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Staging the Techno-logical Sublime: A Computational Aesthetics of the Roller Coaster

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Beyond simple gravity-driven machines, contemporary roller coasters are better understood as precisely choreographed computational systems. This is exemplified in Universal Islands of Adventure's Hagrid's Magical Creatures Motorbike Adventure (HMA), one of the most complex and expensive roller coasters ever built. Through a technical analysis of the computational systems used in HMA's operation, I demonstrate how the aesthetic experience of the ride is inseparable from the logico-quantitative operations of computation. As a form of mechanically-augmented computation, the roller coaster transduces between the discrete, symbolic realm of the digital and continuous, nonsymbolic realm of the analog, thus allowing computational operations to be felt as embodied intensities. These intensities produce an aesthetic experience of disorientation. Throughout the essay, I demonstrate that this sense of disorientation is only made possible through technical operations of orientation. Furthermore, I claim that the experience of disorientation ultimately serves to reorient riders within their contemporary technological milieu, by converting the alienating effects of technological acceleration into an embodied sensation of acceleration as (fearful) pleasure. This contradictory emotional and affective register bears resemblance to 18th century romantic conceptions of the sublime. In this paper, I revisit and critique Immanuel Kant's notions of the dynamical and mathematical sublime in light of the computational roller coaster. Departing the moralistic anthropocentrism of the Kantian sublime, I propose a post-human conception of the techno-logical sublime suggestive of a more synergistic future human-machine relation.

Introduction

ORLANDO, Florida — A machine the size of a football field continuously rearranges itself, rhythmically oscillating between different spatial configurations. Magnetic fields, invisible to the naked eye, propel smaller machines through the twisted steel apparatus. Human laborers move in concert with the machine, ensuring its smooth operation and maximizing its throughput. Occasionally, screams are heard from within the structure, indicating that it is working exactly as expected. Every day from morning until evening, 365 days a year, this patchwork of overlapping energetic, informational, and material systems work together as a nearly fully-autonomous machine for the production of intensities.

The machine in question might resemble a factory assembly line, but does not produce any material products. Rather, it aims at nothing other than the production of aesthetic experience. It is Hagrid's Magical Creatures Motorbike Adventure (HMA), a multi-launch steel roller coaster designed by Intamin Amusement Rides. The ride opened in June 2019 as the centerpiece attraction of the "Wizarding World of Harry Potter" located at Universal Islands of Adventure at Universal Orlando. The ride's $300 million[1] price tag—the most expensive roller coaster ever built at the time of construction[2]—reflects its complex nature, bearing more resemblance to a fully automated logistics center than to the 15th century Russian ice slides from which today's roller coasters trace their lineage.[3,4] Hagrid's Motorbike Adventure contains thousands of sensors and actuators, coordinated by a central logic system that dynamically controls the ride's operation in real-time. Along with many other recent roller coasters, it is better understood as a computational system than a simple gravity-driven machine.

In this paper, I will explore the ways in which the mechanico-computational nature of HMA produces a distinct *aesthetic experience*. While the roller coaster may seem like an unexpected basis for an investigation of both computation and aesthetics, it is not without precedent. In the 1980s, Jean Beaudrillard and Umberto Eco each leveraged the roller coaster in their respective works on Disneyland and hyperreality, in order to probe the increasingly blurred boundaries between reality and fantasy under postmodernism.[5,6] The present work takes another direction, focusing instead on the underlying technical systems that

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1 Joyce, "Universal Orlando's Much Anticipated $300M 'Harry Potter' Roller Coaster Is Now Open."

2 This record has since been broken by the $500 Million "Guardians of the Galaxy: Cosmic Rewind" coaster at Disney's Epcot theme park.

3 These were wooden structures with an ice-slicked ramp. The name for roller coaster used in Romance languages today, *Russian mountains,* reflects this origin.

4 Cartmell, *The Incredible Scream Machine: A History of the Roller Coaster*, 19.

5 Eco, *Travels in Hyper Reality*.

6 Baudrillard, *Simulacra and Simulation*.

produce the roller coaster experience. This approach echoes Alexander Galloway's writing on video games, which sought to reorient analysis away from the narrative form of media objects, towards the underlying computational processes that enable them.[7]

Keeping with the theme of the issue, aesthetics here does not refer merely to the visual appearance of the roller coaster, but something closer to the ancient Greek *aesthesis*: "perception from the senses" as experienced by the roller coaster rider.[8] The roller coaster is a prime object for such an aesthetic investigation, as it aims at nothing other than the production of aesthetic experience (in the service of capital, that is). While more familiar forms of media, such as film and text, are thick with semantic content, the roller coaster is void of meaning: an asignifying machine for the production of intensities. This presents the opportunity to move beyond the primacy of the visual that still dominates many theories of both media and aesthetics. Following thinkers such as Jacob Gaboury, who has argued that "the computer is not a visual medium," I hope similarly to decenter the visual in my analysis of computation as well.[9] Moving beyond surface effects, this account probes deeper into the body, engaging the kinaesthetic and proprioceptive faculties often overlooked in theories of both aesthetics and computation. In short, the mechanico-computational nature of the roller coaster allows us to ask not what computation looks like, but what it *feels like*. This emphasis on the embodied experience of computation follows Mark Hansen's argument that digital media are best understood as interactive processes that only gain traction as they are filtered through human bodies.[10] Similarly, Shane Denson's work on the post-perceptual nature of computational objects is relevant here, as the minute time scales of the computational roller coaster evade direct perception yet still shape the ride's aesthetic experience.[11]

The aesthetic investigation outlined here builds on a long lineage of aesthetic philosophical thought, particularly the notion of the sublime as developed by Immanuel Kant in his *Critique of Judgment* (1790). Kant's formulation of the dynamical sublime speaks to the curious sensations of fear and pleasure induced by an encounter with the raw power of nature. Here, I argue that such fearful pleasure is also produced through an encounter with the roller coaster. In the decades since its original publication, many thinkers have problematized Kant's conception of the sublime and aesthetics more generally. Thinkers such as Gilles Deleuze, Beatrice Fazi, Jennifer Gabrys, and Sianne Ngai have all attempted to rethink the aesthetic in light of the unique problems posed by today's

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[7] Galloway, *Gaming*.

[8] Fazi, *Contingent Computation*.

[9] Gaboury, "Hidden Surface Problems."

[10] Hansen, *New Philosophy for New Media*.

[11] Denson, *Discorrelated Images*.

computational landscape.[12] The present analysis seeks to build upon this legacy, by positioning the roller coaster as an *interface* that mediates the relation between computation and the body, enabling the logico-quantitative nature of computation to be felt. For this, I make repeated use of Alexander Galloway's theory of the interface as a zone of mediation between different realities.[13]

By way of Bernard Stiegler, I will re-interpret the moral implications of the technological sublime through the dyadic lens of orientation/disorientation. While *disorientation* is perhaps the definitive experiential effect of the roller coaster, I will argue that the true nature of the roller coaster is rather one of *orientation*. In fact, said orientation brackets disorientation: the orienting operations of computation produce an experience of disorientation, which ultimately serves to re-orient riders with respect to their contemporary technological milieu. In section 1, I begin by reading the historical development of the roller coaster alongside its contemporaneous sociotechnical milieu in order to introduce the notion of the technological sublime. In section 2, I draw upon Alexander Galloway's notion of the interface effect and Gilbert Simondon's notion of transduction to make the claim for the roller coaster as a transductive interface that unites the computational and aesthetic domains. In Section 3, I examine the challenges that this reading poses for the Kantian sublime and suggest various revisions to our understanding of aesthetics, aesthetic criticism, and the politics of aesthetics today.

1: Desiring Disorientation

The complex mechanico-computational assemblage that is Hagrid's Motorbike Adventure (HMA) is a far cry from its gravity-driven forebears. How did we get here? While the origin of the roller coaster can be traced back to the Russian ice slides of the 15th century, the modern roller coaster finds its origins in industry.[14] The first major railroad in the United States also happened to be its first roller coaster. The *Mauch Chunk Switchback Railway* opened in 1827 to transport coal from the anthracite mines in the Pennsylvania mountains down to the Lehigh canal where it could be transported by boat.[15] From the summit, cars descended entirely by gravity down a rolling sawtooth elevation profile, reaching the previously unheard-of speed of 60 mph (10 mph faster than HMA!). Almost immediately, the railway attracted curious visitors who wanted to ride the industrial wagons for pleasure. Over the next century, it became the second most

[12] Deleuze and Smith, *Francis Bacon*; Fazi, *Contingent Computation*; Gabrys, *Program Earth*; Ngai, *Our Aesthetic Categories*.

[13] Galloway, *The Interface Effect*.

[14] Cartmell, *The Incredible Scream Machine: A History of the Roller Coaster*, 20.

[15] Cartmell, *The Incredible Scream Machine: A History of the Roller Coaster*, 40.

popular tourist attraction in the country, surpassed only by Niagara Falls.[16] To this day, it remains the highest (1,216 ft) and longest (18 miles) "roller coaster" ever in operation.[17] From the beginning, roller coasters have found their roots in industry, seemingly borne out of an inherent human curiosity to *inhabit the machine.*[18]

Figure 1 - Mt. Pisgah Plane at Mauch Chunk

The subsequent century of roller coaster development mirrors this trend, appropriating technical elements from industry for the purpose of pleasure. For Gilbert Simondon, such horizontal transfer is the very engine of technical evolution: "The historical solidarity that exists among technical realities is mediated by the fabrication of elements."[19] Much like orthographic writing enables posterity, the technical element (e.g. a wheel or motor) forms the ground for

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[16] Ibid.

[17] Ibid.

[18] It would be remiss to overlook the fact that many industrial laborers of the time had no choice but to "inhabit the machine," often in highly exploitative and extractive conditions. Here, I specifically mean the desire to convert the machine into a source of amusement.

[19] Simondon, *On the Mode of Existence of Technical Objects*, 68.

technical evolution, as the element's modularity enables it to be endlessly repurposed or appropriated.

It is no coincidence that the "Golden Age" of roller coasters (1880 - 1930) aligns almost exactly with the years of the Second Industrial Revolution. At no other time in history have more roller coasters existed; nearly 2,000 were built during this era, few of which remain today.[20] This explosion in popularity was due in part to the emergence of a new market for mass entertainment, spurred by the adoption of wage labor and its corollary, the production of leisure time. Responding to this newfound appetite, investments in technological innovation accelerated the complexification of the coaster form. Most important was the introduction of the "upstop" wheel—a second set of wheels placed *beneath* the track to prevent the train from flying off during tight maneuvers. This advancement allowed for much more dramatic track shapes and higher speeds.[21] As a result, the 1920s saw the rise of Twister coasters, which folded back on themselves, routing the track through the support structures of other segments to create a thrilling "head chopper effect."[22]

Figure 2 - Crystal Beach Cyclone, Revere Beach (1929)

Each of these formal innovations expanded the possibility space of aesthetic experience, introducing ever more extreme forms of disorientation. The sheer popularity of roller coasters during this era attests to the fact that this disorientation was experienced as (mostly) pleasurable. Interestingly, this desire for disorientation emerged alongside massive societal upheaval, characterized by its own forms of systemic disorientation. During the Second Industrial Revolution, industrial production rendered human labor machinic, demanding

[20] "History - American Coaster (ACE)."

[21] Cartmell, 119.

[22] "Headchopper - Coasterpedia - The Roller Coaster and Flat Ride Wiki."

long workdays filled with monotonous, repetitive tasks.[23] Following Karl Marx, we understand such human subordination to the capitalist logics of production to produce myriad forms of alienation—both material and existential—that work to disorient the subject in their relation to the world.

In his three-volume series *Technics and Time,* Bernard Steigler counters the common assumption that technology creates order, arguing instead that its effects are ultimately disorienting at a societal level. For Stiegler, all technologies initially disorient, insofar as they disrupt formerly codified ways of being (programs) through the acceleration of time, thus necessitating constant re-orientation. Within this framework, the roller coaster can be understood not as mere amusement but as a machine that actively re-channels broader societal disorientation into a domesticated, pleasurable form, counterintuitively acting to re-orient through its own disorienting effects.

The Technological Sublime

For many, the roller coaster is a machine that combines terror and pleasure, or rather: produces pleasure *through* terror. These contradictory feelings resemble the dissonant aesthetic and emotional register of the sublime, wherein pleasure and terror coincide. While the sublime has taken on many different inflections throughout history, I refer here specifically to the 18th-century notion of the "dynamical sublime" developed by Immanuel Kant. For Kant, the dynamical sublime is a subjective experience in which a fearsome encounter with the raw power (*Macht*) of nature produces a feeling of pleasure, something he calls "negative pleasure".[24] Thunderstorms, lightning, and volcanoes are cited as several examples capable of inducing such an experience.[25] Crucially, however, for fear to be converted into pleasure, the encounter must not pose any real threat but merely evoke the possibility of one. Contemplating the possibility of death engages the faculties of reason that allow access to that which lies *beyond* the sensible—the thing in itself (*das Ding an sich*).[26] The supersensibility (immortality) of reason is thus seen as superior to the sensible (mortal) world. The experiencing subject emerges from this encounter with a renewed superiority, rather than humility, towards the power of nature:

> [T]hough the irresistibility of nature's might makes us, considered as natural beings, recognize our physical impotence, it reveals in us at the same time an ability to judge ourselves independent of

[23] "America at Work | Articles and Essays | America at Work, America at Leisure."

[24] Kant, *The Critique of Judgement*, sec. 23.

[25] Kant, sec. 261.

[26] Fernández, "Kantian Sublimity and Supersensible Comfort: A Case for the Mathematical Sublime," 26.

> nature, and reveals in us a superiority over nature that is the basis of a self-preservation quite different in kind from the one that can be assailed and endangered by nature outside us.[27]

Suspending momentarily its anthropocentric hubris, Kant's formulation helps elucidate the way in which the conversion of fear into pleasure acts to reorient the subject in a disorienting world. The same might be said of the roller coaster. By staging a fearsome yet safe encounter with the raw power of the machine, the roller coaster functions to normalize the alienating effects of technological acceleration.

Interestingly, the first amusement parks were created with the explicit intention of facilitating such re-orientation. The enclosed amusement park typology first emerged at Coney Island in the 1880s as a direct response to the brothels, gambling dens, and saloons that populated the area at the time.[28] This reformist movement was spearheaded by roller coaster evangelist LaMarcus A. Thompson, also known as the "father of gravity". In 1884, Thompson opened the *Switchback Railway,* Coney Island's first roller coaster, modeled after the success of the *Mauch Chunk Switchback Railway.* Thompson's motivations were both economic and utopian:

> Many of the evils of society, much of the vice and crime which we deplore come from the degrading nature of amusements entered into. To inveigh against them avails little, but to substitute something better, something clean and wholesome and persuade men to choose it, is worthy of all endeavor... sunshine that glows bright in the afterthought and scatters the darkness of the tenement for the price of a nickel or dime.[29]

Here, the roller coaster is imbued with a salvational power aimed at the reorientation of society at large. While today this appears woefully anachronistic, I do maintain that the roller coaster enables the possibility of "making sense" of rapid technological acceleration. *Making sense* is meant literally here, insofar as the roller coaster enables the sensory, aesthetic experience of *acceleration as pleasure.* At first glance, the roller coaster appears to be the ultimate form of human subordination to the machine. The human rider is stripped of any agency and subjected to the machinic might of the roller coaster. It bears remembering, however, that the roller coaster is designed in the image of the human, a technology aimed directly at the production of pleasure (through fear). This stands in stark contrast to the forms of bodily subordination to the machine experienced

[27] Kant, sec. 281.

[28] Pauline Seltzer, "Coney Island: The Limits and Possibilities of Leisure in Turn of the Century American Culture."

[29] Cartmell, *The Incredible Scream Machine: A History of the Roller Coaster*, 49.

by industrial laborers of the time, in which the economic logics of efficiency sat violently at odds with the physiological and psychological needs of the human.

In the sublime experience, pleasure is not accessed directly but only via the passage through fear. Here, fear is produced via an encounter with the raw power of the machine. At a time of unsafe working conditions and horrific industrial accidents, machinic power was certainly something to be feared. While a lack of historical records makes it hard to say definitively, those that do exist suggest that catastrophic roller coaster accidents of the time were relatively rare.[30] Nonetheless, as anyone who has ridden an older wooden roller coaster can attest, its shaky and haphazard construction produces an experience that feels just on the edge of unraveling. At a time when most individuals were not accustomed to the speed of rail and air travel, such an experience was surely even more exhilarating. As a simulated experience of danger, the roller coaster enables the exhilaration that comes with the loss of control without the consequences. The very same technical elements capable of causing harm in the factory were reappropriated for entertainment, countering alienation *qua* alienation in a way that foreshadows the emancipatory strategies endorsed by the contemporary xenofeminist collective Laboria Cuboniks: *"It is through, and not despite, our alienated condition that we can free ourselves from the muck of immediacy."*[31]

2: Pre-Orientation

Cutting Space, Scrubbing Time

Despite the dramatic evolution of coaster form throughout the 19th and 20th centuries, two characteristics remained unchanged: (1) all are powered by gravity, and (2) all form a single continuous circuit. Hagrid's Motorbike Adventure shares neither of these characteristics. Rather than pulling trains up a chain lift hill to generate movement via gravity, HMA propels them along its 5,053-ft (1,540-m) track through seven separate magnetic launches—the most of any coaster in the world.[32] In a traditional gravity-driven roller coaster, the train gradually loses speed as it progresses through the course. In HMA, however, the coaster is injected with energetic pulses throughout, producing a continuous modulation of speed that peaks only in the final section. Even more interestingly, the track is not a continuous circuit; instead, it consists of five discrete sections connected by dynamic mechanisms known as "switch tracks," which transfer the train between

[30] Ripley's Believe it or Not!, "The Fascinating (And Sometimes Bloody) History Of Roller Coasters."

[31] Cuboniks, "Xenofeminism."

[32] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

different track segments and enable it to travel both forward and in reverse.[33] In HMA, it is not only the roller coaster train that moves, but also the roller coaster itself, continuously reconfiguring the very ground of experience.

Breaking with the two core characteristics of the roller coaster is only made possible through computation.[34] Rather than a form or a substance, computation is better understood here as "a method and a force that, through rules, constraints, and capacities for expression, continually renegotiates its own structures of existence."[35] In the computationally-augmented roller coaster, space is not just folded, it is cut. Time is not just compressed, it is reversed. It is no coincidence that these are also key operations of digital media. Hito Steyerl notes: "Recent 3D animation technologies incorporate multiple perspectives, which are deliberately manipulated to create multifocal and nonlinear imagery. Cinematic space is twisted in any way imaginable, organized around heterogeneous, curved, and collaged perspectives."[36]

In HMA, the nonlinear speeding up and slowing down of the train resembles the speed controls of online video streaming platforms, while the train's reversibility mirrors the scrubbability of computer simulations. It is not simply that the aesthetics of the contemporary roller coaster *bear resemblance to* contemporaneous media forms. Rather, this resemblance belies a shared ontological basis grounded in the abstract nature of computation itself:

> The abstract structures of computation can move fast from one instantiation or occurrence to another (an algorithm can be used for sorting rice grains, faces, or patterns of pixelation, for instance). The movement across multiple sites and occasions of a work is one way of tracing the variable characteristics of computational aesthetics across social forms, and to highlight some of the ways in which the computational is often built into the latter.[37]

Computational aesthetics, in this context, does not refer to art produced by computers but rather to a form of sensory perception made possible only through the logico-quantitative operations of computation. In the case of HMA, computation enables the methods of spatiotemporal manipulation once confined

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[33] Ibid.

[34] Throughout the text, "computation" is used in favor of the "digital". Fazi and Fuller describe: "We understand computation as a method and a force of organization, quantification, and rationalization of reality by logico-mathematical means. The computational … remains a notion wider and more powerful than the digital tools that it subtends." (Fazi and Fuller, "Computational Aesthetics," 281.)

[35] Fazi and Fuller, 282.

[36] Steyerl, "In Free Fall."

[37] Fazi and Fuller, "Computational Aesthetics," 286.

to the digital to be applied to the physical form of the roller coaster itself. In doing so, the nonlinear spacetime of the digital seeps into the body.

Interface Affect

But herein lies a contradiction: can the discrete, symbolic nature of computation truly be said to produce a continuous aesthetic experience? Put otherwise, is it even possible to speak of a computational aesthetics?

Following a Deleuzian interpretation of aesthetics as *aisthesis* (that is, a "logic of sensation")[38], the answer would appear to be no. For Deleuze, "what is mechanical and codified is able to generate neither sensation nor thought."[39] Beatrice Fazi has attempted to resolve this impasse by arguing that the notion of incomputability embeds indeterminacy at the heart of computation, thus making computation inherently aesthetic.[40] Rather than collapsing these two realities by folding the discrete into the continuous, however, I pursue another approach.

It has been stated that HMA is a computationally augmented mechanical system. Perhaps, however, it is better understood as a mechanically augmented computational system. This turn of phrase reframes the mechanical components of the roller coaster (the track, launch systems, ride vehicles, etc…) as an *interface* mediating the relationship between computation and the body. In *The Interface Effect* (2012), Alexander Galloway presents a nuanced reading of computation itself as a form of interface. Galloway's interface is less a two-dimensional screen than a zone of mediation: "An interface is not a thing, an interface is always an effect. It is always a process or a translation… a fertile nexus."[41] The roller coaster-as-interface, then, attends to the way in which the logico-quantitative character of computation is translated, negotiated, and amplified through the particularities of mechanical apparatus. Contrasting Fazi's collapsing of computation and aesthetics under the domain of the aesthetic, such a reading preserves the distinction of the two domains and points to the process by which one becomes the other. To make this act of translation clearer, I will attend to three distinct ride elements only made possible via computation, as well as the logic system that coordinates their behavior.

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[38] Deleuze and Smith, *Francis Bacon*.

[39] Fazi, *Contingent Computation*.

[40] See Fazi.

[41] Galloway, *The Interface Effect*, 32.

Rugged Intelligence

At any given moment, HMA contains around nine trains circulating the track (most roller coasters contain only one or two). The track is not continuous but rather composed of five discrete sections, each of which moves periodically throughout the ride's operation. These complex mechanical gymnastics require the rapid transmission of information, a task handled by the Programmable Logic Controller (PLC)—the brain of the coaster. PLCs are rugged, industrial computers primarily used in factory automation for tasks requiring extreme precision and reliability. Developed in the automotive industry in the 1960s, the PLC replaced the hard-wired relay control systems previously in use.[42] As the name suggests, these devices are programmable (using software rather than just hardware), implement basic logic operations, and control external systems (in this case, the ride mechanics). Their use in HMA is crucial, as thousands of sensors (inputs) and actuators (outputs) distributed around the track must work perfectly and consistently throughout the park's operating hours, 365 days a year.[43]

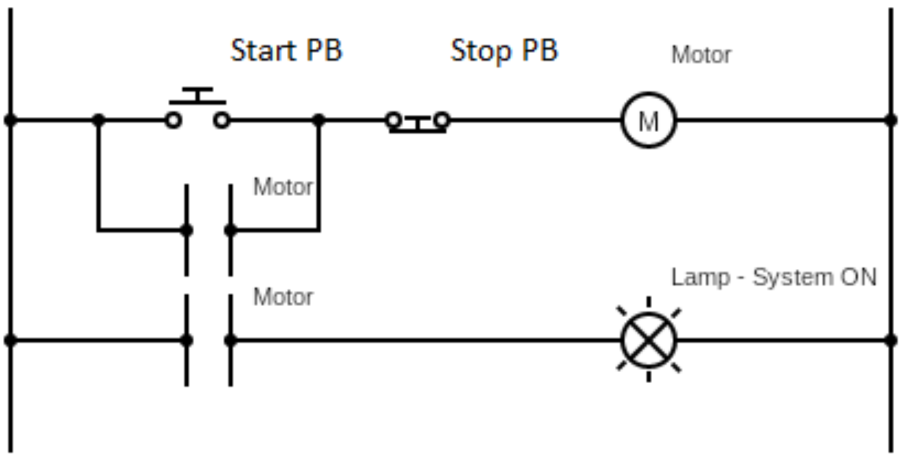

Figure 3 - Ladder Logic diagram (Credit: SolisPLC)

The PLC uses a graphical programming language known as Ladder Logic, which visually resembles the schematic diagrams of the electrical relay systems it replaced.[44] Its structure mimics a ladder, with two vertical rails and horizontal rungs spaced between them. Each rung represents a specific logic operation containing input conditions (e.g., *is the proximity sensor on or off?*) and output actions (e.g., *activate switch track maneuver*), which execute sequentially from left

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[42] Parr, *Industrial Control Handbook*.

[43] "Park Hours for Universal Orlando Resort™ Theme Parks and Universal CityWalk™."

[44] Fehr, "The Basics of Ladder Logic."

to right. Compared to modern object-oriented programming languages, the procedural logic of the PLC is extremely rudimentary. This simplicity is by design, however, as it minimizes the margin for error and enables the rapid calculations required to monitor all ride components in real time. The PLC continuously scans its program—many times per second—from top to bottom and left to right, executing outputs based on the logic conditions of each rung.[45]

In addition to the central PLC system, each train contains its own onboard PLC, responsible for controlling the lights and audio of each vehicle.[46] Many times per second, these PLCs scan all sensor inputs to gather real-time data about the ride's status. This data is almost entirely spatial, tracking the position of trains and track components, among other variables. If the experience of the rider is one of sequential disorientation, the experience of the ride system itself is one of parallelized hyper-orientation. The PLC thus enables a sort of omniscient proprioceptive awareness, enabling precise forms of spatiotemporal manipulation.

Magnetic Rivers

As mentioned, HMA does not make use of a traditional lift hill to generate acceleration. Instead, the ride relies on Linear Synchronous Motors (LSMs), which create precise magnetic fields that smoothly propel trains around the track.[47] Rather than gradually losing speed throughout the course of the ride, the trains receive sudden bursts of acceleration—akin to running over a power-up in a video game. The sudden yet smooth acceleration seems to come from nowhere, playing with the rider's intuitive kinaesthetic perception. The rapid computational operations that enable this acceleration remain largely obscured from the rider, save the distinctive high-pitched electromagnetic thrum that can be heard as the magnetic stators activate along the track.

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[45] Ibid.

[46] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

[47] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

Figure 4 – View down LSM launch track, HMA

LSMs originated in the transportation industry, with the first practical linear motor patented in 1905 to propel trains.[48] Today, LSMs are essential for maglev trains, spacecraft propulsion, weapon systems, and hypervelocity collisions, all applications requiring precise control of acceleration. In essence, they function as an unrolled motor: rather than generating rotational motion, they produce linear motion along a track using alternating pulses of electric current. In HMA, each train contains a magnetic "shoe" with alternating North-South polarities (literally, orientations), which interacts with stators—electromagnetic fins mounted along the track. As the train rolls onto the launch section, the stators generate a dynamic magnetic field via synchronized pulsations of electric current, propelling the train forward.[49] A "magnetic river," as the technology was called in its early years.[50]

Crucially, this system does not follow a fixed, pre-programmed rhythm. To accommodate contingent fluctuations in rider weight, weather conditions, and other variables, the system must calculate in real time the rhythmic sequence and power necessary to propel the train to the appropriate speed. This is achieved through thousands of sensors mounted on both the track and the train, measuring phenomena such as the position and speed of the train as it passes over the launch sequence.[51] For the LSM to function properly, the magnetic fields on the train and

[48] Zehden, Electric traction apparatus.

[49] *MAGNETIC LAUNCH SYSTEMS 3*.

[50] Laithwaite, "Linear Motors for High-Speed Vehicles."

[51] *MAGNETIC LAUNCH SYSTEMS 3*.

on the track must remain perfectly aligned; even a small misalignment would cause the launch to fail.

In each of the ride's seven launches, the mechanical apparatus unites the molecular and the molar, entangling orientation and disorientation across scales —what Gilbert Simondon would call different "levels of being."[52] In this way, the coaster-as-interface can be understood as *transductive*: an operation that resolves incompatibilities between separate levels of being in the process of becoming. Simondon writes: *"By transduction we mean an operation — physical, biological, mental, social — by which an activity propagates itself from one element to the next… and founds this propagation on a structuration of the domain that is realized from place to place."*[53] Here, the transductive operation brings about sensation through the propagation of structure across heterogeneous domains. In the LSM launch, binary digits representing the position and speed of the train are converted into electrical currents, which modulate the orientation of electrons to produce the magnetic field that accelerates the train. This acceleration is then registered in the gelatinous matrix of the inner ear, sending electrical signals to the brain that are felt as a sensation of disorientation.

A transductive continuity is thus established, negotiating across levels of being without reducing one to the other. While the roller coaster does not fully instantiate transduction in Simondon's radical sense—since both the ride and rider pre-exist their interaction—it nonetheless operates within a transductive field where the roller coaster experience is produced by the contingent and continuous interaction of computation, mechanics, and perception. The roller coaster emerges not as an object but as a practice, existing not *in* relation but *as* relation.

Seamed Seamlessness

As the train exits the launch section, it is liberated from this precise computational control and given over to the laws of gravity. Coursing through the track, the train passes over four more LSMs launches before diving into a fog-covered trench. Emerging from the trench, riders find themselves traveling up a vertical spike, only to lose momentum and begin falling backwards down the same track. Most roller coasters are designed to prevent trains from moving in reverse, but HMA integrates this directly into the ride experience. But how does the train keep from rolling back towards the station and colliding with another train? Unbeknownst to riders, while traveling up the spike, a mechanism known as a switch track reconfigures the track behind them, redirecting the train to a new section of track.

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[52] Simondon, "The Position and Problem of Ontogenesis," 6.

[53] Ibid.

While switch tracks have been used in the railroad industry since the 19th century, the one used in HMA is the first to be used in a roller coaster while the train is still in motion, necessitating a rapid yet precise mechanism.[54] Prior to entering the spike, the train made a first pass over a high-speed switch track: two distinct segments of track arrayed side by side on a moving platform. Proximity sensors measure the train's position and send a signal once it clears this portion of the track and heads towards the spike.[55] The switch sequence is then activated: pins holding the track in place are released, and the track moves laterally in rapid motion, replacing the initial curved segment with a straight segment that connects to a new track section fitted with yet another LSM launch sequence.

Figure 5 - Switch Track Diagram, HMA (Credit: AmusementLabs)

As the train falls backward down the spike, the LSMs previously used to accelerate it forward are now used to accelerate it in reverse. This requires only a rhythmic reversal of the stators' electric pulses, producing a magnetic field in the opposite direction.[56] McKenzie Wark: *"In the database, all description is numerical, equivalent in form. In principle everything within it can be related to or transformed into everything else. A new kind of symmetry operates."*[57] In the event that the switch track fails to complete the transfer successfully, position sensors on the switch track

[54] Lee, *The Evolution of Railways*.

[55] "How It Works: Hagrid's Motorbike Adventure - YouTube."

[56] *MAGNETIC LAUNCH SYSTEMS 3*.

[57] Wark, *Gamer Theory*., para. 69.

signal the LSMs, which can then adjust their rhythm to function as brakes, slowing the train before it derails.[58] Taken together, the experience is highly disorienting: falling backward, only to accelerate through a new set of LSMs onto a completely different section of track, all without the visual foresight afforded by forward motion. Without the computational logic of the PLC, such a "seamless" experience would be impossible. Of course, this seamlessness is merely an illusion, made possible through a proliferation of seams that discretize the track and reconstitute it through the discrete symbolic logic of computation.

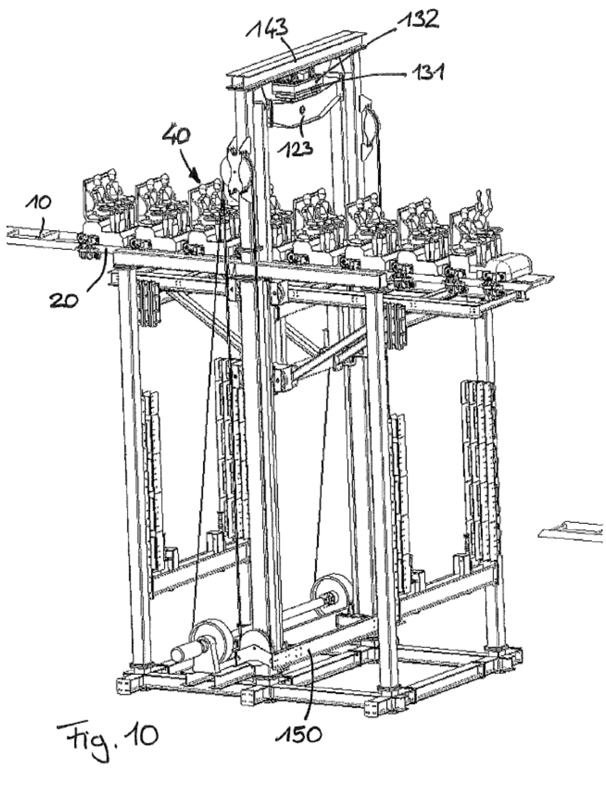

Figure 6 - Drop Track Patent US 8,943,975 B2 (similar but not identical to the one used in HMA)

The train proceeds backward through the next section of track before coming to a stop inside a dark building. Suddenly, riders free-fall 17 ft (5.18 m) before coming to a stop and being released forward onto the final section of the track.[59] Known as a drop track, this element operates on the same basic principles of the switch track but moves in the vertical rather than horizontal direction. The drop track sits within a guillotine-like structure mounted on a large pneumatic

[58] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

[59] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

cylinder buried underground.[60] When proximity sensors identify that the car is safely positioned on the drop track segment, safety pins are removed and air from the pneumatic cylinder is rapidly evacuated, causing the track and attached coaster train to free-fall. Magnetic brakes, mounted vertically on the structure, bring the track to a stop and align it precisely with the new segment leading back to the station.[61] This ride element is unique in that it is the movement of the structure itself—not the train along the structure—that produces sensation. In 3D computer graphics, such a movement is known as a translation: the linear displacement of an object along a three-dimensional plane. By precisely orienting itself along the vector of gravity, this purely vertical movement produces a much stronger (purer) bodily sensation than, say, rolling down a steep hill of the same height: orthogonal intensity.

What happens if one of these elements fails to operate as expected? Given the sheer number of sensors involved, even a single error has the potential to shut down the entire ride. These issues were notoriously frequent in the ride's opening months, leading to near-constant downtime and earning the ride a reputation for unreliability.[62] If any element malfunctions (e.g., a train fails to make it over a hill), this information cascades through the entire system, bringing each train to a stop. In such cases, the ride is often colloquially referred to as having "broken down." More accurately, however, the ride is functioning exactly as designed: according to the rigid rules of computational logic. From an experiential standpoint, these moments of stasis also disorient by disrupting the expected continuity of the ride. These interruptions are not exceptions to the otherwise "normal" dynamic functioning of the roller coaster; rather, they are central components of its computational aesthetic experience. To be suddenly stopped mid-course is to experience a logic gate at work.

Perpetual Motion

Taken together, these three elements highlight the contingent role that the design of the roller coaster plays in making computation sensible. There is nothing intrinsic to computation itself that would render it sensible in these specific forms (freefall, forward/backward acceleration). The roller coaster should not be seen as a prosthetic extension of the computer but rather an intermediary that selects, amplifies, and redirects specific computational operations toward specific aesthetic ends. It is important to keep in mind, however, that production of aesthetic experience is not an end in itself but a mechanism for the production of capital. As a blockbuster ride based on one of the highest-grossing franchises at

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[60] *Ibid.*

[61] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

[62] *Ibid.*

one of the largest theme parks in the world, this ride was designed to draw crowds, and by extension, revenue. To accommodate this massive throughput of riders, the ride was designed to handle 12 trains on the track at a time, leading to a theoretical maximum capacity of 1,848 riders per hour.[63] In practice, however, this number is closer to 9 trains at a time, as 12 trains would require dispatching a new train every 27.3 seconds, a nearly impossible task.[64]

The LSM launches, switch tracks, and drop tracks described above serve not only to provide an exciting ride experience, but also to maximize the number of riders per hour: an aesthetic borne from efficiency. Each of these elements constitutes an independently controllable zone known as a "block zone," which can safely bring a train to a stop if a malfunction on the track requires it. The more block zones, the more trains that can operate simultaneously without danger of collision.

Figure 7 - Load / Unload Station

To further maximize rider throughput, the ride system remains in constant motion. Even in the load and unload station, where riders embark and disembark, the trains never stop moving. Proximity sensors and mechanical drive motors precisely control the train's velocity, synchronizing it with a moving walkway that runs alongside it, thus allowing riders to enter and exit without ever stopping the ride. This not only maximizes capacity, but also charges the ride vehicle capacitors, which power the PLC and audiovisual system onboard each

[63] *Problematic Roller Coasters - Hagrid's Motorbike Adventure - One Of The Most Complicated Attractions.*

[64] *Ibid.*

train. Quite perversely, however, such constant motion is also demanded from the human ride attendants, who must walk continuously against the motion of the conveyor belts to assist riders and perform manual checks on the train's restraints. HMA does not merely appropriate technical elements from industry, but also the organizational logics of a post-industrial information economy. Workers are expected to be flexible, fluid, and hospitable, often navigating difficult interpersonal situations (e.g., when a larger rider cannot fit safely in the seat) without disrupting the flow of the machine.

3: Re-orientation

The Techno-logical Sublime

The complex mechanico-informatic system that is HMA is a far cry from the simple, gravity-driven wooden roller coasters of the 1920s. Can the ride experience still be said to produce a sublime encounter? Answering this requires a reflection on the affective registers produced by the computational roller coaster, as well as a broader interrogation of the socio-technological context in which the ride is situated.

Through the emergence of regulatory standards, computational design software, and advancements in fabrication, today's roller coasters do not evoke the same sensation of danger as they once might have. In HMA, the rider instead experiences a degree of smoothness rarely found in everyday life—a precise choreography of forces simulated and optimized in software simulations prior to construction. Modern, computationally controlled roller coasters produce the curious sensation of being held, guiding the rider through a precise assemblage of technical systems designed to produce *exactly* the sensation that is being felt. Choreographed disorientation. Marketed as a "family coaster," HMA was explicitly designed to appeal to riders of all ages, ensuring that it never produces forces that would be felt as too intense. It is one of the most popular rides in the park, with wait times averaging 1-2 hours.[65] Such popularity underscores its palatability—a far cry from the terrifying nature of the sublime as described by Kant. Instead of terror, a whole cocktail of affective registers (fun, submission, ilinctic disorientation) defines in the ride experience of HMA.

Additionally, HMA sits within a completely different socio-technical epoch than that of the 1920s, and thus within a completely different landscape of disorientation. The transformations of the current era are more informatic than mechanical. Increasingly, computation folds itself into nearly all aspects of life, remaking the world in its image in a process that Jennifer Gabrys calls the

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[65] "Average Wait Time by Year (All Time)."

"becoming environmental of computation."[66] This has resulted in a mode of production that Deleuze coined the "control society,"[67] described by Galloway as:

> the diffusion of power into distributed networks, the increase in local autonomous decision making, the ongoing destruction of the social order at the hands of industry, the segmentation and rationalization of minute gestures within daily life, the innovations around unpaid micro labor, the monetization of affect and the 'social graph,' the entrainment of universalizing behaviors within protocological organization.[68]

More recently, the rapid capability scaling of foundation models over the past year has thrust AI into the spotlight, and for good reason, as these models have proven capable of disrupting entire industries overnight. While a deeper interrogation of the socioeconomic dimensions of the ride remains outside of the scope of this analysis, it is worth emphasizing that the very conditions that enable the aesthetic experience of HMA are borne from the same informatic logics of control and capitalization that lie at the heart of the control society.

Figure 8 - Hagrid's Motorbike Adventure navigating scenography

[66] Gabrys, *Program Earth*.

[67] Deleuze, "Postscript on the Societies of Control."

[68] Galloway, *The Interface Effect*, 92.

In light of these ongoing societal transformations, many thinkers have begun to challenge legacy aesthetic categories such as the sublime altogether. Lauren Berlant broadens the notion of aesthetics to encompass not only art or beauty but also the textures, rhythms, and objects of daily life.[69] Sianne Ngai introduces a new lexicon for thinking through the aesthetic, arguing that "zany," "cute," and "interesting" are more accurate descriptors of subjective experience under late capitalism.[70] In both cases there is a de-dramatization of the sublime, shifting the register of aesthetic experience toward the ordinary and the everyday. In a quite perverse way, even as the raw power (*Macht*) of nature increasingly expresses itself in the form of climate-change induced natural disasters, a similar de-dramatization is at play: the ubiquity of such events, as experienced through social media videos, renders them increasingly banal.

Together, these challenges make clear the need to articulate new revisions to the aesthetic framework first outlined by Kant. However, I am hesitant to discard the sublime as a useful category altogether in favor of the banal and the ordinary. In fact, I would argue that the Kantian sublime is more present than ever, albeit not in the ways that have been explored thus far.

In addition to the *dynamical sublime*, Kant also conceptualized a second category of the sublime—the *mathematical sublime*—which refers to abstract notions such as *the infinite,* accessible only indirectly through the mental process of imagination. The sight of a large mountain or the night sky might stimulate the imagination to "progress towards infinity"—a conceptual awe provoked through a sensible encounter with something too vast to be perceived directly in its entirety.[71] Much like the aesthetic experience of the dynamical sublime, the mathematical sublime also induces a dizzying and overwhelming sensation of the super-sensible.

In the centuries following Kant's original articulation, the passage of computation from theoretical possibility to actuality has similarly transformed the mathematical sublime from passive contemplation to active process. Building on Turing's formalization of universal computation, computation emerges as an abstract system capable of structuring and instrumentalizing infinity, rather than merely evoking it.[72] The logico-quantitative operations of computation suggest a new kind of infinity based not only on sheer size, but on generality and formal expressibility. Kant's super-sensible rationality thus becomes executable, migrating from the human mind to the inhuman logics of the machine: a techno-logical sublime. This flight toward infinity is driven largely by the exponential

[69] Berlant, *Cruel Optimism.*

[70] Ngai, *Our Aesthetic Categories.*

[71] Kant, *The Critique of Judgement*, sec. 250.

[72] Turing, "On Computable Numbers, with an Application to the Entscheidungsproblem."

development of hardware processing capabilities, as indicated by Moore's observation that the number of transistors in an integrated circuit has doubled roughly every two years since 1975.[73] The recent dramatic capability scaling of AI models further demonstrates the coupled relationship between hardware advancements and machinic intelligence. As computation saturates all aspects of life, so too does the mathematical sublime; we carry around bits of infinity in our pockets every day. Interestingly, however, as computation proliferates, it also withdraws.

Pointing to the difficulty of visually representing the structure of the internet, Alexander Galloway identifies a particular unrepresentability at the core of modern information networks. He writes: *"The point of unrepresentability is the point of power. And the point of power today is not in the image. The point of power today resides in networks, computers, algorithms, information, and data."*[74] How does one represent the unrepresentable? Interestingly, by recourse to Jacques Rancière, Galloway cites the sublime romantic art inspired by the likes of Kant as one of the first attempts to do exactly that. J.M.W Turner's sea storms and John Martins apocalyptic landscapes both attempt to represent the raw, infinite power of nature, evoking notions of infinity and grandeur that of course remain impossible to fully represent in their totality.

Pulling G's

But is representation necessary for something to be perceptible, and by extension, knowable? The transductive operation of the coaster-as-interface suggests the possibility of a non-representational aesthetics (*aisthetics*), wherein the deep opacity of information networks is rendered legible in the body. It is worth dwelling a bit more on the nature of this aesthetic experience. While auditory and visual stimuli certainly play a role, I would argue that the dominant aesthetic register of the roller coaster is proprioceptive. In his articulation of the physiological basis of aesthetics, anthropologist André Leroi-Gourhan emphasizes this centrality of this spatial awareness in aesthetic perception, regarding it

> not as a tool, but as the *instrument of our insertion in existence*... The weight of the body is perceived by the muscles; it combines with spatial balance to hold us down in our concrete universe and, by antithesis, to constitute an imaginary universe from which weight and balance have been banished. Acrobatics, balancing exercises, the dance, are to a large extent the material expression of the attempt to break away from normal operating sequences and

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[73] Moore, "Cramming More Components onto Integrated Circuits."

[74] Galloway, *The Interface Effect*, 92.

create something outside the day-to-day cycle of positions in space.[75]

As a machine for the production of disorientation, the roller coaster functions as a bridge between the concrete and imagined universe. In industry parlance, the degree of disorientation can be measured by the g-force (gravitational force). The g-force refers to the standard acceleration of gravity on earth: 1 g = 9.8 m/s^2. "G's" can be experienced positively (e.g., being pressed into your seat), negatively (e.g., the feeling of weightlessness or "airtime" at the crest of a hill) or laterally (e.g., being pressed into your neighbor as you navigate a curve). Under the influence of high g's, one can experience the feeling of "greying out": a sudden decrease in brain oxygen that can lead to a temporary loss of color vision (hence, greyout). This is a highly sought after sensation among hardcore roller coaster enthusiasts.[76] For a greyout to avoid becoming a blackout, roller coasters must operate within a narrow zone of intensity amenable to both human physiology and psychology. Attempting to create one of the first looping roller coasters in 1895, The Flip Flap railway at Coney Island far exceeded this comfortable zone. As the car traversed its small, perfectly circular loop, it pulled up to 12 g's—enough to reportedly snap some rider's necks in the process.[77,78]

Figure 9 - Flip Flap Railway, Coney Island

[75] Leroi-Gourhan, *Gesture and Speech*, 286. (emphasis mine)

[76] "G-Forces and Greyouts."

[77] "Coney Island | Roller Coaster History."

[78] Today, roller coaster loops are clothoid (teardrop) shaped, rather than circular, in order to reduce g-forces exerted in the loop.

Today, an acceptable "aesthetic zone" has been codified in the ASTM F2137 standard: "Standard Practice for Measuring the Dynamic Characteristics of Amusement Rides and Devices."[79] These limits constrain the possibility space of any potential roller coaster, restricting both its form and experience to a palatable (and safe) aesthetic range. The contours of this zone emerge at the intersection of the cosmic and the human. A roller coaster constructed on the moon or for a bat would have a completely different form, shaped by both the gravitational environment and psychophysiological affordances of the rider. While the upper bounds of the aesthetic zone are quite clear, what exactly defines its lower bounds? What distinguishes the banal experience of riding an LSM-driven airport tram from the thrilling experience of a roller coaster?

The answer clearly lies in the degree of intensity. While both experiences are underpinned by the mathematical sublime, it is only the latter in which this sublimity is rendered perceptible. The coaster-as-interface transduces the electrical pulses of the machine into electrical pulses in the inner ear. While HMA may not be as intense as larger roller coasters (let alone the sublime encounters outlined by Kant), it is explicitly designed to maximize the sensation of pleasurable disorientation, which in turn stimulates the multipicity of affective responses outlined above. In contrast to posthumanist fantasies that cast aside the body in favor of brain-in-the-vat virtual transcendence, the vision outlined here is one of deep, cosmic embodiment.

Against a backdrop of increased sedentarization, office work, and doomscrolling-induced desensitization, perhaps one does not need to be terrified to produce the shock to the system necessary for a sublime experience today. In HMA, the shock comes less from the pure experience of intensity than from the gap between the embodied experience of the ride and the conditioned desensitization of the contemporary late-capitalist subject. The ride experience is characterized not by information overload but by reduction: the complex computational operations of the machine are reduced to the sensation of the g-force. For Galloway, the transductive operation of the coaster marks the passage from data to information. *"If data opens a door into the realm of the empirical and ultimately the ontological (the level of being), information by contrast opens a door into the realm of the aesthetic."*[80] While in the database, data has no necessary visual form, as it enters the body it takes shape (*in-forms*) in the body as a sensation of acceleration. In a reversal of Kant's original formulation, it is the mathematical sublime that produces an encounter with the dynamical, rather than the other way around.

[79] F24 Committee, "Standard Practice for Measuring the Dynamic Characteristics of Amusement Rides and Devices."

[80] Galloway, *The Interface Effect*, 82.

Conclusion

It has been argued that the sublime experience consists of an initial disorientation, followed by a reorientation of the subject within the world. In the Kantian sublime, however, this reorientation is superficial—the experience functions as little more than an ego boost. In the dynamical sublime, a brush with death stimulates the contemplation of the relative immortality of reason, while in the mathematical sublime, contemplating the infinite reveals the finitude of sensible reality. In both cases, the affective potency of the experience is ultimately subsumed under the capacities of reason, thus establishing human superiority over nature. In this framework, reorientation does not involve any meaningful transformation in the experiencing subject but merely reinforces and rigidifies the subject's position in relation to the outside world.

Is reorientation possible without reification? In the roller coaster, the sublime experience does not fully reterritorialize asignifying intensity into the domination of the human over the machine. Rather, throughout history, the roller coaster experience seems to point instead towards the dissolution of subject boundaries. In the roller coaster, pleasure is produced precisely through the *fusion* of human and technology, not from their hierarchical separation. In contrast to the detached viewpoint of the spectator in Romantic depictions of the sublime, the roller coaster rider is literally inseparable from the deterritorializing force of the machine.[81] It has been reported that during free fall, pilots can struggle to distinguish between themselves and the aircraft.[82] The experience of the roller coaster leads to a similar collapse of dualisms: subject/object, control/chaos, orientation/disorientation, pleasure/fear.

In HMA, the rider fuses not only with the mechanical apparatus of the roller coaster but also the computational logic underpinning its operation. Over the past century, as rationality migrated from the human mind into the machine in the form of computation, it became clear that reason and logic were never quite human in the first place. The mathematical sublime, while conceivable through human rationality, is in no way exhausted by it. Recent developments in AI, for example, suggest forms of machinic intelligence that extend far beyond human capability, evading any attempts at interpretability. Rather than reifying human intelligence above all else or perceiving these alien forms of intelligence as a threat, the techno-logical sublime might instead prompt speculation about ways in which diverse intelligences might be harnessed to facilitate human pleasure (among other things). While the computational logic underpinning HMA is drastically simpler than the computational paradigms in vogue today, it invites speculation about the mechanical augmentation of these other forms of computation. What might a

[81] Friedrich, *Wanderer above the Sea of Fog*.

[82] Steyerl, "In Free Fall," 1.

mechanically augmented object-oriented program look and feel like? Of a general adversarial network? Of a transformer?[83]

In light of these computational paradigms, the forms of mechanical augmentation might cease to resemble the roller coaster form entirely. While I would certainly not argue that the roller coaster experience resolves the actual material conditions of alienation, perhaps it might orient us toward an alternative, more symbiotic post-human future—less a fixed cardinal direction than a "heterogeneous forcefield through which certain vectors run."[84]

[83] A transformer is a machine learning architecture that uses a self-attention mechanism to understand relationships in datasets. It is behind the rapid capability scaling of foundation models in recent years.

[84] Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*, 251.

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