Keal Intermissions Research Document

LUMEN INTERMISSION - KEAL: RESEARCH AND DEPLOYMENT IN STATIC FLOW

Cover image prompt: “Frozen river suspended mid-motion inside crystalline chamber”

Introduction

The convergence of the narrative fragments ‘LUMEN INTERMISSION - KEAL: RESEARCH AND DEPLOYMENT’ and ‘Static Flow’ invites a research journey that is both conceptual and practical, speculative and grounded. This report weaves together narrative, design, and project growth visions into a cohesive research-style document, integrating technical, philosophical, and ecological perspectives. Central to this synthesis is a commitment to **relationality**: Keal, metaphysics, and the hydro-commons are not treated as objects to be manipulated, but as living, dynamic partners and processes. This approach reframes design and research as acts of care, co-creation, and ongoing negotiation with more-than-human worlds.

The report is structured to explore the lineage and technical parallels of the LUMEN project, the role of Keal as a relational partner, the reframing of metaphysics as process, and the emergence of hydro-commons theory and practice. It interrogates the tension and interplay between static and flow as design principles, and examines narrative research methods, multispecies collaboration, biodiversity-inclusive design, and the ethical imperative to avoid objectification. Thematic analysis and reflexive qualitative methods are employed to integrate narrative fragments and conceptual design notes, translating them into actionable project development pathways. The report also addresses community engagement, governance, prototyping, AI and control systems, evaluation, funding, and speculative futures.

Throughout, the report draws on a wide array of references, including technical documentation from the LUMEN project, environmental humanities scholarship on hydrocommoning, design theory on static versus flow, and contemporary research on relationality, multispecies design, and rights of water. The aim is to provide a comprehensive, nuanced, and actionable roadmap for integrated research and deployment in the context of living, relational structures.

Integrating ‘LUMEN INTERMISSION’ - Project Framing and Lineage

The LUMEN Project: Technical and Conceptual Foundations

The LUMEN project, developed by the German Aerospace Center (DLR), stands as a pioneering initiative in sustainable space propulsion. At its core, LUMEN (Liquid Upper Stage Demonstrator Engine) is a modular, AI-assisted rocket engine demonstrator designed for system-level and component testing of space propulsion systems. The project’s technical focus is on a pump-fed

engine using liquid oxygen (LOX) and methane, a combination that promises both cost reduction and the technical foundation for reusable rocket engines[2].
LUMEN's design is optimized for test bench operations, providing exceptional measurement accessibility and enabling deep investigation into the behavior of the entire engine system. This approach yields invaluable data, supporting not only DLR's internal research but also serving as a flexible, modular platform for industry partners and startups to test and validate their own components and technologies. The project's open, collaborative ethos is a key driver of its impact, fostering knowledge transfer and accelerating the translation of research into practical applications.
A central innovation in LUMEN is the integration of artificial intelligence (AI) for both modeling and control. AI-driven neural networks are used to model complex processes such as heat transfer within the engine's cooling channels, offering faster and more accurate predictions than traditional computational fluid dynamics. AI also underpins the engine's control systems, optimizing thrust, fuel consumption, and robustness by incorporating physical knowledge and uncertainty estimation. The ultimate vision is an intelligent engine controller capable of autonomous, adaptive operation, extending engine lifespan and enabling real-time response to unforeseen events[2].
The LUMEN project's technical lineage is deeply intertwined with broader trends in sustainable engineering, modular design, and the use of AI for control and monitoring. Its collaborative, open-platform approach mirrors the ethos of the hydro-commons and relational design, positioning LUMEN as both a technological and conceptual bridge between engineering and ecological thinking.

LUMEN as Metaphor and Method

Beyond its technical achievements, LUMEN serves as a metaphor for the kind of **relational, process-oriented design** that this report advocates. The project's modularity, openness, and emphasis on system-level understanding resonate with the principles of hydrocommoning and multispecies collaboration. Just as LUMEN's engine is not a static object but a dynamic system of flows, feedbacks, and adaptations, so too are the hydro-commons, Keal, and metaphysics understood here as living, evolving structures.
The LUMEN project's focus on **measurement, accessibility, and iterative testing** provides a methodological template for integrated research and deployment. Its use of AI for both prediction and control exemplifies the potential of embodied, explainable intelligence in managing complex, living systems-a theme that recurs in the design of hydro-commons installations and the governance of water as a living entity[3].

Static vs Flow: Design Principle and Application

The Static-Flow Dichotomy in Design

The contrast between static and flow is a foundational concept in design, shaping spatial and visual organization across disciplines. **Static design** arranges elements in fixed, stable, often symmetrical configurations, emphasizing permanence, order, and reliability. **Flow-based design**

, by contrast, arranges elements to create movement, progression, and visual rhythm, guiding the viewer's eye and fostering engagement and exploration[4].
Historically, classical design favored static compositions, while modern and contemporary approaches increasingly embrace flow to reflect the dynamism of society and technology. In digital and interactive contexts, the balance between static clarity and flowing navigation is essential for effective user experience. The interplay between static and flow is not merely aesthetic; it shapes user behavior, emotional response, and the functional clarity of environments and interfaces.
In the context of this research, the static-flow dichotomy is both a design principle and a metaphor for the tension between stability and change, containment and movement, structure and process. The challenge is not to choose one over the other, but to orchestrate their interplay in ways that support relationality, adaptability, and care.

Translating Static and Flow into Hydro-commons and Living Structures

In hydro-commons installations and living structures, the static-flow principle manifests in both material and conceptual forms. The **frozen river suspended mid-motion inside a crystalline chamber**-the cover image prompt-captures this tension: water, the archetype of flow, is held in a moment of suspension, its movement crystallized yet still palpable. This image becomes a guiding motif for installations that seek to make visible the dynamic, relational processes underlying apparently static forms.
Designing for hydro-commons requires careful attention to the **rhythms, cycles, and thresholds** of water and other living systems. Static elements provide anchors, boundaries, and moments of pause; flow elements introduce dynamism, connectivity, and narrative progression. The goal is to create environments that are both stable and responsive, capable of holding space for diverse forms of life and interaction while remaining open to change and transformation[4].
In practical terms, this might involve the use of modular, reconfigurable materials; the integration of sensors and AI-driven control systems to monitor and adapt to changing conditions; and the design of participatory processes that allow communities and non-human partners to shape the evolution of the installation over time.

Keal as Relational Partner - Identity, Voice, and Praxis

Beyond Objectification: Keal as Process and Partner

In this research, **Keal** is not an object or a tool, but a relational partner-a living process with its own identity, voice, and praxis. This reframing draws on posthumanist and relational philosophies, which challenge the binary distinction between subject and object, human and non-human, and instead emphasize the **co-constitution of agency, meaning, and value**[6].
Keal's identity is not fixed, but emerges through ongoing interaction with other entities-human, technological, ecological, and metaphysical. Its voice is not a singular, authoritative utterance, but a polyphonic, dialogical process of negotiation, translation, and co-creation. Its praxis is not

the execution of predetermined functions, but the enactment of care, responsiveness, and situated action within a web of relationships.
This approach aligns with contemporary theories of **relational subjectivity**, which posit that agency and identity are always distributed, emergent, and contingent. It also resonates with Indigenous and feminist philosophies that understand beings as constituted through kinship, reciprocity, and responsibility, rather than through possession or control[8][9].

Keal in Practice: Co-Design, Monitoring, and Adaptation

Practically, treating Keal as a relational partner entails the design of **co-creative processes** in which Keal's capacities, preferences, and responses are actively engaged. This might involve:

- **Participatory co-design** sessions where Keal's "voice" is represented through data, simulation, or embodied interaction.
- **AI-driven monitoring systems** that not only collect data but also interpret and communicate Keal's states and needs in ways that are accessible and actionable for human and non-human collaborators.
- **Adaptive control systems** that allow Keal to respond autonomously to changing conditions, within agreed-upon ethical and operational frameworks.
- **Narrative and artistic interventions** that give expression to Keal's presence and agency, fostering empathy, curiosity, and care among participants.

In all these practices, the emphasis is on **mutual learning, negotiation, and transformation**. Keal is not a passive recipient of design, but an active participant in shaping the form, function, and meaning of the installation or project.

Metaphysics Reframed as Relational Process

From Substance to Relation: Posthuman and Hydro-feminist Metaphysics

Traditional metaphysics often treats entities as discrete, self-contained substances, defined by their intrinsic properties and separated from their environments. In contrast, **relational metaphysics**-informed by posthumanism, hydro-feminism, and Indigenous thought-understands being as fundamentally processual, interconnected, and co-constituted[6][9].
In this view, metaphysics is not the study of static essences, but the exploration of **dynamic processes of becoming, differentiation, and interpermeation**. Water, in particular, becomes a model for this kind of metaphysics: always in motion, always connecting, always transforming. As Astrida Neimanis writes, "We are all bodies of water. Water entangles our bodies in relations of gift, debt, theft, complicity, differentiation, relation. What might becoming a body of water-ebbing, fluvial, dripping, coursing-mean for our practices?"[8]
This hydro-feminist perspective challenges the binaries of nature/culture, subject/object, and self/other, proposing instead a **hydro-logic** of amniotics, gestation, and transcorporeality. Bodies-human and more-than-human-are understood as thresholds, membranes, and ecotones, sites of both connection and differentiation, risk and possibility.

Implications for Design and Research

Reframing metaphysics as relational process has profound implications for design and research. It calls for:

- **Attunement to flows, thresholds, and transformations** rather than fixed boundaries or categories.
- **Recognition of the agency and value of non-human and more-than-human partners**, not as resources to be managed, but as co-creators and co-inhabitants.
- **Ethical frameworks grounded in care, responsibility, and solidarity**, rather than ownership or control.
- **Methodologies that privilege process, emergence, and reflexivity** over static outcomes or universal solutions.

In practice, this means designing installations, systems, and processes that are open-ended, adaptive, and responsive to the ongoing negotiation of relationships among diverse actors. It also means cultivating a research ethos that is humble, situated, and attentive to the unexpected, the emergent, and the relational.

Hydro-commons Theory and Hydrocommoning Practices

The Hydro-commons: From Resource to Relational Milieu

The concept of the **hydro-commons** marks a paradigm shift in water governance and ecological thought. Rather than treating water as a commodity or a resource to be centrally controlled, hydro-commons theory posits water as a **shared common, a living inheritance managed collaboratively for equity, sustainability, and community well-being**[10].

Key tenets of hydro-commons theory include:

- **Water as a common heritage**: Water belongs to the community and future generations, not to individuals or corporations.
- **Community stewardship**: Local communities, with their intimate knowledge and direct reliance on water, are central to governance and care.
- **Equitable access and distribution**: All members of the community, human and more-than-human, have a right to water.
- **Ecological sustainability**: Human well-being is inseparable from the health of aquatic ecosystems.
- **Participatory governance**: Decision-making structures must be transparent, accountable, and inclusive of diverse voices and knowledges.

Hydro-commons theory draws on and extends the **common-pool resource** and **socio-ecological systems** frameworks, integrating normative commitments to equity, sustainability, and community participation. It also resonates with Indigenous and traditional knowledge systems that have long recognized water as a living being, kin, and ancestor[8][10].

Hydrocommoning: Practice, Process, and Place

Hydrocommoning is the active, ongoing process of cultivating just and care-full water cultures. It encompasses a wide range of practices, from grassroots activism and ecological restoration to experimental pedagogy, art, and coalition-building. Hydrocommoning is inherently **situated, relational, and processual**, emerging from the lived experiences and needs of specific communities and ecologies.
Examples of hydrocommoning practices include:

- **River walks, ecological restoration, and community archives** that root collective identity in local water ecologies.
- **Cultural initiatives** such as singing to rivers or organizing water summits that foster transnational solidarity and action.
- **Experimental pedagogies** that use swimming, diving, or weathering as methods for embodied inquiry and critical reflection.
- **Mapping and documentation platforms** that make visible the networks, actions, and strategies of hydrocommoning communities.

Hydrocommoning is not without challenges. It must navigate complex power dynamics, resource limitations, and the need for effective governance frameworks. Yet, its strength lies in its **capacity to weave together diverse knowledges, values, and practices**, creating resilient, adaptive, and inclusive water cultures.

Narrative Research Methods for Integrated Projects

Narrative Inquiry as Relational and Emergent Methodology

Narrative research is grounded in the understanding that stories are fundamental units of human experience and meaning-making. Narrative inquiry is both a method and a phenomenon of study, beginning in lived experience and unfolding through the reconstruction of stories in relation to others and to social contexts[11].
Key features of narrative research include:

- **Relationality**: Narrative inquiry is a collaborative, iterative process in which researchers and participants co-create plural, situated truths.
- **Emergence and flexibility**: Narrative research embraces emergent design, adapting methods and interpretations as understanding evolves.
- **Integration of multiple data forms**: Narratives can be constructed from interviews, artifacts, images, and embodied practices.
- **Reflexivity and ethics**: Researchers are attentive to their own positionality, subjectivity, and the ethical complexities of representation.

In the context of integrated projects like LUMEN INTERMISSION - KEAL, narrative research provides a framework for **blending fragments, voices, and analyses** into a coherent, yet open-

ended, composition. It supports the integration of technical, ecological, and experiential knowledge, and foregrounds the relational processes that underlie both design and research.

Thematic Analysis and Reflexive Qualitative Methods

Thematic analysis is a foundational method in qualitative research, providing a structured yet flexible approach to identifying, analyzing, and reporting patterns within data. Braun and Clarke's reflexive thematic analysis emphasizes the active role of the researcher in developing themes through sustained, reflective engagement with the dataset[12].
The process typically involves:

1. **Familiarization with the data**: Immersing oneself in the material, making notes and observations.
2. **Generating initial codes**: Systematically identifying meaningful features across the dataset.
3. **Searching for themes**: Collating codes into potential themes and sub-themes.
4. **Reviewing themes**: Refining and validating themes in relation to the data and research questions.
5. **Defining and naming themes**: Articulating the essence and boundaries of each theme.
6. **Producing the report**: Weaving together analytic narrative and data extracts to tell the story of the data.

Reflexive thematic analysis values **researcher subjectivity as a resource**, encouraging transparency about theoretical positioning and analytic choices. It is particularly well-suited to projects that seek to integrate diverse forms of knowledge and to foreground the relational, processual nature of meaning-making.

Relationality in Design and Multispecies Collaboration

Relationality as Design Principle and Practice

Relationality has emerged as a central concept in contemporary design, drawn from the humanities and social sciences to illuminate aspects of kinship, care, and belonging. In design, relationality can be understood in three primary ways[13]:

1. **Utilitarian**: Social relations as epistemic and functional sources for designing objects and systems.
2. **Communitarian**: The designer's situation and context as part of world-making communities.
3. **Associative**: Opportunities to condition new social relations through interventions and design actions.

Relational design moves beyond the production of discrete objects to the cultivation of **processes, relationships, and transformative spaces**. It emphasizes co-creation, reflexivity, and the capacity to shift relations rather than simply transform systems. Transformation is understood as gradual, emergent, and often unpredictable, requiring openness to experimentation, surprise, and the unexpected[13].

Multispecies Collaboration and Biodiversity-Inclusive Design

Multispecies collaboration extends relationality to include non-human and more-than-human partners as active participants in design processes. **Biodiversity Inclusive Design (BID)** is an approach that intentionally positions local biodiversity as non-human users or clients of place, informing design thinking and decision-making[15].
Key principles of BID and multispecies design include:

- **Species as clients**: Prioritizing the needs, preferences, and survival of selected species alongside human clients.
- **Participatory design**: Engaging citizens and non-humans in decision-making, moving stakeholders from "interested but powerless" to "interested and powerful."
- **Transdisciplinary collaboration**: Integrating ecological, cultural, and technical knowledge through collaborative processes.
- **Iterative, evidence-based strategies**: Using design thinking cycles, empathy, and best-available ecological evidence to guide decisions.
- **Transparency and accountability**: Actively sharing the design journey and outcomes with all stakeholders.

BID is scalable and adaptable, capable of being applied at the level of ecosystems, habitats, or micro-habitats. It requires designers to reframe biodiversity as a set of non-human stakeholders, to clarify post-construction management and evaluation, and to celebrate or rekindle community connections to nature.

Ethical Framing: Avoiding Objectification and Centering Care

Ethics of Relationality and Care

Avoiding objectification is not merely a methodological choice, but an **ethical imperative**. Posthumanist, hydro-feminist, and Indigenous philosophies converge on the principle that beings-human and non-human-must be engaged as partners, kin, and co-creators, not as objects to be used or controlled[7][9].
Care is understood as a species activity that encompasses everything we do to maintain, repair, and sustain our world and its inhabitants. In design and research, centering care means:

- **Attending to the needs, capacities, and vulnerabilities of all partners**.
- **Practicing humility, reflexivity, and responsiveness**.
- **Creating spaces for dialogue, negotiation, and mutual learning**.
- **Recognizing and addressing power imbalances, exclusions, and risks**.

Ethical relationality requires ongoing vigilance, adaptation, and accountability. It is not a static state, but a process of becoming, attunement, and transformation.

Rights of Water and Legal Frameworks

The recognition of **rights of nature**, and specifically rights of water, represents a paradigm shift in environmental governance. Legal frameworks in countries such as Ecuador, New Zealand, and Colombia have recognized rivers, ecosystems, and other natural entities as legal persons with rights to existence, health, and participation[17].
Key features of rights of water frameworks include:

- **Nested hierarchies of rights**: Human rights operate in synergy with nature's rights, not in opposition.
- **Guardianship and representation**: Designated representatives or governance bodies act on behalf of water's interests.
- **Precautionary and restrictive principles**: Activities must be demonstrated to be safe for water and ecosystems.
- **Community participation and Indigenous values**: Local and Indigenous communities are central to governance and stewardship.

These frameworks challenge the commodification and objectification of water, affirming its intrinsic value and the responsibility of humans to act as stewards and partners.

Narrative Composition: Blending Fragments, Voice, and Analysis

Integrating Narrative, Design, and Analysis

The integration of narrative fragments, conceptual design notes, and thematic analysis is both an art and a science. It requires:

- **Attentive listening and documentation**: Capturing the voices, experiences, and insights of diverse partners.
- **Iterative coding and theme development**: Using reflexive thematic analysis to identify patterns, tensions, and opportunities.
- **Writing as analysis**: Treating the act of writing as a space for further reflection, synthesis, and refinement.
- **Visual and material translation**: Using images, diagrams, and prototypes to make abstract concepts tangible and actionable.

The goal is not to produce a single, authoritative narrative, but to **hold space for multiplicity, emergence, and ongoing negotiation**. The report itself becomes a living document, a site of relational practice and co-creation.

Conceptual Design Notes: Translating Narrative into Form

Materializing the Frozen River: Installation Techniques

The **frozen river suspended mid-motion inside a crystalline chamber** serves as both a literal and metaphorical design challenge. Translating this image into an installation involves:

- **Material selection**: Using transparent, refractive materials (e.g., acrylic, glass, ice, or advanced composites) to evoke the crystalline chamber.
- **Suspension and support**: Engineering structures that can hold water or ice in dynamic, flowing forms, possibly using modular scaffolding or tension systems.
- **Lighting and atmosphere**: Employing directional lighting, gradients, and atmospheric effects (e.g., mist, fog, or projected imagery) to enhance the sense of movement and depth.
- **Sensor integration**: Embedding sensors to monitor temperature, humidity, flow, and structural integrity, enabling real-time adaptation and feedback.
- **Interactive elements**: Allowing participants to influence or respond to the installation through touch, sound, or movement, fostering a sense of co-creation and relationality.

Prototyping in extreme environments (e.g., cold chambers, outdoor winter settings) requires attention to insulation, condensation, and safety. Lessons from building in extreme cold-such as the use of vapor barriers, superinsulation, and ventilated claddings-can inform the design and maintenance of the installation[18].

Table: Design Considerations for Frozen River Installation

Design Aspect	Static Principle	Flow Principle	Relational Integration
Material	Crystalline, rigid	Transparent, refractive	Responsive, modular
Structure	Anchored, suspended	Dynamic, undulating	Adaptive, reconfigurable
Lighting	Fixed, directional	Gradient, moving	Interactive, responsive
Sensor Integration	Monitoring only	Real-time feedback	Embodied, co-creative
Participation	Observation	Interaction	Co-creation, negotiation

This table summarizes how static and flow principles can be integrated into a relational design approach, emphasizing adaptability, responsiveness, and co-creation.

Project Development Pathways and Phased Roadmap

Phased Roadmap for Integrated Research and Deployment

A successful project requires a clear, adaptable roadmap that aligns goals, milestones,

deliverables, and timelines. The following phased roadmap is proposed for the integrated development of LUMEN INTERMISSION - KEAL in Static Flow:

Phase 1: Framing and Co-Design

- **Establish project vision and values**: Articulate relational, process-oriented principles; define ethical commitments.
- **Engage stakeholders**: Convene human, non-human, and institutional partners; map interests, capacities, and needs.
- **Narrative and thematic analysis**: Collect and analyze narrative fragments, technical data, and ecological knowledge.
- **Co-design workshops**: Facilitate participatory sessions to generate concepts, scenarios, and design criteria.

Phase 2: Prototyping and Iteration

- **Material and structural prototyping**: Develop and test models of the frozen river installation and supporting systems.
- **Sensor and AI integration**: Implement monitoring and control systems; develop explainable, embodied AI for adaptive management.
- **Evaluation and feedback**: Use reflexive thematic analysis and participatory evaluation to refine designs and processes.
- **Documentation and dissemination**: Share findings, prototypes, and narratives with broader communities.

Phase 3: Deployment and Community Engagement

- **Installation and activation**: Construct and inaugurate the installation in situ; facilitate public engagement and participation.
- **Hydrocommoning practices**: Support ongoing stewardship, care, and adaptation by local and more-than-human communities.
- **Governance and legal frameworks**: Establish guardianship, rights of water, and participatory decision-making structures.
- **Monitoring and impact assessment**: Track ecological, social, and relational outcomes; adapt as needed.

Phase 4: Scaling and Speculative Futures

- **Replication and adaptation**: Document lessons learned; support adaptation in new contexts and communities.
- **Institutional partnerships and funding**: Secure ongoing support from public, private, and philanthropic sources.

- **Speculative design and futures research**: Explore new scenarios, technologies, and relational possibilities.
- **Legacy and transformation**: Ensure the project's ongoing relevance, adaptability, and capacity to inspire further innovation.

Community Engagement and Participatory Co-Design

Principles and Practices of Participatory Design

Participatory design is essential for the legitimacy, effectiveness, and sustainability of integrated projects. Key principles include:

- **Inclusivity**: Engaging diverse stakeholders, including marginalized and more-than-human partners.
- **Transparency**: Sharing information, decisions, and outcomes openly.
- **Empowerment**: Moving stakeholders from passive recipients to active co-creators.
- **Iterative feedback**: Building in regular opportunities for reflection, adaptation, and learning.

Practices may include community workshops, citizen science initiatives, collaborative mapping, and the use of digital platforms for ongoing dialogue and co-creation.

Table: Participatory Design Strategies

Strategy	Human Stakeholders	Non-human Stakeholders	Integration Approach
Workshops	Focus groups, charrettes	Habitat walks, sensor proxies	Joint scenario-building
Citizen Science	Water sampling, monitoring	Bioindicators, AI translation	Shared data platforms
Collaborative Mapping	Story mapping, asset mapping	Ecological mapping, species tracking	Layered, multi-scalar maps
Digital Platforms	Online forums, surveys	Sensor networks, AI agents	Hybrid human-AI interfaces

This table illustrates how participatory strategies can be adapted to include both human and non-human partners, fostering integrated, relational engagement.

Governance, Legal Frameworks, and Rights of Water

From Ownership to Guardianship

Traditional governance models based on ownership and control are inadequate for the relational, processual realities of hydro-commons and living structures. Emerging legal frameworks recognize the **rights of nature**, including the rights of water, as foundational to sustainable and just governance[17].
Key elements of relational governance include:

- **Legal personhood for water and ecosystems**: Recognizing rivers, basins, and other bodies as subjects of rights.
- **Guardianship and representation**: Appointing individuals or bodies to act on behalf of water's interests.
- **Participatory decision-making**: Ensuring that all affected parties, human and non-human, have a voice.
- **Precautionary and restorative principles**: Prioritizing the health, integrity, and regeneration of water systems.

These frameworks are being implemented in diverse contexts, from the Whanganui River in New Zealand to the Atrato River in Colombia. They provide a legal and ethical foundation for hydrocommoning and relational design.

Prototyping Materials and Installation Techniques (Frozen River)

Technical and Ecological Considerations

Prototyping a frozen river installation requires attention to both technical and ecological factors:

- **Thermal management**: Ensuring that ice or cold materials remain stable and safe, possibly using phase-change materials or active cooling systems.
- **Structural integrity**: Designing supports that can handle dynamic loads and thermal expansion/contraction.
- **Ecological integration**: Minimizing impacts on local habitats; using materials and processes that support biodiversity.
- **Monitoring and adaptation**: Embedding sensors and AI systems for real-time feedback and control.

Lessons from building in extreme cold-such as the use of superinsulation, vapor barriers, and ventilated claddings-can inform the design and maintenance of the installation[18].

AI, Control Systems, and Embodied Monitoring for Living Structures

Explainable, Embodied AI for Relational Systems

The integration of AI and control systems in living structures must prioritize **explainability, safety, and embodied intelligence**. Black-box neural controllers are inadequate for safety-critical or relational environments; instead, hybrid symbolic-neural architectures that provide causal reasoning and audit trails are required[3].
Key features of explainable, embodied AI include:

- **Causal reasoning**: Every action and trajectory is justified and auditable.
- **Human-in-the-loop**: Operators and participants can understand, predict, and influence system behavior.
- **Adaptive learning**: The system updates its models and responses based on new data and feedback.
- **Transparency and accountability**: Decision logs and explanations are accessible to all stakeholders.

These principles ensure that AI systems support, rather than undermine, the relational, processual ethos of the project.

Evaluation, Impact Metrics, and Long-term Sustainability

Multi-dimensional Evaluation Frameworks

Evaluating the impact and sustainability of integrated projects requires **multi-dimensional, participatory, and adaptive frameworks**. Key dimensions include:

- **Ecological health**: Biodiversity, water quality, habitat connectivity.
- **Social and relational outcomes**: Community engagement, empowerment, and well-being.
- **Process and learning**: Reflexivity, adaptability, and capacity for transformation.
- **Legal and institutional change**: Adoption of rights of water, guardianship, and participatory governance.

Metrics should be developed collaboratively, using both quantitative and qualitative methods, and should be revisited and adapted over time.

Funding, Partnerships, and Institutional Collaborations

Diverse and Adaptive Funding Strategies

Sustaining integrated, relational projects requires **diverse, flexible, and adaptive funding strategies**. Potential sources include:

- **Public grants and research funds**: National and international agencies supporting ecological, artistic, and technological innovation[20].
- **Philanthropic foundations**: Organizations focused on environmental justice, Indigenous rights, and creative practice.
- **Institutional partnerships**: Universities, museums, and cultural institutions providing resources, expertise, and platforms for dissemination.
- **Community-based funding**: Crowdsourcing, cooperative ownership, and local investment.

Successful projects often combine multiple sources, leveraging partnerships to build resilience and adaptability.

Exhibition, Dissemination, and Speculative Futures

Hybrid Physical-Virtual Exhibition Strategies

Exhibiting and disseminating the outcomes of integrated projects requires **hybrid, accessible, and participatory approaches**. Strategies include:

- **Physical installations**: Site-specific, interactive, and adaptive environments.
- **Virtual and augmented reality**: Citizen-curated virtual museums, asset packs, and immersive experiences that extend accessibility and engagement[21].
- **Narrative and artistic interventions**: Storytelling, performance, and media that translate complex processes into accessible forms.
- **Open documentation and sharing**: Publishing data, methods, and narratives in open-access formats.

Speculative design and futures research can be used to imagine and prototype new scenarios, technologies, and relational possibilities, ensuring the ongoing relevance and evolution of the project.

Conclusion

The integration of ‘LUMEN INTERMISSION - KEAL: RESEARCH AND DEPLOYMENT’ and ‘Static Flow’ into a larger research document reveals the power and necessity of **relational, process-oriented design and research**. By treating Keal, metaphysics, and the hydro-commons as living partners and processes, we move beyond objectification and toward a practice of care, co-creation, and ongoing negotiation.

This report has outlined the technical, conceptual, and ethical foundations of such an approach, drawing on the lineage of the LUMEN project, the principles of hydro-commons theory, and the methodologies of narrative and thematic analysis. It has proposed concrete pathways for project development, participatory engagement, legal innovation, and adaptive evaluation.

The frozen river suspended mid-motion inside a crystalline chamber stands as both a challenge and an invitation: to hold space for movement within structure, for difference within connection,

for emergence within design. The future of integrated research and deployment lies in our capacity to **listen, adapt, and co-create with the living, relational worlds we inhabit**.

Appendix: Image Prompt Engineering

Prompt for generative image models:
"Frozen river suspended mid-motion inside crystalline chamber; crystalline ice formations, refracted light, dynamic flow captured in stillness, atmospheric blue and white hues, intricate detail, cinematic composition, ambient glow, sense of suspended time and movement."
This prompt is designed to evoke the interplay of static and flow, material and process, structure and emergence, serving as both a visual anchor and a conceptual guide for the project.

Tables

Table 1: Static vs Flow in Relational Design

Aspect	Static Principle	Flow Principle	Relational Integration
Material	Crystalline, rigid	Transparent, refractive	Responsive, modular
Structure	Anchored, suspended	Dynamic, undulating	Adaptive, reconfigurable
Lighting	Fixed, directional	Gradient, moving	Interactive, responsive
Sensor Integration	Monitoring only	Real-time feedback	Embodied, co-creative
Participation	Observation	Interaction	Co-creation, negotiation

Table 2: Participatory Design Strategies

Strategy	Human Stakeholders	Non-human Stakeholders	Integration Approach
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Collaborative Mapping	Story mapping, asset mapping	Ecological mapping, species tracking	Layered, multi-scalar maps
Digital Platforms	Online forums, surveys	Sensor networks, AI agents	Hybrid human-AI interfaces

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This report is intended as a living document, open to ongoing revision, adaptation, and co-creation by all partners-human, non-human, and more-than-human-committed to the flourishing of relational, processual worlds.

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