Products of Reflection

a practice that discloses the design potential of circumstantial phenomena

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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Products of Reflection

Abstract

This research project elaborates my creative interest in circumstantial phenomenal form generated through the design and use of objects. These phenomena are extraneous or incidental qualities generated in an object or product’s interaction with its circumstance; they don’t appear to belong or align to the object. Such circumstantial phenomena are frequently extraordinary in their form and complexity, but their subtle and contingent character push them to the periphery of awareness and design consideration. If acknowledged, they are deemed inconsequential, either out of practical necessity or due to (pre)conceptions of what constitutes and distinguishes the designed object. The project sets aside assumptions of extraneity and treats circumstantial phenomena as objects of investigation and design. It addresses the question of how consideration of these phenomena might expand a design practice. It speculates that unrealized creative dimensions can be derived from attending to circumstantial effects: unacknowledged dimensions of the objects that populate the designed environment, and unrealized capacities of a design practice that is drawn to these phenomena.

The research examines and elaborates form produced by refraction and reflection phenomena. These are explored in a process of making and generative experimentation, which increasingly pursues subsequent circumstantial results. The experiments produce a series of installation works and design propositions that use reflection effects as a medium of design and construction. Together, they reveal the phenomenal form making potential of mirror polished materials, objects, and products.

An alternative way of interpreting and expanding my design practice develops. Circumstance emerges as an autopoietic resource. Circumstantial phenomena, rather than extraneous and inconsequential, are revealed as expressing immanent capacities of objects in their engagement with their surrounds and other objects. They thereby offer new perspectives on the products of experimentation and design intentions. Consideration of these phenomena extends an inclination in my design practice to activate new possibilities with materials at-hand, by including the circumstantial phenomena at-hand. Acknowledging and activating circumstantial phenomena provide a means to generate unanticipated and innovative outcomes.
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PRODUCTS OF REFLECTION

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FIGURE 1.1–3. Detail of vehicle tail light.

FIGURE 1.1–4. Sun reflected off plastic sheet

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A single subtle and incidental refraction effect precipitates this research project. The subsequent work commences as a generative exploration of the form-making potential of this effect and then more comprehensively the phenomenon of reflection. It develops as two parallel investigations: into the design potential of reflection, and into the nature of my design practice. Each informs the other. Unrecognized capacities of both are progressively disclosed at the intersection of these investigations. The work is a succession of empirical experiments and insight derived from incidental results. Reflection develops as a mode to intervene and construct in the built environment, and a mode to expand a design practice. To convey this progression, the project is presented in a manner that describes the course (or network) of work and ideas as closely as possible to the way it was enacted.†

1.1 MISALIGNED LIGHT-FORMS

DISTINGUISHING LIGHT

Light is ubiquitous, but only indirectly evident: we cannot see the thing by which we see. Light reveals its presence only in its interactions with matter. Perceptions of it are usually coincident with material perceptions: the boundaries of an object seen correspond closely with the boundaries of the object touched. As the mediator of our primary mode of perception, light also remains necessarily withdrawn, so not to distract from the information it conveys. For this reason, matter tends to eclipse light’s presence. However, we do acknowledge light’s presence, as a thing independent from matter and what it communicates. We designate it as a particular entity, we give it a name. So, in what circumstances does light become present and distinct? In the case of this research project, light reveals itself in countless incidental misalignments with the material world. They may be in the guise of a sinuous light-form reflected onto a wall above a sunlit stainless-steel kettle or ceramic bathroom tile, or the reflected street furniture distorted in a vehicle’s polished panel-work, or the cityscape tessellated within the uneven glazing of a high-rise curtain wall. Such instances are abundant and pervade the designed environment, but they are typically overlooked.‡ As a product designer, discerning these incidental light phenomena compels me to speculate on the implications their recognition holds for my practice: what are the consequences of extending consideration to these circumstantial manifestations of light?

Light’s influence in the perception of space and form is well exercised in the disciplines of lighting design and architecture. The articulation and integration of light as artificial illumination and fenestration is effective and sophisticated. Despite this, these incidental light phenomena are disregarded even when

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† A note on annotations and referencing: The document incorporates frequent explanatory and contextual footnotes. These are indicated in the text with traditional symbols. To limit the number of footnotes, cited reference material is separated as numbered endnotes at the end of each section. Many of the explanatory footnotes include cited references. These are also numbered as endnotes, in sequence with those from the main text.

‡ There are exceptions. However, they focus on incidental instances of phenomenal form expressed in other media, such as colour and sound Ross McLeod’s work, Between Field and Form, and as atmospheres in Malte Wagenfeld’s work, Aesthetics of Air.

§ I use phenomenon to express “[…] a thing that appears, […] an occurrence, or change as perceived by any of the senses.”
they are a consequence of design activity. This is unsurprising. They are insubstantial and subtle, and not physically associated with or congruent to the object of design. If acknowledged, they are likely to be judged as ephemeral, or insignificant in an already complex array of design considerations. However, when examined, and as an objects of design, they offer a profound awareness of light as expressing countless obscure interactions between everyday objects. They reveal objects as implicated in their circumstance* in unexpected ways, and they disclose unrealized aspects or capacities of the objects in their relations with that circumstance. The small pivot away from what we typically consider the extent of a design object opens opportunities to influence, perhaps even reconceive, the built environment. The potential of this is explored in the following work, beginning with its implication for my industrial design practice (a practice, where light is typically implicit, or interpreted as lighting fixtures), and broadening to consider the implication for the practice of design more generally.

* Circumstance is another collective description. I use it for its expression of "that which surrounds." Circumstance is also associated with that "which is non-essential, accessory, or subordinate." It thereby implies a typical inclination to distinguish and rank things at the periphery of attention, awareness, or anticipation, as less significant or relevant than things that are attended. It is an inclination that the research attempts to subvert.

The circumstantial also relates to a dependence on circumstances. It represents a position the research adopts that designed objects are inescapably a product of circumstance, as much as they are a product of design specification. It also characterizes circumstance as full of "details or minutiae, minutely detailed; (and) particular," and thereby indicates a vast, intricate, and active domain. Circumstantial also has methodological implications, in its reference to the "[...] adventitious, accidental, incidental [...]" an aspect that becomes important in elaborating how circumstance might actively intervene in design process.
VINIC INSPIRATION

Light demonstrates its emergent potential as an object of design at a dinner table while distractedly fidgeting with an often present glass of red wine. The configuration of the glass, the level and type of wine, the harsh downlighting over a dinner table, and a moment’s distraction from conversation, conspire to reveal an extraordinarily beautiful diacaustic light-form* projected onto the table below the glass (Figures 1.1–1 & 2). It is strikingly complex, vivid and defined. The encounter occupies my design interest well after. It prompts a series of questions concerning the relation between the material object and the light phenomenon: should the luminous form projected onto the table be any less an aesthetic consideration in the design of a wine glass than its material form? Is it a dimension, or an aspect, of the designed product? Is it a thing (or object) itself, or, is it a manifestation of that particular circumstance? The speculations are explored prior to the project. The phenomenon is subject to informal experimentation, limited by time and resource (Figures 1.1–3 to 5). However, those early responses inspire a shift toward the periphery, a subtle expansion in the scope of my industrial design practice, beyond the design of material objects, to accommodate the incidental products† of light. They are the kernel of this research project.

Implicit in these questions are disciplinary, epistemic, and ontological uncertainties. Key amongst these is that light is inherently obscure. It is thus interpreted and expressed in diverse ways, each the subject of its own discipline: physics, optics, lighting design, and architecture. Each discipline has devised its own modes of manipulation and representation: as photons, ray diagrams, photometry; and others too numerous to list. However, my own practice of industrial design has limited vocabulary or discourse that significantly elaborates the role light plays in shaping the perception and the practice of designing products. Light holds a place, but it is implied and indistinct, typically addressed as a material surface property, a colour, or a finish. Even in my work designing light fixtures, the qualities of light are certainly an important consideration, but the emphasis and efforts remain on material considerations such as physical form, material properties, and manufacturing requirements.

However, to design a light fixture, or any other object, is to design a material product, but also an aethereal product, which inescapably entangles the object in its circumstance. Objects require light to reveal their presence and character, and light gives objects influence beyond their material boundaries. Light alters the appearance of surface (colour, highlight and shadow), but in doing so is itself obstructed, absorbed (coloured), and redirected. The light modulated by an object modulates the objects around it: the wine glass’s diacaustic projection alters

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* Caustics are networks of light often seen below the rippled surface of water or reflected off water onto a nearby surface. Diaustics are refracted, cataustics are reflected. They occur when a strong (point-source) light is reflected or refracted by an elaborately surfaced transparent medium and projected onto another surface. They are not without creative attention, occasionally the subject of artworks and installations.

† I attempt to extend familiar concepts, methods, and techniques of my industrial design practice to accommodate circumstantial light phenomena. I wish to interpret them as themselves products, potentially designed. However, in doing so, I evoke the root meaning of product as a consequence of actions, operations, or process. Here, a design product is an amalgam of material, conceptual, socio-cultural, and economic components, but is also a phenomenal composite, mediated by acoustic, olfactory, haptic, and visual actions, and thus a product of phenomena. The confining assumption that matter embodies these is loosened, I am constrained to manipulate matter, to in turn manipulate these ‘products’ (and thus the senses), but I need not be constrained to the conception that material form, or materiality itself, is the defining parameter. The conceptualization treats phenomena as the prima materia. Rather than subordinate light phenomena as a material property, matter is the circumstance of light’s manifestation. Objects delineated by light, aethereal products, need not correspond to any normative delineation of material objects.
FIGURE 1.1–1.
Downlight refracted by a glass of wine.

FIGURE 1.1–2.
Detail of refraction form refracted onto table.

FIGURE 1.1–3.
Halogen lamp refracted by a dish of moving dyed water (Parmington, 2000).

FIGURE 1.1–4.
Halogen lamps refracted by two suspended elliptical dishes water, intermittently disturbed to project animated light forms, installation for Chrysalis exhibition (Parmington, 2001).

FIGURE 1.1–5.
Detail of refracted animated light projection (Parmington, 2001).
the appearance of the table, and the light reflected off the table alters the appearance of the glass. However, the effects are neither a characteristic of table, nor glass, nor wine, nor light source. They are circumstantial, a manifestation of the inter-engagement all of these objects, including the viewer. All are affected in the interaction. This means that although we designate objects as individual entities, they do not exist in isolation. The unique interplay of light and object is elicited from the unique conditions at play in a particular instance. A different incarnation emerges with a change to conditions: the shape of the glass, the position of the light, surface of the table, or the variety of the wine. In this way light mediates an interdependency in the visual appearance of objects. Light, material, object, and circumstance thus are inextricably entangled. To design or even consider light and object, or light and circumstance, as distinct entities, inhibits a comprehensive appreciation of the implications of these interdependencies. It limits the articulation of the phenomenal* complexities of light fixtures, of designed objects, of circumstance. It obscures countless extraordinary capacities of the familiar objects that constitute the built environment.

The acknowledgement of these phenomena exposes a corollary limitation, a practical one. Any attempt to account for the circumstantial influences of light gets quickly tangled in a growing radius of relations. Where should the acknowledgment of implications with circumstance stop? What are the boundaries of a designed object? What should be (can be) designed, and what should be left to the conjuring of circumstance? The refracted light-form on the table, the reflected table distorted in the wine glass, the reflected room and its contents, the magnified weave of table cloth in the thick curved base of the glass, the ringing pitch of glass modulated by swirling wine after a toast – all become contributors. Distinction and focus are an inescapable necessity, though perhaps arbitrary; the research project is itself distinct in its attention to the phenomena of refraction and reflection. We ignore the potentially overwhelming number of phenomena around us in any given moment to maintain focus and fulfill purpose, vaguely and collectively designating them as extraneous or incidental. Although, just because we are unable to acknowledge the full extent of the happenings that constitute a circumstance, does not mean they do not occur, or that they are without implication or value. Such unacknowledged phenomena are ubiquitous, unaccountably outnumbering that which is recognized. They lie beyond attention, knowledge, and assumption. Distinction is necessary, but it can be wielded with an explicit awareness that what is defined is a mere aspect, a glimpse, of an inscrutably larger circumstance, that is capable of activating potential beyond familiar distinctions.

*I frequently use phenomenal as the adjectival form of phenomenon, that which is ‘[…] of the nature of a phenomenon.’ The project work characterizes objects and their circumstances as phenomenal. It regards objects as constellations of phenomena, where these phenomena are expressions of an object’s interactions with its circumstance. This phenomenal and relational understanding gives dimension and capacity to objects beyond normative material distinctions. As a consequence, the notion of phenomenal form emerges in the work, as a class of form that can be generated by material characteristics but can transcend those material characteristics or delineations. Here, insubstantial phenomena, or phenomenal form, can be the object of design. Specific to the work, the concept facilitates the recognition of objects and form generated by refraction and reflection. In everyday usage phenomenal is used to mean ‘[…] very notable or remarkable, extraordinary, [and] exceptional.’ While many of the phenomena I examine accord with this description, this is not the meaning I intend convey by using the term.
1.2 RESEARCHING THE CIRCUMSTANTIAL PRODUCTS OF LIGHT

The project responds with a provocation. It asks that phenomenal characteristics of a design object not be isolated to the material extent of the object; the qualities perceived as constituent of a thing are not necessarily the entirety of a thing. Here, circumstantial phenomena are regarded as congruent and consequential rather than a background to design activity, unconnected or incidental. The research explores them for what they reveal about objects and the creative process, and for their design potential. Inspired by the refraction effects of the wine glass, it initially investigates the caustics produced by transparent objects and materials. Attention is subsequently diverted by incidental reflection effects generated alongside the refraction effects, and reflection emerges as the primary subject of the research. Reflection is explored as a mode to design and construct objects at both architectural scales and as a component of domestic products. These explorations provide an opportunity to interrogate and elaborate a design practice intrigued by circumstantial phenomena.

1.2.1 CONTEXT

The project develops as a series of rapid experiments. Each generates and examines a circumstantial light phenomenon, but each also provides a reference point to survey comparative work of architects, designers, artists, and philosophers. In this way, the experimentation is a device to activate contextual connections. It gathers them into the research. It recontextualizes and reconstitutes them with the results and concepts developing in the experiments toward an alternative perspective of the designed environment and my design practice.

Reflection generates an extraordinary array of forms and spaces, which typically go overlooked in specifying the many polished surfaces of the designed environment. It is just beginning to be recognized and wielded as a design dimension in architecture. Most deliberate applications use reflection to camouflage structures into their environment or visually increase the perception of interior space. Works that employ reflection effects in consumer product design remain rare. The few direct applications tend to fall into the category of novelty products, such as kaleidoscopes, or anamorphic teacups. Discourse within the design disciplines that elaborates the techniques and methodological implications of working with reflection is limited. Overall, there is a little appreciation of the influence reflection exerts and its potential. Existing works that explore effects comparable to the phenomena examined in the experiments are acknowledged throughout the research.

The research refers to the work and writings of several installation artists. Works by Robert Smithson, Anish Kapoor, Olafur Eliasson, Robert Irwin, Dan Graham, and James Turrell are particularly relevant. They supplement a limited design discourse with work and writing that demonstrates a profound interrogation and understanding of reflection. Their emphasis on

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1 The combination of these two expressions as circumstantial phenomena alludes to a plethora of unacknowledged phenomena that inhabit the periphery of any attended situation. It indicates their unrecognized implication and significance in the manifestation of circumstance, where phenomena are expressions of the hidden interactions of circumstance. I acknowledge this extends typical notions of ‘phenomena,’ as being things perceived ‘by’ the senses, or ‘by’ someone.

2 See section 2.3.8 A Stainless-Steel Pot-handle.

3 A detailed survey of comparative work and discourse which explores refraction and reflection, both in design and arts practices, is provided with the description of the experiments in chapter 2 (rather than as an introductory review). The exploratory nature of the research means that its context is revealed with its outcomes, and I endeavour to convey the work and its broader implications as they happened.

4 Specifically, Smithson’s Yucatan Displacements and other mirror works; Anish Kapoor’s mirror works and notions of “non-objects;” Eliasson’s foregrounding of phenomena as the material of art; Irwin’s minimal interventions; Graham’s interplay between the reflectivity and transparency of glass; and Turrell’s materialization of light.
rendering phenomena and circumstance as the subject of art practice over material (object) works offers a cue for a similar proposition in design.

In analysing the work, I later refer to ideas being debated in Object-Oriented Ontology,* specifically the writings of Levi Bryant and Ian Bogost. The work of anthropologist Claude Lévi-Strauss is also referenced. I use Bryant’s (and Bogost’s) interpretation of the immanent capacities of things in combination with Levi-Strauss’s interpretation of bricolage† to unravel and express creative and circumstantial mechanisms at play within the research and my design practice.

1.2.2 METHODS

The research methods commence as a curious amalgam of industrial design, physics, geometry, installation art, and qualitative research methods. Model-making techniques are a key mode of generative idea development, and to a lesser extent computer-aided design. Physical behaviour of refraction and reflection are examined and analysed according to the physics of optics. Perceptual experiences of the phenomena are investigated as installations or interventions in an approach akin to an installation art practice. Conjecture is tested and explored as experiments. The methods are combined in a methodology that has similarities to emergent research approaches employed in social sciences.

EXPERIMENTATION

The various activities that constitute the research are described as experimentation. However, the experiments are not the reductive, rigorously controlled procedures designed to prove or disprove a hypothesis, which might be expected in normative research contexts. Each has an experimental quality in its focussed interrogation of a visible phenomenon, but conjecture and speculation are more appropriate ways to characterize the propositions that drive the work. Even then, the experimentation is, in large part, a generative activity. Consideration of the outcomes is not confined to the determinations that initiate the experiment. Attempts to test conjecture act more as a provocation than an experimental objective. They are used to activate possibilities and generate a variety of outcomes. The results serve to inform further conjecture, and thereby generate further process, material and phenomena. Unanticipated outcomes, failures, and mistakes often present as compelling as those conjected, rendering intentions‡ obsolete.

The experiments are typically rough, but profuse. The emphasis is on the rapid generation of examples, cases, and possibilities toward an extensive body of work situated around the key themes of the research. Some test a speculation; some analyse phenomenal mechanisms; others combine disparate elements of previous experiments without definitive expectation. The aim is to study the mechanisms at play in number and diversity, to reveal design potential in an accumulated appreciation of their varied manifestations, rather than in a targeted and comprehensive investigation. This provides a wide resource that is surveyed, analysed, and compared, from various perspectives, in a search for essential characteristics and interpretations.

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* Object-Oriented Ontology places objects at the centre of interrogations of the nature of being. 19 “placing the human and the nonhuman on equal footing.”20 Relations between objects are afforded a significance equivalent to relations between humans and objects.21

† The technique of employing and adapting what is at-hand to realize what is envisaged.22

‡ I consciously use intention for its multiple connotations in everyday use and philosophy. In ordinary usage it expresses a pre-determination, “that which is intended; a purpose, design.”23 In philosophy it expresses “the direction or application of the mind to an object — a conception formed by directing the mind to some object,”24 or as intentionality, “[…] the directedness of experience toward things in the world, the property of consciousness that it is a consciousness of or about something.”25 In classical (Husserlian) phenomenology, “[…] our experience is directed toward —represents or ‘intends’— things only through particular concepts, thoughts, ideas, images, etc.”26 Within the context of the research, the action of intention, of determination, of directing consciousness, and of conceptualizing predicates an exclusion of the stuff that is unintended, and unacknowledged. I collectively interpret these excluded things as the circumstantial. They are the subject of the research.
Most experiments are performed in the sequestered laboratory setting of my studio workshop or exhibition space, but they also comprise site installations, interventions, and design propositions. Each is concerned with the mechanisms that generate refraction and reflection phenomena, their technical characteristics and principles. As knowledge of these mechanisms grow (from both anticipated and unanticipated results), the modes of generation, analysis and interpretation also evolve.

MAKING

The methods develop with reflection on my own design practices in an introspective process that extends familiar methods. Hand-made models and prototypes hold an unusually significant place in my general design practice. Making is a way of thinking as much as a way of creating; it is a way of realizing in both substantive and cognitive senses. It can also be a way of projecting beyond what is envisaged in a generative (or emergent) process.

The emphasis on an essentially material mode of design may seem contradictory to interrogate the immaterial realm of light. However, the activity is instigative in the expression of these phenomena. It is used as a method of investigation, where I “[...] discover the ‘what’ of things through acting upon them or through the investigation of how they are acted upon by other entities.” Moreover, making offers an intimacy with the object of research (and the object of design) not possible in representational modes. The subtlety and complexity of the examined light phenomena demand that they be experienced to fully appreciate them.

Consequently, most of the research work is empirical, a hands-on manipulation of materials to generate light phenomena, eliciting light to understand light. Even so, there are instances where representational modes are used, particularly computer-generated models, to assist with visualizing and understanding the more inaccessible or geometrically complex manifestations of reflection phenomena. They enable me to explore and realize forms beyond those which can be physically accessed or visualized in material modes.

THE HOARD

To understand my making practice, the experiments, and the research approach requires an acknowledgement of an aspect of my creative practice: the assorted materials, offcuts, salvaged components, obsolete jigs, and broken tools, gleaned and accumulated from twenty-five years of making things. With every project, there is the product of making, and then there are all the by-products of that making process. The number of these contingent products is consistently and disturbingly immense; their generation is a significant ethical challenge, one that I am yet to entirely reconcile. They are kept and recycled as much as available storage space will allow. This is in part to minimize consumption, but also because these typically-discarded things seem to emanate potential. I recognize in each of them an immanent value beyond immediate purpose. This is frequently realized when one of these items proves to be influential, not in its repurposing as a solution to a problem, but by inspiring a re-conception of the problem in its re-purposing, providing a novel approach to the overall task. The hoard is a way of activating possibilities and a consistent source of rich design potential.

The research experimentation in part develops from (and is thus defined by) several items from the stockpile. Although, the items are not extracted arbitrarily, nor at once. I approach the hoard with a vague sense of how I intend to experiment, but items present themselves for selection as much as I select them. The opening objective of the research is to continue with the previous diacaustic projection experiments. The initial query is, ‘what can you (the hoard) offer me that has interesting refractive qualities?’ Also,
‘what sort of light sources do you have?’ I am not necessarily envisaging specific items prior to rummaging; most are forgotten, buried in stacks of vaguely catalogued cardboard boxes. However, the ‘right’ item immediately suggests potential, often beyond what is envisaged. The research is not entirely provided for by this ad-hoc collection. Intentions become more definitive and specific materials and tools need to be sourced elsewhere, but rarely before a brief survey of the hoard, to see if anything advances itself as an alternative.

AN EMERGENT PROCESS
The incidental encounter that inspires the project provokes a research approach that is equally attentive to subsequent incidental encounters, when these prove equally productive in providing new ways to work and interpret that work. Such attention gradually reveals the extent to which circumstantial phenomena accompany the experimental activity. They exceed anticipated results in both number and diversity, but also in creative potential. The experimentation becomes increasingly diverted by these encounters. The potential of circumstantial and unanticipated phenomena to generate new perspective and suggest innovation emerges as a focus of inquiry. Creative attentions and intentions inevitably digress and meander, but with the expectation that they will return with new related perspective.

An Emergent Design approach used in qualitative research provides a useful reference in attempting to structure and express such digressing explorations. Emergent Designs are inductive approaches, which allow for a non-linear research process, when compared with more structured deductive methodologies. “Emergent designs facilitate adjustments when participants, events, or data present unanticipated information.” They accommodate “[...] changes in the conceptualization, data collection, data analysis, and composition stages of research.” Conceptualizations shift, and research methods develop, according to the requirements of testing new concepts or pursuing revised goals. In this approach, expectations and pre-determined methods are de-emphasized. Research questions and objectives evolve “[...] in response to new information and insights.”

A particularly useful notion intrinsic to this qualitative research approach is “sensitizing concepts.” These are concepts that serve as “[...] interpretive devices and as a starting point for a qualitative study.” While typically applied to sociological research, the notion provides a way to understand the experimental approach used in this research. The investigation of refracted caustic-forms as an object of design is an example of one such concept. I know that refraction plays a key role in generating these light forms, and it is a principle I understand. It provides a parameter with which to experiment and enables me to identify and create other objects and situations that produce similar effects. Importantly, sensitizing concepts initiate research, but they do not typically prove defining in framing ultimate conceptions of the work. “A concept is usually provisional and may be dropped as a more viable and definite concept emerges in the course of research.” Experimentation with refraction initiates the work. However, the complementary phenomenon of reflection as an expression of circumstantial relations proves more productive. Sensitizing concepts do not prematurely narrow attention or closedown the scope of the research. “Definitive concepts provide prescriptions of what to see, sensitizing concepts [...] suggest directions along which to look.”

Such an approach is perhaps inevitable in a practice-led research project, where research activity generates ‘data’ for investigation, rather than gathering and analysing existing data. However, it becomes essential and itself defining when the creative potential of the circumstantial emerges as the subject of
research, as is the case in this project. Here, attention is increasingly given to the capacity of experiments to activate and integrate productive circumstantial interactions beyond initial intentions. Circumstantial phenomena generated by the experimentation are assumed and investigated as implicated, even when that connection is not immediately apparent. The intentions of each experiment come to be regarded as a sensitizing concept, as more of those intentions and knowledge are superseded by more significant incidental results.* A definitive concept of the circumstantial, as a mode driving the work in a complementary action to the intentional activity of experimentation, emerges with this compounding series of indirectly disclosed characteristics. The thing investigated develops as a way to investigate.

1.2.3 THREE PHASES OF EXPERIMENTS

The description of the experimentation is presented as a series of causally linked events. This is to demonstrate the increasing influence on the course of the work exerted by circumstantial interactions. The account conveys the work as a generative elaboration of a single incidental phenomenon. Although, the work does not develop in a single sequence of events but instead as a branching delta of digressions, which recombine as creative and conceptual cross-associations. To acknowledge this, it is presented as three phases of experimentation. Each phase is initiated by a set of materials or components retrieved from the workshop store. Each intersects and informs the others. Each culminates and is exemplified by a major experiment.

The experiments are rapid and numerous, equivalent to quick sketches, so the number of results and observations are significant. Difficulties arise in accounting for the course of the work without it growing into a convoluted and arbitrarily interconnected chronicle of digressions. To avoid assailing the reader with minutiae, the account is limited to select experiments. I hesitate at curating the work. It neglects a multitude of influences exerted by excluded results. It goes against two important propositions demonstrated by the work: namely, that all outcomes, no matter how incidental they appear, are implicated in the act and circumstance from which they emerge; that their peripheral status proves only their connection is yet to be revealed. However, the practical need to frame the project as concisely as possible precludes a full description.†

A fragment of transparent casting resin and a roll of mirrored polyester tape play a defining role in activating the first phase. This phase examines projected refraction forms generated by the fragment of resin and other transparent objects in a series of empirical experiments. Attention to projected caustics is diverted by several incidental refraction effects inside these transparent objects. These, in-turn, initiate several experiments with transparent fluids, which are further diverted by internal reflection effects. The discovery of a roll of mirror tape reinforces the shift in research focus to reflection. The work in this phase reveals an embeddedness of objects in their circumstance. The understanding is highlighted by the culminating series of experiments with thin reflective strips of film, and the installation of five-metre mirror poles in the unused light-well of a city building. In these experiments, circumstance reveals and activates the mirror objects, and in reciprocation, the objects reveal and activate aspects of their circumstance.

In the second phase of work, three wardrobe mirrors and an incidentally empty room inspire a series of experiments in which the reflected-form of the researcher becomes the object of study. These present an external point of view (or perspective), as if from the researcher’s

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* See Mapping the Project in the Appendices for an analysis of the extent to which circumstantial outcomes have influenced the course of the research.
† See Appendices for a description of some of the excluded experiments.
reflection. I become witness to my creative participation and explore it in the larger creative circumstance. These works culminate in an exhibition installation that materially recreates a reflected scene, to be entered and explored. The perspectives provided by these experiences recast familiar surrounds, as if experienced anew. The work prompts an interpretation of circumstantial phenomena as providing new ways to perceive objects and circumstance from the perspective of the phenomena. Consequently, the creative determinations of circumstance are increasingly acknowledged, even invited, for new and previously undisclosed insight in the generation of research results.

The third phase of work is precipitated by a faulty diode laser and an offcut of mirrored acrylic. It comprises assorted experiments with structures and spaces generated by recursive reflection. These experiments examine stellated reflections of a laser-beam around the interior of an annular mirror. An incidental act of peering inside the reflected space of the mirror prompts a subsequent series of experiments with kaleidoscopic structures. Several design propositions result. A model for a mirror lined skylight suggests ways to construct fenestrated light, giving it form as it enters interior spaces. A plan for a laneway mirror installation offers a means to visually modify established architecture, opening confined spaces to the sky, and penetrating (or dissecting) solid structure. The phase finishes on experimentation with reflections in a cooking-pot lid. It leads to a proposition for a computer modelling approach for shaping polished products, which demands equal consideration of reflected objects and their real counterparts. These works demonstrate a transcendent form-making capacity of the polished objects and surfaces that pervade the built environment, which is yet to be fully explored for its design potential. They develop reflection phenomena as potential objects and modes of design.

1.2.4 PHENOMENAL BRICOLAGE

The work with circumstantial reflection discloses a way of seeing. It is a small but deliberate displacement of focus to acknowledge and accommodate this incidental phenomenon. It recognizes reflection as revealing an interaction between objects or tasks and their circumstance. The phenomenon entangles and disperses those objects into their surrounds, subverting conceptions of objects as distinct, and notions of creative tasks as isolated activities. Reflection shifts from appearing incidental or inconsequential to expressing wider implications. It offers outside but related perspectives from which to reflect (back) on the objects and design tasks that instigate it. It thereby discloses unrealized capacities of polished materials and objects, but also the work, and design practice. The incidental phenomenon is thereby reappropriated toward reconceiving these in ways that transcend familiar or habitual interpretations.

The work also informs a way of activating: an interpretation of design practice as activating circumstantial responses expressed as phenomena. In this understanding, the circumstance of a making task is a generative and influential agent, rather than a passive backdrop for staging outcomes or a thing to be shaped. I interpret the approach as a phenomenal bricolage. This is because it foregrounds a disposition in my making practice akin to bricolage: a self-imposed constraint to look to what is at-hand for design solutions. Though, in acknowledging circumstantial phenomenal outcomes, this bricolage exceeds its material improvisations: a looking to what is at-hand for insight and possibilities extends to the peripheral phenomena activated by the work. It is recast as a way to activate transcendent capacities,
features, or functions of objects in their relations with each other, and in their relations with circumstance.

A proposition emerges from the work: an acknowledgement and elaboration of phenomena, ostensibly incidental to the research task, can lead to substantive design innovations and valuable re-conceptions of design practice. Most circumstantial manifestations of light do not appear immediately wondrous. The work suggests that characteristics typically relegated as unremarkable or peripheral can harbour undisclosed implications and design potential. There is value to be realized in pausing to reflect on the small (seemingly) inconsequential happenings that pervade a creative practice, even amid the mundanities of everyday design work. Each may be an encounter that can be elaborated (into) to reveal a realm of its own; each may be a threshold of a unique research project. The project is one such elaboration. It invites others to step “through the looking glass,”37 in the pursuit of similar ways to see and activate the potential of circumstantial phenomena in their own practices.*

* This resulting understanding of the project, a phenomenal perspective and phenomenal bricolage, is elaborated at length following the account of the experimentation, as the work discloses and demonstrates these interpretations. See section 3.1 Reappropriating Circumstantial Phenomena.
REFERENCES FOR CHAPTER 1

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24 Ibid.
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2 EXPERIMENTS

2.1 A FRAGMENT OF RESIN AND A ROLL OF POLYESTER MIRROR TAPE

Two objects catalyse the first phase of experimentation, although at different times. The first is a large cracked fragment of transparent polyester resin, from a failed (and naïvely ambitious) attempt at casting a large clear cube. The second is a roll of 30-millimetre wide mirror-coated but scratched polyester tape, excess from an excessively decorated retail merchandising project. They prompt a series of experiments that blur distinctions between space and object, substance and void, reconstituting them as a single interacting circumstance.
The following experimental results and observations are distinguished as two categories: those intended — outcomes that support or refute a conjecture but align with current conceptions of the work (or experiment); and those that are circumstantial — outcomes that are unanticipated, incidental, or (at the time seem) peripheral, but are pursued nonetheless for an intuited potential. The description of the experiments and intended outcomes constitute the body of the document (the main text). The circumstantial results are differentiated from the main text as side-text, which appear in this format and font. As a form of marginalia, they allude to the (seemingly) peripheral nature of the circumstantial encounters they describe. While this highlights the status that might typically be attributed to such results, I use the format to foreground them as more influential than many of the intended outcomes.

MATERIAL AND COMPONENTS
Side panels are likewise used to list in detail the (often incidental) materials and components brought together to initiate each experiment. Their previous uses and incarnations are often included to convey the uncanny capacity of things to conspire to generate and become unanticipated things. They are presented in this form and font.

CONTEXTUAL
References to the creative and theoretical work of others are also situated as side panels. These contextualize (circumstantialize) the research. They are presented in this form and font. References to ‘circumstantial,’ ‘material,’ and ‘contextual’ side-text are indicated in the main text with (See “Title of Side-Text”).
2.1.1 A FRACTURED PIECE OF RESIN

The transparent (but yellowing) irregular fragment of polyester resin captures my interest for its potential to generate diacaustic (refracted) projections. (See A Set of Transparent Polyester Resin Fragments) In work that precedes the project, diacaustic effects produced by transparent vessels of water are the focus of attention. In those, the surface of the water is agitated to modulate the refraction, generating diverse and rich diacaustic forms below the vessel. The complex surface of the resin fragments promises similar results. Projecting light through the resin is the opening experiment. A halogen lamp light is used as a light source, and an old roll-up projector screen provides a projection surface. Given the complexity of the resin surface and the various internal fractures, my expectation is the further generation of intricate forms. The result is disappointing. The diacaustic patterns are not as defined as those achieved in earlier (pre-research) experiments. They are a blur, lacking the distinct coherent form (a thingness) that make the earlier experiments compelling (Figure 2.1–2).
A SET OF TRANSPARENT POLYESTER RESIN FRAGMENTS

The resin fragment is one of a set (Figure 2.1–1) salvaged from a dumpster prior to the research for no specific intention other than they are optically interesting objects. They embody a hurried attempt by a colleague to cast a very large volume of clear polyester resin for an exhibition project. A technical challenge of casting this material is the exothermic nature of the hardening reaction; the additional heat accelerates curing. In this circumstance, a runaway reaction occurs, demonstrated by spontaneous combustion, smoke, and a rush for fire extinguishers. The accelerated chemical reaction is responsible for shattering the material into smaller fragments: non-uniform concentrations of internal stress build up, due to uneven cooling of the casting; the material is not strong enough to maintain contiguity; sections separate at weak points to compensate; the cracks propagate and combine to form larger fractures.
FIGURE 2.1–3
Rig to direct a green laser into fragment of transparent casting resin, with resin supported by turntable bearing (Parmington, 2006).
FIGURE 2.1–5
Discaustic projection generated by a directing green laser through a fragment of resin (Parmington, 2006).

FIGURE 2.1–4
Resin fragment illuminated by green laser (Parmington, 2006).
2.1.2 LASER DIRECTED INTO RESIN FRAGMENT

Later, an old badly focused red-diode laser found amongst my miscellanea ‘asks’ to be tested for its capacity to generate diacaustic form with the resin fragment. I speculate that it might be more effective than the halogen lamp. Based on the last, results my expectations are conservative. The fragment is set in front of the old projector screen and I direct the laser by hand into the resin. The effect generated by this combination is markedly different in its texture and form. It is more detailed but with a nebulous quality. The results are sufficiently intriguing to motivate a search for a higher powered laser that is more accurately focused. A new green diode-laser enhances the effects further. It is vibrant in its intensity, revealing a spray of luminescent green gossamer filaments in the refracted form (Figure 2.1–5). The forms appear electrically textural (Figure 2.1–6). Studying the projected light reveals it is composed of intensely luminous granules, which are difficult to focus on.* It gives the projection an extraordinary ‘buzzing’ appearance, unlike anything generated by white light; the effect is almost palpable.

* The effect is due to the coherent nature of laser light. It is made up of a single wavelength. When a laser is reflected off a surface sufficiently coarse to cause the reflected light to be approximately a wavelength out of phase with the incident light, interference effects cancel out areas of the reflected light, while intensifying others.
MATERIALS AND COMPONENTS

10-milliwatt three-volt green diode laser, wavelength 523 nanometres; polyester resin fragment; 1970s-portable roll-out projector screen and tripod stand; a paint spattered six-inch diameter ‘lazy-susan’ turntable bearing used to rotate objects being painted.

FLUID LIGHT

As the resin’s orientation to the laser is adjusted, the caustic projection dramatically morphs. The light-form often seems to flow from one shape to the next. The transitional effects are so engaging to prompt a more mechanical setup, which enables the resin fragment to be rotated slowly and consistently on a turntable. The nebulous quality is reinforced, but the resulting dynamism of form and luminosity evoke images of solar flares: a celestial fluid flowing across the projector screen (Figure 2.1-9).

FRACTURE FORMS

The attempts to generate refraction projections with a halogen lamp and laser highlight a multitude of internal fractures, which are likely contributing to the diacaustic forms. (Figure 2.1–7) They are unique structures, a combination of complex surface profiles: polished undulating surfaces, ridges, but also arrays of parallel hair-line cracks. Some look like transparent leaves, others are feather-like (Figure 2.1–8). Many external surface features are reproduced in these internal fractures. The complexity of these are extraordinary, as are their unambiguously visible presence; they are little more than inconsistencies, infinitesimal gaps, in the transparent matrix of the material. The fractures and the nature of transparency are sufficiently compelling to investigate the effects by illuminating the resin internally rather than externally in subsequent experiments.
While the animated caustic effects generated by modulating a laser with the resin fragment intimate compelling potential, they join a field of experimentation that is already producing sophisticated outcomes (see Other Work Shaping Caustics). Moreover, the mirrored fractures inside the resin fragment are intriguing, as is the nature of transparent form. These divert the investigation from diacaustic projections.

**FIGURE 2.1-10.**
Image generated using laser refraction, Cartier commission (Levine, Du Preez, Thornton Jones).

**FIGURE 2.1-11**
Refractive skylight propositions (Bompas, 2015-6)
OTHER WORK SHAPING CAUSTICS

The intricate patterns generated with the refracted light are being explored by artists and designers, in diverse ways, with both laser and white light. Light-artist Chris Levine uses lasers to generate abstract and organic imagery, an example is a series of branding images for Cartier (Figure 2.1–10). Architect Philippe Bompas’ work explores the possibility of sun-lit sky-lighting glass that casts abstract caustic forms onto the surfaces of interior architecture (Figure 2.1–11). Mark Pauly, and a team from École Polytechnique Fédérale de Lausanne, with Bompas have been developing ‘caustic lenses:’ transparent, near-flat, panes of acrylic that can generate images. The acrylic is imperceptibly milled on one side and repolished. The surface profile is precisely varied so that the refracted light passing through it is concentrated and dispersed into a coherent projected image (Figure 2.1–12). A team from the Fraunhofer Institute for Technical and Industrial Mathematics in Kaiserslautern, Germany, aspires to develop “freeform lenses” which can be physically varied to generate a desired diacaustic projection. They see such a system as having applications in graphic art and advertising, also for domestic lighting systems capable of modulating a single source to provide controlled and varied illumination across an entire interior.

MIT Media Lab, Mediated Matter, have devised a 3D printing system for molten glass; glass products are accurately computer modelled and printed, to control and generate unique transmission qualities. Works have been displayed as lighting installations, generating complex organic caustic forms (Figure 2.1–13). One installation, for Milan Design Week at the Milan Triennale (2017), was designed to produce animated caustic projections.
INTERNALLY LIT RESIN FRAGMENT

The resin fragment itself is dramatically illuminated by the laser, becoming a fantastical light fixture, vibrating with the buzzing granular intensity of the diacaustic projection (Figure 2.1–4). The laser highlights extraordinary interior structures of the resin, but its intensity prevents close examination. Transformed this way, the resin asks to be internally illuminated as a glowing material. This is later realized using a miniature cold cathode fluorescent lamp (CCFL) inserted in a hole drilled into the fragment. Again, the entire resin fragment glows vividly, but this time with less intensity (Figure 2.1–15).

The internal light source reveals the fractured internal structure of the resin. The smooth curved exterior surfaces magnify and distort these highlighted structures, further emphasizing them. The fractures are various sizes. Many are feather-like in shape with frilled fringes. Magnified and photographed, the fringes reveal an array of finer fractures in a repeated fractal configuration. This organic topography glints intensely. Many cracks appear as highly polished objects, wafer thin mirrors (Figure 2.1–17).

The mirror effect is likely to be an instance of total internal reflection. These transparent gaps in the contiguity of the transparent material are only a fraction of a millimetre thick, wafer thin volumes of air, however, under specific circumstances, they are impenetrable to light. The mirror fractures offer an impression of opacity and solidity, which convincingly belies their true physical nature. Both material and interstice are physically transparent, but at some angles of observation their transition appears reflective. (See Figure-Ground)

* In the classification of glass fracture, large smooth surfaces are called mirror areas, and are usually associated with comparatively slow speed crack propagation; the ridges are called Wallner lines and are signs of fracture under mechanical stress. Whether this also accounts for the characteristics observed in the resin fragments remains uncertain.

† The refraction of light occurs as light transits between two transparent substances of different optical densities. The deflection is due to a slowing or speeding up of its progress (according to the wave theory of light). When light transmitted by a material encounters a boundary with a dramatically less optically dense material (such as glass to air) at an acute angle, this propensity to bend may mean the denser material restricts its passage altogether; the boundary reflects the light back into the denser material. This is known as total internal reflection.

‡ I experience a similar instance of figure-ground reversal in the later vortex experiments. See Appendices, Vortex in Jar (Detail).
MATERIALS AND COMPONENTS

Polyester resin fragment; miniature cold cathode fluorescent lamp, an obsolete lighting system for edge illuminated signage; electronic inverter, to power the lamp; a 12v wall-plug transformer, a component of a failed consumer electronics device.

FIGURE-GROUND

The mirror fractures in resin reverse perceptions of figure-ground; the voids that constitute the fractures are objects and the clear substrate their spatial domain, a phenomenal inversion of material (physical) reality.1 In an analysis of a Rem Koolhaus’s competition proposal for the Bibliothèque National de France, art historian Anthony Vidler suggests that Koolhaus’s “cube of glass” might be envisaged as a transparency “conceived of as solid, not as a void, with interior volumes carved out of a crystalline block so as to float within it, in amoebic suspension.”10 The forms within the resin fragment express this quality. They are scarcely a void but are nonetheless present; they exert an influence upon the passing light that belies their insignificance. They define the internal space of the resin more by this modulation of light, than by their physical presence.

I subsequently encounter a work in resin titled Space as an Object, by Anish Kapoor, exhibited in a retrospective of the artist’s work at the Museum of Contemporary Art in 2013 (although, the work was first executed in 2001). The piece is one of a series. It comprises a large cube of transparent resin with approximately one metre edges. At its centre is an amorphous bubble of air, surrounded by smaller bubbles, all frozen into position (Figure 2.1–14). Each cavity exhibits refractive effects like those revealed in the fractured resin. Kapoor is also cognizant of the perceptual and conceptual multistability embodied by these transparent forms in a clear resin. He reflects on this in an interview with Nicholas Baume: “When a bubble is encapsulated in a transparent block it is as if, in some “proto” sense space becomes an object.”11

These allusions to an object-space inversion (mine, Vidler’s, and Kapoor’s) contradict two fundamental assumptions: matter as a defining characteristic of an object, and physical accessibility as a defining characteristic of space. These empty objects cannot be touched, nor can their transparent but substantial spaces be occupied. Such descriptions could be taken as a contrivance. However, a physical expression of this ambiguity between object and space is familiar to me, in a technique peculiar to my discipline as a product designer. The fabrication and manufacture of products en masse frequently relies on moulding and casting techniques (the origins of the resin fragments). In designing for such manufacture, moulding is one of the joys and challenges of making. Here, conceptions of object and space are in constant exchange. Each transmutation between pattern, mould, and casting requires an involution of object and space, material to void, void to material. It is miraculous and alchemic. Within the context of the project, the fluency between object and space facilitates an equivalent deconstructing of distinctions between material and light.

SOLID FLUID

Under magnified scrutiny, the ridges and cracks inside the resin appear as fluid forms (Figure 2.1–16), perhaps implying the liquid origins of the material itself. The fractures branch organically inside the resin, a miniature landscape of waterways. The resin fragment is a fluid moment made solid, and curiously, the physical details and qualities caused by its fracture seem to support this association.

Most transparent objects that occupy the built environment are materials shaped in a fluid state and solidified to capture that form: whether molten glass (on a layer of molten tin) for glazing, the extrusion or moulding of thermoplastic polymers for clear packaging, or the chemical curing of transparent resin ornaments. The ubiquity of such objects is recent. Prior to these technologies, the optically transparent materials most likely to be encountered were themselves fluid and formless: liquid water and air.

FIGURE 2.1–17.
Mirror reflections, generated by total internal reflection, interior of polyester resin fragment (Parmington, 2006).
2.1.3 VORTEX IN A JAR

The presence of fluid flow-like forms, frozen in the resin fragment, has me reflecting on experiments prior to the research. In these experiments, light was refracted through water. Many of those produced were extraordinarily complex and beautiful.* Unlike the cured liquid surfaces of the resin fragment, the profile of the water’s surface was inescapably ephemeral, and so were the refracted light-forms themselves. The only way to capture the refracted projections for extended study was by photographing or filming them. I frequently wished for an instantaneous fluid curing method, which would hold the mass of water in a single moment of disturbed form. With such a technique, projections could be shaped on disturbing the transparent fluid material. Nevertheless, there are circumstances where both water (and air) exhibit stable but complex form in their fluid state. In the subsequent experiments, transparent form is created with fluids, the first of these being a stable fluid vortex.† I anticipate experimenting with them in a similar way as the resin fragments, using them to generate caustic forms. Fluids of various viscosity are used to see if there are significant differences between the resulting vortical profiles. Water, turpentine, and alcohol are tested (Figure 2.1-18).‡ However, the intentions of the vortex experiments are diverted by an incidental discovery when remnants of water contaminate the turpentine (see Lumps on the Base of the Jar). The qualities of immiscible fluid interfaces become the focus of inquiry.

* See Introduction: Vinic Inspiration, for images.
† Vortices are formed in a rotating fluid medium. The vortical profile emerges from the physical demand to conserve momentum. To do so, fluids at different radii must move at different rotational speeds. Variations in speed result in differences in centripetal force. These radial forces, in combination with gravity and surface tensions, generate the classic vortical form.‡
‡ See appendices, Vortex in a Jar, for more details of the experiment.
§ The refractive index of water is 1.33, compared to turpentine which is approximately 1.47.
MATERIALS AND COMPONENTS

A 1.2 litre glass jar with metal screw top lid, that previously preserved pickled cucumbers; two litres of tap water; black 12-volt direct current cooling fan 80 millimetres in diameter, a component from a redundant personal computer; three 10-watt G4 halogen lamps, ceramic lamp holders, and two metres of 1-amp figure 8 insulated electrical copper wire, that previously illuminated several light fixture prototypes. Later: 2-litres of methylated alcohol, 1-litre of mineral turpentin.

LUMPS ON THE BASE OF THE JAR

While replacing the water in the vortex rig with turpentine, flattened bubbles appear on the bottom of the jar. They look like lumps in the surface of the glass, adopting similar mirror (internal reflection) qualities as the surrounding surface. They are only visible from some perspectives and are more obvious if the jar sits on a dark material. They are remnant drops of water still in the rig. Water is denser than turpentine, so it will sink and remain at the bottom. The surface tension of water must be maintaining the lens-like profile, even when under the weight of turpentine. They are difficult to see. This is likely due to the similar refractive properties of the two clear fluids, meaning light passing between the mediums is not significantly redirected.

VORTICIAL MIRRORS

Astronomical observatories have on occasion used large liquid mercury mirrors for their telescopes; the mercury is rotated to generate the required parabolic shape. The University of British Columbia’s Large Zenith Telescope is an example, located in Malcolm Knapp Research Forest, measuring six metres in diameter.¹⁴
2.1.4 IMMISCIBLE LIQUIDS

The immiscibility of turpentine and water is examined based on the previous encounter. A large spare jar is half-filled with water, then the same amount of turpentine, so that the jar is completely full. The water is denser, so it separates and pools below the turpentine. No discernible difference in transparency distinguishes the two fluids. The only indication is a circle at the interface between them (Figure 2.1–19), with a narrow meniscus around interior surface of the jar, much finer than it would be without the turpentine.

There is something puzzling about the quality of the immiscible boundary between the two fluids, although, I am unable to identify exactly what gives me pause. Later, the jar distracts a couple of studio members from their tasks. They also pause to curiously regard the ambiguous quality of the fluid interface. With further consideration, the ambiguity results from the impression that, in a passing glance, the jar is only half filled with water. Since it is filled to the brim, with the lid obscuring the top surface of turpentine, there is no obvious indication of a fluid above the water. The root of the puzzling impression is that the water surface is not behaving optically as it would when interfaced with air. This is verified when the jar is compared to another containing only water to the same level. The difference becomes obvious. Peering in from the side, and above the water-turpentine boundary, objects on the bench behind the jar are not visible through the interface. The interface appears to behave as a mirror at acute viewing angles, reflecting what is above and behind the jar. In the jar with water alone, viewed from the same angle, the surface is transparent (Figure 2.1–20). When viewing both jars from an angle below the water, the water-turpentine interface becomes transparent, and the water surface alone is now a perfect mirror (Figure 2.1–21). The difference establishes that the layer of turpentine almost completely alters the more commonly observed water-air refraction phenomena.

The curiosity attracted by the jar and its contents likely results from an intuited disturbance in the presumed behaviour of materials. It is intuited, because the peculiarity is not overt; it is a slight disturbance of a familiar experience, ‘not quite right.’ Its recognition is uncertain, a symptom of the lack of consideration we give to such detail in our surrounds; they are subtle characteristics easily hidden in the clamour of the mundane. However, the experience is more powerful because of the equivocation between normal and abnormal. A hint of an unusual thing inspires curiosity and compels investigation. In contrast, the obvious is concealed in its (presumed) overtess. It presents as apprehended and can be dismissed without closer attention. The experience suggests that attention to other light phenomena might be deliberately heightened by contriving such subtle disturbances. (Such interplays become the subject of a later exhibition piece. See Threshold 1)
MATERIALS AND COMPONENTS

A 1.2 litre glass jar with metal screw top lid, previously used in vortex experiments; 600 milliliters of water; 600 milliliters turpentine.

FIGURE 2.1–19 Immiscible boundary between turpentine and water (Parmington, 2006).

FIGURE 2.1–20 Boundary comparison between turpentine/water and air/water, view from above (Parmington, 2006).

FIGURE 2.1–21 Boundary comparison between turpentine/water and air/water, view from below (Parmington, 2006).
2.1.5 POLYESTER MIRROR TAPE

The micron thick mirrors floating in transparent polyester resin, the subtle fluid boundaries, and other parallel work are circumstances that oscillate between the substantial and the phenomenal, between figure and ground, between presence and absence. They continue the exploration of phenomena as objects but also inspire an investigation of peripheral phenomena as modes to interrupt habitual (lack of) perception. This work, and the discovery of a roll of 30-millimetre wide mirrored polyester film amongst my paraphernalia (Figure 2.1–22), prompt a series of experiments that aim to subtly intervene in mundane situations with optical reflection.

VERTICAL EXPERIMENT
The intention is to test the mirrored polyester tape in various places for its capacity to blend into its surrounds. This demands a (close to) homogeneously featured environment, as whatever is facing the mirror will be reflected in it, and this reflection must be consistent with the view beyond (around) the mirror. The studio, while consistently disordered, does not quite meet this requirement. The local reserve serves as an alternative site. Here, a stand of trees provides an opportunity to stretch the tape vertically between a tree branch and the ground. However, the experiment proves inconclusive due to weather conditions (see Oscillating Reflection). Despite this, several unanticipated results do ask to be pursued further, and the experiment is repeated later.

HORIZONTAL EXPERIMENT
In a second experiment, the mirror tape is again tested outdoors in a small gully, as part of a series on experiments with mirror strips and poles. This time it is stretched horizontally, under a moderate amount of tension, and over a greater distance than the first experiment, which places both ends at the periphery of the visual field. The strip thus occupies the entire scene when looking at its midpoint. The gully is well protected from the weather, and the air quite still. To examine the results more carefully, the earlier effect is reproduced by twisting the tape manually (Figure 2.1–23).

As expected, when stable, the tape adopts the colours and visual texture of its environment. It introduces a glitch into the view, strangely like a band of malfunctioning pixels across an LCD screen (Figure 2.1–23). The effect is quite unsettling, even slightly vertiginous. It is a characteristic that was not evident in the vertical installation. There might be several perceptual dynamics at play. Its position in the landscape is difficult to gauge; its depth in the scene is uncertain. The confusion is enhanced by the extensive length of the tape. It may be due to an ambiguity in stereopsis depth perception. The horizontal strip aligns with the plane of binocular vision, and hence, there is minimal or no disparity in view between left and right eyes. The tape is also consistent in width and texture across its length, and therefore, offers no irregularity on which the eyes can converge. Though blurred, the objects (grass, trees, and branches) reflected in the mirror strip could also be contributing to the confusion; to look at them requires me to focus and converge my eyes beyond the physical position of the strip. Twisting the mirror-tape enhances the glitch effect. The strip changes in width, even disappears momentarily. The reflected objects rush up and down within the bounds of its upper and lower edges, with occasional flashes of sky. The extraordinary effects inspire a more deliberate exploration in a subsequent exhibition installation.* (See Resin and Tape)

*These are described below and in the appendices.
MATERIALS AND COMPONENTS

One roll of 30-millimetre wide of mirrored polyester film, surplus to a retail merchandising project.

OSCILLATING REFLECTION

My expectation for the first mirror-tape experiment is to examine it as a narrow mirror column amid the trees of a local reserve. The aim is to gauge the extent to which it disappears, camouflaged by its reflective properties. However, the thin film is particularly susceptible to the wind. The breeze on the day is not overly strong, nonetheless, the mirror tape buzzes and vibrates like a stringed instrument. The effect undermines consideration of its static reflective effect. The mirror strip does oscillate between presence and absence, but it does so arbitrarily, with a frenzied animation; the wind twists it, and as its edge rotates toward the viewer, the middle portion of the tape completely disappears. Polyester film thicknesses can be as slight as 0.025 millimetres (one fortieth of a millimetre); as far as the eye can discern, the strip of aluminized polyester tape is a two-dimensional mirror. The rapid rate of fluctuation between these positions, and between reflected appearance and disappearance, gives the installation a pulsating electrical quality, like a spark jumping between electrodes.

RESIN AND TAPE

Mirror-tape and resin fracture experiments converge. The tape in the landscape is a physical inversion of the fractures that incise the resin. The fractures are impossibly thin ‘mirror gaps’ in the matrix of the resin; the unrolled tape is an impossibly thin ‘mirrored material’ in the matrix of space. The two circumstances are not readily differentiated, and the mirror-tape suggests an incision in the landscape space, which offers a glimpse of a scene behind the real.

FIGURE 2.1–23
Horizontal mirror coated polyester tape amongst trees. Stills from video.
2.1.6 MIRROR ACYCLIC STRIPS

Material and weather subvert the vertical mirror-tape experiment. However, mirrored acrylic provides an alternative way to investigate the reflection effects that thin mirrors exert on the visual field. It is more stable and more reflective than the polyester film. The first of these interruptions (as they have come to be interpreted) takes place at the same well-treed gully as the horizontal mirror strip experiment.

Mirrored acrylic sheet is straightforward to work with. Strips of various widths between 20 to 40 millimetres are cut for the experiment. The longest is 2440 millimetres. The material is more robust than the polyester tape, but nonetheless still quite flexible; lengths of timber adhered to their back surface keep them straight. The strips are positioned by pushing the hardwood into the ground or leaning them against tree branches. Five of them are arrayed in various orientations and combinations, at different heights, together and separated.

The static strips enable a more thorough and contemplative observation. As expected, they have their strongest effect in homogeneous surroundings, where the colour and texture of the reflections correspond closely with the background. The thin width limits the viewer’s presence in the resulting reflections. Their perceptual effects on the surrounding space are difficult to express. They are at once almost absorbed and strikingly present (Figures 2.1–24 to 26). They hide in an overall observation of the scene, but catch the tracking eye, and stand out in the periphery, even in their most camouflaged state. They subtly and simultaneously flatten and solidify the space in the figure-ground inversion experienced with the mirror-tape. When the contrast is high the effect oscillates between a thin reflective object in space (the more acceptable), and a gap in a trompe l’oeil (the more disconcerting), where space and scene contract to a curtain, barely parted onto a similar but different exterior. The effect is most compelling where the tops of the strips are outside the field of vision or obscured by leaves or branches, and when the edges of the acrylic are not obvious. The results directly inform a more substantial installation (interruption) in the courtyard of a building.

*Euclid’s law of reflection.
† In lighting performance situations, a smoke-machine or fogger is used to give the light a degree of solidity.
MATERIALS AND COMPONENTS

One 1220x2440-millimetre sheet of 3-millimetre mirrored acrylic, obtained specifically for experiment; several 2-metre lengths of 19x42-millimetre kiln dried Victorian ash hardwood, surplus to previous construction work; 25-millimetre double sided tape, surplus to previous fabrication work.
2.1.7 COURTYARD INTERVENTION

A small courtyard on the RMIT campus, by which I regularly pass, demands attention as a site for a mirror experiment. Prior to the project, it provokes little consideration. It is a lightwell for three levels of laboratories and classrooms, an in-between space, a short cut to the opposite side of the building, and a convenient outdoor respite for smokers. Symmetries in the environment are becoming more apparent with the explorations of reflection, more intriguingly, so are subtle subversions of those symmetries. This interstitial place is now absorbing and compelling. The courtyard declares itself as near-symmetrical and near-homogeneous in its architecture, materials, and fixtures. It provides an opportunity to highlight, intervene, and perhaps disturb other comfortable symmetries in the architecture of the urban domain.

The area is rectangular, approximately six by eight metres. The southern wall is seven metres high and without windows. The other three are approximately eleven metres with windows at each of the three levels. The walls are red brick. The windows and doors framed with aluminium. To the east and west, the ground floor windows and doors are symmetrical features, but the placement of the upper storey windows break the symmetry of the courtyard (Figures 2.1–27 to 30). They are differences that might be highlighted by dislocating and juxtaposing misaligned features using reflection.

Rigid regulations govern the use of university property. To avoid refusal, and bureaucratic delay, these are innocently overlooked. The work thus needs to be portable, and quick to assemble and remove. The lightwell is not a large space, but its height demands an acknowledgment. It calls for a scale so far unattempted. These considerations generate a series of structural challenges: foremost, the design of a free-standing intervention that is sufficiently tall but avoids the complication and intrusion (aesthetically and architecturally) of supporting elements.

Five free-standing poles result, each clad in mirrored acrylic, each with its own footing, arrayed across the courtyard. The standard metal extrusion length determines their height, which makes each pole six metres tall. A square profile of 50 by 50 millimetres is as thin as they can be made while maintaining stability as self-supporting elements. Mirrored acrylic strips are adhered to the aluminium extrusion with contact adhesive. All four faces of the extrusion are clad. The acrylic mirror panel is three millimetres thick, so the edges of the material will be visible at the corners. Corners are butt-joined, rather than mitre-joined; this creates two opposing surfaces where unmirrored edges are not visible. Mounting anything directly to the courtyard paving is not an option, so similar domestic concrete pavers are used as bases for the poles. They require large mounting spigots, fabricated using galvanised steel pipe, with a steel plate as a base bracket. The brackets are adhered to the underside of the pavers with construction adhesive, with the spigot protruding through a hole in the paver (Figure 2.1–31).

The five mirror clad poles are most effective when positioned evenly along the median line of the courtyard, between the centres of the north and south walls. The inherent symmetries generated by reflection determine the configuration. Thus, looking into the mirrors, the reflected view of walls behind the viewer should correspond in depth to the view of walls behind the poles.
MATERIALS AND COMPONENTS

Five 6.5 metre lengths of extruded 50x50x2-millimetre aluminium square hollow section, obtained specifically for the task; 3 sheets of 2440x1220-millimetre mirrored acrylic sheet, obtained specifically for task; five rectangular 600x300x40-millimetre concrete paving tiles, surplus to a bemused but sympathetic friend’s patio construction needs; several lengths of 25-millimetre nominal bore galvanised steel pipe, offcuts of salvaged plumbing; various pieces of 3-millimetre galvanised steel plate of unknown origin; a short offcut of 45x90-millimetre kiln dried Victorian ash hardwood; contact adhesive; a tube of construction adhesive.
FIGURE 2.1–31
Mirror-pole installation, courtyard RMIT University, view 1 (Parmington, 2008).

FIGURE 2.1–32
Mirror-pole installation, view 2 (Parmington, 2008).
FIGURE 2.1–33
Mirror-pole installation, view 3 (Parmington, 2008).

FIGURE 2.1–34
Mirror-pole installation, view 3 (Parmington, 2008).
The poles are surprisingly successful at interrupting various aspects of the courtyard (Figures 2.1–31 to 34). Dislocated features reflected from behind the viewer overlay these aspects (Figures 2.1–35). The space is most frequently approached and entered from the west, which means that the first glimpse of the intervention is through a series of floor to ceiling windows in the foyer of the building. Seen through the windows, when the extremes of the mirror poles are out of view, they are extraordinarily subtle and easily overlooked, appearing as translucent, blending with reflections in the glazing. On entering the courtyard, they are more apparent. However, their materiality is difficult to resolve. The columns are discernible; the reflected features and textures are almost contiguous to their background, but there are distortions and misalignments. Concrete pavers, brickwork, vents, windows, and wall lights, do not quite superimpose; all possess an altered hue. Subtle instabilities in the plastic mirror surface transmute the strict pattern of rectilinear mortar joints and fixtures; the architecture is subtly rippled, bent, alternately magnified and reduced. Initially, this frustrates my desire for a perfect reproduction of the surrounds. However, with further consideration, the distortions prove to imbue the reflected slices of architecture with a fluidity, particularly as the viewer moves through the space: reflections flow down the poles while approaching them, and upward when backing away. The effects suggest a set of refracting transparent liquid columns rather than reflective surfaces: “five streams of light pouring into the space,” is one response from a viewer.

Most who view the installation find it engaging, but consider the concrete bases, and the butt-joined edges of the acrylic mirror, a distraction (Figures 2.1–35). Several suggest the poles would be more effective if thinner. The footings and the thickness of the columns are admittedly a compromise, borne of site restrictions. The three-dimensionality of the poles is evident when viewed from any position other than directly in front or behind, and the portable footings visually anchor the poles. Ideally, the mirrors would be without thickness, wafer thin, and disappear into the ground without sign of support. The poles are too present as objects; my aspiration is to offer the intervening reflections as the sole objects of scrutiny. Despite this, viewers who remain with the work begin to notice subtler characteristics and become progressively more intrigued and captivated by them. One describes the columns as visually hovering, and their position in the courtyard indeterminate. “Contemplative,” is a consistent comment. Several speak of being enticed into details of the viewing experience, and being held by that experience, even suggesting a difficulty to disengage. One describes the array of visual interruptions as “knife-cuts through the architecture.” A typical but unexpected reaction from those who are familiar with the courtyard is an alteration in the “feel of the space.” Although, none can definitively identify or express what constitutes the change. “They make it a space,” is one comment. They “veil the space”, is another. A further observation, which proves to be a profound influence on the research, is of “the space responding to itself!”
FIGURES 2.1–35
Reflection symmetries in mirror-poles (Parmington, 2008)
2.1.8 REFLECTION AND CIRCUMSTANCE

This phase of experiments represents a small selection of work where refraction and reflection phenomena develop as the materials, spaces, and objects of research. It commences with an exploration of light as independent form, manifested as the caustic projections from an irregular fragment of resin. However, circumstance refuses to allow light to be confined to narrow anticipations or conceptions. Incidental encounters demonstrate that light has the capacity to reveal the subtlest transitions in materiality, as mirror fractures inside a fragment of resin, or as an interface between immiscible fluids. Thin strips of mirrored tape and acrylic perform as expected, disappearing into their environment, but also prove to thicken and dissect space. In this series of experiments, light becomes more present than material; substantial qualities of matter withdraw to the background as distinguishing form and space, displaced by luminal qualities. The shift in emphasis discloses new aspects of the material environment. The RMIT lightwell installation prompts an unanticipated experience of the courtyard, not solely attributable to the hours of scrutiny. Empty, it is liminal and ignored, accumulating redundant furnishings and cigarette butts. With the mirror poles, subtle qualities emerge. Surfaces become dominant. The poles draw reflected red brick and glass into the space and fill it, emptying the architecture as a containing façade. The poles precipitate the volume of light contained by the courtyard, but also the sky framed by its lip (Figure 2.1–36). Where they meet, a red and blue meniscus in each pole indicates the equilibrium between immiscible light-well and firmament. The intervention thus manifests, perhaps even elicits, something vital from masonry, glazing, and space, from the circumstance. I come away with an impression that the intervention provides an opportunity for the place to reveal itself, to express or foreground aspects it could not otherwise. The exercise seems more of a collaboration than a work of design.
**FIGURE 2.1–37**
“Untitled,” mirrored Cubes (Moms, 1965).

**FIGURE 2.1–38**
MIRROR COLUMN WORKS

There are countless examples of minimal installation art that use mirrors in various configurations, going back to Robert Morris’s mirror cubes in 1965 (Figure 2.1–37). They are too many to give full account of. In the period since the RMIT courtyard installation, vertically configured mirrors have been explored by artists such as Jeppe Hein. He has created several public artworks that variously configure mirrored columns. An example, ‘Semicircular Space,’ was displayed by the National Gallery of Victoria in 2016 (Figure 2.1–38). A larger temporary installation by Phillip K. Smith III, titled ‘Quarter Mile Arc’ (2016), arrayed a series of mirror poles along Laguna Beach, California (Figure 2.1–39). According to Smith, "stretching along much of Main Beach, the arc forms a visible marker between the manmade and natural worlds, and reflects the changing colours of the ocean, sky, and shoreline throughout the day and night."15
As with the effects generated by the many examples of outdoor mirror works, I attempt to dematerialize the object, to question the boundary between object and its circumstance. However, rather than just make the objects ambiguous, these mirror works prove to activate their surrounds. This is perhaps akin to Smith’s recognition of a capacity to dislocate and thus highlight aspects of the landscape. Such capacities were explored and exemplified in a much earlier installation piece by Robert Irwin, Black Line Volume (see Black Line Volume). Accordingly, the pole interventions prove to be a tool, an instrument, to reveal how characteristics of the surrounds define the object, but also how the object disturbs the surrounds, and whether these interactions generate something that transcends both. Although, as a designer, I am curious about the perceptual effects that might be elicited by mirror works in more mundane situations.

*In cases of Morris and then later Irwin, questioning the object of art.*
There is an account of a work by installation artist Robert Irwin in his biography, “Seeing is Forgetting the Name of the Thing One Sees.” It describes a work titled ‘Black Line Volume,’ (Figure 2.1–40) which Irwin considers one of his most accomplished. The installation was part of a retrospective show at the Chicago Museum of Contemporary Art in 1975. It was a response to an existing space at the back of the museum, which he described as “awkward.” The room was white with three walls. The fourth side was the entrance into the space, from the remainder of the gallery. The suspended ceiling was a grid of fluorescent lighting diffusers. A white structural column stood directly in the middle of the space. The only other obvious feature was a dark gap at the base of the three walls and the column. Irwin’s only contribution to the space for the exhibition was to adhere a black strip, 125mm wide, six feet into the room across the entrance. It connected the dark line beneath the three walls, to form the black outline of a rectangle at floor level. A local art writer described the resulting effect.

“From inside, the light in the area seemed different, more substantial [...]. From outside the room the tape seemed to lift the plane of the floor upward in your field of vision, and it also made the room seem wider and shallower than it really was. Consequently, a person moving toward the back wall was soon out of whack perspective-wise, because the figure receded faster than the room. The area was transformed into a separate volume; it seemed to lift out of the museum and become so exclusively visual that it could have been any size [...]. It is hard to know whether the tape was actually doing all this or whether, having become visually conscious enough to see the black rectangle, you simply continued to experience the room with this heightened awareness.”

Irwin recounts that reactions were diverse: “some people would not cross the line; [...] a lot of people stuck their hand out to make sure they weren’t going to bump into something, [...] such as] a glass pane, or as if the room space were somehow solid.” Four out of the ten employees of the museum asked him whether he had installed the column. At the time, Irwin’s gauge of success was a heightened awareness prompted by subtle intervention, or as his biographer put it: “maximum transformation with minimal alteration.”
After their appearance in an overlooked RMIT courtyard, the five mirrored poles participate in excursions to elicit characteristics from other environments. For several hot summer months, they surround and perplex visitors in the back-garden of Mulberry Hill.* Five long sundial stripes slowly scan the scene, as visitors uneasily sip tea amongst them. They inexorably creep across grass, chairs and tables, section and accentuate the physical dimensions of the space. In another appearance, they momentarily incise the mudflats and horizon beyond Grantville, a small coastal town on Western Port, Victoria (Figure 2.1–43). Their impossibly thin but nonetheless unmistakable presence distract passers-by. Sand, mud and sunset are captured and coalesced into the geometry of a line, displaced from circumstance to object. However, rather than losing to the transaction, the expanse of sky and waterline seems only the more vast.

The mirror poles offer more than displaced slivers of their surround. They generate an alternate and emergent view beyond my contrivance. Their mirror reflection activates those surrounds. They reveal the entwining threads of circumstance’s visual fabric; circumstance reveals the mirror poles and in doing so reveals itself. (See *Claude Glass* and *Slavonic Catoptriachs*).

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* The country home of Daryl Lindsay, artist and former director of the National Gallery of Victoria, and novelist Joan Lindsay.
† Named after Claude Lorrain, although there is no evidence that he himself used one.21
‡ Arnaud Maillet offers a wide-ranging account of the history of the ‘Claude Glass,’ and its implications in the development of painting. He uses the glass to reflect on similarities and distinctions between perceptions of the mirror space and the painting space, and the conceptual influence they have exerted on each other throughout the history of Western art and philosophy.
§ Although Maillet argues that the that image it produces meets or corresponds to a desired picturesque aesthetic.
CLAUDE GLASS

A tool briefly popular amongst romantic landscape painters of the turn of the nineteenth century was the Claude Glass (Figure 2.1–41). Painters (also many tourists) of the period, in search of picturesque scenes, would wander the countryside, studying and painting it as reflected in this small black convex mirror. The device required them to face away from the scene they were contemplating or rendering. Arnaud Maillet, in his book, "The Claude Glass," argues that in the same way "the painting reduces the objects it represents," the black convex mirror allows the scene "[...] to be grasped, weighed in the hand, apprehended in a single glance" in condensed contrasts of tone and colour, enabling an idealization. He proposes the reversal generated by the Claude mirror is not "[...] an attempt to reproduce nature in picture rather the picture is projected onto nature." The outcomes of the experiments compel me to see such mirror images as revealing an alternate perspective, rather than the projection of one. The mirror image of the landscape can be interpreted in the picturesque fashion, if that is what is pursued, but the view it activates belongs neither to painter, landscape, nor style. The reflection is not a painting and not a reproduction of the scene in direct observation. It is an entirely new aspect.

SLAVONIC CATOPTRIARCHS

Christian Bok, in a work of prose titled "Enantiomorphism," describes an apocryphal sect of gnostics called the "Slavonic Catoptriarchs," who "expressed their contemptus mundi by refusing to gaze upon the world unless it was reflected in a mirror;" each disciple carried in one hand a sheet of silver plating "from which his glance never strayed, even when riding on horseback."
In 1969 Robert Smithson employed the "enantiomorphic" effects of mirrors to catalyse evocative and diverse reflections on place, nature, and art. He performed these "mirror displacements" in various sites, in a range of locations, recording and exhibiting them photographically. He used these to challenge the "[..] strictures of art history, which venerates the static object and divides art from the exigencies of the real world." One such series comprises nine interventions in the Yucatan landscape of Mexico, using a dozen (approximately) square mirrors (Figure 2.1–44). These became known as the Yucatan Displacements. In describing these in the accompanying essay, he deliberates on the act of seeing, and is explicitly "[..] skeptical about all notions of existence, objects, reality etc." Responding to a "displacement" in the rainforests of Yaxchilan (Figure 2.1–45), he writes:

A mirror on the third row jammed between two branches flashed into dematerialization. Other mirrors escaped into visual extinguishment. Bits of reflected jungle retreated from one’s perception. Each point of focus spilled into cavities of foliage. Glutinous light submerged vision under a wilderness of unassimilated seeing. Scraps of sight accumulated until the eyes were engulfed by scrambled reflections. What was seen reeled off into indecisive zones. The eyes seemed to look. Were they looking? Perhaps. [...] Art brings sight to a halt, but that halt has a way of unravelling itself. All the reflections expired into the thickets of Yaxchilan.

In the same essay he reflects that, "Only appearances are fertile; they are gateways to the primordial. Every artist owes his existence to such mirages. The ponderous illusion of solidity, the non-existence of things, is what the artist takes for "materials." The Yucatan Displacements seem to represent a conscious attempt by Smithson to unravel sight; he sees the resulting view as the artist’s "materials" of creation. Similarly, the creative potential of appearances comes to the fore in my work. And, as Smithson seems to imply, they transform mirage into phenomenal substance. Although, rather than access to the primordial, these appearances provide me perspectives beyond imagining. The five mirror poles exert a distinctness, an object-ness, expressed by their materiality. I design and construct their aluminium and acrylic. However, their presence proves more significant as phenomenal objects. Their appearance diffuses into their circumstance; their visual form almost wholly defined in the reflections of each situation, by the characteristics of circumstance, and by the viewer. However, there is also a complementary defining of circumstance. The mechanisms of this reciprocal action are complex and obscure, to an extent that their effect on object or circumstance become unpredictable. Thus, in designing and fabricating the poles, I am cast as experimenter and explorer rather than designer, but as such, I encounter prospects wider than my expectations. In concluding his essay, Smithson quotes George Santayana: ‘Living beings dwell in their expectations rather than their senses.’ The work with the mirror poles marks a realization that the unaccountable influence of circumstance can extend narrow conceptions, of objects, of the designed environment, and of my design practice. These influences emerge from the periphery, the "indecisive zones," the "cavities of foliage [...] under a wilderness of unassimilated seeing." They can be activated by the instrumental probings of reflection and offer perspectives and outcomes that disclose circumstance’s creative autonomy.

* Locations where Smithson intervened with his “mirror displacements” include New York State, Florida, England, Germany, and Mexico.
FIGURE 2.1–44

FIGURE 2.1–45
“Seventh Mirror Displacement,” Yaxchilan, Mexico (Smithson, 1969).
REFERENCES FOR SECTION 2.1

4 Ibid., 43.
5 Ibid.
15 Lawrence Weschler and Robert Irwin, Seeing Is Forgetting the Name of the Thing One Sees: A Life of Contemporary Artist Robert Irwin (University of California Press, 1982), 172.
17 Ibid., 85-6.
18 Ibid., 125.
19 Ibid., 137-46.
20 Ibid., 140.
22 R. Smithson and J.D. Flam, Robert Smithson, the Collected Writings (University of California Press, 1996), 131.
23 Ibid., 120.
26 Smithson and Flam, Robert Smithson, the Collected Writings, 132.
27 Ibid., 128.
28 Ibid., 132.
29 Ibid., 128.
IMAGE REFERENCES FOR SECTION 2.1


Figure 2.1–44. Robert Smithson, Seventh Mirror Displacement, Yaxchilan, Mexico, 1969, accessed February 26, 2018, https://www.guggenheim.org/artwork/5322.
2.2 THREE WARDROBE MIRROR DOORS AND A DESIGNER

The first phase of work commences with a series of experiments interrogating incidental refraction effects. These are diverted by subtle reflection phenomena. Investigation of the reflection effects as a sequence of mirror installations reveal objects as entwined in their surrounds. The mirrored objects are disclosed by their circumstance and reciprocate by disclosing new aspects of that circumstance.

The second phase of experimentation explores incidental reflection as a way of revealing new perspectives on familiar things. It begins with three idle wardrobe mirror doors, which when assembled as an internally-mirrored room generate extraordinary and unsettling effects. The experience inside the space prompts further experiments with reflected perspectives to appreciate their potential. In these, the reflected-form of me, the researcher, becomes the object of study. Rather than a reproduction, my reflected-self proves to be a distinct phenomenal observer, offering an external point of view of the space I inhabit. These works culminate with an exhibition installation, which assembles a series of incidental lighting phenomena to materialize reflected-space. The artifice asks the viewer to reflect on reflection in the play of passing through the mirror. The phase of experiments offers a way to re-see circumstance. It is a phenomenal perspective, which draws out circumstantial qualities camouflaged as the familiar and mundane.
2.2.1 THREE WARDROBE MIRROR DOORS

I am shifting house. Its displaced and jumbled contents line up on the curb waiting to be loaded onto a truck. Seeing my possessions exit the front door is confronting; they seem more than a house can hold. The objects, stripped of their home, removed from their typical relation to one-another and thus much their domestic purpose and meaning, are momentarily recontextualized. This is unsettling, but equally engaging. In this state, sundry items murmur new potential. We have sliding mirror doors on the wardrobes. Prior to moving, they are completely camouflaged in their reflections of domestic clutter and activity. I constantly walk past them, I open them to access clothing, I dress in front of them, all without seeing them. Given my preoccupation with the research, their invisibility is surprising. In their new circumstance, they are obtrusively present. Creative possibilities gather in the empty room and mirror void.

2.2.2 A LARGE SCALE MIRRORED PRISM

At the time of the move, an internally mirrored dodecahedron and pentagonal-icositetrahedron* sit in my studio. The spatial effects generated inside these polyhedra are the subject of investigation. An unaddressed question remains in those experiments: what would be the experience occupying such a mirrored space? The idea of constructing a dodecahedron large enough to physically enter is tempting but challenging. However, the now acknowledged mirror doors and empty room make something similar a convenient possibility. Removed from their tracks, the doors provide the components for an internally mirrored triangular prism. The enclosed space is large enough for a single person to occupy. It is a simpler geometry than the polyhedra: the floor is without a mirror and the top is open. Despite this, they might provide a rough indication of what might be experienced inside multiple mirrored structures.

Entering the tight space and positioning the final wall instantaneously assembles a surrounding throng of people, all duplicates of myself. It is unlike anything I have ever experienced. Encountering one’s reflection is commonplace, but the effect generated within this space is unlike standing in front of a bathroom mirror. Mirror reflection may be vainly alluring, but this experience is cloyingly overbearing. There are hundreds of me, each facsimile oriented in a slightly different direction (Figure 2.2–1). Every possible aspect of myself is revealed in one, or many, of these reproductions. Occupying the space is a perturbing; it is small and the mirrors near, so that my companions are claustrophobically close and dense. The replication is repeated into an impossible distance, beyond the walls of the prism, beyond the walls of the room containing the prism, until it dissolves into a blur of my own countenance.

* See later experiments in section 2.3.3 Kaledescopic Polyhedra.
FIGURE 2.2–1
View toward ceiling while inside mirrored triangular prism (Parmington, 2008).

FIGURE 2.2–2
Inside mirrored triangular prism (Parmington, 2008).
Occupying the space for more than a few minutes causes me to feel physically un-well: a vague and rising lightheadedness, even the beginnings of nausea. Others who enter the space have similar feelings. Perhaps the uncomfortably visceral response is due to the dislocating and decentralizing experience of being surrounded by me. However, the feeling is comparable to motion sickness. It seems plausible that the response is due to an analogous sensorial disparity. Visually, the space appears enormous, but the walls are tangibly and acoustically close. Perhaps visual, aural, and haptic perceptions of the space are unable to be reconciled (see Seeing Yourself Seeing).

* Seeing Yourself Sensing, an installation at Museum of Modern Art, New York, in 2001, is one such exception. The viewer can see their reflection in an array of vertical mirror stripes adhered to a window of the gallery, and at the same time see through the window outside. The exterior view is thereby overlaid with a reflection of the viewer. It acknowledges the displacing effect of reflection, at least with a singular reflection.

† The closing minutes of an imaginative award winning short film, by Virgil Widrich, titled Copy Shop, perhaps conveys the overwhelming feeling more effectively than any description.
SEEING YOURSELF SEEING

The prolific installation artist Olafur Eliasson has produced a diversity of large scale multiple-mirrored environments, which the viewer can enter or pass through (Figure 2.2–3). In describing the conceptual principles of his work, Eliasson has often used expressions such as “seeing yourself sensing” or “sensing yourself seeing.”

“[…] The works] are about trying to introduce relationships between having an experience and simultaneously evaluating and being aware that you are having this experience. It’s not about experience versus interpretation but about the experience inside the interpretive act, about the experience itself being interpretive. You could say that I’m trying to put the body in the mind and the mind in the body.”

Interestingly, he configures most of his mirror works to avoid the observer’s reflection becoming the prime focus of the work, choosing not to confront the viewer in this potentially fundamental way. Though, there are exceptions. Given how prolific he has been in producing mirror works, I would assume he has explored this recursive reproduction of the observer in multiple-mirror environments. Perhaps he assumes (or has discovered) our more narcissistic preoccupations distract from the subtler perceptions he endeavours to inspire. Or, given the disturbing experience of occupying “the large-scale prism,” perhaps such explorations were too unsettling to leave his studio. The description of his motive does seem to provide a fitting interpretation of the encounter inside my own impromptu mirror space. It affords an opportunity to phenomenally, as well as conceptually, see myself seeing, but in this case amplified into the hyper-subjective spectacle of hundreds of jostling and seeing me(s). Here, consciousness of seeing and self is an assault, stronger than any I have experienced in my encounters with Eliasson’s installations. Unlike his clinically curated experiences, mine is a turmoil. Not only do I see hundreds of me seeing in every possible direction, I’i see in every possible direction as I look upon every possible aspect of myself. I am the viewer and the subject, to the disconcerting extent that determining ‘who is viewing’ and ‘who is viewed’ loses clarity. The sense that I am seeing myself through the eyes of a surrounding crowd, a crowd of me, insinuates itself into the experience and becomes inescapable. ’ […] you are in the interior of the reflections, you are in the house of glances, […] your glance weaves and unweaves the threads of the fabric of space, […]” intones Octavio Paz, in his dedication to Roberto Matta. The disembodying implication penetrates my sense of self, undermining it by displacing and dispersing it, and indeed engulfs any tidy contemplation of the experience.

DECENTRALIZED PERSPECTIVE

Despite the display of every possible aspect of me and the overwhelming sensorial experience, the implications of the decentralised and displaced view intrigue me. An incidental characteristic manages to push past the countless facsimiles of myself: each of them (me) stare in a distinct direction. However, due to the recursive reflections that generate the effect (Figure 2.2–4), all views are available to me. My perspective is a composite of theirs, a view that compounds with every reflection. I see in every possible direction at once. It is based on this realization (rather than any fascination with my own visage) that my ‘reflected-self’ becomes the subject of subsequent experiments.
2.2.3 SHAVING

Reflective surfaces have always captivated. When their production was technically challenging and laborious, they were rare and therefore prized (see *A Short History of Mirrors*). With contemporary mastery of materials and mechanized manufacturing techniques, the appeal of reflection is unrestrained. Mirror surfaces now envelop much of the built environment: our interiors, fixtures, vehicles, and appliances. Even amidst this ubiquitous display of reflection, we do not tire of specular surfaces. Why do we find them so compelling? Perhaps it is the hermetic magic of reflected light, glistening surfaces, mysteriously reproduced spaces and objects. Perhaps we have an unconscious need to constantly glimpse ourselves. I frequently catch people (sometimes myself) impulsively glance at their reflection as we hurry through our highly polished cities. Perhaps it is a need to witness ourselves as present in the world. Likely, it is a combination of these. However, the confronting experience inside the internally mirrored prism intimates other dimensions to the encounter with our reflected selves. Fathoming these emerges as inspiration for experiments with my mirror-self in a similar everyday encounter.

MY REFLECTION

Most encounters with my reflected-self are incidental, in windows, in the screen of my hibernating mobile phone, in the distorting polish of a stainless-steel kettle, and more obviously, in the mirror above the sink in the bathroom. The one regular and extended exchange occurs while trimming my remaining hair (Figure 2.2–5). I do this with a pair of electric clippers. It requires 20 minutes of attention to my reflection in the bathroom mirror. This activity provides the scene for a closer examination of the perspectives and capacities offered by the phenomenon of reflection.

A mirror is not necessary to shave, it is possible by touch alone, which on occasion has been necessary. However, it risks the embarrassment of missed hair. The mirror enables visual confirmation of a uniform execution. The fundamental problem is my eyes are placed in the middle of the object of attention, my head. All aspects of the most characterizing part of my body, my face, temples, ears, crown, and neck, are intractably beyond my view. The bathroom mirror allows me to regard these visually inaccessible aspects, by rendering them elsewhere. The resulting ‘extra-cranial’ perspective helps me bring clippers accurately and efficiently to these areas of my head.

A quick experiment before switching on the clippers offers an impression of the degree to which my reflection supports the activity. While facing the mirror and using the movements of my reflected-self for feedback, I attempt to touch the tip of my left earlobe with the corner of the clipper blade held in my right hand. I repeat the task several times. I now perform the same action, but with my eyes closed. With each attempt, the position is held on contact and a glance into the mirror allows an assessment of how close I come. I repeat this several times. The difference in success rate supported by the mirror and unaided is significant. With eyes open, I have no trouble in consistently hitting the target. With eyes closed I come close, most times within 20mm, but only hit the target once.

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* An individual mirror the size of a dinner plate could cost 100 écus (equivalent to US$10,800). The annual demand for mirrors in mid-17th century France, amounted to 100,000 écus (in today’s currency this would be roughly US$10,800,00), putting significant fiscal burden on the country at the time. 7

† The Countess de Fiesque was recorded as saying “I had […] a nasty piece of land that brought in nothing but wheat; I sold it and in return I got this beautiful mirror. Did I not work wonders – some wheat for this beautiful mirror!” 8

‡ These early mirrors were rarely more than 200 millimetres in diameter. 10
A SHORT HISTORY OF MIRRORS

Three centuries ago, the Royal Saint-Gobain Company in Paris developed a technique for casting and silvering glass that enabled the mass production of mirrors. Up until then, the glass-blowing guilds of Venice dominated the fabrication of mirrors. Venetian techniques for silvering were a jealously guarded secret, the envy of other European countries, and the subject of political intrigue and industrial espionage, for good economic reasons. The limitations of glass blowing meant that quality mirrors were small and spherical, slow and difficult to manufacture. They were rare, exorbitantly expensive, and highly desirable; owning a mirror connoted extraordinary prestige amongst the nobility of the time. However, reflective surfaces were prized long before 17th century advances in manufacture. Archaeologists attribute the earliest known mirrors to pieces of obsidian dating back to 6200 B.C.E, found at Çatalhöyük, in Turkey (Figure 2.2–6). Pre-Columbian Mesoamericans also used obsidian for their mirrors. Metals such as lead, bronze, copper, silver, and occasionally gold, were laboriously polished by ancient Egyptians, Europeans, and Chinese.

MATERIALS AND COMPONENTS

- a 1200x1200-millimetre domestic bathroom mirror;
- a pair of 18-watt 240-volt hair clippers;
The next task entails a close examination of my reflection standing on the other side of the mirror plane, paying particular attention to his appearance. He is very familiar to me. This image of him is how I see myself. He is the picture conjured when imagining or objectifying my facial appearance, and parts of my body, even when away from the mirror. He represents me. Regarding others familiar to me in the mirror, it is clear their reflection is not how I identify them. Their reflected appearance is appreciably different from what they present to me face-to-face. Human physiology is often assumed (even perceived) as symmetrical. This is roughly the case. However, by reversing that near symmetry, the mirror has the capacity to expose inconsistencies. We are very sensitive to the features of the faces of others, in meeting a person for the first time, we seem capable of registering their most subtle facial characteristics. Even so, familiarity eventually dulls this sensitivity. Viewing others familiar to me in the mirror is still surprising in the way it reveals idiosyncrasies lost in my face-to-face view of their countenance. It is like a first meeting. Such a discrepancy is not evident in my own reflection, because it is only one of two ways I can encounter my facial appearance. The second is by photography. A comparison of my reflected-self with my photographed-self reveals subtle but clear differences: a crooked nose, a head shape somewhat askew, a slightly slanted mouth, a heavier lidded left eye, unequally protruding ears. My photographed-self appears as odd to me as the reflection of familiar others (Figure 2.2–7). My image of myself and the image others have of me will always be slightly misaligned, and vice versa (see Chirality).
**CHIRALITY**

When I raise the clippers to my beard with my right hand, my reflected-self raises the hand adjacent to my own, his left hand: a left-right reversal. This is how the mechanism of reflection is often superficially explained and understood. However, it is more complex on closer examination. Attempts to explain the mechanisms have a history as long as there have been mirrors. Having mirrored CAD models countless times in years of design, it is clear that a reversal from left to right (and vice versa) does not account for the translation (Figure 2.2–8). Science writer, Martin Gardener, in his book, ‘The Ambidextrous Universe’, provides a succinct description of the transformation: “in a strict mathematical sense the mirror has not reversed left and right at all; it has reversed back and front.” Reflection can be thus interpreted as a reversal of depth. Such a physical translation, while cursorily simple, is not easy to visualize; Gardner’s own explanation is premised with three book chapters on symmetry. One way to envisage this is to imagine only my skin being reflected; let’s say the skin of my face. Reversal of depth is equivalent to: removing the skin, turning it inside out, and placing it on the far side of the mirror, directly opposite.

Reflection’s mechanism is fundamental and unique. No other analogous physical process exists by which it can easily be conveyed and understood. Reflected objects are fundamentally unique. They are contingent to the real world, but singular entities nonetheless. Only a truly symmetrical object can adopt an identical reflected form. My real and reflected selves are similar but unique, distinct enantiomorphs. If my reflected-self could join me in the real world, the differences would be juxtaposed and perhaps more obvious. H.G. Wells’ literary character, Gottfried Plattner, disappeared after a mysterious laboratory explosion, only to reappear days afterwards as his enantiomorph. The attending doctor reported with some disbelief that:

“The right lobe of his liver is on the left side, the left on his right; while his lungs, too, are similarly contraposed. What is still more singular, unless Gottfried is a consummate actor we must believe that his right hand has become his left [...] Since this occurrence he has found the utmost difficulty in writing except from right to left across the paper with his left hand.”

An intriguing material-world manifestation is enantiomorphic molecules. Many chemical compounds, naturally occurring and synthesized, have left-handed and right-handed variations. “[... they have otherwise identical structures, but the ‘right’ and ‘left’ forms can have very different properties. For example, the limonene molecules giving the tastes to oranges and to lemons are exactly the same, except that one is right-handed and the other left-handed. It is this mirror-asymmetry that makes oranges and lemons taste and smell differently. [...] They do this because the sense-detectors of the nose and the tongue are [also] specifically handed. This is like right- and left-threaded nuts and bolts. A right-handed nut will not fit onto a left-threaded bolt. [...] Sugar occurs in two handed forms: only one is accepted for digestion, though both taste sweet. [...] The tragic effect of the sedative thalidomide, given to pregnant women to alleviate morning sickness, was due to only one of its handed molecules. This was in 1961: now, the differently handed molecules of thalidomide can be separated. One is used for treating leprosy; the other (when the female patients are beyond child-bearing) is used for ameliorating arthritis.”

Optically, reflection is a straightforward extension of perspective, an inversion of view with the ‘folding’ of light as it meets the mirror surface. Spatially, it is a chirality, a unique construct: the objects of that mirror cannot be superposed on their real counterparts, so physically, they are essentially different. Phenomenally, looking into a mirror constitutes an idiosyncratic circumstance, a complement to the one I occupy; its objects are similar enough to be recognizable, but uncannily different. Epistemically, shaving at the mirror reveals an alternative aspect of myself; an essential perspective to who I am. Accordingly, reflection also reveals an alternative aspect on the world I occupy.
The view of my reflected-self helps me to orient my hand and position the clippers against my face. However, the touch of the vibrating clippers, and a bodily sensed spatial location of my hand also helps to locate them. For me to gain an impression of the position and motion of the clippers, I must watch my reflected-self. I orient the reflected clippers on his face. I shave by watching the hand, the face, and the motions of another being shaved, but simultaneously feeling haptic and proprioceptive sensory inputs as belonging to me. Whether I copy or control that hand becomes disconcertingly unresolved. Such a disassembly of this familiar task is surprisingly dislocating. It reveals reflection as more than a displaced perspective, rather a shared perspective (see Displaced Perspective).

FIGURE 2.2–9
Real and reflected observers looking at the hand of the other.
DISPLACED (PHENOMENAL) PERSPECTIVE

When I look at the reflected clippers in the mirror, where are the eyes of my reflected-self directed? Looking to his eyes to catch what he is looking at is of course futile; their direction will always mirror with my own. However, this can be extrapolated from the principles of plane mirror reflection. When I look to the reflected clippers against his face, my reflected-self looks back out of the mirror at the real clippers. My reflected-self sees what I endeavour to see (Figure 2.2–9). To momentarily suspend my body-centric reference and imbue my-reflected self with a ‘cognizance’ mirroring my own, the circumstance might be described as a shared task. The real clippers are not available for me to see, but within view of my reflected self. Conversely, the reflected clippers are not within view of my reflected-self but are available to me. While he and his clippers give me an indication where to shave, I provide the equivalent impression to him. The strange phenomenal inversion of space and object I see when looking through the mirror must be a complement to the strangeness with which he views real space. Maurice Merleau-Ponty, in ‘Eye and Mind’, quotes Paul Ferdinand Schilder as observing while “…smoking a pipe before a mirror, I feel the sleek, burning surface of the wood not only where my fingers are but also in those otherworldly fingers, those merely visible ones inside the mirror.”

The mirrored triangular prism generates a similar sense of displaced view; in that case, the enormous number of ‘viewers’ dramatically amplifies the effect. Both exercises prompt confusion over perspective: who is seeing and who is being seen; who is shaving, and who is being shaved? Perhaps in this way, reflection affords a phenomenal perspective (or the impression of one) external to my own.

The glass is watching us. And if a mirror hangs somewhere on the four walls of my room, I am not alone. There’s an other, a reflection which in the dawn enacts its own dumb show.

– Jorge Luis Borges
Reflected objects and spaces are perceived as positioned on the opposite side of the mirror plane, as if beyond a pane of glass. In psychology, this phenomenon is attributed to the visual system of the brain presuming the light from the object has travelled a straight line to the eye. Within this conception, mirror reflection is reduced to a displaced perspective. As such, reflected space is assumed to be an illusory counterpart to the real world, and so contingent to the real. Even when reflections are perceived as spaces, or reflected objects regarded as things, they are typically assumed as virtual, "...simulated, copied, mimicked, that there is an a priori reality that is of greater value and that the virtual version must therefore be nothing more than a simulacrum." The subordination of reflected space is a product of a material conception of our surrounds; space being perceived as a void, contained and unoccupied by matter, and thus defined by matter. It denies the influence of reflection (and phenomena more generally), it overlooks that perception of real space is altered when juxtaposed by an inversion of itself. Robert Morris proposed that:

> With mirrors you can get a special focus on the space itself together with a kind of vision you can't have with just literal space alone: there is the real space, the implied space, space which you can occupy, space you can occupy only visually, magnified distances. With mirrors you can stretch the space and have the real and illusory at the same time.

Reflection affords me an external view, but not of the real world or myself in that world. That world is a chirality of the one I occupy, it is different, and though the differences are subtle, they are essential and perceptually evident.

A traditional trick of portrait painters and illustrators is to regularly view their work in a mirror. It is a check advocated by Leonardo da Vinci.

> I say that when you paint you should have a flat mirror and often look at your work as reflected in it, when you will see it reversed, and it will appear to you like some other painter's work, so you will be better able to judge of its faults than in any other way.

The artist's perception of a subject, and their rendering, become desensitized with extended periods studying every detail of the face or scene. The reflection in a flat mirror appears to regenerate the image as if it were previously unencountered or painted by another artist. The Italian physician, mathematician, and astrologer, Girolamo Cardano, posited that, "The mirror uncovers several things that were latent, [...] by changing the original order that made the painting agreeable in the first place." This countervailing perspective exerts its influence on perceptions of the scene as much as its painted depiction (see Colonel Glenn Ross).

Examining the appearance of my doppelganger, and the appearance of those familiar to me over there in the mirror space, demonstrates that they are not faithful reproductions. They remain recognizable, as do objects, space, and even reflected writing. However, those versions appear as unsettling, not quite right. The value of attending to the reflected world is that it re-presents the familiar, not just as if witnessed for the first time, but as an augmented witnessing of the familiar and the peculiar, simultaneously.

The perspective I experience with my reflected-self is not so much a displaced view as a shared view. The strangeness of the world I glimpse beyond the mirror pane, corresponds to how my reflected-self must experience the world I occupy. In an involute equivalence, by looking into the mirror, I get to experience the strangeness of me and the world I occupy, as if through 'his' eyes.

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* This expression of the virtual is used to define computer simulated realities but is equally apt in describing the virtual nature of reflected environments.
† This countervailing perspective offers clues to how the mirror pole and mirror strip experiments yield a re-rendering of their circumstance. Even such discreetly thin reflected interventions contrast the view of the circumstance around them by overlaying another view of that circumstance. The new circumstance emerges as an interaction between how the observer interprets the scene, and how the mirrored objects interpret the scene.
Colonel Glenn Ross, the protagonist of the 1969 film, ‘Journey to the Far Side of the Sun’, is sent on a joint NASA and European space agency mission to a newly discovered planet, in a diametrically opposite orbit to Earth’s own (Figure 2.2–10). The mission is seemingly aborted when he crash-lands back on earth. Ross, the only survivor, becomes suspicious when everything with which he is familiar is reversed (Figure 2.2–11). The light-switches in his apartment are on the wrong side of the door, clock-hands rotate anti-clockwise, oscilloscopes scan right to left, and he can effortlessly read writing reflected in a mirror.

I envy Ross in this contrived cinematic scenario. The now quaint scale models of spacecraft on wires, and rather overwrought screen-play, obscure the film’s profound premise. Ross is given an opportunity to experience his world as mirror reversed. What would it be like to step into a reflected world? Despite the interplanetary diversion, his encounter is not with an alien planet, a fantastical adventure with Alice, nor a Cocteau-ian myth, nor the desolate parallel domain experienced by H.G. Wells’s Gottfried Plattner. The experience would be subtle, not the sensorial surfeit of encountering a completely foreign situation, but an experience of the recognisable rendered different. Maybe an analogous encounter is making a left-turn at an intersection in a right-hand drive vehicle when you have always driven on the left side of the road. The experience is unlike learning to drive for the first time. Itforegrounds elements of the world typically backgrounded to intention: the bodily actions, gear positions the road, the signs, the curbs, and the lines, are suddenly present, where they have long been relegated to the distraction of drive-time radio, or to planning the fastest route through peak hour traffic. Rather than entirely alienate, a mirrored world would destabilize. The everyday would be re-presented, perhaps affording a fresh aspect on what is known, but consequently neglected. Unfortunately, the film misses an opportunity to elaborate the encounter beyond a motivation to return Colonel Ross to his own planet. We are left to speculate.
2.2.4  THRESHOLD 1
(AN EXHIBITION INSTALLATION)

A small rectangle of abraded paint, which conspicuously blemishes a pristinely restored dining room wall of the Bundoora Homestead, reveals a multitude of coloured strata. The blemish is tolerated because, like tree rings, each coat of paint is a manifestation of a period in the homestead’s incongruous past. Currently, a neutral white covers the walls of many of its rooms, their ceilings, and ornate architectural mouldings. The homestead is a civic art gallery but was designed and built as an opulent turn of the century residence that celebrated the momentary success of a local race-horse owner and breeder (Figure 2.2–12). Other rooms are restored to offer the visitor an impression of the original homestead. However, hiding between the first and most recent coats of paint are the pigment remnants of times when the house functioned as a mental repatriation hospital. The Bundoora Homestead was then designated the Bundoora Convalescent Farm (Figures 2.2–13). It provided accommodation for WWI veterans classified as “neurasthenic” (a nervous debility and general malaise we now understand as posttraumatic stress disorder).

The following experiment and gallery installation, titled Threshold 1, is one of two contributions to Cloudy Sensoria, a group exhibition at the homestead. The curatorial brief called for artists to create site specific works that evoke “time shifting experiences,” as a way of reflecting on the history and architecture of the Bundoora Homestead. “Artists were asked to engage audiences in new ways of ‘seeing’ […] that responded to the building, its location and history of early Australian aristocracy, [its time as] an institution […], and now [as] a cultural centre.”

INSTALLATION

The temporary installation is an illusion of a large pane of glass dividing the exhibition space, heightened by two squares of light either side, and two skeletal representations of a 1920’s hospital bed (Figures 2.2–14). The pane of glass is an artifice; it is a semblance contrived by framing the middle of the room with a thin (12mm) strip of mirrored polyester, supported at its corners with fine fishing-line to form an upright rectangle. The mirror film is the same material used earlier in the mirror strip experiments. The tape bounds a large area, approximately 2.5 metres in length, two metres in height.*

Its material thickness is so fine as to be imperceptible. The reflective surface almost completely camouflages the strip in the darkened space, but also gives it the apparent transparency of a glass edge (Figure 2.2–14). Glints of light, incidentally reflected by the strip as the viewer moves through the space, subtly substantiate its presence as a sheet of glass. The installation is configured to encourage visitors to step through the phantom ‘pane’ into a mirror space.

* The reality of procuring, handling, and installing a material sheet of that scale and thickness would be impossible, perhaps even exceeding the weight capacity of the aging floor boards of the two-storey homestead.
MATERIALS AND COMPONENTS

10 metres of mirrored polyester film, surplus to a retail merchandising project; 2 Kodak S-AV 2050 slide projectors minus carousels, now obsolete presentation equipment, borrowed from a colleague, who maintains them for his projection artworks; 36-millimetres (outer diameter) black steel pipe, purchased specifically for the work.


FIGURE 2.2–13. Hospital ward, Bundoora Homestead (War Memorial, circa 1920).

FIGURE 2.2–14. One of two projectors, and square of mirror tape to generate an illusion of a sheet of glass/mirror (Parmington, 2012).
The site of the installation is the most symmetrical room of the homestead. A geometrical plane could be imagined as dividing the room in half to produce two spaces that are the mirror image of each other. Such a plane would intersect the wall between two identical windows, the centre of a large ornate ceiling rose, and the middle of a fireplace. The room’s floor plan and fixtures determine the position of the illusory pane of glass in that plane. The hospital bed frames are made from round steel tube, painted chalk white, and identical (Figure 2.2–15). These sit either side of the glass in exactly opposing positions. Two old carousel slide projectors configured as profile spotlights reinforce the effect. They cast equally dimensioned squares of light on the floor either side of the glass; one is slightly filtered to a green-blue colour (Figure 2.2–16). Both volumes of light meet at the glass, and they are the same width as the pane. The bed on one side is a dazzling white; the bed on the other adopts the ethereal hue of the tinted lighting. The remaining volume of the room is without direct light and considerably darker. The installation is oriented so that visitors step into the white square of light as they enter the room.

The work reveals a sense of overlaying space and history. It does so by intervening in a way that sensitizes visitors to the surrounds that embody this history, encouraging them to see differently for a moment, to occupy the space differently. It draws on some of the dislocating experiences that result from the experiments with mirror reflection, inviting the visitors to venture into the mirror’s tain, as a way of eliciting doubt then insight. It provokes them (and me) to look beyond surface, and thus beyond superficial perceptions (conceptions) dulled by familiarity. Rather than use physical mirrors, the installation counterfeits an instance of reflection. It appropriates symmetries in the architecture of the exhibition space. It recreates and assembles subtle phenomena, and circumstantial characteristics associated with reflective materials: the glinting impression of the square edge of sheet glass, the physical reconstruction of reflected furniture, and changes to the hue of light in imitation of the greenish tint of thick plate glass.
FIGURE 2.2–15
Detail, Threshold 1 (Parmington, 2012)
FIGURES 2.2–16
Threshold I,
exhibited at
Cloudy Sensoria,
Bundoora
Homestead
(Parmington,
2012).
The installation is the culmination of a series of experiments performed in and around the homestead. The preceding exercises employ reflection as an instrument to inquire in an approach similar to the mirror pole and mirror strip interventions. Although here, the aim is to realize a history embedded in the layers of paint, analogous to the way spaces and objects are realized in the surface of the polished finishes of the homestead. A large mirror sheet used to intervene in various locations within the homestead proves to be the most influential exercise informing the installation. The intention of the exercise is to position it in orientations and places that might simultaneously amplify and subvert symmetries in the architecture. However, this gets diverted by an unanticipated potential of the large mirror (see Big Mirror).

In a 21st century reappropriation of the picturesque painters ‘Claude Glass,’ Smithson’s displacing mirrors, and the polished silver sheets of Christian Bok’s medieval Slavonic Catoptriarchs, and to the bewilderment of many gallery patrons, for several days a large mirror (atop an old ute) is witnessed parked in various locations in the grounds of the homestead. Reflections of the house in this enormous mirror are the subject of examination and photography. Certain viewing angles make the house and its reflection meet at the mirrors edge (Figures 2.2–20). Reflections of the homestead in the mirror are complementary but inverted, almost contiguous with the actual homestead, as if the building fronted a still lake. The results are surprisingly compelling. The architecture morphs into an object, almost symmetrical about the mirror’s edge; a segment of its reflected aspect excised in the meeting of reflected and real. The mirrors edge intervenes between earth and sky, supervening the horizon with a boundary between matter and reflection. The imposition of this false skyline detaches both building and firmament from their foundations, as if unfolded along the crease of a ‘Rorschach ink-blot’. The illusory installation is an outcome of these exercises, a contiguity between present and past modelled on the contiguity between real and virtual (see Real and Virtual, Now and Then).
BIG MIRROR

In accordance with the architectural scale, the mirror is ambitiously sized. It is an entire sheet of mirrored acrylic, 1200 by 2400 millimetres in size, stiffened by a timber frame. It is heavy and unwieldy; it needs to be fastened to the roof rack of my vehicle to transport it to the homestead (Figure 2.2–18). However, even before it is completely assembled, dramatic and unexpected phenomena generated by the large mirror divert my plans. As it sits flat on a studio bench, waiting to be transported, it is already activating the surrounding space in dramatic ways. The object that was the bench, and the floor that supported it, are now a cavity; the table surface is a light-well as deep as the reflected roof is high (Figure 2.2–19). Moreover, looking across this well at its lip, real and reflected objects (and space) unify to generate something that inhabits both. Exploring the potential of this phenomenon in the environment of the homestead becomes the primary mode of creative generation and inquiry.

REAL AND VIRTUAL, NOW AND THEN

The meeting of virtual and real—the imaginary overlaying the actual, generated and separated by an aluminium coating measured in nanometres—has me considering the meeting of past and present. The historical images collected while researching the homestead hold new potential. Guided by them, each location is photographed as it is now from the same perspective. In a digital juxtaposition, images of old meet the new as their reflection (Figures 2.2–17). The exercise casts a reflected presence of the homestead’s history in each room of the house. The effect on my experience of these spaces is significant. Now, each space is an accumulation of countless moments, which press on me, not just as layers of paint, but as layers of space. Those (pre)moments can only be imagined, but such visualizations manifest at the margins of palpability. Conveying this experience becomes a key aspect of the installation.
FIGURE 2.2–20
Two views of Bundooora Homestead across a large mirror sheet mounted to the top of a vehicle. (Parmington, 2012)
A PANE OF GLASS

The encounter with the installation’s contrivance of reflected space, for many visitors, is completely plausible. Gallery staff describe the experience of a small group of children who, on discovering the work, elaborate it into a game of leaping, back and forth, between the real world and some fantasy world of their imagining. I watch one person disinterestedly standing beside the glass for several minutes, while her friend inspects the work more carefully. The latter eventually surrenders to the innate human urge to touch artwork, and her extending hand passes through a seemingly solid sheet of glass. The disinterested onlooker, gasps, and stands incredulous for a long moment, and must ultimately confirm what she has witnessed with her own tentative attempt to touch the glass. The gallery curator relates the encounter of a visitor who finds the revealed illusion so unsettling she needs to be escorted to the cafe for a calming cup of tea. The gallery staff have offices on the same floor as the installation. They are frequently interrupted by exclamations, even shrieks, escaping the exhibition space. Watching the dramatic reactions of visitors relayed via security cameras becomes a diverting break from work. At the other extreme, a colleague, with decades of architectural and theatrical lighting design experience, is left unmoved; he immediately sees through the deception and cannot dispel his material perception of the work.

The work plays with circumstantial phenomena to wield its effect. It is an accumulation of incidental characteristics usually peripheral to the experience of optical reflection. The occasional glint of the reflected gallery in the strip of mirrored polyester, suggest the internal reflections of a thick polished glass edge; the green light bathing the reflected bed and floor, suggest the colour shift of a scene viewed through heavy plate glass. However, there are many inadequacies and inconsistencies, giveaways to the deception. If each feature were juxtaposed with actual examples of these phenomena, the resemblance would be immediately exposed as superficial. The edge of a sheet of glass, even if mirrored, does not reflect as the polyester strip; the feigned green hue is exaggerated; and, while the bed may appear to be reflected in the glass, the viewer never is. Nonetheless, the installation is compelling for many people. The circumstantial effects conjured, while familiar in real situations, are rarely subject to conscious attention. We overlook these details while considering our reflection in a bathroom mirror or moving through the plate glass architecture of the city, preoccupied by the pressing demands of our days. They must be acknowledged at some unconscious level, otherwise the work would be implausible. However, their everyday appreciation must be vague, otherwise the deception would be immediately recognized and discounted. From my observations and from the accounts of the curators, the majority of visitors are initially, with a degree of dubiousness, persuaded by the artifice, and thereby compelled to investigate its intuited inconsistences. The elements of the installation must be perceived as not quite right: sufficiently congruent to be perceptually entertained, but discordant enough to warrant confirmation with further sensorial information. The degree to which inconsistencies are overlooked, either in everyday experience, or in experiencing the installation, in favour of the illusion remains surprising (see Edge of (Im) Plausibility). In manipulating these to subvert perceptions (preconceptions) of object and space, the installation reveals a diversity, an entanglement, and most significantly, a cognitive peripherality of the phenomenal manifestations (interpretations) that constitute perception and determination of space and object. The work deploys this deficit in awareness against us.
The research so far experiments at the fringes of the material and the acknowledged, and the installation uses a series of circumstantial phenomena toward an impression of mirror reflection. Perhaps as interesting is the work’s situation at the fringes of (im)plausibility. It suggests that implausibility is often a response of mind and perception in striving to maintain constancy (an accepted way of seeing or a familiar concept of the world) in the face of evidence. If the reflection illusion were so convincingly executed to be without doubt, it would also be disregarded. The installation derives its fascination, its discombobulation, its vitality, from being at the cusp of these states, perhaps oscillating between them, or as experienced simultaneously. The effect is perhaps analogous to the uncertain curiosity compelled by the immiscible fluid experiment.

At the closing of the exhibition, several professional art handlers have the task of uninstalling the exhibit. One of them is so beguiled by the simulated reflection of the bed, he finds it difficult to dispel the image as counterfeit, even as he dismantles the installation. Disassembly starts with removal of the lighting, then the window blackouts, then the polyester strip. Between packing the various components, he relates with consternation that his perception of one bed as an optical reflection of the other persists. Having submitted to the conceit, the phenomenon endures, with little provocation. I have experienced similar in this and other works, to varying degrees. It’s like a cognitive dissonance; two conflicting states of perception immobilize habitual conceptions leaving a state of ambiguity. Even after the state of mind dissipates, a realization lingers that what is known is untrustworthy. However, rather than being disturbing or debilitating, it is an opportunity to reshape my conceptions and see the world in new unexpected ways.

**FIGURE 2.2–21**
A pane of glass (Parmington, 2012).

I subsequently experience similar substantializations of light in other Turrell installations, such as Orca, 1984, and After Green, 1993, both exhibited at a retrospective hosted by the National Gallery of Australia in 2015.
FRED SANDBACK’S YARN INSTALLATIONS

Fred Sandback’s minimal yarn installations are said to perform similarly to the square traced by the mirrored tape (Figure 2.2–22). These rectangular planes traced in space generate “[…] a gut feeling that this space has become tangibly real. Both the slice of space caught ‘in between’ the lines and the space around it, to which we belong, […] one is inevitably read as figure and the other as ground, but with an eerie equality that leads to the bewildering conclusion that, […] fact and illusion are equivalents.” Christine Mayer Stoll attributes the effectiveness of Sandback’s yarn installations as relying in part on the familiar Cartesian conceptions of space defined by the rectilinear room. Length, width, height; ceiling, walls, floors – these are the basics of our perception of three dimensional space. They allow us to recognise the elements that generate space, […] they are at right angles to each other, the point at which the three intersect is called a node or zero point of origin. In a room, this would be the corner where all three coordinates meet, […] It makes his sculptures possible in the first place, for it is only in the relationship between surfaces and corners – the boundaries of space – that the sculpture becomes tangible […] inscribed in the volume of the room […]”

JAMES TURRELL’S ‘APERTURE WORKS’

James Turrell employs similarly ambiguous and subtle volumes of light in his works to substantialize space, particularly in his wall apertures. I experience this with a work titled, ‘Between that Seen’ (1991), exhibited at the Australian Centre for the Moving Image (ACMI) (Figure 2.2–23).* Occupying its own room, it manifests as a large violet-blue rectangle of light on a darkened wall. Several video-works in the same exhibition provoke an impression that the rectangle is the warm-up screen of a data projector. However, after a few moments, when nothing changes, the odd projection compels further investigation. There is no shadow cast whilst moving in front of it, but more intriguingly, it does not have the acoustic feeling of a wall. A cautious attempt to touch the surface, reveals it as empty space. What appears as an illuminated wall turns out to be a window onto a void lit by violet light. Peering inside, there is no way to gauge the extent of the volume beyond. Despite the tangible evidence that the rectangle opens onto a void, perception of its solidity, its materiality, stubbornly persists.†

LEANDRO ERLICH

Two installation works, created by the Argentinian artist Leandro Erlich, explore reflection phenomena in similar ways to the Bundoora Homestead installation. The earlier work ‘Le Cabinet de Psychanalyste,’ at the Centre d’Art Contemporain Saint-Nazaire, uses a variation of the 19th century theatrical technique called ‘Peppers Ghost’ (Figure 2.2–24). It employs the partial reflection properties of a sheet of glass or two-way mirror to project ghost-like reflections of visitors into a space set-up as a psychoanalyst’s consulting room. The artifice dislocates the visitors into an alternative environment. The second work, ‘Broom,’ employs two brooms leaning against each other to suggest the presence of a mirror (Figure 2.2–25). The effect is further enhanced by mock cracks made of thin strips of metal, which pass between the point where the broom handles meet. The work uses the suggestion of incidental phenomena in ways very similar to the Bundoora work.
The Bundoora installation assembles similar phenomena and experiences encountered in the works of Sandback, Turrell, and Leandro Erlich, but it presses them further to periphery and offers other ways to experience the artifice. The almost-invisibly thin reflectivity of the polyester tape withdraws its material presence, revealing itself only as an occasional flash of reflected light. The two opposing bed frames, glowing in their opposing hues, crystallize the space within (and beyond) this aethereal perimeter, and manifest the boundary between as a thick mirror polish sheet of glass. The bed beyond responds by dissipating to a tinted floating reflection. However, the seemingly solid pane offers a further dimension of engagement by allowing visitors to pass between real and reflected space, as if through the glass. The installation offers further phenomenal and spatial ambiguities. Optical reflection is a phenomenal overlay; reflected objects and space appear parallel to the tangible domain, the space we occupy. Here, the reflected bed is not a reflection (a parallel space), but a material impression; reflected space substantialized to occupy its phenomenal situation. It is a material illusion of a spatial illusion. Their incongruous physical presence as 1920’s metal hospital beds, generates a temporal ambiguity, overlaying the present moment with an earlier period in the homesteads history. The phenomenon of reflection used to momentarily confound and entwine perceptions of space, matter, and time.
2.2.5 A PHENOMENAL PERSPECTIVE

As a consequence of the extended time spent examining reflected perspectives, its strangeness starts to escape the mirror and permeate the real. The effectiveness of the curious installation in the odd gallery space is surprising. The installation is not a comprehensive recreation of passing into the mirror space; the elements are too minimal and abstract. Despite this, and my intimacy with the work, there are moments where reflected space becomes a phenomenal reality. The ‘pane of glass’ provokes a visceral response when stepping through for the first time. Accompanying the step from white-lit space toward green, from real toward imaginary, is a subtle bodily cringe of anticipated collision. It is closely followed by an equally subtle confusion of a passage unhindered; it is a dissonance of denied expectation. On the other side, my hands and then body are cloaked in the same greenish light as the bed next to me. The green pallor emphasizes the sense of occupying another space, distinct from the naturalistic tones defined by the volume of white light. The ‘reflected-space’ exerts a feeling of enclosure, where the white-lit volume does not, as if occupying an interior within an interior. The sensation is tinged with a claustrophobia, like being submersed in a thickened atmosphere. It has the capacity to invoke an impression that one bed is a reflection of the other, which places me on the false side of the mirror. Conceding to this conception of the situation destabilizes the materiality of the green tinted bed next to me. Its substance dissolves into the green light, and the apparition in turn disturbs my own substance. Now, looking back to real space through the illusory glass, it appears more solid, more distinct, but unfamiliar in its new density.

The play of stepping through the mirror pane enacts the dislocating effects experienced in the previous mirror experiments. However, it also surprisingly amplifies and extends those experiences. The installation’s reflected space is a contrivance, and the passage through the mirror to occupy the space is an incomplete illusion. It is nonetheless compelling. What is missing is as evocative as the successfully feigned. Given the hours of contemplating my reflected-self, stepping from the green hue of reflected space back into the volume of white light to again face the illusory hue, my presence is only the more present with the absence of my reflected-self’s returning stare. The return, though equally an artifice and performance, coalesces the work so far. It is an expression of a waver between the actual and the reflected, as if my reflected-self has returned with me, to the real. Now, in contemplating the real, it is imbued with something of the strangeness my reflected-self would experience as he looks through the mirror onto the real. I re-experience the place I inhabit. It situates the previous work (and the work to come), as delivering the peculiarities of reflected space and entwining them into the real (see A Heterotopia). Neither reflected-space, nor actual, sit so comfortably passive and banal at the fringe of awareness.

Reflection recasts the familiar as unique, with a presence and vibrancy it previously lacks. Overlooked and incidental reflection phenomena provide new perspectives on the built environment and reveal qualities and capabilities otherwise unavailable. The dislocating experience prompts a realization that phenomena at the periphery of research (design) activity, generated by that activity, disclose new aspects on that activity. My point of view, my intentions, inherently fall within the conventional, the mundane. More revealing, more compelling, are the perspectives offered by the phenomenal expressions of circumstance.
A HETEROTOPIA

Michel Foucault interprets mirror reflection as embodying a separate but related space (a “counter-site”): a site that is simultaneously with and without locality or place, which contests the spaces (places) we inhabit.37

“In the mirror, I see myself there where I am not, in an unreal, virtual space that opens up behind the surface; I am over there, there where I am not, a sort of shadow that gives my own visibility to myself, that enables me to see myself there where I am absent […] But […] the mirror does exist in reality, where it exerts a sort of counteraction on the position that I occupy. From the standpoint of the mirror I discover my absence from the place where I am since I see myself over there. Starting from this gaze that is, as it were, directed toward me, from the ground of this virtual space that is on the other side of the glass, I come back toward myself: I begin again to direct my eyes toward myself and to reconstitute myself there where I am. […] it makes this place that I occupy at the moment when I look at myself in the glass at once absolutely real, connected with all the space that surrounds it, and absolutely unreal, since in order to be perceived it has to pass through this virtual point which is over there.”38

Foucault presents the mirror as a metaphor for his concept of “heterotopias,” an “[…] attempt to explain principles and features of a range of cultural, institutional and discursive spaces that are somehow ‘different’: disturbing, intense, incompatible, contradictory and transforming.”39 They are “[…] sites embedded in aspects and stages of our lives and which somehow mirror and at the same time distort, unsettle or invert other spaces.”40 His exemplification of reflection as this counteracting space captures the composite perspective I experience in these experiments, an overlaying of real and mirror view. However, more significantly, its “heterotopic” nature captures the impression of space I inhabit as somehow acted-upon by the mirror space, re-made as richly peculiar, in this combination of perspectives.

“If we think we already know what is out there, we will almost surely miss much of it.”41

– Jane Bennett
REFERENCES FOR SECTION 2.2

2 *Copy Shop*, Directed by Virgil Widrich (2001; Austria: Virgil Widrich Filmproduktion), B/W 35mm. (https://www.youtube.com/watch?v=g0jeZabxSAg).
5 Ibid., 35.
6 Ibid., 13.
7 Ibid., 36.
8 Ibid., 31.
10 Ibid., 62.
11 Ibid., 47,50.
17 Ibid., 9.
26 Ibid., 104.
27 Journey to the *Far Side of the Sun* (Doppelgänger), Directed by Robert Parrish (1969).
28 Carroll, *Through the Looking-Glass: And What Alice Found There*.
29 Orphée, Directed by Jean Cocteau (1950).
30 Wells, *The Plattner Story and Others*.
31 Marina Larsson, *Shattered Anzacs: Living with the Scars of War* (University of New South Wales Press, 2009), 159.
32 Ibid.
34 Ibid.
36 Ibid., 14.
38 Ibid.
40 Ibid., 790-1.
IMAGE REFERENCES FOR SECTION 2.2


The first phase of experimentation extends attention from objects of design to the refraction and reflection phenomena they generate. The phenomena express relations between the objects and their circumstance. Circumstance activates transparent and reflective objects to reveal unrecognized characteristics and capacities—new and subtle phenomenal forms—and the objects activate their circumstance in reciprocation. The second phase of experimentation comprises several exercises examining an increasingly complex relationship between reflection, the circumstance it reflects, and the perspective of the maker (researcher/designer). It demonstrates that my reflected-self is incorporated into the design task, not only by contributing to reflection’s phenomenal forms, but by offering a phenomenal perspective. The final phase foregrounds reflected-form, by drawing it out from the perceptual margins into the light of creative attention as a ‘material’ and an ‘object’ of design.

The following series of experiments explore recursive and convex reflection. It commences with the discovery of a badly focused one-milliwatt diode laser (of forgotten origin), and a strip of two-millimetre thick mirror-coated acrylic, an offcut from the reflector of a light fixture prototype (Figure 2.3–1). The laser’s first application was described earlier as an alternative to a halogen lamp in generating caustic projections with the fragment of casting resin. It initially attracts attention as a means to materialize light as a thing, to construct walls and spaces with light. The first experiment of this phase uses the laser and acrylic to objectively realize recursive reflection as a folded beam of light. However, an experience of this phenomenon, as if from the perspective of the laser, proves more interesting. It inspires a series of design propositions. Two of these employ recursive reflection effects to generate form. The last attempts to reconcile the design of material form and incidental reflection in a unified approach. Together, these propositions intimate a transcendent capacity of the polished objects and surfaces of the built environment. It is a domain of reflection, which given appropriate consideration can be used to design and construct functional objects and spaces mediated by reflection.

* See Appendices: Scanned Planar Light Surface.
FIGURE 2.3–1
Faulty diode laser and offcut of acrylic.
FIGURE 2.3–2
Laser directed into an internally-mirrored ring at approximately 10° below horizontal (Parmington, 2007).

FIGURE 2.3–3.
Laser at approximately 30° below horizontal (Parmington, 2007).
FIGURE 2.3–4.
Laser and annular mirror rig (Parmington, 2007).
2.3.1 LASER NETWORK WITHIN AN ANNULAR MIRROR

During the experiments directing the laser through the resin fragment and vortex, the beam reveals particles in the air and water, and is thereby itself revealed. The phenomenon prompts another experiment with the laser. This employs a length of acrylic rolled into a ring with the mirror surface facing inwards to reflect the laser’s beam radially around its interior. I envisage giving extra dimension to the laser’s linear beam using recursive reflection. The anticipation is to optically fill the ring with a plane of light, enough to create the impression of a surface.

A sink of boiling water heats the strip of acrylic sufficiently to soften and bend it into a ring. When cool, the ends are fixed together with a small nut and screw through overlapping holes drilled in each end. Another small hole in the ring allows the diode laser to project inside. The laser must be carefully oriented with the centre plane of the mirror so that the light beam will not work its way closer to the edge with each reflection. A protractor supports the laser allowing the angle of the beam to be accurately adjusted (Figure 2.3–4). To reveal the path of the reflected beam requires an aerosol, a very fine airborne particulate. Initially an incense coil appropriated from a studio colleague serves this purpose, but later some pyrotechnic smoke pellets leftover from a previous special effects project prove more effective. The smoke is collected in a glass jar with, then blown across the path of the laser reflected inside the annular mirror.

At first, the laser is angled just below the horizontal centre line. When activated, the results are disappointing. The number of reflections inside the ring turns out to be unexpectedly limited (a maximum of 12-15) before the beam disperses to nothing (Figures 2.3–2 & 3). Acrylic mirrors have a poor reflective surface; the reflectivity can be as low as 88 percent. Although, the rapid dispersion is also likely to be exacerbated by the 2-millimetre layer of clear-acrylic. The mirror’s aluminium coating is applied to the back of the acrylic sheet to protect it. Refraction of the beam, as it passes in and out of the acrylic, will accelerate dispersion. This could be alleviated with a front coated mirror. (See Geometry of Multiple Reflection).

ELLIPtical MIRROR

An elliptical profile for the mirror is tested next. The circular ring is compressed along its vertical axis with a lightweight bar-clamp to approximate an ellipse. The aperture is now positioned in the upper surface of the profile, and to one side of the vertical centre-line. The laser enters through the aperture at a small (acute) angle from the vertical. Prior to the experiment, my (naive) anticipation is that the elliptical profile will generate a squashed star-form, polygon, or a random array. However, the slight change to the geometry of the mirror profile produces a dramatically different outcome. The laser’s path is now constrained to a space around the vertical axis. Unlike the 360-degree stellated or polygonal symmetry of the circular profile, this one is hourglass-like. The left and right extremes of the elliptical plane are not transited by the beam at all, producing two empty areas rather than the single one exhibited at the centre of the circular profile (Figure 2.3–5).

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* In lighting performance situations, a smoke-machine or fogger is used to give the light a degree of solidity.
† Euclid’s law of reflection.
MATERIALS AND COMPONENTS

10-milliwatt 3-volt green diode laser, wavelength 523 nanometres, as per previous experiments; smoke pellets, excess pyrotechnic materials from a past advertising project; 3-volt direct current power supply, iron wound 240v transformer; half a meter of grey figure-8 insulated copper electrical cable; 30x800mm strip of 2mm mirrored acrylic; 300mm cast steel workshop protractor and steel ruler; 250mm cast steel g-clamp; 38mm injection moulded resin grip clamp; two sheets of A2 black paper, divider in presentation folio sleeve; bi-wall corrugated cardboard box, previous shipping packaging; 2-litre glass jar with metal lid, as per previous experiments.

GEOMETRY OF MULTIPLE REFLECTION

While the experiment falls short of filling the annular mirror with a plane of laser light, it offers an ‘empirical’ ray diagram indicating the pattern of reflections inside the annular mirror. This makes explicit some of the optical geometry at play: the angles of incidence and reflection are repeated for each reflection, determined by the angle at which the laser is projected into the space. If the entry angle is altered, all the subsequent angles of reflection change to the same degree, a folding or unfolding of the pattern of rays. Some angles will generate a geometry where the laser-beam traces over the same path repeatedly. They are 30 degrees from horizontal – generating a triangle, 45 degrees – generating a square, 54 degrees – a pentagon, 60 degrees – a hexagon. Angling the laser at 18 degrees creates a 5-pointed star, and between 12 and 13 degrees creates a 7-pointed star. (Graphically tested later, this extends to 64.3 degrees as a heptagon, 67.5 degrees as an octagon, 15 degrees as a 12-pointed star etc.) Other angles tested give the impression that they would not coincide with an earlier path.
FIGURE 2.3–6
Video stills of shadow forms moving the laser beam network.

* See Scanned Laser Planes experiment described in the appendices.
BLACK CLOUDS

The sporadic process of blowing smoke into the annular ring produces a brief and discontinuous manifestation of the laser path, which quickly disperses. As the smoke moves through the ring, waves of darkness also move across its illuminated geometry: negative-forms that appear fluid, but which are too fleeting to study carefully (Figure 2.3–6). The effect suggests a shadow passing across an illuminated structure. However, the reality is the inverse: the light is the static structural element, and matter (the smoke particles that manifest this structure) the ephemeral element. The passing shadow-forms are material voids. The encounter inverts typical conceptions of light and matter, as did the resin fragments experiments. The shadow-forms and the swirling smoke also hint at other phenomena at the periphery of perception, in this case mediated by air rather than light. Their presence is strikingly apparent again in later experiments with the laser. The complex and animated air-forms are an indication of a wider realm of circumstantial phenomena. They serve to contextualize the work as contributing to parallel research into other modes of phenomenal form. A technique develops in subsequent experiments that manifests incidental air-forms using scanned laser-light and smoke. It proves to be useful to research on interior atmospheres.

CATACAUSTICS

While the annular mirror is lying on the white laminate work bench, it generates a double-crescent light-form on the bench surface inside the annular mirror (Figure 2.3–7). It is a catacaustic profile, generated by the concave mirror surface when reflecting a factory pendant light above my work area. These are frequently encountered in the bottoms of coffee cups, bowls, or sinks under a direct light source. Their distinctive form is mathematically described as a nephroid. The profile re-emerges and proves essential in modelling spherical reflection in the Stainless-Steel Pot Handle experiments.
2.3.2 PARAMETRIC MODELLING OF ANNULAR MIRROR REFLECTIONS

The material properties of the acrylic annular mirror limit the results of empirical experiments. However, the geometries demonstrated are simple enough to extrapolate outcomes, assuming the mirror capable of maximum specular reflectivity and true symmetry.

In a subsequent series of experiments, the geometries are explored as graphical representations, using a CAD algorithm to generate ray diagrams. A range of different perimeter profiles are tested (Figure 2.3–8). (See View Inside an Annular Mirror).

*Light holds no record of its trajectory, other than its direction the moment prior to perception.
THE VIEW INSIDE AN ANNULAR MIRROR

The small hole in the side of the ring compels a curiosity to experience what it would be like to occupy this annular mirror space. Peering through the hole, a reflection of my head occupies the view, intersected by the inside surface of the annular mirror. Inset between top and bottom edges of the mirror is a reflection of the outer edges, and within these a further set of reflected edges. Each reproduction is parallel and recedes into the previous space, to generate a horizon of distortedly regressing views of the surrounding studio (Figure 2.3–9). In the centre of this retreating structure, is the dark hole through which my eye peers. The implication, that the paths of photons entering my eye through the hole trace the paths revealed by the laser, is difficult to reconcile. The two experiences of the same physical mechanism are so distinctive. Both express light’s material encounters with the mirror. However, from the external perspective, the path of light is a series of recursively folded lines combining in geometrically and spatially complex ways. Through the hole, and from the perspective of the laser, the visual information is presented in a single direction receding from the viewer. I see an equivalent to what the laser light experiences as it is infinitely reflected around the inside of the mirror. It is a phenomenal unfolding of the stellar geometry of the laser-forms, in a single extended direction, in a single subjective perspective.*

The starkly different phenomena are two aspects of the same circumstance. Their difference highlights that any one circumstance might be explicated in countless ways. Each offers a range of rich alternative phenomenal perspectives (aspects) and rich creative possibilities. In principle the intended experiment is successful, a range of striking lightforms are proven achievable. However, the more valuable outcome emerges from peering through that hole. It constitutes a phenomenal and conceptual shift in the work that prompts subsequent explorations of mirrored spaces generated by recursive reflection. These prove to be a defining characteristic of the project.

FIGURE 2.3–9
A camera’s view through laser entry point into the annular mirror (Parmington, 2007).
2.3.3 KALEIDOSCOPIC POLYHEDRA

Recursive reflection effects are explored further by extending the annular mirror experiment to a third dimension, with the construction of internally mirrored volumes. The stellated laser-forms reveal symmetries that correspond to polygonal geometries. These geometries inspire a series of experiments exploring the optical effects of polyhedra that have their interiors completely lined with mirrors. The subsequent work proves to be some of the most productive of the project, generating a range of objects described as polyhedral kaleidoscopes and dihedral kaleidoscopes.* The first of these is the construction of a dodecahedron.†

DODECAHEDRON

A sheet of mirrored acrylic and plywood are laminated together. Twelve pentagons are cut from the sheet and their edges chamfered to fabricate a dodecahedron. The assembled object is approximately 350 millimetres between the two furthest vertices. There are many circumstances in our contemporary, highly reflective environment where we encounter multiple reflections, and most people have witnessed the ‘infinite corridor effect’ of two planar mirrors set facing one another. The multiple mirror environment of the dodecahedron is much more complex, twelve mirrors directly facing each other, as six pairs. I remove one face unsure what to expect. The timber of exterior of the polyhedron gives the impression of an oddly shaped jewellery box; peering into it reveals a jewel-like interior. The effect is striking, beyond what I could have anticipated (Figure 2.3–10). Inside is something between a structure and a space, crystalline but infinite, a three-dimensional kaleidoscope (Figures 2.3–11 to 13). The inward facing mirrors gather, multiply, and reconstruct the interior. The cumulative effect generates a phenomenal internal space and structure, configured according to the geometry of the vessel. Each mirror facet holds an accumulation (a record) of all previous reflections, a collection of edges and interior space. With each reflection, more space and more pieces are accumulated. Each reproduction diminishes in scale and withdraws outward with increasing distance. A myriad of broken shards and space infinitely regresses, expanding into the space beyond the walls of the vessel. They eventually diffuse into a hyper-spatial montage: a multi-dimensional **mise en abyme**. “[…] the mirror sinks into itself, drowned in clarity until it is erased in a reflection […]”

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* Segments of polyhedra
† A dodecahedron is a regular polytope. It is made up of 12 identical pentagonal planar faces, 20 vertices at which three faces meet, and 30 edges. It is Plato’s fifth Solid. In his analysis of *Timaeus*, Peter Kalkavage suggests that for Plato, the dodecahedron constitutes the “panels for the constellations,” the solid on which the heavens are adorned.
MATERIALS AND COMPONENTS

1220x2440-millimetre sheet of 3-millimetre mirrored acrylic, obtained to build kaleidoscope; offcut of 16mm C/D grade 11 ply radiata pine plywood, surplus to the construction of a display system; contact adhesive.


FIGURE 2.3–11. Interior of dodecahedral kaleidoscope, externally illuminated through a single opening covered with fabric.

FIGURE 2.3–12. Interior of dodecahedral kaleidoscope, externally illuminated through a single opening covered with paper and aperture for camera.

FIGURE 2.3–13. Interior of dodecahedral kaleidoscope, internally illuminated with a single halogen lamp.
A small halogen lamp is placed into the space to illuminate the interior. Inside the dodecahedron, the single lamp becomes a galaxy (Figure 2.3–13). The effect is so overwhelming it negates any sense of structure or depth. The intensity of repeated reflection is moderated by removing one mirror surface from the dodecahedron. The sense of parallel space is emphasized. A more coherent geometry becomes evident. Replacing panels with backlit translucent materials such as paper and fabric further quietens down the chaos of the initial effect and serves to illuminate the interior for study and documentation (Figures 2.3–11 &12). The edges of the mirror planes reveal the hyper-spatial geometry. The most obvious structure is a set of receding corridors produced by the facing mirrors, which radiate outward, arrayed evenly in the three-dimensions around the centre of the mirror box. However, the pentagonal profile of these facing surfaces is misaligned (rotated) by 36-degrees. Thus, alternating portals define each infinite corridor. The reflections of the dodecahedrons internal space (and edge structure) do not align with each other, there are gaps between the first generation of reflections. Thus, space and edge begin to incoherently overlap with each subsequent generation (Figure 2.3–17). There may be a pattern in the resulting structure, but if it conforms to a geometry, it is complex and elusive. (See *Space Filling Structures*.)
The internal effect, defined by the edges of the mirrors, is like peering into an infinite crystal lattice. While the mirrored geometries generated by the dodecahedron do not align in a coherent way, some basic geometries would, for instance an internally mirrored cube. Inside a cube, each recursive reflection of an edge would align with a previous. The structure would generate a regular cubic lattice, much like the atomic lattice of salt, which is a face centred cubic array of sodium and chloride ions (Figure 2.3–14). It occurs to me that with the appropriate geometry, mirrored polyhedra would recreate other symmetrical crystal structures at their most fundamental level. Another example would be an internally mirrored hexagonal right prism, which would share the same configuration as the hexagonal crystal lattice of carbon atoms that constitutes graphite (Figure 2.3–15). Such kaleidoscopic boxes become a system of construction, architectural space-frames in reflected space. Some regular ‘space-filling’ structures are later investigated as kaleidoscopic boxes, such as a rhombic dodecahedron (Figures 2.3–18 & 19).
PENTAGONAL ICOSITETRAHEDRON

Other geometries are tested, such as a pentagonal icositetrahedron.* A more expedient method is initially used to assemble the kaleidoscope. The edges of the mirrored panels are taped together, instead of laminating them to a substrate. The masking tape used for this purpose, reveals a surprising capacity of the model (see Aethereal Space Frame).

The resulting object is larger than the dodecahedron, approximately 400mm between the furthest vertices (Figure 2.3–20). The extra surfaces seem to accelerate the interior ‘telescoping’ of space and detail, further emphasising the crystalline qualities of the interior space (Figure 2.3–21). As with the dodecahedron, when all faces are in place, the effect tends to overwhelm the sense of expanded space. Again, this is mitigated by removing one, two, or three faces (Figure 2.3–22).

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* A pentagonal icositetrahedron is characterised by 24 faces, each an irregular pentagon. The faces come together at 38 vertices, in arrangements in combinations of either three or four. They share a total of 60 edges.

† See Appendices, Exploded Pentagonal Icositetrahedron Kaleidoscope.
MATERIALS AND COMPONENTS

Various pieces of 3-millimetre mirrored acrylic sheet, offcuts from the dodecahedral kaleidoscope; a roll of 50-millimeter wide masking tape, from accumulated painting accessories.

AETHERAL SPACE FRAME

An unexpected consequence of using masking tape, is that its translucency allows light to leak between the faces. When all panels are in place, the interior is now composed entirely of glowing edges and their reflections. An infinite glowing space-frame now defines the structure and extent of interior space. It grows finer with every reflection, and ultimately reduces to a blurred network of diaphanous cobwebs (Figure 2.3–23). The internal structures generated by translucent edges have me contemplating ways to open-up the kaleidoscope in ways other than the removal of panels. In a subsequent experiment, a system that separates edges to open the kaleidoscope is investigated.†

FIGURE 2.3–23
Interior of pentagonal icositetrahedral kaleidoscope, with three sides blacked out, and externally illuminated edges.
FIGURE 2.3–25.
Open dodecahedron experiments at Kangaroo Ground, Victoria (Parmington, 2007).

FIGURE 2.3–26.
Open pentagonal icositetrahedron experiments, Thornbury (Parmington, 2007).

FIGURE 2.3–27
Open pentagonal icositetrahedron experiments, Thornbury (Parmington, 2007).

*This strange ambiguity of inside and outside proves to have significant implications for following experiments, and for interpreting the research generally.
Removing or separating the faces of the pentagonal icosahedron introduces an ambiguity between interior and exterior. The mirrors have an extraordinary capacity to capture unusual perspectives on their surrounds and reproduce them as fragments throughout their interior, including me and the camera. It becomes apparent that to isolate these interior environments from the outside world is also problematic, even impossible. Opening it even slightly captures and repeatedly recasts surrounding objects into the countless crystal cells, an intertwining of reflected space with real, interior with exterior.

At first, this is intrusive, but ultimately, possibilities generated by the interaction of interior and exterior become the subject of experimentation. The kaleidoscopes go on excursions and the interior effects in various locations are documented (Figure 2.3–25). When opened outside in bright light or sunlight, the interiors transform into a harsh sky-blue environment of shattered glass (Figure 2.3–26), the mirror space seeming to reach back, beyond its faceted sides, toward light and sky. Opened inside, soft white painted walls and ceiling contrast a matrix of silver crystals, crystals constructed from reflections of those regressing walls and ceiling (Figure 2.3–27). Peering into a kaleidoscope while I hold it between my hands, gives me the disconcerting feeling that the expanded space is physically overwhelming my body. My hands, arms, and torso are unsure whether they are being displaced or penetrated by reflected surrounds, as they spill out of the vessel and crystallize the space beyond its walls.

Robert Smithson explores similar effects in a variety of prismatic work constructed with mirror panels (Figure 2.3–24). He describes one such piece as collecting the “[…] reflections of a concatenated interior.” The interior structure of the room surrounding the work is instantaneously undermined. The surfaces seem thrown back into the wall. ‘Space’ is permuted into a multiplicity of directions. One becomes conscious of space attenuated in the form of elusive flat planes. The space is both crystalline and collapsible.

In the initial experiments with the dodecahedron, the interior of the kaleidoscope cannot be isolated from its exterior. It is also impossible to prevent myself the viewer from being captured by the mirror interior. When peering inside, various perspectives of my visage or camera lens are also collected, fragmented, multiplied, and scattered throughout the faceted environment. Regardless of my viewing position or direction, the box recasts my gaze as countless others peering into the vessel with multiple eyes, from multiple positions, from different depths. Some direct their gaze toward me. It is an experience that prompts the second phase of experimentation.
2.3.4 DIHEDRAL KALEIDOSCOPE

The capacity of the polyhedral kaleidoscopes to collect and displace views of their surrounds inspire a series of architectural explorations. These are concepts for installation works, which play with the possibility that outward vistas (outlooks) might be transported through building interiors, from their exterior to windowless interior spaces. The notion is to intervene in an existing space with a kaleidoscopic tube constructed of light-weight mirror membrane, which ‘pipes’ reflected reconstructions of these outlooks (Figure 2.3–30). The anticipation is to experiment with transporting light, but to also reinterpret the significance of a ‘desirable view’ in a playfully incongruent way. However, an encounter while disassembling a model of one of the tube combinations diverts the work (See Virtual Polyhedra).

* The exercise also inspires a successful undergraduate studio program examining ‘daylight harvesting’ in the development of lighting fixtures.
† The encounter with the effect inside the tapered kaleidoscope embodies an increasing inclination to regard reflected form as if it were a fabrication material, which might be used to construct a type of space or object. This is reinforced in the experiments with kaleidoscopes, and it informs a design exercise that endeavours to model reflected form and material form as a single intrinsically entwined object.
MATERIALS AND COMPONENTS

3-millimetre mirrored acrylic sheet, purchased for the exercise; roll of 50-millimetre wide PVC duct-tape.

VIRTUAL POLYHEDRA

Peering into the larger opening of a tapered mirror tube with a triangular cross-section (Figure 2.3–28) (looking toward the other smaller open end) reveals a geometric ball of light that resembles a polyhedron (Figure 2.3–29). It is arrayed in the virtual space around the opening of the tube. Inside typical straight sided triangular kaleidoscopes, the recursive reflection effects tessellate the opening to produce a (virtual) plane of triangular tiles. However, at the end of the tapered tube, this tessellation appears as a ‘three-dimensional’ object. The narrowing geometry seems to roll the reflected plane back on itself to form a sphere of triangular facets. The facets of light appear to fit neatly together at the centre of the sphere, but increasingly lose contiguity toward the outer edges, ultimately and arbitrarily overlapping each other. Countless lines radiate from its surface. These are reflections of light leaking through the adhesive tape crudely joining the mirror edges. The encounter compels me to speculate that reflection could be a medium of object making. It inspires a series of form generating experiments that explore the capacity of kaleidoscopes to assemble virtual polyhedral symmetries. Importantly, rather than diverting the work to an unrelated result, the detour eventually returns to the original proposition, but in doing so provokes a reconceptualization of the initial aims. Instead of transporting a disassembled view, the subsequent proposition generates “reflection objects” from the exterior view.
FIGURE 2.3–31
Exterior of an icosahedral kaleidoscope with scored mirror surfaces (Parmington, 2015).

FIGURE 2.3–32
The interior of the icosahedral kaleidoscope generates a complete virtual space-frame of an icosahedron.

FIGURE 2.3–33
Exterior of a dodecahedral kaleidoscope with areas of the mirror surface removed (Parmington, 2015).

FIGURE 2.3–34
The interior of the dodecahedral kaleidoscope incorporating half-round acrylic rod generates a complete virtual space-frame of a dodecahedron.
FIGURE 2.3–35
A dodecahedral kaleidoscope incorporating a yellow acrylic profile generates a virtual dodecahedron (Parmington, 2015).

FIGURE 2.3–36
Interior of the dodecahedral kaleidoscope without yellow acrylic profile.

FIGURE 2.3–37
Light-globe inside the dodecahedral kaleidoscope.
ICOSAHEDRON

An icosahedral geometry (Figure 2.3–38) provides the basis for the first of these virtual polyhedra. The mirror configuration makes a three-sided pyramid without a base, a segment of an icosahedron. Unlike a typical kaleidoscope, the three mirror faces meet at a point (a vertex) rather than an opening. It uses a technique derived from an encounter while rough cutting a sheet of acrylic (see *Space Frame Polyhedra*). I score the outside faces of the icosahedral kaleidoscope with a single groove close to the vertex of the scope. The grooves meet at adjacent faces to complete an equilateral triangle, which is also visible on the inside of the kaleidoscope (Figure 2.3–31). Despite some doubt during its assembly, the kaleidoscope works as anticipated, generating a complete ‘space-frame’ icosahedron (Figure 2.3–32).

DODECAHEDRON

The subsequent two kaleidoscopes are a section of a dodecahedron: five-sided pyramids (Figure 2.3–39). In the first, instead of scoring the exterior, five lengths of half-round acrylic rod are fixed inside, each with a frosted finish, so they join to form a pentagon. The five mirror walls generate a complete dodecahedron. The mirror coating is removed just behind the acrylic rod, so that any ambient natural or artificial light can permeate the rod inside. The internal dodecahedron is even more distinct, illuminated and floating inside and beyond the walls of the kaleidoscope (Figure 2.3–31). The second five-sided kaleidoscope is left empty, and its mirror surface intact. With this, extraordinary forms can be generated by placing physical objects inside. The first item tested is a five-sided star-like profile cut from translucent yellow acrylic with a large hole in the middle. Placed into the scope, it recursively replicates to generate a complex perforated dodecahedron (Figures 2.3–34 & 35) (see *Circumstantial Dodecahedrons*).

* The score line directs the propagating crack through the material.
Scoring mirrored acrylic is a convenient way to break down large sheets for easier handling. A pointed tool is used to gouge a thin groove of material; the sheet can then be broken by hand along the score line. While scoring one of these sheets, a new dimension to the dihedral kaleidoscopes suggests itself. The scored line cuts through the heavy layer of grey protective paint and the aluminium coating of the mirror. When examined closely, on the mirror-side of the sheet, the groove appears solid. It is not a void, but a small wall with a triangular profile embedded in the transparent acrylic (Figure 2.3–40). Its presence against the reflecting silver of the mirror coating, particularly when lit from behind, suggests the possibility that closed kaleidoscopes could generate space-frame objects. The view inside a tapered kaleidoscope with an open-end gives the impression of a ‘solid light’ polyhedron (Figure 2.3–29). However, only the ‘facets on one side’ of this virtual object are apparent. I speculate that by leaving the kaleidoscope closed at its vertex, and incorporating some strategically scored lines, its mirrors, its geometry, and external light, might collaborate to generate a visually complete polyhedron, constructed from a glowing wire-frame network.

The empty five-sided kaleidoscope asks to have random objects placed inside: mirror offcuts, and random workshop miscellanea, including a light globe. Each combination reproduces the object from 12 different angles and configures them in a dodecahedral geometry (Figure 2.3-37).
ICOSAHEDRON WITH DOOR VIEWER

I later construct a variation on the icosahedral kaleidoscope. This time it is closed on all four sides. Wider areas of the mirror layer are removed from the acrylic. Their profile is less linear. A 160-degree domestic door viewer is mounted into its base to view the interior (Figure 2.3–42). The internal effects are revealed as through a fish-eye lens. It generates a three-dimensional organic starform, amid an array of Reuleaux triangles (Figure 2.3–43).

FIGURE 2.3–42. Icosahedral kaleidoscope with door viewer exterior (Parmington, 2015)

FIGURE 2.3–43 Icosahedral kaleidoscope with door viewer interior


† Another exception is Your Star House, 2011, which looks like it might generate a stellated icosahedron.
‡ Jim Drain and Ara Peterson employed a dihedral kaleidoscope to generate a coherent virtual hexakis dodecahedron with animated faces as a video installation. It was titled Kaleidoscope, 2003.
§ See recent papers by Goodman, Schwabe, and Palmer.
** See paper by Sonoda, patents by Doak, Sandoval, Altman, Frucht, and kaleidoscope products by AHA.
TAPERED KALEIDOSCOPE

An installation space by Olafur Eliasson, titled *Multiple Grotto* (2004), generates similar effects (Figure 2.3–44). It employs a multitude of tapered triangular mirror tubes, connected at their bases, and pointing outward to create a partially enclosed space. The small opening, cut at the end of each protruding scope, generates a small faceted light-object. The geometry of the installation resembles a ‘hexakis icosahedron,’ and the light-forms produced seem to be stellated versions of this geometry. Eliasson uses tapered kaleidoscopic effects for many of his works. Although, in most, he seems unconcerned whether the tessellations configure themselves as mathematically (and thus visually) coherent objects. My interest coincides with his where these kaleidoscopes are configured to generate geometrically precise polyhedral forms. I envisage phenomenal complements (inversions) of the acrylic mirror polyhedra of the previous experiments. The phenomena inside the mirror polyhedra were ‘spaces’ constructed by reflection; the phenomena inside the dihedral kaleidoscopes are ‘objects’ constructed by reflection. They are aethereal manifestations of those material constructions. Eliasson is not the first or the only artist to experiment with such internally mirrored structures. Robert Smithson explored similar effects in the mid-sixties (Figure 2.3–45). However, the principle of polyhedral forms generated by tapered kaleidoscopes has been explored by many mathematicians, scientists, and inventors, earlier than this. All utilize the geometric principles elaborated by mathematician Harold Scott MacDonald Coxeter in the 1940’s. They are variously described as ‘dihedral kaleidoscopes,’ or ‘corner kaleidoscopes.’ There is renewed interest in the mathematics of the phenomenon and as products or spaces for art and entertainment. They are a novel way to generate tessellating kaleidoscopic patterns. In contrast to the conceptual artistic objectives of Eliasson, or the purely aesthetic pursuit of patternmaking, these reflection phenomena suggest applications as objects of design integrated into architecture (see following ‘Skylight’ experiments).
2.3.5 SKYLIGHT

The work with dihedral kaleidoscopes gives coherence to an earlier speculation that mirror lined tubes might be used to move light, and surrounding aspects, through building interiors. In those speculations, I envisaged that the effects generated would be an arbitrary disassembly of the views, similar to the interiors of the kaleidoscopic polyhedra. The explorations were more provocations than feasible design propositions. The subsequent experiments with dihedral kaleidoscopes offer techniques to generate coherent geometrical objects and form employing simple configurations. And, the expectations and potential emerge as more practical. Dihedral mirror configurations might be integrated through the insulation and service cavities, or substantial sections of masonry, necessary in the construction of architecture, much as typical skylights (see Tubular Skylights). However, these dihedral versions would dramatically extend the notion and possibilities of standard skylights. Unlike the dihedral kaleidoscopes, the mirrored interior of a tapered kaleidoscopic skylight would not converge to its apex (Figure 2.3-49). It would be truncated and open, fitted with a window to allow light to pass through. It would gather external perspectives and recursively construct objects made of sky (See Sky Objects).
MATERIALS AND COMPONENTS

3-millimetre mirrored acrylic sheet, purchased for the exercise; roll of 50-millimetre wide PVC duct-tape.

TUBULAR SKYLIGHTS

Interestingly, the use of highly reflective tubes already is a standard approach to domestic architectural skylighting systems. However, these are typically narrow and cylindrical. Their polished internal surface is solely to maximise light transmission (Figure 2.3–46).

OBJECTS OF SKY

New York art director, Tony Palladino, reputedly, to rebuke the notion that sky views are too obscured by high rise buildings in Manhattan to be properly appreciated, asked photographer and friend Kathy Phelon to photograph the New York skies at dusk. He then exhibited them inverted to "create castles in the sky"26 (Figure 2.3–47).
To experiment with the possibilities, three scale models are constructed using mirrored acrylic. The first is a square cross-section, a tapered interpretation of a standard box skylight (Figure 2.3–48). It generates a square-tiled lightform that coalesces as sphere. The squares appear to tessellate uniformly at the centre of the object, but they begin to overlap toward the outer edges. The subsequent two employ the most intricate of the dihedral geometries, a hexakis icosahedron (Figure 2.3–53). The aperture of the first is a simple triangle (Figure 2.3–49). When open to the sky this triangle of light is recursively reflected to generate (a close to) coherently aligned faceted hexakis icosahedron (Figure 2.3–50). The second is more complex; each face is cutaway with a parabolic profile. When assembled they form an irregular compound deltoid (Figure 2.3–51). When open to the sky, the deltoid is coherently reproduced to generate a complex tapered star-form (Figure 2.3–52).

Such tapered kaleidoscopic skylights would provide efficient mechanisms to deliver external light to internal spaces. Their mirrored walls capture a wider perspective of sky than light entering directly through the aperture alone. This is incidentally evident in the range of different blues revealed in each reflection, which indicate the skylight is gathering light from all aspects of the sky. The tapered profiles direct the light downwards with fewer reflections than would a straight walled mirror tube. More significantly, they fundamentally shift the quality of the light they deliver, disassembling the vast gulf of the sky into various perspectives and reassembling it as a geometrical form, giving substance not only to the light, but space, and reflection itself. Passing cloud forms become animated tessellations growing and collapsing out from and into the vertices of this geometry of light.
2.3–51 Exterior of hexakis icosahedral kaleidoscope with deltoid aperture (Parmington, 2018).

2.3–52 Interior of hexakis icosahedral kaleidoscope with parabolic aperture directed at sky.

2.3–53 Spherical hexakis icosahedral geometry and necessary mirror angles (Schwabe, 2005).
2.3.6 TRANSECTING ARCHITECTURE

FIGURES 2.3–54
Physical scale model of mirror-wall laneway proposition. Effect generated looking upwards at various angles (Parmington, 2011).
FIGURES 2.3–55
Mirror-wall proposition. Effect looking into the mirrors.

FIGURE 2.3–56
Exterior of 1:20 scale model (Parmington, 2011).
OPPOSING MIRROR WALLS IN A CITY LANEWAY

The recursive reflection effects experienced while looking into the annular mirror, and the interventions with mirror poles in an urban site, ask to be combined in some substantial application. This manifests as a proposal for a public sculpture commission invited by the City of Melbourne. The city’s objective for this significant commission is to enhance the laneway culture in the central business district. The programme provides an opportunity for a substantial work that provokes alternative ways to see and inhabit the city. The selected site is a narrow throughway between multistorey commercial and residential buildings, connecting two busy streets (Figure 2.3–57). It is dark, overshadowed by red-brick and bluestone. The concept comprises two mirror panel walls facing one another across the laneway, fixed to the five storey buildings either side. The intention is to visually slice the architecture with an infinite reflected laneway perpendicular to the first. The panels would be three metres wide, approximating the width of the laneway, and reach the full height of the facing buildings. At night, a profile spotlight would illuminate the bluestone cobblestones between the two mirrors, precisely connecting their bases with a square of light. The strongly contrasted section of ground, and the viewer in the pool of light, would be multiplied in a recursively reflected luminous path, through the masonry of the buildings either side.

A 1:20 scale model of a section of the laneway is used to examine and demonstrate the effects (Figure 2.3–56). The interior walls of the model laneway are clad with 3-millimetre mirrored acrylic, to mimic the mirror installation. The graffitied redbrick walls and cobblestone paving are photographed, printed and also adhered to the walls and floor of the model. Stands support the model, elevating it, so the effect can be viewed and photographed from underneath.

At ground level, the model generates a corridor perpendicular to the lane, which recedes into each mirror. The mirrors reach the roofline of the buildings either side, so as anticipated, they appear as another laneway crossing the first. The facing mirrors visually cleave the architecture, casting countless reproductions of the viewer into this virtual lane, multiplied as a series of alternating pairs, facing into and out of the reflected passage (Figure 2.3–55). They generate a series of parallel laneways that reduce the buildings’ mass to a sequence of alternating impossibly thin facades, a row of theatrical scenery flats (See Surface). Given their height, they significantly and unexpectedly expand the view of the sky beyond that framed by the buildings and draw daylight into the laneway (Figure 2.3–54). (See Sky)
MATERIALS AND COMPONENTS

6-millimetre medium density fibreboard, collected offcuts; 3-millimetre acrylic, offcuts from previous experiments; 12-volt MR12 domestic downlight; digital camera; colour printer

SURFACE

The extent to which the intervention subverts the substance of the buildings is surprising. The facing mirrors reduce the architecture to a sequence of impossibly thin, alternating facades, and thereby generate a series of duplicate parallel laneways as much as a perpendicular one. The superficializing effect reveals the myth of solidity, and the truth that our perceptions are encounters with surface and interface: the skin of circumstance. However, the reflection effect also demonstrates that beyond demarcating phenomenal extent, surface has the capacity to augment space, even to create space. “What used to be the boundary of material, its terminus, has become an entryway hidden in the most imperceptible entity. From here on the appearance of surfaces and supericies conceals a secret transparency, a thickness without thickness, a volume without volume, an imperceptible quantity.”27 The aethereal perpendicular (and parallel) laneways question typical delineations of space. They suggest that there are unrealized opportunities to expand and affect the space we inhabit by optically subverting the surfaces and architecture that define that space.

SKY

The facing mirrors also fundamentally and unexpectedly expand the view of the sky. Cloudy blue daylight is drawn down into the laneway; the occluding roof tops no longer demand the viewer crane their neck to glimpse a thin slice of sky. The reflected sky is more than a reproduction of the narrow band of blue perceived between the buildings from within the lane. Looking into the mirror toward distant reproductions of roofline is equivalent to projecting the viewer high into the space between the walls of the lane, widening the perspective of the sky; the deeper into the mirror lane the viewer looks, the more the recursive reflections will reveal previously occluded sky (Figures 2.3–54 & 55).
The testing of the lighting proposition proves to be just as successful. The illumination enhances the corridor effect. The glowing pathway dissolves into darkness at a distance deep within each mirror, as each subsequent reflection absorbs and dissipates a fraction more light (Figure 2.3–58). The reflected laneway seems more present in this state than the real.

The proposal alters space by manipulating multiple mirrors. Arguably, this is nothing new; there are many examples of mirror mazes and carnival funhouses that demonstrate similar effects. However, the work is an intervention and a subversion of an everyday environment. I envisage an implementation of such a proposal as abstracting, adding to, and intensifying the orderly grid pattern of the city’s plan, by interposing a parallel grid into its mundane surfaces, by generating an architecture somewhere between material and space, rather than by massing form. This proposition is configured vertically, but it could be as effectively employed horizontally, or at arbitrary angles across the faces of opposing buildings, cutting and widening the view on other aspects in the environment. It also suggests a capacity of recursive reflection to significantly alter the appearance of confined space at architectural scales. The effect destabilizes the solidity of the buildings in a surprising excising of mass. Architecture and the urban realm is hollowed and reduced to a series of phenomenal surfaces. The effect also acts as a functional light conduit. It could widen the many narrow apertures generated by urban high-rise architecture, lightening the gloom of these spaces, but also lightening the overbearing and enclosing weight of masonry.
MIRROR LABYRINTH

The poet, Christian Bok, offers a short apocryphal account of a love letter purportedly from Christian Weiss, a prominent 19th century crystallographer, to his mistress. In it, Weiss tells the story of a Saracen alchemist said to be able to make objects disappear by placing them between two mirrors. Elaborating, he describes the infinite corridor generated by the repeated reflections of the two facing mirrors, suggesting that a person without a soul is able to step into one of the mirrors. He adds that after an eternity of walking the soulless person will eventually step out of the other mirror. Intriguingly, Weiss goes on to speculate that such a person, if armed with a second set of mirrors inside this endless passage, may set them facing each other in an alternative orientation, to create another infinite corridor perpendicular to the first. Also, with many mirrors, that person might create further corridors within corridors, to eventually build an “endless labyrinth of glass.”

FIGURE 2.3–58
Scale model offering an impression of the night-time state of facing mirrors with the square of ground between mirrors illuminated.
FIGURES 2.3–59.

FIGURE 2.3–60

FIGURE 2.3–61

* An angle of 24-degrees recursively reflects the space between the glass walls, so the reflected walls coincide precisely to generate 15 wedge shaped spaces. An angle slightly more or less will generate a random confusion of intersecting spaces.

† Dominique Perrault Architects.
Little attention has been given to the potential of recursive reflection to generate form and structure in architecture. Dan Graham’s design for Café Bravo at KW Institute for Contemporary Art, Berlin, conceived with Architect Johanne Nalbach in 1998, is a subtle but notable exception. It is comprised of two misaligned and intersecting cubes clad in one-way glass. Depending on the combination of interior and exterior light levels, the café’s exterior is either camouflaged in the reflections of the courtyard, or it is transparent, revealing the café’s interior. The design stands out not only for the Graham’s characteristic interplay of transparency and reflection, but also for the narrow wedge shaped space between the two glass cubes. The recursive reflections reproduce the small tapered space, and array it around the axis defined by the intersecting glass walls (its vertex) (Figure 2.3–59). Given the proximity of the angle between glazing to 24-degrees, and given Graham’s extraordinary sensitivity and expertise wielding reflection phenomena, the effect is likely to be deliberate. It generates a second ethereal structure within the space of the material structure. Its form is defined by the reflections of the glass framing. It is ethereal, but also part space and part object. The work extrapolates an incidental effect, frequently evident in high-rise construction where two glass-curtain walls meet perpendicularly; the corner towers of the Bibliothèque Nationale de France generate such an instance. In these circumstances, each glazed exterior reflects the other, each penetrates the other, each completes the other, as if there were two separate intersecting buildings.

There are other applications of recursive reflection in architecture. The internal space of the Skyscraper Museum, in Manhattan’s Battery Park City, designed by SOM, 2004, is an example. By lining the floor and ceiling of the small shop-front space with mirror-polished stainless steel, the designers employ recursive reflection to aptly evoke “[…] the large scale of its subject — the history and development of the skyscraper.” The reflection effects “[…] create the impression of an infinitely vertical space, with reflections of vitrines appearing as soaring volumes within a skyline.”29 (Figure 2.3–60). The triangular mirror-facets of the escalator entrance of the Tokyu Plaza Omotesando Harajuku, by Hiroshi Nakamura and NAP Architects, 2012, generate a more disorienting displacement and expansion of architecture (Figure 2.3–61). Resembling the interiors of the internally mirrored polyhedra of my experimentation, the Tokyu plaza entrance disassembles and dislocates perspectives from inside and outside the interior, and it reassembles them according to the random geometry of the faceted panels.
2.3.7 INCIDENTAL REFLECTION

The skylight and laneway experiments of this phase are two design propositions that develop directly from understandings of reflection and techniques developed in studio experiments. They configure mirror surfaces to generate objects and spaces mediated by reflection. They suggest ways that reflected form and space might be intentionally introduced into the designed environment. They are the first experiments to explore the possibilities for this context. However, the work with reflection discloses an established and wider field of reflected form, which occupies the many mirror polished surfaces of the designed environment. These manifestations are incidental artefacts of our products and architecture. The last experiment presented explores the implications of designing with consideration to the incidental interplays between material form and reflection. It explores the design implications and the technical challenges that emerge from considering reflection’s incidental forms. Before presenting this, I offer a brief description of the source, nature, and extent of incidental reflection effects, and the degree to which they are considered in the design of polished products and architecture.
FIGURE 2.3–66
Ceramic bathroom tiles.

FIGURE 2.3–67.
Glazed curtain wall

FIGURE 2.3–68
A DOMAIN OF INCIDENTAL REFLECTION

“We spend most of our time as professionals creating the buildings and the infrastructure of our cities. Yet most of the sense or feeling of the city comes from incidental things that just happen—seemingly without intention, but with far more impact than most of the architecture to which these things are incidental. What we plan and design—the facades, the bulk, the surfaces and detail—is the armature on which the sensory life of the city is built. Like an armature, our architecture succeeds or fails on its ability to support this stuff of life […].”

– Stuart Pertz

Mirror finishes are alluring. They adorn many of our contemporary manufactured products and architecture. Due to a peculiar collaboration between light, the specular surface, and our visual cognition, beyond each surface we see an inversion of the surrounding environment. Flat mirror surfaces, such as a bathroom mirror, generate a coherent reproduction of the objects and environments they face; they expand impressions of space. Non-planar reflective surfaces distort objects and spaces. Convex surfaces, such as car ducos, chrome tapware and door furnishings, reproduce but diminish their environment (Figures 2.3–63 & 64); cylindrical surfaces compress and extrude their surrounds into arrays of stretched form (Figure 2.3–62); complex undulating surfaces arbitrarily stretch, compress, and bulge, to generate concentric and contoured interior topographies and objects (Figure 2.3–66). Most polished products generate a combination of these geometries (Figure 2.3–65). The phenomena of reflection also exert influence at architectural scales. The most dramatic manifestations are an incidental consequence of our design aspirations for glazing (see Glass). A sheet of glass, so convincingly flat when close, reveals its bowed and twisted surface when tiled en masse. Combined as a shimmering glass curtain wall, they dismantle adjacent structures, distort and reconstitute them as tessellated, camouflaging abstractions of the cityscape (Figure 2.3–67). The darkly reflective properties of windows at night double the space of domestic interiors. During the day, glass shopfronts unsettlingly reveal their displays within the darker reflections of exterior people and objects (Figure 2.3–68) or place those ghostlike reproductions amid their interiors. Terrazzo corporate foyers and polished floor boards produce a phenomenal subterrain; they place the objects, people, and their reflections floating between real and reflected spaces. The riot of reflection is an incidental poiesis of extraordinary space and form, dislocating, deconstructing, subverting, deforming, and reassembling the space we inhabit in startling and disorienting ways. It is a constant visual counterpart to the environment we occupy, a phenomenal realm.

* The most prominent exception was Bruno Taut’s, Glashaus, for the Werkbund Exhibition in Cologne, 1914.
† The Modernist architects were influenced by Expressionist aspirations for glass construction, but not their emphasis on colour.
GLASS

In the early decades of the 20th century, the unprecedented construction potential of glass, its transparent and reflective properties, inspired Weimar architects toward equally unprecedented conceptions of cities and how we inhabit them. They envisaged a phenomenal architecture of transparency, of reflection, of light, which would influence culture and politics. In a Europe "[…] searching for a mechanism to achieve […] new spirit after the failure of the social structure during the war years," glass and its architectural potential came to symbolise (even embody) social aspirations of expressionist architects. Its transparency and flexibility would signify a "[…] purified, changed society." Paul Scheerbart, in his influential manifesto, Glasarchitektur, (1914) declared that:

“If we wish to raise our culture to a higher level, we are forced for better or for worse to transform our architecture. And this will be possible only if we remove the enclosed quality from the spaces within which we live. This can be done only through the introduction of glass architecture that lets the sunlight and the light of the moon and stars into our rooms not merely through a few windows, but simultaneously through the greatest possible number of walls that are made entirely of glass […]"

This future was imagined as a crystal architecture. Unfortunately, few of the wildly speculative propositions of the Weimar architects (Figure 2.3–69 & 70) were constructed. Their enthusiasm for glass was taken up by the Modernist architects of the period, recognising its potential to visually modulate material form.

In analyzing the early propositions of Mies van der Rohe, much emphasis is given to the use of glass to exhibit the buildings’ internal structural makeup. However, in an analysis of the Friedrichstrasse project (Figure 2.3–71), K. Michael Hays identifies other strategies, including the influence of “[…] a building surface qualified no longer by patterns of shadow on an opaque material but by the reflections and refractions of light by glass. […]”

The glass curtain wall, alternately transparent, reflective, or refractive depending on light conditions and viewing positions, absorbs, mirrors, or distorts the immediate, constantly changing images of city life and foregrounds the context as a physical and conceptual frame for understanding the building. Mies himself verifies the importance of viewing the shimmering glass wall and the registration of the contingencies of the site over the demonstration of the building’s skeleton. Mies writes, “My efforts with an actual glass model helped me to recognize that the most important thing about using glass is not the effects of light and shadow, but the rich play of reflection.”

Le Corbusier also saw glass as a key expression of his vision of a modern architectural form in future cities. In his book, ‘The City of To-morrow,’ he conjures a vista of skyscrapers, which are objects of light as much as material form:

“[…] immense geometrical facades all of glass, and in them is reflected the blue glory of the sky. An overwhelming sensation. Immense but radiant prisms.

CONTINUED ON PAGE 135
Despite its ubiquity, reflection is not yet given the consideration (suggested by Mies van der Rohe)\(^5\) it merits in defining the form of the city, and its products. There are few examples* and scant discourse to suggest serious consideration of its perceptual effects on the design of form and space. Recent advances in 3D computer rendering of materials offer accurate representations of mirror-finished products, which can be generated almost immediately in computer modelling. So perhaps reflection is considered consistently but implicitly. Alternatively, it could be argued that comprehensive consideration of the reflection qualities of a product or building are pointless, because its appearance is so dependent on its surrounds, and in most cases those surrounds are inconsistent.

\* Some exceptions are described later.

FIGURES 2.3–72
Reflections of surrounding architecture in the glass curtain wall.

FIGURES 2.3–73
Detail of reflection in glass curtain wall.

FIGURES 2.3–74
Series of video frames of reflections in revolving glass doors. A yellow van parked at the curb races through a corporate lobby along with all the store fronts on the other side of the road.
[...] As twilight falls, the glass skyscrapers seem to flame. [...] It is a spectacle organized by an architecture which uses plastic resources for the modulation of forms seen in light.42

A century later, skyscrapers overwhelm the contemporary city skyline, and glass is an essential and ubiquitous element. However, its extensive use falls short of embodying those early expressionist expectations. An architecture of light has emerged, exposing sun, moon, and starlight to the city’s inhabitants. However, the view is one-way. Glass only partially serves to dematerialize distinctions between interior and exterior, between mass and light. The interior workings of our cities, its inhabitants, and thus perhaps society in general remain enclosed, hidden from external view and distinct from their environment, separated not by the opacity of masonry, but by glass’s other captivating quality, its reflectivity. Our cities embody a “crystal architecture,” but realized more in crystalline imperviousness than in transparency, despite (and perhaps because of) the diverse and extensive application of glass. “[...] skyscrapers with their glass facades [now] are considered symbols of power (economical or political rather than social), [but] they do not in themselves provide any particular identity or bond with the places in which they are constructed.”43 Paradoxically, it is into their environment that these pinnacles of glass withdraw. “Contemporary office buildings use transparent or reflective-glass curtainwalls to eliminate distinction – and contradiction – between inside and outside. They even deny they have an outside with facades that mirror-reflect the external environment or make themselves invisible.”44 Arbitrary distortions of surrounding buildings, objects, and spaces permeate the presence of these vast structures, camouflaging that presence, and deflecting engagement. (Figure 2.3–72 & 73). The pervasive use of glass fails to open the city in the way the Weimar architects hoped. However, it proves to vastly exceed Le Corbusier’s aspiration as a mediator of “forms seen in light.”

GLASS

[...] As twilight falls, the glass skyscrapers seem to flame. [...] It is a spectacle organized by an architecture which uses plastic resources for the modulation of forms seen in light.42

A century later, skyscrapers overwhelm the contemporary city skyline, and glass is an essential and ubiquitous element. However, its extensive use falls short of embodying those early expressionist expectations. An architecture of light has emerged, exposing sun, moon, and starlight to the city’s inhabitants. However, the view is one-way. Glass only partially serves to dematerialize distinctions between interior and exterior, between mass and light. The interior workings of our cities, its inhabitants, and thus perhaps society in general remain enclosed, hidden from external view and distinct from their environment, separated not by the opacity of masonry, but by glass’s other captivating quality, its reflectivity. Our cities embody a “crystal architecture,” but realized more in crystalline imperviousness than in transparency, despite (and perhaps because of) the diverse and extensive application of glass. “[...] skyscrapers with their glass facades [now] are considered symbols of power (economical or political rather than social), [but] they do not in themselves provide any particular identity or bond with the places in which they are constructed.”43 Paradoxically, it is into their environment that these pinnacles of glass withdraw. “Contemporary office buildings use transparent or reflective-glass curtainwalls to eliminate distinction – and contradiction – between inside and outside. They even deny they have an outside with facades that mirror-reflect the external environment or make themselves invisible.”44 Arbitrary distortions of surrounding buildings, objects, and spaces permeate the presence of these vast structures, camouflaging that presence, and deflecting engagement. (Figure 2.3–72 & 73). The pervasive use of glass fails to open the city in the way the Weimar architects hoped. However, it proves to vastly exceed Le Corbusier’s aspiration as a mediator of “forms seen in light.”
Irrespective of the reasons, due to our enamour for mirror finishes, and a neglect of the space and form they generate, specular surfaces are deployed widely but indiscriminately. Reflection’s forms and spaces are arbitrary, without coherence. Their ad hoc specification and pervasiveness generate a correspondingly arbitrary array of liminal spaces throughout the contemporary designed environment. They generate disorienting or distracting effects, misrepresentations of form and space (see Play Time), a confusion of reflected clutter, and obtrusive glare. Further complexity results from the combination of reflective surfaces. In unison, they generate an interstitial crystal labyrinth, more intricate and complex than the spaces we occupy.*

According to an informational interpretation of urban design developed by Nikos Salingaros, “large panes of plate glass create informational ambiguity: the visual signal indicates a surface, but there is no information. […] They are either too transparent, too reflective, or too absorptive to define a spatial boundary.” 46 (Figure 2.3–74) Reflection is reduced to a spatial by-product of architectural finishes and consumer appliances. As such, we devalue it as effecting redundant duplication, too destabilizing to reconcile with the space we inhabit, too insubstantial and inaccessible. So, it remains largely underutilized, or when acknowledged, relegated as illusory and thus incidental and inconsequential. However, with a developing appreciation of its form-making capacity, I see this neglected domain also as an opportunity for an approach to design and construction that amalgamates the material and the reflected.

* See Appendices, Incidental Reflection, for examples of the reflection effects generated at both architectural and consumer product scales.
In his visually (and aurally) rich film, "Playtime," Jacques Tati parodies many of the defining and disorienting characteristics of a modern city, with emphasis on the contingent complexities of navigating an urban environment delineated by glass. The filmmaker had a genius for identifying and subverting circumstantial nuance. In closing the film, he connotes the afternoon traffic jam with a carnival, the cars in a roundabout with a merry-go-round. An oblivious window cleaner, while wiping an awning window, incidentally lifts and drops the reflection of a passing bus (Figure 2.3–75), thereby propelling the bus and its occupants on the precipitous rise and fall of an alluded roller coaster ride.47
These are representative examples. Other well-known and effective utilizations of reflections are: the glass façade of Jean Nouvel’s design for the Cartier Foundation building (1994), which also plays with a reciprocation between transparency and reflection; 52 Foster and Partner’s iconic Reichstag dome (1999), which employs reflection to maximize natural light in the building’s interior, and as a symbolic gesture toward the visibility and accountability of governmental process. 53
EXISTING WORK WITH REFLECTION IN ARCHITECTURE

Reflection at architectural scale is not entirely overlooked. However, it is increasingly being employed to (further) subvert presence or solidity. The Tree Hotel near the village of Harads, in North Sweden, by architects Tham & Videgård Arkitekter, 2010, uses reflection to camouflage (Figure 2.3–76). The hotel’s cabins are one-way glass cubes, approximately four metres in length, width and height. Each is built around a tree, suspended well above the ground supported by the tree itself. Each cabin almost entirely disappears into the surrounding forest.48 A similar example is the ‘Izabelin house’ in Poland, 2015, designed by Marcin Tomaszewski (Figure 2.3–77). In this case, select surfaces of the house, sections of the ground floor fascia, and ground floor walls, are covered with mirror-polished stainless steel. The upper level structure is cladded in flat white panels. The effect levitates the upper floor, separating it slightly from the lower level when viewed from the front and rear, and floating it a several metres above the ground from the side views. The side entrance and a large side window, also set into a mirror façade, hang mysteriously disembodied from the house.

The open-sided ‘Marseille Vieux Port pavilion’ (Figure 2.3–78) designed by Foster and Partners demonstrates a similar attempt at spatial expansion, in this case upward. Here, the ground and space under the mirrored ceiling of the pavilion is reproduced above the ceiling, visually increasing the interior space. Although, it perhaps exerts less of an effect, by weighing on the space below with reflections of granite paving framed against the vastly larger volume of open sky above the port precinct.

A subtler and more considered example is Ibos and Vitart’s contribution to the Musée des Beaux Arts in the city of Lille, completed in 1997 (Figure 2.3–79). It demonstrates the reflective properties of glazing to displace architecture, expanding and shaping an exterior space. “The site is dominated by the existing historic building, the old palace [built in 1892] which is formed in a symmetrical, classical ‘C’ plan. […] The addition create[s] the missing fourth elevation as a largely transparent wing set to one side of, but adjacent to, the central courtyard, in the form of a full-height glass-clad elevation. […] It reflects and provides a foil of transparency between the old and new buildings.”49

Looking onto the façade, across the central square, a darkened silhouette of the old palace is entirely framed in the glazed wall, but rather than a reflected reproduction, it adopts the red and gold patchwork, of the new building’s interior. “[… It] offers a highly specific visual game of light interplay, colour and reflection. Within this game, the glazed wall is manipulated by the response of the reflected images on its surface while the light is purely reflected back, giving the impression of depth and layering of space over all six levels of the building. The total effect is a kaleidoscope of colour and light, generating a raredfied mirage of images that reflect and refract to subvert the visitor’s perception of the space.”50

Jean Marc Ibos describes it as, “an impressionistically alienated form […] that reflects the historic integrity of its site and the existing building in a fresh way, so that the new building acquires an ‘immaterial quality.’” […] The building is a mirror of reality. It is a reflector that explores the meaning of presence, materiality, absence, and tests our sense of place.”51
“Mostly we have dealt with space by displacement or massing of form. While there is an architectural vocabulary referring to the space between, this has rarely been enlivened—it’s more rhetorical than actual. The art that I make covers this ground between form and actually forming space using light.”

– James Turrell

*Another noteworthy artist using mirrors to redefine art space and object is Natasha Johns-Messenger. One of her works, titled Echo, at the Heide Museum of Modern Art, 2016, was a space distorting installation that visitors could move through. It comprised a winding corridor through the museum with four right-angle turns. A sequence of four wall sized mirrors were positioned at each turn, oriented 45-degrees to the path of light down the halls. The configuration was analogous to a corridor-scale horizontal periscope, with a U-shaped kink in it. It connected an existing view from gallery entrance to a large opposite window. The effect generated a straight corridor, which doubled the apparent distance between window and gallery entrance, visually stretching the internal dimensions of the Museum.

The recent work of Timo Nasseri is also notable. It employs complex mirror configurations and reflection to generate spatial abstractions of “[…] traditional Islamic muqarnas, a form of architectural ornamented vaulting used in Islamic and Persian architecture from the eleventh century onwards,” which symbolise infinity. One such piece is Epistrophy (2016-17), a mirror faceted void in a wall, commissioned by the National Gallery of Victoria, for the recent Triennial, 2017-18.*
THE ‘NON-OBJECT SPACE’ OF REFLECTION

A comprehensive and nuanced exploration of reflection’s poietic and phenomenal dimensions is being undertaken in the visual arts. The installation work of artist Anish Kapoor exemplifies such an investigation (Figures 2.3–80 & 81). He observes that “to make new art, the tradition has been to make new space.”55 For him the reflected domain generated by concave mirrors (where the reflected image is perceived as hanging in front of the mirror) is one such space. He interprets his work with concave mirrors as a progression from the representational space of traditional painting, which is “[…] a space that recedes deep into the picture plane,” to another space, one might call the ‘object space’, which is front of the picture plane.”56 In these works, unlike the charade of the Bundoora installation, reflection really does share space with the real. The new space provides him the opportunity to innovate; it demands a reconception of what constitutes the art space and art object.57 In recounting the evolution of his mirror works, he remarks that:

“The previous body of work had been void works – objects with dark interiors. It was an attempt, in a way, to make a non-object, to make an object that doesn’t exist. Now I began to wonder if it is possible to make a mirrored object in the same way – an object full of mirror.”58

My growing appreciation of reflected form accords with Kapoor’s discourse in gallery and public-art space. Such a renegotiation of ‘art-space’ and ‘art-object’ is analogous to the reconception I envisage for ‘design-space’ and ‘design-object’, but also for design practice. The previous two experiments explore reflection in propositions for the designed and lived environment. However, reflection presents as fundamentally implicated in the many polished surfaces of the built environment. Reflection in this context (in contrast to the sequestered environment of the exhibition space) expresses visual relations that are much more complex and influential. Its deliberate manipulation constitutes a significant challenge. However, this same complexity provides an equally rich array of manifestations: a diversity of circumstantial reflected-form to inspire possibilities.
2.3.8 A STAINLESS-STEEL POT-HANDLE

A key speculation that underpins the research is that even the most banal objects of our surrounds can conspire to generate surprising phenomenal form, and that acknowledging and elaborating them can reveal extraordinary capacities and insight. To offer an indication of the nature of a design practice that encompasses incidental reflection phenomena in the designed environment, and to interrogate the implications, I return to a scale familiar to me: product design. Within the realm of product design, there are few examples where incidental reflected space, form, or structure has been explicitly or obviously a key consideration to the design of the object (see Reflection in Product Design).

The task I set for myself is to design a stainless-steel cooking pot. Such an exercise offers an opportunity to extend the work from planar reflection surfaces to convex. It involves instances of reflected form that are more enduring than in other circumstances: instances of self-reflection. Many polished surfaces reflect fixed aspects or elements in their environment. In this case, it is protruding handles reflected in the body of the pot that they are attached to. Other examples are the environments around architectural glazing, or mirror cladding. Such a scenario reduces the complexity of the exercise.

How challenging should an experienced industrial designer find the design of a stainless-steel pot? Under normal circumstances, the task would not be particularly demanding. However, within the context of the research, it proves to be surprisingly complex and difficult, to the extent that I reduce the exercise to a single handle reflected in the pot’s lid. The complexity arises in the seemingly simple act of considering reflection.

The pot-lid obtained for the task is roughly spherical, a shallow dome, approximately 300-millimetres in diameter. The lid handle is stainless-steel and an unusually sculpted design, like a flat C-shape with its centre twisted 90-degrees. The form sits comfortably flat in the fingers, although, aesthetically, it is perhaps a little too organic (Figure 2.3–86). Its reflection in the convex surface of the lid is significantly different. The lid reflection provides another perspective on the handle, as inverted to below the lid’s surface, a virtual view of its underside. The convex reflection reduces the reflected handle’s scale. Its form tapers and distorts increasingly with depth into the reflected space of the lid. Real and virtual objects meet at the lid surface to give an impression of a single form with a mouth shaped opening, which seems to levitate between the space above the lid and the reflected space within.
REFLECTION IN PRODUCT DESIGN

There is no shortage of mirror finishes on products, but they are generally just that, a specified finish for a carefully designed material form. An exception is the diversity of kaleidoscopic toys, novelty products designed as curiosities or to demonstrate physical principles. A surprisingly common example is anamorphic teacups (Figure 2.3–82).

The work of Geoffrey Mann perhaps comes closest in principle (not method) to what I have endeavoured to elaborate here within a product design context. His design for a candelabra materializes the dazzling glints of light reflected off its polished surface in the same solid metal of the candelabra itself. It highlights immaterial and circumstantial ciliary corona generated by the eye’s physiology by solidifying them and advancing them as the defining characteristic of the candelabra (Figures 2.3–83 & 84).
In accordance with the experimental approach so far, my first inclination is to phenomenally 'sculpt' the handle reflection by physically modelling and varying the shape of the lid surface. By variously altering the handle’s circumstance (the surface profile of the lid), a range of different real/reflecte}nd handle combinations would be generated without altering the handle itself. While such an approach potentially elaborates the role of circumstantial reflection in the design of simple products, my objectives are broader than this. I wish to deprioritize the material form, by designing and making the reflected component directly. Ideally, the material-form and reflected-form would be treated as equally contingent on each other, using the same design mechanisms for both, and simultaneously. The aspiration is perhaps unrealistic. Reflecte}nd form is visually accessible, but not physically. To pursue this, and in contrast to the earlier work, the empirical approach is replaced by representing and shaping the handle and its reflection with computer aided modelling. The CAD modelling space offers equal access to reflected and real aspects where physical modelling cannot. The material-form and light-form can be effectively manipulated from the perspective of each, using a single and immediate mode. So, for this experiment my workshop tools lie inactive in exchange for virtual tools.

The task develops as four-fold: a technique to derive reflected-form based on material-form; then the reverse, a system to derive material-form from reflected-form; then a way to develop the profile of the mirror surface according to the combination of material-from and reflected-form. The final task would be to integrate them in a single approach, which regards and manipulates all as interdependent qualities of a singular object. The first task is to virtually establish reflected objects based on their material counterparts and the surface topography they are reflected in.

Computer rendering of reflection has become quite sophisticated in contemporary computer modelling systems and realistic impressions of specular reflection are now commonplace. However, the techniques are inappropriate to achieve my aim. The standard technique is ray-tracing. It is designed to ‘dress’ the surface of a model. It superficializes reflection as a surface attribute, a virtual surface veneer. The approach offers little insight into the transformation of form that takes place with reflection. Even though working representationally, the aim is to precisely model how objects are physically distorted by convex reflection, and their spatial location within a convex mirror space. Ray-tracing algorithms do not use or need that information. The output of a software rendering engine need only be a flattened impression of the virtual scene as viewed from a certain perspective. I attempt to develop my own parametric approach.

* Ray-tracing generates an image, a discrete viewing plane or window that defines the extent of the scene. “For each pixel on the view window, […] a ray [is defined] that extends from the eye to that point. […] this ray [is extended] out into the scene as it bounces off different objects. The final color of the ray (and therefore of the corresponding pixel) is given by the colors of the objects hit by the ray as it travels through the scene.” 59
MATERIALS AND COMPONENTS

one 9-litre stainless-steel stock-pot lid, borrowed from the pantry; 200-millimetre diameter aluminised blowmoulded plastic ball, one of 500 Christmas baubles used in public event project; 3D computer surface modelling application with generative algorithm capabilities; undergraduate physics textbook, a rediscovered and dusted-off remnant of a brief foray studying engineering.
MODELLING FOR THE SHAPE AND POSITION OF REFLECTION BASED ON A REAL OBJECT

The pot lid is approximately spherical, so the well understood principles of reflection in spherical surfaces provide a starting point. Although, a generalized approach even in this basic geometry is challenging. The Gaussian mirror (or lens) equation* is briefly considered as a basis for the modelling. Its effective application proves too specific (see Limitations of Gaussian Mirror Equation), and other more comprehensive algebraic formulations of spherical reflection use mathematics well beyond my knowledge.

Investigating the problem as a series of ray diagrams, using basic optical principles, remains an approach within my capability (Figure 87). The primary principle is Euclid’s law of reflection: the angle of reflection equals the angle of incidence.‡ The other is a phenomenal property of reflection, the perception of reflected objects as situated beyond the mirror surface. Light carries no record of its trajectory, or its previous deflections, prior to striking the retina. We can only infer its origin from the physical orientation of our eyes at the moment of contact. Limited to this, the mind is left to locate the originating object, even if reflected in a mirror, in the direction of gaze. This constitutes the second principle: the position of a reflected object, beyond the mirror surface, is perceived as lying somewhere in the direction of an imaginary ray of light connecting the eye and the final reflection point on the mirror. These assumptions, some research into spherical optics, and an incidental confluence between experiments (see Caustic Connection), provide the parameters for a functioning vector-based approach to the problem (Figure 2.3–88).

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* The Gaussian mirror equation formulates a relationship between: the distance from mirror-surface to mirror-image (d₁); the distance from mirror-surface to real object (d₂); and, the focal length of the mirror (f)—for a spherical mirror this is half the radius.  

\[
\frac{1}{d_1} + \frac{1}{d_2} = \frac{1}{f}
\]

† It is described as a paraxial approximation. Only rays inclined less than about 10-degrees to the principle axis, and lying close to the axis throughout the distance between object and image, are considered paraxial rays.

‡ The angle of the approaching ray, as measured from the normal of the mirror surface (an imaginary line perpendicular to the surface) at the point of reflection.
LIMITATIONS OF GAUSSIAN MIRROR EQUATION

Carl Friedrich Gauss addressed the problem of spherical reflection more than 200 years ago, and framed a generalized solution as a relation between an object’s position (from the mirror) and the perceived reflected position. It is a calculable relationship between the two distances, according to a mirror profile expressed as a focal length. The simple equation makes it straightforward to model spherical reflection. However, to distil the relationship Gauss employed some assumptions. The equation incorporates no parameter for the viewing position and is valid only for a limited latitude of observation, where the surface area of the mirror “has a width that is small compared to the radius of curvature.” It is thus an approximation, valid for applications such as telescope and lens design. It is tested nevertheless, to see how much latitude it affords, to transform and model a simple cuboid form in CAD. A 200-millimetre silver Christmas bauble hoarded years before and a wooden block from the kid’s toy-box serve as tools for comparison. The outcome accords with empirical observations when sphere, reflected block, real block, and viewpoint are approximately aligned. Although, when viewed from a wider angle, the correspondence breaks down: the location of the reflected object within the sphere, as well as its shape, alter significantly with wide changes in perspective.

Gauss’s equation represents a paradigm, a way of seeing, to which the research project reacts. It can be framed as a narrowing of attention in exchange for simplicity and reliability. The realities described by many physical theories, “[…] are governed by narrow-scope laws, that is, laws or generalizations, that for some reason or other cover the workings of only a minuscule portion […] of the world. […] each narrow-scope law describes a mechanism that functions only if certain factors are absent, but such factors are almost universally present – thus, the law holds only in a few isolated systems.” A model of true spherical reflection, which accommodates all parameters, is highly complex and difficult to formulate. Gauss’s genius was to model a very specific circumstance of reflection, so he might formulate it with straightforward mathematical tools. However, there are implications for conceptions of reflection derived from employing such a theory. The overwhelming majority of reflection phenomena, the diverse and rich reality of reflection, remain unaddressed, and thus unacknowledged, relegated to the incalculable, and thus the peripheral. Gauss’s equation is too constrained in its scope. To model reflection beyond the narrow domain of telescopes and other optical instruments, to reveal and manipulate reflection in its rich diversity and potential, a wider array of parameters need to be incorporated: the position of the viewer, and surfaces more complex than planar and spherical.

CAUSTIC CONNECTION

An unexpected confluence with an earlier experiment emerges while representing reflection effects with a ray diagram from an array of viewpoints around a sphere. Two ‘eye-brow’ shaped envelopes generated by the diagram inside the circle (Figure 2.3–87) representing the mirror surface are familiar. They closely resemble the caustic light-form generated on the workshop bench inside the annular mirror as it was lying under a lamp. The light-form and ray-envelope are both nephroids. They reveal this encounter and the earlier as complementary reflection circumstances. The recognition helps me to determine the location of reflection points inside the mirror surface. They necessarily lie on curves that define caustic envelopes. It is a simple and well understood physical principle that enables me to develop a parametric approach to modelling reflected form.
MODELLING FOR THE SHAPE AND POSITION OF A REAL OBJECT BASED ON REFLECTION

I successfully apply the method to generate a representation of a reflected cuboid form (Figure 2.3–89). It appears to work even from extreme viewing angles (See *The Hidden Sides of Reflected Objects*). However, this constitutes only the first step toward the overall objective to explicitly design reflected objects. An approach to developing the material form of the handle is required, so it conforms to a pre-determined reflected form. In other words, so that the material handle is a consequence of the reflected handle, a turn from normative design, which typically relegates reflection as incidental to the material. It is a reverse engineering of the principle used to model the shape and position of the reflection of the real object. The task proves to be more straightforward than deriving the reflected form from the real, as it is equivalent to existing anamorphic translation techniques using ray-tracing (Figure 2.3–91).

“Anamorphic images are images of objects which have been distorted in some way so that only by viewing them from some particular direction or in some particular optical surface do they become recognizable.”66 They are created using a range of media and methods, some are drawings based on perspective principles, others are virtual images generated using the optical distortions of convex reflection. This stage of the experiment is a type of 3-dimensional anamorphosis (See following pages, *2D & 3D Anamorphosis*).

![Algorithm for generating virtual reflection points based on position of viewer and the shape of a real object. (Parmington, 2013)](image-url)
THE HIDDEN SIDES OF REFLECTED OBJECT

We never see the back of an object in reflected space. Moving around the sphere to the side opposite of the timber block cannot reveal its distorted form. With this modelling technique, it is possible to deduce the shape of the hidden rear face of the reflected cuboid, or perhaps more appropriately, its appearance if viewed from within the reflected space of the mirror sphere (Figures 2.3–90).
2.3–91
Raytracing method to generate anamorphic images in a cylindrical mirror (Ucke, 2003).

2.3–92
“Rejuvenation,” (Hurwitz, 2008).

2.3–93
3D anamorphosis in a sphere (De Comite, 2011).

2.3–94
Points along a line translated across concentric spheres to derive a real line from a reflection line (De Comite, 2011).

* The incident-light is a light-ray approaching the mirror from a point on the object, where the reflected ray will be perceived by the eye. The point on the object can be moved (and therefore the shape of the object changed) without altering the reflected form as long as that point remains somewhere in-line with the initial incident light ray.
Documnted investigations of anamorphosis as a visual illusion, and its use in artworks, date back to the 16th century. Mirror (catoptric) anamorphosis usually comprises an unrecognizable two-dimensional image rendered onto a flat sheet of paper or other material, in the middle of which sits a cylindrical or conical mirror. When reflected by these, the distorted image translates into a coherent two-dimensional reflection. Cylindrical mirror anamorphs are constructed by translating a Cartesian coordinate map of the coherent image to a polar (radial) coordinate map, with the mirror at its centre (Figure 2.3–91). Scientist and sculptor Jonty Hurwitz creates three-dimensional versions of this process, which he describes as anamorphic sculptures (Figure 2.3–92). They are distorted material objects that surround a cylindrical mirror. They appear radially stretched, distended and somewhat unsettlingly visceral. When reflected in the mirror, they coalesce into recognisable objects. There are fewer examples that generate and transform three-dimensional objects using spherical mirrors.

Francesco De Comite has developed and demonstrates one approach, which generates coherent geometric patterns from three-dimensional distorted lattice structures (Figure 2.3–93). The pattern coalesces when viewing their reflection in a sphere through the middle of the model. De Comite’s mapping method is computed using ray-tracing software. Rather than map the desired reflected object (and its position in the mirror space) onto a flat surface surrounding the mirror, he maps it onto (and through) a sequence of concentric shells (Figure 2.3–94). This distributes the mapped elements outward from the mirror, as a “volume of distortion,” rather than a “surface of distortion.” Interpolating them produces the three-dimensional anamorph. It means the physical (outward) extent of the objects from the mirror surface is arbitrary, based on the selected spacing of the concentric shells.

De Comite’s method demonstrates that, in generating a 3D mirror anamorph, as long as each mapped point lies on the path of “incident-light,” its placement along the path (the distance away from the mirror), is at the discretion of the designer. So rather than confine myself to the regimen of concentrically spaced rings, this latitude can be used to achieve some outward control over the material-form of the anamorph, while ensuring it will still translate to the prescribed reflected-form (Figure 2.3–97).
To apply this method to the design of the pot-handle, a strictly rectilinear reflected-handle is modelled. The translated *material-handle* visually connects to its reflection at the lid surface. However, unlike the rectilinear reflection, the sides of the material handle splay outward asymmetrically from the lid (Figure 2.3–95). The material handle also tips back from the vertical. The cross-section of each component thickens with the distance away from the lid surface. One side rises higher than the other, due to the off-centre viewing position. The grip is arched upward, also asymmetrically. This resulting form will generate the modelled (rectilinear) handle reflection in the polished domed lid when viewed from a specific angle (Figures 2.3–95 & 96).
Algorithm for generating defining edges of a real object based on position of viewer, and the shape of desired reflection-form (Parmington, 2017).

FIGURE 2.3–97
CAD diagram indicating an extension of incidental rays passing through key points on the real handle. They reflect off the lid to converge on the eye. The form of the real handle can be altered without affecting the reflection, if those points remain somewhere along their corresponding incidental rays.

FIGURE 2.3–96
The reflected handle and the derived material model without the lid.
A UNIFIED APPROACH AND TOOL TO DESIGN REFLECTION

The exercise so far is successful but goes only part way toward its initial aim. In it I contrive the reflected handle to have straight edges, flat sides, and perpendicular angles. These characteristics are rare in convex reflections, so the result would be conspicuous. It would appear an inversion of typical experience: a rectilinear reflection of a distorted material form in a convex surface. More compelling is the potential that combinations between material-form and reflected-form might be conceived, modelled, and presented as single hybrid forms, suspended between real and reflected domains. Here, both material and reflected handle would be designed as if they were a single object. All parameters of the unified object would be correlated in its modelling: its material-form, its reflected-form, the surface-profile, and the viewpoint. This is where the proposition departs from a typical exercise in anamorphosis. It suggests that it is possible to physically derive and alter the 3D reflected-form according to desired changes in the material-form, and vice versa (anamorphosis). It would be a method that allows the manipulation of all parameters of reflected and real. It would be an algorithm that offers the designer control of each aspect, as parametrically connected to all other aspects, and so allow immediate feedback of the overall implications of a change to any of them.

However, even with the development of such a tool, the resulting effect remains perceptually constrained. Any carefully configured combination of material-object and reflected-object would be coherent (revealed) only from a narrow range of viewing positions. In a small product design context, the detection of the combined and configured shape would be occasional and remain an incidental (even though curious) encounter. The additional complexity of such consideration and its development would likely outweigh the benefit. However, at an architectural scale, and where circumstances and viewing angles are more stable, such an approach could facilitate extraordinary possibilities. The work of Aleksandar Ćučaković and Marijana Paunović acknowledges this potential. They highlight the influence that reflection has on the appearance, substance, and construction of architecture, and explore how deliberate consideration of reflection might enhance those characteristics. Although, they confine their propositions to cylindrical mirrored structures (see Architectural Anamorphs). Though, they confine their propositions to cylindrical mirrored structures. The experiment with spherical reflection demonstrates that any of the innumerable polished surfaces of the designed environment could host such phenomenal design opportunities, whether cylindrical, spherical, or other geometry.

Recent advances in computer modelling techniques and construction technology have enabled the development of more organically formed mirror surfaces for architecture.* The pleated stainless-steel mirror façade of the Len Lye Centre, an annex on the Govett-Brewster Art Gallery in New Plymouth, New Zealand, designed by Pattersons (2015) is one such example. The vertical folds of the façade horizontally compress the reflected surrounds of the building, in a recurring array along its base (Figure 2.3–101). The same reflected architecture appears in each convex and concave fold. However, the surface geometry is never repeated exactly, so each reflected artefact is distinctive in its compressed scale and proportion. The façade also reflects elements of itself in its concave sections. These appear as strange tapering columns behind the skin of the building. This new flexibility in the surface profiles of reflective cladding, combined with a system of modelling reflection based on the interpretations and techniques suggested

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* Anish Kapoor’s *Cloud Gate* (2006) in Chicago is a demonstration of the complex organic forms possible in polished stainless-steel from the practice of public art.
ARCHITECTURAL ANAMORPHS

In work analogous to the stainless-steel pot experiment, Aleksandar Čučaković and Marijana Paunović propose that three-dimensional anamorphs might be introduced in curved reflective surfaces of the urban environment (Figure 2.3–99) to change “the urban-architectural ambience.”76 They point out buildings with cylindrical glazing as potential sites and offer a design propositions for distorted street furniture that cohere as cubes when reflected in an existing cylindrical mirror sculpture (Figure 2.3–100).77
by the pot-lid experiment, offers the potential to extrapolate and develop the relationship between material form and reflected form in a deliberate way. It suggests a way to work inside and outside the reflected space of mirror façades. I see this as feasible, but the development of such a design tool is complex and constitutes a development project in itself, with the support of others who have comprehensive programming resources and skills.

However, whether such a tool proves feasible and useful is secondary in pursuing the exercise. With this approach, I wish primarily to provoke attention to reflection itself, reflected-form, and reflected-space, for its wider untapped design potential. By inverting the priority between material and reflection, the neglected influence of phenomenal circumstance in the perception and design of objects is reappropriated. I concede that reflection can only ever be visually experienced. However, regarding reflected-form as an object of design, modelling it in CAD, and phenomenally constructing it, fractionally undermines its perceived peripherality and inaccessibility. It affords reflection a conceptual and phenomenal position in the world; reflected objects and space, whether in models or in CAD space, are realized, if not materialized. They are provided spatial coordinates, perhaps even materially constructed, and thus substantiated, drawn from ephemerality into consideration. As distinctions between reflected space, CAD space, and material space blur, so do distinctions between objects and phenomena. In the process, normative material conceptions of construction and design are subverted and expanded to encompass other interpretations of space and modes of form-making mediated by light. More generally, I also wish to convey the extraordinary insights and possibilities that can be derived from detailed consideration and elaboration of even the most subtle and commonplace phenomena constituting everyday circumstances.

2.3.9 A MIRROR FINISH

Prior to the project, reflection languishes at the edge of consideration in my design practice, an unexplored characteristic of surface finish. The specification of a mirror finish was no more involved than providing a grade of surface treatment, an ATSM specification of number 8 (or the ISO equivalent between, N4 and N1) (Figure 2.3–102). However, implicated in this simple annotation on a technical drawing, is the modulation and generation of extraordinary phenomenal form. It might be neglected as materially incidental, or it may be disregarded as too complex to consider, but to neglect this is also to forgo a creative dimension. To assume that reflection phenomena has limited consequence diminishes the phenomenal effects that reflection exerts on perceptions and design of space and form.

The last phase of work acknowledges this and yields reflection as a construction and design material. It demonstrates that matter can be configured and shaped not (only) to form solid architecture or product, but also to express reflected-form as a transcendent dimension of the built environment. Reflection phenomena themselves emerge as potential objects and modes of design in propositions for recursively reflected skylight forms, and in the transecting of architecture with opposing mirrors. At a product design scale, a speculative exercise giving precedence to reflected form in a stainless-steel pot inspires a virtual technique for manipulating reflection objects. It intimates a type of design-form that amalgamates matter and the misaligned* phenomena of reflection.

* See Introduction.
These outcomes subvert and expand typical notions of object and space. New objects and spaces emerge, which express their own logic and geometry: they construct the impossible; they penetrate solid matter; they provide new perspectives on the familiar spaces we inhabit. They invite new techniques to construct and design, which might significantly affect experiences of the built environment.

Regarded together, the design propositions, and the work of other designers, architects, and artists working with reflection, suggest an unrealized domain of design mediated by the polished objects and surfaces that populate our surrounds. They reveal a dimension and capacity that transcends the material finish of these objects and spaces, but also their intended function. They offer a glimpse of what a design practice might look like, and the work that might result, with extended consideration and elaboration of circumstantial phenomena.

**FIGURE 2.3–102**
Table of stainless-steel surface finishes.

<table>
<thead>
<tr>
<th>Finish Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Rough, dull, non-uniform appearance</td>
</tr>
<tr>
<td>#2B</td>
<td>More reflective, like a cloudy mirror</td>
</tr>
<tr>
<td>#2D</td>
<td>Uniform, dull silver-gray appearance</td>
</tr>
<tr>
<td>BA or 2BA</td>
<td>Bright Annealed - mirror-like with some cloudiness</td>
</tr>
<tr>
<td>#3</td>
<td>AKA grinding, roughing or rough grinding. Coarse finish usually applied before mfg.</td>
</tr>
<tr>
<td>#4 Arch.</td>
<td>AKA brushed, directional or satin finish. Fine uniform polishing lines.</td>
</tr>
<tr>
<td>#4 Sanitary</td>
<td>Much finer than #4 Architectural finish, enhancing physical appearance</td>
</tr>
<tr>
<td>#6</td>
<td>AKA fine satin finish; less reflective than #4 Architectural finish</td>
</tr>
<tr>
<td>#7</td>
<td>Semi-bright finish with some very dull polishing lines</td>
</tr>
<tr>
<td>#8</td>
<td>AKA mirror finish</td>
</tr>
</tbody>
</table>

2.3–102
REFERENCES FOR SECTION 2.3


5 Ibid., 159.

6 Ibid., 32.


9 Ibid., 86.

10 Smithson and Flam, Robert Smithson, The Collected Writings, 393.

11 Ibid.


17 Palmer, “Pieces of Pi.”


30 Ibid., 20.


33 Bletter, “The Interpretation of the Glass Dream.”

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36 Ibid., 187.
40 Ibid., 314.
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43 Ibid.
44 Graham, Dan Graham: Architecture, 27.
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61 Ibid., 50.
63 Mendell, "Euclid, Catoptrics 1."
64 Gregory, Mirrors in Mind, 78.
65 Glaeser, "Reflections on Spheres and cylinders of Revolution."
67 Ibid., 1.
73 De Comite, "A New Kind of Three-Dimensional Anamorphosis," 3.
74 Ibid., 1.
76 Ibid.
IMAGE REFERENCES FOR SECTION 2.3


Figure 2.3–19. Tadeusz Dziewior, 3D *Honeycomb* constructed with rhombic dodecahedron components, 2011, accessed March 8, 2018, https://commons.wikimedia.org/wiki/File:HC_R1.png


Figure 2.3–47. Tony Palladinio & Kathy Phelon, *Untitled*, inverted Manhattan skyline at dusk, in Alan Fletcher, *The Art of Looking Sideways* (Prahdon Press, 2001).

Figure 2.3–53. Caspar Schwabe, *Spherical hexakis icosahedron, Great circles polyhedral corner kaleidoscopes (finite reflexion)*, 2003, in Caspar Schwabe, *Perfect Polyhedral Kaleidoscopes* (Forma, 2006).


Figure 2.3–81. Anish Kapoor, *Sky Mirror, Rockefeller Centre* (Kapoor, 2001), accessed March 17, 2018, http://anishkapoor.com/273/sky-mirror-


Figure 2.3–91. Christian Ucke, raytracing method to generate anamorphic images in a cylindrical mirror, 2003, accessed March 19, 2018, https://web.phys.ksu.edu/ICPE/Newsletters/n38/anamorph.htm


Figure 2.3–94. Francesco De Comite, 3D anamorphosis, 2011, in Francesco De Comite, A New Kind of Three-Dimensional Anamorphosis (Bridges 2011: Mathematics, Music, Art, Architecture, Culture, 2011)

Figure 2.3–99. Aleksandar Čučaković, Cylindrical glazed curtain wall, Imel Group Belgrade, 2015, in Aleksandar Čučaković, Marijana Paunovic, Cylindrical Mirror Anamorphosis and Urban-Architectural Ambience (Nexus Network, 2015).

Figure 2.3–100. Marijana Paunovic, Anamorphosis as utilitarian form, 2015, conceptual design for Tasmajdean Park, Belgrade, in in Aleksandar Čučaković, Marijana Paunovic, Cylindrical Mirror Anamorphosis and Urban-Architectural Ambience (Nexus Network, 2015).


"[...] acknowledging that we’re immersed in things without noticing them is the first step. But that’s the easy part. The hard part is working with things, really digging into and making use of them, [...] recognizing something new in the suffocating, familiar depths to which you and others already have put them to use."\(^1\)

– Ian Bogost.

The many experiments of the project together respond to the question: what are the consequences of considering circumstantial light phenomena for the practice of design? In every design circumstance decisions are made to include or exclude certain parameters (qualities, properties) as meriting creative consideration, what to attend to and what to ignore. The subtleties of refraction and reflection phenomena are typically considered extraneous or inconsequential, if noticed at all, even when they are extraordinary. They are insubstantial and ephemeral qualities of the objects that generate them. Despite this and because of this, they become the ‘sensitizing concepts’\(^*\) for this ranging experimental exploration. The project sets aside assumptions of extraneity to treat circumstantial reflection phenomena as objects of investigation and design. The experimentation leads to several substantive and innovative design propositions. The results suggest there is value to be derived from acknowledging and elaborating such phenomena, even if they appear incidental to the design task. The finding indicates the design potential of these phenomena, but only goes part way to answering the opening question. The other more profound aspect is how consideration of circumstantial phenomena has affected the way I understand and practice design.

Acknowledging the subtle refracted light-form beneath a wine glass precipitates the work. The phenomenon is investigated in an open and generative process. It prompts a succession of subsequent creative digressions, inspired by further incidental and phenomenal outcomes. The work leads to a wider recognition of stray misaligned\(^†\) phenomena generated by the experimentation and the designed environment. Each of these might precipitate a project and a resulting innovation. However, recognition and open investigation of these peripheral forms are only the first-steps, the easy part. The hard part is working with this extensive and unpredictable circumstantial resource with intent, without being lost to the surfeit of incidental and extraordinary phenomenal diversions. The following discussion reflects on this. It sets out an interpretation of circumstantial phenomena disclosed by the experimentation, and by idiosyncrasies in my design practice. It presents how these phenomena have provoked the innovative outcomes of the work, in an extension of those idiosyncrasies. It offers an alternative way to interpret the role that objects and the phenomena they generate can play in the creative process.

\(^*\) See Introduction.
\(^†\) See the Introduction: An Emergent Process.
3.1 REAPPROPRIATING CIRCUMSTANTIAL PHENOMENA

There is a synergy between the circumstantial phenomena, the mode by which they are investigated, and a disposition in my creative practice. These phenomena, once acknowledged, precipitate a cascading awareness of their wider presence and influence. Such a recognition infiltrates design activity. It distracts and destabilizes design intentions, but nonetheless produces extraordinary and worthwhile results. Many of the more influential outcomes of the project develop from examining phenomena incidental to the intentions of the experiment and research, in each phase of work, such circumstantial phenomena reveal previously undisclosed but defining aspects of the thing studied. Circumstantial encounters become a precedent for the project, a mode of awareness that constantly teases attention from the focus of inquiry. An interpretation emerges which explains how these phenomena, and the digressions they provoke, have been adapted towards the outcomes of the work. Also, how they might be further utilized. It is an approach that invites the (ostensibly) extraneous outcomes and reappropriates them, by recursively adopting them as alternate perspectives from which to reflect on the intentions of the work. The novel insights that each provides, thereby compound with each iteration.

The cavernous and crystalline structures generated by the kaleidoscopic boxes provide a way to envisage and interrogate this developing method. Their recursive phenomenal mechanism is analogous to the recursive mechanism of the research. Assembling a kaleidoscopic box is an action of returning light. As each mirror facet is positioned, escaping light and vision is returned to its interior. The recursive reflections generate an extra-dimensional and phenomenal structure, which compounds in complexity with every facet and every reflection. It reaches beyond their walls and their material substance, to permeate their environment, making their extent ambiguous, simultaneously parallel to their circumstance and embedded in that circumstance. In a complementary way, the project’s form and structure emerge (or perhaps immerge), with the acknowledgement of each circumstantial encounter, with each phase of the project, with perspectives provided by optics, installation art practice, and architecture. It manifests as a recursive involution. The complexity created from this simple mechanism offers insight (perspectives) and outcomes beyond what I anticipate. Kaleidoscopic reflection offers a way to understand the development of the work. It suggests the beginnings of a design approach, which repeatedly reappropriates results from the periphery of design attention back into design intentions, to generate innovative outcomes.

The disassembly of a kaleidoscopic box has the countervailing effect, a gradual reduction of its complex structure to its elements. The act distinguishes the essential logic of its phenomenal structure, its polygonal facets, but in doing so deactivates that structure. In concluding the account of the work, I endeavour to distinguish and express essential components of the research and thereby explicate the work. However, I do so cognizant that the reduction of the research to a set of finite and distinct outcomes constitutes corresponding disassembly, and thereby a corresponding deactivation of its form. Such an explication can only intimate the complex and recursive interactions that constitute the

* The effect is revealed by the laser beam in the annular mirror experiments as it is repeatedly returned toward the centre of the ring.
In presenting an interpretation of the creative mechanisms at play, I reflect on the role of an autopoietic circumstance in activating unanticipated phenomena and results of the project. I elaborate how attention to these phenomena shifts conceptions by providing an external and ‘phenomenal perspective’. I integrate these by extending an inclination in my making practice to generate possibilities by adapting materials at-hand, to adapting the circumstantial phenomena at-hand. I resolve a relational way of seeing and activating the immanent design potential of familiar objects and their circumstance. I describe the method as a kaleidoscopic bricolage.

A CIRCUMSTANTIAL COLLABORATION

The strange and complex distortions of objects reflected in a polished stainless steel pot, demonstrate that circumstance is essential in expressing the polished object’s visual form, and distinguishing it from its environment. A mirror polished object is ‘[…] nothing more than a distorted reflection of the world surrounding the object. […] It produces a different image every time it is placed in different scene. Every visible feature belongs to the world surrounding the object rather than to the object itself’.

The only reason these objects are visually distinguishable is that, in reflecting them, they distort, displace, or discolour those surrounds. Reflection forms produced by polished objects do not align with their material form, but they are nonetheless essential in revealing that material form. Though they are an essential characteristic, they are not a property of the object. They speak of an engagement in a broader circumstance.

In an unanticipated reciprocation, the mirrored objects prove to activate aspects of their circumstance; their distortions displace, overlay, and alter their surrounds. This is particularly evident in the mirror strip and mirror pole experiments. In this manner, while they transform with their participation within a changing environment, they also activate and alter their circumstance in an ongoing expression of novel phenomenal form. This is equally true for the kaleidoscopic boxes, the skylight, and laneway propositions. They are intrinsically circumstantial. It constitutes a relational way of considering the objects.

As no two situations are identical, individual polished products could be perceived as essentially countless phenomenal products

(see Plastic Objects. They are thereby imbued with ongoing dimension. The acknowledgment reveals that, while I attempt to realize my objectives in the narrow scope of my creative activity, in the design of reflected objects, but also more generally, much more is provided in unforeseen results. The incidental results highlighted throughout the experimentation are further instances of such activations; this is especially evident in the first phase of experiments.* I need only widen focus to the peripheries of my objectives to begin to appreciate the proliferating effects that radiate from every creative act: in response to the

* A refracted light-form on a table underneath a wine-glass, expansion fractures in a piece of resin, the sky pouring down a mirror pole in a courtyard, smoke vortices curling away from a laser experiment, and the many other extraordinary and unexpected outcomes of the work, represent a mere glimpse of the input of this larger circumstantial realm.

FIGURE 3.1–1

Reflection objects in a polished stainless-steel pot.
PLASTIC OBJECTS

The understanding of polished objects as visually defined by their circumstance disturbs the notion of objects as enduring and distinctive in their possession of specific and consistent qualities or functions. Rather than stable entities, the Object-Oriented Ontology philosopher, Levi Bryant, describes objects “[...] as plastic, as fields of capacities and powers that can be creatively actualized in a variety of ways under different interactions.”

He suggests that understanding objects according to their capacities encompasses and provides for their constantly varying qualities. He uses the phenomenally ambiguous nature of a blue coffee mug in differently lit environments to illustrate this. The example is equivalent to the phenomenal diversity exhibited by polished objects in different circumstances.

“As I look at the mug under the warm light of my desktop lamp, it is now a very dark, deep, flat blue. Now I open the shade to my office window, allowing sunlight to stream in. The mug becomes a brilliant, bright, shiny blue. Sharing a romantic moment with my coffee mug by candlelight, the colors are deep and rich as they were under my office light, but now the blue flickers and dances in response to the shifting intensity of the candle flame. And finally, I blow out the candle and the mug becomes black.”

Bryant emphasizes that the array of colours the mug displays are all aspects of the mug, and that there is in reality no single true colour. He suggests that qualities should not be interpreted “[...] as something an object possesses, has, or is, but rather as acts, verbs, or something that an object does.” He argues that “[...] knowing an object does not consist in enumerating a list of essential qualities or properties belonging to an object, but rather consists in knowing the powers or capacities of an object.”

Looking at the work through Bryant’s ontology, the properties of objects are capacities activated in their circumstantial relations. Phenomena are the expressions of these, whether the blue shade of a coffee mug, or a distorted handle reflection in a polished pot, or a caustic generated by a laser directed into a block of casting resin. Attention to these phenomena reveals these capacities.
design act, beyond it, and in disregard to it (from any action). These effects dramatically exceed, in sum and combined influence, any designed or expected elements; I can assume authorship only in my narrowed attention. Circumstance is poietic beyond comprehension.

This is perhaps disorienting, but equally a source of engagement and creative value. Circumstance’s phenomenal responses are opportunities to look beyond my intentions, to expand an appreciation of the task based on unexpected contributions intrinsically associated to the task. Moreover, to respond to circumstance’s manifestations with my own creative actions positions me as a counterpart, a creative mirror to its conceptions and circumstance a mirror to mine, in a recursive exchange. By acknowledging and accommodating these phenomena, I concede a degree of influence to circumstance’s agency, and I become a component of that creative circumstance. In forgoing a measure of control, I am recompensed with a richly generative resource (see Open Fragments).

OPEN FRAGMENTS

Tucked inside a recently purchased CD album, Felt, by pianist and composer Nils Frahm, is a CD sleeve bearing a printed description of the creative inspiration for the album. It reads:

“[…] I wanted to do my neighbours a favour by dampening the sound of my piano. It was then that I discovered that my piano sounds beautiful with the damper. […] I make sure that the felt between the strings and the hammers of the piano quiets the instrument so that it whispers. […] Other sounds incorporate themselves into the mix, I hear myself breathing and panting, the scraping sound of the piano’s action and the creaking of my wooden floor boards all equally as loud as the music. The music becomes a contingency, a chance, an accident within all this rustling. […] My headphones turn into infinite microscopes that allow me to dive into a world of inaudible sounds. If you decide not […] to finish your compositions but rather keep them as open fragments, you leave yourself open to many happy accidents and coincidences when you perform them. You discover new possibilities; by risking your ideas you create new ones.”

* Some by-products are so extraordinary and surprising, I save them just for their form, texture, or sound (yes, I have occasionally recorded particularly unusual workshop sounds).
The sculptural explorations of New Zealand artist and filmmaker Len Lye in the 1960s and 70s provide some context to the investigations of circumstantial phenomena generated by materials and objects. Lye’s materials of production were spring steel and motors. However, he was not interested in manipulating these to produce material artworks. His “[…] concern was to shape […] ‘figures of motion’ via the technology at hand.” Motion itself constitutes the object. The works are:

“[…] physical objects occupying space like any traditional piece of sculpture, but […] not sculptural ‘lumps’ like a Henry Moore; instead they are spectacular performances – the substance is in what they do, not what they are. […] they have neither a psychological meaning […] nor […] any iconographic cultural reference. As far as it is possible, the works begin entirely from exploring the properties of their materials and mechanisms – developing their ‘behaviour’ into a visceral and present aesthetic experience. That Lye understood and ‘intended’ this is evident in a quote from Shirley Horrocks’s documentary Flip and Two Twisters, where he says: ‘What is important in kinetic art is the emphasis on the pattern of motion rather than the object making it.’”

The materials of my explorations are polished surfaces of everyday materials and objects. Accordingly, I am not interested in the glazed constructions of architecture, the glossy curved panels of vehicles, and the chrome finishes of domestic products, but instead the aethereal and distorted figures of convex reflection, and the complex structures and spaces of recursive reflection that reside within those surfaces. The tensile energies of spring steel are the matter of Lye’s design, reflection is the matter of mine. Where he was shaping “figures of motion,” I am shaping figures of reflection.

Lye’s “patterns of motion” are manifestations of materials pushed to the edge of physical integrity in unconventional ways. In the words of Shane Gooch, Head of Mechanical Engineering at the University of Canterbury, “[…] he does stuff with metal that a sane engineer wouldn’t do. He vibrates it at resonant frequencies. He makes things that are very unstable and we generally like to make things stable. Almost 999 times out of 1000 we avoid resonant frequencies.” Such manipulations invite unpredictability. For Lye they offered new ways to manifest and conceive form.

“[…] he would use motors at their limits, working right on the edge, so they couldn’t actually drive the material in the way an engineer would like because there were unpredictabilities. You can see that in Trilogy: the small perturbations, the flutters, so we’re never entirely sure what we’re going to get, whether we’ll get symmetry within the performance or from one performance to the next.”

The work of this research project also invites unpredictabilities, pursued at the edge of stability. While Lye pushes his works to the extremes of material behavior, my work presses stable conceptions of what constitutes the extent of objects in the search for new understandings of form. Rather than the extremes of material behavior, I look to the circumstantial interactions between materials and their surrounds for the unexpected, for fresh perspective, and for unrecognized capacities of those materials and objects.

Lye “[…] took a pure attitude to his work on both sculptures and film, which was: take this medium, start afresh, discover what you can do with it.” Addressing this from the perspectives explored in my own research, his is a bringing together of materials, objects or systems to elicit new characteristics or capacities from each of those objects: motor meets sheet of steel to elicit new form—the natural modes of vibration of the steel, its sound qualities. Moreover, “although we often concentrate on the movement as the principle aspect [of Lye’s work], its only when the light rebounds or reflects from the work that we see what’s happening.” However, while acknowledging the implication of circumstantial contributions to Lye’s work, I suggest they were implicit and understood solely as mechanisms by which to generate and reveal his kinetic intentions in both film and sculpture.

A further similarity between Lye’s methods and my own is his use of constraint as opportunity to gain new perspective on the task at hand and thereby innovate. For example, “unable to afford to rent a camera or to pay for processing, Lye began to collect unwanted scraps of film from editing rooms and to experiment with them by painting, scratching or stencilling abstract images onto the celluloid. […] This was based on a flash of lateral thinking, or what New Zealanders call ‘No. 8 fence wire ingenuity’ (the discovery of a cheap, ingenious way of using everyday materials).” More significantly, it enabled the entirely new mode of film making that brought him to recognition. Such approaches are similar to my own use of material limitation as an opportunity to re-evaluate the design task and generate new approaches.

The sculptural explorations of New Zealand artist and filmmaker Len Lye in the 1960s and 70s provide some context to the investigations of circumstantial phenomena generated by materials and objects.
A PHENOMENAL PERSPECTIVE

Reflection (and refraction) phenomena are expressions of an object’s engagement with its wider circumstance. Such phenomenal disclosures provide for external but congruent perspectives, toward insights and possibilities. By examining the phenomena (aspects) activated at the periphery of an experiment, by reconstructing and elaborating them, I can reflect on the intentions of the task (or the project as a whole) from an unanticipated perspective, but an intrinsically associated one. In doing so, these ostensibly extraneous phenomena are reappropriated as an alternative frame of reference.

The thin distorted reflections of a building’s courtyard in five mirror poles shift perception from the material of the poles to the substance of the void and the architecture as container. Peering into the annular mirror while generating stellated laser forms, offers a subjective experience of recursive reflection; the objects are revealed as constructing reflected space as much as reflected form. Experiencing the chirality of reflected space while shaving recasts the objects of the space I inhabit as unfamiliar, and thereby seen afresh. A computer modelling approach to shaping a pot-handle’s reflection positions the activity of making and design inside reflected space (see By-Products of Making).

These displaced perspectives, and their capacity to generate novel results, intimate the transcendent nature of the phenomena. They afford a way of ‘seeing the world from the phenomenal periphery,’ as if from (or through) the extraneous phenomena themselves. They are a phenomenal perspective (see Phenomenal Seeing). The perspectives provide new information from sources outside of my intentions, and my making, to prompt a reconception (and consequently an innovation). Such information provides an opportunity to question the initial objectives of an experiment and adapt those intentions toward significant conceptual (serendipitous) shifts. Experiences diminished as insignificant or neglected as the backdrop for more important or more relevant qualities or activities become alternative and productive ways to reinterpret the design task. The objects of my specification are inherently mundane residents of experience. Given appropriate attentions, the obscure phenomenal by-products that appear at the margins of each creative act offer complexity and richness that transcend my familiar imaginings. They constitute a domain of surprise, insight, and innovation. Circumstantial phenomena offer a way to re-see what is familiar, intended or habitual, a way to realize new insight and capacity.

*Some by-products are so extraordinary and surprising, I save them just for their form, texture, or sound (yes, I have occasionally recorded particularly unusual workshop sounds).
†Bogost’s goal, as is the aim of other Object Oriented Ontologists, is to look beyond human episteme as the sole frame of reference for all things. “By revealing objects in relation apart from us, we [..] release objects like ghosts from the prison of human experience.”
As a maker, looking to circumstantial outcomes and phenomena for alternative perspectives on the process of fabrication is routine. The materials of fabrication are constantly making in countless interactions beyond the object of construction. Every process generates a multitude of by-products or side-effects, contingent forms, only one of which is the intended outcome: oddly angled off-cuts, spiralling lengths of swarf, curling fumes, the scorch pattern around a weld, the penetrating pitch of a saw blade spinning at 5000 rpm. These left-over objects may seem inconsequential. However, their forms are often extraordinary and worthy of attention for this alone (Figures 3.1–2 to 4). They can also offer essential information about the action of making: a good metal-turner can gauge the effectiveness of tool choice and setup, as well as the characteristics of the cut, based on the metal chips it generates. The whine of a panel saw can indicate the density and direction of a timber grain and the condition of the blade. Having acknowledged the implication of these incidental forms and products of fabrication, an acknowledgement of the wider presence and implication of phenomenal form is a small step further into an insubstantial periphery.

Phenomenal seeing

Could a circumstance be perceived as if from the point of view of a phenomenon? It may appear a rather naïve and bizarre question. However, game designer and philosopher, Ian Bogost, explores a similar potential, and its difficulties, in his ‘Alien Phenomenology,’ a proposition that phenomenological examination and description of the relations between anything, as if from the points of view of those things, can provide external perspective and insight. He acknowledges the challenge of such an attempt.

"On the one hand, phenomena are objective, often easily measured, recorded, or otherwise identified by some external observer. On the other hand, such an observer cannot have the experience that corresponds with those phenomena, no matter how much evidence he or she might collect from its event horizon. [...] the character of the experience of something is not identical to the characterization of that experience by something else." Rather than see this as an insurmountable separation, he reminds us “[...] that things enter negotiations with each other as much as we do with them; [...] they are constantly interacting. "Objects try to make sense of each other through the qualities and logics they possess." He concedes that this perception can only ever be a caricature, “[...] a rendering that captures some aspects of something else at the cost of other aspects." He advances his alien phenomenology, not as an objective phenomenology, “[...] that clarifies foreign perception by removing distortion—but instead a mechanism that welcomes such distortion.”

Distortion is productive for the designer, just as the curved mirror reshapes the objects reflected in it, displaced and altered perspectives reconceptualize the design task. This is how I see the phenomenal elaborations of the research. They are opportunities to reconceive my surrounds, unavailable to me without the contribution of those phenomenal expressions of circumstance. The phenomenal distortions and the distortion of conception are the substance of a ‘phenomenal seeing’. They are a creative resource, and an opportunity for innovation.
A MATERIAL BRICOLAGE

My inclination to note and investigate circumstance’s phenomenal expressions for their creative potential is an extension of a well-established characteristic of my design practice. It is a willingness to look to the materials at-hand to explore a design problem. The technique employs the rather significant store of miscellanea introduced earlier. The hoard is a disparate array of offcuts, excess materials, and salvaged components from previous projects, which accumulate roughly sorted and boxed in my workshop. They are items I am ‘convinced’ possess a usefulness that is yet to be recognized.* The technique is akin to bricolage (see Levi-Strauss’s Bricolage). However, it is more than a willingness to compromise to the availability of materials. It is a preparedness to concede a degree of direction to the materials at-hand as a way to question work and generate new possibilities. It serves primarily as a means of ‘finding my way into’ a particular task or project. I consult these materials and components as a resource for convenient fabrication solutions, but also to provoke creative and conceptual solutions.

Rummaging amongst the collection, in search for an item to be adapted toward realizing an envisaged outcome, usually instead requires an adaptation of the parameters and objectives of the task. However, this proves to be a compromise only if the criterion for success is solely based on how close I come to achieving what I envisage with what is at-hand.† If I am willing to question my intentions or approach, such adaptations are often serendipitous. As Levi-Strauss also suggests, “bricolage […] can reach brilliant unforeseen results […]” To adapt a task, so it conforms to what is available, I must reflect-on and question the basic assumptions that constitute what I envisage. To do so, frequently inspires more effective ways to achieve the task, or the realization of a novel approach or outcome. They are possibilities I would not seek if I were procuring tools, materials, or components, specific to the demands of the task, if I were not forced to reflect-on these basic intentions (see Bricolage and Play).

* Others around me are often more dubious about the value of these gleanings.
† Lev-Strauss uses the concept of bricolage to “[...] differentiate between two systems of thought—the “scientific” and the “mythical.” He explained that, while the former seeks to go beyond the boundaries of surrounding limitations, the latter remains within them, using only what is available at hand, remixing the preexisting into new sociocultural configurations.”
‡ Although, for the bricoleur, success is likely based also on a validation of their hoarding compulsion.
LEVI-STRAUSS’S BRICOLAGE

According to Levi-Strauss, the bricoleur† is:
“[…] adept at performing a large number of diverse tasks; […] he does not subordinate each of them to the availability of raw materials and tools conceived and procured for the purpose of the project. His universe of instruments is closed and the rules of his game are always to make do with ‘whatever is at hand’, that is to say with a set of tools and materials which is always finite […]”.32

“The set of the ‘bricoleur’s’ means cannot therefore be defined in terms of a project. […] It is to be defined only by its potential use […] Such elements are specialized up to a point, […] but not enough for each of them to have only one definite and determinate use. They each represent a set of actual and possible relations […].”34

Consulting my hoard for solutions could be perceived as limiting. Rather than facilitate exactly what I envisage by employing specialized tools and specific materials, it risks compromise. What emerges usually “[…] bears no relation to the current project, or indeed to any particular project, but is the contingent result of all the occasions there have been to renew or enrich the stock or to maintain it with the remains of previous constructions or destructions.”33

BRICOLAGE AND PLAY

Bogost, in his book, ‘Play Anything’, acknowledges something similar to a circumstantial bricolage in his conception of play. He reconceptualizes the countless constraints that entangle and frustrate us in our everyday encounters as unrecognized opportunities to “play.” In his world of “playgrounds,” play (and fun) are modes that enable “[…] us to see the hidden potential in ordinary things so that we can put them to new uses.”37 And play, “[…] is a kind of creation, a kind of craftsmanship, even. By adopting, inventing, constructing, and reconfiguring the material and conceptual limits around us, we can fashion novelty from anything at all.”38

He sees play as premised on accepting, even inviting, constraints as delimiting but not restraining.29 His acknowledgment of the potential of constrained play has parallels with the project’s approach to bricolage, as a mode to elicit unrecognized potential of objects. The defining of an area of play, a playground, establishes an opportunity to refamiliarize ourselves with the world of the mundane,20 and delve into it.

“[…] play invites you to consider your surroundings as a vast domain of essentially limitless meaning and potential. […] Playgrounds are places where we dig deep, where we mess things up and tear them asunder—ourselves included—in order to discover what else is possible.”41
A KALEIDOSCOPIC BRICOLAGE

The results of the project have me reinterpreting and extending this notion of bricolage. The fractured resin blocks, the faulty diode laser, the scrap of mirrored acrylic, the roll of mirrored mylar, each constitute examples pulled from the hoard in an act of bricolage. Although, in these instances, the intended use is subverted by a phenomenal characteristic of the item (or combination of items). While what is at-hand in my collection initiates the project, the extraneous phenomena at-hand in the results of the experiments further propel the work, in what perhaps could be described as a phenomenal bricolage.

This phenomenal bricolage is an activation of a transcendent mechanism. With the combination of laser and polyester resin block appears an extraordinary caustic form, beyond the "particular histories" or "language" of resin or laser, beyond their material assemblage, and beyond my anticipation. The same applies to the stellated forms produced by the laser and rolled strip of acrylic, to the roll of mirrored film in its outdoor adventures to the vortices of smoke, to the light shining through a scratch in a sheet of mirrored acrylic, and others. The objects are not confined to a single "language," nor is that language a characteristic of the object. New expressions emerge with each engagement or exchange with another object or circumstance, manifest as a phenomenon. The engagement between laser and fractured resin manifests as a nebulous caustic projection, the engagement between laser and annular mirror manifests as luminous stellated form. Resin block and annular mirror each elicit different qualities different phenomena, from the laser in an idiosyncratic exchange. "The qualities a body manifests in one field of bodies will be different than the properties it produces in another field. For this reason, there is always something of the abyss about bodies." Each, in some unfathomable way, reveal and express themselves according to the other, adapt according to the other, in an exchange that confers the role of bricoleur to the objects themselves. For this reason, no matter how limited the array of hoarded paraphernalia available in the workshop is, there can never be "[…] a fully or fixed inventory of those capacities." In contrast to Levi-Strauss’s interpretation, the items of bricolage are unlimited and unconstrained in all their possible relations, if I am unconstrained in acknowledging the diverse phenomenal manifestations of those relations.

The project work is an activation of these capacities, toward new insights and possibilities. It subjects objects to varying circumstances by adapting them, mis-using them or even decontextualizing them (in contrast to their familiar or intended use). The circumstantial phenomena generated are relational, but they nonetheless imply aspects (capacities) of the objects involved, aspects that would remain undisclosed outside that relation. The phenomena and the characteristics they express are unique. Each circumstance elicits its own distinct array of phenomena; each phenomenon reveals its own perspective; each perspective discloses a quality, dimension, or capacity. Identifying them expands, even re-makes, the nature of the participating objects. Acknowledgement of the wine-glass’s caustic form reveals wine-glass and wine as lens, table as projection surface, and light as form-making substance. Construction of reflected-form with mirrored materials reveals polished products and surfaces as a phenomenal domain of space, object, and thereby design, which permeates the built environment. The project reveals the objects of circumstance as infinitely dimensional. They participate in a constant and shifting discourse with other objects expressed in a language of phenomena.
The notion of the work as a phenomenal bricolage expresses the creative mechanisms at play. However, the experimentation extends this generative mechanism. Such phenomenal activations *compound* with the acknowledgement of successive circumstantial results. Each is reflected back toward the objects and intentions of the work as alternative but relevant aspects of the project.

These involutions accumulate dimension as a *kaleidoscopic* bricolage to generate the project. And, just as the recursively-reflected view inside a kaleidoscopic box radiates beyond the confines of its acrylic walls, the potential of a phenomenal way of seeing radiates beyond material conceptions to extend perceptions of the designed environment and design practice.

**FIGURE 3.1–5**
Exterior icositetrahedral pentagonal kaleidoscope (Parmington, 2016).

**FIGURE 3.1–6.**
Interior icositetrahedral pentagonal kaleidoscope (Parmington, 2016).
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1 DRINKING GLASS IN SUNLIGHT

An empty and unremarkable drinking glass on the kitchen bench demands attention when the sun strikes it through a window. The glass is inexpensive and imprecisely manufactured. Its clear glass walls are inconsistent and hazardously thin. They distort the view beyond with subtle ripples. However, the light-form projected onto the bench as the sun catches the glass transcends its inexpensive manufacture. It is a network that might be typically observed when water refracts light; it is the projections at the bottom of a sunlit pool made still.

A few pieces of salvaged cardboard packaging prove useful when configured to shade the sunlight from the areas around the glass; they allow light to fall on the glass but mask the bench surface, increasing the contrast and intensifying the detail of the diacaustic projection. The fluid quality of the light-form infuses it with immanent flow. The detailed complexity of the radiated pattern, and its suggestion of motion, are difficult to reconcile with the solidified simplicity of the object.

Other artefacts emanate from the sunlit glass: a series of concentric rings of light surround its base. Their encompassing symmetry is perplexing. The sunlight falls only on one side of the glass. The portion of the rings between window and glass should be a product of reflection; the portion of the rings beyond the glass should be products of refraction. Yet they appear as almost continuous circles with the glass at their centre. I am left to speculate these are reflection phenomena and inherently reciprocal to the refraction effects.
2 HALOGEN IN A SHERRY GLASS

The experiment tests the diacaustic potential of a set of sherry glasses, which attract my attention during a search through studio contents for transparent objects. The ornate patterns cut into the glasses, their stems and bases, suggest interesting refraction potential.

I perform a few quick experiments holding a halogen lamp in proximity to a sherry glass, directing the refracted light to fall on a vertical sheet of white paper. I mask the outline of the glass to darken a wider extent of the projection surface to reveal more of the diacaustic network. The projected forms show some patterning and a degree of diffraction. There is an optimal distance between lamp and glass to achieve a defined projection. Several small and simple coherent forms are apparent within a more random pattern. The cut-glass features are evident in the projection, as dark forms on the paper.

When the lamp is inside the glass, the refraction features are more defined. In some lamp positions, a ‘star-form’ radiates from the base projected onto the table. The effect is quite striking. The floriated form comprises dark and light elements alternately and radially arrayed on the table around the base of the glass. On close inspection, the dark elements align with the cut decorations in the glass’s external surface. The illuminated elements on the table correspond to the un-cut surfaces of the glass. Where the illuminated areas meet the dark, there is an abrupt increase in illuminance, highlighting the perimeters of the dark areas with thin bands of brighter light. The cuts in the glass array around the outside in a series of fans and cross over with adjacent fans at their base. These cross-cuts express themselves as dark nodes, with a bright line through the middle. Much finer and fainter artefacts of the cross-cuts array concentrically behind the dark nodes. Overall the projected pattern becomes more defined the closer it is to the base of the glass.
A common material of our designed environment is plastic. Some plastics are manufactured with highly reflective surfaces. In this experiment I investigate catacaustic light-forms generated by reflecting sunlight off a sheet of shiny polyester film. Plastic film can maintain its reflectivity when bent or rolled but less so stretched.

The film is positioned on a bench in a pool of sunshine under a window. A cardboard box, placed next to the film, with a sheet of white paper adhered to one side, serves as a vertical projection surface to capture sunlight reflected off the film. A sheet of corrugated cardboard shades the projection surface from direct sunlight, so that only the reflected light falls onto the surface.

I tape the corners of the plastic film to the bench so that the film bulges slightly in places. I control its surface profile (its topography) by placing small objects (pens, bolts, nuts, offcuts of timber, etc.) underneath. The film is flexible but does not stretch, so the complexity of the surface profile is limited. However, even minimal changes reflect extraordinary patterns of light on the side of the box.

The catacaustic forms are ethereal and soft but vivid. They are projected onto a flat surface, but appear three dimensional, floating in a paper space beyond and in-front of the surface. A thin defining bright line highlights the boundary of each form emphasising the visual presence of the light-objects. They are unquestionably coherent things, with character, shape, even life.

Some resemble luminous sheer fabric twisted and knotted by breeze, others translucent organic vessels. The reflected light is sensitive to subtleties in the surface of the film that are invisible to the eye. In some configurations, parallel streaks are visible in the reflected form, perhaps artefacts of microscopic inconsistencies in thickness introduced into the film during the extrusion manufacturing process. The slightest fold, dint, or imperfection in the film is captured usually as darker cells, often ringed by a bright rim or lip.
The aim of this experiment is to generate and study a stable fluid vortex. Vortices are formed in a rotating fluid medium. The first technical challenge of the experiment is to devise a way to effectively rotate the water. The most (seemingly) obvious way to achieve this is to circulate the water around a vessel using a pump, with the pump’s outlet and inlet directed tangentially to the axis of rotation. I locate a largish jar; my collection of workshop miscellanea also includes plenty of lamps, wiring, and power supplies, and even a couple of small pumps. While the pumps I have prove inappropriate, stored with them happen to be an array of small electronic cooling fans, salvaged from unrepairable appliances. Seeing them elicits the (seemingly absurd) idea that I might immerse a small unsealed electrical fan to rotate the water. I am confident that the fan will not short out and that it will spin. I am less confident that it will have the power to move the mass of water.

I wish to maximize views on the vortex, so invert the jar. I drill a single, small, easily sealed hole for the wiring in the lid, and fix the fan on spacers, 20mm clear from the inside surface of the lid. I fill the jar with water, assemble the lid, and attach power. The fan spins, and the water rotates to produce a well-defined vortex.

The dynamics of the vortex are mesmerising. Its animation is striking, and active: extending down and retracting with little apparent regularity or cause. Stable helical features twist down (or up) its profile, then seem to fall away, or collapse, spontaneously and autonomously, making way for replacements, which climb back up the skin of the object. It ceases to be a fluid surface, instead exhibiting a vitality and a thingness.

While documenting the experiment, I invert the video camera to see if this affects the appearance of the vortex. The inverted video inverts perception of the vortex. Rather than a rotating void in the body of water, it appears to be a gyrating fluid form, reaching out of the body of water; water becomes air and air becomes water. The effectiveness with which inverting the perspective prompts a figure ground reversal is noteworthy, as there is a confluence with the reversal experienced in studying the resin fragments.

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* The vortical profile emerges from the physical necessity to conserve momentum. To do so, fluids at different radii must move at different rotational speeds. The smaller the radius the faster the radial motion. Variations in speed result in differences in centripetal force. These radial forces in combination with gravity and surface tensions generate the classic vortical form.

† This may seem ill-advised. General wisdom dictates that electricity and water are an incompatible combination. This is undoubtedly true, for high voltages. However, the fan I consider using is 12 volts, well below the voltage necessary to compel fresh water to conduct. Interestingly, overcoming this presumption for the sake of immediacy, simplifies the subsequent setup. I now avoid the need to drill or cut the glass to accommodate a pump and tubes, and avoid submerged tubes interfering with the flow of water around the jar.
Fritjof Capra, in his book, *The Web of Life*, uses vortices to demonstrate the concept of dissipative structures, a concept developed by Ilya Prigogine to describe an autopoietic (self-maintaining and self-generating) interpretation of life. A dissipative structure is an autonomously stable form or system through which matter and energy continually flow. I find the notion compelling, for the potential insight it offers in studying light: just as water (matter) constantly moves through the vortex in the maintenance of its form, so light (whether particle or wave) analogously moves through our material surrounds in the maintenance of visual form. Arguably, our experience of the visual domain, with its objects and spaces, is enabled by a cascade of photons (or electromagnetic energy) reflecting off material surfaces and flowing into the retina. The seeming stability of that sensorial impression is due to light constantly moving through the system and regenerating vision. Stop the fluid and the vortex collapses, switch off the light and the perception of visual form collapses. Perhaps visual phenomena could be regarded as dissipative systems.
I attempt to generate diacaustic forms by projecting light (initially from a halogen, then with the laser) through the jar and vortex onto a projection surface. The caustic form is bright and linear while the water is motionless. I presume this is due to the jar’s cylindrical form; the round jar of water behaves like a lens. As the rig is switched on and the vortex develops, a caustic form appears to take shape. As the vortex becomes more established it breaks down into random and dispersed flickerings of light.

I try directing the laser into the vortex rig. The resulting diacaustic form is more defined than that produced by the halogen lamp. It is erratic, leaping around the projection surface in a fluttering type motion. It frantically morphs through a range of forms, each never quite repeated. It has a flying insect dynamism. The light-form is made up of a network of weblike filaments; the intensity of these varies from very bright central forms at the centre, to diffuse strands at its fringes. There is a distantly visible line of light where the laser beam passes through the water. I suspect this is due to some turbidity. This illumination of particles clearly reveals where and how the beam enters the vortex. Most of this light is refracted onto the projection surface, however much of it is dispersed, reflected off the inside and outside of the vortex, and off the inside surface of the jar, in other directions. It means that there are many other light-forms dancing around on the table and other objects and surfaces of the studio, though less intense than that projected on the screen. Some light seems to be reflected around the internal form of the vortex; although this may be due to reflections and refractions picked up from stray external sources, it is difficult to say with any certainty. Regardless, the vortex form glows with a buzzing, green luminosity.
Subsequent experiments explore the potential of laser light to delineate space by scanning the laser dynamically using a simple mechanical system to give it extra-dimension. A fixed laser beam will project a point of light onto a surface. Rapidly and repeatedly tracing the laser beam over a path will translate the point into a line or curve of light on the surface. Introducing a fine aerosol in front of a stationary laser reveals its beam as a line of light. Doing the same in the path of a rapidly scanned laser gives the impression of a surface of light. Using this technique, a wide variety of solid light effects can be generated.

Laser scanning has many everyday applications, such as laser levels, light show equipment, and barcode scanners. Commercial laser scanning systems reflect the beam off a moving mirror. They control its direction by altering the angle of the mirror. These mirrors are driven by a set of high speed mechanisms, either galvanometers or stepper motors, which allow for two axes of rotation. They can trace the laser over complex paths, repeatedly, tens of times per second.

In this experiment I develop my own scanning technique. I use a small mirror mounted onto a motor. I drill the centre of a short length of aluminium rod, so it can be mounted and fastened onto the shaft of the small motor. I cut one end of the rod at 45 degrees to make a surface on which to adhere a mirror. I shape a small square offcut of mirrored acrylic into an ellipse, to match the profile created by the 45-degree cut of the aluminium rod. Given the dispersion difficulties experienced in the annular mirror experiments, I remove the protective coating painted on the rear face of the acrylic and expose the aluminumized layer to create a front-coated mirror. The motor, mirror, and laser are mounted so that the laser is directed along the shaft of the motor, and thereby the axis of rotation. The spinning mirror angled at 45 degrees to the laser’s beam should array the reflected beam perpendicularly, much like a light house, but very rapidly. The solid light effect should thus be a plane also perpendicular to the beam.

Smoke generated from a pyrotechnic haze pellet is used to reveal the laser path. The scale of the experiment is small. The aerosol is contained in one of the glass jars used previously to delay its dispersal and maximize time to study the effect. The laser rig is configured so that it cuts through the transparent wall. The speed of the motor and angle of the mirror prove to be successful. The rig generates a distinct wall of light, revealed by the smoke, and bounded by the circular wall of the jar.

Complex morphing forms in the illuminated plane of smoke capture my attention. They are fluid structures defined by light reflected off the smoke particles and variations in the

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* Although, this is an illusion: the projection remains a point of light. We perceive the line or surface as continuous because of a sensorial phenomenon called persistence of vision. The repeat rate necessary to create this effect is over 25Hz.

† The use of lasers to generate surfaces, and the potential to delineate light spaces by enclosing volumes with these surfaces, can be seen accompanying concerts and public entertainment events. The effect has been employed by artists even before the development of lasers. Anthony McCall, with his ground-breaking installation piece, Line Describing a Cone employed a celluloid film technique. It was first installed in 1973 (I had the good fortune to experience the work later in exhibition at ACMI in 2007). He describes the effect generated by this and similar works as “solid light.”
density of the smoke; the more concentrated the smoke, the more the laser light is dispersed by particulates and the brighter that area appears. The different fields interact and flow across one another in distinct streams or layers. Parallel streams, each moving at different rates, compress and expand between other streams, or get trapped and extruded into swirling vortices. The overall appearance is of contour lines mapping a constantly evolving topography. The plane of laser light reveals a section through these animated air-forms. Imperceptible variations in air temperature and pressure drive and define them, much as they drive the immense weather patterns of the wider atmosphere.

This small dissection of space implies a wider, ubiquitous complexity of intertwining three-dimensional volumes and structures in the air: a plethora of phenomenal air-forms (artefacts) incidentally generated by a breeze, by air-conditioning, by simply moving through space, by an exhaled breath, by a closing door, or by convected air rising from our bodies. It is a glimpse of an invisible realm of form and motion which must constantly surround us. We are immersed in it but oblivious to it.

The re-emergence of vortices and fluid structures in the work is intriguing. The intertwined fluid volumes of air revealed by light and aerosol have me again considering ways to demarcate space that do not require massive (solid) form. The forms revealed by the plane of laser light through smoke, and the subtle volumes of light detectable in the diacaustic laser experiments, suggest that such light-spaces are capable of a complexity that would challenge typical modes and understandings of spacemaking.*

* With this experiment, the work intersects concepts being explored by Malte Wagenfeld, in his doctoral project *Aesthetics of Air.*
Having successfully generated a simple plane of light, I set myself the task of generating a standard rectilinear ‘room,’ defined by aethereal laser walls. However, I am given an opportunity to get an impression of the effect while assisting Malte Wagenfeld in an experiment. He has built three laser units that employ the same scanning technique used in the previous experiment; each integrates a laser and a small mirror mounted to a spinning motor to generate a plane of laser light. The aim is to reveal air movement and air-forms in an interior space. He uses the units simultaneously, in several configurations to ‘section’ the space, visualizing the air movement with a smoke machine. During the exercise, we configure the laser planes into a corner of laser defined space (two walls and a floor).

The ‘laser walls’ generate a convincing sense of barrier and enclosure. I am surprised that there is such a persuasive sense of ‘corner’ where the planes of light intersect. I conject that this would be further enhanced if the planes terminated where they met. The division of space is permeable, also with a degree of transparency. However, approaching and passing through the ‘light wall’ induces a subtle perceptual disturbance—a sense of hesitation that a looming obstacle inspires—even though the wall of light is obviously insubstantial. The reflexive hesitation is interesting. It suggests perceptions of walls are strongly associated with materiality and solidity, strong enough to destabilize obvious sensorial information that suggests otherwise. It demonstrates a learned behaviour instilled by frequent encounters, but it also reveals that even subtle and subliminal triggers can provoke appreciable psychological and physiological responses.

A horizontal laser surface generates other associations. When half a metre off the ground, the effect is of a ‘floor.’ Standing amid this raised floor of light, facing toward the laser source, gives the impression of standing in a pool of luminous fluid; the swirling smoke forms illuminated by the laser emphasize this feeling.

I investigate the capacity of laser light to generate nonlinear (and non-rectilinear) forms. The most technically straightforward of these is a cone. Reflecting the laser beam off a spinning mirror angled at 45 degrees to the axis generates a plane. However, changing the angle of the mirror will generate conic geometries. I alter the original laser-scanning rig by fabricating a mirror mount that decreases the angle between mirror and beam. This is equivalent to folding the laser plane (of the previous experiment) back over the laser source.

The conical envelope generated is not large, sufficient in size to accommodate head and torso at its widest. Like the laser room, stepping into it elicits a strong feeling of being completely enclosed. Looking again toward the laser source (the apex of the cone) there is little sense of depth or tapering of the volume. The surrounding cone appears as a flat wall of light. Interrupting the envelope with hands or fingers re-introduces a sense of depth. The shadows generated widen beyond the interruption and extend the remaining length of the cone.

I experiment with the effects produced by modulating the conical laser ‘surface.’ I do this by reflecting the laser off moving water. I direct the laser assembly at an acute angle into a large shallow dish of water. The circular path traced by the laser transforms to an elliptical path as it meets the water surface. However, the path of laser light is restored to circular after it is reflected off the water, projecting a neat circle on the far wall of the spray booth.

On agitating the water, the rippling water surface disturbs and redirects the laser light. The circle projected onto the wall collapses and explodes into random combinations of waves, the effect resembles the waveforms displayed by old, green cathode ray tube oscilloscopes.
The waveforms jump erratically with the initial disturbance, as if modulated by audio signals. Waves appear to simultaneously initiate from the extreme left and right of the circle, bounce toward each other, then back out again, almost symmetrically, the line of light their medium of travel. The overall impression is of a projected form with a life of its own. Ripples on the water surface persist well after the disturbance, but more subtly. The translated form expressed by the laser on the wall responds accordingly; it settles to an undulating ring-like form.

Agitating the water also undulates the laser surface. Variations in luminance are visible along its entire length, radiating from the light source. The forms generated give the impression of transitory ‘folds,’ similar to a breeze ruffled curtain; the ripples in the water translated to ripples in the laser surface.
In the previous experiments, a straightforward technique to scan a laser develops, based on the rotation of reflected light. This system enables planar and conical light surfaces, but no other variation. No matter how complex the path traced by the laser, the volume they generate radiates from a point source. The experimental rig, and even expensive commercial scanners, have this key limitation. The following experiment circumvents this by moving the laser light source and thereby generates more complex geometries. The aim of the exercise is to determine whether the laser beam, a line of light, can be moved rapidly enough to produce a non-linear hyperbolic or ruled surface. These are a family of surfaces that can be circumscribed by an array of lines. The difficulty with moving the laser rather than a reflecting surface is that the motion must be repeated many times per second to achieve a visually contiguous effect. The most straightforward high-speed motion available to me in the studio again is rotational. Single axis rotation enables the creation of a hyperboloid, an hourglass-like surface.

There are other ruled surfaces. They include hyperbolic paraboloids, Möbius strips, and a range of surfaces called right conoids which cover, helicoids, the Whitney umbrella, the Wallis conical edge, and Plücker’s conoid. In principle, all might be generated using a laser. Though, the technical challenge of moving a laser module along the required paths, rapidly enough to create a contiguous effect would be significant, perhaps insurmountable.

The laser module is mounted on a spinning arm. The arm is a length of timber, drilled at the centre to fix an aluminium tube as a shaft. The radius of the rotation is approximately 500mm. The laser module is at one end, batteries are fixed on either side of the shaft and their position adjusted to keep the assembly balanced. Again, the experiment occupies the spray booth. The arm is rotated by an old power drill strapped to a machine tool pedestal.

There are several possible geometries with this rig, all dependent on the angle in which
The laser is directed. If the laser is pointed parallel to the axis of rotation it would trace a circle and the spatial envelope generated would be a cylinder. If directed away from the axis, but in line with it, a truncated cone would be generated. If the laser intersects the rotational axis the result would be two cones, aligned point to point. If angled inward toward the axis of rotation but askew, a hyperboloid should be generated. The first two options are easily visualized, so I go immediately to the more complex.

The resulting effect is surprisingly successful. There is little sense that a line of light generates the form. It is compellingly an object as much as a bounded a space: light substantialized as three-dimensional form. As with the laser generated cone, the hyperboloid has a sense of three-dimensionality due to the uncanny inversion of ‘shading.’

This hyperbolic surface could be animated. With the appropriate mechanism and controls, the position of the laser on the revolving arm and its angle could be altered in real time. The circumference of the surface and the hyperbolic profile (the hour-glass shape) could both be squeezed and widened in a continuous transformation to create a morphing spatial envelope.

The laser volumes explore the potential for light to define space, as would a segment of solid architecture. Their permeability and lack of mass distinguishes them from typical circumstances where light furnishes a sense of space by revealing solid objects and surfaces, as demonstrated by the circle of light on the pavement around street lighting or the chair and wall around a reading lamp. The laser volumes express light itself as a spatial transition rather than a solely a transition of projected form on surface.
Threshold 2 is a gallery installation. It is the second of two contributions to Cloudy Sensoria, a group exhibition of site specific works at the Bundoora Homestead Art Centre. The first, Threshold 1, is described in detail in the main text.

The installation draws directly, in its materials and effect, from the polyester mirror strip experiments. However, in this case the incidental fluctuations of reflection, elicited by the erratic breezes of an outdoor environment, are exchanged for the more mechanical oscillations of an electric motor in an indoor environment. The intent is to slowly rotate a very long strip of mirrored polyester, and to examine the reflection phenomena generated as it oscillates between the full width and the exceptionally thin edge of the strip. I wish to reproduce several of the effects glimpsed in the earlier experiments, but in a more deliberate way.

The site of the installation is a space in the Bundoora Homestead, a short passageway, on the lower level of the house, which connects the main stairwell to an elevator and a rear stairwell. A large, frameless glass door at one end distinguishes the space as part of recent renovations. The walls are white, floor boards are finished with Japan black. The ceiling height is approximately four metres.

The installation is complicated, because of the homestead’s architectural heritage overlay; all mounting or fixing systems that mark or affect the finishes or architecture are prohibited. The mounting system uses threaded steel bar and PVC plumbing pipe to establish a lightweight cross member between the walls, supported by outward pressure and friction. A set of geared motors are mounted onto these tubes with a T-piece plumbing connector. Their position can be adjusted by sliding the T-piece along the tube. The speed of the motors has been stepped down significantly by the gear-box but can be reduced further with a voltage controller. I cut a set of three mirrored polyester strips to mount to the motors. The strips need to be attached to the shaft. This is achieved with a set of aluminium connecting collars the same diameter as the strips. The strips also need to be weighted to keep them straight. Similar aluminium mountings attached to the bottom ends serve this purpose. The rotational movement and long lengths of polyester are likely to start them swaying. To alleviate this, a frictionless pivot is used, which the bottom weights can mount onto. This comprises circular metal flanges adhered to the floor with a thin sewing needle protruding from their centre, which sit in a small hole at the centre of the bottom weights.

I find the resulting effects subtle but compellingly engaging. The rotating strips momentarily vanish when edge-on, and seemingly widen as they move around to face the viewer in full width. Reflections of the surroundings move within the reflected interior of the mirrors, visually translating the rotation into an aperture rather than an object, a parting of the substance of space. The strict rhythm of opening and closing, and of reflected architecture swaying into view, is mesmeric. The grouping of three strips undermines the metronomic stability of the individual mirrors; viewed together the reflected objects dance between each in a disordered series of stuttered leaps.

Visitors are not so engaged. Most offer a glance but move on without any further consideration. Perhaps the work is too subtle or bewildering within the context of the homestead, and visitor expectations; most people visit the house attracted to its period architecture, and its exhibitions of more traditional arts such as painting (often 19th century works). The installation does not...
PRODUCTS OF REFLECTION
fit typical notions of art object; the objectness of the strips is phenomenally, as well as conceptually, indistinct. Perhaps it thereby deflects engagement by not affording a familiar point of access.

A colleague, viewing the work, describes the rotating mirrors as scanning the room, offering continuous but attenuated glimpses of the space around the strip. The observation is an interesting and compelling interpretation of the phenomenal mechanics of the installation. On close observation, the reflections in the rotating mirrors are linearly compressed. They move from one side to the other, and then unexpectedly return, moving in the other direction. The mirrored strips are not flat, despite the straight mountings at top and bottom. Somehow their configuration and material properties have transformed each into a concave mirror on one side and convex on the other. The effect is only around the vertical axis of the polyester, and seems consistent for the full length, and flattens only when adjacent to the mountings. This causes the distortion of the reflections, and their movement. The convex surface compresses the reflection. The concave side will equally compress the reflection, but will also reverse it, hence, the opposing motions.

A subtler implication of the curvature of the mirrors is that the convex faces appear to situate the reflections beyond the strip, on the side opposite of the mirror to the viewer, and the concave faces appear to situate the reflections in front of the strip, between viewer and mirror. The latter is an optical effect employed in Newtonian telescopes. The phenomenon is more apparent with larger mirrors, to the extent that it can be quite unsettling: reflected objects float ghostlike between the viewer and the surface of the mirror. Each rotating mirror strip parses the space in which it is centred, and recasts it as two different spaces, one for each side of the mirror.
12 MIRRORED CORRIDORS

This work experiments with two strips of mirrored acrylic left over from fabricating the mirror poles. It explores the recursive reflection effects generated when they are configured as opposing walls of an extended mirrored corridor.
13 EXPLODED PENTAGONAL ICOSITETRAHEDRAL KALEIDOSCOPE

This experiment elaborates the recursive reflections of light leaking between the edges observed inside the kaleidoscopic polyhedra. It is a rig that allows the pentagonal icositetrahedral kaleidoscope to be ‘exploded’ along its edges. In this configuration, edges, rather than faces, become apertures to admit light and thus aspects of the environment.

A frame constructed of 3mm steel rod suspends this internally mirrored pentagonal icositetrahedron at its centre. Over each face there is a vertex of the frame. At each vertex of the frame is an aluminium bush with a locking screw. Each external face of the polyhedron has a steel rod fixed to its centre, which is aligned perpendicularly to the face. Each perpendicular rod is attached to the frame and held in alignment with an aluminium bush. The geometry of the resulting frame constitutes a snub cubicahedron, the dual of the pentagonal icositetrahedron. I can now adjust the radial position of each face by sliding the rod in the bush and locking it with the screw. In principle, it ‘explodes’ the internally mirrored form to introduce gaps between the edges. The gaps between faces can be varied by expanding or contracting the polyhedron.

The rig is first tested in the studio environment. The edge apertures have a consistent gap around each mirrored face of about 25mm. Peering through these gaps reveals a confusion of reflected colour and form. As with many studios mine is a confusion of work, equipment, and storage. This disorder is multiplied exponentially by the mirrored interior. The earlier experiments expose polyhedra to their environment through open faces. They tend to frame aspects of the surrounding vista and replicate them; they are like windows through which many objects and features are reflected in their entirety and thereby identifiable. In contrast, the environment captured by the exploded pentagonal icositetrahedron is through a series of slots. Therefore, rather than frame aspects of surrounds, views of the surrounds become the frames. The slots dissect objects and features into bands of broken colour. Nothing is identifiable. The interior becomes a shredded reproduction of the exterior. Consistent widening or closing of the gap between edges makes little difference to the effect. When the rig is placed in a dark environment and illuminated by a single exterior light source, the effect is different again. The reflections are recursively broken and repositioned, each evenly separated from the other, and the interior is transformed into pieces of cut glass.
MOBILE MIRROR

As part of the development of the Bundoora Homestead installation, *Threshold 1*, I photograph the homestead reflected in a large mirror mounted to the roof rack of my vehicle. As an extension of this exercise, I mount a video camera behind the mirror. I drive around the streets of Melbourne recording the animated interaction between real cityscape and reflected.
15 SPHERICAL REFLECTION OF A CHAIR

During the pot handle experiment, I become briefly distracted from the initial focus. Using the reflection modelling algorithm, I construct and extract the spherical reflection of a simple straight-backed chair, with the notion that I could use the model to fabricate (materialize) this form. The exercise becomes compelling for the unexpected transformations of form that emerge, purely as objects of aesthetic inspiration. A range of interesting, distorted variations on the chair are generated by repositioning it in different orientations to the reflective surface.
2 Ibid., 164.
3 Ibid., 165.
A series of graphical representations of the project are used to gauge the influence of circumstantial, phenomenal encounters. They map the themes and causal links that connect the experimentation. The task itself evolves into an experiment, an exploration of how the physical and phenomenal mechanisms of reflection might themselves serve as instruments of analysis. The recursive reflection spaces generated in polyhedral kaleidoscopes offer one such possibility. A mapping system develops from the incidental act of laying out the mirror panels of the dodecahedral kaleidoscope flat on a table for assembly. In this unfolded configuration, each panel suggests a node connected to other nodes in a series of multiple branchings.

The resulting mapping system uses pentagonal tiles sequenced in a similar array, edge to edge horizontally and occasionally bifurcating into branches. Each tile represents an action of the research, either an experiment or an outcome of an experiment (whether physical or conceptual). I classify and represent two types of outcome: (1) as conforming to the initial intention or conjecture that drove the experiment, or immediately relevant to it (a dark grey pentagonal tile); or, (2) as extraneous (peripheral) to the initial intention (a light grey pentagonal tile), either unexpected or seemingly irrelevant. The degree of influence exerted by each type of outcome is represented by directing those that are intended to branch upwards, and directing those that are circumstantial to branch downwards. A consequential experiment or action informed by (or in response to) either class of outcome is neutral, progressing forward (to the right) only (a black pentagonal tile). The red tiles represent instances where a conceptual or thematic consideration is precipitated by the experiment. The map uses a horizontal axis as a datum. This represents the starting level, and it offers a qualitative measure of the influence that both intended and incidental outcomes exert on the progression of the project overall.

In theory, if the project were comprised of entirely a of series of experiments that verify or disprove consecutive conjectures, its graph would consistently climb upward. This would perhaps be akin to a series of scientific experiments designed to confirm or refute a (series of) hypothesis. If the project were entirely a sequence of digressions to circumstantial outcomes, it would consistently cascade downward. This might be analogous to a completely responsive process of a creative artistic exploration.*

* See Portable Document Format (PDF) version of dissertation for map details.
The mapping exercise frames the interplay between research intentions and incidental outcomes as a key relationship in the emergence of the work. It reveals where I have allowed the work to be redirected by circumstantial encounters, and the corollary influence of testing, confirming, and pursuing intended outcomes. It offers an indication of the extent of each of these influences. The final mapping of events climbs above and falls below the horizontal starting axis at various points but remains proximal to it. It finds that both anticipated and the unanticipated outcomes drive the experimentation in approximately equal measure. The result suggests equal attention and influence of intended and extraneous results overall.

To conclude much more from the analysis becomes speculative.* However, the other key consideration is that the work overall remains appropriate to the themes of the project, without diverging significantly. When the work does expand or redirect focus, it frequently returns with useful re-conceptions or innovations, which I intuit is consistent with the final configuration of the map. I see that circumstantial results, when pursued, prove useful to the work because, in the act of considering them, I reappropriate (reincorporate) them into the core concepts of the project. I speculate that I am consistently and productively able to do this because these phenomena are more intrinsic and relevant in their association than I might presume.

* I note that the map is predicated on subjective judgements, on what I have assigned as relevant and incidental in each instance of the research.
APPENDIX 3
INCIDENTAL REFLECTION