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It Came From Outer Space!

I write these words on Earth Day, April 22, 2021. Today, many words will be spoken and written, raising legitimate alarms of the risk we face with increasing temperature caused

by greenhouse gases. Among others, former Vice President Al Gore raised this as a primary concern in his books, *Earth in the Balance* and *An Inconvenient Truth*. Bill Gates has just published his perspective in his new book, *How to Avoid a Climate Disaster*. That we are seeing significant climate change seems to me incontrovertible. The correlation of so many thermal observations with increased greenhouse gas in the atmosphere and with the historical record of temperature strongly implicate carbon dioxide and methane as primary causes.

Efforts to move away from reliance on greenhouse gas production for electrical power, heating, cooking, transportation, manufacturing, and a host of other activities of modern society strike me as inescapably important. The sluggish response to this threat is partly a consequence of its long-term character. The most serious problems still lie in the future even though we can document early evidence of their presence including shrinking polar ice and glaciers, rising average and peak temperatures, increasing desertification, acidification of the oceans, and increase in absolute ppm of carbon dioxide.

But there is another, less predictable but potentially equally devastating threat to our modern dependence on electricity. It goes by the name of *coronal mass ejection (CME)* and occurs sporadically as the sun burns its hydrogen into helium and heavier elements. A CME consists mostly of masses of ionized protons in a plasma that are ejected at high speed from the sun's

corona and propagated outward by the solar wind. These ionized ejections create power magnetic fields, which themselves can induce large currents in electrical conductors. One of the best documented CMEs occurred on Sept. 1, 1859 and is known as the Carrington Event after the English astronomer, R.C. Carrington who, along with R. Hodgson, observed and reported the event. Telegraph equipment and wires were overheated and damaged over a wide area. Not all CMEs threaten the Earth; they must intercept Earth in its orbit to do damage.

There have been subsequent events in 1921 and 1989, but of lower intensity and causing less damage than the 1859 event. We are, however, far more deeply dependent on electricity and its transport than ever in human history. In the parts of the planet that are most heavily electrified, we find increased dependence on electrical equipment, especially including computing and

communications. Along with an enormous number of devices dependent on electricity, our communication systems, including satellites, ground radio transceivers, and optical fiber systems are at risk. Subsea optical fibers are especially vulnerable. The CME does not affect the optical fiber but could severely damage the electrically powered repeaters needed to reinforce optical signals for long haul cables.

Because the ionized particles travel more slowly than photons, there could be on the order of 13 hours or more warning from a major flare and CME but the key question is what should have been considered well ahead of the warning to protect electrical and electronic equipment from damage as well as the electrical power grid itself. The concept of a microgrid that supplies power to smaller communities or even portions of large cities and can be disarticulated at need might be one place to start. The resilience of the Internet with alternative paths, including satellite and undersea and land cable as well as high speed laser links, might play a critical part of overcoming the side effects of a major CME event.

It seems to me that now would be a good time to work through the many potential hazards of a CME and to draw conclusions for grid and net design for connectivity and resilience in the face of certain failures for power and for Internet continuity.

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