Submission 1

Inventing the Future of Cognitive Work:

Navigating the "Northwest Passage"

Introduction

Computer scientists, engineers, managers, and practitioners make claims about how new technologies will change cognitive work—how workers in various fields of practice solve problems in analysis, fault management, control, coordination, and replanning. When systems are built and fielded based on these beliefs, the actual effects on practice, including new forms of error, are quite different from what was envisioned as users workaround complexities or exploit new capabilities. The gap between hopes and reality in the changing the face of cognitive work arises for 2 factors: (1) because claims for new technology ignore the research findings of the field of Cognitive Systems Engineering on how people cope with complexity and (2) because advocates for new technology are trapped in a narrow range of possible expressions of the new capabilities relative to the demands of cognitive work. Since design methods have not had the desired impact of guiding designing in the context of cognitive work, the voyage of discovery that should follow from insight though research has been limited. Concepts were identified, but their implementation into the world of practice calls for an extended presence of design thinking in technology application – one that is human centered, not technology oriented.

This research has examined how technologists envision the future of cognitive work and found a variety of oversimplifications that narrow the process of discovery. Based on these results, the paper proposes an integration of methods from Cognitive Systems Engineering and Design Innovation for finding promising directions. The integration, or de:cycle, coordinates three roles (and associated processes and artifacts produced through these design processes): practitioner—how they adapt to complexity, innovator—how they envision what would be useful, and technologist—how they bring the anticipated change into the world of practice.

Finding promising directions is like a voyage of discovery, such as the famous historical search for the Northwest Passage from Europe to Asia. In our case, the goal of discovery is to create potential leverage points and to chart the space of potential leverage points where technology change will support the changing face of cognitive work. This passage is the most intangible sequence in software, engineering and creative design in the ongoing search for affordances between future practitioners and environment under design and for design seeds that represent promising and reusable directions.

The integration uses storytelling concepts to forge a collaborative synthesis across pools of technological possibilities, pools of experience in the field, pools of patterns abstracted through observation. Since designs alter the very situation targeted by developers and the changed practices reshape the artifacts designed, a dynamic

balance across these 3 pools of resources can guide the discovery process even when the ultimate target of “human-centeredness” is as elusive as the Northwest Passage.

Approaching the discussion about design lead by cognitive systems engineering specialists from the perspective of industrial design brings with it a set of observations that reflect on what identifies the expertise of designers. Given that researchers refer to a knowledge base in their field, for example the knowledge base in cognitive systems engineering about how people cope with complexity, the question of how to represent knowledge bases in general lead us to examine how design work is conducted in the context of cognitive systems. . Cognitive systems are work environments that support practitioners in monitoring, controlling, or taking actions in the world. Examples for such environments are flight decks, control rooms for power- or processing plants, and the technology provided in medical settings. All these settings have in common that the practitioners are highly trained specialists, that the applied technology is assumed to be at the most sophisticated level, and that failures have serious consequences. Design work in contexts under these conditions is conducted by many design specialists collaboratively, each one of them carries the label designer in one way or the other, and as the design situation provides various challenges in transition while it proceeds towards a better future, so do responsibilities change by the different participating designers. Making the design process tangible in converging the perspectives of design from the point of view by practitioners, innovators, and technologists presents a rich structure of relationships between differently trained experts, and, so we hope, sheds light on how designing could be represented as a field of expertise that helps Identifying which aspects of design may be attributed to knowledge, skill, and expertise.

Design in technology intense development projects

Designing is concerned with change (Jones, 1970). Change can take the shape of technological innovation in order to provide practitioners with some notion of ‘more’ or ‘better’ support to interact with the world. Crucial is the nature of expectations – the question if ‘better’ from the point of the designers correspond to a ‘better’ from the point of view of those who will interact with the new designs in the future. Participatory design techniques have been developed over the past three decades to involve practitioners as designers into the design stages of defining what the desirable future is into which designers turn the existing situation.
Understanding the relationships between practitioners, technology, and the world has been the mission of work studies from the late 1960s on. Scientist-researcher have approached the study of design in the field from different perspectives. The human factors research approach has explored controlled laboratory environments, and many of the studies about performance and limitations originate in verification interests. Cognitive Systems Engineering specialists have developed applied techniques to study the nature of operation in the field of work, interested in observations that indicate directions for the future and understanding the nature of human/machine interaction. One finding crucial to all design positions is the long term effect of innovations, or the reverberations of change introduced by novelty – the very intent of design, which may have observable in expected short term effects, or take the form of quite unexpected long term behaviors.

Technological innovation may improve the nature of work, but besides that does change the way people may engage in tasks as they adapt to and modify new technology.

Much of the discussion that elevates technological intervention into the one possible format to introduce change is characterized by overconfidence in that technology will handle any new complexity encountered in the world. While generously introducing novelty into a working environment,problem solving by practitioners in analysis, fault management, control, coordination, and replanning is expected to remains unchanged and gets ideally dramatically improved. The introduction of new technology, however will alter the world of practice, and in responding to that situation at the core of the original design intent, may well have introduced new complexities. (Winograd, T. &Flores, F., 1986). Technological change may do more or less than was expected by its release into the field of work

Ill-centeredness of technology design approaches

With the development challenges of introducing new technology arrives a wide range of in-depth trained designers of various specializations. According to Alexander's thoughts about the role of design in traditional environments (Alexander, 1976), broader fields of technology demand a wider spectrum of specialists, and will re-define design work.
With the arrival of radically new technological capabilities, traditional responses to challenge are prone to ill-focus the design situations.
Software designers, interaction designers, and information architects have entered the arena of the classic design fields to respond to the complexities and freedoms provided by computerized systems. A heavy technology focus transfers design responsibility from the generalist (or the counseling role of the court-jester) into that of the alchemist. Technology intense design work can only be conducted with the support of further specialized designers from the engineering fields, prepared to handle complex technological implementation environments within changing specifications and guidelines. This provides for plenty of uncharted terrain in regard to knowledge of how novelty will play out.

Designers trained outside technology programs are as a consequence generally absent from technology intense development projects. Here, technologists produce working solutions with the danger of not utilizing the unconventional, or creative aspects in designing that designers prefer to mystify, and so the future becomes sometimes predictable.
Technology-centeredness, as well as designer centered design pose the danger of not addressing the practitioner's position in regard to introduction of change by design. This becomes critical where new technology is not optional but crucial to confront tasks on the edge of human skills and capacities. Practitioners have oftentimes no choice in regard to which designed artifacts to utilize – full attention is typically focused on their performance as specialists confronting problems that have consequences. Artifacts in the field of work get either used successfully – and only then they truly support, are modified, worked around or thrown away. Practitioners are not just users.The gap between hopes and reality of design intent becomes apparent as claims for new technology ignore the research findings of the field of Cognitive Systems Engineering on how people cope with complexity.

Advocates for new technology are trapped in a narrow range of possible expressions in regard to how novelty will play out, as they are unable to cast the effects of unconventional possibilities into the future. The white map of design exiles outside the grasp for predictable outcomes. The systematic technology development models do not account for the creative stages in design where the design space is explored, possibilities are envisioned, and promising directions are scouted.

The de:cycle as an integrative model for design expertise

Design activity, to be able to respond to the challenges provided by the call for novelty, needs to seek for an organizational structure that coordinates experts at three core stages in design – observe, explore, create - to provide linkage points between traditionally divergent areas of innovation – between the separated pools of research patterns, technological possibilities, and experience in the field. We propose the de:cycle as an integrative model. Three design roles provide their perspectives, associated processes and artifacts in regard to the future under design: practitioner—how they adapt to complexity, innovator—how they envision what would be useful, and technologist—how they bring the anticipated change into the world of practice. Three design stages intersect, and design activity within them is conducted in parallel – which provides for numerous interactions across the de:cycle's center where the future of the design is located.

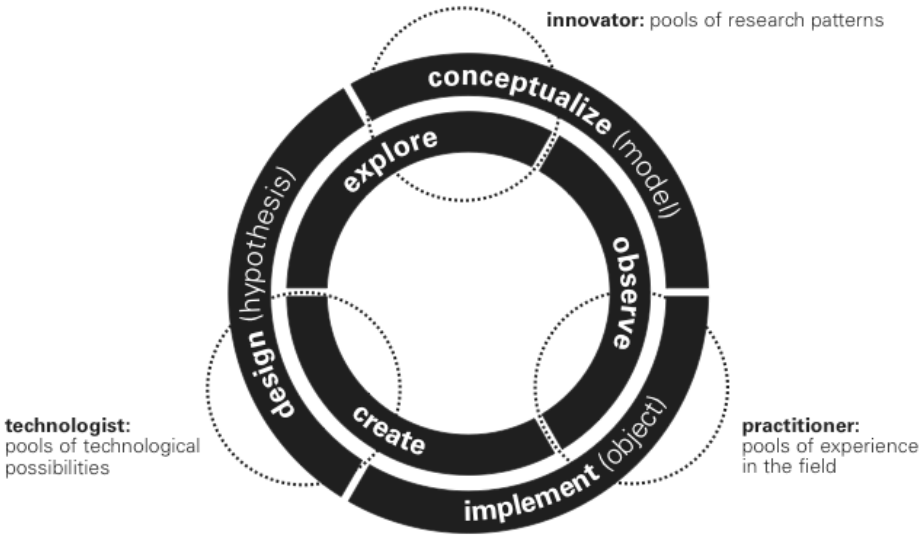

Figure 1: The de:cycle – The three roles in design and their respective interests and expertise. Clockwise moves the analysis of design, as origins are identified, counterclockwise moves design synthesis, as objects are created.

The design focus that is projected with the de:cyle focuses on the perspective of the practitioner who will eventually integrate envisioned technology with the real pressures and demands in the field of practice. The human centered perspective in design reminds that technology provided by design is a shared representation of consent between practitioners, innovators, and technologists. Such design provides the appropriate kind of functionality as it reflects demands and capabilities in the world. It takes into account the skills, knowledge, and expertise of those who work with the provided technology. It represents the utilization of the full scope of possible change. The new design adapts into the context of a world that has previously existed and is now changed by innovation.

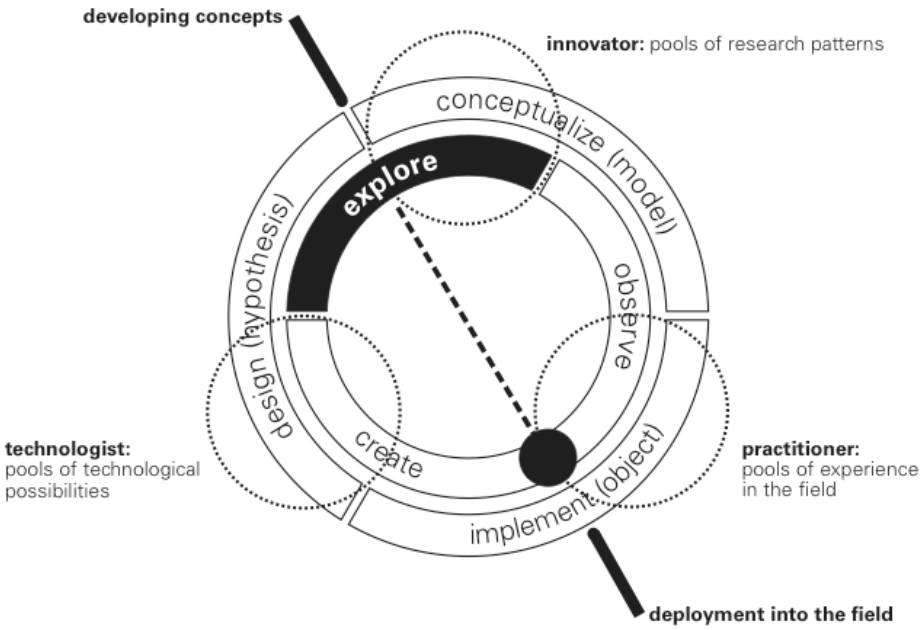

Figure 2: Human centered design: Designers develop concepts focusing on the effects of design change for practitioners in the field

Envisioning the future of cognitive work

Designing is to formulate hypotheses about change in the future relevant to the situation under design. Its basis rests on insight about the situation at hand, and its realization depends on the provision of means to bring the anticipated change about (see also Jones, 1970). Designers start with envisioning the future in making assumptions, estimates, and claims about the effects of various approaches to change. To be grounded in the specificities of the situation under design, the claims need to be in correspondence to an abstract model that represents how the situation under design works, is made, and how it is anticipated to react on changes made within it. Oversimplifications at the foundation of claims and assumptions are a design necessity and may sometimes turn out as designer-error. They can be found in the stories that are told to represent the design to come to others. Developers, for example prefer to tell god's eye view stories of their designs in best-case scenarios. Practitioners, in contrast, refer to expected performances based on their experience with past systems from an in-scene point of view – a perspective that cannot access all options provided, since the entire performance range of the new system is partially obscured. Woods and Dekker have found four classes of oversimplifications that pose the envisioned world problem (Woods, D.D. &Dekker, S., 2000): groundedness, calibration, underspecification, and plurality.
In order to avoid and recover from oversimplification fellacies, designers need to have access to corresponding resources in order to verify assumptions when these are critical. Design tasks change while designing is under way. Designing the full cycle of innovation requires designing as analysis where designers move from concrete to

generalized cases, and designing as synthesis where generalized insight gets channeled back into a concrete world.
Covering the entire process of understanding and intervention, designing is the definition of intent. Intent states the opportunity for action to successfully respond to challenges identified through insight found in the situation under design. Insight into the situation under design lies at the core of designing, and in whichever respect design claims a scientific approach, this gathering of insight can be described as a method that utilizes several techniques. A series of these techniques, administered in the appropriate contexts provided by the situation under design, forms a tentative design process, although the term process is problematic as a characterization for designing, since design may have no beginning or end. (Hoffmann et al., 2004)

Stage 1: Observations made at the intersection of past implementation and future conceptualization

Innovators as design researchers plan observational studies, collect data records from protocols, cognitive task analyses, and other process tracing techniques. Functional decomposition in the analysis of observations leads to an abstract model of conditions and relationships behind the observed concrete situations and allows designers to recognize patterns, provide explanations, and propose alternative scenarios.

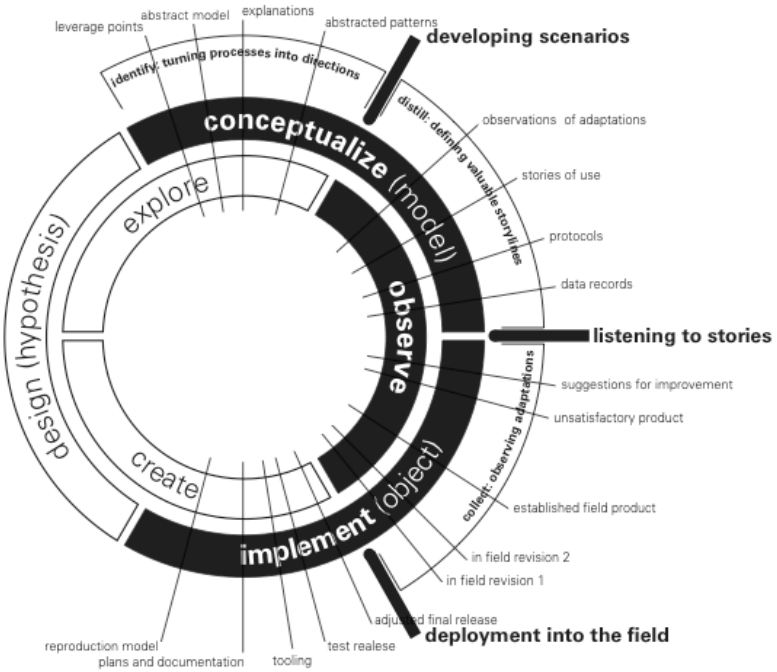

Figure 3: Practitioners tell stories about the realities of past designs in their field of work. Innovators as researchers trace the effects of past innovation in respect to practitioners anticipating change in the future

Stage 2: Explorations at the intersection between conceptualizations about the future and the building of hypotheses as design

Innovators as ideation designers, synthesize between insight and possibility in the envisioning stage of designing – the northwest passage in the de:cycle. They are proficient in interpreting formulated insight into design seeds - concepts that are promising. They are trained in an established set of generation and selection techniques to turn promising concepts into committed design responses. Their focus is in mediating between field insight about the situation under design and technological capacity to extend the possibilities of change towards the improvement desired by practitioners.

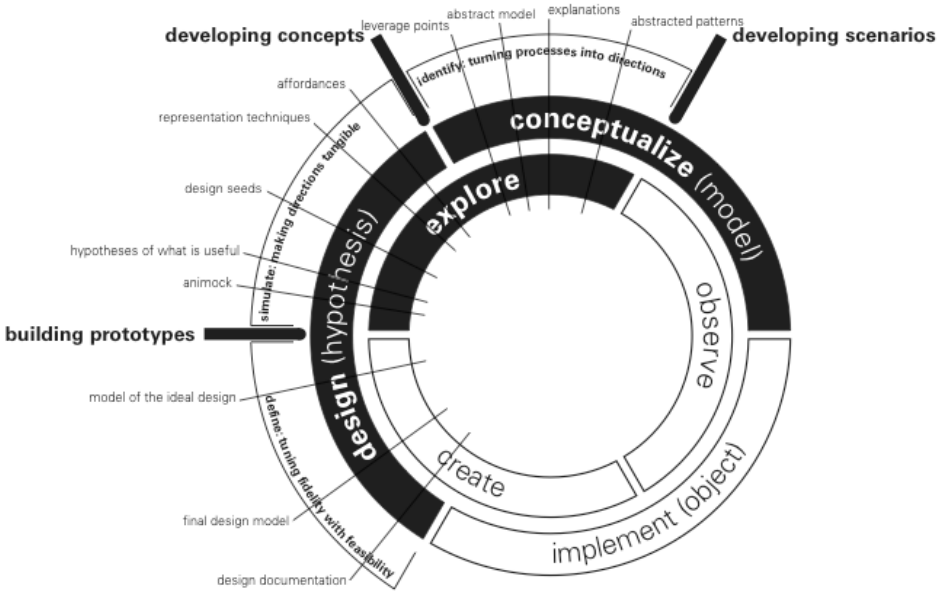

Figure 4: The northwest passage of design

Stage 3: Creating objects at the intersection of formulating hypotheses and implementation

Having to translate conceptual design directions into working realities, technologists choose from a pool of available technologies those that are appropriate for the design task at hand. The appropriateness of applied technologies is evaluated against factors of functionality, reliability, feasibility, safety, and economic feasibility – and how necessary modifications will reflect on the original design program.

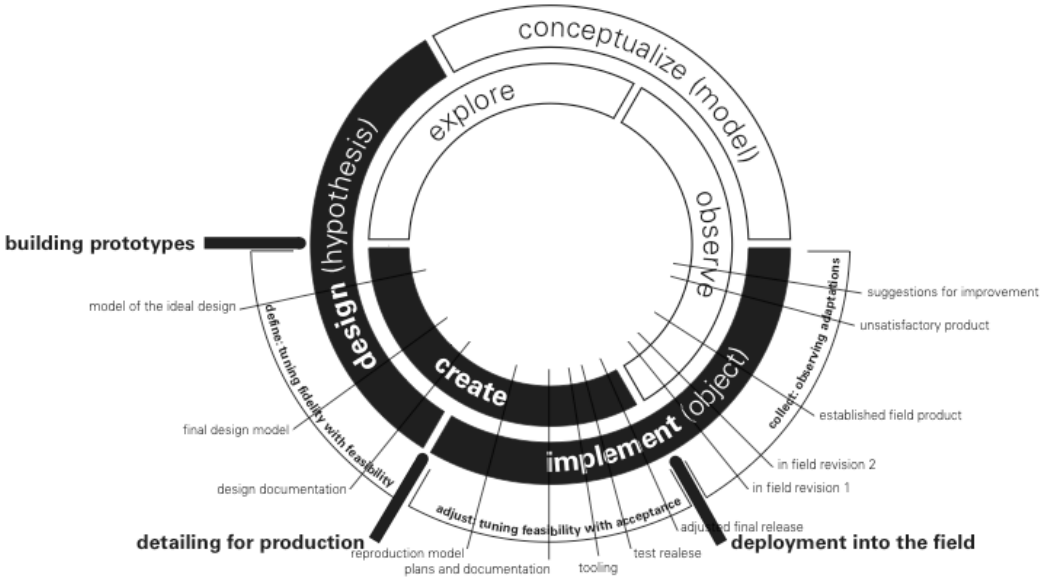

Figure 5: The implementation passage of the de:cycle

Coordinating the various roles in the design process requires a shared understanding between all participants about what designing entails. Collaboration between the various facets of design skill requires handover procedures where knowledge collected by one group can be communicated to the neighboring ones. These teams are concerned with the same design task under the umbrella of their specific work culture. Researchers, designers, and engineers work differently, and it is of little merit to force them into one cultural template. Differences are necessary, provide opportunities, and emphasize the need for exchange platforms at the intersection of different expertise.

Handover products take the shape of knowledge representations and mark deadlines, which allow tracing the structure of designing as it becomes tangible in these artifacts. The handover marks in the de:cycle are both closure point of the design aspect lead by one group of specialists and starting point for the lead of the next group. In the choice of their labels, the handover marks provide centers on the circumference of the decycle:

-Listening to stories - the handover mark between observing adaptations as an activity of collecting and defining valuable storylines, as a process of distilling.

-Developing scenarios at the intersection of turning identified conditions into directions for design.

-Developing concepts at the transfer to the envisioning stage, or northwest passage of design makes directions tangible.

-Building prototypes opens the stage for design definition, or the activity of tuning fidelity with feasibility.

-Detailing for production, is the handover mark into the implementation stage, an adjustment process where feasibility gets tuned with acceptance.

-Deployment into the field marks the release of the design and provides the condition for it to reveal patterns of adaptations - these are of interest for a field study of the design in operation, and stories of use provide the material for the handover mark at the beginning of this list – the de:cycle closes.

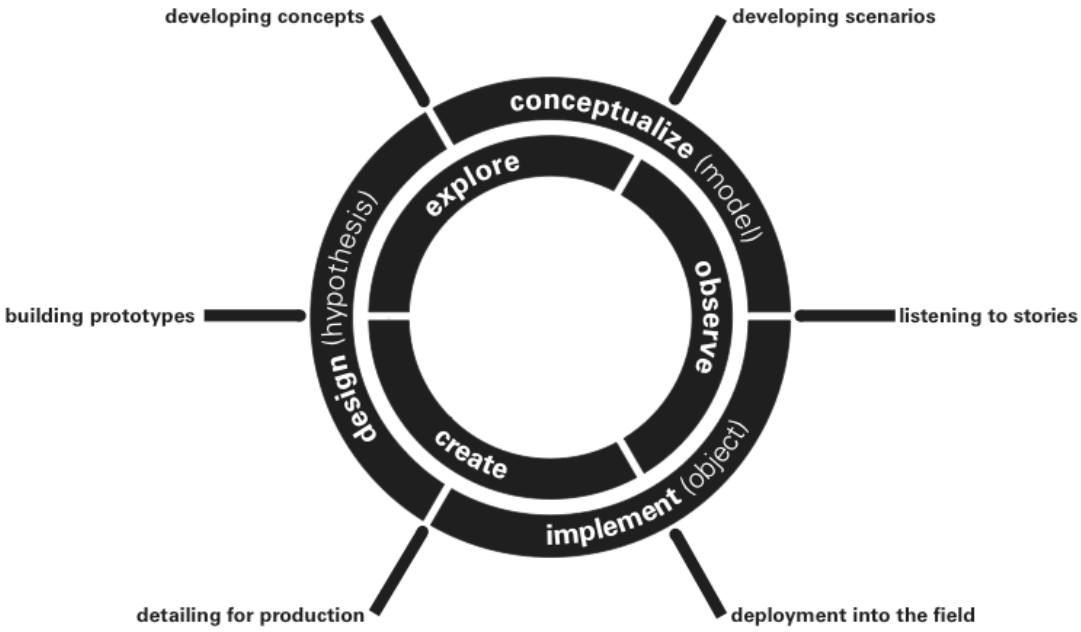

Figure 6: Handover marks in the de:cycle form transition points between several specialized design stages

Process artifacts created along the path of design activity

In the de:cycle, the practitioner's role is located where a novel system is introduced, integrated into work tasks, eventually debugged and revised, until remarks about its renewal rise. Complaints about the system in operation or suggestions for improvement mark a design situation. Design researchers plan and conduct a study in the field of practice to understand the nature of work with the system. They collect stories told by practitioners about the current and their wishes about its future. In the course of the study, research traces get generated such as data records, protocols and recorded observations of use. During data analysis and evaluation, researchers learn about adaptations caused by the fielded artifact-system.

At the north pole of the de:cycle, insight about the situation under design is formulated and structured. Patterns that provide explanations for observed behavior were extracted. Identified explanations lead to an abstract model that represents the innovator's understanding of the situation under design. This functional model

becomes a representation of insight as the basis for generalizing observed concrete patterns into universal ones – necessary to build a research base for similar design situations (the de:cyle itself is an example for an abstract model that represents the activity of designing).
Once an abstract model is created from observations, various alternative scenarios of the situation under design can be run in accordance to what is known about the design situation. This forms the basis for creting authentic scenarios from which innovators are able to make claims about the future. Developing scenarios marks the begin of an exploration into the uncharted terrain of the design.

The Northwest passage of the de:cycle is located polar to where the designed product is deployed into the field of practice or where a fielded design was the staring point of field observations that lead to envisioning the future. Between the most abstract and concrete extent of design, the northwest passage, spans the formative sequence in designing, the mysterious area in which ideas are born.

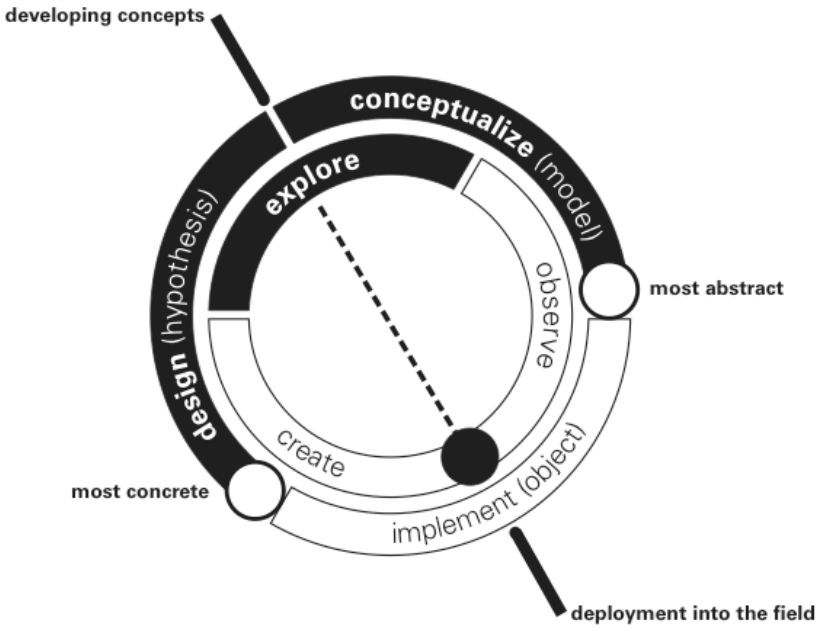

Figure 7: The northwest passage as the area of formation between most abstract and most concrete

The northwest passage is the most intangible sequence in designing. Few artifacts have been identified by designers in the envisioning stage of a design. Envisioning or ideation of a design project starts at the handover mark where designers understand the design situation and realize the scope of possible design intervention – this entails understanding where to apply what design strategy with what design intent. Leverage points indicate where to change aspects in the design fabric of the situation under design. Identifying affordances lays out a program for design. The term affordance goes back James J. Gibson (Gibson, 1979) as a label for the relationship between people and their environment. Affordances are engagement opportunities that are

provided by the constitution and make-up of the physical world that surrounds us. Meaningful features in the environment offer opportunities for people who follow intent in order to achieve goals.
A proposal for change in the format of designing for affordances requires a representation format, may this be the shape and appearance of a physical artifact or the conceptual image of procedures and capabilities that constitute the interpretation of the design-to-come.
Wishes addressed to the future design, in concert with an understanding of the situation under design and the scope of a design program as intent plants design seeds in the situation under design.

Hypotheses of what is useful define the design-to-come. They are commitments towards design directions that mark the transition where the analytical activity of design turns into design synthesis to transform insight into action. A variety of design hypotheses get formulated, some necessarily contrasting with others. A greatest possible variety of alternative directions is crucial to better understand the potential for ideas in respect to the design situation. Prognoses about the future design are playfully set loose in mocked up simulations, and through putting something into the world, the change introduced by that intervention is observed. Quickly created, concepts for alternative futures provide design perspectives that through their inconsistencies to one another cast a more comprehensive picture of the possible design space than provided by the design space itself. Selecting one among many possible design directions becomes the goal of a systematic design evaluation process whose goal is to pick what works better in regard to the outline represented by the abstract model. Correspondence to selection criteria initiates the departure from design concepts that are rather weak than strong – what may entail sacrificing promising solutions in order to improve the overall performance of a refined concept – one which can well be merged from various promising other concepts. Designers arrive at this point at what Alexander calls a sacrificing design solution (Alexander, 1964), or the candidate model for design refinement under resource pressures – which leads the design concept into evaluation by future practitioners and technologists.

Storytelling provides the framework to share simulated futures. For many years, designers have resorted with static images and design models in various degrees of detail. While their mock-ups and rough concept sketches invite for modifications, designers tell stories about the future operations of their designs. With the capabilities of current computerized design tools, the spectrum of design representations has introduced new fidelities in showing, exploring, and observing designs in time and space. One such technique is the animock or animated mock-up, where mocked up design environments provide the scene in which design stories unfold. (Roesler et al., 2004)

Note that the greatest potential for design innovation lays in the exploration of the northwest passage. Here is it where the idea of design is formed and here it is where its range in creating true novelty is explored.

The innovator’s leadership in the de:cycle arrives at the transfer to the technologists’ responsibility with the delivery of a final design concept that marks the opening for design detailing, using refinement models and prototypes. From the technologist’s perspective, design work entails the transfer or implementation of a design brief presented by the design concept into a system that can be deployed into the field and that stands up to the requirements of functionality, reliability, safety, and legal considerations.
Technology design starts with evaluating the innovators’ design concept – which provides a fairly detailed specification space – under these aspects. As shared representation of the design selected during the envisioning stage, a design reference

model is created in order to tune fidelity towards feasibility, taking into account limited resources and best achievable options. This design optimization work under realization pressures moves along a series of working models that are tested and evaluated in working sessions with other development stakeholders, innovators, future practitioners, and investors. Documentation of a final, approved prototype marks the end of the design detailing work and the handover product for manufacturing and distribution, resulting into the new design's release in the field of work.
Designers can now observe the effects of their design as it is fielded and may verify how hypotheses built while under design face the realities of operations.

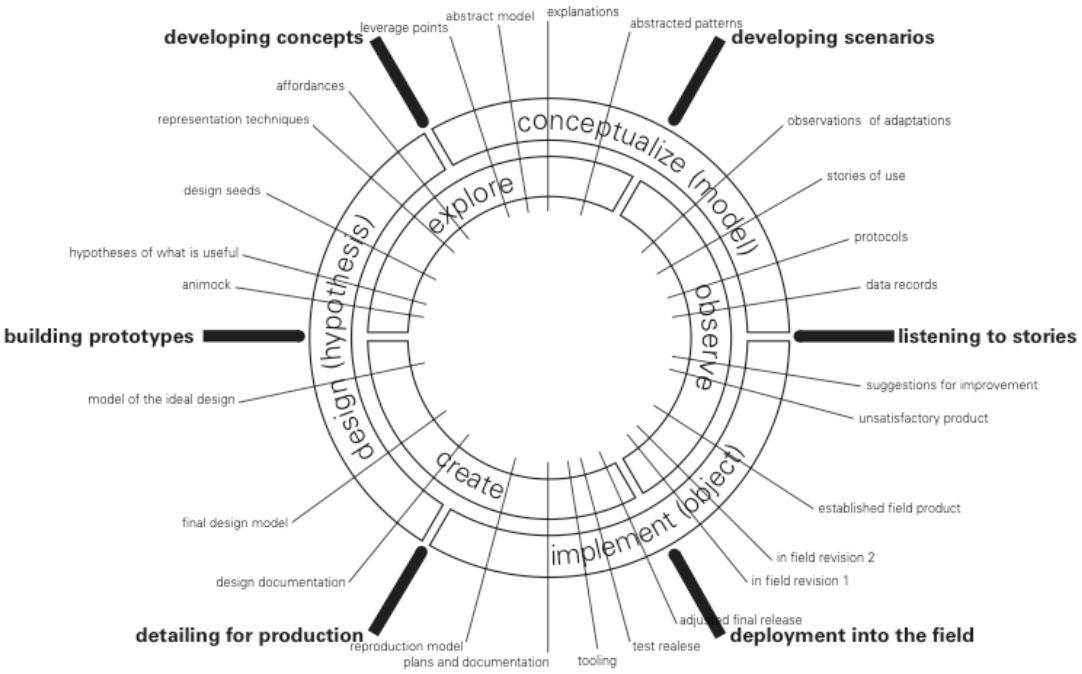

Figure 8: Handover products and artifacts created during design mark the design process

Conclusion: Balancing the roles in designing

The de:cycle provides a series of relationships that help to achieve a dynamic balance across the perspectives of the three roles in designing. As practitioners formulate their view on the systems they are working with, they take into account the relationships between innovators and technologists which formulates which scope of ideas are available to utilize what kind of technology to improve their working conditions (Fig. 9). Usefulness, as subject of this consideration describes what is desired from the point of the practitioner and what in turn can be made possible by the collaboration between innovators and technologists.

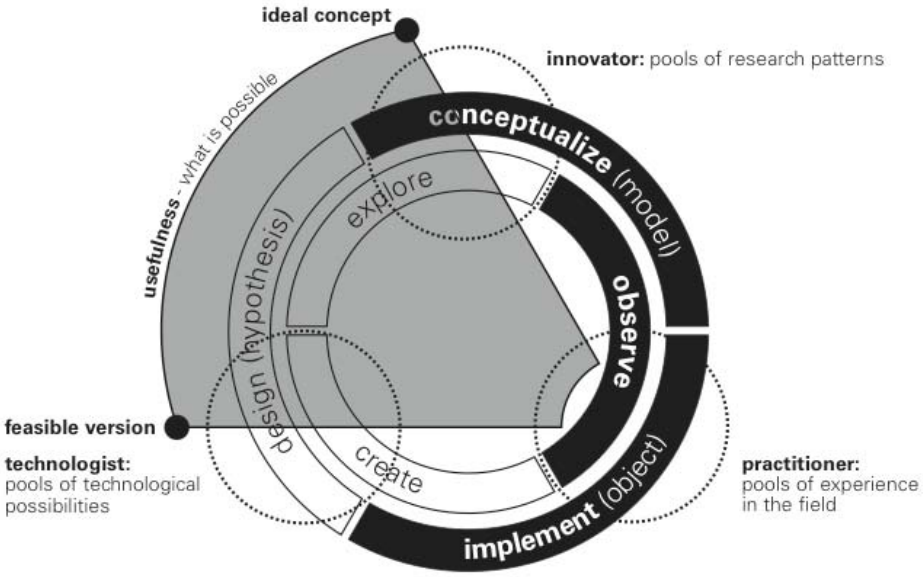

Figure 9: Usefulness as the relationship between technologist and innovator, seen from the practitioner's perspective

Innovators are concerned with usability as they investigate the relationship between technologists and practitioners. They study the usability of technology that was provided to practitioners by technologists in order to improve that technology in a next design iteration(Fig.10). The idea of usability is concerned with making things work from the point of view of all involved in the design process. For the innovators this means to take advantage of the full scope of design innovation possible while centering the design on the practitioner. In regard to the technologist this requires a realistic design program that can be implemented. From the practitioner's perspective, usable artifacts do improve the situation at work without introducing unforeseen complexities that require work-arounds.

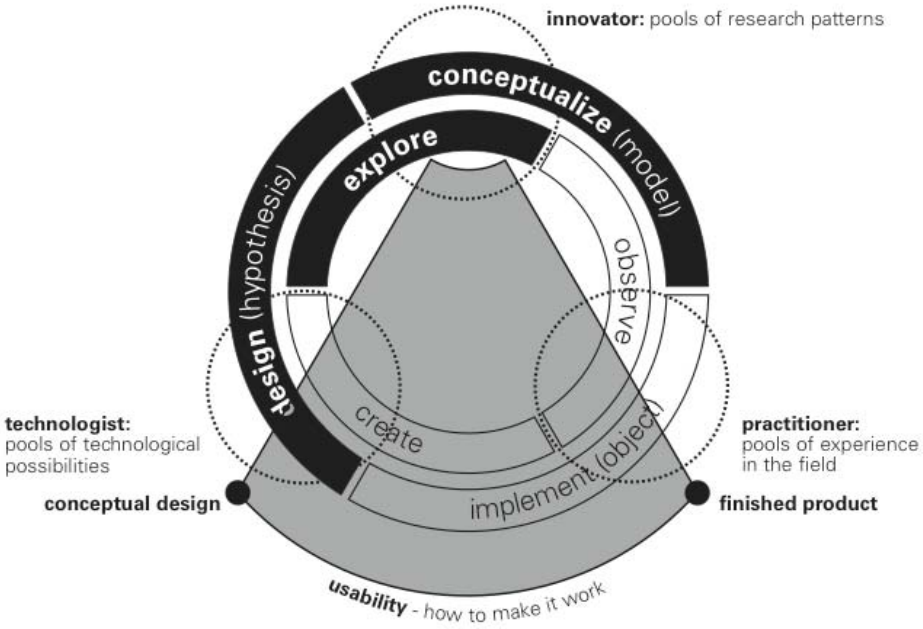

Figure 10: Usability as the relationship between practitioner and technologist, seen from the innovator's perspective

From the technologist's perspective the key in design is applying the right kind of technology to respond to the appropriate challenge. Understanding is established in the relationship between innovators and practitioners (Fig.11). Only the right kind of insight can provide the conditions for designing what makes sense.

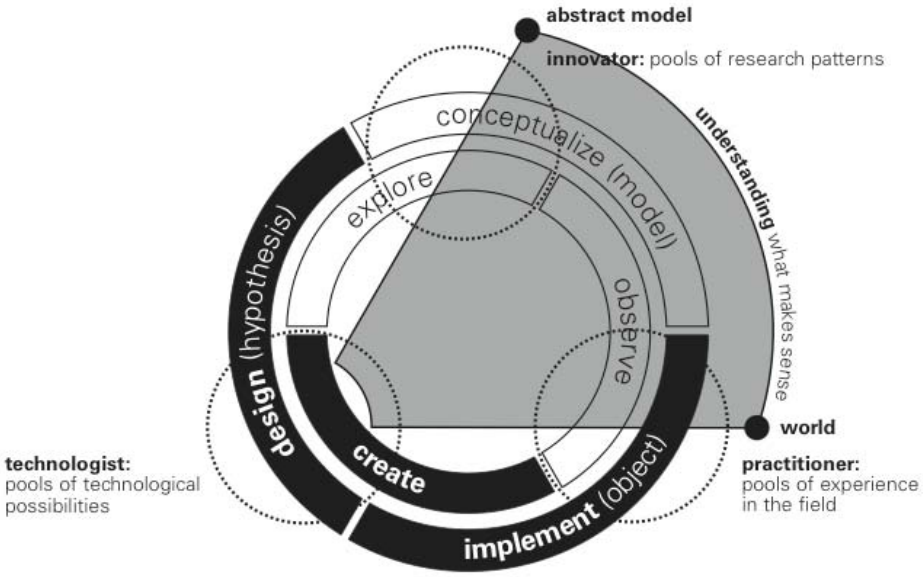

Figure 11: Understanding as the relationship between practitioner and innovator, seen from the technologist's perspective

Design projects are typically conducted as iterations on the bases of previously existing concepts. These iterations do in large scale development projects not only occur in the form of test and evaluation cycles as proposed by the spiral model for software design, but iterations in the face of new technology span the entire cycle from design research, design ideation, over to implementation and revision in the field, since each introduction of knowledge changes the field of work. The resulting reverberations of change call for new field studies that contribute to a growing knowledge base of design and so provide insight into the relationship between people, technology, and work. Collaboration between specialists that conduct these field studies and designers who can formulate design intent as well as technologists capable to realize design concepts as fieldable artifacts, is necessary to cast the full potential of opportunities for innovation into the future.

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