ARTHUR C. CLARKE'S JULY 20, 2019

A DAY IN THE LIFE OF THE 21ST CENTURY

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E R

The best book ever written about the future opens with these words:

> *There are two futures, the future of desire and the future of fate, and man's reason has never learnt to separate them.*
>
> —J. D. Bernal, *The World, the Flesh and the Devil*, 1929

A strict logician, of course, would say that the first four words are nonsense. There's not even *one* future, let alone two, because the future, by definition, does not yet exist.

Nevertheless, we all know what Bernal meant. There *does* "exist," somewhere in every thinking person's mind, a vague image of the future that he or she would like to happen. It is seldom indeed that the real future—the "future of fate"—coincides with human aspirations. Indeed, with billions of conflicting desires and hopes, how could it? Not even an omnipotent God could create such an impossibility. As I write these words, the Iranians and the Iraqis are each praying to Allah for victory, doubtless with equal devotion. . . .

Yet even if it doesn't exist, it is important to think about the future; as has been so often pointed out, we'll spend the rest of our lives there. Some aspects of the future are easier to deal with than others; let me quote from the *second*-best book on the subject:

> *All attempts to predict the future in any detail appear ludicrous within a few years . . . with a few exceptions, I am limiting myself here to a single aspect of the future—its technology, not the society that will be based upon it. This is not such a limitation as it may seem, for science will dominate the future even more than it dominates the present. Moreover, it is only in this field that prediction is at all possible; there are some general laws governing scientific extrapolation, as there are not (*pace *Marx) in the case of politics or economics.*
>
> —Profiles of the Future, 1962

In a comment carefully designed to cause equal displeasure in Washington and Moscow, I went on to say, "Politics and economics are concerned with power and wealth, neither of which should be the

primary, still less the exclusive, concern of full-grown men." And to my displeasure, I've just noticed that the cover of the revised 1984 edition refers to *Profiles* as "prophetic," which is just what it isn't. As the subtitle carefully explained, it's "An Inquiry into the Limits of the Possible." And that's all that any book on the future—including this one—can ever hope to be.

Still, such inquiries can be extremely useful, whether they take the form of science fiction or think-tank computer studies. Although SF requires no justification (as long as it's well written), it does have great social value as an early warning system—something none of us who have survived the year 1984 is likely to forget. It is often difficult to distinguish between "futures scenarios" produced by such organizations as the late Herman Kahn's Hudson Institute and synopses of science-fiction novels—quite a few of which, I hope, will be generated by this volume.

Round about 1970, I suggested a motto for that noble body, the Science Fiction Writers of America: "The Future isn't what it used to be." (I still don't know whether I made this up, or stole it from somewhere—probably the latter.) Certainly I am always changing *my* future, and have done so again while writing this preface.

I'll be only 102 in 2019, which by then will be no unusual age. My great-grandfather Arthur Heal barely missed the century mark, dying in the year I was born and passing on his name to me. Even more to the point, he was still riding horseback when he was as old as I'll be—not in 2001, but *2010*. We farm boys have good genes.

So who knows: The following "Letter from Clavius" may be a self-fulfilling prophecy. Stay tuned.

And if this book is successful enough to demand a sequel (another "future of desire"), may I suggest to my editors a title that Alvin Toffler kindly gave me many years ago: *After the Future—What?*

LETTER FROM CLAVIUS

Clavius City, 20 July 2019

It doesn't *seem* like fifty years—but I cannot be sure which memories are false, and which are real.

Present and past are inextricably entangled. The monitor screen has just shown the ceremony at Tranquillity Base, culminating with the *third* hoisting of the American flag. It was blown down, of course, by the blast of *Eagle*'s ascent stage, and lay there on the trampled Moon soil for thirty-six years until the Apollo Historical Committee reerected it. Then the big quake of 2009 knocked it down again; this time, we're assured, it would take a direct hit by a fair-sized meteor to lower it. . . .

Now, immediately after the live transmission from Tranquillity, they've put on a grainy old tape—yes, *tape*, not vidule!—from exactly half a century ago. And there I am back in the CBS Studio on West 57th Street with dear old Walter Cronkite and wise-cracking Wally Schirra, watching Neil Armstrong take that first step off the ladder. . . .

For the hundredth time, I strain my ears. Neil Armstrong once told me (and by then he must have been heartily fed up with the whole subject), "What I *intended* to say was: 'That's one small step for a man, one giant leap for mankind.' And that's what I *thought* I said."

Sorry, Neil—you fluffed! The "a" got short-circuited between brain and tongue. But it doesn't matter; this time, at least, history has been correctly reedited.

Did I ever imagine, back in 1969, that I would reach the Moon myself? I very much doubt it; yet I'd anticipated the circumstances more than twenty years earlier. If I may be allowed the modest cough of the minor prophet—

(AUTOSEC MARK III: THAT PHRASE ALREADY USED IN LAST THREE DOCUMENT FILES.
Shut up, Hal, or I'll reprogram you.)

—as I was saying before I was rudely interrupted, I'd already thought of a very good reason why I might be on the Moon for my hundredth birthday.

In the summer of '47, writing in exercise books "liberated" during my Royal Air Force days from a bombed-out school in the East End

of London, I concluded my first full-length novel, *Prelude to Space*, with these words:

> The great medical discoveries made at the lunar base had come just in time to save him. Under a sixth of a gravity, where a man weighed less than thirty pounds, a heart which would have failed on Earth could still beat strongly for years. There was even a possibility—almost terrifying in its social implications—that the span of human life might be greater on the Moon than upon the Earth.
>
> Far sooner than anyone had dared to hope, astronautics had paid its greatest and most unexpected dividend. Here within the curve of the Apennines, in the first of all cities ever to be built outside the Earth, five thousand exiles were living useful and happy lives, safe from the deadly gravity of their own world. . . .

Had I thought of it, I could have added another reason. Some thirty years after those words were written, Earth's "deadly gravity" killed my own mother. A very common cause of death among old people is complications following the breaking of bones after a fall. Such an accident is virtually impossible here on the Moon.

"Five thousand" was, I am afraid, a wildly optimistic figure: The present population at Clavius is only one thousand, and that includes administrative and technical staff. But in 1947, very few people would have bet on more than zero.

And if I may switch to my "minor prophet" mode again, I'd like to refer to "Out of the Cradle, Endlessly Orbiting . . . ," written in June 1958 (the summer of the first satellites). It began: "Before we start, I'd like to point out something that a good many people seem to have overlooked. The twenty-first century does *not* begin tomorrow; it begins a year later, on January 1, 2001. . . . Every hundred years we astronomers have to explain this all over again, but it makes no difference. The celebrations start just as soon as the two zeros go up. . . ."

That could be my first mention of 2001—ten years before "Also Sprach Zarathustra" blasted from a thousand speaker systems. (Hello, Stanley—were you involved in putting up that big 1 by 4 by 9 black slab in Tycho on my hundredth birthday? I'm delighted to hear that you're finally shooting *Napoleon*. But what's this rumor about a happy ending, with the French winning at Waterloo?)

(IRRELEVANT TO SUBJECT.
Phooey. INTERRUPT OVERRIDE. *That'll* fix you!)

Where was I? Oh, yes—"Out of the Cradle . . ." It takes place during a very tense moment on the Moon—the first test of the thermonuclear engine for the Mars expedition. Then, to the great annoyance of the narrator—the Russian in charge of operations—everything suddenly stops. The secret has been very well kept: He had no idea. . . .

> There was a click as the circuit was rerouted, followed by a pause full of indeterminate shufflings and whisperings. And then, all over the Moon and half the Earth, came the noise I promised to tell you about—the most awe-inspiring sound I've ever heard in my life.
>
> It was the thin cry of a newborn baby—the first child in all the history of mankind to be brought forth on another world than Earth. We looked at each other in the suddenly silenced blockhouse, and then at the ships we were building out there on the blazing lunar plain. They had seemed so important a few minutes ago. They still were—but not as important as what had happened over there in Medical Centre, and would happen again billions of times on countless worlds down all the ages to come.
>
> For that was the moment, gentlemen, when I knew that Man had *really* conquered space.

Well, that was fiction, back in 1958; now it's fact—though it took a little longer to happen than I had imagined. This is always a problem with technological extrapolation: short-range forecasts tend to be too optimistic, long-range ones usually underestimate. Who could have dreamed how many cars or telephones there would be in the world, a mere fifty years after they were invented?

Certainly none of us early Space Cadets imagined that, after the United States's six landings on the Moon, it would be more than a generation before men returned there. Yet with the twenty-twenty foresight that history gives, that now seems inevitable; we should have learned a lesson from the two closest parallels in the past.

The South Pole was first reached in 1911 by the most primitive of means—skis and sleds. Then it was abandoned; not until almost half a century later it was *inhabited.* When men returned to the Pole, they used aircraft, radio, tractors, nuclear energy. And they settled there in comfort; there was even a sauna at the American base. My old friend Wernher von Braun once told me he'd rolled naked in the snow at the South Pole, which would certainly have astonished Scott and Amundsen. . . .

The other historic parallel is much less famous, but in some ways it's even more instructive.

In 1930, Dr. William Beebe and Otis Barton made the first descent into the ocean abyss. Enclosed in a tiny steel sphere suspended from a cable, a "bathysphere," they eventually reached a depth of almost a kilometer. Beebe was acutely aware of the similarity to space exploration. In his 1935 book *Half Mile Down*—my copy was too battered (and too heavy) to bring with me, alas—he wrote: "Until I am actually enclosed within some futuristic rocket and start on a voyage into interstellar space, I shall never experience such a feeling of complete isolation from the surface of the planet Earth as when I dangled in a hollow pea on a swaying cobweb a quarter of a mile below the deck of a ship rolling in mid-ocean."

But the bathysphere was a dead end—a pioneering experiment never to be repeated. A quarter of a century later, the Piccards developed the free-diving bathyscaphe, which by 1960 had reached the maximum ocean depth of almost eleven kilometers in the Marianas Trench.

Superb technological achievement though it was, the Saturn V rocket that took the first men to the Moon was also a technological dead end; someone once compared it to an ocean liner that carried three passengers and sank at the end of its maiden voyage. Before space travel became practical, it had to be superseded by the fully reusable shuttles and interorbit ferries that we have today.

And their development required more resources in money and engineering skills than any single nation—even the United States—could possibly muster. More than these, it demanded political will, and a degree of international cooperation that we now take for granted but which, back in the dangerous decade of the eighties, often seemed impossible of achievement.

Looking back now, I think I can pinpoint the exact day when the tide began to turn—though it still took many years for the era of sterile confrontation to end. The date was October 30, 1984, when President Reagan signed Senate Joint Resolution 236, "Relating to cooperative East–West ventures in space." I still have the copy that the resolution's sponsor, Senator Spark Matsunaga, presented to me in Hawaii a few weeks later.

It opens with the words:

> Whereas the United States and the Soviet Union could soon find themselves in an arms race in space, which is in the interest of no one. . . .

and ends with:

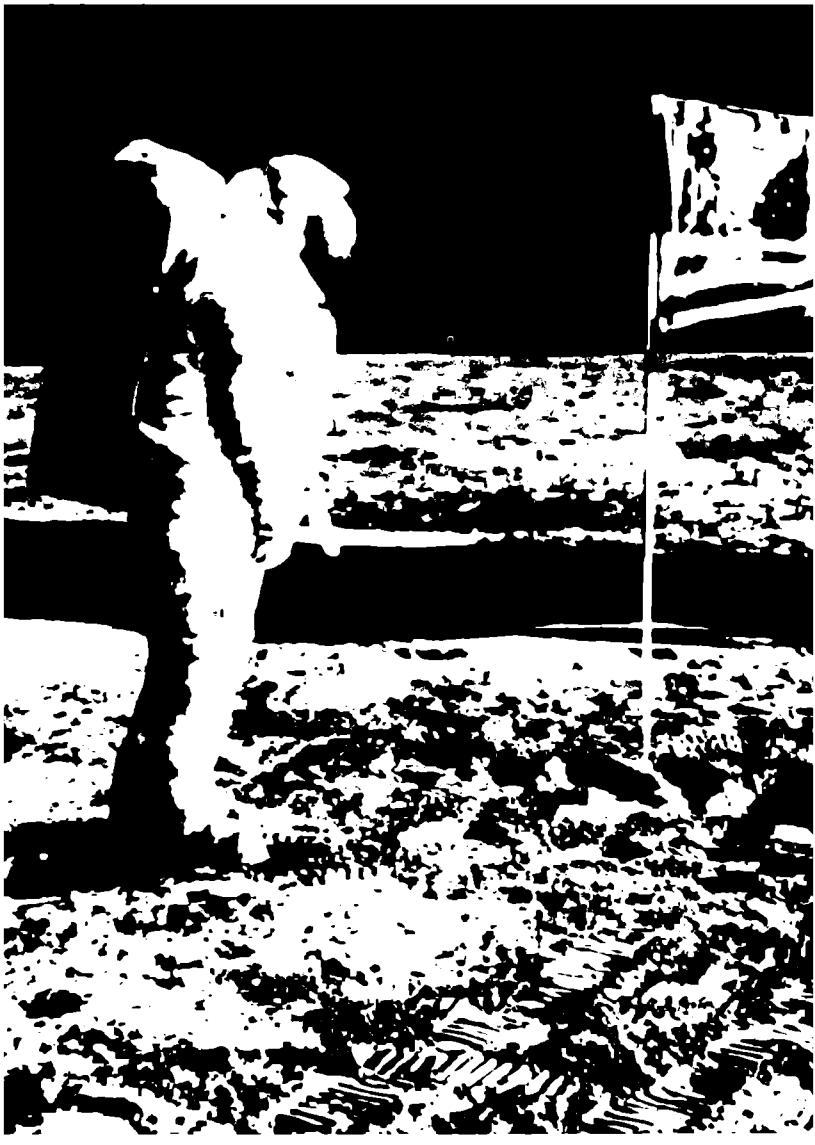
> *Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the President should—
> (1) endeavor, at the earliest practical date, to renew the 1972–1977 agreement between the United States and the Soviet Union on space cooperation for peaceful purposes;
> (2) continue energetically to gain Soviet agreement to the recent United States proposal for a joint simulated space rescue mission; and
> (3) seek to initiate talks with the Government of the Soviet Union, and with other governments interested in space activities, to explore further opportunities for cooperative East–West ventures in space including cooperative ventures in such areas as space medicine and space biology, planetary science, manned and unmanned space exploration.

Those were noble aspirations, and I am happy that, despite many disappointments and setbacks, the president lived to see them fulfilled. . . .

I'm afraid I'll have to finish this later—the monitor's just switched to Neil and Buzz and I want to hear what they've got to say.

At eighty-eight and eighty-nine, respectively, they both look in pretty good shape.

Considering they stayed on Earth.



THE PATH TO 2019
An excerpt from the inaugural speech delivered by the President of the United States in January 1993

America's space movement has been touched by tragedy on numerous occasions over the last three decades. In January of 1967, a tragic pad fire at Cape Kennedy not only took the lives of three of NASA's finest astronauts, but also jeopardized the very future of this nation's space program, halting Apollo spaceflights for a period of over twenty-one months. Then, in 1986, again in the month of January, the shuttle ship *Challenger* exploded seventy-three seconds into its voyage, killing seven brave American explorers, including a high school teacher who had, in vain, prepared her lesson plans for space. Who cannot remember, only seven years ago, this terrifying spectacle—the sickly stream of black smoke, the burst of angry white and orange flames, the hail of debris that fell over the Atlantic Ocean, the funerals for our fallen heroes?

Today, as I speak to you, we are in the midst of another space tragedy of far more terrifying proportions. The astronauts who perished in 1967 and in 1986 at least died in the furtherance of a cause: the exploration of space, the discovery of celestial bodies, the scientific understanding of our universe's origins. The tragedy that afflicts us today is not the stuff of bold newspaper headlines; it produces neither flames that sear the morning sky nor the anguished sighs of relatives that make the news at six. This tragedy's victims are not bodies, but a nation's extinguished spirit. Apathy rarely, in fact, makes news at all. The last two decades, an era stretching from 1973 through 1993, has produced no tangible progress in space exploration. This record constitutes a tragedy of the greatest national proportions.

I'm deeply saddened by many of our senators and representatives in Congress who question the need for a manned space station, even with the knowledge that the Soviet Union has been expanding its *Mir* space station ever since it was placed in orbit just days after our *Challenger* astronauts died. It's imperative—for medicine, for industry, and for reasons of national pride—that America send its own perma-

nently manned space station into orbit before the end of this century—an event that I hope to witness while still in office. I'm also quite appalled at people saying that America cannot land on Mars before 2035. That's absurd. In 1969, the greatest scientific minds of our age predicted that by the end of the Vietnam War, we would have sent a manned mission to Mars—by 1985 at the latest. That mission would have provided an appropriate new focus for American industry and technology. Today, in 1993, we have sadly to revise this schedule. I'm confident that if we renew our efforts to probe the Martian soil, we'll be able to do it by 2010.

And finally, I'm saddened that we have no current plans to return to the moon. Can it really be that astronaut Gene Cernan was the last American to walk on the Moon? "We leave the Moon as we came," he said, "and God willing, we shall return, with peace and hope for all mankind." An entire generation of Americans has been born since the explorer from Apollo 17 uttered those words twenty-one years ago, and *man* is still not willing.

Distinguished Cornell astronomer Thomas Gold described our space malaise more succinctly. "Apollo," he said, "was buying a Rolls-Royce, but leaving it in the garage because you can't afford the gas." The term I begin today will be dedicated to finding the fuel that is needed to establish a permanent lunar base, a fuel that comes as much from the collective mind and will of the American people as it does from the national budget. It will be a term consumed by a national mission to refocus America's sights on space. In undertaking this brave agenda we will bring to an end the era of space apathy that has laid waste to so much native promise and ambition. And if we are indeed successful in our plans, we will not only have sent a space station into orbit and a manned probe to Mars, but also returned to the Moon with a permanent lunar base and settlers, on or before July 20, 2019, the fiftieth anniversary of our first Apollo Moon landing."

LOOKING BACKWARD
A historian of 2019 interprets the first Moon landing.

In the distant summer of 1969, the first Apollo Moon landing seemed to validate the American character at a time when national esteem was on the wane. The Moon walks of NASA astronauts Neil Armstrong and Buzz Aldrin could be celebrated as something quintessentially American, a triumph that brought the spirit of the westward migration out of a previous century and into the age of space. The Apollo 11 Moon mission stirred as much national pride as the Bicentennial celebration that would come seven years later; it generated as much fanfare as the dawn of the new century in the year 2001. But the Apollo triumph was not appreciated only by Americans; it was celebrated by millions of people throughout the world, who had shared the dreams of such space prophets as Galileo, Jules Verne, and H. G. Wells of sending men to the Moon. On that momentous Sunday, July 20, 1969, the Moon landing seemed to alter the course of human history far more profoundly than any international hostilities ever could, for it spoke of change, of peace, and of a future that seemed almost limitless in its grand design.

Despite the ambitious visions that the Apollo mission inspired, the successful landing came at a time, ironically, when interest in space in the halls of Congress was on the decline. The Apollo program represented the last triumph of the American space movement for a period of close to three decades.

President John F. Kennedy's declaration that the United States would land on the Moon "before this [the 1960s] decade is out" was a prophecy that came true with but five months to spare. But was there a future beyond these trips to the Moon? How would NASA survive once Apollo was done and gone? Throughout the mid-1960s, the Apollo missions had all along benefited from the ultimate romantic allure of a Moon landing. Any effort to thwart the path of NASA would have been considered almost unpatriotic, the repudiation of a fallen saint who had prophesied a Moon voyage two years before his fall in Dallas.

Yet there were those who anticipated a Dark Age for space exploration in the thirty-year period following the triumph of Apollo. A few experts, even in 1969, pondered whether the enthusiasm could be

sustained to facilitate a similar landing on Mars or even a permanent lunar base. Wernher von Braun, the renowned twentieth-century pioneer of space rocketry, questioned how long federal funding would survive in a post-Apollo age. The United States had poured over $36 billion (in 2019 dollars, $720 billion!) into the exploration of space since the beginning of its race with the Soviets; von Braun predicted in July 1969 that without the national goal of another space conquest and without a continued Soviet space threat, the cajolery of NASA administrators would no longer sway the policy-makers of Washington. The space movement, without a large budget, would, like Carnaby Street boutiques and Lyndon Johnson's Great Society, become a victim of its time, a fleeting triumph of the culture of the 1960s.

Yet the crowds that came out to watch the blast-off at 9:32 A.M. on July 16 reflected the frenzy of the moment. Close to a million people, in addition to three thousand reporters, lined the highways leading to Cape Kennedy, forming a procession that snaked for miles. Observers likened the scene to a religious pilgrimage from the Crusades. So intense was America's interest in the Apollo mission that the discovery of a twenty-eight-year-old secretary's body trapped underwater in an Oldsmobile (a car model still popular in the 1960s) driven by a senator bearing the name Kennedy hardly made the front page.

Five days after blast-off, *The New York Times*, then still printed on paper, devoted its entire front page to the Moon landing, recording the more mundane events of July 20, 1969 on an inside page. It was, by all appearances, a normal summer Sunday. Melvin and Myra Goldberg, the *Times* reported in its slice-of-life profile of the nation, drove from suburban Scarsdale to visit their children in summer camp in New York's Adirondack Mountains. In New Orleans, Miss Ella Allen celebrated the Apollo landing by hurling herself from the ferry landing at Jackson Avenue into the waters of the Mississippi River. "Dear Lord, here I come," she cried just before two policemen halted her journey to her maker.

Yet it is difficult to claim that life on that languid Sunday continued at a normal pace. The Moon landing produced a nationalistic passion in Americans not seen since the end of World War II, and it inspired pride and keen interest from countries throughout the world. The Apollo 11 success came in the midst of the Vietnam War—perhaps the most controversial and internally divisive war in American history—and seemed to validate the American character as much as the war's

napalm bombings had sullied it. Like the nineteenth-century exploration of the American West, the Moon landing fulfilled the notion of Manifest Destiny, for the Earth, in 1969, had been fully charted, and space represented the last frontier. The Apollo 11 mission, then, was a twentieth-century revival of the frontier drama of a forgotten age, with astronauts Armstrong, Aldrin, and Collins heirs to the grand legacy of Christopher Columbus, Lewis and Clark, and Charles Lindbergh.

In contrast to the Spanish, French, and English who had settled in the New World, the heroes of 1969 seemed hardly motivated by self-interest or colonial greed. A 1967 treaty, signed by nearly a hundred countries, protected the international sovereignty of the Moon, and a belief grew that space would remain free of the colonial, Cold War passions that had divided the planet. Konstantin Tsiolkovsky, the Russian space theorist, had, in fact, believed as early as the late nineteenth century that space would be free of the petty rivalries that afflicted the Earth. The 1969 Apollo venture represented the zenith of such idealism. Scientific pursuit in space, it was then believed, would transcend the pettiness and strife on Earth, and would ultimately deliver man onto a new level of human consciousness. The Moon landing ushered in a fleeting era of idealism that attempted to resurrect a patriarchal image of the United States that had been tarnished in the twenty-four years since the end of World War II.

This excitement reverberated not only through the corridors of NASA, but also through the entire nation. A revolution was in progress on many levels. The United States, in 1969, was undergoing profound social and cultural changes.

As the Apollo 11 mission culminated the American space revolution, the Woodstock concert of 1969 idealized the spirit of the so-called sixties youth movement. Woodstock was a nonstop, three-day affair that featured the top rock musicians of its day and attracted over 300,000 enthusiastic young spectators to a dairy farm in upstate New York. Buried under the dozens of Moon landing stories that ran in *The New York Times* on July 20, 1969, was an understated advertisement for the Woodstock Music & Art Fair, an "Aquarian Exposition" promising "three days of peace and music." Most of the newspaper's Sunday readers, spellbound by the breaking news from the Moon, concentrated on the heroics of Armstrong and Aldrin, only glancing at the Woodstock announcement that included such names as Joan Baez, Arlo Guthrie, Janis Joplin, and the Grateful Dead—musicians popular

in our grandparent's generation. Yet the dizzying spectacle of the Woodstock concert, held three weeks later on the meadows of dairy farmer Max Yasgur, mirrored the revolutionary culture of the 1960s as accurately as the Moon landing reflected the goals of the American space movement.

Many senior citizens, especially those now over seventy, can recall the social import of the legendary festival. It's difficult to imagine that our grandmothers wore mini-skirts that revealed the bottom of their buttocks, that our grandfathers' hair once cascaded down their backs, and that their states of consciousness seemed eternally altered by LSD, then an illegal recreation. But to that generation the concert was the apotheosis of a rebellious spirit that swept the age, and the era—the Woodstock Generation—actually drew its name from the three raucous days of music and revelry that punctuated the humid summer of 1969. Those youths believed that the white male power structure that had existed in the United States since the founding of the Union was about to crumble, yielding to a communal society that stressed love over war, socialism over materialism, drugs over sobriety, and orgies over abstinence. About the generation's pacifist nature, the Sullivan County sheriff, Louis Ratner, commented after the concert, "I never met a nicer bunch of kids in my life."

This announcement from a festival ad in *The New York Times* of July 20 reveals the mood of the 1960s:

> **Art Show**—Paintings and sculptures on trees, on grass, surrounded by the Hudson Valley, will be displayed. Accomplished artists, "Ghetto" artists, and would-be artists will be glad to discuss their work, or the unspoiled splendor of the surroundings, or anything else that might be on your mind.
>
> **Crafts Bazaar**—If you like creative knickknacks and old junk, you'll love roaming around our bazaar. You'll see imaginative leather, ceramic, bead, and silver creations, as well as Zodiac Charts, camp clothes, and worn-out shoes.

Every forty years, as if cyclically programmed, our nation seems to undergo a crisis of values that threatens its most sturdy social foundations. In the 1920s, the proliferation of assembly-line automobiles and the explosive growth of the city threatened the moral fiber of a small-town America that had predominated since colonial days. The flapper

of the Roaring Twenties tore off her corset as defiantly as the hippie of the late sixties burned her bra, as vehemently as the greenie of 2011 rejected her mother's synthetic clothes.

The antitechnological anticomputer revolution—the so-called War for Humanity—that began in this country around 2005, exactly forty years after the first student protests against the Vietnam War, must be viewed in light of the unrest of the 1920s and 1960s. Millions of youths—the greenies—rejected the pervasiveness of computers and robots in their lives, took to the streets to protest the corporate values that they saw as strangling everything virtuous and human. Indeed, the generation that comprises America's grandparents—the hippies—has more in common with its grandchildren—the greenies—than the parents corseted uncomfortably in between.

Reflecting on the vanished summer of 1969, the events of the Apollo Moon landing and the Woodstock concert seem disparate and disconnected, to say the least. The one, man's momentous arrival on the Moon, reflected the crowning accomplishment of the American scientific establishment. Here was a group of men who had used the most sophisticated aerospace and engineering technology to send man away from his home planet. It was a group that had the patina of the military—men dressed in starched white shirts, men with stiff crew cuts, men engaged in brusque, now archaic, dialogue that always ended with "Roger." The other event, the three-day, rain-soaked mud frolic at Woodstock, which culminated in Jimi Hendrix's hard-rock rendition of "The Star-Spangled Banner," projected the antithesis of a Houston Mission Control room. The hippies who frolicked naked in the lily ponds at Woodstock that August preferred Navajo beads to NASA spacesuits, a marijuana "joint" to a cool glass of Tang. To them, the military was a national anathema, responsible for forty thousand deaths in Vietnam, and the Pentagon was the hated symbol of the war they all dreaded.

Yet the two events converged in a way few would recognize even today. In wholly different ways, both events affirmed the peaceful nature of humanity and acted to unify a divided people. Citizens in their seventies or older can remember quite distinctly these two events, even without the aid of the memory-enhancing vasopressin drugs that have become so popular in recent years. Along with the Kennedy assassination of 1963, the July Moon landing seems to remain the most vivid memory to people born before the year 1960. Of

course, the Moon landing altered the course of human history far more profoundly than any band performing on Max Yasgur's farm could have hoped to, but both spoke of change, of peace, and of a future that then seemed, after many barren years, finally imbued with a far-reaching vision.

To modernists of the twenty-first century, the spirit of 1969 seems charmingly naive, akin perhaps to Woodrow Wilson's belief that he could "save the world for democracy" or Neville Chamberlain's declaration of "peace in our time." But who can fault our grandparents for having possessed this spirit? Caught up in the excitement of an event that was being compared to Columbus's discovery of the New World, who would have known in 1969 that the Apollo mission would leave man unchanged? Who could have known that the international euphoria would not linger beyond summer's end? And who would have known that space in the decades that followed would become as armed and as colonially fractured as the African continent in the nineteenth century?

The astronauts—Neil Armstrong, Buzz Aldrin, and Mike Collins—lacked such insights on July 20, 1969. They were, quite understandably, excited about landing on the Moon, but theirs seemed solely a scientific mission. The Apollo flight easily could have not come off at all. Following the tragic Apollo 1 fire in January 1967, no missions were attempted for twenty-one months. When the next Apollo mission was launched in 1968, the national view of space had changed substantially. By that time the budget had become a key issue. The astronauts would have to demonstrate tangible scientific results if funding were to continue.

"The emphasis had shifted from the time of Kennedy's term," Buzz Aldrin remembered. "It had shifted from an American putting a flag on the Moon to a *human being* bringing back rocks. Because the public in 1969 wanted more justification for the expenditure, we had to change the reason for going. Nor was our reason to beat the Russians," Aldrin said. "Yes, Kennedy had committed us to a race, but we had uncommitted ourselves, and the new causes were for science and the understanding of Earth's evolution."

The Apollo mission had, in fact, several scientific goals. The astronauts would attempt to measure solar wind and trap atmospheric particles, calculate the distance from the Moon to the Earth by an accuracy of six inches, set up equipment that would search for tremors

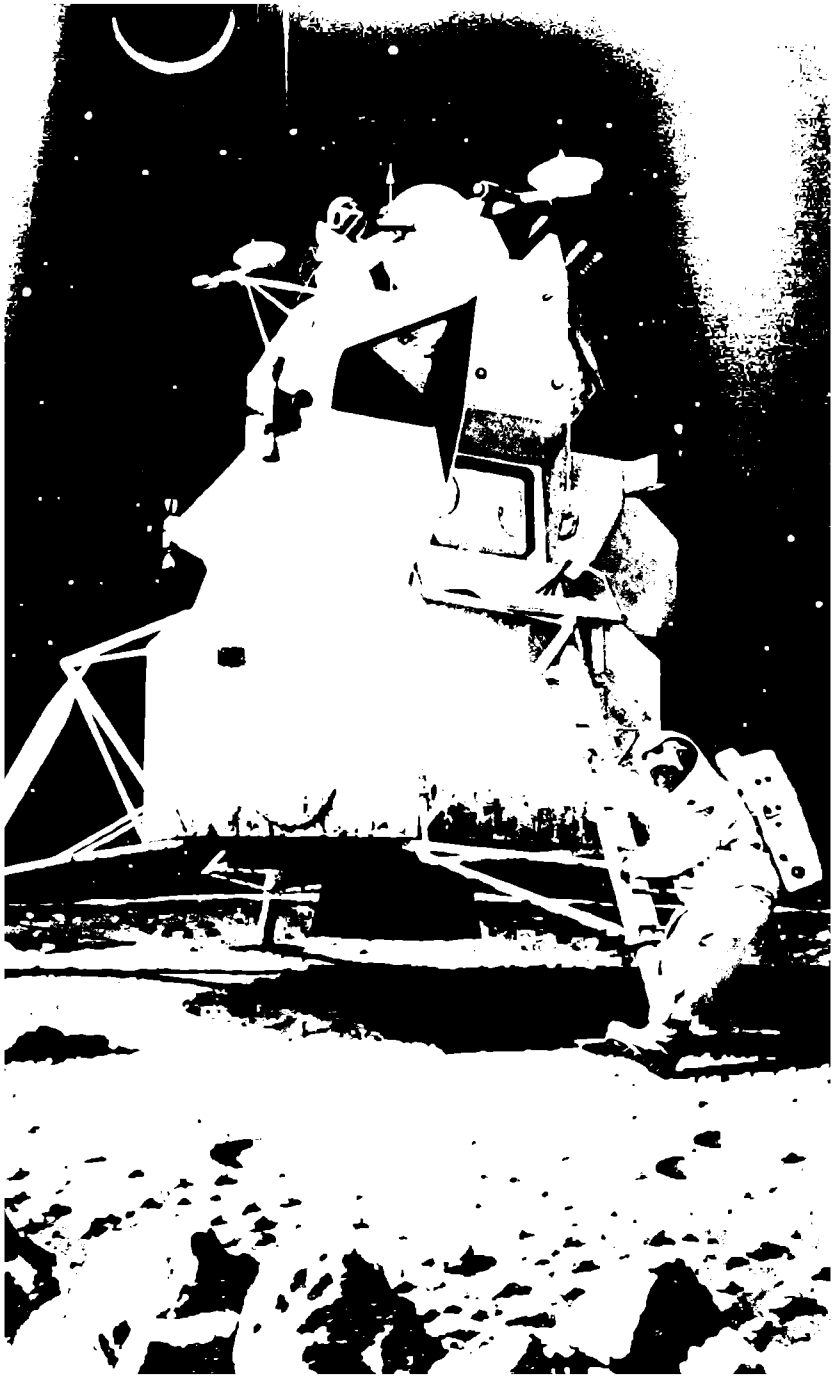
or quakes on the Moon's surface, and bring back about eighty pounds of lunar dust, soil, and rocks for analysis by over a hundred scientists from nine participating nations.

The flight was marked by tension, most of it unanticipated. Unknown either to the astronauts or to their commanders at NASA, an unmanned Soviet craft had been launched on Sunday, July 13, three days before the Apollo blast-off. What was Luna's mission? Was it to observe the Apollo landing? Could the robotic craft rescue American astronauts if they became stranded? The trouble was that the Soviets had on record the trajectory of the Apollo mission, but the Americans had no inkling of the path of the robotic Luna probe. Frank Borman, who had been an astronaut and had top scientific connections in Moscow, called the head of the Soviet Institute of Science in the middle of the night. Even he was unable to get a satisfactory answer. "What damn near happened that is realized by very few people is that a Russian spacecraft crashed onto the Moon in the vicinity of our own landing site. Had Luna 15 been successful in removing rocks from the Moon's surface and returning them to Earth, the story would have been quite a bit different," Aldrin explained years later.

The actual landing occurred on the evening of July 20, and brought tensions of a different sort. The LM, or lunar module—called *Eagle*—carried two days' worth of oxygen and food in its shell, weighed 52,000 pounds, and measured twenty-two feet in length. On the far side of the Moon, Aldrin fired the LM's engines to begin the landing. The lunar craft slowed and dropped about twenty-six nautical miles in its final descent. One hundred feet short of landing, Armstrong and Aldrin spotted a crater the size of a football field, and Armstrong had to steer the craft manually another two hundred to three hundred feet to avoid rocky terrain that was unfit for landing.

Had the craft descended atop a pile of boulders, as appeared imminent, the men's return would have been imperiled. The LM could have easily tipped over. Despite the presence of the robotic Soviet craft, there could be no rescue from the Moon's surface. Thomas Paine, director of NASA in 1969, said, "The landing operation on the Moon was by far the most critical task of the mission," a belief seconded by Buzz Aldrin, who felt that his and Neil Armstrong's lunar walk was an anticlimax to the landing of the lunar module.

At precisely 4:18 P.M., on July 20, the module made physical contact with the Sea of Tranquillity. The American craft scattered lunar dust in

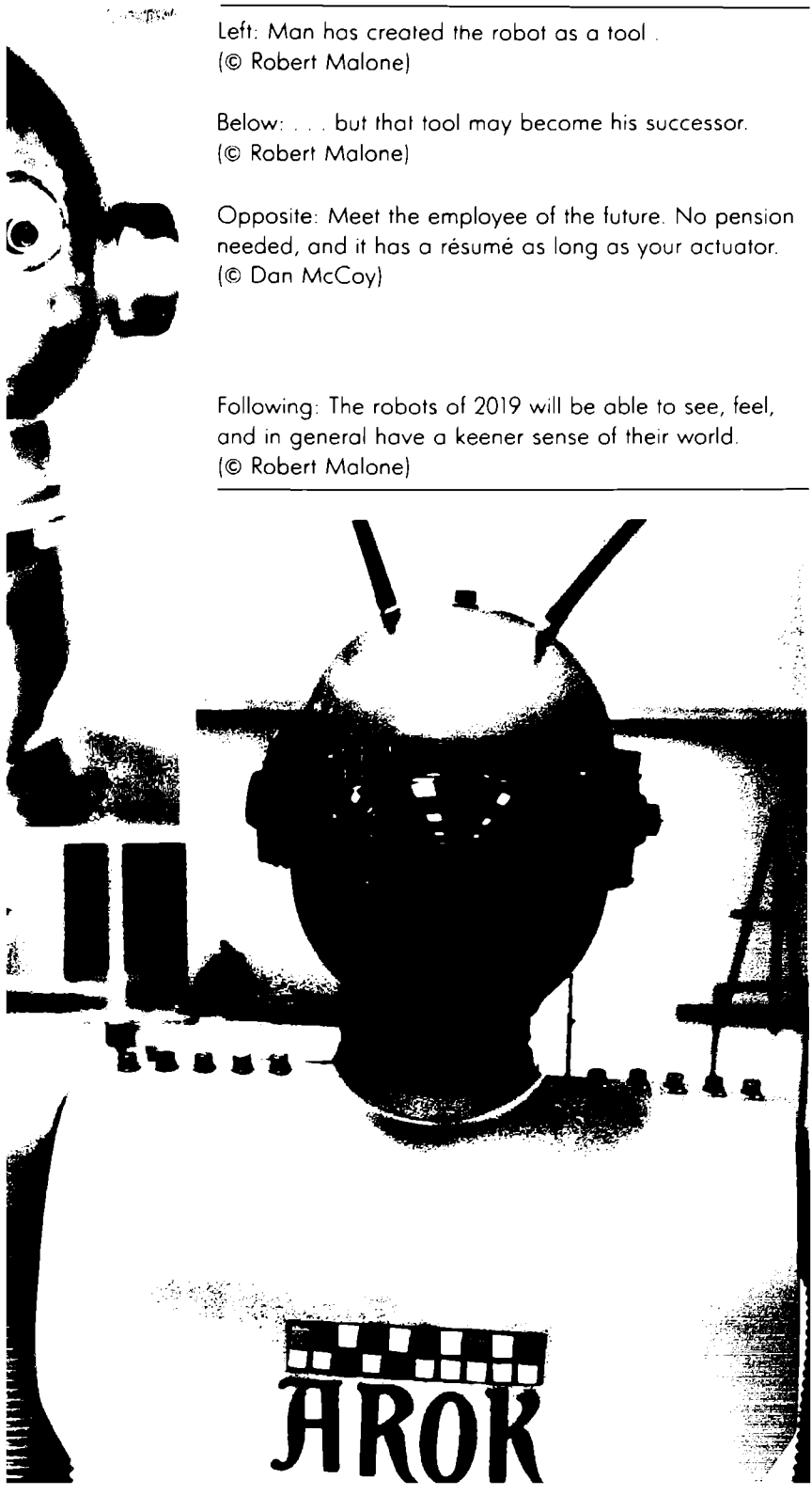


all directions. The soil, the two men would soon discover, was like malleable clay or sand. "Tranquillity Base here. The *Eagle* has landed," reported Commander Armstrong. In the Bronx, New York, the Yankees halted their play and sixteen thousand people sang "The Star-Spangled Banner." In Washington, D.C., President Richard Nixon, four years before his fall from grace, communicated with the astronauts by radiotelephone. Across the world, more television viewers watched the landing and the subsequent walk than any other single event in the history of the planet, before 1969.

The actual walk began at 10:56 P.M. on the evening of July 20. Hundreds of millions of people followed the event with spellbound intensity. Neil Armstrong, a child of the depression, the son of a state auditor from Wapakoneta, Ohio, the commander of the Gemini 8 space-docking flight, took nine steps down an aluminum ladder. Planting his feet solidly on the lunar surface, Armstrong declared, "That's one small step for man; one giant leap for mankind." Armstrong's words, among the most famous and often quoted phrases of America's post-war era, would be repeated by millions of schoolchildren in that time. There have been historical parallels, but it had been almost a complete century since an exploration event so totally stirred the public's imagination. Like Dr. David Livingston and Henry Morton Stanley in the nineteenth century, Armstrong and Aldrin were the heroes of their time. Armstrong seemed a modern-day Christopher Columbus. His *Eagle* was a high-tech reincarnation of the *Santa Maria*, and his crew had not merely opened a virgin continent to a race of Caucasians, but the entire Moon to all of man.

Even today, as we approach the end of this second decade of the twenty-first century, the Moon remains frontier territory, like the continent of Antarctica in the 1980s, the realm of only a few scientists. So many questions have yet to be answered. The Moon's geographic and atmospheric qualities are only now being demystified, so one can imagine the trepidation that Armstrong and Aldrin felt on July 20, 1969. Since the Moon's gravity is only one-sixth that of Earth's, an astronaut who weighed 210 pounds in Houston would weigh only thirty-five pounds in the lunar environment. As Aldrin and Armstrong learned, mobility was very easy, since the body used less oxygen and water. Stopping and turning—motions that involve traction—were far more difficult. Also, the lunar soil, as scientists in more recent voyages can verify, proved far harsher and more inhospitable than NASA had antici-

July 20, 1969: One small step for man . . . (©NASA)



Left: Man has created the robot as a tool .
(© Robert Malone)

Below: . . . but that tool may become his successor.
(© Robert Malone)

Opposite: Meet the employee of the future. No pension needed, and it has a résumé as long as your actuator.
(© Dan McCoy)

Following: The robots of 2019 will be able to see, feel, and in general have a keener sense of their world.
(© Robert Malone)

pated. Aldrin, in fact, had so much trouble with the Moon's soil that he was unable to plant his equipment deeply enough to carry out a solar wind test. Armstrong encountered similar difficulties in staking a mylar-constructed American flag into the lunar ground.

In spite of these obstacles, the Moon landing proved to be an enormous technological triumph in many respects, not the least of which was satellite transmission. One has to remember that commercial television was barely twenty years old then. It was a cultural phenomenon that had not even existed at the end of World War II. Color television had just begun to enter American homes in 1964, while cable television, home satellite dishes, VCRs, and holograms were simply unfathomable. But here, on July 20, close to 202 million Americans, not to mention millions of others around the world, were watching *on a live television transmission* this lunar pas de deux. How were Armstrong and Aldrin coming in so loud and clear? Each man had a microphone attached to his space helmet that relayed sounds into the receiving equipment in the lunar module. Not only sounds, but also atmospheric pressure, module information, and even heartbeat measurements were then relayed from *Eagle* via satellite to a radio telescope—an Earth satellite dish, of sorts—in Goldstone, California, where it was then passed on to the Goddard Space Center in Maryland. Had John Kennedy realized how intricate and sophisticated the technology would have to be to land a man on the Moon, would he still have issued his challenge, before Congress, in 1961?

On the day after the landing, July 21, the lunar explorers prepared for their departure from Tranquillity Base. "You're cleared for takeoff," spoke the voice of Mission Control. Aldrin replied, "Roger, understand. We're Number One on the runway." It was 1:54 P.M. as the top portion of the *Eagle* module lifted off from the Sea of Tranquillity. The engines had been tested over three thousand times, for there could be no failure. The lower section of the lunar craft remained where it had alit just 21½ hours before—now a permanent monument on the Moon, inscribed with the words:

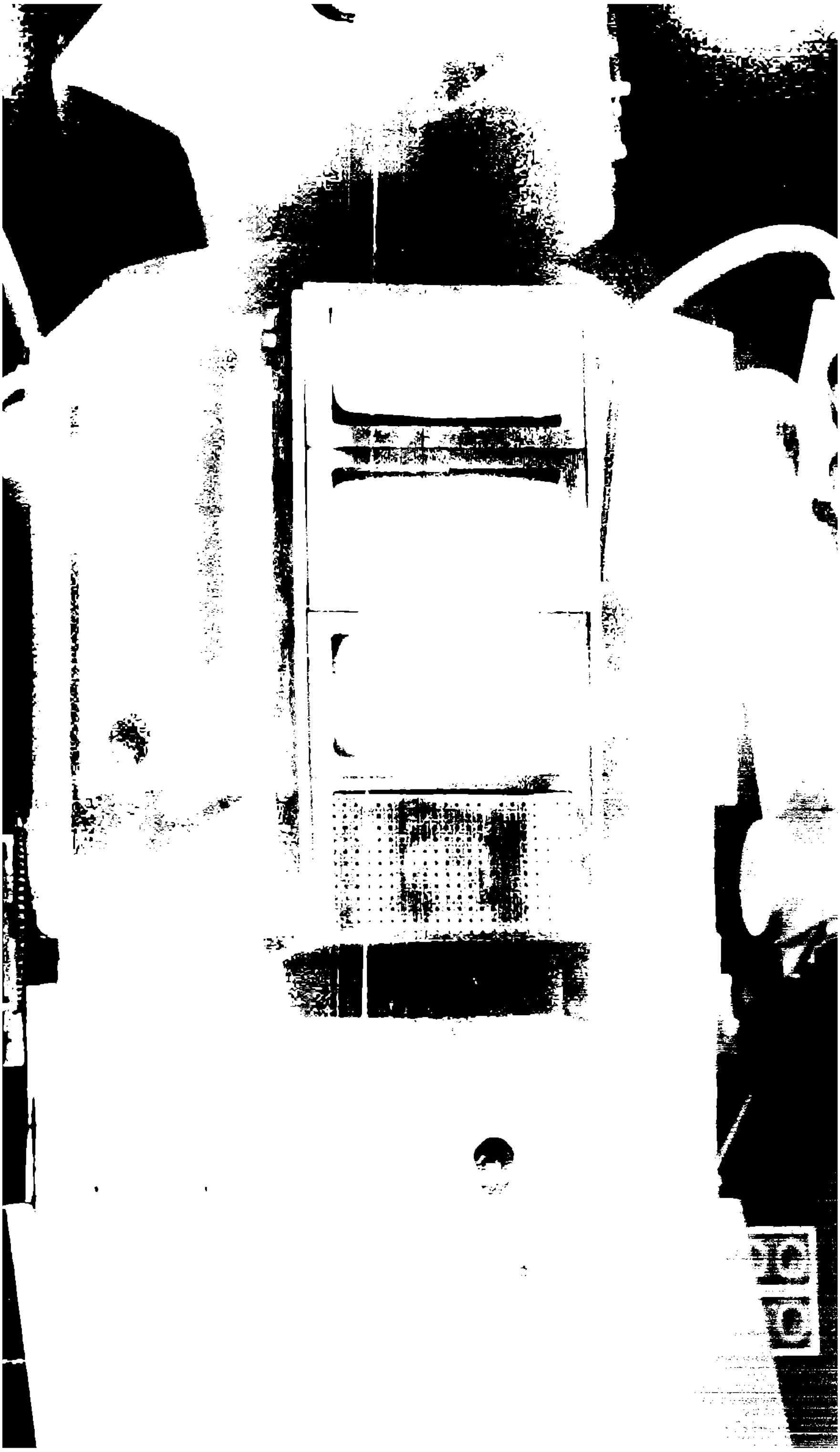
HERE MEN FROM THE PLANET-EARTH

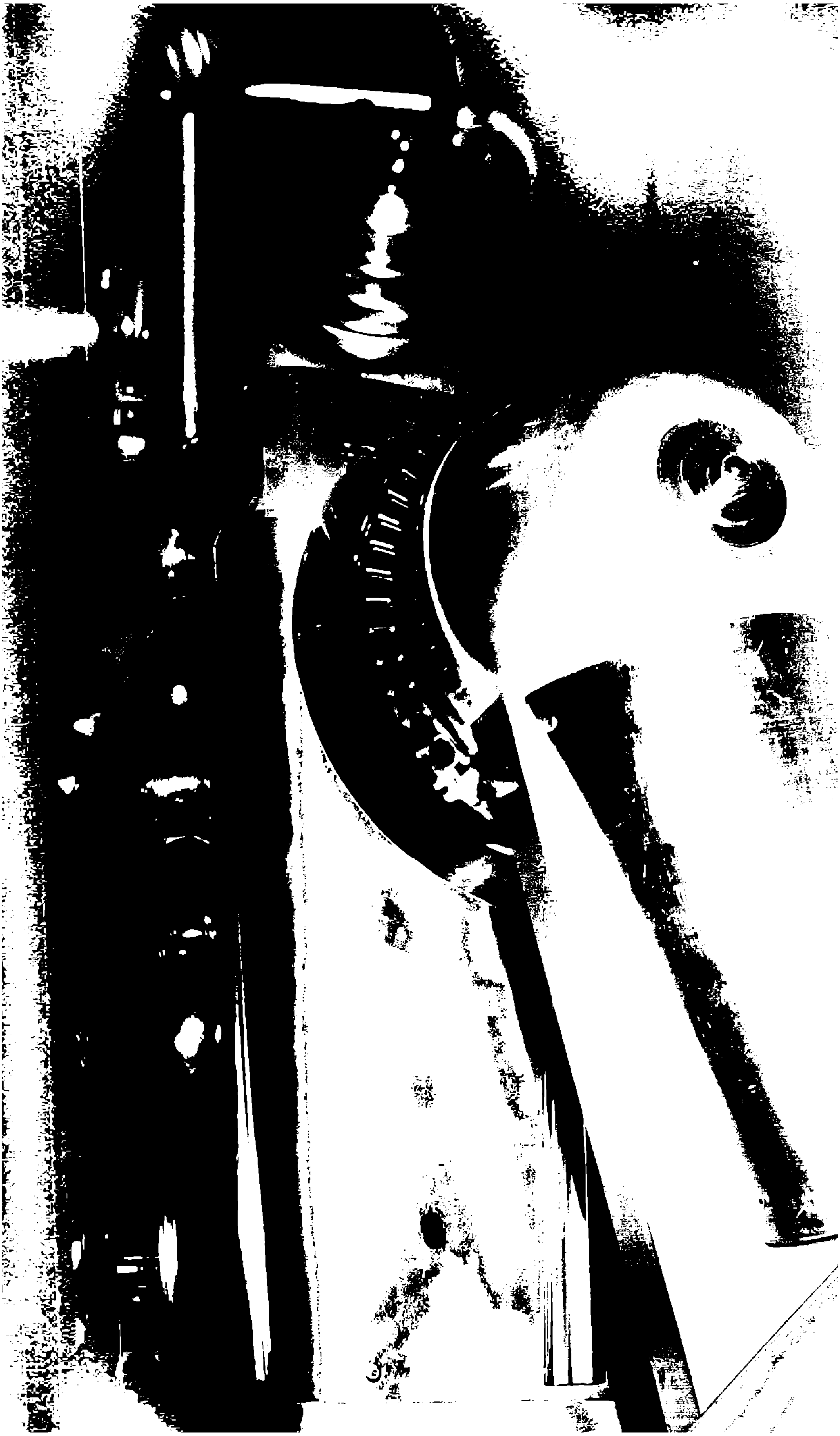
FIRST SET FOOT UPON THE MOON

JULY 1969 A.D.

WE CAME IN PEACE FOR ALL MANKIND

As *Eagle* lifted off that afternoon, the American flag that Armstrong had planted toppled over. Its stars and stripes rested impassively on the Sea of Tranquillity's soil, an image that suggested not so much America's pusillanimity but the Moon's feral and indomitable will. About four hours later, *Eagle*, now a passive vehicle, rendezvoused with the mother ship, *Columbia*, on the far side of the Moon.





The hoopla that had surrounded the lunar landing of July 20 would continue for several weeks. Having survived reentry, *Columbia* first appeared as a tiny orange speck in the Pacific sky, several hundred miles southwest of Hawaii, on the morning of July 24, 1969. "Gee, you look great!" President Nixon exclaimed from the U.S.S. *Hornet* as he looked through the window of the astronauts' quarantine compartment. "This," the president added, "is the greatest week in the history of the world since the creation." It was a political irony, not entirely lost on his Democratic opponents, that Nixon was able to take credit for the spectacular Moon landing, a national experiment that had been launched eight years earlier by a liberal Democrat from Massachusetts. But in this moment of triumph, not even the liberal press of 1969—those hundreds of reporters and editors who had, according to Nixon, unfairly savaged his career since the late 1940s—dared write unkindly about the head of state. Like the Armistices of 1918 and 1945, the Moon landing acted as a healing agent, an event that unified the nation's divided people in a display of celebration and unabashed patriotism. The seemingly endless war in Vietnam had blessedly been banished from the front pages. Its victims' stories would be rendered silent, for at least a month or two, by the feats accomplished on the twentieth of July.

While the three astronauts celebrated in their quarantined Lunar Receiving Laboratory, administrators at NASA were far less sanguine about the future of space. There was every reason to believe that Wernher von Braun's fears about funding in the post-Apollo age would sadly be realized. The Apollo landing of July 20, as spectacular as it was, seemed like a "flash in the pan," for the mission came when NASA's budget had been sharply curtailed. Without a space schedule that included the constant display of new fireworks, the public would grow restless, and Congress would divert the funds to other projects.

True to course, the next twenty-five years proved disappointing in space exploration. The intense fervor that enveloped that day in July dissipated in the subsequent years. The original Moon landing became like a beacon whose brightness was shrouded each passing year by a thicker layer of fog. The public's fascination with space lay dormant throughout the 1970s and 1980s, momentarily awakened here and there with the blaze of a comet or the explosion of a shuttle, but lacking the commitment to sustain the spirit of July 20, 1969. In fact, the predictions made by space experts in 1969 were far too optimistic. Sir

Bernard Lovell, for example, writing in the *Bulletin of the Atomic Scientists* in August 1969, predicted that the United States would send a manned mission to Mars between 1980 and 1985. Lovell's contemporaries, commenting on the post-Apollo age, were certain that a space lab would be in orbit before the end of the seventies, and that a permanent lunar base—a closed environment, a habitat made partly of lunar materials—would be a virtual certainty before the end of the century.

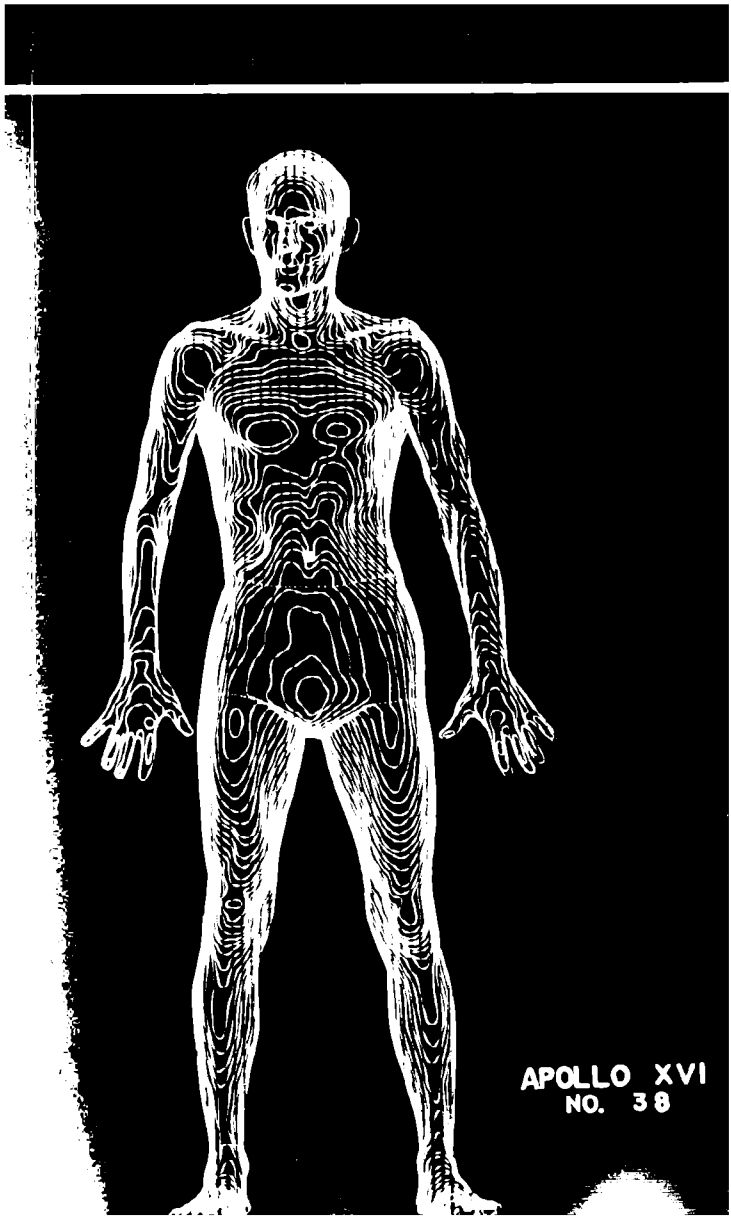
No one could have foreseen, on that historic Sunday in 1969, that only twelve Americans would set foot on the Moon before the year 2000, and that Apollo 17 would make the twentieth century's last manned lunar landing. The spirit of July 20, 1969 was not, in fact, revived until the President's inauguration speech of 1993. Like Kennedy's speech in 1961, it spoke of commitment to space and set the country on a course for the future. Space itself became the vehicle of political power, space's mandate the mandate of the president. The universal excitement in 1969 was carried forth by younger generations, so that the costs of the space laboratory and the manned mission to Mars no longer seemed prohibitive.

While America's new lunar base brings new hope to space exploration, one goal of that 1993 speech remains unrealized even in this twenty-first century. Imagine if Columbus had discovered the New World in 1492 and no settlers had returned? Imagine if the words of the first navigator of Australia, who said, "I've now mapped this continent so thoroughly that no one need ever go back there again," had been heeded?

But the Puritans and the Quakers made the perilous journey to the American colonies, and to the Australian continent came prisoners and brave pioneers. Why should our own twenty-first century be different? Our planet is infinitely more crowded today than it was at the beginning of the seventeenth century. Political oppression and religious persecution have hardly been tempered over the last four hundred years. Overpopulation threatens to destroy the planet over the next decade. The need for emigration to distant terrains is, in fact, more pressing than it has ever been.

"We shall return, with peace and hope for all mankind," were the departing words of the last Apollo astronaut on the Moon in 1973. That's already forty-six years ago. It's 2019, and a permanent lunar base

is hardly sufficient. We must return not only with a hardy band of research scientists, but with thousands of settlers, and plant the flag more firmly this time, so that the spirit of the explorers in that summer of 1969 can be celebrated as we approach July 20, 2019.



T E

Commonwealth of California
Department of Health's
Vital Records

CERTIFICATE OF LIFE

Subject:	Baby boy, Miller
Date of Conception:	November 15, 2018; 12:15 P.M.
Place:	Comprehensive Fertility Institute, Beverly Hills, California
Number of Parents:	Three, including surrogate mother—mother donated egg, father sperm
Method of Conception:	In vitro fertilization followed by embryo transfer. Mother's body had rejected her artificial fallopian tube. After 8 days on pergonal tablets, mother produced 2 eggs. Both were removed during routine laparoscopy and screened for possible defects. Eggs united with father's sperm. After 48 hours in incubator, embryos were removed from growth medium and placed in surrogate's womb. Only one embryo attached itself to uterine wall.
Prenatal Care:	Ultrasound at 3 months. Fetal surgery performed at 5 months to correct small defect in bone of right foot.
Date/Time of Birth:	Jason Lawrence Miller born July 20, 2019; 4:15 A.M.
Father:	Jason L. Miller, Sr.
Mothers:	Amy Wong (natural), Maribeth Rivers (surrogate)
Birth Method:	Newly lifed in Morningstar Birthing Center, division of Humana Corporation. Natural delivery after 5-hour labor. Labor pains controlled though acupuncture. Therapeutic touch used for last hour of labor. Child's father, adopted sister, and natural mother attended the delivery.
Weight/Length:	10 lb.; 25 in.

Eye Color:	Green
Genetic Profile:	Yunis Test shows missing sub-band on chromosome 5, indicating premature graying of hair. Will be totally gray by age 22. Bands on one chromosome upside down; could have fertility problems. Nicked chromosome indicates a greater than average vulnerability to lung cancer.
High-Risk Professions:	Any career that would expose individual to possible lung damage: painting, mining, etc.
Body Type:	Mesomorph. Build well suited to contact sports, such as football. To maximize muscle development and athletic ability, should begin exercise program by age 4.
Projected Life Span:	82 years

At one end of the complex there is the flailing of limbs followed by some heavy breathing. The aerobics class is just about over, and in thirty minutes the room will serve as a lecture hall. "Eating Your Way to Good Health" is the topic on the evening of July 20, 2019. On the second floor two new parents share an intimate candlelight dinner, fresh shark with shallots and wild rice. Just around the corner a group of elderly men and women watch the Marx Brothers' *A Night at the Opera*.

Though it resembles a leisure community, this is in fact a hospital. Here, people come into life, their birth certificates bearing enough biological information to form a blueprint of their future. But the hospital has also become a place for the cultivation of wellness, a place where people can rejuvenate themselves, take control of their lives, even restore their spirits.

Beyond this, it is a commercial unit, a business with an eye toward

the bottom line, an enterprise that vies with other medical establishments for customers, rather than a social institution intent upon ministering to the physical needs of both rich and poor. The surplus of physicians, the improved health of most Americans, the oversupply of hospital beds, and the escalating cost of high-tech diagnostic tests, as well as a reduction in government funding, has forced the hospital to reevaluate its role in the community.

With some thirty-five years to go, the hospital of 2019 is already taking shape. Consider these projections for the mid-1990s, reported in a study conducted by Arthur D. Little, Inc., for the Health Insurance Association of America:

- The shift of care from inpatient to ambulatory settings will accelerate.
- Hospitals will integrate into corporate structures.
- More companies will offer multiple Health Maintenance Organization (HMO) options.
- Consumers will become increasingly responsible for their own health care, thus putting pressure on insurers to design benefits that reward good health habits and penalize poor ones.

The winds of change have already touched us. Investor-owned firms own or operate one hospital in five: The Humana Corporation owns and runs more than eighty for-profit hospitals worldwide; Hospital Corporation of America owns 250 hospitals and manages two hundred more. A half dozen corporations are making a foray into other areas of health care as well, teaming up with insurance companies and hospital supply houses. According to Dr. Paul Ellwood, former president of the health research group called InterStudy, by the year 2000, six out of every ten Americans will have all their health-care needs, including hospital care and health insurance, provided by perhaps a total of ten companies.

At the same time, the number of hospital admissions will continue to drop, and the average length of stay decrease. Outpatient clinics will carry out much of the surgery performed in this country, eliminating many hospital stays altogether. Using lasers, doctors can now speedily and safely remove warts, moles, even skin cancers in their offices, as well as perform delicate eye surgery without admitting the patient to the hospital.

People who enter the hospital for critical procedures, such as liver and kidney transplants, will recover far more quickly than transplant recipients once did. In fact, in St. Paul and Minneapolis, the average hospital stay for the most common problems has already dropped from 5.3 days in 1983 to 4.3 days in 1984. Doctors are slowly cutting down on the number of tests patients must endure and are discharging patients earlier. When possible, people are recuperating at home.

With such progress, suddenly the very institution committed to bestowing good health finds itself ailing. To bolster their hospitals' flagging income, administrators are going to unprecedented lengths to attract "clients." To make a patient's surroundings more pleasant—even therapeutic—hospital planners are consulting with interior designers. The hospital environment is now seen as a medical tool capable of speeding recovery. Furthermore, fitness courses and diet and alcohol clinics are being added to the roster of hospital programs.

To be sure, the hospital of 2019 will still perform such profound procedures as brain surgery and artificial heart implants. But virtually everything else about it will have changed, including the structure itself. Gone will be the scrubbed and sterile buildings fashioned in the 1950s. In fact, the patient entering a hospital thirty years from now may have a hard time remembering when hospitals weren't aesthetically pleasing. The halls will be bathed in sunlight that streams through dozens of skylights and windows circling the main atrium. Sprays of fresh greenery will decorate the rooms, all of which boast a view of either an atrium or well-groomed grounds. Festive paintings will deck the walls, and in the common areas guests will be greeted by aquarium tanks filled with colorful tropical fish.

The first medical establishments to offer patients quality care in a homelike setting were birthing centers. Some are independently operated, others are affiliated with hospitals. All provide kitchens, rockers, playrooms for the baby's siblings, and basic medical equipment, such as IVs and incubators. Spurred on by the centers' popularity as well as by increasing evidence that factors such as architecture, lights, and furnishings can influence healing, planners have begun to pay more attention to the hospital's form in addition to its content.

At the Planetree Model Hospital Project, an experimental wing located in the Pacific Presbyterian Medical Center in San Francisco, patients enjoy a hotel-like environment. The rooms have bedspreads, potted plants, paintings, and track lighting; patients and their families

can prepare snacks or meals in the project's well-stocked kitchen. Even the nursing station, in an effort to break down barriers between patients and staff, is open and indirectly lit.

"Planetree is setting the stage for the future of hospital care," predicts Dr. John Gamble, Pacific Presbyterian's chief of staff. "The incorporation of modern medicine and technology in a setting that upholds the full rights and dignity of the individual patient will add immeasurably to healing."

One study in particular lends weight to Gamble's argument. For eight years, nurses at a Pennsylvania hospital kept detailed notes on patients undergoing gallbladder surgery—the amount of pain that followed the operations, any minor complications that occurred, and the length of the patients' recovery. The researcher who analyzed the data found that one group recovered more slowly and seemed to suffer more pain: the group whose rooms had no view. By contrast, patients who had stayed in rooms overlooking a stand of trees generally went home about a day and a half earlier than the "no-view" patients.

By the year 2019, patients will comparison shop for a hospital, taking into consideration such varied factors as the institution's appearance,

extras it offers, and the costs of certain procedures. In the Columbus, Ohio, region, for example, twenty hospitals joined forces and published a cost comparison guide for patients, listing such diverse offerings as the price of hip surgery and coronary bypass. Across the nation, hospitals are hiring "guest relations" representatives, who see to it that patients receive certain amenities—from gourmet fare to fresh flowers. A few medical centers, hungry for patients, have already begun to tout such items as large-screen televisions, video recorders, and hospital "suites." (One reporter dubbed this competition "the invasion of the bodysnatchers.")

In some cases, the existing amenities will simply be improved. Instead of a candy striper pushing around a rickety little cart supplied with half a dozen Readers Digest Condensed Books and a year's worth of magazines minus their front covers, hospitals will offer a congenial, well-stocked library with extensive files on diseases and their treatment, as well as audio tapes of best-selling novels and special large-print editions of newspapers and literary classics. In the waiting room, soft blue-tinted lights, said to have a soothing effect, will calm anxious patients and their families. As limited visiting hours become a thing of the past, special rooms with extra beds to accommodate family members of critically ill patients will appear in many institutions.

And as Americans take increasing responsibility for their own health, and work to avoid diseases such as cancer and heart disease, hospitals will add wellness programs to their list of offerings. By capitalizing on the national obsession with staying fit, administrators will succeed in finally broadening the hospital's function in the community. The hospital of 2019 will be a resource for those interested in keeping their good health, not simply a sanctuary for the ill.

Administrators have, in just the past few years, looked to Madison Avenue to sell their services and solve the problem of vacant beds and underutilized equipment. There are newspaper advertisements for birthing centers—"design your own private miracle"—and for "hospitels," a hybrid of hospital and hotel. Couples in the twenty-first century will watch late-night television commercials for "feel good" weekends—package deals available from their local hospitals: "While away the three-day weekend in our whirlpool. Consult with our top-notch C-V experts. Heal your body—and mind—at Midvalley Memorial." Clients will check in for a workup that includes a battery of painless tests, a consultation with a nutritionist and three specially

prepared meals a day, an antistress program tailored to the client's particular needs, and a workout in the physical therapy facilities. The weekend might be spent doing aerobic exercises, eating low-cholesterol fare, and producing more alpha waves.

A less obvious—though more far-reaching—change will be the complete computerization of the hospital. In hospital billing departments, nurses' stations, medical labs, and at patients' bedsides, the ever-present computer will process, monitor, record, and retrieve all vital information, in effect becoming the "collective conscious" of the entire hospital. To date, more than a hundred hospitals in the U.S. rely on multimillion-dollar computer systems.

Imagine having millions of bits of information basic to the hospital's operation at your fingertips. For nearly every department, from housekeeping to administration, the advantages are innumerable. Manufacturers of software that links clinical data with financial reports contend that such packages will allow hospitals to be run more efficiently and with fewer staff members.

Dozens of systems already exist, each one tailored to the needs of a particular department. For example, one program gives the physician all the available treatments for various illnesses, from pneumonia to gallstones. It breaks down cost of treatment, provides information on expected recovery time, and tells the physician what other physical problems may ensue. Another system, with shades of Big Brother, allows administrators to monitor nurses'—and doctors'—performance and issues an alert when the staff seems to be ordering unnecessary tests or when a patient is not released on schedule.

Until recently, most hospitals have limited the computer's role to the billing department. But doctors, nurses, unit clerks, and other employees are seeing how computers can enhance patient care. Ulticare, a system being tested in a few hospitals throughout the country, replaces one of the most antiquated, yet vital, components of patient care: the patient's chart. Developed by Health Data Sciences Corporation, the program works like this: A nurse slides a specially coded card into the patient's terminal, and the computer kicks up the same information that would be recorded on a chart, plus what must be done next for the patient. The computer also stores information that would normally be scattered throughout the hospital, such as results of lab tests, X rays, and other procedures.

Once a nurse types in the tasks she's performed and makes any

other necessary notations, she removes the card. According to physicians who use the system at William Beaumont Hospital System in Royal Oak, Michigan, Ulticare reduces hospital costs and the chances of transcription errors. In addition, the system frees nurses from paperwork, allowing them to spend more time caring for their patients. It even warns personnel of possible medication problems. "It hooks up all start and stop orders for medicine, and broadcasts a panic alert if a lab test shows, for instance, exceptionally high blood sugar," says Mary Ann Keyes, Beaumont's assistant director.

It seems as if the computer's abilities are almost limitless. If so, will the computer eventually replace the practitioner? Are we swiftly approaching the day when a robot will take our temperature and blood pressure, listen to our lungs, swab our throats and do the blood workup, and then feed its data into a computer, which will in turn spit out the diagnosis?

More likely, the computer will be used as a consultant of sorts, the source a doctor turns to for a second opinion, or at least for additional background on a disorder. According to Dr. Robert Wigton, associate professor of medicine at the University of Nebraska, the computer will put a vast amount of medical literature at the physician's disposal—instantly. Wigton envisions a day when a doctor will simply request a patient's X rays, and a voice-activated computer will produce them on a screen alongside the patient's bed. Physicians stumped by a medical mystery will type in all of the clues—results of the patient's tests, his complaints, and his general condition—and ask the computer for its "opinion." Because the latest medical literature will also have been programmed in, doctors will be privy to new treatments that have met with success at other institutions.

Wigton's dream will soon be a reality. Computers are already giving doctors quicker access to X rays and CAT (computerized axial tomography) scans. PACS (picture archival communications systems) promise to save radiology departments time and reduce hospital costs in addition to making patients' medical images and files simultaneously available to physicians in different parts of the hospital. AT&T's Commview, a type of PACS, features computer workstations—in the hospital, as well as in neighboring clinics—that hook into a central image-processing system. A doctor treating the victim of a car accident, for instance, could view the results of a CAT scan at the same time a specialist miles away examines them.

The downside of this technological advance is that some clerical and maintenance jobs will be eliminated as computers take on those tasks that humans once performed by rote. Computer mavens, however, will find openings in medicine, as their skills are needed not only to set up systems, but also to maintain them. Staff members in each department will be trained to feel comfortable referring to, even relying on, the hospital's computer's consciousness.

Just as computers will become the hospital's mind, robots will become the hospital's hands. In the twenty-first century, each hospital will be outfitted with a team of capable, tireless robots to help with duties ranging from emptying bedpans to assisting in brain surgery. Some will be simple instruments resembling the industrial arms used in the auto industry; others will be more sophisticated, able to move about, even "speak," like the lovable C-3PO of *Star Wars* fame. And in every area of the hospital, robotic helpers will ease the work load of their human coworkers. Larry Leifer, a mechanical engineer at Stanford University, predicts that these machines will follow preset paths to hand out meals and drop off fresh linen; do tedious—and often distasteful—lab work, such as processing urine and fecal samples; aid patients undergoing physical therapy by flexing stiff joints; and help out in the operating room, passing instruments to surgeons. They will listen to patients' problems, and in the case of quadriplegics, act as an extension of the patient's own body.

A robot's invulnerability to disease and to the radioactive materials used in nuclear medicine make robotic aides particularly appealing. A robot on wheels could, for instance, deliver radioisotopes from a generator housed in a lead vault to the patient's doctor. Placing an empty vial in the generator, the robot would collect the correct dose and carry it to the physician, minimizing human exposure to the radioactive material. Likewise, mechanical arms could process infectious bacteria and viruses without ever coming down with an illness. Robotic lab assistants could transfer suspected herpes infections to culture tubes or sputum from a tuberculosis victim to a microscope slide.

But not all of the hospitals' robots will be doing the drudge work. The world's first neurosurgical robot, Ole, made his debut in January 1985 when he assisted surgeons at Memorial Medical Center in Long Beach, California. Brain surgeons use the six-jointed mechanical arm as a kind of intelligent hand during certain operations. Locked into

position, Ole holds the drill for the surgeon, allowing the doctor to be accurate to 1/2,000 of an inch when draining cysts or removing tumors.

By the year 2019, mechanized "surgeons" will be a vital part of the operating room (OR) team, responsible for implanting tiny radioactive pellets in the center of tumors, guiding surgical lasers to their targets, applying clamps to the surgical site. Human surgeons may eventually have their own robotic assistants, each trained to respond to its master's voice and to take over the more routine tasks, such as closing an incision, when his human counterpart becomes tired, or work in sync with the surgeon when a steadier hand is needed. Because the surgeon will have programmed his skills, even his personality, into the robot's brain, it will be as if the doctor himself were completing the procedure.

The surgeon of 2019 will not only have a robot as an aide, but thanks to more highly developed diagnostic equipment, he will have a far better idea of his patient's condition and the possible outcome of surgery long before the operation begins. The ideal diagnostic tool for any doctor would be a "feinberg," the hand-held device that made Bones McCoy of *Star Trek* fame look like a Nobel laureate. Passed over the body like a magic wand, the feinberg instantly gave McCoy a diagnosis of the patient's condition. Though not as comprehensive as the feinberg, one experimental instrument, the Dynamic Spatial Reconstructor (DSR), will provide the surgeon with far more critical

information than is currently available without first opening the patient up.

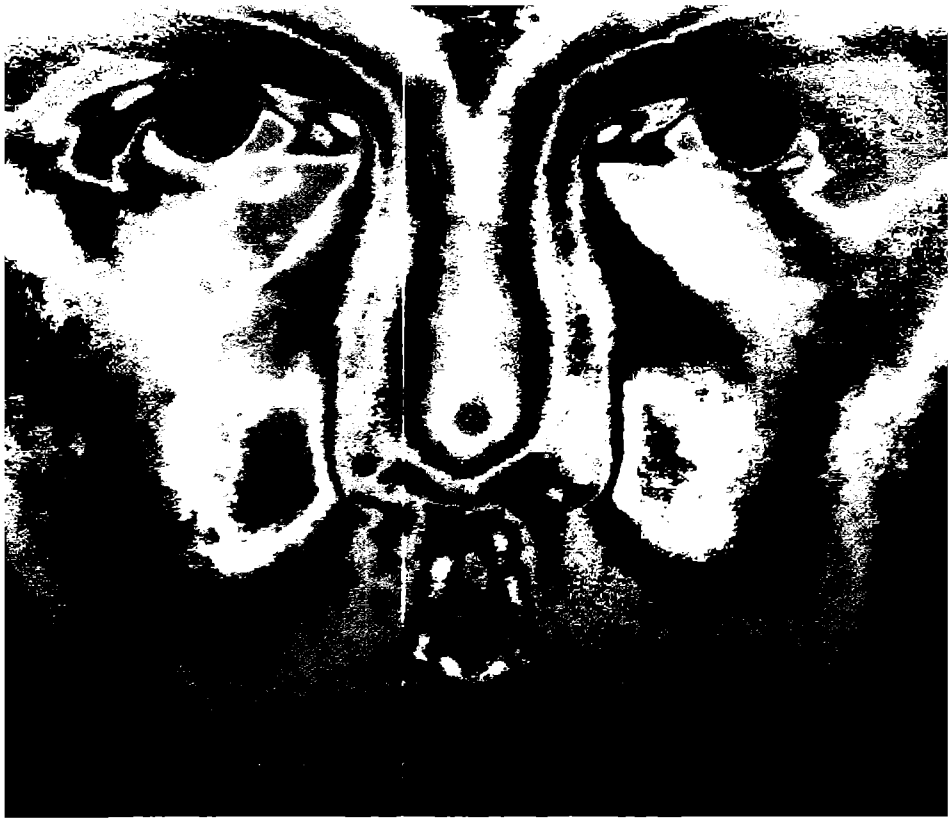
The surgeon performing open-heart surgery or even an artificial heart transplant will first use the DSR to produce a three-dimensional X ray. This device, which was recently developed at the Mayo Clinic in Rochester, Minnesota, allows the physician to do "exploratory surgery" without ever touching the patient. It provides so many pictures of the body that all sides of an organ can be examined before surgery begins.

The operating theater will remain the stage for dozens of latter-day miracles. Virtually every body part will have an artificial counterpart. Prosthetic technology will offer hope to accident victims whose limbs have been smashed beyond repair. Custom-made bones will replace hips ravaged by cancer; bionic arms will respond to the thoughts of their owners. Women who are infertile because of a faulty fallopian tube will conceive with the aid of an artificial one. The deaf will hear; the lame will walk.

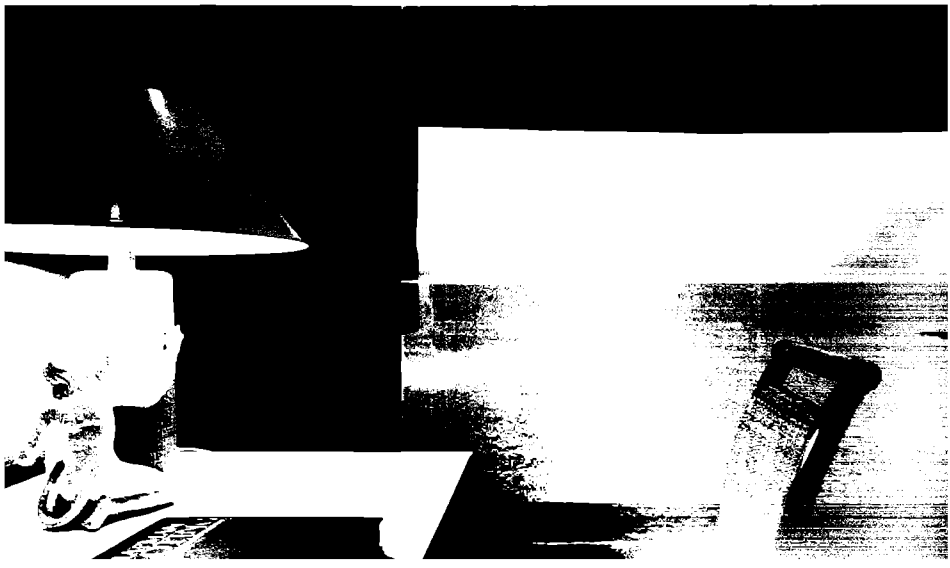
Long before 2019, pumps that dispense insulin will be planted under a diabetic's skin, ending the discomfort of daily injections. Eventually, this procedure will become as common as implanting a pacemaker. Artificial hearts, powered by a tiny battery pack worn on a belt, will beat in their owners' chests indefinitely. Transplants will seem nearly as ordinary as tonsillectomies.

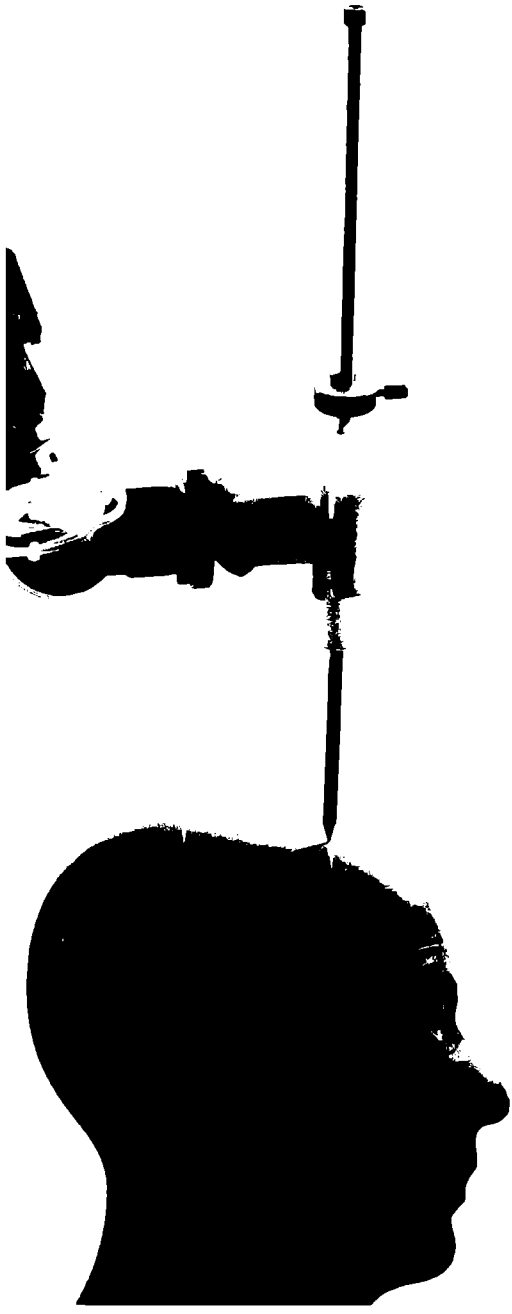
The patient of 2019 will expect to participate in decisions about his own care. This goes well beyond seeking a second opinion for certain surgical procedures or choosing the hospital with the best prices. The sagas of coma victim Karen Ann Quinlan and birth-defected baby Jane Doe have tugged at the heartstrings of millions of Americans, prompting them to ask questions about quality, rather than length, of life, and to want control of their own treatment in the event a tragic accident leaves them dependent on a life support system. A growing number of individuals are writing "living wills," which state that under such circumstances no extraordinary measures should be taken to extend their lives.

Patients are also learning to depend on their own healing powers when undergoing treatment for cancer and other life-threatening disease. Evidence is mounting that attitude often affects healing, and those patients physically and mentally able to do so will tap the healer within themselves. The best-known example of this is author Norman



ı 2019 will certainly be high-tech, but hospitals will be humanized to make people feel
Above © Dan McCoy; *below* © Walter Nelson)





A robot surgical arm takes aim on a dummy patient. (© Dan McCoy)

Man-made skin may revolutionize plastic surgery in 2019. (© Dan McCoy)

Cousins, who, felled by a serious illness, decided to prove that laughter was indeed the best medicine. Hospitalized for a crippling degenerative disease and given little hope of recovery, Cousins conducted his own Marx Brothers film festival. To the amazement of his doctors, Cousins became well. Researchers subsequently found that patients who feel more in control of their illness are quicker to recover than those who show little interest in their therapy.

Other factors will help to make the patient feel in control, not the least of which is the public's changing attitude toward doctors. No longer considered omnipotent, physicians are more likely than ever to be challenged by those patients who grew up with consumerism. Better informed than their grandparents, the patients of 2019 will not only know more, but will demand more of their practitioners. Suddenly, physicians are more accountable for their actions—and for their errors, as witnessed by the skyrocketing cost of malpractice insurance.

The physician glut expected in the twenty-first century will also help upgrade the level of medical care. Patients will be able to select from several physicians, all eager to administer their services and, because they have fewer patients, able to spend more time with each. Increasing numbers of doctors will belong to group practices and receive a salary. As a result, they will be expected to maintain certain levels of excellence.

Physicians themselves will have changed a bit as their training becomes more varied. Both Rochester University Medical School and Johns Hopkins in Baltimore have dropped the Medical College Admissions Test from their list of requirements in an effort to open their doors to students with a liberal arts, rather than a science, background. Slowly, medical schools have been incorporating nutrition courses into their curriculum; by 2019, the medical student will have logged a good many hours in nutrition classes, as well as in classes on robotics and computers. Finally, women will be better represented in the medical profession. With record numbers of them entering medical schools, the proportion of female physicians will grow to 20 percent of all doctors by the year 2000.

A concomitant effect will be the entry of more men into nursing. The demand for nurses with specialties, in intensive care and surgery for instance, will rise sharply. Whereas the physician of 2019 will still concentrate on diagnosing the patient's illness and prescribing the proper treatment, the nurse will become more intimately involved in

the healing process, helping the patient to hasten good health through biofeedback, meditation, and other holistic methods.

Opportunities for nurses will increase appreciably in the twenty-first century as they start their own corporations. One of the first of these, the Health Control Centers in Denver, Colorado, is run exclusively by nurses, who provide patients (often referred by physicians) with such self-healing tools as biofeedback. Using a device called the Mind Mirror, which is similar to an electroencephalograph (EEG), nurses monitor the rhythms of both hemispheres of the brain. Electrodes attached to the patient's head pick up brain activity; a display panel then reveals the type of rhythms being generated: Beta waves are typical of the conscious mind, alpha waves of daydreams, theta waves of subconscious activity, and delta waves of deep sleep. The Denver nurses use this tool to help patients reach a state of deep meditation, which they believe promotes the body's healing properties.

Slowly, health insurers will begin to recognize the validity of such procedures and will be more willing to provide coverage for holistic methods. In fact, medical consumers will have an alphabet soup of health-care plans from which to choose. HMOs (Health Maintenance Organizations), PPOs (Preferred Provider Organizations), and other health plans are gaining acceptability partly because of the spiraling price of hospital care. Employers, crippled by the cost of providing their workers with health insurance, are demanding that health-care providers come up with alternative methods of medical coverage. Some experts calculate that by the late 1990s, nearly half of the people in the U.S. may use HMOs and similar plans. For-profit hospitals have also devised health plans, and corporations like Humana and Hospital Corporation of America are offering a variety of insurance options in an effort to bring more patients into their institutions.

HMOs provide free services to those consumers who enroll in their medical plan for a flat yearly fee. Members select a physician from a list, and use only those hospitals chosen by the HMO. Because these organizations operate on a strict budget, enrollees are carefully screened before they receive approval for hospitalization. With a PPO, a subscriber gets a discount when he sees a physician who is on the insurer's roster. Usually, it's the employer who contracts with a group of doctors and a hospital to which employees have access. In this way a hospital is guaranteed a certain number of clients. Should an em-

ployee decide to go elsewhere or to see a doctor not listed with the PPO, he foots the bill himself.

As employers have more of a say in their employees' medical care, they may be the ones to decide whether the group insurance pays for heroic procedures, such as heart and kidney transplants. For example, Honeywell, Inc., which is among the first companies to approve heart, lung, and liver transplants for its workers, has consistently reviewed these major operations on a case-by-case basis. The question will no longer be, "Are we doing everything possible for the patient?" but rather, "Is this procedure really necessary, and will it enhance the patient's quality of life?" Americans could eventually see the rationing of high-tech costly procedures, such as open-heart surgery. (Already, medical ethicists are wrestling with the idea of limiting availability of certain operations. Said one expert, "The only way to cut costs will be to deny benefits to some people.") Great Britain has used such a rationing system for many years. Waiting lists for elective surgery are typically several years long.

Even the most optimistic social prophets concede that the poor and unemployed will suffer under the evolving health-care system. In the twenty-first century, the medical system may treat the poor one way and the affluent another. Medicare may curtail funds for heroic procedures altogether. Several states already use a gatekeeper system for Medicaid recipients in which a general practitioner determines whether a patient will have access to a specialist. This trend is likely to continue.

The federal government's health-care policies also jeopardize medical care for the elderly. The prospective payment system, put into effect in October 1983, ushered in the era of diagnosis-related groups (DRGs). This system, which applies only to Medicare patients, assigns a fixed rate for a particular illness. If complications arise, or if a patient takes longer to recover than the average, the hospital is not reimbursed for the "extra" fees. Critics of this system claim that it forces hospitals to release patients prematurely, and that it reduces a hospital's ability to take on charity cases.

Social, as well as governmental, forces will cut into hospitals' operating capital. People once turned to the local emergency room for the treatment of minor "emergencies," such as nosebleeds, bee stings, and sprained ankles. Now, in many parts of the country, they have the option of visiting the local walk-in clinic or "Doc-in-a-Box." These are

springing up along the nation's highways, wedging themselves between the Color Tiles and Burger Kings, the K-Marts and Carvels, all tributes to high traffic volumes. Suburban malls even boast their services. Open seven days a week, these centers offer medical treatment at prices often below that of the emergency room and sometimes even below that of the private physician. And there's never more than a ten-minute wait. More than three thousand free-standing clinics in the U.S. provide treatment for relatively minor health problems. By the year 1990, that number will double.

Occasionally, these McMedicines are started by a physician with an entrepreneurial leaning; most are owned by such supermed corporations as Humana. Many are headed up by former emergency-room physicians. Centers are staffed with at least one licensed physician and a registered nurse, and maintain basic medical equipment, including X-ray machines and defibrillators. There's also lab equipment to process blood and urine samples—a measure that saves time and cuts costs.

Some clinics, called surgicenters, cater exclusively to patients who need minor, sometimes elective surgery, such as tonsillectomies, hernia repairs, biopsies, even face-lifts and tummy tucks. As bloodless laser surgery becomes more commonplace, these outpatient operating rooms will take over most minor operations. Patients will spend a few hours in a recovery room and then head for home. Even the critics of such centers admit there's a psychological bonus to one-day surgery: People tend to regard the procedures as simple "repair work" rather than as treatments for an illness.

Although walk-in clinics are a relatively recent development in the medical world, hospitals are already feeling their impact: They have diverted paying patients from the emergency rooms, which are now crumbling under the weight of caring for the poor and indigent, and have reduced the number of operations performed in hospitals. Throughout the country, many hospitals have begun to close down one or more wings. In fact, the National Health Plan Guidelines issued in 1978 suggested that the supply of nonfederal, short-term hospital beds be reduced.

Eventually, as these clinics become more widespread, they may begin teaming up with the local hospital system. Instead of scattering the various sectors of health care, some of the major hospital corporations will consolidate physicians' offices, outpatient surgery services, diag-

nostic centers, fertility clinics, pharmacies, wellness centers, and hospital quarters into a mall-like structure, built around common dining and lounge areas.

The Carter County Medical Mall in Elizabethton, Tennessee, slated to open in late 1986, will hold only a hundred beds. But proponents of the plan say the extra space means that departments like physical and respiratory therapy can be expanded to accommodate a higher volume of outpatients.

Medical malls will also house a diversity of specialty health centers. Periodontists and nutritionists, radiologists and physical therapists will have offices under the same roof. Visitors will shed pounds and learn to change their eating patterns at the obesity clinic, dry out at the alcohol center, and learn how to quit smoking at something that could be called "HabitBreakers." Phobias will be cured at a storefront dubbed "Fear-Less."

But not everyone will have to travel to the neighboring medical mall to receive diet counseling or find out if a sore throat is actually a strep infection. In 1982, Americans bought upwards of 50 million home medical tests in an attempt to evaluate their own conditions. Home pregnancy tests, for example, which account for the biggest share of the market, allow women to begin prenatal care earlier than ever before. By the year 2000, home tests for bladder infections, diabetes, venereal diseases, and asthma will have become so sophisticated—even fail-proof—that patients will be able to diagnose their own ailments.

Ideally, a patient would type the results of such a test into his personal computer, which would then relay the information to a computer in the doctor's office. The doctor would then determine whether or not she need see the patient to prescribe the correct treatment.

Equipment once synonymous with the hospital will be miniaturized and simplified for use in the home. A new, pocket-size heart monitor that measures blood flow to the heart will alert cardiac patients to dangerous arrhythmias. A portable transcutaneous electrical stimulator, which can be plugged into an ordinary outlet, will heal broken bones quickly and thoroughly by guiding the cell repair mechanisms. Children suffering from scoliosis—curvature of the spine—will also be treated at home with an electrical stimulator.

Despite such revolutionary developments, people will continue to

need the type of medical care that can only be administered in a hospital. Architects and medical experts have already pooled their talents to produce today the hospital of the twenty-first century in the form of a one-thousand-foot exhibit that is currently touring the country. First presented at the annual American Hospital Association's 1984 meeting, the project was three years in the making.

Before putting the diorama and multimedia presentation together, researchers at Auburn University in Alabama, and members of the architectural firm Earl Swensson Associates, analyzed such factors as an aging population, alternative health-care systems, communication technology, and other changes that will dictate the shape of the twenty-first-century hospital. They took into consideration the fact that new drugs and vaccines will certainly eliminate some diseases, while environmental hazards and sexual habits will spawn others.

All of the technology highlighted in the exhibit is either currently available or in the prototype stage. There are wrist computers that keep nurses abreast of patients' conditions, specially designed metal detectors that scan an accident victim's body to see if he has any artificial parts, and "high touch" recovery rooms that help a patient get well quickly.

Human life, from the miracle of birth to the mystery of death, will be enhanced in countless ways by these technological achievements, by the robot hands performing precise surgical tasks and computers that instantly analyze and comprehend a welter of confusing symptoms. But even more important, in the year 2019, we, the human masters of such devices, will have gained a greater understanding of ourselves. Peering into our bodies with CAT scans and Mind Mirrors, we will also have seen the wonder of the ways in which we work and are built—all of us the same. The hospital of the future will house and promulgate the ultimate truth: Health is a balance of mind and body and can best be achieved in an environment carefully attuned to both. A visit to the hospital may never surpass a week in the Bahamas, but in thirty years it will certainly have lost most of the dread with which it is greeted today. And that alone, we have recently discovered, may be half the battle.

H A P

E R 4

RÉSUMÉ

Name: Universon Robot
Social Security Number: None
Marital Status: N/A
Age: 58 years old
Sex: Three choices (male, female, asexual)
Height: 5 feet
Weight: 60 to 2,800 pounds (depending on job requirements)
Present Health: Excellent
Medical History: Lost hand (now replaced) in a forge accident; lost memory (restored by tape); blinded in a kiln explosion (new, improved stereoptic vision since installed)
Life Expectancy: 29 man-shift years
Special Abilities/Training: Industrial/heavy-duty outdoor model: Fluent in three robot languages; instantly retrainable with memory replacement module; three-jointed arm has 6 degrees of movement and is capable of lifting up to 2,000 pounds with one end effector (hand). Precise—can work within a tolerance of 1/1000 of an inch; works 24-hour shifts. Personal model: Available in either stationary or mobile configurations; can learn to respond to owner's voice; comes with Level I Conscience, the program of protective ethics, factory installed (not available in warrior mode).
Work Experience: Assembly-line worker, welder, painter—Ford, General Motors, Chrysler
Materials handling—Pittsburgh Plate Glass
Domestic—Engelberger household, Danbury, Connecticut
Operating room nurse/attendant—Long Beach Hospital, Long Beach, California
References supplied upon request

A few years ago, Joseph Engelberger, the cofounder of Unimation, the world's first industrial robot company, dreamed up this robot résumé to impress upon people the wide ranging abilities of his company's industrial drones. It's been updated slightly to reflect the vari-

ants in the kind of intelligent and semi-intelligent machine workers we can expect to see in the twenty-first century. By 2019, more and more of the descendants of those factory drones, like the descendants of immigrants who came to the New World, will be working at more upscale jobs: They will be undersea explorers, heavy-construction workers, crime fighters, nuclear power plant inspectors, cybernetic companions, and astronauts.

By 2019, the machine will be in the first phase of a tremendous evolutionary leap. No longer will the robot be a simple-minded, dumb, insensate machine found only along factory production lines. The machine will have moved out of the cloistered manufacturing plant and into our world. We will work alongside the machines, relax with them, live with them.

Roboticized homes will become more and more common. A first-time visit to one of these homes might be a disappointment. No robot butler will greet you at the door, and there'll be no little androids scurrying about. In the household of 2019, the first phase of home robotization will not be a single robot but a small family of intelligent appliances.

First of all, the house itself could be a kind of robot, an automated building with a central intelligence. The house's various systems—heating, cooling, lighting, security alarms, ventilation, closed-circuit television, light control—would all be subject to the direction of the home's central computer, a kind of automated majordomo. Buyers will assume their new home comes equipped with a central computer as standard equipment the way houses now come with indoor plumbing and fully wired for electricity. (See Chapter 10, "House Arrest," for more details on the home of the future.)

Futurists at the Massachusetts think tank/consulting firm of Arthur D. Little, Inc., suggest that the roboticized home will have automated centers where appliances are linked together into intelligent work teams. Getting a meal ready, they say, could be simplified with a dual unit that's part refrigerator, part microwave oven. In the morning you would preselect a frozen meal stored in your freezer. At the appropriate time that meal package would slide out a door into the microwave oven. By the time you walk in the door at night, a hot meal would be waiting. If you are going to be late, you simply call home and tell your home computer to delay the meal.

Even simple meals could be automated. You might be able to order

a sandwich in the same way. In fact, a grocery store in Yokohama, Japan, has a prototype of a robot sandwich maker. The Ham Slicer is a refrigerated meat container with a robot slicer and scale inside. A human customer simply walks up to it, taps a few buttons on the control console, telling the machine the kind of meat, the thickness of slices, and the weight he wants, and the machine cuts, slices, weighs, and wraps the meat in a matter of seconds. With a little adaptation, the same design could produce a masterpiece of a Dagwood sandwich as well.

Parked out of sight in a closet would be your robot vacuum cleaner. According to a preprogrammed schedule, it would roll out of the closet, cruise over a premapped course on the floor, and do the week's cleaning. The Japanese electronics firm Hitachi already has an experimental model of a robot vacuum cleaner that looks like a sleek, driverless car of the future. It sits quietly in the closet, foraying out to perform its functions. Still experimental and costing ten times what current vacuum cleaners sell for, the robot vacuum will no doubt be part of some of the more upscale, gadget-conscious homes in a 2019 suburb.

Training the machine is relatively simple, and it most likely mirrors how we will housebreak our own helpmates of 2019. First, the human reads off a word list to the robot. From this exercise the robot learns to recognize its master's or mistress's voice. Then the human tries out the voice commands, fine-tuning her ability to control the robot hand. Leifer's robot understands about 90 percent of the commands it hears.

The Stanford helper, like all companions, has three types of duty to perform. One type is the chores of daily living: getting meals and brushing teeth, for example. The second is small jobs or errands, called "vocational tasks": turning the pages of a book, opening a drawer or door. Third is recreational activities: playing a game of chess, for example.

These helpers are precursors of the electronic companion-valet, a robotic module with mix-and-match components. A basic industrial robot today can be outfitted with a wide selection of distinct attachments. For example, there are as many as fourteen different kinds of hands and several different styles of fingers customized to pick up different-shaped objects. Similarly, the homebot would seek out its utility closet and pop on a new hand or a new tool or even a new set of sensors with the same ease with which we change our clothes.

And there will be more and more things for these smart machines to do as they grow more adept. Although few homes have enough work to keep a robot working at the fever pitch of his industrial counterpart, we will no doubt find new tasks for this automated slave to perform. Artificial intelligence (AI) pioneer John McCarthy of Stanford University offered a little insight into what life with an intelligent machine would be like: "If you had this robot to work twenty-four hours a day, you would think of more and more things for it to do. This would bring about an elaboration in standards of decoration, style, and service. For example, what you would regard as an acceptably set dinner table would correspond to the standards of the fanciest restaurant, or to the old-fashioned, nineteenth-century standards of somebody who was very rich. People ask: 'What will happen when we have robots?' And there is a very good parallel. Namely, what did the rich do when they had lots of servants?"

As we get used to the luxury of having slaves at our beck and call, we may want them around for companionship as well. For those who care, robo-dogs and robo-cats will be a luxury we will all be able to afford. Computer game designer and entrepreneur Nolan Bushnell has designed a line of microchip powered, fuzzy animals—Petsters—that gurgle in response to a human voice. "Think of it as replacing biological animals. You get the good things without the bad. It's companionship without the kitty litter," he has said.

By 2019, these little creatures may be walking as well as talking and even coming at the beck of their master's or mistress's call. "There will be a time when you will be able to reconstruct Fido, the family dog, after it dies," suggests Bushnell, "and program the new version with Fido's personality. We may not be able to program a Fido, but we could have an electronic substitute."

Not all robot canines will be just cute pets. After reviewing the ingenious, but inadequate, machines devised as seeing aids for the blind, roboticist Susumu Tachi, of the Mechanical Engineering Laboratory (MEL) in Japan, decided that what the blind really need is a mechanical version of a guide dog. (In Japan, the need is pressing: With over 300,000 blind individuals, there are only about 350 guide dogs available.) By 2019, we may start seeing the first of Tachi's MEL dogs out on the street. He envisions them as compact walking machines with a handle on their backs so they can be picked up and carried onto a bus or up a flight of stairs. They can't be too small,

otherwise they might get stepped on. A good size would be about the bulk of a portable vacuum cleaner. Each would be equipped with a set of sensors and a built-in memory map. A blind person would simply tap a few of the braille-coded buttons on the back of his robot to tell it where it is and where he wants to go. The robot would get a fix on its current location and set off in the right direction, its footsteps premapped in its memory.

To be truly helpful, robots will have to be able to find their way around and to be able to manipulate the world around them. Industrial machines work in areas that have been custom designed for them—work spaces cleared of all extraneous debris and with materials set up within the precise reach of mechanical arms and hands. There is no clutter, nothing decorative. Military pick-and-place robots are now being designed to tolerate battlefield chaos, and this technology may well find its way into the home. But initially, at least, the home of 2019 will probably have to be made "robot friendly."

Today, the average house is a robot's nightmare of obstacles and unexpected challenges: stairs to climb; chairs, tables, and other furniture randomly scattered around; variable surfaces, from shag rugs to wooden floors; pets and small children wandering by at random; and hundreds of objects of varied sizes, shapes, colors, and weights.

A home that is comfortable to a robot domestic will have to correct at least some of these problems. And such rooms as the kitchen and bathroom may have to be customized for robot cleaning and maintenance. Tile walls and floors with a drain in the center would make it easy for a machine to scrub them down. Main rooms in the house would have to be uncluttered or at least cleaned up before the robot vacuumed. The rooms would be spare but airy, with as much built-in furniture as possible. Perhaps the floors would be of a type that a robot machine could spruce up easily, such as short-napped carpeting. Delicate furniture and breakables would be out of sight, perhaps in a family room that a human would clean on occasion. In a two- or three-story house, it might be practical to own a cleaning machine for each floor so you don't have to buy one of those new, very expensive wheeled robots with little extensor legs that let you walk them to another floor like an obedient dog.

By 2019, people may first start buying personal robots—(as distinguished from the domestic housecleaning machines)—simply for the novelty of it and for doing simple fetch-and-carry jobs. These small

and unthreatening machines will be able to do such things as take out the garbage, carry items, set the table.

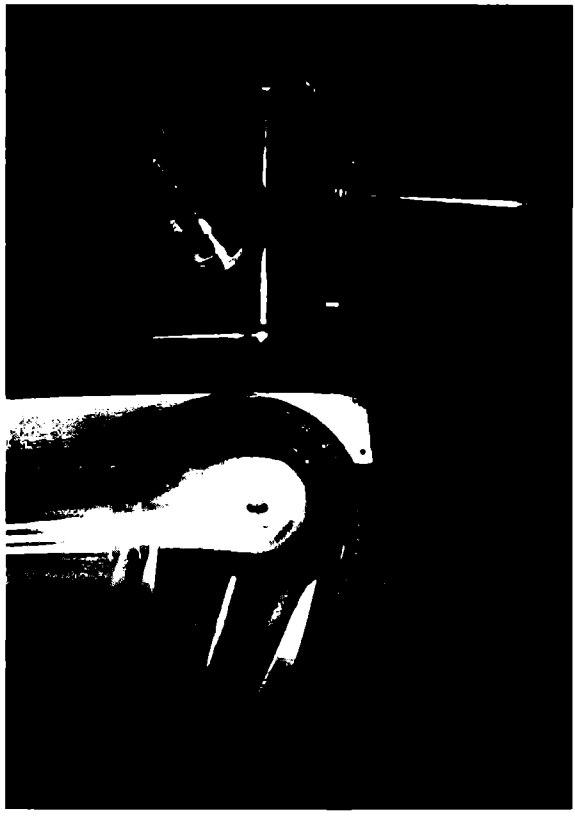
We could control these machines in a variety of ways. The house computer might supervise the comings and goings of all the smart machines. Or we could push a few buttons on a small control unit on our digital watch or the machine's torso to activate a preprogrammed behavior. A simple way to instruct your family robot would be with voice control. Already, today's personal machines have voices, computer memories, and even abilities like voice recognition. One very expensive (close to $7,000) personal robot, called Gemini, can recognize up to three different voices, then say a few well-chosen words itself.

For some people, voice control will be a valuable option. In devising a helper robot for the handicapped, Stanford University researcher Dr. Larry Leifer has already proved that we can make a robot do our bidding. His robot is a small off-the-shelf industrial arm with a two-fingered hand, featuring voice or joystick control and the ability to understand fifty-eight spoken words. By waggling the joystick or merely by telling the machine where to move (up, down, etc.), a wheelchair-bound person can have the machine hand things to him and even do a little fetching. With about forty-five minutes of training, a new user can learn, for example, how to teach the robot to get a glass of water. The Stanford group has already tested their robot with over a hundred handicapped people, aged five to ninety, with encouraging success.

Some experimental robot dogs already are wandering around Tachi's laboratory. The machine is tethered to its owner by an electronic leash through which the MEL dog keeps track of its owner's walking speed and adjusts accordingly. Two rearward-looking sensors help the machine make sure the human is directly behind it. Should the person wander too far to the right or left, the robot guide dog sends a brief electronic pulse to a stimulator on the user's right or left wrist as a gentle reminder to move more directly behind the machine.

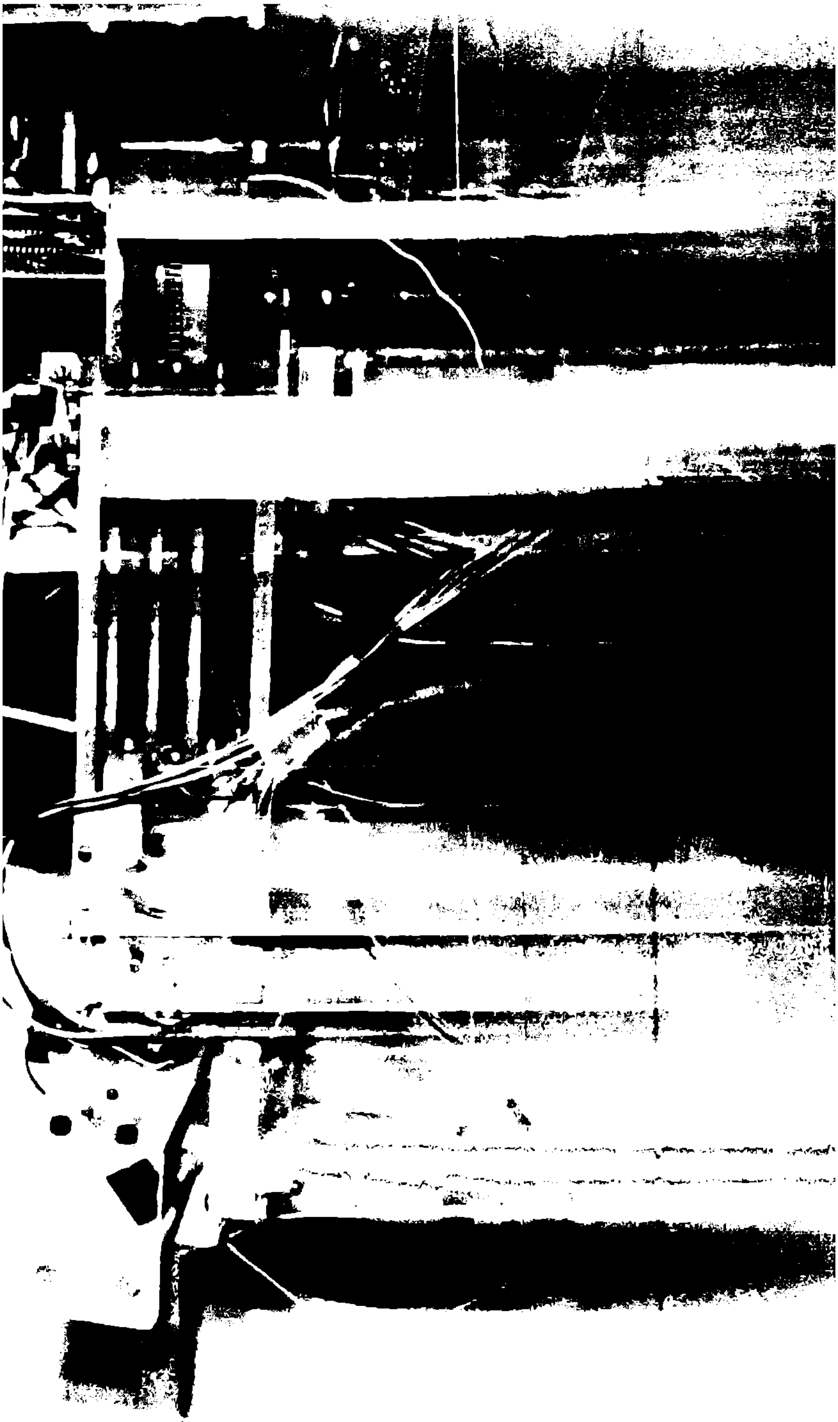
Life will be equally interesting for the robot outside the home, especially back in the factory where it began. By 2019, it will be the most common factory employee. By the turn of the century, experts estimate there could be as many as one million industrial machines in the United States alone, and their presence would affect as many as 3.8 million factory jobs now held by humans.

Robots of the twenty-first century may come in three models: male, female, and asexual.



A walking robot developed by the University of Wisconsin.

AROK the robot—one of the most famous robot sculptures.



The uniqueness of the roboticized factory will be evident as soon as you drive up to a plant. While most of today's industrial complexes are sprawling acres of warehouses and manufacturing facilities swarming with armies of workers, future factories will be more compact structures. They will have fewer people, and that will mean reduced space requirements: smaller parking lots and a lesser need in general for "people facilities" such as lunchrooms and locker rooms.

Because future factories won't need a lot of people, they can be built anywhere a company needs them: in the middle of a city or in a small, backwoods community—anywhere the plants are accessible by a major road or train line. The traditional business strategy of building where labor is cheap will be irrelevant. If the zoning permitted, manufacturers could just as easily erect a plant on Park Avenue as on the outskirts of Detroit.

The factory of 2019 won't have humans on the production lines. The factory of the future will resemble a more sophisticated version of Japan's Fujitsu Fanuc factory, where a hundred robots and only sixty humans produce ten thousand electric motors every month. Different areas of the work floor will resemble an industrial inferno: suffocatingly high temperatures, deafening noises, toxic fumes, and production lines working at killing speeds. Machines can operate easily in situations that are, literally, inhuman.

Rarely will there be a human in sight. Those who are visible will be there in a strictly subservient capacity: tuning up, adjusting, baby-sitting the steel-collar workers. Of course, no worker will be allowed on the floor without his safety coveralls on. Emblazoned on the front and back will be bar-code patterns that warn the worker machine, "Stop! A human is in your area." Since all the machines would have at least rudimentary vision, this is the simplest way of protecting human workers against death or injury. (People will still talk about the so-called robot homicides of the 1980s, when careless workers in both the U.S. and Japan stepped in the way of a blind and dumb machine, with fatal consequences.)

The robots will take many forms: work cells of disembodied arms, roving material-handling smart carts, or multiarmed "jack of all trade machines" that can be moved to a new work area, equipped with a new set of tools, reprogrammed, and put to work. Just as the computer industry began with time-sharing information and computer facilities, we will see time-shared robots, itinerant machine workers moving

from job to job and taught in an instant how to perform a new job.

The small army of sophisticated machines will be supervised by machine as well—the centralized factory computers. In a sense, the factory will be one enormous robot, the computer its guiding intelligence, and the machines on the floor parts of the grand design. "As automation becomes more flexible," explains Joseph Engelberger, "robots may lose their distinct character. They may simply be elements of the entire production organism. Science fiction has given us a counterpart of this phenomenon. In *2001: A Space Odyssey*, HAL is a distributed robot that we never see in an embodiment, but that permeates the space vehicle."

We are already seeing the beginnings of that in automotive plants, where a central computer coordinates the complex frenzy of automatic activity with an electronic chain of command called "local area networks," or LANs. Although different intelligent machines understand different machine languages, they can all be made to work together through a computer-translator-manager that makes machine language Babel coherent and efficient.

With this overlay of computer control, the "set-and-forget" factory will become the rule, not the exception. More and more plants will resemble the one run by the Magnesans Corporation in southern Sweden, where robots haul parts to work areas and every machine works at a typically inhumane pace all week long and straight through the weekend. No on-the-spot monitoring is necessary on the weekends, and the nearest human is ten miles away.

Productivity can be tuned like a car engine. When demands are low, different banks of machines would be turned off. When necessary, the output of such a factory could be herculean. Unlike present factories that operate one or two shifts per day, the automated factory could do the equivalent of four shifts.

As our smart machines take over the distasteful jobs inside our factories and homes, they will provide the same relief outside as well. By 2019, we will be able to call on a breed of machine known as the risk-taker, a kind of automated daredevil that will do deadly or deadly dull work: police work, inspecting the interior of a nuclear reactor or the depths of a coal mine, searching for survivors inside a burning building, and helping authorities defuse terrorist bombs, to name a few.

The Japanese government has mobilized an $88-million effort to

build a breed of risk-takers by the 1990s. By the turn of the century, they expect to have nuclear power plant robots and rescue robot firefighters, as well as robot miners.

To make such machines possible will require a drastic transformation of our regular robot, a transformation that has already begun. To find its way around in a world of random twists and turns and obstacles of all sizes and types, the risk-taker of 2019 will need sight.

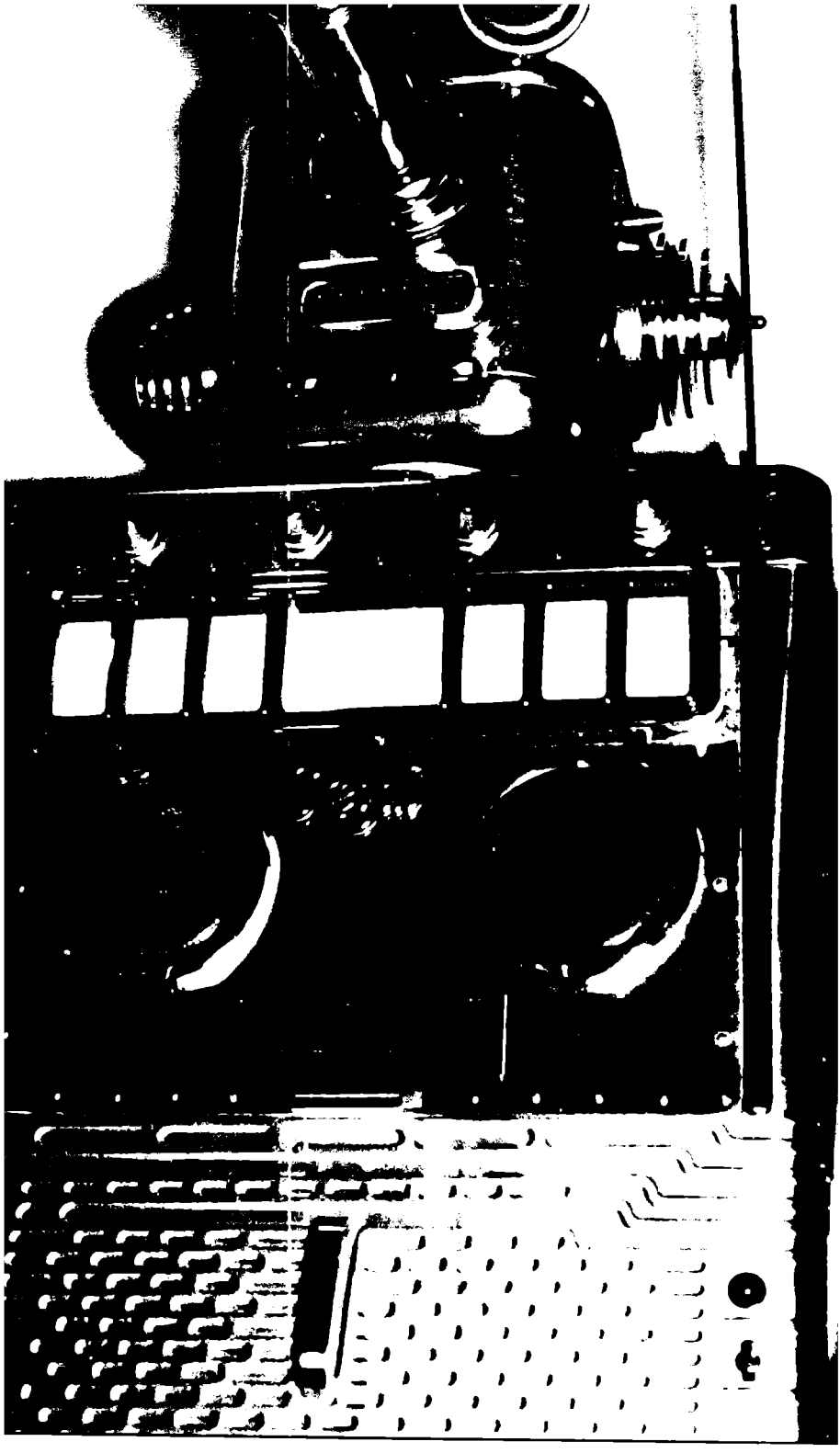
The most obvious choice would be to copy human vision, but it is not the most appropriate. For one thing, it is too complicated to duplicate fully. As vision expert Thomas Binford of Stanford University explains, "The retina of one eye has roughly a hundred million specialized cells and four layers of neurons, all capable of doing about ten billion calculations a second. And this is before any information reaches the optic nerve, which connects the eyeball to the brain." It is his guess that it could take as long as two hundred years to duplicate in a machine what we do every time we open our eyes.

For another, it will probably not be necessary. The eye is a limited sensor. It can detect only a small portion of the spectrum, has a sharply limited range of focus, and can work only under bright light levels.

Because of their specialized work, many of the robots of 2019 will not have anything resembling human vision. And they won't miss it, either. For inspecting radiation leaks, one machine might need "eyes" that are sensitive to gamma radiation. Another machine might function quite well as a roaming sentry with infrared and sonic sensors. (One Massachusetts firm has already built a sentry robot that uses such a system.) Vision will be customized to fit the job.

Outside the factory, on the farm, some Purdue University experts have an experimental model of a weed-killing robot that uses infrared vision to spot plant leaves and identify whether that plant is friendly or hostile before spraying it with weed killer. The University of California at Davis has a lettuce harvester that uses X-ray sensors. The machine focuses a weak radioactive beam at a row of lettuce heads and "reads" the beam that bounces back. In two seconds it can gauge the plumpness and density of a lettuce plant and decide whether the plant is ripe for picking. (In one test it outperformed experienced human lettuce pickers.)

Robots already have hands. What they will have in 2019 is a sense of touch fine enough to cradle an egg or a grip strong enough to pick up an engine block. The secret will be a skinlike covering that has a layer



of force sensors, the electronic equivalent of our nervous system, embedded in it. Already there are several candidates for cybernetic epidermis. At MIT, researchers have designed a three-layer robotic skin. The top and bottom layer is made of a flexible synthetic hide. Within the middle layer is a fine net of electrical conductors. When an object is squeezed against this skin, the points of pressure produce high and low surges of current that a computer translates into touch sensations.

In a variation of this design, Carnegie-Mellon University researchers have freckled the robot hand with pressure-sensitive dots of polymer film that produce an electrical signal when squeezed. University of Florida scientists have designed a rubber skin with a ridged pattern on it, somewhat like an exaggerated fingerprint. When pressure is applied by a squeeze, the ridges vibrate. Sensors under the skin relay these vibrations to a computer that reads them. And one ingenious Stanford University researcher has even suggested that the inside of a robot hand be lined with electronic hairs. Cheaper than some of the more sophisticated skin designs, the whiskers on the "hairy hand" design, as it is called, serve two purposes: They act like the whiskers of a cat and gently guide the hand so it is centered on an object before it grasps it, and, as the hand squeezes the object, they give pressure readings.

So the robots of 2019 will be able to see, feel, and in general have a keener sense of their world. But how can we bestow truly human capabilities on them? One way is to marry machine brawn with the human brain. It's an old idea, one that dates back at least to 1948, when a technician at the Argonne National Laboratory in Illinois was able to handle the hot debris from nuclear fuel with a pair of remote-controlled hands he designed. AI pioneer Marvin Minsky of MIT calls this field of quasi-robotics "telepresence." With telepresence, a human, using controls attached to his hands and arms, can direct a set of mechanical hands and arms at a distant worksite. Direct sensory feedback—touch and vision—from the machine makes the cybernetic limbs an extension of the human. Extending his reach yards, or even miles, with this technique, man can work remotely almost anywhere—from the ocean floor to the airless vacuum of space.

We have already seen the value of this teamwork of human brain and silicon brawn in hostile environments on Earth. Probably the best example of how well we can work in hostile worlds is the new genera-

tion of underwater robots called "submersibles." Humans do not tolerate the depth of the sea well. They can barely go a thousand feet down, are lucky if they can tolerate a few days inside the cramped quarters of a hollow steel diving ball, and the return to the surface is a risky ordeal. As U.S. Navy underwater-robot expert Robert Wernli puts it, "The ocean poses one of the most hostile environments that man can imagine, where extreme pressures, dynamic forces, corrosive attack, turbid water, and other problems usually deal Mother Nature a winning hand. Therefore, it is no wonder that the ocean engineer would rather extend his presence into the ocean remotely, if possible, and remain topside in a warm, comfortable environment next to the coffeepot."

Some robots, like the submersible Argo, developed at Woods Hole Oceanographic Institute, are of the "flying eyeball" variety, equipped to scan the ocean floor only with sonar and television cameras. (It was Argo that helped find the *Titanic*.) Others are hard-working machines. One of the best examples is the SCARAB (Submersible Craft for Assisting Repair and Burial), developed by an international consortium of telecommunications companies. SCARAB is a remote-controlled underwater worker equipped with video and still cameras, a set of electrically powered thrusters, and an on-board tool kit for its two robotic arms. Three people control the machine over a ten-thousand-foot umbilical.

By 2019, more and more people will sit by the coffeepot dispatching their fleets of machines to another hostile environment: space. By the 1990s, some of the first long-term space stations, designed to survive ten to twenty years, will be in orbit. To maintain an orbiting building that long, says NASA administrator Raymond Colladay, will absolutely demand that robots be working out there with humans. By then we will almost certainly begin to see work crews of what he called "expert robots" overseeing the maintenance of the space station.

But they will not work alone. The best space station design is one in which the dominant intelligence is still human, and NASA agrees. Culbertson has said that the ideal space station is one that is manned full time. Man-robot systems simply are more flexible in responding to crises as they occur, and people should be in space to supervise what is going on. Working the robots from an Earth-bound base is feasible, but it has its drawbacks, not the least of which is the time lag of half a

second or more between a command issued from Earth and its execution out in space.

The man-robot team is a formidable combination. We already have a preview of what this means in the robot arm, called the Remote Manipulator System (RMS), installed on the shuttle. With RMS, an astronaut can reach out fifty feet and deftly manhandle an object the size of a bus—sixty feet long, fifteen feet in diameter, and weighing over thirty-two tons. Future shuttles will have a pair of these arms installed on them and will therefore double the working capabilities of astronauts.

Yet even these will seem primitive when compared to robot configurations that will be coming along. Robotics expert Robert Freitas says that robotic arms will eventually cease to be rigid, jointed copies of human limbs, but will instead resemble long, serpentine tentacles, yards or even miles long. And in longer-distance telepresence operations, astronauts could orchestrate the repair of satellites or mining on the surface of the Moon from on board a space station. Already planned is a two-armed remote repair machine with stereo camera eyes called ROSS (for Remote Orbital Servicing System). It would be as dextrous as an astronaut and, with its stereo feedback and gripper controls, almost as sensitive. The human would simply maneuver it as a seeing/touching extension of himself to work around the outside of the space station, to do fine repair work on satellites hauled in for servicing, or even to mine the Moon or nearby asteroids.

To simplify control and make the sensations of the machine more immediate to the human controller, future robot supervisors may wear exoskeleton control units and special vision-hats. Joysticks and switches have too many limitations and don't give telepresence workers the sensation of being where the robot is. We already have prototypes of control units, like the UCLA "master glove" design that feeds back pressures and even temperature from a robot hand to a human one. And in the 1970s, a piece of technology called the Foveal-HAT (for Head Aimed Television) used two small television screens to deliver distant on-the-scene views. The image was so clear that the human wearing the HAT was able to drive a pickup truck through an obstacle course and park it by remote control. A day's work for a space station laborer will begin when he puts on his telepresence sleeves and hat and in a matter of seconds becomes a robot's brain. With stereovision

on the TV goggles and the delicate electronic sensations—all tunable to an operator's preferred level of feedback—an astronaut could perform herculean feats in space without burning up more than a calorie or two.

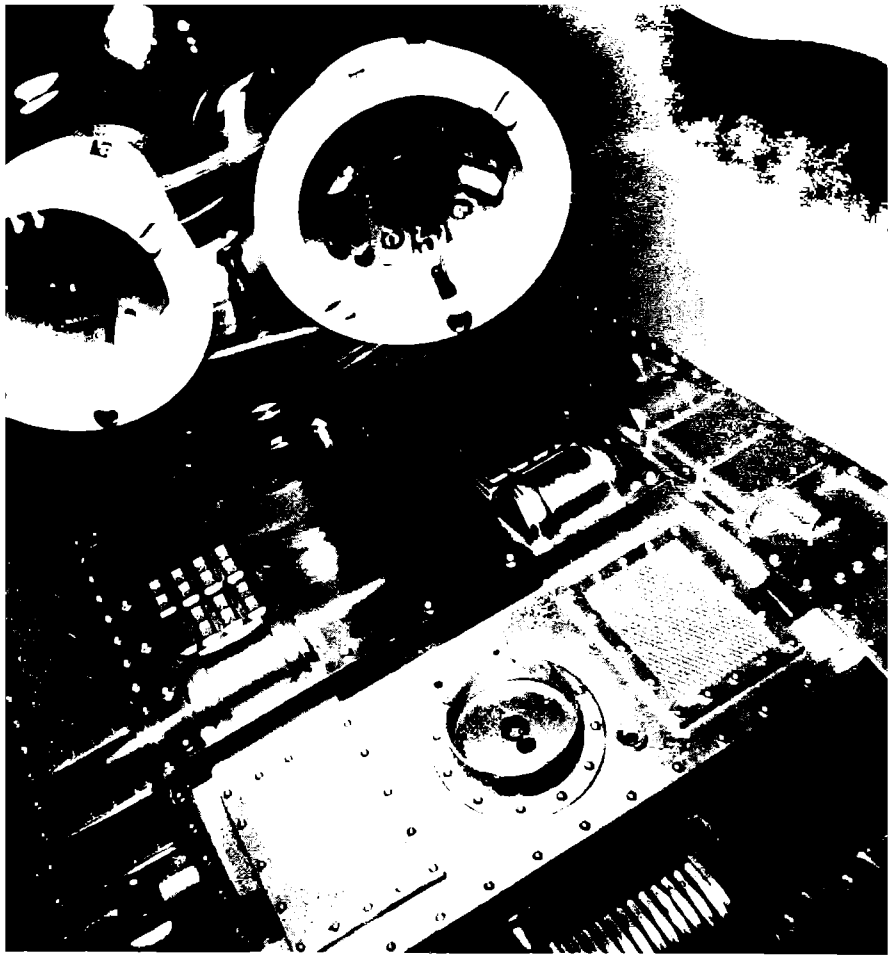
Robotic visionaries are also looking toward the day when humans in space do not have to control a robot's every move, but merely supervise them. Rather than move a machine through every step, astronauts will be able to simply tell their machines to "switch on console" and they will perform the job with well-rehearsed grace.

But what has to be the ultimate in robot participation is the notion first offered by Princeton mathematician John von Neumann. In the 1940s, von Neumann suggested that it was possible for a machine to do the machine equivalent of procreation—that is, replicate itself. Discussed in principle for decades, the idea of the self-perpetuating machine inched closer to reality until two NASA visionaries, George Tiesenhausen and Wesley Darbro, declared in the 1970s that we should think seriously about building a robot capable of making others like itself.

NASA thinkers have already roughed out the kind of von Neumann scenario that could take place on the Moon. Their plan is to set down a one-hundred-ton "seed" of robots on the Moon. On landing, different machines would carry out their programmed destinies. One cadre of machines would go to work erecting a solar-powered factory, while another would start mining operations, extracting raw materials from the lunar surface and hauling it to the factory. At the factory, a processing and manufacturing team would process the raw material into finished products: more factory parts, more machines, more robots. In time, each robotic team could duplicate themselves and go on to any other phase of manufacturing or procreation in their programs.

The idea of robots giving birth to other robots is hardly fantasy. Tiesenhausen and Carbro estimated that we could build the first self-replicating machine twenty years after we began the project in earnest. This means that if we begin now, by 2019 a self-perpetuating robot corps could already be established on the Moon. Then there would be two races of intelligent beings in the solar system able to procreate: humans and robots.

Visions like this raise the specter that for the first time in our history this helpmate—this tool that we invented—is likely to begin a process



of self-powered evolution. In short, what we are facing is the possibility that something we created as a tool could someday be a fellow Earthling.

That the robot will be considered more than just another machine is certain. The clues are all around us. One Japanese union complained that the phasing in of robots and the phasing out of union workers was depleting the union's finances because there were fewer members to pay dues. In response, the company offered to enroll the robots as union members. The Japan Labor Ministry was offended by the idea, declaring, "Robots cannot join a union like human workers." The union leader, however, declared, "We want the robots."

These machines are now dim-witted. Robot expert Hans Moravec of Carnegie-Mellon University says that "present robot systems are now similar in power to the control systems of insects." That will not always be so. By the 1990s, their level of development could be on a par with small animals, shrews, and hummingbirds. And in 2019, they may be

flirting with the beginnings of human-level abilities. Some believe that we are already there. Professor Ichiro Kato, the preeminent robot designer in Japan, says his WABOT 1, an intelligent upper torso that can read music and play the organ, has the approximate IQ of a five-year-old child. And he believes that by the turn of the century we may see experimental machines with the IQ of an older and wiser child of about ten years of age.

What this all means is that by 2019 we will see this amalgam of electronics and machinery beginning to take on a life of its own. As that happens, we will have to decide how to shape this evolving intelligence that we have created: what skills, emotions, and attitudes it will have.

As robots become mobile and begin to mix in the real world, as strange as it may seem, they will require certain attitudes and values in order to survive and do their jobs. The robot of 2019 will need the capacity to sense danger, a cybernetic version of fear. For example, to protect his roving machines from damage, Moravec has programmed into them something called "edge avoidance," a preprogrammed reaction to move away from an edge, such as the top of a step. Susumu Tachi has already installed in his guide dog a sense of self-sacrifice. Should the machine detect anything moving toward its master, the robot dog automatically sounds a warning and positions itself between its human and whatever is coming.

For years, science fiction writer Isaac Asimov has talked about his Three Laws of Robotics, a code of behavior that essentially forbids a machine to ever harm or allow harm to befall a human. Concern about killer robots ceased being the stuff of fiction in 1984 when a company called Robot Defense Systems unveiled a $200,000 robot sentry called Prowler (for Programmable Robot Observer With Logical Enemy Response). Designed for outdoor sentry duty, the machine resembles a small tank, carries an array of sensing equipment, and can easily be equipped with two M60 machine guns and a grenade launcher. Although a company official declared, "In the United States we don't foresee the prowler armed with lethal weapons," he also admitted that "there are countries where there aren't the same political or moral considerations." In other words, they would turn the robot into a killing machine.

Now that the military has asked for, and gotten, millions of dollars

for similar military robots (like an automated tank it hopes to see ready by 1995), we should start worrying about a higher level of values. Marilyn Levine, a professor at the University of Wisconsin, has suggested that we begin an organization she calls SAFE, for the Society for Algorithmic Functional Ethics. Her proposal came in reaction to the heavy military flavor of robotics research. "It became obvious to me that the federal government is spending more and more money on warlike robots. The military has been the primary source for this kind of research because they don't want to expend human beings in war; they want to make mechanical men. But no robot should be allowed to go out and kill," she asserts. "So I started with that premise."

Her suggestion is to program into robots the machine intelligence equivalent of "Thou shalt not kill." For a machine, much of this involves restricting a robot's use of force. "The concept of doing harm comes down to how you apply force," she says. It is a concept, she agrees, that we cannot install in robots now, but one which we will have to think about before it's too late.

By the time 2019 arrives, we will have to face the equally complex questions of what rights these machines hold. John G. Kemeny, an inventor of the computer language BASIC, has already said that computers could be considered a species of life. We could well imagine having to deal with machine rights organizations similar to the militant animal rights groups now in existence. Marvin Minsky of MIT posed the question best when he predicted that once machine intelligence has grown to a certain level, "then we'll be forced to ask ourselves how we should treat the minds we make. . . ."

Putting it in a more down-to-Earth context, Carnegie-Mellon's Herbert Simon, another AI pioneer, suggests, "Suppose we had a race of robots which were exactly like humans with one important difference—they were less subject to mental and physical disease. They were of course made of metal or whatever, but in a way that they were cuddly enough.

"Now we're going to have a referendum," he continues. "We want to transmit our human culture to future generations. Are we going to select these creatures to transmit the culture?" How would he vote? "I don't know," he says, "because voting against the robots almost sounds like a form of race prejudice."

When we come to face these questions, we will also come to a

humbling realization. Just as the tools of primitive man helped him evolve into a creature of higher intelligence, this new tool we have created—the robot—could help us make another evolutionary leap. This time, however, that evolutionary leap may have an ironic twist. *Homo sapiens*, if he is remembered at all, may be noted in the history of intelligent life as just another long-gone evolutionary phase. And the tool he had created will have become his successor.

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You have requested: EDUCATION CREDITS RATING #2A42287—TYI5
Subject: John S. Stanton
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Address: 843 Condo-Tower West, Aquacity, Atlantic-Offshore, Zone 2
Current Employment: Submersible Technology Engineer, Seabed Mining Division, Mobil Corporation

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Age When Earned	Credits
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5—6	Kindergarten, Balsam Central District, Balsam, OR
6—11	Balsam Elementary School
11—14	Balsam Middle School
14—17	Balsam High School (Science Subschool) (A)dvanced (P)lacement Chemistry I (U. of OR, Televideo Instruction Div.) AP Physics I (U. of OR, Televideo Div.) Elementary Robotics (Compuschool, Inc., On-Line Classroom)
17—21	U. of OR, B.A.: major—human expression; minor—physics (for course list, press C-I)
22—26	General Dynamics Corp., Employee U., M.S.: electrical engineering; specialty—low-grav robotics
29	General Dynamics Corp., Employee U., "Lunar Mining Modules" (televideo course)
30	McSchools, Inc., Boston, MA: "Elem. Chinese," "Chinese Philosophy," "History of China"
31	General Dynamics Corp., Employee U., Lunapolis, "Doing Business in China" (disc-class)
33	General Dynamics Corp., Employee U., Peking Branch, "Principles of Submarine Robotics" (televideo course)
35—36	MobilSchool, M.S.: submersible engineering
37	McSchools, Inc., Houston, TX, "Underwater Fun with an Artificial Gill"

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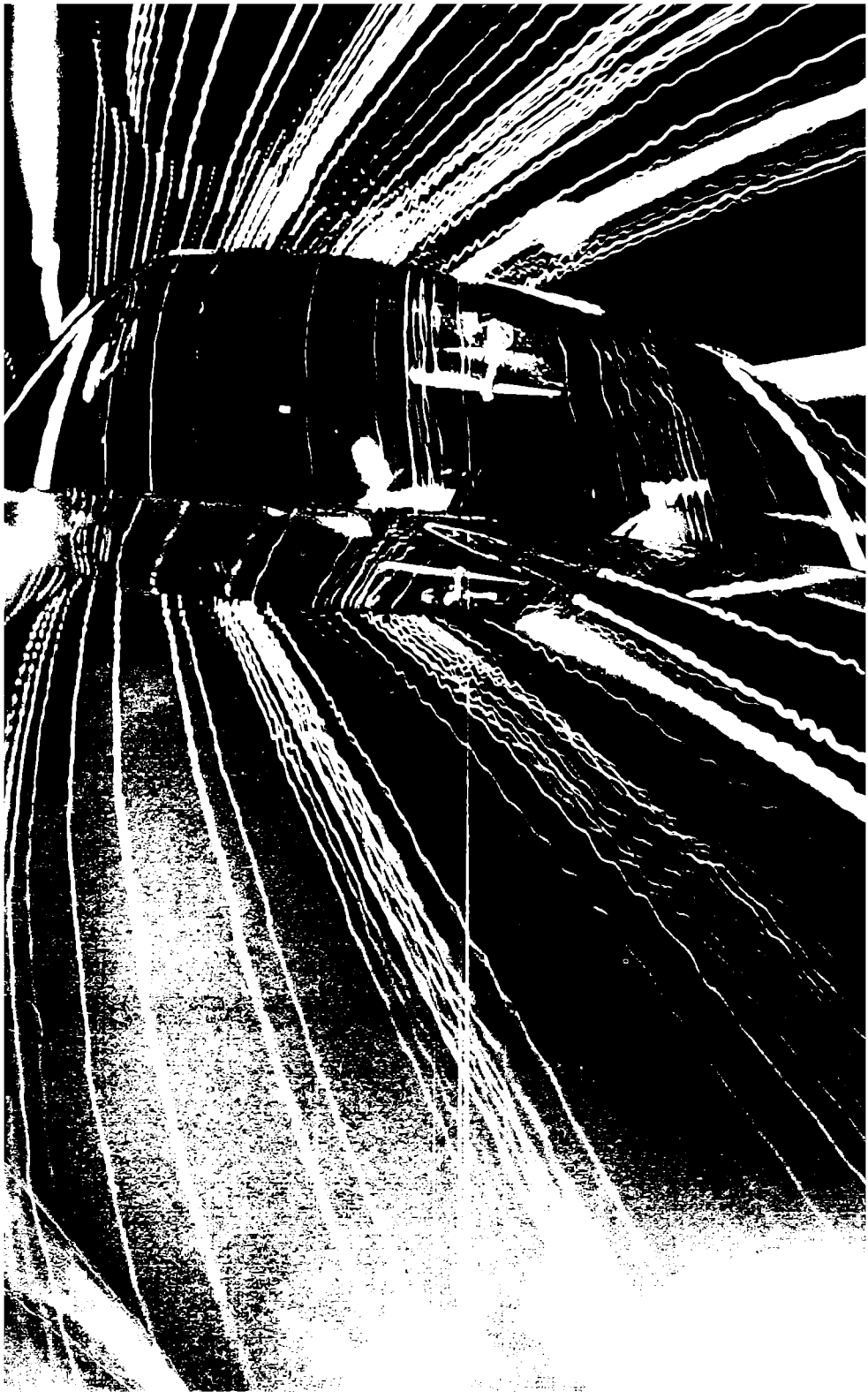

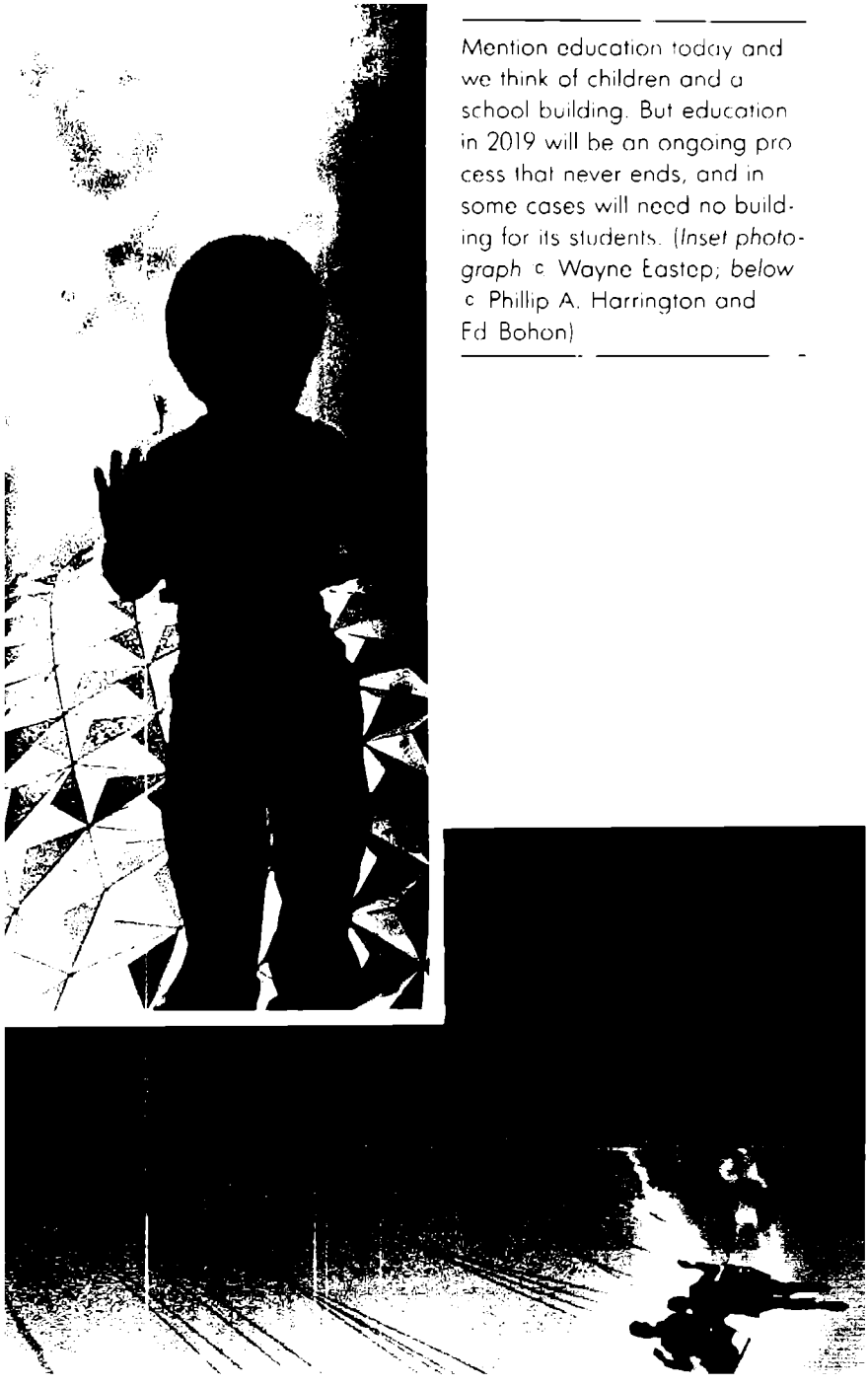

Mention education today and we think of children and a school building. But education in 2019 will be an ongoing process that never ends, and in some cases will need no building for its students. (*Inset photograph* © Wayne Eastep; *below* © Phillip A. Harrington and Ed Bohon)

ARTHUR C. CLARKE'S

JULY 20, 2019

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