The Borg Hypothesis

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What if intelligent computing were centered inside humans? This essay's title is inspired by the nemesis of Jean-Luc Picard, captain of the starship Enterprise in the television series *Star Trek: The Next Generation*. The Borg are—or should we say "is"—a species consisting of organic beings symbiotically merged with technology. Each individual Borg is laden with all manner of appliances, ranging from laser eyeballs to appendages resembling drill presses to computational and communication devices implanted in their nervous systems. The Borg is a collective, meaning that they—or it—possess a single mind. That Borg mind has the single intent of "assimilating" all organic species into the collective. Assimilation involves first injecting nanoprobes that thoroughly transform the organic being down to the molecular level, then grafting on the various appliances (or else growing them de novo like so many cloned carrots in a hydroponic garden). Wending their way through the galaxy in huge Rubik Cube-like vehicles, the Borg assimilate entire planets at a time and carve up starships as if they were roast beef, making them (it) an especially nasty adversary.

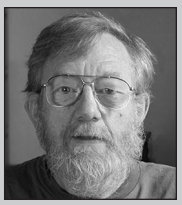
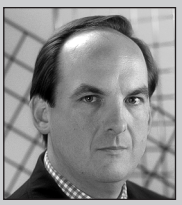
In our real world, we already routinely replace hip joints with titanium and inner-ear structures with microcircuits; we can carry telephones comfortably on our heads, and Web-enabled eyeglasses can augment our view of reality. To counter the effects of drowsiness or inattention, DaimlerChrysler is developing prototypes that continuously monitor drivers' physical and mental states, while DARPA's Augmented Cognition Program is planning an even more ambitious reach to "plug in" the warfighter of the future (www.darpa.mil/ipto/programs/augcog/index.htm).

Portending an even braver and newer world, it's now possible to insert wires into a person's nerves to control appliances. We can even send such signals over the Internet, where they are decoded by computer and then fed into another person's nervous system.[1] Human bodies are getting more and more plugged in.

It's not easy to set aside questions of ethics and choice. It is not even possible. However, in this essay we simply overlook them in order to work toward our hypothesis. To do that, we must take you on a trip into space. Our argument is that if humanity decides to continue human exploration of space, we will sooner or later—probably sooner—be forced to center some intelligent computing inside humans.

Men into space

In 1959 and 1960, Ziv Television Productions and producer Lewis J. Rachmil produced a television series titled Men into Space. This series featured the space concepts of artist Chelsey Bonestell, whose works had a major impact on many writers, including Arthur Clarke, and motion pictures, such as Destination Moon and The Conquest of Space. For his TV series, Rachmil also relied heavily on advice from the US Air Force and the Surgeon General. Men into Space was intended to present the most realistic depiction of what it would be like to establish a space station or moon base and then begin the process of exploring the planets. Episodes included one in which a fold on an astronaut's space suit accidentally became crimped between two large pieces of a space station as he was assembling them in space. The problem: Is there a hole in the suit? If so, freeing the suit could kill the astronaut. In another episode, the crew was stranded at the bottom of a crater on the moon after a crash landing. The problem: Radio waves only move in straight lines, and there is no ionosphere to reflect them to receivers that are out of line-of-sight.

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In one especially pertinent episode, an astronaut on a space walk at the space station becomes stressed out during a repair and botches a wiring job. As a result, a stabilizer rocket on the space station misfires, speeding up the rotation of the space wheel to the point where the crush of gravity makes movement, let alone repair, seemingly impossible. What makes this episode interesting is the explicit focus coming from ideas in human factors engineering circa 1960. The technology on the space station includes a polygraph-like device that constantly monitors the astronauts' stress levels. As the wheel spins faster, readings indicate that the station commander is stressed to the max. But our hero rises to the challenge and manually controls the wheel's stabilizing rockets. This study in human endurance begins with the following voice-over:

> The age of the conquest of space will be an age of men and machines probing far beyond our Earth. And just as some machines will probe deeply into space, others will probe the men who will travel in space. Yet, put to the ultimate test, no amount of machinery will be ever able to determine the measure of a man's inner strength.

As prescient as it was, the concepts presented in Men into Space now seem rather naïve because we have seen what real space flight, space walks, a space station, and a moon landing are like. However, all the accomplishments—and setbacks—of the last several decades represent just our first few tentative steps into space. We already know that traveling to the planets will be a very different affair in many ways than traveling to Earth's moon. Because our experience with long-duration space travel is so limited, our current ideas are almost certain to end up being as naïve as those of Rachmil's courageous space pioneers.

What will it really take?

Long-duration space travel is rather hostile to both our bodies and our machines. NASA still struggles to make systems that provide a lung-friendly atmosphere and stomach-friendly water (not to mention a human-centered interface for control and maintenance) and that will work for years with minimal maintenance. So far, we're working hard to do that right here on the good old Earth.[2] Because keeping an astronaut alive in space is so expensive and risky, we struggle to leverage the capacity of each member of the small crew through devices such as the Personal Satellite Assistant, an intelligent flying appliance.[3] And some of you may recall occasional glimpses of Shuttle astronauts using laptops to assist them in various ways. As a perspective on the challenge of getting the most advanced technology hardened for space, consider that an initial design for the International Space Station specified that the computer monitors would all be black-and-white.

On the biology side, we have a fairly clear idea about the effects of ambient radiation, and it isn't good. Radiation shielding means mass. Lots of it. That means the ship must be much heavier than we'd prefer. We also have some clear ideas about the effects of zero gravity, and they aren't good either. Irretrievable bone loss and muscle deterioration are two of the most obvious effects. A long-duration space mission will almost certainly have a gravity wheel habitat in which astronauts can get some respite from zero-g. But then, we have absolutely no clue about the effects on humans of frequent, repeated forays into and out of zero-g as astronauts go from the habitat wheel into the rest of the ship to perform various duties.

Long-duration space missions will not be possible unless and until human biological evolution has been forced.

We know all about gluing metal contacts onto bodies and measuring physiological indicators such as heart rate. We know a little about putting appliances, machines, and electronics inside bodies. Is it really that much of a step to imagine putting intelligent machines inside humans? But our "Borg Hypothesis" goes boldly beyond even this: Long-duration space missions will not be possible unless and until human biological evolution has been forced. What we are reaching for here is a new meaning of evolution. Geobiological evolution on Earth has yielded creatures (humans) that can reengineer their own physiognomy (for example, artificial limbs), their own anatomy (for example, cochlear implants), and even their molecular biology (for example, gene therapy). Through human-machine symbiosis, we are on an evolutionary threshold where our species is capable not only of deliberately affecting its own evolution but also of changing the rules by which evolution occurs.

Fundamental mechanisms of the evolution of new species include variation and "selection," meaning lots of death. Perhaps our technological advances have set the stage for a new form of evolution, one that does not require lots of death or even genetic change but might nonetheless entail speciation, if only because someone who has been "Borged" might not be able to procreate with someone who has not been "Borged." Once in space, might the transformed humans be stuck there? This brings to mind another idea from science fiction, that the best people to live and work in zero-g are those who have lost their legs (less work for the heart.)

By the traditional criterion in biology, such Borged humans would not be a different species. Biologists may have to change their criterion because survival and procreation will not necessarily be restricted to success in the reproduction of the biology alone. Borged humans might think that their offspring need more than this to be fully "human"—perhaps they would require being "born of woman and then properly engineered."

For long-duration space missions, we must approach Borgification from two directions:

- Machines, as we know them today, must become more biological in certain respects. They must possess functionalities such as self-repair and self-defense, for example. (Scientists at NASA's Jet Propulsion Laboratory are already working on systems that can train themselves to become new circuits.) Not just when the machines are in use, but also as they are created and decommissioned, processes must be more biological—that is, more like growing and recycling than manufacturing and discarding.
- Bodies, as we know them today, must become more machine-like in certain respects. We are already on that path, but taking it further, wouldn't it be nice, for example, to fix our bodies so that radiation and low gravity do less harm? Com-

putational technology also holds great and perhaps more immediate promise, for instance, using artificial intelligence technologies inside us.

For long-duration space missions, we may have to put intelligent technologies inside of us. Brave new worlds are usually described in a context implying choice, choice of paths that might lead either to utopias or to hells. Perhaps humanity made its choice already, eons ago when creatures first began wondering at the stars. ❐

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The authors dedicate this essay to the astronauts of the Space Shuttle Columbia: Rick Husband, Kalpana Chawla, William McCool, David Brown, Laurel Clark, Michael Anderson, and Ilan Ramon.

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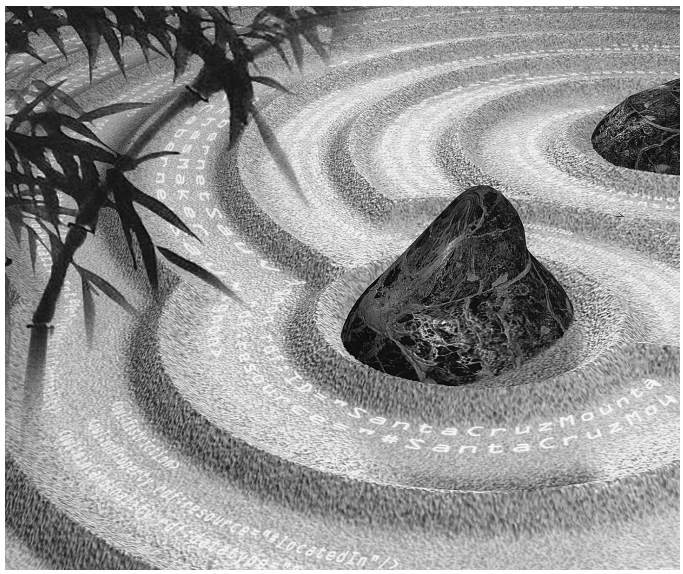

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