Making the future palpable: Notes from a major incident Future Laboratory

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ABSTRACT

Future laboratories allow users to experiment with future technologies in as realistic as possible conditions. We have devised this method because, to realize the potential of ubiquitous computing technologies it is essential to anticipate and design for future practices, but for prospective users it is often difficult to imagine and articulate future practices and provide design specifications. They readily invent new ways of working in engagement with new technologies, though and, by facilitating as realistic as possible use of prototype technologies in Future Laboratories designers and users can define both opportunities and constraints for design. We present 11 scenes from a Major Incidents Future Laboratory held in September 2005. For each scene we point out *key results*. Many raise tough questions rather than provide quick answers. In the discussion we summarize important lessons learnt.

Keywords

Ubiquitous computing, future practice, emergency response

INTRODUCTION

Ubiquitous computing refers to the fact that computation is increasingly embedded in small and large devices (biomonitors, mobile telephones, personal digital assistants, ambulances) and dependent on digital services (connectivity, storage, geographical information services (GIS), location tracking). Ubiquitous computing technologies have enormous potential to support (new forms of) emergency response work. Resources like ubiquitous connectivity and location information, combined with sensors, wireless communication, displays, or data devices like cameras, etc. could enhance people's ability to make sense of emergency situations, to formulate an appropriate response and collaborate with colleagues – both on the scene and remotely, in hospitals, and incident control rooms. However, the urgency of emergency situations makes invention and adoption of new technologies and new practices hard to realize. Two issues in particular hamper innovation:

- *Future practice*. In interaction with new technologies people change established practices. Unpredictable and sometimes unintended consequences ensue. Future technologies should anticipate and support new ways of working. Yet, it is impossible for designers to predict future practices and consequences of change. As realistic as possible experimentation is required. This general challenge is exacerbated in real life emergency response work where there is little room for experimentation.
- *'Invisibility'*. Weiser's 'invisibility' principle for ubiquitous computing (1991) prompts many designers to make computing literally invisible by embedding it and by automating processes e.g. of establishing networks. This protects people from complex choices, but it takes the human 'out of the loop' (Endsley, Bolté and Jones 2003) and makes it hard for people to know what technologies are doing and to trust them.

We carry out field studies, and take a participatory design approach (Grønbæk, Kyng and Mogensen, 1997) to address these difficulties, bringing together an interdisciplinary team of practitioners, designers, and work analysts to design ubiquitous computing technologies for a range of different domains. Researchers/designers have to understand existing and future work practices, as they create prototype technologies, while professional practitioners take part in analysis/design and explore new ways of working. Currently, our main design goal is to provide infrastructural support for making ubiquitous computing 'palpable', that is, 'noticeable, 'manifest, obvious, clear' (http://dictionary.oed.com/). In other words, we seek to enable people to put themselves in the loop where computational processes and services are concerned. The work described in this paper is part of a project called PalCom, which pursues this goal (http://www.ist-palcom.org).

Supporting the work of emergency response personnel is a particularly fruitful part of this work, because there is a clear potential for ubiquitous computing to augment the work and a need to be understand and trust the technology. To maximize the 'hard test case qualities' of emergency work for design, we focus on 'major incidents'. Within Europe, major incidents are declared when massive damage to persons or property is caused or projected. They require collaboration between different emergency response agencies (police, fire services, hospitals, etc.), giving rise to many uses of ubiquitous information and communication technologies.

METHODOLOGICAL BACKGROUND

Within socio-technical innovation in general, naturalistic experiments with new technologies have been used productively. They can inspire ideas, but also function as 'breaching experiments' (Garfinkel 1967) that draw the practices on which participants ordinarily depend to the designers' attention. In one of our examples below, we see, for example, how cumbersome a request like 'take a picture of that victim' can be when one of the speakers is only virtually on the scene and neither knows what the other can see or where s/he is looking.

Within participatory design, approaches such as co-realization (Hartswood, Procter, Slack, Voß, Büscher, Rouncefield, Rouchy 2002) draw experiments, analysis and design inside the process of socio-technical innovation, helping greatly in producing viable and desirable innovations. However, this approach is difficult when more futuristic socio-technical imagination is the goal. In particular, experimentation and futuristic imagination are highly desirable, but impossible to achieve in the context of real emergency response situations. Seen from a practitioners point of view, training exercises are well known and well used, both regarding everyday response and major emergencies, but they are designed to hone use of existing technologies and established ways of working rather than explore the potential of new technologies and new practices.

To facilitate imagination and experimentation, we have devised the method of Future Laboratories. Future Laboratories introduce functional prototypes into realistic enactments of work. They foster the emergence and exploration of new ways of working – not only through discursive 'what if' scenarios, but also as practically discovered, often tacit but observable possibilities. Ideally, the practitioners should be experienced professionals.

THE MAJOR INCIDENTS FUTURE LABORATORY

The major incidents Future Laboratory took place over two days in September 2005. It generated a host of design ideas and activities, described elsewhere (e.g. in Kramp et al. 2006, Kristensen and Kyng 2006, Büscher and Mogensen 2007). It was the first major incidents future laboratory, and the first time we experimented with the prototypes and mock-ups[1]. The first day was held an a training site for emergency response personnel – an area where car accidents, building fires and other incidents can be staged (Figure 1). The participants included 14 researchers, 10 practitioners and 3 'victims'. We started with a short introduction in a class room, then moved into the grounds, where we had staged a car accident (Figure 1), to explore – hands-on – 11 incident 'scenes', planned beforehand. The professionals had brought new radios they wanted to test and, with the help of researchers/designers, they used the PalCom prototypes and mock-ups at the 'accident site' and in an 'Acute

[1] We seek to develop technology to support all the agencies involved in the emergency response effort: police, firefighters, ambulance people and medical teams (doctors and nurses) and all levels of the hierarchies in the emergency response. At the time of the future laboratory described in this paper, we had mainly realised prototypes for the medical staff, but were starting to move into development of technologies also to be used by the police and firefighters. Our location within this overall design process is reflected in the (im)maturity of technology development and the focus of the future laboratory.

Medical Coordination Centre (AMC)' which would normally be at the hospital, but which we had set up in a barn close by. Responders from all major incident agencies participated in the Future Laboratory.

While our main focus is on major incidents, our technologies must also support response to everyday incidents: One key insight from our field studies is that new technologies should not only be used in major incidents situations – they also have to be used and be useful in everyday situations. This – together with the level of maturity of the prototypes – informed the set-up in this first major incidents Future Laboratory. Below we describe the prototypes and the accident set-up, followed by analysis of 11 Future Laboratory scenes – where professionals enact realistic work, using prototype ubiquitous technologies, designed to allow staff to make their functioning 'palpable'. Key results are highlighted after each scene.

Figure 1 A car accident staged at Aarhus 'Brandskolen'. Source: http://www.aarhuskommune.dk

The prototypes and the set-up

To make realistic enactment of work possible, we set up an accident, where two cars have crashed and one has spun several meters away through the impact. There is one severely injured person trapped in the car shown in Figure 1. Petrol is spilling out of this car, which means only specially trained rescue personnel will be allowed to approach it. The other car carried two persons. The passenger has been thrown out of the car and lies, heavily injured, on the roadside. The driver managed to crawl out into the road.

A passer-by has called 112 (911) and the emergency responders arrive at the site. At the hospital AMC is activated, meaning the doctor there opens her connection to the emergency responders and the technologies at site: She can see live video from the scene, she receives pictures of the injured persons, taken by staff on the ground, she can speak with personnel, e.g. the medical responders and she receives signals from biomonitors mounted on injured persons.

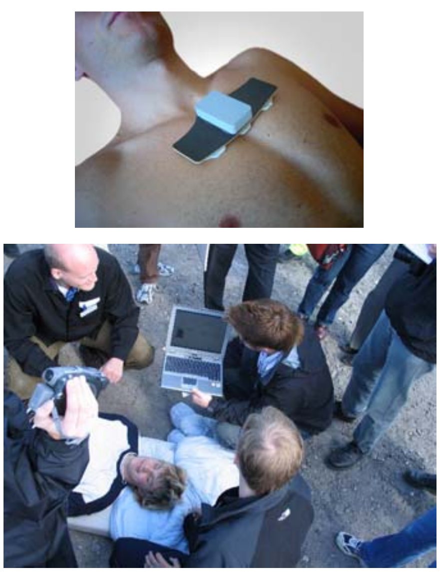

Figure 2 A wireless biomonitor prototype, its data inspected on a 'wearable' display.

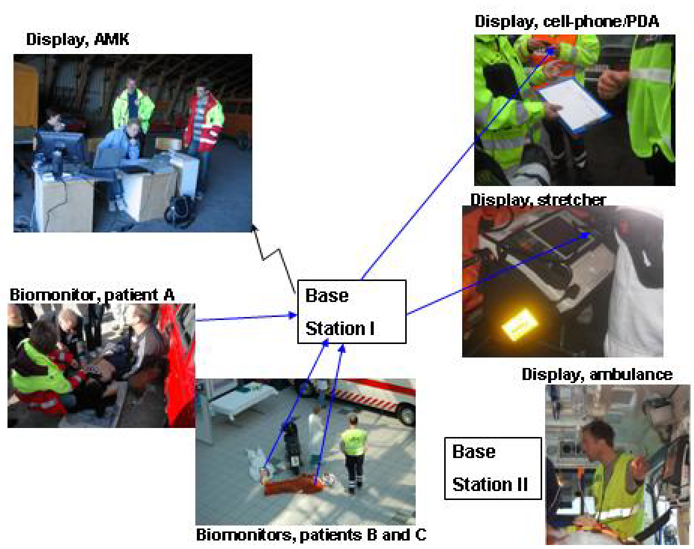

Figure 3 The wireless bio-monitoring system.

To realize a prototypical technological future the researchers/designers set up or brought:

- A wireless network
- Wireless biomonitors (Figure 2)
- Wearable displays (these are simulated by portable PC's)
- Basestations (relaying communication from sensors into the network)
- Still and video cameras
- Mobile phones
- Radios

The wireless biomonitoring system comprises a wireless biomonitor (Figure 2), basestations and connectivity. It works as shown in Figure 3.

As a biomonitor is mounted on a victim, it collects bio signals from the victim's body by use of sensors. The collected signals are – via BlueTooth – sent to a basestation – a computer that can store those signals. From the basestation (and, within a radius of about 100 meters, also by use of Blue Tooth) the signals can be shown on any number of displays. One can see data from all patients on one display or focus on the data of individual patients. In the Future laboratory we had three biomonitors and two 'wearable' displays (simulated by laptops). The data can also be accessed elsewhere, e.g. at hospitals (in AMC or the emergency department) using existing networks such as WIFI, GPRS or ad hoc networks. In the future laboratory a wireless network was used to communicate to the AMC.

A video camera is mounted on one of the 'response vehicles' nearby (in the Future Laboratory this was simulated by a car wreck in the training area, but in 'real life' the camera is meant to be on a telescopic pole on the roof of an emergency vehicle), and live video is transferred to the AMC. Moreover, one of the researchers takes pictures, including pictures of injured persons. In the Future Laboratory a digital camera was used, but in future cameras could be embedded in helmets or glasses, so that the action 'taking a picture' could be done by looking at the point of interest and pushing a button. The process could also be automated – taking pictures at specified time intervals, for example. These pictures are also transferred to AMC (Figure 4).

Figure 4 The 'Overview' relayed to the AMC, and a researcher taking pictures of victims to send to the AMC.

In addition, all the professionals brought mobile phones. They were used for communication (e.g. between the incident site and AMC). The professionals also brought and tested a new radio system for communication across distances and at the incident site.

Exploring socio-technical futures of major incidents work – 11 scenes

Scene 1: Multiple teams arriving

The police, the medical team and the fire service arrive at the scene. They bring with them different kinds of equipment such as wireless biomonitors, wearable displays, cameras, mobile phones, radios and video cameras.

Key results: Enactment and verbal accounts of what would happen if this was real combine and 'take' people 'into the scene', enhancing the realism of this future populated with professionals and future technologies. During a think aloud session researchers and professionals discuss what each group/person would do in this situation. What is needed in terms of information and equipment?

Scene 2: Forming a first picture of the victims

The medical team forms a first picture of the victims on the roadside by examination. In this way they judge who needs help first. One of the victims lay on the ground on his back, the other facedown.

Figure 5 Wireless biomonitors are placed on the injured persons.

Key results: The discussion focuses on whose responsibility this task is: If the doctor is there the responsibility is his/hers. If not, it is the ambulance staff that is responsible. Hands-on experience provides insight into the handling of monitors. An important discussion develops regarding where to place the wireless biomonitor – theoretically it can collect data, no matter where it is placed on the body, but during this hands-on session we realize that it should probably not be on the back since almost all injured persons are placed on their back during transportation.

Scene 3: Patients in dangerous situations

The doctor cannot get close to the injured person trapped in the car, who is also threatened by leaking petrol. The fire fighter places a biomonitor on him. If this was a real situation, he would be wearing thick, heat resistant gloves.

Figure 6 The victim trapped inside the car

Key results: An expansion of the discussion regarding responsibilities begins to explore important questions:

Is it realistic to expect firefighters in a real major incident situation where medical staff are unable to get to injured persons (e.g. in a train), to mount wireless biomonitors? If this could happen – what influence would it have on the emergency response organization and process, regarding division of work, responsibility, accountability and continuity? How would one know from a distance that the biomonitor is working? Taking a more technology focused turn, the discussion explored how biomonitors could be inspected on site and remotely. Moreover, could biomonitors be designed to be more 'foolproof' and robust in terms of the:

- casing that protects their 'insides'
- connections they need to the victim's body
- connectivity they need to be a part of PalCom assemblies?

Scene 4: Collecting information for an overview

The doctor creates connections between his wearable display and the biomonitors.

Figure 7 Linking biomonitors to a wearable display (here a laptop carried by a researcher/designer)

Key results: A series of questions emerged when the professionals tried to establish connections and use the information. For example:

- How does one establish the connection?
- How does one know the connection is working?
- What if there are a number of different biomonitors?
- Are pictures a good way of identifying injured persons?
- What should happen automatically and what should the doctor (or others) do explicitely?
- How should data be presented in the overview and for individual patients?

Moreover, it became obvious that personnel working with injured persons should *not* access their wearable display with their hands – the hands are needed for other work.

Scene 5: Cordoning off the area

The professionals describe and demonstrate how they would cordon off the area and police the boundary

Key results: The professionals had found different movable marking materials. It is common practice to use large cars for cordoning off. However often there will be shortage of responders and equipment, so that other solutions should be investigated. This led to a discussion of ideas that could exploit and augment material practices and material objects to support and police the structuring of the incident site (Büscher and Mogensen 2007).

Scene 6: Freeing the victim trapped in the car

The doctor works with the firefighter to ensure the person is harmed as little as possible in the effort of freeing him from the car. However, the doctor must work from a safe distance, as fuel has escaped and sparks may trigger a fire.

Figure 8 The doctor working with the fire fighter to free the victim from the car

Key results:

- How does the doctor use the information s/he receives from the wireless biomonitors, if s/he is not right beside the injured person?
- What other information does s/he need? How much can intelligibly be displayed on the screen and how?
- Could an audio-visual link between the doctor and the victim be useful? Perhaps a link that shows the doctor what the firefighter sees, using the camera embedded in the fire fighter's helmet?
- If the alarm is coming from a distant source (even a few metres away), the receiver should have some local notification – a beeper, message on radio?
- Should there be audio-visual links to the hospital trauma unit?

Scene 7: Patients' conditions change

As the doctor is treating one of the injured persons, the status of another, who is out of sight, worsens. The biomonitor data reflect the change.

Key results: A discussion of how the the medical team should be supported in perceiving such changes raises a number of important questions:

- Should people routinely monitor all data? How?
- Should there be alarms? How would they be triggered? A system could not easily 'know' when a change is critical. After an accident bio-data that would normally be considered critical (e.g. bloodloss) may not seem critical. Dynamically determined thresholds were discussed. They raise issues about who would do the adjusting. If it was done automatically, how could staff be sure that the levels are correct?
- What form should alarms take in a stressful environment that is already saturated with stimuli?
- What actions are to be taken? Who is to act? What support for coordinating action is available?

Scene 8: Technical failure?

Suddenly the doctor does not receive data from one of the biomonitors.

Key results: The professionals check potential causes and discussion reveals a number of further possible reasons for the lack of data. The person may have died, the monitor may have fallen off, there may be a loss of power, system failure, the network could be down, … (Büscher 2007). The question is how staff could be supported in finding out and addressing the problem. Data streams should not simply stop but document their ceasing according to the cause. Moreover it becomes clear that it will *not* be the professionals on site that can analyze and solve the problems. It is suggested that a person off-site could be responsible for remote inspection and repair. However, an on-site presence of technical responders – already introduced by some large disaster response organizations – seems highly desirable.

Scene 9: The ambulance stretcher

While the patient is moved onto the ambulance stretcher, the data from biomonitors is still received on the doctor's wearable display.

Key results:

- Should there be automatic changes to subscriptions? That is, should data now be displayed on the paramedic's wearable display? On the screen inside the ambulance?
- Should the doctor be notified of the change? Should his subscription be terminated?

Scene 10: Emergency room

The patient arrives in the emergency room with biomonitors, evidence of emergency treatment (e.g. intravenous fluid infusions, neck-collar or bandages) but with very limited records/documentation and a temporary ID.

Key results: Since it is mainly the on site emergency response effort we focused on in this future laboratory we had not established an emergency room setting, so this scene is only discussed, not enacted. Nevertheless important questions were raised:

- How to switch assemblies and subscriptions for data transfers between pre-hospital and hospital systems?

- Should the wireless biomonitor also be used within the hospital setting?
- How could emergency room staff prepare to receive injured persons? – Which information would help?

Scene 11: In AMC at the hospital

For each of the scenes above, Erica, the trauma doctor, was in the AMC. She remotely participated in the activities on the scene and joined all discussions, providing valuable insights from the AMC perspective.

Figure 9 Discussion of events seen from the AMC perspective

Erica's job is to coordinate the transport of victims to hospitals that have the capacity and specialists to deal with the victims' injuries, and to prepare the respective trauma teams for the arrival of the patients. Below we describe key moments in her collaboration with the staff on the scene and her use of the prototypes.

Erica gains a sense of people's injuries from the data she receives from the incident site. On the screen in front of her she sees live video from the scene (Figure 10, left). The camera was mounted on one of the 'response vehicles', and – in communication with Erica – a researcher/designer acting as a 'remote controlled motor' moved it to show an appropriate overview (Figure 10, right).) Erica communicates with her colleagues via radio.

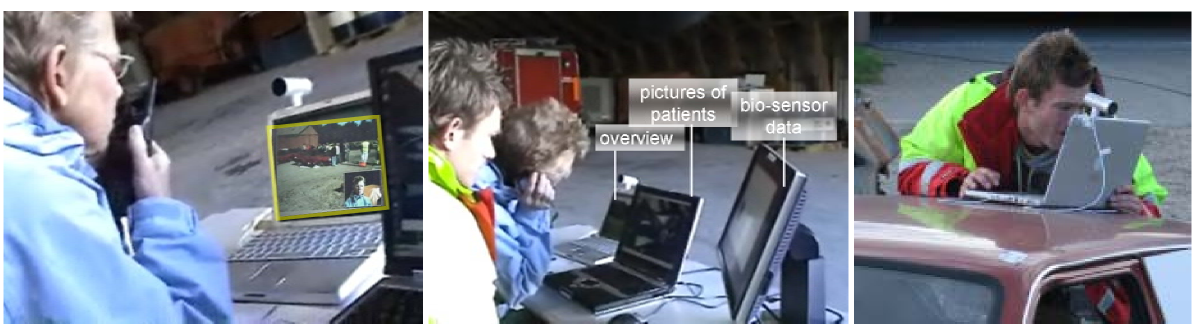

Figure 10 Erica in the AMC, working with colleagues on the scene. A researcher/designer moves the camera.

She has two more screens with pictures of patients and data from the biomonitors placed on victims (Figure 10, middle). Initially Michael, a researcher/designer does takes pictures of victims on the scene. Erica finds it necessary but difficult to know where the victim is located in the video overview, because, while she can see where Michael is taking pictures, their arrival on her screen is delayed (due to a design flaw discovered as a result of the future laboratory). Moreover, Michael is photographing whole victims' bodies, but Erica needs close-ups to see the nature of the victim's injuries. At the discussion after Scene 2 ('Forming a first picture of the victims') she asks whether one of the medical team could take pictures instead. Troels, the on-site doctor, agrees to do so. This provides Erica with a better sense of the victims' injuries. However, in order to tell Troels what she needs to see, fairly cumbersome communications are required:

Yes… Ok…now I received one ((picture)). He lies with one arm under his head and dark hair …

As Erica requests more and more specific pictures, Troels is getting stressed. He needs to treat the victims, not just take pictures of them. He puts his radio in his pocket. Erica notices this on the video overview. She recognizes that she can use the video to find out when it is appropriate to disturb Troels, and when not.

Key results: Scene 11 was carried out in parallel with all other scenes with common discussion regarding AMC after Scene 10. The participants agreed that being able to see the incident site and the injured persons and their biomedical data gives the AMC physician a valuable basis for coordinating work across hospitals. The experience points to design opportunities which Erica summarizes thus:

> *What I need is that I can use [and remote control] the camera myself …. when I get pictures of individual patients, I need to know how [where] are they [located] in the overview? Then I need some identification of the patients because when I say 'oh this was the dark haired guy and this was ...' [it can be difficult for others to know which victim I mean]. And then one thing that is very good is that I can see if the doctor is very busy and then I'll not call him, [knowing that] he's not able to talk to me.*

Moreover:

- Information from biomonitors, video, location information, still cameras, and communication channels should be linked. For example, when selecting an image of an individual patient, the biomonitor data of this patient should be highlighted. The location of this patient should be available. Communication channels (if available) to personnel currently dealing with this patient should be visible.
- The video overview and the data for individual patients creates a sense of involvement and a desire to help as well as a demand for more information. This seems difficult to integrate into the frantic work on the incident site. Moreover, such remote collaboration could complicate the production of situational awareness. However, it *could* be a vital component of the response effort, making the AMC doctor a resource that – because of the distance – can 'keep cool'.

DISCUSSION - SUMMARY OF LESSONS LEARNT

On the following day we split into a researcher and a practitioner group and identified a set of key insights from the different perspectives, before meeting in plenum. The Future Laboratory produced insights and experiences otherwise very hard to gain and allowed us to share them across the team. As staff appropriated the prototypes a host of issues arose concretely, with many pointing to a need for further research:

- The physical design of the wireless biomonitor should be flatter and use softer material.
- Without doubt technologies need to support people in making their states and processes palpable, or to put themselves 'in the loop' (Endsley et al 2003). While staff on the scene of an accident may be too busy to notice and attend to failures of assemblies and opportunities for better kinds of assemblies, staff elsewhere may be able to address some of these issues. Technologies should facilitate inspection, assembly and repair remotely. Such practices require a live representation of assemblies. How this should be realized needs research, as does the collaboration between technical personnel and the professionals on site.
- Bringing the AMC closer to the incident site supports communication and collaboration, but
    - it is difficult to refer to things and patients economically and intelligibly across different spaces. Use of pictures seems useful, but how should pictures be taken?
    - intervention from 'outsiders' (e.g. AMC doctor) could seriously complicate the production of situational awareness.
- It is difficult to notify people of relevant events in appropriate ways and at appropriate times. Research into sense-making practices in stressful situations, and how alarms may fit into these is required.
- It is necessary to explore how wireless biomonitors would be used: How should they be kept before use? What happens when a biomonitor is taken from the bag (?) by a doctor (?)? When is it turned on? When does it connect, to which display? How is it connected to person IDs, location information or pictures? (A separate workshop on this has informed design and will be reported upon in due course).
- If assemblies are automatically established, the professionals need to know whether connections and services have been activated, whether they are (still) working, and which elements belong together. In an assembly of bio-monitors and an ID tag on a patient, how could one be sure that they are in one assembly

(and not sending the heartbeat to the display of the patient on the right). One example we explored were patterns of synchronized blinking (known from marine buoys) (Figure 11)

Figure 11 Bio-monitors blinking in synchronized patterns.

- We should investigate in-hospital efforts, especially the transition and transfer of responsibility for patients, and the change from temporary identifications and rudimentary records to more accurate information.
- In interaction with the new technologies existing work practices change, and ongoing evaluation is needed
- Further research into how the information from the scene can be utilized for situational awareness is needed (Büscher and Mogensen 2007).

CONCLUSION

Future Laboratories, as a part of a participatory design process, are an extremely powerful way of bringing reality and visions of future desirable socio-technical integrations together. By enabling hands-on, as realistic as possible, *experience* of such socio-material-technical integration, Future Laboratories provide insight and knowledge that could not be obtained through discussions or "play" around a table. Most importantly, they give rise to the intuitive, embodied (i.e. more than discursive and rational) invention and exploration of potentially viable future practices emerging around future technologies.

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