


Speculative Industrial Design with Reflective Virtual Prototyping: A Hybrid Approach to Research Through Design and Heuristic Inquiry

Özkal Hüseyin Özsoy^{1*} 

¹Mimar Sinan University of Fine Arts, Architecture Faculty, Industrial Design Department, Türkiye

* ozkal.ozsoy@msgsu.edu.tr

* Orcid No: 0000-0001-5531-3539

Received: July 11, 2025

Accepted: October 27, 2025

DOI: [10.18466/cbayarfbe.1739675](https://doi.org/10.18466/cbayarfbe.1739675)

Abstract

This study explores a hybrid methodological approach to speculative industrial design by combining principles of Research through Design (RtD) with elements of Heuristic Inquiry. The aim is to investigate how reflective prototyping can serve as a tool for critically engaging with imagined futures that may never materialize. Rather than focusing on problem-solving or production-ready outcomes, the research positions the design process itself as a site for inquiry, one that allows the designer to explore alternative possibilities, question prevailing assumptions, and surface latent values embedded in design decisions.

The method was applied in a solo research context through the conceptualization and iterative prototyping of a speculative product scenario. The process followed key phases of heuristic engagement, immersion, incubation, illumination, and reflection, integrated with material and digital prototyping cycles drawn from RtD. The resulting artifacts served not only as design outcomes but as cognitive instruments for exploring socio-technical implications and speculative narratives.

This hybrid approach contributes to industrial design scholarship by offering a flexible and deeply reflective methodology for engaging with ambiguous, future-oriented questions. It expands the designer's role from problem-solver to critical provocateur and foregrounds design as a mode of inquiry in its own right.

Keywords: Autonomous Rescue Systems, Critical Design Evaluation, Heuristic Inquiry, Speculative Industrial Design, Research through Design.

1. Introduction

In an era marked by rapid technological change, shifting societal values, and significant uncertainties about the future, the role of industrial design is expanding beyond traditional problem-solving [1]. Designers are increasingly expected not only to respond to present needs, but also to anticipate and critically engage with emerging conditions, designing for futures that may be unknown, improbable, or even undesirable [2]. This shift requires methods that enable speculative thinking, critical reflection, and the creation of narratives through tangible artifacts [3].

Speculative industrial design emerges at this intersection, blending conceptual exploration with the material realities of prototyping [4]. It moves beyond user-centeredness and market viability to engage with “what if?” questions, envisioning alternative realities and examining the broader implications of design

choices [5], [6]. Yet, while speculative design has gained traction in theory, its methodological foundations in the context of industrial design practice remain underdeveloped, especially for solo researchers and designer-practitioners [7].

This study proposes a hybrid research approach, combining the process-oriented structure of *Research through Design* (RtD) [8] with the introspective and iterative depth of *Heuristic Inquiry* [9]. By integrating critical reflection [10], embodied design practice [11], and speculative prototyping [12], the aim is to establish a robust method for exploring futures that may never be realized, yet hold valuable insights for the present.

While speculative and critical design approaches have long provided frameworks for exploring future-oriented design questions, this study extends these traditions through a hybrid integration of Research through Design and Heuristic Inquiry. This combination emphasizes the designer's reflective experience and

subjective interpretation as active sources of design knowledge.

In summary, this article is guided by the following research question: “*How can a hybrid methodology, integrating Research through Design and Heuristic Inquiry, enable a solo designer to investigate speculative industrial design scenarios through virtual prototyping?*”

2. Literature Review and Background Information

Design is often expected to produce answers, solutions to problems, improvements to systems, or refinements of form and function [13]. Yet not all design outcomes need to be resolved or ready [14]. In contexts where the goal is to question, imagine, or challenge, different methods are needed, ones that support uncertainty, contradiction, and imagination [15]. While critical design often challenges user expectations through provocative artifacts, the present study treats speculative prototyping as an introspective process — a form of reflective inquiry that enables the designer to examine their own assumptions within virtual contexts.

This section traces key ideas in speculative design, Research through Design (RtD), and Heuristic Inquiry, to set the stage for a combined method better suited to reflective, solo design practice.

2.1 Speculative Design within Industrial Design Practice

Speculative design, as introduced by Dunne and Raby [16], moves away from designing for immediate use and instead explores potential conditions that may or may not happen. These speculative artifacts don't aim to be adopted or manufactured. Instead, they're built to expose assumptions, open up possibilities, and allow others to imagine alongside them. In many cases, they're intentionally incomplete [16].

Much of the existing work in this field originates from art, architecture, or critical theory [17], [18], [19]. When brought into industrial design, speculative approaches face a tension: industrial design is typically tied to practical outcomes and production logic [20]. Yet designers increasingly find themselves working on problems with no clear brief, climate adaptation, artificial intelligence, and aging populations, where traditional project cycles fall short [21], [22]. In such cases, speculative design is not a departure from practice but a tool to think through materials, systems, and consequences [23].

2.2 Research through Design (RtD)

RtD offers a structure for inquiry that is grounded in making [24]. It doesn't treat the final design as a

demonstration of knowledge, but rather considers the design process itself as the source of insight [25]. What's learned emerges through iteration, material engagement, and reflection on the shifts that occur as a concept takes shape [26].

This approach fits well with industrial design when the goal is not to validate an idea for the market but to explore possibilities that are difficult to articulate in words alone. While RtD is well-established in interaction design and HCI [27], it has been slower to gain traction in object-based design fields [28], perhaps due to a lack of frameworks that accommodate both physical making and conceptual reflection.

2.3 Heuristic Inquiry in Creative Practice

Originally rooted in psychology, heuristic inquiry is a method that involves gaining insight through deep, personal engagement with a question or problem [29]. It emphasizes intuition, immersion, and reflection over measurement or external validation [30]. While not commonly used in design, it has been adapted for creative research, especially where the researcher is both the observer and the instrument [31].

In solo design practice, heuristic inquiry supports moments of non-linear progress, when understanding unfolds through sketching, pausing, reworking, or simply sitting with uncertainty [32]. It validates personal process as a research path, especially in areas where emergent meaning and ambiguous futures are central to work [31].

3. Methodology

This research adopts a hybrid methodology combining Research through Design (RtD) [8] with selected elements of Heuristic Inquiry [9], developed to support solo, reflective practice in speculative industrial design [16]. The specific needs of this project shaped the approach: to prototype artifacts that do not solve existing problems, but instead question emerging ones, futures that are undefined, complex, and possibly never realized [12]. The method supports designing as a mode of thinking, where form, material, and interaction become tools for inquiry.

The integration of Heuristic Inquiry introduces a structured reflexive layer to speculative design, positioning the designer's internal responses as data that informs and reframes the design direction.

3.1 Design as Investigation

Instead of starting with a fixed hypothesis or brief, the research was developed by designing and prototyping a speculative product idea. Designing was seen not just as a goal but as a way to explore questions that analysis

alone couldn't answer. Each version of the artifact, whether digital or physical, was documented, interpreted, and viewed as a temporary response to a changing problem space. This approach is consistent with RtD, which considers design as a process that generates knowledge through cycles of making, reflecting, and remaking [26].

3.2 Reflective Practice and Heuristic Phases

To support deeper insight during the design process, the structure of Heuristic Inquiry was applied selectively, using four key phases:

- *Immersion:* The designer engaged closely with speculative themes through sketches, reference models as shown in Figure 1, and early conceptual models.



Figure 1. Reference models from the literature [33]

- *Incubation:* The design activity was deliberately paused to allow concepts to evolve subconsciously.
- *Illumination:* Unexpected insights, emerging design tensions, symbolic forms, or contradictory functions were documented as they surfaced.
- *Reflection:* These insights were analyzed alongside the evolving prototypes to inform subsequent iterations and to expose underlying assumptions.

This structure helped maintain a critical distance from work while still allowing intuition and subjectivity to play an active role. It positioned the designer not only as a maker but also as a reflective observer of their process.

3.3 Solo Practice as Valid Inquiry

The research was conducted entirely by a single designer-researcher. While this introduces a degree of subjectivity, it also allows for uninterrupted immersion in the design process and a direct connection between decision-making, intuition, and outcome. The work was documented through journals, screenshots, and annotations that tracked the evolution of ideas, materials, and forms over time. This type of solo inquiry is especially suited to speculative design, where

personal perspective and imaginative framing are integral to the work.

3.4 Prototypes as Knowledge Carriers

Prototypes produced during the research were not intended as final products but as tools for thought, objects that could provoke reflection, frame questions, and expose hidden systems or assumptions. Virtual prototypes, including 3D models, speculative renderings, and scenario-driven simulations, were used in place of physical models. These digital artifacts served as the primary outputs of the design process and are treated not only as conceptual objects but also as evidence of inquiry. Their immateriality did not diminish their role; instead, it enabled rapid iteration, speculative flexibility, and visual clarity while remaining grounded in industrial design logic.

The following section presents the design process as a case study, and its outcomes not merely as sequential developments, but as reflective stages through which the designer's understanding of speculative practice evolved. Rather than treating each iteration as a fixed design step, the analysis emphasizes how the heuristic phases—immersion, incubation, illumination, and reflection—shaped the unfolding design logic and revealed underlying assumptions about technology, autonomy, and responsibility.

4. Case Study, Findings, and Discussion

This section outlines the development process and key reflections that arose during the design of a speculative product: a compact, AI-controlled naval-public search and rescue unit such as the one in Figure 2, envisioned for deployment in near-future maritime emergencies [34], [35]. The project used a hybrid approach combining Research through Design (RtD) and Heuristic Inquiry, enabling the designer to critically reflect on both the artifact and the evolving assumptions behind it. This approach moves beyond established speculative design practices by shifting the focus from provocation to reflection. While traditional speculative and critical design often use artifacts to challenge societal norms or stimulate public debate, the approach adopted here turns that critical lens inward—toward the designer’s own decision-making and meaning-making processes. By integrating Heuristic Inquiry with Research through Design, the method transforms speculative prototyping into a structured form of self-reflective investigation. This allows the designer not only to imagine alternative futures, but also to observe how personal values, biases, and intuitions shape those futures during the design process. Furthermore, by operating entirely within a virtual prototyping environment, the study extends speculative design into the digital realm, demonstrating how virtual methods can support iterative reflection without material waste or production constraints. In doing so, the research reframes speculative industrial design as both a critical and introspective practice—one that expands the designer’s role from commentator on society to active participant in the exploration of design ethics, intention, and authorship.



Figure 2. Autonomous Unmanned Surface Vessel (USV) by Legacy Marine [36]

4.1 Project Overview

The study examines how autonomous design systems might respond to growing humanitarian demands at sea, a future characterized by climate instability, declining public rescue funding, and the increasing adoption of unmanned technology. The speculative product, named ADAX-1, is a 3-meter-long, 1.6-meter-wide autonomous rescue craft designed to locate, stabilize, and carry up to two survivors without a human crew.

Rather than being a scale model of a future product, ADAX-1 functions as a speculative prototype; A vessel built not to be launched, but to question how autonomous humanitarian systems should look, behave, and make decisions. The design process unfolded through sketching, digital modeling, scaled 3D prototyping, and reflective documentation. Each iteration exposed new tensions in the speculative context, prompting further refinement and conceptual redirection.

4.2 Design Evolution and Critical Turning Points

Several key insights emerged during the development of ADAX-1, shaped by iterative design work and reflective immersion in the speculative scenario:

- *From Functional Tool to Emotional Actor:*
Early concepts focused purely on utility, speed, balance, and AI responsiveness. However, heuristic reflection raised questions about the survivor’s psychological experience. What would it feel like to be rescued by a silent machine? In response, the design incorporated subtle interaction cues: ambient lights, a soft hull profile, and an optional auditory interface designed not to mimic human presence, but to offer reassurance without overstepping into simulation.
- *Trust and Form Language:*
Initial sketches, such as the one shown in Figure 3, borrowed elements from drone and military aesthetics, which, upon review, were found to be misaligned with humanitarian goals. The design shifted toward a softer, more stable form, evoking life-saving equipment rather than defense, as shown in Figure 4. The final form emphasizes approachability, with rounded surfaces and low visual aggression, especially when seen from the water level.

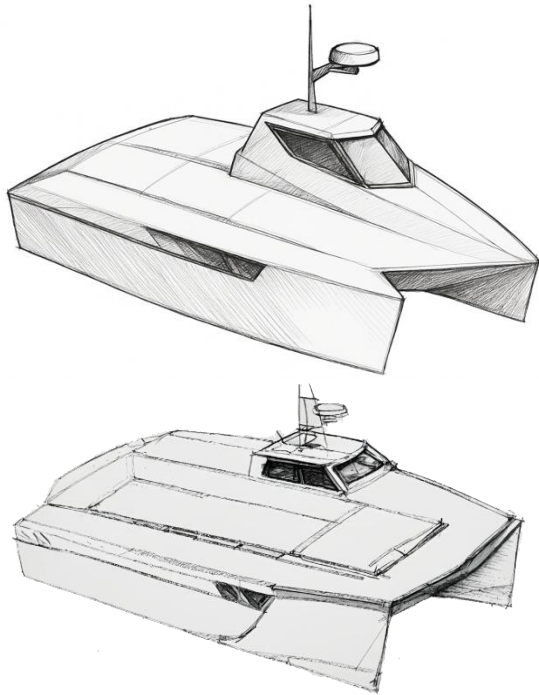


Figure 3. Initial AI-based hull sketches taking ARMA Craft vessel sketches (bottom) as a starting point (Author's work) [37]



Figure 4. The sketch of a softer, more stable form, evoking life-saving equipment rather than defense (Author's work).

- *Decision-Making Transparency:*
One of the most challenging speculative issues involved imagining how the craft might prioritize among multiple survivors. Would it make choices based on biometric data? Environmental risks? Survivability scores? While no definitive answer was reached, this tension was intentionally built into the design. A translucent control interface shows decision logic with abstract visuals in Figure 5, enabling future observers to critique or question the criteria instead of hiding them behind algorithms.



Figure 5. The translucent control interface shows decision logic about rescue priorities.

4.3 Ethical Dimensions of Algorithmic Triage

Within the ADAX-1 speculative scenario, the concept of algorithmic triage—where an autonomous system determines the prioritization of rescue actions—raises profound ethical concerns. These include the delegation of moral responsibility to computational agents, the opacity of embedded criteria, and the potential misalignment between human values and algorithmic logic. Rather than portraying the algorithm as an unquestioned rational actor, the study treats it as a site of design inquiry, where the interface and decision transparency become ethical artifacts themselves. The speculative framing thus positions the designer not only as a technical creator but as a curator of moral negotiations within human-machine systems.

The question of trust in autonomous rescue scenarios extends beyond technical reliability; it involves how design mediates perception, accountability, and moral agency. In speculative industrial design, such systems offer a lens to examine how trust can be constructed through interface transparency and the visibility of decision logic. By visualizing the criteria underlying algorithmic triage—rather than concealing them—the ADAX-1 concept transforms the interface into an ethical instrument, enabling users and observers to critique, question, or even contest algorithmic reasoning. This reflective strategy expands the designer's role toward facilitating ethical discourse around automation rather than merely enabling its functionality.

4.4 AI Agency and Moral Mediation in Rescue Scenarios

The speculative scenario of ADAX-1 situates artificial intelligence not merely as a technical system but as an active agent within humanitarian contexts—an agent tasked with interpreting moral priorities under conditions of uncertainty. Unlike deterministic automation, AI-driven decision-making involves adaptive reasoning processes that can mirror, distort, or replace human judgment. This raises critical questions about moral accountability: Who bears responsibility

when an autonomous vessel makes a life-affecting decision? The speculative design approach employed here does not aim to provide definitive answers, but to make such ethical tensions explicit, transforming AI from a problem-solving mechanism into a subject of inquiry within design practice.

The deployment of AI in humanitarian operations, particularly in autonomous rescue scenarios, introduces a paradox of care: technology is intended to save lives, yet its logic of efficiency may conflict with human values such as empathy, uncertainty tolerance, and moral discretion. Within speculative industrial design, this paradox becomes a fertile space for inquiry. By treating AI as a design material, the research foregrounds the designer's responsibility in framing how such systems perceive, prioritize, and act. The heuristic process, therefore, becomes an ethical design exercise—interrogating the balance between computational objectivity and the humane imperatives embedded in rescue decision-making.

4.5 Toward the Systematic Evaluation of Speculative Prototypes

While speculative prototypes in this study primarily served as vehicles for reflection and critical inquiry, their potential as legitimate research outputs invites further methodological development. Future work could benefit from establishing evaluative frameworks that balance interpretive and empirical dimensions. For instance, integrating user-based narrative elicitation, expert panel critique, or scenario validation could help systematize the assessment of speculative artifacts without constraining their open-ended nature. Such frameworks would not measure functionality in a conventional sense but instead assess conceptual resonance, ethical coherence, and methodological transparency—criteria that align with the epistemological stance of speculative design research. Developing these structured yet flexible evaluation tools would strengthen the credibility and reproducibility of speculative design as a legitimate research mode within industrial design scholarship.

4.6 Findings from Reflective Prototyping

The prototyping process yielded several insights into speculative industrial design in solo research contexts [38]:

- *Design is a question generator, not a solution engine:*
Rather than resolving a problem, ADAX-1 exposed assumptions about technology, care, and automation. The act of designing became a dialogue between the artifact, the imagined users, and the designer's expectations.

- *Form and fiction work together:*
Even when built from speculative assumptions, physical form deeply affects how a concept is interpreted. The same AI rescue function, when housed in an angular, opaque form, reads as militaristic; when enclosed in a soft, translucent hull, it signals care and trust. Design language matters, even when the scenario is imagined.
- *Compact scale enhances critical focus:*
Limiting the vessel length to 3 meters, as shown in Figure 6, forced a tighter design logic; each decision had to be justified. This economy strengthened the speculative frame by grounding it in plausible constraints and resisting overly abstract solutions.

As the virtual prototypes developed, the *illumination* phase became evident through moments of recognition, where design decisions began to carry meaning beyond functionality. For example, certain structural adjustments were not motivated by technical optimization but by the designer's intuitive response to questions of balance, control, and empathy in an autonomous rescue system. These small creative shifts represent the designer's lived negotiation between speculative imagination and ethical consideration, characteristic of heuristic reflection.



Figure 6. Carrying positions for 2 people (Author's work).

The ADAX-1 case study illustrates how speculative industrial design can function not as a prediction, but as a provocation. Through reflective prototyping and focused, self-directed inquiry, the process generated not only a conceptual object but a set of questions about autonomy, ethics, form, and empathy in near-future design. These findings are listed in Table 1 and discussed further in the concluding section.

Across the heuristic cycle, each phase contributed a distinct layer of insight. The *immersion* phase grounded the designer in the thematic context of rescue, risk, and autonomy. *Incubation* allowed ideas to mature subconsciously, leading to symbolic and aesthetic decisions that emerged intuitively rather than logically.

Illumination marked moments of conceptual breakthrough, where the vessel's role evolved from a mere object of rescue to a representation of care and decision ethics. Finally, *reflection* enabled critical distance, revealing how virtual prototyping, as both a

medium and a mindset, can expose the designer's values and biases in real time. This cyclical engagement positioned the act of designing itself as a method of inquiry, rather than a process of production.

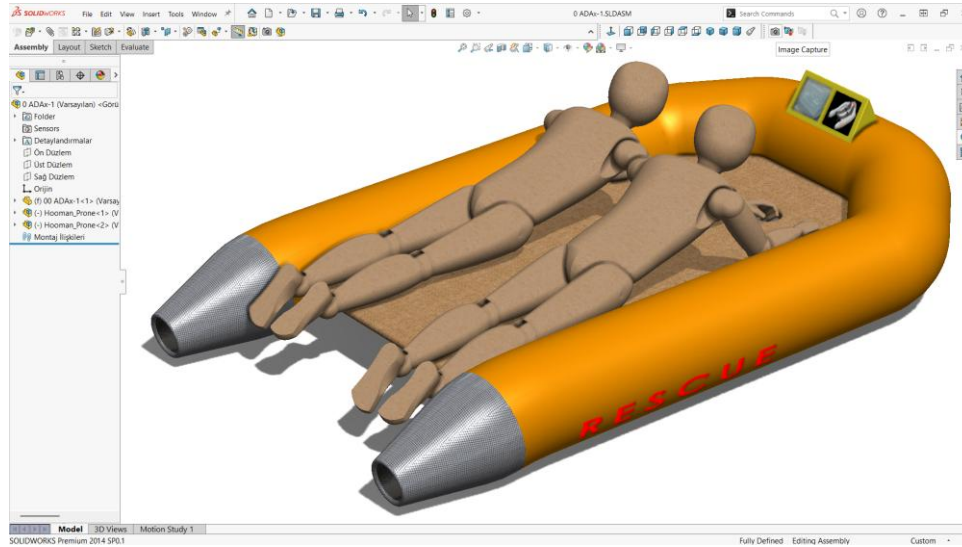


Figure 7. ADAX-01 3D model in SolidWorks (Author's work)

Table 1. Evaluation of the ADAX-1 Speculative Design Case Study

Evaluation Domain	Indicator / Metric	Findings from the ADAX-1 Case Study
Reflective Process	Turning points in design thinking	Shift from utility-focused design to emotional-ethical framing of the rescue experience.
	Role of intuition and personal judgment	Adjustments to form language and user interface were made based on the designer's affective reading of scenario tensions.
	Depth of reflection and conceptual iteration	Four major design redirections were documented across the prototyping cycles.
Knowledge Contribution	Type of insights generated	Ethical decision-making in autonomous SAR; emotional perception of AI interfaces; design language and trust.
	Value of insight into design research	The study contributes to the methodology of speculative industrial design using solo, first-person, iterative practice.
	Novelty and transferability	The ADAX-1 framework can inform future design fictions and speculative systems-based industrial design research.
Speculative Value	Provocative potential	Raises critical questions about ethics, care, and trust in AI-driven humanitarian tools.
	Narrative integration	The artifact is embedded in a coherent future scenario involving distributed SAR systems and climate change

		implications.
	Plausibility vs. ambiguity	Balanced: compact and realistic form, but ethically open-ended decision system maintains critical ambiguity.
Technical Coherence	Formal and functional integrity	Compact form supports 2-person rescue; internal module layout is consistent with industrial feasibility.
	Clarity of system behavior	AI actions are made legible via a semi-transparent interface, which avoids black-box decision logic.
	Scaled realism for 3D prototyping	Hull segmented for modular 3D printing; fabrication constraints integrated into early-stage design decisions.

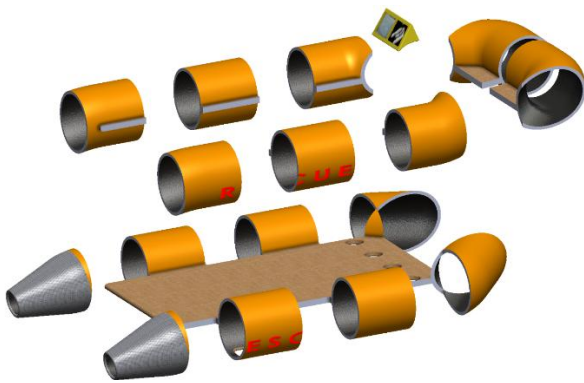


Figure 8. ADAX-01 3D model sliced into smaller pieces for 3D printing (Author's work)

4.6 Epistemological Positioning of the Research

The insights generated through this hybrid methodology occupy an intermediate space between design-specific, ethical, and methodological forms of knowledge. From a design perspective, the iterative prototypes functioned as material reflections, vehicles for exploring how speculative products could embody future-oriented values and technological assumptions. Ethically, the process yielded critical awareness rather than prescriptive solutions, exposing how AI-driven decision systems challenge conventional notions of responsibility, care, and agency in industrial design.

Methodologically, the research contributes by demonstrating how the integration of Research through Design and Heuristic Inquiry can enable a solo practitioner to transform subjective reflection into structured, transferable insight. Thus, the knowledge produced is situated, interpretive, and generative: it does not claim universality but offers a framework through which others can explore similar speculative questions in their own contexts. Additionally, the limited use of AI during the design process proved to be effective, especially during the concept development phase of the design process conforming previous studies [39]. The

use of metaphors [40] in definitions, while working with AI tools, also proved helpful.

5. Conclusion

This study aims to explore how speculative industrial design can be practiced and examined through a hybrid methodology that combines Research through Design (RtD) and Heuristic Inquiry. The case study, an AI-controlled, autonomous naval rescue vessel named ADAX-1, functions not only as a design artifact but also as a medium for critically engaging with questions about the future of humanitarian technology, trust in autonomous systems, and the emotional aspects of machine-led intervention.

Using reflective virtual prototyping as a central method, the process was structured around iterative making and introspective interpretation. The evaluation of the design process revealed multiple turning points that significantly shaped the project's trajectory, most notably, a shift from a strictly functional interpretation of search and rescue toward a more nuanced, ethically aware, and emotionally intelligent framing. These moments of redirection were key indicators of the reflective depth made possible by a solo, immersive design method.

In terms of the contribution of knowledge, the project demonstrated that speculative industrial design could generate insights that are not easily accessed through analytical methods alone. The ADAX-1 virtual prototype, shown in Figure 9, raised critical questions about algorithmic triage, user trust in non-human rescue systems, and how subtle formal gestures (such as hull softness or interface ambiguity) can communicate care or threat. These are not fully resolved conclusions but are knowledge outcomes nonetheless, situated, processual, and open to further interpretation.

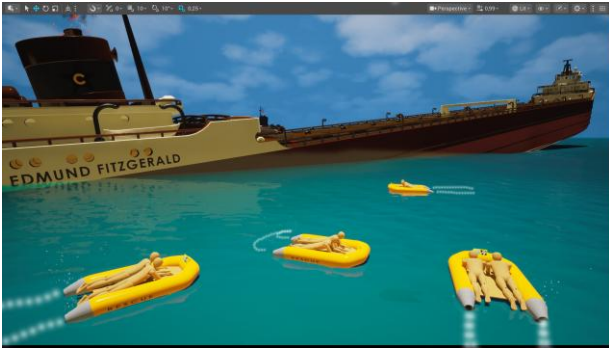


Figure 9. ADAX-1 virtual prototype swarms during a virtual rescue mission in Unreal Engine [41] (Author's 3D models and virtual world design)

The speculative value of the project lies in its capacity to provoke rather than to predict. While the ADAX-1 concept is built on plausible design constraints, such as scale, materials, and fabrication techniques, its real function is to act as a cognitive probe, inviting discussions about technological governance, autonomy, and the shifting emotional relationships between people and machines in crisis scenarios. The decision to keep some aspects intentionally ambiguous, for example, how AI determines which lives to save, underscores the role of speculative design as a tool for surfacing difficult questions, not simplifying them.

While the present study adopts a solo reflective design approach rooted in autoethnographic practice, its insights hold potential for broader collaborative and institutional applications. The self-reflective structure of this process—comprising heuristic phases of immersion, incubation, illumination, and reflection—can be integrated into collective design studios, research groups, or academic design laboratories. Within such contexts, reflective documentation, shared virtual prototyping platforms, and group critique sessions could transform individual reflexivity into a distributed cognitive process. Although the research emphasizes personal experience as a form of situated knowledge, its methodological scaffolding is transferable, offering a framework that encourages critical reflection and speculative exploration among multiple participants.

The study also highlights how speculative virtual prototyping can serve as an ethical laboratory, revealing and contesting the moral assumptions embedded in algorithmic and autonomous decision-making processes.

In expanding its ethical scope toward AI-mediated humanitarian contexts, the study contributes to ongoing discussions on how design can critically frame—*not merely enable*—the moral agency of intelligent systems.

By framing its insights as reflective and situated rather than universal, the study aligns with epistemological

traditions in design research that value interpretation, reflexivity, and designerly ways of knowing as legitimate modes of inquiry.

In terms of technical coherence, the compact scale of the final prototype reinforced a disciplined design logic. The object's internal consistency, including its 3D-printable modularity and swarm-compatible role, was carefully considered, ensuring that even a fictional concept retained industrial plausibility. This coherence strengthened the artifact's credibility, making it a more effective carrier of critical ideas.

The designs depicted throughout this article are not intended to represent fully realized or finalized versions of a functional rescue vessel. Rather, they serve as demonstration images developed to illustrate the speculative design methodology employed in this study. Their primary role is to support critical reflection, conceptual framing, and methodological transparency. By presenting these speculative forms, the study aims to assist other designers in adapting the same research approach to create their own, contextually relevant and technically advanced vessels. The visualizations are thus tools for inquiry, not blueprints for production.

Future research may extend this framework toward collaborative or institutional settings, enabling collective forms of speculative reflection and shared authorship within virtual product development practices. Researchers are encouraged to operationalize structured evaluation methods, such as narrative, ethical, or scenario-based assessment, to further consolidate speculative prototypes as recognized forms of design knowledge within academic research.

In conclusion, the ADAX-1 case study demonstrates that speculative industrial design, when supported by a hybrid research method, can be both rigorous and imaginative. It allows the designer to explore possible futures while remaining grounded in material thinking and reflective depth. The study also suggests that solo design inquiry, far from being limited by its subjectivity, can offer valuable perspectives when properly documented and critically evaluated. The combination of RtD and heuristic reflection proved especially effective in navigating uncertainty, surfacing ethical tension, and producing a design artifact that asks more than it answers, which, in speculative design, may be its greatest strength.

Author's Contribution

Özkal Hüseyin Özsoy: Solely conceived, designed, and conducted the research presented in this study. All phases of the project, including methodological development, virtual prototyping, critical reflection, analysis, and writing, were carried out independently by

the author. The work represents the author's original contribution to the field of speculative industrial design.

Ethics

This study is a design-based, speculative research project conducted solely by the author. It does not involve human participants, personal data, or interventions requiring ethical approval. All design processes, reflections, and virtual prototyping activities were self-directed. No ethical violations or conflicts of interest are present.

References

- [1]. Koch, C. H. W. 2022, The future of industrial design and its role in Industry 4.0, Doctoral, *Swinburne University of Technology*, 348.
- [2]. Ollenburg, S. 2018, Beyond Futures: Designing Futures by Educating Future Designers, *World Future Review*, vol. 10, no. 4, pp. 279–293, doi: 10.1177/1946756718790758.
- [3]. Hook, A. 2019, Exploring speculative methods: Building artifacts to investigate interspecies intersubjective subjectivity, <https://hdl.handle.net/10468/8224> (accessed at 09. 07. 2025).
- [4]. Auger, J. 2013, Speculative design: crafting the speculation, *Digital Creativity*, vol. 24, no. 1, pp. 11–35, doi: 10.1080/14626268.2013.767276.
- [5]. Escobar, A. 2018, Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds. Duke University Press.
- [6]. Tharp B. M. and Tharp, S. M. 2019, Discursive Design: Critical, Speculative, and Alternative Things. MIT Press.
- [7]. Barendregt, L., and Vaage, N. S. 2021, Speculative Design as Thought Experiment, *Journal of Design Economy and Innovation*, vol. 7, no. 3, pp. 374–402.
- [8]. Godin, D., and Zahedi, M. 2014, Aspects of Research through Design: A Literature Review, DRS Bienn. Conf. Ser., <https://dl.designresearchsociety.org/drs-conference-papers/drs2014/researchpapers/85>
- [9]. Douglass B. G. and Moustakas, C. 1985, Heuristic Inquiry: The Internal Search to Know, *J. Humanist. Psychol.*, vol. 25, no. 3, pp. 39–55, doi: 10.1177/0022167885253004.
- [10]. Brookfield, S. 2009, The concept of critical reflection: promises and contradictions, *Eur. J. Soc. Work*, vol. 12, no. 3, pp. 293–304, doi: 10.1080/13691450902945215.
- [11]. Abrahamson, D. 2009, Embodied design: constructing means for constructing meaning, *Educ. Stud. Math.*, vol. 70, no. 1, pp. 27–47, doi: 10.1007/s10649-008-9137-1.
- [12]. Calleo, A. 2024, Playful Prototyping in Speculative Design Practices, DRS Bienn. Conf. Ser., <https://dl.designresearchsociety.org/drs-conference-papers/drs2024/researchpapers/141> (accessed at 09,07, 2025)
- [13]. Brown D. C. and Chandrasekaran, B. 2014, Design Problem Solving: Knowledge Structures and Control Strategies. Morgan Kaufmann.
- [14]. Harfield, S. 2007, On design 'problematization': Theorising differences in designed outcomes, *Des. Stud.*, vol. 28, no. 2, pp. 159–173, doi: 10.1016/j.destud.2006.11.005.
- [15]. Daalhuizen, J. (2014). Method Usage in Design – How methods function as mental tools for designers. (unpublished PhD thesis), Delft University of Technology, Delft, the Netherlands.
- [16]. Dunne, A., and Raby, F. Speculative Everything, with a new preface by the authors: Design, Fiction, and Social Dreaming. MIT Press, 2013.
- [17]. How, A. Critical Theory. Bloomsbury Publishing, 2017.
- [18]. Vishmidt, M. Speculation. MIT Press, 2023.
- [19]. Sever, S. 2024, The Past in the Light of the Future – A Case Study in Speculative Architecture, doi:10.48417/technolang.2024.03.04.
- [20]. Heskett, J. Industrial Design, in Design History, Routledge, 1987.
- [21]. Evans, G. 2013, Ageing and Climate Change: A Society-Technology-Design Discourse, *Des. J.*, vol. 16, no. 2, pp. 239–258, doi: 10.2752/175630613x13584367985027.
- [22]. Verganti, R., Vendraminelli, L., and Iansiti, M., 2020, Innovation and Design in the Age of Artificial Intelligence, *J. Prod. Innov. Manag.*, vol. 37, no. 3, pp. 212–227, doi: 10.1111/jpim.12523.
- [23]. Shao, A. 2023, Designing for Futures at the Intersection of Speculative Design, Storytelling, and Systems thinking, master's thesis. <https://openrepository.aut.ac.nz/server/api/core/bitstreams/1417a02c-8d59-4030-a963-6f4cc3cda68d/content> (accessed at 09,07, 2025).
- [24]. Sadokierski, Z. 2019, Critical Journal / Contextual Portfolio: A framework for documenting and disseminating RtD as scholarly research. <https://opus.lib.uts.edu.au/handle/10453/135917> (accessed at 09,07,2025).
- [25]. Bardzell, J. Bardzell, S. Dalsgaard, P. Gross, S. and Halskov, K. 2016, Documenting the Research Through Design Process, in Proceedings of the 2016 ACM Conference on Designing Interactive Systems, Brisbane, QLD, Australia: ACM, pp 96–107. doi: 10.1145/2901790.2901859.
- [26]. Hummels, C. and Frens, J. in Industrial Design: New Frontiers, IntechOpen, 2011, pp. 147–170.
- [27]. Zimmerman, J., Forlizzi, J., and Evenson, S. 2007, Research through design as a method for interaction design research in HCI, in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, San Jose, California, USA: ACM, pp. 493–502. doi: 10.1145/1240624.1240704.
- [28]. Janevski, S. 2019, From A Tool for Making to a Tool for Thinking: Investigation of the Potential of 3D Printing in Meaning-Making, Master of Design, Carleton University, Ottawa, Ontario. doi: 10.22215/etd/2019-13868.
- [29]. Moustakas, C. Heuristic Research: Design, Methodology, and Applications. SAGE Publications, 1990.
- [30]. N. Sultan, Heuristic Inquiry: Researching Human Experience Holistically. SAGE Publications, 2018.
- [31]. Robin, T. Autoethnography and Heuristic Inquiry for Doctoral-Level Researchers: Emerging Research and Opportunities: Emerging Research and Opportunities. IGI Global, 2019.
- [32]. Crowe, J. V. 1988. Art about teaching: A visual heuristic study of the content and process of teaching art education as a subject for making art, Ph.D. Thesis. The Union Institute Graduate School, Ann Harbor, USA, <https://www.proquest.com/docview/304478297/abstract/2AA06327EC6F47B5PQ/1> (accessed at 09,07, 2025)

- [33]. Ghazali, M. H. M. Satar, M. H. A., and Rahiman, W. 2024, Unmanned surface vehicles: From a hull design perspective, *Ocean Eng.*, vol. 312, p. 118977, doi: 10.1016/j.oceaneng.2024.118977.
- [34]. Rashid, A. B. Kausik, A. K. Sunny, A. Al Hassan and Bappy, M. H. 2023, "Artificial Intelligence in the Military: An Overview of the Capabilities, Applications, and Challenges," *Int. J. Intell. Syst.*, vol. 2023, no. 1, p. 8676366, doi: 10.1155/2023/8676366.
- [35]. Boretti, A. 2024, Unmanned surface vehicles for naval warfare and maritime security, *J. Def. Model. Simul. Appl. Methodol. Technol.*, doi: 10.1177/15485129241283056.
- [36]. Jordan, B. SA yard starts construction on first locally-built USV, International Boat Industry. <https://www.ibinews.com/companies/sa-yard-starts-construction-on-first-locally-built-usv/48033.article> (accessed at 10,07,2025).
- [37]. "ARMA," ARMACRAFT. <https://www.arma-craft.com> (accessed at 10,07, 2025).
- [38]. Erichsen, J. A. B. Pedersen, A. L. Steinert, M., and Welo, T. 2016, Learning in Product Development: Proposed Industry Experiment Using Reflective Prototyping, *Procedia CIRP*, vol. 50, pp. 454–459, doi: 10.1016/j.procir.2016.04.142.
- [39]. Elal, İ., & Özsoy, H. Ö. 2024. Investigating The Effects of Using Artificial Intelligence in The Conceptual Design Phase of The Industrial Design Process. *Gazi University Journal of Science Part B: Art, Humanities, Design and Planning*, 12(2), 255-276.
- [40]. Özsoy, H. Ö. 2009. Endüstri ürünleri tasarımında eğretilmeli anlatımlar ve tasarım yaklaşımı olarak yöntemli kullanımı, Ph.D. Thesis, Mimar Sinan University of Fine Arts, İstanbul, Türkiye.
- [41]. Lee, N. 2023, Unreal Engine, A 3D Game Engine, in *Encyclopedia of Computer Graphics and Games*, Springer, Cham, pp. 1–3. doi: 10.1007/978-3-319-08234-9_537-1.