Devices for Hyper-Polluted Futures

By

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Abstract

This research explores what types of devices humanity might build in order to breathe ambient air in hyper-polluted futures. One such device is the PERA - Personal Ecosystem Respirator Apparatus: a backpack-style wearable which contains the user's personal-ecosystem to provide them with clean air through a respirator mask. Using the approach of speculative design, the intention is to highlight the consequences of our actions and inactions on climate change and show a world in which we have failed to address the issues of air pollution and global warming. Following a hybrid methodology created from a mixed methods approach, the research was conducted through an iterative process. Throughout the research, there was an increasing focus on the symbiotic relationship between the user and their ecosystem, and how one protects and provides for the other. The result of the work is a speculative wearable device which relies on James Auger's theory of perceptual bridges in order to help build a believable and relatable future for the viewer.

Key words: Speculative Design, Air Pollution, Global Warming, Wearables

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1. Introduction

This project focuses on the research into and creation of speculative devices for hyper-polluted futures. Using different perceptual bridges (Auger, 2013), this work seeks to explore how design through the lens of the Anthropocene might be used to create more engaging speculative futures whilst avoiding solutionist outcomes. Throughout the creation process, I aimed continually reevaluate my own assumptions and prejudice and how these were reflected in my practice. In order to research these ideas further, a mixed methods research approach (Burke & Onwuegbuzie, 2004) was used to create a hybrid methodology, which lead the project through a critical-making (Hertz, 2016), research-creation process. The result of this was a series of speculative, wearable devices which would provide a user with breathable air through means of a portable ecosystem.

1.1 About the Issue

Global warming is an ever-looming apocalypse which creeps closer every year. Despite the attempts from governments, corporations and individuals to reduce their contributions to pollutants and greenhouse gas emissions, global warming and air pollution still remain very real and present dangers. It is our responsibility to limit the damage for future generations. According to a special report last year from The Intergovernmental Panel on Climate Change (IPCC), we are on track to surpass the 1.5°C increase in global warming agreed within the Paris Agreement; and the results of this could be truly cataclysmic (IPCC, 2018). Air pollution is just one of the many symptoms of a much bigger problem. For the purpose of scope, this research was limited to this specific issue.

Many studies have concluded the direct and adverse effects of gaseous air pollution on human health. Even 20 years ago, studies were beginning to show the adverse effects of gaseous air pollutants on mortality rates in major cities (Burnett et al, 1998). The effects of particulate matter (PM) air pollution on human health have been, and continue to be, well researched. There is an abundance of scientific evidence for the correlation between PM air pollution and detrimental repercussions on human health. Studies have linked PM to ALRI (acute lower respiratory illness), CEV (cerebrovascular disease), IHD (ischemic heart disease), COPD (chronic obstructive pulmonary disease) and lung cancer (Anderson et al. 2012) (Raaschou-Nielsen et al. 2013) (Shah et al. 2013) (Lelieveld et al. 2015).

Air quality can differ hugely depending on the environment - for instance industrial zones tend to have the highest levels of air pollution, followed by urban areas. One study found that megacities with populations over 10 million people such as New Delhi and Beijing can have PM2.5 levels of 100-300 μg/m^3 compared to an average of 15 μg/m^3 found in smaller cities (Shah et al. 2013). This study also drew some conclusions based on how this affects not only the populations health, but also the countries spending: “In the USA, we estimate that a mean reduction in PM2·5 of 3·9 μg/m^3 would prevent 7978 heart failure hospitalizations and save a third of a billion US dollars a year.” (Shah et al. 2013).

The link between ambient air pollution and mortality rates is clear. According to the one study conducted by The Institute for Health Metrics and Evaluation (IHME) at the University of Washington, mortality rates associated with O3 and PM2.5 grew from 3.34 million globally to 4.23 million between 1990-2016 (IHME, 2018).

1.2 About the Project

With this in mind, I began to think about what humanity might need to survive in hyper-polluted futures. What kinds of devices and technologies would they need to breath in a toxic atmosphere? If humanity intends to survive on the planet their predecessors all-but destroyed, what might that look like?

The project began by positioning these hyper-polluted speculative futures within a Futures Cone. This tool was introduced in 1994 by Hancock and Bezold and has been adapted by strategists in the foresight community (Voros, 2003) and artists alike (Dunne & Raby, 2013). For the purposes of this research, Voros' version of the tool from their paper "A generic foresight process framework" was chosen, as it presents a more well-defined version of the cone than some others.

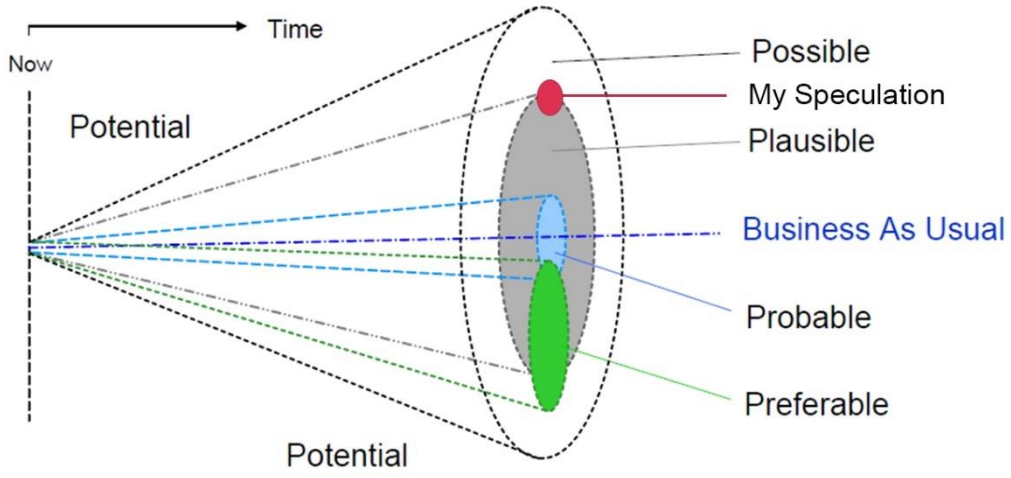


Figure 1 - Futures Cone

Source: *Voros, Joseph. "A generic foresight process framework."* foresight *5.3 (2003): 10-21. Edited for own purposes.*

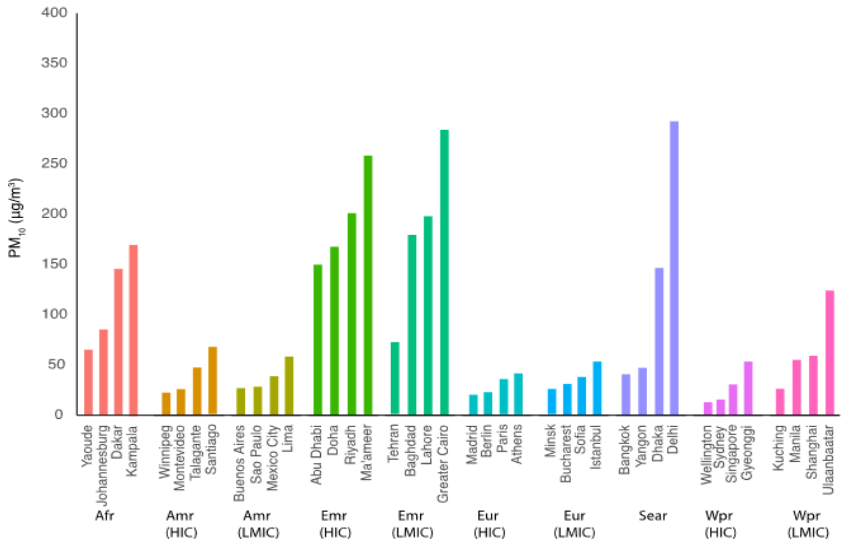
This research straddles the Possible and Plausible cones and is intentionally distant from the Preferable section. The speculation crafted relies on both:

1. "...future knowledge (i.e. knowledge we do not yet possess) ..." (Voros, 2003) in the form of the biotechnology needed for these small ecosystems to be able to convert enough polluted air to breathable air.
2. The current knowledge of air pollution, our dying planet and current political and consumer attitudes which are reluctant (at best) to alter.

Positioning the research within this scope allowed me to be both creative with the types of technology used [incorporating James Augers theory around verisimilitude (Auger, 2013)], while ensuring a recognizable connection between the world today and my speculations [Augers theory of other perceptual bridges (Auger, 2013)].

1.3 Scope and Limitations

During my research, I came to realize that some aspects of my work could be seen as problematic. The issue of air pollution exists today. Although we may not consider the impacts of this in a day-to-day scenario here in Toronto, or even in my home city of Glasgow, Scotland - the speculative world I have created is a reality for those who live in cities such as Gwalior, India; Al Jubail, Saudi Arabia and Pasakha, Bhutan(WHO, 2018). An ongoing database from the World Health Organization clearly shows the disparities between different regions of the world:



PM_{10}: Particulate matter of 10 microns or less: Afr: Africa; Amr: Americas; Emr: Eastern Mediterranean; Eur: Europe; Sear: South-East Asia; Wpr: Western Pacific; LMIC: low and middle-income countries; HIC: high-income countries. [1] Selection criteria: For the latest year of measurement for each city included in the database, the largest for each country within a region was selected. City size ranges from 192'900 to 26 million habitants

Figure 2. - PM10 levels for selected cities by region, for the last available year in the period 2010-2016

Source: WHO. "WHO Global Ambient Air Quality Database (Update 2018)." *World Health Organization*, World Health Organization, 22 Jan. 2019, www.who.int/airpollution/data/cities/en/.

The 'bio-technology' I propose to combat the toxic air is not feasible, at the very least not on the scale I suggest. Throughout the process of my thesis, I was unable to 'solve' this problematic aspect of my work. With the aid of lessons from the writings of Pedro Oliveira & Luiza Prado (Oliveira & Prado, 2014), as well as the inclusion of self-reflection in my methodological approach, via Critical Making (Hertz, 2016) - my hope is that I would avoid creating any other problematic issues within my work.

Although my research asks what types of *devices* might humanity build in order to survive hyper-polluted futures, a conscious decision was made to limit the research to the production of one of such devices. Aligning with a stance in opposition of solutionist speculative

projects, I feel it is important to note that though through this research one such device - the Personal Ecosystem Respirator Apparatus - was created, this is not meant to be presented as any sort of 'solution' for what is a dangerous symptom of a far greater problem.

1.4 Outcomes

Aligning with James Auger's positioning within the practice of speculative design (Auger, 2013), this research examines how speculative and critical design (Dunne & Raby, 2013) has been used to engage with the Anthropocene (Crutzen, 2006) through a wide range of projects. Time was taken to examine criticisms of speculative and critical design and how these might apply to this research. Suitable speculative and critical projects were critiqued and evaluated on the basis of Auger's theory of perceptual bridges (Auger, 2013) and how solutionist their speculations are (Anderson, 2015). A number of consumer products on the market which aim to tackle the issues of air pollution were also examined. Literature on design for wearability was also included in this research as this would be vital for designing believable speculative devices.

Using a mix methods approach (Burke & Onwuegbuzie, 2004), a hybrid methodology was constructed in order to best answer the research questions. This hybrid - A Critical Industrial Design Methodology - was comprised from four different frameworks and methodologies including Design Thinking (Both et al. 2009), Critical Design (Dunne & Raby, 2013), Speculative Design (Auger, 2013) and Critical Making (Ratto & Hockema, 2009, Hertz, 2016). With this approach, a number of different prototypes were designed and built. These included:

Pollution Pipe

An airtight pipe and gas sensor which tracked CO_2 and TVOC (Total Volatile Organic Compounds). These were used to test the air quality around the city of Toronto and test polluted air samples from car exhaust.

Swamp Boxes

Two ecosystems which constructed from collected natural material. These ecosystems were kept for and maintained in order to learn the intricacies of caring for complex ecosystems in smaller, controlled environments. This prototype also highlighted the symbiotic relationship between user and ecosystem, and relates to Donna Haraway's theory of "making kin" (Haraway, 2016).

Concept Generation and Selection

Based on the perceptual bridges of the mundane and the uncanny (Auger, 2013), the single concept was chosen to proceed with the research. The chosen concept consisted of an ecosystem, a backpack-style protective housing and a respirator mask.

Respirator Mask

Using an iterative approach, the design for the mask was inspired by respirator dust masks often found in workshops or the construction industries. By utilizing this familiar design, the mask adheres the principles of design for wearability (Dunne & Smyth, 2007, Motti & Caine, 2014), as well as exploiting the perceptual bridges of the mundane, the uncanny and verisimilitude (Auger, 2013).

Backpack

The backpack was designed to protect the ecosystems while in use, as well being an everyday device for the user. Taking the insights from *Pollution Pipe* and *Swamp Boxes*, the design for the

backpack consists of a 3D printed hard-shell body, which houses not only the ecosystems in their containers, but also the subsystems which are required to keep both ecosystems and user alive.

The PERA

The Personal Ecosystem Respirator Apparatus (PERA) is the culmination of *Swamp Boxes, Respirator Mask* and *Backpack*. The result includes the combined research of all previous prototypes in the form of this wearable device. As part of this, two foresight tools were used to explore the wider speculative world building: a Futures Wheel (Glenn, 2009) and a VERGE Analysis (Lum, 2014). In addition, the research findings from the previous prototypes were amalgamated to design a 'Best Practices and Maintenance Manual' for the PERA.

2. Literature Review

My two main research interests at the beginning of this process were the practice of speculative design and how this might be used to challenge the issues around global warming through the lense of air pollution. Starting from James Auger's theory of perceptual bridges (Auger, 2013) and Kayla Anderson's criticisms of speculative work within the lense of the Anthropocene as "solutionist and masculinist" (Anderson, 2015), a number of projects which deal with issues around global warming and air pollution were critiqued. These include work by artists, designers and researchers; as well as a number of consumer products.

2.1 Speculative & Critical Design

Critical Design was a term coined by Anthony Dunne and Fiona Raby in the mid-nineties. Their definition at this time was "critical design uses speculative design proposals to challenge narrow assumptions, preconceptions and givens about the role products play in everyday life" (Dunne & Raby, 2013). Critical design is associated with a group of similar design practices such as design fiction, design probes, discursive design and speculative design (Auger, 2013). In his paper "Speculative Design: crafting the speculation", James Auger states:

"There is much overlap between these practices, the differences are subtle and based primarily on geographical or contextual usage: all remove the constraints from the commercial sector that define normative design processes; use models and prototypes at the heart of the enquiry; and use fiction to present alternative products, systems or worlds." (Auger, 2013)

He continues to explain that his preference for the term speculative design is largely based on semantics, as it implies a connection from the viewers' perception of reality to the idea

being presented to them. As this research aimed to explore this field, Auger's definition of this term spoke to my own preferences for speculative work which exists in worlds that are recognizable, believable and relatable.

Furthering this theory, Auger continues by outlining his definition of speculative design as a methodology; with the use of building what he refers to as 'perceptual bridges': "In effect, a design speculation requires a bridge to exist between the audience's perception of their world and the fictional element of the concept." (Auger, 2013). This is one of the key contradictions between his work and that of his teachers and original coiners of the term Critical Design; Dunne & Raby - who are very clear about their opinion that CD should be thought of as an approach or position rather than a clearly defined methodology (Dunne & Raby, 2013). Auger presents not a full methodology, but instead, a basis on which one can be built by using perceptual bridges throughout the creative process in order to ensure a clear, well-defined and plausible speculation is crafted.

Auger outlines six different approaches to building perceptual bridges, presenting examples of projects which embody each approach:

- "Design for context: the ecological approach", which positions the work in a specific 'space' - be this geographical, cultural, political etc.
- "The uncanny: desirable discomfort", the goal of maintaining some sort of familiarity whilst provoking cognitive dissonance, a method often used in horror fiction which can be utilized by speculative designers when approaching traditionally taboo subjects such as sex or death.

- “Verisimilitude: design fiction or design faction?” the practice of presenting the artifacts as real or working or true: “where truths are blurred and disbelief is suspended” (Auger, 2013).
- “Observational comedy: rooting the speculation in the familiar” taking insight from observational comedians, the designer can explore broader possible futures by positioning it in or around the mundane and the familiar.
- “Alternative presents: counterfactual and alternate histories” creating alternative pasts, presents or futures as a method of critiquing our own society, creating a “What if ….” scenario.
- “Domesticating technology: literally” basing speculation on the advancement of real-life science and technology. (Auger, 2013).

In reality, many of the successful projects which Auger presents as examples use multiple bridges simultaneously in order to effectively build and maintain the speculation. This can also be seen in the broader context of speculative design projects. This research drew from many of these approaches, though the mundane, the uncanny and verisimilitude were utilized the most.

2.2 Differences of Speculative & Critical Design

In their book, ‘Speculative Everything: Design, Fiction and Social Dreaming’, Dunne & Raby outline successful perceptual bridges without using that specific term coined by Auger. They discuss the power of negativity to promote positive action; the use of dark, satirical humor; the avoidance of “parody and pastiche” (Dunne & Raby, 2013); absurdity; and deception and verisimilitude. As a former student of the duo, Auger clearly has many similar views around these design practices, however there are a few more key disparities between their definitions.

In ‘Chapter 6: Physical Fictions’, Dunne & Raby separate speculative design objects from film props:

> “The objects used in design speculations can extend beyond filmic support function and break away from cliched visual languages that prop designers are often obliged to use. Yes, it makes reading the objects more difficult but this process of mental interaction is important for encouraging the viewer to actively engage with the design rather than passively consuming it.” (Dunne & Raby, 2013)

One could argue that reliance on established visual languages may be a useful perceptual bridge, especially when engaging with particularly far-fetched speculations. Careful manipulation or perversion of established visual languages may also be used to create bridges of the uncanny. Some key aspects of this research rely on the perversion of everyday objects which the audience will be familiar with - a backpack - but by subverting the understood functionality. Using established visual languages in this way can be a very effective method of building relatable and understandable speculative scenarios for the viewer.

2.3 Criticism of Speculative & Critical Design

While exploring practice and theory, I believe it is important to recognize the criticism of both academics and practitioners. It is specifically important to outline this within my own research, as some of this criticism could very easily be applied to my own work. After learning more, this theory directly influenced how I approached the research.

Artists and academics such as Francisco Laranjo and Cameron Tonkinwise (Laranjo, 2016; Tonkinwise, 2016) have both been quite outspoken in their opinions of Dunne & Raby’s

teachings. One of which is that they have a Eurocentric-bias, by offering speculations which pose dystopic futures in Western settings which exist in other countries across the world today. Both Laranjo and Tonkinwise are advocates for a decolonization of speculative and critical design as a practices and encourage diversity in the field.

At a public discussion during Speculative Now workshop in Split, Croatia in 2016, two PhD students, Luiza Prado and Pedro Oliveira from Brazil were openly critical of both the practice and pedagogical approach to speculative and critical design, and those who create the work, including Auger and Dunne & Raby:

> "...what we feel is that the way that it's been practiced is problematic. That goes not only for the projects themselves but the educational aspect of it, how speculative design has been taught within educational institutions. The critique is rather shallow, superficial." (Public Discussion, 2016)

Oliveira & Prado also published two blogs in 2014: "Questioning the 'Critical' in Speculative & Critical Design" (Oliveira & Prado, 2014) and "Cheat Sheet for a Non (or Less) Colonialist Speculative Design." (Oliveira & Prado, 2014). The second of these posts outlines one way in which my work could be seen as colonialist:

> "**Check Your Facts:** ask yourself *"does my dystopia happen already in other 'invisible' (sic) places of the World?"* It is good to know if what would be terrible for you and your audience isn't already reality for others. Before asking *"what if...?"* ask *"is there...?"* Particularly if you consider how colonialism helped shape the power inequalities and uneven economic relations we currently live in." (Oliveira & Prado, 2014)

This is entirely applicable to my project, which could easily be criticized as problematic. Everyday people in cities across the world are unable to breathe clean air due to the high levels of pollution in certain areas. The speculative dystopia I am creating here already exists elsewhere. Although I understood that this is a very current and pressing issue, as well as much of the causation of these issues coming from colonialism, consumerism and capitalism; Oliveira and Prado made me reconsider the ethical stance of my project. My hope was that going forward, my work could highlight the capitalist and colonist issues that we perpetuate as consumers in the West and may pose the question to the viewer of their position and responsibility in these regards.

2.4 The Anthropocene

The Anthropocene, a term which has been used in scientific fields as early as 1873, was popularized by Paul J. Crutzen to define the current epoch in which we live. Although many academics argue when this age began, Crutzen traces it back to the 1782, and James Watt's invention of the steam engine:

> "Because human activities have also grown to become significant geological forces, for instance through land use changes, deforestation and fossil fuel burning, it is justified to assign the term "anthropocene" to the current geological epoch." (Crutzen, 2006)

Crutzen, along with Steffen and McNeill, followed up with another paper published which tracked the Anthropocene through history in relation to the rise in global C02 levels - which was applicable to this research. The paper begins examining the history of humanity's

impact on the Earth System: "… the suite of interacting physical, chemical and biological global-scale cycles and energy fluxes that provide the life-support system for life at the surface of the planet" (Steffen et al, 2007). This includes oceans, the atmosphere, the Sun and human factors. Humanity has been using fossil fuels as early as the Song Dynasty (960-1279), however the environmental impacts were kept at a local level and unable to challenge the immense power of Nature (Steffen et al, 2007).

In their conclusion, the authors propose a third (and preferably final) stage of the Anthropocene named "Stewards of the Earth System"; to which this research would be concerned with. The authors state "Humankind will remain a major geological force for many millennia, maybe millions of years, to come." (Steffen et al, 2006). Although it is not clearly stated, there is an implied assumption that humanity will continue to survive and that our actions will have long term consequences. This is one of many examples of the great contradiction between the research in the arts and sciences: much of the previous (pre-2010) scientific-community believed humanity's presence post-Anthropocene is a given, whereas more recent stances, as well as many from the arts, believe it shouldn't be assumed as such. It's worth noting that much of the recent scientific research that has been published is more pessimistic in regard to humanity's survival of the situation which we have created. For the purposes of the speculative future of this research, humanity is still present, however, I suspect that they will be in far fewer numbers than we have today.

Their paper also outlines three possible approaches to society going forward: Business-as-Usual, Mitigation, and Geo-engineering. Each of these comes with significant risks and potential benefits, with the authors explicitly pointing out the potential long-term damage of geo-engineering solutions. One of the more interesting aspect of any of the options was the large focus on mitigation, and how this would rely heavily on changes of societal behaviors and

attitudes; a goal which might be achieved by a creative practice which questions the audience to think critically about their relationships with the world around them - such as speculative design.

Critical theorist Donna Haraway has quite different opinions of what a post-Anthropocene future might take form. In her book "Staying with the Trouble: Making Kin in the Chthulucene" (Haraway, 2016), she states that, in her experience, issues around the Anthropocene and Capitalocene (an associated term Haraway uses, refocusing the blame on human factors being the cause of change, onto the real causes being capitalism, colonialism and consumerism) are often met with one of two responses. The first:

"...a comic faith in technofixes, whether secular or religious: technology will somehow come to the rescue of its naughty but very clever children, or what amounts to the same thing, God will come to the rescue of his disobedient but ever hopeful children." (Haraway, 2016).

The second viewpoint she describes as: "...a position that the game is over, it's too late, there's no sense trying to make anything better..." (Haraway, 2016). Haraway proposes a different approach - making kin. She presents her idea of the Chthulucene; making note to distance it from H.P. Lovecraft and his "misogynist racial-nightmare monster Cthulhu (note spelling difference)" (Haraway, 2016). Haraway's Chthulucene revolves around the idea of making kin with other species, embodied by her chosen slogan: "Make Kin Not Babies" (Haraway, 2016). She suggests that humanity should make kin with the other species, focusing on building multispecies relationships instead of continuing to overpopulate the planet, stating:

"Over a couple hundred years from now, maybe the human people of this planet can again be numbered 2 or 3 billion or so, while all along the way being part of increasing well-being for diverse human beings and other critters as means and not just ends" (Haraway, 2016)

The relevance of Haraway's theory on making kin and living with other species did not become apparent to this research until later in the process, yet when it did it was so very intrinsic to the outcomes of the project.

2.5 Speculative Design & The Anthropocene

Due to the inherent links between speculative thinking, humanity's future on this planet and the Anthropocene, it is no surprise that this is a recurring theme within speculative projects. They cover a vast breadth of mediums, styles and approaches with some more successful than others.

In her paper "Ethics, ecology, and the future: art and design face the anthropocene." (Anderson, 2015), Kayla Anderson's criticism is not of speculative and critical design as practices, but instead of how many practitioners use them to address the subject of the Anthropocene. Much of her criticism can seen to be a direct opposition to Steffen, Crutzen and McNeill's assumption that humanity will be present in the future.

The paper critiques a number of approaches from the world of art and design to tackle the Anthropocene. Anderson is critical of practices that they see as "solutionist and masculinist, and that re-assert human dominance over the planet." (Anderson, 2015), favoring instead ideas and work that challenges how we look at our relationships with political and social structures, science and technology and the environment that we have shaped - or more accurately,

destroyed. This opinion resonates with Haraway's critique of the "technofix" (Haraway, 2016) attitude that she discusses in 'Staying with the Trouble'.

Anderson highlights the work of a number of artists, designers and makers which operate within the theater of critical and speculative design; including Marina Zurkow, Una Chaudhuri, Oliver Kellhammer, Fritz Ertl and Sarah Rothberg; Anthony Dunne and Fiona Raby; and Jae Rhim Lee. Throughout the paper she highlights the ways in which these particular creators produce work which challenges the viewer/user and their perceptions and biases while avoiding the "easy solution" (Anderson, 2015).

Anderson commends their work from different approaches. *Dear Climate* (Zurkow et al.) has a distinct post-humanist tone, in which the user is asked to consider their relationships with other species living in the Anthropocene, asking "After all the damage we've done—both for our own species and others—what non-humans would want to help us?"(Anderson, 2015). Again, the idea of multispieces relationships and making kin (Haraway, 2016) can be seen in this work.

Dunne and Raby's work - including *Is This Your Future, Designs for an Overpopulated Planet: Foragers* and *United Micro Kingdoms* - bridges many mediums in the speculative and critical arenas' as well as scope in terms of the Possible/Plausible/Probable/Preferable Futures (Voros, 2003). Anderson highlights their use of the uncanny and the mundane in order to elicit critical thought from their user/viewer.

Lee's *Infinity Burial Project* addresses the effect our burial practices on the environment. The human body is filled with many toxic pollutants, all of which are released upon the environment and have ramifications after our deaths; whether we are buried or cremated. Lee's TED talk in 2011 caused a great deal of controversy due to the taboo nature of the topic of death, however it is in this aspect that lies its power - to spark the question of our

relationship between the human body, death and a continued responsibility for the natural environment.

Therefore, to consider evaluation criteria of the contextual landscape of speculative design projects, two potential frameworks for analysis could be:

1. The perceptual bridges that are built, and how successful these are used.
2. Their approach in regard to how solutionist they are presented.

It could be argued that a third criteria could be "Does the project breach Prado and Oliveira's Cheat Sheet?" however, as a European, white, lower-middle class industrial designer, I may not be in the best position to judge others for their colonist approaches. Instead, I intend to critically reflect on my own work and practices throughout the project, to ensure I minimize the effect of my own prejudice and privilege.

2.6 Design for Wearability

As the resulting device is intended to be a wearable, it was important to identify theory which would aid in the design process. Design for Wearability has a unique importance to this research for two key reasons. Firstly, these devices are intended to be everyday objects for the user, of which its primary function is to protect the user from danger. Secondly, incorporating good standards of design for wearability into the device will aid in building a more realistic and familiar object. In turn, this will aid in the building of perceptual bridges (Auger, 2013).

In their paper "Psychophysical Elements of Wearability" (Dunne & Smyth, 2007), Lucy E. Dunne and Barry Smyth discuss the importance of wearability in regard to protective wearables:

> "Wearability is essential to the function of wearable devices for many reasons: most importantly, a device that is "unwearable" (meaning in this context that it causes discomfort or is difficult to wear, not that it is impossible to mount on the body) simply will not be adopted by its user. There are numerous examples of this behavior in studies of protective clothing: garments that are uncomfortable or even just considered unattractive by users will simply not be worn, or will be worn in a modified way, even if this means putting the user's life in jeopardy." (Dunne & Smyth, 2007).

The authors go on to propose that one of the key issues in making a device wearable is the relationship between said device and the user's "body schema" - a term for how a person perceives their own body in size and shape and how it occupies space (H Head & Holmes, 1911). They hypothesize that a successful wearable device is one which can be incorporated into the user's own understanding of their body schema without drawing any cognitive attention from the user. The authors do make a point to note that most humans would eventually adapt to almost any wearable devices as long as they do not cause the user harm.

Clint Zeagler's work on BodyMaps (Zeagler, 2017) offers quantitative data related to wearables and approximate sizes and ideal locations for weight distribution for wearable technology.

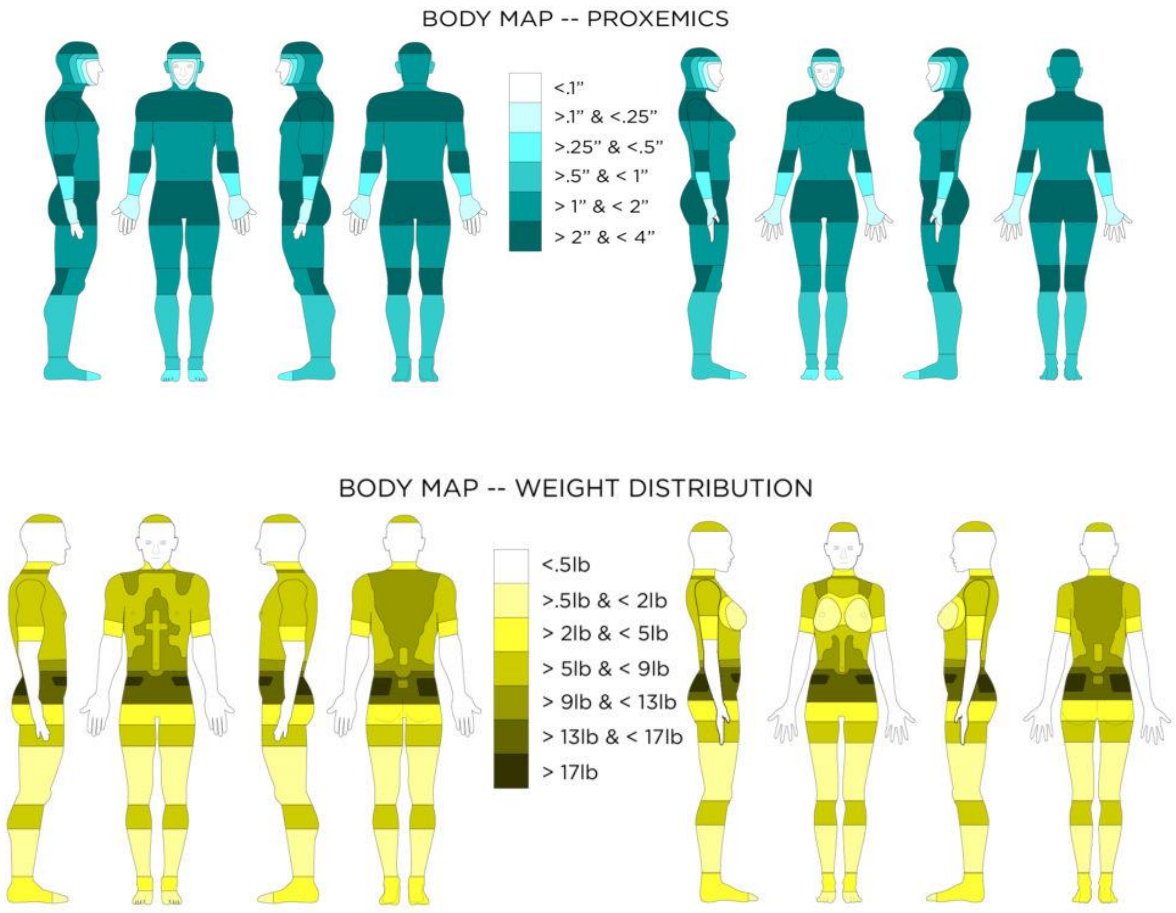


Figure 3. - Body Map -- Proxemics & Weight Distribution.

Source: Zeagler, Clint. "Where to wear it: functional, technical, and social considerations in on-body location for wearable technology 20 years of designing for wearability." Proceedings of the 2017 ACM International Symposium on Wearable Computers. *ACM, 2017.*

The dimensions of my wearable device exceed the scale of Zeagler's ranges, however it would be important to consider how this will affect the wearability and time for adaption. Weight is also an important consideration, as there will need to be a balance between weight and protection for the ecosystems.

In order to help tackle the design challenged in balancing wearability and time for adaptation, I looked to the work of Vivian Genaro Motti & Kelly Caine in their paper "Human Factors Considerations in the Design of Wearable Device" (Motti & Caine, 2014). Here, the authors outline an approach to incorporating human-centered design principles into the design of wearables in order to decrease the time for adaptation and reduce rejection of the device over time.

Motti & Caine identify 20 design principles which should be considered in the design of a wearable. Some of these principles were more relevant to this research than others, and as such, the following four were chosen as being the most applicable:

> "P3) Comfort. Concerns the freedom from discomfort and pain."
> "P4) Contextual-awareness. The scenarios in which the wearable device will be used must be clearly understood and considered during the design process."
> "P7) Ergonomy. Refers to the physical shape of the device, its ergonomic aspects regarding the respect to the body anatomy, its constraints and how users perceive it."
> "P20) Wearability. Considers the physical shape of objects and their active relationship with the human form." (Motti & Caine, 2014)

The importance of both comfort and wearability are already prominent from the work of Dunne & Smyth, and ergonomics are a must when considering a product which requires human interaction. The significance of contextual-awareness was one of the most important considerations, especially in how this relates back to Auger's perceptual bridges of the mundane and uncanny. In designing a device which is intended for everyday use, contextual-awareness

could aid in both designing for wearability, as well as strengthening perceptual bridges as mundane objects.

In relation to my research, it is important to bear in mind how my designs will interact with the user's body schema and how long a user might need to adapt to theses as every-day wearable devices. The use of human-centered design principles for wearables as identified by Motti and Caine will be used to help guide the design process.

3. Context Review

3.1 Speculative Projects

There are a plethora of examples of creators who are working within the contexts of speculative design and the effects of the Anthropocene. These projects have been chosen specifically for both their relevance in subject matter to this research, but also to highlight both positive and negative uses of perceptual bridges and solutionist design. As Anderson has presented examples of non-solutionist projects, consideration began with their use and effectiveness of perceptual bridges.

3.1.1 Anthony Dunne & Fiona Raby - Is This Your Future?

Figure 4. - Dunne, Anthony, and Fiona Raby. "Blood/Meet Energy Future & Hydrogen Energy Future."

Source: Dunne and Raby, *2004, www.dunneandraby.co.uk/content/projects/68/0. Photograph by Jason Evans.*

This installation proposed future scenarios of energy production. The project is aimed at children, and therefore must establish very clear and easily understandable perceptual bridges. Much of the work relies on familiar objects seen in new-lights, using the power of the uncanny to provoke speculations; such as the *Hydrogen Energy Future - Contract-Birthday Card* and *Blood/Meat Energy Future - Book for Parents*. These scenarios are based on existing technologies, situating them in real world scenarios. As Anderson notes, Dunne & Raby's presentation of their work are some of the most impressive examples of creating the uncanny from the mundane. They subvert details, functions and norms to propose their speculative futures as being like our world but somehow not. They are experts in this craft. My work will aim to create devices which replicate the everyday yet uncanny nature of these projects.

3.1.2 Jae Rhim Lee - Infinity Burial Project

Figure 5. - Lee, Jae Rhim. "Jae Rhim Lee: My Mushroom Burial Suit."

Source: Coeio, *Coeio, 2016, http://coeio.com/press/*

Infinity Burial Project not only uses the bridge of the uncanny to shock the viewer, but also utilizes an ecological approach to the work. Lee's ecological approach is clear in her TED talk where she discusses the ability of certain mushrooms to cleanse toxins. She presents her work with dark humor paired with a playful verisimilitude. Lee presents the scientific issues with her mushrooms while also exploring alternative routes she has researched. The combination of dark humor in dealing with a taboo subject, a strong scientific basis, and the questions left by the viewer at how much they have been shown is 'real' results in a very effective speculative project. Lee has created a multitude of perceptual bridges gripping the audience despite the morbid subject matter.

After a fellowship at Hasso Plattner Institute of Design at Stanford (the d.school), Lee founded Coeio. The company has since developed the original design and are now taking orders to produce and sell Infinity Burial Suits. These biodegradable burial suits use a biomix containing mushrooms and microorganisms that help decompose the body, while neutralizing the toxins expelled and providing nutrients for the surrounding environment. In this way, this project can be considered a functional viable product which was the result of speculative design project.

3.1.3 Jun Kamei - Amphibio

Figure 6. - Kamei, Jun. "Amphibio Visual Prototype." & "Underwater Cathedral Rendering"

Source: Junkamei, 27 June 2018, www.junkamei.com/amphibio. Photography by Mikito Tateisi. Model: Jessica Wang. Rendering by Kathryn Strudwick.

Amphibio by Jun Kamei is a project that tackles rising water levels - an issue that has been exacerbated by the increase of global warming. Inspired by water-diving insects, Kamei created a 3D-printed wearable device which would allow the user to breath underwater for longer periods of time without the use of expensive scuba-diving equipment. One of the most interesting aspects of Kamei's work is that he provides a working prototype to show the functionality of his design. In this way his work could be considered solutionist, however, the device is not meant to enable people to *live* underwater. The accompanying renderings of the device show wearers exploring the drowned ruins of cities and chapels, painting a future where exploration of a sunken past is a common past-time of the surviving population. These renders help to contextualize the speculative future that has been created. Kamei presents this project as near future, however, misses the opportunity to create a bridge of verisimilitude by clearly stating the required surface-area of the device would be too large to function. This arguably would have been a more interesting project had the alternate reality been presented as realistic.

Much of Kamei's work straddles the boundaries of innovative technology and purely speculative work, which may explain his preference to explicitly state the restrictions of his technology.

3.1.4 Philips Design Probes - The Microbial Home

This project was to design a cyclical ecosystem within the home; the output from one object would be the input for the next. This project asks the user to consider their relationship with waste, energy use and sustainability by challenging the taboo of waste as fuel; including sewage, effluent, garbage and wastewater.

The Microbial Home included:

- The methane-biodigester: A device used to prepare and cook food. Human waste and vegetable waste are combined into a functional fuel source. This powers the gas cooking element and heats water for other devices in the system.
- The Larder: A evaporative cooling storage device/dining table. The innovative solution can both heat or cool food items based on where they are stored.
- A filtering squatting toilet: A zero-external energy human waste solution, which would provide power for the rest of the system. The design is also linked to health benefits, such as a decreased risk of colorectal cancers.
- The Paternoster: A plastic up-cycling machine that can create edible mushrooms from plastic waste.
- Biolights: A lighting solution that requires no electricity. This device can work from bioluminescent bacteria or fluorescent proteins.
- The Urban Beehive: a personal honey-factory which challenges the user to reconsider their direct relationship with other species and the interdependence that we rely on.

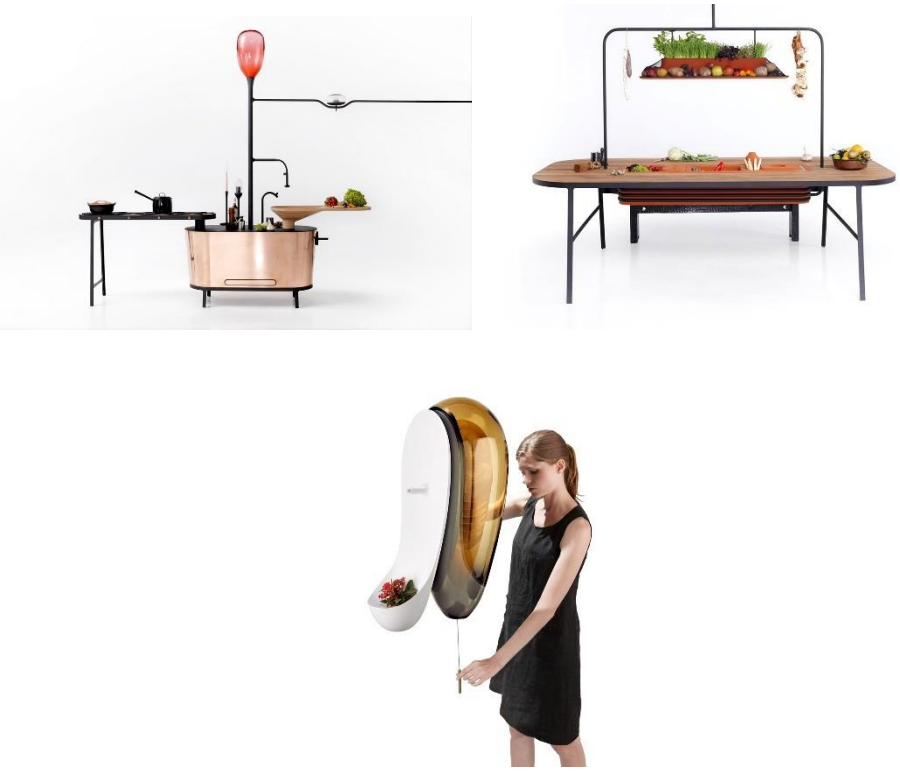


Figure 7. - Philips Design. "Microbial Home Project".

Source: Materiability*, 2011, materiability.com/portfolio/microbial-home/.*

The high quality of these devices certainly benefit the building of the speculation; though for the most-part were based on the establishment of near-future technology. The system is also presented as a complete, self-contained circular eco-system which places the user within the cycle - not unlike this research. A major critique of this work is that it is highly solutionist. It proposes a world where everything is recyclable and there is no need for traditional energy consumption. It implies that science and technology will save us all. The ideas they present are interesting and the devices are incredibly well-designed, however, the scenario they paint is an unattainable utopia. There is no acknowledgement of the extremely high costs that such a system would require and the accessibility of sustainable materials. Projects such as these are why I entirely empathize with Anderson's view that solutionist speculative projects are

problematic. They may have something critical to say, yet their work does not pose any real questions or challenges to the viewer.

3.1.5 Superflux - The Future Energy Lab

Superflux is an example of a design agency which has been very successful working within the speculative field. Partnered with a foresight company Rorosoro, the Superflux team worked for the United Arab Emirates Ministry of Energy to aid with key decision making related to the country's future energy policy. The group designed, developed and presented five future scenarios which followed different stances on energy policy. These scenarios not only showed potential solutions and benefits of investing in renewable energy but reinforced their importance by highlighting the consequences of relying too heavily on polluting fossil fuels.

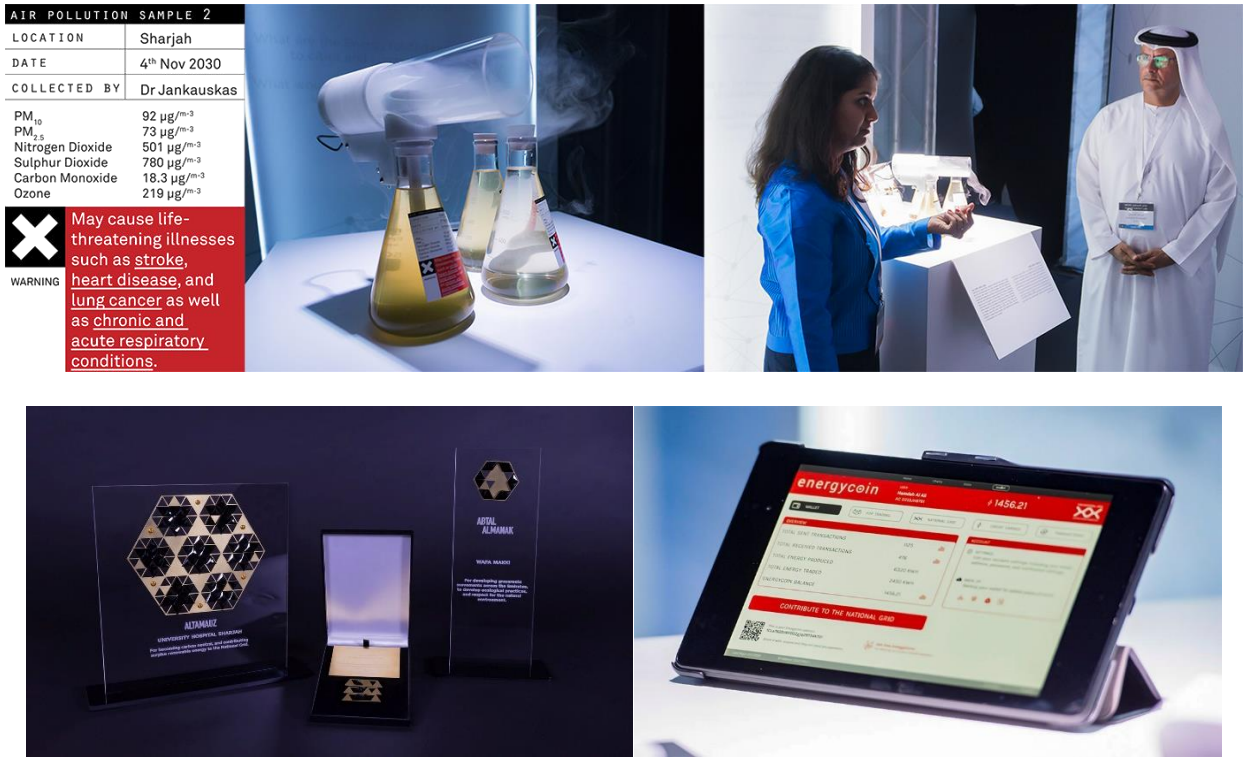


Figure 8. - Superflux. "The Future Energy Lab."

Source: Superflux, *2017, superflux.in/index.php/work/futureenergylab/#.*

Each scenario modelled projections for the economic, social and environmental future of the country, and included a wide range of policy suggestions, speculative design artifacts and data visualizations. The team realized that they did not only have to convince the decision makers they met with, but also had to provide policy suggestions which would encourage societal change by benefiting the general population. This involved a number of speculative design initiatives, including a public renown system for those who encouraged more sustainable energy practices and a cryptocurrency which could be exchanged for goods and services. Each of these potential futures required different mediums and tools to properly build these scenarios in ways which could be relatable for the decision makers. I do not view this project as solutionist; despite solving a very real issue. By presenting the potential outcomes of the decisions being made, the speculations crafted by Superflux influenced a change in policy from a government which only two years prior had the highest average levels of PM2.5 (World Bank, 2015).

This project is one of the most applicable examples of the power of speculative design and its ability to positively influence change. As a direct result, the UAE government announced a plan to invest $163 billion in renewable energy, and easing their reliance on fossil fuels (Superflux, 2017). This will have a great impact on the air quality of the people of UAE as well as a lasting effect on the global environment. This project acts as an aspirational example of the real change that can come from speculative design.

3.2 Design Solutions & Consumer Products

As more and more studies confirm the dangers of air pollution, there has been a rise in personal dust masks in highly polluted cities. Although some studies have shown the benefits of reduction

to exposure (Langrish et al, 2009), more recent evidence has suggested that a majority of dust mask sold are insufficient at properly protecting the user from air pollution (Cherrie et al, 2018).

As such, there are a number 'solutions' available to consumers - some exist as design concepts, while others have made the step to market. While these products are not applicable to same theoretical scrutiny as the speculative projects above, they do showcase some interesting solutions which we have already made to combat the increases in air pollution.

3.2.1 Plant Bag

The idea of using the recycling properties of the natural world is not a wholly original idea as there are a wide range of different projects which focus on harnessing the power of biotechnology. One of which came from a group of students from Delft University of Technology, Netherlands in 2016, who created an award-winning backpack for children which used a combination of HEPA filters and plant life to create safer air for the user (van Uffelene, 2016). Although this project has some very clear overlaps with my own project, their design focused on a practical solution for modern day instead of speculative thinking or scenario building.

Figure 9. - Van Uffelene, Connie. "Plant Bag."

Source: TU Delft, *Delta, 2016, www.delta.tudelft.nl/article/prijs-voor-luchtzuiverende-plant-bag*.

3.2.2 Plume Labs - Flow

Figure 10. - Plume Labs. "Flow."

Source: Plume Labs*, 2018, plumelabs.com/en/*.

Flow is a wearable air pollution sensor which allows the user to monitor their exposure to air pollution both in real-time and retrospectively. The IOT device is meant to be attached to the user via a strap, which uses LED lights to communicate the current levels of air pollution. The device has a partner app, which uses a combination of GPS data from the user's smartphone, real time data from monitoring stations and AI and algorithms to plot out 'pollution maps'. The intention is to allow the user to better plan their traveling times in heavily polluted areas. This device would be a useful data collection tool; however, one might question how effective it would be as a tool for helping the user to avoid heavily polluted areas.

3.3.3 WAIR

WAIR is a French company which offers a range of scarf-style respirator masks. The company pride their product in offering a greater deal of protection through their patented technology, which protects the user from particulate matter as small as PM0.1 (WAIR, 2018). They also use eco-friendly materials and offer a range of styles to cater to different lifestyles.

Figure 11. - WAIR. "WAIR Anti-Pollution and Scarf."

Source: WAIR, *June 2018, www.wair.fr/en/wair-products/54-anti-pollution-mask-wair-essentiel-3770009993029.html, www.wair.fr/en/anti-pollution-masks-scarves/15-85-anti-pollution-mask-scarf-pattern-seastorm-3770009993043.html#/26-motifs-sea_storm.*

WAIR are not the only company who intend to profit from air pollution. Competitors such as totobobo, Vogmask and Respro all offer products which protect their user from harmful exposure to air pollution. As well as WAIR, Vogmask and Respro offer a range of different styles in an attempt to appeal to their customers aesthetics.

With the exception of Jae Rhim Lee and Coeoi's Infinity Burial Suit, these products offer current consumers the ability to monitor or reduce their exposure to the dangers of air pollution. However, they fail to critically challenge our relationship with the environment. As an industrial designer, I understand why these products are increasing in popularity, but as a speculative designer, this type of work has less relevance to this current research. It also increases my respect and admiration for Lee's work, in that she has been able to take her speculative work to create a product which not only provides a beneficial solution to the problem

of pollution after burial, but also highlights and informs people on these problems simultaneously.

4. Methodology

Taking a mixed methods approach (Burke & Onwuegbuzie, 2004) to the research, a hybrid methodology was created to guide the work. By combining multiple methodologies and frameworks, the intention was to tailor the research process to better answer the research questions.

The methodology is a hybrid, titled 'A Critical Industrial Design Methodology'. It was been constructed from 4 different approaches or methodologies which have been augmented into this new form; these include Design Thinking (or bootleg) from the d.school at Stanford (Both et al. 2009), Critical Design from Dunne and Raby (Dunne and Raby, 2013), Speculative Design from James Auger (Auger, 2013) and Critical Making from Matt Ratto and Stephen Hockema, and by Garnett Hertz (Ratto & Hockema, 2009, Hertz, 2016). Each approach or methodology adds a different component to my existing creative practice which helped me focus on answering my research questions and building my thesis project.

4.1 Design Thinking

The traditional approach follows 5 stages or 'modes'; Empathize, Define, Ideate, Prototype and Test. Empathize is a research stage, where the designer is tasked with empathizing with the user(s), to gain insight into the problems or issues which the project is attempting to solve. The Define stage allows the designer to collate all the data they have absorbed from the previous stage in order to define the real source of the problem; for example, the project brief may be to solve Problem A, however during the Empathize stage the designer(s) realizes that Problem A is just a causality of Problem B. They may choose to try and solve Problem B as a long-term solution to the brief. Ideate is for concept generation, selection and development. The

designer(s) then builds Prototypes of their chosen solution(s) which is moved into the Test stage. As with most standardized design methodologies iteration is encouraged, therefore, if time allows, the Test stage would include extensive user testing which would lead back into the Empathize stage, and the cycle would begin again.

The 'Empathize' stage, which was intended to be the very beginning of the cycle, has been replaced with the new 'Evaluate' stage at the end. The intention was to allow reflection on not only my own experience with the creation of the work (Critical Making), but also in how the work might provoke the kind of critical thought and discourse intended. By removing the user from the start point, it completely 'breaks' the original intention of the methodology - yet somehow still providing a formulated template for the research.

4.2 Critical Design

Critical Design is defined by its creators Anthony Dunne and Fiona Raby as "…more of an attitude than anything else, a position rather than a method" (Dunne & Raby, 2013). However, I would argue that a framework and an attitude are one in the same; and a methodology is a framework in practice. And what is a methodology but a framework for your practice? With this, the intention was to build the 'attitude' of critical design into a methodological approach. To achieve this, there are a number of key principles of critical design which would be reflected upon during each stage of the process.

One of these principles is the intention of the work: "to challenge narrow assumptions, preconceptions and givens about the role products play in everyday life." (Dunne and Raby, 2013). This includes challenging the status quo, offering alternative to current political, cultural or societal norms. In terms of this work, this related to how we interact with the natural world,

with the very air we breathe. How do we leave our homes when the atmosphere is toxic? How do we adapt to survive? What is the price of survival, and is it worth paying? As the project developed, the importance of the world building and narrative elements of the speculative future have been guided by these questions.

4.3 Speculative Design

As discussed in the previous chapter Auger's theory of the perceptual bridges have been greatly influential in the direction of this research. This meant juggling the crafting of the speculation and designing the working object. For me- someone who was used to working very much in the real world, the here-and-now, and maybe-in-five-years - this required a substantial learning curve. The juxtaposition between designing real world products, and those for a world that does not yet exist, was an exciting challenge throughout the research process.

For 'A Critical Industrial Design Methodology', Auger's perceptual bridges were incorporated into the methodology. At the end of each stage or prototype the work was evaluated on how strong the bridges were, if the bridges had changed or altered through the making, and how that would affect the speculation being built.

4.4 Critical Making

Ratto and Hockema first coined the term Critical Making in 2009 as:

> "an elision of two typically disconnected mode of engagement in the world – 'critical thinking', often considered as abstract, explicit, linguistically-based, internal and cognitively individualistic; and 'making', typically understood as material, tacit, embodied, external and community-oriented." (Ratto & Hockema, 2009).

This idea of think, make, reflect and make again speaks to the iterative creative process which I am familiar and comfortable with. Reflection on the creation process is key, and bridging the gap between the theoretical framework and the resulting prototypes would help to better answer the research questions and guide the project forward. Ratto's definition of critical making and his own practice often scrutinizes the relationship between technology and society; thusly he often works with a larger community of individuals in his research. Although this principle of the methodology did not fit within the format of my individual thesis project, I did benefit from the discussions and feedback from professors, my Advisory Committee and my peers within the cohort.

Garnet Hertz, an academic who has written much on DIY culture, maker culture and critical making has also discussed other benefits from this approach to making. Although not the origin of the term, Hertz provided a slightly different (and arguably more relatable) definition for the term. He discusses the '"learn-by-doing" (Hertz, 2016) factor that often comes from critical making projects, how this can be a humbling experience and how the learning process of tackling challenges through this lens can be incredibly insightful for your own project or practice: "to step back and reevaluate the assumptions and values being embedded into their technological designs" (Hertz, 2016). The intention of this addition to the methodological approach was to remind me to challenge my own assumptions and values, and by extension the users', and to be conscious of how they are translated into my work. This will also include a continual reflection on Prado and Oliveira's 'guidelines' for creating less-colonial SCD projects.

4.5 A Critical Industrial Design Methodology

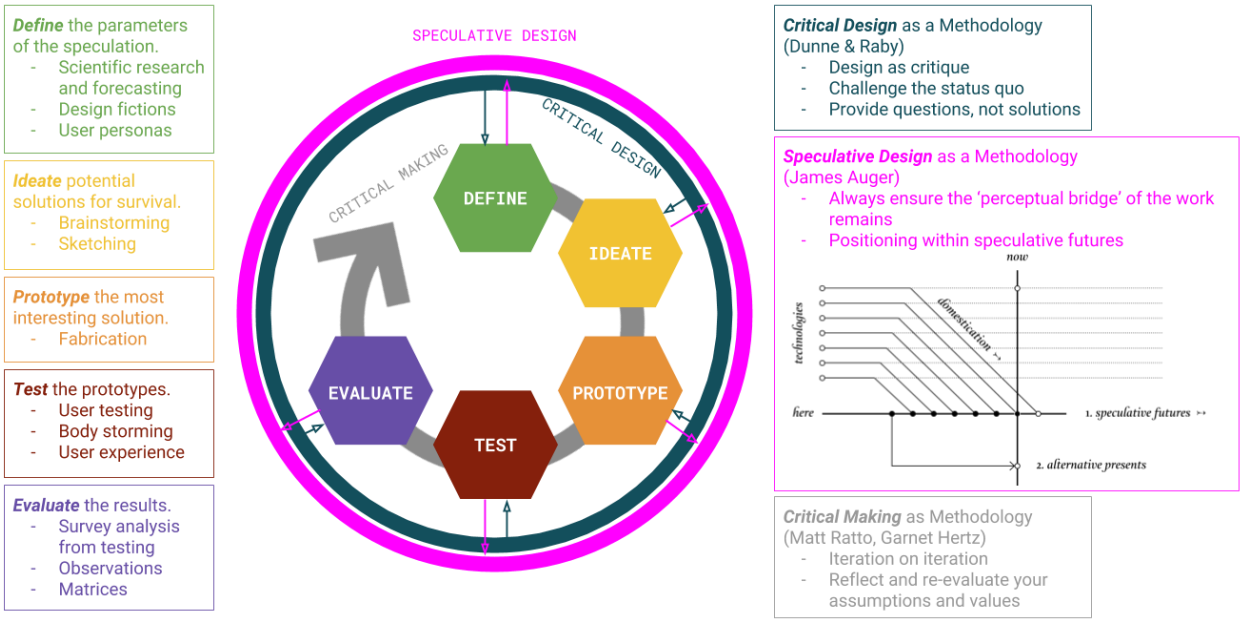


Figure 12. - A Critical Industrial Design Methodology

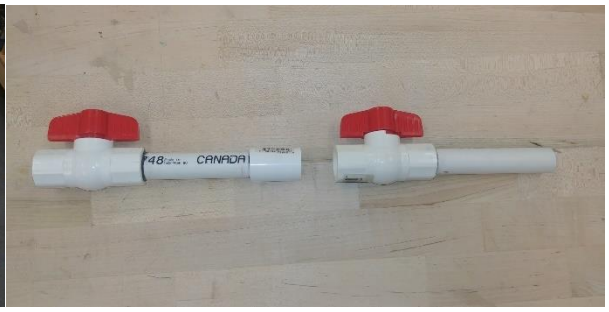
From these methodologies and frameworks, the appropriate components of each were assembled in order to construct this hybrid approach. With the structure of Design Thinking; the positioning of Critical Design; the perceptual bridges from Speculative Design, and the reflection on assumptions and values throughout the making process from Critical Making - each added a different component which aided in the creation of the research.

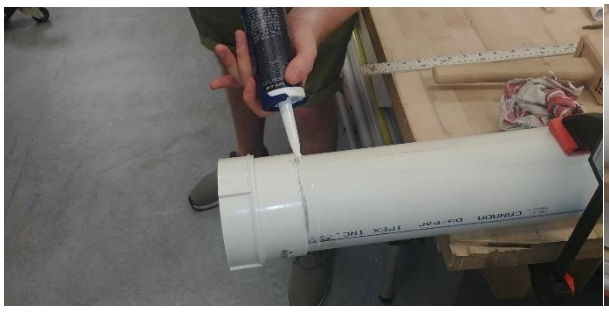
5. Prototypes

Following this methodological approach, the research-creation was developed through a series of experiments and prototypes that examined the effects of pollution, methods for caring for an isolated ecosystem, and the factors of wear-ability. Each prototype resulted in important findings, all of which were formative in the design of the PERA.

5.1 Pollution Pipe

The Pollution Pipe was created to examine the effects of concentrated air-pollution, and act as a potential testing chamber. From this, I was able to test polluted air samples, and compare these to current levels of air pollution around Toronto. The pipe itself was constructed using PVC piping, some plumbing components including ball-valves, and a bonding agent with silicone to create the seals.





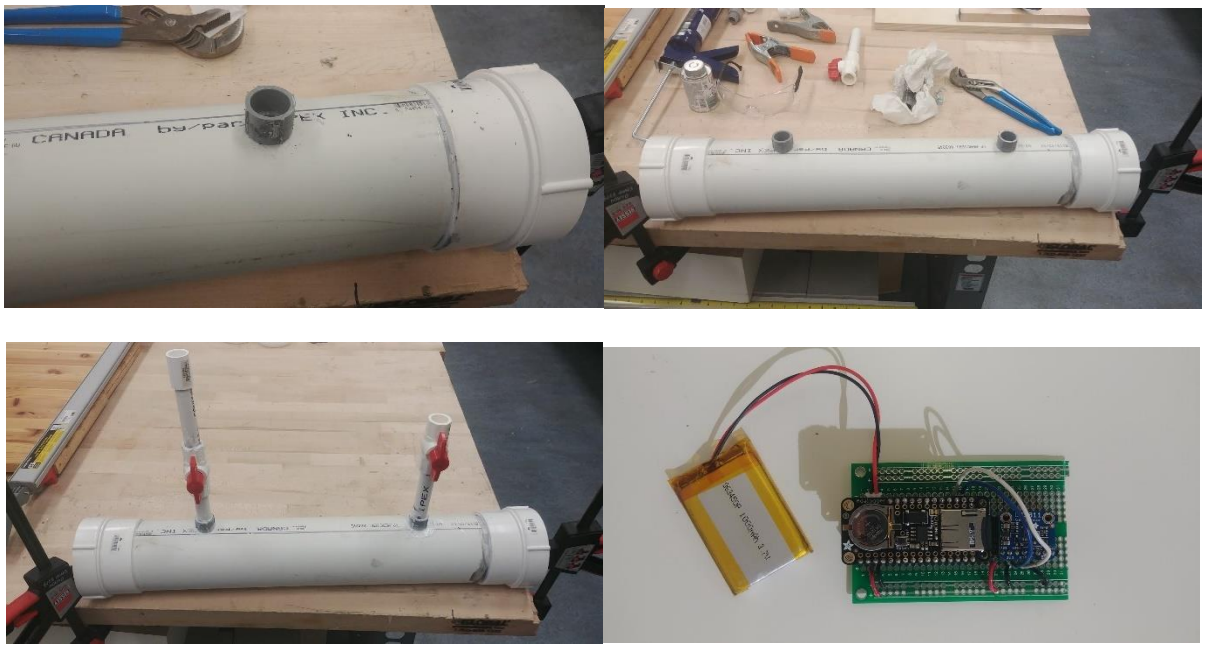


Figure 13. - Construction of the Pollution Pipe and sensor unit.

The sensor unit was comprised of an Adafruit Feather, a CCS811 gas sensor, a datalogger Featherwing and lithium polymer rechargeable battery. After calibration, I began to test the unit to compare different areas of Toronto. The sensor logged the CO2 in ppm (parts per million), and the TVOC (total volatile organic compounds) in ppb (parts per billion).

LOCATION	CO_2 (ppm)	TVOC (ppb)
Studio, 205 Richmond St.	466	10
Street Level, Downtown Toronto	1191	120
Subway	2285	287
Apartment, Midtown Toronto	420	3
Street Level, Midtown Toronto	887	74

Figure 14. - Table of sensor readings around Toronto

The results were not unexpected. The low air quality of the subway system is a known issue, and unsurprising due to its underground nature. One unexpected finding was that the air quality outside of the Downtown-core was rather low, however the location is at a fairly busy intersection and close to an above-ground railroad.

The pipe was tested for being airtight by submerging the container into a bathtub. Once this was ensured, testing with polluted air samples could begin. Vehicle exhaust was chosen for its known contribution to air pollution and ease of access. The vehicle was a Nissan Rogue, with a 2.5L engine with average CO_2 emissions of 205 g/km (Nissan, 2018). To put this into perspective, the provisional data from a report from the European Commission on newly sold passenger vehicle CO_2 emissions had an average of 118.5 g/km (European Commission, 2017). The container was safely filled with polluted exhaust, which was then stored in a well-ventilated area.

The sensor unit was programmed to track temperature and time. As you can see from the data below, the chamber was filled between 16:10 - 16:40. Unfortunately the lithium polymer rechargeable battery pack did not have enough charge to last for more than around 20 hours of continual use. A larger battery would be required for longer tests.

TIME	CO2 (ppm)	TVOC (ppb)	TEMP (degrees)
14:40:58	403	0	25.00
15:10:56	674	41	32.37
15:40:54	951	83	27.16
16:10:53	3813	519	27.16
16:40:54	7992	1156	25.64

Figure 15. - Table of results of exhaust pollution

As well as providing tangible data about Toronto's air quality, this prototype provided useful insights for building air-tight devices and the best methods of joining and sealing components. All of this was extremely useful when it came to designing and building the wearable device.

5.2 Swamp Boxes

The Swamp Boxes were created to understand the care required to sustain living ecosystems. From this I learned a great deal of the maintenance and upkeep required to sustain such ecosystems, as well as best-practices to do so. The ecosystems were constructed of natural

material collected from a public park in Mississauga and stored in plastic storage containers on University campus.

There were many considerations for what kind of technology which might be used in the device. Inspired by the work of John Todd (Todd et al., 2003) and his 'living machines' - manufactured eco-systems that were being used to treat waste and polluted water - the decision was made to focus on biotechnology. Todd designed and created these ecological environments were on a much larger scale than anything could be made wearable, however the idea of using the natural restorative properties of the environment proved to be fundamental to this work. As the restorative properties of the natural environment are a known fact, the choice of using biotechnology would also act as another perceptual bridge within what Auger defines as "Design for context". (Auger, 2013)

After speaking to biology expert Dr. Ian Clarke, I was advised that the best way to build an ecosystem was through collection. By taking samples from the natural environment, the microorganisms that they required to survive would also be collected. This was important, as it would increase the probability the ecosystems surviving. The collection area was chosen in Mississauga as it provided more natural environments to collect from. The specific collection site was close to marshlands, which would also increase the diversity in types of biological material that would be able to be gathered. Significant care was taken to ensure that too much material was not taken, with as little disruption made to the site as possible.

Figure 16. - Documentation of collection process.

Photography by Kristy Boyce.

Included in the samples were water and plant life from stream, rocks with algae, clay and mud from the surrounding areas, grass, and a log with some moss. Due to the seasons (mid-late Fall), there were not many living plants to collect.

Two separate ecosystems were constructed. This would be necessary as cross-pollination would be required to encourage genetic diversity. This occurs naturally in the environment, but something that I as the user and caretaker would now be responsible for. Due to their size, this risk would be increased.

Meet Blue and Grey:

Figure 17. - Documentation of the assembled ecosystems (Blue and Grey).

One of the most critical pieces of advice I received from Ian was inconsistency was key. Ecosystems do not thrive under stable and routine conditions. In nature, nothing is consistent. As the user, I would have to introduce periodic disruptions; change the amount of light they would receive each day, starve them, overfeed them, drown them, as well as introducing new biomaterial to encourage genetic diversity.

I checked on the ecosystems every day when I arrived at the university. I would usually begin by checking for any signs of new life or decay. I would check the water-level, and note how

long it had been since they had last been fed. I would turn on their LED grow-lights and set the timer to turn them off after a set period of time. I would check that I had enough 'Plant Juice' set aside for the coming days - a third storage container which contained a mix of tap water and an organic compost tea. The water would sit for at least 24 hours to ensure that any chlorine or fluoride had dissipated.

It was around this time that the focus of my research changed significantly. My daily ritual of nurturing and caring for these two systems was building a relationship between ecosystems and myself. The bond reminded me of Haraway's theory how the humanity's survival maybe reliant on 'making kin' with different species: "...only with intense commitment and collaborative work and play with other terrans, flourishing for rich multispecies assemblages that include people will be possible" (Haraway, 2016). This speaks a lot to the budding (pun intended) relationship that was growing (also intended) between my ecosystems and I. The symbiotic relationship was mutually beneficial - I kept the alive so they could keep me alive. But it was more than that, I wanted to see them grow and flourish. I wanted them to thrive.

After a few weeks, both systems began to show new signs of life. The leafs were greener, and new buds started to blossom.

Figure 18. - Documentation of the growth of the ecosystems.

Photography by Max Lander.

This prototype was hugely influential on the focus of the symbiotic relationship between the user and their ecosystem. Highlighting the importance of this relationship lead into further developments of the design of the device, and how it would be protected. It also taught me what subsystems would be required to sustain the ecosystems which would have to be integrated into the device. The lessons learnt from my daily maintenance ritual would later help build best practice guides and manuals.

5.3 Concept Generation and Selection

During the initial concept generation phase, I explored both present-day examples of breathing apparatuses as well as more speculative designs. There are many examples of equipment and clothing that protect people in hazardous environments; including firefighting equipment, scuba diving equipment and even spacesuits. Although these all offer protection, the speculative aspect of my research afforded me the opportunity to think about more creative solutions.

One such design was an algae-inspired jumpsuit. Polluted air would be drawn into the wearable algae farm from a small intake at the users lower back. The pipes of the algae farm would be made of a flexible piping which would wrap around the user's limbs and torso. The flexibility in the piping would allow free-movement for the user.

Figure 19. - Algae-farm Jumpsuit Concept

Another concept was inspired by a conversation with an advisor and a study from 2016 which aimed to compare black carbon and particulate matter between readings from ground level and those from a tethered balloon 800 meters above (Bisht et al, 2016). This design would use weather-balloon to float high above the air pollution smog and allow the user to breath the fresher air of higher altitudes. The design included zip-line tethers which would negate the threat of the balloon flying away and allow the user to traverse urban areas.

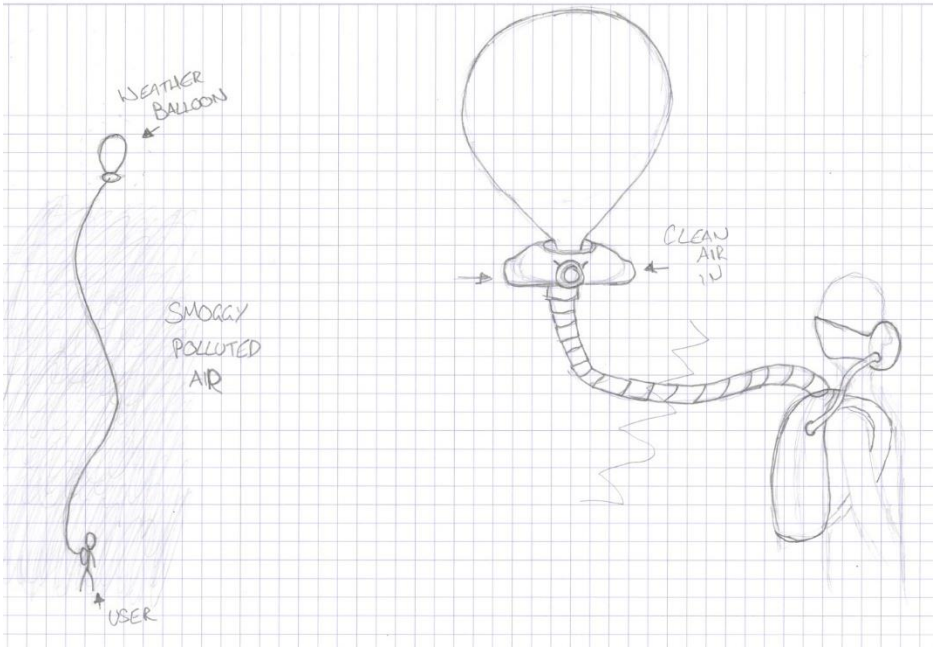


Figure 20. - Weather Balloon Airpipe Concept

Ultimately, I found many of these possible initial designs at odds with Auger's theory of perceptual bridges. This became the guiding factor in my concept evaluation, which eventually lead me to the backpack-ecosystem design.

The chosen design for first of the device would be made up of 3 components:

- A living ecosystem
- A back-mounted housing (read: backpack)
- A respirator-style mask

Figure 21. – Elevation sketches of the chosen concept.

Photography by Kristy Boyce. Sketches by Sean Harkin.

Much of this design revolves around building perceptual bridges of the mundane and the uncanny (Auger, 2013). The mundane comes from the backpack, an everyday object for many. Although facemasks are becoming more common, especially in urban areas, the respirator-style adds an aspect of uncanny to the design. The subversion of the function of the backpack; as a housing for the ecosystem within, which is easily visible to any passers-by, was also intended to add a further degree of uncanny. Each of these components of the device would be designed and built concurrently, and when completed, would be assembled together.

5.4 Respirator Mask

The respirator mask was created as a part of the first version of the device. Drawing inspiration from established forms of masks or rebreathers, I was able to design and produce a mask which fit to my specific requirements. It was produced through an iterative process using CAD modeling and 3D printing.

Keeping within the realms of Auger's ideas around subverting everyday objects, as well as familiar visual languages (Auger, 2013), there were a multitude of masks to draw inspiration from. I began with dust masks and respirator masks as familiar objects. As is the case with most consumer products, my assumption was that they would have been designed for the 95th percentile, and that they would have been specifically designed for wearability (Dunne & Smyth, 2007, Motti & Caine, 2014), meaning they were a good base to start from.

Figure 22. - Testing dust mask and respirators.

As expected, the paper dust mask offered both significantly less comfort and a less of a seal than the industrial respirator. The silicone seal and the strapping system at the back of the

head offered a much more functional solution. From the viewpoint of wearability (Dunne & Smyth, 2007, Motti & Caine, 2014), as well as research which was critical of simple dust masks for protection (Cherrie et al, 2018), the industrial respirator was chosen as the base model for the design.

From here, the design was created through sketching, CAD modeling and prototyping. Through this iterative process, a range of different shapes, sizes and fits were explored. Using 3D printing, a prototype could be printed in around 6 hours. This meant there was a short time between iterations. Since I was designing the device specifically for myself - it allowed for a greater degree of freedom and customization in the design. The first design stuck too rigidly to the specifications of the respirator which acted as inspiration. As a result, the design was altered quite considerably for the second iteration, choosing more organic shapes which would mirror the natural ecosystems.

Figure 23. - First and second iterations of mask design.

For the third iteration, the overall size of mask was reduced. It was slightly less comfortable but far more form-fitting to my face, which would result in a better seal. Functionality was chosen over comfort. Although this was contradictory to the wearability and

length of time for adoption (Dunne & Smyth, 2007, Motti & Caine, 2014), this decision was made in order to create a more believable and realistic device, following the perceptual bridge of verisimilitude (Auger, 2013). Using some elastic bands, I was able to decide on the best position for the mounting slots.

Figure 24. - Third iteration of mask with straps.

Design considerations were still needed for connecting the hose to from the mask to the backpack, but this would be done after the backpack was complete, as specific dimensions were required.

5.5 Backpack

The prototype backpacks were created to explore both the best way to protect the ecosystems housed inside, as well as being a comfortable everyday wearable for the user (Dunne & Smyth, 2007, Motti & Caine, 2014). From this I learnt the best structures to protect the ecosystem, as

well as how to mount the required subsystems. Through multiple iterations, a wide range of materials and fabrication methods were used.

The backpack device itself is arguably the most critical prototype. Not only does it have to properly protect the ecosystem while in transit, but also needed to be comfortable device for everyday use (Dunne & Smyth, 2007, Motti & Caine, 2014). As a speculative artifact, it also offered a great deal of possibilities in creating a number of perceptual bridges through the mundane and the uncanny, as well as perversion of it's understood function.

A key criteria for the backpack required a transparent section; firstly so that the viewer could easily see the ecosystem but also so that the user would be able to monitor their ecosystems during use. The first prototype was a cheap backpack that could be quickly modify and test with. A section of the front panel was removed and replaced with a vacuum-formed plastic window.

Figure 25. - Failed backpack prototype.

This was not a successful prototype. The plan had been to place a plant into the backpack, and test how the vulnerable plant life would survive in a standard backpack. However, when trying to find a plant which would be able to be housed in the backpack, I realized just how difficult this task might be. Not only was the backpack fairly small, it lacked the depth and rigidity to avoid crushing any plant which might be stored within.

Standard backpacks are not designed to carry living things. However, some research lead me to the ideal base model: The Cat Backpack. These were specifically designed to carry around a living creature, ensuring protection and stability. A suitable model was procured to be modified for the second iteration.

Figure 26. - Comparison of failed prototype to base model for design.

This model was far superior. The depth of the backpack would easily be enough to store the ecosystem, and the plastic shell provided both greater protection as well as the desired window to see into the interior. With this being said, the backpack was not ideal for this project's specific requirements and would need to be highly modified. The mid-section of the backpack was made of a mostly-meshed fabric. This would let in far too much air outside, making the ecosystem essentially useless in its function of recycling the polluted air. The fabric section also did not provide enough structural support or protection.

My time with Grey and Blue (the ecosystems) had taught me the subsystems which would be required to sustain a living ecosystem. The design challenge came from incorporating space for these systems into the device.

Light was the most important, and UV through the plastic bubble would not be effective. Building a custom LED grow-light would be the ideal solution, but time and cost were important

factors. For this prototype, Adafruit Neopixels would act as a stand in. Staying true to Auger's idea of verisimilitude (Auger, 2013), the Neopixels would not provide enough power nor the correct wavelengths to be suitable grow-lights, but they would be very passable to the average viewer.

The ecosystems require maintenance, cross pollination and a sealed environment. All of these factors contributed to the design being a bag-within-a-bag. The interior bag would be a partially-sealed environment that would allow the ecosystem to recycle the polluted air. This polluted air would need to be drawn into the bag by small fans - another consideration for the design. I began designing these subsystems and how they might be integrated into the backpack.

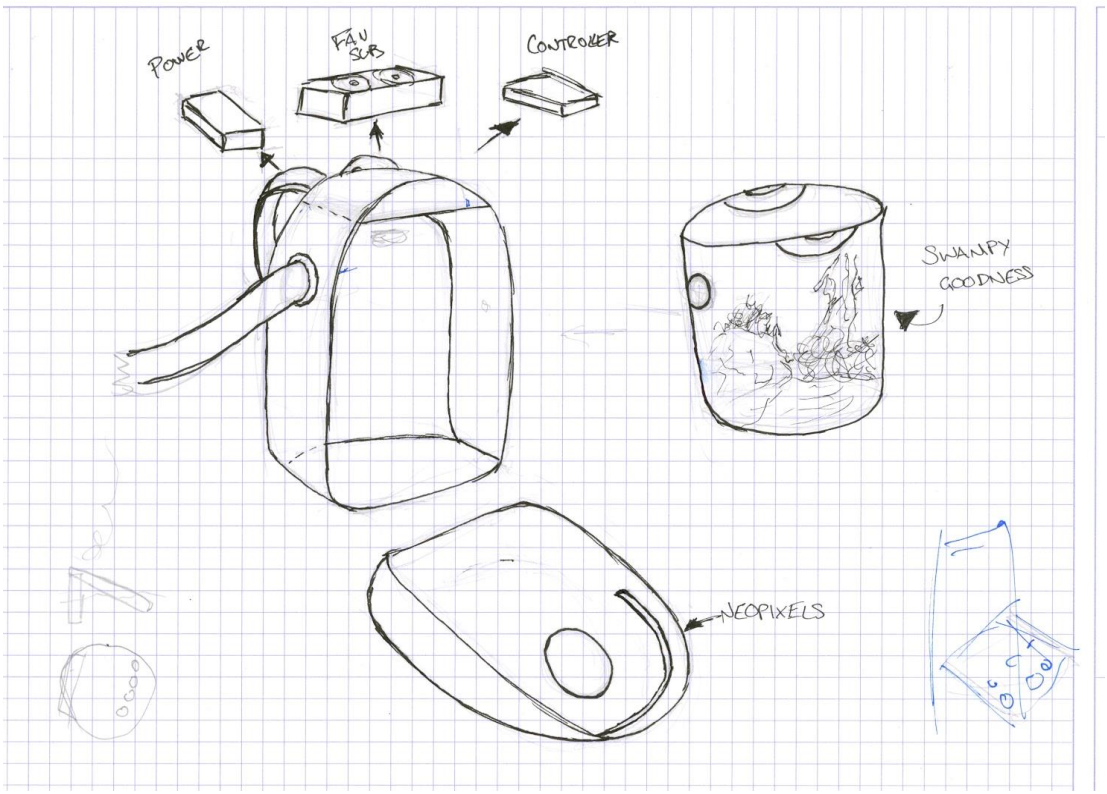


Figure 27. - Exploded sketch of subsystems within the backpack.

The Cat Backpack was dissected and cannibalized for parts. Not only were these salvageable and useful components, but the rear-section had already been designed for ergonomics with padded sections for support. Utilizing the shelled front, the rear section with straps, as well as the zippers would all be useful in later builds. As a result, only the mid-section which would contain the subassemblies and ecosystem would have to be fabricated.

Figure 28. - Salvaged components from base model.

The initial plan was to use textiles to fashion the mid-section. For a multitude of reasons - and for the purposes of full-honesty, one of which was a lack of skills and experience with working with textiles - I quickly moved onto consider more rigid materials which would offer better protection for the ecosystems. This eventually led me to consider 3D printing the mid-section of the backpack. The filament options offered a wide range of versatility in terms of form and function, and it would easily offer the protection the ecosystems required.

The mid-section was sketched and then modeled using CAD. The overall dimensions were dictated by the existing components taken from Cat Backpack, however due to the size restrictions of the 3D printer's plate (Lulzbot TAZ 6), the component would have to be printed in 5 separate sections. These would then be constructed into one solid piece, which would be sewn into the rear-section (the straps) and the front-section (the plastic shell). Small ridges were added to both the front-facing and rear-facing edges, which small holes to allow for saddle stitches.

Figure 29. - Documentation of the design, printing and assembly of the backpack.

Due to a slight overestimated the accuracy of the 3D printer, the slot-joints all had to be filed and sanded down to be able to connect properly. The holed-ridges worked very well for the saddle-stitching, however due to the small clearance between the holes and the edge, a number of these holes broke and could not be used as part of the seam. Once this part was constructed, the first version of the device was constructed.

5.6 The PERA

Figure 30. - Front, sides and rear elevation of documentation of the first assembled device.

Photography by Kristy Boyce.

Above are the pictures of the PERA - Personal Ecosystem Respirator Apparatus. The process of designing and building this first assembled version of the device brought with it an array of insights which would be incredibly useful in future iterations. To begin with the joining mechanisms could be improved. The slot joints worked fine, but due to estimations made around tolerances and print-resolution, modifications were required during the build. A different interlocking joint mechanism could negate some of these issues. Due to some experimentation with the position of the print on the print-bed, some faces of prints had uneven surface finishes. These could be fixed with post-processing methods; however, the next iteration would be planned to limit the need for this.

There were some improvements that could be made to the top section. The slots for the fans were designed specifically to have a solid transition fit, which worked well. However, due to a print-setup error, part of the casing had failed. The next iteration could also make better use of the space below the fans with the addition of a filter for the incoming air, as well as more space to properly store the electronic components required for the subsystems.

There were issues with some of the ready-to-use components which had been purchased for the build, including the plumbing components and hose. A better use of the plumbing fixtures would mean fewer components with simpler joints. I will note that 3D printing threads is problematic, and my ability to convert metric to imperial is still an issue. For the next iteration, more flexible hose would be used to connect the backpack to the respirator mask. The strength was useful for prototyping but caused issues with comfort when moving around. The design of the connection between the hose and the interior bag was less secure than required and would need to be improved upon.

This iteration of the respirator mask was largely similar to the one previous, the only change was an added threaded section which would act as part of the joining mechanism. Comfort was not an issue before, but the addition of the hose caused a shift in weight-balance, and as a result the mask was particularly uncomfortable when moving around. In terms of wearability, this was a serious issue (Dunne & Smyth, 2007, Motti & Caine, 2014). The face is one of the most sensitive parts of the body (Zeagler, 2017), meaning that the comfort of this component must be improved. The addition of a silicone seal might have provided more comfort, however a more radical redesign involving both silicon with extra padding was considered.

Further modification was required to the front-section of the backpack (the plastic shell). Both the bubble and plastic-shell had air-holes which would need to be blocked. Some very simple fixes using clear plastics with the aid of a laser cutter and a vacuum-former. On a more personal note, I was never a fan of the turquoise-blue shell. Future versions would include painting in the aid of creating a more 'professional' looking device, in the hopes of building stronger perceptual bridges of the uncanny and verisimilitude (Auger, 2013).

The interior bag was a modified Ziploc vacuum storage bag. Initially, it seemed to fit the specifications of housing the ecosystem well. However, after modification, it was found that it was far too narrow to properly house an ecosystem. Following iterations would need an improved interior bag, with greater depth and preferably a means of separating the water and rocks from the more delicate soil and plant life - while maintaining a degree of contact between all parts of the system.

Figure 31. - First prototype of interior ecosystem bag.

The solution came in the form of using a more rigid container for the ecosystems. Modified food storage containers provided the support and protection which was necessary. The modifications included attaching 2 pipes which acted as intake and outlet airways, and a simple separator which would separate the water and rocks from the soil and grass. Samples were taken from the Swamp Boxes prototype to construct these versions for the device and then installed.

Figure 32. - Eco-Container modifications and installation.

The device was complete, and a ‘day-in-life’ style testing and documentation session was conducted in order to test the wearability and functionality of the assembled working prototype.

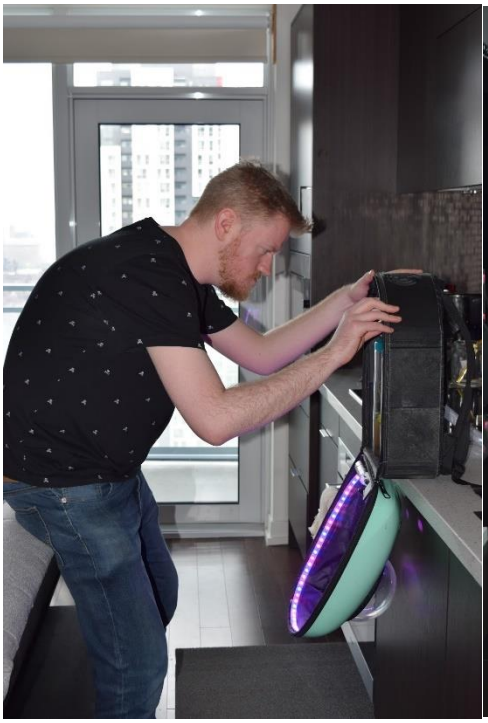



Figure 33. - Day-in-the-Life Documentation.

Photography by Emma Britto & Savaya Shinkaruk.

The day-in-the life testing session lead to some interesting insights when evaluated against Motti & Caine's human-centered design principles for wearables; namely comfort, contextual-awareness, ergonomy and wearability. (Motti & Caine, 2014).

As previously discussed, there were some issues with the comfort of the mask. Much of this had to do with the hard-plastic. This could be improved with a silicone seal, or a padded section around the edge. In terms of the backpack, there were no issues of comfort. Despite the extra weight added from 3D printed hard-shell section, the ecosystems and the required subsystems, the device caused no issues in terms of weight, even after prolonged used (Zeagler, 2017).

The inclusion of the salvaged components from the Cat Backpack helped greatly in regard to the ergonomy. The padded below the straps provided additional comfort, as well as an airflow channel. The zippers provide easy access to the interior of the backpack, and the subsystems had been designed specifically to be removed for cleaning and maintenance, then reassembled and secured.

In regard to contextual-awareness and wearability, the device proved to be fairly robust. A conscious decision was made during the design of the backpack to increase the depth. This was to ensure a decent wall thickness for rigidity and protection, and to ensure sufficient interior space for the ecosystems and their necessary subsystems. Unfortunately, I had not considered the ramifications of this in terms of wearability. The combination of the increase in size as well as the plastic window resulted in some difficulty when navigating narrow areas, such as doorways or elevators. During use, I knocked the device into multiple door frames. Thankfully the protective structure meant no damage to the secured ecosystems or electronics contained with. Due to my daily use of a large-laptop-backpack, it did not take long for me to account for the increase in my body schema (Dunne & Smyth, 2007).

5.6.1 Speculative World Building

At this stage, I had designed and produced two vital components of my device using CAD and rapid prototyping techniques. It also struck me that I was designing the device specifically for myself. Any other user might have different specifications, needs or wants for their device. In order to consider how my device would affect the speculative world I was building, I decided to use two foresights tools: a Futures Wheel (Glenn, 2009) and a VERGE Analysis. (Lum, 2014)

Figure 34. - Futures Wheel.

The Futures Wheel I created was more of a way to visually plot out how my future came to happen, and why certain aspects of my work were either discarded or focused upon further. It also focuses on the environmental effects of the human population affected, as this was more appropriate to the scope of my research.

The addition of the Maker and Grower cultures was a result of the development of the project as the focus shifted from the difficulty of using the device to the protective and nurturing relationship between user and ecosystem. These were important things to consider at every stage of the making, as I knew these types of devices would be expensive to produce and maintain, there would be a resulting growth in modifying and repairing devices to be functional for longer. These ideals were mirrored in materials, components and production methods I had used throughout the research.

I used the VERGE Analysis tool created by Richard Lum and Michele Bowman (Lum, 2014) to analyze the impact that my device would have on the future I'd created. This foresight tool was suggested to me by one of my professors as it focuses on impacts rather than drivers.

Figure 35. - VERGE Analysis

This tool helped me to consider a wide range of ramifications that may result from the introduction of these devices. The community that might emerge from the reliance on the cross-pollination for genetic diversity in users' individual ecosystems was interesting to consider. The ecosystems would require new (yet suitable) microbiomes and organic material in order to survive, and this would be the responsibility of the user to introduce these. This may require actively seeking new people to share components of your ecosystem with. The Destroy section was quite difficult, as it forced me to think of the negative impacts that these devices might create. There would be a definite divide between those who could afford these devices and those who could not. A more optimistic person might hope that these devices would be government

issued or subsidized, however, the realist in me struggles to envision that sort of future. This would result in a largening of the wealth gap, as those who could not afford such devices would likely suffer from worsening health. The links to wealth inequality and poverty are cyclical; worse health leads to more poverty, which in turn leads to worse health (Marmot, 2005). On a more positive note, being faced with the negative implications of my devices was one of the factors which helped with the actual design of the device. Understanding that these would likely be expensive and in daily-use, I was further committed to using as many stock components and 3D printed parts as possible; all of which builds on the increase of the maker/mod cultures.

5.6.2 Best Practice & Maintenance Manual

With the goal of crafting a deeper speculative world, a brochure-style guide was designed which would accompany the PERA. Taking the lessons from the previous prototypes and experiments, the guide outlines some of the best practices for maintaining both the ecosystem and the device itself. Enlarged versions of the manual can be found in Appendix A. The intention is that these tri-fold guides would be printed on recycled paper and would provide vital information to users.

Inconsistency is *Key*

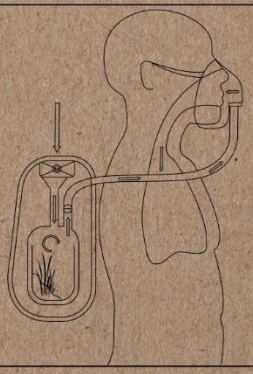
Ecosystems do not thrive in stable environments. They require periodic disruptions, to simulate the forces of nature. Tips include:

- Check your system daily for signs of deterioration, this includes signs of mould or decay.
- Your ecosystem needs between 9-15 hours of LED grow-light per day.
- Ensure that the system is kept fed and watered - unless it is planned starvation or drought.
- Starvation or drought periods should last no longer than 4 days.

In Case Of Emergency

- If your PERA is unoperational for any reason avoid exposure to any ambient air. If this is not possible, relocate to a well-ventilated area as quickly as possible.
- If your PERA runs out of power, contact a friend or family member to retrieve a backup power supply .
- If your PERA is damaged during use, relocate to a well-ventilated area as quickly as possible. If you are unable to repair the device, contact a friend or family member who may have access to a secondary device for you to use.
- If you ecosystem is damaged, take immediate steps to remove and replace any damaged material. If your ecosystem is damaged to the point of no repair, you should collect new material as soon as possible. You may be able to purchase new ecological material from trusted retailers.

*P*ersonal *E*cosystem *R*espirator *A*pparatus



Best Practice & Maintenance Manual

Care And Maintenance

Daily Care

In order to ensure that your ecosystems operate at full-efficiency, it is important that you conduct daily maintenance and checks. You should check daily for any decomposing material, as this could affect the air quality produced by the ecosystem. Scheduling daily checks can also be useful to ensure that you are maintaining all aspects of both your ecosystem and backpack device.

Lights

Light is one of the most vital aspects to the continued health and wellbeing of your ecosystem. You should ensure the ecosystem receives between 9-15 hours of light each day. You should vary the length of time within this range.

Your LED's should be set primarily between the ranges of 460nm (blue) and 640nm (red) for the ideal wavelengths to optimize growth.

Nutrition

You can provide natural nutrition to your ecosystems with the aid of a composting toilet. This is the ideal form of nutrition to promote healthy and sustainable growth.

If for any reason this is not a viable option for you, or if additional sustenance is required, there are a wide range of slow-release, natural based compost solutions available on the market. Please see the rear panel of this leaflet for more information.

Cleaning

Proper and regular cleaning of your PERA will ensure good health for both you and your ecosystem.

Your device should be cleaned at least once a week.

The containers for your ecosystem should be cleaned at least once every 2 months. Only use non-abrasive cleaning products to avoid damage to the device and ecosystem.

Fans

Maintaining your intake fans will ensure the maximum efficiency of your ecosystems recycling capabilities. The fans should be operational at all times during use. Ensure that your fan casing is not blocked, and that your filter is checked daily.

Power

Check your battery before entering ambient air scenarios. Do not-overcharge as this will reduce the lifespan of the battery. It is recommended that you should carry replacement batteries incase of emergency, or if you intend on using your PERA for extended periods of time. ***Note this not advisable.***

*E*xposure to polluted air can increase risks of acute lower respiratory illness, cerebrovascular disease, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer.

Figure 36. - Best Practice and Maintenance Manual for PERA

6. Conclusions & Reflections

When beginning this research, I was inspired by the question: what might humanity build in order to survive hyper-polluted futures? Using Auger's principles of perceptual bridges, the intention was to design and create devices which would engage with viewers perceptions of reality. In order to achieve this, I embedded a multitude of these bridges within my designs, while simultaneously considering the wearability of such devices. The intention remains to encourage the viewer to think critically about their relationship with air pollution and global warming by showing them the types of devices future generations of humanity might need in order to survive hyper-polluted environments.

6.1 Reflections on Methodology

I have some reservations about the hybrid-methodological approach I took to this research. In some regards, it was extremely useful; I found the iterative process incredibly rewarding. Sketching and planning every aspect of the design is necessary, but more lessons were learnt through the process of building the prototypes.

Although not the original coiner of the term, Hertz's definition of the practice of critical making struck a chord with me. I realized it had become such an integral part of my process as I was reading Oliveira & Prado's "Cheat Sheet for a Non (or Less) Colonialist Speculative Design." (Oliveira & Prado, 2014). Their writings opened my eyes to a lot of problems in my work that I had previously not seen - which only lead to further self-reflection of how often I let my own assumptions or values slip into my work. The effect this has had on my own creative practice going forward might be one of the most significant results of this research to me personally.

As mentioned, the methodology was not without flaws. To begin with the structured stages that work well on paper rarely pan out as simply in practice. Using such a rigidly structured approach was a failing on my part to understand how different an industrial design project and a speculative design project really are. My intention was to use my skills from the former to explore the latter, where as in reality a more flexible approach would have been more effective.

Due to the nature of the device, I did not complete a Research Ethics Board application for this research. This did allow me to refocus on how I might specifically tailor a device for myself. As a result, there was a significant gap in terms of user feedback, which can be vital in the development process. However, it did mean that the Test and Evaluate stages were much more informal, and that time between iterations were considerably shorter. Creating a device which was less personalized and more accessible to a wider range of users would have been a very different research journey; and something that might be considered in the future.

6.2 Reflections on Prototypes

Auger's theory on how to build different perceptual bridges was one of the guiding concepts behind this research. These perceptual bridges have been scattered through my work; using familiar objects as bases for development in the forms of respirator masks and backpacks; subverting the understood functions of these familiar objects; framing the technology used as being based in understood science; all of these factors hopefully contribute to a successful speculative artifact.

The Pollution Pipe was extremely useful as a learning exercise in building airtight devices but offered little as a testing environment for future prototypes. This was partially due to

the shift in focus from a device that provides breathable air for the user, to a device that protects and provides for a living ecosystem.

My experience with the Swamp Boxes was formative. I can safely say I've never had a more taxing and simultaneously rewarding relationship with a prototype. Although my research will be judged on the merits of this paper and the thesis exhibition, neither would have been possible without two boxes of marshy swamp. The lessons from that prototype were central to the design of the device as a whole.

The final prototype of the PERA would not have been possible without the lessons learnt from all of the previous work. The inclusion of the design for wearability as both guiding principles in the design process, as well as a criteria for evaluation were helpful in creating a believable wearable device. Having spent time living with the device, I am proud to say that I successfully built an everyday, wearable which (if functional) would provide the user with cleaner air, without having a detrimental effect on the user or their day-to-day life.

The most interesting and insightful outcomes came from my time caring for the ecosystems and building the devices. These were easily the most pivotal to the direction of the research. What began as an exploration into what kinds of strange and bizarre devices humanity might create in order to survive in hyper-polluted futures morphed into a study of the symbiotic relationship between user and ecosystem. The device merely keeps us safe both safe as we go about our daily lives together. The symbiotic nature of the relationship changed my entire life, from my daily routine to how I moved around the world.

6.3 Reflections on Exhibition

The exhibition offered an opportunity to show the completed work to a much broader audience and led to a great deal of insightful feedback and interesting conversations. After some feedback from a professor that the Day-in-the-Life photos could be mistaken for a product pitch, the decision was made to reshoot the photos for the final installation in a more stylized fashion.

Figure 37. - Stylized photo shoot for speculative positioning.

Photography by Max Lander.

Another key aspect of the final installation was the addition of 2 earlier concepts which had been designed, but not built. These designs were CAD modeled and rendered, then mocked-up onto a human figure. It was vitally important to include these as to avoid the audience

assuming that the PERA was being presented as *the* solution to what is a far more complex problem.

Figure 38. - Earlier Concept Mock-Ups

Photography by Kristy Boyce. Modeling and renders by Sean Harkin.

Along with these new photographs and concept renders, the installation included:

- The device itself, shown on a mannequin.
- The current ecosystem ‘swamp-box’.
- The ‘Best Practice & Maintenance Manual’ for the PERA.
- A laser-cut version of the sectional system diagram.

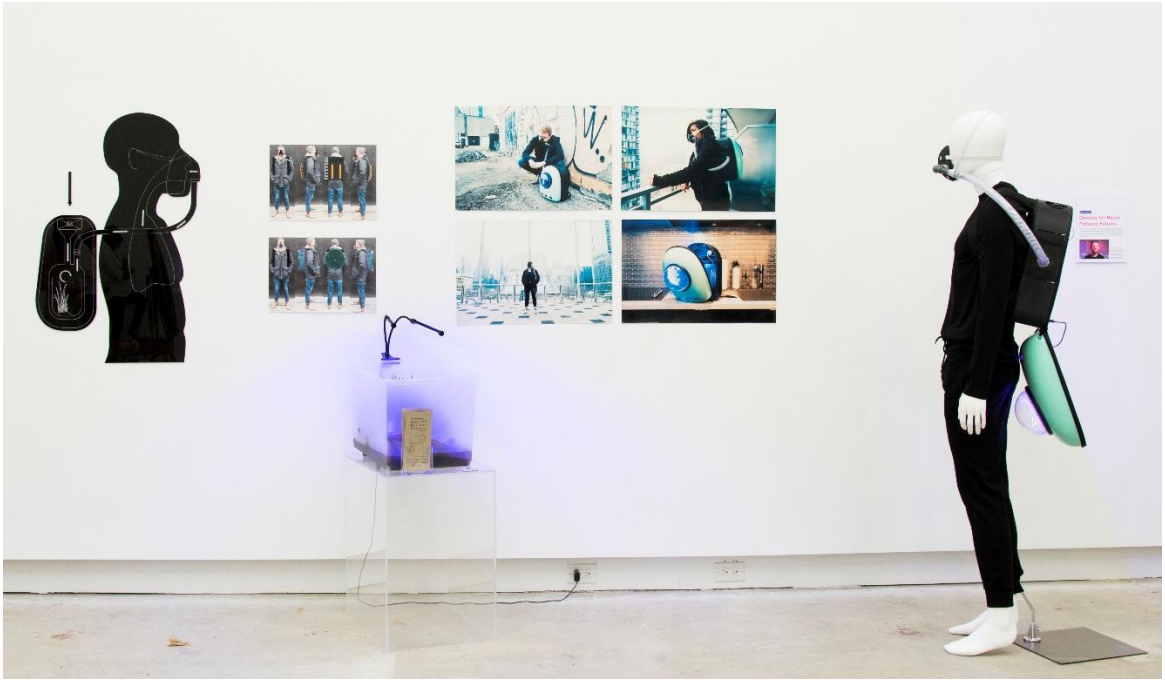


Figure 39. - Documentation from Graduate Exhibition Show.

Photography by Kristy Boyce.

The most interesting aspect of the graduate exhibition was being able to show my work to an audience who had no prior knowledge of the project. These conversations lead to possibilities I had not thought to explore; for example, one individual asked if the user would modify their ecosystem. After explaining that each user would have their own very specific ecosystem that they would nurture and care for, they clarified that what they meant was that would they be able to modify the taste of their air? By adding different aromatic flowers, would they be able to add scent or taste to their air? I had only ever considered modifying your own ecosystem to be more efficient, or to require less maintenance. These types of conversations highlighted the oversights which I missed during my speculative world-building; however, all which could be used in further development of the device.

The feedback I received was very positive. Many viewers immediately understood the device, it's function and the speculative worldbuilding that was being proposed to them. Others

were intrigued by the device and had questions; the most common by far being “Does it actually work?” This spoke to my intention of using verisimilitude as a key perceptual bridge. A couple of viewers even informed me that they understood the meaning behind the work, and immediately began to think critically about their own relationships to air pollution. In these ways, I am able to look at the project as a success.

6.4 Further Research

After feedback from my professors during my critique, I intend to make a short-film. This is common practice with speculative projects but was out with the scope of this particular research. With more free time I will be able to create better documentation for the work.

Though I have previously outlined the merits and lacks of the methodological approach, I would like to revisit A Critical Industrial Design Methodology. Be it further research with this particular speculative scenario or an entirely new one, I believe the lessons learnt from this project could lead to some considerable improvements to the framework.

Given the opportunity, I would also like to revisit some of other devices imagined. As stated earlier, there was simply not enough time nor resources available to properly produce more than one working prototype. Though they would require more development, I feel as though this work would have benefited from being able to show multitudes of the device and may negate the assumption that this research is presenting a solutionist outcome. The CAD mock-ups for the other devices shown in the installation were both backpack-style wearables, though given the opportunity I would like the time to explore different types of wearables.

It is a fundamental belief that I hold that design does not operate optimally in a vacuum. Perhaps this is a hang-up from my time in industrial design, however I know that I work best as part of a team. Working within a team comes with a huge array of issues and difficulties, but I have witnessed the incredible results when a group of creative, skilled and co-operative individuals come together on projects in the past. As such, I would love to have an opportunity to collaborate with like-minded folk on developing not only the device itself but the speculative world building elements that surround the future I have only just begun to conceive. Given more diverse opinions, I may not have overlooked aspects of the project which came from conversations with viewers from the exhibition.

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Appendix A: Enlarged Manual

Inconsistency is ***Key***

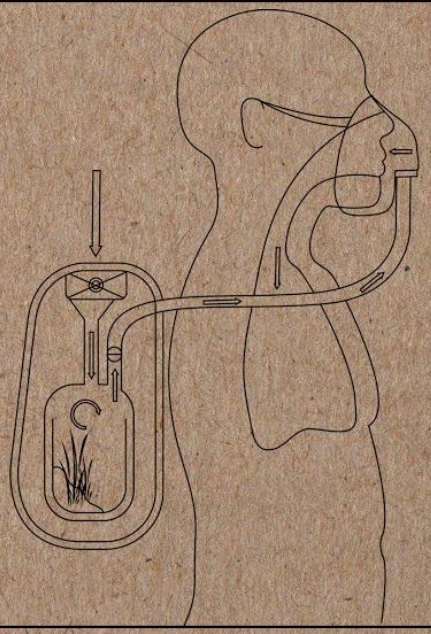
Ecosystems do not thrive in stable environments. They require periodic disruptions, to simulate the forces of nature. Tips include:

- Check your system daily for signs of deterioration, this includes signs of mould or decay.
- Your ecosystem needs between 9-15 hours of LED grow-light per day.
- Ensure that the system is kept fed and watered - unless it is planned starvation or drought.
- Starvation or drought periods should last no longer than 4 days.

In Case Of Emergency

- If your PERA is unoperational for any reason avoid exposure to any ambient air. If this is not possible, relocate to a well-ventilated area as quickly as possible.
- If your PERA runs out of power, contact a friend or family member to retrieve a backup power supply .
- If your PERA is damaged during use, relocate to a well-ventilated area as quickly as possible. If you are unable to repair the device, contact a friend or family member who may have access to a secondary device for you to use.
- If you ecosystem is damaged, take immediate steps to remove and replace any damaged material. If your ecosystem is damaged to the point of no repair, you should collect new material as soon as possible. You may be able to purchase new ecological material from trusted retailers.

Personal ***E***cosystem ***R***espirator ***A***pparatus



Best Practice & Maintenance Manual

Care And Maintenance

Daily Care

In order to ensure that your ecosystems operate at full-efficiency, it is important that you conduct daily maintenance and checks. You should check daily for any decomposing material, as this could affect the air quality produced by the ecosystem. Scheduling daily checks can also be useful to ensure that you are maintaining all aspects of both your ecosystem and backpack device.

Lights

Light is one of the most vital aspects to the continued health and wellbeing of your ecosystem. You should ensure the ecosystem receives between 9-15 hours of light each day. You should vary the length of time within this range.

Your LED's should be set primarily between the ranges of 460nm (blue) and 640nm (red) for the ideal wavelengths to optimize growth.

Nutrition

You can provide natural nutrition to your ecosystems with the aid of a composting toilet. This is the ideal form of nutrition to promote healthy and sustainable growth.

If for any reason this is not a viable option for you, or if additional sustenance is required, there are a wide range of slow-release, natural based compost solutions available on the market. Please see the rear panel of this leaflet for more information.

Cleaning

Proper and regular cleaning of your PERA will ensure good health for both you and your ecosystem.

Your device should be cleaned at least once a week.

The containers for your ecosystem should be cleaned at least once every 2 months. Only use non-abrasive cleaning products to avoid damage to the device and ecosystem.

Fans

Maintaining your intake fans will ensure the maximum efficiency of your ecosystems recycling capabilities. The fans should be operational at all times during use. Ensure that your fan casing is not blocked, and that your filter is checked daily.

Power

Check your battery before entering ambient air scenarios. Do not-overcharge as this will reduce the lifespan of the battery. It is recommended that you should carry replacement batteries incase of emergency, or if you intend on using your PERA for extended periods of time. ***Note this not advisable.***

*E*xposure to polluted air can increase risks of acute lower respiratory illness, cerebrovascular disease, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer.