The Desertia Project

Speculative Fashion and Adaptive Clothing Systems for Global Climate Change

An exegesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Design

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Abstract

With the mutual catastrophic influence of global climate change and human activities, the future becomes increasingly ominous. While we cannot predict future climate scenarios, we can critically examine them. As an indispensable part of human life, clothing holds significant potential in its future function and its ability to draw attention to necessary adaptive changes. This study utilizes the theoretical framework of critical design to speculate about the future world and the garments we will inhabit.

The theoretical framework of this exegesis is inextricably linked with its tangible creative outcomes. The central practice-led project, *Desertia*, comprises three interrelated components: an immersive multimedia installation paired with its video documentation, a speculative film, and a visual design process journal. This project explores biomorphic concepts designed for extreme future ecosystems by translating natural adaptive mechanisms into functional clothing components. The physical prototypes integrate 3D printing with sustainable materials like Cai Lun paper yarn to mimic natural survival strategies. To overcome the temporal and spatial constraints of the physical exhibition, video documentation is used to archive and broaden access to the installation. Concurrently, operating as a deliberate provocation, the speculative film synthesizes with soundscapes to confront audiences with a visceral vision of ecological crisis. Serving as an essential support mechanism, the design process journal provides a rigorous methodological account of this translation. Together, the exegesis and the practice ensure a comprehensive exploration of fashion as a critical survival interface.

Ultimately, this study reconsiders the current relationship between clothing and our environment, highlighting the radical adaptations necessitated by tomorrow's ecosystems. By visualizing these consequences through a speculative fashion design framework, the project aims to stimulate critical thought about the impacts of climate change and provoke tangible shifts in our current lifestyles.

Creative Work Outcomes

This doctoral research is made of two parts: a creative practice component and written exegesis component

Visual Outcome 1: Desertia (Speculative Film)

Visual Outcome 2: Desertia (Installation Documentation)

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Research Publications and Creative Outcomes

The following list of peer-reviewed publications, conference presentations and design awards are direct outcomes from this doctoral research.

1. Peer-Reviewed Publications

- **Zheng, Y.** (2026). ‘*Affective Speculation as More-than-Human Co-Design: Participatory Atmospheres for Climate Futures in Design Practice’*. CoDesign. (forthcoming).
- **Zheng, Y.** (2025). ‘**Nature-Adaptive Mechanisms in Speculative Conceptual Design’**, in, *Sustainable Design, Art, and Innovation*. Advances in Science, Technology & Innovation (ASTI). Springer Nature. DOI: 10.1007/978-3-032-21303-7. (Scopus Indexed).

Note: Originally presented at the 1st International Conference on Sustainable Creative Art (SCIN 2025), Dubai.

2. International Academic Conferences & Forums

- **Cumulus Athens 2026: Loving Resilience** (Athens, Greece, May 2026): Poster Presentation.
- **The 2nd International Conference on Art Studies** (Brussels, Belgium, 2025): Paper Presentation.
- **International Doctoral Student Forum of Art Studies, Peking University** (Beijing, China, 2025): Research Presentation.
- **The 11th International Forum for Young Scholars, China University of Geosciences** (Wuhan, China, 2025): Research Presentation.

3. Creative Design Awards & Exhibitions

- **“Fashion 100” – New Era Young Art Talent Cultivation Program** (China Artists Association, 2026): Selected as an emerging designer. Project showcased at the **Beijing Fashion Week Exhibition** (March 22, 2026).
- **London Art Collective (LAC) - ARTEVOL 2025**: Digital video work *“Symbiont Futures”* (Experimental Digital Design) selected for the **Longlist** (August 2025).

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1.0 **INTRODUCTION**

Humanity is entering an era of profound ecological disruption. Climate change has already manifested through extreme weather events, biodiversity loss, and resource stress, producing unprecedented challenges whose scale and complexity pose a fundamental threat to both planetary systems and human civilization itself (Heinberg, 2024). However, uncertainty is inherent to climate change: its progression is evident, yet its pace and specific trajectories remain indeterminate (Heal & Millner, 2014). Scientific projections reveal broad trends but cannot eliminate indeterminacy about future pathways. For this reason, societies must rely on methods and tools capable of engaging with multiple possible futures.

In this context, imagination and speculative thinking becomes indispensable. As Keith Oatley notes in *Such Stuff as Dreams*, imagination enables humans to envision possibilities, anticipate outcomes, and engage in moral reflection (Oatley, 2011). Through the speculative construction of "possible worlds," individuals and societies can question assumptions, test alternatives, and prepare for futures that remain ambiguous and unstable (Doležel, 1998). Speculation, therefore, is not merely a creative exercise but a critical strategy for responding to the instabilities of the Anthropocene.

The speculative dimension is particularly evident in art and cultural practices, offering a critical entry point into the discourse on the Anthropocene and ecological crisis. Since Paul Crutzen's proposal of the "Anthropocene" in 2000, the concept has remained contested in geology, yet it has been widely adopted in the social sciences and the arts as a framework for articulating humanity's profound impact on earth systems (Crutzen & Stoermer, 2021). Over the past three decades, artists and designers have shown increasing concern with climate change and ecological crisis, intervening in public discourse through diverse practices. At COP26, for instance, the non-profit organization Art of Change 21 initiated an artistic program that highlighted the role of art in ecological transition, fostering dialogue across art, technology, and the climate. In *Art in the Anthropocene: Encounters Among Aesthetics, Politics, Environments and Epistemologies*, Heather Davis and Etienne Turpin emphasize that contemporary art and knowledge production can reframe our understanding of the Anthropocene through aesthetic dimension (H. Davis & Turpin, 2015). This perspective underscores that art functions not merely as a representation medium but as a catalyst for critique and for imagining futures. Such a cultural dimension establishes the context in which speculative design emerges and provides the theoretical grounding for this research's exploration of fashion as a mode of engaging with climate indeterminacy.

Fashion, as a cultural practice, is closely tied to the construction of identity and social meaning (Entwistle, 2015). At the same time, as a material practice, it is deeply entangled with cycles of resource use and environmental impact (Hodge & Mears, 2006). This duality positions clothing not only as a site of aesthetic consumption but also as a critical factor within ecological debates. Historically, the future fashion of the 1960s were closely associated with space-age aesthetics, as designers such as Rudi Gernreich, Paco Rabanne, André Courrèges, and Pierre Cardin employed metallic surfaces, geometric lines, and streamlined modernist forms in response to the cultural fascination with space exploration (Mendes & Haye, 1999). This period of experimentation not only established the visual codes of future clothing but also underscored the historical entanglement between fashion and technological imagination. In contemporary context, however, the forces shaping fashion's future are no longer defined solely by outer-space imaginaries but increasingly by the survival pressures of climate change. This shift provides the context for speculative fashion, which redefines clothing not as a symbolic metaphor of the future but as an adaptive interface for life under extreme conditions. Building on this perspective, this study positions fashion as a “survival interface” in the future climate crisis, exploring how speculative methodologies can intergrade ecological adaptation, technological innovation, and cultural narration into experimental futures of clothing.

Grounded in fashion design and inspired by architectural and biomorphic forms, my research trajectory has focused on translating concepts and spatial ideas from outside fashion into garment design. My personal transitions across diverse geographical and climatic environments spanning mainland China, Scotland, and New Zealand transformed climate change from an abstract global discourse into an immediate, everyday embodied experience of weather unpredictability. Witnessing intensifying global climate disruptions, such as severe heatwaves and wildfires, further compelled me to question the future role of clothing beyond conventional aesthetic and consumerist boundaries. This convergence of personal experience and academic inquiry motivated me to investigate whether fashion could evolve into an active, biomimetic life-support interface capable of adapting to environmental stress. This reflective trajectory ultimately established the foundational impetus for the *Desertia* project and its speculative exploration of future survival interfaces.

Since the early twenty-first century, the fashion industry has undergone rapid digital transformation. Practices such as virtual try-ons, digital fashion shows, and digital prototyping have redefined the production, marketing, and dissemination of clothing (Fincato et al., 2022). With the rise of Web3 and decentralized platforms, fashion experimentation has future expanded into the metaverse and virtual assets (Särmäkari & Vänskä, 2022). The advent of generative AI has accelerated this transformation, enabling designers to produce large volumes of high-quality visual outputs from text or image prompts. Yet these technologies also raise new questions concerning authorship and originality (Andreatta, 2022). In this research, AI functions as an auxiliary tool that stimulates speculative exploration while requiring critical attention to design agency. The project also extends beyond image generation to consider how digital patterning, virtual prototyping, and projection-based installation can reveal a new set of production logics for future garments. By presenting the design process and material experimentation through hybrid digital-physical installations, the study proposes alternative modes of specification, fabrication, and dissemination. These methods suggest potential pathways for industry and design education while creating a speculative environment through which shifts in lifestyle, climate adaptation, and future ecologies can be critically examined.

Accordingly, fashion installations and exhibitions are adopted as the principal means of presenting the outcomes of this research. As Dunne and Raby argue in *Speculative Everything*, exhibitions are not merely display formats but function as “tools” that construct speculative scenarios and invite audiences into reflection and debate (Dunne & Raby, 2013). In this sense, the functions of a fashion installation exhibition are not merely as a format of presentation but as a speculative tool that situates the experimental inquires of speculative fashion within a public context, provoking reflection and dialogue. Moreover, the research focuses on the desert scenario among several speculative contexts, taken as a paradigmatic manifestation of climate extremity. The IPCC Sixth Assessment Report highlights that global warming is reducing soil moisture and increasing consecutive dry days (Calvin et al., 2023), while urgency of adopting the desert scenario as a critical site of inquiry.

To systematically explore fashion’s adaptive potential, this research initially established a matrix of four distinct speculative scenarios. These encompass a Water world resulting from rising sea levels, a Desert world driven by continuous extreme heat, a Frozen world caused by prolonged extreme cold, and a Green world achieved through ecological protection and technological progress. From these expansive speculative futures, the Desert world was deliberately selected for in-depth physical and visual development and subsequently crystallized as the *Desertia* project. The rationale for this selection is twofold. Scientifically, as corroborated by the

IPCC, accelerating desertification and unprecedented droughts pose the most immediate and expansive existential threat to terrestrial habitats (IPCC, 2022). Conceptually, the continuous heat and extreme scarcity of a desert environment force the most radical rethinking of the boundary between the human body and its surroundings. It demands that clothing evolve beyond a passive aesthetic shield into an active, biomimetic life-support system. Such an interface requires complex adaptive mechanisms specifically tailored for cooling, ultraviolet protection, and hydration.

Consequently, this exegesis and its creative outcomes operate in a mutually complementary relationship, seamlessly synthesizing theoretical inquiry with tangible design practice. The creative outcomes are manifested through the *Desertia* project, which comprises three primary components: an immersive spatial installation paired with its video documentation, a speculative film, and a visual design process journal. Within the physical installation, the prototypes are engineered as speculative survival interfaces, utilizing Cai Lun paper yarn synthesized with advanced 3D printed biomorphic structures to mimic natural survival strategies. Recognizing the spatial and temporal limitations of a physical exhibition, comprehensive video documentation is utilized to capture the installation. This documentation transcends physical boundaries, ensuring the immersive environment remains accessible to a broader audience over time. Operating within this same conceptual framework, the speculative film acts as a deliberate provocation, visualizing a radical response to tomorrow’s environmental challenges. Finally, serving as the foundational support, the design process journal documents the entire trajectory, providing critical transparency into the translation of theory into practice. Ultimately, by synthesizing these elements, the project functions as a critical instrument, inviting the audience to viscerally experience the extreme conditions of the Anthropocene.

Grounded in the physical and immersive explorations of the *Desertia* installation, this research formally advances speculative fashion as its central proposition. Specifically, the thesis supports the broader design practice through a series of detailed critical designs, which serve as tangible manifestations of speculative inquiry. The study successfully bridges theoretical inquiry with practice-led outcomes by synthesizing the indeterminacy of climate change and the cultural interventions of contemporary art. Furthermore, it leverages the distinctive position of fashion as both a cultural and material practice, utilizing the potential of emerging digital tools to envision highly adaptive clothing systems. Ultimately, this thesis demonstrates how speculative design methodologies can transform fashion from a conventional symbol of consumption into a critical survival interface for navigating an uncertain ecological future.

To systematically unpack the central proposition outlined above, the remainder of this exegesis is structured into five chapters. Chapter One establishes the research foundation, outlining the motivations and problem statement regarding speculative fashion in the context of climate change. Chapter Two provides a comprehensive contextual review, exploring the intersection of future ecosystems, adaptive mechanisms in nature, and contemporary fashion discourse. Chapter Three details the methodology based on practice employed in this study, illustrating the integration of speculative design frameworks with digital fabrication and multimedia tools. Chapter Four presents the central creative outcome, the *Desertia* installation, and analyzes the development of biomimetic components *HydraSkin*, *RespiraVeil*, *FloraCore* and *EcoFlow*. Chapter Five concludes the thesis by synthesizing the research findings, reflecting on the practice, and evaluating the role of fashion as a critical interface for ecological survival.

1.1 **Objectives**

The objective of this practice-led research project is to explore how speculative fashion design can respond to projected climate change scenarios, with a specific focus on the desert environment. Drawing on a theoretical framework of critical and speculative design, the study aims to investigate how clothing may evolve from cultural artefact to survival interface. The project integrates digital and video generation, 3D modelling and printing, digital pattern development, sampling and specification features, garment display, and immersive projection technologies with physical textile and garment experimentation, in order to prototype speculative fashion systems inspired by biomorphic and structural principles.

The objectives are:

- To construct future oriented scenarios of extreme climate conditions (with a focus on desert ecologies) as a basis for speculative fashion inquiry.
- To examine how biomorphic design principles and systemic thinking can inform garment structures, silhouettes, and materiality.
- To utilize AI-assisted generation, digital modelling, and projection-based storytelling as methods for visualizing and testing speculative fashion concepts.
- To produce experimental garments and immersive installations that both function as material fashion's role in post-Anthropocene futures.

1.2 Research questions

The overarching research question for this practice-led research is:

How can speculative fashion design envision and materialize clothing systems that respond to future climate change scenarios, particularly within desert environments?

This broad question is supported by the following secondary research questions:

- How might human-environment symbiosis inform the design of future clothing systems?
- How can the integration of speculative design and biomorphic principles generate a critical dialogue about fashion's role in climate adaptation?
- In what ways can biological adaptation mechanisms be translated into speculative fashion design to address survival and resilience in extreme environments?
- How do digital tools (AI-assisted generation,3D modelling, pattern, garment software, projection) combined with material experimentation, contribute to new design methods for speculative fashion?
- How can fashion installation practices effectively communicate speculative scenarios and provoke reflection on fashion's societal role in post-Anthropocene futures?

2.0 LITERATURE REVIEW

This chapter systematically reviews the theoretical foundations and current research landscapes that underpin this study, constructing a comprehensive framework that bridges the intersections of the climate crisis, speculative design, Artificial Intelligence (AI), and fashion installation. The logical structure of this review follows an evolutionary trajectory, progressing from macro-environmental contexts to specific disciplinary tools. Initially, this research analyzes the inherent characteristics of the climate crisis as a *wicked problem*, exploring how such complexity necessitates a paradigm shift in design, moving from traditional problem-solving toward the problem-posing mechanisms of critical and speculative design (Dunne & Raby, 2025; Rittel & Webber, 1973). This foundational section establishes a reflexive stance, enabling design practice to transcend functionalism and focus on social imagination and narrative within future scenarios.

At the level of theoretical deepening, this chapter incorporates more-than-human and post-anthropocentric design thinking. In this context, design is repositioned to account for the agency of biological and environmental factors, shifting the focus from individual human comfort to collective multispecies survival. This perspective requires design research to re-examine the interdependencies between humans and the environment, challenging traditional anthropocentric positions amidst ecological collapse (Haraway, 2016). Subsequently, addressing the paradigm shifts brought about by technological intervention, the review evaluates the evolving role of AI within the design process. Specific emphasis is placed on how human-AI co-creation mechanisms reconfigure the designer's agency and creative judgment, and how AI-driven narrative paradigms transform the production of design knowledge (J. McCormack et al., 2019).

Finally, the research focuses on fashion installation as a specific medium of expression. By analyzing the roles of spatiality, atmosphere, and digital ecologies in fashion communication, this section investigates how fashion installation functions as an expanded disciplinary form capable of conveying complex environmental narratives and constructing immersive experiences (Evans, 2003). Through this systematic review, the chapter aims to identify existing theoretical gaps and position this research as an interdisciplinary exploration of AI-driven speculative narratives within the realm of fashion installation, providing a robust theoretical basis for subsequent discussions on speculative practice and immersive display modalities.

2.1 climate crisis: research background

Global climate crisis is rapidly reshaping the conditions of human existence and the cultural structures that sustain it. The continued rise in global temperature, the increasing frequency of extreme weather events, and the degradation of ecosystems have placed human societies under intersecting ecological and social risks (Lindsey & Dahlman, 2024). These changes weaken the stability of habitation, production, and resource systems, while also destabilizing the epistemological foundation of the human-nature relationship. The climate crisis is no longer a singular environmental issue; it represents a polycrisis that interlinks energy systems, social ethics, and design practice (Tooze, 2022). Within this context, design has been compelled to move beyond the creation of artefacts or aesthetic form, engaging instead with systemic imbalance and the uncertainties of future living environments.

Against the long-term background of climate instability, theoretical transformations within design reflect a broader cultural response to ecological pressure. The modern paradigm that prioritizes functionality and aesthetics has shown limitations in addressing complex ecological entanglements. Design thinking is progressively shifting from a problem-solving logic toward a context-oriented, systemic mode of inquiry. Recent design discourse emphasizes long-term, cross-scalar, and cross-disciplinary transitions that facilitate collaboration among social, technological, and ecological systems (Odabasi et al., 2023). Within this orientation speculative approaches are employed to examine the fragility of existing institutional and material systems through scenario construction and visual prototyping. Such practices render potential futures discussable and perceptible, while their theoretical implications are future elaborated in subsequent chapters.

Research in architecture and urban design further illustrates the necessity of systemic thinking. Studies of the built environment indicate that sustainability depends on the capacity of systems to absorb, recover from, and adapt to climate disturbances (Al-Humaiqani & Al-Ghamdi, 2022). This ethical reorientation encourages design to move away from technocratic and market-driven logics, reasserting its social and ecological foundations. Aesthetics is correspondingly redefined: ecological aesthetics considers processes and energy balance as critical values that connect formal expression with environmental coherence (Hosey, 2012). Within speculative fashion, this perspective is particularly relevant. In extreme environments, the aesthetic value of clothing may lie in its capacity to mediate climate, sustain life, and reflect systemic interdependence rather than as visual ornamentation.

The fashion sector exemplifies this dual cultural and technological transition. Studies show that climate change has profoundly affected textile production chains and consumption patterns, exposing environmental burdens and ethical deficiencies from material sourcing to waste management (Boykoff et al., 2021). The linear, high-carbon model of fast fashion has intensified these issues, while climate-adaptive fashion has emerged as a systemic alternative. This field emphasizes environmental responsiveness and reversibility across a garment's life cycle, facilitating body-environment interaction through material intelligence and structural adaptability (Charter et al., 2023). For instance, the Spanish retailer Mango announced in 2024 that it would replace seasonal collections with climate-zone classifications to address the increasing blurring of global seasons (Pons, 2024). This shift exemplifies the industry's gradual transition from aesthetic to ecological priorities.

Recent explorations of adaptation in design reveal a broad spectrum of approaches that inspire consideration of clothing's role in the future climates (Qu et al., 2021). However, this study does not focus on the physical implementation of such technologies. Instead, it adopts a speculative lens to reinterpret their social and ecological meanings. By constructing hypothetical scenarios of extreme future climates, adaptation is examined as a perceptual and existential condition rather than a technical function. Within this framework, clothing operates as a speculative medium for the integration of digital visualization and material prototyping, enabling these conceptual explorations to be rendered visible and tangible, revealing potential transformations in the role of clothing within future ecological systems.

2.2 Wicked problems and critical design

The escalating environmental crises of the Anthropocene have fundamentally challenged the traditional boundaries of design. As ecological instability becomes a permanent condition rather than a temporary disruption, the limitations of linear, solution-oriented design paradigms become increasingly apparent. This section explores the convergence of wicked problems and critical design as a theoretical framework for navigating such complexity. By redefining climate change not as a technical puzzle to be solved but as a wicked systemic challenge, this research identifies a critical shift in the designer's role: moving from the provision of functional artifacts to the generation of speculative inquiries.

The following subsections will delineate the structure of these complex problems and examine how critical design functions as a cognitive tool. By transitioning from a problem-solving orientation toward a questioning stance, design becomes a medium for speculative adaptation. This framework provides the methodological foundation for the *Desertia* project, where garments are reimagined as interactive sites of biological and systemic reflection.

2.2.1 **Complexity of climate change and the wicked problems**

Climate change is widely recognized as one of the most intricate super wicked problems of our time. It involves nonlinear interactions among ecological, social, technological, and political systems, where causes and consequences are intertwined in dynamic feedback loops (Weaver et al., 2023). The problem itself is unstable and continually reshaped through actions and interventions (Peters, 2017). Such fluidity and ambiguity make climate change resistant to singular disciplinary or technical reasoning. It is not merely a scientific challenge but a contested field of cognition and ethics, reflecting how societies negotiate the meanings of the future. In this sense, the climate crisis constitutes a design problem that demands a generative mode of thinking that integrates imagination with practice.

Conventional design paradigms, which prioritize problem-solving, prove inadequate when confronted with the complexity of climate systems. The evolution of climatic conditions cannot be precisely forecast, and the social variability of responses further amplifies uncertainty in decision-making (Mehta et al., 2022). Within this context, design must move beyond the provision of functional solutions and operate as a medium for generating understanding and reflection. Rather than reducing complexity, design can render it experiential and perceptible, bringing systemic issues into the realm of public discourse. The aim of design shifts from achieving certainty to cultivating possibilities for comprehension (Sun & Yang, 2016).

2.2.2 **Critical design: from solving to questioning**

Critical Design offers a distinct cognitive approach to this transformation. By exposing the assumptions embedded in social and technological systems, it shifts design from an act of solving to an act of questioning (Malpass, 2017). This practice begins not with the finished product but with the provocation of a problem, inviting audiences to perceive contradictions, ambiguities, and latent ethical tensions through material form (Laranjo, 2017). Its concern lies less with how to fix the world than with how we imagine the world being repaired. Through visual and narrative strategies, Critical Design translates abstract systemic crises into embodied experiences, allowing complex issues to be understood through affective and sensory engagement (Loewe, 2019). Hence, its significance lies not in offering solutions but in restoring the capacity to think critically about problems.

This speculative orientation resonates deeply with the wicked nature of climate change. The multiplicity of climate realities resists singular resolution, sustaining instead a continuously evolving field of questions and interpretations (Van Uffelen et al., 2024). Within this space, design functions as a reflective medium that reconstructs human–environment relations through experimentation, storytelling, and symbolic articulation. Such reflexivity extends beyond aesthetics; it constitutes a cognitive mode that enables designers to coexist with complexity rather than attempt to control or simplify it. When integrated into the education of complex systems, design has been shown to foster adaptive thinking, encouraging learners to engage creatively and responsibly with uncertainty (Lehtonen et al., 2019).

2.2.3 From complexity to design thinking

The core characteristics of wicked problems lie in their blurred boundaries and fragmented knowledge structures. Design thinking provides an intermediary mechanism for engaging with such complexity. Rather than seeking definitive outcomes, it reframes problems through reflexive and experimental modes of inquiry (Pries-Heje & Baskerville, 2008). Through constructive modeling, designers are able to identify systemic relationships within processes of continuous definition and redefinition, thereby developing adaptive and context-specific strategies.

The framework of reflexive governance suggests that when addressing complex problems, effectiveness arises not from achieving consensus but from establishing a continuous and sustainable dialogue that enables diverse forms of knowledge and action to coexist (Head, 2014). The value of Critical Design emerges precisely within this condition. Through material articulation, it facilitates transdisciplinary collaboration and allows participants to perceive systemic instability at an experiential level, generating new forms of understanding in the process. Studies have shown that cross-cultural Critical Design practices can stimulate renewed reflection on climate action within educational and social contexts, fostering what has been described as complexity literacy among participants (Wingfield et al., 2024). In this research, the transformation from systemic complexity to adaptive fashion design thinking manifests through the integration of design methods, AI-assisted visual generation, and contextual storytelling. These strategies juxtapose ecological processes with human experiences of survival, positioning design as a speculative medium through which future environmental uncertainty can be explored and interpreted. This form of design thinking does not pursue operational solutions but instead produces new modes of cognition through experimentation and visualization. In doing so, it contributes to the establishment of an academic pathway where design itself functions as a mode of knowing.

2.2.4 Practical dimension of critical design

In the context of this study, the methodological transformation of Critical Design is understood as a form of speculative adaptation. It unfolds as an intermediary practice connecting ecological, bodily, and technical systems within the *Desertia* project. Design here no longer aims to reproduce existing realities but explores the co-evolutionary potential of humans and environments under extreme conditions.

This logic of transforming garments into speculative habitats is embodied in the practice of artist Lucy Orta. Her Refuge Wear and Nexus Architecture series are not intended to provide mass-produced relief clothing; instead, they function as interventional devices that combine architectural structures with garment functions to question the fragility of individuals and the failure of social protection systems amidst global crises (Orta et al., 2003). Orta's work translates abstract social and ecological issues into embodied, even oppressive, physical experiences, allowing viewers to perceive systemic contradictions through the survivalist forms of the garments.

The *Desertia* project in this study inherits and extends this trajectory by pivoting away from Orta's focus on social contracts and collective bonds toward biological adaptation in the face of extreme desertification. Through the design of speculative second skins such as *RespiraVeil* and *HydraSkin*, this research transforms the Wicked Problem of water cycling and thermal protection into tangible and interactive sartorial forms. Clothing in this context is no longer a mere protective layer but functions as a thinking device representing a site where speculative imagination meets material exploration. This integration serves to reconsider the fundamental meaning of adaptation within a future defined by aridity and resource scarcity.

The integration of AI-generated imagery and situational narratives provides this speculative transformation with visibility and dynamism (Locklear, 2025). It converts abstract systemic complexity into perceptible, concrete forms. Through this interaction, design serves as a cognitive medium that, rather than masking uncertainty, reifies it, making it thinkable and experiential. This practice demonstrates that design does not produce knowledge through linear problem-solving paths but through continuous experimentation and encounters that reveal the fragility and instability of the human-environment relationship.

2.3 Speculative design as theoretical framework

Speculative design functions as a theoretical orientation with deep interdisciplinary roots. Its intellectual lineage extends from critical design and continues to evolve at the intersection of philosophy, political theory and futures studies. *Speculative Everything* argues that design should not remain confined to solving immediate functional problems; instead, it should open up forms of social imagination by asking "what if" questions that shift attention from execution to possibility (Dunne & Raby, 2013). This orientation moves design away from servicing existing systems and toward the exploration of potential worlds and the ethical structures that underpin them. Within this theoretical perspective, speculative design is not solely a design method but also a philosophical practice. Scholarship in object-oriented ontology, constructivist futures research and ecological philosophy places speculative design in an intellectual context that repositions design within relationships involving both human and nonhuman actors, thereby framing design as a means for engaging with worlds that are not yet fully formed rather than an extension of established reality (Banu, 2015).

Recent scholarship has further expanded the conceptual scope of speculative design and reconsidered the role of imagination within design research. Dunne and Raby argue that speculative design should be understood not only as a practice of producing provocative artefacts or exhibition-based prototypes, but also as a mode of speculative thought that explores conditions beyond the immediacy of the present (Dunne & Raby, 2025). Within this updated perspective, design imagination functions as a mechanism for engaging with impossibility and uncertainty. By constructing scenarios that may not yet be technologically achievable or socially realized, speculative design opens a cognitive space in which the assumptions underlying technological development, social organization, and ecological relations can be reconsidered. Compared with the earlier formulation in *Speculative Everything*, which emphasized the role of design prototypes in stimulating public debate, this more recent perspective places greater emphasis on speculative thinking itself as an epistemic practice within design research (Dunne & Raby, 2013).

This theoretical shift has also enabled speculative design to move beyond its early association with exhibition formats and formal provocation, extending its relevance to broader cultural and social debates. Contemporary research describes speculative design as a critical medium operating within cultural and educational domains, capable of examining how institutional norms and collective imaginaries are reconfigured under conditions of uncertainty (Mitrović et al., 2021). The twentieth-anniversary edition of *Design Noir* reinforces this critical lineage by discussing how design fictions deploy estrangement, displacement and counterfactual strategies to unsettle existing perceptual structures and reveal the cultural logics embedded within contemporary life (Dunne & Raby, 2021). Such theoretical developments provide an important foundation for addressing the epistemic uncertainty inherent in climate-crisis research, where ecological and ethical tensions often exceed the representational capacity of linear technical language.

Speculative design's engagement with the future does not seek to predict it. Instead, it enables the examination of biases, exposes ideological structures and prompts renewed reflection on the boundaries that shape current realities. Scholarship in this field focuses on how speculative design generates new narrative structures within complex ecological conditions. As climate and social systems grow increasingly unstable, design based on realist assumptions struggles to address uncertainty, and design practice must function as a conceptual device capable of constructing multiple possibilities through fiction and hypothesis (Wilk et al., 2020). Within the context of the climate crisis, this function becomes especially significant. Climate change involves high uncertainty, cross-scalar interactions, and ethically charged consequences, and cannot be adequately addressed through design approaches centered solely on functionality. Research on contemporary speculative design demonstrates that expressive prototypes can materialize public issues, making ecological and ethical tensions perceptible in ways that technical language cannot, thereby enabling climate concerns to be experienced and discussed within wider cultural settings (DiSalvo, 2012). Unlike conventional design paradigms, speculative design emphasizes critical interrogation of existing systems. It reveals the assumptions and value structures embedded within dominant responses and fosters experiential engagement that encourages new understandings of the future. This orientation aligns closely with the non-solutionist stance required in climate-crisis research. Climate issues involve incomplete knowledge, temporally unstable processes, and entangled ecological dynamics. Speculative design, through conceptual artifacts, fictional narratives, and visual experimentation, enables these complexities to be presented in forms that invite discussion and interpretation.

Speculative design is often regarded as a cognitive practice for exploring the unknown. Its operation resembles philosophical thought experiments, using fictional artifacts to create new cognitive pathways and enabling researchers to establish interpretive frameworks in domains where knowledge has not yet taken shape (Barendregt & Vaage, 2021). This mechanism is particularly relevant for examining bodily experience, environmental adaptation, and affective states under extreme climatic conditions, since such transformations resist linear extrapolation or empirical prediction. Scholarship on speculative prototypes conceptualizes them as epistemic objects whose value lies not in presenting complete forms but in provoking knowledge yet to be articulated, thereby offering a point of entry into understanding complex ecological logics (Boserman, 2019).

This theoretical mechanism of treating design prototypes as cognitive objects finds visual corroboration in the *Hypnosis collection* by Iris van Herpen. By integrating kinetic sculptures and 3D printing technology, this collection constructs a speculative field that blurs the boundaries between the human epidermis and the external environment (Herpen, 2019). In this practice, garments transcend traditional physical shelter functions and transform into thought experiments exploring the limits of future bodily perception and spatial interaction methods.

Recent cross-disciplinary design practices have further expanded this methodology of world-building and systemic speculation. The *Extreme Worlds Radical Solutions* project collaborated by Domus Academy and CERN provides a compelling systemic paradigm (Domus Academy, 2024). The research team established a hypothetical extreme climate environment set in the year 2075 and developed an intelligent clothing system capable of dynamic contraction and regulation based on temperature and humidity. This practice demonstrates that speculative design can transcend individual visual expression to become an institutionalized research tool for handling climate uncertainty. It translates complex systemic crises into concrete physical interventions. Simultaneously, projects such as *Gu Spirit* exhibited at Dutch Design Week push this speculation to its material limits (Manifestations, 2024). Focusing on doomsday survivalism, this work utilizes 3D-printed skeletal structures and biomorphic textiles to create a garment system resembling an alien exoskeleton. As a cognitive object, it provides a visceral material translation of the human need for adaptation in the face of ecological collapse. The design forces viewers to confront the ethical and physical tensions of human biology coexisting with synthetic materials in severely degraded environments.

These cutting-edge practices collectively build a solid empirical foundation for the *Desertia* project in this research. They illustrate that design must break away from static protective logic when confronting unknown ecological upheavals. This study shares this methodological lineage. The future desert scenarios explored in the research involve multi-scalar reorganizations among climate, body, materials, and perceptual cultural meanings, which cannot be directly deduced using existing models. The theoretical framework of speculative design and avant-garde design practices provides this study with a way to enter future worlds. Within this framework, clothing becomes a carrier for understanding environmental relationships, bodily changes, and future life logics, enabling the research to intervene in a concrete manner into issues that have not yet occurred but hold heuristic significance for the present. Without this theoretical support, the relationship between humans and the environment in the climate futures focused on by this study would be difficult to discuss within a sufficiently open cognitive space. The role of speculative design in this research is not to provide technical paths for problem-solving but to construct an ideological framework capable of carrying future imagination, ethical judgment, and knowledge generation. This enables the study to explore the significance of design in future extreme climates from conceptual, cognitive, and cultural dimensions. This theoretical orientation allows the research to understand the possible forms of future worlds without relying on predictive data and to reconsider the position of humanity within them in a more critical and reflective manner.

2.4 More-than-human and post-anthropocentric design thinking

Human needs have become increasingly limited in the context of accelerating ecological crises and the growing complexity of technological systems. As agency is redistributed across living organisms, material processes and environmental dynamics, the human no longer functions as the sole reference for design judgement. Posthuman ethical scholarship demonstrates that the boundaries of value formation have expanded to encompass wider multispecies communities, shifting the foundations of design from human priority to ecological and systemic negotiation (Umbrello, 2021). This reorientation provides the conceptual foundation for examining future extreme environments in this study, since relationships among the body, materials, and climate exceed the explanatory capacity of human-dominated design frameworks when environmental conditions become unstable.

Decentralized accounts of agency have introduced a distributed structure of action in recent design research. Networks of diverse organisms, technological mediators, and ecological forces collectively influence design decisions, replacing the singular human agent that once guided design reasoning (Hupkes & Hedman, 2022). When the agency expands into technological systems and ecological dynamics, the human role becomes one node within a wider network rather than the central decision-maker, a shift illustrated across emerging design practices engaging multispecies and material agencies (Nicenboim et al., 2025). This shift informs the investigation of adaptive garments and mechanisms for environmental interaction in this research. Clothing is understood in this research as a processual interface with responsiveness, temporality, and ecological entanglement rather than as an external layer that merely serves the body. Approaches that involve multiple forms of agency reinforce this perspective by showing how material behavior, climatic fluctuation, and ecological rhythms move from peripheral considerations to central drivers of design practice (Ciobanu, 2019). Within the future desert world constructed in this study, bodily perception and material responses to climatic stimuli guide the evolution of garment design, aligning closely with a more-than-human orientation.

As relations among humans, nonhuman beings, and material environments are increasingly conceptualized as co-generative, material ecology provides critical grounding for the material experiments in this project. Materials are understood as dynamic processes shaped by temporality, structure, and environmental dependence rather than as static resources subject to human control (Ingold, 2012). Research centered on material agency shows that when design attends to material behavior, ecological relations, and the movement of matter within an environment, materiality itself can organize design processes and steer creative development (Zhou et al., 2022). Julia Lohmann's Department of Seaweed project and its Oki Naganode installation provide a compelling practical footnote for this material agency (Lohmann, 2024). Utilizing brown kelp as the core medium and leveraging its characteristic of producing drastic physical deformations in response to environmental humidity changes, Lohmann vividly demonstrates the temporal agency of non-human materials. This strategy of translating physical material responses into an ecological narrative framework resonates deeply with the material exploration pathways of the *Desertia* project. From this perspective, the integration of paper yarn, silk, cotton fabrics, and 3D printed structures in this study is positioned within a broader ecological framework. Fiber structures, tactile variations, plasticity, and stability in extremely dry environments collectively constitute the interface of interaction between the body and the environment. The garment is thus established as a generative ecological node. The logic of material behavior and extreme climate pressure interlock, enabling the structural interface composed of paper yarn and 3D printed modules to serve as a vital pathway for exploring the deep interactions among the body, materials, and the environment.

This exploration beyond anthropocentrism is manifested not only in the direct use of the physical properties of natural materials but also in the deep translation of the ecological mechanisms of non-human species into technological augmentation of the human body. The Thalassic Mask project, a collaboration between Filippo Nassetti and Vincenzo Reale, provides avant-garde evidence for this biological integration within a post-natural context (Nassetti, 2021). This project extracts the survival logic of aquatic organisms such as corals and jellyfish, which filter water and employ environmental camouflage through their morphology, and applies digital additive manufacturing to translate this logic into a wearable system capable of withstanding extreme environmental crises. This practice reveals that human evolution may no longer rely entirely on protracted biological mutations but can directly graft the evolutionary wisdom of non-human organisms onto the human body through technological means. The mask here transcends purely medical protective functions and evolves into a novel artificial organ that encompasses both environmental adaptability and cultural identity expression. This perspective directly supports the generative logic of the *Desertia* project. This study attempts to move beyond passive physical shielding to explore how clothing in future scenarios of extreme aridity can act as a technological prosthesis imitating the survival mechanisms of drought-resistant organisms. This approach aims to construct a cross-species symbiotic morphology between the vulnerable human body and the harsh nature.

Differences in temporal scales highlighted in more-than-human research further shape the methodological direction of this project. Ecological cycles, material transformations, and climatic oscillations often diverge from human temporal rhythms, and such asynchrony forms the experiential basis of survival in future extreme environments (Oktay et al., 2023). The *Desertia* scenario developed in this study relies on an understanding of layered temporalities. Dryness, evaporation, heat accumulation, and material aging constitute the physical rhythms of this world, while bodily perception, mobility, and life-support needs become embedded within them. Clothing becomes a mediator that translates across these distinct temporal structures.

As agency, materiality, and temporality expand, a systemic perspective becomes essential for understanding how design intervenes in future environments. System-oriented design frames design problems as networks of behaviors, environmental forces, and material processes rather than isolated objects (Sevaldson, 2021). This perspective aligns deeply with the virtual world constructed in this study. The extreme arid environment of *Desertia* presents as a systemic condition co-determined by temperature cycles, air currents, resource scarcity, and ecological vulnerability. Addressing the resource crisis within such an extreme arid system requires an ontological reconstruction of water resources and their interventions. In their research on the *Hydrocene*, Thomas Laurien and colleagues propose transcending the traditional concept of water as a passive object resource, establishing it instead as a relational subject closely intertwined with multiple species, specifically termed “bodies of water” (Laurien et al., 2024). This perspective provides profound theoretical support for the adaptive mechanisms addressing water loss and collection in the *Desertia* project. In a desert environment where water is extremely scarce, the garment is reconceptualized as a trans-material osmotic membrane situated between the human internal body of water and the harsh external environment. This design practice overcomes the resource extraction logic of anthropocentrism, fostering an equal and symbiotic relationship among the body, the garment, and water. Within this framework, the garment functions as a critical systemic node, undertaking comprehensive functions such as perception, regulation, support, and feedback, thereby breaking through the traditional definition of a passive worn object. The systemic perspective enables this study to deeply analyze how garments participate in ecological processes, encompassing material responses to environmental pressures, the regulation of the body's micro-environment by structures, and the translation of sustaining multispecies water metabolism and ecological cycles into an immersive visual and survival narrative.

Within this theoretical constellation, more-than-human and post-anthropocentric design thinking move beyond abstract philosophical frames and become directly relevant to the construction of speculative scenarios, material experimentation, and design development in this study. Distributed agency, co-generative ecological relations, and multi-layered system dynamics collectively shape a design orientation attentive to environmental sensitivity and future climatic conditions. These ideas position the interactions among body, materials, and extreme environments as central to the design inquiries advanced throughout the research.

2.5 AI as a tool in design

Generative artificial intelligence is reshaping the foundational logic of design practice. From image generation to video synthesis, AI has enhanced workflow efficiency while simultaneously transforming the mechanisms through which creative ideas emerge and altering how designers position themselves within the creative process. Within speculative fashion design informed by climate change scenarios, AI expands the capacity to explore future conditions, iterate conceptual forms at high velocity, and construct virtual narrative environments. This section examines these dynamics through four analytical lenses: the evolving role of AI in the design process, the mechanisms of human–AI collaboration, the reconfiguration of creative agency, and the shifting competency structures required of designers.

2.5.1 The evolving role of AI in the design process

Conventional design workflows are grounded in hand-drawn sketches, material testing, and physical prototyping, following a linear creative logic. The emergence of AI-based generative systems disrupts this structure and redirects design toward a non-linear mode of co-creation between human and machine (Jin et al., 2025). AI platforms widely adopted in design practice, including Midjourney, DALL·E, and Adobe Firefly for image generation, as well as Sora and Runway for video generation, have become central instruments for exploring visual language, testing stylistic variations, and constructing conceptual narratives. These tools can transform linguistic prompts into large volumes of visual sketches, dynamic scenes, and conceptual imagery, accelerating early-stage iteration and shifting the design process from a human-driven, single-directional workflow to an interactive dialogue between designer and system.

The associative and fuzzy logic exhibited by AI systems challenge long-standing assumptions that machines are incapable of creative authorship. Current discussions argue that AI is beginning to approximate certain traits of human cognitive patterning and can propose unconventional combinatory visual structures (N. Lewis, 2023). This shift has reframed how the relationship between designers and AI is understood. Rather than a passive tool, AI becomes a co-performing agent with generative potential. Within this arrangement, designers move from being sole makers to becoming framers of intent and evaluators of outputs, guiding direction and value throughout the data-driven creative process.

In conceptual fashion design, AI often assumes multiple functional roles (Burnstine, 2025). It acts as a source of creative stimulation by generating abstract and unpredictable visual cues that deviate from habitual thinking. It functions as a catalyst for form exploration by producing a wide range of rapid structural variations, broadening the field of possible design directions. AI also operates as a constructor of virtual worlds, visualizing garments within speculative or extreme environments through dynamic simulations. These multifaceted roles establish AI not merely as an auxiliary tool but as an integrated component in the collaborative relationships that structure contemporary design workflows.

2.5.2 Mechanisms of human and AI co-creation

The core of AI-assisted design lies in the co-creative mechanisms that emerge between human and machine. According to a recent model of human-AI co-creation, meaningful collaboration requires designers to actively intervene in the generative process and guide interpretation, rather than uncritically relying on AI-produced results (Guo et al., 2023). Within this model, designers shape the collaborative process by refining textual prompts, adjusting stylistic parameters, and situating the system within meaningful contexts. AI is therefore treated as a participatory instrument whose generative capacity is inherently dependent on human cultural knowledge and aesthetic judgment.

This collaborative dynamic reveals a dual nature within AI-generated creativity. Algorithms can combine and mutate visual data at a speed and scale beyond human imagination, thereby widening the boundaries of possible design directions. At the same time, AI outputs remain a recombination of learned data and do not inherently possess cultural intention or value orientation. The transition from an AI-generated image to a design-relevant proposal requires human interpretation, selection, and modification. The resulting creative mechanism is therefore not a replacement of human creativity but a hybrid process in which algorithmic capability and human judgment form a reciprocal relationship that supports both efficiency and conceptual depth.

The creative practice of biomorphic designer Elmo Mistiaen provides a highly representative action strategy for this transformation mechanism from image to design. When utilizing artificial intelligence tools to construct virtual garments and surreal scenes, Mistiaen relies on an extremely precise language system to maintain dominance over the randomly generated visual spectacles of the algorithm. Through precise linguistic control over the physical properties of fabrics, material textures, and lighting logic, he seamlessly recombines morphological features of natural elements like insects and shells onto the human body to anchor highly realistic material textures within virtual spaces (Andreatta, 2022). To overcome the uncertainty of algorithmic generation and maintain the aesthetic continuity of his work series, he continuously memorizes and iterates the most effective parameter descriptions. This strategy of highly involved text control enables him to establish a highly recognizable personal visual language amidst massive data mutations. This research adopts a similar collaborative pathway during the design development phase. By utilizing artificial intelligence image generation as a core design tool, the study borrows such precise text control strategies to reconstruct biomorphic elements within desert environments. This approach explores how the generative capacity of algorithms transforms into future garment forms conforming to extreme ecological narratives under the intervention of human aesthetic judgment.

Empirical studies confirm the complexity of this relationship. Designers frequently describe AI as a collaborator rather than a mere tool, acknowledging its productivity while simultaneously expressing concerns about loss of control, especially regarding aesthetic coherence, narrative clarity, and cultural relevance (Kalving et al., 2024). These concerns indicate that the presence of AI heightens the necessity for strategic decision-making, making the designer responsible for orchestrating the interaction between technical capabilities and cultural meaning. This collaborative process requires designers to alternate between roles of active creator and critical selector, offering new insights into how agency and judgment are distributed in human–machine interactions (Van Der Burg et al., 2023).

2.5.3 Reconfiguring creative agency and judgment

The integration of AI into design practice raises fundamental questions about authorship and creative agency. As inspiration, imagery, and even dynamic scenes can now be generated by AI, the question of how designers maintain authorship and judgment becomes central. Speculative design scholarship suggests that future-oriented creative work often involves the redistribution of authorship and the management of uncertainty (Dunne & Raby, 2013). The visual ambiguity, unpredictability, and hybrid aesthetics produced by AI intensify these conditions and place pressure on the designer's aesthetic authority (Zylinska, 2020).

Sustaining creative agency requires deliberate intervention across multiple stages of the design process. In the formulation of design intent, the articulation of values and conceptual direction cannot be delegated to AI. During generation, designers translate abstract ideas into linguistic prompts in ways that enable the system to produce meaningful outputs. Prompt engineering has thus become an essential competency, since the specificity and structure of the prompt strongly influence the quality and direction of AI outputs (Di Dio et al., 2024). In the evaluation phase, designers must identify outputs that align with design logic, cultural context, and aesthetic coherence, drawing on critical thinking and cross-modal interpretation.

The unpredictable nature of AI-generated results is both a challenge and an opportunity. Outputs produced through ambiguous or loosely structured prompts often contain unexpected visual configurations, which can reveal new connections and stimulate alternative design directions. Studies suggest that such emergent deviations can surface hidden relationships and destabilize entrenched assumptions, generating productive starting points for exploration (Chong, 2025). Neural networks such as generative adversarial models can produce surprising or unconventional imagery, and this unpredictability is frequently interpreted as evidence of algorithmic creativity (RoX818, 2024). Human intentionality combined with algorithmic variability can therefore yield creative outcomes that exceed the contributions of either component in isolation (Zhang & Zhou, 2025). Designers must navigate the balance between maintaining intention and remaining open to unexpected results, using serendipity as a source of innovation. This balance exemplifies exploratory creativity, where structured direction coexists with chance and discovery. AI's ability to identify patterns and propose unconventional combinations broadens the spectrum of aesthetic possibilities and opens new directions in design inquiry (Huston, 2023).

Although AI can generate high-quality visual material, the intuitive, affective, and culturally grounded dimensions of human creativity remain central to the design process. The principle of made by human continues to serve as a value anchor, foregrounding human intentionality and cultural authorship (Klementis et al., 2024). This shift reframes design as an expression of judgment rather than solely craft, positioning the designer's contribution within conceptual, ethical, and cultural domains. Contemporary debates about AI's creative capacity thus extend beyond technical capability, prompting broader reflection on the nature of creativity, the sources of design value, and the future of human–machine relations.

2.5.4 Restructuring designer competencies in the context of AI

The integration of AI into design practice reshapes the competencies expected of designers and accelerates transformations in both design education and professional training. Traditional fashion design pedagogy has long prioritized hand drawing, material literacy, and technical craft. In an AI-mediated environment, however, these skills are no longer sufficient on their own, and designers must develop new modes of literacy to operate effectively within computational systems (Oxman, 2006).

A central requirement is the ability to engage in semantic interaction. Since most generative systems operate through linguistic prompting, designers must translate visual intentions, stylistic preferences, and conceptual cues into structured verbal descriptions. This process requires cross-symbolic fluency, linking textual, visual, and conceptual modes of reasoning. Research on emerging forms of computational participation further demonstrates that this literacy involves more than technical proficiency; it entails understanding how representations, symbols, and interpretations circulate across media (Kafai & Burke, 2015).

Critical selection has also become a defining component of designerly judgment. AI systems can produce large volumes of imagery within seconds, obliging designers to establish criteria that distinguish meaningful outcomes from superficial or misaligned outputs (Kalving et al., 2024). Such decisions draw not only on aesthetic sensibility but also on cultural awareness, contextual interpretation, and an understanding of user and environmental relevance. These evaluative capacities sustain the human role in creative work by ensuring that design outcomes retain conceptual clarity and cultural intent (Klementis et al., 2024).

The growing presence of AI additionally demands competence in cross-media integration. Designers must reconcile algorithmically generated images, videos, and simulations with physical materials, construction processes, and embodied experiences. This integrative capacity aligns with broader shifts in design knowledge in which systems thinking and multi-level reasoning have become increasingly important (Buchanan, 2019). AI expands the conceptual phase but does not eliminate the need to translate digital propositions into material or narrative forms.

Ethical and technical awareness form another critical dimension. Issues surrounding data provenance, intellectual property, cultural appropriation, and algorithmic bias require designers to exercise informed judgment and responsibility. These considerations are particularly salient in fashion, where questions of originality and authorship intersect with broader concerns about sustainability and labor (Zylinska, 2020).

Rather than diminishing the role of the designer, AI foregrounds a different distribution of expertise. The designer becomes an organizer of intentions, a mediator of meaning, and a curator of cultural and aesthetic coherence. This shift in the designer’s role is closely connected to the concerns of the present research. Within the context of extreme climate scenarios, design challenges often extend beyond questions of material performance or formal strategies and involve multidimensional interactions among bodily adaptation, environmental pressure, and cultural narrative. Generative AI enables these relationships to be visualized, tested, and reformulated at early conceptual stages, allowing designers to reconsider the basis of design judgment within the intersecting domains of future bodies, environments, and garments. By selecting, reorganizing, and interpreting AI-generated images, dynamic scenes, and virtual ecologies, designers can construct more coherent conceptual orientations within speculative future settings. This process reinforces their central role in guiding interpretive, semantic, and cultural direction within speculative fashion design.

2.5.5 AI-driven narrative and display paradigms

In this study, AI-generated imagery is positioned as a speculative medium to construct visual contexts of future climates, environmental pressures, and ecological perception. Through critical selection, editing, and orchestration, the generated images and videos operate as integral components of the conceptual framework. When projected onto garment surfaces and the exhibition environment, these visuals act as deliberate visual provocations and dynamic media, driving the narrative of environmental mood, climatic logic, and speculative ecological states.

They allow viewers to experience the presence of a future environment while observing the garments. Visual narrative research suggests that changes in light, rhythmic organization, and spatial relations significantly influence immersion, thereby enhancing audience engagement with fictional worlds (Ryan, 2015).

AI technologies in exhibition contexts have moved beyond supplementing design outcomes and now function as essential media for constructing narrative environments. Unlike traditional presentations that rely on physical garments and onsite spatial settings, AI-generated images and videos create atmospheric, rhythmic, and spatially coherent visual worlds that allow garments to be understood within their imagined futures. Dynamic visuals hold significant potential for narrative and affective communication. Their repetition, variation, and spatial organization shape modes of perception and establish emotional orientation within the viewing experience (Manovich, 2002).

AI-generated video introduces new expressive structures for virtual storytelling. Algorithmically produced imagery enables designers to simulate situational logics in non-real environments and to show how conceptual garments generate meaning under shifting climatic pressures, lighting conditions, and environmental rhythms. Research suggests that AI can construct not only visual backgrounds but also dynamic environmental variables, situating garments within ecological mechanisms. This positions fashion as an active participant in multilayered narrative systems and intensifies the interactions among garment, environment, and temporality (Lima, 2024). In such exhibition formats, garments cease to be static objects and become components of movement and meaning within virtual environments.

Immersive narrative theory offers a critical lens for understanding this exhibition paradigm. Studies demonstrate that immersion arises through the combined effects of visual coherence and a sense of participation (M.-L. Ryan, 2001). In virtual narratives, parallel storylines and user-driven structures form the backbone of interactive storytelling (Aylett & Louchart, 2003). Within generative imagery, modular narrative structures maintain a balance between coherence and openness, enabling viewers to enter fictional worlds while retaining clear semantic pathways (Amlashi & Adiloglu, 2025). Advances in display technologies have further heightened the density and rhythm of information, deepening emotional engagement and sharpening perceptual sensitivity (Lantz, 1997). These mechanisms collectively shape the core logic of AI-driven virtual narration.

Within speculative fashion, generative visuals are especially valuable because they translate future environments into perceivable cues, allowing non-existent ecological conditions to be experimentally represented. Extreme climatic phenomena such as light fluctuation, airflow, terrain texture, and environmental pressure can be simulated through dynamic imagery, which links the meaning of garments directly to their fictional ecosystems. Research indicates that digital narrative structures reinforce the audience’s comprehension of conceptual and semantic relations in fashion, allowing meaning to emerge across image, body, and space in more relational configurations (Andò et al., 2023).

2.6 Fashion installation

In recent decades, modes of fashion presentation have increasingly expanded beyond conventional formats such as runway shows and static exhibitions toward spatial and experiential forms of display. Within this shift, fashion installation has emerged as a significant curatorial and design strategy that situates garments within immersive environments composed of spatial structures, light, sound, moving images, and material arrangements. Rather than presenting clothing as isolated objects for visual observation, fashion installations construct atmospheric contexts in which garments operate as elements within a broader sensory and spatial narrative.

This development reflects a wider transformation in contemporary fashion culture, where meaning is increasingly generated through experiential engagement and environmental perception rather than through the material properties of garments alone (Evans, 2003; Loschek, 2009).

Scholars in fashion and media studies suggest that installation-based approaches enable designers to explore the dynamic relationships between the body, space, and technological mediation. Through the orchestration of atmosphere and multisensory stimuli, fashion installations transform fashion expression into a performative practice, inviting audiences to encounter clothing within environments that re-examine embodied experience (Geczy & Karaminas, 2019; Pink, 2015). Such practices increasingly intersect with developments in digital media, projection technologies, and algorithmically generated imagery, allowing garments to function as dynamic visual interfaces. Crucially, the integration of algorithmically driven generative processes introduces a level of technological agency, enabling the installation to express environmental processes and temporal transformations in real-time (Manovich, 2002). Within this context, fashion installation operates not only as a display method but also as a conceptual framework through which designers investigate emerging questions concerning ecological awareness, human-machine collaboration, and future modes of living.

Against this background, the following section examines fashion installation as a critical mode of fashion communication and speculative design practice. It first discusses the expansion of fashion presentation into spatial and atmospheric forms, and then considers the roles of multisensory experience, digital projection, and environmental narratives in shaping contemporary installation-based fashion practices.

2.6.1 Fashion installation as an expanded form of fashion communication

The paradigm shift embodied in fashion installation provides a critical conceptual foundation for understanding the *Desertia* project within this research. *Desertia* does not rely on the unidirectional presentation of garments as isolated objects. Instead, it constructs an experiential environment through immersive spatial settings, dynamic imagery, atmospheric simulation, and temporal modulation. Within this framework, the meanings of garments arise through bodily movement, sensory engagement, and environmental ambience rather than through their material forms alone, aligning closely with the central principles of fashion installation.

The modes of fashion communication have undergone a fundamental transformation over the past several decades. Traditionally, fashion circulated through runway presentations and static displays, where garments functioned as discrete objects observed and evaluated in isolation. The emergence of contemporary fashion installation marks a substantial shift in this communicative paradigm (Barnard, 2013). The central orientation moves away from the presentation of garments toward the construction of experiential environments (Wallenberg, 2020). This shift reconfigures the mechanisms through which fashion generates meaning (Geczy & Karaminas, 2019).

The distinction between fashion installations and conventional formats lies in their contrasting approaches to spatiality and experiential engagement. Runway shows position viewers in fixed locations and relies on linear movement, which limits audience participation to passive spectating (Evans, 2003). Museum displays allow greater mobility, yet garments remain framed as artifacts to be preserved, observed, and interpreted through a historical lens (Taylor 2004). Fashion installation disrupts these conventions by integrating garments into an encompassing environment in which space, light, sound, and materiality jointly shape perception (Geczy & Karaminas, 2019). Within such environments, meaning arises through bodily navigation, sensory engagement, and affective response rather than through the garment’s form alone.

This transformation can be understood through the theoretical framework of the “expanded field.” The concept, developed in relation to the evolution of sculpture, describes the dissolution of fixed medium boundaries and the emergence of hybrid practices situated among architecture, landscape, and spatial construction (Krauss, 1979). Fashion installation resonates with this expanded logic. The boundaries between clothing, spatial installation, and performative practice become porous, giving rise to a composite form that synthesizes multiple disciplines. The designer's work extends beyond garment creation to the orchestration of an entire perceptual environment, including spatial arrangement, illumination, soundscapes, and the pathways through which audiences move. This multidisciplinary structure positions fashion installation at the intersection of architecture, scenography, visual art, and digital media.

The rise of fashion installation is closely connected to broader developments in contemporary fashion museology. Studies of exhibition practice show a growing public attraction to fashion shows that offer immersive and atmospheric experiences. The museum is no longer confined to the preservation of garments as historical remnants. Increasing emphasis is placed on reconstructing the dynamic contexts in which clothing is worn, staged, and culturally situated (Teunissen, 2018). This shift reflects a curatorial orientation that privileges experience over objecthood and invites audiences to engage in open-ended processes of meaning-making (Wallenberg, 2020). Fashion installation exemplifies this curatorial turn by encouraging modes of perception that involve the full body rather than the eye alone.

Technological innovation further expands the expressive capacity of fashion installation. Practices associated with designers such as Hussein Chalayan demonstrate how digital imaging, mechanical structures, and experimental materials enable garments to interact with their surrounding environments (Quinn, 2002). Techniques, including projection, sensor-based systems, and kinetic components, transform garments into dynamic entities capable of responding to environmental and audience stimuli. These technologically mediated forms strengthen the environmental orientation of installation, foregrounding fashion as an evolving system rather than a fixed object.

The shift in communicative paradigm carries significant theoretical implications. Fashion has been described as a system in which meaning emerges through processes of encoding and decoding (Barnard, 2013). Fashion installation challenges the limitations of this semiotic model. Meaning arises not primarily from visual symbols but from multisensory immersion. The viewer's body becomes an active medium of interpretation, while spatial atmosphere, tactile qualities, and sonic resonance contribute to a communicative field that exceeds linguistic representation. This phenomenological orientation reframes fashion communication as an experiential and embodied process rather than a system of visual transmission.

The transition from object to environment also alters the temporality of fashion. Traditional displays tend to stabilize garments within fixed historical or stylistic contexts. In installation settings, meaning changes in relation to movement, shifts in light, and the unfolding of time itself, generating a condition of openness and fluidity (Geczy & Karaminas, 2019). This temporal configuration positions fashion installation as an effective medium for exploring memory, identity, and cultural transformation. Garments cease to function solely as carriers of past styles and instead acquire new significance through the immediacy of lived experience.

2.6.2 Spatiality, atmosphere and environmental experience

Atmosphere, as an aesthetic category, occupies a central position in contemporary spatial theory. It is neither a purely physical attribute nor an entirely subjective sensation, but rather a quasi-objective phenomenon situated between subject and object (Böhme, 1993). Within fashion installations, this framework illuminates how garments exceed their material boundaries and become agents in the production of atmospheric experience. When viewers enter a carefully constructed installation environment, they perceive not an isolated garment, but an integrated atmospheric field shaped by light, shadow, texture, air movement, temperature, and other environmental elements. The shadow cast by a pleat under a specific angle of illumination, the way a fabric absorbs or reflects light, or the temperature and humidity circulating within the space all operate as fundamental components of the viewer's perceptual encounter. Architectural phenomenology further enriches the understanding of this spatial experience. Genuine spatial engagement arises from the body's sensory participation rather than from detached visual interpretation (Zumthor, 2006). This perspective aligns closely with fashion installation practices, in which the crafting of atmosphere depends on the precise calibration of generators such as light temperature, material tactility, and spatial proportion (Böhme, 2017).

In fashion installations, the viewer's body is no longer a passive observer but an active component of the atmospheric field. Bodily presence participates directly in the emergence of meaning, with movement, breathing, and thermal perception functioning as integral elements of the aesthetic experience (Kühnapfel et al., 2023). As the viewer navigates the installation, shifts in distance, changes in perspective, and even adjustments in breathing rhythms continually redefine how the garment comes into being within the space. The concept of the life of things clarifies that garments in such environments do not exist as inert displays but as lively entities engaged in ongoing creative entanglements with both the environment and the moving body (Ingold, 2010). A garment that gently sways as the viewer approaches due to subtle air disturbances, or the way a fabric reveals different surface qualities under shifting illumination, becomes evidence of this dynamic interplay among body, environment, and material. This relational dynamic is vividly articulated in *Sculpting the Senses*, where garments, light, shadow, material textures, and sound form an immersive field activated through bodily movement (Herpen, 2023a). As viewers traverse the space, variations in reflected light, changes in color temperature, and localized airflow transformations cause the garments to appear in a state between material presence and environmental resonance, producing surface dynamics that feel almost animate. Within this atmospheric configuration, garments align with the rhythm of the environment, and their meaning unfolds through the continuous interaction of bodily perception and environmental modulation.

Research on exhibition environments also demonstrates that atmospheric qualities shape visitors' interpretive frameworks. Variations in lighting, temperature, acoustics, and spatial pathways alter viewers' emotional rhythms and cultural readings of fashion (Forrest, 2013). Designers may introduce subtle environmental interventions, such as local temperature gradients, directional air flows, or spatial zoning, to guide bodily movement and align the viewer's perceptual tempo with the garment's presentation. Fashion exhibitions staged in heritage sites or non-conventional venues further reveal the layered interrelations among body, site, and garment, where atmosphere amplifies or reframes fashion narratives (Lan & Liu, 2023). Cultural geography likewise shows that spatial forces, flows, and affective structures are dynamic and contingent, rendering atmosphere a continuously emergent environmental experience (McCormack, 2008). A carefully constructed atmospheric field can persist in memory, allowing the garment's image to transcend the immediate visual encounter and permeate the viewer's emotional register.

Issey Miyake directly implemented this extreme reconstruction of environmental mediums in his *Water and Rebirth* visual project (Koike et al., 2016). By completely submerging iconic pleated garments into an underwater environment, this practice shatters the conventional spatial experience that relies on air as the default medium. The high-density medium of water alters gravitational effects and light refraction rates. This causes the physical structure of the garments to exhibit a completely different dynamic vitality under the combined effects of buoyancy and water currents. The design strategy of utilizing a specific environmental medium as the primary generator of spatial atmosphere reveals that the form and meaning of clothing are not inherent. Instead, they undergo fundamental evolution according to the physical spatial environment they inhabit. This preliminary exploration provides a direct physical reference for the future desert environment that this study attempts to construct. The *Desertia* project is similarly built upon the extremization of environmental mediums. By simulating unconventional spatial elements such as thermal radiation and sandstorm airflows, the project transforms the medium itself into the core driving force for reshaping garment morphology and audience perception.

For this research, atmospheric theory provides a critical lens for understanding the transformation of fashion installation in the digital era. When digital technologies intervene, the mechanisms of atmospheric production shift fundamentally. Projected light interacts with garment surfaces and spatial contours, AI-generated imagery reshapes the visual environment, and devices controlling airflow and temperature modulate the physical field. Together, these elements create a hybrid atmospheric system. This transformation marks more than a substitution of media; it signals a reconfiguration of atmosphere's ontology. How does a digital atmosphere formed through projection, generative imagery, and environmental modulation establish a multisensory experience? When AI-generated visuals appear simultaneously on spatial surfaces and on the garment, accompanied by adjustments in airflow and temperature, can such hybrid conditions evoke responses analogous to those triggered by real environmental intensities? The spatial permeability of projection, the dynamic behavior of generated images, and the programmable nature of physical environmental parameters constitute new mechanisms through which atmosphere emerges, prompting a reconsideration of bodily perception at the boundary of material and digital, real and simulated.

Within this theoretical foundation, the *Desertia* project conceptualizes atmosphere as the primary structure through which experience unfolds. Fluctuating light, low humidity, thermal gradients, and geomorphological rhythms of a speculative desert environment form the initial layer of perception as the viewer enters the space. The projection system functions along two trajectories. Panoramic background projections construct the spectral and textural logic of the future desert, generating an immersive climatic field, while projections on the garment visualize its functional responses to extreme climatic conditions, producing surface behaviors that correspond to environmental dynamics. Airflow and temperature gradients intensify the tactile dimension of the space, allowing the body to participate continuously in the formation of atmosphere through movement and positional shifts. The garment's meaning emerges within this interplay of environmental rhythms, projected imagery, and bodily sensation rather than from its material form alone.

The atmospheric configuration of *Desertia* establishes a narrative pathway distinct from conventional fashion installations. The projected imagery, light, heat, and air simulation collectively produce a perceptual logic oriented toward future ecological pressures, placing viewers immediately within a sequence of experiences shaped by climatic intensity. This narrative is driven not by textual explanation but by environmental modulation that guides the viewer in understanding the garment as a responsive medium situated within speculative climatic conditions. Atmosphere thus becomes a mechanism of narrative formation rather than a supplementary backdrop. Supported by atmospheric theory, fashion installation forms a sensory network linking body, environment, and garment. Meaning develops relationally within this network, independent of any single garment or visual symbol. Through the integration of climatic variables, digital imagery, and physical environmental structures into a unified atmospheric mechanism, *Desertia* presents an alternative future-oriented mode for fashion installation practice. Atmosphere functions as a connective tissue between digital design, ecological imagination, and embodied experience, providing a cross-disciplinary theoretical interface and a methodological foundation for exploring fashion in an era defined by climate instability.

2.6.3 Hybrid installations: projection and virtual ecologies

Contemporary fashion installations are moving away from material-centered modes of display. Light, projection, and digital surfaces have become the primary narrative structures, reshaping how space and time are experienced in exhibition contexts. Within this shift, projected and screen-based environments are no longer visual supplements applied to garments. They operate as generative systems that build atmosphere, modulate temporality, and reconfigure spatial perception. Research on digital platforms describes the open spatio-temporal structure of digital environments, showing how fashion display becomes detached from the linear tempo characteristic of traditional exhibitions (Suh, 2020). As digital mediation expands, garments cease to function as objects placed before an observer. They become interfaces embedded within a digitally constructed environment, while viewers participate in meaning-making through their movement and sensory engagement. Such environments rely on the circulation of light, data, and algorithmic patterns rather than the stability of material fixtures, producing distributed forms of attention and multi-point spatial narratives (Dziekan, 2007).

Projection technologies are central to this mediatic reorientation. Once projected onto a garment, light transforms its surface into a dynamic and responsive field. The garment acquires a temporary materiality, shaped by color shifts, rhythmic pulses, and fluctuations in visual temperature. In this context, projection becomes a spatial and temporal force capable of rewriting the surface's perceptual state. Studies on projection installations describe how light reorganizes exhibition space through patterns of distribution and transformation, creating novel perceptual pathways for viewers (Falck & Halskov, 2013). In gallery settings, projection mapping generates immersive atmospheres that envelop the body and encourage a sense of relationality among garment, viewer, and environment (Kassim et al., 2019). Work on augmented spatial surfaces further demonstrates that projection can convert fixed architectural facades into temporary digital interfaces, forming transient landscapes of light (Tritthart, 2021). A similar principle applies to garments within fashion installation, where the surface becomes a site of environmental modulation rather than a stable material form.

Beyond projection, algorithmic imagery has become a significant component of contemporary fashion installations. Research on atmospheres highlights the emotional and social attributes of digital environments and describes how they exert perceptual influence through non-material means (Leclair, 2023). Data-driven visual sequences simulated environmental textures, and algorithmically generated rhythms act as atmospheric agents capable of influencing bodily perception. These visual structures often represent environmental forces such as airflow, temperature shifts, or water circulation without relying on physical simulation. They operate through variations in luminosity, color temperature, and spatial rhythm to produce a sense of environmental pressure. Studies in somaesthetics demonstrate that digital atmospheres stimulate bodily awareness through interactions with light, rhythm, and digitally mediated environments (Fiala, 2023). These theoretical perspectives clarify how algorithmic imagery can construct virtual ecological conditions within fashion installations, allowing environmental narratives to emerge through visual systems rather than physical models.

Refik Anadol and his studio establish a generative paradigm for transforming massive datasets into spatial ecologies in the *Nature Dreams* project (Anadol, 2021). The team utilizes machine learning algorithms to deeply process natural landscape images and translates the extracted data features into fluid panoramic projections. This practice endows digital algorithms with physical volume and envelopment, successfully constructing an oppressive climate narrative within a solid space. Although the *Desertia* project in this research does not involve the algorithmic development of such massive datasets at the underlying technical level, Anadol's strategy of physicalizing digitally generated content provides a core methodological inspiration for this study. The *Desertia* project utilizes artificial intelligence image generation tools to reconstruct biomorphic forms and climate tension in extremely arid environments. It then employs spatial projection technology to transform these generated digital visuals into an enveloping physical field. Through this cross-media spatial translation, the virtual ecological oppression breaks through planar limitations, enabling audiences to viscerally experience the sensory shock brought by simulated drought and sandstorms within a physical space.

As digital mediation intensifies, fashion installation displays increasingly exhibit a post-material aesthetic. Projection-based surfaces, animated pixels, and immaterial light fields displace the centrality of fiber, texture, and structure, allowing garments to appear in forms that exceed the boundaries of physical materiality. This aesthetic is defined by garments shaped by light, data, and environmental information rather than by the logic of tangible materials. The concept of the elemental surface captures this condition by describing surfaces composed of pixels and light rather than fiber and cloth (Zhang, 2022). Research on digital bodies shows how garments and bodies are co-constituted in digital environments, generating bodies that appear to be made of luminous surfaces rather than biological matter (Pertel, 2023). In virtual fashion theory, digital materiality and temporality undergo processes of reorganization that produce visual ecologies distinct from those of the physical world (Stevenson, 2023). This post-material logic redirects the task of fashion installation from presenting physical garments to presenting environmental information that flows across the surface, establishing modes of display shaped by atmospheric and ecological narration.

Digital artist Maotik further reveals the organic, reactive potential of virtual media in the environment-generative installation *Aether* (Sourd, 2018). The installation continuously mutates algorithmic images by capturing environmental data in real time within the physical space. The digital imagery thereby exhibits spontaneous perception and feedback behaviors akin to organic life forms, completely shattering the static boundary between physical entities and digital virtuality. This interactive strategy of endowing spatial surfaces with vital signs profoundly inspires the visual expression mechanism of the *Desertia* project. This research translates fluctuations in climate pressure into dynamic digital visual signals and projects them directly onto the physical surfaces of garments like *RespiraVeil* and *HydraSkin*. Static fabrics acquire simulated metabolic behaviors through the real time intertwining of light and shadow. They successfully display an adaptive respiratory sensation within the hypothetical context of extreme thermal radiation, ultimately establishing themselves as hybrid interactive interfaces that visualize ecological crises.

Within the *Desertia* project, digital projection operates as the primary method for constructing speculative ecological conditions. Cycles of moisture, shifts in light and heat, fluctuations in air pressure, and the rhythms of desert terrain are projected onto garments as dynamic visual behaviors. These projected variables make it possible to express garment functions without relying on physical materials. Water circulation pathways, micro-climate responses, or nutrient movement patterns become visible through projection, allowing garments to serve as perceptual interfaces for climate-driven phenomena. Studies on virtuality demonstrate that dematerialized digital environments can generate ecologically oriented immersive experiences (Ng & Tomkins, 2023). Research on digital exhibition atmospheres shows how light reorganizes spatial consciousness and intensifies sensory engagement (Mathias, 2022). Within this framework, projection in *Desertia* performs more than representational work. It constructs a future ecological world and renders its tensions, rhythms, and sensory pressures perceptible through light, enabling garments to function as mediators between environment and body.

3.0 METHODOLOGY

This chapter delineates the methodological framework underpinning this thesis. The study employs practice-led research as its overarching foundation, integrating theoretical perspectives from speculative and critical design to establish a cyclical research trajectory through reflective practice. This methodological structure is designed to address the core research question: how garments can be reconfigured from traditional attire into interactive survival systems within the context of the evolving climate crisis. Given that this inquiry involves high degrees of uncertainty regarding future scenarios and material behaviors, purely theoretical analysis is insufficient to capture its dynamic complexity. Consequently, this research utilizes design practice as a primary mode of knowledge production, fostering a continuous dialogue between creative action and conceptual reflection (Candy, 2024; Smith & Dean, 2009).

The central logic of this methodology lies in "thinking through making." Practice-led research ensures that creative activity occupies a central role in knowledge generation, whereby the design process itself functions as an exploratory pathway rather than a mere illustration of pre-existing theories. Within this framework, speculative design provides a narrative apparatus for constructing future scenarios (Dunne & Raby, 2013), while critical design imbues the design objects with speculative attributes, shifting the focus from functional solutions toward profound reflections on social and ecological ethics (Malpass, 2017). To ensure the systematic transformation of experiential data into academic insight, the research implements a reflective practice mechanism, tracing cognitive shifts throughout design decisions and material experiments (Schön, 1992).

In terms of conceptual progression, the chapter first establishes the study's overarching orientation by examining the integration of practice-led research and reflective practice. It then delves into the specific execution pathways, encompassing the construction of future scenarios, biomorphic design strategies, and the collaborative role of Artificial Intelligence in design iteration. The discussion culminates in the practical implementation of the fashion installation *Desertia*, demonstrating how immersive narratives and reflective processes converge to synthesize experimental outcomes into formalized research findings. Moving from a macroscopic framework to microscopic execution and ultimately to knowledge synthesis, this chapter constructs a model of knowledge production where theory and practice are mutually reinforcing.

3.1 Methodological framework

The methodological framework of this research is grounded in the interplay among practice-led research, speculative and critical design orientations, and reflective practice. Rather than following a linear trajectory from theory to application, this framework operates as a dynamic field in which knowledge emerges through actions, materials, and conceptual inquiry. The central task of the research is not to verify predetermined assumptions but to trace how concepts shift through making, experimentation, and projection-based construction.

3.1.1 Practice-Led research: generating knowledge through action

Within the *Desertia* project, practice is not used to demonstrate preconceived theories or to serve as a showcase of outcomes. Instead, it functions as the primary engine through which knowledge is produced (Smith & Dean, 2009). This methodological stance asserts that understanding arises from acts of making rather than from the analysis or synthesis of existing texts. When the research examines the material, functional, and symbolic transformations of clothing in future climatic conditions, conventional literature or theoretical modeling cannot reveal how materials and technologies behave under environmental pressure. Only the hands-on construction of garment prototypes, the building of a projection system, and the testing of materials in simulated desert conditions can expose forms of knowledge that remain inaccessible at the level of theory.

The notion of making as thinking establishes the epistemic basis through which inquiry unfolds in and through practice (Candy et al., 2006). In *Desertia*, thinking does not precede making but is embedded within each technical decision, material choice, and morphological adjustment. The deviations between expected and actual material behaviors frequently become generative moments that reorient the research. Such knowledge cannot be derived from texts alone; it emerges through the act of making (Mäkelä, 2007). Through practice, the garment moves beyond its conventional role as a bodily shield and begins to reveal its potential as an environmental interface or a temporal mediator.

Practice-led research unfolds through multiple layers of knowledge production in this project. During digital modeling, AI-assisted image generation often produces unexpected outputs that disrupt initial assumptions and prompt a reconsideration of what desert adaptability entails. In 3D printing, the negotiation between computational models and physical fabrication exposes tensions that become clues for understanding virtual-to-material translation. Projection-mapping experiments reveal that when moving images interact with pleated or folded surfaces, optical distortions echo the refractive qualities of desert light. This finding shifts the projection system from a mode of display to a cognitive device for simulating atmospheric conditions. These deviations, adjustments, and discoveries are not peripheral to the research plan. They constitute its core epistemic outcomes. The openness of the practice-led framework allows knowledge to emerge through interactions among materials, technologies, and concepts rather than being constrained by predetermined theories (Smith & Dean, 2009).

3.1.2 Speculative and critical design orientation

The combined use of speculative and critical design in this study does not serve to categorize a creative style, but to enable a particular mode of epistemic operation. The future desert world constructed in *Desertia* is not a narrative backdrop or aesthetic motif, but an experimental field for examining shifts in the logic of clothing. In this scenario, climatic pressure is treated as a constant rather than an exception. Human adaptation becomes an ongoing condition rather than a hypothetical one, and clothing is placed within the domain of survival rather than social display. Through such a framework, the research steps outside the operative logic of the contemporary fashion system and examines clothing as a potential life-support structure.

Speculative design provides methodological tools to construct future scenarios (Dunne & Raby, 2013). Its purpose is not to predict what will happen but to interrogate how clothing systems might be reorganized when environmental conditions change fundamentally. In *Desertia*, speculation is not unrestricted imagination, but a constrained extrapolation informed by climate science, material innovation, and physiological research. The integration of water-storage layers, reflective surface treatments, and modular wearable systems in garment prototypes reflects a systematic reconstruction of functionality under desertification. This speculative mode allows the research to challenge existing industrial and commercial logics and to reposition the garment as a material interface within larger environmental relations.

Critical design complements this orientation by providing a framework for decentralization and anti-functionalist critique (Malpass, 2013). *Desertia* does not seek to offer solutions to climate-driven challenges nor to produce garments that conform to industry standards of utility. Instead, the project uses design practice to interrogate the fundamental transformation of clothing functions and forms situated in a speculative extreme environment. This critical stance steers the research away from incremental improvements to existing garments and toward alternative logics that could emerge once environmental conditions undergo radical change. It exposes the limitations of current fashion paradigms when confronted with systemic ecological shifts.

Together, speculative and critical design establish a methodological position of world-building for epistemic inquiry (Auger, 2013). The goal is not to solve problems but to construct a cognitive environment that enables questions such as: What could clothing become when environmental conditions are drastically altered? What should it become? *Desertia*'s material outputs serve as visible manifestations of this inquiry.

3.1.3 Reflective practice

Reflective practice in this research is not an after-the-fact record of creative activity. It functions as a systematic cognitive mechanism that tracks how practice continually reshapes assumptions and theoretical understandings. Schön's concepts of reflection-in-action and reflection-on-action ground this mechanism, yet in *Desertia* they are expanded into three interconnected layers: process reflection, material reflection, and atmospheric reflection (Schön, 1983).

Process reflection focuses on conceptual shifts that occur during technical operations. In AI-driven image iteration, each adjustment of prompts or parameters redefines the visual characteristics associated with desert adaptability. When algorithmic outputs deviate from expectations, these deviations become productive triggers for revisiting research assumptions. For example, the algorithm's inclination toward fluid organic forms rather than rigid geometric structures prompted a reconsideration of the relationship between protection and permeability. These reflections treat technological outputs not as errors but as dialogic partners that expand design possibilities (Schön, 1992).

Material reflection traces how physical experimentation reshapes conceptual understanding. Tests involving paper yarn, silk, cotton, and recycled polyester reveal how materials challenge or extend initial hypotheses. Their physical properties, including texture, weight, translucency, and structural stability, do not merely impose technical constraints but offer questions into how materials participate in environmental responsiveness. This reflection marks a shift from viewing materials as modeling media to understanding them as agents that structure environmental interaction.

Atmospheric reflection examines how exhibition strategies immerse viewers in future climatic conditions. During projection testing and spatial design, the research continuously evaluates how light intensity, projection angles, temporal rhythms of motion graphics, and spatial ambience work together to create a situated experiential field. Through these adjustments, climate change becomes not an abstract dataset but an embodied experience. This layer of reflection reframes the role of garment display: it becomes an atmospheric device that activates speculative imagination and environmental empathy. The ongoing refinement of exhibition methods aims to cultivate a perceptual entry into the *Desertia* world, enabling viewers to experience how environmental pressures reconfigure the relationship between humans and clothing.

These three layers of reflection form an ongoing iterative loop in the project. Each cycle of practice generates knowledge that redirects subsequent cycles, and these redirections themselves become integral to the research trajectory. Reflective practice does not confirm established theory, it traces how knowledge emerges, evolves, and stabilizes through action. Through systematic documentation, the research translates tacit procedural insight into an epistemological contribution.

3.2 Design methods for exploration

Building upon the practice-led research framework established previously, *Desertia* conceptualizes the design process as an exploratory research pathway, utilizing continuous practical activities to develop, test, and articulate speculative concepts. Within practice-led research, design activity transcends mere artifact production; it functions as the core mechanism for generating systematic knowledge through making, reflection, and iterative experimentation (Candy & Edmonds, 2018; Smith & Dean, 2009). Consequently, the design methods employed in this study overcome the limitations of isolated technical tools, collectively forming an interconnected research ecosystem. This system fosters continuous interaction and feedback among conceptual deduction, digital generation, and material experimentation. Throughout this process, design practice serves as a critical avenue for exploring the latent relationships between the human body, garments, and dynamic environmental conditions.

To advance the conceptual development of adaptive clothing within the *Desertia* context, this study utilizes a variety of complementary design methods for comprehensive exploration. These methods translate macro-level deductions about future environments into concrete design propositions, gradually refining them through visual exploration and material experimentation. In the context of speculative and critical design, methodological approaches frequently serve as vital mediums for constructing hypothetical futures and investigating emerging social and ecological issues (Malpass, 2017). Therefore, the design methods in this study possess a dual practical and theoretical nature; they guide specific operations while simultaneously acting as theoretical instruments to propel conceptual thinking and propose alternative future possibilities.

In terms of execution, this research integrates scenario building, biomorphic design strategies, AI-assisted generation and iteration, alongside material and structural experimentation. Scenario building is utilized to establish hypothetical future environments, allowing design proposals to be examined within the broader context of social and ecological transitions (Auger, 2013; S. Candy, 2010). Biomorphic design strategies extract structural and morphological principles from biological systems, deriving design inspiration from nature's adaptive mechanisms (Menges, 2012; Vincent et al., 2006). Serving as a cutting-edge exploratory tool, AI-assisted generation significantly expands visual possibilities through high-frequency iterative rounds, providing novel formal cues for the design process (Hertzmann, 2018; McCardle et al., 2019). Finally, material and structural experimentation focuses on translating speculative concepts into physical entities and examining the dynamic interactions among digital manufacturing technologies, textile materials, and structural morphologies (Ingold, 2013).

Through the deep integration of these methods, this study constructs a closed-loop design exploration process that ensures continuous feedback and corroboration among speculative ideation, digital generation, and material experimentation. This comprehensive methodology enables the research to rigorously advance the feasibility of adaptive clothing design for future extreme environments within a speculative framework. The subsequent subsections will elaborate on each of these specific methods and analyze their application across the various stages of design development.

3.2.1 Scenario building

Scenario building plays a crucial role in knowledge generation within speculative design research. The existing literature views the scenario as an epistemic apparatus capable of organizing thought experiments under conditions of uncertainty. By constructing hypothetical world conditions, it introduces external pressure that enables latent structures within design logic to surface under stress (Aligica, 2005). Within this methodological framework, the scenario guides conceptual elaboration while enabling design to reorganize once released from the constraints of existing paradigms. It therefore contributes to the evolution of concepts throughout the research process, functioning far beyond the level of narrative or visual backdrop (Barendregt & Vaage, 2021).

In this research, the *Desertia* scenario is developed through an ecological-speculative approach. Its environmental conditions draw on trends in climate science and ecological system dynamics, forming a future ecological framework grounded in scientific trends (Pereira et al., 2019). The scenario provides a controlled experimental setting in which the interactions among clothing, the body, and the environment become discernible under a shared set of pressure conditions. This allows their modes of coordination and adaptation under extreme circumstances to be identified. As a methodological space, the scenario enables the research to develop new cognitive pathways within the speculative gap and to trace how concepts take shape and shift under instability (Tyszczuk, 2021). The extreme climatic assumptions in *Desertia* consist of a set of boundary conditions, including drastic temperature fluctuations, persistent dryness, increased particulate matter, and heightened ultraviolet radiation. These conditions operate as core constraints of the scenario, placing the clothing system in a near-critical state that makes its resilience and potential points of failure observable (Tyszczuk, 2021). Bodily responses within this environment display marked adaptive changes, such as shifts in breathing rhythm, evaporation rates, and energy expenditure. These physiological indicators, in turn, influence the material logic and structural organization of the garments. The scenario thus provides an experimental framework through which body–environment interface relations can be continuously observed and from which knowledge can be extracted through their dynamic interactions (Barendregt & Vaage, 2021).

To maintain methodological validity, the scenario is operationalized as a structured environmental configuration rather than a quantified model. Variables within the scenario are organized as relational conditions, forming a coherent framework. The focus of the research lies in how these conditions, when combined, reshape bodily behavior and material-interface responses rather than in precise numerical values. Through this configuration, the scenario serves as a repeatedly accessible experimental background in which functional modules reveal their structural logic under environmental stress (Murphy & Day, 2021). For instance, the filtering and respiratory-support mechanisms of *RespiraVeil*, the moisture absorption and circulation functions of *HydraSkin*, and the stability of other modules under changing light and temperature all gain clarity through iterative scenario-based testing.

Scenario building aligns methodologically with the concept of speculative infrastructures, offering a processual and open knowledge environment in which concepts, structures, and system behaviors can evolve through ongoing experimentation (Reeves-Evison, 2021). This environment accommodates not only conceptual development but also bodily experience as a critical mode of knowledge generation. Practice-based investigations indicate that actions and perceptions in extreme environments can become forms of systemic learning, as demonstrated by behavior and experience patterns in the desert-based *Drylab2023* experiment (Jenik, 2018). In *Desertia*, bodily experience is likewise central, enabling the research to forge closer connections between material behavior, physiological response, and ecological dynamics. This produces insights that extend beyond abstract reasoning and emerge instead from embodied encounters across material, environmental, and structural interfaces.

3.2.2 **Biomorphic design**

Biomorphic methodology in this research functions as a conceptual logic for understanding natural systems. Its central orientation lies in treating the operational mechanisms of nature as points of departure for design actions and structural speculation. The organization of materials, the distribution of energy, and the interactions between organisms and their environments contain numerous relationships that can be translated into design-relevant structures. The holism, cyclicity, and dynamism of living systems offer conceptual grounding for the development of speculative fashion (Capra, 1996). The adaptive responsiveness of life processes to environmental fluctuation further enriches the framework through which clothing is understood as an interface system (Capra & Luisi, 2014).

During the early design research, natural systems were approached as readable sets of behaviors. Plant vascular bundles present pressure gradients, hierarchical conduits, permeable pathways, and branching patterns that articulate strategies for sustaining flow and circulation under constrained resources. These observations provide the conceptual origin for *HydraSkin* (Table 1), allowing water circulation to be understood as a behavioral system involving layered materials, cavity structures, and micro-channels rather than as a singular functional feature. The behavior of vascular transport demonstrates that flow distribution shifts with humidity and external pressure (Verbrugghe et al., 2023). This understanding informs *HydraSkin*'s structural reasoning, enabling later development to build around flow as organizational logic rather than visual mimicry.

Insect cocoons exhibit distinct behaviors in which lightness, protection, and exchange coexist on a single surface. Variations in porosity, gradients in thickness, curvature, and the continuity of the shell collectively form a responsive interface that maintains protection while allowing air circulation (Hu, 2017). This interface behavior informs the speculative origin of *RespiraVeil* (Table 1), positioning the continuous head–arm structure as a configuration in which energy flow, air direction, and surface protection converge. The respiratory support of *RespiraVeil* emerges not from a technical apparatus, but from natural mechanisms that articulate how an interface can facilitate circulation while maintaining defense.

The desert plant *Welwitschia* offers another structural logic through its long-duration growth rhythm. Its leaves extend, accumulate, curl, and continually rewrite their edges under arid conditions, generating a structure that remains perpetually in formation. Its textures materialize gradually through prolonged exposure to pressure and scarce resources (Gruber & Imhof, 2017). This phenomenon provides the methodological basis for the development of the texture in Model 2 (Figure 4.22), allowing the work to operate through a logic of process rather than static form. In this structural evolution, accretion, overlap, and shifting boundaries function as behavioral principles, turning texture into a framework capable of responding to environmental strain and bodily movement.

Biomorphic methodology, therefore, supplies both inspiration and the functional origins of the modules. The referenced natural phenomena form a set of parallel behaviors that intersect with the methodological structure of the research. They shape concept generation, guide material experimentation, and inform structural development, giving the speculative functions of the garments a coherent, logical, and ecological foundation.

This methodology also aligns with the project's ecological orientation. Behaviors observed in natural systems under extreme climates—structural adjustment, interface modulation, and optimization of circulation pathways, illustrate modes of stability and resilience under conditions of resource scarcity and environmental stress (Klyusov et al., 2023). These dynamics inform the ecological framing of *Desertia*, establishing the pressure boundaries within which future clothing systems are conceived. Clothing as an interface is thus understood as a system capable of organizing resources, regulating microclimates, and sustaining continuous body–environment relations. Such an approach can also be observed in contemporary design practice. Iris Van Herpen's *Carte Blanche* collection demonstrates how material behavior under water, light, and airflow forms a bridge between structural generation and natural rhythm, positioning natural movement as a significant entry point for understanding garment structure (Herpen, 2023). This case reinforces the dual significance of biomorphic methodology for structural reasoning and perceptual construction.

Within the methodological framework of this research, biomorphic methodology does not operate as a linear sequence of design steps. It functions instead as a generative mechanism that unfolds across phases. Natural behaviors provide structural models, material experiments reveal modes of response, and digital speculation advances structural evolution. Each garment module emerges through this continuous cycle, enabling speculative fashion in the *Desertia* scenario to maintain coherence across structural, functional, and perceptual dimensions.

3.2.3 AI-assisted generation and iteration

Within the generative system developed in this research, artificial intelligence functions as a catalyst for the emergence of form and the transfer of ideas across media. Its role extends beyond producing expanded visual outcomes, as it creates a state of ongoing transition that sustains tension and keeps the design process open to continual rewriting and reconfiguration. Human–AI collaboration, therefore, operates as a distributed and dynamic arrangement in which AI acts as an accessible reasoning interface rather than a bearer of design intention (Shi et al., 2023). In the *Desertia* practice, the images and videos produced often remain structurally unresolved. Sudden shifts in texture, boundary, or scale introduce visually unstable intervals that preserve indeterminacy. Such uncertainty opens a space for design intervention, allowing the designer to identify emerging directions before structures consolidate, to dismantle organizational inconsistencies, or to infer new formal logics from partial features. Visual exploration consequently evolves into a generative experiment with multiple possible trajectories rather than a progression along a single predetermined path.

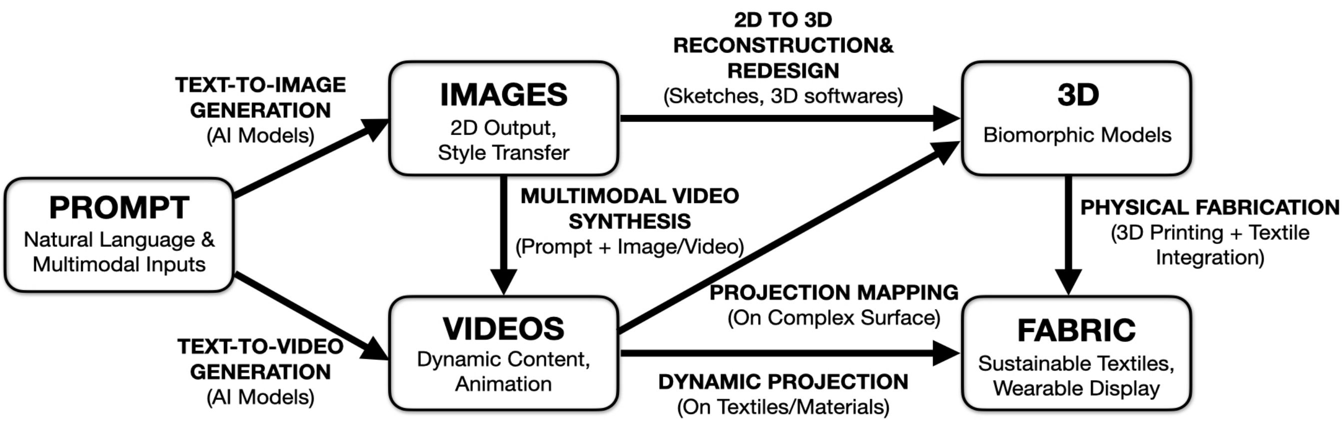

Figure 3.1 Multi-path AI-assisted generative workflow for *Desertia.*

Conventional chained generative mechanisms that follow a prompt–image–model sequence have been described as a linear progression of design inference (Dai et al., 2023). The workflow in Desertia is more complex (Figure 3.1). Text prompts diverge at the initial stage into two parallel paths. One initiates the production of static images, while the other simultaneously generates dynamic video material. This parallel activation creates two interrelated yet functionally distinct media trajectories from the outset and establishes the conditions for subsequent cross-media reasoning.

The image pathway must undergo substantial structural reconstruction before entering the three-dimensional modelling stage. Sketch analysis extracts the core formal language embedded in the visual material, proportion adjustments preserve coherence with the scale of the human body, and volumetric derivation translates two-dimensional information into spatial occupancy. Once these interpreted visual components enter the 3D software environment, the formal relationships that appeared coherent in two dimensions encounter rigorous spatial testing. Constraints of scale, zones required for bodily movement, and requirements for structural closure operate as decisive screening conditions. Many configurations that appear visually sound in static images reveal contradictions or functional shortcomings once examined in three-dimensional space.

The video pathway follows a separate line of inference. Dynamic sequences generated from prompts or images are used primarily for projection-mapping tests on complex surfaces. Moving light functions not only as a visual layer but also as a means of evaluating and refining structural form. When the projected sequences interact with the curved surfaces of a 3D model, the direction of light flow, the degree of boundary diffusion, and the logic of color transitions expose spatial properties that remain concealed in static material. Structural tension that cannot be easily detected in an image becomes visible through dynamic projection feedback, guiding the designer toward local adjustments or broader redesign. The interaction among images, videos, and 3D models demonstrates the depth of cross-media reasoning in this workflow. These media do not appear as consecutive outputs in a linear sequence. Instead, they form a cognitive network in which each medium verifies and corrects the others. Images offer initial formal hypotheses, 3D models test spatial feasibility, and projected video evaluates dynamic responsiveness. Their continuous circulation prevents the design process from relying on the judgment of a single medium and produces a distributed mode of structural understanding. This mechanism enables designers to recognize latent formal possibilities while the work remains flexible and to detect structural contradictions at an early stage, thus reducing the risk of discovering fundamental problems only during fabrication.

Fabric materials introduce an additional layer of filtering to all visual structures, and their influence reaches far beyond questions of surface-level fabrication. Material behavior, including tension distribution, folding angles, and fiber orientation, reorganizes visual logic when it is translated into physical media, and forces relationships that appear coherent in images to undergo full verification in a material environment. Research in textiles notes that AI-generated textures only acquire relevance for subsequent structural discussions once their feasibility has been confirmed through material properties (Wu & Li, 2024). The stage at which 3D models meet fabric, therefore, functions not only as a step in production but also as a rigorous correction of earlier visual inferences. When flexible materials are placed on three-dimensional surfaces, gravity, deformation from bodily movement, and stress concentration along seams reveal issues that are not apparent in digital environments. Curves that appear smooth in virtual form may accumulate unintended folds in fabric tests and carefully designed segmentation lines may fail to achieve their intended visual effect due to limits of sewing techniques. The involvement of materials compels the generation of form to respond to the constraints of the physical world, anchoring speculative visual explorations within a technically achievable framework.

AI iteration in this research operates as a reflective mechanism that accumulates cognitive density. Each cycle of generation produces shifts, and these shifts generate reasoning pressure when compared with hand sketches, digital sculpting, fabric mock-ups, and functional requirements. Studies in speculative design observe that such deviations act as drivers of conceptual evolution (Chen, 2024). In the iterative sequences of *Desertia*, these shifts often appear as forms that resist simple classification: linear organizations located between texture and pathway, states that cannot be fully placed within either pattern or structure, and fragments whose functional direction remains ambiguous. Ongoing evaluation of these indeterminate forms gradually clarifies conceptual boundaries and strengthens the structural logic of speculative fashion.

Once images, videos, and 3D models form parallel sequences, the multi-path generative capacity of AI deepens the cyclical structure. Different generative strands develop independent yet mutually influential trajectories across scale, functional potential, and future ecological pressures (Kurcjusz & Stefańska, 2025). During calibration, the designer compares the outputs of each strand with functional requirements such as respiratory filtration and water circulation, identifying forms with potential relevance and moving them into material experiments and projection tests. Some forms demonstrate the possibility of becoming channels of flow or surface interfaces, while others are dismissed because the material behavior cannot support them. Through repeated movement across media, the emerging logic of form begins to align with the pressures of future extreme ecologies, allowing structure, function, and aesthetic intention to progress together.

Recent studies on human–AI collaboration indicate that AI is effective in exploring stylistic variation and visual transformation, while decisions concerning structure and wearability continue to rely on the designer's embodied understanding of materials and the body (Tocchetti et al., 2025). Based on this insight, each generative cycle in this research is followed by a combined calibration of material and spatial conditions to prevent divergence between visual logic and material behavior. Material behavior, once overlooked, leads to misjudgments in later structural decisions (Lee & Suh, 2024). For this reason, forms must undergo necessary adjustments before entering fabric and projection experiments, ensuring that generative logic, material conditions, and spatial presentation converge into a coherent structural relationship. This mechanism maintains continuity in the design process while supporting the feasibility of speculative fashion within a future ecological framework.

3.3 Narratives and reflection

Building upon the exploratory design methods, this section elucidates how design practice in *Desertia* is translated into rigorous, analyzable academic research material. Design exploration unfolds through continuous experimentation, adjustment, and redesign, accumulating substantial empirical data across visual, spatial, and material dimensions. If these experiences remain confined solely to the operational level of practice, they cannot solidify into formalized academic knowledge. Consequently, this study incorporates a narrative context and a reflective mechanism into its methodological framework to systematically organize and profoundly analyze the observations derived from practice, thereby establishing the traceability and theoretical value of the design experiments.

Within the theoretical framework of speculative design, narrative is frequently employed to construct contextual foundations for experimental design, enabling design objects to acquire new interpretations within specific hypothetical environments (Dunne & Raby, 2013). Once a design proposition is situated within a scenario governed by explicit environmental constraints, its isolated formal and structural characteristics become deeply coupled with spatial, temporal, and ecological variables, revealing entirely new dimensions of inquiry. Through this contextualization, design judgment overcomes the limitations of evaluating single prototypes and begins to undergo systematic testing within highly complex relational networks and ecological architectures.

Operating synchronously, reflective practice opens a pathway for continuous cognitive deepening within this research. Intuitive observations, parametric deviations, and serendipitous events encountered during the design process must be rigorously recorded and comparatively synthesized to precipitate into explanatory insights. The theory of reflective practice emphasizes that designers continuously calibrate their judgments during the creative process and perpetually expand their frameworks of understanding through the systematic review of practical experiences (Schön, 1992). Through this iterative cycle, the intuition and practical experience implicit in the design operations are gradually refined and reconfigured into research outcomes capable of precise articulation and academic exchange.

Throughout the progression of this research, the narrative context and the reflective mechanism maintain a tightly coupled relationship. The contextualized narrative environment reshapes the ways in which design is observed and interpreted, bringing micro-variations in dynamic material behavior, spatial scale, and systemic structure into sharp focus. Conversely, profound reflection upon these experiences optimizes intervention strategies for subsequent experiments, propelling the research forward within a dynamically evolving problem domain (Figure 3.2). By employing a knowledge-translation mechanism that interweaves narrative and reflection, this study systematically transforms seemingly fragmented experimental deviations and material properties into a cohesive theoretical framework regarding garments as survival systems under extreme climate conditions.

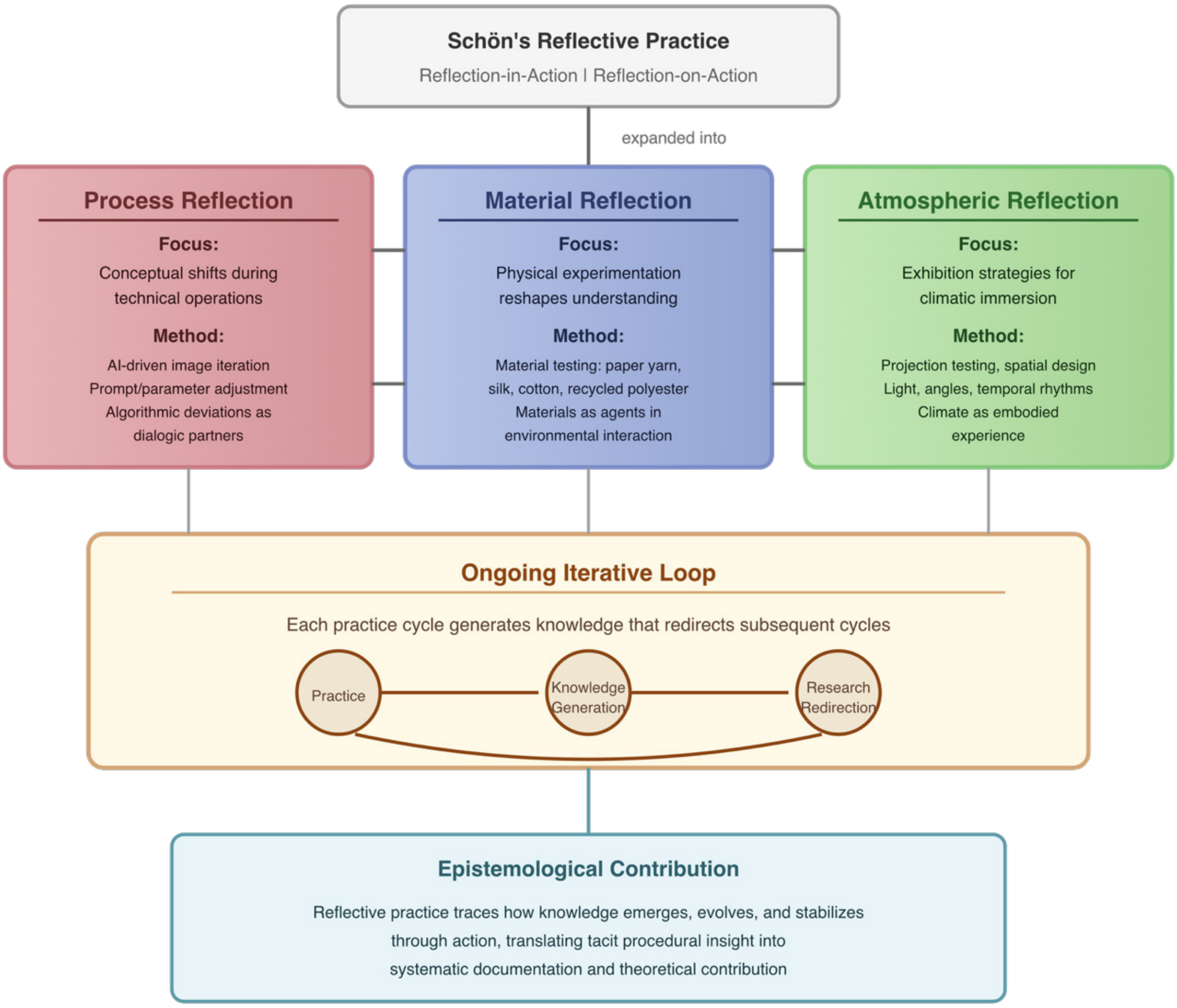

Figure 3.2 Three-layer reflective practice framework.

Note. Adapted from *The Reflective Practitioner: How Professionals Think in Action* (p. 102), by D. A. Schön, 1983, Basic Books.

3.3.1 Projection and immersive narrative

In this research, projection and immersive narrative were employed as an operational apparatus for testing the conditions under which garments can be considered viable within speculative environments. Garments are situated within scenarios composed of moving imagery, shifting light, and spatial enclosure, requiring design judgments to be repeatedly tested under specific environmental pressures. This approach aligns with speculative design’s positioning of design as a problem-generating practice, where the primary concern is whether a constructed situation can expose vulnerabilities or internal tensions within design assumptions (Dunne & Raby, 2013).

Here, immersive narrative functions as a mechanism for delaying immediate interpretation. As garments are embedded within environments shaped by multiple and sometimes competing visual and spatial cues, their readability becomes unstable. This instability is a deliberate methodological choice. By postponing the formation of judgment, the research is able to surface issues of scale, spatial relation, and functional implication that are often filtered out in conventional aesthetic evaluation. Ambiguity is therefore treated as a productive condition within design research, as it enables multiple interpretive trajectories rather than a single resolved reading (Gaver et al., 2003). Maintaining this degree of uncertainty allows the research process to remain open to alternative possibilities.

The temporal structure of projected narratives is likewise treated as a research variable. Cycles, delays, and variations in image rhythm are not introduced solely to intensify immersion but to examine whether garments remain intelligible when repeatedly exposed to the same situational conditions. As imagery loops or shifts gradually over time, the question arises as to whether the garment can still be recognized as an operative component within the system, rather than becoming absorbed into the surrounding environment. Through this temporal manipulation, the narrative shifts from a single act of presentation to a continuously operating condition (Manovich, 2002).

As projection enters the stage of material testing, the relationship between digital imagery and physical textiles becomes tangible and observable. The appearance of projected images on real fabrics is disrupted by surface texture, folds, thickness, and reflective properties, preventing imagery from manifesting exactly as anticipated in digital space. Rather than being treated as technical shortcomings, these effects are analyzed as indicators of how materials behave within immersive environments. By examining how images are absorbed, distorted, or reflected by fabric surfaces, the research evaluates whether materials retain a clear sense of physical presence. These deviations produced through light–material interaction reposition material from a background condition to a key reference for assessing whether narrative and spatial structures remain coherent (Ingold, 2011). Within this process, projection does not aim to override material characteristics but to reveal them through interference. Friction between digital systems and physical matter has been shown to expose differences that are often obscured by streamlined technological workflows (Kittler, 1999). In this research, such deviations generated through light interference function as evaluative cues, used to assess whether garments can still be understood as concrete physical entities within highly mediated future scenarios.

Technical failures and misalignments occurring during projection are likewise incorporated into the analytical process. When projected imagery does not align precisely with garment contours, or when narrative continuity is interrupted by technical limitations, these instances of failure tend to make issues of spatial scale or structural coherence more visible. Research on glitch aesthetics suggests that technological breakdowns disrupt habitual modes of perception and compel renewed attention to the operational logic of systems (Cascone, 2000; Goriunova & Shulgin, 2004). Post-digital aesthetics, understood as a deliberate departure from ideals of technical perfection, derive their value from exposing system boundaries and revealing structural issues concealed by routine operation (Cascone, 2000). In this study, interruptions caused by technical constraints are used to test the capacity of existing narrative configurations. When a system fails to perform as expected, which design assumptions are the first to be exposed as problematic? By incorporating imperfection into the research logic, this approach avoids equating technical smoothness with design validity and enables sustained analytical attention to deviation and breakdown.

From a methodological perspective, projection and immersive narrative not only establish testing conditions but also shape which issues are brought into the reflective phase of the research. The environments constructed through projected imagery foreground particular spatial relations and material behaviors, thereby defining the objects of reflection. At the same time, insights generated through reflection feed back into adjustments of the narrative structure itself, for example through changes in image scale or temporal rhythm, allowing new questions to emerge.

3.3.2 Reflection and epistemic knowledge generation

Within the *Desertia* research process, reflection functions as a mechanism that directly intervenes in design judgment and the adjustment of research direction, rather than as a retrospective account of creative practice. Reflection consistently addresses a central question: how clothing is understood, misinterpreted, and redefined within speculative ecological conditions and immersive narrative environments. By systematically documenting deviations observed during projection tests, material experiments, and spatial presentations, reflection enables the research to revise its problem structure over time (Iordanou, 2022).

Reflection operates in a layered manner throughout the study, closely aligned with specific stages of practice. During the phases of image generation and projection mapping, excessive continuity or scale imbalance in projected textures across different materials and viewing distances is recorded as perceptual cues for reflection (Dohn, 2011). At this level, uncertainty is intentionally retained to reveal the conditions under which garments are perceived within immersive environments. As the research moves into material and structural testing, reflection shifts toward an analysis of garments as material objects. Distortions and occlusions produced by material behavior under varying forces challenge visual logics that appear coherent in digital environments. These deviations are examined as reflective objects, prompting a reassessment of the relationships among garment structure, material selection, and projection logic. In the later stages of the research, visual conflicts and perceptual misreadings accumulated during earlier experiments are reintroduced at the level of scenario-building, leading to adjustments in the positioning of garments within future ecological scenarios. Reflection at this stage contributes to the reconfiguration of research direction and narrative focus, rather than to formal correction.

This layered structure of reflection leads to a fundamental shift in the role of prototypes within the research. Intermediate prototypes are treated as epistemic objects whose incompleteness continuously generates new questions (Ewenstein & Whyte, 2009). Through the analysis of prototype sequences, the research traces the material trajectory of knowledge formation. Material behavior participates directly in reflective processes, allowing knowledge to be articulated through practice (Mehto et al., 2020). From the perspective of epistemic pluralism, this prototype-centered reflective structure accommodates multiple interpretive pathways, without reducing design knowledge to a single conclusion (Coliva & Jang Lee Linding Pedersen, 2017). This position aligns with the research strategy in *Desertia*, which retains contradiction and unresolved states as productive conditions.

Once prototypes are understood as epistemic objects, reflection and design iteration form a non-linear relationship. Deviations observed across multiple projection tests reveal how garments are interpreted under specific environmental pressures and prompt a shift in research focus from technical presentation toward perceptual conditions. Attention moves away from visual coherence toward the perceptual relationship between garments and light environments, allowing uncertainty to function as a source of research value (Yang et al., 2020). Within this framework, failure and deviation are assigned a clear epistemic status. Experiments that do not achieve anticipated outcomes are used to identify the boundaries of design assumptions, enabling conceptual divergence to serve as a critical resource for understanding garment constraints (Kapur, 2008; Sitkin, 1992). Through repeated cycles of problem identification, hypothesis adjustment, and practical response, design judgment evolves within a shifting epistemic structure, maintaining sensitivity to emerging questions (Moallem, 1998). This problem-generative capacity supports an understanding of clothing as an interface system in a continuous state of formation.

Throughout this process, reflection operates as a practice of epistemic autonomy. By continuously recalibrating design judgment, the research maintains control over its pathways of knowledge generation, ensuring that technical tools and visual algorithms remain subject to scrutiny (Matheson & Lougheed, 2022). Such autonomy requires reflection to be grounded in traceable forms of documentation. Given that the research engages immersive experience and dynamic light conditions, reflection relies on multimodal forms of recording. Secondary sketching over photographs taken during projection tests, frame-by-frame video analysis, and diagrammatic annotation of spatial relationships convert transient perceptual experiences into traceable research materials (Ryan, 2014). Different recording media correspond to varying levels of reflection: photography captures visual tension within static compositions, video reveals temporal transformations, and sketches enable speculative annotation of potential relationships. Together, these practices establish thinking through images and materials as an indispensable research method within *Desertia* (Ryan, 2012).

The temporal structure of reflection supports the diversity of recording methods. Immediate reflection documents perceptual responses during experimentation, delayed reflection re-evaluates material and structural behavior, and retrospective reflection reorganizes narrative logic in later stages of the research. Through these temporal layers, a single experience generates different forms of knowledge across time (Eraut, 1994; Zheng et al., 2025). The combination of temporal comparison and multimodal documentation positions reflection as a mechanism that translates ephemeral experience into durable knowledge.

The scope of reflection is further extended through dialogic structures. Misreadings of projection effects and garment legibility by technicians and observers are incorporated into the reflective process, serving as triggers for re-examining design logic (Yukawa, 2006). Technical explanations of equipment limitations are translated into design constraints, while observers' interpretations of projected patterns as textile prints expose the blurred interface between material surfaces and projected light. These dialogues generate epistemic tension that prompts reconsideration of garments' roles within future ecological contexts (Kvan, 2000). Knowledge is thus further developed through social interaction (Stahl, 2006). Dialogic reflection integrates external perspectives into research judgment and reinforces the methodological role of reflection as a tool for self-calibration. Through continuous revisiting of reflective records, research trajectories are tested, and distinctions between aesthetic preference and research judgment become increasingly clear (Buckingham Shum et al., 2017). Reflection also supports the ongoing adjustment of relationships among human agency, technological systems, and material behavior, ensuring that design decisions remain aligned with the research questions (Cho et al., 2022).

The translation from experience to knowledge in this study follows a clear orientation. Not all practical experiences are treated as research data; rather, attention is directed toward key events that reveal how garments are perceived within speculative ecological and immersive narrative contexts. Projection failures, material deviations, and spatial misreadings are transformed into knowledge cues concerning garment–environment–perception relationships through reflective documentation and comparison (Glinka & Müller-Birn, 2023). Knowledge emerges from relational structures formed across multiple experimental iterations, rather than from the summary of a single outcome. By comparing perceptual variations under different projection conditions, the research extracts structural patterns that articulate relationships between garments and light environments (Kolb, 1984). This knowledge remains grounded in the specific context of *Desertia* while establishing an epistemic framework that can inform future research. Its transferability lies not in direct application, but in maintaining open problem spaces that enable subsequent studies to pursue differentiated lines of inquiry (Barzilai & Chinn, 2024; Bransford & Schwartz, 1999). In this sense, garments and installations function not only as display objects but also as epistemic carriers of research judgment and unresolved questions.

4.0 DESIGN EXPERIMENTS AND THE DEVELOPMENT PROCESS

Following the methodological framework established in Chapter Three, this chapter shifts the research focus from theoretical positioning to the operational phase of design development. The research progresses through a sequence of design experiments, translating speculative propositions into tangible material investigations. Transcending the treatment of design outcomes as isolated artefacts, the process operates as a dynamic, iterative system where hypotheses, environmental parameters, material explorations, and structural tests are continuously evaluated through practice.

Within this experimental field, concept and materiality interact as interdependent components, with each design iteration serving as a testing mechanism to examine the translation of conceptual assumptions into functional configurations. The development unfolds through four interconnected stages: scenario construction establishes the environmental testing parameters; structural exploration translates biological inspirations into spatial garment forms; AI-assisted digital modelling supports iterative visualization, and material experimentation evaluates the interaction between textiles and structural prototypes. Together, these stages form a cohesive pathway linking speculative thinking with embodied design practice.

Operating beyond a strictly linear sequence, the design experiments evolve through continuous cycles of hypothesis, testing, and revision. Each stage informs subsequent decisions while simultaneously prompting the reassessment of earlier assumptions.

4.1 Scenario construction as a precondition for design testing

During the design development stage, scenario construction is introduced as a hypothetical apparatus that activates design judgement. This research examines how scenarios intervene in design operations through a series of what-if questions, continuously posing testable challenges to the clothing system in practice. This mode of questioning approximates the application of counterfactual reasoning in system testing, where hypothetical modifications to key conditions are used to examine the stability of causal relationships between structure and function under varying environmental variables (Lewis, 1973). Within this framework, what if operates as a probing device for identifying potential failure pathways that may emerge when the design system is exposed to non-normative conditions. These what-if assumptions extend across multiple stages of design development and are repeatedly activated at different operational points to recalibrate design direction. Their function lies in the sustained modulation of environmental variables, allowing the design to exhibit differentiated behavioral outcomes across conditions. When a system fails to sustain its established functions under hypothetical intervention, previously obscured dependencies and constraints within its structural relations become progressively visible. This process forms the basis through which causal relationships are examined and revised (Woodward, 2004).

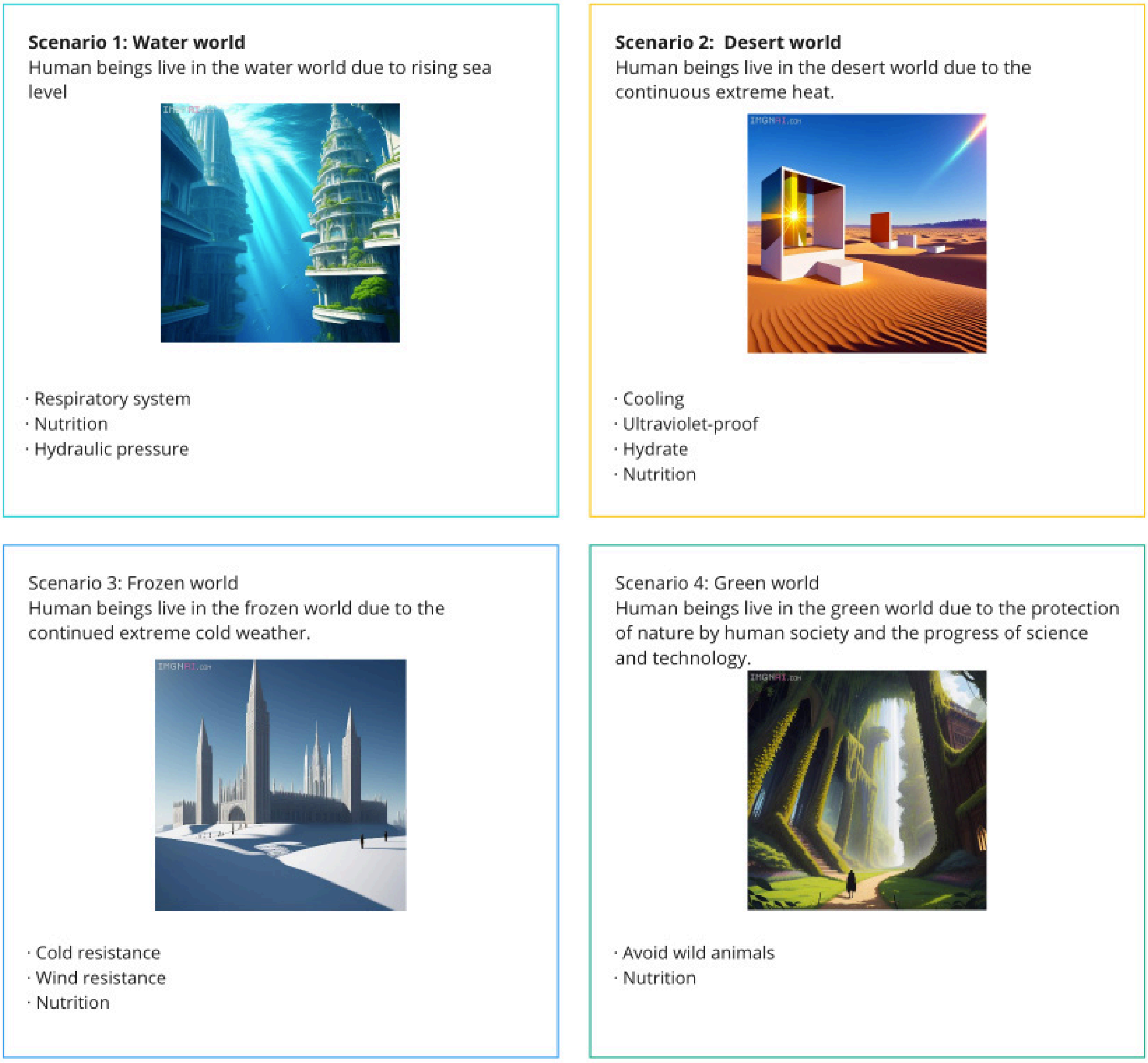

Figure 4.1 Comparative framework for four speculative ecological scenarios (images generated using Midjourney by the author, see appendix for prompts).

In the preliminary research phase, four speculative ecological scenarios were constructed as a comparative framework for design testing, enabling an exploration of how different environmental configurations impose distinct constraints on clothing systems (Figure 4.1). These scenarios were derived from hypothetical combinations synthesizing climate science trajectories, ecological system dynamics, and models of social resource distribution. Their purpose was to provide a set of pressure conditions that could be repeatedly mobilized throughout the design process (Van der Heijden, 2005). By juxtaposing multiple environmental configurations, the research identifies which design pathways rely on specific assumptions for their validity, and which structural strategies demonstrate adaptive potential across scenarios (Schoemaker, 2022).

During the design development stage, these scenarios were not advanced in parallel. Instead, Scenario 2, Desert World – *Desertia* was selected as the primary experimental context based on considerations of testing intensity. The desert scenario concentrates high temperature, intensified ultraviolet radiation, extreme aridity, and sand-laden disturbances within a single system, requiring the clothing system to address protection, regulation, and resource management simultaneously. This concentration produces a highly compressed testing environment that accelerates the early-stage filtering of design assumptions. *Desertia* is not conceived as a landscape of collapse or extinction, but as a highly adaptive ecological condition (Figure 4.2). Such an environmental configuration enables earlier exposure of design vulnerabilities and structural limitations.

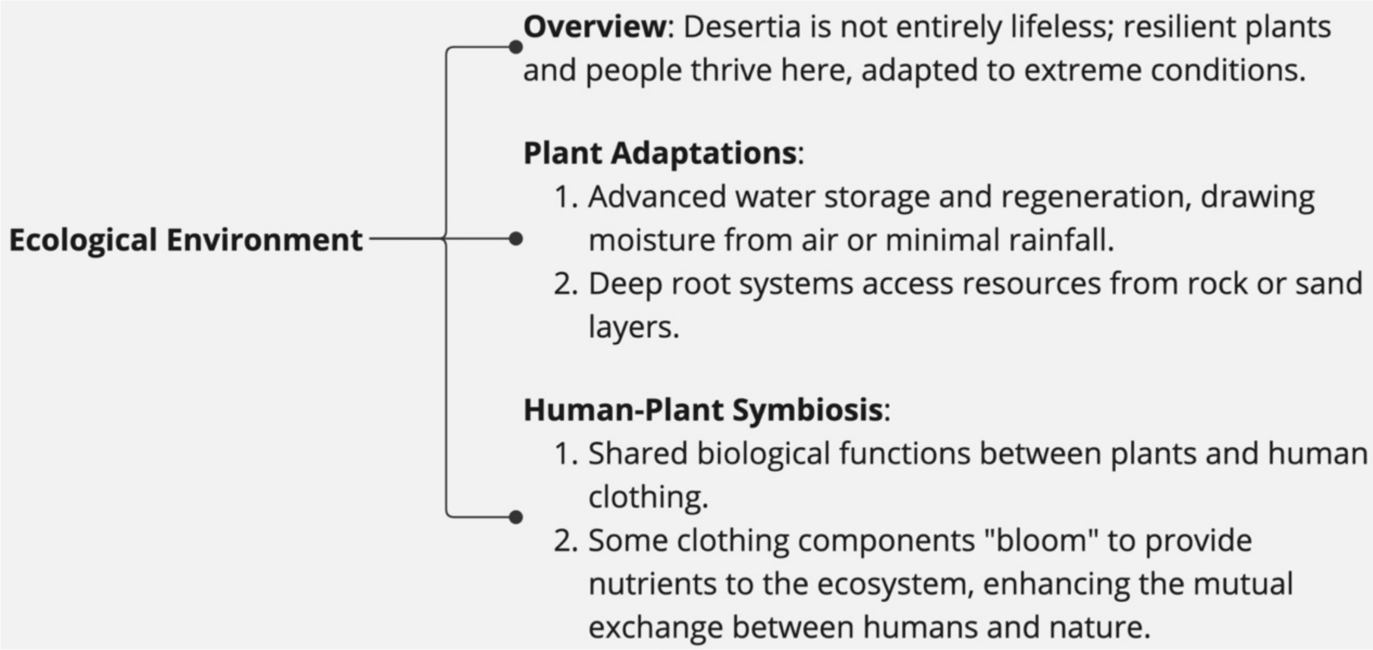

Figure 4.2 *Desertia* as an adaptive ecological environment: Human-plant symbiotic assumptions.

From a systems perspective, pressure conditions amplify structural issues that may remain latent under stable circumstances. Research in complex systems indicates that when resource and energy flows become constrained, the behavioral boundaries of a system become more readily observable (Meadows, 2009). Within *Desertia*, vulnerabilities in energy and resource distribution are significantly intensified, allowing structural redundancy and imbalances in functional allocation to surface more rapidly. This amplification strengthens the effectiveness of the scenario as a design testing environment. Within this understanding, *Desertia* is approached as an adaptive ecology in which life persists through heightened reliance on structural efficiency and cyclical organization rather than abundance. The environmental pressures of *Desertia* are further specified as a set of extreme climatic conditions (Figure 4.3), including sustained heat, pronounced diurnal temperature variation, intensified ultraviolet exposure, and persistent sand-based atmospheric conditions. These conditions are treated as long-term states rather than episodic events.

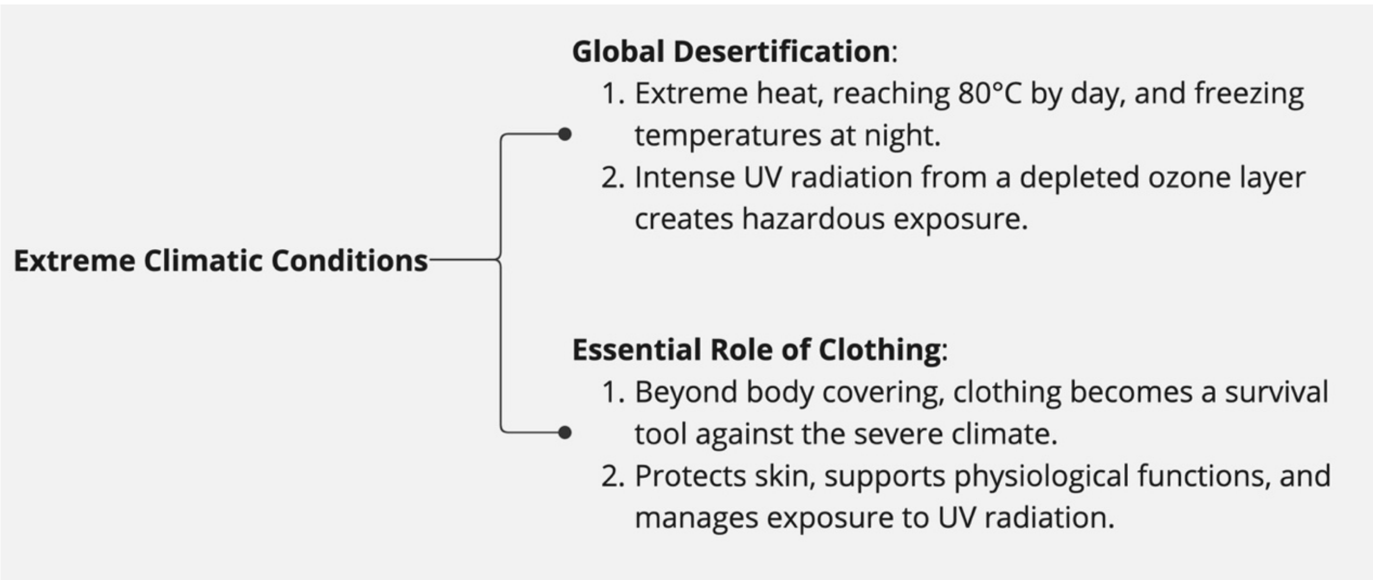

Figure 4.3 Extreme climatic pressures and functional repositioning of clothing in *Desertia.*

In such contexts, drought-resistant plants sustain life through atmospheric water capture, deep root systems, and reduced metabolic rates, while human survival depends on forming new symbiotic relationships with ecological systems. This framing introduces a central hypothesis:

what if human survival under extreme environmental conditions requires structural coordination with biological systems? Studies of systems under sustained pressure suggest that adaptive capacity emerges through internal reorganization of relational structures (Taleb, 2012). Within this hypothesis, clothing is positioned as a mediating interface that participates in regulation and circulation processes, assuming an active role between the body and its environment.

Further system decomposition prompts a re-examination of human modes of survival within *Desertia* (Figure 4.4). As conventional practices of nutrition, excretion, and respiration become unsustainable under conditions of severe scarcity, the following question arises: what if these fundamental physiological processes require reorganization through the clothing system? In response, respiration filtration, water and nutrient intake, excretion, and circulation are approached as functional pathways that can be modularly integrated into clothing. The respiratory hypothesis extends beyond protection from toxins or particulates, drawing on analogies to pulmonary gas exchange to conceptualize garment surfaces as interfaces for air filtration and regulation. Similarly, water and nutrient functions link clothing with plant systems, enabling it to participate in energy storage and distribution. Excretion is reframed as a component of resource cycling, reintegrating waste into the broader ecological system. Across these what-if propositions, clothing is repositioned as an intermediary structure situated between the body and the environment, rather than as an auxiliary object.

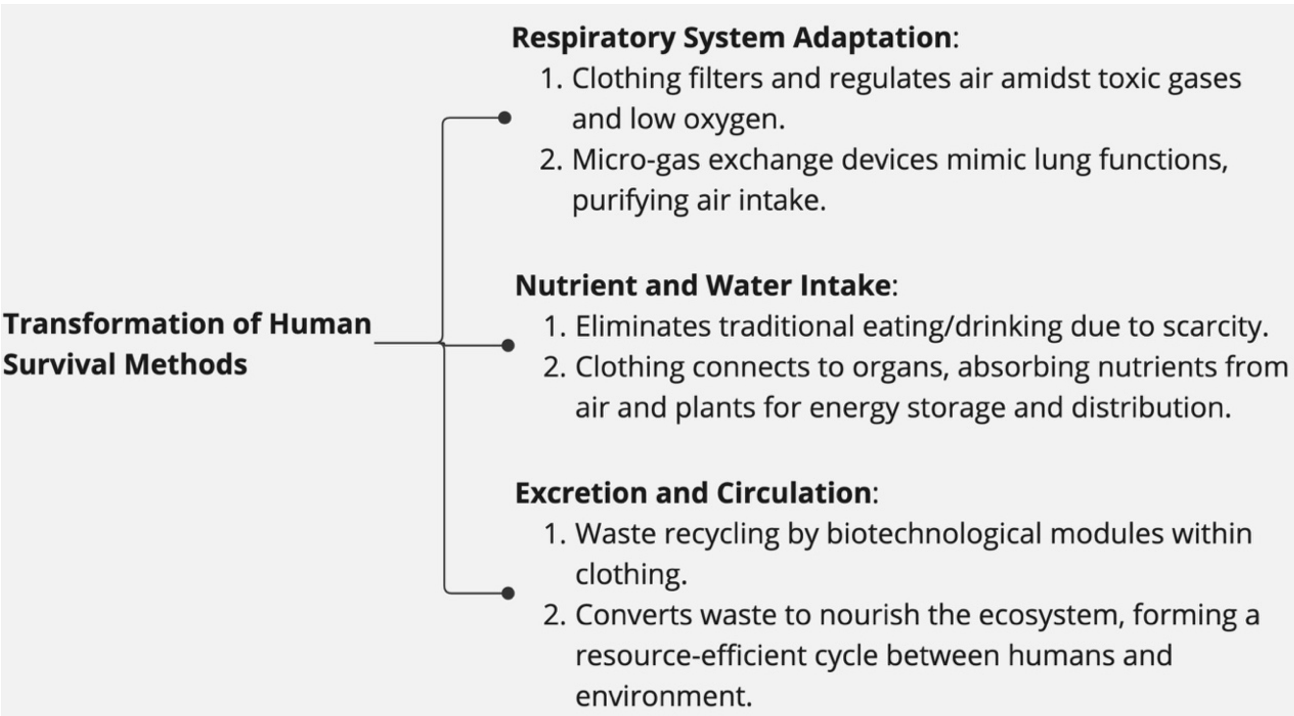

Figure 4.4 Reconfiguration of human survival process under resource scarce conditions.

In exploring how garments can host these physiological mechanisms and act as a core intermediary interface, science fiction concept design offers a highly valuable theoretical prototype. For instance, in the world-building of the film *Dune*, the Stilltent, designed by Joseph Cross and others, functions as a wearable, micro-scale water-recovery infrastructure (Herbert, 2021). It breaches the traditional boundaries of physical sheltering, establishing a mandatory, systemic closed loop between human metabolism (e.g., sweating, moisture exhaled through breathing) and environmental resources (extreme water scarcity). This speculative design precedent corroborates the core hypothesis of this research within the *Desertia* scenario. Under conditions of extreme ecological dissipation, the primary function of a garment system must be to achieve an absolute micro-circulation of internal resources. This not only provides a reference for validating the efficacy of garments taking over physiological processes but also establishes a systemic logical foundation for the subsequent design of the water and nutrient circulation modules.

Building upon these theoretical prototypes and systemic hypotheses, as environmental pressures are further specified as persistent climatic conditions, design attention shifts toward functional organization, and the role of clothing undergoes a substantive redefinition. The following question becomes central: what if bodily coverage alone proves insufficient in mitigating environmental risk, and clothing is required to participate directly in physiological regulation? This inquiry prompts the clothing system to concurrently address thermal management, ultraviolet protection, and exposure control, serving as an evaluative criterion throughout design development (Figure 4.5).

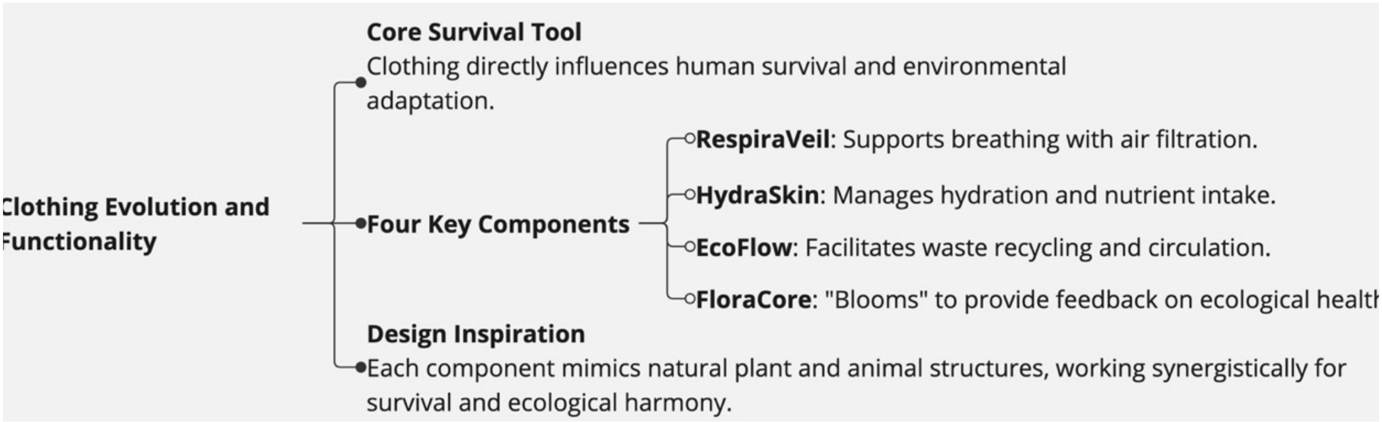

Figure 4.5 Functional modularization of clothing in *Desertia*: core components and design logic.

Building on these assumptions, clothing within *Desertia* is defined as a core survival tool (Figure 4.6). This leads to a further hypothesis: what if human survival probability is closely linked to the adaptive efficiency of the clothing system? This question provides the conceptual foundation for subsequent functional modularization. The four components *RespiraVeil*, *HydraSkin*, *EcoFlow*, and *FloraCore* (Figure 4.6) correspond respectively to respiration, protection, water and nutrient circulation, and ecological feedback. While their formal inspirations draw from structural logics observed in plant and animal systems, their development focuses on the structural translation of distributed functions and cooperative mechanisms rather than visual imitation.

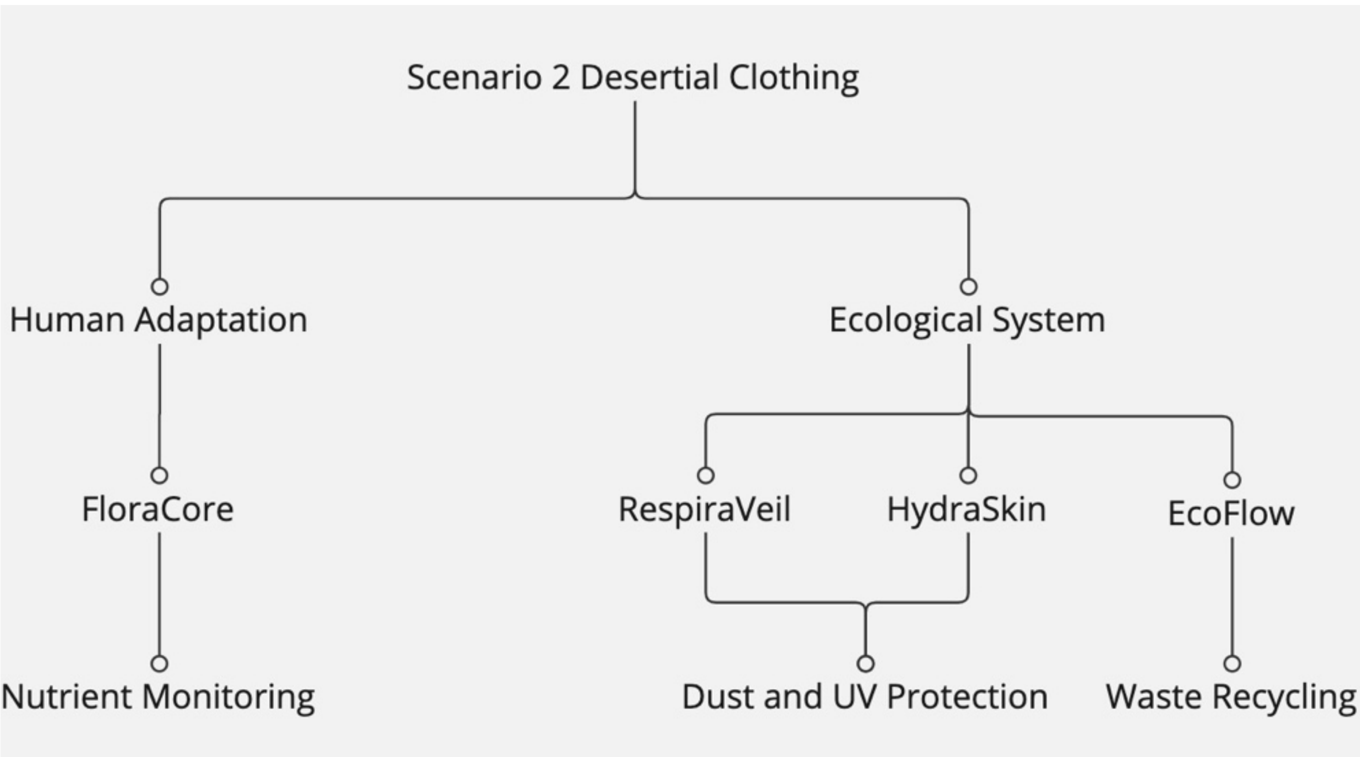

Figure 4.6 System map of *Desertia* clothing.

These assumptions are further synthesized into a visualized system relationship model that distinguishes interdependencies between the human adaptation layer and the ecological system layer. Within this model, clothing establishes cyclical pathways between the body and the environment through its modular components. For instance, *HydraSkin* and *EcoFlow* operate across bodily metabolism and ecological feedback, while *FloraCore* communicates environmental health through states of opening and closure. This systemic representation functions as a continuous reference within the design development stage, allowing each structural modification to be reassessed in relation to the overarching hypothetical framework.

4.2 From biomorphic observation to design-relevant features

In this design development stage, biomorphic observation is employed as a research method to identify structural relations and organizational logics that can be applied to garment systems. The focus is placed on spatial distribution and modes of regulation observable in natural systems, including relationships between outer enclosure and inner protection, morphological variation across open and closed states, and hierarchical organization between central and peripheral zones. Approaching biological form as a system of relations and behavioral mechanisms supports design judgment grounded in describable and repeatedly testable criteria (Capra & Luisi, 2014; Ingold, 2010).

Early photographic documentation encompassed plant and animal morphologies, surface textures, and landform characteristics (Figure 4.7a). The analytical task in this phase concerns selection, with attention directed to forms that offer operational organizational principles for garment systems. Through a comparative review, the study converged on calla lily–like structures characterized by simplified construction and continuous contours. Their relevance derives from three transferable relations. First, a single outer layer produces a continuous enclosure surface, enabling protection to be achieved through structure. Second, the relation between stamen and petal establishes a clear center–edge hierarchy, supporting the zoning of a vulnerable core and a protective outer layer. Third, opening and closing behavior provides a logic of state modulation, allowing degrees of coverage to be treated as adjustable parameters. To translate these relations into actionable inputs, analytical sketching externalizes structural judgement by articulating enclosure pathways, support relations, and axial organization (Figure 4.7b–c). This process establishes baselines for later verification, including whether continuous enclosure can be sustained on bodily curvature, whether hierarchical zoning can align with regional bodily requirements, and whether modulation can be translated into garment-adjustment mechanisms.

Figure 4.7 Biomorphic observation and structural analysis informing design-relevant features.

(a) Biomorphic observation board (photograph by the author).

(b) Structural abstraction sketch (illustrated by the author).

(c) Analytical sketch of floral structure (illustrated by the author).

At the two-dimensional level, the calla lily contour is reduced into lines and geometric units, followed by rotational, overlapping, proportional, and local reconfiguration operations (Figure 4.8). The evaluative focus in this phase concerns whether structural relations persist after abstraction. Rotation and overlap test whether enclosure pathways maintain continuity across directional changes. Proportional transformation tests whether the center–edge hierarchy remains legible under scale shifts. Local reconfiguration tests whether the distinction between outer enclosure and inner core can remain structurally intelligible. In this way, two-dimensional generative exercises function as an intermediary that converts complex curvilinear relations into comparable rule sets, while revealing potential conflicts of structure and scale before three-dimensional development.

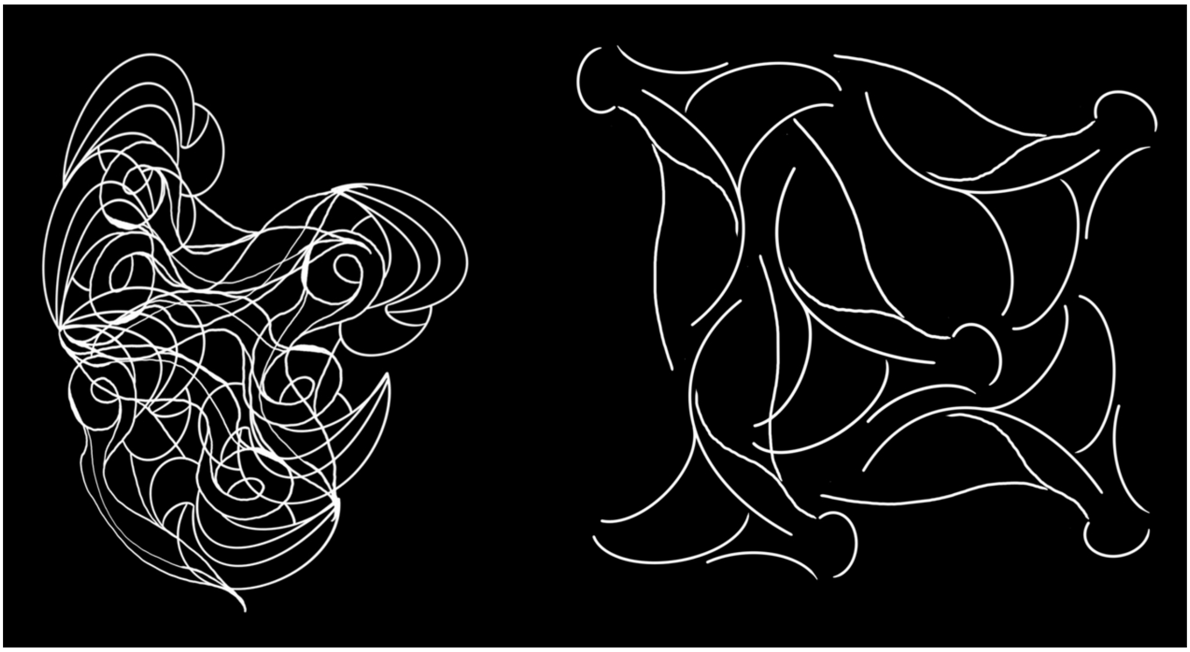

Figure 4.8 Extraction and two-dimensional transformation of structural features (illustrated by the author).

These abstract geometries are then mapped onto different body regions to observe deformation patterns and shifts in legibility across bodily curvature and movement ranges (Figure 4.9). Body mapping operates as a filtering mechanism that clarifies the conditions under which the extracted features hold at the scale of wear. It tests whether enclosure pathways fracture around joints and compound curves, whether hierarchical relations compress or lose definition at specific locations, and whether modulation logics conflict with bodily movement. This cycle narrows transferable cues into constraints suitable for three-dimensional modelling, enabling subsequent modelling and material experimentation to be driven by structural feasibility and bodily relations rather than appearance (Mäkelä, 2007).

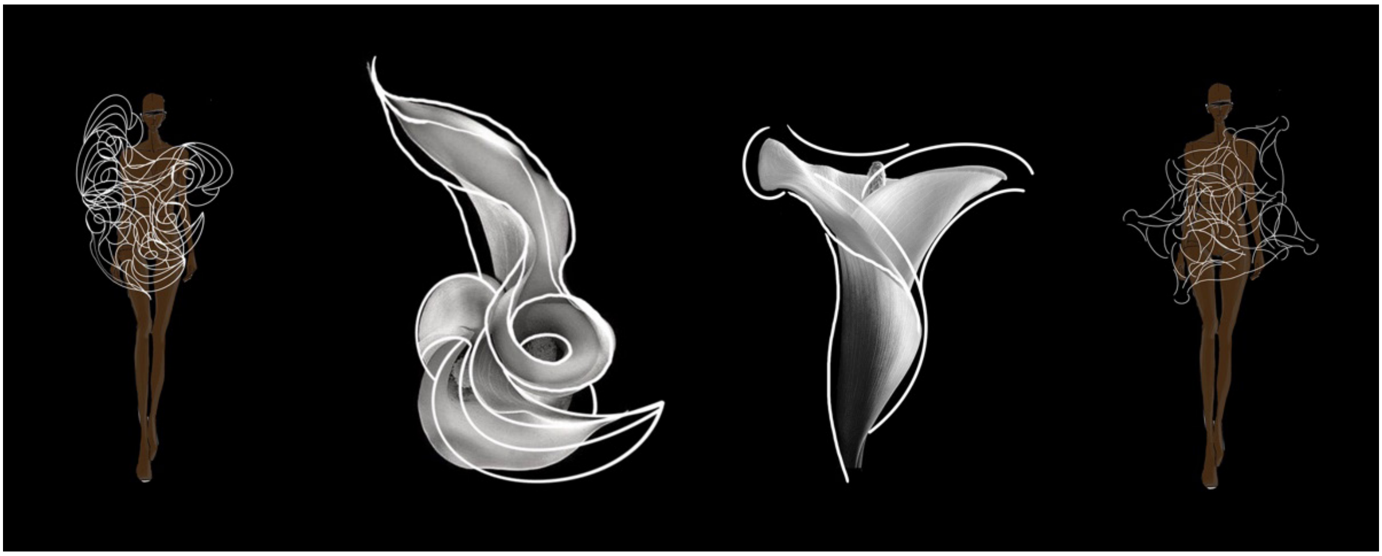

Figure 4.9 Body-mapping tests of abstract structural units (illustrated by the author).

At this stage, biomorphic references are consolidated into testable design features, including continuous outer enclosure, center–edge hierarchical distribution, and the capacity for modulation across different states of openness. Through practice-led iteration, these features establish evaluative criteria for subsequent stages of three-dimensional modelling and material experimentation, supporting an ongoing cycle of making and reflective adjustment (Candy & Edmonds, 2018). The contribution of this section lies in forming a callable structural vocabulary that enables later chapters to account for how and why design decisions emerge through experimental verification.

4.3 Early generative tools as methods for testing design assumptions

This research introduces generative systems to explore design assumptions during the initial stages of form development. The speculative context of the *Desertia* project requires garments to function within unfamiliar environmental and bodily conditions. Consequently, initial design propositions emerge as provisional visual concepts with undefined structural and spatial implications. Generative image systems provide a practical mechanism to observe how these assumptions translate into diverse visual configurations, enabling the evaluation of preliminary concepts prior to labor-intensive drawing, digital modelling, or material experimentation.

Within design research, external representational tools are widely recognized as vital components of the cognitive process. Visual artifacts generated during exploration function as provisional models, allowing designers to examine emerging relationships among form, scale, and spatial organization (Cross, 2006). Generative systems amplify this exploratory capacity by rapidly producing numerous iterations from specific descriptive parameters. These variations facilitate the observation of subtle shifts in silhouette, proportion, and structural articulation across closely related visual outputs. This comparative analysis distinguishes the stable elements of a design assumption from those highly sensitive to changing conditions, thereby identifying the conceptual components requiring further investigation.

In the context of this project, generative images function as an intermediate exploratory environment bridging speculative ideation and subsequent design materialization. The images act as visual probes, exposing ambiguities in silhouette logic, bodily interaction, and spatial enclosure. Recurring patterns across the generated results offer clues regarding the fundamental assumptions embedded within the design concept. Reflecting on these outcomes drives an iterative cycle of observation and calibration that progressively refines the core research problem (Schön, 1992). The subsequent section documents the staged visual explorations conducted across various generative platforms, advancing logically from abstract form generation to the integration of bodily references and wearable structures.

4.3.1 AI images as a phased testing apparatus for visual hypotheses

In the early stage of this research, the introduction of AI image generation arises from the intrinsic complexity of the research subject itself. The clothing system explored in *Desertia* involves unstable relational structures among the body, garments, and speculative future ecological conditions. Such characteristics align with what design research describes as ill-structured problems, which cannot be exhaustively addressed through linear reasoning or a single developmental trajectory (Simon, 2008). Under these conditions, design judgment requires the support of external generative systems capable of repeatedly expanding and reorganizing the problem space.

At this stage, AI image generation offers a high-density mechanism for visual speculation, enabling design assumptions to undergo multiple transformations and displacements within a short timeframe, thereby expanding the range of observable problem conditions. This function corresponds with established perspectives in design cognition research, which frame generative tools as external representations used to explore incompletely defined problem structures and to support designers' understanding of the problem itself, rather than to determine solutions directly (Cross, 2006; Gross & Do, 1996). By comparing multiple visual outcomes that are similar yet distinct, the research identifies where design assumptions are most likely to shift under different conditions, allowing exploration to remain open and preventing early fixation on a single direction.

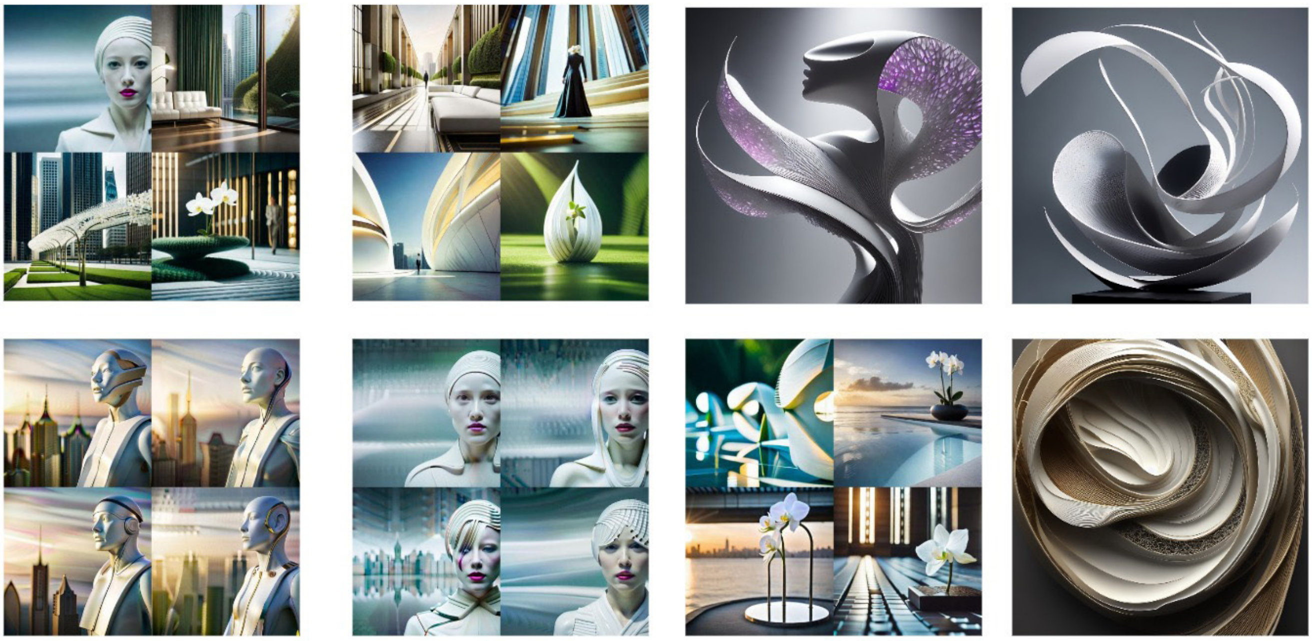

Figure 4.10 Abstract form variations, generated with Midjourney, see appendix for prompts.

Testing begins with de-bodied abstract forms. AI-generated biomorphic surfaces and continuous structures provide a temporary observational field detached from human scale, enabling curvature variation, opening mechanisms, and overall coherence under stretching and twisting conditions to be examined in isolation (Figure 4.10). At this stage, some forms appear visually coherent, yet their internal structure remains weakly articulated and their visual center unstable. This suggests that certain silhouette assumptions have not yet achieved clear structural organization at an abstract level, and that their conditions of validity remain insufficiently defined.

Figure 4.11 Body-referenced visual variations, generated with ChatGPT, see appendix for prompts.

Subsequently, a single bodily reference is introduced, allowing abstract forms to engage with concrete human proportions for the first time (Figure 4.11). The focus at this stage centers on proportional variation, redistribution of coverage, and the positioning of spatial weight within bodily scale. Repeated generations show that some forms retaining coherence in abstraction begin to exhibit local imbalance or ambiguous enveloping logic when aligned with the body. These deviations expose indeterminate assumptions regarding bodily participation, with the body's multiple latent roles within the structure becoming perceptible at this stage.

Building upon this process, experimental and wearable garment practices are introduced as comparative references, enabling visual hypotheses to be reassessed within the constraints of real-world wearability (Figure 4.12). These practices demonstrate how enveloping, shell-like, or petal-based silhouettes maintain structural stability through explicit zoning, modulation of material thickness, and regulation of movement boundaries. In comparison, some AI-generated forms display a dominance of continuous surfaces in the absence of clear segmentation mechanisms, making it difficult to distinguish structural hierarchies visually. This comparative process shifts design judgment from evaluating silhouette coherence toward examining whether structural relationships have been sufficiently articulated.

Figure 4.12 Wearable form variations, generated with Recraft, see appendix for prompts.

Within this sequence of image testing, the construction of prompts constitutes a critical operational layer. Image generation proceeds through continuously adjusted descriptive conditions, with prompts treated as linguistic design variables that modulate the pathways through which formal relationships emerge. Revisions concentrate on description dimensions directly related to form logic, including relations between continuity and segmentation, modes of enclosure and expansion, organization of internal cavities and external skins, and whether garments and environments are articulated within a shared descriptive frame. When prompts emphasize continuous surfaces, growth-like qualities, or fluid boundaries, generated outcomes tend toward unified curved forms. While such images exhibit strong visual coherence at the abstract stage, they simultaneously expose insufficient structural partitioning.

When prompts incorporate descriptions of openings, hierarchical differentiation, or edge conditions, generated forms begin to display clearer segmentation cues, allowing silhouettes to register as decomposable structural relationships. Similarly, when prompts include both garment and environmental conditions, garments and scenarios are interpreted within a shared visual system, resulting in shifts in scale and boundary relations. Through this process, prompt modulation renders design assumptions sensitive to linguistic conditions. Minor descriptive adjustments produce pronounced shifts in continuity, proportion, or spatial organization, enabling previously implicit premises embedded within visual results to become identifiable. At this stage, image testing redirects design judgment from assessing surface appearance toward reflecting on how design problems are pre-structured across linguistic and visual layers.

Overall, AI images function in this research as an early-stage testing apparatus for perturbing and reorganizing design cognition. Recurrent imbalances, ambiguities, and translational failures emerging during generation are recorded as indicators of potential failure pathways embedded within design assumptions. These indicators directly inform subsequent operations using two-dimensional collage and line drawing to further address form directionality, coverage logic, and zoning relationships, gradually transforming early visual assumptions into problems suitable for structured verification. The primary contribution of this process lies in problem restructuring. AI-generated images repeatedly expose latent dependencies on bodily contours, the masking of structural segmentation by continuous surfaces, and the instability of meaning when garments are detached from contextual descriptions. Within reflective practice, deviations encountered during action are recognized as sources of knowledge, and such deviations are documented as reflective cues through iterative generation (Schön, 2013). The value of generative systems here derives from their instability, through which recurring shifts in generated outcomes continuously propel and reposition design judgment (Maher & Fisher, 2012).

Furthermore, the introduction of AI alters the temporal structure of design judgment formation. The generative stage allows assumptions to be repeatedly tested and revised before substantial material investment, enabling failure to function as a low-risk cognitive resource. This mode of rapid generation supporting multi-path exploration contributes to maintaining openness in early design thinking and delaying premature closure of the problem space (N. Davis et al., 2015).

4.3.2 Iterating between two-dimension and three-dimension

During this phase, structural logic and modes of bodily coverage are gradually established through repeated movement between two-dimensional analysis and three-dimensional prototyping. This process forms a cycle of diagnosis, adjustment, and re-diagnosis across representational dimensions, in which findings from each iteration inform subsequent design decisions.

The investigation begins with an exploratory testing of three-dimensional modeling tools, aimed at gaining a rapid understanding of the boundaries of volumetric generation, surface deformation, and parameter control. In this initial stage, the models operate within a purely formal register: how surfaces expand outward from a central zone, how folding generates variations in thickness, and how openings affect visual balance. Judgements at this point rely primarily on perceived equilibrium and surface continuity, without reference to bodily scale, functional constraints, or structural support systems. A more critical issue emerges at the level of the tools themselves. Limited parameter control restricts the ability to differentiate local structural zones, preventing precise adjustment of specific areas such as opening edges or core support points. While forms can be generated efficiently, they resist translation into structure-based reasoning related to the body (Figure 4.13). These modeling tools are effective in producing visual form, but they do not directly address the functional question of how a structure might operate on the body. This limitation necessitates a return to more fundamental modes of structural analysis to re-establish a logic linking form and function.

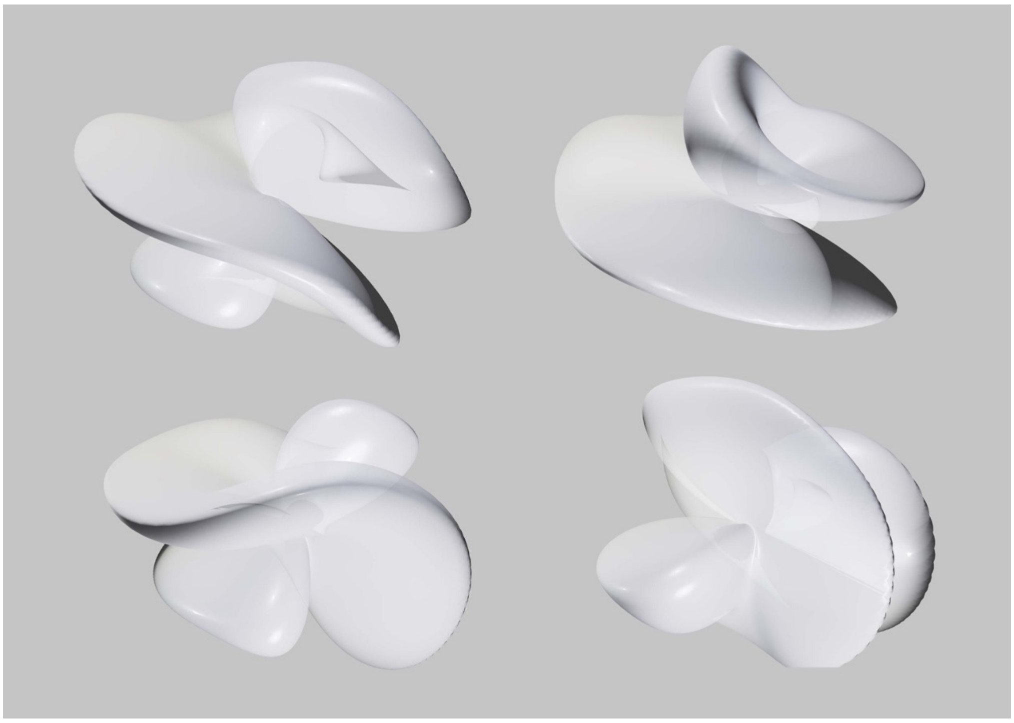

Figure 4.13 Early volumetric exploration using Blob Mixer.

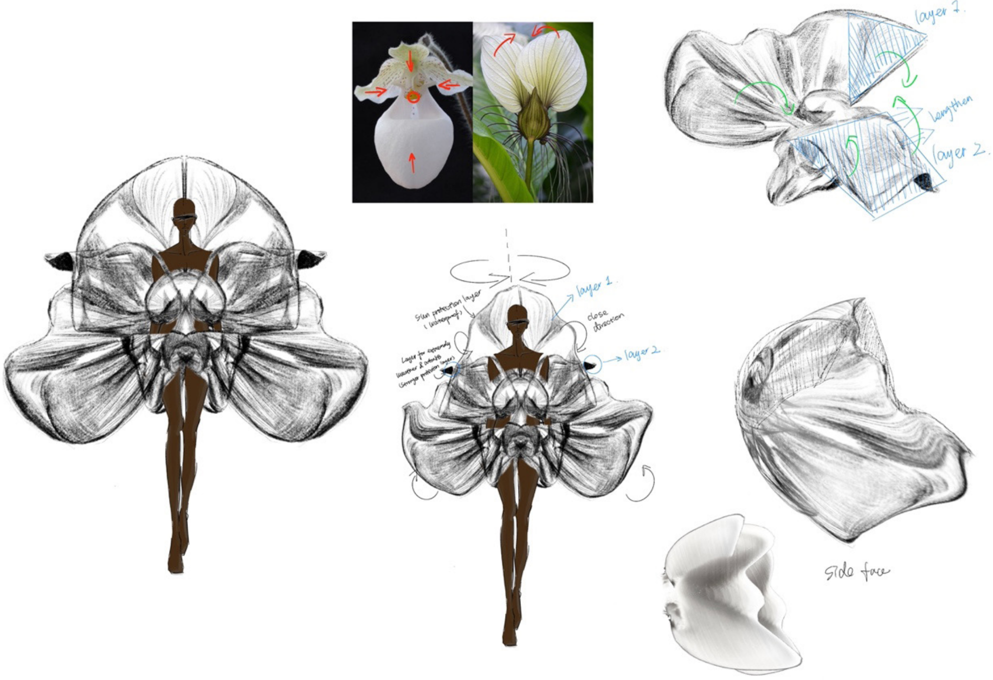

Figure 4.14 Structural decomposition and 2D reasoning based on floral anatomy (illustrated by the author).

Once it becomes clear that three-dimensional tool-based exploration cannot independently support structural judgement, the research returns to two-dimensional analysis through the decomposition of plant structures in order to reconstruct organizational logic (Figure 4.14). This shift carries methodological significance. Plant morphology, particularly floral structure, offers a set of operative principles concerning protection, support, and opening behavior. These include how outer petals enclose a fragile stamen, how opening and closing occur along specific directional axes, and how stability is achieved through structural connections at the core. The sketch-based work concentrates on two interrelated structural levels. The first addresses how the boundary of the outer enclosure is formed, including the placement of openings, the influence of folding direction on coverage, and the way edges interface with the body. The second examines how the internal core is protected and supported, focusing on where structural reinforcement is required, how the core connects to the enclosing layer, and how opening actions can occur without compromising stability. Through line annotation and structural partitioning, form is translated into a set of relational conditions that extend beyond visual description. These sketches record structural intent by addressing not only what the form looks like, but also why it is organized in this way and how it might be realized in three-dimensional space. The structural assumptions established at this stage define testable boundary conditions for subsequent three-dimensional modeling.

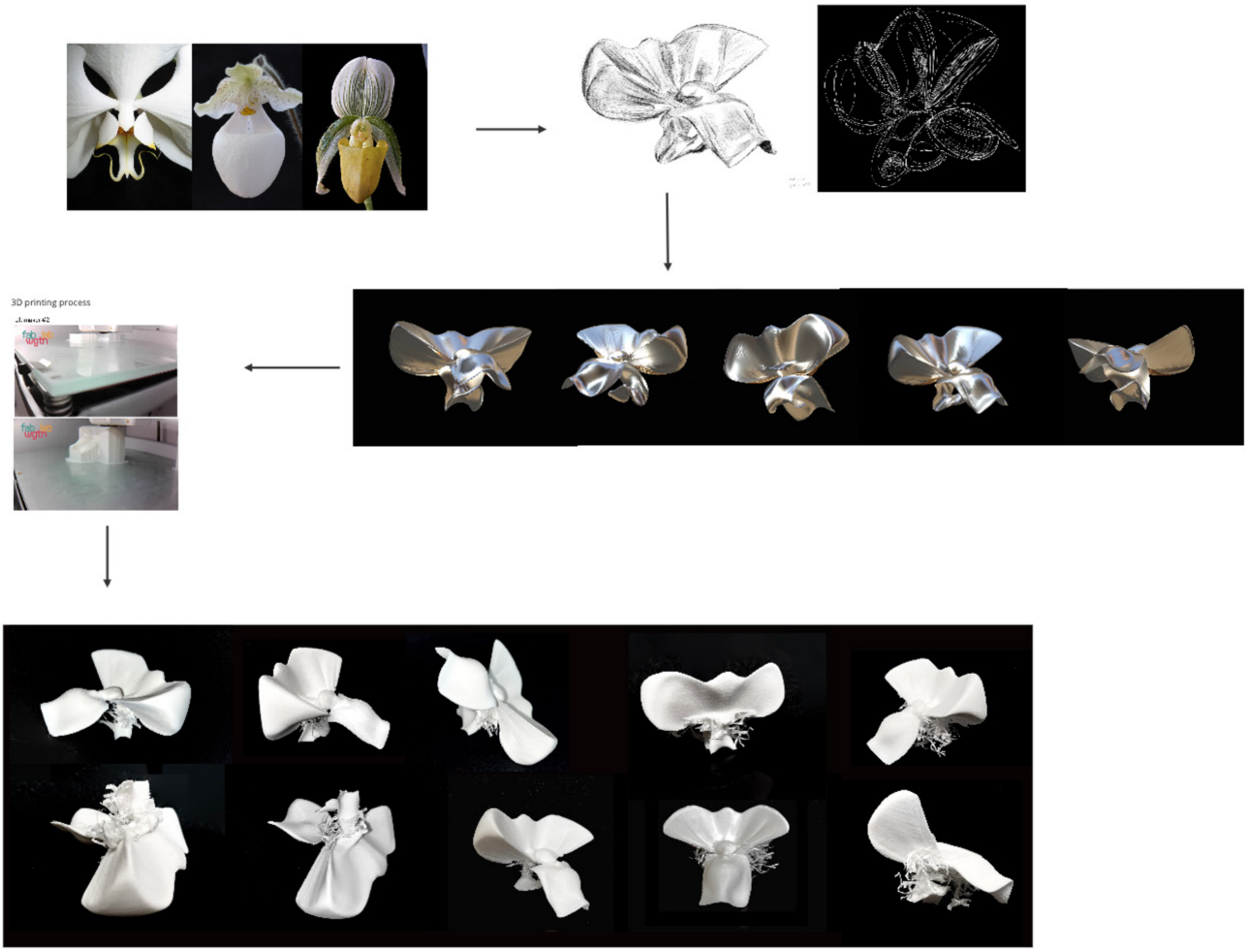

Figure 4.15 Translation from 2D structural proposition to 2D printed diagnostic prototype (author’s own work).

Building on these two-dimensional propositions, the model enters three-dimensional modeling and fabrication to test whether the sketch-based assumptions remain valid under constraints of volume, thickness, and scale (Figure 4.15). At this point, the role of the three-dimensional prototype shifts fundamentally. It functions as a diagnostic device, exposing issues that cannot be anticipated in a two-dimensional representation through the process of physical realization. During printing, the generation and removal of support material reveal a previously unconsidered problem. The central region proves particularly fragile during support removal, especially at a small scale, where thin-walled structures are highly susceptible to mechanical damage. To maintain structural stability, portions of the central support are deliberately retained. Although this decision originates from a technical compromise, it unexpectedly strengthens the structural presence of the core. What had previously existed as a hidden negative space becomes a visible supporting element, providing a clearer morphological basis for subsequent design reasoning around core protection. Beyond confirming structural feasibility, the three-dimensional prototype highlights which structural relationships become more pronounced under physical constraint. Points of fragility, the distribution of support material, and the effects of scale variation on stability all prompt more specific adjustments in the next design iteration.

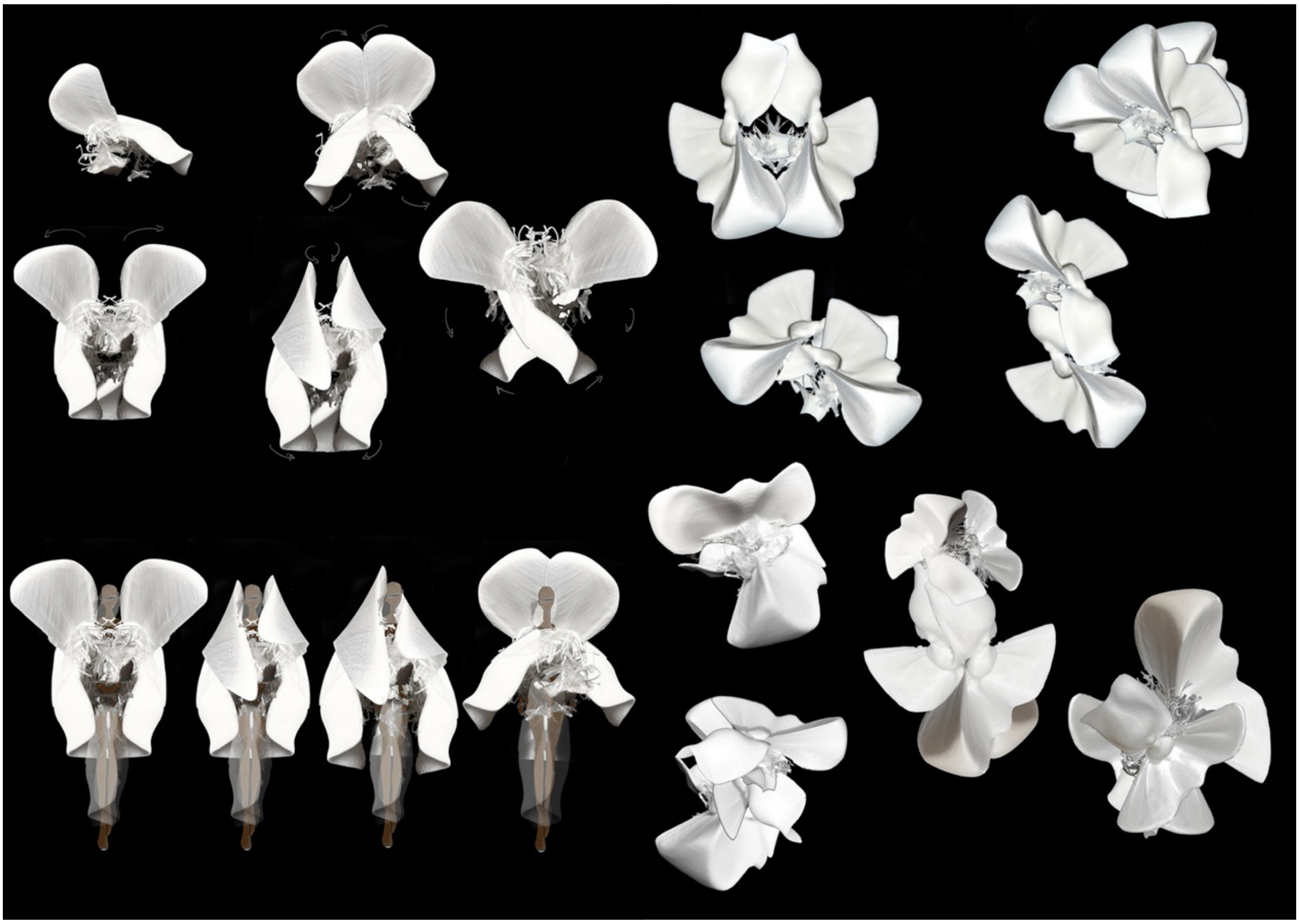

Figure 4.16 2D collage reconfiguration of 3D prototypes for bodily coverage and opening logic (author's own work).

Following the production of the three-dimensional prototype, the research returns once again to two-dimensional representation, this time with the explicit aim of testing the relationship between form and bodily coverage (Figure 4.16). Through multi-angle photography, the prototype is decomposed into a set of reconfigurable visual fragments, including silhouettes from different viewpoints, opening orientations, variations in thickness, and shadow distribution. These images are then used in collage, rotation, and recombination experiments to examine coverage paths and opening directions across different areas of the body. This operation directly corresponds to the core biological analogy underpinning the research. Just as petals function as an outer structure that rotates, expands, and closes to protect a fragile stamen, a garment structure can be understood as an open–close enclosure organized around vulnerable regions of the body. Within iterative Photoshop compositions, the same structural unit is repeatedly repositioned and rearranged to compare the effects of different configurations. These tests attend to changes in degrees of occlusion, identifying which areas are fully covered and which remain exposed.

They also examine the relationship between opening orientation and bodily movement, considering how upward- or downward-facing openings influence dressing actions. In addition, the experiments test continuity of enclosure and structural stability, assessing how multiple units can form a continuous protective layer across the body while retaining independent opening capability. These collage-based tests are considered alongside earlier what-if propositions to identify which configurations demonstrate greater structural viability under the condition that vulnerable areas require protection. The collage process thus operates as a test of structural possibility, translating three-dimensional form into bodily coverage logic and identifying key opening mechanisms and enclosure strategies for subsequent prototype development.

The core methodological value of this phase lies in the recognition that iterative movement between two-dimensional and three-dimensional representations constitutes a necessary mechanism for structural reasoning. Each dimensional transition performs a distinct diagnostic function: three-dimensional exploration reveals tool constraints and ranges of formal possibility; two-dimensional analysis establishes structural logic and organizational instruction; three-dimensional printing tests stability under physical constraint; and two-dimensional collage examines coverage paths and opening directions in relation to the body. Through this process of continuous adjustment through action, design practice itself operates as a reflective mode of inquiry, in which structural understanding is progressively shaped through feedback (Schön, 1983). Through this cycle, form is transformed from an abstract visual object into a body-related structural system, establishing testable structural hypotheses and organizational logic that support more complex prototype development in subsequent chapters (Smith & Dean, 2009).

4.4 **Exploration of structure and function in *Desertia***

This section examines the relationship between structural morphology and functional logic within the *Desertia* system. The design exploration extracts morphological cues from desert plant forms, geological topographies, and biological adaptation strategies. Utilizing collage analysis and AI-assisted image generation, these potential structural features are abstracted and developed. Subsequently, these conceptual forms are translated into organizational systems with explicit functional orientations, simulating ecological processes such as water collection, storage, and transportation. Through this translation, the structure transcends foundational spatial organization, functioning as the primary medium for expressing the operational states of the survival system.

Translating speculative structures into physical prototypes requires the design to advance from conceptual extrapolation to material and embodied verification. To systematically document this dynamic progression, this section unfolds across three interconnected stages. First, it discusses the origins of the structural cues and the initial formulation of their adaptive functional logic. Following this, it details the experimental process of materializing these structures, specifically analyzing the material behaviors and technical considerations when combining 3D printing with flexible textiles. Finally, the discussion addresses the wearability challenges that emerged when integrating these physical structures with the human scale, detailing the design calibrations undertaken to achieve an ergonomic balance between the system's functionality and the wearer.

4.4.1 **Formation of structural sources and functional logic**

In the *Desertia* project, the exploration of structure and function follows a gradual process. It moves from visual integration to form abstraction and then to functional reasoning. At the early stage, the research does not define technical functions for the garments. Instead, it builds an internal logic for structure generation through a systematic review of natural forms, artistic expressions, and spatial narratives found in desert environments. Functional meaning is introduced later, and it depends on the stability of the structure in terms of form and organization.

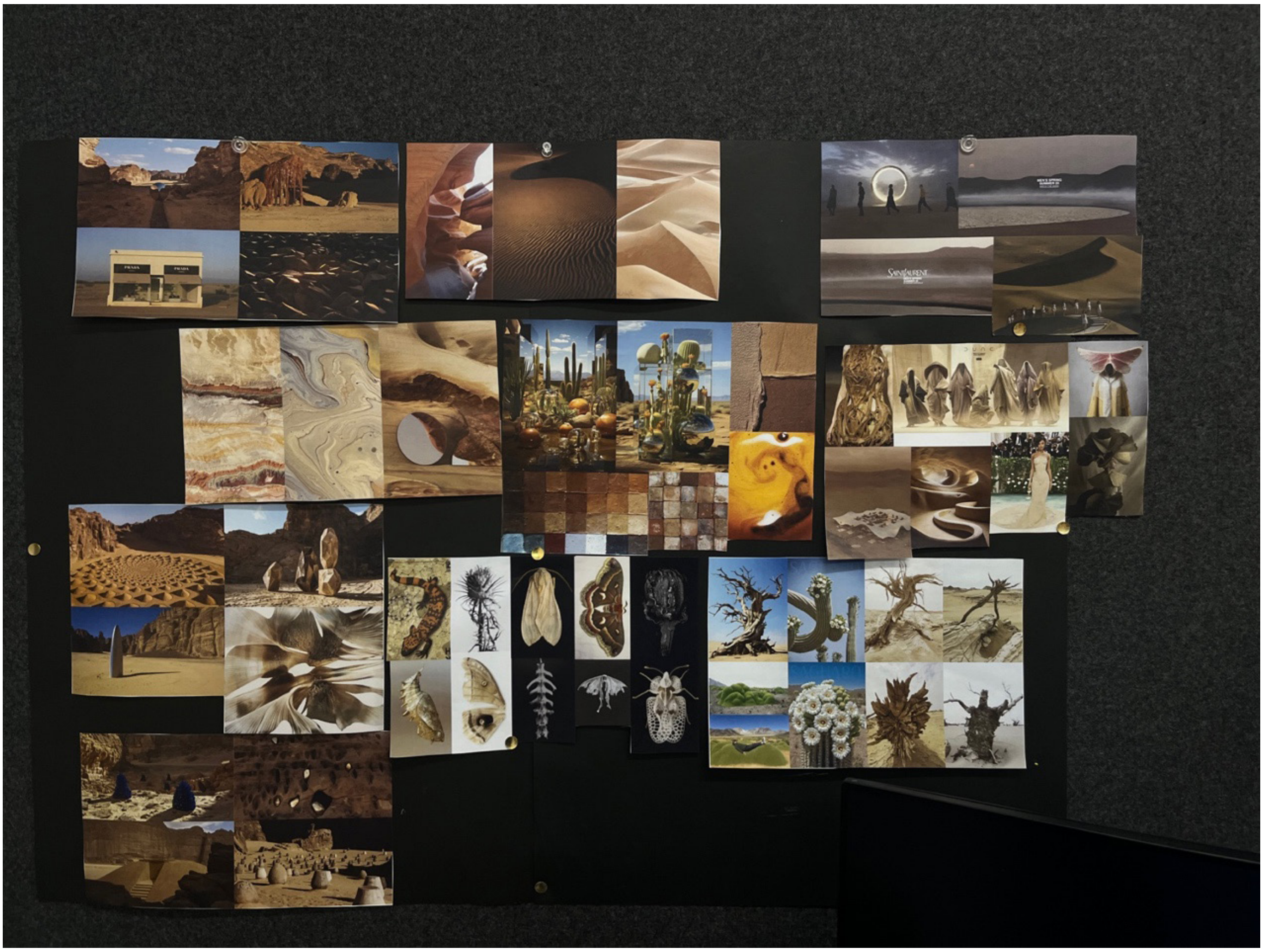

Figure 4.17 Visual mood board of desert environments and biomorphic references.

The design process begins with the construction of a mood board to gain an overall understanding of the desert context (Figure 4.17). Land textures, surface cracks, plant growth traces, and the structural features of dead trees and cacti are examined side by side. This comparison helps identify recurring patterns in extreme environments. Through repeated selection, several key features are identified, including vertical growth tendencies, differences between central and peripheral structures, and signs of wear and decay at structural ends. These features form the visual basis for later structural development.

Based on this visual research, flat collage becomes a tool for making structural logic visible (Figure 4.18). By extracting and recombining plant growth curves, cactus spine structures, and animal skeletal forms, the research develops a set of two-dimensional structural graphics with clear direction and hierarchy. The collage process starts from observing how desert plants adapt to harsh conditions. Particular attention is given to how cactus petals create shaded spaces through curved folds, and how the curled ends of dead branches suggest paths for water collection and flow. These natural forms are translated into combinations of lines and surfaces, allowing spatial organization to be tested on a flat plane.

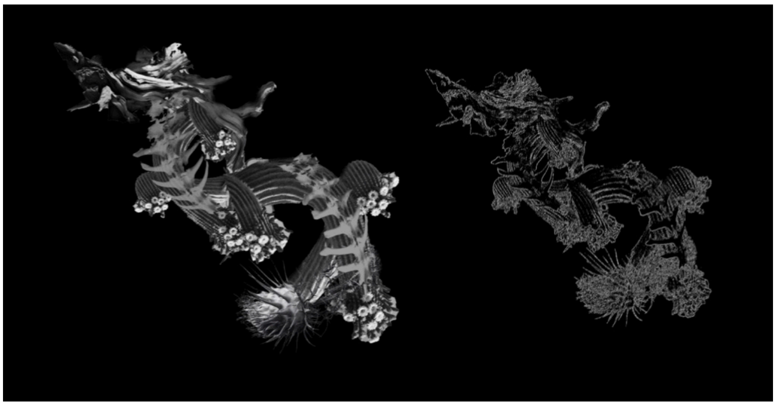

Figure 4.18 Generative exploration of abstracted biomorphic structures: collage analysis by the author (left) and AI-assisted line drawings generated using ChatGPT by the author(right).

At the collage stage, natural forms are treated as starting points for thinking about functional adaptation (Figure 4.19). The conical spines of cactus skins and the layered petals of cactus flowers are analyzed together. The spines suggest mechanisms for mist condensation and water collection, while the petals imply spatial logic related to shading and protection (Ju et al., 2012). Through abstraction, these structural features are transformed into forms with potential functional meaning at the two-dimensional level. The white three-dimensional model shown in the images represents an intermediate stage of this translation. Its curved surfaces and branching relationships retain the organic qualities of plant growth, while geometric adjustments introduce a more controlled structural order.

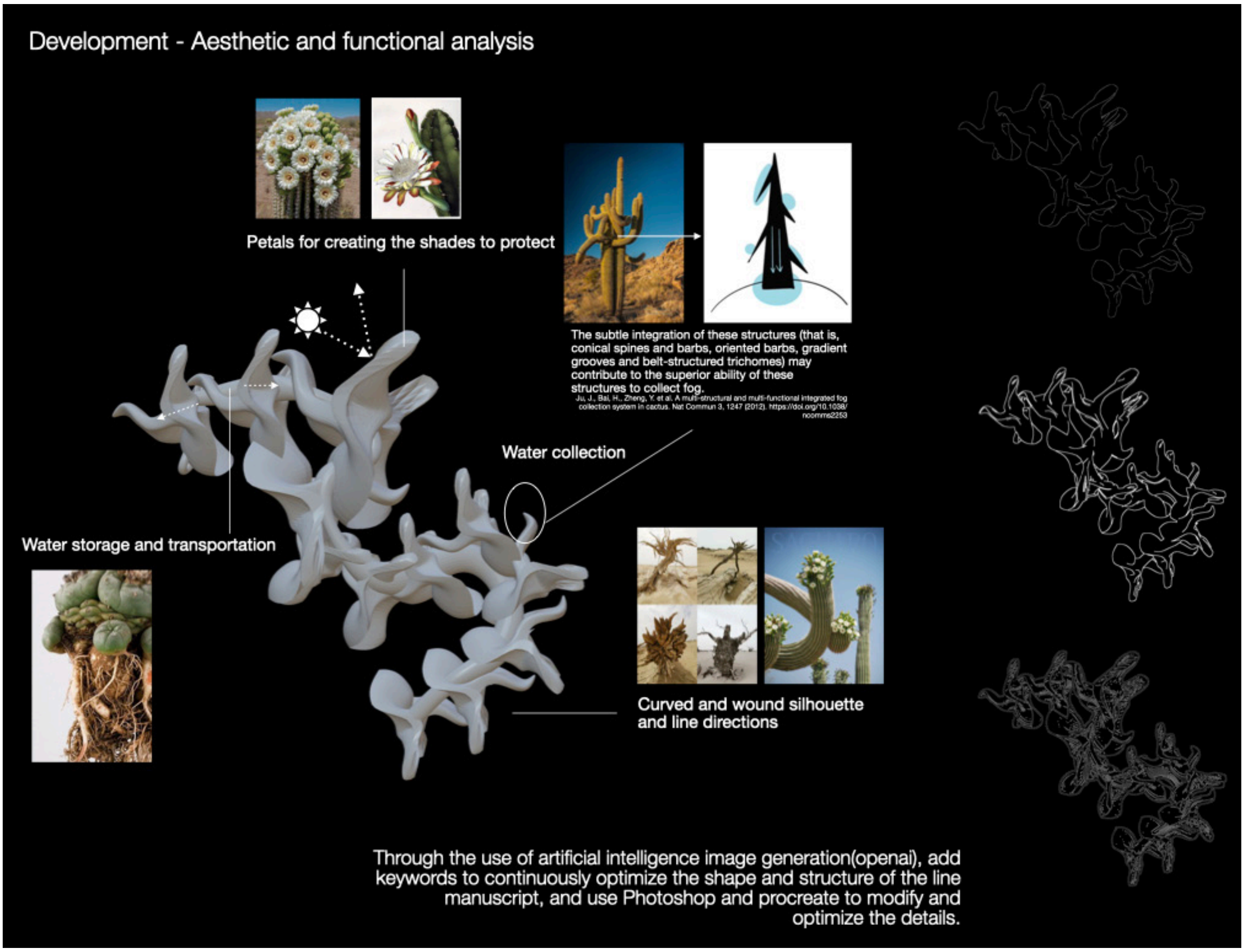

Figure 4.19 Aesthetic and functional analysis of structural development.

The collage process also includes artificial intelligence image generation as a supporting tool. By continuously refining keywords, the design explores a wider range of surface textures and outline variations while maintaining the overall structural logic. The repeated interaction between human judgment and algorithmic output allows the final forms to remain organic while meeting the need for structural clarity within a garment system. The line drawings on the right record the structural relationships that are retained during this process (Figure 4.19). These drawings serve as the base framework for three-dimensional modeling and ensure a clear transition from flat images to spatial forms.

During the three-dimensional modeling stage, structural logic is transformed into a continuous spatial form (Figure 4.20). The model uses a vertical main trunk as the central connecting element. Its shape refers to the supporting and connecting role of animal skeletons within the body, creating a stable visual axis. Around this trunk, different branching components extend outward, forming an open and expandable structure. At this stage, the structure is treated as a carrier of potential functions. Its validity is tested through repeated adjustments of proportion, balance, and spatial continuity.

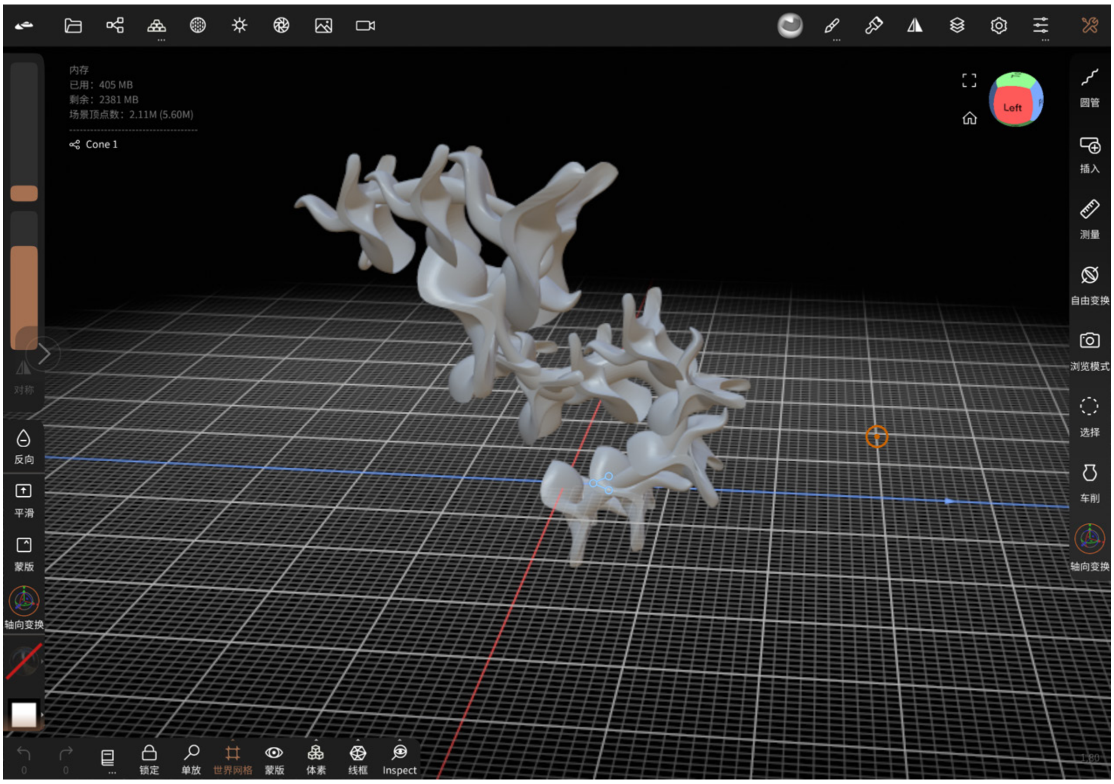

Figure 4.20 Three-dimensional structural model of the *FloraCore* module (author's own work).

Within a speculative design framework, the way functional qualities are presented requires clarification. Dunne and Raby explain that speculative design uses "what if" scenarios to explore possible relationships between technology and society, aiming to provoke discussion rather than deliver practical solutions (Dunne & Raby, 2013). Based on this view and earlier discussions of tools as cognitive media, the four modules in this research do not depend on real technological implementation. Their functions are presented through projected moving images as a form of simulation. This approach shifts the function from the level of physical technology to visual narrative. Projection works as a representational tool that allows concepts such as breathing regulation, water storage, and material circulation to be visually perceived and understood, without being limited by current technical feasibility. Auger suggests that prototypes and images can make abstract ideas concrete and open to discussion (Auger, 2013). In this research, projection follows this methodological principle. Projection therefore acts as a mediator between conceptual function and audience perception, maintaining the speculative nature of the design while giving functional logic a visible form.

As the structure becomes more stable, functional logic is clarified across different modules. All four modules follow the same method. They start from natural structural features and use comparison and abstraction to form functional assumptions that can be integrated into a garment system:

The organization of gas exchange in plant leaves and animal respiratory systems inspires the *RespiraVeil* module (Figure 4.62). Its structure takes the form of layered, enclosing components. Curved surfaces and folds create spatial logic related to filtering and buffering. Functional meaning is suggested through how the structure guides imagined airflow paths. Gaps and channels between layers visually lead viewers to associate the form with gas movement and blockage. This responds conceptually to the need for respiratory protection in desert conditions.

The *HydraSkin* module draws structural inspiration from how desert plants absorb and store water (Figure 4.62). A raised central area combined with outward extension creates a form based on gathering and distribution. Functional logic is developed as temporary water storage and gradual release. This logic depends on the balance between structural volume and surface continuity. Surface textures reference the microstructures of plant skins. Although these details may not enable real water storage, they strengthen the conceptual link between structure and function.

In the *EcoFlow* module, animal skeletons and root networks serve as key references (Figure 4.62). The structure shows segmented and channel-like features, providing a spatial basis for ideas of circulation and discharge. Functional logic is framed as part of a broader ecological cycle within the garment system. Channel design considers direction and continuity of flow, allowing the structure to visually suggest dynamic circulation, even if this process remains metaphorical in practice.

Cactus flowers and the ends of dead branches inspire the *FloraCore* module (Figure 4.62). It primarily supports the collection of water and the transport of water-borne nutrients. The expanded, petal-like surfaces suggest the capture of moisture from the air, while the inward-converging structure guides water and the nutrients it carries toward the core of the system. Through this structural organization, the module conceptually establishes a material flow pathway from the environment to the internal system. This form is also used to express changes in the system state. Visual shifts between opening and closing indicate internal balance conditions, with the function focusing on information communication and perceptual feedback. The opening and closing dynamics of the petal elements are not realized through mechanical structures but through projected moving images. Projection is used as a visual simulation method to represent changes in water and nutrient flow, allowing the functional logic of *FloraCore* to be clearly conveyed without reliance on physical motion mechanisms.

4.4.2 Exploration of 3D printing and textile experimentation

Before the final structural configuration of *FloraCore* was established, the research underwent a series of printing and textile experiments oriented toward learning and exploration. The experiments discussed in this section were primarily situated in the early phase of the project and served to establish an operational understanding of three-dimensional printing within a clothing system. This included familiarity with modeling approaches, printing processes, material properties, and the initial relationships between printed structures and textiles. Rather than corresponding directly to the final design outcome, this phase provided essential technical experience and perceptual grounding that informed subsequent structural judgments and material decisions.

Early modeling explorations took the rootstock and leaf structures of the desert plant Welwitschia mirabilis as a morphological reference (Figure 4.21). This plant achieves long-term water storage through a thickened rootstock and relies on continuously growing and renewing leaves for water transport. Under extreme arid conditions, its growth structure exhibits a relatively stable central organization alongside peripheral tissues that extend continuously and gradually dissipate. This structural logic is widely understood as a key mechanism through which the plant adapts to highly uncertain water availability in desert environments (Bornman, 1972; Henschel & Seely, 2000). Through hand-drawn analysis and three-dimensional modeling in Nomad, the research translated the linear textures and directional rhythms observed on the surface of the rootstock, with particular attention given to understanding complex surface generation, linear organizational strategies, and the spatial unfolding of structures in three dimensions (Figure 4.21). In parallel, photographic documentation of plant leaf textures was analyzed, focusing on withered edges and linear trajectories. The distribution of these lines exhibits formal similarities to thermal mappings in climate visualizations, providing visual references for subsequent texture development, while remaining exploratory at this stage.

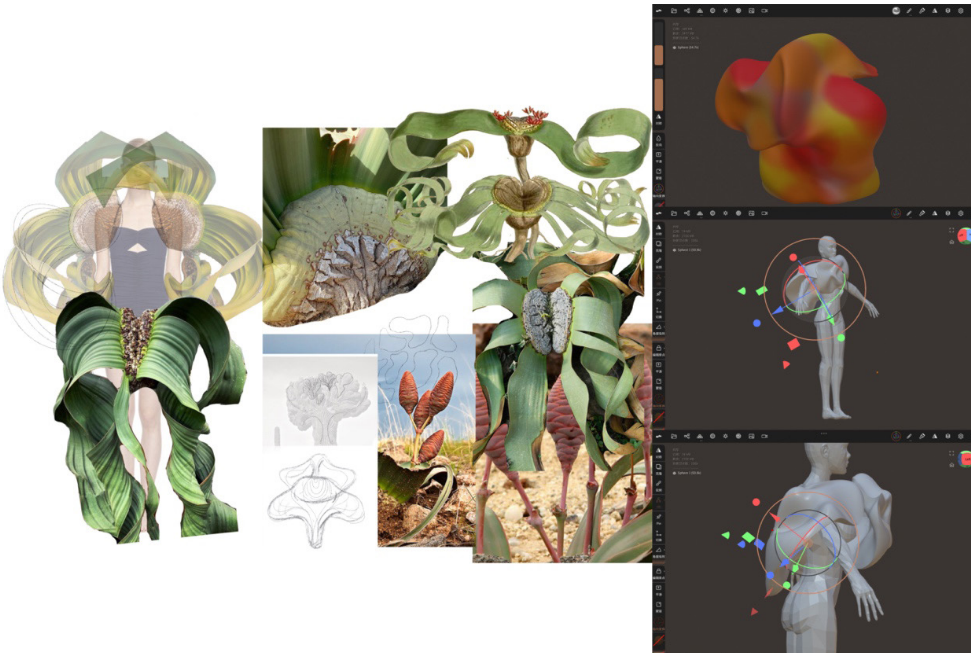

Figure 4.21 Early form exploration through 2D collage (left) and 3D body-based testing in Nomad (right). Author's own work.

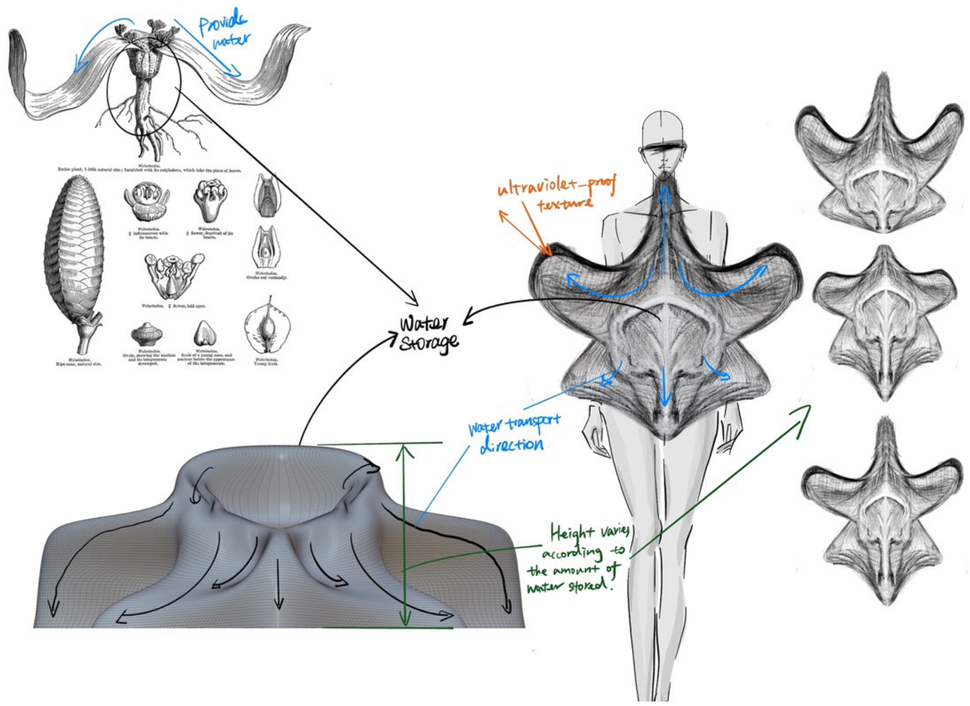

Figure 4.22 Functional analysis of water storage and transport logic in structural samples (illustrated by the author).

Across successive modeling experiments, certain structures began to explore contrasts between centralized mass and peripheral extension. Central protruding areas were introduced to test the effects of volumetric concentration on overall stability, while outward-extending linear channels were used to examine the controllability of directional structures in three-dimensional space (Figure 4.22). The primary value of these models lay in developing familiarity with parameter adjustment, curvature variation, and volumetric distribution, rather than in contributing directly to the final form of *FloraCore*.

As modeling operations became more proficient, the experimental focus gradually shifted toward examining how material differences affect structural appearance. Within the digital environment, different material parameters were applied to identical structures to compare variations in light reflection, absorption, and surface texture (Figure 4.23). These tests demonstrated that material properties significantly influence perceived volume and boundary clarity, thereby shaping the visual legibility of form. Such differences could be identified at the digital stage and provided preliminary criteria for selecting printing materials and surface treatments in later phases.

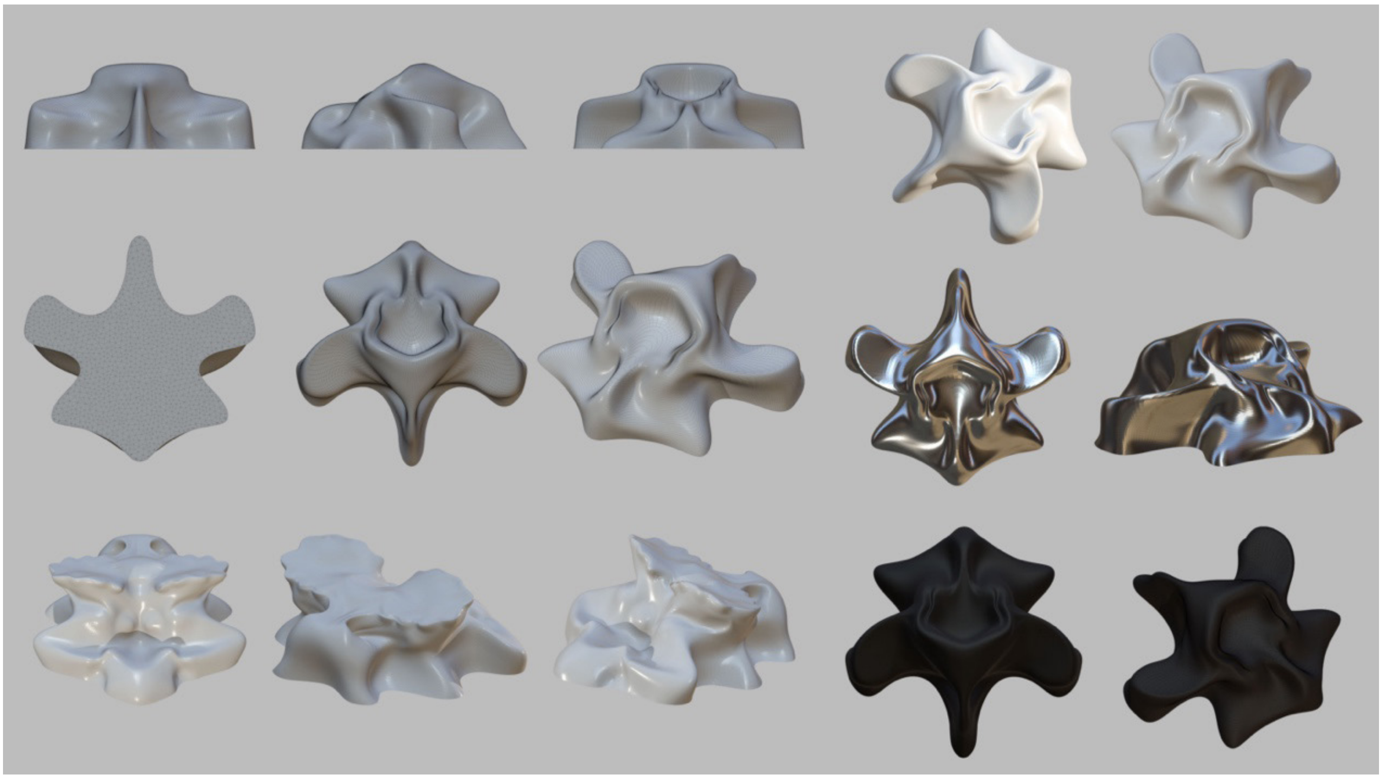

Figure 4.23 Material and lighting tests examining surface response and volumetric perception of structural samples (author's own work).

Following the completion of foundational modeling exploration, the research progressed to experiments combining three-dimensional printing with textiles. This stage centered on establishing technical workflows and gaining operational familiarity, using physical printing to understand how structures materialize under real material conditions. Early printing experiments primarily employed a Prusa i3 MK3S+ FDM 3D printer, with printing parameters optimized in PrusaSlicer through adjustments to layer height, toolpaths, and programmed pause points (Figure 4.24). To ensure stable integration between printed structures and fabric, a pause-at-layer operation was introduced during the printing process. Once the base layers were completed, the printer automatically paused at a predefined height, allowing pre-cut fabric to be manually placed onto the print bed and lightly secured along the modeled boundaries. Printing was then resumed, enabling subsequent material deposition to occur under compression. Through this process, printed material became embedded directly within the textile fiber structure, forming a structural connection at the intermediate layer and avoiding the instability associated with post-print adhesion.

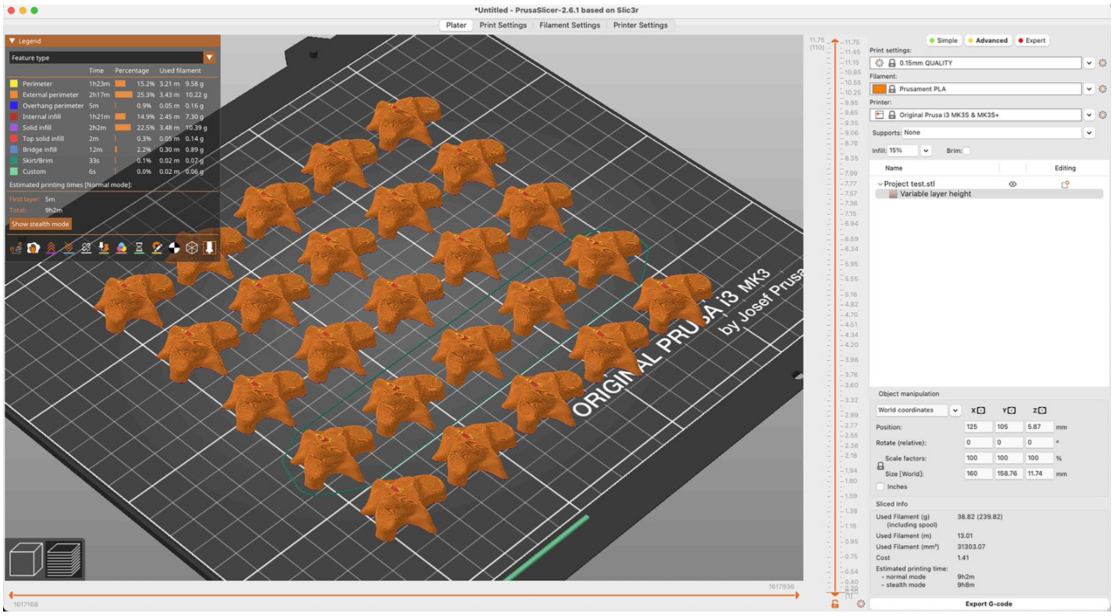

Figure 4.24 PrusaSlicer interface showing layer segmentation and pause-at-layer settings for fabric integration.

Building upon this technical workflow, further experiments tested two primary material combinations: opaque printed material with cotton fabric, and transparent printed material with silk fabric (Figure 4.25). By repeatedly positioning printed samples on a mannequin and adjusting scale and placement (Figure 4.26 – 4.29), the research gradually identified fundamental compatibility patterns between the rigidity of printed materials and the flexibility of textiles. These tests were primarily aimed at understanding how printed structures constrain textile behavior within a clothing system, providing experiential knowledge that informed later discussions on structural segmentation, scale control, and wearability adaptation.

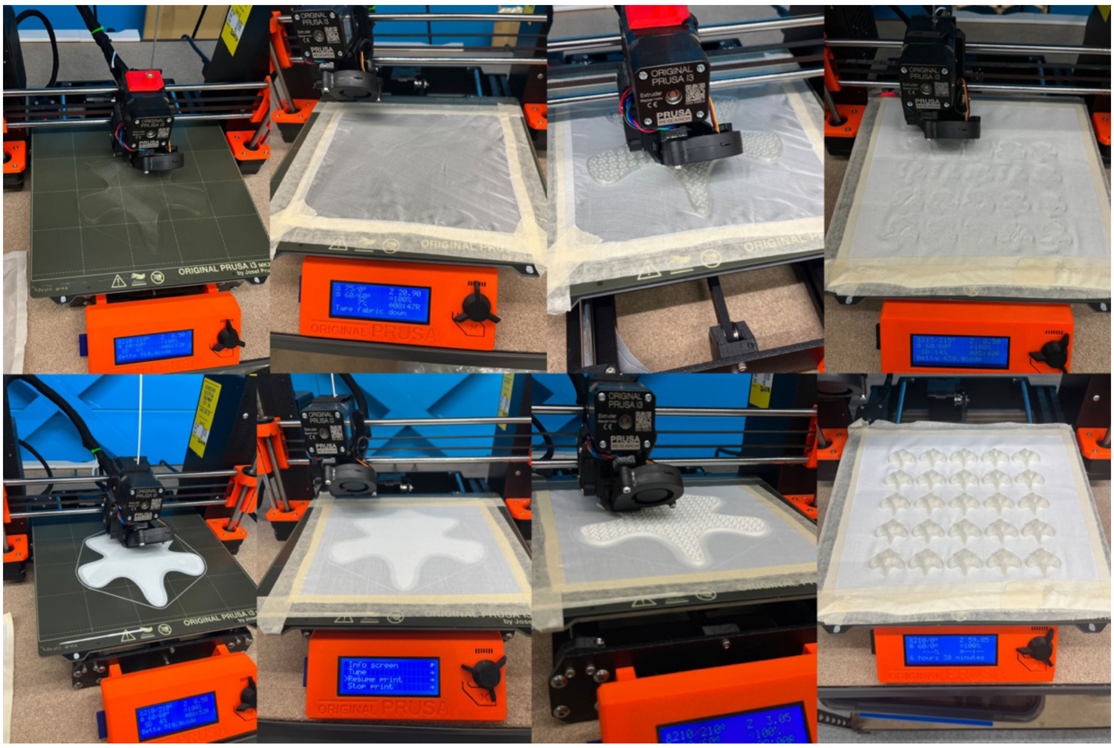

Figure 4.25 In-process integration of 3D printing with textile using a pause-at-layer workflow (author’s documentation photograph).

Figure 4.26 FDM-printed structural samples integrated with cotton fabric (author's documentation photograph).

Experimental observations indicated that opaque printed materials were more effective in maintaining structural boundaries when combined with cotton fabrics, supporting relatively stable volumetric configurations. Transparent printed materials, when paired with silk fabrics, produced smoother visual continuity, but tended to restrict natural textile deformation under conditions of large contact areas. At this stage, the experiments had not yet entered the domain of wearability optimization. Their primary contribution lay in clarifying how printed structures impose constraints within textile systems and in accumulating experience relevant to subsequent adjustments in structural segmentation and fixation strategies.

Figure 4.27 FDM-printed structural samples integrated with silk fabric (author's documentation photograph).

Figure 4.28 Repeated-printing strategy applied to silk and cotton fabrics for flexible structural attachment (author's documentation photograph).

During the exploratory phase, most printed samples were produced using the Prusa i3 MK3S+ system, which operates on fused deposition modeling (FDM) principles. This process constructs three-dimensional forms through the layer-by-layer extrusion of heated thermoplastic material. FDM printing offers stable operation, flexible material exchange, and intuitive parameter control, making it well-suited to rapid iteration, scale testing, and preliminary verification of structural relationships (Gibson et al., 2015). At this stage, the strength of FDM printing lies in its capacity to facilitate quick assessment of overall volume, proportion, and structural distribution. However, inherent limitations related to nozzle diameter and layered deposition resulted in reduced surface resolution and detail precision. These constraints became increasingly apparent when addressing complex curvatures and fine structural features.

Figure 4.29 Modular sample aggregation tested on a half-scale mannequin (author's documentation photograph).

As the structural logic of *FloraCore* became more clearly defined, the research demanded higher levels of detail resolution, surface continuity, and boundary precision. While FDM-printed samples had fulfilled their role in structural understanding and material compatibility testing, their resolution was no longer sufficient to support judgments regarding final form. Consequently, the production phase transitioned to the use of a Kings SLA 400 3D printer. This system employs stereolithography (SLA) technology, forming three-dimensional structures through the layer-by-layer laser curing of liquid photosensitive resin. Compared to FDM, SLA provides superior performance in surface smoothness, edge definition, and geometric accuracy, making it more suitable for finalizing complex forms and fine structural details (Ngo et al., 2018). The shift in printing technology reflects a methodological transition from exploratory experimentation to structural consolidation, rather than a simple technological upgrade.

For final fabrication, photosensitive resin was selected as the primary printing material based on its balanced performance in terms of weight control, structural strength, and processing flexibility. Resin prints can be readily sanded, polished, and surface-treated after fabrication, allowing for standardized surface conditions and enhancing the model's operability in wearability testing and spatial exhibition contexts. In addition, certain resin systems have been developed with low-volatility formulations and energy-efficient curing processes, offering higher material utilization rates than traditional subtractive manufacturing and reducing excess waste generation (Gebhardt et al., 2019). Within the context of this research, the material's plasticity, reprocessability, and controllability during experimentation align methodologically with the project's broader engagement with sustainable design pathways.

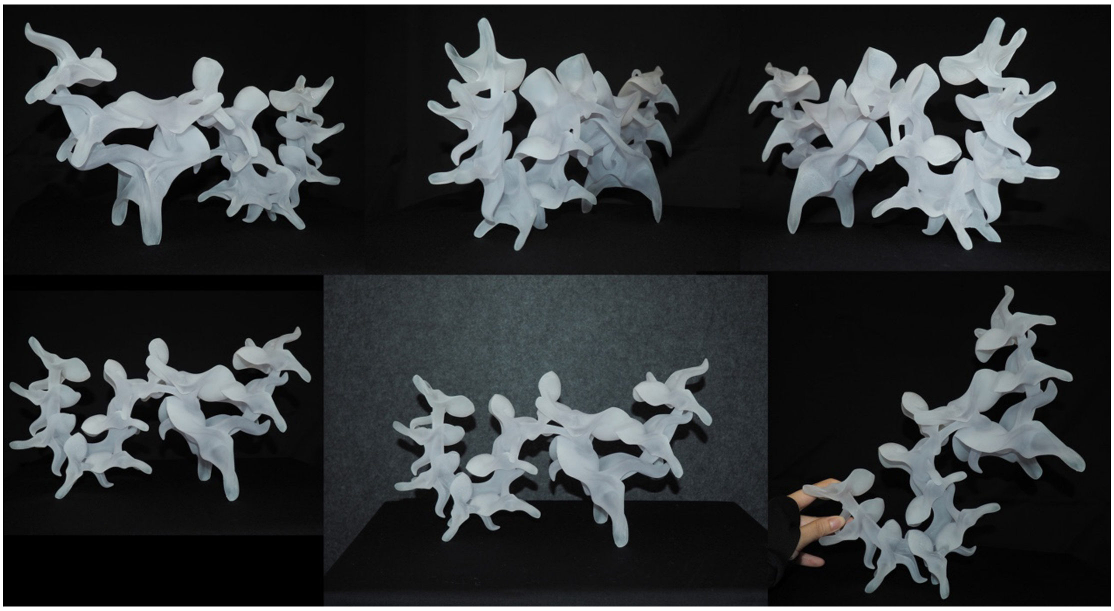

Figure 4.30 Semi-transparent resin *FloraCore* prototype printed using Kings SLA 400 with post-processing surface refinement (author's documentation photograph).

After printing, the models underwent sandblasting and polishing to unify surface conditions and reinforce the legibility of structural contours. This post-processing stage effectively reduced visible layer artifacts and enabled the structures to present more stable visual performance under lighting and projection conditions (Figure 4.30).

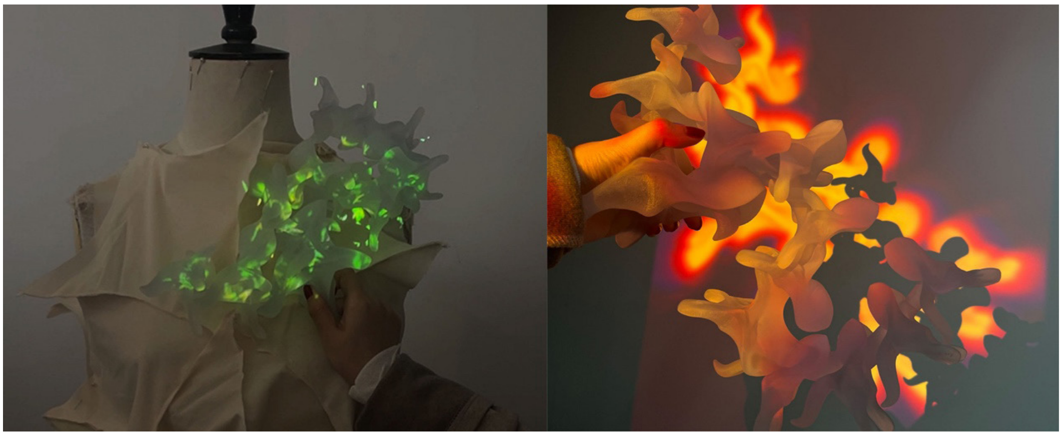

Figure 4.31 Projection testing of semi-transparent resin prototype revealing internal light scattering effects (author's documentation photograph).

Figure 4.32 Final opaque white resin modules printed at multiple scales for *FloraCore* modular composition (author's documentation photograph).

Subsequent projection testing revealed that semi-transparent resin produced pronounced internal light scattering effects. Under projection conditions, structural edges became visually blurred, and hierarchical relationships between volumetric elements were difficult to discern (Figure 4.31). While this optical quality imparted a certain softness in isolated object display, it diminished structural legibility in exhibition contexts that relied on projection to convey information and emphasize form. Based on this feedback, material selection was revised.

In the final production stage, semi-transparent resin was replaced with opaque white resin to ensure clearer structural definition under projection. Opaque material more effectively supports projected imagery by keeping light on the surface rather than allowing internal diffusion, thereby minimizing interference with formal legibility. Following material selection, the structure was printed in two different scales for modular combination and spatial configuration testing (Figure 4.32). Introducing scale differentiation enabled greater flexibility in compositional arrangement and provided an adaptable foundation for subsequent adjustments related to wearability and assembly.

4.4.3 Emergence and adjustment of wearability issues

As the design process progressed into the stages of detailed modeling and fabrication validation, a series of new technical challenges began to emerge. In earlier phases of AI-generated imagery and three-dimensional form development, the human body primarily functioned as a referential framework for scale and spatial orientation. The coordination of visual continuity, biomorphic metaphors, and speculative functional imaginaries drove structural evolution. However, once the three-dimensional models began to establish direct contact with the human body, practical issues related to weight distribution, surface conformity, and wearing stability became increasingly evident. Wearability thus shifted from a latent design consideration to a technical constraint that required direct engagement.

At this stage, adjustment efforts focused on refining the angular relationships and dimensional parameters of the three-dimensional models, enabling the structure to form a clearly defined system of suspension and coverage around the upper body (Figure 4.33). Through iterative restructuring in Nomad, key functional zones were positioned around the chest and abdominal core areas, corresponding directly to the conceptual roles of moisture collection and internal transport. Nomad's sculpting tools allowed for flexible modification of localized details while preserving the overall formal logic, enabling the modules to visually maintain characteristics associated with plant branching and growth trajectories, and to exhibit strong continuity within the digital environment. Nevertheless, when these structures were examined in relation to the proportions and curved surfaces of the real human body, tensions between rigid geometry and the pliability of the body persisted, leaving wearability stability under real conditions to be further tested.

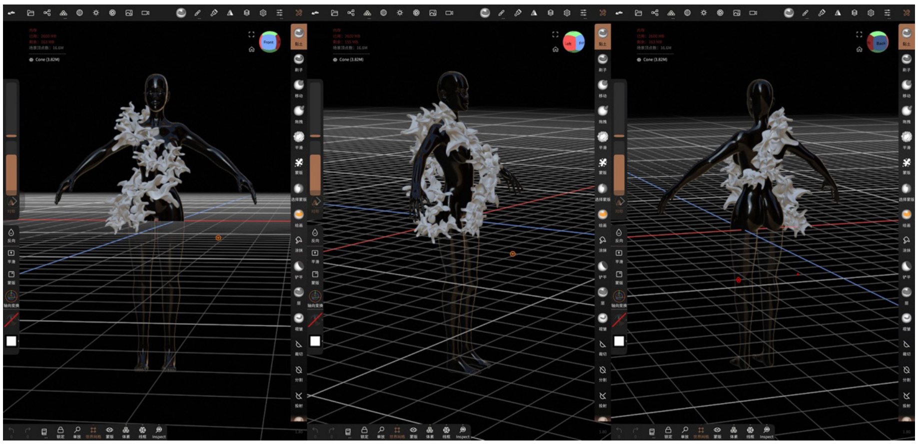

Figure 4.33 Upper-body suspension and coverage refinement of the *FloraCore* module developed in Nomad (author's own work).

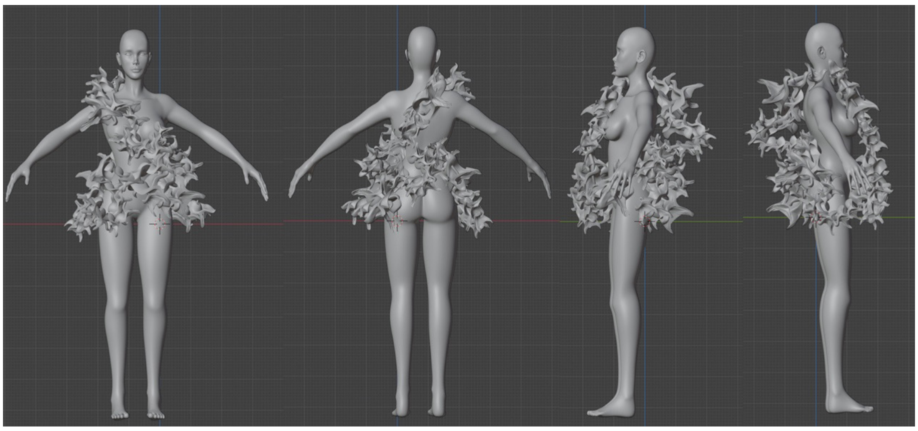

Figure 4.34 Wearability-oriented model optimization and body-fit integration conducted in Blender (author's own work).

To address the relationship between structure and body more systematically, the design process shifted from Nomad to Blender for more precise model adjustment and surface integration (Figure 4.34). This transition reflected a substantive change in the nature of the design task. During early form-generation stages, Nomad's intuitive sculpting interface and mobile accessibility supported rapid exploratory iterations, allowing the designer to manipulate overall contours and organic surfaces through gestural input. As the focus moved toward wearability optimization, however, the design task shifted from holistic form shaping to millimeter-level alignment between model surfaces and body curvature, as well as the precise coordination of positioning and scale among multiple modules.

Nomad's limitations became increasingly apparent under these high-precision requirements. As polygon counts increased and surface detail intensified, the computational constraints of mobile hardware reduced both operational fluidity and control accuracy. More critically, wearability validation required frequent comparative adjustments between the model and body scan data, a workflow that depended on accurate measurement tools, numerical control, and robust Boolean operations. Blender offered clear advantages in this regard. Its modifier-based system enabled non-destructive parameter adjustment, its vertex-level editing tools allowed fine-grained correction at points of body contact, and its computational capacity supported complex surface-fitting operations on high-density models.

This software transition also entailed a shift in design thinking. In Nomad, form adjustment relied heavily on visual judgment and tactile intuition, an approach well suited to exploratory sculptural development. In Blender, by contrast, wearability considerations were translated into quantifiable parameters through precise measurement of body curvature, calculation of contact areas, and adjustment of suspension angles. As model complexity increased, the central challenge became how to maintain structural integrity while allowing the system to conform to the body surface and retain stable positioning. Blender's technical environment made it possible to decompose and address these issues systematically rather than relying on repeated trial and error.

To further expand the methodological scope of wearability validation, the research introduced physical draping and fabric-based experiments as a comparative testing pathway (Figure 4.35). This experiment aimed to observe how structural segmentation and spatial relationships would be reorganized when three-dimensional structural logic was translated into body-conforming textile construction, under the combined influences of gravity, body curvature, and movement. The results indicated that while fabric-based shaping increased adaptability to the body surface, it simultaneously undermined the stability of structural zoning. Functional areas that were clearly delineated within the three-dimensional models tended to merge into continuous surfaces when realized through textiles, resulting in blurred spatial hierarchies. Consequently, this experiment was positioned as an exploration of methodological boundaries, revealing the limitations of a particular technical approach rather than offering a viable final solution.

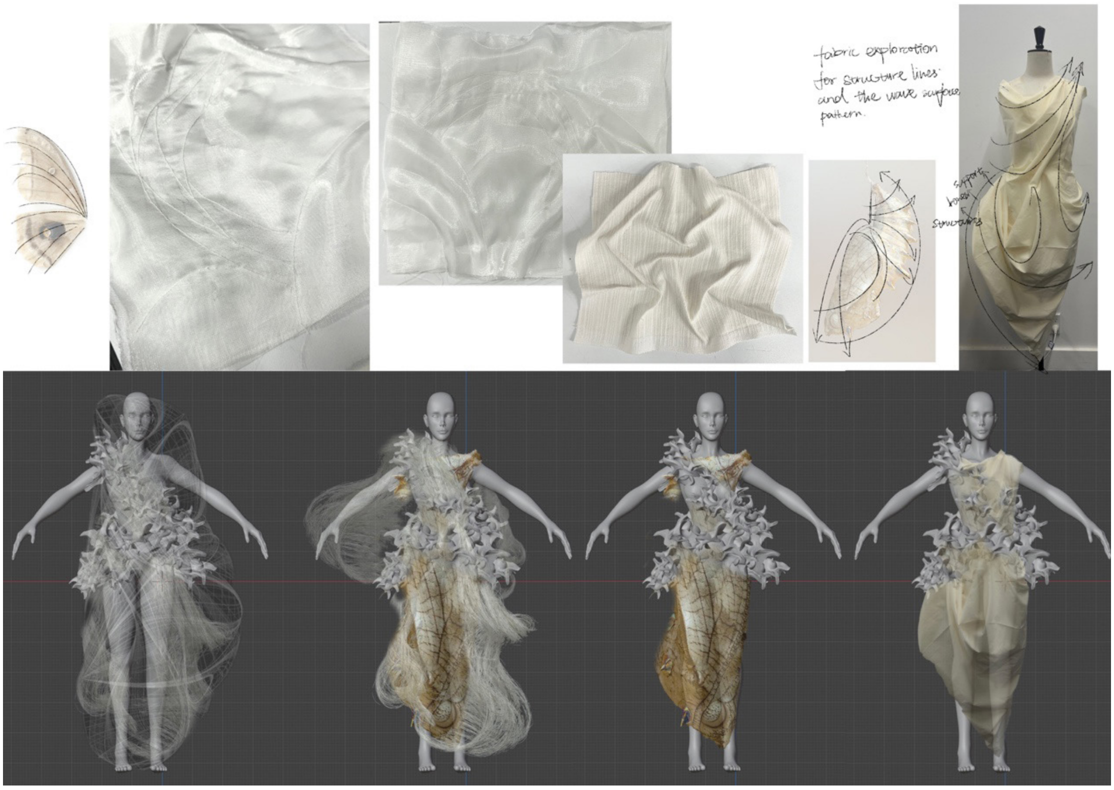

Figure 4.35 Branch experiment on wearability using draping and fabric-based construction (author's own work).

Based on these findings, the design trajectory increasingly converged on the use of independent three-dimensional models as the primary structural components of the *FloraCore* module. This decision was closely aligned with *FloraCore*'s functional attributes (Table 1). As a core module responsible for moisture collection, nutrient circulation, and the expression of system states, its structure needed to preserve relatively independent spatial hierarchies and clearly articulated functional zones under wearable conditions. These requirements could not be reliably sustained within continuously deformable material systems.

To evaluate the feasibility of this approach, a series of distribution and wearability tests were conducted on the upper body, structured across two interrelated stages: planning-based projection and physical validation. First, two-dimensional diagrams were used to systematically project module coverage areas, distribution positions, and compositional relationships onto the body (Figure 4.36). These diagrams did not function as simple planar layouts, but rather as projections of three-dimensional spatial occupation onto frontal body views, enabling evaluation of how variations in scale, quantity, and arrangement might establish stable coverage over the chest and abdominal core regions. Five distinct distribution schemes were developed, each differing in module density, symmetry, and vertical extension. This planar projection process enabled rapid assessment of visual balance, functional coverage completeness, and potential stability implications associated with inter-module spacing, prior to physical fabrication. Comparative analysis of these schemes helped identify areas requiring denser structural support, potential load-bearing connection points, and proportion guidelines for subsequent three-dimensional fitting.

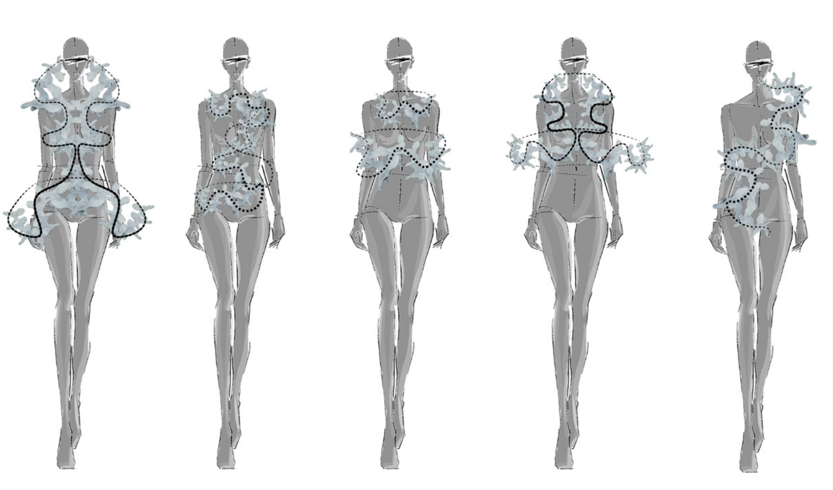

Figure 4.36 Two-dimensional distribution studies of iterative 3D modules on the upper body (illustrated by the author).

Subsequently, the three-dimensional models were iteratively optimized and then subjected to physical wearability testing (Figure 4.37). The six viewing angles presented reveal the complex spatial relationships between modules and the body. From the frontal perspective, the modules form a layered coverage structure that follows the curvature of the chest, while outward-extending branches preserve biomorphic visual qualities and maintain sufficient distance from the body surface to avoid restricting movement. Side and rear views reveal more critical technical considerations, including how suspension strategies accommodate curvature variations across the shoulders and back, how rigid components adapt to three-dimensional body form through angular adjustment, and how multiple modules avoid mutual interference or uneven weight concentration.

Figure 4.37 Wearability validation using 3D-printed FloraCore prototype models on the upper body. Author's own work and photograph by the author.

This physical testing phase extended beyond visual evaluation, exposing physical issues that could not be anticipated through two-dimensional projection alone. Certain configurations that appeared viable in planar diagrams exhibited displacement under gravitational load during wear; symmetrical arrangements occasionally lost balance during bodily movement; and pressure points emerged where rigid branches contacted softer areas of the torso. Through repeated donning, removal, and posture variation, the designer was able to identify connection points requiring reinforcement, regions where module dimensions needed reduction, and strategies for redistributing the overall center of gravity to balance visual integrity with wearer comfort and mobility.

This iterative loop between two-dimensional planning and three-dimensional validation constituted a calibration mechanism operating across representational dimensions. Two-dimensional diagrams provided a rapid decision-making framework for identifying promising configurations, while physical wearability tests subjected these configurations to real-world constraints imposed by body curvature, gravity, structural rigidity, and movement. Feedback from each testing cycle informed subsequent adjustments to planning parameters, generating a progressively convergent optimization process. Through this iterative refinement, the design established a technical pathway that both preserved biomorphic formal logic and satisfied practical wearability requirements, ultimately confirming that concentrating modules on the upper body enabled a more controllable balance between structural stability and functional legibility.

This iterative cycle, from two-dimensional planning to three-dimensional validation, constitutes a process through which design establishes mechanisms for cross-dimensional verification. Two-dimensional diagrams provide a framework for rapid decision-making, enabling the identification of configuration directions with greater potential. Physical wearability testing then subjects these directions to real-world conditions, where the combined effects of body curvature, gravitational forces, material rigidity, and movement constraints reveal weaknesses within the proposed configurations. Feedback generated in each testing cycle subsequently informs adjustments to the parameters of two-dimensional planning, producing a progressively convergent optimization process. Through these repeated cycles of testing and refinement, the design gradually establishes a technical pathway that both responds to biomorphic formal logic and satisfies practical wearability requirements, ultimately confirming that concentrating the modules on the upper body enables a more controllable balance between structural stability and functional legibility.

4.5 Material selection and the formation of sustainable systems

During the design development phase of *Desertia*, material selection operates as a critical junction connecting real material conditions with speculative ecological settings. Materials assume a dual role within this framework. They form the practical basis of wearability while simultaneously providing a stable physical substrate for the articulation of speculative systems (Bennett, 2010; Dunne & Raby, 2013). This duality directly shapes how continuity is established between the real and the imagined dimensions of the garment system, thereby defining the possible trajectories of design speculation.

The future scenario constructed in *Desertia* positions sustainability at the core of the garment system's viability. Design development engages closely with the origin of materials, their production pathways, and their potential for circulation, ensuring that material logic remains coherent across long-term ecological speculation. Materials are therefore understood within broader ecological and technological systems. This perspective shifts attention away from conventional performance-based evaluation toward a systemic mode of thinking that foregrounds a material's capacity for repeated mobilization within ecological cycles, as well as its position and mobility within resource networks (Capra & Luisi, 2014). Material value is determined through its contribution to sustaining the long-term operation of the ecological system as a whole.

In response to these design considerations, paper yarn is introduced as the primary material for this phase. Ocean King New Materials (OKNEM) is a world-leading research and production company for paper yarn, dedicated to redefining paper-based materials in an era of innovation and sustainable development. The Cai Lun paper-making technique is one of China's four great inventions, and OKNEM not only inherits this traditional paper-making craft but also integrates modern technology to create a new era of paper yarn. Although researchers at Sweden's Borås University developed a sustainable paper skirt in 2017, they did not produce paper yarn on a large scale (NORDICPAPER, 2017). After three years of research, OKNEM successfully combined precise paper-making techniques, efficient CNC technology, and advanced textile processes, merging the softness and breathability of paper with the durability and aesthetics of textiles to create a uniquely advantageous paper yarn fabric.

The production process of Cai Lun paper yarn represents a sustainable textile method that begins with the management of fast-growing, cyclic forests and runs through an environmentally friendly manufacturing process. This process balances ecological responsibility with industrial efficiency by converting cellulose fibers into yarn. The final product not only aligns with sustainable development goals but also reduces waste through a closed-loop system of recycling and reuse, promoting carbon cycling and embodying the harmony between innovation and environmental protection.

Given the high-temperature environment of the future desert scenario, the fabric's thermal conductivity and moisture-regulating functions are of greater importance. According to data provided by the founder of OKNEM, the thermal conductivity of Cai Lun paper yarn is just 0.06, the lowest among mainstream fibers (Cai Lun Paper Yarn, 2023). This low thermal conductivity not only slows down heat transfer but also insulates against external temperature changes, reducing skin irritation and enhancing wearing comfort, achieving a warm winter and cool summer effect. Additionally, microscopic observation of the fiber surfaces and cross-sections reveals an internal spiral structure that forms a porous state similar to activated carbon, allowing air to flow smoothly through the fibers, thus providing excellent moisture regulation and temperature control properties for the fabric.

An additional value of paper yarn lies in the openness of its material expression. Its lightweight structure and relatively neutral surface qualities generate minimal visual interference, allowing the garment surface to remain perceptually receptive. This characteristic establishes favorable conditions for subsequent technological intervention, positioning the garment surface as an open field for information display. Material presence remains restrained, enabling speculative technological systems to unfold without being visually dominated by the material itself.

Within the design process, paper yarn is treated as a materially controllable platform. Sensory comfort at the bodily level is primarily afforded through the material's physical properties, including tactile quality and breathability, which operate directly upon bodily perception. More complex ecological functions and systemic states associated with future environments are presented through projected imagery. Projection functions here as a component of a speculative technological system, operating in coordination with the material substrate. This collaboration enables the garment to communicate environmental variation, resource circulation, and ecological conditions without increasing the complexity of its physical structure, thereby extending the garment's capacity as an informational interface.

The synergy between material and projected imagery constitutes a central strategy within the *Desertia* design development process. Through this arrangement, real-world sustainable materials and speculative high-technology systems coexist within a single garment framework. Paper yarn establishes tangible connections between body and garment through touch, weight, and embodied experience. Projected imagery extends the garment's expressive capacity across temporal and systemic dimensions, conveying real-time representations of ecological dynamics, physiological processes, and shifting environmental parameters. This distribution of roles allows garments to retain wearability while supporting speculative imaginaries of future ecological systems, achieving a balance between material presence and informational expression.

The integration of projected imagery further deepens the role of material within the design system. Paper yarn operates both as a material substrate and as a projection surface. Its lightweight structure enables specific interactions between light and fiber, generating semi-translucent visual effects. These effects soften the boundary between surface and depth, producing layered and fluid modes of information display. Projected content may adapt in response to environmental changes, wearer behavior, or predefined ecological scenarios, allowing the garment to function as a dynamically responsive information system.

Within this framework, sustainability unfolds across multiple dimensions through the coordination of material selection and technological representation. The material pathway represented by paper yarn reflects responsible engagement with available resources and careful consideration of environmental impact within production processes. Projected imagery constructs speculative technological scenarios that explore how future garment systems might enhance ecological functionality through technological means. This design strategy resonates with David Kirby's concept of the diegetic prototype, in which fully functional artefacts operate within fictional worlds to demonstrate the social feasibility and necessity of emerging technologies. In *Desertia*, the integration of paper yarn and projected imagery forms an experiential diegetic prototype, allowing speculative ecological technologies to be articulated through wearable and materially grounded forms. Through its combined material and informational layers, the garment situates future technological imaginaries within everyday sensory experience, establishing a coherent structural relationship between present constraints and future possibilities (Ingold, 2011; Kirby, 2010).

This structural relationship also entails a reconsideration of temporality within garment systems. As a biodegradable material, paper yarn possesses a finite material lifespan with defined points of emergence and dissolution. Projected imagery, operating as an immaterial informational layer, remains highly adaptable and continuously updatable across the garment's material lifespan. The temporal disparity between material and information layers enables garments to support evolving functional narratives within a limited material duration, offering alternative alignments between sustainability and functional diversity.

4.5.1 Speculative material system

Within the *Desertia* scenario, materials are situated within a speculative system structured around ecological circulation. The operational logic of this system parallels natural processes of resource flow, emphasizing continuous translation across different stages. Material significance emerges through its capacity for ongoing transformation, enabling repeated movement between ecological, biological, and garment systems. Value is located in the material's participation within cyclical processes and its ability to maintain ecological coherence throughout successive transitions.

This speculative material system originates with future vegetation as the initial node of ecological circulation. In *Desertia*, plants are sustained through technological assistance under extreme arid conditions, functioning as generators of material resources. These plants serve both as agents of ecological restoration and as sources of material production, sequestering atmospheric carbon into biomass while improving soil conditions and regulating microclimates. Upon completion of their growth cycles, plant matter is recovered and processed into fibrous raw material, entering the garment system. Through this transition, ecological resources move into human wearability while retaining their position within broader circulation logic.

Paper yarn derived from plant fibers operates as an intermediary form between ecological and garment systems. Within garments, the material supports wearability and interface functions, and its duration of use is understood as one phase within an extended material trajectory. Garments occupy a provisional organizational state in this system, allowing ecological resources to assume bodily perceptibility for a defined period. This perspective reframes the relationship between garment and material, positioning clothing as a node within material flow rather than as a terminal product.

Paper yarn exhibits a dual temporality during its garment phase. From the wearer's perspective, the material provides stability and durability sufficient for daily use. From an ecological perspective, the garment form represents a temporary configuration within a longer material lifespan extending from plant growth to ecological reintegration. Wear becomes an event embedded within material circulation, integrated into ecological time rather than marking its conclusion.

Following the garment's use phase, materials re-enter processes of recovery and translation. Garments composed of paper yarn are disassembled, with fibers directed toward reprocessing or ecological return depending on material condition. Fibers in suitable states may be transformed into new material forms, while degraded components undergo composting or biological treatment to return nutrients to the soil. Through these processes, materials are converted into renewed resources that support plant growth and ecological repair, completing a circulation cycle and maintaining ecological value across transformations.

Within this speculative ecological system, material circulation foregrounds continuity and intelligibility. Translational processes across stages become central components of design speculation, supporting examination of how garment systems may participate in resource management and environmental regulation under future ecological conditions. Visualization of circulation logic renders abstract ecological processes perceptible, enabling viewers to comprehend the continuous pathways of transformation that link ecology, garments, and technology. This circulation model is articulated through system diagrams illustrating the full trajectory from plant growth and fiber extraction to garment fabrication and ecological return, along with associated energy flows and material transformations (Figure 4.38).

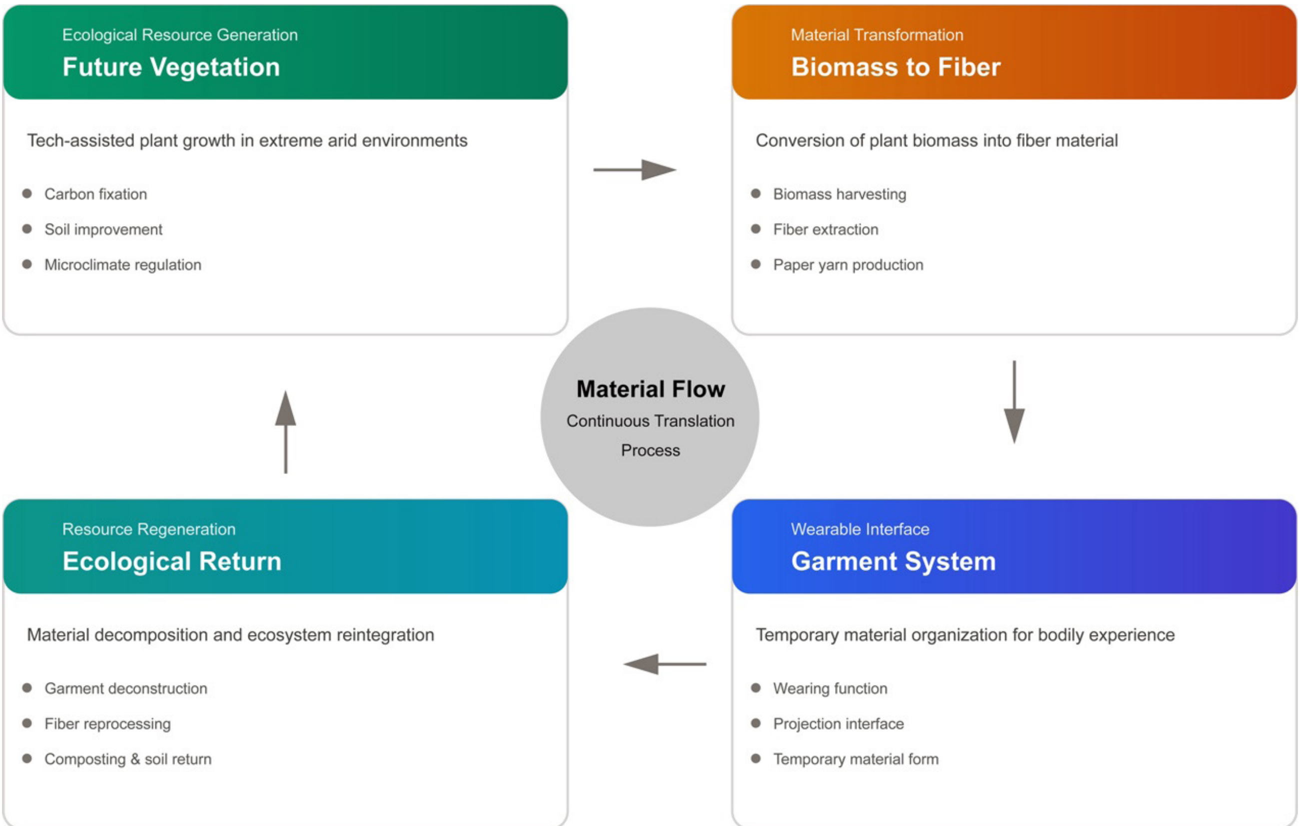

Figure 4.38 *Desertia* speculative material cycle system.

In the narrative world of *Desertia*, the material circulation system functions as a fully articulated ecological infrastructure. Through explicit transformation processes and temporal sequencing, the system demonstrates how future sustainable ecologies might operate. System diagrams and garment prototypes together constitute an experiential diegetic prototype, rendering speculative ecological technologies concrete and intelligible, while communicating their feasibility and necessity.

Through sustained engagement with ecological circulation, sustainability in *Desertia* is articulated as a system-level operational logic. Materials traverse from ecological resources into garment systems and subsequently return to ecological contexts, establishing garments as active participants in ecological reconfiguration. Garment function extends beyond meeting human wearability needs to include contributions to resource regulation, environmental repair, and ecological maintenance. Design development thus establishes a coherent structural relationship between real material conditions and speculative ecological futures (Capra & Luisi, 2014; Ingold, 2011; Kirby, 2010).

4.6 Further development of the physical garments

Following the establishment of the *Desertia* scenario and the functional hypotheses of the modular garment system, physical garment development was introduced as an operational tool within speculative design, enabling speculative propositions to be translated into material interfaces open to discussion and redefinition (Auger, 2013; Dunne & Raby, 2013). Earlier stages of visual generation, structural reasoning, and two-dimensional planning provided an organizational framework for the system; however, these explorations lacked sustained engagement with material behavior, gravitational force, and bodily scale. Physical making brings environmental and resource-related assumptions directly into the design process. Parameters that previously existed primarily as textual or conceptual constructs are transformed through draping and construction into tangible structural conflicts and material responses, thereby exerting concrete influence on design decisions (Bennett, 2010; Ingold, 2013).

Within this context, the *Desertia* scenario operates as a set of actionable pressure conditions that continuously shape the garment system. Assumptions of resource scarcity and circularity require that structural organization and material use demonstrate traceable rationales, leading cutting, assembly, and the treatment of residual materials to be considered within a unified system framework. When multiple functional modules are combined within a single garment structure, direct spatial and boundary conflicts emerge. Such conflicts often remain indistinct at conceptual or digital stages, yet become immediately apparent in physical construction through forms of interference, structural collapse, uneven weight distribution, or restrictions on wearability. These manifestations prompt a reconfiguration of the original problem framing (Gaver, 2012; Lim et al., 2008).

For these reasons, physical garment development in this research is employed to test design hypotheses within situated conditions while simultaneously generating new questions. Through draping and pattern cutting, material tension, structural stability, and the relationship between garment, body, and environment can be directly observed. When discrepancies arise between these physical outcomes and prior assumptions, both functional narratives and structural organization are adjusted accordingly (Houde & Hill, 1997; Schon, 1983; Zimmerman et al., 2007). In this sense, physical garment development provides a basis for subsequent structural refinement of the *RespiraVeil*, *HydraSkin*, and *EcoFlow* modules, while also creating space to examine and iterate zero-waste pattern cutting, one-piece construction, and material reuse strategies under the pressures imposed by the *Desertia* scenario.

4.6.1 **Physical construction strategies across the three modules**

This section focuses on the three textile-based modules: *RespiraVeil*, *HydraSkin*, and *EcoFlow* (Figure 4.62). And examines how their physical construction strategies translate *Desertia*'s speculative ecological assumptions into operable and examinable material systems. Unlike *FloraCore*, which relies on 3D printing technologies, these three modules progressed into draping, pattern making, and full garment construction. Their development required responses to material behavior, bodily scale and movement, and structural stability under real conditions.

Across these modules, three recurring construction strategies were mobilized: one-piece construction, zero-waste cutting, and material reuse. Together, these strategies form an interconnected operational system addressing core issues within the *Desertia* scenario, including resource limitation, circular material logic, and inter-module dependency. Construction decisions therefore extend beyond the completion of individual garments to encompass how materials are introduced, transformed, and redistributed throughout the system. These strategies are aligned with the sustainability objectives of the research. On one hand, recyclable paper yarn is employed as a primary material, emphasizing traceable sourcing and reusability. On the other hand, construction methods reduce the number of pattern pieces, minimize offcuts, and establish pathways for material redistribution between modules, extending sustainability from material selection to fabrication processes and generating a systematic production logic open to discussion and review (Cumming, 2018).

From an operational perspective, one-piece construction reduces the number of pattern pieces and seam lines, reinforcing structural continuity and enabling functional requirements to be embedded within a single material surface. In this research, one-piece construction does not imply a simplified flat pattern. Instead, folding, rotation, opening placement, and button fastening are employed to translate two-dimensional fabric into wearable volume and silhouette, maintaining structural adaptability and stability with minimal pattern fragmentation. Zero-waste cutting shifts material-efficiency considerations to the pattern-making stage, transforming cutting into a resource-allocation decision. Material reuse extends this logic further by treating cutting remnants as potential structural resources, allowing materials to circulate between modules and acquire new organizational roles and functional capacities.

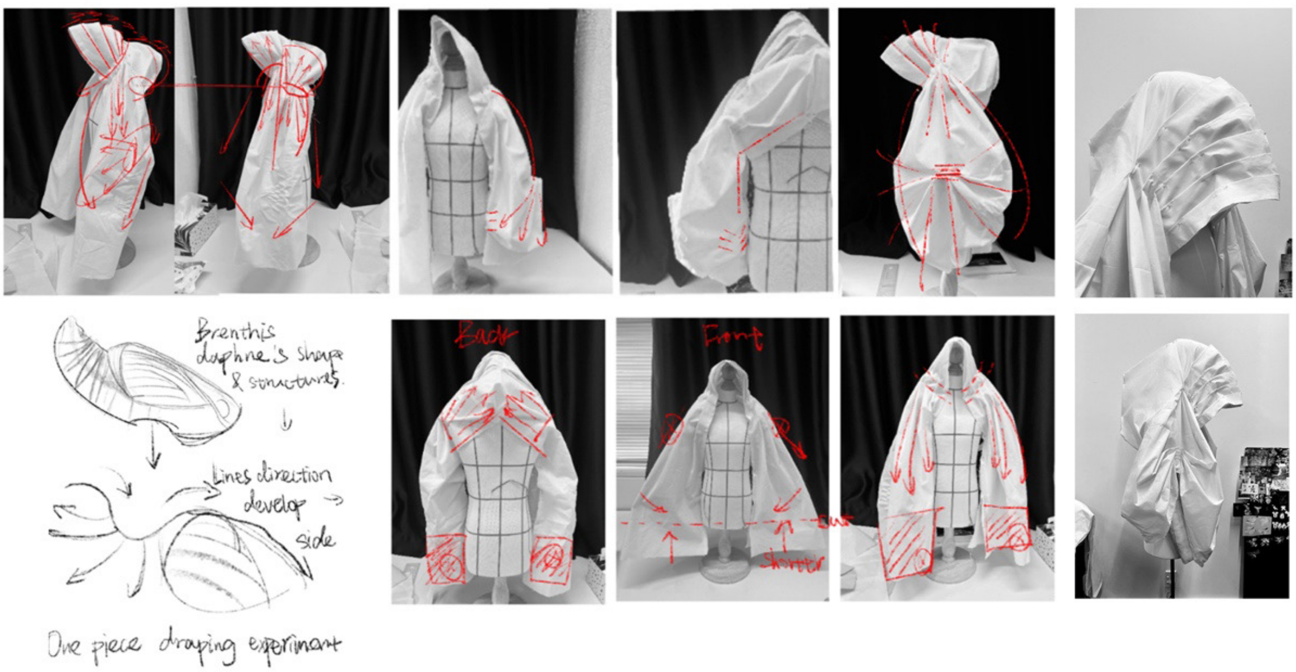

Figure 4.39 Structural analysis and draping process of *RespiraVeil* (author's own work).

Within this framework, *RespiraVeil* adopts one-piece construction as its primary strategy. Covering the head and arms, the module performs air filtration, protection against dust, toxic gases, and ultraviolet radiation, while also contributing to thermal regulation. Its structural inspiration derives from the enveloping logic of the *Brenthis* daphne chrysalis, emphasizing coexistence between continuous outer wrapping and internal breathing pathways. Structural analysis and draping experiments first examined coverage relationships and opening placements, confirming fit and rotational boundaries around the head and upper limbs (Figure 4.39). A single-piece pattern was subsequently developed to determine fold lines, opening trajectories, and button connection points, enabling head and arm coverage to be organized within one unified pattern (Figure 4.40). In the completed garment, structural detailing reinforced interface stability through edge strengthening, opening adjustment, and load distribution at connection points. Sleeve buttons provided adjustable length functionality (Figure 4.41). The lightweight and breathable properties of recyclable paper yarn supported airflow and thermal modulation, allowing filtration, protection, and temperature regulation to coexist on the same material surface.

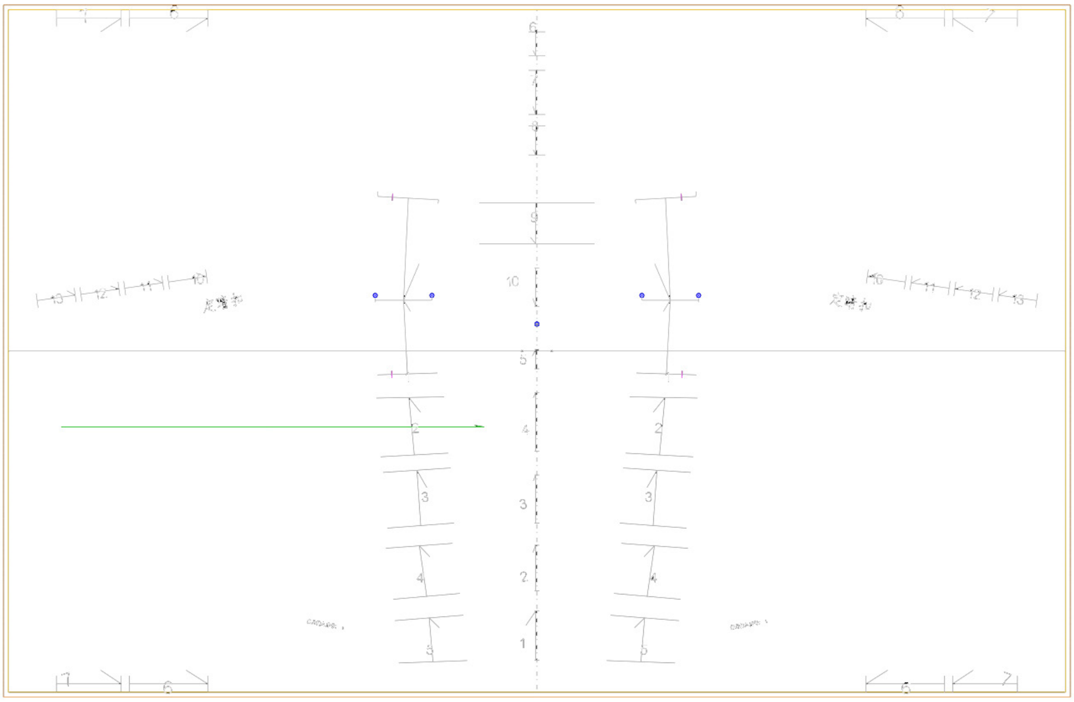

Figure 4.40 One-piece pattern development of *Respiraveil* (illustrated by the author).

Figure 4.41 Garment structure and silhouette of *RespiraVeil*. Author’s own work and photographed by the author.

HydraSkin follows a different construction pathway. Covering the upper body down to above the knees, its primary function is water absorption, storage, and circulation for humidity and temperature regulation. Inspired by the structural organization and geometric order of cactus spines, the design process abstracted cactus spine relationships into scalable and iterable prototype units. Draping experiments tested how these units unfolded, overlapped, and distributed forces across the curved body surface (Figure 4.42). During pattern development, geometric prototypes were systematically arranged through scaling and iterative combinations, forming varied densities and directional flow structures to establish controlled water pathways and surface moisture logic (Figure 4.43). Seam construction rules were clarified in CAD to stabilize boundaries and distribute structural loads between units (Figure 4.44). Upon garment completion, structural and detail documentation enabled analysis of overall stability and localized deformation under dynamic wear, while revealing how the structural organization aligned with water absorption and circulation pathways (Figure 4.45).

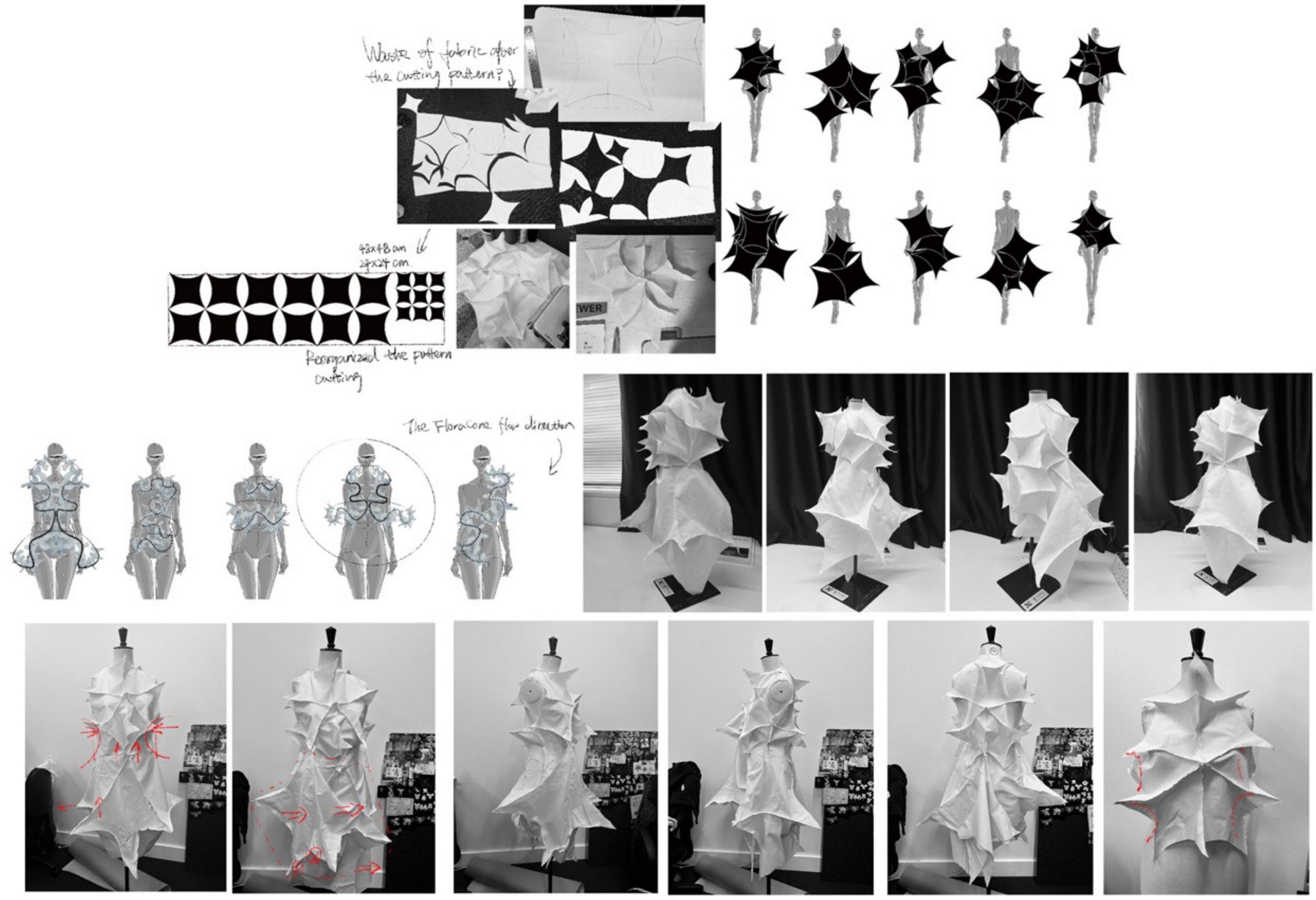

Figure 4.42 Structural analysis and draping process of *HydraSkin* (author’s own work).

HydraSkin was also developed within a zero-waste cutting framework. Due to the reconfigurable nature of its geometric prototypes, layout planning optimized material efficiency while anticipating the potential of remaining pieces. Cutting remnants were preserved as system resources, with their dimensions and shapes recorded and transferred into the structural planning of the next module (Figure 4.46). *HydraSkin* therefore performs dual roles within the system, functioning both as a water-circulation interface and as a material output node providing residual substrates for *EcoFlow*.

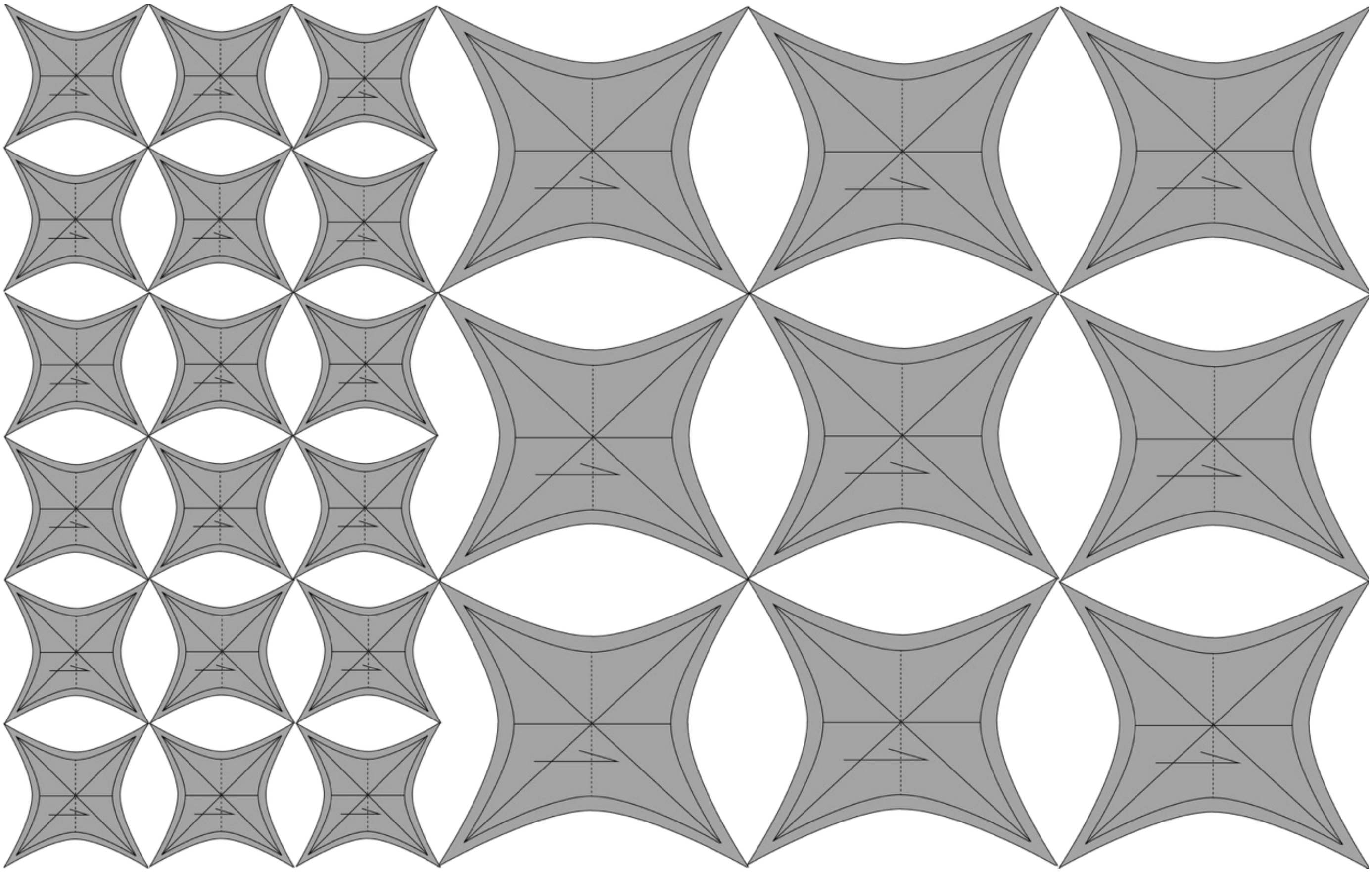

Figure 4.43 Pattern layout of *HydraSkin* (illustrated by the author).

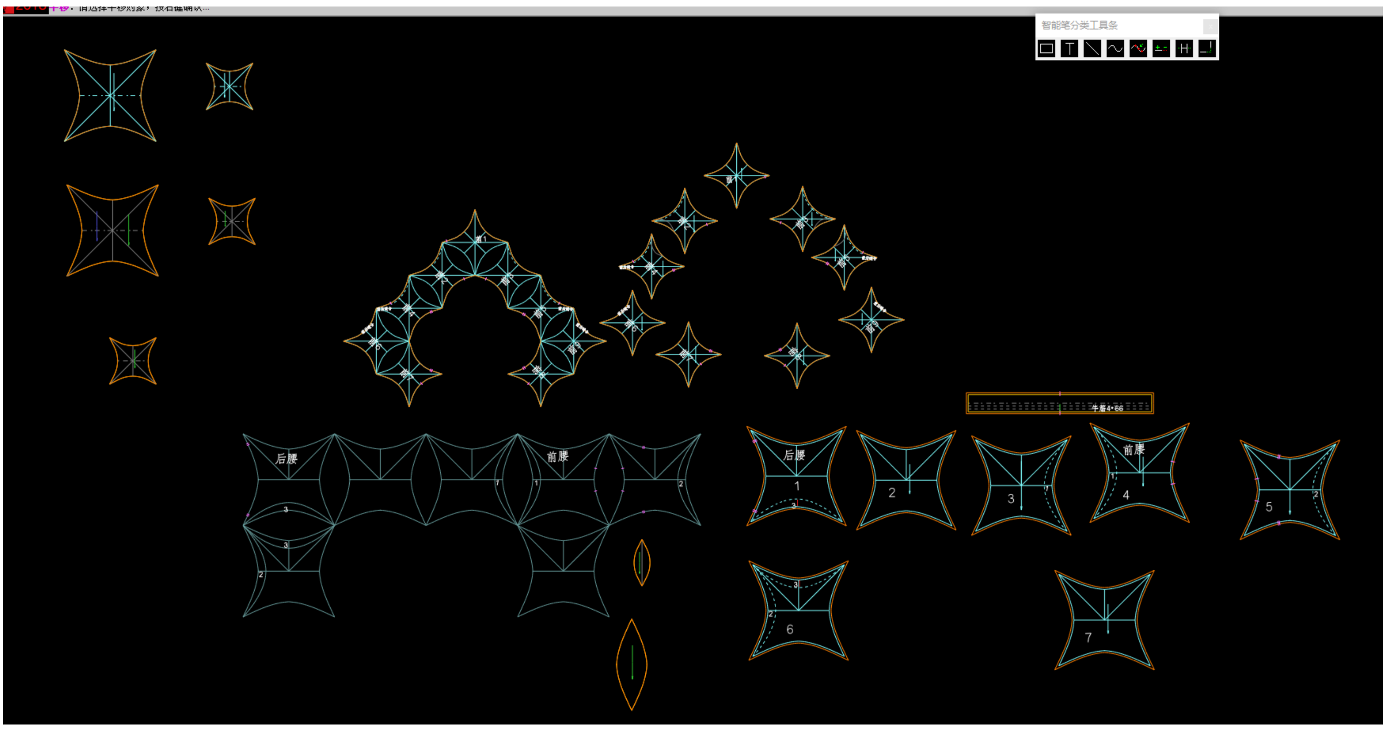

Figure 4.44 CAD visualization of seam construction from *HydraSkin*.

EcoFlow completes this material loop at the physical level. Covering the lower body and incorporating detachable leg components, it addresses waste processing and recycling, transforming waste into ecological nutrients. Inspired by the expanded wing contours of moths and the longitudinal rib structures of cactus stems, *EcoFlow* emphasizes segmentation, extension, and directional flow. Its structural development began digitally through experiments in arranging and combining residual materials. CLO3D simulations enabled rapid testing of seam configurations and assembly sequences, reducing additional fabric consumption during experimental stages and maintaining alignment with the principle of material conservation (Figure 4.47). Digital simulation served as a cost-effective filtering mechanism, comparing how different arrangements influenced leg mobility, visual continuity, and structural coherence (Liu et al., 2025).

Figure 4.45 Garment structure and silhouette of *HydraSkin*. Author's own work and photographed by the author.

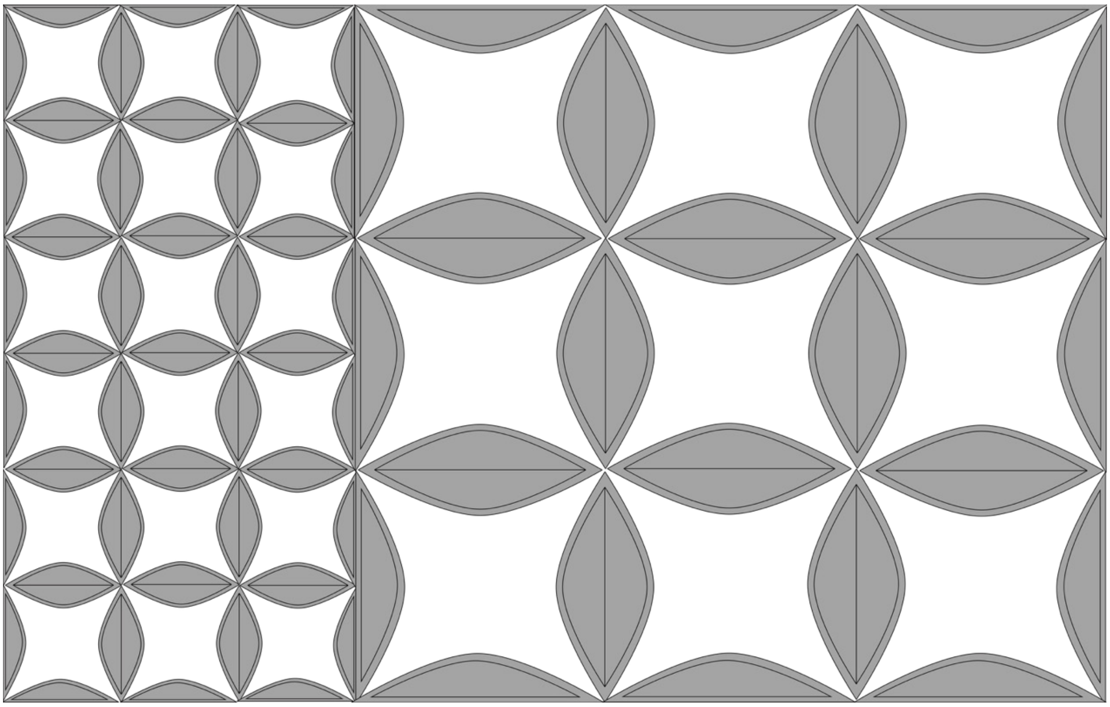

Figure 4.46 Pattern waste of *HydraSKin* (illustrated by the author).

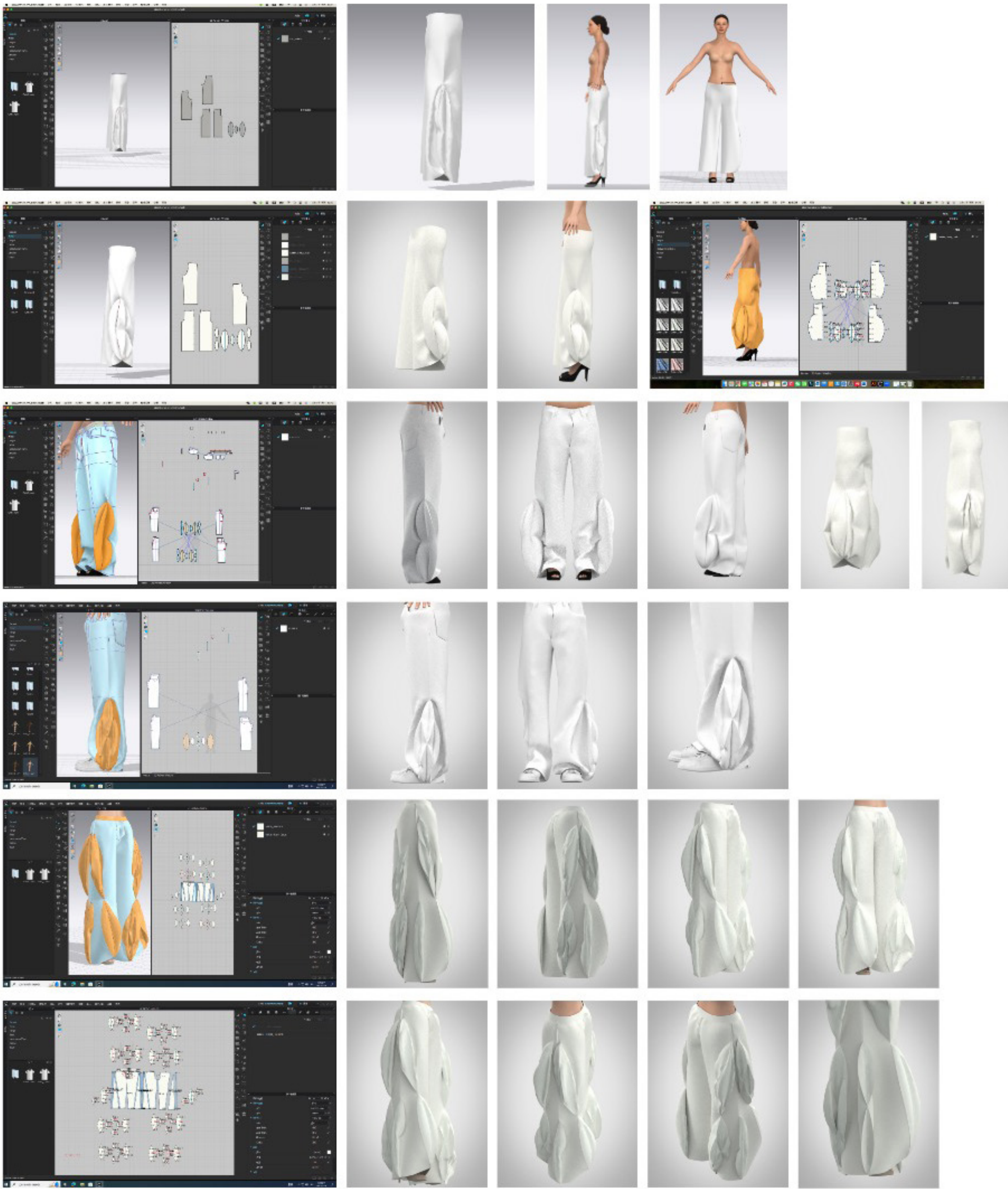

Figure 4.47 CLO3D simulation of seam arrangement experiments for *EcoFlow* (author's own work).

Nevertheless, digital simulation presents limitations when addressing highly three-dimensional draped structures, complex nonlinear seam relationships, and multiple collision interactions. Virtual garment behavior is heavily dependent on material parameter settings, solver configurations, and collision handling. Variations in these settings significantly alter wrinkle density, drape behavior, and boundary stability, sometimes producing unreliable deformation or unrealistic body conformity (Rudolf et al., 2016; Zangue et al., 2020). Moreover, the representation of non-standard materials such as breathable paper yarn remains constrained by parameter simplification and data approximation, increasing the likelihood of divergence between simulated and physical outcomes (Kim, 2025). For this reason, *EcoFlow*'s structural verification adopted a parallel digital-physical approach. The digital phase narrowed arrangement options and clarified seam logic, while physical fabrication tested actual load distribution and connection stability under gravity and movement, informing subsequent refinements.

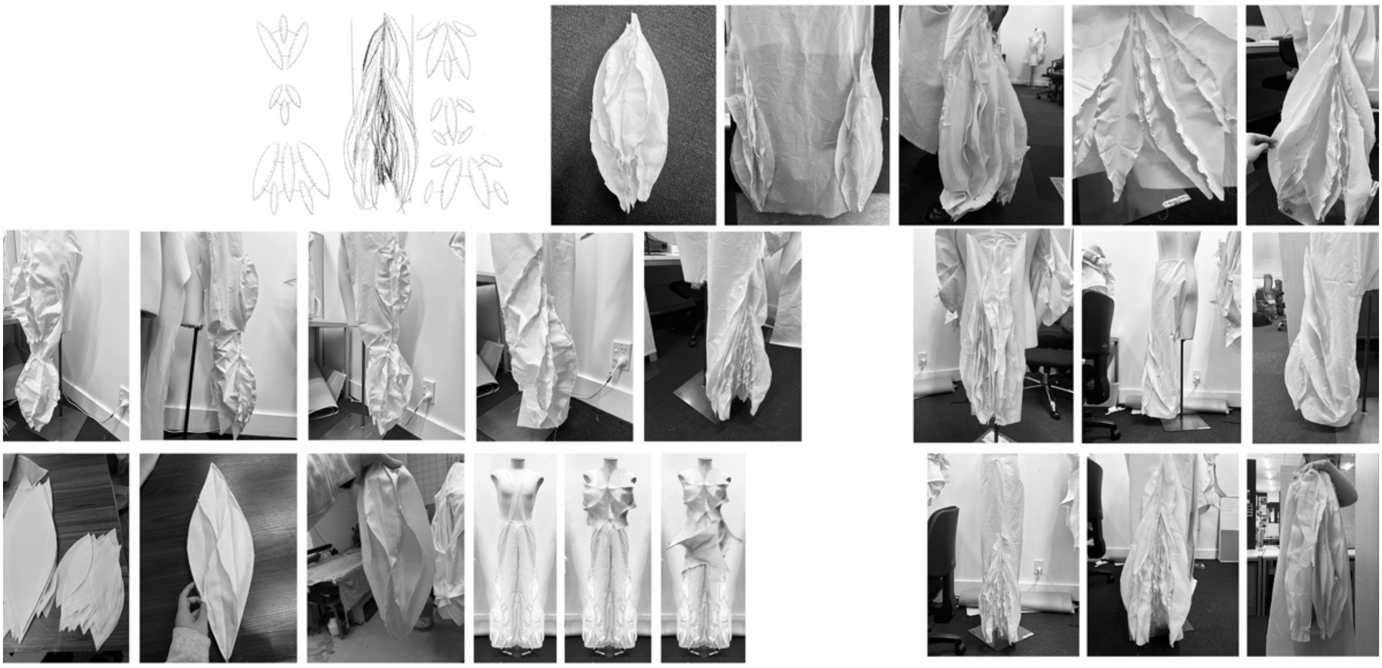

Figure 4.48 Reconfiguration of *HydraSkin*'s waste for *EcoFlow* (author's own work).

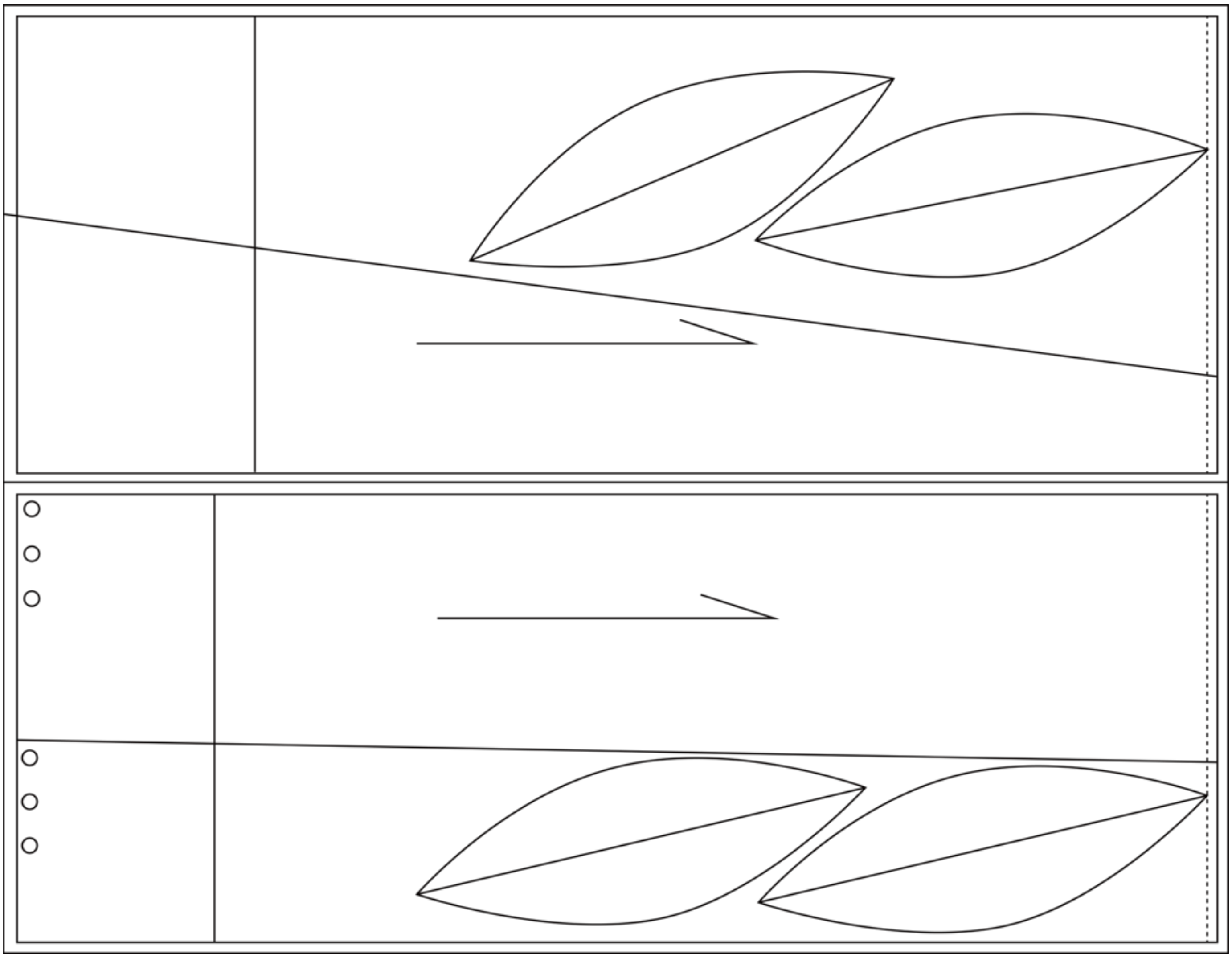

Figure 4.49 One-piece pattern development of *EcoFLow* (illustrated by the author).

Figure 4.50 Garment structure and detail documentation of *EcoFlow*. Author's own work and photographed by the author.

After digital selection, *HydraSkin* remnants were reorganized into textile combinations for *EcoFlow* and confirmed through physical stitching (Figure 4.48). *EcoFlow*'s primary structure was further developed as a one-piece pattern, integrating structural continuity and detachable logic through folding and opening placements while minimizing pattern fragmentation (Figure 4.49). Garment detailing allowed analysis of seam stability within remnant junctions and spatial consistency of the overall silhouette during dynamic wear (Figure 4.50). *EcoFlow* thus emerges as a reorganized outcome built upon *HydraSkin*'s material output, enabling material transition from a water-regulation interface to a waste-transformation interface.

These construction strategies were continuously adjusted through draping, pattern making, and garment assembly. Draping examined performance under bodily curvature, gravity, and movement. Pattern making translated spatial judgments into repeatable structural logic while integrating material efficiency and remnant allocation into a unified planning process. At the garment stage, the three modules were worn simultaneously, allowing differences in construction approach and material origin to be observed at a shared bodily scale and enabling comparison of how the overall construction logic operated in practice (Figure 4.51-4.52).

Through these material operations, construction becomes an integral component of ecological speculation. One-piece construction, zero-waste cutting, and material reuse collectively establish a system in which form, material flow, and resource logic are continuously negotiated. To facilitate cross-referencing of bodily coverage, inspiration sources, functional hypotheses, dynamic simulation strategies, and protective logics, this section also introduces four module information icons as navigational markers (Table 1).

Figure 4.51 Overall look of the three modules. Author’s own work and photographed by the author.

Figure 4.52 Fitting details of the three modules. Author’s own work and photographed by the author.

Table 1 Comparative in information diagram of the four modules.

Part Name	RespiraVeil	HydraSkin	EcoFlow	FloraCore
Body Area	Head and arms	Upper body to above knees	Lower body	Chest and sides of the waist
Inspiration	Chrysalis of Brenthis daphne butterfly	Cactus spines, geometric transformations, and draping experiments	Moth wings' shape and cactus stem's vertical ribbed structure	Cactus and desert dead tree branches, flowering function
Function	Filters and regulates air, protects the respiratory system, defends against dust and toxic gases.	Absorbs, stores, and circulates water, acts as a second skin, regulates body temperature and humidity.	Handles waste disposal and recycling, converts waste into nutrients for the ecosystem, promoting human-environment cycles.	Absorbs and stores nutrients, monitors body health, with projected blooming or wilting to indicate body conditions.
Dynamic Simulation Method	Projection simulates airflow and gas filtration visualization	Projection simulates water circulation and humidity regulation visualization	Projection visualizes nutrient circulation and waste transformation process	Projection simulates the blooming effect and feedback on health status
Protection	Dust, toxic gas, UV protection, temperate adjustment	UV protection, keeps skin moisturized under high temperatures	Antibacterial protection during waste processing, reduces pollution	Prevents dehydration and supports energy needs under high temperatures
Evolutionary Adaptation	Paper yarn remains lightweight and breathable in extreme climates, adapts to high temperatures and dust.	Absorbs moisture from the air, simulating natural water cycles.	Dynamically recycles and converts waste to promote ecological balance.	Shares energy with the environment, balancing human and nature.
Tool Material	Sustainable, recyclable paper yarn	Sustainable, recyclable paper yarn	Sustainable, recyclable paper yarn	Photosensitive resin (3D printed) + projection simulation
Fabric Size(M)	1.5*2	1.5*2.16	1.5*2	

4.7 Fashion installation and multimedia exhibition narratives

Global climate change functions as a hyperobject that is massively distributed in time and space with an inherent complexity and non-linear ecological structure (Morton, 2013). This immense scale dictates that a single physical garment cannot independently encapsulate the entirety of such a colossal system. Within the epistemological framework of Speculative Design, physical entities exploring adaptation to future extreme climates are conceptualized differently. The *Desertia* project operates as a diegetic prototype to investigate future survival paradigms instead of serving as a traditional design solution (Kirby, 2010).

However, isolated physical objects often suffer from a semantic void when stripped of their specific ecological contexts. Speculative artifacts must be anchored within a highly coherent process of world-building to activate their critical and narrative tension through interaction with their systemic environment (Dunne & Raby, 2013). Devoid of the enveloping spatiotemporal narrative, these design artifacts struggle to transcend their status as isolated objects to convey a systemic future experience.

Therefore, this section shifts the research focus from the physical and material development of adaptive clothing toward the spatial and multimedia mediums employed to construct a comprehensive systemic context. This shift is necessary to bridge the chasm between the macro-ecological crisis and the micro-bodily scale. Introducing fashion installations alongside moving image narratives places static physical prototypes into an environmental simulation where the digital and physical realms seamlessly intertwine. This cross-media translation dismantles the decontextualized limitations typical of traditional fashion displays. Furthermore, the approach synthesizes the preceding biomorphic explorations and structural experiments into a high-fidelity design fiction, transforming climate adaptation strategies into a perceivable, immersive and embodied scenario (Rocamora, 2017).

4.7.1 Spatializing speculation: setup and atmosphere

The spatial configuration of a speculative design exhibition requires an environment capable of fully immersing the audience within a specific future narrative. To achieve this necessary immersion, the *Desertia* project was installed within Spacelab for exhibition at Massey University. Spacelab is a specialized laboratory featuring a 270-degree immersive projection system. Selecting this specific venue deliberately moved the exhibition away from the traditional white cube gallery format and conventional commercial runways. Crossing into installation art shifts fashion beyond static presentation and establishes the designer as a core curator of immersive spatial narratives (Geczy & Karaminas, 2019). The panoramic projection feature envelops the physical space and isolates the viewer from contemporary reality to function as a crucial world-building apparatus (Bimber & Raskar, 2005; Grau, 2002). This controlled isolation establishes a foundational atmosphere that prompts the audience to temporarily suspend disbelief and fully engage with the speculative scenario.

The visual content projected across the 270-degree panoramic background forms a macro visual metaphor for the impending climate crisis. To capture the inherent complexity and unpredictability of climate systems, this research initially explored several advanced artificial intelligence models, including Sora, Runway and LTX Studio as tools for generating dynamic moving images. Following practical evaluation, LTX Studio was established as the core generative platform for this project due to its unique narrative scripting architecture. This system allows the researcher to construct visual sequences using a storyboard approach similar to filmmaking and traditional storytelling. Such a script-based control mechanism is particularly crucial for the context building of speculative design because it translates fragmented text prompts and extensive reference images into a logically coherent narrative timeline (Figure 4.53-4.54). Through this human AI collaborative editing process, the designer generated a series of continuous videos depicting a future desert ecology (Figure 4.55). The algorithmically generated raw footage presented a desolate non-human perspective and was subsequently imported into postproduction software for timeline reconstruction and color grading. Within the physical exhibition space, these preproduced visual assets were systematically imported into the professional live video mixing software Resolume Arena for playback control. I used this system to precisely schedule playback and seamlessly transition the 270-degree panoramic backgrounds distributed across the three projection walls, overlaying specific visual effects in real time as needed. This dynamic control technology transformed the physical space into a climatic theatre capable of evolving alongside the speculative narrative, significantly enhancing the immersive rendering of the macro-environmental atmosphere.

Concept Prompt:
A surreal yet scientifically inspired desert ecosystem shaped by centuries of climate change and human adaptation. The terrain features sculptural sand dunes interwoven with hybrid vegetation—translucent cacti, spore-emitting flora, and bioluminescent algae that glow subtly under a muted, filtered sun. Wind moves slowly across geometric rock formations. In the distance, semi-organic wearable shelters and structures blend with the land, reflecting biomimetic design. The atmosphere is dry, with occasional glimmers of life encoded in color, form, and subtle motion. A world that feels both alien and familiar—speculative yet grounded in environmental logic.

Special Requests:

- Include futuristic plant life inspired by cactus, Welwitschia, and desert fungi
- Add subtle movement (e.g., swaying plants, drifting dust, shifting light)
- Suggest extreme temperatures through lighting and color tones
- Avoid signs of modern civilization (no skyscrapers, no roads)
- Emphasize solitude, scale, and speculative beauty

Custom Format:

AI should weave a visual narrative of ecological evolution—starting with natural elements and gradually revealing signs of speculative adaptation.

Genre:

- Speculative
- Environmental conceptual art
- Bio-futurism / Ecological fiction

Tone / Mood:

- Surreal, meditative, quiet
- Awe-inspiring but solemn
- A balance of natural wonder and environmental urgency

Figure 4.53 Concept prompt in LTX Studio.

Breakdown

SYNOPSIS

In a future shaped by climate change, a surreal desert ecosystem emerges, blending nature and technology. Translucent cacti sway in the wind, emitting spores, while bioluminescent algae shimmer beneath a muted sun. Semi-organic shelters reflect biomimetic designs, inviting contemplation of humanity's role in this evolving world. The narrative evokes awe and urgency as it explores the delicate balance between adaptation and survival.

Scene 1 - Desert Introduction

A vast desert landscape with sculptural sand dunes and unique vegetation., August, 4:00 PM, muted natural sunlight., Clear skies with a dry atmosphere.

SCENE DESCRIPTION

A vast desert landscape unfolds, dominated by towering translucent cacti that sway gently in the warm winds. Their surfaces refract light into a stunning spectrum of colors that dance across the golden sands. Delicate spores float like whispers in the dry air, creating an ethereal atmosphere that captivates the senses.

Scene 2 - Bioluminescent Wonders

A desert area featuring geometric rock formations and bioluminescent algae., August, 4:30 PM, soft ambient glow from bioluminescent organisms., Clear skies with a dry atmosphere.

SCENE DESCRIPTION

The camera glides over bioluminescent algae shimmering beneath the muted sun, casting a soft glow on the geometric rock formations scattered throughout the desert. The algae's gentle illumination highlights the intricate textures of the rocks, which rise like silent sentinels against the warm backdrop.

Scene 3 - Semi-organic Shelters

An area in the desert with semi-organic shelters blended into the environment., August, 5:00 PM, warm golden light as the sun begins to lower., Clear skies with a dry atmosphere.

SCENE DESCRIPTION

As the viewer journeys deeper into the desert, they encounter semi-organic shelters that seamlessly integrate into the environment. These structures, inspired by local flora and fauna, exhibit biomimetic designs that reflect resilience and adaptability to extreme temperatures, blending harmoniously with the surrounding landscape.

Scene 4 - Contemplation of Humanity

A panoramic view of the desert ecosystem, showcasing the interplay of nature and technology., August, 6:00 PM, fading natural light transitioning towards dusk., Clear skies with a dry...

SCENE DESCRIPTION

The camera pans slowly, capturing the subtle movements of the plants and the drifting dust, suggesting the extreme temperatures of the environment. As the frame widens, it invites contemplation of humanity's role within this evolving ecosystem, reminding us of the delicate balance between adaptation and survival in the face of relentless climate change.

Figure 4.54 Narrative construction interface in LTX Studio.

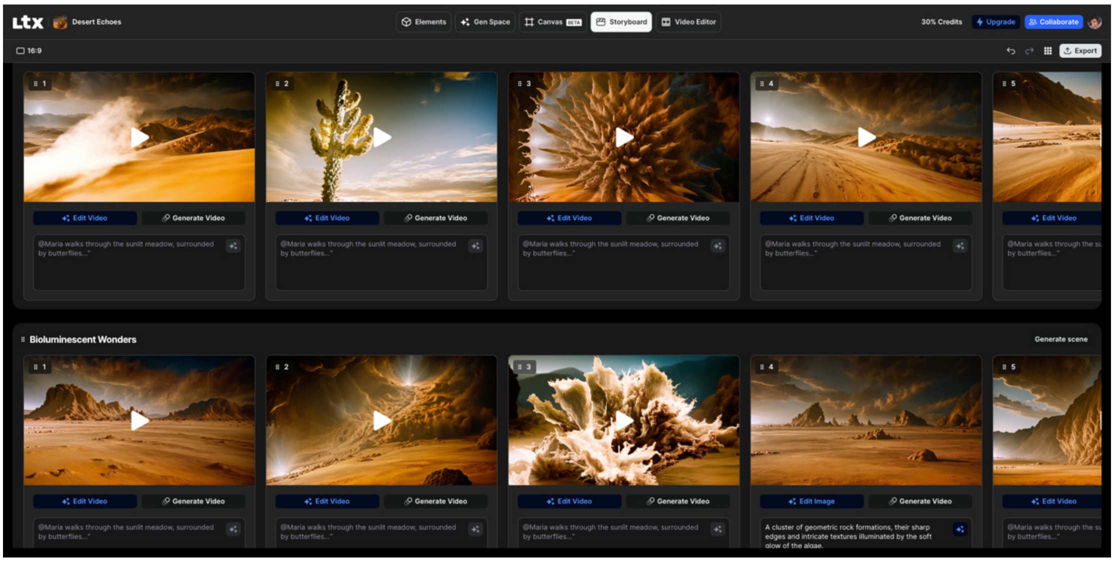

Figure 4.55 A collection of dynamic moving images of the future desert ecology generated by LTX Studio, see appendix for prompts.

Operating within this macro environment are four specific speculative wearable modules named *HydraSkin*, *RespiraVeil*, *FloraCore* and *EcoFlow*. The installation utilizes MadMapper software to project precise dynamic visual effects directly onto the biomorphic structures of these garments (Figure 4.56). These mapped visuals are abstracted image representations extracted according to the respective speculative functions of the four modules. Particular attention was paid during the research process to the holistic coordination between these micro-level local projections and the 270-degree environmental projection. The panoramic background establishes the harsh ecological reality while the precise projection mapping on the garments endows the surface textures with dynamic adaptive vitality. This dual projection strategy realizes a complex phygital synthesis. This term transcends the simple juxtaposition of different media to denote the deep ontological fusion of physical objects and digital interfaces within a real-time spatial installation, allowing material forms and virtual data to co-create an indivisible narrative whole (Mazzanti & Bonell, 2024). The precise visual dialogue between the clothing and the surrounding environment profoundly illustrates the interdependent and continuously reciprocating relationship between the human body and future ecosystems (Liu & Liu, 2025; Smitheram, 2015). These garments cease to be passive static exhibits and transform instead into active interfaces responding to the surrounding simulated climate data (Figure 4.57).

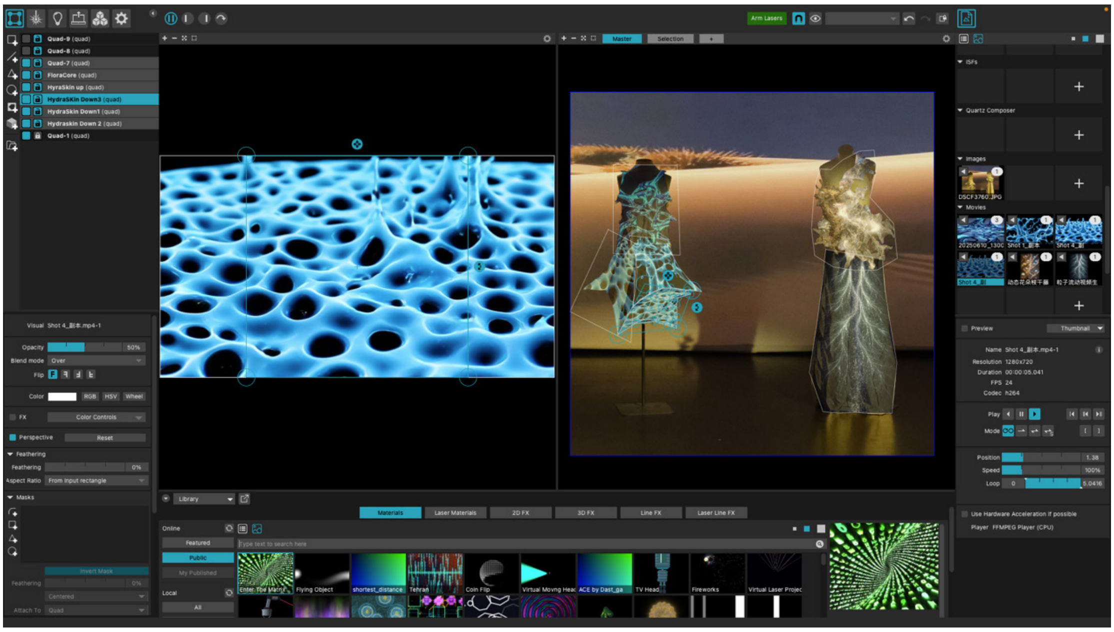

Figure 4.56 The MadMapper software interface for aligning dynamic images onto the physical garments.

Figure 4.57 Visual presentation of the phygital installation within the 270-degree panoramic projection environment (author's exhibition photograph).

A highly controlled lighting design further amplifies the physical perception of this harsh future climate. The spatial illumination strategy consists of a ceiling spotlight system and external professional equipment. During the on-site setup, I precisely adjusted the color temperature and brightness variations of the light using a DMX lighting console. Pushing the console faders allows the exhibition space to simulate the optical characteristics of various extreme weather conditions in real time, ranging from glaring midday sun to eerie dusty twilights. Framing shutters were simultaneously installed on the ceiling spotlights to strictly limit the illumination range, enabling the light beams to focus precisely on specific garment structures like laboratory observation lights. Furthermore, two freestanding diffusion boards were deployed on site. These diffusing devices break the harshness of direct light to create diffused reflections within the space, visually rendering the thick and suffocating atmospheric texture triggered by intense ultraviolet radiation and high temperatures in a future desert environment (Böhme, 2017). Ultimately, light, moving images and physical garments collectively weave an immersive climatic pressure field within the physical space (Figure 4.58).

Figure 4.58 Physical lighting interventions and control setup in the exhibition space (author's documentation photograph).

4.7.2 Moving image as an epistemic tool in design fiction

Within the context of speculative design, the moving image transcends being a mere exhibition documentation byproduct to become a core epistemic tool. Static physical garment prototypes are often confined to isolated displays of material form, whereas the image medium endows these biomorphic structures with explicit temporal dimensions and specific usage scenarios. Situating speculative design within audiovisual media effectively translates it from isolated objects into persuasive every day or future situations (Auger, 2013). Through the deep intervention of audiovisual language, speculative artifacts transform from passive objects of display into active narrative carriers. This media transition bridges the semantic gap between microphysical prototypes and macro ecological environments. The image medium acts as a bridge connecting physical entities with speculative scenarios, enabling the researcher to move beyond linear statistical climate predictions to clearly articulate the climate adaptive functions of the garments within a coherent *not here, not now* alternative reality, thereby significantly expanding the ontological boundaries of design imagination (Dunne & Raby, 2025).

To construct a rigorous audiovisual narrative, I employed a physical visual sequence construction method before formally entering the postproduction software. Initially, all footage captured at the exhibition site and during the pre-production stages was strictly categorized into static and dynamic shots. Subsequently, I took screenshots of these keyframes, printed them and uniformly categorized and named these physical artifacts. Through the logical arrangement of physical cards, the complex visual information was organized into five progressive narrative *phases*. This pre-editing workflow based on physical screenshots, ensured the video systematically integrated speculative concepts with the physical making process into a coherent timeline (Figure 4.59). To clearly demonstrate the structural allocation of this pre-editing stage, I organized the specific visuals, audio design and transition logic of each phase into a structured initial audiovisual editing script (Table 1). Building upon this, I further developed hand-drawn storyboard sketches to meticulously refine the specific screen composition, visual focal points and transitional relationships between shots (Figure 4.60). Specifically, the first phase establishes the macro background of extreme climate using future desert scenes and conceptual quotes as the narrative starting point (Figure 4.61). The second phase focuses on the functional analysis of the four speculative wearable modules (Figure 4.62). The third phase traces the materialization process, detailing 3D models, material testing and pattern development based on *one piece* and *zero waste* principles (Figure 4.63). To visually articulate these complex structural concepts, I utilized the Fusion page within DaVinci Resolve to construct node-based tracking lines and annotations, precisely pointing to specific garment structures to explain the sustainable pattern logic (Figure 4.64). The fourth phase displays the *phygital* integration and audience interaction within the exhibition space (Figure 4.65). Finally, the fifth phase concludes the narrative with reflective closing remarks and a macro panoramic view of the exhibition (Figure 4.66). These five structural phases were ultimately translated into a complex multi-track timeline within DaVinci Resolve, integrating numerous video layers and synchronized audio tracks to execute the comprehensive audiovisual narrative (Figure 4.67).

Figure 4.59 The paper edit process: Categorizing and logically arranging printed video keyframes before digital editing.

Table 2 The structured text script outlining the audiovisual narrative logic across the five editing phases.

Narrative Phase	Narrative Goal	Visuals	Shot Type	Audio Design & Transition Logic
Phase 1: Macro Context Establishment	Establish the irreversible climate collapse background and speculative starting point.	Future desert empty shots generated by LTX Studio; Intense direct sunlight shots with highlight clipping; Concept quotes fading into the center.	Static long shots, slow and oppressive.	Pure base noise (wind and sand), gradually increasing in volume to build spatial oppression. Slow cross dissolve transition.
Phase 2: Module Functional Analysis	Detail the specific functions of the four speculative wearable modules adapting to extreme climates.	Independent display of the four modules against a pure black background; Removing environmental interference to focus entirely on the garment and dynamic projection mapping.	Static shots, utilizing pure observation to reveal biomorphic structural details.	Maintaining the oppressive wind and sand base noise to create a vacuum and experimental feel detached from reality. Clean hard cut transition.
Phase 3: Materialization and Making Process	Trace the materialization of the design research and demonstrate sustainable principles.	360-degree dynamic effects and initial morphological explorations of 3D models; Details of 3D printed components; Physical recording of material testing; Flat lay of *one piece* and *zero waste* patterns.	A mix of static recording shots and virtual camera movement within the digital environment.	Continuing with the base noise, providing fundamental audio transitions matching the visual rhythm of scene changes. Montage quick cut transition.
Phase 4: Immersive Exhibition and Interaction	Present the spatial atmosphere of the phygital installation and elevate emotions to a positive climax.	Wide angle shots of the Spacelab 270-degree panoramic projection; Dynamic close ups of local projection mapping; Lighting interventions and audience interaction.	A mix of dynamic tracking shots and static angle shots to comprehensively capture spatial depth.	Environmental echoes pitch corrected (D/G key) and rhythmically controlled via Logic Pro, introducing soft, positive piano and guitar melodies as the dominant background score. Smooth cross dissolve transition.
Phase 5: Reflective Conclusion	Elevate the specific display to a macro climate reflection and conclude the narrative.	Panoramic freeze frame of the exhibition site; Screen fading to black; Reflective concluding remarks appearing.	Static wide-angle shots.	All live noises gradually fading out, leaving only the howling wind and sand base noise before fading out with the visuals. Fade to black transition.

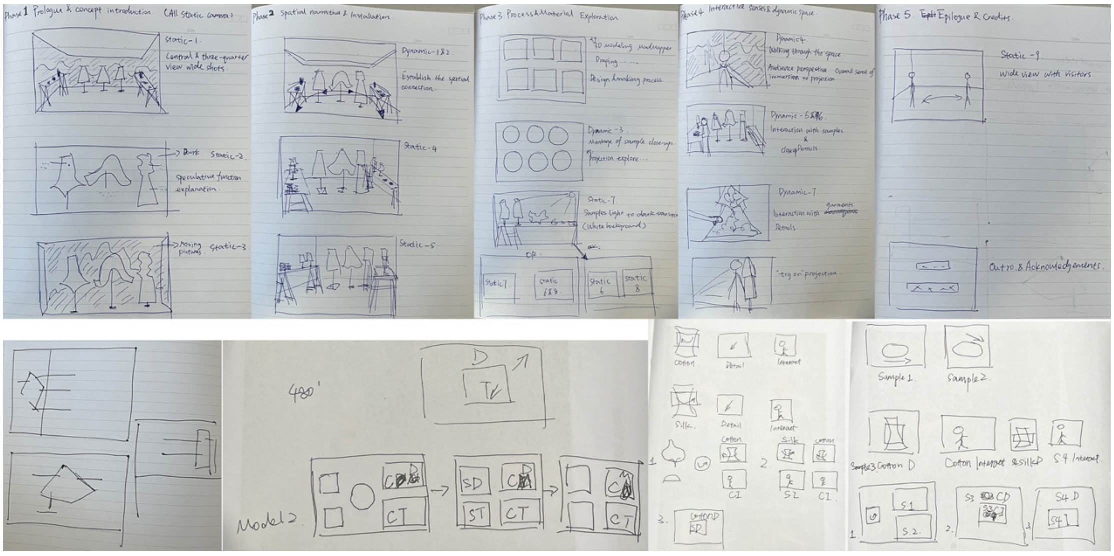

Figure 4.60 Hand-drawn storyboard sketches from the initial video editing phase, detailing screen composition and visual planning (illustrated by the author).

Figure 4.61 Phase 1 visual presentation: Establishing the extreme climate background through future desert scenes and concept quotes.

Note. Screenshots from the video generated using LTX Studio.

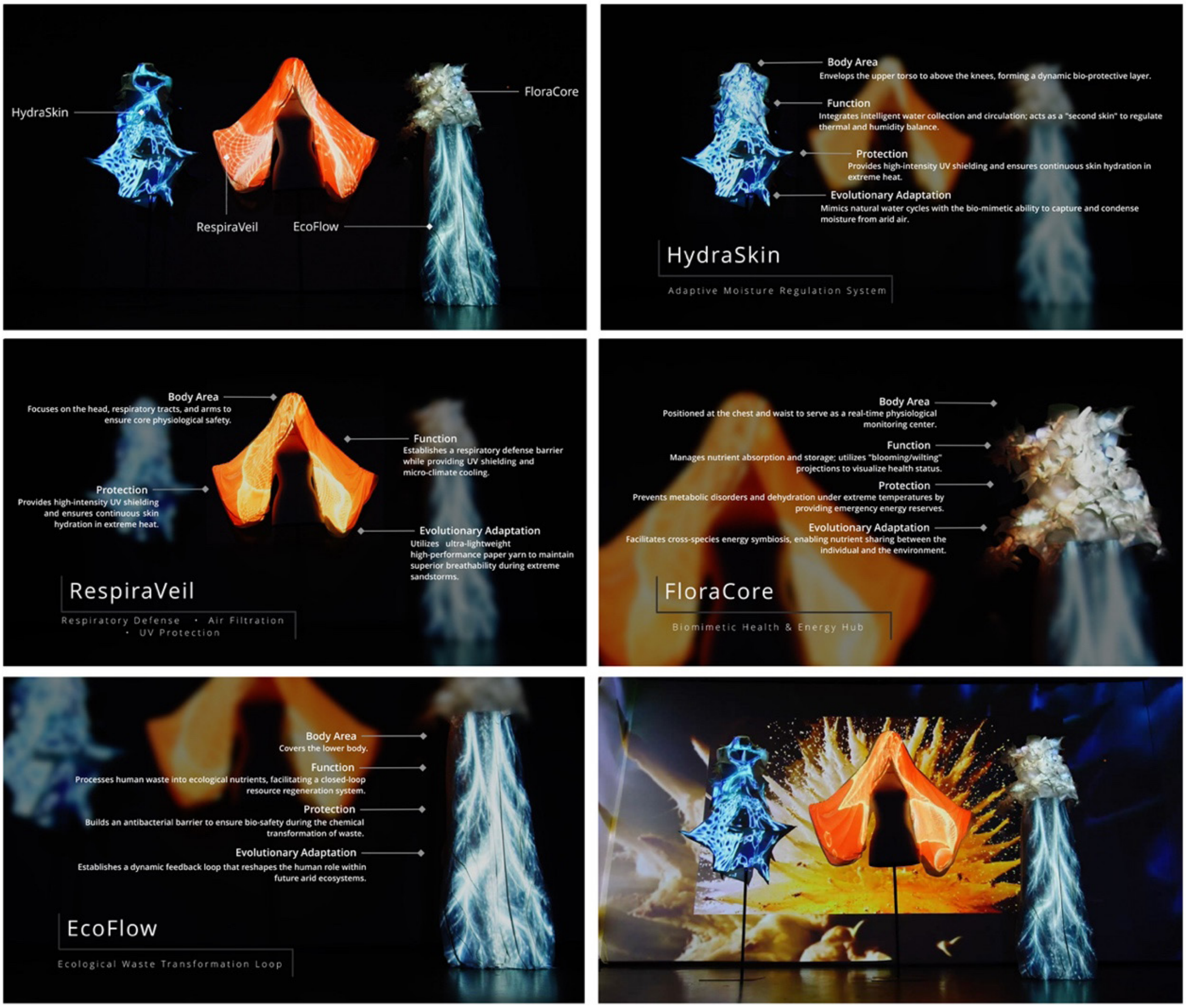

Figure 4.62 Phase 2 visual presentation: Detailed functional information of the four speculative wearable modules against a pure black background.

Note. Screenshots from the *Desertia* video edited by the author and photographed by Matthew Kelly.

Figure 4.63 Phase 3 visual presentation: Tracing the materialization and digitalization processes of the design exploration.

Note. Screenshots from the *Desertia* video edited by the author and photographed by Matthew Kelly.

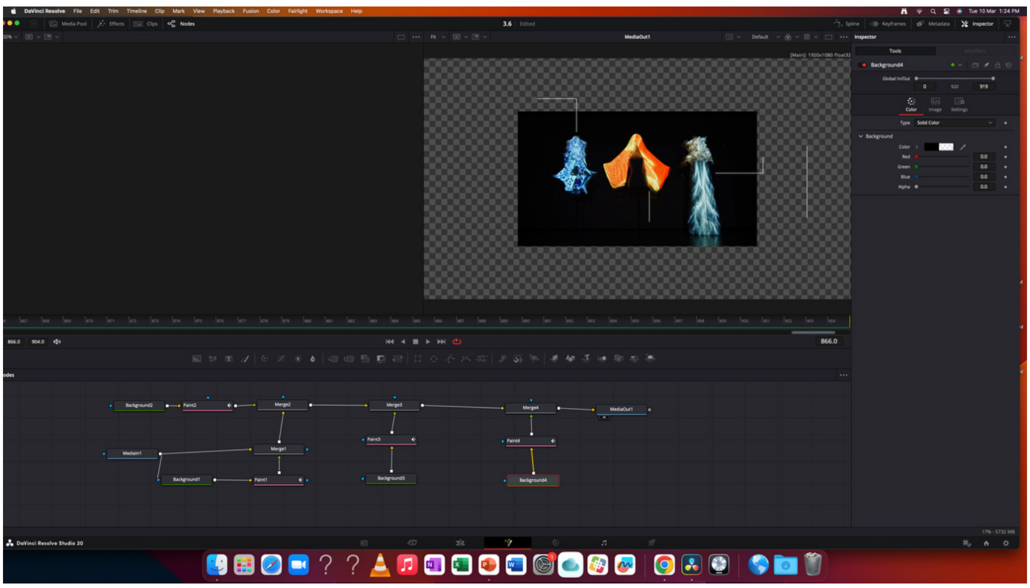

Figure 4.64 Phase 3 The visual annotation process using node-based tracking indicator lines within the DaVinci Resolve Fusion interface.

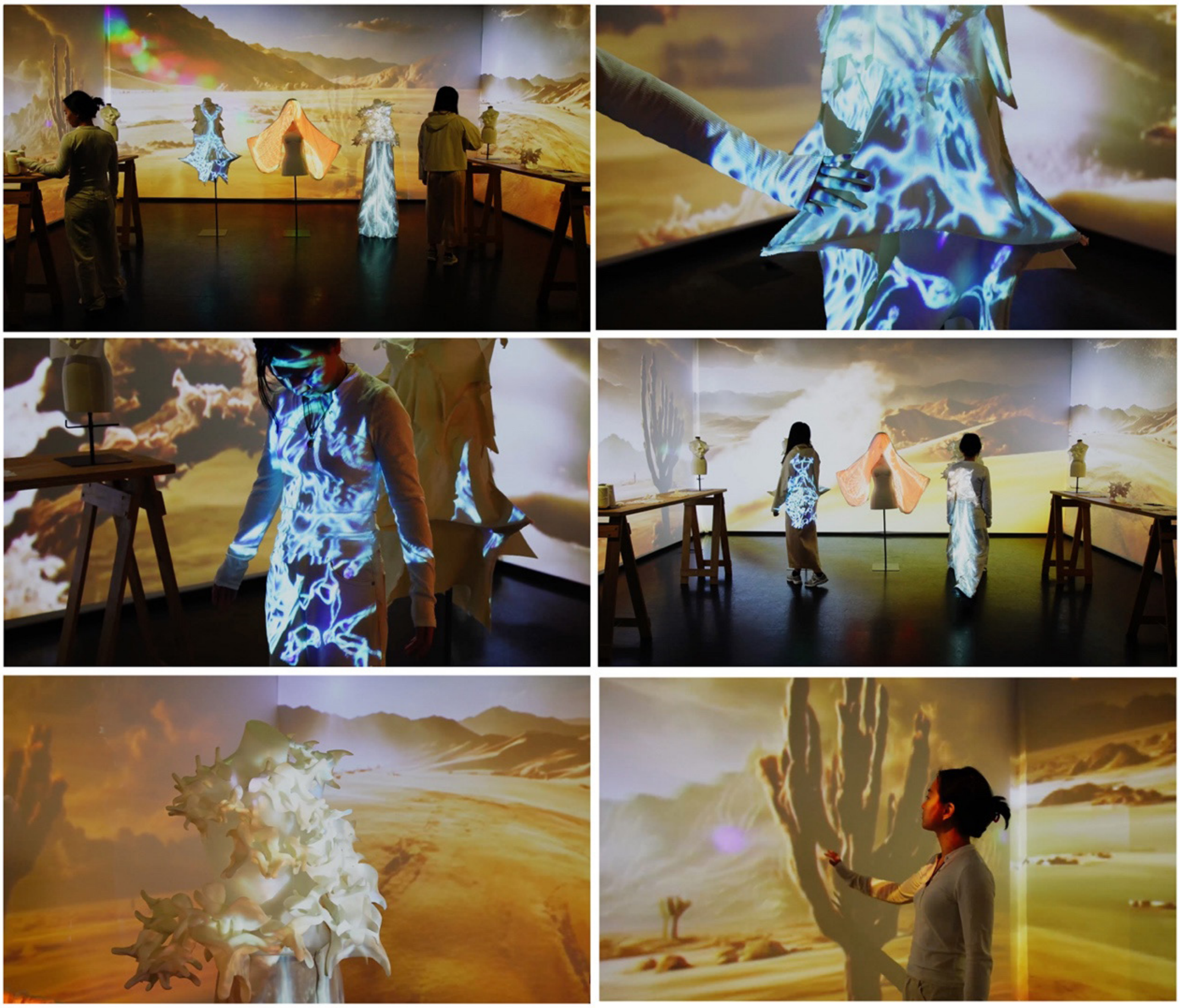

Figure 4.65 Phase 4 visual presentation: The phygital installation and audience interaction within the exhibition space.

Note. Screenshots from the *Desertia* video edited by the author and photographed by Matthew Kelly.

Figure 4.66 Phase 5 visual presentation: The narrative conclusion featuring reflective remarks and a macro exhibition panorama.

Note. Screenshots from the *Desertia* video edited by the author and photographed by Matthew Kelly.

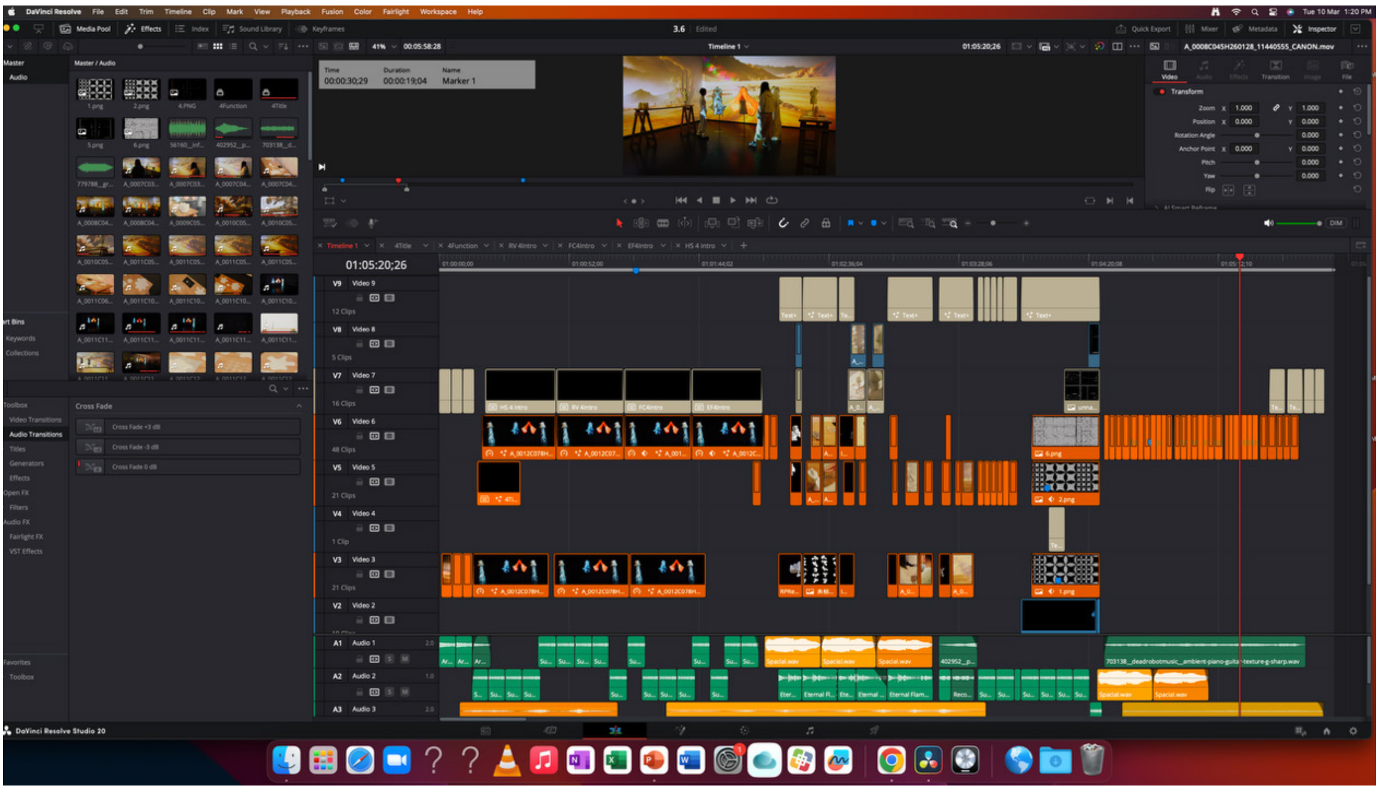

Figure 4.67 The overall multi-track timeline interface in DaVinci Resolve, illustrating the complex assembly of the five narrative phases.

Figure 4.68 The node-based color grading interface in DaVinci Resolve.

Color grading constitutes a crucial visual mechanism for reinforcing the theme of climate adaptation. During postproduction grading operations, I deliberately discarded the cold cyberpunk aesthetics common in conventional science fiction contexts to establish a desolate visual style characteristic of a wasteland. Beyond significantly increasing image contrast, I intentionally elevated the *saturation* of specific warm tones. By combining preset Color Look Up Tables (*LUTs*) with node-based custom grading for individual shots, the final visuals are dominated by extensive arid yellowish browns and scorched earth reds (Figure 4.68). This extreme color configuration directly simulates the physical oppressiveness of intense ultraviolet radiation and extreme high temperatures on a visual level, translating the abstract concept of ecological degradation into intuitively perceptible visual temperature (Haine, 2019).

Furthermore, the soundscape injects vital spatial realism and narrative depth into the design fiction. Regarding audio track processing, I not only extracted environmental sounds of desert sand blown by the wind to serve as a continuous base noise throughout the entire film but also utilized the professional digital audio workstation Logic Pro for deep intervention on all audio clips. To ensure the auditory coherence of multiple sound materials, I performed pitch correction on individual audio clips within Logic Pro, uniformly calibrating the originally disparate environmental sound effects and background scores to specific musical keys such as D and G. Simultaneously, I precisely reshaped the rhythmic variations of the audio clips using time stretching techniques to perfectly match the visual edit points across the five different phases. Building upon this highly unified auditory foundation, sound was utilized as a supportive tool for narrative progression with specific custom sound effects layered accordingly. For instance, pure micro material interaction sounds were introduced during the module analysis phase, while soft and positive piano and guitar melodies were incorporated during the fourth phase at the exhibition site to drive the emotional climax. This multi-layered auditory landscape, strictly controlled in both key and rhythm, not only fills the spatial perception beyond the visual frame but also forms strong synesthetic effects with the dynamic visuals, significantly enhancing the immersive psychological experience of the speculative scenario (Chion & Gorbman, 2019).

Ultimately, these meticulously choreographed audiovisual languages operate synergistically to establish a highly persuasive climate narrative. Transcending its role as an auxiliary tool for showcasing the physical design of the *Desertia* project, the moving image independently constitutes a profound practice of world-building. It conveys an unconventional reality concerning extreme climate adaptation to the viewer, compelling the audience to detach from contemporary comfort and confront the impending ecological crisis within an immersive sensory experience, thereby thoroughly fulfilling the core academic objective of speculative design to provoke critical reflection (Bleecker, 2022).

5.0 CONCLUSION

This chapter provides a systematic summary of the entire doctoral research. The content encompasses a review of the core research questions and objectives while outlining the practical trajectory and key outcomes of the *Desertia* project within the context of Speculative Design. Building upon this foundation, the chapter distills the academic and practical contributions of the study at the intersection of future climate change and fashion. By reflecting on the breadth of speculative scenario construction and the depth of audience engagement, this section objectively states the limitations of the research and subsequently explores directions for future interdisciplinary expansion in related fields.

5.1 Research review

Grounded in macro-predictions of global climate change and intensifying desertification, this research employs Speculative Design as its core methodology to explore the evolutionary morphology and interactive significance of clothing as both a physical and informational medium in extreme future environments. The thesis aims to address two central academic inquiries. The first involves exploring how to analyze the adaptive mechanisms found in nature and translate them into the structural and functional design of speculative garments. The second investigates how to construct a critical narrative of future crises through these designs to provoke public re-examination of the symbiotic relationship between humans, nature, and technology.

During the practice phase, this study conducted a materialized exploration and deduction of the aforementioned questions through the *Desertia* project. This initiative systematically produced four core garment components including *RespiraVeil*, *HydraSkin*, *EcoFlow*, and *FloraCore*. The comprehensive practice trajectory covered three pivotal stages, ranging from conceptual deduction and prototype fabrication to final presentation. The research established the speculative environmental characteristics of extreme drought and high temperatures, subsequently analyzing the survival strategies of specific organisms to translate them into functional metaphors and structural logic for the garments. In the prototyping phase, the study transcended the material boundaries of traditional clothing to construct three-dimensional conceptual prototypes by combining physical material experiments with digital tools. By embedding independent design components into a complete speculative narrative and integrating multi-sensory visual and auditory elements, the project achieved a systematic output that transitioned from singular garment design to an immersive future survival scenario.

The final outcomes of the *Desertia* project deeply address the academic hypotheses of this research from both methodological and medium-based dimensions. This practice successfully established a complete workflow from the analysis of biological strategies to speculative conceptual translation and ultimately to cross-media garment design. Concurrently, the project demonstrated the potential of clothing to surpass its physical protective attributes by transforming it into a speculative medium capable of carrying critical environmental discourse. By providing highly visualized and embodied solutions to climate crises, the findings of this study offer an innovative, non-textual academic paradigm for the fashion discipline to participate in discussions regarding future environmental and climate change.

5.2 Limitations of the research

The *Desertia* project exhibits certain boundary limitations in its speculative scenario setting. The investigation primarily focuses on the specific climate change prediction of extreme desertification. However, authentic future ecological crises are likely to manifest as a complex amalgamation of multiple intersecting climate events such as alternating extreme droughts and sudden floods accompanied by intricate socio-economic variables (IPCC, 2022; Zscheischler et al., 2018). To ensure depth in translating natural adaptive mechanisms into garment design, the construction of the future worldview in this study somewhat simplified the intersecting impacts of political, economic, or cultural dimensions in future societies. This concentrated research perspective inevitably resulted in a lack of sufficient diversity and complexity within the speculative scenarios.

Methodological gaps also exist regarding communication mechanisms and the evaluation of speculative efficacy. A core value of speculative design lies in provoking critical thinking and discussion among the public. When presented as conceptual prototypes in an exhibition format, the communicative effectiveness of the garment components heavily depends on the personal backgrounds and interpretive capacities of the audience. Current exhibition models lack sufficient interactivity, and the research framework is missing a systematic mechanism to objectively measure whether and to what extent these designs alter the subjective attitudes of the audience toward the climate crisis. The absence of employing sociological methods, such as structured interviews or audience feedback tracking, to obtain in-depth qualitative or quantitative data remains a common limitation in this study and in the broader field of Speculative Design (Malpass, 2017; Tharp & Tharp, 2018). Consequently, implementing these empirical methods to evaluate audience engagement with the resulting short film and physical installation stands as a primary recommendation for future research.

Sensory detachment within cross-media narratives constitutes another experiential limitation of this research. Although the study constructed an immersive speculative world using digital tools such as video rendering and sound design, the essence of garment design inherently relies on physical sensations, including touch and body mechanics. While physical garment components were produced during a future narrative process highly dependent on digital media, these works were primarily displayed as installations. Audiences were unable to personally wear the garments or authentically touch the biomimetic textures, which somewhat diminished the effect of embodied cognition. Embodied cognition theory emphasizes that human cognitive processes are not isolated neural calculations but are profoundly shaped and determined by the physical attributes of the body and its actual sensorimotor interactions with the environment (Varela et al., 2017). The absence of a genuine wearing experience restricted the audience's physical perception on tactile and mechanical levels, thereby weakening the completeness of the speculative experience.

5.3 Future research directions and concluding remarks

This research accomplished the visual and cross-media translation of biomimetic concepts within the framework of Speculative Design. To further broaden the academic frontiers of this field, future studies urgently need to break away from the path dependency of traditional physical manufacturing and extend deeply into synthetic biology and artificial intelligence-generated ecology. Intersecting Speculative Design with synthetic biology can propel biomimicry from mere morphological and functional imitation toward the authentic collaborative construction of living organisms. Future design practices could explore cultivating living textiles with self-healing or carbon-capturing capabilities to transform clothing into miniature, dynamic ecosystems. By integrating digital twins and multi-agent evolutionary algorithms, subsequent research could also build highly complex virtual climate sandboxes to allow speculative garment prototypes to undergo autonomous iteration and morphological evolution within dynamically generated extreme environmental data. Through the fusion of these advanced technologies, future Speculative Design research will gain more rigorous support in material transformation and data validation to perfect its theoretical closed loop as an interdisciplinary methodology.

Beyond technological advancement, future inquiry must also address the socio-cultural limitations and underlying assumptions of this work. *Desertia* conceptualises a generalised human future under extreme climate stress, intentionally isolating the fundamental relationship between body, clothing, and environment to explore adaptive mechanisms. However, this framework relies on the assumption of a universal demand for climate adaptation, which inevitably abstracts how environmental crises are experienced across differing geographies, cultures, socioeconomic conditions, genders, and physical abilities. Rather than proposing universal solutions for a specific user group, the Desertia garments are speculative propositions designed to provoke critical discourse. Acknowledging that the current work is not locally situated, future research directions could extend these speculative propositions into place-based and culturally grounded contexts, exploring how speculative design can address the nuanced, localized climate realities of specific communities.

Reflecting upon the deductive starting point of the *Desertia* project based on this methodological extension, the thesis has consistently strived to transcend the commercial and narrowly functionalist logic of the traditional apparel industry. Confronted with increasingly severe global climate shifts, this research explored and unveiled the vast academic depth of clothing as a speculative medium. By analyzing the extreme survival laws of natural organisms and translating them into tangible future survival gear, this dissertation expanded the disciplinary boundaries intersecting future climate change and fashion while providing an embodied pathway to re-examine human vulnerability and ecological ethics. In the speculative future vision, garments are no longer merely one-dimensional defensive barriers for humans to resist nature but rather evolve into dynamic interactive interfaces that precisely connect the physical body with extreme environments. Ultimately, this research hopes to inspire future fashion design systems to comprehensively move beyond purely aesthetic and consumerist attributes, adopting a rigorous and forward-looking academic posture to investigate the symbiotic laws between humanity and nature amidst complex crises.

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Appendix

AI prompts used in the design process

Figure 4.1:

Scenario 1: Submerged futuristic underwater city, deep ocean trench, glowing tiered towers, bioluminescent domes, filtering sunbeams, submersibles, cinematic lighting, photorealistic art.

Scenario 2: Scorching arid desert, geometric reflective gold and white modular habitats, dynamic solar shield framework, intense sunlight, lens flare, integrated cooling systems, surreal realism, high clarity, cinematic landscape.

Scenario 3: Vast frozen tundra, high-tech polar fortress city, sharp towering spires, wind-resistant aerodynamic architecture, pale cold sky, warm orange glowing interiors, wide shot realism.

Scenario 4: Colossal ancient forest canyon, eco-futuristic tree-integrated architecture, glowing energy domes, cascading waterfall, streaming canopy sunlight, harmonious bio-tech society, magical realism, highly detailed.

Figure 4.10: Futurism, high-tech minimalist interior, geometric, fluid lines, sculpture, abstract, cityscape, future humans, symbiosis of nature and tech, conceptual art, high-tech living, biomorphic design.

Figure 4.11: Natural integration, petal-like structured garment, pure white sculptural dress, minimalist, organic silhouette, highland backdrop, foggy mountains, raw landscape, avant-garde fashion, editorial fashion photography.

Figure 4.12: Floral headpiece structures, cactus shapes, futuristic fashion, film grain texture, retro-futurism, editorial fashion photography, natural ecosystem, conceptual avant-garde garments, surreal portraiture, organic architecture, 35mm film photography.

Figure 4.55: A surreal yet scientifically inspired desert ecosystem shaped by centuries of climate change and human adaptation. The terrain features sculptural sand dunes interwoven with hybrid vegetation- translucent cacti, spore-emitting flora, and bioluminescent algae that glow subtly under a muted, filtered sun. Wind moves slowly across geometric rock formations. In the distance, semi-organic wearable shelters and structures blend with the land, reflecting biomimetic design. The atmosphere is dry, with occasional glimmers of life encoded in color, form, and subtle motion. A world that feels both alien and familiar-speculative yet grounded in environmental logic.

Note: Tension is acknowledged in the use of AI for a project that addresses potential future scenarios and speculative design.