

**Elemental infrastructures for atmospheric media:
On stratospheric variations, value, and the commons**

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Abstract

This paper draws together ongoing efforts to recast the materiality and meaning of infrastructures with recent critical and creative engagements around questions of the elemental. In doing so, the paper develops the concept of elemental infrastructures in order to grasp how the elemental is not just a material resource acted upon or transformed by infrastructures, but is becoming part of the generative ontology and condition of infrastructural capacities. The argument of the paper is developed via a discussion of recent experiments with contemporary forms of atmospheric media in which different configurations of the elemental, from helium to stratospheric winds, are being worked together in order to shape new infrastructural arrangements. In speculating with these experiments the paper considers what it might mean to develop an expanded sense of infrastructural value from variations in an elemental commons.

Key words: atmosphere, commons, elements, infrastructure, media, stratosphere

Introduction

This paper draws together two research trajectories. The first concerns ongoing efforts to recast the materiality and meaning of infrastructures, particularly those that emphasize how infrastructures are more than technical arrangements and how they modify the affective capacities of different forms and arrangements of life (Larkin, 2013; Stewart, 2014; Starosielski, 2015; Berlant, 2016). The second trajectory revolves around recent critical and creative engagements with questions of the elemental as a differentiated category designating, variously, a chemical entity, an environmental milieu, or a shifting ontological condition (Galloway and Thacker, 2007; Adey, 2015; Squire, 2016; Cohen and Duckert, 2016). By drawing these trajectories together, the aim of the paper is to explore what it might mean to think of the elemental not just as a material resource or ‘substrate’ (Leigh-Star, 1999) acted upon or transformed by infrastructural systems or networks: the elemental, I argue, needs to be understood as infrastructural. In developing this claim, I propose the concept of elemental infrastructure in order to speculate about how specific configurations of the elemental, through ongoing experiments, might be reworking the generative conditions in which infrastructural capacities are valued.

This discussion is developed via an engagement with infrastructures that underpin contemporary forms of “atmospheric media” (Hansen, 2012; 2015). Following a range of scholars (see, for instance, Hermida 2010; Rickert, 2013; Groening, 2014; Morais, 2015; Parikka, 2015; Ash, 2015; Leszczynski, 2015; Adams, 2016; Cardona, 2016) I understand atmospheric media here as media that are now more ambient because their infrastructures and devices have become part of the background of life, operating below thresholds of sensing. At the same time, they have an enhanced capacity to generate affective foregrounds as spacetimes of variable

extensity and intensity (Hansen, 2015). My aim here is not to engage with the affective or experiential qualities of these media, but to explore how their infrastructural arrangements and capacities are becoming atmospheric in an elemental sense. I am interested in how they are being reworked through experiments with the conditions, properties, and capacities of different elemental entities and forces, from helium to stratospheric winds. Paralleling recent accounts of the excessive materiality of atmospheres as both affective and meteorological (McCormack, 2008; Anderson, 2009; Adey, 2013; Ingold, 2015), my speculative proposition here is not a metaphorical one: I am not arguing that the effects of contemporary atmospheric media are analogous to meteorological phenomenon because they are becoming more cloud-like. Instead, and taking my cue from efforts to reveal the infrastructures of ‘cloud geographies’ (Amoore, 2016; Ash, Kitchin, and Leszczynski, 2016) I want to speculate on the possibility that media infrastructures are making new kinds of use of the movement and materiality of the elements in order to generate different kinds of value. These infrastructures are not defined in terms of the distinction between the material and the immaterial, the natural or the constructed. Instead, they can be understood as infrastructures that move with the dynamic conditions and variations of the elemental as assemblages in ongoing composition through different mixtures of hardware and software (Serres, 2012). Because of this, I argue, the elemental, whether in the sense of the physico-chemical or environmental milieu, cannot be grasped primarily either as a medium for the distribution of atmospheric media or as a resource used in the process. Rather, the elemental must be understood as part of the reworking of infrastructural capacities for generating value in an expanded sense of the commons (Berlant, 2016). Precisely how value is generated through these capacities, and how it is distributed, therefore become important questions.

In thinking about these questions, the paper focuses on experiments that bring together different configurations of the elemental, from helium to stratospheric winds, in shaping new infrastructural arrangements for atmospheric media. My approach to these experiments is deliberately speculative. In part, this is a result of the relatively secretive nature of the way in which some of these experiments are conducted. But it is also because a speculative approach can help us think about the conditions under which new kinds of objects or events are taking shape through the ontological experiments of infrastructure (Bruun Jensen and Morita, 2016; See also Roberts, 2014). As I shall show, these experiments simultaneously rehearse aspects of much older experiments while also presaging new possibilities for the elaboration of infrastructural value. The paper is organized as follows. In the first part I review work on infrastructure before bringing this into conversation with recent engagements with the elemental. In the second section I develop this discussion via a consideration of the relation between atmospheric media and the elemental, before turning to a discussion of Google's ongoing experiments in the stratosphere with high altitude platforms (HAPs) for expanding Internet coverage. In the final sections of the paper I consider how these experiments raise questions about the kinds of value generated through infrastructures for an elemental commons.

Infrastructures and the elemental

The question of infrastructure continues to be an important focus of efforts to understand the socio-spatial organization and experience of contemporary forms of life. Work on infrastructures is diverse, but a number of important themes are worth drawing out. First, while interest in spectacular megaprojects remains, there is certainly increased emphasis on examining the mundane infrastructures that sustain everyday life while remaining for the most part unremarkable (Merriman and Jones,

2016; Merriman, 2016). Second, there is attention to how infrastructures are maintained by various practices of monitoring and repair (Graham and Thrift, 2007; Starosielski, 2015). Third, there is continued attention to how infrastructures become part of complex rationalities of government, and in a way that produces and reproduces the distribution of different degrees of exposure to life and death (Amin, 2014; Barnes, 2016; Barry 2014; Cowan, 2014). Fourth, the politics of infrastructure is also increasingly approached in terms of its affective, aesthetic, and poetic dimensions (Harvey and Knox, 2012; Larkin, 2013). Infrastructures, here, are not just technical arrangements, but organized assemblages of material, technology, and practice generative, in turn, of different worlds, or of what Kathleen Stewart (2014) calls ‘registers’ of intimacy and alienation (See also Wilson, 2016). In this view, infrastructures are simultaneously engineered and affective arrangements of technical capacities and aesthetic forms (Larkin, 2013) whose ‘lively’ qualities (Amin, 2014) offer resources for various forms of life. Or, as Lauren Berlant has recently put it in this journal, “infrastructure is not identical to system or structure, as we currently see them, because infrastructure is defined by the movement or patterning of social form. It is the living mediation of what organizes life: the lifeworld of structure” (2016: 395)

Perhaps because of this ongoing work, infrastructure remains “conceptually unruly” (Larkin, 2013: 239). And central to this unruliness is the blurred materiality of infrastructure. Indeed, infrastructure has simultaneously become an important focus for efforts to rethink materiality at the same time as the question of its materiality has become increasingly contested (Latham and McCormack, 2004; Lancione and McFarlane, 2016). This implies more than saying that physical structures, whether roads, rail, or airports, are layered with different kinds of meaning, but extends to

include efforts to understand the materiality of infrastructures as an assemblage of materials, practices, and representations (Merriman and Jones, 2016). It also goes beyond thinking of infrastructures as a “system of substrates” (Leigh-Star, 1999: 380) for the more active forces of societies. And it also involves thinking about how the materiality of infrastructure is becoming more and more digital while remaining dependent upon discreet but highly complex physical sites and connections (Amoore, 2016; Ash, Kitchen, and Leszczynski, 2016; Bergmann, 2016).

Infrastructures are understood increasingly as complex assemblages of forces and devices with capacities to act that are irreducible to human-centred accounts of agency. This claim can be figured through different theoretical approaches (cf, Kaika, 2005; Gandy, 2005; Bennett, 2010; Barry, 2013). However, at stake in all these analyses are a number of inter-related issues. The first is how to account for the participation of non-human forces in the organization, practice, and political life of infrastructures. The second is the question of whether not we can persist in thinking of infrastructures as something ‘built’ (Larkin, 2013). And the third question develops this further: to what extent can we continue to think of infrastructures in terms of how they operate upon, modify, or modulate supposedly natural agencies, processes or materials? How can we think and experiment infrastructurally in ways that do not presume this implicit distinction between infrastructures and the matter upon which they act?

To pose these questions is to think of infrastructures as “ontological experiments” (Bruun Jensen and Morita, 2016). To develop this further here I bring it into conversation with engagements with the broad issue of the elemental. Even if a concern with the elemental can be traced through various traditions of scientific and philosophical thinking, there has been something of a renewal of interest in this

question across various disciplines (see, for instance, important interventions by McCauley, 2010; Adey, 2015; Durham Peters, 2016; Cohen and Duckert, 2016).

While the elemental, no less than the infrastructural, remains an unruly concept, it can be parsed into a number of distinct, but related versions. The first is the most all embracing, and can be grasped through the association between the elemental and the ontological. This is the elemental conceived, for instance, in terms of the four classical elements of earth, wind, air, and fire (Squire, 2016). It is the elemental understood as states of matter from which every other material is derived. More than an imaginative resource, this is the elemental as a speculative proposition about the nature of the world: the elemental as a kind of generative chaos from which things and perception take shape: a condition and horizon of sensible involvement in the world (Deleuze and Guattari, 1987). This is the elemental as the question of where speculative realities begin: with process, with object, with thing, with event, or with movement.

The second sense of the elemental is a refinement, or filtering, of the first sense. This is the elemental as the physico-chemical: as the electromagnetic organization of matter-energy into patterned entities with relatively predictable properties and capacities (Adey, 2015). To foreground this sense of the elemental is not to invoke some kind of naturalism or scientific reductionism. Nor, indeed, is it to think about the periodic table as a kind of map of entities preexisting the organization of this table: this table is a diagram for the production of different elements operationalized through a range of scientific practices, devices, and relations. To attend to the elemental in this sense is therefore to foreground how the properties and capacities of particular objects, bodies, and forms of life are shaped and sustained by bonds, affinities, and reactions.

A third sense of the elemental marks the mingling of the first two: this is the elemental as an environmental milieu within which different forms of life are immersed, enveloped, and take shape (Jackson and Fannin, 2011; Martin, 2011). While it can just as easily refer to water, the marine, and the oceanic, this sense of the elemental is also often understood meteorologically: it refers here to variations in the atmosphere that operate far beyond the immediate orbit of the human, but which can nevertheless be sensed by objects, bodies, and devices of different kinds (Ingold, 2015). My point in identifying these three senses of the elemental is not to say that they exist in isolation. Nor is it to suggest that they be specified in ways that reduce or contain the excessive force of what Peter Adey calls the “force of the elemental” (2015). Indeed, as Adey’s work demonstrates, one of the appeals of the elemental as a category is that it foregrounds the liveliness of materiality while also reminding us that this liveliness comes with a waywardness irreducible to the agency of human life (see also Bennett, 2010). As I show in the remainder of this paper, this waywardness has important implications for understanding the relation between the infrastructural and the elemental.

Atmospheric Media

As Lauren Berlant has written, “an infrastructural analysis helps us see that what we commonly call “structure” is not what we usually call it, an intractable principle of continuity across time and space, but is really a convergence of force and value in patterns of movement that is only solid when seen from a distance” (2016: 94). This sense of things in flux is amplified when the infrastructures in question are not yet fully formed, fleeting, vaporous, as is the case in the example I discuss below. Given this, how then to understand elemental infrastructures? If we take the elemental in the sense of the physico-chemical we might understand these infrastructures as systems of

extraction, storage and distribution through which various elements, from hydrogen to uranium, circulate (Hecht, 2012). Equally, if we take the elemental as an environmental milieu, elemental infrastructures are systems through which this milieu is monitored or modified. There is a long and well-documented history of experiments with infrastructures involving the organized circulation, storage, and distribution of gases as part of the effort to modify and modulate the conditions of different elemental milieus composed of human and non-human bodies (Sloterdijk, 2009; 2011). The ability to modify these milieus through infrastructural technologies is central to the engineering of inhabitable spheres of experience, security, and comfort, and conversely, to their destruction (Gissen, 2013; Adey, 2014).

Here I develop these entanglements further by understanding the elemental as infrastructural rather than something upon which infrastructure acts. To pursue this I focus on the development of contemporary forms of atmospheric media, situating this in relation to ongoing work across the social sciences and humanities about the role of air and atmosphere in the materiality and meaning of different forms of life (McCormack, 2008; Choy, 2011; Adey, 2014; Engelmann, 2015a; Ingold, 2015; Philippopoulos-Mihalopoulos, 2015; 2016). Of course the claim that media are atmospheric is hardly new. Central to the history and development of broadcast media is the elaboration of an atmospherics in which different spheres of imagination and immersion are produced in ways that complicate proximity and distance, presence and absence (Connor, 2008; Adams, 2016). Moreover, acting upon and modulating this atmospherics has been an important process in shaping the affective qualities and conditions of spacetimes of cultural experience across different domains of life (Anderson, 2014; McCormack, 2013; Stephens, 2016). Recent work suggests, however, that media are becoming *more* atmospheric (Rickert, 2013; Sheller, 2015).

They are becoming increasingly ubiquitous as backgrounds that condition how and what shows up in and for experience (Thrift, 2014). These ambient backgrounds take the form of screens that work as surfaces of captivation (Thrift, 2008a) for producing allure. They are also becoming atmospheric insofar as they involve the generation of spacetimes of experience in which what is sensed is ever more vague but no less valuable as part of what James Ash calls “interface envelopes” of variable intensity (see Ash, 2015).

Such developments have precipitated questions about the materiality and ontology of media infrastructure. To be fair, such questions have been abroad for quite some time as part of a more materialist understanding of media infrastructure, influenced by the work of figures such as Friedrich Kittler (1999; see also Packer and Crofts Wiley, 2011; Kahn, 2013). But recent accounts of media infrastructures suggest they have become more fluid and unstable, complicating any straightforward division between ground and air, inside and outside, nature and culture (Näser-Lather and Newbert, 2015; Durham Peters, 2015; Parks and Starosielski, 2015). For Alex Galloway and Eugene Thacker, notably, this means that media need to be understood in a more elemental sense: for them, the elemental aspect of media networks resides in their ‘ambient’ or ‘environmental’ aspect, that is, “all the things that we as individuated human subjects or groups do not directly control or manipulate” (2007: 157). Considered thus, media networks therefore have a spatio-temporality defined by condensation, precipitation, dispersal, and condensation. Moreover, this spatio-temporality needs to be grasped, according to Galloway and Thacker, through a “climatology of thought” which almost imitates the conditions with which it engages. For Galloway and Thacker, then, media are atmospheric insofar as they operate in a way analogous to the elemental: they operate as a diffuse field of relations that can be

configured technically in ways that precipitate localized clouds of affective intensity operating below and above thresholds of human consciousness (see also Groening, 2014).

This claim, while important, needs some qualification. Arguments about the elemental quality of atmospheric media need to remain attentive to the mundane devices and practices that underpin these networks. There is sometimes too much emphasis on what is novel about media in favour of that which is rather less alluring: for instance, as Nicole Starosielski (2015) has documented so well, much of the information that circulates around the globe continues to do so through unglamorous infrastructural networks of pipes and cables rather than in the cloud, and does so through a complex set of negotiations between the properties of specific materials and the movement and effects of the dynamic elemental milieu of the oceans. In that sense, Starosielski's work also reminds us that the elemental infrastructure of atmospheric media is not necessarily meteorological in orientation. But to say this is not to somehow ground or anchor the immaterial tendencies of arguments about elemental media in a more terrestrial or concrete sense of the infrastructural. It means paying attention to how experiments with different devices and materials complicate the clear distinction between the elemental and the infrastructural (see also Packer and Crofts Wiley, 2014; Adey, 2014). It also means thinking about how these experiments are significant because they combine existing and new technologies in arrangements that enhance the technical and affective capacities of infrastructures (see also Durham Peters, 2015)

A second important qualification is this: the claim about the elemental quality of atmospheric media is more than metaphorical. It is not just that the materiality of atmospheric media is now such that its ontology can only be grasped via

meteorological metaphors. It is also that atmospheric media are elemental in a literal sense because they depend upon new configurations of the relation between the physico-chemical and the environmental sense of the elemental. Consider, for instance, how particular elements in the physico-chemical sense facilitate new experiences of atmospheric media. As Jussi Parikka has written, “techniques of experimenting with different reactions and combinations of elements and materials are also media practices” (2015: 25). While there are many ways in which we can trace novel combinations of the chemical through media practices, technologies, and networks, one way is via attention to a single element, helium. As a noble gas, helium has a kind of aloof, non-relational coolness. Unlike hydrogen, or oxygen, helium is utterly recalcitrant: under most conditions it resists forming compound relations. But it is precisely this coolness that makes helium valuable within the elemental infrastructure of contemporary atmospheric media. Formed in the earth through the decay of other elements, helium finds its way to the surface, being trapped by natural gas deposits, from which it is extracted. Some of this finds its way into the storage devices built by companies like HGST for Netflix.¹ Helium, being less dense than air, allows the discs in these devices to spin with less resistance, generating less heat, and making them more efficient. In this way, the elemental properties of helium link the deep cosmological time of radioactive decay in the earth with the changing temporality of atmospheric media.

Stratospheric infrastructures

My claim is that the infrastructure of atmosphere media can be understood as elemental in a way that is not only metaphorical. In the remainder of the paper I want to focus on experiments with elemental infrastructures that to some extent depend upon the elemental in the physico-chemical sense but which more obviously

foreground the elemental as dynamic environmental milieu. In particular, I am interested in elemental infrastructures in which the dynamics of the atmosphere, particularly wind, become crucial to how these infrastructures operate. In order to develop this further I want to think about efforts to use the stratosphere as part of the elaboration of an elemental infrastructure and, more specifically, efforts to do this via experiments with a deceptively simple device: the balloon.

Focusing on the stratosphere reminds us, of course, that the meteorological atmosphere, while turbulent, is also layered. The stratosphere is generally taken to begin at about 12-15km and to extend up to about 30-40 km. Crucially, unlike the troposphere below, the stratosphere is characterized by a gradual increase in temperature with altitude, caused by the absorption by ozone of ultraviolet radiation from the sun. Because of this, the stratosphere is defined largely by patterns of horizontal movement rather than by the vertical movement that characterizes the troposphere. The winds of the stratosphere are therefore relatively predictable over a considerable distance and time.

On one level, the relation between the balloon and the stratosphere can be told in terms of how the former contributed to the rendering explicit of the latter as part of the emergence of the infrastructural globalism of meteorology (Hare, 1962; Edwards, 2006; Null, 2013; Fleming, 2016). The existence of the stratosphere was revealed at the beginning of the 20th Century by the French meteorologist Léon Teisserenc de Bort (Goody, 1958). Using sounding balloons, De Bort identified the existence of an “isothermal layer” above which temperature no longer decreased with altitude. Although the existence of this zone was claimed also by the German meteorologist Richard Assmann (Hare, 1962), de Bort coined the term by which it is now known (Goody, 1958). While it continued to rely upon the balloon, the process of sounding

the stratosphere became progressively more complex throughout the 20th century. Consider, for instance the GHOST (Global Horizontal Sounding Technique) project undertaken during the 1960s. Involving a scientific collaboration between the National Centre for Atmospheric Research (NCAR) in the US and agencies in New Zealand, and led by Vincent Lally, the central aim of the GHOST project was to test the feasibility of balloons to act as “roving weather stations which can collect atmospheric data to be used in global weather forecasting”. This data was to be used to aid the development of “numerical models of the atmospheric general circulation, which will be used to forecast weather by making it ‘happen’ in the electronic circuits of a computer faster than it happens in the real atmosphere” (NCAR, 1968: np). Framed by the geopolitical tensions of the Cold War, the GHOST project was to be a precursor to a distributed assemblage of devices, including up to 10,000 balloons, in addition to satellites, and sea buoys, through which the dynamics of the atmosphere could be sounded on an ongoing, long-term basis.

On one level, such experiments are reminders that “practices of meteorology are mediatic techniques that give a sense of the dynamics of the sky” (2015: 12-13; Thornes, 2008). But they are also reminders that meteorology mobilizes the elemental conditions of the stratosphere itself as an infrastructure of distribution and circulation. This is also central to a more recent and ongoing experiment, upon which I want to focus in the remainder of the paper. In mid-2013 Google Corporation announced it had been undertaking experiments with stratospheric balloons as High Altitude Platforms (HAPs) for increasing Internet coverage in parts of the world where more conventional infrastructures are either underdeveloped or as yet unavailable. In essence, the project involves creating a network of stratospheric balloons equipped to distribute Internet data beamed from ground stations. This can then be picked up by

devices in locations hundreds of miles from the nearest terrestrial infrastructures. Led by the Google X team, Google's secretive research facility based at Mountain View, California, the first large scale pilot test of project Loon took place in New Zealand. Subsequently, in early 2016, Google announced it was developing Loon in other locations, confirming partnerships with the Information and Communication Technology Agency (ICTA) of Sri Lanka, and with telecom companies in Indonesia and Australia.²



Figure 1. A photo from the Google Loon launch event of June 2013. Source: Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Google_Loon_-_Launch_Event.jpg.

Intended for contexts where conventional infrastructures are ‘uneconomical’, Loon is explained as an attempt, in the words of the project’s Technical Lead, Baris Erkman, to “take a terrestrial infrastructure and sort of lift it up to the stratosphere”.³

But even this does not capture the infrastructural entanglements of the experiment. Loon is arguably about more than replicating a terrestrial infrastructure in the stratosphere. It is an experiment with making the stratosphere infrastructural: it seeks to make the trajectories of the stratosphere into streams of movement for the distribution and circulation of devices that extend the connectivity upon which forms of atmospheric media depend. Critical to its ambition is how Loon uses stratospheric wind trajectories to achieve a degree of dirigibility. The project differs significantly in this regard from earlier projects such as GHOST. These experiments involved the release of free balloons into the atmosphere where their direction and speed was determined by the movement of air in the atmosphere. Project Loon also uses stratospheric trajectories, but does so to achieve a degree of dirigibility, both for individual balloons, and the stratospheric platforms they compose.

The technical feasibility of the project is premised on the ability of ground operators to remotely control the altitude of the balloons so that they can take advantage of the direction and speed of winds aloft. To this end, Loon uses balloons that are in fact composed of two envelopes: an outer balloon, which contains helium to generate the lift to take it into the stratosphere, and an inner balloon (or ballonet) which can take in or release air in order to modify the altitude once aloft. The amount of air in the balloon is controlled via a system of valves and fans controlled remotely. With the capacity to remain aloft for up to 187 days, the balloons in the network are subject to a form of partial control performed by operators in Google HQ at Mountain View, California (Popper, 2015). These operators track the balloons, modify their altitude, and also liaise with air traffic control in various jurisdictions. The remotely operated system uses live data sets from the National Oceanic and Atmospheric Administration (NOAA), which are then analyzed by algorithms designed by Google

engineers. These algorithms use predicted wind trajectories up to about 15 days ahead to try to estimate the best altitude at which balloons in the Loon network can pick up these trajectories in order to reach a particular destination. According to some reports, the balloons now have the capacity, not always realized, to circumnavigate the globe and arrive within 500 metres of their target destinations (Popper, 2015).

At the same time, the feasibility of the Loon project depends upon the capacity of the balloon to act as a platform for communication via a distributed mesh network (Butler, 2013). As one project member puts it, each of these platforms is in motion, “free-floating... swaying and bobbing”. As he continues, the relations between balloons in the network can be understood as a “dance if you will between the two balloons where the lasers are trying to keep locked onto one another as they drift in the sky”⁴. This reported level of accuracy allows Google to offer its network of balloons as stratospheric assemblages leasable to telecoms companies. According to Mike Cassidy, project leader, in effect, the Loon network consists of “floating cell towers in the sky” (cited in Popper, 2015).

A number of points about this elemental infrastructure are worth making. First, insofar as we can understand Loon in terms of an experiment with elemental infrastructure, it is one that transforms the capacities of very old technologies by using them in combination with more recent innovations. Balloons are very old technologies, but the algorithms via which their altitude and therefore direction is controlled are much more recent. Second, the Loon experiment is still very much an ongoing process of iterative testing and inventiveness. Certainly, this is part of how the story of Loon is told: in the promotional material made available by Google, Loon takes on the aura of the kind of experimental amateurism that gathers around Google X projects. According to Cliff L. Biffle, flight systems engineer on the project, Loon

began when he walked by a whiteboard which had a balloon drawn on it with “WiFi for the world” written next to it. Taking up the suggestion, which apparently emerged from “a long standing fascination that Google’s founders, Larry Page and Sergey Brin, had with high-altitude balloons” (Popper, 2015), he and others crafted a simple device from equipment sourced off the Internet, undertaking a number of launches that demonstrated the feasibility of radio communication via this platform while also revealing the difficulty of manufacturing balloon envelopes of sufficient durability.⁵

Third, Loon, as an elemental infrastructure, takes shape through ongoing experiments with a range of materials from which to fabricate envelopes. Part of this involves sourcing the correct kind of plastic, in this case polyethylene, from which to construct the film for the envelope, part of a much longer series of experiments with crafting envelopes through different fabrics from silk to latex to Mylar (see McCormack, 2014). Part of it involves developing techniques with which to fabricate the envelopes. Where early versions of the Loon balloon were taped together by hand, and made by people “hired from the fashion industry” (Simonite, 2015: np) more recent versions draw upon manufacturing techniques developed by corporations like Raven Aerostar and modified by Google. The process of fabrication also involves testing this material in the kinds of conditions encountered in the stratosphere, conditions that caused many early Loon balloons to become brittle and shatter. To this end, Loon balloons are tested at the McKinley Climatic Laboratory in Florida. Operating since the late 1940s the lab is essentially an insulated and refrigerated aircraft hanger in which US military equipment is tested in extreme cold conditions (down to -50 degrees C). As Project Loon’s head of manufacturing, Mahesh Krishnaswamy, puts it, “McKinley actually allowed us to bring the stratosphere down to the ground”.⁶ Loon engineers also had opportunity to simulate multiple daily cycles

in which the pressure of the balloon increases with the heat of the sun and decreases during the night. In essence this artificial envelope generates the elemental conditions, in part at least, in which to test the materiality of stratospheric envelopes.

While it remains a pilot project for something potentially more extensive, Project Loon is interesting because it points to the possible emergence of distinctive elemental infrastructures that combine very old devices with new forms of their arrangement and organization. Its premise is the necessity of a network of stratospheric devices that connect terrestrial devices by using variations in the stratosphere as part of an infrastructure of distribution and circulation. As such, it suggests how the experimental reach of media networks may be extending into an increasingly diverse range of technical and environmental domains that recall but go significantly beyond the scope of earlier projects: it is an experiment with the becoming infrastructural of the elemental as both a condition and a set of variations that afford opportunities for developing new envelopes of connection and immersion.

My wager here is that it is precisely this kind of experiment that provides an occasion for speculating upon how the ontological elementality of infrastructures may be changing in the way that thinkers such as Alex Galloway and Eugene Thacker (2007) have outlined. Critically, Loon points to how this transformation is not only metaphorical: it is also quite literal. As a result, rather than being defined in terms of a distinction between the material and the immaterial, elemental infrastructures can be understood along a gradient defined in terms of what Michel Serres (2012) calls, typically enigmatically, the hard and the soft. On one level, the difference between these terms would seem to rehearse a distinction between the material and the immaterial, the concrete and the insubstantial. However, Serres uses them to refer to a continuum of material differentiation, force, and duration that cannot be mapped

straightforwardly onto these distinctions. The distinction between the hard and the soft allows Serres to grasp variations in the material shape and force of circumstances to which bodies and forms of life are exposed, and within which sensory experience precipitates (see also Cresswell and Martin, 2012; Anderson and Wylie, 2009). Elemental infrastructures, seen thus, are infrastructures that incorporate the dynamic conditions of the elemental within assemblages composed of different mixtures of hardware and software. They are infrastructures populated by what Serres has elsewhere called “messenger-angels” with the capacity to move with the “fluxes of nature” (1995: 25).

Grasped in these terms, then, we can think of Project Loon in terms of how a process of material envelopment creates a messenger-angel of sorts: a device, in the shape of the balloon, through which the soft elemental messages of the stratosphere are translated into an infrastructural capacity to distribute other forms of software and code. In the guise of Google Loon, the balloon becomes a messenger-angel at the centre of an elemental infrastructure for translating the trajectories of the wind via algorithms into the circulation and distribution of atmospheric media. As one of the contributing engineers on the project, the wonderfully aptly named Astro Teller, puts it: “We’re using the sunlight, we’re using the wind, we’re using all of these things to build this network in the sky”. As he continues: “We can sail with the wind, and shape the waves and patterns of these balloons, so that when one balloon leaves, another balloon is set to take its place”.⁷

The politics of stratospheric infrastructures

Teller’s depiction of Loon is, of course, rather fanciful. Moreover, in thinking of Loon in these terms, and in foregrounding the elemental, my aim is not to sidestep critical-political issues: it is, rather, to consider the possibility that the conditions in which

these kinds of questions are posed, and the kinds of entities to which they are addressed, may be changing in important ways.

Certainly, Loon might prompt us to think about how the incremental elaboration of elemental infrastructures for atmospheric media is underpinned by the dream of being everywhere, always on, always connected. This is the promise, to use Franco 'Bifo' Berardi's phrase, of a condition in which, "we can reach every point in the world but, more importantly, we can be reached from any point in the world" as part of a process of endless solicitations to respond and participate in the circulation of waves of affective value (2009: 108). While such dreams are of course not new, what is distinctive about the version of this dream in which Loon is entangled is that it is premised upon the blurring of distinctions between atmospheres in an informational, affective and meteorological sense; being and becoming atmospheric is taken to be a necessary condition of any relation with the world, with each other, and with whatever else is assumed to be present; a dream in which potentially everything can be sensed and connected, even if much of the infrastructure for this capacity operates below or indeed above thresholds of human consciousness. There are some obvious questions that can be posed in response to this promise. What, for instance, of the prospect that a corporation like Google could become the dominant operator of a modified and extended form of atmospheric 'envelope power' that stretches from screen to stratosphere, and whose medium is sky as much as silicon (Ash 2015)?



Figure 2 Skies painted with Unnumbered Sparks. Vancouver, 2014. Source, Wikimedia Commons.
https://commons.wikimedia.org/wiki/File:Skies_Painted_with_Unnumbered_Sparks.jpg.

Other works, while not quite the same as Loon, hint at how the experimental fringe of a corporation like Google is generating the kinds of associations and collaborations through which these envelopes can be stretched. Consider, for example, *Skies Painted with Unnumbered Sparks*, a 2014 work by artist Janet Echelman, developed in collaboration with Aaron Koblin, Creative Director of the Data Arts Team in Google Creative Lab. 700 feet long, the work consisted of a braided synthetic fibre knotted together between two major buildings in Vancouver, and installed to coincide with the 2014 TED conference. The shape and form of the work unfolded in response both to the gestures of those who connected wirelessly with it via mobile devices and to the wind. The work became a moving meshwork of synthetic fibre, onto which was projected a “web browser. The lighting on the sculpture [was] actually a single fullscreen Google Chrome window over 10 million pixels in size”.⁸

And yet, even as we might read this kind of experiment alongside Loon as the early elaboration of a new form of envelope-power, a little tempering of this reading is necessary. This is not least because it may be no bad thing to try to increase Internet coverage through experiments that make the trajectories of the stratosphere infrastructural, especially because this coverage is in places patchy and at worst unavailable. From the point of view of parts of the world where access to such wireless internet coverage is a given, and where this coverage is almost exclusively provided by for-profit operators, it is problematic to say the least to critique the extension of this coverage by such providers to parts of the world where it is patchier. A second reason for tempering a critique of project Loon is that this experiment could fail: it might be that providing high altitude platforms for internet coverage through networks of balloons turns out to be little more than a minor footnote in the history of infrastructural experiments with the elements. This is not to ignore, of course, how the failure of experiments is easily presented as a virtue in Google.⁹

Other critical responses to Loon are also possible, of course. It is easy to see Loon as a fringe project aligned to the elaboration of a version of the Apollonian gaze through which regimes of security are underpinned, regimes which have been subject to extensive critique (Kaplan, 2006; Gregory, 2011). This reading is amplified if we consider the operation of Project Loon alongside the acquisition by Google of Titan Aerospace, a high-altitude drone manufacturer (Newman, 2014). At the same time, Loon can be framed in terms of the elaboration of new volumetric spacetimes, and of the political questions of atmospheric governance and ownership these volumes pose (Banner, 2008; Elden, 2013). Such questions include the way in which high-altitude platforms complicate the relation between territorial jurisdiction, regulation, and the movement of volumes of air that are not easily partitioned (Philippopoulos-

Mihalopoulos, 2016). Certainly, these experiments with elemental infrastructures have to contend with the uncertain legal status of the volumetric entanglements of stratosphere, HAPs, ground based infrastructures, and territorially organized jurisdictions. It is no coincidence, then, that the location chosen for some of the initial trials of the Loon balloons was Christchurch, New Zealand. This is the same site from where, during the 1960s, the GHOST balloons launched by NCAR were also launched. One of the most important advantages of this site is that it avoids some of the potential complications that might arise if a balloon overflies a country such as China and Russia. More generally, it also makes air traffic control issues a lot more straightforward, with fewer jurisdictions to negotiate and liaise with as the balloon moves around the earth in the stratosphere. Equally, the issue of the dirigibility of the Loon balloons renders their legal status more uncertain, both under Federal Aviation Authority (FAA) and International Civil Aviation Organization (ICAO) guidelines. If they are free balloons, one set of restrictions apply, while if they are categorised as unmanned aircraft, drones, unmanned aerial vehicles (UAVs), or unmanned aircraft systems (UAS), another set may apply (see Butler, 2013; John, 2015).

But speculating about such experiments may also be politically important for other reasons. This concerns the generation of infrastructural value from elemental variations. The generation of value in this way is not necessarily new, of course. Developments in commercial sailing can be understood in terms of the emergence of new technologies and techniques for generating infrastructural value from variations in the elements (Durham Peters 2015). This relied in turn, on a whole set of embodied skills and tacit knowledges about weather and sea. However, while earlier sailors were skilled at reading the weather and waves, they did not have real time, medium term weather prediction. Equally, in many parts of the world sailing is no longer a

commercial form of transport. Nor is ballooning. Indeed, notwithstanding early claims in the late 18th century about the revolutionary potential of the balloon, the failure of ballooning as a commercial mode of mobility and transport can be understood in terms of the failure of the capacity to generate infrastructural value from this device. One of the most significant aspects of Loon, therefore, is the way in which it demonstrates how new algorithmic technologies of sensing are increasing the capacities of these older devices to generate infrastructural value from elemental variations. Here, the wind is not something that throws things off course or slows them down: it becomes a stratospheric trajectory that can be used to allow a device or assemblage of devices to move in a particular direction. In other words, infrastructural value is generated because, not despite, variations in elemental conditions. Project Loon aims to transform the very condition of stratospheric variation into a source of value, as part of a wider process of capitalistic value generation through mobilizing the dynamics of elemental powers latent in the environment.

In addition to the question of regulation outlined above, this question of value is a matter of political concern for at least two reasons. The first reason concerns the kinds of infrastructural value that might be generated through these kinds of experiments. As Felix Guattari writes, it remains critical, as part of an expanded ecological politics, to open up new “universes” of value and, indeed, to “reappropriate” existing universes through experiments that resingularize their different elements (Guattari, 1995). An experiment like Loon has the potential to do this, but it re-territorialises this universe around capitalist value-generation. A second reason that a project like Loon becomes a matter of political concern revolves around the question of the technical capacity to generate and experiment with this wider sense of infrastructural value. So while Loon may well be opening up new

configurations of elemental infrastructures in the stratosphere, it may also be restricting the capacity to use and hack these infrastructures. A sign of this is the number of patents that have been filed by Google in relation to Project Loon, the effect of which is to reduce the accessibility and availability of technologies for open-source experiments in being and becoming elemental (Shapiro, 2015).

Because it remains relatively proprietary, it may not be in projects such as Loon that sources for crafting new forms of elemental infrastructural value will be found. Instead, such opportunities are more likely to be found in forms of experiment that mix the aesthetic, the technical, and the political in more open-source, and less proprietary, ways. Admittedly, the shape of these works might share something with Loon: they might consist of assemblages of elemental infrastructures in compositional formation, taking shape by moving along lines of drift and dispersal while also drawing new forms of collective equipment into speculative operation. Indeed, as Etienne Turpin, in the context of a discussion of the work of Berlin-based artist Tomás Saraceno, has argued, artistic experiments have the potential to play a particularly important role in instigating “renewed attention to infrastructures as the basis for the emergence and articulation of politics” (2015: 177). For Turpin, insofar as the atmosphere is concerned, the kinds of politics and, we might add, the kinds of political spacetimes that can emerge through aesthetic experiments are not necessarily delimited by the volumetric dimensions of territorial jurisdiction. These experiments with elemental infrastructures, exemplified, for instance, in Saraceno’s open source collaborative ‘Aerocene’ project, have the potential to pilot experiments that unground the very space of the political in novel ways by redistributing capacities toprehend, feel, and sense the force of the elemental (Saraceno, Engelmann and Szerszynski, 2015; Engelmann, 2015b; McCormack, 2015). The form these

experiments take will not necessarily be premised on increasing connectivity, even if they use a range of technologies of communication: instead, they will take shape as minor infrastructural experiments for making explicit the elemental force of “air’s poetics” (Choy, 2012; Engelmann, 2015a) through a range of ‘minor gestures’ (Manning, 2016) that mix technical capacities, aesthetic values, and political concerns in novel ways.

Conclusion: Variations for an elemental commons

My aim in foregrounding Project Loon in this paper has been deliberately speculative: I have used it in order to speculate about the possible emergence of distinctive forms of elemental infrastructure. To repeat, I am not saying that elemental infrastructures are new: rather, my claim is about the emergence of novel configurations of elemental agencies, devices, and arrangements that generate new possibilities for working on the infrastructural and atmospheric background of everyday life.

Loon exemplifies this elemental infrastructuralism in at least each of the three senses outlined at the beginning of this paper. It is elemental, most obviously perhaps, because it takes advantage of the movements and trajectories of the stratosphere. It is also elemental because it uses the gaseous form of specific elements to generate lift: while its envelopes have thus far been filled with helium, concerns about shortages have led to the possibility that hydrogen, which is also considerably cheaper, might be used by Loon. Loon is also elemental because it involves the organization of infrastructural arrangements with variable extent and intensity in ways that generate ontological questions about the kinds of things or processes we mean when we speak or write or think about infrastructure. Certainly, in order to understand Project Loon it is not enough to continue to think of the infrastructures of atmospheric media in terms of an implicit distinction between natural phenomena, technical entities, and code.

Rather, Loon marks the emergence of elemental infrastructural assemblages defined not in terms of the distinction between the material and the immaterial, but in terms, following Serres, of variations along a material continuum of hardware and software. Seen thus, Project Loon marks the ongoing iterative emergence of a distinctive kind of elemental infrastructure: this infrastructure emerges and takes shape through the co-fabrication and co-organization of infrastructural assemblages composed of devices, code, and wind.

My discussion of Loon also remains speculative in that sense that it remains a pilot project. But this should not diminish the value of engaging with it. Piloting, after all, is an ongoing process of tentative experimentation that draws together different associations of bodies, elements, and energies. Experiments like Loon perform a “piloting role” in that they “construct [...] a real that is yet to come, a new type of reality” (Deleuze and Guattari 1987: 142). More accurately, Project Loon can be seen as part of a series of pilot experiments with the emerging and increasingly complex “environmental fringe” of media, which, in the words of Mark Hansen, constitutes a “crucial element in the rhythmic compositional dance that is our multi-scaled, disparate agency in the world” (2015: 183). Critically, this environmental fringe is not just elemental in a metaphorical sense: it is also becoming literally elemental in that it consists of moving associations that gather and disperse according to the prevailing atmospheric conditions in the stratosphere, on the ground, and according to the envelopes of control enabled by informational software.

Finally, perhaps, these kinds of pilot experiments should move us to think about how a new kind of elemental commons is being reconfigured through infrastructural experiments. This commons overlaps in some ways with ideas, albeit different, of an atmospheric and perhaps ambient commons (McCullough, 2013). But

this version of the commons is no space of shared togetherness, no romantic aerial pastoral (see Amin and Howell, 2016; Weideman, 2014). In a recent paper, Lauren Berlant (2016) has argued for the importance of understanding the infrastructures that might sustain different forms of the commons in a time of precarity. For Berlant, infrastructure is “that which binds us to the world in movement and keeps the world practically bound to itself” (394). As she continues, “one task for makers of critical social form is to offer not just judgment about positions and practices in the world, but terms of transition that alter the harder and softer, tighter and looser infrastructures of sociality itself” (394). Infrastructural experiments, in these terms, might provide opportunities for resingularizing the elemental commons: that is, for reworking its capacities to generate new sources of value. Berlant’s project is a different one to mine, but here it reminds us that to think in response to Project Loon is to see it as an opportune occasion for wondering what it might involve to devise infrastructures for moving with the condition and “force of the elemental” (Adey, 2015), not so much to construct a space of assumed value through connectivity, but to generate counter trajectories and eddies that, through drift, may produce unanticipated sources of value or new “movements in perception” (Simone, 2015: 151). To think in response to Loon is to wonder what it might mean to invent forms of assembly and association facilitated by elemental infrastructures that may well have the capacity to circumnavigate the globe but whose logics of connectivity, attachment, or association are not routed inevitably through the global dreams of corporations such as Google or Facebook. As these and other corporations become increasingly invested in exploring the possibilities of high-altitude, stratospheric infrastructures, the importance of the stratosphere as an elemental commons linking the affective infrastructures of more terrestrial concerns will become increasingly important. In this case, the politics of

atmospheric media will take shape around the distribution of diverse capacities to affect and be affected by minor variations in an elemental commons. In that sense, the value of thinking speculatively with a pilot project like Loon is that it points to the importance of enacting, imagining, and speculating with infrastructures that redistribute a concern for the value of elemental variations in a commons in movement.

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Notes

¹ See <http://www.hgst.com/company/media-room/press-releases/HGST-Helium-Filled-HDDs-Rise-to-New-Levels-Achieve-Industry-Leading-Milestone-in-Field-Reliability>. Last accessed 9 September 2016.

² See, Project Loon: Google balloon that beams down internet reaches Sri Lanka, *The Guardian*, Tuesday 16th February 2016. Available at <http://www.theguardian.com/technology/2016/feb/16/project-loon-google-balloon-that-beams-down-internet-reaches-sri-lanka>. Last accessed March 9 2016; Google installing hundreds of Internet enabled balloons in Indonesia, *The Guardian*, Wednesday 28th October 2015, available at <http://www.theguardian.com/technology/2015/oct/28/google-installing-20000-internet-enabled-balloons-in-indonesia>. Last accessed 8 March 2016.

³ “Delivering connectivity”. <https://www.youtube.com/watch?v=BEC0G2HbuiE>. Last accessed 9 September 2016.

⁴ “Delivering connectivity”. <https://www.youtube.com/watch?v=BEC0G2HbuiE>. Last accessed 9 September 2016.

⁵ “Ask Away: how did Project Loon begin?”. https://www.youtube.com/watch?v=5mD6m3V02n8&list=PLi7C1_I60LN7Z_CEMhl2wOpKVlwzlwmrs. Last accessed 9 September 2016.

⁶ “Manufacturing for the stratosphere”, <https://www.youtube.com/watch?v=YVhS1axhzRs&feature=youtu.be>. Last accessed 9 September 2016.

⁷ “The unexpected benefit of celebrating failure”. Available at <http://www.google.com/loon/>. Last accessed 12 November 2015.

⁸ See <http://www.unnumberedsparks.com>. Last accessed 9 September 2016.

⁹ See Astro Teller: The unexpected benefit of celebrating failure, available at http://www.ted.com/talks/astro_teller_the_unexpected_benefit_of_celebrating_failure#/t-14599. Last accessed 9 September 2016.

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