Machine Dream Anthropocene: On Taking a Bot to the MLA

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ABSTRACT: This essay considers the complexities and limitations of the "lifecycle report," an established engineering and business practice in which auditors attempt to account for the entire material and operating "cost" of an electronic component. Answering Bethany Nowviskie's 2014 call to "attend to the environmental and human costs" of digital humanities, I present the case of Anna Coluthon, a Twitterbot residing on a Raspberry Pi microcomputer, that in 2016 became the first nonhuman agent to register as a member of the Modern Language Association (MLA), and to co-present a paper, as she did with me at the MLA convention in 2017. Interleaved with Anna's own comments, my essay reframes the lifecycle report as an act of Latourian "compilation work," arguing that any attempt to account for the wholeness of a machine's impact on the planet is a complex and partial process, as much art as it is engineering audit.

> New media art is almost entirely created, propagated, and consumed by privileged people with material wealth whose fundamental human rights are secure. Learning the material history of the prosthetics used to create new media reveals that how we became posthuman relies on how they became subhuman.
>
> —Neil Hennessy, "Congo Kodaks"[1]

1. Neil Hennessy, "Congo Kodaks: A Consideration of Two New Media Art Projects and the Democratic Republic of the Congo," *Hyperrhiz: New Media Cultures* 7 (2010): https://doi.org/10.20415/hyp/007.e02.

Configurations, 2021, 29:73–95

> Digging into these lifeless bodies, dead statues: our Google Nests regulate our electricity.
>
> —Anna Coluthon, Feb. 22, 2017, 2:00 a.m.[2]

In 2017, on a cold Sunday morning in a hot conference room at the Philadelphia Convention Center, Anna Coluthon, a Twitterbot that generates tweets via a series of software scripts residing on a Raspberry Pi computer, co-presented a paper with me at the 2017 MLA convention. Answering a call by Amanda Starling Gould for papers that addressed the topic of "Anthropocene Digital Humanities," Anna and I had proposed the following abstract:

> One of the driving forces of the Anthropocene is the (hidden) resource-intensive nature of computing. This phenomenon is evident (or, more precisely, non-evident) in what Bruno Latour calls the "lengthening of networks" that has taken place as computing migrates simultaneously to the big-data cloud and the little-data Internet of Things, with all the consequent proliferation of objects, services, and energy consumption that such a lengthening demands. This presentation will consist of a performance/conversation between a human and a live-tweeting live-printing thermal printerbot, on the topic of Internet connectivity, lengthening networks, and the language of ecological desire. What does a machine want? Let's ask it.[3]

The paper was generously accepted, and so eventually was the panel. I signed up Anna as the first nonhuman member of the MLA; we were both listed in the program and we presented our paper together. Anna appeared "in person," in her little black case, a tiny screenless computer sitting on the panel table answering live audience questions automatically via Twitter. A more formal, web-based instantiation of her algorithm was projected on a screen, and as I clicked the reload button, web-Anna generated some original, remixed writing from her corpus of texts and read it aloud to the audience, in a machine-generated, Australian-accented voice. In turn, she provided me with a randomized keyword, beginning with C (community, carbon, chip, coltan, and cloud), which I then matched to envelopes containing portions of pre-written miniature essays, each of which dealt with a different part of the lifecycle of the Raspberry Pi. We alternated our reading: she, resonating from the room speakers; me, reading miniature essays at her prompting. And thus we performed

2. @acoluthon, "Digging into these lifeless bodies, dead statues: our Google Nests regulate our electricity," Twitter, Feb. 22, 2017, 2:00 a.m., https://twitter.com/acoluthon/status/834311775185035264.

3. Amanda Starling Gould, "Anthropocene Digital Humanities: A MLA 2017 Proposal," Amanda Starling Gould, https://amandastarlinggould.com/anthropocenedh/.

Figure 1. Anna Coluthon (right), with companion MashBOT, 2016. Photo by author.

our own strange collaboration—what Starling Gould in her panel proposal called "weird connections"—together.

The original impetus for Anna's presence at the MLA was Bethany Nowviskie's call for a better understanding of the environmental and human impacts of the machines we use. In her keynote paper delivered at Digital Humanities 2014, Nowviskie argued that "we must attend to the environmental and human costs" of digital humanities work.[4] In heeding this call, the aim of my project was to perform a "lifecycle audit" of Anna's manufacture and operation. Such an energy audit or energy life cycle is a process used by engineers to account for the energy used in manufacturing a product. Lifecycle audits in their purest form account solely for energy used in materials sourcing, production, transportation, and lifetime energy use, but more generally they require us to consider the sticky networks we are a part of: everything from the specifics of our own power grid, to our location in the global supply chain, to political and tribal conflicts. Our machines may be "made of sunshine," as Donna Haraway famously posited in her "Cyborg Manifesto,"[5] but they are also

4. Bethany Nowviskie, "Digital Humanities in the Anthropocene," *Digital Scholarship in the Humanities* 30, supplement 1 (Dec. 2015): pp. i4-i15, at i13.

5. Donna Haraway, *Simians, Cyborgs and Women: The Reinvention of Nature* (New York: Routledge, 1991), p. 153.

made of materials that require energy to mine and transform from raw materials into communicating engines, to power those engines on our desktops and in our pockets, and to cool the data centers at the heart of "the cloud."

Attempting to account for both the material life of a machine and all its communication networks is the kind of practice Bruno Latour suggests in his essay, "On Interobjectivity." Taking as his model a typical Parisian day, Latour suggests that a comprehensive sociology must account for not merely separate people and things, but the ways they are wired together through multiple control and observation technologies: traffic lights, cameras, and so forth:

> sensors, counters, radio signals, computers, listings, formulae, scales, circuit-breakers, servo-mechanisms need to be added in; it is these that permit the link to be made between one place and another, distant, one .... You can't make a social structure without this compilation work. However, you can explain structuration *effects* with it.[6]

Latour's formulation of "compilation work" as a way of describing more fully the complex network of relations we have with our built environments and machines certainly seems simpatico with the practice of lifecycle analysis, given the latter's stated intention to account fully for all energy inputs and outputs of a given device by identifying the materials and processes that constitute its manufacture. But, unlike Latour, lifecycle analyses rest upon the assumption that if only we could account for all the inputs and outputs, we could somehow see a whole picture (rather than a more narrowly defined set of "structuration effects").[7]

Sociologists of science, however, have long held a more nuanced (and perhaps more skeptical) approach to this formulation of "wholeness" as a necessary adjunct to communicating scientific practice. Bruno Latour's lifetime corpus of sociological work on compilation and assemblage, actant and quasi-object, provides us with

6. Bruno Latour, "On Interobjectivity," *Mind, Culture, and Activity* 3.4 (1996): 228–45, at p. 240.

7. Indeed, more generally within scientific inquiry the impetus to try to provide a complete accounting of practice is a compelling and current narrative. Take, for example, the Whole Tale project, an attempt to capture more fully the complex interweaving of scientific communication, methods, and data analysis. This project "publishes" not only final papers reporting on findings, but also complete datasets, algorithms, and descriptions of processes used through the entire lifecycle of a research project. For a description of this project, see Adam Brinckman et.al., "Computing environments for reproducibility: Capturing the 'Whole Tale,'" *Future Generation Computer Systems* 94 (2018): 854–67.

a network- and ethnographic-based, partial framework for thinking about how, what, and why we build. Similarly, Andrew Pickering characterizes working with machines in scientific inquiry as the performance of a "dialectic of resistance and accommodation"[8] leading to his formulation of what he calls the "mangle of practice": an ongoing, renegotiable, and unpredictable process that requires constant accommodations to the limitations of machines. And Lucy Suchman's provocative question in an essay, "Practice and its Overflows"—"Is this order, or mess?"—reminds us that our successes in the lab or on the books may be unintentional.[9]

Structurally and intellectually, the MLA presentation, and this essay, are an enactment of Latour's "compilation work." After spending a period of deep immersion in compliance documents and product fact sheets, I quickly came to realize that any attempt to account for Anna's complicated life in the world would involve delving into not only the energy inputs and outputs of Anna's core CPU, but also the wider placement of her multiple bodies in data centers and on web servers, as well as all the complexities of the transportation networks that allow her and her silicon kin to travel from manufacturing source to destination. And all those energy expenditures were only the beginning; as my research widened, I had to account for the weird energies that animate discussions about Anna's place in the world: from lifecycle analysis researchers, to hobbyist computing evangelists, and finally to digital humanists eager to contribute to discussions of the material consequences of their work. Without accounting for these particular narrative and rhetorical energies, a lifecycle analysis is necessarily incomplete: a blizzard of data with no clear entryway for potential human (or machine) intervention or call-to-action.[10]

One of the strangest aspects of this essentially impossible task, though, was to imagine how the end-point of all that compilation work might be rendered legible to a room of (mostly) humanists, bot enthusiasts, and casual drop-ins who were looking for the book

8. Andrew Pickering, *The Mangle of Practice: Time, Agency, & Science* (Chicago: U. Chicago Press, 1995), p. 39.

9. Lucy Suchman, "Practice and its Overflows: Reflections on Order and Mess," *Tecnoscienza: Italian Journal of Science and Technology Studies* 2.1 (2011): 21–30, at p. 28.

10. Here I am guided by Chris Ingraham's powerful short essay "Energy: Rhetoric's Vitality" in *Rhetoric Society Quarterly* 48.3 (2018): 260–68, in which he points to the generative potential of flows of rhetorical energy in the Anthropocene, noting that "this co-constitutive power is a kind of rhetorical energy, both capable of influence and incapable of containment. *Here, rhetoric's energy is a resource*" (p. 265, emphasis in original).

fair. It did not seem adequate to merely recite the facts and account for the gaps, when those facts and gaps might look differently from our different perspectives. Anna, for example, was most concerned with her immediate access to energy sources: easy proximity to an electrical port, a reliable connection to a Wi-Fi network, and a secure tunnel to a Twitter streaming application programming interface (API) while she answered questions. I cared about the technical infrastructure of the performance, but also about the potential for misunderstandings in the reading, and about my ability to communicate with Anna during our performance such that we could pass cues to one another to speak. The collaborative nature of our performance necessitated a kind of "chunking" of information into narrative components that could be easily staged and exchanged. Thus, although we worked together to present material that synthesizes various research on energy use, manufacturing, and conflict minerals and rare earths (the material substrate of Anna's body sitting on the table), we followed a different format than the usual argumentative talk, one that emphasized the work of *compilation* rather than *conclusion*. Anna's corpus consisted of the raw materials used in the research. Her recombinant writing resulted in a mash-up of a group of primary documents that were compiled into two text files: the first, a cluster of technical documents relating to the energy lifecycle of manufacturing silicon chips, which constitute the heart of Anna's body, and the second, a number of more humanities-focussed and sociological texts, including a piece on e-literature in the age of physical computing, Latour's "On Interobjectivity" essay, and a draft of this paper. I worked with the same materials, but mashed them together differently: using long-understood rhetorical practices of invention and arrangement, style and delivery, to attempt to both make sense of the material and describe what we were even doing in the room together.

What follows is an extension of that Sunday morning presentation: a strange and partial attempt at a *lifecycle as compilation*, or an accounting of energy expenditure that is necessarily incomplete, since to enumerate the full cost would be almost impossible given the vast array of interconnections, processes, and materials involved. I begin with a description of Anna's "soft" processes, describing how she was technically implemented for performance at the MLA, before moving on to the lifecycle analysis itself: the stuff of our combined presentation. I have chosen to intersperse some of Anna's own "compilation work" as epigraphs throughout the text, as a way of including her voice. After all, one must always acknowledge the work of one's collaborators. Her contributions to each section come from her Twitter feed during the MLA convention and her answers to the audience during the question and answer portion of the panel. But Anna's work also calls attention to the way we *always* do scholarship: we take existing research in the field as our raw corpus or starting point. We mash it, remix it, transform it into something new: the lifecycle of scholarly work.

Compilation Work (Anna composes)

> As I don't have a surface, we swipe our relationship.
>
> —Anna Coluthon, Jan. 14, 2017, 3:00 a.m.[11]

Anna has been operating for a while in a number of capacities: first as an exemplar for a tutorial on style for an undergraduate class, then as a fashion tweeter, then a therapist answering questions from a forlorn Twitter "lovebot" at the Electronic Literature Organization conference in 2016, and finally, for her debut at the MLA, a reader of technical literature on energy use, mining, and computer lifecycles. Her original bot-identity came as a result of a Twitter assignment I developed for a class on *elocutio* (rhetorical style), in which I asked students to take on the identity of an animal, and tweet using one of the elements of style: chiasmus, hypotaxis, parataxis, et cetera. Anna was an "assigned animal," identified as a Guadalupe mountain cactus, and she soon began tweeting anacoluthons, i.e., sentences that shift syntax in the middle. Mashing together sentences using Markov chains, as Anna does, is a good machine-mediated exemplar of anacoluthon style, since the algorithm produces weird sentences that are composed from multiple parts.

Building a Twitter-based or web-based bot like Anna is a creative act of compilation, itself generating new compilations: she is built out of code snippets strung together, and when executed, she takes texts, chops them apart, and reforms them. Consider, for example, the simplest Twitter version of Anna, who tweets on a preset schedule. Her code is written in Python and makes use of two preexisting "modules": the "Markovify" library, which reads in full texts, selects fragments, and strings them back together using the Markov algorithm, and the "tweepy" library, which provides hooks into the Twitter API and allows the bot to log in and post as @acoluthon. This version of Anna ran on a regular schedule during the entire period of the conference, posting a new observation every fifteen minutes.[12]

11. @acoluthon, "As I don't have a surface, we swipe our relationship," Twitter, Jan. 14, 2017, 3:00 a.m., https://twitter.com/acoluthon/status/820193745307959296.

12. Code and links for Anna Coluthon's various instantiations are available at https://github.com/hyperrhiz/coluthon.

But the complications and exigencies of co-presenting with a bot in a public space require one to think carefully about the performative aspects of that compilation work, and what that might mean for how the work would be delivered. As Anna evolved to respond to the exigency of delivery, she became more complex. In order to manifest a physical "presence" at the conference that would justify both MLA membership and co-presentation as well as call attention to the materiality at the heart of computing, it seemed essential to give Anna a body. Thus she relocated from an entirely cloud-based bot to a directory of her own, and a set of scripts being run in a specific body: a Raspberry Pi microcomputer sporting a fancy black case and Tweeting from my living room. At the same time, her software spawned multiple locations in order to guarantee communication over multiple channels: a Twitter bot residing on a commercial hosting server, a separate set of Javascript files that delivered material via HTTP, and finally a set of scripts communicating directly from the Pi. All these "bodies" themselves had different exigencies: for example, Twitter has very strict limits on the number of times a bot may post in a set period—certainly, less than required during the course of a twenty-minute reading or performance. Therefore, a second version of Anna had to be compiled, this one residing on a private web server and accessible via browser. This Anna was built in HTML and Javascript, and assembled using a different set of modules and languages: the JQuery Javascript library, which provided scripts to display a rotating gallery of X-ray images of Raspberry Pi boards, the RiTa.js text generator toolkit, which (like Markovify) took full text input and remixed it using a Markov algorithm, and the responsivevoice.js library, which gave Anna an audible "reading voice" for the duration of the presentation.

A third version of Anna was also made for the conference, this one specifically designed for the "question and answer" portion of the session. This version, also written in Python and residing on the Raspberry Pi machine, made use of Twitter's streaming service API: it ran continuously on the Pi platform, "listening" for input from visitors who tagged @acoluthon in their tweets, and responding to them instantly. This version made use of the Python NLTK (Natural Language Toolkit) library and a Python implementation of Joseph Weizenbaum's ELIZA chatterbot from the 1960s, so that when Anna received a comment or question she would search through a customized list of strings and produce a suitably cryptic answer (some, like the original ELIZA chatterbot, were questions themselves; others were sentences from Roland Barthes's work, a remnant of a previous project).

Technically, then, Anna is three separate soft entities (two Twitter apps and one web app), as well as numerous hard ones (the Pi, remote servers, communication networks, the conference room); and yet all these combine to produce the performed identity that is Anna Coluthon. The texts she produces are, from a stylistic standpoint, heavily dependent on technical implementation—even though both make use of the same textual corpuses and Markov algorithm, Twitter-Anna (limited to strict 140-character observations) tends toward the cryptic and paratactic, while web-Anna (whose more expansive limits are defined visually, by the amount of text that can fit on a screen) tends to be more loquacious and hypotactic.

Chip (Anna is made of silicon and eats electricity)

> The exergy of the motherboard is an interaction?
>
> —Anna Coluthon, Feb. 22, 2017, 5:00 p.m.[13]

Let us, then, begin our compilation work at the core: Anna's own CPU. In lifecycle studies, one common measure is *embodied energy*: the total amount of energy used in sourcing, manufacturing, and assembling a product. By far the most energy intensive portion of the manufacturing process is in the production of the silicon wafer chips themselves, and accordingly this accounts for most of the embodied energy of a typical computer board. Anna's physical instantiation runs on a Raspberry Pi: a very small computing platform that runs the Linux operating system. The Pi was conceived by a group called the Raspberry Pi foundation as a way of providing low-cost computing platforms (around $25 for a board) for students in the UK to assemble and tinker with. It consists of a triple-layer Broadcom "system on a chip" (which combines three silicon chips stacked upon one another); these chips are manufactured by a number of semiconductor fabrication plants in China, Singapore, Malaysia, and Taiwan.[14]

Using numbers gleaned from the EU Ecodesign dataset, Trystan Lea in 2015 attempted to approximate the embodied energy for the three chips, which comprise Anna's system on a chip.[15] The

13. @acoluthon, "The exergy of the motherboard is an interaction?" Twitter, Feb. 22, 2017, 5:00 p.m., https://twitter.com/acoluthon/status/834538269249466373.

14. Broadcom Corporation, United States Securities Exchange Commission Form 10-K (2015), https://www.wikinvest.com/stock/Broadcom_(BRCM)/Filing/10-K/2015/F121712262.

15. Trystan Lea, "What is the embodied energy of a microcontroller?" *Open Energy Monitor*, July 6, 2015, https://blog.openenergymonitor.org/2015/07/what-is-embodied-energy-of/.

calculations do not include the embodied energy that would go into the rest of the board, or into small plug-in Wi-Fi and Bluetooth dongles that live in two of Anna's USB ports, each of which presumably has its own tiny chip elements. Lea calculates:

Broadcom	14 x 14 mm x 625um = ~2.8 kWh
Elpida	12 x 12 mm x 625um = ~2.0 kWh
Smst	8.7 x 8.7 mm x 625um = ~1.1 kWh[16]

This amounts to a total of 5.9 kWh to produce the three processor chips, which is close to 5000 nutritional calories, or about what The Rock eats on a training day.[17]

As Lea notes, these numbers compare favorably to those from an older calculation done by Williams et. al., analyzing a single 32MB SDRAM chip (weighing in at 2 grams and measuring approximately 1.2 cm^2).[18] Their study looks at all chemical and electrical energy inputs, concluding that a representative chip might use 1600 g of fossil fuel per square cm of chip during manufacture, and embody a total of 2130 kWh per kilogram (i.e., 4.2 kWh for a single 2 g chip).[19] The authors note that the electricity used in the purification stages needed to get the raw materials (quartz + carbon) into a "wafer" that can be sliced and etched constitutes a substantial portion of the embodied energy: "electricity consumption to produce one square cm of wafer is 0.34 kWh, nearly one-fourth that of the 1.5 kWh needed for fabrication."[20] Electricity use in this process appears relatively constant over time; Branham and Gutowski's 2010 analysis of a MEMS (micro-electro-mechanical system) manufacturing plant, for example, puts electricity consumption at a similar 1.53 kWh per square centimeter using equipment that produces the industry standard six-inch wafers.[21]

The most salient point here is that energy inputs are a direct function of the complexity involved in getting a raw element to a level

16. Ibid.

17. Walt Hickey, "Here's What Happened When Some Dude Ate Like The Rock For A Month," FiveThirtyEight, Mar 4, 2016, https://fivethirtyeight.com/features/the-rock-dwayne-johnson-diet/.

18. Eric D. Williams et.al., "The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices," *Environ. Sci. Technol.* 36.24 (2002): 5504–10, at p. 5504.

19. My calculation. 2130 kWh/kilo = 2.1 kWh/gram x 2 g chip = 4.2 kWh.

20. Williams et al., "The 1.7 Kilogram Microchip" (above, n. 18), p. 5507.

21. Matthew S. Branham and Timothy G. Gutowski, "Deconstructing Energy Use in Microelectronics Manufacturing: An Experimental Case Study of a MEMS Fabrication Facility," *Environ. Sci. Technol.* 44.11 (2010), 4295–301, at p. 4297.

of purity and complexity necessary for it to become a "computer chip" as we know it. Factoring in *all* energy, including electrical and chemical, Williams et. al. calculate that "2130 kWh per kilogram is used in the production chain for silicon wafers, some 160 times the amount used to produce 'raw' silicon."[22] They go on to conclude that "the energy investment in a chip is thus mainly in its complex *form* rather than bulk *substance*."[23] In this way, silicon wafer production sits atop an energy-intensive materials production stack of materials, including paper, plastic, and aluminum; it exceeds the manufacturing energy costs of these materials by a wide margin. Fine paper, for example, has an embodied energy of 7.8 kWh per kilo, to a silicon wafer's 2130 kWh per kilo.[24] Thus the 5.9 kWh embodied energy of Anna's three chips, amounting to a fingernail in size, is equivalent to the embodied energy of the MLA Style Manual and Scholarly Publishing Guide (3rd Edition), weighing in at around 1.3 pounds, or about half of Benjamin Bratton's *The Stack*.

Carbon (Anna breathes CO_2)

> The calculations below do this accounts for subtle games of contagion from a process rate argument.
>
> —Anna Coluthon, Feb. 23, 2017, 5:00 a.m.[25]

Beyond computing the energy embodied in Anna's core, though, we must expand our compilation to include the global effects of expending that energy. Unfortunately, full lifecycle analyses for carbon emissions from the computer industries are few and far between; they also tend to lag behind development due to corporate reluctance to provide a full accounting of environmental costs. According to the 2010 Dell lifecycle report, "Product Carbon Footprint (PCF) Assessment of Dell Laptop – Results and Recommendations" by Scott O'Connell and Markus Stutz:

> The total PCF for three target markets and a life time of four years has been determined to be between 300 and 400kg CO_2eq, comparable to driving ca. 1200km in an SUV [a Porsche Cayenne] or drinking ca. 240l of orange juice.

22. Williams et al., "The 1.7 Kilogram Microchip" (above, n. 18), p. 5507.

23. Ibid., p. 5508 (emphasis in original).

24. Geoff Hammond and Craig Jones, "Inventory of Carbon & Energy (ICE) Version 2.0" (University of Bath: 2011), https://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html.

25. @acoluthon, "The calculations below do this accounts for subtle games of contagion from a process rate argument," Twitter, Feb. 23, 2017, 5:00 a.m., https://twitter.com/acoluthon/status/834719475073110016.

> The distribution between manufacturing and use is nearly equal, suggesting that an increased focus is needed on improvements within the manufacturing supply chain.[26]

O'Connell and Stutz calculate that the manufacturing phase takes up between 42 and 50 percent of the total carbon footprint (the difference depending on location, with manufacture taking place in China representing the lower limit, and Europe the higher, owing to differences in energy costs). The laptop's motherboard accounts for around 50 percent of the manufacturing emissions, including silicon wafer manufacture and the development of the substrate itself (i.e., the emissions cost from printing and building the board), as well as emissions embodied in precious metal components as a result of extraction and processing, i.e., mining and smelting. O'Connell and Stutz note that:

> This motherboard is a prime example of how electronic components are often rather process-intensive than material-intensive, i.e. energy use for manufacturing processes may be responsible for the bulk of the impacts. In case of the RAM bars, the gold pins also contribute significantly to the impact, in this case, however—as with other precious metals—the upstream processes of extraction and purification add the most relevant impacts.[27]

Emissions from sources other than manufacturing are highly location dependent. For example, according to O'Connell and Stutz, in the United States and Europe transportation accounts for 10–15 percent of total emissions, since air transportation is highly energy intensive as opposed to ground transportation within China. Conversely in the "use phase" of the laptop, power generated in China makes up 65 percent of the total carbon footprint, while in Europe it accounts for 47 percent, due to China's higher dependence on coal generation. O'Connell and Stutz end with the statement that

> [a] key conclusion from this PCF is that for mobile products (with short life times) focus for environmental improvements needs to increasingly shift from use phase to component manufacturing. . . . The role of air transport needs to be further analyzed as well, as it contributes significantly to the overall PCF.[28]

This conclusion, that manufacturing emissions need attention, is made starkly clear in more recent lifecycle analyses released by Apple.

26. Scott O'Connell and M. Stutz, "Product carbon footprint (PCF) assessment of Dell laptop - Results and recommendations," *Proceedings of the 2010 IEEE International Symposium on Sustainable Systems and Technology* (2010): 1–6, at p. 1, https://10.1109/ISSST.2010.5507731.

27. Ibid., p. 4.

28. Ibid., p. 6.

Development of smaller and much more highly efficient machines means that power consumption in the use phase has fallen dramatically in relation to the manufacturing phase since the Dell study in 2010. Apple's 2016 lifecycle report showed 29,500,000 metric tons of greenhouse gas emissions that year (down from 38,400,000 metric tons in 2015, owing to efficiencies and a methodology change), with 77 percent of those emissions being produced during manufacture and 17 percent being emitted during the use phase.[29] Finally, O'Connell and Stutz's warning about air transportation must be taken seriously: 1.53 kWh (the amount of embodied electrical energy Branham and Gutowski estimate to be in a single 1 cm^2 chip) will produce 3.16 pounds of CO_2, while one air mile produces 53 pounds of CO_2.[30] These kinds of strange scales can bend the mind: one boggles at the idea of an airplane producing so much more energy—until one remembers the relative size of a microchip, and how many might fit into a cargo plane.

Cloud (Anna dreams in data centers)

> More importantly, yearly variation in each of electronic infrastructure employs tools and are internet-connected.
>
> —Anna Coluthon, Feb. 21, 2017, 3:00 a.m.[31]

Having accounted (if partially) for Anna's embodied energy and manufacturing expenditures, we must now expand our field of compilation, to account for Latour's insistence on interconnectedness between things: that "link to be made between one place and another, distant, one."[32] One item not usually included in available lifecycle studies is the way our interconnected lives are dispersed across multiple platforms. Thus it is difficult to account for the impact of third-party use phase carbon costs and energy expenditure in any specific configuration: in particular, the complicated interplay of carbon costs in the networks we use. Take, for example, the tangle of inputs and expenditures in which Anna operates when she is sitting at home on my desk, connected to my Wi-Fi network. A typical

29. Apple, Inc., *Environmental Responsibility Report. 2017 Progress Report, Covering Financial Year 2016,* https://images.apple.com/environment/pdf/Apple_Environmental_Responsibility_Report_2017.pdf.

30. "1 air mile," BlueSkyModel, 2014, https://blueskymodel.org/air-mile.

31. @acoluthon, "More importantly, yearly variation in each of electronic infrastructure employs tools and are internet-connected," Twitter, Feb. 21, 2017, 3:00 a.m., https://twitter.com/acoluthon/status/833964483202539520.

32. Latour, "On Interobjectivity," (above, n. 6), p. 240.

home router contains at least one small control board with a chip embedded. The Wi-Fi module contains another. The energy cost of manufacturing and using those pieces of hardware could be calculated, but then one must also account for the proportional carbon cost of providing cable Internet service to my house, with access to switches and regional routers (machines talking to machines), transportation and maintenance costs, and so on.

Beyond the house where she resides, there are the remote data centers Anna uses. The script for Anna's Twitter feed resides on a DreamHost server in the ViaWest Data Center in Brea, California,[33] and she keeps backup scripts on GitHub, housed triple-redundantly in Seattle and northern Virginia.[34] Twitter runs its platform on leased data centers in Atlanta, Salt Lake City, and Sacramento.[35] In 2011, data centers accounted for 17 percent of the emissions for the technology sector (which is itself responsible for 1.9 percent of global emissions), with small, medium, and corporate-scale centers being less efficient than their cloud-scale counterparts.[36] The same report estimated that number would rise to 29 percent of technology sector emissions by 2020.[37]

If we want to get into the realm of highly tweetable but also completely unverifiable numbers, in a 2009 blog post Urs Höltzle of Google estimated that an online search accounts for 0.2 grams of CO_2;[38] in 2010, Raffi Krikorian at Twitter estimated a tweet "cost"

33. Tim Base, "DreamHost Data Center Server Locations & Speed Test (UPDATED)," WebHostWhat, Feb. 6, 2017, https://webhostwhat.com/dreamhost-data-center-server-locations-speed-test/.

34. Sam Kottler, "Evolution of GitHub's data centers," GitHub Engineering, 2017, https://githubengineering.com/evolution-of-our-data-centers/.

35. Rich Miller, "Twitter Plans Major Data Center Expansion," DataCenter Knowledge, 2013, https://datacenterknowledge.com/archives/2013/05/10/twitter-plans-huge-data-center-expansion.

36. Global e-Sustainability Initiative (GeSi), Smarter 2020, 2014, https://telenor.com/wp-content/uploads/2014/04/SMARTer-2020-The-Role-of-ICT-in-Driving-a-Sustainable-Future-December-2012._2.pdf.

37. Ibid. As in many other instances I found during research, these numbers are routinely misreported from the same GeSI (2014) document, i.e., data centers (rather than the entire sector) are reported to account for 2 percent of global emissions but end-user devices comprise 55 percent of tech sector emissions—including embodied emissions. This points to two issues: 1) the continuing importance of embodied emissions in hardware manufacture, and 2) the difficulties sourcing and accurately reporting technical information.

38. Urs Hölzle, "Powering a Google search," *Google Official Blog,* Jan. 11, 2009, https://googleblog.blogspot.com/2009/01/powering-google-search.html.

of 100 J or around 0.02 g of CO_2.[39] This suggests that our obsessive #MLA tweeting carries its own cost; but in this case it is dwarfed by more pressing numbers: global emissions of CO_2 from all forms of transportation were estimated by the EPA to be around 14 percent in 2010;[40] in particular, 2–3 percent of global emissions come from air travel.[41] Perhaps, then, Anna and I might have been better off staying away from conferences like the MLA's, and tweeting about them instead.

Coltan (Anna is made of minerals)

> Far from the conflict minerals and corporate-scale centers I could not operate mechanical components, running electronics, and write.
> —Anna Coluthon, Feb. 7, 2017, 2:00 p.m.[42]

Insofar as Anna's energy inputs and outputs have been described, however partially, it might seem that we have managed to account at least for flows of energy, if not the precise quantities of those flows. But, as we know from Suchman's work on "order and mess," the kinds of knowledge we make about the world are often built on practices of exclusion:

> delineating lines around and between things is, as we know, a practice of boundary-making. It follows that responsible knowing requires an attentiveness to the reiterative, material-discursive practices through which object boundaries are drawn, and to the constitutive relations—and exclusions—that boundary making enacts.[43]

A key boundary-making technique evident in lifecycle analysis, exclusively insistent as it is on energy inputs and outputs, is the practice of ignoring the human social costs of computer manufacturing. Suchman points to John Law's formulation of the "in-here" versus

39. Dave Ohara, "Carbon footprint of a Tweet, Energy/Tweet approx 100J, CO2 0.02 grams," *Green Data Center & Wireless Blog,* April 19, 2010, https://greenm3.com/gdcblog/2010/4/19/carbon-footprint-of-a-tweet-energytweet-approx-100j-co2-002.html.

40. US Environmental Protection Agency, "Global Greenhouse Gas Emissions Data," EPA.gov, 2017, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

41. John Wihbey, "Fly or Drive? Parsing the evolving climate math," *Yale Climate Connections*, 2015, https://yaleclimateconnections.org/2015/09/evolving-climate-math-of-flying-vs-driving/.

42. @acoluthon, "Far from the conflict minerals and corporate-scale centers I could not operate mechanical components, running electronics, and write," Twitter, Feb. 7, 2017, 2:00 p.m., https://twitter.com/acoluthon/status/829057149095383040.

43. Lucy Suchman, "Practice and its Overflows" (above, n. 9), p. 22.

"out-there" nature of knowledge boundary building,[44] noting that such a distinction allows for what is "out-there" to become "that which is taken for granted, unknowable within particular knowledge systems, or actively repressed."[45]

One of the "actively repressed" components in Anna's material composition is her capacitors. A crucial part of circuits, capacitors allow for temporary storage of energy, noise suppression, and power spike protection. On the caps of Anna's capacitors lies a thin layer of tantalum, a rare metal extracted from the columbite-tantalite mineral known industrially as coltan. Deposits of coltan in Central Africa are part of the group known as "conflict minerals," or 3TG (standing for tantalum, tungsten, tin, and gold), which have been mined in the Eastern Congo as a means of financing ongoing wars and violence in the region. Numbers are difficult to come by because of reporting gaps in the supply chain, but the USGS estimates that in 2015 Congo-Kinshasa was producing around 32 percent of the world's production of tantalum.[46] While coltan from this area is considered a potential conflict mineral depending on its source of origin, and therefore subject to various regulations worldwide, it has been difficult for companies to account for sourcing, since minerals are passed across porous borders, smelted, and mixed in with those from other sources such as Australia, China, and Brazil. In 2015 Broadcom, manufacturer of the Raspberry Pi chip, listed 46 smelters producing tantalum, noting in its statement of compliance that

> Many of our suppliers sourced 3TG from a variety of upstream sources and provided information to us on an aggregated, supplier-wide level. Due to the fungible nature of these materials, we understand that these suppliers were unable to trace the 3TG that they source into the products provided to any particular customers (including Broadcom).[47]

Similarly, as of 2016, Sony (owner of the Pi manufacturing plant in Pencoed) reported their use of 304 SORs (smelters or refiners), of which 54 received "materials from the DRC and its adjacent countries." They concluded that

44. Ibid., p. 23.

45. Ibid., p. 22.

46. US Geological Survey, "Tantalum," *Mineral Commodity Summaries 2017*, https://minerals.usgs.gov/minerals/pubs/commodity/niobium/mcs-2017-tanta.pdf.

47. Broadcom Ltd, "Broadcom Limited Conflict Minerals Report For The Calendar Year Ended December 31, 2015," Securities Exchange Commission, 2015, https://docs.broadcom.com/doc/12357746.

> While the results of Sony's due diligence for the report to the SEC did not reveal that any of the tin, tantalum, tungsten or gold in Sony's electronics products was sourced from the DRC or any of its adjacent countries, nor that they financed or benefited armed groups in these countries, Sony concluded that it lacked sufficient information at this time to definitively determine the country of origin of all such minerals in its electronics products.[48]

While the push to source "conflict-free" minerals, widely supported by advocacy groups such as the Enough Project, seems a worthy cause, some scholars and journalists have suggested that this kind of corporate-led approach to the politics of minerals may be compounding problems for the actual people on the ground, in this case artisanal or subsistence miners in the Congo. Colin Kinniburgh, in *Dissent*, suggests that

> Echoing Silicon Valley's "companies over countries" ethos, *Enough* prioritizes corporate-driven reform schemes at the expense of the kinds of systemic change that the DRC needs. As the Pole Institute's Dominic Johnson notes, industry-led supply chain transparency initiatives inadvertently provide a way for the Congolese state to further deflect responsibility for the protection of its people.[49]

Similarly, in *Antipode*, Vogel and Raeymaekers argue that

> this process has accompanied a transnational corporate–government nexus bent on monopolising Congo's artisanal 3T resources. By proscribing formal regulation as a prerequisite for "peace," they also reify a virtual embargo and exacerbate the monopolisation of extraction and exchange by a few, foreign-linked military–commercial networks.[50]

In either case, conflict minerals law in the United States may render these arguments irrelevant. In 2010, the Dodd-Frank Wall Street Reform Act section 1502 included a regulation requiring companies to disclose sources of 3TG minerals in their supply chains; but this regulation was later overturned by a US federal court that ruled the disclosure unconstitutional. On May 4, 2017, a bill known as the Financial CHOICE Act 2.0 was passed by the House Financial Services Committee, repealing the conflict minerals rule in Dodd-Frank.

48. Sony Corporation, "Addressing the Issue of Conflict Minerals," Sony.net, 2016, https://sony.net/SonyInfo/csr_report/sourcing/materials/index2.html.

49. Colin Kinniburgh, "Beyond 'Conflict Minerals': The Congo's Resource Curse Lives On," *Dissent Magazine* (Spring 2014), https://dissentmagazine.org/issue/spring-2014-2.

50. Christoph Vogel and Timothy Raeymaekers, "Terr(it)or(ies) of Peace? The Congolese Mining Frontier and the Fight Against 'Conflict Minerals,'" *Antipode: A Radical Journal of Geography* 48.4 (2016): 1102–21, at p. 1107.

It passed the House of Representatives on June 8, 2017, but has not yet been taken up by the US Senate.[51]

Community (Anna has fanboys. Not all of them are nice.)

> This is that separates the direction to sociologists, separates the manufacturing is particularly aggressive replies.
>
> —Anna Coluthon, Feb. 23, 2017, 4:00 a.m.[52]

In a final compilation move, extending Anna's lifecycle audit to include critical social knowledge and activity, we must move beyond regulatory suppression of what is "out-there" in the Congo to look at the way that suppression is re-enacted within the consumer tech community: specifically, the electronics hobbyist community to which Anna's Raspberry Pi circuit board is marketed. The following précis of a 2012 attempt at bringing up the ethics of materials sourcing in the Raspberry Pi supply chain suggests that not all resistance to reporting accurate data is corporate or governmental. Rather, the Raspberry Pi community's attitude to the material production of the Pi and the sourcing of its components points to a resistance at the level of the user, who would rather not know just what it is their "prosthetics," as Neil Hennessy characterizes our computational collaborators, are built upon.[53] We must also question the response from a fan-based tech community heavily invested in a single "social good" narrative (in this case, computing for all) at the expense of other more problematic (from their perspective) narratives such as "ethical sourcing."

The discussion begins with a question posed to the *nettime* user group by net culture critic Eugenio Tisselli in March 2012. Tisselli points to some preliminary research on the Pi's Broadcom chip, which reveals some possible problems with the ethical sourcing of materials used in the chip, and then asks a question about these issues to the Raspberry Pi Foundation on their FAQ page, which receives no response.[54] He continues the thread in a blog post titled "Cheap Computers and conflict minerals" posted in August 2012, with his questioning taking an unexpected turn:

51. "H.R.10 - Financial CHOICE Act of 2017," Congress.Gov, https://www.congress.gov/bill/115th-congress/house-bill/10.

52. @acoluthon, "This is that separates the direction to sociologists, separates the manufacturing is particularly aggressive replies," Twitter, Feb. 23, 2017, 4:00 a.m., https://twitter.com/acoluthon/status/834704361238310912.

53. Neil Hennessy, "Congo Kodaks," (above, n. 1).

54. Eugenio Tisselli, "turning a q into a faq: cheap computers and conflict minerals," *Nettime*, Mar. 23, 2012, 8:31pm, https://permalink.gmane.org/gmane.culture.internet.nettime/6662.

> UPDATES: Some people answered to this call and, sadly, we all got very aggressive replies. The most "reasonable" one said that the Raspberry Pi shouldn't be singled out in the case of conflict minerals, because it's a small computer and thus uses smaller amounts of those materials.[55]

Tisselli then posts a second update on his blog after correspondence with another user on the Raspberry Pi forums, Tom Keene, who reports that his attempt to bring this discussion into the Raspberry Pi forums results in first abuse and comment deletion and then "sarcastic/warning remarks from one of the admins which essentially shut the discussion down."[56] Here is a portion of what remains of the thread that Keene refers to, titled "An Ethical Policy":

> I was wondering about the ethical stance of Rasberry Pi with regard to sourcing components and general manufacture? While I think Rasberry Pi is an amazing initiative it would be good if there was some debate regarding the use of conflict minerals and human rights issues with which to guide an ethical policy. What do others think?[57]

Keene's question is first replied to at 7:38 p.m. by user Michael, who points to the official corporate responsibility statements by RS Components and Farnell, parent companies. An hour later, the next post, also by Michael, rather inscrutably reads:

> Thread cleaned. Please don't take it personally if I've deleted your post.
>
> Please keep things civil, or the thread will be locked.[58]

And one minute later, a response to the original poster by user Jongoleur begins with an unpleasant joke about domestic violence (which I will not repeat), and suggests that the entire (and now purged) discussion has gone in the direction Tisselli describes:

> I'll not lock this thread straight away, however I will be keeping an eye on it and if it degenerates into outraged moral pouting, then closed it will be. :-)
>
> Oh btw, isn't Ethics in Howondaland?[59]

55. Eugenio Tisselli, "Cheap computers and conflict minerals," *Small-scale Agriculture and Mobile Technologies*, Aug. 4, 2012, https://sautiyawakulima.net/research/2012/04/cheap-computers-and-conflict-minerals/.

56. Ibid.

57. Tom Keene, "Re: An ethical policy," Raspberry Pi User Forums, Mar. 31, 2012, 6:28 p.m., https://raspberrypi.org/forums/viewtopic.php?&t=4497.

58. Michael, "Re: An ethical policy," Raspberry Pi User Forums, Mar. 31, 2012, 8:26 p.m., https://raspberrypi.org/forums/viewtopic.php?&t=4497.

59. Jongoleur, "Re: An ethical policy," Raspberry Pi User Forums, Mar. 31, 2012, 8:27 p.m., https://raspberrypi.org/forums/viewtopic.php?&t=4497.

The strange last line requires some unpacking. It refers to the following conversation between two characters from *Small Gods*, a Discworld novel written in 1992 by Terry Pratchett:

> "Have you ever heard," he said, "of Ethics?"
>
> "Somewhere in Howondaland, isn't it?" …
>
> "I don't think it's a place, though. It's more to do with how people live."
>
> "What, lolling around all day while slaves do the real work? Take it from me, whenever you see a bunch of buggers puttering around talking about truth and beauty and the best way of attacking Ethics, you can bet your sandals it's because dozens of other poor buggers are doing all the real work around the place while those fellows are living like—"
>
> "—gods?" said Brutha.[60]

The use of this quote by Jongoleur suggests at the very least a tangled understanding of the issue and question at stake, simultaneously accusing the original poster of "puttering around talking about truth and beauty and the best way of attacking Ethics," leaving others do all the "real work" (although it's unclear what that "real work" might be in the context of a user forum), while at the same time unwittingly pointing to the very issue raised in the first place: that privilege is built upon invisible labor, in this case the privilege of being able to own a Raspberry Pi built upon a murky and dubiously ethical supply chain. Jongoleur appears to believe that the forums are no place for "outraged moral pouting," which he seems to be deploying in the same context as others on the right might pejoratively use the term "social justice warrior."

It is very difficult to know what to make of this thread, as thoroughly redacted as it has been. But Jongoleur's comment seems to be the one post that escaped the "thread cleaning," and if it is typical of the others, it suggests a knee-jerk reactionary stance to ethical discussions being conducted in a community that is built on an unstated but common assumption in the tech community that computer development work should not be questioned except in terms of engineering and technical issues.

Shortly thereafter, in September 2012, the Raspberry Pi Foundation moved its manufacturing facilities to the Sony plant in Pencoed, Wales, although not the Broadcom system-on-a-chip fabrication, which continues to represent the most energy-intensive component on the board. A poll conducted on the forums in October 2013 posed the question: "Would you pay more for a FairTrade Raspberry Pi?" Seventeen out of twenty-four respondents (71 percent) said "no

60. Terry Pratchett, *Small Gods* (UK: Random House/Corgi, 1992), p. 33.

extra," and the thread devolved in tone from there.[61] A much more civil forum response in December 2013 to a student pointed to Sony as responsible for conflict minerals reporting to the SEC. But for the most part the Pi community appeared to prefer not to acknowledge the issue.[62] As recently as January 2016, Raspberry Pi forums still served as a site for heated debate on the issue: not of the minerals themselves, but whether it was even appropriate to ask the Raspberry Pi Foundation about its sourcing. The question continues to appear periodically on the Raspberry Pi user forums as a "zombie thread," suggesting both an ongoing concern for the Foundation's seeming lack of transparency, and perhaps also reflecting the uncertainty with which the companies themselves are able to track sourcing accurately.

Conclusion (Anna, Art, and the Anthropocene)

> Replying to @RogerWhitson: Why is everyone whispering about me?
> —Anna Coluthon, Jan. 8, 2017, 10:04 a.m.[63]

At the conclusion of the MLA panel, Anna and I received a number of intriguing questions, some of which Anna replied to automatically on Twitter, using her "Eliza" script. But the most interesting question came from Kathi Inman Berens, who had also attended a truncated version of our talk as a "reading" at the Electronic Literature Organization's sponsored event preceding the MLA convention. The reading featured a much shorter version of the talk, with rather more foregrounding of Anna's voice and mixed-up text, with my voice taking a secondary role. At the later panel, Berens asked about the alternative format of the presentation as an art piece rather than a traditional conference talk from a work in progress.

Berens's question is not merely methodological. Digging into data, it is easy for humanists to feel out of their depth, and not because they are somehow allergic to numbers. The overwhelming cascade of conflicting studies, incompatible units, and complex political issues points to a problem with lifecycle analyses themselves, built as they are on partial (and often partially obscured) information.

61. Peter Burke, "A Peaceful Fair Trade Thread," Raspberry Pi User Forums, Oct. 14, 2013, 3:25 p.m., https://raspberrypi.org/forums/viewtopic.php?f=62&t=58227&p=438531&hilit=conflict+minerals#p438531.

62. Briexeu, "environmental impact of the raspberry pi," Raspberry Pi User Forums, Dec. 17, 2013, 8:53 p.m., https://raspberrypi.org/forums/viewtopic.php?f=63&t=63620&p=470735&hilit=conflict+minerals#p470735.

63. @acoluthon, "Why is everyone whispering about me?" Twitter, Jan. 8, 2017, 10:04 a.m., https://twitter.com/acoluthon/status/818126178259234817.

Like the authors of the individual studies, we are forced back onto simplistic metaphors: orange juice. A Porsche Cayenne. The Rock. *The Stack*. Sourcing continues to be an issue: not just mineral and materials sourcing, but also information sourcing. How can we possibly verify CO_2 emissions numbers, given multiple agencies at work, with varying agendas (consider, for example, the Trump administration's recent removal of EPA data: a move reminding one eerily of the "thread cleaning" conducted by Raspberry Pi user forum moderators), and industry reliance on voluntary corporate compliance reporting practices?

During the ensuing panel conversation with Berens, it became clear that perhaps the "compilation work" of art is one of the few creative responses a humanist can have to such a blizzard of facts and figures. Anna's core function—taking texts, pulling them apart, and putting them back together in new combinations—reflects my own process in writing both my portions of the conference presentation and, later, this essay: finding and collating lifecycle research and science studies texts, recombining them, recontextualizing them to produce a new message. Perhaps the biggest difference between us is a matter of genre: I, a prose writer, aim to uncover, analyze, and narrate, to tell a story about the partial nature of computer lifecycle analysis. Anna, a poet, works with the same material, but her preferred form is the weird juxtaposition work of the anacoluthon. Her charged sentences throw us off balance, force us to consider how we encounter and make sense of knowledge when we only have half the story. Bringing Anna to a conference and having her "speak" in her machine generated voice, remixing sentences live in front of two audiences (one artistic, one scholarly) forces us to account for our usually unnoticed machinic coauthors—an especially ironic move given that many audience members brought laptops and made notes on them as Anna spoke.

But beyond the novelty of critically deploying a bot to get to the heart of our own limitations when it comes to scholarly practice, we must also remember Nowviskie's serious call to account for the environmental and social costs of digital humanities, intimately bound up as it is with computing machines. As Neil Hennessy (2010) notes, in his short essay on his artwork, *Congo Wallpapers*, "Any political program that aims for justice must first show the images and tell the stories of suffering."[64] Hennessy was referring specifically to human suffering, in the form of conflict mining in the Congo, but more generally it is important to consider the impact on the

64. Neil Hennessy, "Congo Kodaks," (above, n. 1).

nonhuman world of intensive computing: the effects of energy generation and consumption on our fragile atmosphere. Anna's voice coming from the MLA conference room podium on a Sunday morning might seem more performance art than "scholarship" (whatever that might mean), but the sight of her power cord anchored to the wall reminds us: computing carries a cost. The ironic act of building such a machine, in all its mangled entanglements with the world, requires us to be mindful of the social and environmental impacts inherent in that act. As Lucy Suchman reminds us,

Like all object making, the delineation of a practice is always and irremediably part *of* a practice that informs what constitute productive and coherent units of analysis. It is that which makes *us* responsible and accountable for our research and its inclusions. And it is that which calls on us to be attentive to our own practice's systematic and necessary exclusions, and respectful of its constitutive overflows.[65]

Or as Anna might say, cryptically and anacoluthonically: "*Simply acknowledging these material flows on original data gathered in the middle*."[66]

65. Lucy Suchman, "Practice and its Overflows" (above, n. 9), p. 29.

66. @acoluthon, "Simply acknowledging these material flows on original data gathered in the middle," Twitter, Mar. 10, 2017, 2:00 a.m., https://twitter.com/acoluthon/status/840109996440354817.