Running out of energy

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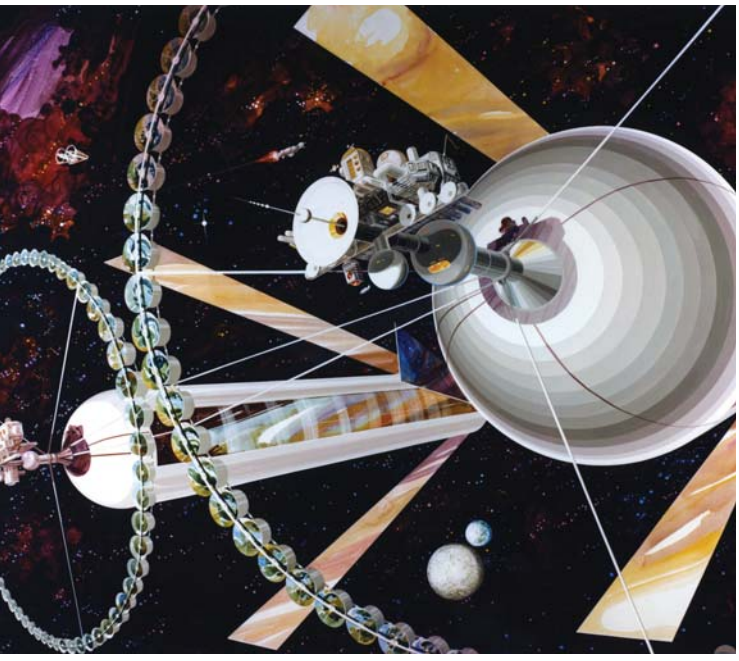
The cover of the November 2019 issue of *The Atlantic* highlights a 15-page article by Franklin Foer entitled "What Jeff Bezos wants: His master plan, and what it means for the rest of us." The cover image shows the Amazon founder's shaven head in profile. To convey his mental preoccupations, the cover artist has superimposed a patchwork of quasi-hand-drawn zones with labels such as "tax avoidance," "more Jeff-bots," and "Prime day!" By far the largest zone, at the top of the mogul's head, is "colonize outer space."

The apportionment seems justified, and it reflects Bezos's long-held, undimmed enthusiasm for space. In his article Foer recounts that long after Bezos had graduated high school, reporters tracked down his high school girlfriend. "The reason he's earning so much money is to get to outer space," she told them. Foer also notes that as an undergraduate at Princeton University, Bezos attended seminars given by particle physicist Gerard O'Neill.

In 1956 O'Neill published a proposal for a device, a particle storage ring, that could accumulate particles from an accelerator for release later in an intense beam.[1] CERN's Large Hadron Collider, Fermilab's Tevatron, and Brookhaven National Laboratory's Relativistic Heavy Ion Collider all use, or used, particle storage rings. But by the time Bezos attended Princeton, O'Neill had shifted his attention to space. His September 1974 article in PHYSICS TODAY (page 32) outlined the design of vast rotating space habitats.



GERARD O'NEILL proposed building vast cylindrical space habitats whose rotation provides artificial gravity. (Rick Guidice, NASA's Ames Research Center.)

Bezos has invested at least $500 million of his fortune in Blue Origin, a company he founded in 2000 to develop technologies for private access to space. Part of his motivation lies in the glamorous promise of life and travel in space. He is an avowed fan of utopian science fiction, such as the *Star Trek* franchise and the Culture, the post-scarcity civilization in the novels of Iain M. Banks. But Bezos also worries that Earth will run out of energy. "We have to go to space to save Earth," Foer quotes him saying.

As soon as I encountered the notion of running out of energy, my curiosity as a physicist was aroused—and not just because energy, being conserved, doesn't run out. I am perhaps less pessimistic than Bezos is about humans' ability to invent new ways to make energy. That said, I realized that I had yet to encounter an estimate of how quickly new fossil fuels are being made. All the estimates I remembered seeing had addressed a different question: How long would Earth's existing supply of the fuels last.

It proved surprisingly difficult to find estimates of the fossil-fuel replacement rate. The best and most plausible I came across was a 2003 study[2] by ecologist Jeffrey Dukes, who is now at Purdue University. Oil starts off as the decomposing bodies of aquatic algae. Pressure, heat, and time convert it to natural gas and crude oil. Dukes recognized that each step adds inefficiency—to the point, he calculated, that a US gallon of gasoline originates from 90 tons of ancient organic matter. Earth's vast reserves of oil and gas correspond to an even vaster amount of plant material squashed and cooked for eons.

By 1888, Dukes estimated, humanity's rate of consumption of plants in the form of fossil fuels exceeded the rate at which new plants were produced. Given how inefficiently plants are converted to fossil fuel, our rate of using fossil fuels likely exceeded their production rate soon after we started using them.

References

1. G. K. O'Neill, *Phys. Rev.* **102**, 1418 (1956).
2. J. S. Dukes, *Clim. Change* **61**, 31 (2003).

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