Disrupting by Design: Assessing Imaginaries of Techno-Futures

Stefanie Ollenburg, Marius Land

Abstract *Any technology is embedded in complex socio-technological, ecological, and political systems and entangled in a contested space of biases and assumptions. We need to find solutions for today's crises beyond the technological trajectories.*
The role of design within the context of technological development and research is ambiguous. Often, design shares complicity in enhancing and legitimating existing paradigms and can constrain new emerging ways of thinking. Yet, is there the possibility for design to critically challenge existing paradigms of technological solutionism?
To address this issue, we draw on our ongoing research project, ScenAIR2050, as a case study to reflect on the role of design linked to futures research and its relationship to technology-driven disciplines. We are reviewing the process of Research through Design and the corresponding methods from design and futures research to build a process to critically accompany fundamental technological research.
In this paper, we want to critically discuss the role of design and futures research in relation to technological research and development. We reflect on technology-driven procedures and examine the extent to which transdisciplinary design research can enable and hinder disruptive transformative pathways of future developments.

Author keywords *(de)futuring; research through design; critical futures studies; alternative futures; techno-solutionism; transformation design*

1. Introduction

Technology is often perceived as the key to solving the climate crisis. Yet, it can be said to be embedded in complex socio-technological, ecological, and political systems and entangled in a contested space of biases and assumptions. Thus, solutions to multiple current and future crises can rarely be found along linear technological paths when they utilise tools similar to those that have led to the problem.

To steer complex technological and societal systems towards sustainable pathways calls for a system-wide "second deep transition" (Schot & Steinmueller, 2018, p. 1565). This would imply a fundamental transformation of current assumptions regarding production, consumption, and distribution along multiple socio-technological systems. To adequately address and understand this complexity, transdisciplinary frameworks within research, development, and design are essential.

Taking an ongoing research project about the possible futures of the Air Transport System (ATS) as a case study, this paper reflects on the role of design and futures research within fundamental technological research. The project has the objective of providing exploratory and normative user-centred scenarios for a future ATS. The scenarios intend to provide a holistic perspective on the field of aviation, departing from the paradigm of linear trajectories of techno-futures. The addressees for the scenarios in the project are colleagues from an excellence research cluster with disciplinary backgrounds in various types of engineering and the natural sciences.

Fundamental technological research is often defined by its disciplinary pathways and a certain type of agenda-setting. Design and futures research, with their disciplinary ties to the humanities, arts, and social sciences, can challenge these boundaries to trigger new lines of thought.

Here, we reflect upon how design practice combined with futures research can serve as an inspiration for decision-making beyond the obvious. Furthermore, we consider how the process itself offers a learning path towards change and other possibilities (Jonas et al., 2015). This may enable technological development as "radical innovations [that] emerge in niches, on the fringe of existing regimes" (cf. Geels et al., 2017, p. 465). It is necessary for stakeholders to learn and challenge the system for it to adapt:

> "It is therefore insufficient to rely solely upon technically rational criteria for decision-making, whereby experts use computer models to determine an "optimal" transition path which is then implemented by policymakers." (Geels et al. 2017, p. 474)

Therefore, the scenarios in the ScenAIR2050 project, on the one hand, present possibilities to explore plausible as well as (un)desirable development paths and, on the other hand, attempt to devise methodologies to further the intended transdisciplinary decision-making within the limits of the ATS as a complex system.

The task is to create a transdisciplinary and participatory process and to work with the challenges of given disciplinary boundaries. In the research process, we realised that the understanding of the issues to be addressed by the project changed throughout its course. On that premise, this paper reflects on the ongoing research process and explores how the combination of design and futures research methods and tools can elicit responsible approaches to future technological developments.

Specifically, we ask: How might design critically engage with and challenge existing paradigms and trajectories of complex socio-technological systems?

First, we introduce the case study, its objective, and its framework. This is followed by a reflection on our position in the field of design and its connections to futures studies. In the section that follows, we expand the understanding of linear technological trajectories and technological solutionism by introducing socio-technological systems. In our conclusion, we reflect on our process by drawing on the discussion on design research, its critical perspective, and the spaces of possibility it can offer for socio-technological research. Finally, we conclude with an outlook on further research.

2. ScenAIR2050 – A Case Study

Aviation is responsible for one-third of the emissions of the global transport system (IEA, 2021). At the same time, the air transport system (ATS) is a complex system spread across different dimensions (social, environmental, political, economic, etc.) and other systems (technology, policy, security, etc.). Research questions regarding its sustainable future range from technological issues to systematic considerations that include the overall aviation environment and its various stakeholders.

The project discussed here, ScenAIR2050, is part of the excellence cluster for Sustainable Energy Efficient Aviation (SE^2A), an interdisciplinary research consortium on technologies for a sustainable and eco-friendly air transport system (ATS). It combines three integrated cluster areas (ICA): ICA A focuses on the 'Assessment of the Air Transport System', ICA B on 'Flight Physics and Vehicle Systems', and ICA C on 'Energy Storage and Conversion'. Most of the projects are concerned with fundamental research for technological developments (Technological Readiness Level 2–3). Thus, they address technical and economic optimisation issues, and the primary research methodologies are quantitative.

As part of ICA A, ScenAIR2050 explores alternative futures for an ATS in 2050. It combines futures and design research and their qualitative methods such as future scenarios, user research, and participatory methods. By integrating social, technological, economic, environmental, and political factors (STEEP environments) and possible lifestyles of future stakeholders, we provide a holistic perspective on the field of aviation, going beyond the paradigms of linear technological trajectories. This methodology establishes a tension between the dimensions of technology and stakeholder interests that, through the qualitative scenarios, allow ambiguity and uncertainty to emerge, giving space to alternative futures for an ATS in 2050.

The ScenAIR2050 key objectives are: (1) to deliver critical contextual knowledge on plausible future developments as an orientation for research; (2) to integrate the future passenger as a stakeholder within the research; and (3) to create platforms

that drive the exchange within and beyond the cluster. Thus, the main research questions in the project are:

- What are plausible scenarios for the development of a sustainable and energy-efficient ATS until 2050?
- How might people travel in the future, and who might thus be the future airway passengers?
- How do we consider which technological developments might be more acceptable to future stakeholders?
- What are 'alternative' or other futures that need to be recognised as plausible?

For the expected outcomes, the research design includes foresight scenario techniques (Bishop et al., 2007; Kosow & Gaßner, 2008) and design approaches. The groundwork is established by defining the boundaries and identifying the connectivity within the complex ATS through analysing the STEEP environment. Following this, explorative scenarios are developed, offering a first glimpse of possible directions and plausible futures. Further, through integrating different stakeholder perspectives, for instance by using metaphor analysis in order to extract specific requirements and concerns, the (un)desirable futures are mapped out as normative scenarios. The research process contains several touchpoints for knowledge exchange and enquiries (surveys, workshops, co-creation labs) to foster the intended transdisciplinarity and to challenge existing assumptions within the research cluster.

3. A project of Research through Design

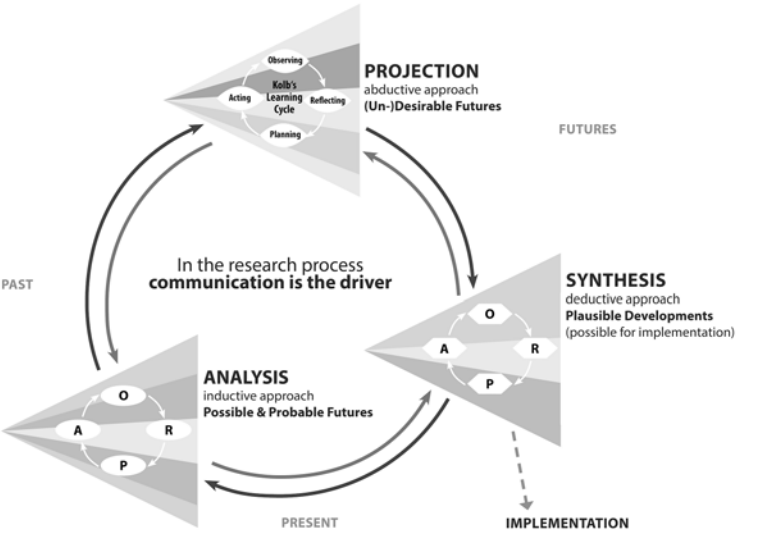
The scientific approach of ScenAIR2050 is grounded in Research through Design (RtD). It bridges knowledge generation through systematic scientific research and practice-oriented designerly way of knowing methodologies (cf. Cross, 2006; Jonas et al., 2015). An existing situation is studied having designers, scientists, and addressees as active researchers without the divide between scientific observers and the observed. As a transdisciplinary research process, it aims to integrate the expertise, creativity, and design competencies of all actors and thus enables a diversity of methods (Findeli, 2010, p. 297). For a comprehensive process, RtD is underpinned by the hypercyclic generic design process model consisting of the macrocycle phases of Analysis, Projection, and Synthesis. Each includes an experiential learning cycle (Jonas, 2007, p. 1374) of the phases of experience/research, reflection/analysis, thinking/synthesis, and action/realisation (Jonas. 2007; Stock & Kolb, 2021).

The RtD phases (APS) of the macrocycle combine principles of scientific logic with design methodology: (1) Analysis asks "How is it today?" Researchers study past

and current facts through Induction. (2) Projection concerns "How could it be?" A phase that considers values, beliefs, and visions, and uses abduction as a logic of scientific creativity to induce new insights and ideas by combining observation with intuition. (3) Synthesis focuses on "How will it be tomorrow?" The findings of the previous phases are combined, and deduction is used to identify results and possible effects of potential developments (Chow & Jonas, 2010, 2008; Jonas, 2007; Ollenburg, 2019, p. 55).

4. The Project's Framework and Research Design

Figure 1: Futures-Design-Process Model combining the concept of possible, probable, desirable, and plausible futures with the Generic Design Process and Research through Design (Ollenburg 2019:57/update by author).



The framework connecting design and futures research in ScenAIR2050 is based on the "Futures-Design-Process Model" (F-D-P Model). The F-D-P Model combines the RtD process model phases with the Futures Studies concept of probable, (un)desirable, and plausible futures, respectively (Bishop et al., 2007; Inayatullah, 2013).

The model is meant to "systematically enclose the concepts and methods derived from futures studies, utilise the inspirational momentum of design, and measure up to scientific standards of reproducibility and transparency" (Ollenburg, 2019, p. 52).

Through this model, the project design becomes an instance of structured research in an iterative process. In the Analysis Phase, the systemic boundaries for the ATS relevant to the SE²A cluster are defined by taking into consideration the results from previous related scenario projects (Mozuni et al., 2019). With continuous literature review and engagement with research partners, a STEEP factor analysis is the first step to identify key factors for building explorative scenarios (Kosow & Gaßner, 2008, p. 50 ff.). The analysis and projection phases are in a permeable transition. Thus, through a protracted process, we identified 15 key factors, and in co-creation with cluster members, we developed several future projections for each. They are the building blocks for the explorative scenarios that, with a software-based morphological box, are then calculated.

The remaining steps of the project until the end of 2024 are the furthering of the projection phase by developing normative and user-centred scenarios. Further, all derived scenarios are mapped and visualised in the Synthesis Phase. The different scenarios serve as tools to analyse and assess trajectories and research findings of the cluster. This can be done by inserting a specific set of questions, using future personas, or simulating disruptive developments (e.g., Wild Cards). Using the scenarios for workshops and games, they become a platform for participatory reflection within and beyond the cluster.

5. Design Facilitating Research

In the ScenAIR2050 project, design is understood as more than generating artefacts such as products and their interfaces but as a process to foster transformation. This understanding of Transformation Design (TD) plays a crucial role in bridging disciplines and laying pathways for the transition of complex systems. All artefacts, such as a whiteboard in a workshop, storytelling, or visualisations of cluster activities, create relationships between the object, its user, and the environment. Deploying RtD, the process utilises skills, experience, and trial and error with uncertain results. In our project, we understand that "[d]esign takes place in the world of imagination, where one invents and manipulates ideas and concepts instead of the real thing – in order to prepare the real intervention. […] Design terminates with a commitment to a plan which is meant to be carried out" (Rittel, 1988, p. 1).

Thus, in ScenAIR2050, we understand the role of design as a unique point of view that allows a shift of perspective:

> "…, an understanding that recursively embeds another person's understanding in one's own, even if, and particularly when, these understandings disagree, contradict one another, or are thought by one to be wrong or appallingly un-

> ethical. This recursive understanding of understanding is a [S]econd-[O]rder [U]nderstanding" (Krippendorff, 2006, p. 66).

With its fundamental technological research and its aircraft design efforts, most projects in the SE²A Cluster with quantitative empirical methodology revolve around e.g., optimisation of technical parameters of saving fuel through gradual retrofitting, clean propulsion technologies, as well as optimising existing design concepts to lower the energy consumption and reduce CO^2 and atmospheric gases. ScenAIR2050 adds qualitative research methods and a critical perspective to accompany the technological-focused studies with the aim of enhancing reflexivity and transformative capabilities within the cluster. Thus, it provides a setting for "second-order learning" to reflect on the primary research findings to approach them from a distanced and detached perspective (Grin & Van De Graaf, 1996; Pätzold, 2011; Schot & Geels, 2008).

6. Perspectives on Design

As designers and researchers with the capability to facilitate dialogues, we seek to articulate and assess worldviews and visions of the cluster community to provide orientation and support actors to participate and to become active (cf. Krippendorf, 2006). As such, the project follows Herbert Simon's claim that "everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (Simon, 1996, p. 55), to take into account certain perspectives on design.

First, there is the basic temporal core to design, as an act of the imagination from the present situation into the future. Designing is an act done in the present for an undetermined future (Krippendorff, 2007, p. 72). Second, if everyone designs, design itself becomes an ontological concept that prefigures, shapes, and acts in our daily lives. As such we are deeply engaged with and dependent on design. The ATS, as an example, shows that while advancements in aircraft design and related services help to enhance global connectivity, it does enable systemic dependencies of environment-damaging infrastructures, mobility patterns, and services. Third, transforming an existing situation into a preferred one is a political act, since it is an ongoing negotiation on preference when there is no single right answer, as in recent discussions on design and sustainability (Boehnert, 2018; Mazé, 2013).

Design philosopher Tony Fry even argues that design is the foundation of our modern existence, as it shapes power structures, is operationalised as technology (Pater, 2021), and is enmeshed in "industrial, post-industrial and consumer culture that made unsustainability a structural feature of the environment of shaping our 'natural' world" (Fry, 2020, p. 6).

7. Transformation Design as Design Futuring

By arguing that "we design our world, while our world designs us" (Fry, 2020, p. 5) Fry highlights the impact and responsibility of design, which inherently is interwoven in shaping futures, and further puts forward the question of how can "a future actually be secured by design?" (Fry, 2009, p. 3).

With "Design Futuring" Fry (2009) engages design into a broader cultural critique of transformative processes considering the entire ecology of modern existence. He challenges and reframes current unsustainable cultural narratives. Calling for a "design intelligence" that is aware of the "dialectic of sustainment" (Fry, 2020, p. 4), acknowledging that everything we bring into being entails consequences. Those can rarely be fully anticipated which make most design problems "wicked problems" (Rittel & Webber, 1973).

The field of Transformation Design (TD) understands itself as a reaction to the above dilemma. Instead of generating artefacts, design is about responsible negotiations within complexity. TD turns "[…] towards a society-centred attitude [it is about] open communication processes, which serve for a creative enquiry into new potentialities […] designed and realised in the form of new organisational structures and cultures, systemic innovations, or collaborative educational forms. The final goal is behaviour change – individually, locally and globally" (Jonas et al., 2015, p. 9). TD can be understood as the means to approach the still unimaginable and its implications, accounting for the degree of involvement and responsibility for the ethical obligations of the designers.

8. Systems of Technology

As transformation designers in a project that deals with a highly complex technological system such as the ATS, we need to acknowledge that technology is embedded in systemic and socio-technical arrangements, including economic, individual, cultural, and political aspects (Carlsson & Stankiewicz, 1991; Geels, 2002, 2004, 2010; Hekkert et al., 2007). While technological innovations brought certain conveniences, they also created severe social and ecological consequences. The notion of sustainable development (World Commission on Environment and Development, 1987) gained momentum against such a backdrop. Sustainability, here, becomes a design problem as technologies are developed with the specific need for ecological sustainment. Steering towards sustainable pathways requires the 'Technological Transitions' of complex systems, which include changes in user practice, symbolic and cultural relationships, policy regulations, the industrial complex, and infrastructure (Geels, 2004; Hekkert et al., 2007).

Thus, for ScenAIR2050, as part of the interdisciplinary SE²A cluster striving for sustainable technological innovations, we argue with Geels' Multi-Layer Perspective (MLP) (2002; Geels & Schot, 2007). It provides a comprehensive framework on how radical systemic change emerges and analyses the complex system interdependencies. It looks at the interaction between three levels: the *niche* in which innovations and experiments emerge, the *regime* in which existing practices and technologies become established, and the *landscape* in which the effects of external factors, including social norms and policies, are defined. To include sustainability in the innovation process, "the analytical challenges around normativity, directionality, and social mobilisation, innovation studies may need to broaden its analytical scope to include additional dynamics related to civil society, social movements and consumer behaviour" (Geels, 2010, p. 508).

Consequently, it takes transdisciplinary and experimental environments for innovations to thrive (Schot & Steinmueller, 2018). Yet, based on the faith "that we can control and take charge of the world in which we live, and that we have sufficient knowledge and technology to do this in a way that will improve our situation" (Sætra, 2023, p. 3), the current predominant technological research is based more on pre-defined "solutionism". The term critiques a narrow-minded focus on technological fixes that understands "all complex social situations either as neatly defined problems with definite, computable solutions or as transparent and self-evident processes that can be easily optimized" (Morozov, 2013, p. 5). Thus, the normative agenda-driven pursuit for sustainable technological solutions raises the question of whether "technology can be used to fix the very problems caused by technology" (Sætra, 2023, p. 5).

Conclusion

Aviation is a complex system in which all actors are interdependent. Today, flying is often interpreted as a metaphor for freedom and technological advancement (cf. Howarth & Griggs, 2006). In a globalised world, travelling by aircraft has become a convenient way to discover foreign cultures or visit family and friends. Long-distance flights seem to be the only reasonable solution to reach a destination in our fast-moving era. Thus, for a systemic transformation towards sustainment, it will need not only viable technical solutions but also the transformation of the social status and mindset on flying.

Shaping Futures by Design

In ScenAIR2050, we understand the complexity of the ATS as a socio-technological system that cannot be easily fixed. The development of alternative futures to explore

design, sustainability, and technological innovation within a broader societal landscape can provide opportunities for mutual learning. With over a year remaining until the end of the project, at this point, we reflect and critically assess the research process to date. As future-oriented research, the initial project objective aims to connect the various engineering projects, drive innovative design solutions, and provide decision support for recommendations on technological research. As tangible outcomes, the different types of scenarios can indicate plausible future paths and interlink disparate technological developments. However, because they are based on qualitative data, their nature is speculative and normative, which is at odds with quantitative research for decision-making. Based on today's common engineering logic for technological development, using mainly quantitative research can create path dependencies (Grunwald, 2014, p. 2; Tiberius, 2011, p. 13), leading to solutions that tend to treat sustainability only as a technological problem.

With our design and futures research approach, we aim to enable such critical engagement and challenge existing paradigms of complex technological systems such as the ATS. We encourage this by applying the design principles of sustainment and user-centred research, using RtD with the APS/F-D-P model for an iterative learning process, as well as integrating thinking in futures. Workshops and surveys are meant to facilitate participation and co-creation in the sense of aspiring towards transdisciplinarity. As stated above, we understand that the results are not so tangible.

Our approach has the potential to identify assumptions and evoke new questions, and it might challenge the current framing of the problem and spark uncertainty. We want to encourage a process of reframing to advance the discussion on transformation beyond tech-solutionism.

Reframing by Design?

It might prove difficult to assess whether ScenAIR2050 contributes to the necessary systemic changes. Nonetheless, the idea is that through its iterative design process, the user-centred scenarios, and the trans- and interdisciplinary touchpoints, it holds the potential to intervene and possibly disrupt current conceptual frames to open transformative viewpoints towards pathways for the unexpected.

The methodology offers the opportunity to challenge the existing logic of sustainability and to broaden the scope by creating narratives that engage both humans and non-humans. This may raise difficult questions that go beyond aviation, such as those of economic distribution: Who will be the passengers in 2050? What status will flying have in the future? What metaphor will flying stand for in the future? Rather than constituting results, design and futures research seeks to open a space of possibility. It aims to promote reflexivity and recognition of the fact that the handling of

complex systems and future developments is based on the principle of uncertainty (Jonas et al., 2015, p. 114 ff).

The question remains if ScenAIR2050 has the agency to foster such transformative research processes and practices through RtD. It includes the plurality of design possibilities and to understand the solution space as an iterative communication process (Hugentobler et al., 2004; Jonas, 2007). The F-D-P Model adds to the exploration of images of diverging futures and engages in thinking in multiple futures. Generally, there is a need to include the management of perspective change in the research design.

While the alternative perspectives and emerging futures from the ScenAIR2050 process may seem intangible to the concrete technical requirements, they are invaluable in highlighting problematic issues that extend beyond the air transport system:

"Problems are more important structurally than solutions, […], for 'problems' do not present themselves spontaneously; the ability to raise questions already implies a conceptual scheme in which something is defined as an issue. It suggests at least the prerumblings of an emerging intuition of what the shape of that problematic world is like and puts us on a path to sharpening the focus of a full-scale paradigmatic vision" (Collins 1986 cited by Geels, 2010, p. 508).

The scenarios can open perspectives that, at first, may seem unwanted for an industry and research agenda solely based on aviation. But considering that only a fraction of the world population has access to aviation for mobility and that there is a growing community of people who avoid flying as a means of transportation, new (design) questions may arise. Is flying only for certain communities? Who is part of those communities—are they privileged or working nomads? What status does air travel have for society or the individual? If we are uncertain of how aviation will develop, what type of aircraft design and infrastructures can be assumed today considering the long development and certification processes? How will these current design decisions affect the futures of aviation? This project can foster the process of generating questions that contribute to breaking current path dependencies and stimulate divergent paths that are essential to developing sustainable innovations.

Considering that the project has one year to go, the discussion in this paper puts forward the possibility of a re-orientation of our research agenda from using scenarios to derive recommendations towards using them as tools to engage other researchers in a reflexive participatory learning process. In our understanding, RtD, and thus Transformation Design, offers the methods and tools that, with an emphasis on the Analysis and Projection phases, go beyond a culmination and visualisation of results in the Synthesis phase. The methodology is meant as a point of departure to discuss and reframe plausible concepts of uncertain futures. The potentially unexpected outcomes can open a space for questions meant to lead to fruitful debates not only on the complexity of problems but also on unusual solutions.

Outlook on Further Research

In order to engage in the second deep transition, a re-orientation of institutional arrangements and governance structures is needed as well as "individuals with capabilities for bridging social and scientific and technological domains (Schot & Steinmueller, 2018, p. 1564).

Though inter- and transdisciplinarity within the SE^2A Cluster are fundamental, engaging in collaborative research, giving workshops, or exchanging results with the cluster have brought up the disciplinary boundaries (Bobbe et al., 2023; Nicolescu, 2014). Design and futures research are based on iterative methods and tools with communicative values, calling for a constant exchange and critical feedback between researchers. Yet most of the technological research methods target unambiguous and often computable results. These allow for more goal-oriented research processes, mirroring the need for streamlined development pathways (Geels, 2010; Schot & Geels, 2008).

To overcome such barriers, the ScenAIR2050 project has only peripherally employed didactical means to achieve qualitative results. The project seeks to promote knowledge transfer by probing future images from and for cluster partners, questioning assumptions on factors, and using questionnaires addressing future users. Further, we plan to visualise the resulting scenarios and put them into narrative form. All of the above is done to challenge the framing and foster a *transformative mindset* that enables individuals to acknowledge the complexity and realise the uncertainty of the futures. Within the concept of second-order learning this would mean further research in competence to build "new sets of skills for bridging the social sciences and the science, technology, engineering and mathematics (STEM) fields" (Schot & Steinmueller, 2018). Based on concepts such as Futures Literacy (Miller, 2018) and Education for Sustainable Development (Michelsen & Wells, 2017), the research team identified the need to collaborate with education and communication sciences to develop further formats and evaluations to measure effectiveness. Furthermore, there is a need to establish a typology of competencies required for actors who can drive ethical and radical transformation in the field of technological development.

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