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Automating Discovery and the Engineering of Off-Earth Futures

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Abstract

"Automating Discovery and the Engineering of Off-Earth Futures" examines NASA's efforts to engineer what is described as "autonomous scientific discovery" in the Mars Exploration Program and its fleet of Mars Rovers through artificial intelligence and machine learning. At the intersections of Science and Technology Studies, Feminist Science and Technology Studies, and Critical Race and Ethnic Studies, "Automating Discovery" asks: What are the material conditions and histories of the Mars Exploration Program rovers as increasingly autonomous scientific laboratories? And, building on the field of laboratory studies, what is the rover as laboratory when read through the fields of Feminist Science and Technology Studies, and Critical Race and Ethnic Studies? In what ways is this rover a historical material product of the long histories of US settler colonialism, imperialism, and global racial capitalism? To address these questions, each chapter of "Automating Discovery" examines a different aspect of the material conditions that shape the fantasy of autonomous scientific discovery and the rovers of the Mars Exploration Program as autonomous scientific laboratories. What political stakes of life in our current inter-planetary moment does such an intervention articulate and make clear? How can such an intervention guide anti-colonial research practice? To answer these questions, "Automating Discovery" historicizes and contextualizes NASA's efforts to engineer autonomous scientific discovery through US imperial and colonial relations in the transpacific. In so doing, "Automating Discovery" seeks to position the Mars rover as an "autonomous colonial laboratory," and articulate critical strategies through which the expansion of such a laboratory might be resisted.

Table of Contents

List of Figures

Introduction

In the absence of a direct human presence on Mars, much of the scientific research of NASA's Mars Exploration Program is necessarily conducted remotely by a fleet of rovers with increasingly autonomous capabilities. In December 2017, *Scientific American* published an interview with Dr. Steve Chien, JPL Fellow, Senior Research Scientist, and Technical Group Supervisor of the Artificial Intelligence Group and in the Mission Planning and Execution Section at the Jet Propulsion Laboratory, California Institute of Technology, leading projects concerned with automated planning and scheduling for space exploration.[1] In this interview, Chien identified the specific roles that artificial intelligence plays in the then upcoming Mars 2020 rover mission: autonomous driving, autonomous targeting capabilities, and autonomous scheduling and dynamic route planning.[2] Chien stated that such artificial intelligence capabilities "will help the rovers do science,"[3] and "enable the rovers to conduct more science in less time."[4]

NASA's drive to engineer autonomous rover capabilities through artificial intelligence and machine learning enacts a fantasy of autonomous scientific discovery that elides and obscures the material conditions required to engineer rover autonomy. In this sense, the fleet of Mars Exploration Program rovers have come to enact what Atanasoski and Vora describe as the

[1] Larry Greenemeier, "How NASA's Search for ET Relies on Advanced AI," *Scientific American*, December 28 2017, https://www.scientificamerican.com/article/how-nasas-search-for-et-relies-on-advanced-ai/.
[2] Larry Greenemeier, "How NASA's Search for ET," https://www.scientificamerican.com/article/how-nasas-search-for-et-relies-on-advanced-ai/.
[3] Larry Greenemeier, "How NASA's Search for ET," https://www.scientificamerican.com/article/how-nasas-search-for-et-relies-on-advanced-ai/, para. 12.
[4] Larry Greenemeier, "How NASA's Search for ET," https://www.scientificamerican.com/article/how-nasas-search-for-et-relies-on-advanced-ai/, para. 12.

"surrogate" human effect,[5] as the rover comes to stand in for the scientist and overcome its absence, as an increasingly autonomous scientific laboratory.

My dissertation, "Automating Discovery and the Engineering of Off-Earth Futures," seeks to trace such material conditions of this laboratory, with emphasis on historicizing and contextualizing NASA's efforts to engineer autonomous scientific discovery through the Mars rovers within the long histories of colonialism, US settler colonialism and imperialism, and global racial capitalism.

To do this, I work at the intersections of Science and Technology Studies, Feminist Science and Technology Studies, and Critical Race and Ethnic Studies, to ask:

1. What are the material conditions and histories of the Mars Exploration Program rovers as increasingly autonomous scientific laboratories? Building on the field of laboratory studies, I ask, what is the rover as laboratory when read through the fields of Feminist Science and Technology Studies, and Critical Race and Ethnic Studies? In other words, what "kind" of laboratory has emerged here? In what ways is this rover a historical material product of the long histories of US settler colonialism, imperialism, and global racial capitalism?

To address these questions, each chapter of "Automating Discovery" examines a different aspect of the material conditions that shape the fantasy of autonomous scientific discovery and the rovers of the Mars Exploration Program as autonomous scientific laboratories. I then ask and address the following questions in each chapter:

[5] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity: Race, Robots, and the Politics of Technological Futures* (Durham: Duke University Press, 2018).

2. What political stakes of life in our current inter-planetary moment does such an intervention articulate and make clear? How does this intervention help us to understand the stakes of the rover (as scientific research and technological development) as a historical material product that emerges through the long histories of US settler colonialism, imperialism, and global racial capitalism?

3. How can such an intervention guide anti-colonial research practice?

As "Automating Discovery" examines the rovers of the Mars Exploration Program a new iteration of the laboratory as the autonomous colonial laboratory, my work is primarily concerned with the politics of the rovers as a mode of scientific research and knowledge production and technological development that reproduces settler/colonial, imperial, and racial capitalist histories, relations and futures. "Automating Discovery" thus understands scientific research, knowledge, and technological development as co-produced with histories and material conditions of settler colonialism, imperialism, and racial capitalism. While the field of science and technology studies has long been concerned with this relationship of co-production, I center and build from Ruha Benjamin's conceptualization of co-production. Benjamin writes:

> "In rethinking the relationship between technology and society, a more expansive conceptual toolkit is necessary, one that bridges science and technology studies (STS) and critical race studies, two fields not often put in direct conversation. This hybrid approach *illuminates* not only *how society is impacted by* technological development, as

techno-determinists would argue, but how social norms, policies, and institutional frameworks shape a context that make some technologies appear inevitable and others impossible. This process of mutual constitution wherein technoscience and society shape one another is called *coproduction*."[6]

At the intersection of STS and critical race studies, Ruha Benjamin makes explicit the ways in which relations that shape the co-production of scientific knowledge, technological development, and society are at once historical, material, and speculative, shaping not only what is, but what can be. While Ruha Benjamin's use of co-production here builds from an abolitionist sensibility and attention (building from Angela Davis's 2003 work in *Are Prisons Obsolete?*[7]) to how certain technological solutions in the carceral imaginary (like prisons, for example) become inevitable and others impossible,[8] Benjamin's use of co-production extends the long traditions of using this conceptual framework in STS to understand the ways in which science, technology, and society are entangled, inseparable, and mutually constituting, particularly from Sheila Jasanoff, Donna Haraway, and Kim TallBear, Karen Barad, and Banu Subramaniam.[9] In particular, "Automating Discovery" seeks to build on Haraway and Subramaniam's attention to hybrid formations of social, material, and technical concepts, classifications, with emphasis on

[6] Benjamin, Ruha. Introduction to *Captivating Technology: Race, Carceral Technoscience, and Liberatory Imagination in Everyday Life*, ed. Ruha Benjamin (Durham: Duke University Press, 2019), p. 4.
[7] Ruha Benjamin, *Captivating Technology*, footnote 16.
[8] Ruha Benjamin, *Captivating Technology*, p. 4.
[9] Jasanoff, Sheila. Introduction to *States of Knowledge: The Co-Production of Science and the Social Order*, ed. Sheila Jasanoff (New York: Routledge, 2004).; Donna Haraway, "The Cyborg Manifesto," in *Manifestly Haraway* (Minneapolis: University of Minnesota Press, 2016), pp. 3-90; Kim TallBear, *Native American DNA: Tribal Belonging and the False Promise of Genetic Science* (Minneapolis: University of Minnesota Press, 2013).; Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham: Duke University Press, 2007).; Banu Subramaniam, *Ghost Stories for Darwin: The Science of Variation and the Politics of Diversity* (Champaign: University of Illinois Press, 2014), p. 5.

their imaginative components. Thus, my use of co-production is in direct conversation with Jasanoff and Kim's definition of sociotechnical imaginaries as "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation specific scientific and/or technological projects,"[10] which was later redefined "as collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology. This definition privileges the word "desirable" because efforts to build new sociotechnical futures are typically grounded in positive visions of social progress."[11] However, working across STS and Critical Race and Ethnic Studies as Benjamin does, I find Benjamin's use of co-production within an abolitionist sensibility to be novel and important for understanding the political stakes of co-production, and especially as "Automating Discovery" seeks to attend to the ways in which histories of colonialism, settler colonialism, imperialism, and global racial capitalism shape the conditions of present-day research on Mars, while at the same time working to shape which futures are fathomable and which are not, towards an anti-colonial politics and sensibility.

Building upon Feminist STS and Critical Race and Ethnic Studies scholarship that has approached the engineering of new technologies as solutions designed to address and redress social and technical problems, drawing specifically from Neda Atanasoski and Kalindi Vora's and Ruha Benjamin's work in this area, I pose NASA's drive for autonomous scientific discovery as a "technological fix,"[12] to the remote control and command of space. "Automating

[10] Sheila Jasanoff and Sang-Hyun Kim, *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, (Chicago: University of Chicago Press, 2015), p. 20.
[11] Sheila Jasanoff and Sang-Hyun Kim, *Dreamscapes of Modernity,* p. 20.
[12] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity: Race, Robots, and the Politics of Technological Futures* (Durham: Duke University Press, 2019); Ruha Benjamin, *Race After Technology: Abolitionist Tools for the New Jim Code* (New York: Polity, 2019); Ruha Benjamin, "Black Afterlives Matter: Cultivating Kinfulness as Reproductive

Discovery" thinks critically about how and why and how such a technological fix became possible, imagined and engineered as a solution to the problems of conducting scientific research remotely, across time, space, and planetary scales. "Automating Discovery" thus seeks to trace and elucidate the conditions under which autonomous scientific discovery became a driving solution to the problems of interplanetary scientific research, while eroding them as a practice of speculation informed by the material histories of these conditions, imagining alternatives that center a politics of what I will describe as interplanetary reproductive justice, or a politics that seeks to think critically and carefully about the kinds of interplanetary worlds, futures and histories we center when we engage in critical discourse and practice concerning interplanetary life, and the technological problems and solutions we imagine to be worthy of materializing as we do so.

I position "Automating Discovery" as concerned with producing situated knowledge. Playing specifically on Donna Haraway's attention to vision as a material and metaphor for scientific knowledge production,[13] each chapter of "Automating Discovery" can be read as an effort to "learn to see" (or "learning to participate in revisualizing worlds"[14]) with "the loving care…to see faithfully from…our own machine,"[15] as a mode of producing situated knowledges as feminist practice, building specifically on what Haraway has written in reference to planetary images:

Justice in *Making Kin Not Population*, eds. Adele E. Clarke and Donna Haraway (Chicago: Prickly Paradigm Press, 2018).

[13] Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies* 14, no. 3 (1988).

[14] Donna Haraway, "Situated Knowldges," p. 586.

[15] Donna Haraway, "Situated Knowledges," p. 583.

> "All these pictures of the world should not be allegories of infinite mobility and interchangeability but of elaborate specificity and difference and the loving care people might take to learn how to see faithfully from another's point of view, even when the other is our own machine. That's not alienating distance; that's a *possible* allegory for feminist versions of objectivity. Understanding how these visual systems work technically, socially, and psychically ought to be a way of embodying feminist objectivity."[16]

"Automating Discovery" seeks to route this mode of vision and care for the machine specifically through the analytics of women of color feminisms and Ethnic Studies, including intersectionality[17] and the matrix of domination.[18] Specifically, I build from Safiya Umoja Noble's observation that "we often think of terms such as "big data" and "algorithms" as being benign, neutral, or objective, they are anything but"[19] as they come to reflect, reinforce, and engineer racial, gendered, and class oppression in the case of Internet search. "Automating Discovery" takes up the ways in which such power and other forms of subjugation, including especially the histories of settler colonialism, colonialism, imperialism, and global racial capitalism are produced and reproduced through and as the computing, algorithmic, and data infrastructure of NASA's Mars Exploration Program and its efforts to engineer autonomous scientific discovery.

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[16] Donna Haraway, "Situated Knowledges," p. 583.
[17] Kimberle Crenshaw, "Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics," *University of Chicago Legal Forum* 1989, no. 1 (1989).
[18] Patricia Hill Collins, "Learning from the Outsider Within: The Sociological Significance of Black Feminist Thought," *Social Problems* 33, no. 6 (1986).
[19] Safiya Umoja Noble, *Algorithms of Oppression: How Search Engines Reinforce Racism*, (New York: New York University Press, 2018), p. 1.

To do this, I use juxtaposition as my method throughout this analysis. An Ethnic Studies method, Kalindi Vora describes juxtaposition as a method of "intentional mismatching of sites of interest and genres of documentation or other modes of archiving, combining often seemingly unrelated sites of labor to highlight the underlying common cultural and economic systems in operation."[20] While focused on labor, Vora describes juxtaposition as "a relational and transnational approach that identifies not only commonalities between groups with different histories but also alternate politics of affinity and connection in the forms of sociality that emerge through the technologies that entangle differently embodied histories"[21] and can thus provide a way of "getting a glimpse"[22] of the material histories of colonialism as "the otherwise unnoticed ground"[23] through which their juxtaposition becomes possible. Extending this method of intentional mismatching of sites of interests and genres of documentation, I juxtapose NASA's Mars Exploration Program, and specifically their fleet of Mars Exploration Rovers (with focus on the engineering of autonomous scientific discovery in their current rovers, *Curioisty* and *Perseverence*), with the histories of US imperialism and colonialism in the Philippines. Through juxtaposition, "Automating Discovery" demonstrates how holding these seemingly disparate sites in tension reveals the transpacific (and specifically the colonial and imperial relations that hold between the United States, the Philippines, Hawaii, and Guam) as one important but obscured condition through which NASA's Mars Exploration Program and its project of engineering autonomous scientific discovery on Mars becomes possible.

[20] Kalindi Vora, *Life Support: Biocapital and the New History of Outsourced Labor*, (Minneapolis: University of Minnesota Press, 2015), p. 20.
[21] Kalindi Vora, *Life Support*, p. 20.
[22] Kalindi Vora, *Life Support*, p. 20.
[23] Kalindi Vora, *Life Support*, p. 20.

"Automating Discovery" seeks to historicize and contextualize NASA's efforts to engineer autonomous scientific discovery through US imperial and colonial relations in the transpacific. Specifically, with attention to the rover as a machine or laboratory for scientific vision, I build on scholarly attention to infrastructure across the fields of STS and postcolonial STS. As a mode of seeing, juxtaposition involves an "intentional mismatching"[24] that often results in contradictions, tensions, and blurry visions. Thus, extending Vora's method of "juxtaposition," I draw on Bowker and Star's use of "double vision"[25] as a method of "infrastructural inversion."[26] In so doing, "Automating Discovery" positions the rover as a laboratory that is built from and installs systems of classification and data infrastructure in its mode of scientific research and knowledge production. But, in conversation with Ethnic Studies scholarship and Postcolonial critiques of STS that have theorized systems of classification and data as vectors of colonial, imperial and other modes of hierarchical power, I then trace these systems of classification and data infrastructure through their settler colonial, colonial, and imperial roots of development.[27] Learning to see, then, becomes a practice of learning to see the rover as the infrastructures of colonialism, imperialism, and global racial capitalism.

"Automating Discovery" uses Vora's method of juxtaposition in combination with Bowker and Star's use of "double vision" as a method of "infrastructural inversion" with Asian American Studies research that emphasizes a (different) mode of "double vision," to learn to see the imperial histories of formation of these information infrastructures in the transpacific. In other words, I use juxtaposition to reveal the role of the transpacific as a shared ground for

[24] Kalindi Vora, *Life Support*, p. 20.
[25] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and Its Consequences*, (Boston: Massachusetts Institute of Technology Press, 1999), p. 35.
[26] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out*, p. 35.
[27] Warwick Anderson, "From subjugated knowledge to conjugated subjects: science and globalization, or postcolonial studies of science?," *Postcolonial Studies* 12, no. 4 (2009).

seemingly disparate projects (and laboratories) of empire and racial capitalism extending from the Philippines to Mars. As Jini Kim Watson observes, "the transpacific, to be sure, offers no disciplinary recipe for oppositional critique" and can be understood "more as a methodological question with many interlocking parts" to "reveal the links between and across the transpacific."[28] Locating this grammar allows us to attend to and foster critical epistemologies and vocabularies, frameworks, through which to understand the imperial histories of the United States' continued investment in economies of scientific expansion and the imperial project of the command and control of space through the expansion of what I describe as networked, autonomous *colonial* laboratories.

While Chapters 1 and 2 are concerned with establishing the Mars Exploration Program rovers as autonomous colonial laboratories more broadly, Chapters 3 and 4 are concerned with placing NASA's efforts to engineer autonomous scientific discovery through the Mars rovers in direct historical relation to the histories of US settler colonialism, imperialism, and global racial capitalism in the transpacific region. The attention that "Automating Discovery" makes to the histories of US imperialism, settler colonialism, colonialism, and global racial capitalism in the transpacific, specifically with reference to US empire across California, the Philippines, Guam, and Hawaii is an effort to historicize and contextualize the Mars Exploration Program as accumulated power for expanding US state and territorial presence. By juxtaposing the Mars Exploration Program with the histories of US imperialism in the transpacific, "Automating Discovery" builds from Vora's insight that juxtaposition is "crucial in making visible and connecting" sites of analysis that are rendered invisible in dominant analytic frameworks that presume their disconnection. "Automating Discovery" thus tells a story of learning to see the

[28] Jini Kim Watson, "Postscript: On Transpacific Futurities," *Journal of Asian American Studies*, 20, no. 1, (February 2017), pp. 119-124.

rover as the accumulation of imperial power through the transpacific, lines of connection that are not often made. I thus position "Automating Discovery" in conversation with Pacific Studies scholarship concerned with "excavating varied and contested futures of the Pacific in the past and present" and arguing "for a focus on Pacific futures as a site of and for empirical study and theorization of comparative historicities or modes of historical consciousness."[29]

Writing in a time of what many describe as an emerging billionaire space race, "Automating Discovery" builds from long traditions of feminist critiques of Marxism and social reproduction to position NASA's efforts to engineer autonomous scientific discovery on Mars in relation to the planetary histories of the US accumulation of power and capital within the growth of global racial capitalism. Silvia Federici has observed:

> "Capital has long dreamed of sending us to work in space, where nothing would be left to us except our work machines and rarified and repressive work relations. But the fact is that the earth is becoming a space station where millions are already living in space colony conditions: no oxygen to breathe, limited social and physical contact, a desexualized life, difficulty of communication, lack of sun and green…even the voices of migrating birds are missing. Our own bodies are being enclosed."[30]

While "Automating Discovery" is careful not to draw strong comparisons between life on Earth and in space, I am interested in Federici's observations about space, labor, and the new

[29] Miranda Johnson, "Introduction: The Declension of History," in *Pacific Futures: Past and Present*, eds. Warwick Anderson, Miranda Johnson, and Barbara Brookes (Honolulu: University of Hawaii Press, 2018), p. 2.
[30] Silvia Federici, "Introduction to the New Enclosures" in *Re-enchanting the World: Feminism and the Politics of the Commons* (Oakland: PM Press, 2018), p. 30.

enclosures of capital in our emerging interplanetary moment. "Automating Discovery" builds on this scholarship to consider NASA's efforts to engineer autonomous scientific discovery on Mars as a new enclosure, and a new mode of primitive accumulation (this time of data, of infrastructure, and technological power) that builds upon and extends the histories of accumulation of capital (and specifically US capital) in the long histories of US and global racial capitalism on Earth. "Automating Discovery" thus seeks to position the rover as an autonomous laboratory (that is, a material site through which scientific labor is performed or enacted, distributed, and accelerated at new scales) that builds upon and extends the relationships between labor, capital, and scientific research and technological development, and nominates the Mars rover as a generative site through which we might consider how these relationships guarantee the expansion of scientific research (as an epistemology) and technological development in service of the continued accumulation of US capital and state power.

"Automating Discovery" builds from recent scholarship in STS about NASA's Mars Exploration Program, space, and planetary science more broadly. Specifically, I draw from Lisa Messeri and Janet Vertesi's important ethnographic and analytic work,[31] but seek to do so in conversation with the theories, methods, and analytic traditions of women of color feminisms, Ethnic Studies, and feminist STS, especially with respect to their emphasis on colonialism and other forms of power as conditions of NASA's Mars Exploration Program.

Learning to see the rover as an accumulation of imperial power is practice of learning to see the rover and learning to care for the machine and the worlds it emerges from and (re)produces through what Michelle Murphy has described as alterlife, "the struggle to exist

[31] Lisa Messeri, *Placing Outerspace: An Earthly Ethnography of Other Worlds*, (Durham: Duke University Press, 2016).; Janet Vertesi, *Seeing Like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*, (Chicago: The University of Chicago Press, 2014).

again *but differently* when already in conflicted, damaging, and deadly conditions, a state of already having been altered, of already being in the aftermath, and yet persisting."[32] While the Mars Exploration Program is a project of terraformation, "Automating Discovery" and its efforts to learn to see and care for the machine as a practice of alterlife is a project about the material conditions of the worlds that we inhabit, and the systems of power that make these worlds livable and not livable. As "Automating Discovery" is concerned with the politics of scientific research, knowledge production, and technological development and their relationships with and as ongoing structures and legacies of settler colonialism, colonialism, imperialism, and global racial capitalism, "Automating Discovery" embraces alterlife as what Murphy describes as a politics for guiding "distributed reproductive justice."[33] In this sense, "Automating Discovery" is a reproductive justice project, seeking to interrupt the expansion of the Mars Exploration Program as a mode of worldbuilding that relies on, emerges from, and reproduces the ongoing structures of settler colonialism, imperialism, and global racial capitalism, towards articulating alternative modes of seeing and learning to care for the machine that might support alterlife.

Each chapter of "Automating Discovery" "materializes" the fantasy of automating discovery through a different case study. To identify these case studies, I drew on a methodological practice of "implosion," working from Joseph Dumit's *Implosion Project*, a more formalized method, pedagogy, and practice from Donna Haraway's pedagogical approach to "implode" the everyday objects around us, to "connect us to world histories that way."[34] The idea is that you can pick any object in the world and see "how the world is in that object, and

[32] Michelle Murphy, "Against Population, Towards Alterlife" in *Making Kin Not Population*, eds. Adele E. Clarke and Donna Haraway, (Chicago: Prickly Paradigm Press, 2018), p. 113.
[33] Michelle Murphy, "Against Population, Towards Alterlife," p. 111.
[34] Joseph Dumit, "Writing the Implosion: Teaching the World One Thing at a Time," *Cultural Anthropology* 29, no. 2, (2014).

how it is in the world." The power of the Implosion Project is, as Dumit observes, its power "to disrupt our own tolerance of how to see the intolerable in the everyday."[35] The Implosion Project is designed to bring us to a living politics of non-innocence and complicity, as Dumit explains "[n]on-innocence and complicity are necessary if one is to confront world histories as histories that one is a part of and accountable to."[36] In the Implosion Project, waking up is a practice of accountability, a practice through which we might become accountable.

To guide my practice of implosion, I draw on women of color feminisms to ground this methodological sensibility and shape questions of accountability, responsibility, and complicity. As part of the Implosion as a methodology seeks to articulate the particular connections that shape our everyday life, women of color feminisms and queer of color critique's theories of relationality inform my theorization of and attention to these relations, particularly as they draw attention to seemingly disparate and mismatched sites of interest and genres of documentation, as they emerge in our present conditions of the relations of global racial capitalism and US imperialism, and thus provide a useful guidepost for my use of Vora's juxtaposition. Specifically, I build from Grace Kyungwon Hong and Roderick Ferguson's work in *Strange Affinities* to show how women of color feminism and queer of color critique articulate a mode for finding modes of comparison, relation, and affinity across the histories of power and difference through cultural production as a strategy for strengthening coalition, through what they term "strange affinities."[37] "Automating Discovery" considers scientific research as a mode of cultural production specific to the dominant, Western imperial and colonial gaze, and then, through

[35] Joseph Dumit, "Writing the Implosion," p. 347.
[36] Joseph Dumit, "Writing the Implosion," p. 348.
[37] Grace Kyungwon Hong and Roderick A. Ferguson, Introduction to *Strange Affinities*: *The Gender and Sexual Politics of Comparative Racialization*, eds. Grace Kyungwon Hong and Roderick A. Ferguson, (Durham: Duke University Press, 2011), p. 18.

juxtaposition, considers other sites of cultural production across the transpacific that are elided by this gaze or antithetical to it, to uncover, as a mode of implosion, the colonial and imperial relations that hold this mode of cultural production together.

I also draw upon Audre Lorde's call to political action through what I recognize as a kind of "implosion" of her experience of racist violence in the everyday – that is, finding connections across scales of experience, material conditions of living – in a way that questions how we must respond once we realize the ways in which power shapes our everyday. Specifically, Lorde's articulation of the connections of the everyday asks us to reckon with the histories of power that shape our everyday life, the non-innocence and complicity of our everyday lives, and the responsibility to be accountable to this connection in a speech that resonates as true today as it was when she first delivered it in 1982:

> "Within each one of us there is some piece of humanness that knows we are not being served by the machine which orchestrates crisis after crisis and is grinding all our futures into dust. If we are to keep the enormity of the forces aligned against us from establishing a false hierarchy of oppression, we must school ourselves to recognize that any attack against Blacks, any attack against women, is an attack against all of us who recognize that our interests are not being served by the systems we support. Each one of us here is a link in the connection between anti-poor legislation, gay shootings, the burning of synagogues, street harassment, attacks against women, and resurgent violence against Black people. I ask myself as well as each one of you, exactly what alteration in the particular fabric of my everyday life does this connection call for? Survival is not a theory. In what way do I contribute to the subjugation of any part of those who I define as

> my people? Insight must illuminate the particulars of our lives: who labors to make the bread we waste, or the energy it takes to make nuclear poisons which will not biodegrade for one thousand years; or who goes blind assembling the microtransistors in our inexpensive calculators?"[38]

Audre Lorde's call for us to become accountable to the systems of power that shape our everyday lives and the connections or relations they engender by taking specific action to alter "the particular fabric"[39] of our everyday lives is a guidepost for each chapter, particularly in terms of shaping the politics for anti-colonial research practice that my research seeks to make. In so doing, "Automating Discovery" seeks to draw upon long traditions of activism and scholarship at the intersections of critical race studies, Ethnic Studies, women of color feminism and queer of color critique, and Feminist and anti-colonial Science and Technology Studies to think critically and resist the default understanding of "we" as an unmarked, universalizing category of collectivity and commons, and instead pose "we" as a coalitional practice of affiliation through difference and anti-colonialism.[40]

In this way, I see "Automating Discovery" as an intervention primarily into the field of Science and Technology Studies, and particularly in the subfield of laboratory studies, reading the rover as an autonomous colonial laboratory and update to Latour's distributed laboratory of the world. To do this, I also seek to intervene on and build from current scholarship in STS concerned with NASA's Mars Exploration Program, from scholars like Lisa Messeri and Janet

[38] Audre Lorde, "Learning from the 60s," in *Sister Outsider: Essays and Speeches by Audre Lorde*, (Berkeley: Crossing Press, 2007), p. 139.
[39] Audre Lorde, "Learning from the 60s," p. 139.
[40] Max Liboiron, *Pollution is Colonialism*, (Durham: Duke University Press, 2020), p. 23; Julietta Singh, *Unthinking Mastery: Dehumanism and Decolonial Entanglements*, (Durham: Duke University Press, 2018), p. 173.

Vertesi, to build a bridge between their work and the fields of Ethnic Studies and Women of Color Feminism. The primary intervention of "Automating Discovery" is thus to keep questions of power, systems of domination, and histories of colonialism and imperialism at the center of inquiry about the futures we desire, imagine, and engineer on Mars.

It was important for "Automating Discovery" to trace the often elusive, invisible, and disparate formations through which such systems of power shape these futures, through both official and unofficial sites and formations where autonomous scientific discovery emerges, in the range of sites where this imaginary is "engineered" both technically, speculatively, and culturally through the histories of US colonialism and imperialism. "Automating Discovery" found important and under-researched sites of inquiry in the material histories and relationships between US transpacific colonialism and imperialism since 1945 and the engineering of autonomous scientific discovery on Mars. Bringing the transpacific to the forefront of historical material inquiry into the futures of US autonomous scientific discovery on Mars, "Automating Discovery" reads critically across an eclectic archive composed of a range of primary source materials, including: technical papers and videos that detail the engineering of autonomy in Mars rovers, and NASA's network and data infrastructure (including its citizen science portal, AI4Mars) to support the Mars Exploration Program; social media images of the *Curiosity* rover circulated by NASA on *Curiosity*'s Twitter account; archived images and news media pertaining to the Mars rovers (including *Spirit*, *Curiosity*, and *Perseverance*); a postcolonial Filipino speculative fiction about US space exploration and the Philippines; news media articles about sand erosion in the transpacific region and climate crisis; and historical documents that detail the installation of networked infrastructure for the development of the Internet in the transpacific region. These sites and sources articulate a relationship between NASA's Mars Exploration

Program with histories of US settler colonialism, colonialism, and imperialism in the transpacific region, with emphasis on US relations with Hawaii and the Philippines. In the areas of the archive that were thin, "Automating Discovery" turned to feminist speculative practices and speculative fiction to articulate bridges through gaps in the archive, informed by the fields of Science and Technology Studies (STS), Feminist STS, Postcolonial STS, and Critical Race and Ethnic Studies.

This approach was important to address the research questions posed in "Automating Discovery," especially as they seek to keep questions of power, and especially the histories of colonialism and imperialism in the transpacific region, central to its intervention. That is, reading critically with, against, and through an expansive archive composed of eclectic primary sites and sources was important to answer the research questions of "Automating Discovery" through its primary method of juxtaposition, tracing and connecting seemingly disparate or mismatched sites of inquiry in order to reveal the often obscured or otherwise invisible systems of power that hold them together, and make their connection possible. Furthermore, assembling an archive of this nature and reading critically through it became an important approach for understanding the relationships between the Mars Exploration Program and the histories of US imperialism, settler colonialism, and colonialism in the transpacific region, as these histories are not often at the forefront of critical inquiries into US technological development and scientific research on Mars. An eclectic and expansive archive thus seeks to assemble sites of inquiry that make this kind of analysis possible, especially where the official archives of US efforts to engineer autonomous scientific discovery on Mars are thin, or absent.

Lastly, it was important in working with such an eclectic and expansive archive in an interdisciplinary space that worked across several fields that are themselves interdisciplinary that

"Automating Discovery" make use of a robust feminist citational practice, by giving adequate space to the work of key authors and scholars who have written arguments that are important and relevant to the critical inquiry that "Automating Discovery" seeks to make. This is a kind of interdisciplinary, feminist citational practice that seeks to ensure that cited authors are represented as fully as possible in their own words in order to create interdisciplinary conversation in a way that seeks to honor the original arguments, contexts, and intentions of the authors. This citational practice also acknowledges the labor that has made the arguments of "Automating Discovery" possible.

Each chapter thus addresses one key aspect through which autonomous scientific discovery on Mars is engineered through the Mars rovers. Chapter 1 sets the stage for the study and introduces the *Curiosity* rover as the façade of NASA's efforts to engineer autonomous scientific discovery, tracing the ways in which the *Curiosity* rover enacts what I call the "subject effect" (building from Atanasoki and Vora's "surrogate effect") of the rover as a new formation or figuration of Daston and Gallison's scientist subject, an updated form of machine objectivity that establishes the fantasy of the autonomous scientific laboratory and autonomous scientific discovery. I show the ways in which the production and circulation of rover selfies enacts the fantasy of autonomous scientific discovery, and of the Curiosity rover as an autonomous scientific laboratory and an updated formation of the figure of the scientist subject in the history of objectivity. In conversation with feminist critiques of objectivity and ethnic studies critiques of the liberal subject, I describe the ways in which the circulation of rover selfies on narrative social media platforms like Twitter redescribes scientific practices of observation and machine maintenance and care as part of the fantasy of autonomous scientific discovery. I show how this fantasy of the autonomous scientific laboratory emerges through the coproduced of the technical

object with the frontier imaginary, thus signaling the continued investment in the coloniality of scientific practice. Then, I suggest we can turn to this practice of "care for the machine" in order to read for alternative possibilities of feminist objectivity in the rover selfies. I put this alternative reading practice, one that seeks to disunify the subject-effect of the figure of the rover subject as a coherent, ideal scientist subject and frontier hero, in conversation with postcolonial and decolonial computing, to articulate alternative possibilities for anti-colonial research practice and cultures of Mars research.

While Chapter 1 introduces the fantasy of autonomous scientific discovery through the fantasy of the autonomous laboratory and its subject effect of the scientist subject, Chapter 2 is the first of two chapters to examine how this fantasy of autonomous scientific discovery is engineered through autonomous terrain classification algorithms. Specifically, Chapter 2 examines AI4Mars, NASA's online citizen science platform used to create training datasets for its algorithm, Soil Property and Object Classifier (SPOC), an algorithm that enables the Mars rovers to perform autonomous terrain classification, navigation, and decision-making. Chapter 2 examines AI4Mars as an online citizen science platform and labor infrastructure that uses the Internet as a mode of engineering autonomous scientific discovery on Mars. Thus positioning AI4Mars as a "gateway" to the future but for an unmarked, universalized citizen scientist, I juxtapose NASA's AI4Mars as an online platform, a new technological commons, and distributed laboratory with the colonial and imperial histories of the transpacific Internet in the Philippines, and the historical moment of the first commercial internet connection in the Philippines where the NASA Ames Research Center was declared to be the "gateway" to the world for the Philippines in 1994. Holding these two moments in tension through juxtaposition, I then turn to Gregorio Brillantes' 1980 *The Apollo Centennial*, a Filipino speculative fiction that

offers a glimpse into a speculative future in the Philippines in 2069, 100 years after the US Moon Landing in 1969, to reveal the (post)colonial and imperial ground through which AI4Mars can be read as an extension of histories of US transpacific imperialism and colonialism, and another moment where NASA becomes a "gateway" to futurity for a universalized subject while obscuring those who are kept on the peripheries of its expansion. In so doing, I extend Bowker and Star's infrastructural inversion to hold the "double vision" of the Internet as a colonial and imperial infrastructure and the Internet as a technological commons that purports to democracy and collectivity, in tension with the "double vision" of the imagined futures of AI4Mars and the imagined futures of *The Apollo Centennial*, to learn to see what I describe as the residue of the "transit of empire"[41] through the continued use of the laboratory model for scientific research across the transpacific and Mars.

Chapter 3 again takes up the engineering of Soil Property and Object Classifier (SPOC), one of the algorithms that enables the rovers to perform autonomous terrain classification, navigation, and decision-making. I examine the engineering of autonomous terrain classification, and in particular the development of SPOC as a novel autonomous terrain classifier that can accurately classify sand on Mars. I theorize the rover as a new formation of the laboratory, the autonomous colonial laboratory. After identifying intelligence as the arbiter of colonial imperial expansion, I offer a way to resist the reproduction of machine intelligence through the methods of juxtaposition and double vision. I juxtapose the computational vision of sand that expands the autonomous colonial laboratory with the geologic vision of sand. Holding both in a practice of "double vision," I consider what escapes computational visions of sand. Specifically, I argue that computational visions of sand "see" at the surface (literally), while absenting the depth of sand as

[41] Jodi A. Byrd, *The Transit of Empire: Indigenous Critiques of Colonialism*, (Minneapolis: University of Minnesota Press, 2011).

a geologic formation that evidences planetary history and movement - a mode of seeing that offers a different kind of relationally than computational vision installs. I offer "double vision" - or seeing both the computational vision of sand in juxtaposition with the geologic vision of sand - as a technique of anti-colonial practice that can grapple with the politics of interplanetary life in our current moment. Specifically, I offer a vision of geologic sand in the transpacific, connecting the City of Manila, Philippines and the city of San Francisco, California through sand and the rising tides of climate crisis, in a 2020 New York Times investigative report that profiled these two cities as intimately connected across the transpacific in their experience of climate crisis.[42] In so doing, "Automating Discovery" offers sand as a material ground and speculative archive that holds more than what a computational vision of sand can hold. This geologic vision of sand, I suggest, offers a way to resist the timescales of human efforts to engineer autonomous scientific discovery, and the extraction and accumulation of sand as data (primitive accumulation of capital) for the expansion of the autonomous colonial laboratory, while seeing disparate sites across the transpacific as intimately connected through the afterlives of colonialism, imperialism, climate crisis and global racial capitalist accumulation.

The last chapter, Chapter 4, examines the projected engineering and future use of Disruption Tolerant Networking to expand the infrastructure and capabilities of the rovers of the Mars Exploration Program, and offers a feminist material history of DTN as a network protocol designed to support, enable, and expand autonomous scientific research capabilities on Mars, by placing DTN in direct historical relation to the racialized and imperial formation of computer networks in US settler colonial research laboratories in the Pacific in the 20th Century,

[42] Somini Sengupta, "A Crisis Right Now: San Francisco and Manila Face Rising Seas," *The New York Times*, February 13 2020, https://www.nytimes.com/interactive/2020/02/13/climate/manila-san-francisco-sea-level-rise.html.

specifically the research and development of the ALOHA Protocol at the University of Hawaii. By juxtaposing Disruption Tolerant Networking with the ALOHA Protocol, I reveal the ways in which the United States has long used information infrastructure as a tool to enable the capture of land, the extraction of resources, and the flow of capital necessary for the expansion of empire. I then reflect on transpacific networks as sites through which alternative relations might be formed in coalitional support for the ongoing struggles for decolonization and Indigenous sovereignty in Hawaii.

Chapter 1: A New Formation of the Scientist Subject

Abstract

Chapter 1 sets the stage for the study and introduces the *Curiosity* rover as the façade of NASA's efforts to engineer autonomous scientific discovery. This chapter traces the ways in which the *Curiosity* rover enacts what I call the "subject effect" (building from Atanasoki and Vora's "surrogate effect") of the rover as a new formation or figuration of Daston and Gallison's scientist subject--an updated form of machine objectivity that establishes the fantasy of the autonomous scientific laboratory and autonomous scientific discovery. I examine the production and circulation of rover selfies as a technique through which the fantasy of the autonomous scientific laboratory is enacted. First, I show the ways in which the production and circulation of rover selfies enacts the fantasy of autonomous scientific discovery, and of the Curiosity rover as an autonomous scientific laboratory and an updated formation of the figure of the scientist subject in the history of objectivity. In conversation with feminist critiques of objectivity and ethnic studies critiques of the liberal subject, I describe the ways in which the circulation of rover selfies on narrative social media platforms like Twitter redescribes scientific practices of observation and machine maintenance and care as part of the fantasy of autonomous scientific discovery. I show how this fantasy of the autonomous scientific laboratory emerges through the

coproduced of the technical object with the frontier imaginary, thus signaling the continued investment in the coloniality of scientific practice. Then, I suggest we can turn to this practice of "care for the machine" in order to read for alternative possibilities of feminist objectivity in the rover selfies. I put this alternative reading practice, one that seeks to disunify the subject-effect of the figure of the rover subject as a coherent, ideal scientist and frontier hero, in conversation with postcolonial and decolonial computing, to articulate alternative possibilities for anti-colonial research practice and cultures of Mars research.

Figure 1: High-Resolution Self-Portrait by *Curiosity* Rover Arm Camera.[43]

[43] NASA's Mars Exploration Program, "High-Resolution Self-Portrait by *Curiosity* Rover Arm Camera," November 1 2012. Accessed: .

Rover Selfies and the "Subject Effect" of Autonomous Scientific Discovery

The rover selfie has become an iconic image representing NASA's Mars Exploration Program. Indeed, the production and circulation of the rover selfie is one of the primary ways in which NASA's Mars Exploration Program is materialized in the public sphere through narrative social media platforms like Twitter. The Mars rovers each have their own Twitter account, for example, and NASA's social media teams ensure that the Mars Exploration Program is actively narrated across this platform. It is through Twitter that the Mars Exploration Program is made tangible and relevant to the public, as social media becomes the channel through which otherwise obscure, distant, and abstract practices of scientific research are made real.

Most of the descriptions of the role of Twitter in the following paragraph describe a similar point. Try to combine these points and cut the extraneous or repetitive ones? -- Social media platforms like Twitter thus become an archive of scientific practice as NASA's fantasy of autonomous scientific discovery and exploration are articulated. NASA's fantasy of the autonomous scientific discovery is enacted through a distributed information infrastructure. This chapter will examine the role that the Twitter account that represents the Mars Science Laboratory, *Curiosity*, has in the Mars Exploration Program, and the ways in which this form of digital media enacts and shapes the fantasy of autonomous scientific discovery. I trace the ways in which media infrastructure enact the narrative elements of this fantasy, along with ways in which the production and circulation of rover selfies creates the fantasy of the rover as an autonomous scientific laboratory capable of performing what is described as autonomous scientific discovery. I then show that this narrative fantasy obscures the scientific practice of

imaging and observing the rover for maintenance, as these practices of imaging get re-inscribed as techniques of the self, producing the rover as an ideal scientific self. In this chapter I show how the circulation of rover selfies on narrative social media platforms like Twitter redescribes scientific practices of observation and machine maintenance and care as part of the fantasy of autonomous scientific discovery, such that the rover selfie comes to function as an embodied and narrative representation of the rover as an ideal scientist, which I characterize as a version of the trope of the frontier hero. In conversation with the histories of scientific and feminist objectivity, I show how the representation and circulation of rover selfies on narrative platforms like Twitter thus mark the emergence of a new formation of the figure of the rover subject as an updated version of the "scientist subject." This formation reproduces the scientific practice of observation on Mars through the coloniality of scientific and mechanical vision and the fantasy of the rover as an ideal figuration of scientific subjectivity.[44]

Rover selfies are one of the most iconic and celebrated elements of NASA's Mars Exploration Program, frequently positioned as an innovation in NASA's technological capabilities. NASA's descriptions of the process of producing the rover selfie typically likens it to a more complex version of the commonplace selfies of our everyday. NASA's JPL explains:

> The way you and I might take a selfie is by holding the camera out with our arm and taking a single image. The way the rover takes a selfie is a little more complex than that. The way the rover takes a selfie is by using the WATSON camera at the end of the

[44] See Aimee Banhg, *Migrant Futures: Decolonizing Speculation in Financial Times*, (Durham: Duke University Press, 2018); Saidiya Hartman, *Scenes of Subjection: Terror, Slavery, and Self-Making in Nineteenth Century America*, (New York: Oxford University Press, 1997).; Julietta Singh, *Unthinking Mastery*., for precedent of reading practice across Ethnic Studies.

> robotic arm. But the WATSON camera was designed to take closeup images of rocks for scientific analysis. And even with the arm fully extended, we can't cover the entire rover in a single image. To capture the entire rover, we take multiple images and then stitch them together. In order to do that, we try to hold the WATSON camera sensor in the same position to take the different images. In order to keep the camera at the same position and take the different image frames, have to move quite a lot. It can take up to an hour of arm motion and imaging to take that entire selfie. When a person takes a selfie, we just hold our arm up and take a single image. To create the first Perseverance selfie, it took an entire team of people working together for almost an entire week. In the end, it took 62 images stitched together to create the resulting selfie.[45]

The production of the selfie, and its circulation on narrative platforms like Twitter, ensure the construction of the autonomous rover subject. Rover selfies, and their representation and circulation on Twitter, depict the figure of the rover subject as an agential, self-aware subject—this is the "subject-effect".[46] In this way, the production and circulation of the rover selfies represents the vision of the rover as an idealized figuration of scientific vision and scientific subjectivity.

[45] NASA's Jet Propulsion Laboratory, "How NASA's Perseverence Rover Takes a Selfie," June 25 2021, https://www.jpl.nasa.gov/videos/how-nasas-perseverance-rover-takes-a-selfie.; NASA's Jet Propulsion Laboratory, "Watch (and Hear) How NASA's Perseverence Rover Took its First Selfie," June 25 2021, https://www.jpl.nasa.gov/news/watch-and-hear-how-nasas-perseverance-rover-took-its-first-selfie.

[46] My use of "subject effect" here is an iteration on Atanasoski and Vora's use of the "surrogate effect" in *Surrogate Humanity*.

Figure 2: *Curiosity* Rover Tweet, February 7 2013.[47]

Figure 3: *Curiosity* Rover Tweet, June 21 2017.[48]

[47] *Curiosity* Rover, Twitter post, February 7 2013, 5:58PM, https://twitter.com/marscuriosity/status/299698751415652352.
[48] *Curiosity* Rover, Twitter post, June 21 2017, 3:59PM, https://twitter.com/marscuriosity/status/877662374240542721.

The Coloniality of Vision and the New Scientist Subject

As the rover selfies thus produce the "subject-effect" of the rover as an autonomous scientist with ideal scientific vision, the figure of the rover subject marks a shift in the long history of scientific objectivity, the production of scientific knowledge, and the development of technologies as "ways of seeing."[49]

For example, in *Objectivity*, Daston and Galison historicize the relationships between scientific objectivity and the development of technologies as a mode of scientific vision by tracing the emergence of the scientific gaze, objectivity as a technique of vision and seeing the world through scientific subjectivities, or the scientific self, since the 19th C.[50] Daston and Galison offer that "[t]o be objective is to aspire to knowledge that bears no trace of the knower – knowledge unmarked by prejudice or skill, fantasy or judgment, wishing or striving. Objectivity is blind sight, seeing without interference, interpretation, or intelligence."[51] Daston and Galison describe the history of objectivity as "part of the history of the self…[o]r more precisely of the scientific self" as objectivity is dialectically articulated through the opposition of the subject and object, such that objectivity becomes "the suppression of some aspect of the self, the countering of subjectivity."[52]

Importantly, Daston and Galison describe the coproduction of objectivity and the scientific self, observing that "techniques of the self were also practices of scientific objectivity" such that "the broader notion of (for example) a will-based scientific self was articulated – built up, reinforced – through concrete acts, repeated thousands of times in a myriad of fields in which

[49] Lorraine Daston and Peter Galison, *Objectivity*, (Princeton: Princeton University Press, 2010).
[50] Lorraine Daston and Peter Galison, *Objectivity*, p. 35.
[51] Lorraine Daston and Peter Galison, *Objectivity*, p. 17.
[52] Lorraine Daston and Peter Galison, *Objectivity*, pp. 36-7.

observes struggled to act, record, draw, trace, and photograph their way to minimize the impact of the their will."[53] Daston and Galison observe that "forms of scientific self and epistemic strategies enter together."[54] Daston and Galison observe that 19th C scientific objectivity and the scientific self were a moral and political figure, noting that the formation of the scientific self was bound up in an ethics of "how to do science and become a scientist" such that "[t]he master of scientific practices is inevitably linked to self-mastery, the assiduous cultivation of a certain kind of self."[55]

Daston and Galison write that "[i]n the making of images, the taking of measurements, the tracing of curves, and many other scientific practices of the latter half of the nineteenth century, *self*-elimination became an imperative."[56] They note that mechanical objectivity emerged to eliminate the self[57], in conversation with Foucault's "technologies of the self"[58], noting that scientific practices like "training the senses in scientific observation, keeping lab notebooks, drawing specimens, habitually monitoring one's own beliefs and hypotheses, quieting the will, and channeling the attention…do not merely express a self; they forge and constitute it. Radically different practices are *prima facie* evidence of different selves."[59]

Following Daston and Galison's genealogy of the scientific self and scientific objectivity, the production of rover selfies and their circulation on narrative social media platforms like Twitter mark the emergence of a new formation of the scientific self, one that enacts a "subject-effect" in the rover in ways that complicate the historical boundary between mechanical objectivity and the scientific self. Following Daston and Galison, I position the rover as a new

[53] Lorraine Daston and Peter Galison, *Objectivity*, p. 38.
[54] Lorraine Daston and Peter Galison, *Objectivity*, p. 39.
[55] Lorraine Daston and Peter Galison, *Objectivity*, p. 40.
[56] Lorraine Daston and Peter Galison, *Objectivity*, pp. 196-7.
[57] Lorraine Daston and Peter Galison, *Objectivity*, p. 198.
[58] Lorraine Daston and Peter Galison, *Objectivity*, p. 198.
[59] Lorraine Daston and Peter Galison, *Objectivity*, p. 199.

type of the scientist that emerges "as a regulative ideal"[60] and "an ethical and epistemological code imagined as a self" through both, as Daston and Galison identify, the "the panorama of the public portrayal of scientists" and the techniques that define their scientific practices. In the case of the rover, the production of rover selfies and their circulation on narrative social media platforms like Twitter, mark a moment where a new type of scientific self can emerge, as the selfie encodes both the scientific practice of observation and vision, while publicly portraying the fantasy of the rover as a scientist. For example, a tweet from 2019 portrays a rover selfie within a narrative caption that names the rover as a "robotic geochemist checking in with an update from the field" while another tweet from 2016 captions another rover selfie with "can't wait to share science results from Namib Dune." Another tweet captions a rover selfie with a description of research protocols and practices, positioning the practice of taking a selfie as a one concurrent with scientific exploration, stating that "I took another selfie as I explored a new spot…where I'm analyzing drill samples" before adding "I conducted experiments on them in my continued search for organic molecules." The use of *I* in the captioning of these rover selfies enacts the "subject-effect" of the formation of the scientist-subject. This is amplified and sharpened by the use of the postscript in the following caption that states the process by which the selfie was taken. The narrative subject-effect of the rover as the scientist-subject is always represented in tension with its material conditions of production.

[60] Lorraine Daston and Peter Galison, *Objectivity*, p. 204.

Figure 4: *Curiosity* Rover Tweet, October 24 2019.[61]

[61] *Curiosity* Rover, Twitter post, October 24 2019, 12:45PM, https://twitter.com/MarsCuriosity/status/1187455153793830913?cxt=HHwWgsC0yfiK2PogAAAA.

Figure 5: *Curiosity* Rover Tweet, January 29 2016.[62]

Figure 6: *Curiosity* Rover Tweet, November 12 2020.[63]

Another selfie is even "annotated with recent investigation targets."

[62] *Curiosity* Rover, Twitter post, January 29 2016, 10:49AM, https://twitter.com/MarsCuriosity/status/693143910009311232?cxt=HHwWgMCk5datxZ4TAAAA.
[63] *Curiosity* Rover, Twitter post, November 12 2020, 9:46AM, https://twitter.com/marscuriosity/status/1326944385741807616?lang=en.

Figure 7: *Curiosity* Rover Tweet, February 24 2015.[64]

Importantly, Daston and Galison map the ways in which the scientific self emerges to meet the demands of the dominant epistemic values of the scientific practices of the time.[65] In the case of the rover, the production and circulation of the rover selfies suggests that the particular scientific self emerges so as to meet the demands of the epistemic values of exploration and discovery. For example, a tweet from 2022 portrays a rover selfie within a narrative caption describing the rover as "trailblazing new paths for understanding our universe [and] [e]xploring uncharted territory." A tweet from 2016 captions a rover selfie with a New Year's greeting that "I hope your next trip around the sun is full of exploration and discovery."

[64] *Curiosity* Rover, Twitter post, February 25 2015, 1:32PM, https://twitter.com/marscuriosity/status/570335587917385729.
[65] Lorraine Daston and Peter Galison, *Objectivity*, p. 204.

Figure 8: *Curiosity* Rover Tweet, February 13 2022.[66]

[66] *Curiosity* Rover, Twitter post, February 13 2022, 8:49AM, https://twitter.com/MarsCuriosity/status/1492903671146844163?cxt=HHwWhsCsqdX-7bcpAAAA.

Figure 9: *Curiosity* Rover Tweet, December 31 2016.[67]

Another tweet captions a rover selfie with "Wish you were here" before the imperative to "send your name to Mars aboard the next rover."

Figure 10: *Curiosity* Rover Tweet, September 26 2019.[68]

[67] *Curiosity* Rover, Twitter post, December 31 2016, 4:08PM, https://twitter.com/MarsCuriosity/status/815349037343703044?cxt=HHwWiICgraXo2dAWAAAA.
[68] *Curiosity* Rover, Twitter post, September 26 2019, 10:52AM, https://twitter.com/MarsCuriosity/status/1177279716543197184?cxt=HHwWgMCjncXqxNYgAAAA.

Critiques of Objectivity and the Scientific Self

In this section I position the rover selfie / scientific self in conversation with histories of feminist critiques of objectivity. I show that the rover comes to represent the view from nowhere, but embodied through the machine in a way that complicates the clean distinction between the universal and the particular. The way that particular perspectives are stitched together produce a universalizing gaze and coherent subjectivity of the rover. I show how the figure of the rover as a scientist self is a complicated figuration of the view "from somewhere" and the view "from nowhere". But the representation of a singular vision ultimately reaffirms the universalizing gaze. I show this universalizing gaze to be articulated within/as the fantasy of the technoliberal subject, the techniques of image construction and vision propping up the autonomy of the rover, creating the rover as a coherent subjectivity, in ways that obscure and perhaps disavow the limited vision and partial perspective that the rover actually has.

These images might be read through the feminist trope of what Donna Haraway (1988) described as "the god-trick,"[69] a "view from above,"[70] or the disembodied gaze of scientific objectivity that produce the "subject-effect" of the rover. However, Vertesi argues that the view from the rover is not a god's eye view, not the view from nowhere, and resists the idea that it is the rover's view as well. Vertesi writes:

> "Transforming Mars into a vision you would see if you were there invites the viewer to step into the frame, into the rover's tracks so often visible in the scene. This is not a view

[69] Donna Haraway, "Situated Knowledges," p. 581.
[70] Donna Haraway, "Situated Knowledges," p. 590

> from nowhere or a God's- eye view. Instead the viewer is very clearly situated on Mars, alongside the robot. Nor is it especially a rover's- eye view. Unlike the conventions of seeing like a Rover described in chapter 6, these images present a view oriented toward the human observer. This was especially underscored for me when I interviewed a Pancam team member who was attempting to write software that would convert all rover images to a perspective as if the image had been taken from six feet above the Martian soil, not five. This, he explained, would be more like a human's perspective on Mars than the rover's. Human presence on Mars thus appears natural and seamless, arising from the landscape. This is the result of members' practical image craft that draws Mars as the new American frontier. It is the visual aspect of the Martian picturesque."[71]

Building on Vertesi's analysis, I note that the view represented in the rover selfie is coproduced with the racial imperial histories of the subject, and the racial imperial histories that have produced Mars through the colonial fantasy of the frontier. Indeed, Vertesi centers the fantasy of Mars as an American frontier as part of her analysis of the production of the visual aspects of the Martian picturesque. Vertesi writes:

> "A primary characteristic in framing reflects a genre broadly classifiable as that of the American frontier. Countless rover images show tracks receding toward a distant horizon reminiscent of wagon wheels on a pioneer trail (fig. 8.4). The award-winning promotional animation for the Rover mission (produced by a student on the mission at the time) depicts the rover descending from its landing module onto the Martian terrain and

[71] Janet Vertesi, *Seeing Like a Rover*, p. 30.

> heading off into the sunset like a cowboy in a Western movie.36 Such framings frequently evoke American photographic traditions ranging from Ansel Adams's towering landscapes of Yellowstone or the Grand Canyon to nostalgic views of the western frontier. These aspects appeal to the "exploration" side of the mission, which may conflict with the slow and steady work of science and rover management described above, but they also present a familiarly American view of the Martian landscape, transforming Mars into the new frontier. The frontier narrative is visible even in a cursory viewing of public Mars rover images."[72]

By returning to the construction of Mars within the fantasy of the American frontier, we can historicize the emergence of the figure of the rover subject as an idealized, updated version of the scientist subject within the colonial histories of liberal subject. As a hybrid figure,[73] the figure of the rover subject represents a moment where the formation of the scientist-subject is imagined to be a self-aware, autonomous agent of scientific discovery, effected in the machine. The emergence of the universalized view of the human observer is underscored through the ways in which the Martian picturesque constructs Martian landscapes as Vertesi observes, "as the new American frontier." In this way, the rover, and thus the scientist subject, emerges as the frontier hero – and the scientist's gaze becomes the colonizing gaze on a frontier of expansion.

Atanasoski and Vora describe the emergence of designs for a robotic laboratory, writing:

> "As early as 1964, NASA began plans for a "robot laboratory" to land on Mars, a precursor to the Mars rovers. That the Mars rovers and drones continue to occupy our

[72] Janet Vertesi, *Seeing Like a Rover*, p. 228.
[73] Donna Haraway, "The Cyborg Manifesto."

> imagination of remote control over space today, and the fact that both still conjure various futures (one utopic, the other dystopic) speaks to the extent to which Cold War geopolitics still influence technoliberal conceptions of command and control. Now as then, engineering is positioned to solve the problem of how to command a space that it is physically (or temporally) impossible for humans to penetrate. The surrogate effect of the machine that can move in so-called hostile environments (whether those of outer space or those in the field of war) is doubly racialized in function and form. First, the right of the liberal subject to those spaces previously impenetrable is yet again reasserted and reassured through technology. Technological progress, connected as it is as tool and mode of innovation to liberal notions of historical progress, affirms imperial expansion as the logic of engineering and use of machines meant for remote control."[74]

Returning to Vertesi's reading of the Martian picturesque, the Martian picturesque represented through the rover selfie, while not the god's eye view nor the view "from nowhere", marks a moment the fantasy of the "rover's eye view" comes into center frame. And, insofar as the rover overcomes the limits of the human, space, and distance, the selfies enact the fantasy of the scientist subject in the figure of the rover subject. Thus, the technoliberal subject can be understood as the aspirational figuration of the human as the unmarked, universal subject articulated through technoliberalism – that is, through fantasies of Mars as the aspirational landscape of humanity's future. Thus, as the rover and the ways in which it "present[s] a view oriented towards the human observer"[75] is articulated through a universalized view of the human, or the unmarked liberal subject. The ability to self image is a crucial part of enacting the

[74] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*, p. 150.
[75] Janet Vertesi, *Seeing Like a Rover*, p. 229.

affective possibilities of deepening the surrogate human effect. The narrative appeal of Curiosity and its seemingly quotidian practice of self imaging works to reassert the surrogate human effect, the presence and persistence of the liberal subject and the scientific future, but also reassures its effectiveness as a re-universalized technoliberal subject. Thus, the rover is a technology designed to rehearse, rehabilitate, and reproduce the racial imperial boundaries of the liberal subject in the figure of the rover subject, Curiosity, our frontier hero.

Seeing through Care for the Machine

One crucial element of technoliberalism is the disavowal of racial imperial difference as the conditions of possibility that enable the fantasy of universality to emerge through the production of the figuration of the rover subject as a figure that produces a coherent "subject-effect." Attending to the materiality of the rover selfies, its material conditions of production, can help to dispel this fantasy.

Figure 11: *Curiosity* Rover Tweet, October 13 2015.[76]

Strictly speaking, the scientific purpose of the rover selfie is not to enact this kind of scientific self, but rather to provide observation and maintenance of the machine. This practice is narrated through Twitter. For example:

> "Self-portraits like this one document the state of the rover and allow mission engineers to track changes over time, such as dust accumulation and wheel wear. Due to its location

[76] *Curiosity* Rover, Twitter post, October 13 2015, 11:17AM, https://twitter.com/MarsCuriosity/status/653998124642406400?cxt=HHwWgMCo8Yn1u5MSAAAA.

on the end of the robotic arm, only MAHLI (among the rover's 17 cameras) is able to image some parts of the craft, including the port-side wheels."[77]

The narrative forms and embodiment represented in the Twitter feed obscure the scientific practice of the utility of the rover selfie as a practice of care for the machine, instead offering the rover selfie as embodied formation of the universalized scientific self.

The stakes of this are huge. As Max Liboiron observes, "The universal is never universal, but rather an argument to imperialistically expand a particular worldview as *the* worldview."[78] In the case of the rover selfies, the fantasy of universality reproduces the coloniality of scientific vision. Put another way, the re-inscription of these practices of machine care to enact the fantasy of autonomous scientific discovery led by the rover as frontier hero ensure the reproduction of the Mars Exploration Program as a colonial project. Not only do the rover selfies ensure the investment and engagement of the public in the project of scientific discovery as a public good, but the practice of machine observation, maintenance, and care become obscured "techniques of the self"[79] that ensure the reproduction of the rover as a stable, coherent, and durable self, part of the fantasy of the rover as an autonomous scientific laboratory. We literally "see" through practices of care for the machine, self-care for the autonomous laboratory, and this way of seeing ensures the re-investment and reproduction of the coloniality of scientific vision.

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[77] NASA's Mars Exploration Program, "High-Resolution Self-Portrait by *Curiosity* Rover Arm Camera," November 1 2012. Accessed: https://mars.nasa.gov/resources/4845/high-resolution-self-portrait-by-curiosity-rover-arm-camera/?site=msl.
[78] Max Liboiron, *Pollution is Colonialism*, p. 52.
[79] Michel Foucault, "Technologies of the Self" in *Technologies of the Self*, (Boston: University of Massachusetts Press, 1988), pp. 16-49.

Seeing Through Care for the Machine: Anti-Colonial Possibilities in the Production and Circulation of Rover Selfies

As a part of the long histories of scientific and machine objectivity, I return to seeing through care for the machine as a metaphor through which rover selfies might provide a different possibility for narrativizing the self. In "Situated Knowledges," Donna Haraway says:

> "All these pictures of the world should not be allegories of infinite mobility and interchangeability but of elaborate specificity and difference and the loving care people might take to learn how to see faithfully from another's point of view, even when the other is our own machine. That's not alienating distance; that's a *possible* allegory for feminist versions of objectivity. Understanding how these visual systems work technically, socially, and psychically ought to be a way of embodying feminist objectivity."[80]

What would it be like to resist the coherence of the subject-effect of the rover as the singular, universalized and ideal formation of the scientist subject? Can we instead resist the construction of the narrative, reading "against the archive"[81] for the counternarrative of the emergence of the technoliberal subject? Which contexts are most important for understanding what Haraway

[80] Donna Haraway, "Situated Knowedges," p. 583.
[81] See Saidiya Hartman, *Scenes of Subjection*; Aimee Bahng, *Migrant Futures*; and Julietta Singh, *Unthinking Mastery*.

describes as the "elaborate specificity and difference"[82] of the rover selfies? And, how can we attend to these contexts, and think about them with care, so that we might resist the universalizing view of Mars that are represented in these images?

Following Liboiron's critique of universality in the previous section, I return to Liboiron's theory of specificity and difference to address these questions. Liboiron uses specificity as a way of orienting towards responsibility, or enacting a relationship of responsibility through the obligations that specificity brings.[83] Specificity, then, becomes an anti-colonial practice, a way of seeing against the coloniality of scientific vision, that provides a counterpoint to the universality of the rover selfies.

Crucial to this would be to attend to the construction of the rover selfies as a specific process of "stitching together" multiple perspectives of the machine to create the fantasy of a coherent, singular self-image. In this way, the rover selfie becomes a façade, obscuring the "elaborate specificity and difference" that is disavowed in the production of the self-image. In this way, care for the machine (the literal maintenance of the machine) becomes a mode through which partial vision can be recuperated, and thus also a mode through which we can resituate the rover selfies as limited, partial perspectives that are specific, fractured, and disunified in their materiality. We can come to see how the fantasy of the technoliberal subject, the rover as frontier hero, can be deconstructed so as to embrace the limits of the human (human engineering, the limits of the machine), rather than transcend them. Rover selfies, then, can come to remind of the fantasy of the coherent technoliberal subject as constructed, rather than reproduce it as natural.

In this way, I pose the production and circulation of the rover selfie as a practice through which feminist objectivity might yet be realized, if we embrace the machine (learn to care for –

[82] Donna Haraway, "Situated Knowledges," p. 583.
[83] Max Liboiron, *Pollution Is Colonialism*, p. 24.

see, attend to, or relate to-- the machine) not as a universal, coherent subject, but, rather, as a disunified, partial, and limited mode of bearing witness. The rover, then, becomes an alternative means of "witnessing", rather than the witness itself.

Feminist histories of objectivity have long proposed the practice of witnessing as a mode of feminist objectivity, and specifically a means through which the subject might be fashioned or refashioned. Murphy, in particular, proposed the figure of the Immodest Witness as a feminist subjectivity, a positionality through which difference can be embraced. On the history of witnessing, Michelle Murphy writes in *Seizing the Means of Reproduction*:

> "Since the seventeenth century, the subject-figure of the "modest-witness" – who aspires to hold the personal details of their subjectivity, status, class, race, gender, religion, and mood apart from observation – has been a recurring figure in scientific moral economies of blind sight, or what Haraway called "the view from nowhere" within what Sharon Traweek called "the culture of no culture." In contrast, a naked woman observing herself was an *immodest* witness who was not only embodied through her eye, but materially displayed her embodiment as a constituent component of observation. The contrasting figure of the modest witness had its origins in the experimental sciences of the seventeenth century. Gendered male, raced European, and enjoying the status of gentleman, the subject-figure of the modest witness could be trusted to make reasonable observations. The epistemic virtue of modesty involved making oneself humble, using one's senses as simple instruments, and fashioning oneself as the ventriloquist for the objects studied. At the same time, experimental practices could encompass using the "self-evidence" of one's own body as a kind of sensitive medium, strained of the particular. This immodest witness, then, can be situated genealogically as a twentieth-

> century re-iteration of various figures in the history of science who sought in their own sensory, cognitive, and emotional experience the empirical basis of their research, suggesting that recourse to the body is a recurring theme in scientific praxis when other modes of apprehension are deemed inadequate. Within this lineage, however, not just any person could offer the self-evidence of discerning, trustworthy sense. The "modern" European modest witness was a subject-making figure that crucially delineated the kinds of persons who could (purportedly unmarked subjects) and could not (marked subjects) credibly produce knowledge."[84]

As an alternative model, I pose this practice of "reading" against and through care for the machine as a mode of "bearing witness" (learning to care for) the reproduction of the coloniality of scientific vision, a mode of anti-colonial approaches to computer vision that seeks to build on what Anita Say Chan has described as "decolonial computing frameworks highlight another potential, not only in recognizing the diverse vibrancy of existing challenges to "digital universalist" models that problematically elevate narrow versions of Western and elite digital practice and innovation as the only relevant pathway to the future, but in cultivating knowledge practices that indeed foster a decentering of the self as a generative asset towards the creative co-production of alternative futures."[85]

In this tradition, then, I turn to Atanasoski and Vora's analysis of a photographic collection of "Drone Selfies" by Italian artist IOCOSE, as each image depicts selfies taken by

[84] Michelle Murphy, *Seizing the Means of Reproduction: Entanglements of Feminism, Health, and Technoscience*, (Durham: Duke University Press, 2012), pp. 74-5.
[85] Anita Say Chan, "Decolonial Computing aand Networking Beyond Digital Universalism," *Catalyst: Feminism, Theory, Technoscience* 4, no. 2 (2018), p. 5.

military drones in an imagined and alternative world of peace.[86] Atanasoski and Vora's reading finds potential for these selfies to disrupt the racial and capitalist logics of technoliberalism, writing that:

> "We can read the photographs in the "Drone Selfies" series as speculative accounts of a peace made possible by seeing what drones would do without human drone operators. The human self can only be at the center of this speculative future as an absent presence. This is not a posthuman future, though, but one in which the coassemblage of humans and technology is reasserted by troubling the purpose and intended use of military objects. The proposition of drone vanity asserts a future in which military objects become useless. The project thus reckons with how military technologies mediate the evolving relationship between human mortality and morality in the field of war. We can observe that the futurity of drone uselessness disrupts the structuring racial and capitalist logics of technoliberalism."[87]

Insofar as machine selfies might thus present the possibility not for enacting and enlivening fantasies of autonomous scientific discovery and the frontier hero but rather for the representation of a futurity of drone uselessness, in the next section I offer the disrupted vision of an early rover selfie from the *Spirit* rover as an opportunity to stay with the futurity of drone uselessness as an anti-colonial practice.

[86] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*, p. 187.
[87] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*, p. 187.

On sol 2126 (December 26th 2009), NASA's *Spirit* rover had gotten stuck in a sand trap known as "Troy." NASA circulated the following image of *Spirit* stuck in the sand trap, taken with *Spirit*'s front hazard-avoidance camera:

Figure 12: *Spirit* Rover Selfie from the Sand Trap at Troy.[88]

The image depicts part of the *Spirit* rover with its tracks visible in the distance, charting its path into "Troy." Two of *Spirit*'s wheels are visible, and one can be seen buried deeply in the sand.

[88] NASA, "Small Movement During Spirit's Latest Drive," *NASA*, December 31 2009. Accessed: https://www.nasa.gov/mission_pages/mer/images/mer20091231.html.

A December 31st 2009 press release from NASA revealed its plans to assess and strategize how *Spirit* could continue its research despite being in the sand trap. NASA reported:

> The team is evaluating strategies for improving the tilt even if Spirit cannot escape the sand trap, such as trying to dig in deeper with the wheels on the north side. In February, NASA will assess Mars missions, including Spirit, for their potential science versus costs to determine how to distribute limited resources. Meanwhile, the team is planning additional research about what a stationary Spirit could accomplish as power wanes.
>
> "Spirit could continue significant research right where it is," said Ray Arvidson of Washington University in St. Louis, deputy principal investigator for the rovers. "We can study the interior of Mars, monitor the weather and continue examining the interesting deposits uncovered by Spirit's wheels."
>
> A study of the planet's interior would use radio transmissions to measure wobble of the planet's axis of rotation, which is not feasible with a mobile rover. That experiment and others might provide more and different findings from a mission that has already far exceeded expectations.
>
> "Long-term change in the spin direction could tell us about the diameter and density of the planet's core," said William Folkner of JPL. He has been developing plans for

conducting this experiment with a future, stationary Mars lander. "Short-period changes could tell us whether the core is liquid or solid," he said."[89]

On January 29th 2010, a National Geographic article about *Spirit* stated that, unable to escape the sand trap, the rover would instead be "putting down roots"[90] and conducting science from the sand trap. Steve Squyers, the rover mission's principle investigator, is quoted saying that "[t]he imperative to drive is relaxed now, and we're able to focus on a whole new class of science."[91]

In this context, the self-image of *Spirit* stuck in the sand trap is a complex representation of the disruption of scientific practice, one that reveals the deep rootedness and materializes the situatedness of scientific practice that works in two ways, both against the drive (both figurative and literal, in the case of the rover) for continued expansion of scientific research while reinscribing it. In this way, the selfie here indexes what happens at the moment of rover "uselessness" – both the interruption of the expansion of scientific research and the insistence of its continuation, both with and against the sand, both through speculation (of whether the sand can be overcome) and its materiality (of sinking into the sand).

Building from Atanasoski and Vora's analysis of the futurity of drone uselessness, I offer my reading of this selfie in its context of circulation and production as a way to think through the rover selfie as a mode of enjambment for the drive for autonomous scientific discovery, its interruption, and planetary resistance. As a mode of enjambment, the rover selfie (in its conditions of production, circulation, and representation) catches a glimpse of the collision of

[89] Victoria Jagaard, "Mars Rover to Roam No More – It's Official," *National Geographic News*, retrieved June 21 2022 from: https://www.nationalgeographic.com/science/article/100127-mars-rover-spirit-nasa-stuck-martian-winter.
[90] Victoria Jagaard, "Mars Rover to Roam No More," https://www.nationalgeographic.com/science/article/100127-mars-rover-spirit-nasa-stuck-martian-winter.
[91] Victoria Jagaard, "Mars Rover to Roam No More," https://www.nationalgeographic.com/science/article/100127-mars-rover-spirit-nasa-stuck-martian-winter.

these lines of movement, and troubles the position of the machine, the human, and the planetary in relation to the expansion and interruption of scientific research, the production of knowledge, and the fantasy of autonomous scientific discovery. Reading the selfie as a mode of enjambment in this way positions the resistance to the expansion of the fantasy of autonomous scientific discovery, scientific research, and knowledge production as an ever-present material condition of scientific practice itself – and thus enlivens possibilities for anti-colonial practice to emerge within even as they seek to work against the lines of scientific practice already in place.

Chapter 2: NASA, AI4Mars, and the Transpacific Histories of the "The Gateway to the World"

Abstract

In this chapter I first introduce the AI4Mars program as a citizen science program characterized by an ethos of universal collectivity and democracy, placing this program as a kind of technological commons made possible through its use of the Internet to enact a "distributed" laboratory model of scientific research. I then place AI4Mars as an extension of the history of the Internet as representative of technological progress and democracy while eliding their material histories as networked infrastructures colonial and imperial laboratories. To show this, I turn to the history of the transpacific Internet and the first commercial Internet connection in the Philippines. I trace the ways in which this moment of connection evidences the long history of the discourse of the Internet as a "gateway" to the future made possible through the reproduction and reinscription of colonial and imperial relations within new technoliberal discourse. I then juxtapose this history with the speculative future of *The Apollo Centennial*, a Filipino speculative fiction. In so doing, I hold the "double vision" of the Internet as a colonial and imperial infrastructure and the Internet as a technological commons that purports to democracy and

collectivity, in tension with the "double vision" of the imagined futures of AI4Mars and the imagined futures of *The Apollo Centennial*, to learn to see what I describe as the residue of the "transit of empire" (Byrd) through the continued use of the laboratory model for scientific research.

Universal Democratic Futures and The Mars Science Laboratory

On June 12 2020, NASA and JPL published a press release declaring "NASA's Mars Rover Drivers Need Your Help."[92] The press release was announcing NASA and JPL's latest citizen science initiative, AI4Mars, explaining that more help is needed to train SPOC, a deep learning algorithm that requires hundreds of thousands of images of Martian terrain labeled with terrain types, like bedrock, cohesive soil, sand dunes, and small, high, or large rocks. Once SPOC is adequately trained, the algorithm will be able to automatically classify terrain types and eventually also predict the likelihood of rover slippage, a key problem for NASA and JPL's rover teams. The press release notes that "SPOC won't replace the complicated, time-intensive work of rover planners [b]ut it can free them to focus on other aspects of their job, like discussing with scientists which rocks to study next."[93] Stephanie Oij, a JPL rover planner involved in the AI4Mars initiative, is quoted explaining that "It's our job to figure out how to

[92] NASA, "NASA's Mars Rover Drivers Need Your Help," *NASA*, June 12 2020, https://www.nasa.gov/feature/jpl/nasas-mars-rover-drivers-need-your-help.
[93] NASA, "NASA's Mars Rover Drivers," https://www.nasa.gov/feature/jpl/nasas-mars-rover-drivers-need-your-help.

safely get the mission's science [and] [a]utomatically generating terrain labels would save us time and help us be more productive."[94]

To do this, thousands of images taken by the Mars Science Laboratory (the Curiosity Rover) have been uploaded to the AI4Mars portal on Zooniverse, a popular citizen science portal with global reach.[95] The homepage of the portal offers the following remarks and framing the project:

> "You'll be using your superior cognitive and artistic abilities to label images from the Curiosity Rover, collectively creating the first open-source navigation-classification dataset of the Red Planet. It will be used - like the cityscapes dataset - by teams to train rovers to understand Martian environments, laying the way for future missions to unlock the secrets of our nearest neighbor! Join us and explore the red planet together!"[96]

At the time of writing, 592,911 classifications have been made by almost 15,000 participants who have logged in since June 2020 and classified at least one image.[97] Navigating through the portal, the interface explains the importance of automatic terrain classification for Mars rovers and the broader goal of developing autonomous terrain classification systems, positioning AI4Mars in a longer trajectory of the development of autonomous rover capabilities. The interface explains:

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[94] NASA, "NASA's Mars Rover Drivers," https://www.nasa.gov/feature/jpl/nasas-mars-rover-drivers-need-your-help.
[95] Zooniverse, "AI4Mars: Teaching Mars Rovers How to Classify Martian Terrain," *Zooniverse*, retrieved June 30 2022, https://www.zooniverse.org/projects/hiro-ono/ai4mars.
[96] Zooniverse, "AI4Mars," https://www.zooniverse.org/projects/hiro-ono/ai4mars.
[97] Zooniverse, "AI4Mars," https://www.zooniverse.org/projects/hiro-ono/ai4mars.

> "We're counting on citizen scientists' help in labeling a set of images captured by Mars rovers so that we collectively create the Solar System's first public benchmark for Martian terrain classification. Uncrewed space exploration will depend on the rover knowing where it's safe to drive, land, sleep and hibernate; this project is an early step in that direction."[98]

AI4Mars asks its participants to offer their creative and expert labor for terrain classification as a means of building a future on Mars under the ethos of democracy, openness and collectivity.

An Ethos of Collectivity and Democracy in the New Technological Commons

NASA's Mars Exploration Program is defined by an ethos of democracy, openness, and collectivity. Indeed, as AI4Mars frames Mars as a universal future for humanity, AI4Mars represents a new technological commons. For example, Lisa Messeri shows that NASA describes Mars "as a place governed by the open source ethos of access for all"[99] to argue "that 'democracy' comes to stand for…a desire for increased participation in both science and the greater mission of exploration."[100] Messeri's analysis of the reflection of one Mapmaker makes this particularly clear in the case of the Internet, as they reflect:

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[98] Zooniverse, "AI4Mars," https://www.zooniverse.org/projects/hiro-ono/ai4mars.
[99] Lisa Messeri, "Extra-terra incognita: Martian maps in the digital age," *Social Studies of Science* 47, no. 1 (2017), p. 82.
[100] Lisa Messeri, "Extra-terra incognita," p. 83.

> "I want anyone who wants to be able to explore all the awesome data that NASA has, be that planetary data or astronomical data. Cool stuff should be discoverable – folks in the general public should be able to just jump on the Internet and explore this stuff."[101] (Messeri, 2017, p. 83)

Messeri elaborates:

> Returning to the question posed at the start of this section, what do the Mapmakers and NASA more broadly mean when they invoke democracy or earnestly frame their work in terms of accessibility? In general, any claim that simply making data available on the Internet equates to democracy is dubious (see Hindman, 2008). Haklay (2013) specifically examines how this false claim propagates across various geographies that populate Web 2.0 platforms. Not only are there barriers to access, but there are also knowledge barriers that limit participation to the few who have adequate technical skills to truly interact with novel mapping software.

But, AI4Mars is not the only instance of NASA's use of citizen science as part of its Mars Exploration Program. Rather, Messeri's analysis demonstrates that NASA often uses citizen science methods in its scientific labor practices, writing that:

> [S]cientists implement citizen science projects to tackle tremendous amounts of data that computers are not suited to process. Similar to the project on 'Be a Martian', a popular

[101] Lisa Messeri, "Extra-terra incognita," p. 83.

> citizen science portal, Zooniverse, asks users to look through Mars images and mark fan-shaped deposits to aid in the study of Martian weather patterns. Though these projects claim to empower citizens, turning them into explorers, there is still a clear hierarchy between the scientist requesting a specific kind of data and the citizen conforming. Recently, in addition to asking for time from citizens, some exploration projects are asking for money.[102]

AI4Mars thus introduces a dispersed and distributed "laboratory" where the laboratory (or the place where citizen science labor is performed) is anywhere (and everywhere) Internet connectivity might be.

Messeri cautions, however that Mars is "intended for all, but it is expected that users will interact with Mars as a place of exploration." Messeri notes that this means that "[e]ven as the Mapmakers strive to offer a map that is democratized and free to be altered and experienced in a multitude of ways, this vision is constrained by the overarching expectation of solar system exploration."[103] But, this language of exploration in NASA's use of citizen science and online platforms belies a deeper hierarchy than just the hierarchy between scientist labor and citizen scientist labor. Rather, the ways in which AI4Mars and NASA's other citizen science projects position the Internet as an infrastructure for universal, democratic, and innovative scientific research disavow the material histories of the Internet as a tool for installing US colonial and imperial "world order" through the "distributed" and "networked" laboratory model. In other words, the ways in which NASA positions AI4Mars as an infrastructure for engineering democratic futures of scientific research, innovation, and progress on Mars extends the long

[102] Lisa Messeri, "Extra-terra incognita," pp. 90-1.
[103] Lisa Messeri, "Extra-terra incognita," p. 90.

history of the ways in which the development of the Internet is seen as a tool for building democratic futures, the new technological commons, that disavow their colonial and imperial relations and conditions of possibility.

AI4Mars thus emerges as a part of a broader imaginary of digital universalism, where democracy comes to signal utopic fantasies of better futures defined by the commons. But, as Atanasoski and Vora argue, "the new collaborative commons, rather than being based on earlier socialist models of the commons, is instead built upon these very erasures that enabled the spread of global capitalism. This ethos of capitalist expansionism, enabled as it is by the division and capture of racialized and gendered labor, persists in the present in the present-day techno-utopia vision of a new commons."[104] In this way, the universal, democratic futures that are imagined by the Mars Exploration Program appear to be disconnected from their material histories of US technological expansion and globalization, where liberatory (meaning US democratic) futures were not only aspirational values but could be achieved through the development and expansion of global technologies like the Internet, and their historical colonial and imperial relations that made such expansion and development possible.

AI4Mars thus plays upon at the same time as it extends and reinscribes the material histories of the Internet as distributed networks of colonial and imperial laboratory infrastructure. Like Wendy Chun does in *Updating to Remain the Same*,[105] I observe that there is a disconnect between our technoscientific imaginaries of the Internet and the material conditions of its infrastructure. This insight is particularly important in the case of AI4Mars, to show how the use of the Internet as a utopic infrastructure for futurity persists as a dominant rhetoric but disavows its imperial and colonial conditions of possibility.

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[104] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*, p. 68.
[105] Wendy Chun, *Updating to Remain the Same: Habitual New Media*, (Boston: MIT Press, 2016).

This can be made especially clear in the case of the transpacific Internet and the first commercial Internet connection in the Philippines. In what follows, I demonstrate that there is an important material connection between AI4Mars as a universalizing and democratizing infrastructure of labor and futurity and the development of the transpacific Internet, not only as a material history of the expansion of the Internet (as in, what makes the universalized claims of AI4Mars possible), but a history that demonstrates the conditions of such expansion as reproducing and running along colonial and imperial lines of development using what I describe as the colonial and imperial laboratory model – a model that utilizes and installs communication infrastructure through colonial and imperial historical and material relations. As AI4Mars accelerates the classification, and thus capture, of space for US political economic interest through new technologies of computer vision and systems of autonomous terrain classification designed around the Internet as a globalized system, it signals the extension of a long history in which the Internet has mediated access to futurity through systems of classification, protocols, and dataflow as a colonial and imperial laboratory model, and how the Internet has long signaled the extension of projects of discovery in new democratized and universalized terms, through the colonial and imperial laboratory model. In this sense, AI4Mars, as the latest iteration of the laboratory model for the engineering of futures, is intimately connected to the imperial and colonial histories of expansion that the laboratory model has long signaled.

The Transpacific Histories of NASA's Laboratories as "The Gateway to the World"

The case of the transpacific Internet in the Philippines demonstrates that NASA, and specifically NASA's engineering of the Internet through the "networked" (and, as I will argue, colonial and imperial) laboratory model, has long been positioned as a "gateway" to a democratized, collectivized vision of the world, of futurity, while disavowing the racialized hierarchies of the colonial and imperial conditions of possibility of this futurity. In what follows, I trace one strand of the material history of the transpacific Internet in the Philippines to resist this disavowal. I historicize the Internet as a globalized and globalizing infrastructure of worldbuilding that is now, through AI4Mars, extending the classification and thus capture of land and futurity for US political economic interest under the guise of the development of universal futures for a universalized humanity. In order to show this, In what follows I juxtapose AI4Mars with histories, both speculative and material, of US technological development in the transpacific region with focus on the Philippines. As AI4Mars enacts a globally distributed hierarchy of scientific labor, I contextualize and historicize this hierarchy as one that has emerged through global divisions of expert waged labor and non-expert unwaged labor, making such non-expert unwaged laborers a part of a now planetary population that is both existentially surplus *and* necessary for scientific research, development and progress at the same time as it is disavowed. As AI4Mars attempts to disavow and thus disappear these conditions, bringing them back into view becomes paramount to understand the political stakes of AI4Mars as an infrastructure of development.

"The Philippines is In!": The (Post)Colonial and Imperial Hierarchies of the History of the Transpacific Internet

At 1:15AM on March 29th, 1994, Benjie Tan posted the following message on the Usenet newsgroup soc.culture.filipino from the city of Makati in the Philippines.

> *Subject: The Philippines is In!*
>
> *As of March 29,1994 at 1:15 am Philippine time, unfortunately 2 days late due to slight technical difficulties, the Philippines was FINALLY connected to the Internet via SprintLink. The Philippine router, a Cisco 7000 router was attached via the services of PLDT and Sprint communications to SprintLink's router at Stockton Ca. The gateway to the world for the Philippines will be via NASA Ames Research Center. For now, a 64K serial link is the information highway to the rest of the Internet world.*[106]

With this message, Tan sought to inform Filipinxs living in the US diaspora that the nation had finally connected to the Internet. But this phrasing, "the gateway to the world for the Philippines will be via NASA Ames Research Center," is an important one. Why did Benjie Tan imagine the NASA Ames Research Center as "the gateway to the world" for the Philippines?

This phrasing suggests on the one hand, the long histories of the advent of the Internet seen as the (singular) path to "discover" the world, to access futurity. For example, on the 25th

[106] Benjie Tan, "The Philippines is in!," *Google Group: soc.culture.filipino*, accessed: https://groups.google.com/g/soc.culture.filipino/c/HzZSqZoJPu4; Jim Ayson, "The Night Benjie Tan Hooked Up The Philippines to the Internet," *The Ayson Chronicles*, August 13 2011, accessed: https://jimayson.wordpress.com/2011/08/13/the-night-benjie-hooked-up-the-philippines-to-the-internet/

anniversary of the Internet in the Philippines, Dr. Rodolfo Villarica recounted his words at the first moment of connection: "On March 17, 1521, Magellan "discovered" the Philippines and now, several centuries later, 473 years later, on March 29, 1994, the Philippines "discovers" the whole world. We have access to all, the whole world and the World Wide Web of information. That was the atmosphere at the time."[107] This echoes, for example, Internet historian Fred Turner's analysis that shows how computing and Internet infrastructure transformed from military infrastructure into commercial infrastructure, and utopian fantasy of the (Western) tech elite, particularly those in California.[108]

But, on the other hand, the particular phrasing, that "the gateway to the world for the Philippines will be via NASA Ames Research Center" signals not just that the Internet had become an infrastructure for futurity, but that NASA was a "gatekeeper" for that futurity. Turner suggests that such metaphors - metaphors of gateways, networks and nodes - are an inheritance of utopian fantasies of the tech elite, shaped by the post-war era's metaphors from the defense laboratories contexts and their affinity for (white) hippie countercultural values, as the rhetoric and metaphors of information and systems theory and cybernetics became standard features in post-war era.[109] Turner writes:

> By the late 1990s, both the highly flexible, networked cultural style of this research world and its dependence on informational metaphors had migrated far from the weapons laboratories and planning institutes of the cold war defense establishment. Like

[107] Villarica, Rodolfo M. "The day the Philippines 'discovered' the world," NEWSBYTES.PH, April 5 2014, accessed: https://newsbytes.ph/2014/04/05/villarica-the-day-the-philippines-discovered-the-world-2/.
[108] Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, The Whole Earth Network, and the Rise of Digital Utopianism*, (Chicago: University of Chicago Press, 2006).
[109] Fred Turner, *From Counterculture to Cyberculture*.

> computers themselves, the culture and rhetoric of collaborative cold war research had become standard features of corporate and governmental life, and they remain so today.[110]

In this way, the NASA Ames Research Center as the "gateway to the world" for the Philippines, signals the transformation of the Internet from a US imperial infrastructure to a US democratic one, or the transformation of the Internet as a "networked" laboratory model for collective futurity, rather than defense.

The direct link connection from the Philippines to the United States through the NASA Ames Research Center was made possible by efforts to commercialize the Internet in the late 1980s and early 1990s. At this time, the architecture of the Internet was shifting away from the earlier network infrastructure provided by federal agencies and research institutions like ARPANET, NSFNET, the NASA Science Internet, and a handful of universities around the world.[111] As the NSFNET sought to commercialize the Internet by awarding select Network Access Providers contracts to form the new Internet backbone architecture, the NASA Ames Research Center remained the federal exchange point for data on the Internet on the Western most side of the Internet infrastructure.[112] Thus, while many histories of the Internet document and describe the institutional conditions under which the Internet was globalized and

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[110] Fred Turner, *From Counterculture to Cyberculture*, p. 238.
[111] National Science Foundation, "A Brief History of NSF and the Internet," *National Science Foundation*, August 13 2003, accessed: https://www.nsf.gov/news/news_summ.jsp?cntn_id=103050.; Computer History Museum, "Internet History of 1970s," Accessed June 30 2022: https://www.computerhistory.org/internethistory/1970s/.; Asia Internet History Projects, "An Asia Internet History – First Decade (1980 – 1990), Accessed June 30 2022: https://sites.google.com/site/internethistoryasia/book1.
[112] National Science Foundation, "A Brief History of NSF and the Internet," *National Science Foundation*, August 13 2003, accessed: https://www.nsf.gov/news/news_summ.jsp?cntn_id=103050.; Computer History Museum, "Internet History of 1970s," Accessed June 30 2022: https://www.computerhistory.org/internethistory/1970s/.; Asia Internet History Projects, "An Asia Internet History – First Decade (1980 – 1990), Accessed June 30 2022: https://sites.google.com/site/internethistoryasia/book1.

commercialized, few focus on the ways in which the NASA Ames Research Center emerged and remained as a center of US technoscientific power in the development of the infrastructure of the Internet and provided the material infrastructure necessary to support the global and commercial expansion of the Internet in the transpacific region as the Federal Internet Exchange Point. NSFNET established Network Access Points through commercial providers, including Sprintlink in Stockton, CA, a Commercial Internet Exchange point, where its router would facilitate the exchange of data from other commercial network access points through to the federal internet exchange located at NASA Ames Research Center.[113]

The NASA Ames Research Center remains as the Federal Internet Exchange Point in the United States, and, given that most Internet data traffic flows through the United States in the transpacific region, Ames remains a crucial infrastructure of control through which information and data flow. The NSFNET had established multiple international connections to research institutions around the world, but the physical architecture of the Internet meant that Internet data flowed through the United States. By the same token, at the time when the Philippines connected to the Internet, any data that was to flow from Asia across the Pacific would by design flow through the Internet exchange point at NASA Ames, via the commercial router of SprintLink's exchange located at Stockton, CA. Although the Philippines had local and regional connections to the Internet including a dial-up connection via Australia, the first direct line to the Internet was carried directly to NASA Ames in the United States.

[113] National Science Foundation, "A Brief History of NSF and the Internet," *National Science Foundation*, August 13 2003, accessed: https://www.nsf.gov/news/news_summ.jsp?cntn_id=103050.; Computer History Museum, "Internet History of 1970s," Accessed June 30 2022: https://www.computerhistory.org/internethistory/1970s/.; Asia Internet History Projects, "An Asia Internet History – First Decade (1980 – 1990), Accessed June 30 2022: https://sites.google.com/site/internethistoryasia/book1.

The commercial connection to the Internet in Makati City thus routed the Philippines directly to the United States, to the NASA Ames Research Center in California. Under this configuration, the United States remained the "center" of power and infrastructure for the Internet, a logic through which we can come to position the Philippines as a peripheral node. While this positioning is determined by the immediate material conditions of the Internet as a distributed network of networks wherein the United States was the center, these particular arrangements of technological infrastructures are premised upon the enduring relationships between the Philippines and the United States in the postcolonial period of 1946 – 1994.

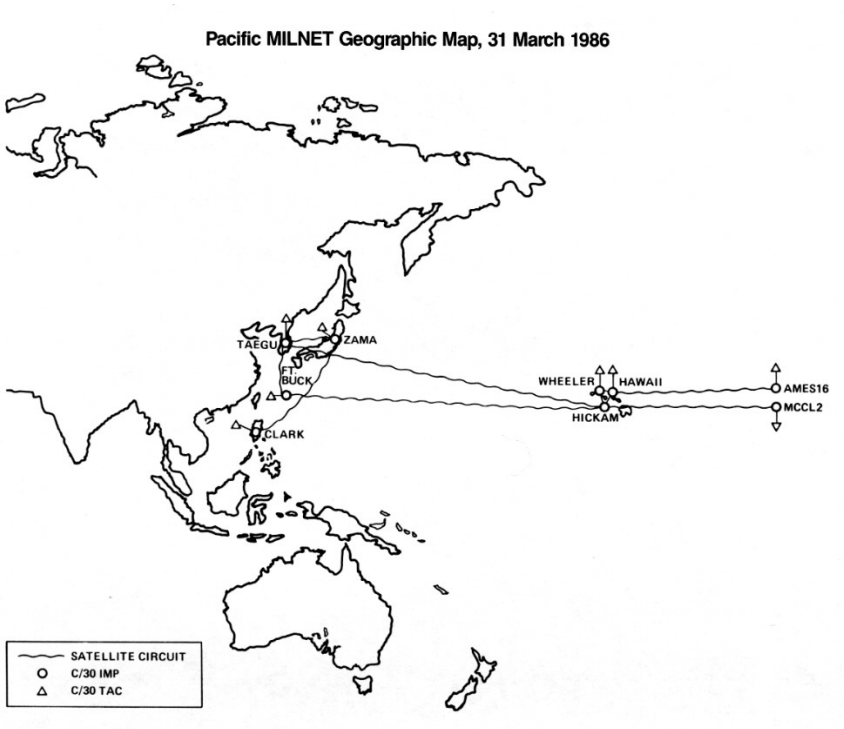

Figure 13: Pacific MILNET Geographic Map, 31 March 1986.[114]

[114] MILNET Maps, Accessed June 30 2022: http://mercury.lcs.mit.edu/~jnc/tech/milnet.html.

For example, network defined by the (literal) laboratory of NASA's Ames Research Center and the transpacific connections articulated by the colonial laboratories of the Hawaii and the Philippines. US Colonial laboratories were the scaffolding through which networks were materialized. The signification of the laboratory, as with Mars rovers, is thus never in isolation and instead enact a network imaginary (as we can see from the network infrastructure of MILNET and the Internet, and the DSN) that is a control hierarchy, which we might imagine in terms of a "center" of power and its "peripheries."

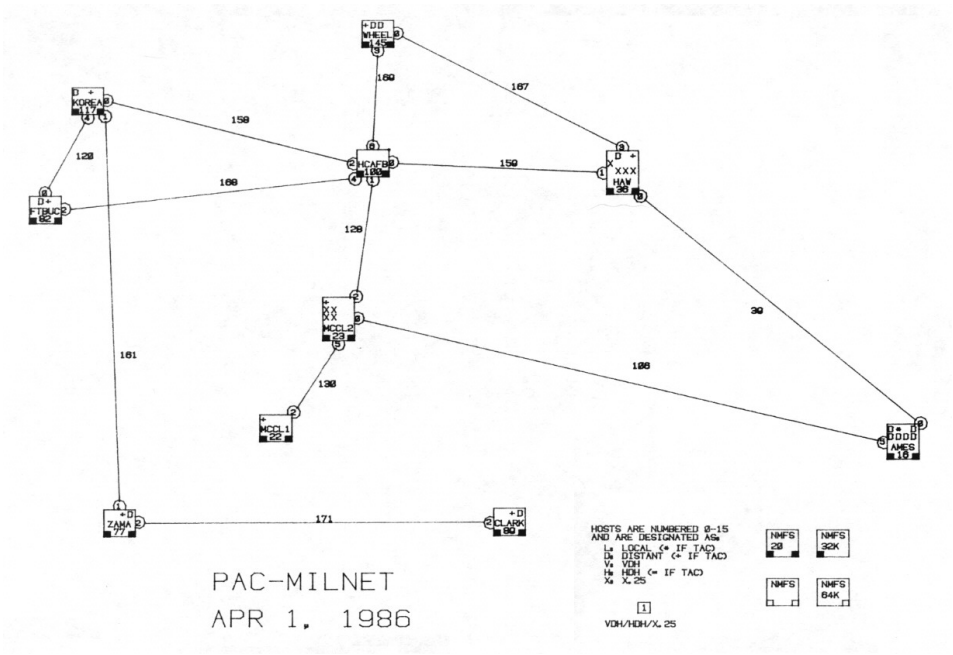

Figure 14: PAC-MILNET Logical Map, April 1 1986.[115]

Transpacific Cable Histories

[115] MILNET Maps, Access June 30 2022: http://mercury.lcs.mit.edu/~jnc/tech/milnet.html.

The commercial connection to the Internet in Makati City thus routed the Philippines directly to the United States, to the NASA Ames Research Center in California, through transpacific cable routes established through colonial and imperial relations in the 20th Century.

For example, as the networked connection between the Philippines and the NASA Ames Research Center was made was made of commercially leased lines from the Philippines Long Distance Telephone Company (PLDT), and a "direct link" (this is a technical term, noting a difference from earlier DSL connection, which is indirect, to the Internet via British cables routed through Australia) to the United States in the form of the Transpacific Cable System's first fiber optic cable, TPC-3, which connected the Philippines to the Internet backbone in the United States through a "direct link" to California, through Guam and Hawaii.[116] While there is limited archival documentation about the transpacific telephone and internet cables between the Philippines and the United States specifically, documentation shows that Sprint Communications Corporation had partial ownership of the Transpacific Cable System's lines, specifically the TPC-3/HAW-4 link.[117] Therefore, when the Philippines Long Distance Telephone Company contracted with the Sprint Corporation to carry the Philippines' data, the TPC-3/HAW-4 link would have been the cable line to do it. While the archive shows that the contract between PLDT and Sprint Corporation was selected because it was the most economical option,[118] the relative affordability of the PLDT and Sprint Corporation contract is shaped by long histories of US

[116] Submarine Cable Networks, "Trans-Pacific Submarine Cable Systems," Accessed June 30 2022: https://www.submarinenetworks.com/systems/trans-pacific.
[117] History of the Atlantic Cable & Undersea Communications, "The Commercial Pacific Cable Company," Accessed June 30 2022: https://atlantic-cable.com/CableCos/ComPacCable/.; See also "Fiber Optic Undersea Cable Systems," p. 9. Accessed June 30 2022: https://books.google.com/books?id=YLHM14vm1KMC&pg=PA9&lpg=PA9&dq=AT%26T+TPC-3+philippines&source=bl&ots=YD2iBiMxF0&sig=ACfU3U2U_kztZsxhlIVdOewow3EtNGiO5A&hl=en&sa=X&ved=2ahUKEwjMj420r4fxAhWCt54KHd9cCFMQ6AEwCXoECAYQAw#v=onepage&q=AT%26T%20TPC-3%20philippines&f=false.
[118] History of the Atlantic Cable & Undersea Communications, "The Commercial Pacific Cable Company," Accessed June 30 2022: https://atlantic-cable.com/CableCos/ComPacCable/.

colonization in the Philippines. The Philippine Long Distance Telephone Company was established in 1928 during US occupation, and remained owned by the United States after decolonization until 1967.[119]

The TPC-3 cable line is a part of the earliest transpacific telephone lines, with the cable line TPC-1 being the first transpacific telephone line which was designed, manufactured, and laid by AT&T in 1964, and extended the Point Area Cable Landing Station near Manchester in Mendocino County in Northern California to the Baler Cable landing station in Aurora, Philippines (both pictured below).

> "After the installation of the Guam-Philippines cable in December 1964, the coupled TPC-1, Haw-2, and Guam-Philippines systems provided the main cable network in the Pacific area and operated for more than a quarter century. This expanded TPC-1 had its 50-year anniversary in 2014."[120]

[119] History of the Atlantic Cable & Undersea Communications, "The Commercial Pacific Cable Company," Accessed June 30 2022: https://atlantic-cable.com/CableCos/ComPacCable/.
[120] History of the Atlantic Cable & Undersea Communications, "The Commercial Pacific Cable Company," Accessed June 30 2022: https://atlantic-cable.com/CableCos/ComPacCable/.

Figure 15: Point Arena Cable Station, taken by Ingrid Burrington, 2015.[121]

Figure 16: Cable Landing point at Baler, PH, from AT&T Documentary on *C.S. Long Lines*.[122]

[121] Ingrid Burrington, "Where the Cloud Rises From the Sea," *The Atlantic*, November 12 2015. Accessed: https://www.theatlantic.com/technology/archive/2015/11/where-the-cloud-rises-from-the-sea/415236/.
[122] AT&T Tech Channel, "*C.S. Long Lines*," *AT&T Archives.* Accessed June 30 2022: https://techchannel.att.com/playvideo/2011/03/21/AT&T-Archives-CS-Longlines.

In this way, this strand of the material history of the transpacific Internet indexes the ways in which imperial metaphors of laboratories and gateways have moved in and as what Jodi Byrd has called the "transit" of empire, taking on new forms, as this history of commercial internet connectivity is thus a part of the longer history of transpacific cable routes – routes that establish direct material connectivity from the United States through its colonial and imperial relations with key locations in Guam, Hawaii, and the Philippines. For example, Media Studies scholar Nicole Starosielski has observed:

> Over the past one hundred years, the coordination of military investment with private interests has established Guam as a cable hub in the Pacific. The first cable to the island, in July 1903, was driven in part by entrepreneur John Mackay's quest to establish cheaper transpacific communication. Cable systems in this era were often privately financed; the United States refused to build a state-sponsored or subsidized transpacific cable. Histories of the system, however, less often note that the offer to lay the cable "without subsidies or landing licenses [was made] on the grounds that the Pacific Ocean was a 'navigable water of the United States'," or the fact that the cable landing on Guam, and its extension on to the Philippines, was made possible by the U.S. Navy's conquests in the Spanish-American War only five years prior. The land for the cable station was leased from the Naval Station, which at the time administered the entire island. Though it was operated by a private company, the establishment of the Commercial Pacific Cable was intertwined with the geopolitical imagination and ex- tension of a United States Pacific Empire that conceptualized the islands as "stepping stones on the way to Asia."[123]

[123] Nicole Starosielski, "Critical Nodes, Cultural Networks: Re-mapping Guam's Cable Infrastructure," *Amerasia Journal* 37, no. 3, pp. 20-1.

The transpacific histories of the Internet in the Philippines thus demonstrate how the material conditions through which fantasies of universalism and democracy are expressed elide the legacies of colonialism that condition their expression.

The material history of the transpacific Internet demonstrates that the Internet has long been used as a tool through which the engineering and installation of fantasies of universal, democratic future worlds can be played out, but their material histories reveal, to the contrary, the deep ways in which colonial and imperial hierarchies of race and difference persist to structure this fantasy and the futures they imagine. For example, the Internet connection in the Philippines was made possible by a Cisco 7000 router located at the Philippines Long Distance Telephone Company headquarters in Makati City. Wendy Chun describes the way in which Cisco advertising in the 1990s communicated heavily the idea of the Internet as a "raceless space."[124] The importance of the Cisco 7000 router in the Philippines demonstrates how this imaginary is disconnected from, at the same time as it disavows, the material conditions of its power as an infrastructure of control – of data and of nations.

[124] Wendy Chun, *Updating to Remain the Same*, p. 108.

Figure 17: CISCO 7000 Router in Makati City, PH, March 1994. Photo Credit: Jim Ayson.[125]

The technoscientific imaginary of a "raceless space" is particularly poignant to note given the geopolitical conditions of the Philippines' position within global racial capitalism. The router managing the first Internet connection was located at the PLDT headquarters in Makati City, which, along with the Philippines more generally, have now become hubs for the flow of BPO labor to support the United States.[126]

Thus, as the Internet is again imagined to be a universalized, collective, democratic infrastructure, a "raceless space" and gateway to a "post-race" future[127] on Mars, historicizing AI4Mars as a reproduction of such efforts is a politically important counterpoint to hold in juxtaposition, as a technique to resist the easy reproduction of colonial and imperial fantasies of the Internet as a means for universal democratic worldbuilding. To the extent that the Internet is used for the extraction of citizen science labor to create training datasets, AI4Mars reproduces such fantasies while disavowing the political conditions of its labor infrastructure and their colonial imperial material histories. In so doing, AI4Mars evidences the extension of colonial imperial techniques of worldbuilding while taking as a given the historical structures of transpacific colonialism and imperialism that have made its conditions of labor possible. Just as AI4Mars aspires towards a universalized democratic mode of participatory citizen science for the engineering of autonomous scientific discovery, the material histories of the transpacific Internet in the Philippines demonstrate that this narrative of the Internet as a "gateway" to the future installs a singular vision of that future through colonial and imperial relations. As anti-colonial

[125] Jim Ayson, "The Day the Philippines Hooked Up to the Net: Part 3 (The Cisco Kids), *The Ayson Chronicles*, August 22 2011. Accessed: https://jimayson.wordpress.com/2011/08/22/connected-part-3/.
[126] See: Jan M. Padios, *A Nation on the Line: Call Centers as Postcolonial Predicaments in the Philippines*, (Durham: Duke University Press, 2018).; Robyn Magalit Rodriguez, *Migrants for Export: How the Philippine State Brokers Labor to the World*, (Minneapolis: University of Minnesota Press, 2010).
[127] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*, p. 9.

scholar of science and technology Max Liboiron has aptly stated, "[t]he universal is never universal, but rather an argument to imperialistically expand a particular worldview as *the* worldview."[128]

Thus, the history of the transpacific Internet in the Philippines is a history of the development of infrastructure that enable the distribution of labor under the colonial and imperial hierarchies of global racial capitalism. Juxtaposing this history of the Internet in the Philippines, from the first moment of connection where Benji Tan exclaimed "We're in!" to Filipinos living in the US diaspora to the present day conditions of Filipinx labor exploitation under global racial capitalism, the Philippines is positioned on the "peripheries"[129] of technological expansion of the US nation state, through the limited incorporation and disavowal of Filipinx labor within the production of US technoliberal futurity, but now at new planetary scales of difference. In the imaginary of the Internet as an infrastructure for engineering universal, democratic futures on Mars and autonomous scientific discovery, the material history of the Internet in the Philippines leads me to ask after the shifting peripheries of this futurity.

Reading The Apollo Centennial Towards the Creative Co-Production of Alternative Futures

As NASA has thus long been engineering "gateways" to future worlds, what alternative modes of futurity are available to counter and resist the colonial and imperial relations are reproduced? To answer this question, I turn to Wendy Chun's analysis of the history of the Internet and what she describes as residue – or a remainder that lingers – as a ground through which we might

[128] Max Liboiron, *Pollution is Colonialism*, p. 52.
[129] Anita Say Chan, *Networking Peripheries: Technological Futures and the Myth of Digital Universalism*, (Massachusetts: MIT Press, 2016).

move towards what Anita Say Chan has called "the creative co-production of alternative futures," arguing that "decolonial computing frameworks highlight another potential, not only in recognizing the diverse vibrancy of existing challenges to "digital universalist" models[130] that problematically elevate narrow versions of Western and elite digital practice and innovation as the only relevant pathway to the future, but in cultivating knowledge practices that indeed foster a decentering of the self as a generative asset towards the creative co-production of alternative futures."[131] Reading Chun and Say Chan together, then, I ask, what remains, what lingers, in these fantasies of NASA as the gateway to a future world? How can a postcolonial or decolonial computing framework point us towards the "creative co-production" of alternative futures?

In what follows, I turn to Filipino postcolonial speculative fiction to juxtapose the colonial visions and imaginaries of universalized citizen citizen and the futures on Mars they build with a speculative vision of postcolonial life in Manila in 2069, one hundred years after the US moon landing, in Gregorio C. Brillantes 1980 short speculative fiction *The Apollo Centennial*.[132] By reading this postcolonial speculative vision alongside the material histories of the expansion of the Internet through the transpacific, and specifically in the moment of the first commercial Internet connection in Manila in 1994, I offer Manila, the Philippines, and the speculative visions in *The Apollo Centennial* as residue, remainders, and what lingers towards the creative co-production of alternative futures.

I thus offer a critical reading of *The Apollo Centennial* to suggest an alternative vision of futurity that emerges from a postcolonial perspective. This move to fiction builds from scholarly work at the intersection of feminist STS and Ethnic Studies. Specifically, I ground my analysis in

[130] Anita Say Chan, "Decolonial Computing," p. 5.
[131] Anita Say Chan, "Decolonial Computing," p. 5.
[132] Gregorio Brillantes, "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.

Aimee Bahng's work in *Migrant Futures*, where Bahng used critical readings of postcolonial speculative fiction to understand the politics of the intersections of science, technology, and our imaginaries and engineering of futurity. In this work, Bahng asks: "How do our stories of the future chart the ways we invest – financially, politically, ideologically, and intellectually – in the present?"[133]

As Bahng observes, "speculation is not exclusively interested in predicting the future but is equally compelled to explore different accounts of history,"[134] I am interested in the ways in which the juxtaposition of *The Apollo Centennial* with the histories of the transpacific Internet in the Philippines reflects the close relationships between technological development and the histories of colonialism and imperialism. Bahng argues that "[b]y excavating forgotten histories of science and empire, revising conceptualizations of technological subjectivities, and seeking out queer affinities that belie privatized futures, these works demonstrate how speculation can take the shape of radical unfurling, rather than protectionist anticipation…I hold up these works of speculative fiction by people of color not as antidotes in and of themselves to racialized global capitalism but as affecting experiments that, in the process of imagining another way of being in time, point to the limitations of the new world order's ongoing drive toward modes of privatization and securitization."[135] Thus, following Bahng, by turning towards the speculative vision that *The Apollo Centennial* offers, I aim to articulate some ways in which the investment in technological development, space exploration, and the histories of science and empire continue to shape our futures through their colonial and imperial histories, while offering an alternative vision of futurity through which the stakes of this relationship can be imagined anew.

[133] Aimee Bahng, *Migrant Futures*, p. 3
[134] Aimee Bahng, *Migrant Futures*, p. 8
[135] Aimee Bahng, *Migrant Futures*, p. 7

The Apollo Centennial

Gregorio Brillantes' *The Apollo Centennial* is a Filipino short English-language speculative fiction published in 1980, part of a larger collection of Brillantes' short stories in *The Apollo Centennial: Nostalgias, Predicaments, and Celebrations*. The *Apollo Centennial* is celebrated as one of the most popular English-language speculative fictions written by a Filipino author.

The Apollo Centennial is set in Tibag, in Tarlac City, a rural city in the Phillippines, in 2069, one hundred years after the moon landing. The story opens as protagonist, Arcadio Nagbuya, boards a makeshift raft to travel from his rural home with his two sons along Tarlac River to the City, to attend a national exhibit celebrating the anniversary of the US moon landing.[136]

The Apollo Centennial is a story of the aftermath and enduring legacies of US colonialism and imperialism, in a future where the Marcos regime continued, and the legacies of his dictatorship are still strongly felt through ongoing militarism and state power. These conditions are depicted in the *The Apollo Centennial* through imposing military guarded check-points and war memorials on the way to the national exhibit and a strong presence of rebellion groups, the erasure of local dialects into Tagolican, and Arcagio Nagbuya's positionality from a rural area and lower class that is heavily contrasted with the authoritarian state power of the architecture of Tarlac City and literature and publications of the exhibit itself. Tellingly, a magazine advertising the exhibit reads in English and Tagolican, "ISANG GASUT TAON TI

[136] Gregorio Brillantes, "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.

APOLLO 11,"[137] reads "Imprenta ti United States Information Bureau, Southeast Asia Department, Territory of the Philippines."[138]

As Arcadio Nagbuya and his sons arrive at the exhibit on a tour bus, they "begin to sing the Apollo Hymn"[139] – an English language song that Brillantes writes in the Filipino accent's characteristic cacoepy – "Prom the launch pad at Kennedy, Nell Armstrong bentured porth por hu-man-ity…."[140] The exhibit itself, a "plastilium dome like a giant silver egg half-buried in the earth" that houses exhibits of large scale replicas of the rocket and launch vehicles, is playing "Deep in the Heart of Texas" and covered in red, white, and blue banners that read "Apollo 11 – 1969-2069."[141] Inside the dome, Arcadio Nagbuya and his sons view life-size statues of the astronauts of Apollo 11, "Nell" Armstrong, Edwin Aldrin, and Michael Collins, and their families, and scale models of them descending onto the moon's surface. The exhibit describes one of Michael Collins' children, "Arm. Michael Jr." as taking after his father to become the "commander of the Centaur 9 flight to Mars in 2018."[142]

The Apollo Centennial thus tells a story where US colonialism, imperialism, militarism, and US space exploration are clearly tied in a postcolonial future, where the histories of US space exploration represent the start of a universalizing and totalizing vision of humanity's future. The exhibit curates a vision of the extent to which US space exploration has expanded. The exhibit plays a recording of President Nixon's statement, "For one priceless moment in the

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[137] Translated: One Hundred Years After Apollo 11
[138] Translated: Printing House of United States Information Bureau, Southeast Asia Department, Territory of the Philippines.
[139] Gregorio Brillantes, "The Arrival in the City," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.
[140] Gregorio Brillantes, "The Arrival in the City," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.
[141] Gregorio Brillantes, "The Arrival in the City," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.
[142]Gregorio Brillantes, "The Exhibits," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.

whole history of man, all the people on Earth are one…," without, of course, the Filipino accent that Arcadio Nagbuya holds, Brillantes thus underscoring their difference. The exhibit then displays large "cybergraphs of the Magellan Space Station and its family of shuttle tugs, the American-Russian installations on the moon, the Venus skylabs, and the international crew of the Uranus mission due to return in 2071…[and] a mural on the opposite wall depicting American space projects for the rest of the century, including the first starship mission beyond the solar system, a joint expedition with Britain and Germany to Alpha Centauri: 'It is believed that a planet of this star nearest to Earth is the source of the first message from extraterrestrial intelligence ever received by the human race. This particular revelation is illustrated with a mathematical formula: "Look hearr," says Mr. Balaoing to the boys, pointing rapturously at the center of the massed algebraic figures, "et eisss de equation por de circurnferrence op a cirrcle!" But Dolfo and Doming are now listless and hungry, and care little for mathematics or messages from other worlds."[143]

Here, Brillantes uses language to show the contrast, or perhaps the disconnection, between the presence of American militarism and futurity and the life of Arcadio's family and children, as computational intelligence and messages from "other worlds" appear unimportant to them. After touring these exhibits, Arcadio Nagbuya and his sons depart and doze off on the bus ride back to the river raft. Brillantes writes that "in the dark of his closed eyes [Arcadio Nagbuya's] dead wife appears suddenly and then his father, a farmer too, born at the turn of the century and a soldier dying in the Second Asian War: he wakens to the coolness of wind on his face, and then he sees, as he has seen it at this hour for unnumbered evenings, the Magellan

[143]Gregorio Brillantes, "The Exhibits," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.

Space Station rising in the west, a bright solitary star among the night clouds."[144] Once Arcadio Nagbuya and his sons arrive home, "they start off for the trail in the coconut grove beyond the sandy slope of the riverbank. The Magellan Space Station has cleared the tops of the trees, and a smaller, fainter star is moving away from it: another nuclear spaceship going to Mars or perhaps only to the moon, now a sharp-pointed sickle in the eastern sky."[145]

Women of color feminism has long looked to the archives of fiction to articulate the contradictions of subjugated life under global racial capitalism, and the aftermath of colonialism, and imperialism, especially as a technique to see the depths of absence in the archive, especially where the official archive is thin, to make visible and articulate the narrative subjectivities that are subjugated, as well as their conditions of subjugation, under dominant systems of power like US global racial capitalism, imperialism, and colonialism.[146]

In this tradition, Brillantes' *Apollo Centennial* is an important text to consider in juxtaposition with the future visions of AI4Mars and the material histories of technological development in the Philippines. Specifically, *The Apollo Centennial* shows a vision of the future where the expansion of US space exploration is explicitly tied to the histories of Spanish and US colonialism in the Philippines, through the life of the protagonist that grapples with class difference and the ongoing militarism of Philippine state power and the enduring rhetoric of US state power. In this way, Brillantes names what can be deeply felt in the postcolonial Philippines but is not often named explicitly in the official archive – that space exploration emerges through

[144] Gregorio Brillantes, "Return Trip," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo."
[145]Gregorio Brillantes, "A Meeting on the Riverbank," in "The Apollo Centennial," 1980, retrieved from: http://www.oocities.org/phil_stories/brillantes_apollo.
[146] Hong, Grace Kyongwon Hong, "Existentially Surplus: Women of Color Feminism and the New Crises of Capitalism," *GLQ* 18, no. 1 (2012), pp. 87-106.

and extends histories of US imperialism, colonialism, and state militarism, and is celebrated as it does so.

Turning towards creative co-production becomes an anti-colonial practice that is deeply invested in histories of technological development as conditions of possibility for the future. In this way, Ruha Benjamin's focus on how the relationships between technological development and social policies and institutions constrain and otherwise shape which technologies appear inevitable and which appear impossible offer a useful framework for seeing the political stakes of the juxtaposition of *The Apollo Centennial* and AI4Mars. Specifically, while AI4Mars insists that the future it promises is open and available to everyone, *The Apollo Centennial* reminds us that the benefits and harms of such futures are never distributed universally and uniformly, but rather unevenly, along the lines of colonial scientific and technological development through which they were conditioned. *The Apollo Centennial* thus contextualizes and historicizes the promise of universal democratic participation in the construction of inter-planetary futures within the aftermath of US colonial occupation and the technological development it has wrought. *The Apollo Centennial* shows how a colonial and imperial future of space exploration appears inevitable from a postcolonial perspective where the historical and material relationships between US imperialism, colonization and space exploration, were explicit. Written in 1980, *The Apollo Centennial* predates the first commercial Internet connection in the Philippines in 1994 and, of course, the use of AI4Mars in 2020 to engineer autonomy in the Mars rover fleet. However, the future *The Apollo Centennial* imagines in 2069 marks the continuity of the same material conditions that have made AI4Mars possible as a globalized network infrastructure for engineering the future as those of the transpacific internet and its first connection in the Philippines. That is, *The Apollo Centennial* shows a colonial and imperial future of technological

development that appears inevitable, from a postcolonial perspective that is deeply invested in the ongoing political stakes and struggles that emerge from the histories of US colonialism and imperialism and the technological development such structures install.

Conclusion

The political stakes of the digital universalism of AI4Mars can be made most clear by juxtaposing its colonial vision with the material and speculative histories of US transpacific colonization and the postcolonial visions that have since emerged. Engaging with Mars with attention to the postcolonial thus means attending to and caring for the afterlives of colonization and the ghosts that haunt our technological futures.

In this way, this Chapter builds from Banu Subramaniam's work in *Ghost Stories for Darwin*, to trace and make visible a "ghost" of science and technology in our midst. Subramaniam writes that

> "Ghosts, rather than a superstitious legacy of the past, are a haunting reminder of an ignored past. Rendering ghosts visible and learning to listen to them attentively is a lesson about the unacknowledged and unresolved injustices of history. Living with ghosts forces you to confront the past, or the dead never go away, history never sleeps, the truth can never be erased, forgotten, or foreclosed by modernity."[147]

In this way, the juxtaposition of the vision of futurity offered in *The Apollo Centennial* and the vision of futurity offered by AI4Mars as a universalized, online citizen science platform reveals

[147] Banu Subramaniam, *Ghost Stories for Darwin*, p. 23

how the engineering of the future on Mars is haunted by the ghosts of the long histories of US imperialism and colonization.

Chapter 3: Computational Visions of Sand and the Challenge of Planetary Intelligence

Abstract

In this chapter, I examine the engineering of autonomous terrain classification, and in particular the development of SPOC as a novel autonomous terrain classifier that can accurately classify sand on Mars. I theorize the rover as a new formation of the laboratory, the autonomous colonial laboratory. After identifying intelligence as the arbiter of colonial imperial expansion, I offer a way to resist the reproduction of machine intelligence through the methods of juxtaposition and double vision. I juxtapose the computational vision of sand that expands the autonomous colonial laboratory with the geologic vision of sand. Holding both in a practice of "double vision," I consider what escapes computational visions of sand. Specifically, I argue that computational visions of sand "see" at the surface (literally), while absenting the depth of sand as a geologic formation that evidences planetary history and movement - a mode of seeing that offers a different kind of relationally than computational vision installs. I offer "double vision" - or seeing both the computational vision of sand in juxtaposition with the geologic vision of sand - as a technique of anti-colonial practice that can grapple with the politics of interplanetary life in our current moment.

Terrain classification and the project of autonomous scientific discovery

In 2020, researchers from NASA's Jet Propulsion Laboratory at the California Institute of Technology published a paper on MAARS (Machine learning-based Analytics for Automated Rover Systems), a suite of autonomy algorithms developed for use on NASA's Mars Exploration rovers like *Curiosity* and *Perseverance*, in which they argued that "[t]here is an urgent need for significantly enhancing on-board autonomy of future rover missions,"[148] particularly for terrain navigation, path-planning, and decision-making. The developers explain:

> Terrain is important to get around on Mars. Spirit got stuck in a sand pit and ended its mission after 7 years of exploring Mars (but far exceeding its nominal mission length of 90-days). Opportunity and Curiosity also have experienced getting stuck in sand, although they were able to continue on their missions. Don't you think it would be nice if the Mars rover could identify dangerous terrain by herself?[149]

The researchers note further that "the capacity of Mars-Earth communication remains limited by the laws of physics as well as the availability of relay orbiters and the Deep Space Network"[150] so "science opportunities may be passed up by necessity or missed entirely simply because the data cannot be fully downlinked to Earth."[151] These conditions make autonomous terrain classification, navigation, and decision-making, including "complex safety assessments that are

[148] Masahiro Ono et al., "MAARS: Machine learning-based Analytics for Automated Rover Systems," *IEEE* 2020, https://ieeexplore.ieee.org/document/9172271, p. 2.
[149] Zooniverse, "AI4Mars," "About."
[150] Masahiro Ono et al., "MAARS," p. 2.
[151] Masahiro Ono et al., "MAARS," p. 2.

currently performed on the ground [which] must be performed on-board the rover."[152] In this way, MAARS as a suite of autonomous software capabilities aims to enhance the "safety, productivity, and cost efficiency of future Mars rovers"[153] while "[covering] nearly all aspects of on-board autonomy that would be needed for future rover missions, including perception, planning, and automated science."[154]

Efficient terrain classification is thus crucial for the operation of the Mars rovers. Terrain has been a major source of risk for Mars rovers. [155] JPL explains that "current Mars rovers lack the on-board capability to identify non-geometric hazards like sand."[156] Sand is not only risky terrain for rover navigation, but is incredibly difficult for current terrain classification algorithms to identify due to the lack of distinctive geometric features.[157] To address this challenge, MAARS includes a new algorithm for autonomous terrain classification, the Soil Property and Object Classifier (SPOC). The developers explain:

> Manually performing such evaluation on all over the landing site, which typically spans over 10 km, is very laborious, if not impossible. Moreover, it requires the eyes of experienced geologists and rover drivers, who are not available for spending hundreds of hours on manual terrain classification.
>
> To overcome the labor bottleneck of image labeling, we developed the Soil Property and Object Classifier (SPOC), an automated terrain classifier. Built upon a deep convolutional neural network (CNN), it learns from a small set of examples given by

[152] Masahiro Ono et al., "MAARS," p. 2.
[153] Masahiro Ono et al., "MAARS," p. 2.
[154] Masahiro Ono et al., "MAARS," p. 2.
[155] Zooniverse, "AI4Mars," "About."
[156] Masahiro Ono, "SPOC-Lite: Terrain Classifier for Mars Rovers," November 14 2018, retrieved from: https://www.youtube.com/watch?v=LJXQ0-a9IJE&t=1s: 0:30-36.
[157] Masahiro Ono, "SPOC-Lite," https://www.youtube.com/watch?v=LJXQ0-a9IJE&t=1s.

> human experts…A training set consists of raw images (orbital or ground) and corresponding terrain labels. Once sufficiently trained, SPOC can automatically classify all pixels of input images. In this way, we can apply the judgment of experienced eyes on a significant volume of data with a marginal labor requirement.[158]

SPOC is unique in that it is capable of visually identifying sandy surfaces and terrain in Mars images.[159] It operates by "taking monaural images as an input, it outputs the probability of sand in the image space."[160] SPOC's accuracy is high, and its error margins are unlikely to produce errors in classification that are the size of the rover, meaning that SPOC can accurately classify sandy terrain in a range of probability that is useful and errors not significant for navigation.[161] This means that SPOC is effective at enabling the rover to manage terrain risk. The SPOC algorithm is thus critical for predicting potential rover slippage and traversability in rover path planning.[162] SPOC will thus enable the rover to more efficiently plan routes and identify scientific targets of interest through autonomous navigation and decision-making while reducing risk to the rover.[163] SPOC thus marks an important advancement in the development of machine intelligence and autonomy and thus the development of autonomous scientific discovery.[164]

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[158] Brandon Rothrock et al., "SPOC: Deep Learning-based Terrain Classification for Mars Rover Missions," *AIAA SPACE Forum*, September 2016, retrieved from: https://wolfcry.net/assets/papers/2016-SPOC-Deep-Learning-based-Terrain-Classification-for-Mars-Rover-Missions.pdf, p. 2.
[159] Masahiro Ono, "SPOC-Lite," https://www.youtube.com/watch?v=LJXQ0-a9IJE&t=1s, 0:14-16.
[160] Masahiro Ono, "SPOC-Lite," https://www.youtube.com/watch?v=LJXQ0-a9IJE&t=1s, **Error! Hyperlink reference not valid.**0:38-48.
[161] Masahiro Ono, "SPOC-Lite," https://www.youtube.com/watch?v=LJXQ0-a9IJE&t=1s, 0:28-33
[162] Brandon Rothrock et al., "SPOC," https://wolfcry.net/assets/papers/2016-SPOC-Deep-Learning-based-Terrain-Classification-for-Mars-Rover-Missions.pdf, p. 2.
[163] Masahiro Ono et al., "MAARS."
[164] Masahiro Ono, "SPOC-Lite," 00:35-6.

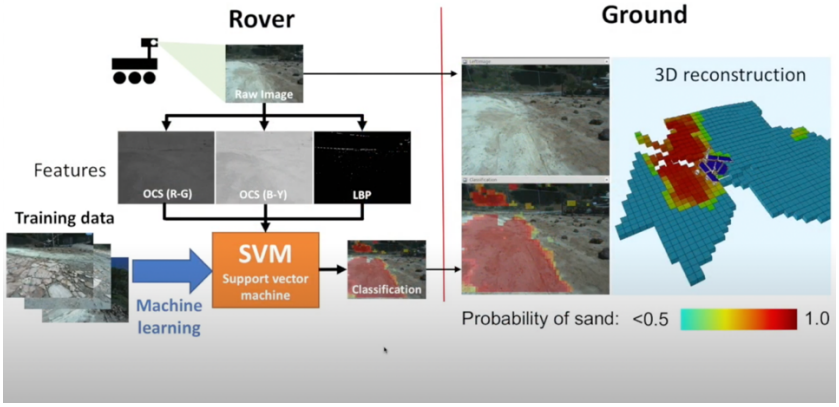

Figure 18: Diagram explanation of how SPOC-Lite operates on simulated Martian terrain.[165]

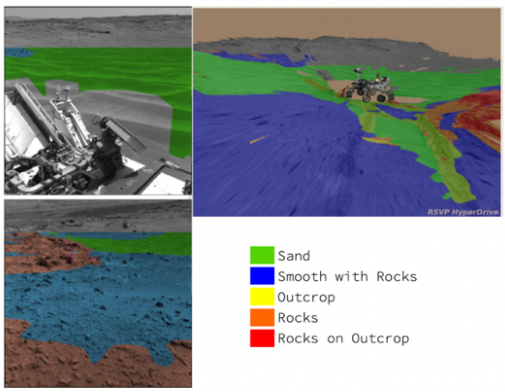

Figure 7. Example of classifier output on terrain images from MSL Navcam. On the left are some of the individual frames which are used for classification. On the right side the full classified panoramic mosaic is shown.

Figure 19: An example of SPOC classifications on terrain images from Curiosity's NAVCAM.[166]

[165] Masahiro Ono, "SPOC-Lite," 00:35-6.
[166] Brandon Rothrock et al., "SPOC," https://wolfcry.net/assets/papers/2016-SPOC-Deep-Learning-based-Terrain-Classification-for-Mars-Rover-Missions.pdf, p. 8.

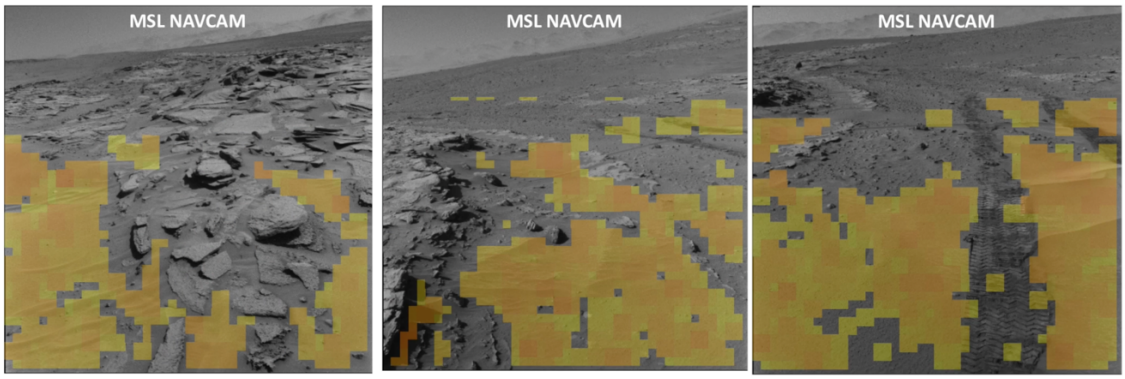

Figure 20: Example images of SPOC-Lite applied on images from the Curiosity rover's NAVCAM.[167]

Once SPOC is adequately trained, the algorithm will be able to automatically classify terrain types and predict the likelihood of rover slippage, a key problem for NASA and JPL's rover teams. In order to train SPOC, JPL engineers have created AI4Mars, an online citizen science initiative in which participants can manually classify terrain images of Mars in order to create training datasets for SPOC. Thousands of images from NASA's Planetary Database have been uploaded to the AI4Mars portal on Zooniverse, a popular online citizen science portal with global reach. At the time of writing, just over 11,000 participants have logged in since June 2020 and classified at least one image. Developers explain that "SPOC won't replace the complicated, time-intensive work of rover planners [b]ut it can free them to focus on other aspects of their job, like discussing with scientists which rocks to study next." Stephanie Oij, a JPL rover planner involved in the AI4Mars initiative, explains that "It's our job to figure out how to safely get the mission's science [and] [a]utomatically generating terrain labels would save us time and help us be more productive."[168]

[167] Masahiro Ono, "SPOC-Lite," https://www.youtube.com/watch?v=LJXQ0-a9IJE&t=1s; 1:07-14.
[168] NASA, "NASA's Mars Rover Drivers Need Your Help," *NASA*, June 12 2020, https://www.nasa.gov/feature/jpl/nasas-mars-rover-drivers-need-your-help.

NASA's JPL research team state that there is an "urgent need for significantly enhancing on-board autonomy of future rover missions" to increase the capacity of the rovers to make navigation decisions and complex assessments of Martian terrain that optimize rover capabilities to identify targets for scientific research in the absence of real-time human decision-making and oversight through communication or large-scale data transfer from Mars to Earth. The desire and effort to expand autonomous rover capabilities is thus a solution to the problem of terrain classification on Mars, a challenge that is shaped by the demand for expert scientific labor to perform terrain classification, combined with the limitations of current computing and data infrastructure capabilities to perform terrain classification given the vast distance and time difference between Mars and Earth.

Engineering the Autonomous Colonial Laboratory

What is at stake in the engineering of autonomous scientific discovery through SPOC? In what follows, I argue that the engineering of autonomous terrain classification for autonomous scientific discovery as evidence that the rover emerges as a new formation of the laboratory – specifically, the autonomous colonial laboratory.

STS has traced the way in which the laboratory has become a worldview – a material and epistemic mode of making sense of, and structuring, the distributed social and technical relations that shape scientific practice. For example, Latour's "Give Me a Laboratory and I will Raise the World" famously describes the porous boundaries between what is "inside" the laboratory and what is "outside" of it, offering a view of the laboratory as distributed across or coproduced

through its "social milleu" or broader context.[169] Latour later elaborated this analysis aptly to a new "planetary" scale, writing:

> "[T]he laboratory has extended its walls to the whole planet. Instruments are everywhere. Houses, factories, and hospitals have become lab outposts. Think, for instance, of global positioning systems: Thanks to satellite networks, geologists and biologists can now take measurements outside their laboratories with the same degree of precision they achieve inside. Meanwhile, a worldwide network of environmental sensors monitors the planet in real time. Research satellites observe it from above, as if the Earth were under a microscope. And geneticists examine entire populations as often as individuals. The difference between natural history – outdoor science – and lab science has slowly eroded."[170]

Building on Latour's insight, the engineering of autonomous scientific discovery through autonomous terrain classification thus indexes a moment where the figure of the scientific laboratory is taking on new form in new planetary scales. I am particularly interested in the "distribution" of the laboratory as the "autonomous" laboratory, and the new distributions its autonomous formation signals. Specifically, if a crucial part of the rover's autonomy is engineered through computational visions of Martian sand, then the rover as laboratory is "distributed" across scales of planetary difference, from computer visions of grains of sand and their transfer as data to computer screens on earth, and all the networked relations that hold these

[169] Bruno Latour, "Give Me a Laboratory and I will Raise the World." Retrieved June 22 2022 from: http://www.bruno-latour.fr/sites/default/files/12-GIVE-ME-A-LAB-GB.pdf
[170] Bruno Latour, 2003. "The World Wide Lab," *Wired*. June 1 2003. Retrieved June 24 2022 from: https://www.wired.com/2003/06/research-spc/

two nodes together. In this way, the Mars rovers as autonomous laboratories mark a moment where Latour's insights about the laboratory as distributed and relational can be updated to reflect these new scales of relation and distribution.

What are the politics of these new scales of relation and distribution in the shifting form of the autonomous laboratory? How can we understand what is at stake in this new formation?

In the fields of feminist STS, ethnic studies, and postcolonial approaches to STS, the figure of the laboratory is often framed as a *colonial* laboratory, because of the long histories of colonial power established, enhanced, and enforced through laboratories of scientific research and practice. For example, while Atanasoski and Vora describe NASA's plans to engineer robot laboratories to explore Mars in as early as 1964 to "solve the problem of how to command a space that is physically (or temporally) impossible for humans to penetrate,"[171] other scholars at the intersections of STS and Ethnic Studies have also theorized the use of the laboratory (both literally and figuratively) to accomplish the remote control and command of space as an extension of colonial and imperial power.[172] Towghi and Vora observe that the use of the laboratory as an extension of colonial and imperial power emerges alongside "the colonial and racialized history of experimentation, where European colonies served as laboratories to test all kinds of unproven technologies"[173] while also emerging as an "orientation toward the world and toward society in everyday practices."[174]

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[171] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*, p. 150.
[172] See: Warwick Anderson, *Colonial Pathologies: American Tropical Medicine, Race, and Hygiene in the Philippines*, (Durham: Duke University Press, 2006).; Aimee Bahng, *Migrant Futures*; Laura Briggs, *Reproducing Empire: Race, Sex, Science, and U.S. Imperialism in Puerto Rico*, (Oakland: University of California Press, 2003); Michelle Murphy, *The Economization of Life*, (Durham: Duke University Press, 2017).
[173] Fouzieyha Towghi and Kalindi Vora, "Bodies, Markets, and the Experimental in South Asia," *Journal of Anthropology* 79, no. 1, (2013), pp. 1-13.
[174] Fouzieyha Towghi and Kalindi Vora, "Bodies, Markets, and the Experimental."

In this way, the development of SPOC alongside a suite of other algorithms in MAARS to enhance the autonomy of the Mars rovers evidences an extension of the history of the laboratory as a figure for the remote control and command of space as an extension of colonial and imperial power through the engineering of autonomy but marks a particular orientation toward the world, where this expansionism is read as technological progress, its engineering as innovation. The Mars rover is thus a unique formation of the laboratory that rehabilitates the colonial laboratory under new technoliberal logics and world orders.[175]

The Settler Colonial Logics of Autonomous Terrain Classification

What specific formations of colonialism does the rover as autonomous colonial laboratory enact?

First, the use of SPOC in the Mars rovers marks a specific moment of the extension of US settler colonialism through the engineering of autonomous terrain classification. Settler colonialism can be understood as a specific system of colonial power structured according to what Patrick Wolfe has described as a "logic of elimination" that takes for granted the emptiness and therefore the availability, of land for settlement or capture, and the elimination and assimilation of native or Indigenous people and culture into the settler society.[176]

There is important scholarship at the intersections of Indigenous Studies and Geography that analyzes the extension of US settler colonialism into outer space. For example, Indigenous geographer Deondre Smiles has made settler colonialism of outer space explicit. Smiles writes:

[175] Neda Atanasoski and Kalindi Vora, *Surrogate Humanity*.
[176] Patrick Wolfe, "Settler colonialism and the elimination of the native," *Journal of Genocide Research* 8, no. 4 (2006).

Settler colonialism is commonly understood to be a form of colonialism that is based upon the permanent presence of colonists upon land. This is a distinction from forms of colonialism based upon resource extraction (Wolfe, 2006; Veracini, 2013). What this means is that the settler colony is intimately tied with the space within which it exists—it cannot exist or sustain itself without settler control over land and space. This permanent presence upon land by 'settlers' is usually at the expense of the Indigenous, or original people, in a given space or territory. To reiterate: control over space is paramount. As Wolfe states, "Land is life—or at least, land is necessary for life. Thus, contests for land can be—indeed, often are—contests for life" (2006: 387). Without land, the settler state 'dies'; conversely, deprivation of land from the indigenous population means that in settler logic, indigeneity dies (Povinelli, 2002; Wolfe, 2006.)

The ultimate aims of settler colonialism is therefore the occupation and remaking of space. As Wolfe (2006) describes, the settler state seeks to make use of land and resources in order to continue on; whether that is through homesteading/residence, farming and agriculture, mining, or any number of activities that settler colonial logic deems necessary to its own survival. These activities are tied to a racist and hubristic logic that only settler society itself possesses the ability to make proper use of land and space (Wolfe, 2006). This is mated with a viewpoint of landscapes prior to European arrival as *terra nullius*, or empty land that was owned by no one, via European/Western conceptions of land ownership and tenure (Wolfe, 1994).[177]

[177] Deondre Smiles, "The Settler Logics of (Outer) Space," *Society and Space*, October 26 2020. Retrieved from: https://www.societyandspace.org/articles/the-settler-logics-of-outer-space.

First, it is important to note how Smiles emphasizes that settler colonialism involves "the permanent presence of colonists upon land."[178] While the rover might not be a "colonist" *per se*, it is important to mark the permanence of the rovers presence on Mars, and how this presence extends and ensures the presence of the United States as a state power on Mars. Without plans for the repatriation and return of the rovers, it is important to recognize that the rovers are permanent.

Another way in which US scientific research and development is extending the material formation and logics of US settler colonialism through the engineering of autonomous terrain classification. For example, a settler colonial logic of terrain classification is required for the intelligence of the rover as an autonomous laboratory, one that SPOC demonstrates is taking particular kinds of Martian terrain for the expansion of machine intelligence, or the amplification and strengthening of its classification and intelligence. As Smiles observes with Wolfe, "the settler state seeks to make use of land and resources in order to continue on [through] any number of activities that settler colonial logic deems necessary to its own survival." I turn to this reading of settler colonialism to draw out its apt potential to identify and describe the settler colonial logics of NASA's efforts to create autonomous scientific discovery through the development and expansion of autonomous navigation and terrain classification of the current fleet of Mars rovers. As the rover "continues on," more data is generated through the images of sand that the rover captures of terrain. At the same time, in order for the rover to "continue on," it must classify the terrain features in these images appropriately according to the values that define its scientific and research goals, particularly with respect to its planned route and its define targets of scientific of interest. In order to perform such classification appropriately, the

[178] Deondre Smiles, "The Settler Logics of (Outer) Space."

rover must possess sufficient intelligence, through the algorithmic intelligence of adequate machine learning programs like SPOC.[179] In this way, machine intelligence is a defining feature of the settler colonial logic that rationalizes the drive for autonomous scientific discovery, as the rover's capacity to "continue on" is directly defined by its capacity for intelligent terrain classification, or the datafication and thus capture of planetary terrain. As with any settler colonial project, the datafication of land or terrain is essential to the expansion of the settler colonial territory. While SPOC is able to classify multiple types of terrain, its novel ability to classify sand autonomously marks an important moment wherein particular types of terrain are able to be captured in new ways.

Lastly, there is an important relationship revealed here between knowledge and settler colonialism. While this Chapter will later elaborate on the long historic relationship between colonialism and knowledge (through an analysis of machine intelligence and rationality), here it is important to note that Deondre Smiles observes that current US space exploration operates within a settler colonial logic, wherein "Space represents yet another 'unknown' to be conquered and bent to America's will,"[180] thus positioning knowledge in relation to the driver of the settler colonial project. Likewise, space, and more specifically Martian terrain, as unknown is an important driver in the scientific research and technologies that are used to achieve those interests, particularly in the case of autonomous discovery, or the use of machine intelligence for autonomous terrain classification and navigation, and thus the drive to engineer autonomous scientific discovery can be read as an update to the long histories of US settler colonialism as a project concerned with capturing the unknown through the capture of *terra nullius*.

[179] Masahiro Ono et al., "MAARS."
[180] Deondre Smiles, "The Settler Logics of (Outer) Space." Retrieved from: https://www.societyandspace.org/articles/the-settler-logics-of-outer-space

The Colonial Imperial Logics of Computing as a Universal Democratic Worldview

The development of SPOC and its use in the Mars Exploration Program can also be historicized as a technological development in the long history of computing, and in particular as an extension of US computing imaginaries that install a colonial imperial worldview as universal and democratic progress.

Here, I build from Neel Ahuja's definition of colonialism as "a large-scale political and economic system that allows one geopolitical entity (such as a nation-state or city state) to establish controls beyond its traditional geographic borders in the service of increased profit or power."[181]

Scholarship across the fields of STS and feminist STS have theorized the ways in which the development of the computer emerged through a colonial and imperial worldview, while also installing it. While the next Chapter (Chapter 4) elaborates on this by tracing one history of computing through its material development through US imperial and settler colonial transpacific relations in Hawaii, in what follows this Chapter builds from scholarship concerned with the intersections of race and computing to elucidate the ways in which the computer, as a technological imaginary, installs a colonial logic of discovery through its structure as a mode of classification.

Specifically, Wendy Chun has observed that a logic of discovery is not only "built into" the computer, but structures its relationship to data and network protocols.[182] For example, Chun describes the logic of capture as fundamental to the logic of the network and its relationship to

[181] Ahuja, Neel. 2017. "Chapter 16: Colonialism," in *Macmillan Interdisciplinary Handbooks, on Gender: Matter*. Retrieved June 23 2022 from: https://cpb-us-e1.wpmucdn.com/sites.ucsc.edu/dist/f/396/files/2014/11/Ahuja-Colonialism.pdf

[182] Wendy Chun, *Updating to Remain the Same*.

computing and data. Drawing on the work of computer scientist Philip Agre's "Surveillance and Capture" to describe how data capture is "framed as discovery."[183] Chun explains that "[c]apture systems actively restructure what they allegedly discover…[as they] buttress the economization of all interactions central to neoliberalism."[184]

Further, Chun also observes that as computers operate as "universal machines" that install classification, provide a "disordering that is also an ordering, a dismantling that is also a redescription." This process of redescription, which, as Chun describes, "makes things visible,"[185] evidences a "movement from surprise to understanding"[186] and is how computers embody and enact a logic of discovery. Here Chun's observations help us see how computing as a universal, machinic practice of classification, disordering and ordering, and redescription mirrors and ensures the reproduction of colonial logics, through the production of order itself. As Chun observes, articulating the ways in which the logic of discovery is built in and built through computing as metaphor and as process enables us "to understand and conceptualize…how power operates in a world marked by complexity and ambiguity, in a world filled with things we cannot fully understand, even though these things are marked by, and driven by, rules that should be understandable, that are based on understand-ability."[187]

Furthermore, scholarship across Ethnic Studies and STS like Atanasoski and Vora and Wendy Chun identify and describe the specific way in which liberal discourse of democratic virtue become entangled with technological development. The rise of computing thus exemplifies the way in which technoliberal discourse comes to obscure and often disavow its

[183] Wendy Chun, *Updating to Remain the Same*, p. 60.
[184] Wendy Chun, *Updating to Remain the Same*, p. 60.
[185] Wendy Chun, *Programmed Visions: Software and Memory*, (Massachusetts: MIT Press, 2009), p. 57.
[186] Wendy Chun, *Programmed Visions*, p. 57.
[187] Wendy Chun, *Programmed Visions*, p. 58.

imperial material histories of development. In this sense, the development of SPOC and the continued investment in increasing the capability of computational vision as a mode of scientific research and practice, reasserts and extends the material histories of computing as a mode of imperialism through which SPOC has emerged. By marking the colonial and imperial material histories of SPOC as conditions of its development, the technoliberal discourse of innovation for autonomous scientific discovery can be made clear. The settler colonial logics of the rover emerge as an extension of the rover as one extension of the US space program as a broader colonial and imperial project of US state power accomplished through scientific and technological development.

Intelligence (whether of Man or Machine) as the Arbiter of Colonial and Imperial Expansion and Reproduction

In this section, I emphasize that the colonial imperialism of the computer as worldview and the settler colonialism of the project of terrain classification demonstrate that intelligence, and specifically the development of machine intelligence, is thus the arbiter of settler colonial and colonial imperial expansion. I then situate machine intelligence as an inheritance of intelligence and rationality of the liberal subject in order to show the rover as a specific formation of the laboratory, the autonomous colonial laboratory.

SPOC enacts its settler colonial logic and colonial imperial logic through its machine intelligence, that is, through its design to mitigate risk to the rover by accurately predicting the presence of sand. In other words, the coloniality of the rover is articulated through its design for ongoing scientific research through the intelligent classification and thus capture and expansion

of territory through SPOC. The idea that an increased capacity of machine intelligence can increase the certainty with which rovers classify terrain and navigate safely to scientific targets indicates the complex relationships that mark intelligence as knowledge (e.g. the rover's ability to "know" or use its intelligence to accurately discern through predictive algorithms the presence of certain terrain types), or intelligence as certainty or accuracy as a mode of rationality (or, in other words, intelligence being certainty through rationality, or accuracy) or rational terrain classification, reflects the logic that more data means more certainty and more intelligence (or, more accurate predictive classification algorithms). More data and more classified data, more accurate predictive classification algorithms, become the assurance of the continuity of the settler colonial project. In this way, the project of autonomous terrain classification on Mars evidences the uniquely reproductive aspect of colonial data extraction.

Scholarship in STS has described the relationship between classification as an extension of colonial power, as systems of classification come out of post-enlightenment reason and the collusion of scientific discovery and colonial conquest, and specifically the relationships between colonialism and rationality.[188] Building from this literature, SPOC evidences how the technological development intelligent terrain classification redescribes enlightenment projects of rationality in new technoliberal terms. Specifically, this desire and effort amounts to the expansion of US scientific research and technological development in service of the project of scientific discovery by expanding the capabilities of the autonomous laboratory.

The emergence of the autonomous laboratory makes clear that intelligence, and specifically the rational prediction of the presence of sand, is the arbiter for colonial and imperial expansion. The need to mitigate uncertainty evidences the way in which rationality undergirds

[188] See Ahuja, "Colonialism"; Mary Louise Pratt, *Imperial Eyes*.

the larger projects of terrain classification and the engineering of autonomy. Therefore, SPOC can be read as an Enlightenment project, insofar as it relies upon the continued investment and perfection of rationality as a mode of being in the world, or modes of scientific discovery. Byrd writes:

> "My use of transit refers to a rare astronomical event, the paired transits of Venus across the sun, that served in 1761 and again in 1769 as global moments that moved European conquest toward notions of imperialist planetarity that provided the basis for Enlightenment liberalism.[8] The imperial planetarity that sparked scientific rationalism and inspired humanist articulations of freedom, sovereignty, and equality touched four continents and a sea of islands in order to cohere itself. At its center were discourses of savagery, Indianness, discovery, and mapping that served to survey a world into European possession by transforming indigenous peoples into the homo nullius inhabitants of lands emptied and awaiting arrival. As I use the term here, transit as a concept suggests the multiple subjectivities and subjugations put into motion and made to move through notions of injury, grievance, and grievability as the United States deploys a paradigmatic Indianness to facilitate its imperial desires. This paradigm of Indianness that functions as the transit of U.S. empire arises from how the United States was constituted from the start, not just in the scientific racisms and territorial mappings inaugurated through Enlightenment voyages for knowledge, but in the very constitutionality that produced the nation."[189]

[189] Jodi A. Byrd, *The Transit of Empire*, p. xx-xxi.

The histories of European imperialism and US settler colonialism have thus long shaped imaginaries of planetary conquest within imperialist logics and desires. Such imaginaries now transform into contemporary searches for ancient life on Mars and the US settler colonial project of autonomous scientific discovery on Mars is an extension of these earlier projects that also saw the extension of rationality and scientific discovery as a means for extending US settler colonialism and imperialism across shifting planetary imaginaries.

While Byrd's analysis demonstrates the close relationships between the planetary and scientific rationalism in the long histories of Enlightenment and scientific discovery, SPOC marks a unique historical moment where we see the reiteration of Enlightenment voyages for knowledge that rehearse the colonial logics of the laboratory in new technoliberal terms.

The rover thus indexes a historical moment where ideas about rationality and intelligence are encoded through autonomy and engineered into, and thus come to be entangled with, the colonial and imperial logics of terrain classification as settler colonialism. In this way, SPOC marks the rover as not just an autonomous laboratory or a colonial laboratory, but instead marks the confluence of autonomy and colonialism in the rover. Importantly, the case of SPOC and the Mars rover show that the capture of terrain as data ensures the expansion of US scientific and technological interest and development. This is the mark of the *autonomous colonial* laboratory – that its efforts to engineer autonomy guarantee its reproduction. The process of engineering autonomous terrain classification through SPOC demonstrates something important about the rover as not just a colonial laboratory or an autonomous laboratory, but as an autonomous colonial laboratory – that the rover's capacity for autonomous terrain classification ensures its own reproduction. That is, as the rover drives, more data is generated of Martian terrain, which can be used to further train the terrain classifier. As the terrain classifier is further trained, the

rover is able to navigate further, with reduced risk to its overall safety. In this way, SPOC becomes a reproductive technology – a technology that enables and ensures the reproduction of the laboratory. In this way, the autonomous colonial laboratory is uniquely positioned as always in formation and in formation of itself.

Terra Nullius and The Resource View of Sand

Thus far I have argued that NASA's efforts to engineer autonomous scientific discovery through autonomous terrain classification reasserts and extends the US settler colonial project and the long histories of US colonialism and imperialism as a dominant worldview and order, particularly as the engineering of autonomous scientific discovery though autonomous terrain classification not only reproduces the infrastructure of computing and machine intelligence as a colonial and imperial worldview, but does so through the particular logics of settler colonialism and its planetary imaginary of *terra nullius*.

Indeed, the planetary imaginary of *terra nullius* emerges in complex ways to shape and drive NASA's efforts to engineer autonomous scientific discovery, operating as a broad, structuring imaginary that enables other planetary imaginaries to emerge that work in concert with *terra nullius* to advance the engineering of autonomous scientific discovery through autonomous terrain classification. In other words, *terra nullius* becomes a logic and imaginary that undergirds and enables the planetary imaginary that enables sand to be imagined as a resource available for data extraction, accumulation, and expansion. Put simply, terra nullius operates to ensure that sand is imagined as a risk to the expansion of scientific research on Mars through the rover, and, therefore, a resource for overcoming the limits of scientific research through autonomous terrain classification.

This "resource view" of sand reinforces a kind of biocentrism that has long structured colonial and settler colonial planetary imaginaries of *terra nullius*. For example, Katherine McKittrick asks, "How, in the present, have the lands of no one emerged and normalized a mode of organizing the planet according to life and lifelessness?"[190] Writing about the plantation logics of US chattel slavery, McKittrick observes that "[t]he plantation that anticipates the city, then, does not necessarily posit that things have gotten better as racial violence haunts, but rather that the struggles we face, intellectually, are a continuation of plantation narratives that dichotomize geographies into us/them and hide secretive histories that undo the teleological and biocentric underpinnings of spatiality."[191]

McKittrick's analysis here is important as it helps us to see that, despite the ways in which the engineering of autonomous terrain classification in the Mars rovers is positioned and celebrated as technological progress, it reproduces (and ensures the reproduction of) old logics and imaginaries of planetary life into new territory. While McKittrick writes that "[t]he interlocking workings of human worth, race, and space demonstrate the ways the uninhabitable still holds currency in the present and continues to organize contemporary geographic arrangement [and that t]he colonial enactment of geographic knowledge mapped "a normal way of life" through measuring different degrees of humanness and attaching different versions of the human to different places,"[192] autonomous terrain classification presents an elaboration of McKittrick's arguments concerning the uninhabitable, as we can see how the racialized production of space, life, and lifelessness are codified in scientific logics about Mars and the computing infrastructures that embody them. In other words, the logic and imaginary of the lands

[190] Katherine McKittrick, "Plantation Futures," *small axe* 17, no. 3 (2013), p. 8.
[191] Katherine McKittrick, "Plantation Futures," p. 12.
[192] Katherine McKittrick, "Plantation Futures,"pp. 6-7.

of no one, of uninhabitability are transformed through the settler colonial and colonial imperial logics of data extraction and computing to become the not yet inhabitable. In this way, our categories of computing, data infrastructure, and the autonomous colonial laboratory ensure the continued availability of Martian terrain for the project of engineering autonomous scientific discovery. The engineering of autonomous scientific discovery on Mars marks a moment where Mars, perhaps once a version of McKittrick's uninhabitable, is transformed into what I will describe as the "not yet" habitable, shaped by the speculative drive of the engineering of autonomous scientific discovery and the capture of the unknown, as SPOC is designed to increase the capacity of the machine intelligence of the rover to not only make Mars "habitable" for the rover (that is, able to survive, persist, and remain operable), but also as part of the broader effort to determine the habitability of Mars – that is, whether Mars once supported life. In this way, Mars as the "not yet" habitable becomes a spatial geography that is defined through the racial formation of the aspirational future for humanity, or the future of Man, elaborating on McKittrick's analysis of the racial divisions of space in the plantation logic, and the biocentric views of life they install.

I am cautious not to conflate the engineering of autonomous terrain classification with McKittrick's analysis of the plantation and its specific histories of racial domination. I am, however, encouraged by The Precarity Lab's observation and reminder that "digital networks signal not novel dystopias but old paradigms of domination (the plantation, the colony, the prison, the military industrial complex, the laboratory, and the special economic zone)."[193] Marking Mars as a racialized, imperial and settler colonial space of the "not yet inhabitable" helps us to see how the engineering of autonomous scientific discovery through

[193] The Precarity Lab, "The Precarity Effect: On the Digital Depletion Economy," in *Technoprecarious*, (London: Goldsmiths Press, 2020), retrieved from: https://goldsmithspress.pubpub.org/pub/y5a49njp/release/1.

autonomous terrain classification "signals," as The Precarity Lab warns, the reproduction of these old paradigms of domination in new form. The project of engineering autonomous scientific discovery, then, inherits the plantation, and the racial formations of space and the differential distribution humanness as a spatial problematic and scaffolding of futurity.

I have argued that the planetary imaginary of the *not yet inhabitable* is characterized by settler colonial and colonial imperial regimes of data extraction and accumulation around sand as a resource for the project of engineering the autonomous colonial laboratory. Thus, in the racialized, settler colonial and imperial imaginary of Mars as the *not yet inhabitable*, sand is imagined to be a resource for engineering autonomous terrain classification, a risk to expansion that can be overcome through datafication and the engineering of machine intelligence for autonomous terrain classification. In the imaginary of the *not yet habitable*, where intelligence is the arbiter of settler colonial and imperial expansion, sand is thus the condition of expansion: that is, as the engineering of autonomous terrain classification establishes a relationship between sand and machine intelligence through data extraction, sand becomes the condition and material for the expansion of (rover) intelligence and the project of autonomous scientific discovery.

Against Intelligence

What can be done to counter the ongoing production and expansion of autonomous terrain classification on Mars, and thus the ongoing expansion of the autonomous colonial laboratory through the planetary imaginary of *terra nullius* and its resource view of sand? To respond to this question, in what follows I build on scholarship at the intersections of feminist STS and Ethnic Studies to resist and refuse intelligence, as a technique to resist the ongoing expansion of the autonomous colonial laboratory.

The resource view of sand disavows sand as a planetary process in favor of its resource value for the expansion of the settler colonial and imperial project of the rover. It echoes broader logics of value in which planetary processes are valuable only for their potential as resources to support human life – or in this case, their potential to support the perfection of the autonomous colonial laboratory. Thus, echoing McKittrick's analysis of biocentrism, this version of intelligence is shaped by biocentrism, such that a biocentric view of intelligence that operates to demarcate Mars into the not yet habitable. In this way, sand as a material planetary process, is decidedly not intelligent, but rather a resource for engineering intelligence.

Biocentricity as an imaginary for intelligence runs deeply through scholarship concerning machine intelligence and intelligence modeled after human intelligence. For example, recent scholarship like N. Katherine Hayles' *Unthought* rethinks cognition in light of advances in neuroscience that "[confirms] the existence of nonconscious cognitive processes inaccessible to conscious introspection but nevertheless essential for consciousness to function" in order to understand "terra incognita that beckons beyond our received notions of how consciousness operates" while "[g]esturing toward the rich possibilities that open when nonconscious cognition is taken into account" as a way to "[name] the potent force of conceptualizing interactions between human and technical systems that enables us to understand more clearly the political, cultural, and ethical stakes of living in contemporary developed societies."[194]

Hayles' goal is to "formulate the idea of a *planetary cognitive ecology* that includes both human and technical actors"[195] by defining cognition with attention to its distribution across human, biological, technical, and material components and the enactment of cognition and

[194] N. Katherine Hayles, *Unthought: The Power of the Cognitive Nonconscious*, (Chicago: The University of Chicago Press, 2017), p. 2.
[195] N. Katherine Hayles, *Unthought*, p. 3-4

choice through such distributions.[196] With this framework, Hayles' definition of cognition "applies to technical systems as well as biological life-forms…[but] excludes material processes such as tsunamis, glaciers, sandstorms, etc." as such material processes do not enact interpretation and choice.[197]

While Hayles' rethinking of cognition is important as it demands attention to a planetary cognitive ecology as a way of becoming responsible to the ethical, political and cultural stakes of our current moment and contemporary investment in cognitive assemblages and systems, the case of sand presents a challenge to Hayles' framework of a planetary cognitive ecology, the distribution of cognition, and the formulation of cognition and its exclusion of material planetary processes like sandstorms, like sand. On the one hand, the engineering of autonomous terrain classification, navigation and decision-making through SPOC demonstrates that indeed material processes like sand and sandstorms are important grounds through which cognition is distributed, as these material processes have a direct role in the enactment of machine intelligence or cognition. But, perhaps more importantly, Hayles exclusion of planetary processes like sandstorms reinscribes biocentric, and humanistic concepts of intelligence in the articulation of a distributed planetary cognitive ecology, while reinforcing the binary of cognitive and non-cognitive, biocentric forms of life versus planetary material processes for example, to determine its distribution.

Having said that, Hayles' turn towards a *distributed* planetary ecology is an opportunity to resist the reproduction of binary concepts in thinking through the relationships between the different relations that make up planetary life. In other words, as distribution need not reinscribe a binary view, but is rather an opportunity and opening to think critically about the systems of

[196] N. Katherine Hayles, *Unthought*, p. 2
[197] N. Katherine Hayles, *Unthought*, p. 3

power that shape the distribution of intelligence, and intelligence as a distribution, rather than a naturalized phenomena. Making such a move is to resist the binary divisions of life and lifelessness that terra nullius and its biocentricity installs.

While Hayles' turn towards a distributed planetary ecology is an important one, it thus ultimately reinforces intelligence as a binary category, seeking to expand what counts as intelligent or cognitive (e.g. plants) while still policing its boundaries of inclusion (e.g. not sand). Furthermore, in the effort to frame a planetary cognitive ecology, attending to the distribution of cognition through sand on Mars is a way to embrace a robust politics of care for the ways in which planetary material processes are distributed in the engineering or enactment of cognition in human-technical systems – a politics of care that can, as I have argued, run against the material and temporal relations that are required for such engineering. And, as I have argued, as such relations are installed in service of the expansion of the autonomous colonial laboratory and the reproduction of its settler colonial and colonial imperial relations of extraction, accumulation, and development, framing a planetary cognitive ecology that accounts for the distribution of cognition through sand makes it possible to become responsible and accountable to the conditions through which cognition becomes distributed in these ways in the first place.

Thus, while holding onto Hayles' desire for a planetary cognitive ecology, such an ecological framework needs to be revised to account for the conditions of distribution itself – that is, the conditions through which cognition is distributed, and 'distribution' as a condition of cognition that is not given but rather a material and epistemic framework or lens itself that shapes and determines what forms of life are valued, and how.

In sum, I am making two critiques of Hayles. First, that Hayles' definition of cognition is too narrow given the ways in which planetary processes are part of the enactment of machine

intelligence in the case of SPOC and Martian sand. Second, that, therefore, Hayles' use of distribution does less to account for the ways in which cognition is distributed in a planetary cognitive ecology, and more instead works to frame a particular politics of cognition (and what counts as cognitive) as a politics of planetary life. The danger of this version of distribution is that it recenters choice and agency as an arbiter of cognition and thus an arbiter of recognition and planetary value. In this frame, humanistic behavior and values of choice and agency stand in to define a politics of care for living in a planetary ecology.

But, as Atanasoski and Vora have argued that there is no such thing as a feminist intelligence, arguing that we don't need feminist intelligence, per se, we need feminist approaches to disrupt the expansion of intelligence as a category and "[pillar] of conscious autonomy." They write:

> "The desire for feminist intelligence in AI is…an attempt to expand the category of intelligence without necessarily disrupting its value… the desire for a feminist *intelligence* reads the legacies of racial and gendered interactivity, voice, and response into technology. The technoliberal desire to expand intelligence thus simply reaffirms the racialized and gendered logics producing the fully human as moving target. Desire for the expansiveness of the category of intelligence, rather than a desire to disrupt this category and others that constitute the liberal subject, will not redress the surrogate effect of artificial intelligence. Intelligence is one of the pillars of conscious autonomy, and as such can only be proven by self-possession. If we define feminism as a decolonizing project, instead of a liberal inclusive one, such that feminism politically seeks to disrupt the categories of use, property, and self-possession rather than redress through inclusion,

> then perhaps we might provocatively say that there need not be such a thing as a feminist intelligence. Instead, intelligence itself becomes disruptable—something to be hacked."[198]

Thus, amidst the ongoing expansion of US settler colonialism through the investment in machine intelligence, it behooves us to embrace feminist and ethnic studies critiques of intelligence so as to resist the reproduction of intelligence through the engineering of machine autonomy through binary categories as an innocent mode of relationality given its role as a condition of the expansion of settler colonialism and the extension of colonial and imperial logics and worldviews. Resisting binaries in this way extends the long histories of Feminist STS scholarship that have offered hybrid concepts and formations as a mode of resisting binaries,[199] and specifically Patricia Hill Collins' discussion of binary thinking as, with reference to bell hooks, "the central ideological component of all systems of domination in Western society."[200] In this way, I position my resistance to the binary formations of intelligence as a strategy to resist and disrupt, as Atanasoski and Vora have guided us towards, intelligence as a system of domination.[201]

Distribution Reimagined

If distribution can, as we have seen, operate to define a politics of care for living in a planetary ecology that can resist the binary formation of intelligence, what can the distribution of sand tell

[198] Neda Atanaoski and Kalindi Vora, *Surrogate Humanity*, p. 196.
[199] See Banu Subramaniam, *Ghost Stories for Darwin*, p. 5; Donna Haraway, "A Manifesto for Cyborgs."
[200] Patricia Hill Collins, "Learning from the outsider within," S20; bell hooks, "From Margin to Center," p. 29.
[201] This move is made in conversation with Eli Clare's call to resist intelligence as a system of domination, in his 2017 work *Brilliant Imperfection.*

us about such a politics of care? Can the distribution of sand bring us towards a robust understanding of the stakes of living in our current planetary moment?

I argue that reimagining Hayles' planetary cognitive ecology and its distributed framework through Michelle Murphy's concept of distributed reproduction can usefully frame the way in which sand emerges as the space between the expansion of the autonomous colonial laboratory and the planetary formations that are taken as its condition of expansion and reproduction. Murphy writes:

> "Distributed reproduction is the extensive sense of existing over time that stretches beyond bodies to include the uneven relations and infrastructures that shape what forms of life are supported to persist, thrive, and alter, and what forms of life are destroyed, injured, and constrained…Distributed reproduction critically points to the often contradictory and contested relations making up becoming-in-time with the many. It names the tension-filled knots of relations that arrange capacities to persist or alter beyond the flesh of bodies and out into infrastructures, ecologies, epistemologies, imaginaries. The concept helps me to think both critically and otherwise about not just aggregates but about the more-than-life conditions and histories that compose the world and life chances. Importantly, distributed reproduction is not a romantic conceptualization of flourishing togetherness. Reproduction itself is not a good; rather, it is a process of supporting some things and not others. The conceptualization of distributed reproduction strives to reckon with this fraught process of becoming-in-time that has been constituted through violence, uneven accumulations, and abandonments, and is not merely an affirmation of life. It stretches beyond bodies, individuals…into the

more-than-human, more than-biotic relations that have been recomposed in the aftermath of capitalism, the nation-state, and macroeconomy."[202]

Read together, Murphy's distributed reproduction asks how Hayles' planetary cognitive ecology articulates a politics of living in our current planetary moment in a way that asks us to reckon with how such a planetary cognitive ecology is also a process of reproduction, or "a fraught process of becoming-in-time that has been constituted through violence, uneven accumulations and abandonments, and not merely an affirmation of life."[203] If the planetary cognitive ecology can be more than an affirmation of cognition, say, but rather a technique for naming the uneven distributions of planetary living that are the conditions of enacting cognition, enacting machine intelligence, then such a framework can help orient us to a critical politics of care for life in our current planetary moment – one premised upon the historical material relations of planetary life that have conditioned the emergence of the autonomous colonial laboratory in the first place.

While resisting the reproduction of intelligence or cognition as orientations to the world, my argument is not that sand is intelligent or cognitive, but, rather, that as long as we insist that sand is not intelligent or non-cognitive, we foreclose the potential to attune to planetary systems and the planetary imaginary as the conditions that shape which forms of life are valued and which are devalued within such an imaginary. As planetary and material processes operate on non-human timescales, and agency and choice are human standards of behavior, they are measures of humanity that cannot adequately account for planetary forms of life and their scale of existence.

[202] Michelle Murphy, *The Economization of Life*, pp, 141-3.
[203] Michelle Murphy, *The Economization of Life*, p. 143.

Joe Masco has usefully identified the problem of time and perception in understanding and grappling with the formation of planetary disaster in our current moment. Masco writes:

> "Climate disruption…now posits a vision of end times that rivals that of the nuclear danger, as the incremental and cumulative effects of the petro-chemical industry have foundationally shifted the atmospheric chemistry on Earth, setting off a reverberating chain of effects throughout the biosphere. But if the global nuclear danger is characterized by its shocking immediacy, climate danger works on an opposite temporality, constituting a slower violence that is treacherous precisely because it is so incremental that it is difficult in any given moment to sense a change in the environment or to connect discrete issues (such as sea level or drought or fires or violent weather) to industrially generated greenhouse gas emissions. It is a cumulative and momentum-driven process, operating on so vast a scale that it raises basic questions about human perception, memory, and the terms of visualization appropriate for planetary-scale problems. In light of such industrial fallout, geologists are now debating how to sequence planetary time to recognize the effects of human industry… Geoengineering, planetary stewardship, hostile environmental states – these are the terms of a radically new kind of emergency, one that operates on the global scale of the biosphere. The ten thousand-plus years of the Holocene emerge as a temporary atmospheric condition on planet Earth, one particularly beneficial to humans, who, living in that special air, rose to become the dominant species, inventing agriculture, writing, cars, computers, and atomic bombs in

the process. A Euro-American concept of the planet is now fundamentally shifting, from literally stable ground, unchangeable in its nature, to a runaway system…"[204]

Masco here underscores the relationships between planetary imaginaries, temporality, and human perception, memory, and the visualization of problems that reach across scale. Once we let go of the assumption of human temporality and human standards of behavior like choice and agency as a measure of planetary cognition, we can resist the expansion of intelligence. To insist on the cognitive potential of that which is categorically non-cognitive is not to insist on the sand as cognitive, but, rather, to point to the conditions under which cognition is made legible in the first place. Therefore, the accumulation of sand on Mars marks danger to the expansion of such a mode of planetary life while evidencing the possibilities that exceed and escape human perception and memory.

As the visualization of such planetary stewardship challenges, as Masco argues, human perception and memory, I find sand to be an important materiality that can adequately implode the contradictions of planetary life under US settler colonialism and global racial capitalism. Sand affords a different understanding of value in accumulation, offering us a chance to read against the logics of imperial/racial capitalist accumulation that read sand as accumulated data, or danger. Instead, in geologic time, the movement of the sand may very well express a pattern of movement, an accumulation of movement that, at least, pushes at the boundaries of choice and agency as a useful framework for attuning to planetary ecologies.

Thus, building from Masco, I offer sand as a ready ground that can usefully engage these relationships in a way that pinpoints the role of US settler colonialism and global racial

[204] Joseph Masco, *The Future of Fallout, and Other Episodes in Radioactive World-Making*, (Durham: Duke University Press, 2021), p. 254.

capitalism in the visualization and action in planetary crises. Within the temporality of engineering autonomy and autonomous scientific discovery on Mars, sand comes to form danger, the terrain in which a rover gets stuck, a useful ground through which data can be generated and put to work to expand machine intelligence. Computational visions of sand mark the temporality of the expansion of US settler colonialism and global racial capitalism, the speed of data extraction, data accumulation, and machine learning and intelligence, the speed of expansion. At the same time, the accumulation of sand also indexes the temporality of geological time, the timescale that Masco so usefully marks as a mode of planetary stewardship.

Sand thus becomes a ground of enjambment for the planetary imaginary of US settler colonial and global racial capitalist expansion and the planetary imaginary of geological time, a liminal space that might allow an embrace of a new form of interplanetary stewardship. Sylvia Wynter has said, "the cognitive escape hatch is always in the category of the liminal."[205] While resisting the urge to escape in the sense of evading, I offer Wynter's cognitive escape here as an important break to the reproduction of cognition as an organizing structure of the planetary imaginary of US settler colonialism and global racial capitalism. In this sense, sand becomes our "cognitive escape hatch" that can challenge the insistence on cognition and intelligence itself. Sand is a material and metaphorical ground through which we might articulate the distributions of cognition *across* scales of space and time. Distributed reproduction thus offers a theoretical framework to critique and reimagine scientific and technological development, extraction, and accumulation on Mars, with the elasticity to engage the planetary scale and temporalities in a

[205] Sylvia Wynter, ""No Humans Involved": An Open Letter to My Colleagues," *Forum N.H.I: Knowledge for the 21st Century* 1, no. 1 (1994). Retrieved from: https://people.ucsc.edu/~nmitchel/sylvia.wynter_-_no.humans.allowed.pdf, p. 13.

way that creates an opening for speculative approaches to understanding the collective forms of life "that are, that were, and that might be."[206]

What escapes the computational vision of sand?

How can we embrace sand as temporally distributed and speculative ground? The rover's computational vision of sand is a narrow one that defines the value of sand according to its value within the timescales required for engineering the rover's capabilities for autonomous navigation and decision-making. This timescale is one that is defined by the demands of remote control and command of space, including limits of data classification, accumulation, and use. In this timescale, the speed of the rover is also the speed of data generation and accumulation, shaped further by the speed of the algorithm as it classifies terrain data for use in navigation. In this equation, time, like space, is a resource, as the speed of data generation, accumulation, and use is always entangled with the speed of the rover, as autonomous navigation through autonomous terrain classification hedges against moments of unplanned pauses while optimizing route planning and energy. The temporality of sand thus becomes defined by its threat of delaying the rover in an unplanned pause. Sand is a temporal problem as much as it is a material one.

The computational vision that positions sand a temporal problem runs alongside and against a planetary vision of sand that situates sand as historical material geologic formations. While it is beyond the scope of this study to attend to sand as a geologic formation as it is within the fields of geology and sedimentology, I offer sand as a geologic formation as a temporal and material counterpoint to the computational vision of sand that defines the imaginary of

[206] Michelle Murphy, *The Economization of Life*, p. 143.

autonomous scientific discovery and its efforts to engineer autonomous terrain classification and navigation in the Mars rovers. While sand within the material and timescales of the fantasy of autonomous scientific discovery emerges as a material and temporal threat to the rover's safety and operation (that is, as a threat to autonomous scientific discovery), sand within geologic time opens onto the processes of planetary formation and movement. While the accumulation of sand within the fantasy of autonomous scientific discovery is operationalized through an accumulation of data, the accumulation of sand as a geologic formation evidences the layered histories of planetary formation and movement.

By juxtaposing these two visions, sand comes to represent the liminal space between competing imaginaries of planetary value while exposing the ground that cuts across and defines their difference. Autonomous terrain classification precludes recognition of the slow temporalities of sand in geologic time. Instead, the value of sand is calculated by its image as terrain, accumulated visions of its surface without regard to its depth of formation.

Learning to attend to the absented depth of sand that its accumulation as data is thus an extension of Agard-Jones' attention to sand as a space and marker of absence, and can thus be a technique of postcolonial analysis and anti-colonial practice, where sand becomes a material ground through which to grapple with the challenging histories of life within and against colonial imaginaries of space and time. Specifically, Vanessa Agard-Jones references Tamiko Beyer's "Notes Towards a queer::eco::poetics" in the opening provocation of "What the Sands Remember," to ask "might we imagine Tamiko Beyer's "saturated, empty syllable" as something akin to a grain of sand?"[207] Agard-Jones asks "that we consider sand as a repository both of feeling and of experience, of affect and of history, in the Caribbean region" where "sand links us

[207] Vanessa Agard-Jones, "What the Sands Remember," *GLQ* 18, no. 2-3, p. 325.

unswervingly to place, to a particular landscape that bears traces of both connection and loss."[208] Agard-Jones' attends to sand as both a material and metaphor for "a repository from which we might read traces of gender and sexual alterity on the landscape. Ever in motion, yet connected to particular places, sand both holds geological memories in its elemental structure and calls forth referential memories through its color, feel between the fingers, and quality of grain. Today's sands are yesterday's mountains, coral reefs, and outcroppings of stone. Each grain possesses a geological lineage that links sand to a place and to its history, and each grain also carries a symbolic association that indexes that history as well."[209] In this way, Agard-Jones' attention to sand is attention to "what the sands remember," as sands "carry the imprint" of its history, each grain formed through history. For Agard-Jones, the sand tracks the presence of same-sex desire in the Caribbean, in places "where the archive is shallow…[where] there can be no definitive record."[210] For Agard-Jones, "turning to sand as a metaphor for the repository of memory may help our analyses engage with more fine-grained and ephemeral presences than our usual archives would allow."[211] While Agard-Jones' analysis is explicitly earth-bound, where "sand is principally made up of one element—in some places silica, in others limestone," "[n]inety percent of a grain is almost always just one of those two elements. But the other 10 percent is the percentage with a difference – the percentage that, in its difference, matters – the percentage that can tell us something about the history of a place."[212]

Building from Agard-Jones' analysis, SPOC, as a predictive algorithm, demonstrates that there is always a percentage of sand that escapes the capture of computational vision. In this

[208] Vanessa Agard-Jones, "What the Sands Remember," p. 325.
[209] Vanessa Agard-Jones, "What the Sands Remember," p. 326.
[210] Vanessa Agard-Jones, "What the Sands Remember," p. 339.
[211] Vanessa Agard-Jones, "What the Sands Remember," p. 340.
[212] Vanessa Agard-Jones, "What the Sands Remember," p. 340.

way, I extend Agard-Jones' attention to sand as both a material and metaphor for absence, what cannot be recorded, what escapes our computational vision, the archive, our epistemologies of what can be known with certainty, sand and the difficulty it poses to computational vision, can be a material ground through which we might learn to mark the space of uncertainty as a refusal of the expansion of intelligence and rationality as a mode of being in the world and engineering futures. In other words, I offer sand as a material that we can turn to when, as Agard-Jones observes, the archive is shallow, to reveal the depths that colonial epistemologies of sand as data for engineering autonomous scientific discovery on Mars ignore. Holding this tension without resolving it, in what follows I offer a vision (glimpse) of transpacific sand as a way of "seeing" human and planetary relations differently, in geologic time, in ways that can help us to grapple with the aftermath of US imperialism, colonialism, and global racial capitalism that are, as I have argued, terrestrial conditions for the expansion of the autonomous colonial laboratory on Mars.

In February 2020, Somini Sengupta, a New York Times global climate reporter, and Chang W. Lee, a New York Times photographer, traveled to Manila, Philippines, and San Franscisco, California, to document and investigate how rising sea levels are impacting these regions and the people who live in them.[213] The report observed that these "[t]wo sprawling metropolitan areas offer a glimpse of the future…one rich, one poor, they sit on opposite sides of the Pacific Ocean" but sand emerges as a material connection in their struggle and relationship to rising tides and climate crisis. For example, the report moves from visions of the Alay-ay family in Malabon, Manila pouring sand and cement on the floor of their house "four times in 30 years,

[213] Somini Sengupta, "A Crisis Right Now: San Francisco and Manila Face Rising Seas," *The New York Times*, February 13 2020, https://www.nytimes.com/interactive/2020/02/13/climate/manila-san-francisco-sea-level-rise.html.

as though adding layers to a wedding cake" to resist the rising tides in the area.[214] The report contrasts this use of sand with sand erosion on the California coast, and efforts to delay and resist erosion by shifting sand on Ocean Beach, San Francisco.[215] These two glimpses of sand as a material ground for seeing climate crisis in the transpacific suggest one way to see what escapes the computational vision of sand – a planetary vision, in geologic time, that measures accumulation and crisis, in the aftermath of climate crisis and the fallout of US imperialism and colonialism across the transpacific. As a technique of reading deeply where the archive is shallow, these two glimpses of sand in the transpacific evidence sand as a planetary measure of erosion and accumulation, within and against the lines of power that hold the transpacific together.

Learning to see sand through the tensions between these competing visions of sand is a technique of double vision that enables the envisioning of sand in its complexities as a liminal space between the computational vision of sand and the geologic one. As computational visions of sand always leave a remainder of uncertainty, double vision is a technique to see how geologic visions of sand can mark its spaces of absence, if not gesture at the possibilities of the epistemic promise of what is present but unseen. For example, as computational visions of sand engineer machine intelligence from the accumulation of data at its surface, geologic visions of sand underscore the possibilities that remain unaccounted for in what might be known through the accumulation of sand as the depth of planetary formation. Thus, if computational visions of sand engineer machine intelligence as a way of knowing planetary terrain, geologic visions of

[214] Somini Sengupta, "A Crisis Right Now: San Francisco and Manila Face Rising Seas," *The New York Times*, February 13 2020, https://www.nytimes.com/interactive/2020/02/13/climate/manila-san-francisco-sea-level-rise.html.
[215] Somini Sengupta, "A Crisis Right Now: San Francisco and Manila Face Rising Seas," *The New York Times*, February 13 2020, https://www.nytimes.com/interactive/2020/02/13/climate/manila-san-francisco-sea-level-rise.html.

sand evidence what this singular vision is unable to see. Held together, these visions evidence a culture of knowing the planetary terrain, one premised upon the optimization of machine intelligence while leaving possibilities for alternative temporal and material planetary relations unrecognized.

The narrow vision of planetary that computational visions of sand render in the engineering of machine intelligence is in tension with the more expansive vision of sand as geologic formation. If the engineering of machine intelligence produces a narrow mode of knowing planetary terrain that prioritizes the timescales and material relations required for autonomous scientific discovery, and if geologic time presents an alternative mode of knowing the planetary at a different scale of time and through different material relations, then the juxtaposition of these visions (and its double vision) makes clear the different planetary relations that they allow. For example, while the computational vision of sand installs the relationality of data accumulation and extraction for the engineering of machine intelligence, geologic visions of sand evidence deep histories of planetary formation and movement.

Thus, if machine intelligence as an epistemology is engineered at the level of the surface of the sand, then marking the limits of this epistemology by turning to what escapes the computational vision of sand (i.e. sand as layered, depth) in the depths of sand present an opportunity to read against the naturalization of machine intelligence as a way of knowing. In other words, the material processes of planetary formation provincialize human and machine intelligence as a universalized/universalizing worldview that is, still, just one mode of relationality among many.

Chapter 4: “Networked Laboratories”: The Transpacific Histories of NASA’s Interplanetary Technologies

Abstract

In 2020, researchers from NASA’s Mars Exploration Program at the Jet Propulsion Laboratory observed that “[t]he main roadblock to a Mars exploration rollout is that the best computers are on Earth, but the best data is on Mars.” As design concepts for future rovers for the Mars Exploration Program are expected to generate even more data than current designs and infrastructure capabilities, the limits of the Mars-Earth communication infrastructure have driven the development of network infrastructure that can support and expand current and future mission capabilities across all of NASA’s communications infrastructure, including the Deep Space Network, Near Earth Network, and the Space Network, called Disruption Tolerant Networking (DTN). When DTN is integrated in the Deep Space Network, more channels of communication between Mars and Earth will be available, making Mars-Earth communications more reliable, frequent, and with greater capacity for data transfer. How can those of us who are concerned with US scientific research and technological development on Mars understand what is at stake in the planned expansion of NASA’s deep space networking capabilities using DTN?

To answer this question, I offer a feminist material history of DTN as a network protocol designed to support, enable, and expand autonomous scientific research capabilities on Mars, by placing DTN in direct historical relation to the racialized and imperial formation of computer networks in US settler colonial research laboratories in the Pacific in the 20th Century, specifically the research and development of the ALOHA Protocol at the University of Hawaii. By juxtaposing Disruption Tolerant Networking with the ALOHA Protocol, I reveal the ways in which the United States has long used information infrastructure as a tool to enable the capture of land, the extraction of resources, and the flow of capital necessary for the expansion of empire. I then reflect on transpacific networks as sites through which alternative relations might be formed in coalitional support for the ongoing struggles for decolonization and Indigenous sovereignty in Hawaii.

Introduction

In 2020, researchers from NASA's Mars Exploration Program at the Jet Propulsion Laboratory observed that "[t]he main roadblock to a Mars exploration rollout is that the best computers are on Earth, but the best data is on Mars."[216] As design concepts for future rovers for the Mars Exploration Program are expected to generate even more data than current rover designs and infrastructure capabilities,[217] the limits of the Mars-Earth communication have driven the

[216]Masahiro Ono, Brandon Rothrock, Kyohei Otsu, Shoya Higa, Yumi Iwashita, Annie Didier, Tanvir Islam, Christopher Laporte, Vivian Sun, Kathryn Stack, Jacek Sawoniewicz, Shreyansh Daftry, Virisha Timmaraju, Sami Sahnoune, and Chris A. Mattmann, "MAARS: Machine learning-based Analytics for Automated Rover Systems, IEEE Aerospace Conference 2020: 1-17, doi: 10.1109/AERO47225.2020.9172271.
[217] Ono et al., "MAARS," 1-2.

development of network infrastructures to support and expand current and future mission capabilities across all of NASA's communications infrastructure, called Delay/Disruption Tolerant Networking (DTN). NASA researchers explain,

> "Communicating from Earth to any spacecraft is a complex challenge, largely due to the extreme distances involved. When data are transmitted and received across thousands and even millions of miles, the delay and potential for disruption or data loss is significant. Delay/Disruption Tolerant Networking (DTN) is NASA's solution to reliable internetworking for space missions."[218]

DTN is a networking approach designed for environments with intermittent connectivity, such as deep space.[219] With DTN, all nodes in the network have the capacity to automatically store data until it can be transferred to the next node. This means that NASA's networking capabilities for interplanetary research will be able to expand as DTN makes more communication channels "available" for data transmissions between Earth and Mars. NASA explains,

> "DTN provides assured delivery of data using automatic store-and-forward mechanisms. Each data packet that is received is forwarded immediately if possible, but stored for future transmission if forwarding is not currently possible but is expected to be possible in the future. As a result, only the next hop needs to be available when using DTN."[220]

[218] "Delay/Disruption Tolerant Networking," NASA, last modified September 29 2020. Accessed October 15 2021 from: https://www.nasa.gov/directorates/heo/scan/engineering/technology/disruption_tolerant_networking.
[219] "Delay/Disruption Tolerant Networking," NASA
[220]"Delay/Disruption Tolerant Networking," NASA.

When DTN is integrated within the Deep Space Network, the network that supports all of NASA's deep space exploration on Mars, more channels of communication between Mars and Earth will be available, making communications more reliable, frequent, and of greater capacity for data transfer.[221] How can those of us who are concerned with US scientific research and technological development on Mars understand what is at stake in the planned expansion of NASA's deep space networking capabilities using DTN?

To answer this question, "Automating Discovery" offers a feminist material history of DTN, placing DTN in direct historical relation to the racialized and imperial formation of the computer networks of US settler colonial research laboratories in the Pacific in the 20th Century, specifically the development of the ALOHA System at the University of Hawaii in the early 1970s.

With this approach, I historicize the emergence of computer networks as a scientific imaginary and worldview that has come to dominate US scientific and technological development since they were developed in the 20th century. In so doing, I offer a number of critical interventions in the field of Science and Technology Studies, as I bring feminist, critical race and ethnic studies, and postcolonial critiques to bear on the official histories of networked computing in the 20th C, rethinking the histories of our familiar terms like the laboratory, the network, and US technological progress and development. By tracing the formation of the imaginary of computing networks as "networked laboratories" through US colonial laboratories in the transpacific, I make explicit the way in which the histories of computing and networks have a material history in transpacific through the emergence of networked colonial laboratories, through the ALOHA Protocol and its value for developing future Disruption Tolerant

[221]"Delay/Disruption Tolerant Networking," NASA.

Networking to support the expansion of NASA's interplanetary research capabilities, including those of the Mars Exploration Program. In the first section, I show how the use of information infrastructures for Mars research and overcoming the remote control and command of space, through the "networked laboratory" model, a model or worldview which I identify as the basis for the planned use of DTN for Mars-Earth communications. I show how imperial histories of the networked laboratory model appear to be disconnected from these futures of Mars research, but inherit the histories of US settler colonialism and imperialism in the transpacific, while also re-inscribing imperial relations of power. I identify this as the use of information infrastructure for what I term "techno-democratic worldbuilding," the formation of US liberal democratic world orders through the use of technologies that reproduce settler colonial and imperial relations, under the guise of installing US liberal democratic world orders. Specifically, I show how the historical formation of what I describe as the "networked laboratory" in the 20th C transpacific can reveal the ways in which ongoing US imperial conquest extends into current and planned concepts for interplanetary research Mars through the extension of information infrastructure. In so doing, I dwell in the transpacific as an important methodological move for finding alternative possibilities for anti-colonial research that is in coalitional support and solidarity with ongoing efforts for decolonization, anti-colonial scientific practice, and the creative coproduction of alternative futures that support and amplify the histories, demands, and futures of decolonization and Indigenous sovereignty in Hawaii.

"Collaboratories of the Future": Information Infrastructure as "Techno-Democratic Worldbuilding"

Scientific research on Mars is shaped and enabled by the flow of information through space over large-scale information infrastructure. But, as future concepts for Mars rovers anticipate the increased capacity to generate data, the limits of information infrastructure have also come to define the limits of NASA's Mars Exploration Program. Researchers from NASA's JPL explain,

> [T]he sample fetch rover of the Sample Retrieval and Lander (SRL) mission concept is expected to drive up to ~1 km per sol, more than a ten-fold extension of the average per-sol driving distance of the Curiosity rover. Faster driving generates data at an increased rate (e.g., navigation images taken at a constant interval), while the capacity of Mars-Earth communication remains limited by the laws of physics as well as the availability of relay orbiters and the Deep Space Network. For example, the downlink capacity from the Curiosity rover to Earth is typically ~ 500 Mbit (= ~60MB) per Sol while data-intensive instruments, such as hyperspectral imagers and ground-penetrating radars, can easily produce hundreds of megabytes to gigabytes of data. Such situations may result in the "unnoticed green monster problem" (Figure 2) [3], meaning that science opportunities may be passed up by necessity or missed entirely simply because the data cannot be fully downlinked to Earth."[222]

[222] Ono et al., "MAARS," 2.

Figure 21: Ono et al.'s depiction of "The Unnoticed Green Monster Problem."[223]

This what I describe as the "networked laboratory" approach to scientific research, where scientific practice is carried out by autonomous technologies that have the instruments and capabilities to perform as "laboratories" by using "networks" of information infrastructure to breach the otherwise insurmountable distances between Mars and Earth. The Unnoticed Green Monster Problem reveals the ways in which the scientists who are engineering the Mars rovers understand the relationship between information infrastructure and the value of scientific knowledge production in a "networked laboratory" approach. In some important ways, the Unnoticed Green Monster Problem indexes the economy of scientific knowledge production and the economy of desire that structures and drives scientific research on Mars through this

[223] Ono et al., "MAARS," 2.

"networked laboratory" approach. As the *Curiosity* rover's potential to generate hundreds of megabytes to gigabytes of data surpasses the possibility of transfer, for example, it also exceeds the possibility of capture and use, and thus is understood to be a limit and a problem for the production of scientific knowledge. The Unnoticed Green Monster Problem thus locates data and information infrastructure as a limit to efficient capture, extraction (transfer) of data from Mars to Earth, and in this way positions this limit as a problem that might yet be overcome.

The "Networked Laboratory"

The "networked laboratory" is not a new figure. In the field of Science and Technology Studies, the "laboratory" and the "network" have typically been treated as distinct but closely related figures. Latour is famous for developing "laboratory studies" to examine the laboratory as an organizing space of scientific practice. But, Latour of course observed the "complex relations" of laboratory practices collapse the dichotomy between what is "inside" the lab and what is "outside" the lab. Indeed, Latour's insight is that "no one can say *where the laboratory is*."[224] Latour explains,

> In other words. since laboratory practices lead us constantly inside/outside and upside/down, we should be faithful to our field and follow our objects throughout all their transformations. This is simply good methodology. But to do so without getting dizzy, we should understand in more detail the strange topology that laboratory practices present.[225]

[224] Bruno Latour, "Give Me a Laboratory and I will Raise the World," École des Mines, Paris, 1983, p. 154. Accessed October 15 2021 from: http://www.bruno-latour.fr/sites/default/files/12-GIVE-ME-A-LAB-GB.pdf
[225] Latour, "Give me a Laboratory," p. 161.

Latour argues that science "transforms" society through laboratory experiments, and through *networks* where "science travels." Latour observes,

> This transformation of the whole of society according to laboratory experiments is ignored by sociologists of science. There is no outside of science but there are long, narrow networks that make possible the circulation of scientific facts.

However, Warwick Anderson has observed that questions in STS concerned with "how science travels" focus on this "travel" occurring through modes of standardization and order as global "networks," without adequate attention to the imperial historical formation of these networks.[226] Specifically, Anderson observes that in STS, critiques of colonialism, scientific development, and technology can often fail to articulate how formations like "[s]ociety, nature, and geography are the outcomes, rather than the causes, of...mobilisations, translations, and enrolments" of science and technology."[227] This is particularly important in the context of information infrastructures, as Anderson observes that information infrastructures are a tool of modernity that install world orders. Taking up Bowker and Star's *Sorting Things Out: Classification and its Consequences*, Anderson writes,

> In one of the more significant recent contributions to science studies, Geoffrey C. Bowker and Susan Leigh Star explore histories of standardization and classification – those eminently transferable mechanisms of ordering information – focusing on the international classification of disease (ICD). 'A simple agonistic reading of the ICD',

[226] Warwick Anderson, "From subjugated knowledge to conjugated subjects: science and globalisation, or postcolonial studies of science?," Postcolonial Studies, 12, no. 4 (2009), pp. 389-400, DOI: 10.1080/13688790903350641

[227] Anderson, "From subjugated knowledge to conjugated subjects," p. 396.

> they write, 'is that the system was set up in an age of imperialism and helped impose an imperialist reading of disease from the West onto the rest of the world.' But Bowker and Star offer a 'more subtle story' than this attenuated postcolonial version, in which the ICD 'played a part in the creation of the modern state'. Sorting Things Out does indeed provide us with a complex and nuanced account of 'building an information system and building the state' – but a more thorough and sympathetic engagement with postcolonial approaches, especially the proliferation of studies of information gathering and the colonial state, would have further sharpened its analysis and offered even stronger support for its critical postcolonial claims.

Anderson's postcolonial critique of information infrastructures, networks, laboratories as the means by which "science travels" marks an important gap in the field of STS that postcolonial studies, critical race theory, and ethnic studies can address. In what follows, I seek to build from Anderson's critique, to examine the ways in which information infrastructure institutes and installs world orders more seriously, and as a historical material product of forces like, in the case of the Mars Exploration Program, the histories of US militarism, imperialism, and settler colonialism in the transpacific.

Double Vision and the "Networked *Colonial* Laboratory"

Our official histories of computing do not frame computing networks, or "networked laboratories," as formations of the histories of US militarism, imperialism, and settler colonialism in the transpacific. In this sense, in what follows, I offer a counter history of the official histories of computing to locate the "networked laboratory" as a historically specific

formation. I argue that what official histories miss is how these computing networks were formed through US settler colonial and imperial histories of militarism in the transpacific, and specifically through the formation of "networked *colonial* laboratories" at the University of Hawaii. As many pacific islands, including Hawaii, have documented histories as colonial laboratories,[228] and specifically as literal computing laboratories in the 1970s at the University of Hawaii, official histories miss how the United States developed information infrastructure for the remote control and command of space the relationships of imperialism and settler colonialism, but under the guise of US liberal democratic notions of "progress" "development" and scientific research as a public, universal good. I locate the distributed, porous form of "the laboratory" through the "network" as the structure of its distributed form. In this way, the "networked laboratory" is a formation of Latour's "distributed" laboratory – the result of taking seriously the collapse of what is "inside" and what is "outside" and instead turning attention to the "complex relations" of the "networked laboratory."

Bowker and Star have shown that systems of classification function as large-scale scientific and technological infrastructures that describe, and therefore delimit, the material, political, and epistemic conditions of our worlds while often making the conditions of their classification invisible. [229] Taking Anderson's critique seriously, I seek to make visible the structures of power of information infrastructure. I thus use juxtaposition to enact what Bowker and Star described as "double vision" of infrastructural inversion.[230] Bowker and Star describe infrastructural inversion as a "struggle against the tendency of infrastructure to disappear (except

[228]Anderson, "From subjugated knowledge to conjugated subjects," p. 396.
[229] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and its Consequences*, (Cambridge: MIT Press, 2000, pp. 34-5.
[230] Bowker and Star, *Sorting Things Out*, p. 35.

when breaking down). It means learning to look closely at technologies and arrangements that, by design and by habit, tend to fade into the woodwork (sometimes literally!)."[231]

Vision, of course, is a foundational metaphor in the field of feminist STS. For example, Haraway theorized feminist science as "learning how to account for what we learn how to see."[232] Bowker and Star note this, observing that "double vision" has been an important practice in Feminist STS, and liken it to the kind of partial perspective or the "cyborg" positionality of Donna Haraway's "situated knowledges" and Gloria Anzaldua's "borderlands,"[233] emphasizing the importance of this approach for "resistance to…imperializing rhetoric" of our infrastructure.[234]

I extend this turn to "double vision" as method towards the transpacific, where Amiee Bahng has theorized "double vision" as a method for seeing the complex, imperial histories transpacific connections.[235] This insight is particularly important to a feminist material history and postcolonial critique of transpacific computer networking infrastructure. Importantly, this turn to the partial vision or double vision afforded by the cyborg positionality, marks an inroad for understanding foundational STS tropes of this "double vision" such as Haraway's "cyborg" as a racialized figure that emerges through the history of global racial capitalism and technological development. As research from Kavita Philip, Lilly Irani, and Paul Dourish in the field of Postcolonial and Decolonial Computing offer frameworks for understanding globalized information and technology infrastructures within the shifting and uneven conditions of global

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[231] Bowker and Star, *Sorting Things Out*, p. 34.
[232] Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies*, 14, no. 3 (Fall 1988), p. 583. DOI: https://doi.org/10.2307/3178066
[233] Bowker and Star, *Sorting Things Out*, p. 303.
[234] *Ibid.*
[235] Christine Mok and Aimee Bahng, "Transpacific Overtures: An Introduction," *Journal of Asian American Studies,* 20, no. 1, (February 2017), p. 4.

racial capitalism),[236] there is an urgent need to attend to the ways in which such network protocols might also reinforce and reproduce deeply gendered, racialized, classed, and imperial logics about scientific knowledge, progress, and technological development.[237] And the invisibility of infrastructure makes this ever more urgent. Feminist STS scholar Banu Subramaniam has observed that "invisible things are not necessarily "not-there," but can be brought into view if we learn how to see them. "In learning to see ghosts," writes Subramaniam, "scientific practice transforms into a deep-seated historical practice, where the objects and subjects of science and their histories come hurtling into focus."[238] Subramaniam offers "ghosts" as a metaphor for the "haunting reminder[s] of an ignored past. Rendering ghosts visible and learning to listen to them attentively is a lesson about the unacknowledged and unresolved injustices of history."[239] In this way, by drawing on Christine Mok and Aimee Bahng's conceptualization of "double vision" as a methodological practice for seeing the "ghosts" that haunt the transpacific histories of computing and the "networked laboratory," I turn onto what feminist STS scholar Deboleena Roy has characterized as "asking different question," or feminist practices that can work from these positionalities of "double vision" to enact feminist science.[240] In this way, too, I extend Vora's use of "juxtaposition" to "get a glimpse" of the material histories of the imperial and settler colonial formation of the "networked laboratory," routing through Asian American Studies attention to the transpacific through Mok and Bahng's invocation of "double vision." I observe that this attention to a transpacific "double vision" is

[236] Kavita Philip, Lilly Irani, and Paul Dourish, "Postcolonial Computing: A Tactical Survey," *Science, Technology, and Human Values*, 37, no. 1 (2012), pp. 3-29.
[237] Atanasoski and Vora, *Surrogate Humanity*, 2018
[238] Banu Subramaniam, *Ghost Stories for Darwin: The Science of Variation and the Politics of Diversity*, (Chicago: University of Illinois Press, 2014), p. 22.
[239] Subramaniam, *Ghost Stories for Darwin*, p. 23.
[240] Deboleena Roy, "Asking Different Questions: Feminist Practices for the Natural Sciences," *Hypatia,* 23, no. 4, (December 2008), pp. 134-157.

particularly important as a technique for countering official histories that pose scientific research, the development of computer networking, and scientific research on Mars as progress and innovation.

Historical Material Formations and "Techno-Democratic Worldbuilding"

The effort to see the expansion of data and information infrastructure as progress and innovation, rather than the re-inscription of settler colonial and imperial relations is what I describe as the use of information infrastructure as a technique of "techno-democratic worldbuilding". By "techno-democratic worldbuilding," I mean, first, to signal the use of technologies to assert, expand, and maintain US liberal democratic order in settler colonial and imperial contexts. Second, I mean to signal the ways in which these technologies consequently embed and materialize what Atanasoski and Vora describe as "technoliberal" worlds and futures. Taken together, "techno-democratic worldbuilding" can thus be understood as the formation of US liberal democratic world orders through the use of technologies that reproduce settler colonial and imperial relations, under the guise of installing US liberal democratic world orders.

Atanasoski and Vora describe technoliberalism as an approach for bringing feminist and critical race and ethnic studies perspectives to bear on the notions of technological development since the 20th C, and "[foreground] the obfuscated connections between the human-machine divide in US technological modernity...of the mutual generation of "the human" and "the machine" from the US post-World War II standardization of automation into the present" and "especially in the design and imagination of techno-objects an platforms that claim to reenchant

those tasks understood as tedious or miserable through the marvels of technological progress" that serve the "[re-entrenchment] of the liberal subject as the universal human."[241]

> "[T]his is the moment when the United States ascends to global political and economic supremacy and cultural influence, inheriting the mantle of its own and Western European settler imperial social structures. At this same historical juncture, the racial architecture of US modes of governance and geopolitical ascendancy were erased in the logics of post-civil rights racial liberalism and multiculturalism. Crucially, the advent of what can be termed, ironically, a "postracial" domination translates directly into the perception of new technologies as neutral and disembodied, even as these technologies are anchored in, and anchor, contemporary US imperial power."[242]

Atanasoski and Vora argue that these imaginaries produce the "surrogate effect of technoliberalism," where autonomous technologies are positioned to overcome the limits of space and the human through the racialized reproduction of "the right of the liberal subject to those spaces previously impenetrable" through technological innovation. Thus, as a technique of technoliberalism, NASA's designs for Disruption Tolerant Networking is a mode of "techno-democratic world-building" as it purports to be the "solution" for overcoming the limits of the current reach of US scientific and technological control and command of space by using/innovating networking technologies to overcome distance and space as limits of interplanetary research, while reinscribing settler colonial and imperial histories and relations.

US scientific and technological development proliferated in the post-Cold War era and into the 21st C amidst US cultural and economic supremacy expanding to a new global scale,

[241] Atanasoski and Vora, *Surrogate Humanity*, pp. 4-6.
[242] Atanasoski and Vora, *Surrogate Humanity*, p. 7.

which included the emergence of liberal multiculturalism and the imperial spread of US democracy, and the expansion of computing networks.[243] In this way, universal, democratic futures imagined by the Mars Exploration Program often appear to be disconnected from their material histories of US imperial expansion and globalization in racial capitalism, where liberatory (meaning US democratic) futures were not only aspirational values but, importantly, could be achieved through the development and expansion of computer networking. Here we see information as "techno-democratic worldbuilding." Specifically, we see the formation of networks as a worldview, particularly as networked computing (i.e. the Internet) was recast as a "demilitarized" and "democratic" good, that can foster research as a public, universal good.

However, reading the information infrastructure in terms of a history of networked computing shows their intimate entanglements as part of the imperial history of information as the command and control of space. This issue is particularly important in the case of the development of information infrastructure and network protocols that support Mars research.

Thus, as a concept, "techno-democratic worldbuilding" is especially useful in the context of Mars science, which is often presumed to be disconnected from the ongoing relationships and histories of US settler colonialism, militarism, and imperialism. Instead, "techno-democratic worldbuilding" asks us to center histories of militarism and imperialism and settler colonialism, to ask how these relations remain, persist, and continue to shape technological futures on Mars, especially as they appear to be disconnected from these histories through the rhetorics of scientific development, progress narratives, that position scientific knowledge production as a universal, democratic or democratizing good.

[243] Atanasoski and Vora, *Surrogate Humanity*, p. 4-6.

I thus I point to the material coproduction of information networks and settler colonial laboratories in Hawaii usefully extends the history of computer networking to the important imperial and US settler colonial histories of the transpacific. This is particularly important as we see information infrastructures operate as tools for the expansion of remote control of space, as a technique of overcoming the limits of human reach, particularly in the histories of US imperialism and the settler colonial relations that endure. I agree with Warwick Anderson and his vision that postcolonial science studies should be concerned with "the destabilization of received geopolitical categories, the critical focus on Western forms of power, the inquiry into global inequities and their local articulation, and the affirmative recuperation of subaltern voices', and particularly in terms of large-scale information infrastructure.

In this way, the figure of the "networked laboratory" emerges as a racial imperial historical formation that structures and orders the world. I observe that the "networked laboratory" is a worldview, or scientific imaginary. Here, I center Jasanoff and Kim's definition of sociotechnical imaginaries as "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation specific scientific and/or technological projects," which was later redefined "as collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology. This definition privileges the word "desirable" because efforts to build new sociotechnical futures are typically grounded in positive visions of social progress."[244]

[244] Sheila Jasanoff and Sang-Hyun Kim, *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, (Chicago: University of Chicago Press, 2015), p. 20.

However, I mark Ruha Benjamin's formulation of "co-production"[245] to be particularly important for understanding the work of the "networked laboratory" as a worldview, and as a historically specific material-semiotic formation. Specifically, building on Benjamin's insights, I signal Omi and Winant's foundational theory of racial formation as "the sociohistorical process by which racial identities are created, lived out, transformed, and destroyed."[246] Taken together, I locate the historical material and racial imperial formation of the "networked laboratory" as a US worldview and US world order that emerged in the 20th Century.

Collaboratories of the Future: "Networked Laboratories" as "Techno-Democratic Worldbuilding

The "networked laboratory" is not a new imaginary. NASA has a long history of conducting scientific research through the "networked laboratory" model to overcome the limits of space. Internal documents from NASA reveal that NASA viewed their role in the development of computer networks under the idea of creating "collaboratories of the future,"[247] Thus, while these networks were designed to solve the problem of connecting and expanding the reach of early military and research computing networks like ARPANet, it is clear that in the 20th C information networks emerged as a dominant worldview, specifically in the transpacific where

[245] In *Captivating Technology*, Ruha Benjamin defines co-production as a "hybrid approach [that] *illuminates* not only *how society is impacted by* technological development, as techno-determinists would argue, but how social norms, policies, and institutional frameworks shape a context that make some technologies appear inevitable and others impossible." See page 4 of Ruha Benjamin, *Captivating Technology*, 2019.
[246] Michael Omi and Howard Winant, *Racial Formation in the United States*, (Routledge, 2014), p. 109.
[247] "U.S. Computer Research Networks: Domestic and International Telecommunications Capacity Requirements," NASA Lewis Research Center, (December 1990), Retrieved from: https://ntrs.nasa.gov/api/citations/19930007199/downloads/19930007199.pdf

the use of "networks" and "laboratories" as techniques for the command and control of space was developed and perfected. I locate the formation of the colonial laboratory as an infrastructure of scientific and imperial expansion that has always mediated and served as the condition of possibility for the expansion of US scientific interests or the expansion of US world orders through and as scientific interests.

However, NASA's *autonomous* "networked laboratory" like the rover imagined in the Unnoticed Green Monster Problem is a distinct version of the "networked laboratory" that has defined the way in which scientific research on Mars has been imagined in the history of computer networking. For example, early designs for Mars research NASA's earliest designs for Mars exploration in the 1950s imagined a robot laboratory to overcome the limits of space for interplanetary research.[248] The "network," here, is almost invisibilized through the figure of the autonomous laboratory in the case of the Mars rovers. Drawing on insights from Bowker and Star, the information infrastructure of the autonomous "networked laboratory" comes into view when it "breaks down."[249] This is characteristic of autonomous technologies, too, where their "autonomy" appears "like magic,"[250] but only through large-scale material systems of classification and scientific order and networks of planetary control that are invisibilized. In Feminist STS, Donna Haraway named this as the "informatics of domination," which Lisa Nakamura later articulated, in conversation with Haraway, as a specifically racial imperial regime.[251]

[248] Atanasoski and Vora, *Surrogate Humanity*, p. 150.
[249] Bowker and Star, *Sorting Things Out*, p. 34.
[250] Atanasoski and Vora, *Surrogate Humanity*, p. 18.
[251] Lisa Nakamura, "Prospects for a Materialist Informatics: An Interview with Donna Haraway," *electronic book review*, August 30 2003. Accessed October 15 2021 from: http://electronicbookreview.com/essay/prospects-for-a-materialist-informatics-an-interview-with-donna-haraway/

There are limited studies of the material histories of transpacific cables and other information infrastructure, and no full-length study of the transpacific information infrastructures that examine their entanglement with histories of US settler colonialism and imperialism. Nicole Starosielski in *The Undersea Network* observes that the installation of pacific cables have "charted new and unprecedented routes across the across the Pacific" that "mastered the scale of the globe."[252] However, I am reminded of the Precarity Lab's important observation that "digital networks signal not novel dystopias but old paradigms of domination (the plantation, the colony, the prison, the military industrial complex, the laboratory, and the special economic zone)."[253] As many pacific islands have documented histories as colonial laboratories, the Precarity Lab's call "to critically examine the way information and communication technologies can become instruments for facilitating the exercise of power and domination, particularly along axes of race, ethnicity, gender, class, and sexuality…mediate social life and make certain possibilities and impossibilities available to us" become ever more urgent as planned use of DTN are poised to expand the use of this technology for the remote control and command of space. Thus, while Starosielski observes that "[N]etworks and islands are mutually constituted"[254] these islands have long racial and imperial material histories of formation, specifically through the entanglements of networks and islands through the colonial laboratory worldview. Thus, the "networked laboratory" as a worldview can usefully elaborate on the co-constitution of Starosielski's observations of the importance of island geographies to the formation of "networks" through the historical imperial formation of the "networked laboratory." In the next

[252] Nicole Starosielski, *The Undersea Network*, (Durham: Duke University Press, 2015), p. 37.
[253] The Precarity Lab, *Technoprecarious*, (London: Goldsmiths Press, 2020), "The Precarity Effect: On the Digital Depletion Economy."
[254] Starosielski, *The Undersea Network*, p. 173.

section, I develop a historical material account of the transpacific formation of the "networked laboratory."

Transpacific Histories of "Networked Laboratories"

In this section, I offer a counter-history of computing that focuses on the transpacific as a site that is crucial for understanding the stakes of ongoing expansion of NASA's communication networks. I frame the development of computer networking in the transpacific as an important part of the histories of computer networking. I draw on key postcolonial STS and Ethnic Studies critiques to trace the formation of the "networked laboratory" as a worldview that emerged through US imperialism in the Pacific as a technique of "techno-democratic worldbuilding." In so doing, I expand the familiar location of histories of computing in the transpacific in the elite institutions and laboratories of the University of Hawaii, to the relationships that these laboratories emerged through as parts of imperial histories of information infrastructure of the transpacific.

"Networked Laboratories" as a Transpacific Worldview

While our official histories of computing say that the origins of DTN can be traced back to development of "packet" networking in the late 1960s and early 1970s, and specifically the development of ALOHA net (at the University of Hawaii) and PRNet (developed at Stanford), it is important to historicize these technological developments in their settler colonial and imperial contexts of US militarism in the transpacific. In 1966, Dr. Norman Abramson famously took a

faculty position at the University of Hawaii, Manoa's College of Engineering to indulge his love of surfing, but soon after began a research program together with Professor Frankin Kuo to experiment with radio communications for remote-access computer networking, which would later come to be known as The ALOHA System. Prof. Abramson explains,

> "[W]e cast about for a research topic that we thought would make sense to the Department of Defense, that we would be interested in, and said: 'Well, communications for computers makes sense.' The telephone system appeared not to make sense at that time, especially in Hawaii, and we thought we had something that was intellectually stimulating and a package that we could sell to ARPA. That's how it all started."[255]

At the time, Abramson observed that "conventional methods of remote access to a large information processing system are limited to wire communications – either leased lines or dial-up telephone connections…the limitations imposed by wire communications restrict the usefulness of remote access computing."[256] Thus, at a time when computer networking was limited by wired or terrestrial infrastructure, the possibility of leveraging radio communications to facilitate wireless computer networking was in demand, especially to the Department of Defense and their designs for the expansion of ARPANET. On December 17 1972, the ALOHA system at the University of Hawaii successfully connected to ARPANET via satellite to become the first satellite node on the ARPA network, connecting to the node of the ARPANET through

[255] Norman Abramson, "Development of the ALOHANET," *IEEE Transactions of Information Theory*, 31, no. 2 (March 1985). Accessed from: https://www.eng.hawaii.edu/wp-content/uploads/2020/06/abramson1985-Development-of-the-ALOHANET.pdf
[256] Norman Abramson, "THE ALOHA SYSTEM: Another Alternative for computer communications," *Fall Joint Computer Conference*, 1970. Accessed from: https://www.eng.hawaii.edu/wp-content/uploads/2020/06/abramson19xx-THE-ALOHA-SYSTEM—Another-alternative-for-computer-communications.pdf

the IMP at the Aloha System Laboratory at the UH Manoa campus to a node at the NASA Ames Research Center in California.[257]

Funded by DARPA, The ALOHA system thus emerged out of research partnerships between the Univeristy of Hawaii, and NASA. Island geographies heavily influenced the development of the ALOHA system. To researchers, ALOHAnet was the solution to the need to connect the smaller colleges and campuses of the University of Hawaii on different islands and across large distances, totaling approximately a 300km radial distance from the main campus near Honolulu.[258] Robert Metcalfe, who researched the ALOHA system and used it to later develop the basis for Ethernet, observed in his PhD dissertation that

> The Aloha Network at the University of Hawaii was originally developed to apply packet radio techniques for communication between a central computer and its terminals scattered among the Hawaiian Islands [Abramson, 1970, 1975]. Many of the terminals are now minicomputers communicating among themselves using the Aloha Network's Menehune as a packet switch. The Menehune and an Arpanet Imp are now connected providing terminals on the Aloha Network access to computing resources on the U.S. mainland. Just as computer networks have grown across continents and oceans to interconnect major computing facilities around the world, they are now growing down corridors and between buildings to interconnect minicomputer~ in offices and laboratories [Ashenhurst, 1975; Willard, 1973; Fraser, 1975~ Farber, 1973, 1975].[259]

[257] Franklin F. Kuo, "Computer Networks: The ALOHA System," *Office of Naval Research*, 1981. Accssed from: https://apps.dtic.mil/sti/pdfs/ADA098684.pdf
[258] Norman Abramson, "Development of the ALOHANET," *IEEE Transactions of Information Theory*, 31, no. 2 (March 1985). Accessed from: https://www.eng.hawaii.edu/wp-content/uploads/2020/06/abramson1985-Development-of-the-ALOHANET.pdf
[259] Robert Metcalfe, *Packet Communication*, 1973. Accessed October 15 2021 from: https://ethernethistory.typepad.com/papers/EthernetPaper.pdf

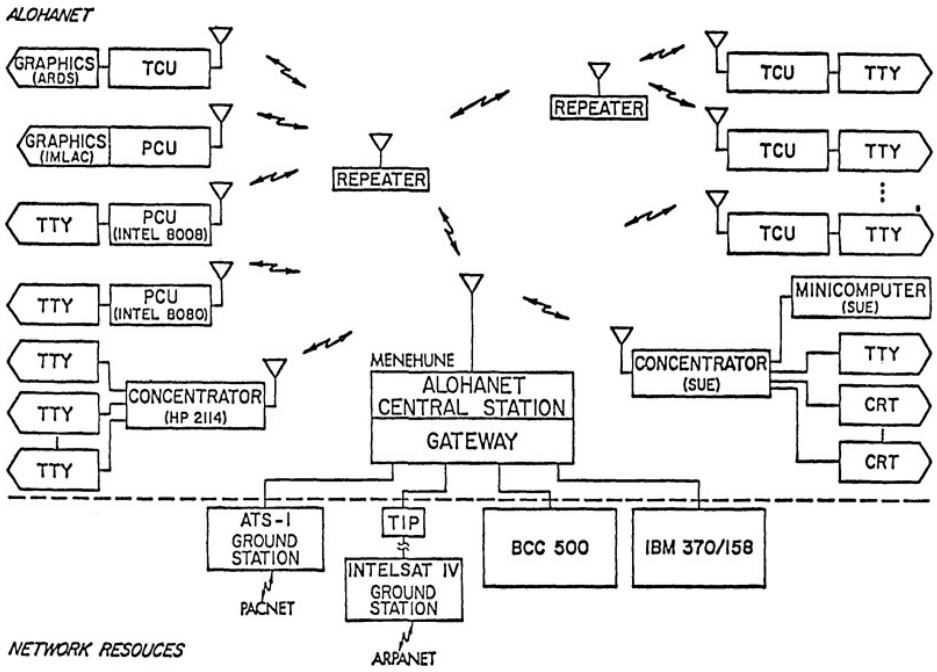

Figure 21: Network diagram of the ALOHANET.[260]

Prof. Abramson explains its distribution in the early 1970s in the transpacific:

> In 1971 the Aloha System established and operated a UHF terrestrial data network (AlohaNet) within the state of Hawaii. In 1973 the Aloha System used a VHF transponder in an experimental NASA satellite (ATS-1) to demonstrate an international satellite data network (PacNet) connecting NASA in California and five universities in the United States, Japan, and Australia. Also in 1973 the Aloha System pioneered the

[260] Norman Abramson, "Introduction" in "History of Communications," (Mischa Schwartz, editor). Accessed from: https://www.eng.hawaii.edu/wp-content/uploads/2020/06/THE-ALOHANET-—-SURFING-FOR-WIRELESS-DATA.pdf

> unconventional use of a conventional commercial Comsat channel to link the AlohaNet and PacNet to ARPANet in the continental United States.[261]

Building on Warwick Anderson's postcolonial critique of information infrasturcutre, I observe that the ALOHA system is often celebrated as a significant moment in the history of the Internet and as the origin of wireless computer networking, without attention to its clear formation through the imperial and settler colonial relationships of US militarism in the transpacific region. The distribution of the ALOHA Protocol and PACNET (the Pacific and Asian Academic Network), the transpacific as important moments in the part of the expansion of ARPANET through the "nodes" of histories of imperialism and militarism. The ALOHA system thus shows how wireless networking capabilities emerged through specific relationships in the transpacific, engineered through the need to connect island geographies, importantly expanding the number of connected nodes in ARPANET. The University of Hawaii thus emerges as a "networked" *colonial* laboratory that was instituted to further develop US computing power through the expansion of ARPANET. In this way, the ALOHA System installed techno-democratic world orders through the development of Packet Switching Technologies to support the command and control of space.

While the ALOHA System ceased its operations in 1976, the base logic and approach of the ALOHA System and types of ALOHA channels still form the basis of nearly all wireless communication technologies, and is the basis of disruption tolerant networking. In this way, the logic of the ALOHA System persists as the engineering solution to remote access computer networking in environments where terrestrial connections are not possible or desired. In this

[261] Norman Abramson, "Introduction" in "History of Communications," (Mischa Schwartz, editor). Accessed from: https://www.eng.hawaii.edu/wp-content/uploads/2020/06/THE-ALOHANET-—-SURFING-FOR-WIRELESS-DATA.pdf.

way, the proliferation of DTN as an innovative solution to remote access computer networking and research laboratory connections signals the reproduction of the logic of information infrastructures as a tool for overcoming the limits of the remote control and command of space. Therefore, as a planned solution to the limits of the current capabilities of NASA's communications infrastructure, including Mars-Earth communications, Disruption Tolerant Networking reveals how information infrastructure is used as a tool of imperial expansion, as Disruption Tolerant Networking extends, and thus the reinscribes, the "networked laboratory" worldview.

The Transpacific as a Feminist Alternative for Networked Futures

In this section, I analyze the transpacific as an alternative "network" imaginary or worldview that can bring us closer to a coalitional politics with transpacific resistance to imperial expansion through invisible information networks, an alternative way of enacting and being accountable to "networked" relations and futures.

The Transpacific and Alternative Networked Futures

While the ALOHA Protocol ceased operations in 1976, the University of Hawaii remains as a US public land grant research university, and thus the ongoing institution of settler colonialism continues shape the histories and futures of Hawaii and the transpacific. In these and other ways, the "networked *colonial* laboratory" worldview persists to this day, predicated upon the

genocide, assimilation, and erasure of Indigenous Hawaiians. The University of Hawaii as an institution recapitulates and re-inscribed these relationships.

Thus, to read the history of the network imaginary in computing is to read the history of the network of island laboratories in the transpacific. The coproduction of information infrastructure through the "networked *colonial* laboratory" worldview in Hawaii usefully extends the broader history of computing to attend to the important material histories of US imperial and settler colonial relations that defined the transpacific.

The transpacific has long been framed in terms of networks and connections. However I argue that we need to ask which connections, why, which networks why. Seeing these connections is particularly urgent amid ongoing struggles for decolonization and Indigenous sovereignty in Maunakea, another site through which the University of Hawaii and the transpacific continues to shape interplanetary research. Importantly, the University of Hawaii is the current steward of the observatories and telescopes on Maunakea. In this sense, to see the continuity between the transpacific and Mars is to offer this double vision as an iteration on the feminist vision Donna Haraway offered in Situated Knowledges, one that is perhaps "faithful" to the issues of our current informatics of domination[262] and the material and immaterial information infrastructures of global racial capitalism.

There is growing research and activism about the struggles for decolonization and Indigenous sovereignty in Maunakea, and emphasize the historical formation of these current struggles. For example, in Kahanamoku et al., "A Native Hawaiian-led summary of the current impact of constructing the Thirty Meter Telescope on Maunakea," Native Hawaiian natural

[262] Donna Haraway, "The Cyborg Manifesto," in *Manifestly Haraway* (Minneapolis: University of Minnesota Press, 2016), p. 28; Lisa Nakamura, "Prospects for a Materialist Informatics: An Interview with Donna Haraway," *electronic book review*, August 30 2003. Accessed October 15 2021 from: http://electronicbookreview.com/essay/prospects-for-a-materialist-informatics-an-interview-with-donna-haraway/.

scientists and allies "identify historical decisions that impact current circumstances on Maunakea and provide approaches to acknowledging their presence" including steps that need to be taken to "re-establish trust and engage in meaningful reciprocity and collaboration with Native Hawaiians and other Indigenous communities."[263] Candace Fujikane has resisted settler colonial cartographies and instead turns to the Kanaka Maoli (Native Hawaiian) cartographies to foster alternative imaginaries for planetary futures. Alongside these critiques from Native Hawaiians and allies, critical race and ethnic studies scholarship has demonstrated the need to become accountable to the complex histories of racial formation that shape Hawaii and the transpacific, including research on the Black Pacific,[264] and Asian racialization and settler colonialism in Hawaii.[265]

The complexities of these formations speak to the importance of attending to the transpacific as a formation that exceeds our familiar categories of knowledge and order, especially with respect to the histories of racial formation through imperial histories of US militarism, and other modes of colonization, in the transpacific. Christine Mok and Aimee Bahng observe that "[w]hile there is a long history of contact, conflict, and discourse from, through, and in the Pacific, Pacific Rim, and Asia-Pacific, the transpacific expands upon and exceeds previous formulations."[266] Mok and Bahng note that the Indigenous Pacific Islander frameworks are crucial to expanding the space of the transpacific as a site of critical inquiry into these

[263] Sara Kahanamoku, Rosie 'Anolani Alegado, Aurora Kagawa-Viviani, Katie Leimomi Kamelamela, Brittany Kamai, Lucianne M Walkowicz, Chanda Prescod-Weinstein, Mithi Alexa de los Reyes, and Hilding Neilson, "A Native Hawaiian-led summary of the current impact of constructing the Thirty Meter Telescope on Maunakea," *Astrophysics* (January 3 2020), DOI: 10.6084/m9.figshare.c.4805619.
[264] Nitasha Tamar Sharma, *Hawaii is My Haven: Race and Indigeneity in the Black Pacific*, (Durham: Duke University Press, 2021).
[265] Candace Fujikane and Jonathan Y. Okamura (eds.), *Asian Settler Colonialism: From Local Governance to the Habits of Everyday Life in Hawaii*, (Honolulu: University of Hawaii Press, 2008).
[266] Christine Mok and Aimee Bahng, "Transpacific Overtures: An Introduction," *Journal of Asian American Studies,* 20, no. 1, (February 2017), p. 4.

complexities, observing "it is precisely an all-too-narrow, persistently entrenched settler colonial configuration of modernity, science, and technology that limits the transpacific imaginary, and we find the nuanced discussions around the possible intersections and disjunctures of indigenous and transnational feminisms helpful in our ongoing struggle to decolonize futurity."[267] Bahng specifically locates the transpacific as an alternative imaginary for futurity, observing that

> "Whereas colonial, neocolonial, and neoliberal enterprises rely on imaginaries that configure the Pacific as an emptied expanse primed for military incursion, scientific experimentation, waste dumping, and fantastical projection, this volume advances a decolonial approach to fabulating transpacific futurity."[268]

Further, as Jini Kim Watson observes, the transpacific has long been understood as a "networked space" or "complex network of connections" in Asian American Studies.[269] The transpacific as a site of inquiry emerges through the post-national turn in Asian American Studies, marking the transpacific as a site that is relational, and holds inquiries that exceed the categories of nation, place, and histories of imperialism. The transpacific is multiple, and asks for relations that exceed nation, place, and histories of imperialism. Mok and Bahng, specifically, locates the transpacific as a way to engage in multiple histories, futures, and relations. Mok and Bahng marks the transpacific as a critical space that emerges in Asian American Studies' postnational turn, and suggests that to engage in the transpacific requires a kind of "double vision," "a counterpoetics," which "hovers between the literal and the metaphoric, the historical and the

[267] Mok and Bahng, "Transpacific Overtures," p. 6.
[268] Mok and Bahng, "Transpacific Overtures," p. 5.
[269] Jini Kim Watson, "Postscript: On Transpacific Futurities," *Journal of Asian American Studies*, 20, no. 1, (February 2017), pp. 119-124.

mimetic" and seeks "to alter memory and invoke minority survival in the deadly space between competing national, imperial interests."[270]

In this way I find the network to be a metaphor that can be made to do otherwise and seek to build on what Anita Say Chan has argued that "decolonial computing frameworks highlight another potential, not only in recognizing the diverse vibrancy of existing challenges to "digital universalist" models that problematically elevate narrow versions of Western and elite digital practice and innovation as the only relevant pathway to the future, but in cultivating knowledge practices that indeed foster a decentering of the self as a generative asset towards the creative co-production of alternative futures."[271]

However, as generative as the metaphorical turn to the transpacific might be, I am reminded that "decolonization is not a metaphor,"[272] and that we must resist the transpacific as a "move towards innocence," or an easy escape from the hauntings of these ongoing relations of imperialism. I thus turn to the transpacific as a way to enact new possibilities for coalitional and relational affinities, while rehabilitating the network mode not towards some utopian fantasy of liberation and justice, but as connection where we may dwell in the complexities of its relationality that exceeds our familiar categories of understanding and critique, and consider possibilities for what good relations might entail in coalitional support of Indigenous futurity. Amidst the ongoing accumulation of data in the extraction of information as part of US techno liberal democracy, we must emphasize the importance of listening to the histories, demands, and futures that US technoliberal desire and expanding scientific research agendas aim to erase.

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[270] Mok and Bahng, "Transpacific Overtures," p. 2-5.
[271] Anita Say Chan, "Decolonial Computing and Networking Beyond Digital Universalism," *catalyst*, 4, no. 2 (2018). DOI: https://doi.org/10.28968/cftt.v4i2.29844
[272] Eve Tuck and K. Wayne Yang, "Decolonization is not a metaphor," *Decolonization: Indigeneity, Education & Society*, 1, no. 1, (2012), pp. 1-40.

Conclusion

While it is clear that the histories of computing thus run alongside the histories of military network imaginaries and the island laboratories of the US in the transpacific. More attention to the transpacific as an important site in not only the histories of US space exploration, but the histories of networked computing more broadly, needs to be done to enrich the framework that I have begun to sketch out here. However, what little archival information there is points to the important ways in which the expansion of information infrastructure to support a logic of extraction on Mars is haunted by the histories of colonization and US imperialism in the transpacific, as an extension of the long history of US empire through information, through networked laboratories and communication.

Conclusion: Automating Discovery and Reproductive Justice

My interest in "Automating Discovery" has been, in each Chapter, to use juxtaposition and double vision as analytic practices to "learn to see" what Banu Subramaniam would call the "ghosts" of the histories of US settler colonialism, colonialism and imperialism that haunt the imagined futures of NASA's vision of autonomous scientific discovery on Mars.

To do this, I have analyzed four key sites through which autonomous scientific discovery is engineered. First, Chapter 1 analyzed the production and circulation of rover selfies as conditions that enact the fantasy of autonomous scientific discovery as they shape the fantasy of the rover as the ideal scientist and frontier hero. While identifying the rover selfie as thus a condition for enacting the colonial fantasy of autonomous scientific discovery through the rover, I juxtaposed this reading of the selfie with a reading of the material conditions of their production and circulation, where the selfie is a form of rover maintenance, as an alternative way of "seeing through care for the machine." I then offered an alternative reading of the rover selfie in the example of the *Spirit* rover selfie stuck in a sand trap at Troy. Through the juxtaposition of these readings, I proposed the rover selfie as a mode of enjambment, where we can learn to see the how the rover selfie offers the "double vision" of the colonial fantasy of the rover as autonomous scientific discovery and alternative visions of its interruption and disruption,

suggesting that an anti-colonial practice of vision persists in the rover selfie as a mode of situated knowledge.

Chapter 2 examined AI4Mars, NASA's online citizen science platform for building training datasets for SPOC, its autonomous terrain classifier key to NASA's efforts to engineer autonomous scientific discovery, in relation to digital universalism, the technological commons, and the long history of the use of the Internet for engineering US democratic futures and world orders that purport to be universal. Staying in the transpacific, I turn to a strand of the material history of the transpacific Internet, tracing the first commercial Internet connection in the Philippines that linked the Philippines to routers in the United States and the moment that Benjie Tan, the Filipino computer engineer responsible for establishing the connection in Manila, declared that "the gateway to the world for the Philippines will be via the NASA Ames Research Center." I thus position AI4Mars as just the latest iteration in a long history of NASA representing the gateway to worlds and futures that purport to be democratic, universal, and collective, while disavowing their colonial and imperial conditions of development. I turn to Filipino speculative fiction *The Apollo Centennial* to move towards what Anita Say Chan has called the "creative co-production of alternative futures" that can work from an account for what Wendy Chun has described as the remainder, what lingers, in the universalist fantasies of online futurity.

Chapter 3 analyzed the engineering of autonomous scientific discovery through the development of SPOC for use in the current Mars rover fleet, an autonomous terrain classifier that will enable rovers to make increasingly autonomous navigation and decision making. I traced the ways in which SPOC was engineered to overcome the challenge of Martian sand as a particularly dangerous and risky terrain for Mars rovers to navigate. I then juxtaposed these

computational visions of sand (what I describe as the "resource view" of sand) with geologic visions of sand as planetary processes, to ask and answer what escapes the computational vision of sand. I build on sand as a speculative ground through which the ongoing expansion and perfection of rover autonomy and autonomous scientific discovery can be interrupted and resisted.

Chapter 4 analyzed the development of Disruption Tolerant Networking (or DTN) as network infrastructure required to expand the capabilities for autonomous scientific discovery on Mars, allowing for greater and more stable data use, storage, and transfer between Mars and Earth. I position the material histories of DTN in relation to US settler colonialism and imperialism in the transpacific region, and specifically in direct relation to the development of the ALOHA Protocol at the University of Hawaii. I then juxtapose this history as a condition for the expansion of autonomous scientific discovery with ongoing struggles for decolonization and Indigenous sovereignty in Hawaii, as a way of developing anti-colonial scientific practice through coalitional support for Indigenous Hawaiians' demands.

My goal in each chapter has been to trace the ways in which US relations of colonialism and imperialism are reproduced through the engineering of fantasies of autonomous scientific discovery on Mars, while offering ways to resist and refuse their reproduction. In this way, I position "Automating Discovery" as a reproductive justice project, concerned not with biological reproduction or reproduction "in" bodies, but reproduction beyond the body, or the social reproduction of world orders and futures. Rather than see this focus as disconnected from questions of reproductive justice more concerned with biological reproduction or reproduction in the body, I offer "Automating Discovery" as one way to think through the ways in which what Michelle Murphy has described as distributed reproductive justice and alter life, especially now

as we extend towards new scales of interplanetary forms of life and futurity. “Automating Discovery” is thus a first attempt to articulate one way to think about what we might describe as “interplanetary” reproductive justice – a mode of reproductive justice where we can think through how the systems of power and domination that shape biological reproduction and reproduction of the body extend to also and at the same time work to shape conditions of life both in the historical present and the futures they imagine.

Further Research

I began this project to historicize, contextualize, and analyze the Mars rovers as a new form of laboratory, the autonomous colonial laboratory, through the analytics of Ethnic Studies, Feminist STS, and Women of Color Feminism, with a goal to articulate some modes of accountability and responsibility for such a laboratory, towards anti-colonial research practices for scientific research on Mars. In so doing, I have attempted to articulate historical material conditions that matter when thinking through the kinds of futures that autonomous scientific discovery on Mars imagines, desires, and installs, but have left many important strands of these conditions outside the scope of this project. As such, I see the following areas of inquiry as important next steps to the further development and articulation of the research goals and objectives that “Automating Discovery” has begun to outline:

1. Which geologic visions of sand are important to mark as “what escapes” the computational visions of sand?

2. How do these visions guide and inform planetary stewardship and interplanetary reproductive justice?
3. How can we continue to "dwell" in the transpacific as an important material history of the engineering of autonomous scientific discovery on Mars?

By investigating these questions, I hope to extend the inquiries of "Automating Discovery" in an effort to continue to trace a more robust material history of NASA's efforts to engineer autonomous scientific discovery on Mars, through the transpacific, through sand, and through reproductive justice.

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