aluminium or because some people buy them separately and lastly some small copper pieces welded to the motherboard. If the computers or electronic devices were still functional, he would send them to the Moroccan neighbour traders. The method used to work this out is a pretty simple one: he plugged them in. If they turned on, they are OK. Nevertheless, he maintained that everything is repairable in Africa, quite unlike what happens in Europe. “You are used to throwing things out and buying another one”, Marcel said” (Excerpt from Blanca’s fieldnotes).



Fig. 1 – Waste-picker in the squatted warehouse in Barcelona extracting some copper pieces welded in a motherboard. Taken by Blanca Callén (14/12/2012) and used with permission.

In such explorations, waste-pickers tried many different methods before knowing if a given object was a valuable find or before stating a clear diagnosis. It would seem clear that all electrical devices have some copper inside but one never knows how much. The act of weighing things, such as in the example of the lamp, gives some clues – there might be a transformer inside and, hence, also copper. But despite the expertise of people such as Marcel, for him distinguishing the different kind of metals that the lamp was composed of required a new test involving the use of a magnet plus scratching. Through these actions, he could know first the existence and then the value of something of worth inside the lamp. In this case, the objective was not to repair a physical breakage or an electric vulnerability, but to extract something valuable from it.

These vulnerability tests are related to sensing the object's properties, creating conditions to let “matter speak” in order to know about it – to use Sanne's (2009) wording in his analysis of the on site diagnostic work of railway maintenance technicians –. For instance, a great part of waste-pickers' tasks consist of checking the things they have found in order to determine their properties, or to know if the devices work properly or not, leading to troubleshooting moments where practitioners must decide what to do, guided by preliminary diagnosis.

Many of these repair and maintenance situations are indeed sensory practices (Dant and Bowles 2003; Dant 2010) in which practitioners engage in “[...] rhythmic repetitions of gesture entailed in handling tools and materials [...] set up through the continual sensory attunement of the practitioner’s movements to the inherent rhythmicity of those components of the environment with which he or she is engaged” (Ingold 2013, 115). Indeed, this is what happens when weighing findings or when scratching and observing emerging colours under the scratch, or when carefully listening to whistles from the CPUs. To use Leroi-Gourhan’s words, these waste-pickers’ practices entail “a dialogue between the maker [or repair practitioner] and the material employed” (quoted in Ingold 2013, 115), where material nuances and potentialities emerge. Through situated and sensuous cognitive practices “in the wild” (Hutchins 1995) that almost never follow “logical” or “standard” procedures of thought (Denis and Pontille 2014a), waste-pickers produce a particular version of vulnerability: entailing practical knowledge over the material weaknesses and potentialities of those things they are putting their hands on, in order to know if they can keep on manipulating them or if their ontological status must be shifted and altered to continue exploring the life of materials (see Ingold 2013).

### **3.2. Setting Informal Experiments: Vulnerability as a Property of Technical Systems**

Nevertheless, vulnerability tests are not limited to the materiality of technologies discovered through sensing and manipulation. Sometimes they also entail opening up apparently “closed” objects or technical systems (see Fig. 2). The guys from *Obsoletos* know this well, as it became evident in one conversation with Blanca, telling the story of a computer found in the bin:

Fernando said, “It was only the graphic card that was ruined”. Probably, Fernando continued, the owners had thought that since they could not see anything it had stopped working. And, as they state, the same thing happens with the 90% of the computers that they find. Indeed, the cause of their breakdown is not “material” or “physical” but “human”, as they say. In that particular case, they just changed the graphic card replacing it with a reused one that was extracted from another obsolete computer. “In any case, if you rescue two obsolete computers, you have 98% of possibilities of getting a working one. If you have three computers and it still doesn’t work, you are a jinx”. This is why, as they say, in order to repair and refurbish computers, or even for hacking, it is extremely important to have plenty of functional spare parts and components. But having a huge amount of them, without knowing if they work or not, has absolutely no value (Excerpt from Blanca’s fieldnotes).



Fig. 2 – Exhibition in La Casa Encendida (Madrid) in May 2005 where Obsoletos displayed an opened-up but still running computer to show its functioning to public. Taken from <http://obsoletos.org/2008/05/ordenador-abierto-mayo-de-2005/> and used with permission.

Indeed, another day in Madrid around that same time, visiting the Cyclicka workshop Blanca suggested throwing away a damaged hard disk from a broken computer:

Javier, Cyclicka founder, appears out of the blue and tells me not to do it. He explains me that they could still use it as an external data hard disk. The same happens a while after when collectively exploring a damaged CD player, whose motor could still be useful to make or hack new devices. Or with several old-fashioned keyboards, whose printed circuits could still be used for videogame consoles (Excerpt from Blanca's fieldnotes).

This way, a computer is not treated as an entire closed part or standard object with a unique function, but as a “system” of heterogeneous components. This is the basis for testing computers' functionalities as, in an analogy with a particular version of the scientific method, the isolation of different variables through “trial and error” becomes crucial for detecting problems and finding solutions. After repairing the aforementioned computer, that with the damaged hard disk, people from Cyclicka put a sticker on it with the name of the collective to whom it was going to be donated. When they came to pick it up, the repairer asked them as

soon as they arrived: “What exactly are you going to use it for?”. “Editing texts and designing some flyers,” they answered. “In that case, it’s OK”. Probably, if the future functions of the computer had been much more complex, the power or CPU’s outputs would not have been enough.



Fig. 3 – Shelves with donated computers, in Cyclicka’s workshop, waiting to be refurbished or cannibalized. Taken by Blanca Callén (4/11/2012) and used with permission.

Unlike other devices, the preliminary diagnosis of computers is easier because of their similarities: all have the same type of components with their same respective functions, are made from the same kind of materials, and everyone knew it. Their accumulated knowledge about standard functions and dysfunctions allowed them to very quickly identify the reasons for the damage. If the computer’s screen in the bin was completely black and there had been current coming into the CPU, then, it was likely that it would have to do with something technical related to visualization, such as the graphic card. However, there is usually not just one reason for the failure and there are not straightforward ways to know what they are. The connection between the event (e.g. a black screen) and its potential cause (e.g. graphic card) is a very direct and common one. In many cases, the diagnosis is also based on sensory and attentive bodily dispositions by repairers. As Tilan, one of the waste-pickers who worked also as repairer explained, “Often, you know what the problem is because of the whistle it makes. You remove what

doesn't work and put in components that work. And if it doesn't whistle then it works". But when the failure signal is not so obvious or even there are no signals, the possible causes multiply. In that case, repairers and refurbishers manage several hypotheses and, as in scientific trial-and-error practices, they try to isolate causes, one by one, rejecting options and clearing up reasons for damage (if possible). Whilst these practices also entail sensing matter, we believe that here lies another form of vulnerability test, related to setting up informal experiments.

Although in much STS literature the experiment as *experimentum* or controlled setting is cast off from the world of *experientia* – or the “sheer liveliness and messiness of quotidian practices” (Tironi 2014, 116), we could consider these informal sites and events as experimental settings of a kind, whereby a particular enactment of vulnerability emerges out. In fact, most of the recent literature on experimental cultures in STS (Knorr-Cetina 1999) signals the very particular, situated and non-standard conditions of experimentation, involving active testing, that take place in many spaces beyond “the lab” (Gross and Krohn 2005), and which could help us reframe experimentation as a methodical learning device about matter using different probes (see Dickel et al. 2014).

In the case of waste-pickers, if computers seem to work after a precarious check – i.e. plugging in – it means that they might sell them, for instance, as a whole to Moroccan traders. If through these tests a useless or dysfunctional device emerges, its matter is requalified: it is dismantled for components or materials. A similar thing happens in Obsoletos and Cyclicka's cases: once they have checked that the computer does not work properly, a diagnosis is needed in order to know which part to change. Except for the motherboard which, “if it is burnt, then everything is burnt and there is no option of mending. That [computer] can already be taken to the scrapheap, to be destroyed”, Tilan, the waste-picker/repairer told Blanca. Afterwards, they might be “cannibalized” and broken down into disperse spare functional parts that will be used for reviving other, better machines. But if the processor and motherboard are in a good enough state and have reasonably good capabilities – which can be known by the age of production – then repair might be attempted.

Through these trial and error moments, if successful, computers appear as a “system” composed of a myriad co-functioning components. And in this practical recognition of the computer's openness and modularity resides the possibility of reuse, repair or hack. Then, the computers' states are transformed from pieces of matter into functioning devices, from “black-boxed objects” into “modular systems”. Just by daring to open it and start working on experimental hypotheses about the role of components and variables, by isolating them and testing different combinations, the observed participants can manage to reuse their obsolete computers and parts and transform them into a completely different functioning entity. Such informal menders are establishing and

proposing different ontologies for electronics that emerge in the space they open between apparently non-working computers and potential realms of waste. In this sense, they experimentally prove the possibilities of material existence and resistance: a computer is not valued and considered here “for what it is, but for what it “might become” (Gregson et al. 2010, 853). And these electronic components still have a life due to their ‘fluid ontology’ (cf. de Laet and Mol, 2000), that is, because of the adaptation, reconfiguration and changeability they allow in practice.

Isabelle Stengers’s (2010) arguments on the importance of experiments might be of great interest to apply to these situations: experiments enable us to pose new questions, whereby if successful we grant different agencies the power to allow us to say something new about the world. This is what happens in the transformation of e-waste residues into electronic or metal resources, or in turning passive consumers into daring hackers and menders. Indeed, we would suggest referring to the aforementioned empirical stances as informal “atmospheres of indagation,” “unfolding”, “multiform” and “ambiguous ambiances”, “meticulous, open and agonically needed” inquiries (Tironi 2014, 118-119) whereby material vulnerability is enacted through informal experimental settings. In these settings discarded computers are submitted to functioning-tests in which they are re-valued, engaging in the production of relevant knowledge to hack, mend, circulate or extract metal from them.

### **3.3. Intervening Obsolescence: Vulnerability as a Sociomaterial Order**

By collecting, repairing, refurbishing or taking apart e-waste, the observed menders and waste-pickers are not only addressing material vulnerability through sensory gestures or building some knowledge around breakages and wear through trial and error. Alongside the aforementioned vulnerability tests, they also, more importantly, engage in world-making interventions. In putting their hands on these devices and objects they are affecting and displacing what is understood as the core of e-waste, that is, obsolescence. And we believe that in these interventions, a third enactment of vulnerability emerges in the shape of an entire socio-material order. In other words, a particular regime governing socio-material conditions that regulates how electronic vulnerabilities are tackled and distributed – through uneven epistemic repertoires and divisions of labour, legitimacy and responsibilities – is put to the test. Sometimes, such vulnerabilities suddenly emerge from a very quick glance. In other cases, they are disclosed in the shape of the waste-pickers’ tools. No matter how big, this socio-material order can be revealed in very mundane gestures:



“[...] there are many people that see [us] as miserable or think that we are stupid”, explains Marcel. And “sometimes it bothers me when you are working and someone looks at you in a way... as if you were scrap”, just as the same waste that they collect (Excerpt from Blanca’s fieldnotes).

Using the magnet or plugging in the devices to see if they work, in the case of waste-pickers, become indexes of alternative ways of dealing with and constructing knowledge on what would be called “e-waste”:

Most of their tools also come from the streets: “We find them, as scrap. But sometimes we have to buy tools such as pliers, because they are not so easy to find”, Marcel explained. They also need to use maths and economy... and physical capabilities, “to break things”. Because, “if you find a fridge on the street, who is going to help you? One day [...] I had to take one over my head” (Excerpt from Blanca’s fieldnotes).

Nevertheless, such knowledge is not necessarily based on formal education, such as some *Obsoletos* and *Cycklicka*’s participants have. In the case of waste-pickers, they pass through self-teaching processes just by:

“[...] being near of people with a higher level than yours [...] That’s why I’ve learnt [to repair computers]”, *Tilan* said. He lived with some Eastern European housemates whom he learnt from just by “watching, watching...”. Like the case of *Marcel*, who learnt from his times in *Libya*, where he used to work as labourer and also “watched” and “paid attention to what the technician did” (Excerpt from Blanca’s fieldnotes).

In this way, such epistemic settings speak of their vulnerability, as illegal migrants, that urges them to take advantage of dumped objects in order to make a living through irregular methods and informal circuits. So, leaving aside the fact that many of them do not necessarily know about electronics, the urgent need for money and the lack of proper tools or space, can also explain why most of their finds are more likely to become spare parts and extracted metals than repaired devices.

But something analogous happens the case of *Cycklicka* and *Obsoletos*, where what was a black computer’s screen for the original owner became the component of a refurbished computer, or where two useless computers for their respective owners were decomposed and recomposed into a completely refurbished computer for a cultural project plus spare parts. Such interventions and ways of dealing with e-waste speak of their conditions of possibility and the very particular “epistemic culture” (*Knorr-Cetina* 1999) of these mending projects, more or less closely connected with access to education in science and technical areas.

Despite the differences between the waste-pickers and the menders’ approaches, as an effect of both alternative ways of dealing with these materials and technological systems, electronics’ obsolescence is

intervened in by displacing its limits, and the “consumerist economy” category of waste<sup>7</sup> is put to the test. Indeed, as one of the waste-pickers once said: “I’ve never accepted the word “rubbish” because everything has been found in the street and has some value”. Only if you submit it to particular vulnerability tests, we could add. Then, while for original owners those old or broken devices had entered the realm of “waste”, for these informal and precarious menders a potentially new next shape is attempted through several different troubleshooting efforts. And through these scrapping and repairing practices they are revalued and might be reused as, for example, raw material for industry, in the case of scrap and metals sold by informal trash collectors, or as old refurbished computers.

In the same vein as in Garfinkel’s (1967) “breaching experiments,” the kind of vulnerability tests that are set up when intervening in obsolescence might reveal underlying orders that we had taken for granted. They reveal the orders ruling how to describe such things as computers, and how to manage them at a certain point as waste. And in doing so, these mending practices put to the test what counts as “vulnerable” and in need of repair, who has the legitimacy to deal with our infrastructural vulnerabilities, or under which conditions this can be done. Such tests reveal to us “who,” “in what way,” “under which conditions” and “exposed to what risks” is making the fragility and vulnerability of our everyday material infrastructures<sup>8</sup>, such as electronics and computing networks, matter. That is, the sort of epistemic agencies and knowledge production that can be fostered in alternative repair practices.

This way, both daring to take something negligible from the streets and recovering discarded old electronics interfere with e-waste ontologies and social legitimations, making space for other possibilities than the contemporary “e-waste regimes”<sup>9</sup> (Callén, unpublished; Gille 2010) that regulate societal relationships with discarded electronics. With “e-waste

<sup>7</sup> Involving end-users’ ready-made conceptions of how a computer functions, mostly reduced to higher speed computer processing, bigger capacity, lighter weight and newer aesthetics. These make devices “more vulnerable” – as unknown, closed-up and inaccessible ready-to-use objects that rapidly turn into waste – and very dependent on service economy circuits, mostly limited to guarantees from manufacturers and the expertise of official technical services.

<sup>8</sup> See Sánchez Criado et al. (2015), for an analogous development of design experiments showing the vulnerability of their makers and things through the prototyping of DIY technical aids.

<sup>9</sup> The utility of this concept lies in framing: “waste regime is a macro-level concept but is concerned with the production, circulation, and transformation of waste as a concrete material” (Gille 2010, 1056). For a more detailed description about the Spanish “waste regime”, in a transition point between a “metal regime” – where e-waste did not exist as a particular category –, and a promising but limited “e-waste regime” presenting several failures and margins for improvement, see Callén (unpublished).

regimes” we refer to those regimes and orders that rule the transformation between different ontological states of things and their circulation along formal or informal circuits and channels. The current “e-waste regime” that these waste-pickers and menders practices intervene in is also a very particular legal arrangement. Based on a European Directive<sup>10</sup>, the actual managerial system of e-waste pivots around the Extended Responsibility Principle, which puts producers in charge of their own products’ environmental effects, engaging them in the prevention of contamination due to wrongly or irregularly treated hazardous materials and components. These policies practically foreground “recycling” as the main solution to the problem of e-waste. In this equation citizens only play a role as consumers who have the right and duty to dispose of their electronic appliances using specified circuits of recollection (partially paid for by them through invisible fees on purchase). Once the devices are thrown out, their legal status changes: they are formally considered “waste”, in custody by administration, and cannot be put back into circulation, no matter if they are still functioning. The status of this waste can only be changed by the producers, who have the right to make profit from it, as recycled raw matter. The “selection and extraction of waste placed in the public thoroughfare” is in many places considered a “minor infraction” prosecuted and fined<sup>11</sup> but also condemned through scornful, degrading gazes.

Nevertheless, practices of recovering, reusing, repairing or refurbishing obsolete devices resist and test the limits of this current order while pointing to different ones, more connected with circular and “green” economies (McDonough and Braungart 2002; Ellen MacArthur Foundation 2013). Hence, they make perceptible some of the vulnerabilities of our unsustainable patterns and cycles of production and consumption, re-materializing electronics and problematizing the attached utopian imaginaries of innovation and progress (even bringing other more materialistic utopian imaginaries to the fore (Callén, forthcoming). By putting their hands on them, they intervene and subvert the electronics’ material-semiotic core: “obsolescence”, the quality of being out of date, in disuse or devalued due to a depletion or loss in its original functionality, desirability or value; a key factor in increasing consumption, fostering innovation and, as a consequence, producing waste. Obsolescence might indeed be the most powerful mechanism ruling our economic, industrial and symbolic relations to electronics from the 1930s onwards (Macyroft 2009, 26). A mechanism that defines the

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<sup>10</sup> See Official Diary of the European Union (2003).

<sup>11</sup> For instance, the Municipal Ordinances of Barcelona – similar to other city hall measures in the country – play an important role here as another legal layer, charging these illegal extraction activities with a 450,76€ fine (BOPB 2001).

ever-increasing need for new objects by stressing their value of power, speed, novelty, high-performance, lightness or mobility.

However, these practices of mending might indeed bear witness to how the capitalist logics of consumption is not entirely deterministic on our relationships with things and, in fact, can be altered. Proving, in a nutshell, that the current “e-waste regime” cannot be taken as a final step but as a disputed, unfinished and temporary system whose effects, at different levels – human, material, economic or ecological –, should be contested and mended, not without great effort. Through these practices obsolescence is put to a test: hence, the kind of vulnerabilities that appear as relevant are not only related to material properties or to dis/functioning technical systems, but rather to socio-material orders as a whole. That is, to particular policy regulations about how material vulnerabilities are unevenly distributed through power relationships, different epistemic repertoires and divisions of labour, legitimacy and responsibilities.

#### **4. Concluding Remarks. Matters of “Care for Matter” in Mending e-Waste**

Summing up, through an empirical ethnographic account of the practices of different informal menders – waste-pickers in Barcelona, and the *Obsoletos* and *Cyclicka* workshops in Madrid – we have tried to understand the important role that “vulnerability tests” play in reckoning the different meanings, values and distributions of vulnerability through exploration. Indeed, we have tried to explore three sets of vulnerability tests, namely: (a) sensing matter: manipulative practices of electronic waste whereby vulnerability is enacted as a property of materials; (b) setting up informal experiments: more or less methodical practices of trial and error whereby vulnerability appears as a result of dis/functioning technical systems; (c) intervening in obsolescence whereby sociomaterial orders regulating how electronic waste vulnerabilities are distributed are put to test.

These tests might help us reframe how we approach material vulnerability, not as something to be avoided, dismissed or “repaired”, but as something to think more responsibly. That is, not incurring in “one size fits all” obsessive vindications of safety and security (Bijker 2006). In fact, through these tests – or through other variations and innovations on them – we are indeed taught how to “think carefully” about material vulnerability (Puig de la Bellacasa 2012, 204): that is, being attentive to how vulnerable matters are performed (Denis and Pontille 2014b). As we see it, carefully thinking about vulnerability could very well point to a more careful way of empirically and materially intervening in knowledge production in STS (Munk and Abrahamsson 2012; Ratto et al. 2014).

Indeed, we would like to suggest an engagement in the production of what might be called matters of “care for matter”.

Care, in the broad sense given to it by Joan Tronto as “[...] everything that we do to maintain, continue and repair “our world” so that we can live in it as well as possible” (Tronto 1993, 103), involves not only “care-giving” or “care-receiving” activities, but also forms of “taking care of” and “caring about”. Very much along the same lines, “thinking with care” for Maria Puig de la Bellacasa implies developing “matters of care”, that is accounts that count in: “[...] participants and issues who have not managed or are not likely to succeed in articulating their concerns, or whose modes of articulation indicate a politics that is “imperceptible” within prevalent ways of understanding” (Puig de la Bellacasa 2011, 95).

In our case, we have considered that the main result of the different vulnerability tests performed by informal menders make perceptible to us not only some of the vulnerable effects but also the ecologies of practices (see Stengers 2010) necessary to take care of vulnerable things, such as electronic objects that have been thrown away. And in doing so, they show us how to think carefully is closely related to how we might care about such things, beyond e-waste. In dialogue with STS and repair and maintenance literature (Jackson 2014; Rosner et al. 2013), these variegated tests to “care for matter” show not only how the object of mending might go beyond “materials” but could also include socio-material orders.

Echoing feminist care ethics reflections (Tronto 1993), we could say that the mending interventions of waste-pickers and the *Obsoletos* and *Cyclicka* workshops also test how “care of things” regimes bring to life and sustain particular sociomaterial orders (Denis and Pontille 2014a), helping to politicize the regime of obsolescence’s way of impeding that abject and discarded matters might be intervened in to change their status beyond “waste”, together with its “differential distribution of vulnerability” (Butler 2004) and its North-South divides. Indeed, these mending practices bring about a different nuance to maintenance and repair going beyond the conservation of given socio-material orders – repeatedly reinstalled through sensory and attentive negotiations or attunement with people and materials, such as in much infrastructural repair work (Denis and Pontille, 2014a; Henke, 1999; Orr, 1996) –. In deploying their particular vulnerability tests menders intervene and engage in active alterations, or even subversions, of the vulnerable social-material orders of electronic waste, showing us powerful ways to care about material vulnerability, and alternative forms of engaging in its maintenance and repair.

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# Reassembling Repair: of Maintenance Routine, Botched Jobs, and Situated Inquiry

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**Abstract:** This paper draws upon a video ethnography of building care and makes this work available to an investigation of how “non human agency” is sustained in actual cases of repair and maintenance activities. Therefore, the paper homes in on a particular situation of maintenance work, bringing together a caretaker and a couple of tenants, regarding a low water pressure problem (LWPP) at the couple’s flat. The paper examines how the participants engage in a situated, temporally unfolding, collaborative and yet distributed inquiry regarding the encountered problem and its candidate solutions. Maintenance routine, in the course of the examined situation, appears to stand in an asymmetrical relationship with repair work due to a prior ‘botched job’, and the outlined video analysis demonstrates just how the involved participants establish, elaborate and, eventually, suspend this relationship. The expression “reassembling repair” encapsulates this moment of suspension, when the caretaker, upon the tenants’ final hint, indeed repairs the LWPP (by reassembling and removing its ‘root cause’), instead of sustaining his maintenance routine (to temper only the problem’s ‘symptoms’). In describing participants’ situated inquiry, their practical deliberations and its eventual denouement, the paper offers an apt opportunity to reflect upon socio-material approaches that simplify, simply invoke, or actually “neglect the situation” in favor of renewed epistemologies or generalized ontologies in Science and Technology Studies.

**Keywords:** situated inquiry; respecification; building care; caretaker; maintenance routine; reassembling repair.

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## I. Introduction

One cannot decline to have a situation for that is equivalent to having no experience, not even one of disagreement (Dewey 2008[1938], 74)

Of late, repair and maintenance work has become a topic of both empirical and conceptual interest in Science and Technology Studies (STS). Given that repair and maintenance has presumably always constituted the flipside of the artifacts, infrastructures, and technologies devised by man- and womankind, one may wonder why – and how – it has become an important part of the topical agenda of current STS. That it has entered the core concerns of STS seems without doubt, at least ‘from within’ the field. Indeed, not only does this special issue of *Tecnoscienza* bear testimony to the special place given to this special topic, but prior and parallel research endeavors do so as well (e.g., Denis and Pontille 2015; Jackson 2014; Jarzabkowski and Pinch 2013). In our view, this topical emphasis and renewed interest in maintenance and repair (see already Graham and Thrift 2007; Henke 2000; Orr 1996) might be usefully related to the emphasis on “non human agency” (cf. Sayes 2014) put by “actor-network theory” (ANT) and its successor projects, in and beyond the field of STS (see, e.g., Latour 2005; Law 2009; Mol 2010). It seems indeed only a small step from placing one’s methodological emphasis on “non human agency” – or, less technically put, the material features of the social world – to investigating how such agency is sustained, if not secured, in actual cases. One way of doing so, then, is to closely examine particular practices of maintenance and repair, as such practices can be shown to constitute and support those material features. Recently, several ethnographic studies have been conducted on urban infrastructures and public transport systems in this vein (e.g., Denis and Pontille 2010, 2015; Tironi 2015), some of which point “beneath materiality” (cf. Denis and Pontille 2015), and others “beyond repair” (Ureta 2014)<sup>1</sup>.

Drawing upon a video ethnography of building maintenance, this paper offers an ethnomethodological study of repair work. In doing so, the paper gives a particular twist to the “small step” evoked in the previous paragraph. More specifically, the study analyzes through which practical methods of situated inquiry – or locally deployed “diagnostic work” (Buscher et al. 2010) – the filmed participants – a married couple of tenants and the caretaker of the block of flats they live in – engage in recognizable courses of repair work to have a particular problem fixed – a low water pressure problem (henceforth, LWPP) at the couple’s flat. Hence, the paper’s title – “reassembling repair” – hints at the participants’ repair

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<sup>1</sup> For a trajectory of STS as a series of provocative ‘reversals’ (e.g., from the sociology of scientific knowledge to ANT), see Woolgar (2004).

work in situ, rather than a theorist's revolutionary project in STS (e.g., Latour 2005, 2006). How does the situation that had brought participants together, the LWPP at the couple's flat, actually unfold? How do they manifestly repair the problem in reaching a common "definition of the situation"? In answering this twin question, the outlined paper should prove of double interest:

- on the one hand, the paper contributes to empirical inquiry on repair and maintenance work in STS by delivering a case study that homes in on participants' work of "accomplishing materials and activities in context" (Jarzabkowski and Pinch 2013, 581). More specifically, it focuses upon lay participants' working at "reassembling repair" as a particular concern of housing (by said couple of tenants) in the face of a professional's studious display of maintenance routine regardless of this concern (as in the case of the caretaker, to begin with; see already Hughes 1951);
- on the other hand, the study questions the inclination of leading practitioners in (post-) "Actor-Network Theory" (ANT) to address issues primarily on a theoretical level (for example when substituting a "script" or "affordance" approach with an "accomplishing" one, as in the case of Jarzabkowski and Pinch). In turn, the paper points out that any such conceptual substitution – even if we may agree with it (as we largely do with Jarzabkowski and Pinch) – typically assumes, rather than explicates, a prior understanding of the everyday situations that it uses for illustrative purposes (in particular, the practical understanding that participants display to each other, in and through their situated conduct)<sup>2</sup>.

In answer to the critical argument, the paper follows Garfinkel's pivotal recommendation to turn the phenomena of everyday life and the situated inquiries conducted by their participants into an explicit topic of analysis, rather than to rely upon them as a tacit resource for a theoretical move. Hence, the present paper does not privilege this or that conceptual definition of "the social" and its "reassembly" as a theoretical choice (see Latour 2005, 2006, and section 6 below). Rather, the paper describes how participants' own conduct already entails such choices as a practical matter, as their recognizable courses of repair work do entail particular "definitions of the situation", be it in terms of maintenance routine, urgent repair, or both (see sections 2 and 4)<sup>3</sup>.

In ethnomethodology, this strategy of relocating theoretical issues in

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<sup>2</sup> In other words, any theoretical interpretation of situated conduct in general terms (e.g., those of ANT) presupposes its intelligible achievement by participants in particular situations (otherwise, there would be nothing to be interpreted, let alone generalized by the theorist). This intelligible achievement, in turn, remains ethnomethodology's key phenomenon (cf. Garfinkel 1967, 2002).

<sup>3</sup> On Garfinkel's recommendation to avoid the conflation between analytic topic and mundane resource, see Zimmermann and Pollner (1970). On recovering "ANT" as a situated, analyzable, mundane phenomenon, see Lynch (2013); Quéré (1998) and below (sections 5 and 6).

practical concerns is referred to as “respecification” (e.g. Button 1991; Garfinkel 1991; Lynch 1993). Before introducing more fully our video ethnography and ethnomethodological approach, let us turn to a first example to briefly indicate in which sense such respecification may prove instructive.

## 2. Maintenance Routine as a Situated Achievement: a First Definition

How do participants configure a problematic situation that brings them together, such as the situation involving an unresolved low water pressure problem (LWPP)? How do they orient their respective inquiries, trial-and-error procedures, and verbal formulations, in the manifest attempt to solve this particular problem? A pervasive feature of the examined situation of pending repair was that its participants – a couple of tenants and a caretaker<sup>4</sup> – would define their encounter in alternative ways, with the result of opening up alternative trajectories of diagnostic work, regarding alternative “problem/solution pairs” (Livingston 2008, 235). A first definition of the problematic situation at hand and its potential solution *in situ* is offered by the caretaker (Edy) as he enters the tenants’ (family S.) flat. Consider the following field-note excerpt to begin with:

### *Excerpt 1 (bathroom)*

On the morning of 30 November 2013 water supply was shut down in the residential building Kanalweg 26 by caretaker Edy and plumber Thomas, to replace some 20 bonnets of gate valves on the head water pipe of this building. Once this replacement work finished and water turned back on, family S. on floor 13 let caretaker Edy know that there was hardly any water flowing at their flat. That, at least, is what he told us.

We follow Edy with the video camera as he goes into the flat of family S., to change sink and bathtub aerators. This, according to Edy, is a common thing to do after a shut down and restart of water supply in residential buildings: aerators can indeed get clogged by flushed shed material and mineral deposits from the pipes.

Edy enters the flat and walks straight into the bathroom. Without checking the water flow he begins changing the aerators. After some minor difficulties, Edy finally succeeds in changing the aerators of the two sinks in the bathroom. Then he begins working on the aerator of the bath-

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<sup>4</sup> The caretaker works full time for the real estate agency. He is in charge of five buildings (78 flats) but does not live there. He has a workshop-office in one of the buildings. When faced with a problem, tenants can either call him or find him in his office. When the task is too technical or requires too much time, he may call a technician.

tub spout. After several tries he still cannot untwist the aerator on the bathtub and gives up, saying that the plumber is needed to solve this problem.

This field-note excerpt, which also describes the filming situation, makes available Edy's definition of the LWPP and its attendant solution (i.e., changing the aerators) in terms of his *maintenance routine*. Several aspects of his conduct manifest that he defines the situation in just these terms: first, he casts the LWPP as a typical problem of prior maintenance (i.e., the gate valve replacement on the head water pipe), problem which then lends itself to a typical solution (i.e., aerator replacement at the 'concerned' flat). Second, he attempts to reach that typical solution without examining any particular manifestation of the problem involved (i.e., "without checking the water flow he begins changing the aerators")? Third, he appeals to the plumber's help as he encounters difficulties (when attempting to "untwist the aerator on the bathtub"). Having taken part in the initial maintenance (i.e., the building's gate valve replacement), the "plumber Thomas" is now being recruited to complete its routine achievement (i.e., by solving its incidental problems, as encountered at family S.' flat). Taken together, these three aspects of the caretaker's conduct *recognizably* define the encountered situation in terms of maintenance routine (rather than "urgent repair", as we shall see), notably by preempting any situated inquiry into the flat's particularities (which remain part of the "environment", cf. Quéré 1998, 239)<sup>5</sup>.

This first description of repair work proves instructive, insofar as it demonstrates how such work develops and draws upon a particular "definition of the situation". That is to say, the very way in which Edy, our caretaker, goes about his repair work implies not only a particular definition of the working situation (as a "routine" encounter), but also a particular understanding of the work to be done in that situation (a "maintenance" intervention). This mutual elaboration of situation and work may change and, as it manifestly does, will be further described. The offered description, so far, affords us with an ethnomethodological respecification of the "definition of the situation" as a sociological notion: a definition of the situation is already implied and manifestly disclosed in Edy's embodied professional practice, without (or prior to) any discursive formulation, which is not to say that it cannot be formulated, either by Edy

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<sup>5</sup> Edy's pre-emptive move appears to be twofold at least, as he walks not only "straight into the bathroom" (instead of asking the tenants for a specification of the problem, for instance), but also starts working on the pre-decided typical solution at once (i.e., changing the aerators). In refraining from engaging in conversation with the tenant couple, he embeds his maintenance routine in the local setting without further investigating its particular features, thereby making the maintenance routine visible as "maintenance routine" in the first place (regardless of particular setting features, its parties' local knowledge, etc.).

or by a professional sociologist. The remainder of this paper spells out some of the key consequences of this kind of practice description for our empirical understanding of repair work, STS more broadly, and Latour's notion of "reassembling the social" in particular<sup>6</sup>.

### 3. Video Ethnography and Ethnomethodology

The previous section offered a first glimpse at how a video ethnography of building maintenance makes this work available to an "ethnomethodological respecification". The video ethnography that this paper is based on involved one of us in documenting over a one-year period the working routines of professional caretakers and building maintenance personnel in Switzerland. Therefore, over twenty-four hours of video recordings were made and eventually organized into a searchable data basis. The main purpose of this ethnographic effort was to make visible the caretaker's ordinary work – indeed, mostly men at work were filmed – in its recurrent patterns, conditions and contingencies, whilst highlighting the technical and social problems that building maintenance would ordinarily deal with. The video footage, then, was based upon ethnographic fieldwork that involved 'shadowing' individual caretakers when they were making their daily rounds and fulfilling their routine duties. To get the ethnography under way, specific working days were agreed upon between the filming team and the filmed caretaker. To start with, the work of three caretakers was filmed and documented in this way<sup>7</sup>.

The outlined video ethnography allowed us to take a renewed empirical interest in a "low status" occupation, with a special focus on its everyday tasks and technical argot. In so doing, the video ethnography took up the classic interest of field studies in occupations of all kinds as promoted by E. Hughes at the "Chicago school" in the 1940s, an interest which had also led up to a prolonged ethnography of caretakers' work in urban areas (e.g., Gold 1950, 1964). Based upon participant observation and interviews, this now seminal ethnography paid special attention to the peculiar relationship, typical encounters and characteristic tensions between tenants and caretakers. Yet, as an ethnographic study written in a "realist" mode (cf. Van Maanen 1988), the study left unanswered the ethnometh-

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<sup>6</sup> For further discussion of the notion of "situation" and its continued "neglect" in some quarters of the social sciences, see Quéré (1998).

<sup>7</sup> *Building Care: That's why our cities do not fall apart* (Ignaz Strebel and Susanne Hofer, 41 min, Swiss German, German, Subtitles E). The documentary movie can be accessed via <http://vimeo.com/ethwohforum/building-care>. From the outset, the documentary movie was also made with the intention to afford us with audiovisual recordings to be used in an ethnomethodological analysis. The consequences of this double use remain to be analyzed. On non-fiction film more generally, see Macbeth (1999).



odological concern for just how the realities described were recognizably achieved as such:

- Just how did any caretaker effectuate his everyday tasks so that they could be made accountable to a standard of proper building care?
- Just how might tenants, on any given occasion, become involved in the practical effectuation, verbal formulation, and visual monitoring of caretakers' tasks?
- And just how would tools, materials, and objects be used at work?

Whilst these questions remained largely unstudied, a video-based approach offers us an apt opportunity to have them (re-)addressed. The actual *situation* of building maintenance and repair work is thus foregrounded and, as we shall see, the contingency of the situation upon itself – that is, upon how the situation may become a participants' issue from within its very unfolding, regarding notably its definition and the kind of repair work that this definition entails<sup>8</sup>.

In what follows, an *ethnomethodological respecification* is offered, insofar as our (video) ethnographic interest in building maintenance is developed in a distinctive direction. This direction has perhaps been best indicated by Sharrock and Anderson, when they distinguished “ethnomethodology’s query: how do people organize their social actions so that sense can be made of them?” (1986, 56) from the “general investigative question which any sociologist may ask, namely ‘how are social actions organized’” (ibid.). Accordingly, our description shall bear upon how co-present participants – a caretaker and a couple of tenants – *make intelligible* to each other the kind of social activity they engage in, in situ and in vivo. “Ethnomethodological respecification”, then, involves two tasks: first, an empirical description or *specification* of participants’ practical methods of repair work, methods through which they make that work intelligible to each other in its actual course (for example, through the embodied definition of the situation that is presupposed in “maintenance routine”). Second, a *reexamination* of existing concepts and concerns in STS (such as Latour’s notion of “reassembling the social”) in the light of that prior empirical specification. For this second task, the final discussion of this paper will draw upon the video analysis conducted in the next section.

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<sup>8</sup> That we focus on how caretaker and tenants deal with a deficient tap does not mean that we ignore or neglect classical themes in the sociology of building maintenance, such as the status gap between caretaker and tenants or the influence of the presence of the latter on the former’s work. We rather stick to how such themes may or may not emerge from within the situation. In the present case, the first theme did not emerge but as we shall see the second did, though in a very specific way.

#### 4. Problem Formulation as a Situated Achievement: two Redefinitions

As we have seen in the second section of the paper, caretaker Edy replaces all aerators in the bathroom except one. He then proceeds to the kitchen with the manifest intent to pursue his maintenance routine, as visible on our video recording. His very conduct manifests (t)his intent, as he rushes into the kitchen with the special aerator screwdriver in his right hand (to remove the presumably clogged kitchen sink aerator) and then fish out a clean one from his pockets with his ‘free’ left hand. To reach the kitchen, Edy has to pass through the living room, where the tenants, Mister and Misses S., have taken a seat waiting for him to finish his technical intervention. As Edy rushes into the kitchen and attempts to do so, he offers Mr. S. an opportunity to spell out the problem at hand, as the following video recording excerpt suggests<sup>9</sup>:

*Excerpt 2 (kitchen)*

- 1 Edy: und hier in der Küche  
*and here in the kitchen*
- 2 MrS: ‘ja das ist das ist das Problem  
*‘yes this is this is the problem*  
*‘((gets up and follows Edy into the kitchen))*
- 3 MrS: da ist immer weniger Wasser gelaufen seit er ‘das mon-  
tiert hat  
*there is less and less water running since he has installed*  
*‘this*  
*‘#1 ((taps on new mixer tap))*
- 4 MrS: heute Morgen ist folgendes passiert  
*this morning the following happened*
- 5 dass praktisch kein warm Wasser mehr ausläuft  
*there was virtually no warm water running*
- 6 also nur ganz wenig  
*well, only very little*
- 7 Edy: gut  
*okay*
- 8 MrS: das kalte auch, ganz wenig  
*cold too, very little*
- 9 warum ‘weiss ich auch nicht, ich weiss auch nicht was der  
do gemacht hat  
*why ‘I do not know [...] what he has done here*  
*‘((walks out of the kitchen))*
- 10 Edy: ((removes kitchen sink aerator, turns on water flow))
- 11 #2 ((only little water flows))

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<sup>9</sup> Transcription conventions are to be found in Appendix I. Screenshots (numbered #1, #2, etc.) follow the transcribed excerpts.

12 Edy: hhh oi  
bbb ob



#1 ((Mr. S. taps on new mixer tap))



#2 ((only little water flows))

Upon Edy's place formulation ("and here in the kitchen", line 1), Mr. S. follows him into the kitchen (line 2) and ventures a formulation of the problem (from line 2 onwards). That is, Mr. S. formulates the LWPP as requiring an *urgent repair* (due to a previous seemingly 'botched job' "since he has installed this", line 3), rather than as being simply addressed as part of general maintenance routine (due to the building's central gate valve replacement). How does Mr. S. achieve this redefinition of the situation, *recognizably* so? First, he points out a particular problem in the

kitchen, regarding the “new mixer tap” in the kitchen sink, namely the problem that “there is less and less water running” (line 3). Second, he hints at an alternative cause of this problem, relating it back to the plumber’s prior intervention in the kitchen, a potentially ‘botched job’ (“since he has installed this”, *ibid.*), rather than to the plumber’s joint maintenance routine with Edy in the morning (the general gate valve replacement). Third, the latter’s maintenance routine is identified as occasioning the *acute expression* of the problem, which would thus require an urgent repair (its cause remaining the potentially ‘botched job’, (“I do not know what he has done here”, line 9). In walking out of the kitchen (at line 9), Mr. S. demonstrably leaves the floor to Edy for making the pending repair, then and there. Edy, in turn, seems to be responding to this *technical expectancy*. Indeed, he does not only engage in the routine task as before (by removing the kitchen sink aerator, line 10), but he also checks its local grounds now (by turning on the water flow *prior* to replacing the aerator with a new one, *ibid.*). As only little water flows even without an installed aerator (*ibid.*), no clogged aerator can be the cause of the LWPP, much to Edy’s surprise (“oh”, line 12)<sup>10</sup>.

In particularizing the problem and relocating its cause, the described redefinition of the situation (by tenant Mr. S.) raises the question of its specific solution *in situ* (rather than its standard solution across sites). After his local solution attempt fails (see note 10 above), Edy – manifestly at his wits’ end – decides to call plumber Thomas. His call builds upon Mr. S.’ redefinition, whilst spelling out his own efforts in the kitchen so far, as can be seen in the following video excerpt:

*Excerpt 3 (kitchen call)*

- |   |      |  |
|---|------|--|
| 1 | pb:  | Ja Edy, hallo?<br><i>Yes Edy, hallo?</i>   |
| 2 | Edy: | #3 Grüss Dich ((Thomas))<br><i>Hello ((Thomas))</i>  |
| 3 | Edy: | Du? du hast doch bei Frau Familie S. eine neue Mischba-<br>terie reingemacht?<br><i>you have put in at Mrs ... family S. a new mixer tap, right?</i> |
| 4 | pb:  | bei Frau?<br><i>at Mrs?</i>  |
| 5 | Edy: | S Familie S<br><i>S. family S.</i>   |
| 6 | pb:  | eh in welchem Block wohnt sie?   |

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<sup>10</sup> In the sequel to the examined episode, Edy starts opening up the shutoff valves of both the hot and cold water supply in the kitchen. These valves are to be found underneath the kitchen sink (cf. Appendix II). However, as the water flow remains the same, the LWPP remains, at least as far as the hot water supply is concerned (see below).

- 7 Edy: *uh in which block do they live?*  
 sechundzwanzig  
*twenty six*
- 8 pb: ja  
*yes*
- 9 Edy: jetzt, Kaltwasser war der Hahn fast zu  
*now, coldwater the tap was almost closed*  
 10 den habe ich jetzt aufgemacht  
*I have now opened it*  
 11 und jetzt auf der linken Seite ist der Warmwasserhahn  
*and now on the left side is the hot water tap*  
 12 den kannst Du nicht weiter aufmachen und es kommt fast  
 kein warmes Wasser  
*this you cannot open more and there is almost no hot water*
- 13 pb: ja  
*yes*
- 14 kannst Du das dann noch anschauen  
*can you have a look at it again*



#3 Edy: Grüss Dich ((Thomas))

How does caretaker Edy, in turn, reformulate the problematic situation at hand, if only for plumber Thomas to recognize it as such (rather than in terms of their unproblematic maintenance routine)? Edy's call to plumber Thomas is interesting, insofar as it accepts and elaborates Mr. S.' prior redefinition of the problem and its cause (the 'botched job', requiring an urgent repair), whilst shifting the burden of the problem's solution (from himself to Thomas, identified as being initially or at least potentially responsible). In so doing, Edy reproduces indeed Mr. S.' prior redefinition (in terms of a "particular problem," its "alternative cause," and now "acute expression"). There is, however, one aspect of Mr. S.' redefinition that Edy modifies, and that is the "technical expectancy" that he, Edy, being already present in the kitchen, should and would repair the prob-

lem at hand. Indeed, Edy first reports his unsuccessful efforts so far (lines 9-12), and then solicits the plumber to step in (line 14). In suggesting his sustained *maintenance routine* to have failed, Edy manifestly makes the case for the plumber's next *urgent repair* (or arguably *urgent repair*)<sup>11</sup>.

## 5. Reassembling Repair as a Situated Achievement: Denouement

As we have seen, the LWPP at family S.' flat has been defined and re-defined in alternative ways: first in terms of "maintenance routine" (by Edy, the caretaker), then in terms of "urgent repair" (by Mr. S., one of the tenants), and finally by taking into account maintenance routine for achieving swift repair (by Edy, on the basis of Mr. S.' prior definition, in view of the plumber's subsequent intervention). The participants' configuration (and reconfiguration) work suggested that, and how, maintenance routine stands in an asymmetrical relationship with urgent repair – that is, not only both of which, maintenance and repair, mobilized alternative scales ("building" vs. "kitchen"), alternative problem formulations ("standard" vs. "particular"), and alternatively expected solutions ("replacement" vs. "repair"), but it also took the involved participants *work* to establish, exhibit, and elaborate this asymmetrical relationship (starting with Edy's studious display of maintenance routine). The participants' encounter, however, came to a temporary ending with the *suspension of this manifest asymmetry*, as the final video excerpt suggests:

### *Excerpt 4 (living room and bathroom again)*

- |     |      |  |
|-----|------|--|
| 1   | Edy: | da kommt dann der Sanitär schnell vorbei<br><i>there the plumber will drop by quickly</i>                        |
| 2   | MrsS | ja, ja<br><i>yes, yes</i>  |
| 3   | Edy: | also das Kaltwasser ist jetzt offen, das ist gut<br><i>the cold water is open, this is fine</i>                  |
| 4   | MrsS | ja, ja,<br><i>yes, yes</i>   |
| 5   | Edy: | der Hahn war fast zu<br><i>the tap was almost closed</i>   |
| → 6 | MrsS | ja, 'eben warm kommt ja im Badezimmer auch nicht<br><i>yes, 'hot water is not flowing in the bathroom either</i> |

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<sup>11</sup> In the remainder of the call, the urgency of this next repair is further elaborated by Edy – "maybe you can do it straight away", "when are you coming?", etc. – as well as by the plumber – "should I come right now?" – to whom Edy responds: "that would be good, we can then do that, then we can tick it off." Participants' conduct displays thus the relative urgency of the repair.

- 7 Edy:        ‘( ((walks into bathroom)) )  
 auch ‘nicht?  
 also ‘not?  
 ‘( ((follows Mrs S. to bathroom)) )
- 8 MrsS        nein  
 no
- 9 Edy         dann hat er     ‘hier nicht geöffnet  
 then he has not opened ‘here  
 ‘( ((points to main hot water tap of the  
                   flat)) )
- 10 MrsS       ’schau jetzt hier  
 ‘look here now  
 ‘( ((points to water taps in bathroom sinks)) )
- 11 Edy:        ja dann ist klar, also da habe ich jetzt zwei neue Siebchen  
 reingemacht  
 yes then it is clear, here I have put in two new aerators
- 12 MrsS        ja, ja,  
 yes, yes
- 13 Edy:        die waren verkalkt  
 they have been calcified

In what sense may we speak of a “denouement” of the unfolding situation and its manifest asymmetry between maintenance and repair? The video excerpt selected from the closing of the encounter suggests that its participants, through their respective formulations and situated inquiries, reach a new definition of the situation. Through that redefinition, the situation not only caused the LWPP (at Mr. and Mrs’ S. flat) in the first place, but may also be mobilized to have this problem solved (namely, the “(closed) main hot water tap of the flat”, line 9). In the selected excerpt, Edy starts with summarizing the situation in asymmetric terms, namely by announcing the upcoming repair in the kitchen (“there, the plumber will drop by quickly”, line 1), whilst making sure to highlight his partially successful maintenance so far (“the cold water is open, this is fine”, line 3). In so doing, Edy recognizes the pending problem in the kitchen (the unsatisfactory hot water flow). At the same time, he manifestly assumes his prior intervention to have solved the LLWP in the bathroom (as he already did when rushing from the bathroom into the kitchen). Mrs S.’ interjection (at line 6), in turn, challenges this basic assumption, as it singles out the remaining “hot water” problem in the bathroom, too (in addition to the blocked aerator on the bathtub, for instance). Her interjection, then, contributes to the denouement of the situation, insofar as it connects the various expressions of the acute LWPP (in the kitchen and in the bathroom) and hints at their common cause, eventually spelled out by Edy: the “(closed) main hot water tap of the *flat*” (line 9; emphasis added). Incidentally, the asymmetry between “maintenance routine” and “urgent repair” seems to be *dissolved*, as the prior definition and redefinition that it hinged upon (made by both Edy and Mr. S.) now turn out to be false (in the light of Mrs. S.’ interjection). In conclusion, we may speak

of the situation's denouement as its participants' "reassembly of repair," insofar as the situation's denouement challenges the studious display of maintenance routine and calls for material intervention to fix the local problem at hand<sup>12</sup>.

## 6. Discussion and Conclusion: 'Reassembling Repair' as a Members' Phenomenon, STS Implications

In *Reassembling the Social*, Bruno Latour invites his readers, addressed as "interested enquirers", to actually do so: "It is to help the interested enquirers in *reassembling* the social that this book has been written" (Latour 2005, 8). A closer look at Latour's invitation is in order, prior to spelling out some of the implications of our video analysis of repair work for ANT, if not for STS more broadly.

Latour's invitation takes a both programmatic and methodological form. The invitation takes a programmatic form, insofar as said book is intended as an "introduction to ANT" (at least if we stick to its ironic subtitle). This introduction, then, sets up ANT, as the renewed "sociology of associations," in competition with the received "sociology of the social" (Latour 2005, 1-17). The latter, arguably, has become part of "common sense" well beyond the social sciences: "Offering comments about the inevitable 'social dimension' of what we and others are doing 'in society' has become as familiar to us as using a mobile phone, ordering a beer, or invoking the Oedipus complex – at least in the developed world" (Latour 2005, 4). ANT, in turn, challenges this "common sense" assumption of an inevitable and homogenous "social dimension" which, as part of a stable and objective "society," may be routinely invoked for explanatory purposes (e.g., whenever an economic explanation fails to account for an economic phenomenon). Instead, ANT sets out to explain how the inevitability, homogeneity, stability, and objectivity of "the social" (or, better, "*a* social") were themselves achieved as its consequential properties, and that is, so the alternative assumption goes, as a contingent result of "*associations* between heterogeneous elements" and "things that are not themselves social" (Latour 2005, 4). The methodological task, then, becomes the empirical task of "*tracing*" these intricate associations and their assumed effectiveness – if not in practice, then at least in principle<sup>13</sup>.

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<sup>12</sup> In sum, Mrs S.' interjection turns this maintenance routine into an instrumental part of the pending repair (in contrast to Edy's prior delegation of repair work, in his pervasive attempt to stick to and sustain his maintenance routine only). In so doing, she is "reassembling repair" by defining its proper scale: the "flat", rather than the entire "building" or sole "kitchen".

<sup>13</sup> In so doing, we may add, the empirical inquiry risks turning into an "applied metaphysics" (Latour 2006, 73), or an "actant-network ontology" (Lynch 2013, 10), where "the theorist's monism frames the heterogeneous



Drawing upon a video ethnography of building maintenance, this paper examined repair work and its situated “reassembly” as a society-members’ phenomenon, rather than a social theorist’s strategic choice. An ethnomethodological respecification was thus not only offered of the initial video ethnography and its documented realities, but also of ANT, similarly generalized ontologies, or alternatively renewed epistemologies (e.g., Jarzabkowski and Pinch 2013) in STS. A single situation of maintenance routine (and, eventually, repair work) was examined for how its participants’ configured its manifest course. Particular attention was paid to their respective (re-)definitions of the situation, inquiry procedures and verbal formulations, as part and parcel of the practical methods in terms of which they managed to recognize and solve a particular housing problem (the LWPP at Mr. and Mrs. S.’ flat). In that sense, participants could be observed at “reassembling repair,” rather than simply taking for granted an established maintenance routine. In what sense, however, might this ethnomethodological description of the unfolding situation *differ* from an ANT, “ANO” (Actor-Network Ontology) (see footnote 13 above), or related conceptual framework in STS? Set aside our methodological choice to use a video recording (rather than more common documentary sources), the difference may be briefly elaborated upon by returning to Latour’s theoretical exercise in “reassembling the social.” How is this exercise conducted<sup>14</sup>?

One feature of its conduct, as a discursively available phenomenon, is that it introduces working definitions and, on that basis, builds its sociological arguments (at least in the “programmatic” and “methodological” form, as highlighted above). For example, Latour introduces three working definitions of “the social” (numbered as such in the French edition, cf. Latour 2006, 93-101):

*Definition no. 1:*

“I have argued that most often in social sciences, ‘social’ designates a type of link (as in ‘*social ties*’): it’s taken as the name of a specific domain, a sort of material like straw, mud, string, wood, or steel” (Latour 2005, 64, emphasis added).

*Definition no. 2:*

“For ANT (...), the definition of the term is different: it doesn’t designate a domain of reality or some particular item, but rather is the name of (...) an enrollment. (...) Thus, social, for ANT, is the name of a type of *momentary association* which is characterized by the way it gathers together into new shapes” (Latour 2005, 64-65, emphasis added).

*Definition no. 3:*

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ontologies *attributed* to the actors within the frame” (Lynch 2013, 10, emphasis added).

<sup>14</sup> On “social theory as a practice,” see also Taylor (1983).

“the *local*, face-to-face, naked, unequipped, and dynamic *interactions*” (Latour 2005, 65, emphasis added).

In contrast to Latour’s theoretical exercise, the key point of this paper, as an ethnomethodological respecification, was *not* to make an argument for *this* or *that* working definition of “the social” (for example, by favouring definition no. 3 over definitions no. 1 and no. 2). Rather, it was (or would be) to turn such arguments themselves into observable phenomena. In the examined case of building maintenance, it could thus for instance be observed how the involved participants themselves would act under the auspices of alternative “working definitions” of the social. To begin with, caretaker Edy could be seen to be acting under the auspices of conventionally characterized “social ties” (*definition no. 1*), which imply an asymmetric, socially sanctioned distribution of knowledge, in terms (say) of “caretaker expertise” vs. “lay knowledge” (indeed, Edy *attempted* to sustain his maintenance routine, regardless of any untrained intervention by the co-present tenants). Bringing the examined encounter to a close, Mrs S.’ final interjection in turn challenged these conventional auspices and, more interestingly, achieved a “momentary association” (*definition no. 2*) of a different kind (which, indeed, involved her and her partner, Mr. S., in the diagnostic work – no longer the silent prerogative of the professional – leading up to the pending repair). Finally, Mr. S.’ problem-formulation-in-the-kitchen, and demonstrative walking-away-out-of-the-kitchen, could be seen as initiating a particular “local interaction” (*definition no. 3*), if only to have its addressee (caretaker Edy) fix the indicated problem<sup>15</sup>.

Where does the outlined difference leave us with respect to STS and other studies of repair and maintenance work? What our video analysis has offered, we trust, is an empirical reminder of *just how* participants themselves do not only act and interact *in situ*, but do also configure the very site and situation of their (inter-)action *in vivo*. This configuration work, as we have attempted to show, includes their own progressive (re-)definitions of inquiry, (re-)definitions which build upon each other, in and as the unfolding situation, rather than providing them with mutually exclusive “definitions of the social” (e.g., Latour 2005, 131). Accordingly, and with respect to repair and maintenance *in situ*, “the problem is not so much to break out of the situation as to understand fully how it allows the finite beings that we are [including Edy, Mr. S. and Mrs S.] to gain access to the world and the type of control it exercises on experience and activity” (Quéré 1998, 239). Whether “full understanding” in that direction is

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<sup>15</sup> In contrast to Mrs S.’ achievement of a new “momentary association,” Mr. S. seems to base the “local interaction” initiated by him on the conventional “social ties” implied and enacted by caretaker Edy’s conduct. Incidentally, this contrast may also to exhibit participants’ orientation to a *gendered* distribution of expertise (cf. Lagesen 2012).

to be reached by video analysis or any other means, in the domain of building maintenance or elsewhere, must remain an open question. In a nutshell, we have not so much attempted yet another “reversal” in STS (cf. Woolgar 2004) or introduced “yet another axis of symmetry” (Lynch 2013, 6-7), so as to then figure out how questions of “multiplicity” and “unity” (cf. Mol 1999), “sociality” and “materiality” (cf. Law and Mol 1995), or “stability” and “fragility” (cf. Denis and Pontille 2015) play out in particular situations. Rather, we have tried to make explicit the particular situation under scrutiny, including its participants’ ways of defining and redefining it *in their own terms, concepts, and distinctions* (such as “hot water is not flowing in the bathroom either”). “Common sense” was thus not to be challenged, but to be described in its situated operation, affording us with the very basis for the listed questions to be asked.

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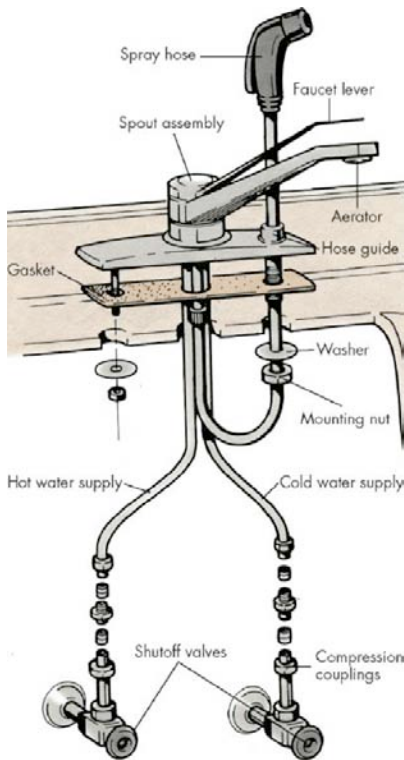
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### Appendix I: Transcription conventions and screenshots

pb	plumber
und hier	German language line
and here	English translation line
( )	incomprehensible passage
(go ahead)	uncertain hearing
((does))	description, comment
'	comment on simultaneous non-verbal activity; if there is a verbal line, marked on the verbal line and again on the comment line
	Ex.: 'I do not know
	'((walks out of the kitchen))
#1	indication of video still placement in the transcribed activity

### Appendix II: Schematic representation of mixer tap



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# Instances of Failures, Maintenance, and Repair in Smart Driving

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**Abstract:** The paper focuses on technology designers' representations and discourses about advanced driving assistance systems (ADAS). This issue has been empirically explored by means of seven in-depth interviews with academic experts in intelligent transportation systems (ITS). Two main areas are investigated: 1) the meaning of advanced driver assistance and 2) the failures in intelligent driving and the consequent need to cope with them. The overall aim is to identify dominant views about the instances of "failing" and the possibilities for control, which are inscribed in the design processes of ADAS. One of the main findings concerns the designers' emphasis on the continuous supervising, correction, and enhancement of human functioning as the core of driver assistance. According to this view, human senses, reactions and interactivity with technology turn into subjects of continuous supervision, prevention, correction, improvement and restriction – a sort of "real-time human maintenance and repair".

**Keywords:** intelligent technology; advanced driver assistance; driver monitoring; human-machine co-agency; automobilities.

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## I. Introduction

The usual perspective about maintenance and repair of conventional technology (i.e. which does not carry the labels "smart", "advanced", or "intelligent") is that humans in various roles are the only ones able to check its functionality, to observe and fix eventual failures. The internal elements, motions and operations in such technical systems are easily visible and the relationship cause-effect for faults and failures is quite clear. Therefore, conventional technology can be easily dismantled into comprehensible pieces, which can be re-assembled for new purposes. In this view the malfunctioning of various infrastructures contains the germ of

innovation in its core (Graham and Thrift 2007; Jackson 2014). The necessity to fit the technological systems “to the sticky realities” (Jackson 2014, 227) of the real-world driving, living, working, communicating, etc. should in principle encourage the involved actors (users, technology designers) to improvise and come with sometimes unconventional, but reality-friendly solutions.

However, in “advanced technologies” such as ITS (intelligent transportation systems) the humans confront with a much higher complexity, a hidden autonomous activity, and a high interactivity of technology (Rammert and Schulz-Schaeffer 2002). In-and-out sensors embedded in vehicles and road infrastructures perceive changes in the environment. Data from various sources are then processed and turned into integrated information, which is further provided to human users through user interfaces. Advanced technologies operate in “intelligent spaces” that are “environments that continuously monitor what’s happening in them, communicate with their inhabitants and neighbourhoods, make related decisions, and act on these decisions” (Wang et al. 2006, 68-69). Such systems pretend to be active to the extent that they even seize their own repair and maintenance in a process of “self-healing” (Graham and Thrift 2007). The self-supervision of functionality, automatic fault detection/diagnosis, and self-repair are currently established abilities of advanced technologies. The current paper proposes a perspective on “maintenance in repair” according to which technology designers of advanced driver assistance systems increasingly see humans as possible subjects of failures and breakdowns. In this vision drivers should be constantly supervised and restored to functionality if they become fatigued, stressed, distracted or show signs of health deterioration. This perspective is explored by means of interviews with experts working in the field of Intelligent Transportation Systems and completed by a brief review of the technological state-of-the-art.

The present article is structured in five parts. The first part is dedicated to the introductory analysis of the current perspectives on maintenance and repair. This is followed by the presentation of designers’ scripts on ADAS and further developments such as vehicle automation, based on the study of the field literature. The paper continues with the description of the methodology of the qualitative study and the presentation of results. The last part is dedicated to the discussion of the empirical findings and the directions for future research.

## **2. Perspectives on Maintenance and Repair in Hybrid Systems**

Despite the fact that maintenance and repair are considered central issues for the understanding of modern societies, they have been so far in-



sufficiently studied and understood (Graham and Thrift 2007). Nevertheless, their importance comes clearly to light when their disruptive effects manifest in economy and society. Let's only mention the impact of cell phone disconnection on healthcare and health (Gonzales et al. 2014), the nightmare of electricity and IT systems blackouts, or the failing of traffic signalization in a big city. As Graham and Thrift (2007) emphasize: "Things only come into visible focus as things when they become inoperable- they break and stutter and they then become the object of attention. Such disconnection produces learning, adaption and improvisation" (Graham and Thrift 2007, 5).

The social sciences literature comes with various perspectives about the concepts of maintenance and repair. For Graham and Thrift (2007) the importance of maintenance and repair is justified by some particularities of material things such as: intrinsic power (things are "transductions with many conditions of possibility and their own form of intentionality"), pluriculturalty, increase in number and complexity (fact that requires even more maintenance and repair), the difficulty to define the border of "things" (they could represent more than supposed). It is also emphasized that: "Breakdowns come to have an essential quality to them, since they may well affect large numbers of people simultaneously" (Graham and Thrift 2007). Ureta follows Foucault in defining repair as: "a particular form of power that, first, recognizes a certain normal state to which the failing system should evolve and, second, develops different strategies to reach it, usually involving the deployment of particular disciplinary devices. The ultimate aim of such practices is usually not only the improvement of the system but centrally the maintenance of a certain kind of power" (Ureta 2014, 368). The Human and Computer Interaction branch sees repairs as: "acts of sustaining, managing, and repurposing to cope with attrition and regressive change", advocating for its high importance in design of ICTs (Rosner et al. 2013).

The research on maintenance and repair has focused, amongst others, on the unification of the social and material in urban cities as social systems for maintenance and repair (Graham and Thrift 2007; Hall and Smith 2015), the "remediation work" in the travel sector as response to terrorist attacks (Ball et al. 2014), the repair of failing large sociotechnical systems (Ureta 2014), the vulnerability of systems enacted in repair and maintenance practices as a dimension of material ordering processes and care for things (Denis and Pontille 2015), the improvisation and creativity resulting from the possibility to disassemble technology, attending of consumer objects within the home (Gregson et al. 2009)<sup>1</sup>.

In the "tightly drawn" infrastructural networks (Graham and Thrift, 2007) of the present, the distinction between things and human actions is

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<sup>1</sup> For a review of studies on repair and maintenance from the perspective of Human computer Interaction (HCI) in connection with a CHI workshop on this topic see Rosner et al. (2013).

blurred and hybrid constructs emerge. The driver-car represents such an assembled social being that depicts the properties of both sides (Dant 2004; Urry 2006). As of lately, intelligent transportation systems (ITS) have grown into a spinal socio-technical cord of human-machine activities integrating movement, communication, and information into a complex structure. More than being a good illustration for actor-network theory (Graham and Thrift 2007), the mix of bodies and machines in the current advanced technological systems puts new challenges to the study of maintenance and repair.

One of the most important challenges regards the blurring of agency fields of humans and technologies. Pervasive technologies are in general subject of confusing accountability of agency: “in many instances we are unable (from an outside point of view) to distinguish human action from non-human action, because the system’s behavior is almost identical” (Weyer 2005, 10). If we take the example of modern aviation, both human and non-human elements could be involved in failures and system breakdowns to various degrees, as well as in the activities of maintenance and repair. The causes of aviation accidents combine “pitfalls of automation, organizational failure, insufficient training of humans, as well as divergent safety cultures and unresolvable conflict” (Weyer 2006). It is extremely difficult to determine a “decisive” contribution of one or other of these causes to accidents, because the responsibilities and actions of technology and humans are widely distributed (Weyer 2006a). In this distributive constellation, one core responsibility of the advanced technology (in ADAS, cockpit automation, Smart Homes, etc.) is to achieve the control of the environment also through the intensive supervision of technological and human functionality. In the context of generalized monitoring the supervised humans may be prevented from acting strategically and from learning from past failures because: “they try to avoid situations in which the individual can fail (and learn) – by presenting or rather constructing a “perfect” world, that shows up according to the system’s rules, the user does neither know nor understand.” (Weyer 2005, 7). The logic of intelligent systems is the “preventive avoidance of learning (by doing or by experience)” (id.).

Against this background, failures and repair in hybrid systems in which artificial agents and humans interact and act together (Weyer 2006b) represent complex topics that need to be addressed more in detail by the research dedicated on maintenance and repair. There is still need for research about the contexts and possibilities and failing in such systems, the accountability for this (who/what acts, who/what is responsible for the consequences of maintenance and repair), and the solving possibilities.

### **3. Technological Scripts of Driver Assistance: from Advanced Driver Assistance to Driverless Cars**

The current assistance in ADAS (advanced driver assistance systems) ranges from information providing (navigation systems, Traffic Master and RDS-TMC receivers), feed-back with the intention of reducing drivers errors and traffic violations (longitudinal collision warning systems, lane departure warning systems and lane-change assistant systems) to intervention in vehicle control without completely supplanting the driver such as intelligent speed adaptation, Adaptive Cruise control, Stop and Go (Carsten and Nilsson 2001).

The strongest motivation for the development of solutions for driver assistance is the enhancement of traffic safety. Traffic safety research has generally established that static characteristics such as age, gender, cognitive and motoric internal characteristics, level of experience, influence the way in which drivers behave on the road (Evans 2004; Shinar 2007). Some categories seem to carry the “unsafety” germ in their core, such as: “the adolescent driver” (Glendon 2011), “old drivers” (Schultheis and Manning 2011), males, among them particularly the “the sensation-seeking” ones (Rosenbloom and Wolf 2002). The youngest drivers seem to manifest a tendency for risk taking and immediate rewards, have a rather irrational, disorganized thought pattern and manifest a delayed processing of critical information about generically dangerous situations (Glendon 2011).

The focus of traffic safety research has been placed also on the negative effects of dynamic states such as inattentiveness and sleepiness/drowsiness (Evans 2004). In the last times there have been growing efforts to detect such dynamic drivers’ states, which resulted in various driver monitoring systems to monitor sleepiness, drowsiness, distraction, or inattentiveness on the road (Wang et al. 2007; Rogado et al. 2009; Park et al. 2011; Regan and Hallett 2011). Volvo has developed a fatigue monitoring system based on a sensor anchored in the instrument panel that registers the direction in which the driver looks, how far his eyes are open and how he or she holds her head. If fatigue signs are detected, the car increases the distance to the car ahead as a precautionary measure and warns the driver. Such system should also be able to warn drivers before nodding off. Technical solutions are developed according to “scripts” described by Akrich (1992) as: “the end-product of the designers’ hypotheses and visions about the entities that make up the world into which the object is inserted” (Akrich 1992, 207-208). As the literature on advanced driving assistance systems and particularly monitoring systems shows, the dominant representations of technology developers about driving are populated by dangers that can be intelligently detected and prevented through the in-advance recognition of some “bad or dangerous” characteristics of the involved elements.

This smart recognition should enable the warning of drivers (and thus the correction of their behavior). Technology should even take over the control when humans are not able to control the vehicle anymore. In the last time, in parallel to the efforts for a better understanding of the drivers' behaviours, there are significant efforts to further decrease the arbitrariness of human actions by means of autonomous driving. The vision of driverless cars has been lately enthusiastically adopted by the many engineers working in the ITS field, as the recent ITS IEEE conferences testify. A true "revolution" in vehicle automation is expected, made possible by the low-cost sophisticated sensors (Denaro, 2013). Ideally, the autonomous driving should bring liberation from the strains of driving, a better employment of humans' mobility time, and a higher in-car comfort. The concrete realization of this vision has technical, as well as human and social requirements and paths of action. From the technical point of view the road towards the establishment of automated driving systems is marked by implementations such as: automatic gears and power steering, servo systems open windows, roof lights, sensor-based monitoring system that adjusts the heat inside and responds to the outside environments by switching wipers and lights on and off, anti-lock brakes and devices that control suspension and over-steering. (Laurier and Dant 2011).

Recently DIBOX implements the vision of smart cars communicating with drivers and answering to questions such as: Have I lock up the car? Should I refuel the car today? How much time do I spend in the car? How I have driven in the last time? Other developments are Adaptive Cruise Control (ACC) and platooning (cars driving automatically a row with short spacings between them). Also the field of Cooperative Traffic Systems features pilot projects with corresponding policy recommendations. In the project Drive Me<sup>2</sup> (2014-2017) self-driving cars will ride on about 50 km of selected roads in and around Gothenburg. This will be made possible by the cooperative traffic technology that enables the interaction between vehicles and street infrastructure. The control of the road and traffic is combined with that of the driver. The official homepage of the project highlights some individual benefits for drivers that should derive from the mix of autonomous and active driving:

Autonomous driving will fundamentally change the way we look at driving cars, as you can plan your drive with a mix of autonomous and active driving. This makes the journey more time-efficient. You can safely interact via phone or tablets or simply choose to relax. The self-driving technology used in the pilot allows you to hand over the driving to the car when the

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<sup>2</sup> The pilot project will be conducted von Volvo Car Group in cooperation with the Swedish Transport Administration, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park, and the city of Gothenburg: [www.multivu.com/mnr/64153-volvo-self-driving-cars-unique-swedish-project](http://www.multivu.com/mnr/64153-volvo-self-driving-cars-unique-swedish-project) (last access: 28/10/2015).

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circumstances are appropriate comments. (Håkan Samuelsson, CEO of Volvo)

The google car project has recently (2014) allowed reporters from Spiegel to act as test passengers through the dense traffic in Silicon Valley. Their most striking feeling was that the driverless car had not behaved in the fluent traffic differently from other cars: “The car accelerates and brakes smoothly, changes lines as it should, stops at zebra crossings for pedestrians, avoids cyclists, and follows a modified traffic routing at a construction site” (Schulz 2014). The autonomous driving mainly challenges the possibilities for human agency and the perspective of driving as an activity accomplished with others (Laurier and Dant 2011, 228). Technology designers expect that the task of driving disappears, as cars turn into uncoupled small train carriages – a new hybrid form of car-train assemblage (Laurier and Dant, 2011). As Thrift emphasizes: “what is thought to be a mature technology is currently changing and transmitting into quite different by an oblique route” (Thrift, 2004, 48). Autonomous technology should in principle make the traffic more predictable and faultless, as “driverless cars will follow the rules, abide by speed limits, and stop at stop signs without growing bored, tired or resistant of doing so” (Laurier and Dant 2011, 239). However, perverse effects concerning the objective of the reduction of congestion may appear, since the attractiveness of driverless cars will bring more vehicles on the road (ivi). The variety of emotionally charged actions in which drivers and passengers are currently involved while inhabiting the car: story-telling, learning, planning, complaints, mundane economica (Laurier and Dant 2011, 229) might be reduced through automation. Distraction and fatigue as important sources of road accidents should be eliminated. Vehicle automation could lead to less social interaction between humans and more concentration on “insular activities such as reading or working on computer” (Laurier and Dant, 2011, 237), relaxation and entertainment. However, for the present moment, the ITS community emphasize that “autonomous driving” or “automated vehicles” should not be made equal to “driverless” since drivers should remain an important part of the system. As the own observation of conference presentations and informal discussions at the IEEE ICTS2013 has confirmed, the designers’ community believes that drivers should not be alienated from driving and be relieved from the responsibility for the driving process. The future inhabitants of automatic cars should retain the responsibility for the consequences of driving (for regulatory reasons, industry interests). A new dilemma occurs for this transition phase: how reach and maintain both driver inclusion and exclusion in driving a semi-autonomous car? It can be observed that the visions of the community of technology designers about how to assist humans in their mobility are not without tensions and contradictions. The inclusion and exclusion of humans from driving activities has to be sometimes implemented in the same wave of technology development, as the

future development of driver awareness solutions in semi-automated cars will show. In this vision, the role of drivers will be rather that of “watching absents”, who are allowed to work, read, play and sleep, while also keeping their eyes on the machine controls and the road. The monitored humans will still have to monitor the technology.

## **4. The Empirical Study**

### **4.1. Methodology**

Adopting a phenomenological approach based on qualitative methods, the main objectives of the research in the current paper are to analyze how designers’ scripts about advanced driver assistance relate to the topic of failures, maintenance and repair in intelligent driving. The working hypothesis of the empirical study is that technology designers regard failures and breakdowns in traffic as mainly deriving from human behaviour. They are open therefore to a necessary monitoring of human drivers that is necessary to make up a world of “safe and pleasant mobility”.

Seven interviews were conducted in 2014 with academic researchers working in the field of ITS research and development in Austria, region of Carinthia. Their main area of expertise is advanced driver assistance systems, road traffic signals, and driver and driving monitoring. All interviewed persons were males, aged from 25 to 46 years. Their experience in the field ranges from 2-3 years to more than 20 years (2 persons). In spite of the recognized importance of gender issue for the analysis of technology scripts (Oudshoorn et al. 2004), due to local circumstances it was not possible to include female experts in the study. The results have to be therefore interpreted in terms of technological scripts of male designers about driver assistance. The interview partners were approached face-to-face and informed that the study aimed at exploring their attitudes about the new developments in the field of intelligent vehicles, driver assistance and vehicle automation.

An interview guideline has been developed on the basis of the operationalization of the concepts. The perspective on the assistance of drivers adopted in the study relies on the combination of three dimensions: support of safety (either by actively supporting the driving task, or passively supporting the car itself), information (traffic or situational information, such as navigation and traffic information receivers), and support of entertainment and car environment (video, music and multimedia, light and temperature). Failures and breakdowns have been explored in these areas, with a particular focus on the safety dimension. During the questioning of the meanings of driver assistance no definition of concepts or dimensions has been previously given to the interview partners. The objective was to obtain spontaneous wordings, representations, and examples.

Although the interview participants were encouraged to freely follow spontaneous ideas as they had appeared, special attention was paid to the following topics:

- General cognitions and attitudes about ITS and ADAS;
- The role and intervention powers of humans/technology in intelligent driving;
- The meaning of driver assistance with examples;
- Types of failures in the ADAS supported driving. Coping with failure and breakdowns;
- Attitudes towards driving automation.

The interviews were audio-recorded. The length of expert interviews was between 45 minutes and 1 ½ hours. Five interviews were conducted in English and two in German (translated afterwards by the interviewer).

## 4.2. Results

### 4.2.1. Background Representations of Advanced Driver Assistance

The experts' representations about driver assistance technologies provide the interpretation background for the section dedicated to the failures of human and technological elements and the coping with this. The main goal of the analysis has been to establish how advanced technologies are supposed to support humans by means of semi-autonomous actions and human-machine communication, particularly in the case of incongruence between driving goals and actual behaviour, at the strategic, tactic and operational levels.

The meaning of driver assistance enjoying highest consensus among technology developers is synthesized by the expert 7 as: "the support of human perception; reasoning, and action (support to drive)". Related to perception, expert 7 stresses the importance of issues such as the range of perception and its reliability. Sensors can represent here a key problem, because they can break down, or have a low reliability. The resulting perception can be not good enough or fail in particular conditions such as rain, night vision or fog. Driver assistance is understood also as a necessary extension of drivers' powers and senses, not only in what concerns the provision of night vision or dead angle visualization but also related to their fluent integration in the traffic flow:

for example the system can warn you that if you still drive that speed you will reach red light and you slow down a little bit you will be green and so on...so it can make the traffic flow to make it more fluent. (Expert 3)

A good perception provides the basis for the best reasoning about what to do in a given driving situation. The particular emphasis in the support of human reasoning lies on the transforming of real-time driving data into information useful for drivers. As Expert 6 maintained, “driver assistance is about providing information in correct time to help the user make the right ‘correct’ decision”. Last but not the least, it is expected that the assistive technology improves the adequacy of human actions to the challenges of the driving context and also enhances the rapidity of manoeuvres. This is because human reactions are slow compared to automated actions. In addition, if the driver is tired his/her attention decreases and wrong manoeuvres are performed and good manoeuvres may be disregarded.

During the interviewing process I have become aware of a strong apprehension of the experts about humans as dangers in traffic. As spontaneously emphasized by expert 7, the current state-of-the-art cars are very reliable and predictable. On the contrary 90% of the problems in traffic appear due to the human component, therefore the necessity to monitor what happens to the human driver over short periods of driving. Expert 2 generally agrees with the necessity of “automating” human processes and minimizing human errors:

I believe that wherever people work, there are dangers and problems. I believe that the traffic and the technology has become so complex, so many areas are loaded with dangers and problems that such risks and potential dangers are getting bigger. The traffic volume is generally growing. If one thinks at the air traffic, the volume of air traffic continues to grow, more and more machines start and land, the processes become more complex, ...increasingly more technology is needed to automate the human factor. (Expert 2)

This belief is also shared by Expert 1:

I believe that currently humans represent for me the most serious danger area, for they are the ones who more or less cause accidents. Here could technology a bit intervene, to minimize or eliminate this cause...Fully eliminate is not possible, I believe that no one gives up the 100% control. Not even myself I want this... (Expert 1)

The reserve of this particular expert about the reduction of all human errors by technology represents an interesting illustration of how engineers often feel when working in human-centred technology projects. On the one side, there is a high enthusiasm about the technical possibilities opened in intelligent transportation systems, which is often reinforced by successful development and testing of prototypes and encouraging theoretical results. The reverse of the coin is a growing awareness about difficulty of understanding and grasping the full complexity of human behaviour in system modelling. Some experts manifest an open scepticism



about the possibility to understand and control human drivers:

The human being is the most intelligent system to perform in real-time, and in an intelligent way while machines follow a program and are usually not pro-active” and “Humans are chaotic systems with a great degree of unpredictability”. (Expert 4)

The same expert states that human beings are endowed with the flexibility to create new rules and to react to new, previously unknown conditions. On the contrary intelligent systems are programmed to react to a variety of situations imagined by the human being, while not being able to create and invent new rules.

An additional challenge for the design of intelligent systems assisting humans is represented by the high complexity and non-linearity of both human and technical systems. If these two complexities are brought together in a socio-technical system such as the modern traffic, the predictability of system’s behaviour is strongly challenged. As expert 3 emphasizes:

If you look at the traffic modelling or traffic controlling, you see that they are complex systems, random and non-linear. The main cause of this non-linearity is driver behaviour. Traffic rules set frames to drivers, they should behave as such to respect the rules and move between limits of what the traffic should be. Rules are related to some risk in speed, lane change, but there are other behaviours that affect in another way the traffic modelling. I mean the distance between two cars: you have safety margins between them but some drivers do not really follow it or the old women are too afraid to come closer to the car ahead ...it is not forbidden to do that but it also affects the traffic (fluidity). (Expert 3)

The experts’ acknowledgment of the mixed human and technical problems (failures, breakdowns) in intelligent systems is important for the topic of maintenance and repair insofar it suggests that failing and support (also in the sense of coping with failures) represents a matter of distributed decision and action in which drivers must accomplish themselves some functions of system support. In particular, it is emphasized that humans should remain “actively involved in car operation”. Expert 3 stresses that humans should still play the biggest role in driving because “at the present the car alone still cannot follow the traffic rules and interact with other cars alone”.

#### **4.2.2. How Does an Advanced Assistance System Fail? And how can its Failing be Recognized and Handled?**

Usually the failures of conventional technology can easily be perceived and their causality understood. On the contrary, the failing of intelligent technology is not always immediately visible and manifest. Complex

technological systems feature high nonlinearity, fact that makes the comprehension of the impact of a minor failure on the functioning of systems of systems (such as aircrafts) difficult. In addition, some bad parts or processes could be automatically detected by intelligent supervision instances and repaired without involving the end-users. As Expert 7 remarks, there are soft failures, where the performance goes below a specific threshold but the system still functions and the problems are not perceived by users, and system breakdowns, which are fully perceptible by users. Failures can also be intermittent, therefore the real-time monitoring of failures and fault detection are crucial.

The possible failures of driving assistance systems range from poor vehicle stabilization to navigation information that is not correlated with the external context of driving and with the context-based behaviour of the driver. Referring to navigation systems, the interviewed technology designers emphasize that drivers should preserve their awareness and concentration to the road events and properly reason about the information received from the driving information/navigation systems:

Navigation systems... sometimes give you this direction and this direction is forbidden, you cannot go there. It is maybe because the maps are not updated, therefore the humans should be always aware about this ... if the navigation tells you to go to the right you should not trust it completely... You see with your eyes that you can't go to the right. (Expert 4)

Next to such information flops in the databases of navigation systems, a variety of errors and failures may occur at the tactical and operational levels of driving.

If the system fails, you have a catastrophe. In airplanes, if technology fails they usually move to maneuver mode. In automatic cars they should have such a possibility, for example the car should stop suddenly...alarm or call police/emergency should have procedures when accidents or problems happen. So the idea is also to use technology to call the police, this is also automated. They know the position of your car and can intervene. (Expert 4)

Referring to auto-braking:

As I gave you this example of auto-braking when the car suddenly comes closer to another car, then it brakes automatically... maybe some drivers really rely on their cars that they really brake. When, something in the system is wrong, they crash together. (Expert 3)

About the parking assistant:

The sensors have uncertainty and usually normal people are nor really good in information technology and they think that the systems and sen-

sors are 100% accurate, which is not always the case. (Expert 3)

Or: “You get messages that your engines are not working, but they are really working and you don’t know what to do!” (Expert 5).

As the quotations above highlight, failures often involve a chain of misunderstandings between humans and technology, ranging from confusions of intentionality (technology usually does not accurately grasp the goal of humans) to the overreliance of humans in technology (drivers are sure that the ADAS will function properly all the time). These tensions between humans and technology are complicated by the reality of modern drivers as laymen who cannot understand anymore “why” things go wrong inside the complex car.

The experts emphasize that particularly the operational failures (related to the driving on the road) should be handled through the possibility to switch to human control or to automatically involve the repair instances. Another important possibility is through the own systems’ supervision and control:

Nowadays, if you don’t follow the technology you’ll miss everything (talking about the usage of computer to check malfunctioning). Now a screen is connected and you can see which part is damaged. It depends what you want to change or repair. If a tire is kaput the driver can change this, even the sensors, you can change them in principle, but checking them is made by the computer. It is easier not to go there but to look on the computer. For example now by means of the computer you can know how the CPU is working, the state of the hard memory, you should not look inside anymore. (Expert 4)

The opinion that drivers, even if they are monitored by the car systems, should place themselves in the active position of a watchful trust in intelligent technological systems is shared by the majority of the interviewed experts. Drivers should gain trust from the long-term functioning of systems without grave errors, at the same time keeping an open eye on what is happening on the streets and in their cars. Such distributiveness of attention and concentration on different areas is not a simple job and contributes to the worsening of the information overload:

The driver should not really be outside of this. You can give the role to the system alone, but they (drivers) should be aware that the system can make mistakes... (Expert 4, opinion shared also by experts 2 and 5)

Even if it is desired that drivers should be able to supervise the system:

This could prove sometimes difficult since there are not always signs such as red lights (in the car) that may warn drivers that something starts to be wrong with the system. (id.)

## 5. Discussion

### 5.1. Maintaining and Repairing Intelligent Technology... or Humans?

The current paper has explored the representations of technology designers about advanced driver assistance, failures in intelligent driving, and failure mitigation strategies (who, how, with, what consequences). The expectation has been to identify a dominant view about the instances and possibilities for control and handling of failures that is inscribed in the process of the development of advanced technologies for driver support. To check this expectation, the results of the interviews have been corroborated with the examination of the state-of-the art technology development.

According to the findings, one important function of the advanced driver assistance technology is to ensure that human drivers and driving remain within the desired borders of functionality. This function is distributed on technology and humans. Advanced drivers assistance and particularly driver and driving monitoring systems can be regarded from the perspective of the maintenance and repair topic as forms of “real-time maintenance and repair of drivers”. This occurs through the interaction of humans with technology at both latent (technology seamlessly observes human driving behaviors and states through sensors) and manifest (the artificial agents communicate with humans and vice versa) levels.

The classification below concerns mainly the goals of this type of M&R and is inspired from the maintenance categories of informatics systems including: the corrective maintenance (repairing of errors, modifications of systems to repair errors in design, programming or implementation), adaptive (ensuring the functioning of the system in various changing conditions), perfective (related mainly to the system improvement, new developments), and the continuous support (Alkhatib, 1992). Partially borrowing these terms above, the real-time M&R of drivers can include

A corrective and preventive M&R:

- The automatic recognition of errors, traffic violations, and dangerous driver states, warning (with further possibility of takeover, automatic braking, stop, etc.);
- The maintenance of drivers in a safe state (awake, aware, concentrated) or the enhancement of their context awareness through louder music, automatic adaptation of the car environment (light, temperature).

Perfective maintenance: understood as the extension of human senses to the in-car and out-car perspectives not available before

Restrictive maintenance: the lift out of humans from decisions and actions if the technological monitoring systems automatically classify human states and reactions as risky in a given context.

The intelligent technological assistance understood as “support of human perception, reasoning and actions” (Expert 7) implies that humans remain in the centre of technological actions and assume a variety of responsibilities. In the circle of reciprocal monitoring in Figure 1 the activities of monitoring and fault detection are thus distributed on humans and technology (Figure 1).

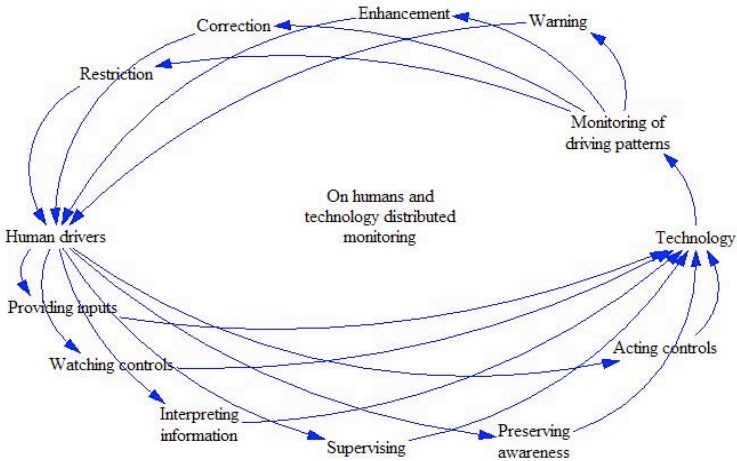


Fig. 1 – The technology script about the reciprocal technology-human monitoring.

The technological monitoring contains various actions such as sensing, data collection, interpretation of information, warning, correction, enhancement and restriction. Some of them require an open interaction with humans, others occur automatically. At their turn drivers give destinations and missions, supervise the car controls, interpret the information in function of the driving context, try to preserve their situational awareness on the road, and (still) drive. A human monitoring of technology functioning is still necessary, even if at a non-expert, superficial level. In driverless cars it is possible that this action range is greatly modified, with the elimination of some actions and decisions and the insistence of the preservation of awareness (doing other things while focusing on the road and technology). There is place for creativity and improvisation in this domain. One such possibility commented by Büscher et al. (2011) refers to participatory sensing. Even the passive car inhabitants of the driverless

cars can be endowed with abilities to “sense” their environment and its functioning and to collaboratively contribute to a user-based mutual adjustment of actions and collaborative mobility. The monitoring of a smart system can benefit from the ability of drivers of “reading” the situation and to be creative about this.

It can be concluded that the perspective on maintenance and repair as distributed reciprocal monitoring can represent a good topic for the sociological analysis of the technological co-action in intelligent socio-technical systems (Rammert and Schulz-Schaeffer 2002; Rammert 2007; Weyer 2009; Weyer and Schulz-Schaeffer 2009; Weyer et al. 2015). Particularly “automobilities become more and more hybrid entities in which intelligence and intentionality are distributed between human and non-human in ways that are increasingly inseparable: the governance of cars is no longer in the hands of driver but is assisted by more and more technological add-ons to the point where it becomes akin to a Latourian delegate” (Thrift 2004, 49). Also information infrastructures “are often shaped and intertwined with networks of distributed agency” (Mongili and Pellegrino 2014, xxi). In this context of hybridization answers have to be given about who/what maintains and repairs the hybrid actor (Latour 2006) human-car, or, at a higher level, the “heterogeneous constellation of the intelligent transportation system” (Rammert 2007).

The growing intervention of artificial agents in the daily life and the eventual triumphal march of driving robots will make necessary the empirical investigation of the co-agency of intelligent technology. The expectation is that this will give concrete evidence to its status as a symmetrical actant in the Actor-Network-Theory sense (Latour 2006, 488). It will become more obvious that agency does not represent only the realm of humans, but a connection of actants (ibid, 490) involved in driving, technical failures, and co-monitoring jobs. Recent experiments with an agent-based computer simulation show that human test persons indeed attribute agency to the technical systems” (Fink and Weyer 2014, 47). If driving robots and artificial agents in recommender systems are perceived by users as communicative counterparts and partners in decisions and actions then it makes sense to put questions and do research about the concrete parts that are ascribed to each of them in M&R. Fink and Weyer report about a computer simulation based on an own sociological model called HMSE, allowing them to perform interactive experiments and to observe the issue of distributed agency empirically by identifying the sets of actions performed by humans/technology and ascribing an agency value to them (Fink and Weyer 2014, 60). This approach can stimulate future experiments on the topic of the distribution of roles/agency in the M&R of advanced system-technologies.

## 5.2. Directions for Future Research

The current empirical study represents the explorative phase of a larger future project that aims at interviewing a larger sample of designers working in various ITS projects. A particular attention will be paid to the consideration of the opinions of female experts, in order to properly consider the impact of gender on the studied topic.

The presented perspective on M&R has the potential of opening new research directions about the problems of monitoring and the chances of advanced technological assistance of humans in general.

A possible problem induced by the technological monitoring of human functionality is the “preventive avoidance of failures” (Weyer 2005) induced by these systems. This could negatively affect the knowledge and the strategic abilities of humans to plan their decisions and reactions in advance. Therefore design strategies to avoid this are required from future research. In relation to intelligent transportations systems it is stressed that the distributiveness of perception, reasoning/decisions and activities on humans and machines in future socio-technical constellations of driving should leave room for human self-initiative; own responsibility; control of personal data; intervention capacity; and the human decision about the real usefulness of applications (Rammert 2007).

The consideration of maintenance and repair as real-time correction, enhancement and repair of human functioning does not only concern the advanced technologies for driving but also other technological systems, which aim at assisting humans in various fields, such as Ambient Assisted Living, Remote Health Care Systems. A comparative analysis of these systems from the maintenance and repair perspective could represent a captivating topic for future research.

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# Repair in Socio-technical Systems

## The Repair of a Machine Breakdown that Turned into the Repair of a Shop

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**Abstract** This article aims to deepen our understanding of repair work in sociotechnical systems. It is based on three main bodies of literature, which are specifically attentive to materiality: STS studies on repair, studies of breakdowns and technological change in organisation studies and the sociology of work, and occupation studies in industrial workplaces. The present case study deals with a repair of a material device that is used by managers to repair the shop's organization and restore their authority in the workplace. However, this attempt to repair the shop jeopardizes the repair of the machine. It reveals that the repair of socio-technical system combine different lines of repair – material and organisational, mundane and transformative – which are for some of them complementary, divergent for others.

**Keywords:** repair; maintenance; organisation; opacity; sociotechnical systems.

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### I. Introduction

Failures and breakdowns in socio-technical systems are moments of disruption, vital to the understanding of the processes by which these systems actually work, are maintained, and evolve over time. These events can be seen as forms of “unblackboxing” (Graham and Thrift 2014, 8), for at least three reasons. First, even if the failure of a single machine is identified as the principal cause, unanticipated consequences for the rest of the system create a “tight coupling” (Perrow 1999) between its elements. Second, as repair becomes a major concern, this usually invisible

work comes to the fore (Star 1999, 385). Third, investigations to identify the causes of breakdowns reveal patterns of organisation, work practices, and cultural processes in professional groups such as “normalisation of deviance” (Vaughan 1996) that lead actors to misperceive, misunderstand (Vaughan 1999) and ignore crucial elements (Turner 1978). As a consequence, the repair of breakdowns in socio-technical systems concerns both material and social order and consists in fixing social structures and practices as well as the defective machine.

The scope of repair and associated changes can vary. At one end of the continuum, repair can largely restore the status quo before the breakdown and preserve existing structures of practices and organisation. At the other end, repair can consist in major organisational restructuring, reallocation of human and economic resources, and modifications of control and decision processes, in order to make relationships between actors, as well as between actors and equipment, more ordered and predictable (Turner 1978). In this case, repair can be described as “the process communities and institutions engage in to sustain their existence, identity, and boundaries” (Sims and Henke 2012). Breakdowns in socio-technical systems can be compared to technological change analysed in the sociology of work and occupation and organisation studies (see for example Barley 1990; Orlikowski 2000). According to this perspective, breakdowns “will engender opportunities for social change to the degree that they open arenas of negotiation” within organisations (Barley 1988, 51). Their repair can be described as a process by which “technical constraints, social power, on-going actions and interpretations mingle to create social order” (Barley 1988, 52). Negotiations<sup>1</sup> consist in “carefully balanced discursive, institutional and material change” (Sims and Henke 2012, 326). However, negotiations can be conflictual for at least two reasons. First, the technology’s multiple and contradictory implications for the organisation of work (Chateauraynaud 1991). Second, because, depending on the social and economic context, some actors may seize on the repair as an opportunity for more radical change in existing structures and practices (Sims and Henke 2012). In such cases, conflicts can occur because the redistribution of resources enhance or degrade the authority and position of groups in the division of labour.

In this article, my aim is to deepen our understanding of repair work in sociotechnical systems. When a major breakdown in a socio-technical system occurs, how do actors repair material and social practices and structures? How do they combine and balance these different dimensions of the repair work? How do they use repairs as opportunities for more extended changes in the workplace? Depending on the social and material context, what contradictions are they confronting with?

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<sup>1</sup> In his article (1988), Barley named this perspective “interpretive materialism”.

## 1.1. Presentation of the Case Study

To explore these questions, I study the repair process of a major breakdown in the biggest shop (54 employees, 7300 m<sup>2</sup>, 6 floors) of an industrial pharmaceutical plant (650 employees). This study is part of a larger ethnography (2003-2006) (Colmellere 2008). Before being closed in 2009, this shop was in activity seven days a week, 24 hours a day. Started in 1986, it was dedicated to the production of two intermediate drugs (beta blockers and anti-inflammatory), over periods lasting four to six months. Even if extensively automated and computerized, the processes utilized presented dangers for operators' health and safety. Organic matter regularly clogged the pipes because of the ups and downs of the processes. This required manual interventions to clear products that were carcinogenic, had teratogen effects and could cause genetic mutations. Over the years, this shop gained a strong reputation within the plant for its unmanageable<sup>2</sup> and strike-prone production teams, and became known as the "Gallic Village".

The breakdown studied here occurred on April 17, 2004. It caused considerable disturbances to the workplace because it occurred during the start-up phase of a major modification project involving the replacement of the shop's computer systems to comply with European and U.S. Food and Drug Administration regulations. These regulations required that the new computerized system record and document data for each individual action during batch processes. As these records allow for extensive control over operators' actions, plant and shop managers considered this new computerized system as an opportunity to reinstate hierarchies within operators' teams and restore their authority over them.

In this shop, managed by a production engineer and a deputy plant manager, maintenance was not a key concern, despite aging and dilapidated equipment. Persistent and recurrent failures of routine equipment revealed that production workers institutionalized threats to equipment. As much as possible, production teams tried to postpone basic repairs (sensor failures, leaky pumps, etc.) until scheduled maintenance outages. They routinely ignored these failures and disconnected defective materials from the computerized control system. In addition, since 1990, daily repairs and scheduled maintenance had been increasingly outsourced. During production periods, sub-contractors performed repairs under the control of the production technician in charge of consignment and de-consignment. The two maintenance technicians dedicated to the shop were used to work far from the equipment. They had to manage contracts with maintenance companies, plan and prepare maintenance outage control, take care of complex equipment (like the "beast of grief") and perform major equipment modifications. In addition, traceability and feed-

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<sup>2</sup> Over the last three years, three production engineers left the shop's management team because of difficulties in managing production teams.

back remained poor.

The breakdown occurred after an initial six-month period of equipment incidents and persistent IT outages. It concerned a complex and highly sensitive device – a nozzle<sup>3</sup> – tightly coupled with other equipment components. It was usually referred to as “K”, after the name of the company that made its first version. Production workers discovered the failure as soon as they restarted production after the maintenance outage control. Screens indicated that the level of pressure increased in the K’s main body i.e., the air-tight vacuum was impossible to maintain. However, neither data recorded nor local examinations were sufficient for operators to identify the breakdown causes. This failure exacerbated already tense relationships: workers vehemently insisted on the responsibility of the production engineer and plant management for the lack of resources to restart production under proper conditions.

The repair work – diagnostic phase and the repair itself – lasted three weeks, during which production was completely interrupted. After one day of trial and error to restart the “K”, the production engineer called in the director of the maintenance department and the plant processes expert on a task force. After three weeks of false diagnoses and unsuccessful trials, the team despaired of finding a solution and finally decided to ask for help from the K’s maintenance expert. The repair itself took a few hours. The technician diagnosed a small fix, which was performed by his colleague, the other maintenance technician dedicated to the shop. According to him, his colleague did it to improve the equipment’s performance. The technician at fault was never officially penalized but members of the task force and their superiors emphasized his lack of skills. However, diagnostic difficulties and the repeated complaints of production teams revealed the shop’s lack of resources for proper repairs and maintenance. Plant management – the plant director, the manufacturing director, and the technical services director – decided to strengthen shop management. They created a “plant management team” composed of the production engineer, the deputy plant manager and a maintenance engineer. In some respects, the maintenance manager succeeded in obtaining more resources. However, they made no changes to either the number of maintenance technicians dedicated to the shop or the sub-contracting conditions. The shop continued to be plagued by conflictual relationships between operator teams and management as well as equipment problems.

The dynamic of this repair presents an opportunity to explore socio-technical repair so as to deepen our understanding of combination between discursive, material and organisation changes. Therefore, I consider the degree to which their choices to perform technical repair and organizational repair resulted from social (Stroobants 1993) and power rela-

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<sup>3</sup> A conduit with a variable cross-sectional area in which a fluid accelerates into a high-velocity stream (see McGraw-Hill Concise Encyclopaedia of Engineering, 2002).

tionships (Alsène 1990; Thomas 1994) in the shop and in the plant as a whole. The “beast of grief” case presents the story of an equipment repair that is used by managers to actually repair their shop’s organization. In this case, repairing organization means repairing operators’ material and social practices. According to managers, it consisted in restoring hierarchies within operators teams, between operators teams and the two shop’s managers, and, moreover relationships in the workplace.

Compared with the cases studied in the literature dedicated to repair work, this case presents three major specificities that will guide my analyses of the concrete practices of diagnosis and repair. First, the repair of this “beast of grief” is more than the repair of a machine. “As a technology that became embedded in a matrix of interpretations, [the beast of grief] acquires the status of a social object whose meaning and use were progressively uncoupled from its physical design” (Barley 1988, 47). This machine is fragile and non-stabilized; as Denis and Pontille demonstrated for Paris subway signs, “[each] intervention inevitably goes with uncertainty about materials. Instead of being stable resources, the material properties of signboards are important issues of the maintenance work itself” (Denis and Pontille 2011, 7). In the case studied here, uncertainty is due to the equipment non-stability because of its transformations through one mundane maintenance operation to another. Thus, I will consider the representations associated with this material object and the way its various states are represented and evoked in the workplace.

Second, issues of power and social relationships are explicit, thanks to two interconnected aspects: the specific context within which the breakdown occurred and the status and position of the managers who participated actively in the repair. The context included the particular economic and social situation of the shop and the extended start-up phase of the new computerized system. This reinforced the degree to which these managers were caught up in the repair of the shop.

Third, this case presents a combination of repairs: material, organisational, mundane fixes and transformative operations, which complementarities and divergences have to be considered.

My paper is structured as follows. In a first part, I explore the relevant literature and outline the characteristics of the repair of breakdowns in socio-technical systems. I have drawn on three main bodies of literature specifically attentive to materiality: STS studies on repair, studies of breakdowns and technological changes in organisation studies and the sociology of work, and occupation studies in industrial workplaces. I first describe the characteristics of repair work. As the present case study involves actors who are not repair specialists, I outline the skills and issues specific to repairs in socio-technical systems. I emphasize the non-stability of technologies as a specific issue. I then provide an overview of evolutions in the organisation of maintenance activities in industrial sectors since the 1980s — an overview that reveals the link between the invisibility of repair work and organisational opacity. Finally, combining these

points and preparing the discussion of actor choices in the empirical section, I explain how these evolutions call into question relationships in workplaces and organisations.

In the second part of the paper, I describe the methodology employed, providing additional context to make clear the conditions of my fieldwork in this shop and on this breakdown in particular.

The third part is empirical, divided into three sections. First, I describe the diagnostic work by focusing on material and discursive practices. Second, I draw links between the two interrelated dimensions of repair: material and social structures and practices. I insist on the fact that the organizational repair is based on an incomplete diagnosis of the social practices that caused the breakdown. I provide explanations of the managers' diagnosis of the breakdown as the consequence of individual error. Third, I focus on the way the maintenance engineer's choice (to reinforce maintenance management in the shop) go along with the production management willpower to restore authority over operator teams and to correct their practices. This combination ultimately served to repair the shop's material and social orders. In this empirical part, I specifically highlight the conditions of repair linked to the breakdown context: the opacity of maintenance and latent conflicts between management and operator teams.

Finally, I conclude with a discussion of the theoretical and methodological issues raised by the study of the repair of major breakdown in socio-technical systems within a framework that combines the sociology of work and occupations, organisation studies, and STS.

## **2.2. Repairing Breakdowns in Socio-technical Systems: a Review of Studies on Skills, Opacity, and Power**

### **2.1. Drawing on Resources and Coping with Contingencies**

STS studies of repair work analyse it as an on-going process of negotiation between humans with intentions (Akrich 1992) and non-humans, both considered as parts of a network. Combining this network perspective with sociology of action, this approach places particular emphasis on materiality. It analyses repair work as a blend of material and discursive practices that consist in taking care (Puig de la Bellacasa 2011) of fragile and vulnerable objects (Denis and Pontille 2011). It imports from ethno-methodology and studies of situated activity the emergent character of social order and the dialectical relationship between human activity and setting (see for example Suchman 1987; Hutchins 1995) – referring to the physical environment and the sets of social and material relations surrounding action – or workplace that constitutes a “network of associations between the social and material” (Henke 2000, 59). These studies



emphasize a triangular relationship between technicians in charge of repairs, machines and users (or customers) (Orr 1996), based on discursive practices and on close connections between bodies and objects to repair (Henke 2000).

Repair work is composed of two main phases: diagnosis and the repair itself. Diagnosis consists in “the creation of a coherent account of the troubled state of the machine from available pieces of unintegrated information” (Orr 1996, 2). Both phases take place in settings and workplaces that are arenas (Dodier 1993) in which technicians perform “mediations” (Akrich 1993) between things and users in order to change their representation of objects and of the workplace. In this approach, repair work concerns not only machines but users as well (Thomas 1928, cited in Henke 2000), highlighting two main points: first, as mentioned in the introduction of this paper, the status of machines as “social objects”; second, the importance of the relationships between repair workers and users (Orr 1996) whose maintenance depends on the technicians’ ability to take care of machines.

Therefore, improvisation, “bricolage”, innovation and ingenuity are essential characteristics of repair work (Graham and Thrift 2007). Repair specialists are able to combine acute skills that are not completely explicit even for those who are experts (Orr 1996): kinesthesia, sensory-motor, discursive (Barley 1996). As emphasized in sociology of work and organisation studies on technicians, these skills are distributed (Cicourel 1994) and collective (Barley and Bechky 1994; Barley 1996). They are developed and maintained through the sharing of experiences with machines, people, workplaces and their relationships, relationships in the specialists’ communities and professional networks, documents on repairs such as procedures, repair logs, repair sheets (Denis and Pontille 2014), and the maintenance of a shared history via “war stories” (Orr 1996). A skilled repair worker draws on a range of resources within the workplace and outside it, according to the level of difficulty of the breakdown and contingent circumstances.

What are the specific issues entailed in repairing breakdowns in complex socio-technical systems, like the one studied in this article? At this point, three major issues arise, linked to the fact that diagnosis and repair must be considered in the context of the system of which the broken machine is an interrelated component. First, as for copiers (Orr 1996) and signs (Denis and Pontille 2010), fixes and misuses of the machine are permanent issues in repair work. Technology remains unstable because transformed through one maintenance operation to another and eventual threats. Moreover, as shown in the literature on major breakdowns (Perrow 1999; Perin 2004), because component parts of socio-technical systems are tightly coupled, the act of fixing – with “technology that compensates for, repairs, or replaces faulty technology” (Perrow 1983, 525) – has two faces: a positive one because it consists in repairing; a dark one, because of its unanticipated and dangerous consequences for the system.

Second, in a certain sense, repair work is even more complicated when facing tricky issues where the relationship with users is at stake. There are few ways to escape, for example, as with copiers, replacing the machine to save the relationship with customers. Third, and linked to the previous point, repairs introduce changes to the workplace. Yet, organisation studies<sup>4</sup> based on the practices of people working to implement technological change highlight the interrelation between technological and social changes and explore this aspect thoroughly. Therefore, repairs in socio-technical systems question the combination of material and social components and the way they influence one another. Thus, to understand precisely how actors repair material social practices and structures in socio-technical systems, two questions must be addressed: to what extent does the technology (to be repaired) shape organisational choices (social structures and practices)? Conversely, how do existing organisation influences repair practices?

These issues are studied in the first two sections of the empirical part of this paper. I turn now to another characteristic of repair work that makes its consequences for systems difficult for actors to foresee: its invisibility and opacity.

## 2.2. Opacity

STS studies on machine and infrastructure repair work highlight its invisibility (Henke 2000; Graham and Thrift 2007; Graham 2010). They suggest that failures and breakdowns render these usually hidden aspects of organisational life visible. In several studies on technicians, bridging the sociology of work and occupations, organisation studies and the sociology of science, Barley insists on the status of technicians within organisations as one of the root causes of their invisibility. Technicians work at the interfaces, as intermediaries between groups of people and between people and objects, as “buffers” (Barley 1996, 420). As such, they connect the material world and they master with the symbolic world of the people for whom they work. Therefore, they must harness language, theories, plans, know-how, and tricks of the trade to perform diagnostics and obtain data that they then translate into a symbolic language accessible to their customers. As “brokers” (Barley 1996, 422), they also have to translate user needs, which requires establishing and maintaining strong relationships with their occupational community. Their opportunities for professional advancement are more constrained than for other occupations, especially in organisations where career opportunities are mainly hierarchical (Barley and Bechky 1994). However, repair specialists often prefer to remain in their teams and their community rather than becoming

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<sup>4</sup> See Orlikowski and Barley (2001) for a synthesis of organisation studies in the field of information technologies, which takes into account the institutional context and the materiality of technologies.

ing managers or experts (Orr 1996). Quality work, the ability to fix tricky failures and cooperative relationships with customers are the main sources of professional recognition.

Even if invisible most of the time, repair workers are presented as powerful because organisations are vulnerable to the loss of their expertise. This gives them leverage to negotiate resources and working conditions (Crozier 1964; Shaiken 1984). Nevertheless, since the 1980s, industrial organisations have implemented changes in their structures and practices to the detriment of local repair and maintenance workers whose activities were not fully understood. This change affected resource allocation for repair and maintenance, relationships within workplaces and with machines.

As many studies of industrial organisation have shown, repair and maintenance activities have been pushed, since the 1980s, to the margins of industrial systems through progressive out-sourcing. Routine repairs and maintenance outage control operations have been increasingly entrusted to outside companies. Maintenance in local departments has been steadily reduced to control, preventive maintenance, planning, contracting and major equipment modifications. At the same time, group cohesion was gradually undermined. It became more difficult to ascertain and appreciate the condition of installations because knowledge about them became more difficult to gather. This knowledge was unequally distributed between the different groups of workers in charge of the different aspects of repair and maintenance: permanent employees of the plant, sub-contractors of varying status depending on the terms of their contract. In addition, systems of traceability and accountability were not properly redesigned in light of increasing outsourcing. Despite successive improvements, local repair and maintenance workers face more technical and relational issues in their activities. Knowledge of local idiosyncrasies concerning equipment, practical know-how, and relationships between users and equipment became simultaneously more critical and more difficult to acquire and maintain.

These characteristics and the non-stability of technologies to be maintained have led to the “opacity” of maintenance within industrial organisations (Hannan et al. 2003). It reinforces its invisibility and misunderstandings of what is entailed. Analysing the breakdown of the British Bank, Barings Brothers, Hannan et al. describe opacity as a consequence of organisational architecture, which can be extended to maintenance organisation in industrial socio-technical systems. They outline the characteristics that allowed a trader to operate and cause the demise of the bank. Firstly, people working in the organization had limited awareness about how different units in their organisation were interconnected and worked together. Secondly, the structure of the organisation was porous with no clear lines of responsibility and accountability. Thirdly, the matrix structure of trading activities does not work properly in practice because of confusion in lines of reporting, ambiguous responsibilities, lack

of traceability and poor communication between different organizational sub-units.

The design of such organisational structures was the work of engineers and managers who considered technologies as stable despite successive repairs and considered repair work as “little more than applying procedures” (Orr 1996, 3) to solve problems that could be anticipated, described and decoded using procedures and guidelines (Duclos 1991). As a consequence, they neglected the workplace’s characteristics as well as the distributional and collective dimension of knowledge.

These representations were reinforced by the extent of automation in modernising production processes. As many studies in the sociology of work have shown, industrial processes and organisations are adapted to the degree of automation (Neville 1963; Shaiken 1984; Terssac 1992; Stroobants 1993; Dodier 1995; Terssac and Maggi 1996). Organisation, working practices, technical devices and production facilities kept pace with a “chimerization” of industrial processes. Based on the model of oil refining, *fluidity* was expected even in processes including material and solid products (Vatin 1987). Computerized systems were commonly set up. Because of the economic, organisational and human costs of these systems, considerable resources were invested to enhance their reliability and performance. Dedicated technical and engineering departments were created. Production work became more and more abstract and issues of automation and control, especially man-machine interfaces, were established as priorities to the detriment of the enhancement of working practices in installations. “Silos” between design, production and repair activities were reinforced (Perin 2004).

The developments described above go a long way to explaining the invisibility of maintenance and repair. They consist in the redistribution of resources and changes in relationships within organisations. In the following sections, I examine the consequences of these changes on the influence and opportunities of actors involved in maintenance and repair.

### **2.3. Influence and Power**

The opacity of repair and maintenance in the workplace and the developments in industrial organisation described above had crucial consequences on the working conditions, practices and the effective influence of internal repair and maintenance workers. It affected their relationships with users as well as machines. Because less numerous and cohesive, working far from the equipment, these workers had to find resources that were more individual and specific to the idiosyncrasies of the workplace, and to become more flexible. However, they lost visibility, recognition and power. Classic conflicts concerning the availability of machines and working conditions described in organisations studies (Crozier 1964; Bourrier 1999) became concealed. Actually, this is not to say that these workers completely lost resources or influence. I only mean to point out

that even if they remained close to the “technicians” described in the literature, their influence was based on practices, relationships, and networks that are more difficult to identify. It explains why other workers and managers know so little about their work and practices, and sometimes disparage them. Combined with the dilution of workers’ influence and the opacity of maintenance activities, this misreading creates an “area of uncertainty” (Crozier and Friedberg 1977). Non-specialists can then use repair work as a resource to serve their objectives, in the case studied here, other repairs.

Considering the importance of the issues of relationships within organisations outlined above and the characteristics of repair work in socio-technical systems described in the first section of this article, the questions that guide my investigation can be formulated in the following terms:

How do actors combine material and social structures and practices to repair breakdowns in socio-technical system? How do material characteristics, local social practices, structures (Alsène 1990) and relationships within the workplace compel their work?

I address these questions in depth in the empirical part of this article, and then further explore the way “technical constraints, social power and on-going actions and interpretation mingle to create social order” (Barley 1988, 52).

But let me first describe in further detail the methodology employed, and specifically the organisation and practices of repair and maintenance in the shop, in order to make clear the context in which I studied the “K’s” breakdown.

### **3. Methodology**

I began conducting ethnographic research on this shop in February 2003. I was able to gain access to this place after meeting the plant manufacturing manager, the shop manager (production engineer) and the computerized system project manager. Because of the risks, I underwent a medical examination and safety training. The reason for my fieldwork in this plant was that I was interested in major modifications in high-risk industries. More specifically, I wanted to study how technicians and engineers consider human and organisational issues during design projects. I chose this project because of its scope and the issues concerned: technological and organisational changes and the explicit management desire to enhance operator practices and restore their authority over production teams.

The breakdown concerned a nozzle, designed specifically for the shop, was equipped, improved and adapted over time according to the shop’s processes, needs and optimizations. Usually referred to as “K”, after the name of the company that made its first version, this machine was

nicknamed by former and current shop workers the “beast of grief”. According to the shop workers, “beast” derived from its “unpredictable”, “capricious behaviour”, due to its extreme sensitivity to external conditions (temperature, pressure, humidity). “Grief” referred to the consequences of its malfunctioning. If it did not work properly, the production process could not run. Moreover, any repairs or modifications were bound to have unexpected consequences for the entire shop and its activities. Such situations might have been frequent occurrences, because the machine had to be restarted after each maintenance outage control (three to four times a year). But, they rarely happened because one of the two maintenance technicians assigned to the shop had specific knowledge and skills to “domesticate and master the beast”, in local parlance. Therefore, production operators and managers considered the “K” as a “black box” whose functioning was taken for granted and whose failure remained only a potential catastrophe.

When the failure of the “beast of grief” occurred (April 2004), I had already spent more than a year studying people at work in the shop and on the project. I had already observed small equipment breakdowns and significant failures in the new computerized system.

During my fieldwork, I used semi-structured interviews and non-participant observations of production, repair and maintenance activities, project meetings and computer programming work. I studied documents related to work in the shop and on the project: procedures, handbooks, guides, plans, and regulations. I gained access to all areas concerned: the main control room, the shop’s equipment installations, its dedicated laboratory, the meeting room, the lounge area and the cafeteria. During the repair of the “K’s breakdown, I observed formal and informal meetings, conducted interviews<sup>5</sup> with 20 people and observed them at work: production workers, managers, members of the task force, maintenance technicians, and the former shop maintenance engineer who was the expert on the “K”.

When the breakdown happened, the production engineer had been working as shop manager for six months. The other members of the task force had been working at the plant for at least ten years. The two shop maintenance technicians were highly experienced. The one who identified the fix and solved the problem had been working at the plant for almost 40 years and as a supervisor for ten years. The technician who performed the fatal fix was less experienced. However, he had been working in the shop as a technician for five years and at the plant for more than twenty. Both had spent their entire careers working in maintenance departments in the chemical industry.

In my investigations, I was keen to resituate the breakdown and its repair in the larger project dynamics. For each actor I interviewed, accord-

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<sup>5</sup> Despite my repeated and insistent efforts, the maintenance technician who did the fatal fix on the machine refused to meet me.

ing to the situation, I tried to understand what was at stake for them, their involvement in the repair work, their diagnosis of the breakdown, their contribution to decision-making, and the way they imagined subsequent operations. I interviewed production operators more specifically on what mattered most in the situation (of breakdown and repair), how they understood the breakdown, the work of the people involved in the repair, how they anticipated restarting production and the shop's activities with the K repaired and the new computerized system.

I will now move on to the empirical description, analysing actors at work in diagnosing and repairing the breakdown. Let me first provide further details about the resources that maintenance workers can employ in response to failures and breakdowns: observations revealed that routine repairs were performed under the control of production teams. Most of the time, they followed a request by operators to their colleague, the production supervisor in charge of consignment/deconsignment. These requests were written on dedicated forms or remained informal depending on the level of emergency and gravity as perceived by operators. The production supervisor would then contact the sub-contractors concerned and prepare their intervention: a formal authorization, the license to operate at the facility, lock-out/tag-out sheets. He entered in the shop logbook the nature of the intervention and the time (start, duration, end), its location, the number of people working, the specific risks. However, interventions were not systematically reported because operators sometimes asked subcontractors for them directly without mentioning it to the supervisor. In addition, traceability and feedback on repairs were not formally reorganised with the development of subcontracting and the number or the extent of repairs performed were not systematically reported in the dedicated logbook according to procedures.

Repairs are one of the items on the agenda of daily shop meetings. The deputy plant manager conducted these meetings, every day at 13:30. They consisted of a review of the actions completed, currently underway, and scheduled in the shop (production, quality of production, repair and maintenance operations). Maintenance technicians did not systematically participate in these meetings. Moreover, they spoke only if they were invited to do so, in answer to specific questions.

Daily meeting, shop meeting room, November 11, 2013:

Deputy plant manager: "Maintenance?"

Maintenance technician: "I'll pass".

Production supervisor, consignment-deconsignment: "I will clean the oven if I find one or two people tomorrow. There was a problem with the heating of the (equipment) 41. This morning, there was a strange noise so we added water but the noise did not stop. It was a defective chromatograph. There was no alarm, but I have a sense that there are failures. I got on the elevator; there were three serious drips at flanges so we just started. Still, I requested a top flange from the silo to avoid drips".

Local maintenance technicians were called for the repair of some specific equipment and to prepare and set up modifications. They prepared and reported repairs in the same way as described above. They used to consult production documents (procedures, manuals, etc.). However, they barely used the computerized system themselves to diagnose failures and test equipment. They asked operator teams, if necessary.

Our work is based on what we see. We use the IT system very little. There are other signs that indicate what is happening: noises, smells, heat, etc. At the beginning, the system crashed all the time so it was hard for us to use. Now it has been stabilized, but we didn't receive any specific training. I learned some basics with colleagues (the electrical service instrumentation maintenance), but most of the time we avoid using it... We ask production staff, those who know how to use it. Usually it works well that way. (Maintenance technician, expert on the K)

They were used to cope with difficulties in gathering data and information, because operators were not cooperative.

The technician who solved the problem explained the main difficulties of diagnosis:

One of our difficulties is the transparency of information. To solve technical problems, it would be easier if everyone would forget the idea that they were responsible. When a piece of equipment fails they are not necessarily responsible. For us technically, it would be easier if we had more information to diagnose and repair properly. When we are working on a problem, it is hampered by a lack of availability on the production side. (Maintenance technician, expert on the K)

They would document modifications using technical modification forms, investment demand forms, validation forms.

In addition, they were in charge of internal and external scheduled equipment inspections and their documentation. Finally, when interviewed, maintenance technicians regretted the loss of skills and knowledge of equipment and criticized the growing power of the companies contracted for maintenance.

Developing my empirical description further, I will now explain how production and maintenance managers repaired the K's breakdown and seized on it to repair their authority over operator teams and finally the shop itself. I first show that despite a highly structured and systematic process they failed to diagnose the breakdown. I then outline the ongoing collapse of the relationships between operators and production and maintenance management. In the second part, I describe the task force's partial diagnosis of social issues in the shop, analysing it in terms of individual and collective attempt to repair the shop's organisation. In the



third part, I deepen this analysis to explore two issues: Why did the task force refuse to call for external help for three weeks? Why did they analyze the failure as the consequence of a single individual's faulty action? Finally, I have synthesized these results to show how production and maintenance managers focusing on the repair of the shop have jeopardized the repair of the breakdown.

## **4. Fixing the “Beast of Grief”: toward a Repair of the Shop**

### **4.1. Unsuccessful Technical Diagnosis**

The repair consisted of the diagnosis and the repair itself. The task force began the repair with the diagnosis. They rapidly realized that the K's breakdown was an “un-described situation” and a tricky one. As Orr describes it, in the case of difficult diagnosis, “if the problem is not recognized, however, an analysis must be done using information from a variety of sources, and the most difficult diagnoses are those for which none of the information sources provides a clear answer” (Orr 1996, 115). However, for the three members of the task force, diagnosis and repair remained, for almost three weeks, a technical issue.

The three engineers organized their work to perform diagnostic tests according to three interrelated principles. First they gave priority to formal methods. Second they adhered to a work style based on compliance with rules and methods. Third, as a consequence of the first two points, they preferred heuristics derived from formal knowledge than those based on experience. Their work took place in a small meeting room, close to the main control room. At certain moments, as needed, they joined the main control room or equipment installations, in the K's area.

Now, I turn to their physical and discursive practices. They considered the K as if it was an isolated device, disconnected from the rest of the equipment, except for the computerized system. They started by gathering together the plans and schemas for the K and its operation as well as the modification and repair log which would turn out to be incomplete. Then, they began to work on the diagnosis itself. They followed a procedure they described as “normal” and “classic”. Based on “functional analysis” - used to design new systems - it consisted of dividing the K into parts and examining and testing each to see if it runs properly.

There, I intervened because we were not making any progress. This was the first time we met with big problems. I tried to understand the operation of the equipment K. I knew a little but I'd never seriously looked at it. I tried to understand how it was built and how it worked. With V (manufacturing engineer and head of the workshop), we understood that a parameter escaped us. In

that case, I brought in the method. We checked all the equipment to be sure there were no abnormalities. Meanwhile, we had documentation on this type of equipment. (29/06/2004, Maintenance Engineer, Head of the Maintenance Department of the Plant)

The examination had a physical dimension but bodies were only partially engaged: most of the time, the maintenance engineer visited equipment installations in the K's area. He had a look at the parts that were tested and compared their appearance with descriptions on plans, schemas and documents. Observations revealed that he paid attention to the visible features but hardly used sensory-motor skills (sound, smell, etc.) to complete his examinations and pre-diagnosis. Neither he nor other members of the task force demonstrated any close connection to the machine through their bodies, and "the ability to make sense of subtle differences in the appearance of materials and the behaviour of machines" (Barley 1996, 425). The maintenance engineer reported his observations as factual descriptions, close to the formal description of procedures and technical descriptions like those written on schemas and plans. He detailed his observations in terms of conformity/differences with what was indicated on the documents. He described his practices as a "systematic" and "methodological" way of working.

To perform tests and gather and interpret data, the three engineers relied on two intermediaries: the new computerized system and two computer processes specialists. They asked the latter to participate because they did not know how to use the system to launch tests, experiments and batches, or how to read and interpret the information on the screens. However, they refined their practices while advancing through the diagnostic process.

In their initial statements, they attributed the same importance to all of the K's parts. They described the condition of its various parts and the way they functioned according to the manual's procedures and descriptions. However, after one week of systematic research, the test results and the study of the repair and modifications log helped them to identify the most sensitive parts of the machine. They determined the function that had failed and its cause: leaks in the machine made it impossible to maintain the airtight vacuum in the main body of the K. They then began to search for leaks. This part of their work consisted in a very long protocol, because it concerned each component of the machine. They inferred from these tests and from reports on previous modifications to solve this kind of problem that defective ejectors were the most probable source of leaks.

After a physical inspection of the equipment, in a systematic and methodical way, after one week we had not found anything. We thought, it's not normal ... what is difficult is that you are under pressure to restart quickly. We are forced to go fast when I know from experience that we can spend a lot of time looking to the side of the target. (Maintenance Engineer, Head of the Maintenance

Department, task force)

However, because they were not sure of their diagnosis or of their proposed fix, they decided to ask for external help from experts at the company which designed and installed the K.

*Task force at work, meeting-room close to the main control-room:*

Maintenance engineer: "The problem is to maintain the vacuum; therefore, ejectors are needed. Perhaps we have to know more about the ejector failures".

Production engineer: "Don't know..."

Discussion revolves around the machine's plan to determine the part of the machine that caused the failure...

Plant processes expert: "I am still not convinced... I don't know".

Maintenance engineer: "Perhaps we can call the manufacturer of the K, they could tell us if the problem..."

Production engineer: "We have no other option for the moment".

...Pause

The maintenance engineer called the specialists who designed device. He returned back to the team without any firm answer: "They said it was not the problem. Actually they think the problem is that we did so many modifications and improvements that it makes any diagnosis tricky. According to my description of the breakdown and of the efforts we have made until now, they said we could not infer that the ejectors are the issue".

At the beginning of the repair phase and during the entire diagnostic phase, members of the task force never asked operators to participate in the tests. However, as mentioned in the methodological section, maintenance technicians were used to doing so. Operators did, however, remain informed about the repair process. Every day, at the beginning of the production meeting, the deputy plant manager updated them on the progress of the diagnostic process. In addition, he filled out the shop's field notebook, noted the trials and results and provided specific instructions to follow, especially for evenings, nights and weekends.

Ejectors were dismantled on K. Nothing to report, the result is always the same. So for this evening and tonight, make it work by supplying 18% of the VC (volume capacity)". Message signed by the deputy plant manager. (Extract from the shop's field notebook, April 20, 2004)

He mentioned in interviews the fact that he deliberately limited the information to facts in order to "preserve operator morale and keep them motivated for the restarting." This empirical statement shows that, in the minds of this actor and the task force, the most important element of relationships within the shop was authority based on credibility.

Observations in the workplace during this period showed that these

practices deepened divisions in the workplace: divisions between management and operator teams, between design (computerized system replacement) and production. It widened the cracks in the relationship between operator teams and management and revealed the extent to which the relationship between maintenance workers and production were broken. I will now elaborate on these two points.

Even informed operators exhibited strong reactions to shop management and the task force. They considered that the failure prevented them from doing their jobs. They insisted on the strong constraints they were subjected to because of the combination of the K's failure, the unreliable new computerized system and defective shop materials:

*This scene took place in the main control room. Operators explained their situation to me; two members of the task force are present.*

“If the filter is running and the K works, we can start up. But we do not manufacture, that’s not manufacturing!... If we put the product in a new filter and then it drips, it would be ok. But they do not want to put up the cash. We make the raw product with a Z (equipment), and its pure part with an ancient filter from the Middle Ages! The oven is fully loaded, a ton and a half rather than a ton! How can it work?”

Moreover, during one production meeting, they expressed resentment and doubts as to the task force’s ability to solve the problem.

*This scene took place in the main control room, operators complained to their manager (production engineer):*

“Give us the means to do our job...the manufacturing director must provide money. Nobody cares about our situation here... it still doesn’t work!”

Production engineer, shop manager: “No, H [Maintenance Engineer, Head of the Maintenance Department] stayed twenty hours last week.”

Operator, loudly: “For what purpose? None!”

Two days later, operators mandated their union delegates to give the manufacturing manager a grievance letter. This deterioration of the situation changed the task force mind. They decided to call for help.

At this point, we have some concrete illustrations of engineers engaging in repair work to maintain a common objective, which was first associated with the replacement of the computerized system, of restoring management’s authority in the workplace. More specifically, the members of the task force tried to demonstrate their capacity through actions guided by compliance with methods and procedures. With the help of two computer processes specialists, they worked to change operator representations of the computer system and its performance, their relationship to procedures, materials and practices. However, the task force did not succeed in diagnosing the cause of the breakdown. Because of the context in

the workplace and because they stuck to compliance with rules and procedures, they preferred not to improvise fixes or “bricolages”. They recognized their insufficient knowledge of the “beast of grief”. But, they did not want to give operator teams further reason to criticize their actions and run the risk of a strike action.

They reached a point at which they had no other choice but to ask for external help. They called on the maintenance technician expert on the K, justifying this decision in terms of the need for a “fresh perspective” on the problem. The technician listened attentively to what had been done to examine and diagnose the failure. However, he went to the machine, inspected it meticulously and understood immediately what happened: a small modification – a small piece added - prevented the K from functioning. He took off the added device, checked and tested the K carefully, and restarted it successfully.

Concerning earlier vain attempts at a diagnosis, the technician pointed out the task force’s misunderstandings and errors. In doing so, he emphasized the specific skills needed to repair the K. At the same time, he described divisions between production and maintenance and the local maintenance specialists’ lack of credibility when dealing with sensitive equipment issues:

They solved the most obvious issues but they didn’t go to see and understand what was happening at the exit of the device...(where the small modification had been made).

He pointed out that some diagnostic errors were due to the methods employed. Because they studied the K as an isolated device, they had not noticed certain things and misunderstood what was rendered by the computerized system. In terms of skills, what was necessary was the ability to construct a representation of the state of the machine based on the correct association of information read on the screens and physical phenomenon observed on the machine:

In this context, the diagnosis was false and the problem was that the effect of trials and errors which could produce facts different from what the computerized system indicates.” (Maintenance technician, expert on the K)

Moreover, he emphasized the fact that the task force, even while intending to work in a professional manner, reproduced habits that consisted in fast forwarding to solutions before properly performing diagnostic tests:

More fundamentally, one of the main problems here, in this case and in this shop, is that when facing a problem, people offer solutions but didn’t know how to do the intermediate work of analysis...

The former maintenance engineer confirmed this when interviewed:

When the K doesn't work there are many managers who have ideas but they actually don't know how it works...we had an operating method in which we had specific reliable procedures for tests with nitrogen. Using nitrogen sensors, we tried to find the leaks... One day, we had water in the K. It was catastrophic! Actually, it was the result of some operators' oversight. But the deputy plant manager thought that the K was leaky. We (maintenance) knew that this was not the case but we spent the whole weekend making a heat exchanger, because the management of the shop was sure of its diagnosis.

According to both actors it is due to the fact that production managers didn't recognise the specific skills of maintenance and when confronting serious problems opted to consult external specialists rather than having confidence in the local maintenance specialists.

I could give you an example, but there are so many. Some years ago, before the K became reliable, we had problems maintaining a constant quantity of steam. The deputy plant manager insisted on installing a steam "super heater". I knew and said at the time that this was not the correct solution; moreover, it will have consequences for the rest of the machine. But they insisted. That's why I asked someone at SP to explain, with strong technical arguments that steam functions with constant flow but not by heating. So, they accepted that it was not a good solution. (Maintenance technician, expert on the K)

However, they didn't pay specific attention to an important statement of the K maker: one of the problems to diagnose the failure was the successive modifications and adaptations made on this equipment.

These two points show that social repair was needed. There was opposition between local maintenance specialists and production managers, which reflected conflicts between local maintenance technicians and operators because of the latter's practice of neglecting equipment. Thus, I now turn to the aspects of the diagnosis and repair work that explicitly concerned social structures and practices.

## **4.2. Repairing Organisation but not Social Practices**

The diagnosis concerned not only material causes but also practices that led to the fatal fix. Sociological studies on compliance with procedures and rules have demonstrated that non-compliance can be used to compensate poor organizational design (Bourrier 2003): organisational lacunae, improper working conditions (Terssac 1992). In the present case study, because of successive reorganisations, maintenance became opaque for internal maintenance specialists as well as for all actors working in the shop, even managers.

On this part of the diagnosis opinions diverged, specifically between technicians and managers. The maintenance technician explained his colleague's fix in terms of an attempt to repair a dysfunction:

It is an untraceable modification, unofficial. But there were visible traces, insulation installed to make an isolation box. Someone who knew the piece of equipment well would have seen it [...] In fact, this is a vacuum management system using ejectors. The double steam envelope that covers the ejector leaked. My colleague stepped in and put a tracer on the steam envelope to isolate it. But it created condensation in the ejector that made it impossible to obtain the vacuum level required. (Maintenance technician, expert on the K)

At the same time he outlined developments in maintenance organisation that led to the loss of repair memory and organisational choices that made work difficult.

On the other hand, the maintenance engineer, the production engineer and the manufacturing director explained it in terms of personal misconduct, due to a lack of skill and knowledge and non-compliance with procedures. In shop meetings, in informal reports addressed to the operator teams and in interviews these actors never cited the name of the technician who performed the faulty modification. In their statements, they used the expression "the person who made the modification" to refer to the technician in question:

There was a change that the person found to be not significant. This was a problem of reflection and analysis. The person had not seen the scope of the modification, since the modification was not traced, we have not been able to identify ... This demonstrates the usefulness of the procedure and in particular modification procedures; the person who made the change did not say anything because they did not consider it as important. (Maintenance engineer, head of the maintenance department, task force)

However, despite his position in the hierarchy, the Maintenance engineer never explicitly pointed to the responsibility of the technician and did not take any steps to sanction the technician.

He joined the two other members of the task force and the manufacturing director to insist on the lack of resources for managing the shop:

This has revealed a deep problem: the state of the shop. It was really a pity that nobody knew how to proceed when facing such a problem... No Proceed engineer dedicated to daily production. The new production engineer who is facing an incredible number of problems, and who doesn't master the proceeds or the general situation... This shop is disorganised, unable to call for help. (Plant processes expert, task force)

Yet, they did not question that these organisational choices were ones for management – their peers and themselves. They did not try to elicit the working conditions of the local maintenance technicians, which would be to understand working practices as linked to structures and equipment transformations through mundane maintenance, successive adaptations and improvements. However, observations revealed that maintenance technicians had to cope with a workplace where non-compliance was a widespread and institutionalized practice. Because of the fragmentation of maintenance and repair, they had to work with incomplete information on the state of equipment. Due to poor internal resources, they sometimes overcame failures and breakdowns on their own, as in the case of the technician who set up the fatal fix. However, this reality remained unknown to the maintenance and production managers because of the increasing opacity of maintenance and repair work through successive reorganisations and successive equipment evolutions.

Moreover, members of the task force did not look for organisational explanations for the difficulties they faced during the diagnosis. As a result they asked of and obtained a strengthening of the maintenance hierarchy in the shop, without modifying concrete resources for local technicians. They considered hierarchical forms of organisation as the solution for repairing failures due to the previous matrix form. By reinforcing the hierarchical structure of the shop, they denied any form of power related to skills and the necessity for maintenance specialists – engineer and technicians themselves – to benefit from the resources of an “interface-actor” (Francfort et al. 1995) in the organization: between workers and equipment, between subcontractors and production, able to understand, document and record equipment evolutions and transformations. They decidedly lost the prerogative of the “marginal-secant” (Crozier and Friedberg 1997), unable to “reach a whole series of possible resources, especially relations with the environment ... the control of information and the allocation of resources but also membership in an informal network, to control rules and cultural enhancement within the company” (Francfort et al. 1995, 164). They underestimate the consequences of the non-stability of technologies, more specifically, the unpredictable interactions between fixes, which, as Perrow outlined it, threaten the system.

At this point, one question remains: why, despite difficulties in performing the diagnosis, were members of the task force reluctant to bring skilled maintenance specialists into the process? To explore this question, I will now turn to an analysis of how managers engaged in the task force tried to combine the repair of the breakdown with the replacement of the computer system to repair their shop. This will also help us to deepen our understanding of the manager’s diagnosis in terms of individual fault.



### 4.3. Contradictory Repairs

Why not ask for specialists' help in the shop and at the plant? One might imagine that it was due to the "silos" between production shops and others departments. However, the pressure to re-start production was at a climax. Paradoxically, according to the maintenance director, the public character of the breakdown made it difficult to seek external assistance:

The breakdown has become the business of the plant; when this shop coughs, the plant catches a cold! But at the same time, the public nature of the problem makes it difficult to ask for external assistant and bring in people with real skills. (Maintenance Engineer, Head of the Maintenance Department)

At issue here was the credibility of the management of the shop, concerning both production and maintenance.

The stakes for the maintenance director were to demonstrate his expertise and show operators and production managers that internal maintenance was still useful and had sufficient skills to resolve major breakdowns. Even though they were forced to work at a distance from the equipment for many years, except during scheduled maintenance shutdowns. Moreover, the breakdown was an opportunity for the maintenance director to develop strong, on-going relationships with production managers, especially with the production engineer and his deputy. With their support, he gained a position from which negotiate resources for maintenance. Because he participated in the resolution of the shop's difficult situation, he supported the new production engineer in his delicate attempt to establish his authority.

In return, the production manager and his deputy supported him; the deputy plant manager knew exactly who had the skills to solve the problem but, like the managers, he wanted to deal with it without external assistance. At the same time, his desire to protect operator morale participated in restoring the credibility of maintenance and production management. He tried to protect the task force from the operators, who saw the task force at work without knowing exactly the issues they were facing. This was successful during the diagnostic phase.

As the manufacturing director explained, the presence of the task force and its members' efforts to demonstrate their involvement in solving the problem were vital to repairing the relationships between operator teams and management.

I suppose that people react to problems according to your level of involvement. If you show that you have an interest... With our teams, people are waiting for help. They know that you are in a position in the hierarchy and that you can act. Not taking that into account would be a lack of consideration. The boss is not only the one who gets the most out of the situation. He is the one who gets

the job done. It takes time and effort. I consider it an important part of the job. (Manufacturing director)

People are aware of the weaknesses of the shop; they expect a sign from us to show the importance that we give to this shop. (Manufacturing director)

The production manager and his deputy could explain their reluctance to call in external assistance: this breakdown and the replacement of the computer system were opportunities to recover authority over independent and unpredictable teams. The repair was an opportunity to demonstrate operator skills and credibility, and, consequently, to reset the shop's working atmosphere and relationships. The reorganisation of the plant management team established the production engineers as powerful actors because able to negotiate and obtain resources from the plant's upper management. In addition, for the recently hired production engineer, dealing with problems was a way to demonstrate to his supervisors that he was able to control and manage shop activities and cope in a competitive environment. Finally, they used the repair of this device to repair their shop and its reputation within the plant. They considered the "K" as a machine which complexity made its repair delicate. However, they didn't understand that the successive small fixes, not systematically documented and recorded constrained the breakdown's diagnosis and repair.

In light of these interrelated strategies the diagnosis of the faulty fix as the consequence of individual error can be better understood. First, this explanation tracks that used to justify the characteristics of the new computer system: operators reluctant to follow procedures. This argument was at the centre of the specifications of the system and linked to the necessity to restore authority. This perspective opposed the rationalisation of the actions of unpredictable and unmanageable operators to the regulation and reliability of actions imposed through the new system. In the case of the fix performed on the "K", the only way to control human error was to reinforce control through the presence of a maintenance manager. Finally, the individual worker and collective action are represented as the unmanageable elements of the systems that need to be fixed with technical systems linked to hierarchical authority.

In the end, the maintenance engineer, the shop manager and the deputy plant manager succeeded. They obtained permanent resources following the diagnosis of the shop's situation that they reported to the plant management: the shop's management was reorganised into a "plant management team" composed of a production engineer, deputy plant manager and a new maintenance engineer. This reorganisation aimed to increase communication between maintenance and production, and make clearer the lines of reporting for issues coming out of the respective departments.

However, this reorganisation was focused on the control of production teams and their relationship to equipment issues. Except for this new

maintenance engineer, the organisation of repair and maintenance activities remained the same as before: the allocation of material, human and economic resources, the distribution of tasks and responsibilities between local maintenance technicians and subcontractors, the contract terms with subcontractors, the control of routine repairs — all were maintained unchanged.

## 5. Conclusion

In this article, I have studied in depth a specific empirical context to show how managers seized on the repair of a complex machine in a socio-technical industrial system to serve their strategy, which aimed at restoring their authority over production operator teams. Ultimately, this local repair participated in a more large strategy oriented toward the reparation of the material and social orders in the shop. The repair of the “beast of grief” was part of a fragmented maintenance, distributed among actors and collectives of workers. It consisted in a cautious and delicate intervention that required precise skills, but also the ability to deal with the opacity of maintenance in the workplace. This repair can be described as a process by which “technical constraints, social power, on-going actions and interpretations mingle to create social order” (Barley 1988, 52).

To conclude this article, I want to discuss some theoretical and methodological issues raised by this study of a major breakdown, within a framework that brings together the sociology of work, organization studies and STS. In the case study presented here, I adopted an intermediate perspective between workplace repair and infrastructure repair. I considered organisation, the dynamics of social relations and practices, and the history of the shop so as to understand how the repair of a complex device, which constitutes a small part of a socio-technical system, is used to repair the shop’s material order and its organisation.

As emerged from the presentation of empirical data, the shop existence and its identity were at stake. However, the actors who performed the diagnosis and repair were not specialists. As a result, the study of their work revealed the specificities of machine repair in this kind of socio-technical system and the state of the relationships in the workplace. Because of these features, the case and its study allows a discussion with the sociology of socio-technical repairs initiated by Sims and Henke (2012) on three main points. First, the strategy of weapons specialists to restore their credibility was to embed their tacit knowledge in the new socio-technical context. In the case study, discussed here, actors considered the new computerized system as a support for organisational change. When facing the K’s breakdown, they tried to embed it in the IT outages and equipment failures.. They considered that diagnosing and repairing the breakdown would help them to overcome the issue of their credibility towards operators’ teams. However, this strategy that consisted in the combination of technical and organisational repair failed. Actually, these

categories of repairs have appeared contradictory depending on their scope and their nature. 1) As Perrow (1983) has noticed for other cases, small and bigger technical repairs on the same equipment appeared to be conflicting; small fixes performed on the defective equipment introduced constraints to the breakdown diagnosis and the repair, because of their unexpected consequences and their invisibility for non-experts; 2) technical and organisational repairs were not complementary. Actors engaged in the task force to repair the shop's organization paid attention to technical repair. However, their focus on the shop's organisation and ultimately on its reputation within the plant threatened the diagnosis and the repair of the defective equipment. Actually, they understood the breakdown according to the framework they derived from their main objective: they analysed it in terms of individual errors, procedures non-compliance, that would call for control over operators' teams and reinforcement of hierarchies.

Third, Sims and Henke (2012) presented tacit knowledge as the main resource for nuclear weapons scientists' strategy. In this paper, I highlight how the issue related to tacit knowledge is linked to opacity of maintenance in the workplace: local maintenance specialists knowledge – experts of the “K” device – were not enough articulated, because of successive reorganisations of mundane maintenance and repair and because of broken relationships in the workplace and within the plant. These weaknesses were strengthened by managers' acceptance of technologies as stabilized objects, with strong boundaries they could seize on to solve higher-level issues. Their choices revealed that they were trapped in a “technological fix” strategy: they tried to repair broken relationships, organisational failures with the new computerized system. However, they neither “used the power of technology in order to solve problems that are non-technological in nature” (Volti 1995, 23), nor they tried to simplify problems that are intrinsically social and technological and too complex to be solved as a whole (Weinberg 1967). The case of this breakdown revealed an intermediate situation where technological and organisational repair were only partially combined. As a result, studies on the repair of sociotechnical systems could be deepened. First, the “sociotechnical repair” category could be refined with the notion of “technological fix” and its discussions (see for example Rosner 2004; Scott 2011). Second, we could consider maintenance as an on-going process of work (cf. Barley 1988 cited above) on the categories of repair that actors try to combine, and on the potential conflicting issues between them. This offers the opportunity to precise what “socio-technical” means in the case of repair and the links between repairs practices and maintenance issues in the workplace.

I insist here on three additional steps in developing a sociology of repair that brings together the sociology of work and STS.

First, from a methodological perspective, this article is an attempt to investigate an intermediate level, halfway between studies in ethnometh-

odology and analyses of macro scale structures. However, this can be refined (see for example Grossetti 2011). At this “meso” level lays the difficulty of understanding human actions in the construction and the conflicting dynamics of social order. Because of the micro situations they mainly analyse, ethnomethodological studies tend to overshadow structural issues in order to explore material properties and relationships to things. Therefore, I considered organisation studies on technological change. This perspective allowed me to understand how actors considered and combined the material components and social practices and structures they repaired. Moreover, it drew attention to the fact that these combinations were not only consequences of smooth negotiations and machine properties but depended on organisational structures, social practices and power. The maintenance of material and social orders depended on local individual and collective strategies that were due to actors negotiating their participation in organisation. This participation is not systematic and depends, among other things, on the social context and on history. For this reason, it would be useful to consider historical dimensions in a more extensive manner than I was able to in this study. I presented only the elements of the history of the shop that highlighted the breakdown and the maintenance practices in the shop. One problem here is that it focuses on the elements that are important to the situation studied and downplays others. For example, it would be interesting to consider, while studying repair and maintenance of industrial processes, the history of collective resistance and mobilizations, major breakdowns and accidents. This attention to history would deepen our understanding of the way actors’ actions are linked to their intentions, to their adhesion to the workplace productive order. Moreover, we would be able to specify the underlying social dynamics of the workplace order.

Second, I focused here on the work of maintenance technicians, with no attention to the work of subcontractors. It would be interesting to explore their relationship to equipment and their participation in the material and social order as intermittent actors. This orientation would enrich the notion of the workplace so as to deepen the analysis of the dynamics of construction of collective skills and distributed skills.

Finally, this repair of a major breakdown in a socio-technical system is a good case study for extending the “sociology of repair” initiated by Henke (Henke 2000) and extending it to higher levels including power issues. It offers insights for STS researchers who study scientific activities in organised workplaces as well as for sociologists of work who are interested in analysing the links between technical work and social order. It opens perspectives for developing case studies on repair, to complete the results of organisation studies on technological change, and understanding “why people do the things they do with technology and why organizations and practices acquire the forms they acquire” (Leonardi and Barley 2008, 172). Further theoretical discussions about theories of action including actor intention, and the ways technology and organisations shape

one another, are needed to develop a complex frame of analysis. This would stimulate further discussion of material and social determinism and voluntarism, along the lines initiated by Leonardi and Barley (Leonardi and Barley 2008).

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# A Transdisciplinary Gaze on Wireless Community Networks

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**Abstract:** This conversation aims at offering a transdisciplinary gaze on the phenomenon of wireless community networks: an emerging typology of local wireless infrastructures, which is built by activists as political and technological statement to face the hierarchical governance of the Internet and the issues of surveillance and control over digital networks. By a transdisciplinary gaze – emerging from the dialogue between science and technology studies (STS), legal studies, and computer science – this conversation focuses on the multi-modal ways and perspectives that can be adopted to study CNs; it also offers a reflection on challenges and opportunities arising from transdisciplinary scientific work. In the field of STS, a growing body of literature has addressed CNs as an emblematic case study to analyse the engagement of activists and lay people in the emergence of socio-technical infrastructures and technologies. From a computer science perspective, community networks represent a challenge to develop new routing protocols, and standards to technically implement a bottom-up-approach in the building and management of innovative network architectures. Finally, from the point of view of legal studies, CNs offer the case of a still largely unregulated emerging technology, offering a novel field to test existing laws, especially under the point of view of the possible allocation of civil liability.

**Keywords:** wireless community networks; transdisciplinarity; media infrastructures; sustainable network growth; distributed architectures regulations.

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## **Wireless Community Networks, “Inverse Infrastructures” and the Challenges of an “Interdisciplinary Assemblage”**

*Stefano Crabu and Paolo Magaudda*

### **I. Wireless Community Networks from an STS perspective**

Wireless community networks (CNs) represent a multi-dimensional phenomenon that in recent years has multiplied in several parts of the world including both the US and the EU due to the lowering of the costs of wireless devices and tools. CNs are grassroots network infrastructures based on a so-called “mesh” or “distributed” architecture (Flickenger 2002) and which are built and self-managed by groups or “communities” of people, including a wide range of profiles such as hackers and geeks, engineering students, young political activists and citizens. In many CN experiences, groups gather at the local level to build wireless networks from scratch. These are independent of the global Internet network, and their construction involves an activity that is at the same time technical, social and political, such as the set-up of hardware and software protocols, the physical installation of antennas on roofs (usually upon activists’ homes), organizational work aimed at coordinating the group’s activities, as well as a social and political effort to enrol new activists and find local support in order to expand the network. CNs require heterogeneous work in which material and technical practices need be constantly aligned and held together with symbolic, political and organizational activities. All this considered, CNs represents an exemplary environment which offers the opportunity to investigate at the local level the processes of heterogeneous “infrastructuring” (Star and Ruhleder, 1996; Star and Bowker 2002) in the domain of digital media technologies (Parks and Starosielski 2015).

The cultural origins of CNs, as counter-networks alternative to the global Internet infrastructure, can be traced back to the very origins of the Internet and to one of the first grassroots networks: the well-known “Memory Project” established in Berkeley in 1973 (see Levy 1984). In the ’90s, several alternative (non-wireless) network projects were established in many cities, as in the case of the Seattle Community Network Project (Schuler 1994). These highlighted how, at least in the US, community networks based on users’ maintenance were at that time already a relevant phenomenon, in some case also framed within municipal and institutional activities (Carrol and Rosson 2003). Since the early 2000s, the diffusion of low-budget wireless technology allowed these projects to shift from an emphasis on the “local community”, to the possibility of establishing a fully autonomous infrastructure, potentially disconnected from the ordinary cables and phone-lines of the global internet and, in so doing, envi-

sioning an emergent way to offer a political alternative to the market- and corporation-driven Internet global network (De Filippi and Treguer 2015).

Several CNs were developed in Europe in the 2000s by adopting such a political framework, as in the case of the CNs Freifunk in Germany, Wlan Slovenija in Slovenia, Ninux.org in Italy and Guifi.net in Spain. This last one, started in the region of Catalonia in 2004, is currently the largest CN in Europe, being used by more 45,000 users, who are also attracted by the possibility to obtaining Internet access independently of the commercial ISPs. Other networks such as Freifunk, Wlan Slovenia and Ninux.org did not develop primarily as competitors of traditional commercial ISPs, but originated mainly from political activism. Consequently, they focussed primarily on the importance of building decentralized and autonomous networks. In these last cases, while the initial drive was for political and ideological reasons, in their development these communities needed to offer to possible new users suitable services in order to expand away from the narrow niche of media activists and experts (De Filippi and Treuger 2015, 6). Especially after the Snowden scandal in 2012 and the mainstream visibility gained by Anonymous's cyber-political actions, public concerns about internet privacy and corporate surveillance increased, turning WCN into a strategic technological instrument in political agenda of countercultural and social movements (Milan 2013).

Being built and maintained by the same users, CNs clearly represent novel emerging places for socio-technical innovation. It is prevalently in this vein that, in these last few years, these phenomena have attracted the interest of several STS scholars, who have identified these phenomena as being cases for the study of the shaping of new models of innovation, and to unfold tensions and contradictions within these emerging "technologically dense environment" (Bruni et al. 2013). Of course CNs represent a relevant case of bottom-up processes of innovation, where the social and technical participation of the end-users (Oudshoorn and Pinch 2003) represent a crucial peculiarity. The growing relevance of these models of "bottom-up" innovation, established by activists and end-users outside the work of institutions or industries, also represent a way in which democratic participation can become a crucial driving force in the processes of construction of science and technology (Jasanoff 2005). CNs are, in fact, a paradigmatic case which recognizes the active role of the user community in the construction of infrastructure, software and services from a collective work, most often disconnected from research centres or public institutions.

In this regard, a study by Van Oost, Verhaegh and Oudshoorn (2009), based on qualitative interviews with participants in the wireless community network of the city of Leiden in the Netherlands, has highlighted the role of users in terms of the dynamics of innovation of these networks, both in the design phase and during the work of maintaining and upgrading the infrastructure (see also Verhaegh and van Oost 2012). The model

of innovation resulting from this CN project has been defined in terms of “innovation community”. This concept has been used by authors to identify the process through which an innovation emerges from the collaborative work carried out by a group of people, who are usually considered simply as the end-users of these same technologies.

The ability of grassroots CNs to generate alternative patterns of innovation has also been highlighted in research carried out by Söderberg (2011) into the Czech CN. In fact, the collective work deployed in developing this Czech network has led the participants to create a new hardware device, able to send data through a beam of red light. The research by Söderberg reconstructed the collective work and negotiation through which this new hardware has been developed, highlighting how its design incorporated and reflected a particular philosophy shared among this community, and how it is related with the use of technology. This philosophy was mainly based on the idea that people with few technical skills have to be able to assemble the tools needed to run such a network.

## **2. Ninux.org and the “Infrastructural Inversion” of an “Inverse Infrastructure”**

In Italy, the most relevant example of CNs is the project Ninux.org, that was originally started in Rome in 2001, but in the last few years has spread to other cities such as Florence, Pisa and Bologna. Although independent from each other, all the networks in these different cities are part of the same wider national platform, which is a common framework for all participants. Groups of activists directly involved in the project share a common vision on the role of CNs in society, and on the strategies and goals that these networks should adopt. This common view has been formulated in a “Manifesto” available on the project’s website (<http://wiki.ninux.org/Manifesto>). Major features highlighted in this document include the adoption of a decentralised and mesh architecture; the role played by CNs as democratizing tools and as resources to fight digital divide; their relevance within the current debate on the freedom of expression in the digital society, and also a wider criticism of the hierarchical governance of the Internet. These several instances reflect a whole set of beliefs, motivations and political drives that sustain the discourses and practices of the Italian CN.

In recent years, both this ensemble of motivations, and the citizens’ participation in the Ninux.org project have been strengthened following the relevance and visibility that the “Snowden affair” achieved in terms of the public debate about freedom and surveillance in a “connected society”. Snowden’s revelations about secret programs of mass surveillance of digital communications between the United States and the European Union have brought to the centre of public discussion the complex relation-

ship between national security policies and citizens' right to privacy, especially in relation to the growing pervasiveness of the Internet in daily life. Following these revelations, in the public perception the Internet has increasingly become a controversial digital space deeply interlaced with government strategies and political power struggles, and at times risky and unsafe when it comes to privacy. In this sense, the Snowden affair triggered the opening of the "black box" of the Internet, highlighting the way in which the majority of the network services (such as e-mail, social networks and clouds) are managed centrally by a few operators who not only monitor all data exchanged by users, but also allow governments – both democratic (Clement 2014) and authoritarian (Wilson 2015) – to control citizens' behaviours. This ensemble of issues has pushed a growing number of people to engage in the construction of alternative infrastructures, and is the basis for growing participation in the Ninux.org wireless network.

As previously pointed out, the increasing relevance of these projects has attracted a great deal of attention from STS scholars, who more generally have also focussed on the concept of "inverse infrastructures" (Egyedi and Mehos 2012) to theoretically capture the emerging typology of infrastructures that are not owned and controlled by government or large private firms. Conceptually speaking, these wireless infrastructures are defined as being "inverse", because they feature peculiar modalities of emergence and development, which are opposed to those that characterize more traditional and institutional kinds of networks (such as energy networks and railways), for instance those described by Hughes (1983) in terms of "large-technical systems". Indeed, via the concept of "inverse infrastructure", it is possible to address the process through which these networks are developed from the ground roots, independently and outside of the control regimes of institutions and governments.

Overall, inverse infrastructures, and in particular the CNs rooted in a radical critique of contemporary governance of the Internet, bring to the attention of STS a relevant issue pertaining to the shape of new configurations of power relationships among citizens and governments, and also regarding the asymmetries in distribution in respect to the growing pervasiveness of digitally-mediated communication. In other words, CNs appears as alternative approaches, counteracting the pervasive practices associated with the centralized control of digital communications, therefore shaping more autonomous and self-governed digital interaction spaces. Therefore, CNs, through the effort to materialize specific political claims by shaping an alternative architecture for digital communication, show the potential to trigger a redefinition of power relations pertaining to Internet governance.

As a whole, inverse infrastructures highlight how power is a crucial dimension in the study of technologies and their relevance to daily life, not only because technical devices also emerge as a network of social and power struggle, but because they are an entity that is able to produce and

re-distribute power in multi-modal ways. This considerations open up a crucial question: *how does the concept of power contribute to an analysis of "inverse infrastructures" that may subvert the institutional governance of digital technologies?* Despite its relevance to the foundations of social sciences, the concept of power has been little addressed within the STS. Here, the theoretical and analytical attention to power has instead turned towards the concept of *politics*, and related processes of the politicization of science (Brown 2014). In this context, from a theoretical point of view, the reflections of Foucault can be particularly useful for shaping a dialogue between STS and the notion of power. In fact, the French philosopher analyses power, and its situated articulations, as the emerging outcome of social relations, discursive practices and technical devices. Following Foucault, power must be analysed in relation to the "...strategies, the networks, the mechanisms, all those techniques by which a decision is accepted" (Foucault 1988, 104).

Such reflection suggests to STS scholars the need to take into account power relationships as constitutive elements of the mutual entanglements between human and technology, and to consider the latter as a vector of the production and distribution of power. In this light, CNs represent specific "inverse infrastructures" that open to a re-organization of the political rationality of Internet governance. In other words, CNs define a new type of alignment between the design, management and practices of technologies, redefining the balance of power between users of digital infrastructures and the governance processes that normally shape these same infrastructures. Therefore, in the study of inverse infrastructures, the adoption of an analytical strategy that is able to capture the process by which these alignments are shaped, becomes crucial.

Another concept from the STS toolbox that is useful in terms of making sense of CN is that of "infrastructural inversion" (Bowker 1994), coined in order to emphasize a specific dimension of the "infrastructuring" work through which technologies are designed and maintained. More precisely, the idea of "infrastructural inversion" relates to an analytical sensitivity that allows us to observe infrastructures, their design and their routine use closely. Thus, this concept helps to reveal the multiplicity of discursive elements, political claims, and technical entities that are incorporated in them. In this light, CNs represent a phenomenon that specifically incorporates both discursive elements and technical devices that can support the shaping of new power relationships, and which are able to re-configure and intervene the governance of digital technologies.

This analytical sensitivity has been adopted in this transdisciplinary study<sup>1</sup> of the Italian WNC Ninux.org. In particular, we have emphasized the ways in which the Italian CN embodies specific political motivations, and how these motivations intersect with the technical evolution of the

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<sup>1</sup> See research project's website at the following link: <http://goldstein.disi.unitn.it/caritro/>.



network. In so doing, we have grounded these reflections in terms of an “infrastructural inversion” sensitivity, which allows the study of the mutual entanglement of social, the political and technological aspects in the shaping and maintenance of these networks. This analytical strategy also permits us to highlight how CNs’ technical issues are strictly connected and intertwined with the political and cultural frames shared by members of the project. Moreover, in this way, we have the chance to unfold the particular tensions and negotiations that occur between the technological aspects and the political claims connected to a critique of the evolution of Internet governance.

### 3. CNs as an Interdisciplinary Assemblage

This transdisciplinary research into the Italian CN has represented not only a case study about a heterogeneous “work of infrastructuring”, but also offers a further occasion to develop and reflect on a trans/interdisciplinary research activity, whose this “conversation” represents a partial and work-in-progress account. Our transdisciplinary research group has been constituted from the start, sociologists mainly rooted in STS, network engineers interested primarily in morphology and the robustness of bottom-up networks; and law scholars especially focussed on how these emerging network technologies challenge current regulations concerning, for instance, liability, privacy and responsibility (for a wider account of the research see: Caso and Giovannella 2015).

As highlighted by the different and complementary perspectives presented in this “conversation”, the object of CN is not only a case where a heterogeneous infrastructure can be studied from a STS perspective, but also a multifaceted entity, which interrogates, in very different ways, the diverse fields and disciplines associated with it. Therefore, this on-going transdisciplinary investigation of the Italian CN has raised several issues connected with the practice of trans/interdisciplinary research, inviting us constantly to develop a reflexive understanding about the opportunities and the constraints arising by the collaboration between different disciplines or “epistemic cultures” (Knorr-Cetina 1999). As Andrew Barry and Georgina Born have recently argued when debating about the configurations of inter/transdisciplinarity in today’s research:

“Interdisciplinarity should not be thought of as a historical given, but as mobilising in any instance an array of programmatic statements, policy interventions, institutional forms, theoretical statements, instruments, materials and research practices – *interdisciplinary assemblages* that have acquired a remarkable and growing salience” (Barry and Born 2012, 10)

In our inter/transdisciplinary research project with regard to CNs, the multiple presence of different disciplines has required not only to share and interchange our distinctive starting problems and research questions, or specific conceptual and theoretical frameworks. A further work has been also necessary to align and harmonise other crucial dimensions of the scientific work, including writing practices, the paper's rhetoric, dissemination strategies, and so on. A phenomenon such as CN is in itself a great invitation for STS practitioners to deploy conceptual tools aimed at understanding innovation processes and the heterogeneous nature of socio-material phenomena. However, at the same time, there is a need for a transdisciplinary perspective that also represents a challenge to put into play a further reflexivity about our research questions and conceptual frameworks, and more in general about the whole set of similar scientific practices: a contingent, processual and work-in-progress activities oriented toward the construction of a specific "interdisciplinary assemblage".

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## **Sustainable Growth for Community Networks: New Solutions to Avoid Known Pitfalls**

*Leonardo Maccari*

### **I. My Engagement with Community Networks**

In the first half of the year 2000s in the ICT research community (to which I belong) there was a high attention for distributed systems and for the so-called mesh and ad-hoc networks. These networks are wireless distributed networks built with a non-planned approach. A mesh network may start with as few as two persons climbing up to the roof of their houses to mount wire-less antennas to communicate with each other. Then, a third person joins the network connecting his own antenna to one of the existing ones. Then a fourth, a fifth, and so on. At the time, Wi-Fi consumer devices were starting to be affordable and a little of antenna-hacking allowed to cover distances of several hundreds of meters or even kilometers, which made this vision possible.

In the same period public administrations were supporting the deployment of broadband connections in cities, and were facing hard times trying to imagine how to bring them also to rural areas. Matching the two

concepts was intuitive. Many scientific papers imagined a world in which “last mile” connection was not going to be provided by a cable, but by a mesh network. Many speculations were made on how in a few years mesh technology would have defeated the digital divide. Irrespective of the optimism of many authors, mesh networks never really become a mass phenomenon, even if they maintained their importance in certain niches.

It was 2012 when I found myself in an Italian hacker-camp, the MOCA camp in Pescara, and discovered the existence of Ninux.org, a wireless community network set-up by a lively group of people in Rome. These people, together with other European communities, were able to set-up mesh networks made of hundreds, and in some cases thousands of nodes. At the time I used network simulators (as many ICT researchers do) to study mesh networks that could scale up to tens of nodes, and I realized that there were in-production infrastructures made of thousands of nodes. Not only, many of these networks were present in densely inhabited areas where both home and mobile broadband connections were available. Those CNs, that were relegated to the role of “last mile replacement” by ICT researchers, had been silently growing as alternative networks up to a scale than my network simulator never allowed.

From that day I dedicated most of my time researching on this theme. Quickly enough, though, I understood that CNs are not just like all other networks, plus “distributed”. They are distributed networks because they could not be anything else. The communities that run them (albeit different one from the other) consider a CN not much a network that connects people but primarily a community that builds a network. And since technology does not force them to build a hierarchical network infrastructure, they also try to maintain a horizontal social infrastructure. This in turn produces a feedback to their technical choices, meaning that some solutions that are applied to other contexts cannot be used in a CN. Not because they are technologically incompatible, but because the community would not accept them. Technology influences the community, and the community gives constraints on the technology.

At that point it was clear that research that wants to help CNs to grow must be trans-disciplinary, and thus started the cooperation with the other authors of this “Discussion” space.

## **2. Technical Research on Community Networks: Background and Motivations**

Communication and information management are central to modern society but they remain anchored to traditional, centralized and market-based models. CNs instead are participatory, co-operatively governed, commons-based initiatives, that represent a successful alternative approach to traditional networks. CNs are blooming in many European

countries, the most prominent example being the Spanish network [www.guifi.net](http://www.guifi.net) with currently about 30.000 nodes.

Some CNs are connected to the Internet, thus giving Internet access to the participants at a generally lower price than purely commercial initiatives, therefore, the initial scientific interest for CNs in the early 2000s was driven by their potential as a tool to overcome the digital divide (Jain 2003). Still today, CNs are a key component for the ICT4Dev (ICT for development) research community (Saldana et al. 2015).

But CNs are more than just a replacement for last-mile Internet connectivity. A CN acts as a small-scale local Internet populated with community-managed services (telephony, cloud-based services, peer-to-peer exchanges etc.) and managed with a peer-to-peer (P2P) technological and social approach. This original approach gained importance in the light of recent events that showed how the Internet, and networking in general, is a key instrument both in the hands of those that want to defend democracy, and in the hands of their adversaries. A key example is provided by the already mentioned “Datagate” scandal, which revealed that a single agency, cooperating with a very restricted group of network operators and service providers uses the Internet as a mass-surveillance instrument. The progressive centralization of networking infrastructures (in the hands of a few network providers) and of cloud-based services (in the hands of a few giant companies) contributed to make this scenario possible. A second example is the acknowledged importance that networking has played in many countries where people are fighting for democracy: networks act as an amplifier of the outer visibility of the protest, and as an internal system of organization of the protests themselves (Howard and Muzammil 2013). It is no surprise that regimes actively monitor, filter, control and disconnect personal communication platforms in order to turn them against their opponents (Morozov 2012). CNs use a decentralized approach both in the technical and social layer which reduces the number of single points of failure and makes it hard to filter, censor, or to shut down the whole network. Under this lens, the existence of independent, community-owned, locally managed networks that offer some protection against intrusion, disconnection, and commercial influence is an important novelty in the ICT panorama.

For this reason CNs recently re-attracted the attention of the research community. In the last few years, dedicated scientific workshops have been realized, special issues on relevant scientific journals have been published (both in the ICT and in the social science field<sup>2</sup>), and Dagstuhl seminars have been organized in order to reunite the diverse scientific communities active in this field (Crowcroft et al. 2015). At the same time, CNs have become an attractive topic even for funding agencies. The Eu-

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<sup>2</sup> See the forthcoming “Special Issue on Community Networks” in the Elsevier Computer Networks Journal, and the “Special Issue on Alternative Internets” in the Journal of Peer Production.

ropean Union has financed various research projects focused or at least related to CNs (such as the CONFINE, CLOMMUNITY, P2PValue, and netCommons ICT projects accounting for more than 12M€ in the last 4 years) and some of them use an inter-disciplinary approach.

One theme in which technical research itself cannot cope with the complexity of this subject is given by the challenges of a sustainable growth for CNs, that is the core of this contribution. To introduce this theme, it is worth to quote a discussion I had with a well-known professor in the networking field, active in the P2P community. We were both watching a presentation from a Ph.D. student that was trying to justify his research on P2P systems, “because centralized systems cannot scale easily, while instead, P2P systems naturally scale with the number of users”. This was an assumption that was easy to find in many technical research papers in the 2000s, and today we can say that it was groundless in many cases. In 2013 Facebook opened a new datacenter in Luleå, Sweden<sup>3</sup>, claimed to contain the equivalent of four soccer fields filled up with servers. Servers that are powered only by renewable energy sources, and cooled by the “fresh air” of Northern Sweden. Such data center operates with an efficiency level that any distributed system can not even dream to reach. We changed the motivation of the Ph.D. to “we do P2P systems, because we don’t like centralized ones”. The reason why we don’t like them can not be only technological, and CNs are an exciting experimentation field to understand it.

### 3. An Open Research Theme: Sustainable Growth for CNs

The definition of a suitable concept of sustainability that can be successfully applied to CNs is an open research theme. The sustainability of a commercial ISP, for instance, can be split into technical sustainability and economical sustainability. The first is given by a technical design that allows to scale-up the network and deliver good services when the user-base grows. The second is given by a positive economic balance. While some CN do have a business model, the cost of the infrastructure is generally crowd-shared by the community. A CN indeed offers a social model, thus, a CN needs to achieve technical sustainability together with social sustainability.

At the network layer, CNs face scalability problems that commercial networks do not have to face. Commercial networks are organized with a top-down network design. Given the market demand in a certain area the network is organized in a hierarchical infrastructure implemented using different technologies. The Internet Service Providers (ISP) network

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<sup>3</sup> See: <http://www.theguardian.com/technology/2015/sep/25/facebook-datacentre-lulea-sweden-node-pole>

generally starts in our own houses with a wireless router that we rent from the ISP. A copper/fiber/wireless connection covers the “last mile” to a first switching center, connected to a larger switching center, and so on. Every level of this hierarchy operates with different hardware, different network protocols, and requires distinct expertise to be managed. Their management is hierarchical, meaning that the technical choices that are taken on top of the pyramid are then propagated down to the base. This kind of organization is cost-efficient, it is widely used and the market offers many professionals that can be hired to manage one of the network layers. It is also one of the reasons why it was possible for the NSA to set-up a mass surveillance system. If a few high-level technologists and managers handle the data of billions of people, it is easy to force them to share such data in a stealthy way.

CNs instead enlarge when a new person joins the community. The growth of the network is spontaneous and unpredictable so it is extremely hard to apply any state-of-the-art planning strategy used for other kinds of networks. Moreover, a wireless mesh network is in itself a flat architecture. There is no specific technical provision to make a certain node more important than any other, and any person could be the owner of a very important node (a node in a strategic position of the network). This is a key feature of a CN.

Under a technical point of view, this is extremely challenging. CNs tend to grow with a flat architecture, and push their network protocols to their scalability limit, but the most interesting research is not technological only. CNs have a social goal, that is to re-empower the users with the control on their communications and use a decentralized organization to avoid the concentration of power: since the technology allows to have a flat infrastructure, there is no need to build a hierarchical social infrastructure. Experience has shown that having a non-hierarchical technical and social organization does not allow to justify the assumption that the network is less controllable, less fragile and more fairly managed than any other kind of network (Goh et al. 2001). Many different kind of networks, spontaneously evolve towards a network topology in which very few nodes are extremely important, and the large majority of nodes are irrelevant. We have shown in the past that CNs are no exception, that even in networks made of hundreds of nodes as few as five nodes route more than the 90% of the traffic, and if a few key nodes are removed, the network is badly partitioned in tens of disconnected islands (Maccari 2013; Maccari and Lo Cigno 2015). The reason for this evolution is intuitive, even if people genuinely attempt to build decentralized networks, a centralized system is simply easier to reproduce. Consider for instance the typical initial situation of a CN: when activists create the first nodes the network is composed by only a few disconnected links. Then, it may happen that a new person installs a node on a geographically dominating position (i.e. on top of a hill) and suddenly allows to connect all the disconnected stubs. That node becomes important, and the community starts to

invest in it. New people that want to join will help with its configuration and will finance the installation of new antennas to cover a wider section of the city. This will make it more likely that new people will join the network connecting to that node, which will make it even more important. This kind of growth reflects the Preferential Attachment algorithm introduced by Barabasi and Albert (1999). The B-A algorithm creates so-called scale-free networks, which are pervasive in our world and have a distinctive feature: a few nodes are critical for the life of the network and a large majority of other nodes are unimportant. This trend shows that the natural tendency of a CN is to go towards a centralized network topology, hidden behind the idea of a decentralized one.

Something similar happens with the social organization of CNs. It is not sufficient to claim to have a horizontal organization in order to have a well-balanced community. It is not sufficient to use a mailing list as the principal communication means to claim that the community is horizontal (Lovink 2004). Again, CNs are no exception, in previous works we have analyzed how the group of people behind a large Italian CN is actually led by a very small number of individuals that own the majority of the critical nodes and influence the discussions in the CN mailing list (Crowcroft et al. 2015).

A distributed socio-technical network that relies on a very small number of nodes, owned by an even smaller number of people that also influence the decisions of the community is not a P2P organization, and will collapse when this small group of people will leave the network or start to misbehave for any reason.

#### **4. Network Metrics: the Pulse of the CN**

One way to help the development of CNs is to define “sustainability metrics” that represent the state of the network and guide its growth. Those metrics will represent the “pulse” of the CN with respect to the founding political motivations and will guide future decisions.

This first step to design such metrics is to analyze qualitatively the founding principles of the CN. CNs are all different, there are some that have a strong political motivation and other ones that behave like cooperative ISPs. Qualitative research is needed to understand what are the founding values of each community, and to set-up instruments to self-assess the level of satisfaction that the community has reached, related to those founding values. This phase of the work is extremely important because it is necessary to capture those values and translate them in suitable metrics that can be analytically and automatically computed.

The second step is to analyze the network. The primary source of information is the network graph enriched with information about the ownership of the nodes and the services available on the nodes. A second source of information is the graph of interactions of the community

members acquired via the analysis of social networking instruments (mailing lists, forums, bug-trackers, Q&A systems and so on). Using this approach, known metrics can be applied to the graph in order to determine the cliques of nodes and persons that achieve an excessive control on the CN. Social scientists have defined several metrics to determine the importance of a node, or a group of nodes in a social graph, such as centrality metrics (Freeman 1977). These can represent a base on which to build suitable socio-technical metrics to periodically analyze the state of the network.

Finally, these metrics can be integrated in the on-line instruments that the communities use to manage the CN (Kos et al. 2015). These instruments are used to visualize, organize and debug the network, and are vital for the CN. With enriched metrics, they can be used to take important decisions on the life of the network. For instance, the community can decide on the creation of a new link, or a new node in order to reduce the centrality (and thus the degree of control) that a single person has on the network. Also the management of existing key nodes, or key social functions in the community organization can be split among people in a way that keeps a low concentration of control and enforces a rotation of responsibilities.

The final goal of this research is to produce information that will guide the community to grow in a way that is respectful of the founding principles they have set for themselves, and avoid known pitfalls. We have to remember that even if the Internet has been going through a centralization process, at its very beginning it was imagined to be a decentralized network, and CNs should not follow the same path.

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## **Community Networks under the Lenses of Private Law**

*Federica Giovanella*

### **I. A New Instance of an Old Problem. Namely, “Law vs. Technology”**

Community networks represent a new instance of an old problem: when dealing with a new technology, law needs to evolve and adapt. As it often happens with the advent of new technologies, the birth and development of CNs has come as an unexpected event for lawmakers. Some of



the peculiarities of CNs are especially thorny, because they challenge existing laws. CNs go even further: they challenge the very same rationale behind some of the current regulations, a rationale that is the result of century-long theories and of their application.

Many aspects of CNs call for the attention of law and legal scholars. A first peculiarity of CNs is their “distribution”. Distributed networks have been analyzed by legal scholars for many years (Elkin-Koren 2006), but they have gained much more attention in the last years due to their increasing application in different spheres of the information and communication technology realm. Famous phenomena like BitTorrent or Bitcoin rely on distributed structures; but distributed technologies have been applied to many other kinds of services, such as data storage, microblogging, social networking. In distributed architectures both contents and actions can be distributed, with great impact on some rules, like those regulating liability, as I shall later explain.

Another aspect of CNs is their attention to anonymity. Even if each node has its own Internet Protocol (IP) address, users can choose their own IP address and change it at any time. Furthermore, contrary to what happens in the Internet environment, there are no databases in which these IP addresses are registered. There are no obligations to retain these data. Since a single IP address can be used only by a single user, users usually have a prospect in which they publicly display the IP address they self-assigned to their node. But this prospect is far from reliable, since it can be changed very easily by any member of the community. This feature of CNs, coupled with the use of anonymizing software or encryption techniques, greatly impairs the applicability of liability rules, since the possibilities to identify the person behind the screen decrease dramatically.

In the meantime, anonymity represents also an effective tool to enhance freedom of expression and to protect users’ privacy. Under this point of view, CNs pose legal scholars some enduring questions: should users’ privacy prevail or should other rights prevail and obtain enforcement? Should anonymity be preserved at any price? Such questions cannot obviously be answered in a vacuum; rather, they need to be placed within a concrete case.

Another aspect that characterizes many CNs is the absence of norms for their internal organization. More precisely, within a community network there are neither written norms to regulate relations among users, nor rules that attribute special powers to a possible central authority. Normally, there is a list of principles to which users have to agree (such as the “Pico Peering Agreement”)<sup>4</sup>. These principles only reflect the behavior of users taking part to CNs. People who join the network are typically motivated and, most importantly, they share the common principles of community participation and knowledge diffusion. It is up to other

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<sup>4</sup> See <http://www.picopeer.net/PPA-en.shtml> (retrieved on November 7, 2015).

members of the community to decide whether to accept the newcomers or not. There is no formal board or authority, even if some people can be seen as representing the heart of the community; these people can decide whether new users can join the network or not. Another aspect peculiar to many CNs is that, once a person joins the community, if she infringes its (more or less informal) rules, the community can take technical measures with the aim of excluding her. For instance, if a node moves its antenna to point in another direction, this can cut off some of the connected nodes, namely the nodes of those who are not accepted by the community anymore.

Given these peculiarities, CNs probably constitute a case of system governed by social norms, meant as informal standards and rules applied within a given group, which that group perceives as binding. Hence, for legal scholars the internal governance of CNs can constitute a fascinating field of re-search.

Legal implications of CNs are not limited to those mentioned so far; for instance, CNs could also potentially be used for illicit purposes of different kind, such as sharing data protected by intellectual property or organizing cyber- or terroristic attacks. This short paper will focus only on the issue of civil liability and the hurdles posed by CNs to the structure of civil wrongs as we have known it for centuries.

## **2. Wrongful Actions and Damages without Liability? The Challenge posed by CNs to the Law of Extra-contractual Obligations**

In this section I focus on what I believe is one of the main challenges posed by CNs to private law, namely: the apparent impossibility to enforce “extra-contractual obligations”. Extra-contractual obligations are those arising outside the realm of contracts, and that typically require a person to pay for the damages caused. The distributed structure of CNs implies the fragmentation of conducts, so that it becomes difficult, if not impossible, to define who committed a specific action. The object of the illicit action might be allocated to a high number of different users’ machines, which makes it not only technically, but also legally very problematic to define who contributed to the violation of a right (Dulong de Rosnay 2015).

The issue becomes even more problematic if one considers that the IP addresses of the people taking part to these networks are usually undetectable or, at least, are very hard to match with real identities. When anonymization software or encryption techniques are applied, the situation worsens.

To explain which kind of obstacles the structure of CNs poses to the enforcement of law, I shall make an example. Let us suppose that a net-

work's user – and owner of a node – acts in a way that defames a subject either within or outside the network. In a “classical” case of defamation, the person causing the damage would be identified, sued and eventually condemned to pay damages. In the realm of Internet the wrongdoer would be identifiable through her IP address: with the collaboration of the Internet access provider, the damaged person would obtain the real identity of the user and then sue her<sup>5</sup>. In some specific instances, in accordance with European Directive 2000/31 on Electronic Commerce<sup>6</sup>, also an Internet service provider could be held liable (Julià-Barceló and Koelman 2000; Baistrocchi 2003; Verbiest et al. 2007).

Transposing this example into CNs world, one could imagine the following liability situations: the first involves the user-wrongdoer; the second concerns the provider, for the case the wrongful action destination is placed outside the CN; the last one implicates the CN itself. In addition, another user – different from the wrongdoer – could also be held liable for the case she shares her Internet connection with other nodes, acting as a so-called “gateway node”.

With regard to user's liability, as mentioned, the first step would consist of identifying the person behind the screen, meaning the owner of the node from which the wrongful content came. Here comes the first “wall” that CNs erect against law enforcement: given the above-illustrated impossibility to identify users behind screens, technology could not be useful in finding the possible infringer and the damaged person could not reach its goal of obtaining justice. This represents a first “failure” for extra-contractual obligations enforcement.

Whenever the illicit action is made through the gateway node, a narrow space for action could remain. The gateway node can be identified since it has public IP address. However, at least in the Italian framework, the gateway node owner would not be held liable, as there are rules introducing this kind of third-party liability (Giannone Codiglione 2013, 123-135). A possibility would be to consider the owner of the gateway as concurring in the wrongdoing (for example under art. 2055 of the Italian civil code). This technique might be a solution to find a way for the victim to obtain redress for her damages; however, under the point of view of the sustainability of the network, such a solution would be a deterrent for a node's owner in sharing her Internet connection with other users and, ultimately, with the community.

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<sup>5</sup> This is a simplistic description of a scenario that can actually be much more complicated. For the sake of clarity let us assume that it works this way. More generally, the description made in this paper is necessarily limited, for a deeper analysis see Giovannella (2015).

<sup>6</sup> Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market.

In the last case illustrated, namely: if the wrongful actions are committed through a gateway, the provider supplying the Internet connection to the gateway user may be considered as a possible defendant. These providers enjoy the liability limitations introduced by Dir. 2000/31 under art. 12. Put it simply, they cannot be held liable if they do not take part in or somehow affect the transmission of illicit content made by users. In addition, very often contracts between users and access provider include a liability limitation clause and expressly forbid the customer to share the connection. The user sharing her connection would therefore breach the contract and be liable for that; in addition, the user might also be asked to act as a warrant for damages suffered by the provider as a consequence of the illicit conduct committed through the gateway (Giannone Codiglione 2013, 107; Mac Síthigh 2009, 366-369; Robert et al. 2008, 217 ff.).

Finally, in case the wrongful action takes place entirely within the CN, one could wonder whether the network itself could be liable. As earlier highlighted, CNs originate spontaneously within communities. These communities are self-organized and without a central authority. Contrary to what happens to a provider, they are not incorporated as companies. CNs do not have a person in charge that could be held liable for cases of wrongful actions. As a matter of fact, in the majority of cases CNs do not have legal personality and it would not be possible to sue them as entities. The only possibility would be to sue them as a community, i.e. to sue all the people within the CN. However, the same consideration made above for users' and gateway nodes' liability applies here.

A different conclusion could be reached in case the CN organizes itself as an association or takes another form, such as a foundation<sup>7</sup>. In this event, specific norms, which already exist, would apply.

It follows from what has been told so far that the structure and functioning of CNs pose a number of hurdles to the enforcement of liability rules. Normally, acting directly against the final users would be the most straightforward solution. It would also be the correct one, given the general rule that each person is liable only for her own actions. However, from a technological point of view this solution tends to be impossible.

### **3. The Interplay between Different Sciences as a Tool to Overcome Current Hurdles**

The described scenario provides an idea of the challenges that law must face when a new technology arises. Lawmakers should consider whether to adopt specific laws for CNs and, if so, what regulation would

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<sup>7</sup> This is for example the case of the Barcelona network 'guifi.net', which is part of a foundation; see <http://fundacio.guifi.net/index.php/Fundaci%C3%B3> (retrieved on November 7, 2015).

be the most effective. It would be fundamental to implement solutions that balance CNs' needs with right holders' ones, in order to discourage wrongful actions while allowing CNs to further develop and prosper (Dulong de Rosnay 2015; Giovanella 2015). However, regardless of the possible solutions that law-and policy-makers could (or should) apply to fill the existing gaps and overcome the illustrated difficulties, there might be solutions that CNs themselves could implement.

As emerges from the previous paragraphs, CNs are currently in a vacuum as for civil law enforcement. However, it might not be distant the time in which things will change. As CNs are growing both in number of people involved and in popularity, the possibilities that wrongful actions occur and that someone seeks redress are also growing.

In this perspective, the interaction between different sciences might play a key role. There might be technical tools that the network could implement taking into account existing laws and possible infringements. The enactment of specific technical measures – such as filters or detectors – might be both a deterrent for infringing conducts and a possible defence in case of lawsuits. In this situation, lawyers and engineers could work one with another with the aim of strengthening CNs: both could detect the weaknesses under their own point of view and try to help the network in gaining a stronger structure. While this would aid the “physical” aspect of the network, a similar approach could be taken for the “intangible” aspects of the community. This could be possible through the study of the internal relationships between the community's members, as well as of the role of some specific users. This task clearly reminds of sociological research. The study of the dynamics among users could reveal whether there are some users that *de facto* represent the network or manage it. Since these users could be more easily the subject of legal claims, such a study would help again strengthening CNs.

All in all, transdisciplinary research proves to be not only fruitful, but also necessary for legal scholars to confront new and emerging technologies and to understand both their effects on law and, in turn, the effects of law on these technologies.

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# The Future as Practice

## A Framework to Understand Anticipation in Science and Technology

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**Abstract** The future has become a common theme in governance of contemporary societies, particularly in the context of technological development. It is presented as open and uncertain, which, either as an opportunity or as a threat, demands a sense of urgency. Concretely, the future is embodied and made present through expectations, which have a performative effect in the constitution of socio-technical fields. These expectations are embedded in socio-material practices, through which they are produced, shared, shaped and contested. In this essay, I propose a framework to understand anticipation as a set of interrelated techno-scientific practices, which I call an anticipatory assemblage. This perspective has two contributions: first, it allows an in-depth understanding of phenomena such as technological hype cycles. Secondly, it frames the performative aspect of expectations in relation to governance, by considering how a series of anticipatory practices co-produce techno-scientific fields. I specify this framework using the case of two emerging technologies: graphene and 3D printing, for which I stress some of the differences in anticipatory practices and governance.

**Keywords:** anticipation; sociology of expectations; governance; anticipatory practices; futures.

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### I. Living in the Future: Emergent Technologies and Contemporary Life

It can be argued that emerging technologies only exist in the future. For many new technologies, what is said, shared, visualized and even traded only exists as speculative statements about their possibilities. Yet,

these promises and expectations seem to be forceful enough to create associations, promote investments and market products. In fact, this compulsion to look and act in relation to the future is at the core of capitalist dynamics and liberal democracies (Anderson 2010; Beckert 2014).

It is for this reason that the future has become a category of social inquiry in and of itself. A large and heterogeneous set of literature in the social sciences has been devoted to the study of “the future.” While traditionally the social sciences have been a past- or present-oriented discipline (Brown and Michael 2003; Emirbayer and Mische 1998; Poli 2014), in recent years scholars from diverse areas of the humanities and social sciences have engaged actively in the study of the social, cultural and political aspects of the future (Adam and Groves 2007; Andersson and Rindeviciute 2015; Appadurai 2013; Beckert 2013).

For contemporary societies, the future is highly uncertain. While this might seem self-evident, it is a profoundly contemporary phenomenon to perceive the future as empty, open-ended and unpredictable (Adam and Groves 2007)<sup>1</sup>. Despite this unpredictability, there is an increasing need to act in relation to the future, particularly to prevent potential risk or to profit from big promises. This implies that an uncertain future is made “actionable” by a set of societal arrangements, attitudes and interventions that can be legitimized in the name of what is yet to come (Anderson 2010; Beckert 2014; Massumi 2007).

What can or should be done in relation to the future varies across cultures and historical times (Koselleck 2004). Despite their uncertain and indeterminate nature, futures are known through a range of methods. Modern forms of prediction are characterized by a techno-scientific rationale in which calculative and modelling practices play an important role (Schubert 2015).<sup>2</sup> Adam and Groves (2007) argue that there are three forms of knowledge about the future: (1) the future as an extension of the present, as the consequence of ongoing developments, in terms of its individual, socio-cultural or natural components; (2) the future as a continuation of the past, which can be rationally grasped by scientific methods of correlation and calculation; and (3) mapping possible, probable or preferable futures in a non-deterministic way, as a basis for choices, decisions and actions. The last two forms can be observed in modern ways of relating to the future.

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<sup>1</sup> In contrast to an unpredictable future, Adam and Groves (2007) refer for example to a “divine future” determined by the Gods, which is a future that can be known, seen and anticipated because it is a pre-given future. This form of future thinking was important for pre-industrial western societies.

<sup>2</sup> One recent development is to move from exploratory forms of prediction such as foresight, which are aimed at making visible the forces and assumptions embedded in future thinking to the use of “Big Data”. This approach to prediction shows – and creates – trends, without paying attention to the forces that explain their existence (Couldry 2014).

Starting from the post-World War II period, a number of specialized methods and institutions have been created with the purpose of knowing and controlling the future. With the establishment of the RAND Corporation and other related institutes across the western world<sup>3</sup>, the future was established as an object of knowledge, expertise and governance (Andersson and Keizer 2014). These organizations developed methods such as forecast, Delphi<sup>4</sup> and scenarios to understand future threats or predict the success of future technologies. The future emerged “as a field of study, constituted by actors through a wide repertoire of instruments, technologies and narratives, held together by their ambition to shape and reshape the modern world” (Andersson and Rindzeviciute 2015, 5).

This range of methods and actors contribute to building up futures as an element of current societies. The future has become an object of governance, a category of both scientific and political intervention (Andersson and Keizer 2014). However, it is not a neutral construct; instead, how it is framed, such as what and who is included or excluded, is central to accounting for the choices made, particularly in relation to technology policy decisions (Skjølsvold 2014). In fact, actions in the present need to be understood not solely as the ultimate outcome of past events, but rather as an outcome of ideas and perceptions of the future (Beckert 2014).

The concept of anticipation captures the modes and effects of acting in the name of the future. It refers to ways of action that are future-oriented, in which futures are grasped, known and articulated so that particular interventions may take place (Anderson 2007, 2010). Anticipation pays attention to the ways in which the future is constructed in the present; it is not about prediction, but about the mutual adjustment between future expectations and contingent dynamics.

## 1.1 Anticipation in Science and Technology

Anticipation is a process through which the present is transformed, intervened in and ultimately governed in the name of the future (Adams et al. 2009; Anderson 2010; Rip 2012). It is both a cognitive mechanism and a social process (Kinsley 2012). Schutz (1976) argues that despite the impossibility for social actors to predict the future, since it does not have a pre-existing ontology, actors nonetheless anticipate what is to come and are interested in controlling it. While anticipation itself can be considered almost an “anthropological category” proper to all human beings (Beck-

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<sup>3</sup> The development of techniques and technologies to know and control the future is not just a feature of western democracies. Similar developments can be found in the East, particularly in the ex-USSR in relation to the notion of cybernetics (Andersson and Rindzeviciute 2015; Barbrook 2007).

<sup>4</sup> Delphi methodology is a forecasting method that is based on the opinions of a panel of experts, such that opinions are expected to converge after various rounds to the most likely predictions.

ert 2013; Poli 2014), “anticipation” as a form of governance is the result of understanding the future as highly dynamic, uncertain and indeterminate (Massumi 2007).

Anticipation is an important part of innovation processes, particularly for emerging technologies. It has been argued that promises and expectations play a particularly important role in shaping technological developments (Rip and Van Amerom 2010; Rip 2012). Innovation actors coordinate in relation to future expectations through the creation of a shared “agenda” (van Lente and Rip 1998). Anticipation is enabled by expectations, visions and imaginaries. For example, socio-technical imaginaries shape the structuration of large-technical systems such as energy, in a process in which an imaginary of a technology as well as an imaginary of society are co-produced (Jasanoff and Kim 2009; Levidow and Papaioannou 2013). Visions and more specific expectations also play an important role in shaping technological developments; in fact, in early stages of development, promises about a technology are often overenthusiastic, in a process known as hype, which promotes collective action but which also leads to over-exaggeration and disappointment (Dignum 2013; Gisler et al. 2011; Pedersen and Hendricks 2013).

It has been suggested that there are two contrasting forms of relating to the future for new and emerging technologies, in the process of co-construction of technologies and society. These two regimes have been characterized as *techno-scientific* or *collective experimentation* (Felt and Wynne 2007). These notions aim to capture ideal forms in which future orientation shapes technological development. The *regime of economics of techno-scientific promises* (ETP) is characterized by a linear, top-down and centralized model of innovation. In this regime, fictions are used to attract resources, drawing from an uncertain future that stresses competition, but these fictions do not account for the broader societal aspects of a technology. In contrast, the *regime of collective experimentation* (CE) represents a distributed, collective, and open process of innovation. In this case the emphasis is on the democratization of technological development and on the expectations produced through the engagement of users and experimentation around new socio-technical configurations (Felt and Wynne 2007).

These modes represent two normative models of technological development, which relate respectively to two different models of society that are being performed. In the regime of ETP, promises and hype drive the actions of innovation actors. In contrast, in the regime of CE, the future is not depicted in terms of promises and expectations, but rather technologies are constructed by free, open experimenting, without attributing to the future a steering role. While such distinction refers to ideal types, it can be expected that empirically, future orientation and expectations play a role in both cases, although enacted and mobilized in different ways. Furthermore, for both cases there might be not be one but multiple fu-

tures, as this is often the result of a nonlinear process in which claims and counterclaims are contested (Brown et al. 2000, 5).

This normative characteristic of socio-technical innovation has been used to develop approaches to the steering of these processes into desired directions. One of them is known as “anticipatory governance,” which can be defined as the capacity to rehearse future possibilities prior to “diving into the future” (Guston 2014). Similarly, calls for “steering” the development of emerging technologies, recently under the label of “Responsible Innovation,” are based on the capacity of actors to anticipate how technologies will become embedded in society (Nordmann 2014). In particular this last approach has been strongly taken up in policy cycles as an implicitly future-oriented governance approach to emergent technologies, which steers its development towards socially desirable situations (Simakova and Coenen 2013).

In sum, anticipation as a way of knowing and acting in relation to the future is a central aspect of technological development. Yet this is a complex process that requires a specific arrangement of knowledge, expertise, actors, practices, and institutions. In this process, expectations – as promises or concerns – play an important role. It is through expectations that discourses about the future are produced, shaped and circulated. It is necessary to make explicit the relation between anticipation and expectations: anticipation refers to a process in which ideas of the future are made present through knowledge, affects, practices, etc.; this is broader than just expectations, but expectations are central to the process. An extensive area of research has been developed to understand the role of expectations in technological development, known as the Sociology of Expectations (Brown and Michael 2003). In the next section I introduce the main aspects of the study of expectations.

## 2. The Sociology of Expectations

Anticipation today can hardly be separated from techno-science: on the one hand, for every new technology, futures are imagined and mobilized. On the other hand, these technologies are used to portray (and know, and even predict) specific societal futures: they are used as political tools (Beckert 2013; Brown 2003; Kinsley 2011). With new technologies, expectations about the future are circulated in order to obtain resources, and to guide and legitimize innovation processes. Within Science and Technology Studies, an area of research named Sociology of Expectations<sup>5</sup> has extensively discussed the role of expectations in innovation processes.

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<sup>5</sup> Brown and Michael actually introduce this area of research as the Sociology of Futures and Anticipation (2003, 4).

This analytical approach can be characterized “as a detailed examination of forms of action and agency through which the future is both performed (as a temporal representation) and colonized (as a spatial and temporal locus)” (Brown and Michael 2003, 5). Its focus is on the examination of the role of promises, visions and concerns, which are largely discursive but also embedded in material practices. Expectations, in the form of promises, visions and concerns, play a central role in shaping the socio-technical arrangements of emerging technologies. In cases when innovation actors are confronted with high uncertainties and indeterminacies (Joly et al. 2010; van Lente 1993), these expectations shape the “conditions of possibility” for emerging techno-science (Horst 2007). Expectations can be defined as “real time representations of future technological situations and capabilities” (Borup et al. 2006, 286). They correspond to collective ideas about the future, in contrast to those belonging to an individual or particular actor group. These collective expectations gradually become taken for granted, as if they were a self-evident statement that does not need to be justified (Konrad 2006b). Expectations are both discursive (as narratives about desires and future states), and simultaneously embedded in technologies, emerging actor-networks and socio material practices (Konrad 2006a, 2). As “wishful enactments” of desirable futures, expectations are highly normative, since they embody particular ways of considering how society should be (Eames et al. 2006; Hedgcock 2003). These promises or concerns embody specific values, hopes and fears (Milne 2012), which are always interrelated: just as there are big promises, there are also concerns and fears (te Kulve et al. 2013). Furthermore, their specific content tends to be a reflection of current concerns, promising to solve societal challenges that are relevant to the present. In this sense, collective expectations tell us more about how society is understood today than about the future itself (Konrad 2006b).

This area of research treats expectations as discursive elements that have an effect in innovation processes. This means that expectations do not merely narrate the future, but actually have an effect on the technologies they refer to: they are performative. More than just providing a reference point, expectations contribute to steering the innovation processes (Borup et al. 2006; te Kulve 2011). They fulfil specific functions and contribute to the configuration of the field they refer to: mobilizing actors and resources, providing guidance and coordination, enabling sense-making processes, and legitimizing socio-technical arrangements (Brown and Michael 2003; Swanson and Ramiller 1997).

## **2.1. Performativity of Expectations**

The performative aspect of expectations refers to the fact that they are constituent of innovation processes, particularly for emerging technologies. A well-known and extreme case of performativity, which is often considered a self-fulfilling prophecy, is the case of Moore’s law (Merton

1948; van Lente and Rip 1998). This so-called law refers to the increasing power of computing while reducing its cost. This expectation is largely maintained by the ITRS, an association of semiconductor industries and researchers that yearly forecasts and organizes the future of Moore's law. The success of this prophecy is the result of a highly coordinated network of actors and the strong interdependencies between the semiconductor's industries and other industrial sectors (Le Masson et al. 2012; Schubert et al. 2013; Sydow et al. 2012).

In contrast to Moore's law, not all expectations present such strong and highly coordinated forms of performativity. Instead, their effect is more diffuse: performativity can only be addressed in hindsight by tracing back the ways in which statements about the future changed and the world they constituted changed in relation to each other. This does not imply in any sense a full or complete alignment between expectations and the way technologies develop (Waterton 2010). In fact, in most cases expectations do not materialize (Bátiz-Lazo et al. 2014; Geels and Smit 2000); nevertheless, they have a strong effect in structuring and shaping actual developments in a field (van Lente et al. 2013). Stressing the performative aspect of expectations is an analytical approach which highlights "the ways in which techniques deployed in marshaling anticipated futures are engaged in reflexive processes of world making" (Kearnes 2013, 459).

Some scholars have suggested explanatory mechanisms for the performativity of expectations. One of these propositions attributes the performativity of expectations to the effect they have in the mutual positioning of actors and the creation of agendas. Van Lente and Rip (1998) have called expectations "prospective structures to be filled by agency," as they show some of the effects of structures but do not have their endurance and stability. They become forceful through what is called a "promise-requirement cycle" in which a promise is turned into a requirement for innovation actors, which then leads to other promises. These cycles are reinforced by "umbrella promises" (Rip and Voß 2013), open ended and broad promises that are broadly shared by innovation actors. The relation between umbrella and specific promises happens in a cycle of "dual dynamics of expectations" in which the specific promise-requirements cycles support the validity of an umbrella promise (Parandian et al. 2012).<sup>6</sup>

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<sup>6</sup> These umbrella promises are overarching ideas about the future, which in many cases can be considered as visions. Visions are distinct from promises in the sense that they embody general narratives about solving a specific problem that is relevant for society at large, and they come with specific values (Dignum 2013). For example, a vision is the "hydrogen economy," which refers to a certain socio-technical system that provides "clean and sustainable energy." In relation to these broad visions, the more specific expectations might refer to the role technologies, institutions or certain actor groups play in fulfilling this vision.

Such an account pays attention to the relation between expectations as discursive elements, and the effects that the articulation of this discourse has in the activities of innovation actors. However, expectations are not only rhetoric: they become embodied in artefacts, institutions and practices. The performative effect of these expectations depends on these material embodiments that mediate their operation, negotiation and circulation, be it in the form of prototypes, standards or procedures (Borup et al. 2006; Hyysalo 2006; Milne 2012; Wilkie and Michael 2009). As explained by Michael (2000) in his introductory work to the *Sociology of Expectations*,

The performativity of these representations does not take place in some abstracted, a-material domain. It is conducted in material settings, where bodies and texts, for example, come into contact or close proximity at least (ibid, 292).

More specifically, expectations are embedded in socio-material practices. This is particularly evident in design processes, where expectations of developers, designers, and sometimes users become embodied in prototypes (Hyysalo 2006). Wilkie (2014) describes prototypes as “expectational devices” with the capacity to “reify the future in the present” as experiments that translate the interests of implicated actors, encoding future practices. While this performativity approach to expectations has shown that they do have an effect in the constitution of technological fields, and that this means that they fulfil specific functions, it has provided only scattered accounts specifically referring to the forms, practices and materiality that constitute this process. For this reason, I propose to look closely to the broader notion of performativity and to re-assess its use in the *Sociology of Expectations*.

## 2.2. Some General Notions of Performativity

To weigh the claim of the performativity of expectations it is necessary to dig into the concept itself. While I do not intend to offer a full historical account of the use of this concept (du Gay 2010), which has also been revitalized in the broader debate about the “ontological turn” (Escobar 2007; Pellizzoni 2015; Van der Tuin and Dolphijn 2012), I would like to discuss its use in one area which is closely related to the study of expectations in science and technology: the study of economic processes. Callon (1998) has drawn attention to the way in which economics, as an academic discipline, and the economy, as a phenomenon, are reciprocally constituted. The main claim is that “economics is performative.” But what does it mean to say that economics is performative? Performativity is described as theories contributing towards enacting the realities that they describe (Law and Urry 2004). Within this framework, the “social” is understood beyond the dualism agency-structure; agency is action that emerges from



within a network in which it is embedded (Callon 1998).<sup>7</sup> That is to say, the social is not an external category, a specific type of “substance,” but rather it accounts for the formation of linkages – the assembling – within a network of heterogeneous elements, and it is present only as long as it is performed (Latour 2005). In this context, agency is performed in certain socio-technical *agencements*, roughly translated from French as “arrangements” or “assemblages.” *Agencement*, with its root in the word “agency” is not just a network; instead, it stresses the capacity of these assemblages to act or operate differently in different configurations. In other words, the way in which these heterogeneous elements are arranged explains its capacity to act in the world and its effects – in other words, its agency (MacGregor Wise 2014). An assemblage includes elements as diverse as meanings, discourse, material elements, actors, institutions, networks and practices, and involves the process of arranging, organizing and fitting these elements together – it is a “becoming” that brings things together (*ibid*).

These assemblages explain the relation between statements and their worlds; they have the capacity of acting differently depending on their configurations or positions in the actor-network. The effectiveness of statements cannot be dissociated from the position they come to occupy in the socio-technical assemblage (Callon 2009). This approximation re-frames the concept that ideas can be true or not true by considering instead that the world described by an idea or a theory is actualized. It considers the social not as given, but instead as performative, meaning that the definition is valid as long as it is performed, and for the same reason it has potential to disappear or change (Latour 2007). The actualization depends not only on the constant adjustment of the theory, but also on the adjustment of the world to this theory (Callon 2009).

One can think for example that ideas such as patterns of technological change are persistent because actors think they are persistent. From this perspective they resemble self-fulfilling prophecies: a firm would believe that other firms will take a certain trajectory, and for this reason they will follow the same path (MacKenzie 1998). However, not all performativity is like a self-fulfilling prophecy. MacKenzie (2007) proposes four types of performativity. General performativity refers to the cases in which an aspect of economics, such as a theory, model or concept, is used by participants in the economic process. Effective performativity occurs when the practical use of an aspect of economics has an effect on economic processes (irrespective of what the exact effect is). Barnesian performativity<sup>8</sup>

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<sup>7</sup> Callon (1998) gives the example of the notion of social capital, which introduces this dualism by thinking in terms of action and resources. While, instead, he argues that the “social capital” of an actor is given by its relations within a network and the ability to mobilize them.

<sup>8</sup> Barnesian performativity is in reference to Barnes’ notion of performativity, “I have conceived of a society as a distribution of self-referring knowledge sub-

is the most extreme case, and it occurs when the practical use of an aspect of economics makes economic processes become more like their depiction by economics. Last, counter-performativity, which also refers to self-negating prophecies, corresponds to the cases in which a practical use of an aspect of economics makes economic processes less like the description.<sup>9</sup>

These definitions of performativity are useful when assessing processes that took place in the past, but they do not refer explicitly to emergent processes, to the constitution of what is not yet, and might never be there – such as the future (Massumi 2007). The question arises of how to then assess the performativity of expectations, which can only be assessed in retrospective. This is particularly troublesome for the study of emerging technologies in which no stabilization has yet been achieved.

A second aspect of this notion gives more clues in relation to how to trace it empirically. The notion of performativity brings attention to the materialities that comprise a certain assemblage, which explains the occurrence of unexpected and independent events that are beyond what is formulated in theories or models, and yet are the performative effect of these assemblages. The effectiveness of a theory – or a statement, or an expectation – lies in what it does; and this does not happen by acting alone, but it operates through its embedding in a system of institutions, sets of information, agencies, resources, etc. (Mitchell 2007). Performativity points to the fact that for statements to be true it is not just a matter of implementing an idea in reality, but rather, it is a question of assembling and aligning diverse components and practices so that they might operate as a more or less stable and coherent working ensemble, even if the stability was always only ever transient. Central to that process of forming a working ensemble, are the instruments that link or mediate between the various elements (Miller and O’Leary 2007). As such, performativity is a social process, not an effect. As explained by Didier (2007):

Rome cannot be changed in a day. That is why the process is di-

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stantially confirmed by the practice it sustains” (Barnes 1988; as quoted by MacKenzie 2007).

<sup>9</sup> The ‘ends’ of Moore’s law, that is, the expectations that at some point it will not be possible to continue with the pace of innovation dictated by this proposition has been present since the 1960’s. This can be understood as a self-negating prophecy. But this end has not been reached and moves every year further and further away into the future, making “the ends of Moore’s law” a self-negating prophecy. The performance of these self-fulfilling and self-negating processes is achieved by active orientation and coordination of interested actors to the future; in this case through the ITRS (Le Masson et al. 2012). Both the negating and fulfilling sides of the prophecy reinforce each other, creating the conditions for coordination to emerge. Most importantly, the emergent phenomena, Moore’s law, is more than what any actor on its own could achieve or expect; there is de-facto governance happening.

luted over time, and the theory is said to act only *gradually*. So the world does not arise, like Athena, fully armed and shouting cries of victory; rather, it came, *little by little*, to conform to economic theories (ibid, 300, emphasis in the original).

This means that to trace performativity, we need to pay attention to the small adjustments that happen in the world, in which a statement or an idea aligns to the reality it describes. Particularly, to the material practices and institutional conditions that enable this performativity to take place, and that change through the process as well. This understanding draws attention to the way in which the material and the discursive world constitute each other.

The materiality in which the future and the anticipation of this future is embodied is fairly evident. In recent years, methods and actors have emerged that are specialized in the production of expectations and the coordination of anticipatory processes. Among these, there are consultancies (Pollock and Williams 2010), specialized media providers (Morrison and Cornips 2012), and think-tanks (Wilkie and Michael 2009). Particularly interesting is the emergence of specialized expectations actors, organizations whose role is to act as intermediaries in the production, circulation and performance of expectations. Pollock and Williams (2010) have introduced the term “promissory organizations” to refer to these consultancies, whose role is to produce expectations or knowledge about the future, to be used by other innovation actors in emergent technologies. This type of future knowledge is of a very particular nature, since it is associated to a type of expertise that is highly interactional and requires the embodiment of the object studied (Evans 2007; Pollock and Williams 2015; Reichmann 2013)<sup>10</sup>.

Such developments stress how the institutionalization of the future has become a matter of inquiry, intervention and consequently, of governance. This trend has been developing since the 1960s and has become stronger in association to notions of risk (Beck 1992). This is particularly striking for new technologies; their development is often a process of weighting and negotiation between promises and concerns (te Kulve et al. 2013), which means that expectations are a core element of governance processes in emergent technologies (Rip 2012). I suggest that governance aspects can be grasped by thinking in relation to the performativity of expectations.

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<sup>10</sup> Producing knowledge about economic futures is a process in which the experts “embody,” i.e. actively represent parts of the object of study that is shaped by the interaction with other experts. In this way, economic and technology forecasters can acquire knowledge about the future of the object of study by interaction with other relevant experts (Reichmann 2013).

### 2.3. De Facto Governance of Expectations

Governance can be understood as an analytical perspective that makes comprehensible complicated processes of collective action at the level of the state, the economy and society (Benz 2007; Borrás and Edler 2014). It corresponds to forms of coordination among heterogeneous but interlinked actors, which involves political guidance as well as forms of self-control and self-regulation (Mayntz 2003). Such forms of coordination can be characterized as hierarchies, networks, markets or negotiations (Benz 2007; Treib et al. 2007).

Taking a governance perspective to the study of expectations and anticipation means to focus on the way expectations and associated anticipatory practices contribute to collective action in a technology field. This perspective has been developed under the notion of anticipatory governance, either as an analytical concept (Anderson 2010) or as a normative framework (Barben et al. 2008). Both refer, from different angles, to the role of “the future” in coordinating action in the present. A more specific perspective is introduced by the notion of *governance of and by expectations*, which has been introduced to capture the different modes in which expectations contribute to the coordination of innovation processes. *Governance of* refers to the way in which expectations themselves are coordinated by the activities of innovation actors; *governance by* expectations refers to the fact that expectations influence innovation (Konrad and Alvial-Palavicino 2015). It is important to note that this is an analytical distinction, and that in reality governance of and governance by are part of the same processes.

Rip (2006; 2012) has argued that anticipation is proper to any governance process, and that it has in particular an especially relevant role in shaping emergent technological fields. Expectations about particular futures can solidify into a societal agenda to govern strategic choices – what he calls “delegation to the future.” From this angle, expectations contribute to de facto governance of innovation through this structuring effect, by enabling and constraining, coordinating, and orienting innovation activities, which is often an unintended and collective effect of their circulation, contributing to lock-in and path-dependency (Konrad 2006a, 2006b). De facto governance refers to the patterns and structures of coordination that emerge largely non-intentionally from the interaction of many actors, through mutual dependencies of perspectives and action (Rip and Van Amerom 2010, Rip et al. 2006). De facto governance can be understood as a patchwork of governance arrangements. Nevertheless, they are interrelated; in fact, intentional governance can be considered one element of de facto governance.

A way of thinking about governance of and by expectations is in terms of their performativity. Performativity is about reconfiguring reality, which has to be transformed in order to fit the models and expectations that represent it (Voß 2014). In this respect, expectations relate to pro-

cesses of collective action by which innovation actors intentionally or implicitly align their activities to future expectations. In addition to a performativity perspective, a governance perspective stresses the relation between local developments and global effects, seen as coordination at the level of society or the economy. It can either be the result of the aggregated effect of multiple local practices, as well as the result of specific practices that have the particularity of connecting local developments with the global. For example, publishing a research paper in a high-impact journal can potentially increase immensely the visibility of a research area and its promises, and serve as a starting point for its expansion (Alvial-Palavicino and Konrad submitted).

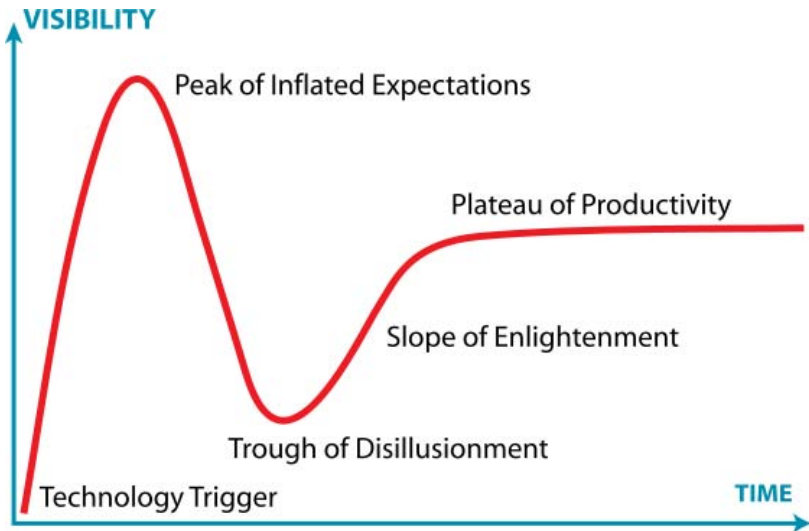


Fig. 1 - Gartner's hype cycle. Source: Wikimedia Commons, under Creative Commons license.

It is important to note that governance, as performativity, is a two-way process, in which both expectations and the world they represent align to each other through the activities of innovation actors. Additionally, expectations have dynamics of their own which are influenced by changes in the innovation field. In fact, there are explicit attempts to “govern” expectations, as reflected by the development of future-oriented methodologies, and the emergence of specialized expectations actors (Pollock and Williams 2010). These developments reflect the active and reflexive action of innovation actors, who are aware of expectations, their dynamics and their role in innovation, and strategically and actively influence expectations to suit their objectives (Konrad et al. 2012).

The dynamics of expectations show temporal and spatial variations, as well as a variation in the effects they have in different actor groups (Borup *et al.* 2006; Brown and Michael 2003). The variation in the type (from positive to negative) and attention of expectations is known as the “hype-cycle” (Figure 1). This cycle, introduced in the ICT world by the Gartner group consultancy, describes cycles of media attention and content of expectations that go from over-promising to disappointment, and stabilization (Fenn and Raskino 2008). Besides its particular use by the Gartner group as a tool for management of emerging technologies, hype-cycles have been identified as a recurrent pattern in expectations dynamics often referred to in expectation studies. I will detail the main aspects of this cycle in the next section.

#### 2.4. The Dynamics of Expectations: Hypes

For many emerging technologies it is often the case that early expectations are overly optimistic. This optimism might lead to exaggeration, followed by disappointment when these promises are not fulfilled. From high temperature superconductivity (Felt and Nowotny 1992) to fuel cells (Bakker and Budde 2012; Konrad *et al.* 2012), and the hydrogen economy (Dignum 2013), and from genomics (Fortun 2008) to biotechnology (Gisler *et al.* 2011) multiple technologies and technological concepts have gone through one or many cycles of high attention followed by disappointment – also known as “hype cycles.” While hypes might have a negative connotation, they are at the core of innovation processes in emergent technologies (Brown and Michael 2003).

In general, hypes and hype-cycles are understood as the circulation of over exaggerated promises, often through media, which might lead to unfounded excitement and disappointment. But before going into extensive discussions about the dynamics of hypes, it is first necessary to introduce two clarifications about the use and definition of the notions of hype and hype-cycle.

Hype is commonly understood as the act of exaggeration of the promises and expectations of a technology. Often accusations of hype emerge in scientific discourses, being attributed to the system of incentives and competition of science, closely entangled with the system of press releases and media relations (Caulfield and Condit 2012; Master and Resnik 2013; Nerlich 2013; Rinaldi 2012). Similarly, hype as act of exaggeration is a common feature of the discourse of technology actors – it often fulfils a strategic function for the diffusion and long term development of the technology (Gisler *et al.* 2011; Ramiller 2006). The hype-cycle has been strongly established in the imagination of innovation actors, to become a shared belief or “folk-theory” among innovation actors (Rip 2006), who might look for signals of hype and anticipate its occurrence.

Thus, there may be two understandings of hype: one that refers to the active production of exaggerated claims (to hype) and another that focus-

es on the collective effect these exaggerated claims have in the field, and on what this tells us about the technology (hype-cycles). I would argue, however, that to understand hypes it is necessary to use a hybrid definition that situates between two distinct ontological levels: the basic action of hyping and the meta-level phenomenon of hype. In this definition, hype-cycles are more than the sum of individual actions and more than the additive effect of exaggerated claims: hypes have intentional as well as unintended effects to which innovation actors need to respond (Konrad et al. 2012).

It is this last understanding of hypes that I want to develop further. In doing so, I propose to understand the performativity of expectations in the context of hypes as the active assembling, or bringing together, of multiple elements which constitute emergent technology fields. Such assembling can take different forms, which often do not fit the description of the Gartner group. In fact, their shape and extension varies considerably: there are technologies that can go through several hype cycles, and the depth of the disappointment and the extension of the peak will vary among different technologies (van Lente et al. 2013). For example, the case of high temperature superconductivity during the 80s is a case of very sharp and short hypes (Felt and Nowotny 1992). In contrast, we can look to fuel cells (Ruef and Markard 2010), artificial intelligence (Gomes 2014) and peer to peer networking technologies (Oram 2001) as examples of technologies that have been through multiple cycles of hype and disappointment without losing out all their credibility.<sup>11</sup>

Nevertheless, hype is a useful concept to understand the relation between technology development and expectations, since it refers to their specific and dynamic interrelations. Innovation actors are aware of these cycles of expectations and might strategically respond to them by getting involved in raising high expectations (Ramiller 2006) or develop specific innovation activities in moments of strong attention, such as investments, products or press releases, etc. (Konrad et al. 2012). The responses to hype vary among innovation actors. While core innovators or developers of a technology commit for long-term to certain expectations, even during disappointment, other actors might enter or exit the field during different stages of the hype (Dignum 2013). Even those who do not agree with the promises often react and develop strategies in relation to hypes (Gisler and Sornette 2013; Konrad 2006b). A particularly interesting case is that of venture capital markets, which behave like and are closely coupled to

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<sup>11</sup> The case of artificial intelligence is particularly interesting, because although the vision itself is rather old (one could say at least more than a 100 years) and it has gone through several disappointments – the last in the '80s – it is going through a recent revival under the notions of “big data” and “machine learning.” One example of this current hype is the Human Brain Project, which has been funded as an European Flagship project and which has a strong emphasis in the development of brain-like computing mechanisms (Frégnac and Laurent 2014).

hypes (Gisler et al. 2011). Investors would react not only in relation to expectations about the technology, but also in relation to expectations about the behavior of other financial actors; thus, they need to understand the hype to develop their own strategies (Wüstenhagen et al. 2009). Hypes, therefore, do not merely rearrange expectations, but also have an effect on the relations between innovation actors. An example is the way in which venture capitalists change their attitudes toward opportunistic investors, who seem to be responding to hype: they anticipate disappointment and consider forming exit strategies.

These accounts show that hypes are constructed not only by the formulation of a certain type of discourse, but also by the actions of actors, enabled and embedded in specific material settings. In this respect, the analogy of hypes with “social bubbles” highlights the notion that such hypes emerge and produce strong social interactions, reinforcing feedback cycles which in turn lead to extraordinary commitments for a technological project; secondly, this creates entanglements of financial resources, technical capabilities, hopes and expectations, and investments (Gisler and Sornette 2010). This understanding of hypes stresses two important aspects: the first is that hypes are the result of a process of assembling heterogeneous elements, and therefore they can be understood as an assemblage. Second, because this particular assemblage fulfils certain social functions, there is a performativity aspect to the hype itself. For this reason, it is possible to speak about the performativity of hypes as a particular way of framing, modeling and thinking about expectation-technology dynamics, in addition to the performativity of expectations. I propose to think of hypes as an anticipatory assemblage that is composed of a set of interrelated practices. I will develop this idea in the following section.

### **3. Anticipatory Assemblages: Understanding Anticipation through Practices**

In order to develop the notion of anticipatory assemblage, I focus here on the practices that mobilize expectations and constitute hypes. This perspective stresses the material embedding of expectations (Brown and Michael 2003), and the way in which the active arrangement of expectations leads to overall patterns and patchworks of performative expectations. In doing so, I examine how specific ways of doing expectation work in specific local contexts contribute to the construction, stabilization and governance of an emergent technological field.<sup>12</sup>

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<sup>12</sup> It is important to note that by introducing local/global relations I do not refer to distinctions such as micro/meso/macro that have been introduced earlier in the study of expectations (Konrad et al. 2012; van Lente 1993). That is to say, I do not consider different levels of expectations, but instead I look at the processes of



To this end, I focus on the study of practices that compose processes of anticipation in emergent technologies. I will use the term *anticipatory practices* to refer to the socio-material practices in which expectations are embedded, following and further developing the approach introduced by Anderson (2007; 2010). By doing so, I want to understand how expectations are produced, and what are the conditions that enable their production and performative character.

The study of anticipatory practices is not completely new to STS. Previous studies have focused on either implicit, situated design practices (Hyysalo 2006; Kinsley 2012; Wilkie 2011), or on the study of explicit forms of expectation work, such as foresight. These latter are explicit techniques and tools used for knowing and anticipating futures (van Lente 2012). However, these accounts are limited to the analysis of local and specific practices, and say little about the relations that emerge between them. Against this background, I am interested in how local and specific practices produce macro scale phenomena, such as hype-cycles. To explore this aspect, I will discuss and compare two examples of emerging technologies that have recently gone through a hype cycle: graphene and 3D printing. There are interesting differences between these two technologies: graphene stands for a science-push discovery that is turned into a commodity. In contrast, 3D printing is the result of the activities of user communities; it represents a bottom-up development that is now being taken up by market actors. These two technologies, while both hyped, embody (in principle) different forms of doing “techno-science” (Nordmann 2010), which can be roughly related, respectively, to the regime of economics of techno-scientific promises and to the regime of collective experimentation (Felt and Wynne 2007; Joly 2010). While graphene follows the path of a scientific discovery that is transformed into a marketable technology, 3D printing is a “grassroots”<sup>13</sup> technology that is in the process of becoming a mainstream technology. The type of actors, institutions, networks and even expectations of these two cases are different, however, strong similarities can nonetheless be identified.

In what follows, I introduce the analytical categories required to explore the relations between local anticipatory practices and global dynamics for emerging technologies. I will start by revisiting the very notion of practice, and later build up conceptually, in order to address the complexity of the emergence of technological fields.

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assembling expectations, actors, practices which lead to the temporal stabilization of a specific field.

<sup>13</sup> Some of the aspects of consumer 3D printers, such as their inception in hacker and makerspaces, and development of initiatives such as FabLabs, can be considered “grassroots.” By this, I refer to a bottom-up development which lacks a hierarchical governance structure and that resembles a social movement to some extent. For a critical review on the topic see Smith et al. (2013).

### 3.1. Practice Theories

Science and technology studies have introduced a practice perspective to study science not only as knowledge, but as “practice” (Latour 1987). This approach stresses the material culture of science, which is neither knowledge nor social relations; rather, science is understood as a hybrid between the material and the social (Pickering 2008). Practice approaches have been used to understand the development of infrastructure (Bowker and Star 1999), organizations (Orlikowski 2007), and marketing (Araujo et al. 2008), etc. Along these lines, Anderson (2007; 2010) has introduced the notion of anticipatory practices, to refer to those practices which actively contribute to shaping “futures.”

Clear examples of anticipatory practices are the methodologies for future technology assessment, including forecast, scenarios, and foresight, among others. These methodologies have evolved from probabilistic forms of prediction, into more open and exploratory approaches that study alternative futures and their underlying frameworks (Martin 2010). This demonstrates that practices which actively engage with the future have a history and trajectory of their own. As Anderson (2010) argues, these practices are central to understanding future-oriented governance in liberal democracies: they guide and legitimize action. I propose to go one step further, and argue that this future orientation is not only reflected in explicit practices aimed at shaping the future (as methodologies, methods, tools, etc.) but also embedded in other common techno-scientific practices, from grant applications to venture investment. Taking this perspective brings to existing studies of techno-scientific practices the analytical tools to understand how these practices contribute to expectation dynamics, and consequently, to shaping the future. For example, what is the role of a practice such as “filling a patent” in promoting and/or shaping certain expectations? How does it relate to other practices, and, particularly, to more explicit forms of anticipation?

Despite the relevance and novelty of this analytical perspective, Anderson does not provide a detailed “theory of (anticipatory) practices” that could guide an in-depth analysis. Therefore, it should be clarified what a practice means for this anticipatory perspective: practices are essentially forms of collective action (Barnes, 2001), which generate order in the social world as a relational and performative effect (Law and Lien, 2012). They are a form of routinized behaviour, but the routines in question can be filled in multiple ways (Glynos and Howarth 2007; Reckwitz 2002), involving both humans as well as technical artefacts (Pickering 2002).

In introducing a conceptual definition of practice, it is important to keep in mind what is to be learned about emergent fields from the study of anticipatory practices. I am interested in the role of expectations in the emergence, shaping and structuration of technology fields. This means, I

am not only interested in the detailed accounts of a practice, but also in how practices evolve in relation to a field and its expectations. In order to explore this aspect, I follow the practice approach introduced by Elizabeth Shove *et al.* (2012), which focuses on the way practices evolve and change. Using this approach, she describes, for example, how the practice of driving a car has evolved from the end of the XIX century to the present, which includes not only changes in terms of technologies, but also in the competences required to ride a car (more evident now with self-driving cars) and the meaning attributed to the practice. In this context, my intention is to understand the role of specific anticipatory practices in technology fields, and how they relate to other practices and to changes in the field itself. As Shove states, paraphrasing Latour, the approach allows to “follow the practices” and in this way understanding the social.

Shove *et al.*'s (2012) notion is composed of a double conceptualization of practices, both as entities and as performances. This double definition highlights the interdependencies between multiple elements. A practice exists as

a recognizable conjunction of elements, consequently figuring as an entity which can be spoken about and more importantly drawn upon as a set of resources. At the same time practices exist as performances. It is through performance, through the immediacy of doing, that the ‘pattern’ provided by the practice-as-an-entity is filled and reproduced (ibid, 7, *emphasis in the original*).

This definition refers to two aspects of practices: firstly, that practices as performances take place in a certain spatio-temporal context and so they are unique every time this happens. It is important to note that “performance” here is different from the Callonian notion of performativity that I have introduced earlier. The performance of a practice means “doing” a practice, the act of making a practice happen or when a practice takes place. Secondly, that practices as entities are referred to and talked about, i.e. there is a recognizable meaning of a practice that is more or less unchanged between performances (Feldman and Pentland 2003; Shove *et al.* 2012). This aspect highlights that practices, despite their repeatability and recognizability, are inherently improvisational, and so the way they are carried out is always somehow novel. It pays attention to the material dimension of these practices that is mobilized when they are performed, while underlining that practices have a meaning beyond individual instances of enactment.

### 3.2. Anticipatory Practices

For conceptualizing anticipation as a set of practices, it is necessary to introduce some specifications about the type of practices involved. Anderson (2007, 2010) introduces the notion of “anticipatory practice” to

speak of and analyse the practices involved in processes of anticipation.<sup>14</sup> Anticipatory practices are practices that give content to futures, and make them present through specific materialities (Anderson 2010). These practices range from calculation techniques, forms of imagining futures such as scenarios, to forms of performing futures such as gaming, role-playing, etc.; these are collective practices that involve the circulation of collective expectations (Konrad 2006). This notion accounts not only for those practices that are explicitly performed in order to give shape to specific futures (as it is the case for forecasts, models, trends and so on), but also practices which implicitly shape future expectations and contribute to the process of anticipation, such as setting up standards, prototyping, filing patent applications, etc.

Drawing on Anderson's work, I further develop the notion of "anticipatory practice," drawing on the conceptualization of practice by Shove et al. (2012) introduced above. In general, practices can be considered anticipatory if some form of future orientation is at the core of the practice itself. Everything that people do has a history and a setting, and is in principle future-oriented (Schatzki 2010). Nevertheless, not all practices are anticipatory. Here I shall introduce a more strict definition of anticipatory practices, in which a practice can be considered anticipatory if it fulfils two conditions: firstly, the meaning attributed to it must relate to a non-immediate and collective future. This means that anticipatory practices refer to futures that are far enough to be uncertain, and on which a variety of actors have to agree and ultimately act, despite their uncertain nature. An example is practices which are expected to have a long-term effect such as investments (Wüstenhagen et al. 2009). Secondly, a practice is anticipatory when expectations about the future are mobilized in doing the practice, and as a result, other future-oriented activities are triggered. For example, a practice that enables the circulation of expectations such as the writing of policy reports about a technology (Wilkie and Michael 2009).

I will illustrate this definition with two techno-scientific practices, drawing examples from the cases of graphene and 3D printing. The first case is the graphene roadmap developed in the context of the application

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<sup>14</sup> Anderson (2007; 2010) introduces the broader concept of "anticipatory action" as a framework to understand future-oriented interventions. This is defined as the "seemingly paradoxical process whereby a future becomes cause and justification for some form of action in the here and now" (2010, 778). He is interested in the relation between the future and particular modes of future-oriented governance in liberal democracies, such as preemption, prevention, and precaution. More broadly, he is concerned with the particular mechanisms that enable these processes to happen in the first place. He argues that futures are anticipated in the assembling of three elements: styles, practices and logics. While I do not follow his approach fully, I take the notions of anticipatory practice and logics, and develop an interpretation that is adjusted to my research interest.

process to the Flagship funding scheme.<sup>15</sup> This collective practice is presented as a way to understand what is the most plausible future of graphene, in terms of both science and applications. In this way, graphene's full potential to create social and economic growth can be developed. Creating such a roadmap requires compiling and coordinating the expectations of a large and diverse community, from researchers to industry to investors, and it is composed of many micro practices such as gathering opinions through a website, expert meetings, etc. The effect of such a practice is to enable this future coordination by distributing certain structure and roles to specific actors within the field; it also serves as a legitimating device for innovation activities.

A second example of an anticipatory practice is the creation of standards, a process often caught between being too early to have concrete definitions, or too late to regulate, as in the line of Collingridge's dilemma (1980). Standards are necessary for the diffusion of a technology, and so while there is no certainty that a particular product will succeed in the market, its diffusion can only take place when there are appropriate standards to support it. For this reason, actors involved in standardization processes have to anticipate the possible socio-technical configurations of the technology in order to develop useful standards. This process is not devoid of contestation, as many of the actors involved in the process have their own ideas and agendas about the best configuration possible, for which they mobilize and attempt to position certain expectations. Thus, the meaning of the practice is related to the future embedding of a technology in society. To perform it, actors strategically mobilize expectations to push for their particular interests in the process. The outcome of the practice has a strong impact on path dependency: it will enable certain developments while excluding others.

With these two examples, I wish to highlight that for a practice to be considered anticipatory, it is not necessary to aim explicitly at shaping expectations. However, it is necessary that "the future" contributes to the meaning of the practice, that expectations take part in the practice itself, and that its performance contributes to anticipation. A caveat is that although this definition helps to identify those practices that are anticipatory, it does not explain why some practices are preferred while others are not, in a given context. Therefore, to characterize the conditions that structure sets of anticipatory practices (e.g. enable and constrain them, as understood in Rip and Kemp 1998), I use the notion of anticipatory logic.

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<sup>15</sup> The FET Flagship funding scheme was initiated by DG Connect of the European Commission to fund "ambitious, large and science driven research initiatives that aim to achieve a visionary goal, providing a broad basis for future technological innovation and economic exploitation, as well as benefits for society" (<http://cordis.europa.eu/fp7/ict/programme/fet/flagship/>).

### 3.3. Anticipatory Logics

It is possible to argue that the hype related to graphene is based on a different set of practices than the hype around 3D printing. While it seems intuitive that different actor groups, such as scientists versus venture capitalists or industries, would engage in different forms of anticipation, it is nevertheless important to analyse the conditions that enable different practices to take place in each case. These practices produce and sustain a specific social order. However, this order is not static: in fact, when different actor groups come together, as in the case of the production of the consumer 3D printer, where the interests of hackers, makers and industrialists met, practices change and new ones emerge. In this respect, a concept such as “logic” captures the relation between a diverse set of practices and their context, and the evolution thereof.

Logic refers to the “grammar” or rules of a set of practices, and the conditions that make the practice both “possible and vulnerable;” i.e., the conditions of possibility or impossibility of a practice (Glynos and Howarth 2007).<sup>16</sup> Anticipatory logics refer to “a coherent way in which intervention in the here and now on the basis of the future is legitimized, guided and enacted” (Anderson 2010, 788).<sup>17</sup> We can think of this concept in terms of two forms of acting in relation to future threats: precaution and preemption. The logic of precaution<sup>18</sup> operates under the assumption that through a precautionary act, a catastrophic event will not take place, stopping something before it reaches the point of irreversibility (Stirling, 2008). In contrast, a preemptive logic puts emphasis on action under complete uncertainty about a future event, but in a world of strong interdependencies. It does not follow the logic of risk as a calcula-

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<sup>16</sup> Glynos and Howard (2007) introduce three types of logics: *social logics* are related to the maintenance of certain practices, *political logics* are related to challenge and transformation, which leads transformations in institutions, and *fantasmatic logics* account for why a specific practice and regime grips subjects, or the resistance to change of social practices.

<sup>17</sup> In particular Anderson refers to logics that are mobilized under potential threats, and that involve actions that “aim to prevent, mitigate, adapt to, prepare for or preempt specific futures” (Anderson 2010, 779). Nevertheless, these logics need to be constantly reassembled for each of the cases in which they are enacted, which explains their transformative capacity. These logics function as a repeatable means of instantiating the conditions for anticipation – which are based historically on the presumption that certain forms of knowing the future are possible (Kinsley 2012). In fact, forms of prediction and anticipation are often a highly contested, yet contingent and culturally inflected activity (Andersson and Keizer 2014).

<sup>18</sup> A well-known example of the logic of precaution is the “precautionary principle,” which states, “when an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically” (1998 Wingspread Statement, from <http://www.sehn.org/ppfaqs.html>).

ble entity, and instead it acts in the face of indeterminacy of the nature of a threat (Massumi 2007).<sup>19</sup> There is a fundamental difference between precaution and preemption: the former acts upon processes that are known, on empirically apprehended threats. The latter calls for action on threats that have not yet emerged or even been fully identified. These two logics embody two different ways of knowing the future – and the assumption of what can be known and by which means – which enable different forms of intervention, and, ultimately, different forms of anticipatory governance.<sup>20</sup>

These forms of acting upon the future can be related to or originated from idealist or ideological discourses (Kinsley 2011). In fact, different logics can co-exist in a certain field such as in the case of 3D printing, in which at least two logics characterize anticipation: techno-economic and open source.<sup>21</sup> While the former characterizes practices in which the future is associated with a sense of urgency and competition, the latter refers to practices in which the future is reflexive and is a space for experimentation. A techno-economic logic will include practices such as the economic assessment of promises and risks, or the spread of high expectations through media. An open source logic, in contrast, emphasizes practices such as the development of open source hardware and open standards, in which the specificities, aims and ethos of the machine are negotiated among members of a community.

A logic provides a certain way of seeing and knowing the future, codifying for specific practices and setting a specific context for a present sense of “futuraity” (Kinsley 2011). In this sense, logics “enable and constrain” forms of knowing and acting in relation to the future, and for the same reason they can be subject to dissent and contestation (Brown et al. 2000). Thus, there is a political dimension to anticipation. While I will not develop extensively this aspect, it must not be ignored, especially when framing expectations in relation to governance. Beckert (2014) has emphasized the distributive and political dimension of expectations and anticipation. He argues that the contingent nature of expectations makes them open to interest-based politics.

If decisions have distributive consequences, and if decisions

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<sup>19</sup> Massumi (2007) uses as an example of the logic of preemption the American invasion to Irak in 2003, an event that was justified on the basis of a threat that was not concrete neither could be identified by any methods.

<sup>20</sup> I use the term “anticipatory governance” in the way Anderson (2010) does. Thus, it is important to distinguish it from the more normative understanding of “anticipatory governance” (Barben et al. 2008) which has been developed in the context of steering innovation processes.

<sup>21</sup> These two logics are related to the two regimes as introduced by Felt and Wynne (2007) and Joly (2010): economics of techno-scientific promises (techno-economic) and collective experimentation (open source).

are based on expectations, then actors have an interest in the expectations of other actors. Influencing expectations has become a central task of both political regulation and business and is a major part of discourses on business and the economy (*ibid.*, 11).

The “politics of expectations” are played out, for example, in the way open source 3D printers are developed and promoted, against proprietary technology. Similarly, it is embedded in the way the “future of graphene” becomes a European project, through the flagship, by rearranging a scientific, technological and industrial community with the purpose of exploiting the economic promises of the material. This political aspect is related to the normative considerations that inform certain practices, their ideological commitments and the way in which anticipation creates inclusions and exclusions.

#### 4. Anticipatory Assemblages

In order to fully characterize processes of anticipation, it is necessary to pay attention to the relations between different practices and their effects. For this reason, I introduce in this last section the notion of assemblage, to account for how different practices come together among a multiplicity of elements, i.e. how they influence each other and their joint effects. I use this notion as a heuristic to account for the multiplicities of practices involved in anticipation, their different contexts and the relations that emerge from them. Future expectations, as a dynamic phenomenon (e.g. hypes) can be understood as an anticipatory assemblage, a process that develops over time, in which local activities lead to global effects. Such is the case of both graphene and 3D printing, technologies that are currently going through a hype phase; yet the types of actors, practices and logics that characterize these hypes differ. However, despite these two technology fields being in principle substantially different, it is possible to recognize some common dynamics.

To understand this apparent conundrum, I focus on two aspects of assemblages: the first one is its reference to a set of heterogeneous elements that are brought together, which is constantly re-enacted and has performative effects. The second aspect is that although this specific arrangement can be found in various contexts, local and global, it is more than a pattern, because its structure is not given but is constantly rearranged. Along these lines, one can think about hypes as the result of a set of expectations, practices, technologies, and others that are brought together, partly because of the strategic activities of actors, but largely as a result of an arrangement of stabilized anticipatory practices that shape the future in specific and recurrent ways. A hype is both a local and a global phenomenon; it is the result of strategic and specific actions with local implications but also global aggregated effects.

The notion of assemblage, as introduced by Deleuze and Guattari



(1988), stresses the way in which heterogeneous elements are brought together to generate effects that are more than the sum of their parts (DeLanda 2006).<sup>22</sup> It is a way to go beyond the agency/structure dualism, and instead focus on how “the social” as a whole emerges as a result of the coming together – or assembling – of its parts (Latour 2005). Because of its focus on action as embedded in a network, an assemblage can be essentially seen as a theory of practices which stresses that relations within the assemblage are not given, but made and remade through practices (Ong 2014). This is a result not just of contingency, but also of the reflexive action of actors (Callon 2007), and it is thus necessary to study the practical work required to build an assemblage (Bueger 2014).

For example, we can think about the way in which different anticipatory practices across science, policy and industry are assembled to produce the “graphene hype.” Scientific actors voice expectations through practices such as high profile scientific publications, conferences, and grants applications, which are supported by policy actors. These expectations are translated into a language that relates to economic growth and societal impact, which in turn results in opportunities and protected spaces being created. This brings in industrial actors with their own dynamics of market creation, which in turn translate expectations into values for future markets and opportunities for investment. In this process, expectations are circulated, translated and contested across different actor groups, a process in which a variety of anticipatory practices are deployed.

More than just an arrangement of practices, the notion of assemblage refers to the performativity of a particular set of practices. An anticipatory assemblage has a performative effect on a technology, as collective expectations align to and co-produce the world they refer to (Konrad 2006b). This assemblage fulfils specific functions, helping to generate a specific order in the world, which is constantly adjusted. For example, hypes fulfil the social function of bringing together actors to take high risks that otherwise would not be taken individually (van Lente et al. 2013). Thus, it is possible to consider the Graphene Flagship as a concrete result of the hype on graphene. In this case, a set of anticipatory practices aligned and coordinated scientific, industry and policy actors and their expectations, into a large-scale project with the aim of profiting from the promises of graphene.

The second characteristic of assemblages that I refer to is that assemblages happen both locally and globally, occurring in different spaces while at the same time connecting to one another. This dimension has been introduced through the notion of global assemblage (Collier and

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<sup>22</sup> Assemblage theory is a complex body of work; I do not use all the conceptual framework of assemblage theory as developed, for example, in the work of DeLanda (2006). Instead, I use the notion of assemblage as a heuristic to position and guide other elements of my analysis.

Ong 2005), which refers to global forms of techno-science, expert systems or economic rationalism that operate at a transnational level and can be found in diverging (cultural and geographical) contexts.<sup>23</sup> In a similar way, while expectations about a technology are generalized and shared by different actor groups, the way they are performed, their anticipatory practices and their performative effect change in each case. For example, hypes take place across different actors' groups and institutional settings. The promises of a technology are often voiced in different spaces, with each space having its own ways and practices to articulate and receive these expectations. While the voicing of an expectation happens locally, in specific practices, some of these practices can have a global effect and translate the effects of an expectation beyond the particular setting in which they are embedded. This is, for example, the way the consultancy organization Cientifica characterizes the graphene hype. In a 2013 report, they introduce what is referred to as the typical "nanomaterial hype" which starts from academia, moves into the corporate domain and then to financial actors. As a cumulative effect, a sort of bubble is created, which then "bursts" and provokes disappointment (Cientifica 2013). Expectations move and are translated across different spaces, creating linkages between them. The resulting effect is more than the sum of the individual dynamics of each space, and has an effect on each of them.

Here, the notion of *space* refers to a specific arrangement of actors, practices, rules and institutions, such as science, industry, the financial sector, etc.; or institutionalized socio-technical configurations that are characteristic of a certain actor group and can be recognizable as such. Space in this respect is more than a reference to a spatial and temporal configuration, and more than just a metaphor for a particular type of social dynamics. Spaces have dynamics of their own, i.e. their own rules and structure (Rip and Joly 2012)<sup>24</sup>; they can themselves be considered as a

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<sup>23</sup> These assemblages are constituted by a series of what they call "reflexive practices" which include technological, political and ethical forms to organize social life. These practices are translated into multiple contexts, replicating the assemblage in different locations at the same time. The global character of the assemblage is largely provided by the technical systems that compose it – calculations, models, etc. (Prince 2012). This universality means that the assemblage is decontextualized and recontextualized, having the ability to move through diverse social and cultural situations in such a way that its functions and effects are maintained. This is not to say that an assemblage is something that occurs "locally" or is the result of structural forces. Rather, it is "the product of multiple determinations that are not reducible to a single logic" (Collier and Ong 2005, 12), because the forms within the assemblage are always shifting.

<sup>24</sup> Rip and Joly (2014) argue that spaces are not just a metaphor, but that they actually have dynamics of their own and specific characteristics: there is a certain spatiality where actors can "move about" (and which allows room for deliberation and experimentation; the space itself has boundaries that are more or less permeable; and last, it has an internal structure given by the rules of interaction inside

particular type of assemblage, because they are configured by a set of heterogeneous elements, and are constantly reconfigured through the interaction with other assemblages.

The concept of space refers to the concrete spatiality<sup>25</sup> of an assemblage as well as its ability to produce and sustain new spaces.<sup>26</sup> In that sense, the space is a property of the assemblage and it is at the same time produced by it. For example, in the case of consumer 3D printers, additive manufacturing technologies which underpin 3D printing are an established technology for industrial prototyping – an “industrial” well-established space. In contrast, the consumer 3D printer was developed in a different space, constituted by hacker and maker communities. The development of the consumer 3D printer led to the emergence of hybrid spaces such as TechShops or FabLabs<sup>27</sup> where radical ideas and practices meet and merge with market logics (Schneider 2015).

I will close this essay by making explicit the relation between the elements that have been introduced earlier: expectations, performativity, governance, anticipatory practices and logics, and assemblages and spaces. I should restate that my analytical focus is on practices and sets of practices as a means to understand the performativity of expectations locally and globally, and its relation to governance. In this context, the notions of assemblage and space are used as a heuristic to make sense of practices that come together. As represented by Figure 2, this framework has two analytical foci: first, it addresses anticipatory practices at the local level, as instances for the creation, shaping, mobilization and contestation of expectations. The practices that do or do not take place are the result of a particular combination of logics. In this context, there is a reflexive relation between expectations and practices, which is located in specific spaces and at the same time reshapes these spaces. The second analytical focus is what happens when practices come together. Anticipatory practices do not act in isolation, they act in bundles of practices. Furthermore,

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the space. Spaces are both stabilized and emergent, they are constantly changing but they are, at the same time, easily recognizable arenas of interaction.

<sup>25</sup> By spatiality I want to make explicit that assemblages are not just discursive, but that they enable certain social interactions through technologies, devices, rules and institutions, shaping the social – and even the physical, as argued by Anderson (2010, 2012) – world.

<sup>26</sup> Space here does not only refer to a geographical space, but it can take the form of any platform in which a set of actors come together. This includes institutions (both explicit, such as municipalities, and more abstract, such as “science”) as well as online spaces, emergent platforms, etc.

<sup>27</sup> Fablabs and Techshops, and other types or makerspaces are shared machine facilities that resemble industrial production facilities, but they are at small scale and open to the public. In these spaces people of diverse backgrounds an interest meet to fabricate what is of their own interest (Walter-Herrmann and Büching 2014; Nascimento 2014)

they can move between different spaces and translate expectations from one space to another and from the local to the global. Such a dynamic can be conceptualized as an anticipatory assemblage, which I describe in relation to the practices and expectations that compose it, and which are brought together and make “the future” actionable and anticipation possible.

Through this approach, I introduce to the Sociology of Expectations a perspective that stresses both the way in which expectations are built, and the agency of actors and materiality in producing certain expectations dynamics. While such an approach is implicit in the basic assumptions of the sociology of expectations (Borup et al. 2006; van Lente 1993), I introduce an analytical framework explicitly tailored to empirically capture this phenomenon.

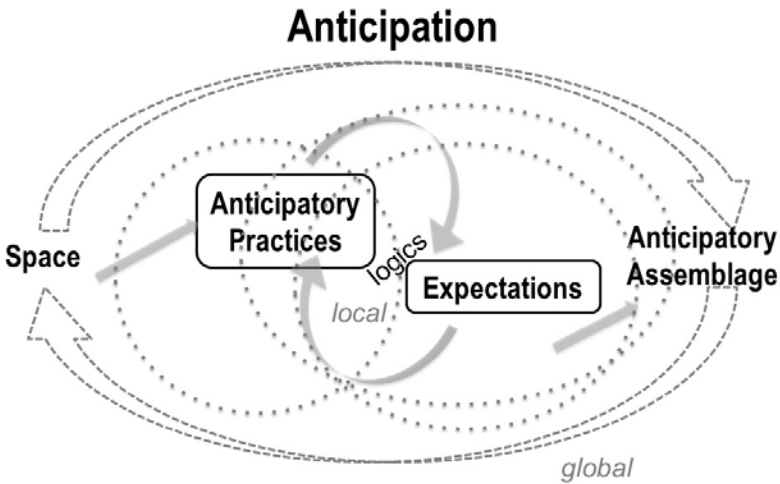


Fig. 2 – Anticipatory Assemblages and spaces. The notion of assemblage accounts for the multiple ways in which anticipatory practices and expectations are arranged, and for their performative effects. These assemblages have effects locally, but as they occur in different spaces, they also result in global effects due to their influence on the relations between these spaces.

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*L'invisibile intersex: storie di corpi medicalizzati* [The invisible intersex: histories of medicalised bodies]. Pisa: Edizioni ETS, 2013, pp. 192

by *Silvia Fornasini and Enrico M. Piras*

**P. Forterre, L. d'Hendecourt, C. Malaterre  
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*De l'inerte au vivant. Une enquête scientifique et philosophique* [From Inert to Living: a Scientific and Philosophical Inquiry]. Paris: La ville brûle Éditions, 2013, pp. 256

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by *Giacomo Poderi*

**Daniela Crocetti**

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We would like to start, if we may, with a critical note: the title of Daniela Crocetti's work does not do justice to the complexity and the richness of its content. Intersexuality and its medicalization are only a part, albeit significant, of a more extensive discourse proposed to the reader, a journey starting from the Classical antiquity and continuing to this day. *L'invisibile Intersex* examines in depth the history of hermaphroditism, intersexuality and DSD (Disorders of Sex Development), the scientific observation of the gendered body, and the social approaches towards gender and bodies. If on the one hand the author has suggested to highlight some intrinsic levels of social perception in the scientific theories of the gendered body, on the other hand she tried to gaze on the experiences related to such scientific theories.

The book is open to a wide range of interpretations. The first, as suggested by the author, is a historical approach that shows the relationships between professions, bodies of knowledge, explanations, classifications, bodies, and their changes in the course of time. If we imagine the book as a play, the first act would take place during the western ancient times, and on the stage we could spot philosophers-physicians discussing on the hermaphrodite, a body where the shape of the genitals does not match the expectations suggested by overall appearance. The second act, that brings the story until the sixteenth century, would show the Church around the hermaphrodite, interested not so much to the body but rather in searching the origin of the "monstrosity" and its moral implications. Only from the third act we could see the medicine appear: it acquires undisputed authority in the field, and uses also deeply invasive methods of inquiry. It is precisely with the arrival on the scene of medicine as an independent science from philosophy and religion that we can strictly talk about medicalization.

With the "gonadic era" (1870 – 1915) medicine, by now a discipline legitimized to discuss about the body, takes an interest in the biological construction of sex starting from hormones, genes and chromosomes, which illustrates the sexual distinction in scientific (and more and more normative) terms. During this period the definition of hermaphrodite itself appears to be disputed: it is first restricted by "pseudo hermaphroditism", and fully overcome by "intersexuality" during the twenties. As the author says, the linguistic change reveals the transition from a classificatory logic to an interventionist one. The surgical techniques allow to act on



the “different” body and bring it back to “normality”. Starting from the fifties and until 2005 the interventions aimed at modify children’s genitals become the main part of a medical procedure, resting on the assumption that a healthy psychosexual development depends on the genital’s appearance. In this third act we can find medical knowledge, or better, several exponents of a more and more specialized discipline (endocrinologists, surgeons) but also of similar disciplines (psychologists, geneticist). Not only the scene became more and more crowded, but the term “intersexuality” is modified in specific syndromes (an explosion of syndromes, as the author explains), until it is replaced by DSD. In the fourth act of our hypothetic play, we would observe the body coming alive on the stage. Patients and their relatives become vocal, show an interest in informed consent and right to information, disapproving the interventionist model and building their presence through the associations, contributing to the advent of the PCC (Patient Centred Care Model) in which patients, parents and doctors are invited to collaborate as experts. We can say that we have seen a transition from a paternalistic model (where patients have no role whatsoever), moving from a period of disagreement, and coming to a condition in which we can speak about expert patients and able to negotiate.

In addition to the historical reconstruction, the readers of “Tecnoscienza” will find in the book some familiar recurring themes, although not addressed by the author through the lenses of the STS debate. To be brief, we will simply considerate only a few.

The first theme is the production of body through the professional gaze. The body is brought into being through a multiplicity of practices: it is sliced, colored, probed, talked about, measured, counted, cut out or prevented (Mol 2002). Each professional community observe the DSD in different terms: surgeons focus on some aesthetic and functional characteristic of genitals; endocrinologists only consider hormones and genetics; gynaecologists are interested just in sexual and reproductive functions; geneticists some selectable markers; psychologists the psycho-social and gender issues; patients and their parents the informed consent and right to information; social scientists the bioethics issues related to gender medicalization.

A second theme is the ethical and political dimension of classification system which often are only partially interested in what is categorized. The book shows accurately how the body of ‘hermaphrodite’ / ‘pseudohermaphrodite’ / ‘intersex person’ / ‘DSD patient’ is an ‘object’ that does not fit a dichotomic male-female scheme. In these cases, to put it with the words of Geoffrey Bowker and Susan Leigh Star: “the individual’s trajectory— [...] — is at each moment twisted and torqued by classifications and vice versa” (Bowker and Star 1999, 324). Daniela Crocetti shows how the ‘torquing’ becomes dramatic when the classification system and surgical procedures are aligned and they allow the success of the interventionist model through which, for half a century, bodies were altered to

make them fit with the predominant classification system.

A third theme is that of the silent bodies that build their voice organizing in associations contributing to knowledge production and sharing, recalcitrant bodies that do not fit in classification schemes that build their legitimacy in the arena of medical experts. The last chapter of the book is dedicated to Italian DSD associations and to the analysis of their role as they gain respect and participate side by side with healthcare professionals. STS scholars will find significant resemblance with the body of work on patients associations and, in particular, with the notion of “evidence based activism” (Rabeharisoa et al. 2013) through which patients’ expert knowledge is transformed into credentialed knowledge.

These three themes are not just what might interest the STS community but also some topics we hope the author will develop in forthcoming publications.

Let us take the last theme as an example. The book focuses only on Italian associations but their relevance could emerge more clearly if compared more extensively with international ones. Another theme that could be further developed are the narratives of the patients which, presented in the frame of medical congresses, lose part of their relevance becoming somehow marginal. In more general terms, while we found the historical part of the work accurate, the last sections of the book does no justice to a 5-years ethnographic work. And we look forward reading more about it.

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**Patrick Forterre, Louis d'Hendecourt, Christophe Malaterre et Marie-Christine Maurel**

*Da l'inerte al vivente. Una enquête scientifica e filosofica* [From inert to living: a scientific and philosophical inquiry]. Paris: La ville brûle Éditions, 2013, pp. 256

**Francesca Merlin** *Université Paris I Panthéon-Sorbonne and CNRS*

This book is quite original in its format. Published in French in the Series “Collection 360” of the publisher “La ville brûle”, it explores the multidisciplinary debate on the question of the origin of life, which is both a philosophical and a scientific question. The general aim of this Series, directed by the journalist Sylvestre Huet, is to offer a plural insight on various issues related to science and society through the direct confrontation of researchers in the natural and the human sciences. More precisely, this Series relies on the idea that scientific questions concern both knowledge and society, and are also a matter of economical and political power. Thus, by offering and crossing different perspectives on a given issue, it aims at analysing the way science, man, and society work together and influence each other.

The director of “Collection 360”, Sylvestre Huet, directly participates to the book reviewed here: he conducts a very successful interview of the invited researchers and succeeds in highlighting the way their thoughts and questions are connected and articulated. To address the question of the origin of life, i.e., the passage from the inert matter to the living, he invites four researchers: the molecular biologist Patrick Forterre, the astrophysicist Louis d'Hendecourt, the philosopher of science Christophe Malaterre, and the biologist and biochemist Marie-Christine Maurel. The diversity of disciplinary affiliations convened for the discussion is the direct manifestation of the interdisciplinary character of the issue at stake: the origin of life is an age-old problem, having received mythological or religious answers in ancient times, which cannot hope today to be tackled in the domain of just one discipline (whether it be biology, chemistry, astrophysics, philosophy, etc.).

The structure of the book is particularly well-designed in order to help the reader to gradually get accustomed to the debate on the origin of life. In this respect, the book is suited to a varied and wide public: some sections are rather technical, but the issues discussed and the general message are easily accessible to any kind of reader. A section composed of short biographies of the four authors opens the book (pp. 11–23). Each of them speaks in the first person about his/her own career: this is a valuable way to provide to the general public, especially young scholars, an idea of the reason why they wanted to get involved in scientific research, of how they became scientists or philosophers, and to give a flavour of the everyday life of people doing science or philosophy as a job. In the introductory section, the authors talk again about their intellectual and professional journey and extensively say why they have been interested in the issue of the origin of life (pp. 25–37). This is also the place for giving a historical overview of the way this issue has been addressed, from its emergence as a scientific question at the end of the XVIII<sup>th</sup> century to current debates in various disciplines (organic chemistry, astrochemistry, molecular biology, synthetic biology, etc.) on prebiotic chemistry, its features, and its role in the evolution of living entities.

The two wider sections – “The scientific debate” (pp. 39–147) and

“The societal debate” (pp. 149–189) – constitute the core of the book. The first is somewhat technical dealing with debates over the emergence of life from prebiotic chemistry, the nature of chemical evolution and its irreversibility, and various hypotheses about the primitive RNA world, the origin of the genetic code, the evolution of cells and of LUCA (i.e., the last universal common ancestor of all living organisms). The second deals with the management of interdisciplinary research about the origin of life, its features and limits, and on the potential relevance of on-going projects such as the exploration of Mars or other planets looking for water. The book finishes with a short but effective conclusion, resuming the main points of the scientific debate and its future challenges (pp. 191–196). An appendix, a glossary, and reading lists suggested by the authors usefully complete the volume (pp. 199–223). I think it is worth reading this book because it offers a panoramic view on the research question of the origin of life: it is a non-partisan introduction addressing multiple aspects of this interdisciplinary issue from diverse points of view.

Let us focus on the core of the book, which covers in depth the main issues researchers have to deal with when asking the question of the origin of life. In the section “The scientific debate”, the four authors discuss in details the main historical and concurrent hypotheses about the origin of life: they raise the question of the source of organic matter on Earth, which could be exogenous (delivered by a meteorite) or endogenous (present below the terrestrial magma); they introduce the controversy about whether chemical evolution preceding life was Darwinian or not; they exchange about the irreversibility of the evolutionary process at the origin of life and on the contingency of its final current result; among other research topics, they also discuss in details the hypothesis of an original RNA world. Throughout all these discussions, two more general issues, respectively a conceptual and a methodological one, are particularly worth of consideration: the issue of the definition of life, and the issue of the method used to address the question of the origin of life. Let us look at each of them.

As the philosopher of science Christophe Malaterre notices at the beginning of the book (p. 26), the question of the origin of life, to get an answer, requires that we know what life is. But the molecular biologist Patrick Forterre replies that most of his colleagues are not interested in defining life (pp. 44–45): it is a question for philosophers; biologists rather prefer to be silent about it and assume that biological entities and processes are living and the result of a historical evolutionary process on Earth which is still going on. This divergence of interests, I maintain, points not only to the difference between philosophy of science and science but also, and mostly, to the kind of relationship between the two. Is philosophical research useful for scientific practice when it consists in clarifying and defining concepts used in science (e.g., life)? In the specific case of the origin of life issue, what would biologists gain in adopting one particular definition of life provided by philosophers of biology? Would

this improve their work or, on the contrary, limit the potential scope and development of their research? The book partly consists in a dialogue between philosophy and science, but does not clearly address all these questions. A deeper reflexion is needed, not only on the relationship between philosophy of science and science, but also and primarily on what philosophy of science is (philosophy of biology, in this case), and even should be: is it different in nature with respect to science or does it produce the same kind of knowledge than science? More explicitly, does philosophy of science consist in a meta-reflection on scientific practice (its epistemic standards and methods as well as its ethical and societal implications)? Or rather, is it involved in the same fight as science, trying to solve scientific puzzles in a more conceptual and theoretical way? These two ways of conceiving philosophy of science are not necessarily incompatible, can coexist, and are indeed both represented in the international community of philosophers of science, in Europe as well as elsewhere. To adhere to either of them is a matter of intellectual attitude about the very nature and aim of the philosophical work.

The other important issue emerging from this section is methodological. As the biologist Patrick Forterre says again and again throughout the book, two approaches are possible in order to investigate the origin of life (e.g., see p. 69): the bottom-up and the top-down approaches. The first consists in trying to recreate the initial conditions when Earth formed in order to find out how organic materials could have accumulated and formed molecular complexity. The second approach starts from the study of currently living organisms and looks for fossils which could allow to go backward into the past. As biologist, not surprisingly, Forterre adheres to this second approach. Actually, the bottom-up and the top-down approaches characterize two different sets of disciplines represented in the book: astrochemistry and prebiotic chemistry on the one hand; biological disciplines on the other. Such a striking methodological difference comes from the specific research objects of these disciplines: the chemistry of inert prebiotic matter and living organisms, respectively. It is also due to the emphasis biologists particularly put on the historical and contingent character of the emergence of life, which can be seen as in conflict with the strict regularity of physical and chemical laws. The main hope, expressed throughout the book, is that the bottom-up and the top-down approaches will converge at some point to deliver a coherent account of the origin of life.

Despite this methodological divergence, later in the book all the authors agree in claiming that synthetic biology does not really contribute to research on the origin of life (pp. 122–132). It is a sort of extension of genetic engineering whose objective it not to go back into the past but to create new evolutionary paths by producing, by tinkering, organisms with new features. Some research programs in synthetic biology also aim at creating a minimal genome or cell, i.e., the minimal set of characteristics common to all living organisms. However, again, this has nothing to do

with the question of the origin of life on Earth because such researches rely on current evolved features of life (DNA and, more specifically, the set of genes characterizing currently living organisms). And even when synthetic biologists try to create forms of life using chemical reactants that probably already existed when life emerged, they do not pay much attention to the question of the original environmental conditions on Earth. They rather create those conditions that are suitable for their reaction, and so lose sight of the question of the origin of life.

The other section constituting the core of the book, “The societal debate” section, is worth reading because it raises general questions about the current features of management of scientific research, in particular the widespread call for interdisciplinarity. A recent issue of the international journal *Nature* (17 September 2015) is devoted to this hot topic, analysing its difficulties and advantages, and shares the book’s analysis in this domain. The problem is that, even though interdisciplinarity has been highly promoted by public and private funders for a few decades, and despite the fact that the reasons why it should be promoted are clear (no single scientific community owns the variety of expertise and skills required to deal with multifaceted questions such as the origin of life issue), interdisciplinarity seems more a fashion than a real scientific project because of the way it is actually applied and perceived. First of all, few researchers actually do interdisciplinary work, which means integrating, rather than just juxtaposing, research in different disciplines on a given topic. Moreover, when the interaction involves the natural and the human sciences, the latter are too often dismissed and considered as having a service role rather than a symmetrical and constructive one: this is not interdisciplinarity at all! Last but not least, the few researchers involved in interdisciplinary research are often blocked in their career precisely because they have scaled disciplinary walls and no instance exists to assess their work and promote them. Moreover, interdisciplinarity undeniably takes more time than disciplinary research because it involves people with different intellectual backgrounds that are not used to work together, often talking a different language and using different research methods. Hence, interdisciplinarity is unfit in the “publish or perish” system dominating science today. So, I fully agree with the authors that this is an urgent problem we all have to address, in particular in order to raise interdisciplinarity in science from a fashion to an actual team work tackling and solving society’s main issues (such as climate change, the impact of new technologies, research on cancer, but also other topics, such as sex and gender issues).

To conclude, I strongly recommend this book because it is perfectly designed in order to deal with the interdisciplinary question of the origin of life, which is both philosophical and scientific, and because of the intrinsic interest of this issue. If I were to mention a weak point of this book, I would say that the only hitch is that it does not give enough emphasis to the economical and political aspects of scientific research on the

origin of life. This is unfortunate because of one of the objectives of the Series "Collection 360", which is to highlight that scientific questions are also a matter of economical and political power. But this is just a trifle compared to the many qualities of the book, most of all, the fact that it raises urgent questions about how and why to promote and improve the relationship between different sciences working on the same research topic. These are timely questions because of the interdisciplinary character several current issues addressed by the society: they concern all of us, whether we are scientists or philosophers, and the lay man above all.

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**Lisa Parks and Nicole Starosielski (eds.)**

*Signal Traffic: Critical Studies of Media Infrastructures.*

Urbana, Illinois: University of Illinois Press, 2015, pp. 292

**Paolo Magaudda** *University of Padova*

The collective book *Signal Traffic*, edited by North American scholars Lisa Parks and Nicole Starosielski, represents a noteworthy and stimulating effort to intersect the study of digital media with the STS-rooted approach of infrastructure studies. In this sense, the book enters a wider space of convergence already under development during these last few years. Indeed, recently we are assisting to the increasing interest in the contamination between STS and a broad area involving media, communication and cultural studies. This has been the cases, for example, of the book *Media technologies*, edited by Gillespie, Boczkowsky and Foot for MIT Press in 2014 and of the workshop titled *Roads Less Travelled. Exploring New Connections Between Media Research and STS*, held at the University of Siegen in February 2015 (see Sørensen and Schubert 2015). Of course, this book adds a further significant contribution to this emerging space of convergence.

Proceeding at the intersection between STS and media and cultural studies, the aim of *Signal Traffic* is to enrich the study of digital media environment thinking to it in terms of "infrastructure", thus considering media primarily as "situated socio-technical systems that are designed and configured to support the distribution of audiovisual signal traffic" (p. 4). In their introduction, editors ask readers: "what can media studies gain by adopting an *infrastructural disposition*?" and consequently the book develops by considering several infrastructural dimensions in digital media technologies, including data centres, digital compression, Internet protocols and environmental consequences of the media infrastructure

nature and so on. Parks and Starosielski offer a comprehensive sketch of how media infrastructures are conceptualized along the book chapters, identifying six main features of media infrastructures that assume relevance in the collection of essays presented: their scale, the relationality of their nature, difference and unevenness in their appropriation, labour and maintenance required to make them working, their relationship with natural resources and, lastly, the role of affects in their shaping.

One of the fundamental dimensions emerging from the book is, quite predictably, the role of materiality in the shaping and working of digital media infrastructures. As it has been also recognized by the aforementioned *Media Technologies*, materiality of media constitutes one of the most manifest levels on which STS and media studies have converged up to now. After several decades marked by a marginal interest toward the ways media technologies are materially embodied in society, communication and media scholars are finally increasingly recognizing this issue as an essential part of the understanding of the media environment.

The framework traced by the editors is obviously far from being an all-inclusive mapping of relevant focal points in the study of media infrastructures; nevertheless editors are able to offer a useful chart to navigate the multiform universe of media infrastructures, giving functional *signals* helpful to the readers to move in an orderly way in the *traffic* of digital media infrastructures. Looking more carefully to these *signals*, many of them are directly rooted in STS and since the introduction, it is easy to recognize how the conceptualization adopted borrows heavily on STS, not just on the works of scholars such as Star, Ruhlleder and Bowker, but also on other references, including ANT, Thomas Hughes's history of large technological systems and feminist science & technology studies. In this sense, the book - and especially some of the chapters contained in the volume - can be read as a genuine outcome of the STS field and especially of the area of infrastructure studies in STS. While there is no space here to enter in the contents of each chapter, I can sum up saying that the eleven chapters offer a set of mainly empirically-based perspectives on different kinds of media infrastructures, including the global undersea cable network, urban media infrastructures, data centres, the internet in Zambia, e-waste, cellular phones in Israel, with multiple chapters understandably devoted to internet protocols.

However, the attractiveness of the book lies not just on the adoption of conceptual tools from STS and their application to an object traditionally belonging to other intellectual fields, i.e. media and communication studies. On the contrary, the richness of the book is located also in the attempt to trace a wider intellectual matrix, enriched also by other influences that can undoubtedly supplement the mainstream STS perspective on infrastructures. Indeed, the book put together other instances coming from different intellectual domains that assume relevance in the overall framework proposed by the volume. Clearly, several crucial inputs are recognized as relevant in the field of media studies, as in the case of the



works by James Carey, Armand Mattelart, Harold Innis and Manuel Castells. In addition to these classical works in communication, the book brings also light on less-renowned areas in media studies, for instance *environmental media studies*, *media archaeology*, *platform studies* and *format studies*. By the way, it is rightly in *format studies* that we can trace back an earlier efforts to mix together the field of media studies with a STS-rooted perspective on infrastructures, i.e. Jonathan Sterne's 2012 book on the origin of the mp3 audio format, in which the author unfolds the infrastructural nature of compressed digital formats. Thus, it is not by chance that the opening chapter of the book after the introduction is by the same Sterne, who presents here a development of his research on data compression, extending his work toward a more general history of digital compression, showing how the process of compression is a circular process, which both adapts media contents to the infrastructure and shapes this same infrastructure in accordance to the need of representation in specific media sectors (p. 35).

Besides these satellite fields in media studies, other influences add interest to the book's overall theoretical picture, including urban studies, "maintenance and repair" and the "affective turn". At this regard, it is hard to resist to play the game of finding missing pieces in the puzzle, so I will not resist to it and therefore give my own contribution, by picking up two further influences that would sharpen even more the theoretical panorama of the book. A first addition would be the tradition of social anthropology and ethnography of consumption, especially in the cases when these areas approached the use of media in everyday life, for instance in the case of the seminal Daniel Miller's and Dan Slater's (2000) research on Internet in Trinidad; this will allow to stress even more the way global infrastructures emerge also from local and very contingent conditions. Secondly, I see fitting very well in the book's approach the perspective on infrastructures in consumer studies, especially through the work of Elizabeth Shove and other scholars on utilities (Van Vliet et al. 2005) and on home technologies (Shove 2002). While these works do not deal directly with digital media, they can anyway offer a relevant add-on to the understanding of the infrastructural configuration of technologies and distributed services in everyday life, especially in connection to the issue, explicitly raised by *Signal Traffic*, of environmental sustainability of media infrastructures.

All things considered, there is no doubt that *Signal Traffic* offers a stimulating contribution both for STS practitioners and scholars in media and communication, adding a valuable voice to the evolving debate on the study of digital media technologies, understood not just as material and isolate phenomena, but as parts of an heterogeneous, wide-ranging and multi-situated network of relationships.

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**Miguel Sicart**

*Play Matters*

Cambridge, Massachusetts: The MIT Press, 2014, pp. 176

**Giacomo Poderi** *University of Trento*

*Play Matters* belongs to the *Thinking Playfully* series of the MIT Press, which is designed to provide readers with short, readable and argumentative books that combine depth with readability. The volume fits well into this series as an agile, yet engaging and thought-provoking manuscript on a topic, the one of play, that has never been so central in the academic debate since the time of Huizinga's seminal work *Homo Ludens* (1938). This is particularly evident in game studies and in those fields of cultural studies or social sciences that recently started facing the need to confront with breakthrough societal changes. On the one hand, pushed by the game industry and by the growth of a widespread gaming/participatory culture, video games became a dominant form of entertainment media; on the other hand, the emergence of strong semantic entanglements and cross-contaminations among different human domains blurred the very meaning of play: (i) game-related elements started entering non-gaming domains; and (ii) aspects which were typically disassociated from games, started converging into that domain, as it is generally hinted by the emergence of areas such as *professional gaming*, *gamification*, *serious games* or

the overall idea behind *playbour*.

In *Play Matters*, Sicart provides readers with “a romantic theory (or rhetoric) of play, based on an idea of creativity and expression that has been developed in the highly post-romantic cultural environment of the early twenty-first century.” (p. 5). By avoiding the instrumental and functionalist view on play that is often pushed by postmodern culture industry, this work offers a theory of play that is based on an ecological approach in which all elements have strong network relations to each other and are not hierarchically structured. Sicart sees play “as a portable tool for being. [Play] is not tied to objects but brought by people to the complex interrelations with and between things that form daily life.” (p. 2). In this theory, play is a 'mode of being human' characterized and performed as an activity which is: contextual, carnivalesque, appropriative, disruptive, autotelic, creative and personal. Throughout the chapters, the author clearly explains the implications of such an approach on the most typical dimensions that play is associated with. For instance, toys – the materiality of play – become “affordances for appropriation” which are hinted at playing and which become fundamental elements for understanding the technological and physical contexts of play. Similarly, Sicart's aesthetics of play is a nonformalist one and goes beyond the exclusive focus on form which is portrayed by many conceptions of aesthetics of play. Indeed, here it is a performative understanding of the beauty of play that comes to the fore: the aesthetics of play “as the action of appropriation and expression of and within a context” (p. 63).

The volume is structured and divided in small chapters each of which frames one of the key elements of Sicart's theory of play. Namely: *Play Is*; *Playfulness*; *Toys*; *Playgrounds*; *Beauty*; *Politics*; *Architects*; and *Play in the Era of Computing Machinery*. The book starts with three independent sections that provide explanations on the design of the book within the Thinking Playfully series, the acknowledgements, and the instructions for reading the book. It also ends with three rich sections related to the Notes, References and Index.

As a critical remark for a book that has been written to be agile to read, the Notes section deserves a few words. Sicart himself states in the opening that the large amount of notes included in this work, it has been purposely intended for making possible more than one kind of reading: one which can focus on the core content of the book, stripped of in-text, unnecessary or marginal comments and one which allows the reader to dwell on many different details, anecdotes and explanations by relying on the notes. Notes are placed at the end of the book, in form of endnotes divided and numbered per each chapter. However, I have found it somewhat unfriendly to move back and forth from the chapters to the note section, in order to find the proper note among the various ones. Endnotes at the end of each chapter, or even notes numbered progressively for the whole book could have been a much more usable and accessible way to include notes.

Finally, the book seems to be written with practitioners and academics who focus on games and playful dimensions of human endeavours as the key target audience. However, the language is very simple and the use of jargon is basically non-existent, which makes the book accessible to any kind of reader. I found particularly intriguing how Sicart manages to provide a theoretical account of play which is clear and effective in its structure and, at the same time, clearly detaches the activity of play either from the concept of game and of playfulness. Conceptually, this is a sound move that, in my opinion, makes of his work a useful lens for framing, studying and talking about the entanglements mentioned above in the opening of this review.



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Cover Dispatchwork by Jan Vormann

**Special Issue: Maintenance and Repair in STS**

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## Book Reviews