# THE ALLIANCE TO RESCUE CIVILIZATION: A LUNAR BASE FOR PLANETARY DEFENSE

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There is a character named Osepok in Buzz Aldrin's and John Barnes's epic tale of crossed civilizations, *Encounter with Tiber*. She is the skipper of a huge intergalactic spaceship and is a very wise woman. (I imagine the authors gave command of a large star cruiser to a woman because women ask for directions.) At any rate, Osepok preaches the imperative to explore and settle distant worlds. The reason, however, has nothing to do with the usual, vague, reference to humanity's innate drive to see new places for the sake of sheer adventure. The operative word is 'imperative.'

"There's not a place in the universe that's safe forever," Osepok warns her crew. "The universe is telling us, 'Spread out, or wait around and die.'"

Spread out, indeed. But not for so many reasons that by sheer number they fragment to the point of paralysis. I must therefore tell you that gaining a foothold on the Moon, contrary to what is on this meeting's agenda, will indeed require one single strategy. It will require focusing the space program on the single objective that no one could call self-serving, frivolous, or socially insensitive. It is a strategic goal that is truly imperative: to maximize the chances of our species' survival in an abidingly dangerous world. It is a strategy that calls for using space, including a large habitat on the Moon, to protect Earth. This will necessarily require continuous access to low Earth orbit and beyond, and that, in turn, means creating the astronautical equivalent of a commuter jet: a reusable single or two stage to orbit spacecraft that will open the way to the establishment of a lunar base and then a large self-sustaining colony. Industrial and scientific research, tourism, mining helium and precious metals, ice recovery, and the rest will follow. But it seems to some of us that the very "diversity" called for by the foundation, while appearing to generate synergy by covering several bases, in fact does the opposite because of its inherent diffusion. Put bluntly, there are too many pigs at the same trough, so all are going hungry. The space program is in serious disarray for lack of a single, truly vital, and far-reaching goal. That goal should be to protect Earth from catastrophe.

The fact that danger is everywhere is not news to astronomers or to the space scientists who have been studying this solar system since Mariner Venus inaugurated planetary exploration forty years ago. Even before then, telescopic views of a severely pockmarked Moon and large impact craters right here on Earth were stark evidence of catastrophic collisions between both bodies and intruders moving at 20,000 miles an hour or faster. The astronomers have seen stars in their death throes erupt as supernovas – the largest thermonuclear weapons in creation – and spew immense heat and poisonous radiation in all directions. And thanks to the Hubble Space Telescope, they have been awed watching whole galaxies come together in massive, phenomenally violent, collisions.

Their colleagues in physics, chemistry, geology and other disciplines who study the planets – this one included – and their retinues of orbiting mini-worlds know there is irrefutable evidence everywhere in nature that there have always been immensely destructive forces at work and that they will continue for eternity. Whatever else the phenomenal imagery sent back by the Vikings and Voyagers revealed, it showed

explicitly that chaos and violence are everywhere. Mercury, Mars and several of Jupiter's and Saturn's moons – Ganymede, Callisto, Io, Enceladus, Mimas and Tethys, for example – bear scars that are vivid evidence they have suffered an endless rain of blows by asteroids and comets that wander around the neighborhood at fearsome velocity. In 1994, incredulous astronomers got their first look at a massive cosmic collision when a string of twenty-one huge fragments from the disintegrated comet Shoemaker/Levy-9 plowed into Jupiter's gaseous atmosphere and disappeared in the violent storm that never ends on that planet. Each of those fiery fragments would have immolated Earth.

Our home has taken its own hits, some of them calamitous. One cosmic wanderer exploded over the Tunguska region of Siberia on June 30, 1908, scorching and leveling trees within a radius of twenty miles and knocking people to the ground forty miles away. Eyewitnesses reported seeing a bluish-white flash and hearing a tremendous explosion. We now call objects that strike Earth with that kind of force "city busters," and it certainly would have busted this city. There was one obvious blessing about the Tunguska Event, and one not so obvious. Obviously, it happened over a forest, not a heavily populated area. Less obviously, it didn't happen over either the Soviet Union or the United States during the Cold War, when it could have been taken to be the beginning of a nuclear attack and triggered a response in kind.

That having been said, there are as many as ten nuclear powers on this planet, most of which do not have very good early warning systems. Brig. Gen. Simon Worden of the Air Force, who is himself an astronomer, said at a National Space Society meeting in Denver in May that where Earth-bound asteroids are concerned, he tends to "sweat the small stuff." U.S. Defense Support System satellites parked at geosynchronous that look for ballistic missile launches spot roughly thirty meteors detonating in the upper atmosphere every year in a kiloton or higher explosion, Gen. Worden said. That's dangerous enough. But if a Tunguska size rock turned into a fireball and exploded over New Delhi, Islamabad, or Tel Aviv, he added, it could be confused with a nuclear detonation and trigger an unspeakably terrible reprisal.

There have in fact been many impacts over the millennia, some of them still in evidence in what is now Arizona, Quebec, Chad, and elsewhere. Undoubtedly the two worst are thought to have rung up the curtain on the dinosaurs and then rung it down.

The first, which happened roughly 251 million years ago, seems to have been the mother of all Earth impacts. It either caused or coincided with a colossal volcanic eruption and molten lava flood. Together, both events severely contaminated the atmosphere, poisoned the oceans, and killed off roughly ninety percent of marine species, seventy percent of land animals, and most vegetation. That was the bad news. The good news, at least for dinosaurs, was that it seems to have cleared the way for them by annihilating the competition for scarce food.

But the reptiles got theirs roughly 190 million years later when another asteroid or comet, this one estimated to be seven miles wide, slammed into what is now the Yucatan

Peninsula, finishing off almost all of the dinosaurs and an estimated half of other species. And it did more than that, as Carl Sagan vividly explained in his homage to Earth and humanity, *Pale Blue Dot*:

"In sequence, a world-immolating fire burned vegetation to a crisp all over the planet; a stratospheric dust cloud so darkened the sky that surviving plants had trouble making a living from photosynthesis; there were worldwide freezing temperatures, torrential rains of caustic acids, massive depletion of the ozone layer and, to top it off, after the Earth healed itself from these assaults, a prolonged greenhouse warming [set in]. It was not a single catastrophe, but a parade of them, a concatenation of terrors. Organisms weakened by one disaster were finished off by the next. It is quite uncertain whether our civilization would survive even a considerably less energetic collision."

Sagan's tribute to solar system exploration warned about the threat of collisions with Earth-crossing asteroids and used the menace as another justification for colonizing other worlds. The stone or metal cosmic wanderers are very likely themselves the progeny of other violent collisions with what he called once-larger worldlets.

The most recent visitors to our neighborhood arrived this year. At 6:37 eastern time on the evening of January 7th, a dirty rock the size of a large shopping center suddenly streaked out of space at 68,000 miles an hour and crossed our path at a distance of 515,000 miles. It had been discovered only two weeks before by astronomers at Mount Palomar in California. That distance may not seem close by earthly standards, but it amounted to a near miss in astronomical terms. (Sagan preferred "near hit" to "near miss.")

Two months later, on March 8th, a second one, measuring roughly 200 feet, flew even closer: 288,000 miles. Because it came from the direction of the Sun, it wasn't even spotted until four days after it passed us.

Then, on June 14th, yet another one streaked by. At a distance of 75,000 miles, it was less than a third of the distance to the Moon. The 100-yard-rock, which was promptly named 2002 MN when it was spotted three days after it passed, was moving at 23,000 miles an hour. Astronomers think several close passes – though not that close – occur every year but are undetected.

None of these asteroids threatened Earth, nor are they expected to in this century when they swing around and return during their long orbits around the Sun. Furthermore, the destruction they or any other Earth-crossers could inflict depends not only on their size and velocity, but on their composition. All else being equal, it's better to be hit by a lightly compacted rock than by heavy metal.

The astronomical community was emphatically not disconcerted by the flybys. It's not that astronomers are impervious to the danger posed by so-called near-Earth asteroids, or NEAs. To the contrary, they are inured to it. They know that about fifty times a year, 100-meter asteroids pass within Moon distance of Earth and, as I said, some a lot closer.

Brian Marsden of the Harvard-Smithsonian Center for Astrophysics in Cambridge called the passing of 2002 MN "a close shave." And Grant Stokes, another asteroid specialist, said that in the unlikely event it had plowed into a populated area, it would have released as much energy as a large nuclear weapon and there would have been "considerable loss of life." Marsden, Stokes, and others know an asteroid doesn't have to be a city-buster to cause appalling death and destruction.

The rule of thumb is that the probability of taking a world shattering hit is far less than colliding with a big city-buster, and the chances of running into a city-buster are in turn less than getting beaned by one that's 100 meters. The "small" asteroid that streaked by on March 8th would have hit with the equivalent force of a five megaton hydrogen bomb and decimated a small city.

The probability of colliding with a 100-meter asteroid has been calculated at roughly once every 100 to several hundred years. An Earth-crosser with that kind of heft plowing into a populated area would cause substantial death and destruction. It would also disrupt the social infrastructure in many ways.

Astronomers who are especially knowledgeable about the danger posed by asteroids and comets are therefore trying to devise ways to avoid an impactor by disrupting or deflecting it or otherwise mitigating the danger of a collision. More about defense when we review two films. A major workshop on mitigating hazardous comets and asteroids is scheduled to be held in Arlington, Virginia from September 3rd to the 6th under NASA's auspices.

Meanwhile, Congress and the space agency are sufficiently concerned about the impact threat that the NASA is sponsoring a program called Spaceguard to catalogue at least ninety percent of Earth-crossers that are a kilometer or larger. Astronomers in Great Britain and Italy are also searching the heavens for potentially dangerous intruders, and so are others at various universities in this country, including the scientifically-oriented Spacewatch Project at the University of Arizona, and the Harvard-Smithsonian Observatory, which publishes a continuously updated Potentially Hazardous Asteroid list that currently lists 725 through the year 2178 that will come with a half AU of Earth.

NASA's newly created Near-Earth Object Program Office is also operating a highly automated monitoring system called Sentry that is supposed to continuously update the orbits, future close Earth approaches, and impact probabilities of all near Earth asteroids. That's how seriously the threat is being taken.

And, understandably, everyone is calling for more powerful telescopes and increased funding. It's hard to argue with the reasoning, since a dangerous impactor obviously can't be deflected or destroyed unless its size, velocity, composition, and trajectory are precisely known decades ahead of time.

The answer, for Gen. Worden, is to intensify planetary defense by cataloguing all objects that are potentially threatening, even those smaller than a kilometer. He also

favors using a small armada of satellites, including microsatellites, to keep track of all potentially dangerous rocks.

The visitor that passed on January 7th, by the way, was in the bigger-than-city-buster class. It would have demolished a large part of a country the size of France and in the process set off climate problems and a global economic meltdown. (An old friend with a wry sense of humor has pointed out that nuclear winter or its asteroid-induced equivalent would be beneficial because it would counteract global warming.)

Even if Spaceguard eventually succeeds in cataloguing virtually every city-busting Earth-crossing asteroid, there remain other bodies out there whose trajectories cannot be predicted. I refer to long-period comets in the Oort Cloud, which is more than 50,000 astronomical units from here, and which is infested with them. Shoemaker/Levy-9's attack on Jupiter is generally well known, at least in astronomical circles. Less well known is the fact that comets have been grazing or plowing into the Sun at least since 1680, when Edmund Halley saw one barely miss it. P78-1, an Air Force scientific satellite, spotted six others that passed close by, or collided with, the Sun between 1979 and 1985 when the spacecraft itself was destroyed in a Department of Defense anti-satellite weapons test that stunned P78-1's scientists. Talk about fire and ice. The "kamikaze comets" were called SOLWIND 1- 6 and none of them was spotted from the ground. Solar Max, which recorded SOLWIND 5's shot at the Sun, saw ten other sungrazing comets on its own before it disintegrated during reentry in December 1989. They struck or streaked by without warning. And Jupiter has had its own run-ins with comets other that Shoemaker/Levy-9. Its powerful gravitational pull has drawn comets very close. One of them, called Wild 2, actually went into a very eccentric orbit around Jupiter in September 1974. Its perihelion was very close. So unlike asteroids, which can be catalogued, many comets defy prediction. That makes them the potentially dangerous wild cards of the neighborhood.

One facet, as noted, has already begun. On the reasonable assumption that the first rule of self-protection is to know your enemy, Spaceguard went into effect a decade ago. The organization puts out a Near Earth Object, or NEO, newsletter on the web periodically with the latest information on which potential Earth-crossers are where and other material germane to the project.

An asteroid or comet that is on a collision course with Earth will obviously have to be dealt with. On that score, the Robert Duvall-Bruce Willis asteroid defense plan – blowing the thing up with one or more nukes as they did in the films Deep Impact and Armageddon – is not taken seriously in the real world. In both films, nuclear weapons were planted in holes bored into the asteroid, then they blew the dirty rock into two huge pieces. In Deep Impact, one piece hit the ocean, causing a horrendous city-smashing tidal wave. In Armageddon, the Texas-sized asteroid was neatly blasted in half. Each chunk streaked harmlessly past Earth at a distance of 400 miles. The world was saved and Bruce Willis, playing the planet's preeminent oil driller who set off the explosion in the hole by hand, was martyred. In reality, blowing up an asteroid would turn a cannon ball into grapeshot, probably transforming a large city-buster into several town-busters, especially if the explosion is set off at close range.

However improbable Deep Impact and Armageddon were, by the way, they were appreciated by the people who are working on the real thing. Donald K. Yeomans, who heads the Near-Earth Object Program Office at JPL, has said that both films were welcome because they got the public's attention and therefore Congress' as well.

Space Command has commissioned at least one think tank to come up with plausible scenarios to prevent getting clobbered. There is general agreement that nothing remotely like the Star Wars ballistic missile defense will work. That's because waiting until the intruder is bearing down on us at 20,000 miles an hour or faster before zapping it with a laser or rail gun or a nuclear weapon would not only create the grapeshot, it would allow it to get too close for a second try if the first doesn't do the job.

The idea, at least as it looks now, would be to spot the intruder decades ahead of projected impact, which is the essential reason for the Spaceguard catalogue. That would give the Space Command plenty of time to meet the asteroid and deflect it – turn it away – so far ahead of a collision that its tremendous velocity could be safely overcome. The hardest part would be the rendezvous. And that has already been done. In February of last year, the Near Earth Asteroid Rendezvous Shoemaker spacecraft that had been orbiting a twenty-one-mile-long asteroid named 433 Eros and sending back thousands of pictures and other data for about a year actually landed on the speeding rock and returned still more details from as close as anything could get. It was the first time a machine from Earth landed on an asteroid and it opened the way for all sorts of possibilities, scientific and commercial. Needless to say, NEAR Shoemaker's project scientists were ecstatic. And at $223 million it was a cheap mission.

Nor, of course, is the threat to Earth restricted to foreign body impacts. The subject of nuclear winter – postulated in 1982-83 by Sagan and four colleagues after seeing pictures of a global dust storm on Mars sent back by Mariner 9 – brings to mind the possibility of thermonuclear war. And as is the case with asteroids, one need not go back to ancient history – in this case, the cold war – to find the source of danger. Aside from all the residual nuclear weapons and fissile material under dubious protection in Russia, a number of nations have active nuclear weapons programs and two of them, India and Pakistan, were recently eyeball to eyeball and, as far as I know, are still on some kind of alert. India's prime minister was quoted only last month as saying his country was prepared to risk a nuclear attack by Pakistan to end terrorism in Kashmir and elsewhere. Such an attack would of course be answered in kind.

To large missiles of rock or iron and nukes add chemical and biological agents that remain stockpiled in the former Soviet Union, have been produced by a number of so-called rogue states, including Iraq, and by talented amateurs in Japan. And there can be no doubt that apocalyptic terrorists of one stripe or another want to produce or acquire them. The witch's cauldron includes anthrax, cholera, plague, and a slew of nasty and easily transmitted viruses such as ebola, smallpox, and yellow fever.

To those diabolical concoctions add the increasing possibility of a naturally occurring pandemic. Writing in the *New England Journal of Medicine* in December 2000, Dr. Cynthia G. Whitney, an epidemiologist, attributed a clear increase in resistance to penicillin to "survival of the fittest" in the bacteriological world. Bacteria with natural resistance to a given antibiotic manage to survive and multiply. And if the same antibiotic is given again, she reported, the process repeats itself until, gradually, the resistant bacteria predominate. Tuberculosis, which was almost wiped out by antibiotics after World War II, is back. A drug resistant strain is not only on the rise in poor countries, but in better off ones as well. Laurie Garrett, a Pulitzer Prize-winning science writer, has written a heavily researched account of the microbial menace in *The Coming Plague: Newly Emerging Diseases in a World Out of Balance*. As human population surges, ecologies collapse and simplify, she explained, and disease organisms move into the gaps. She predicted that globalization will probably worsen the situation since diseases can migrate as fast, as far, and as frequently as planes can fly.

There is the possibility of truly catastrophic volcanism, in which a flood of super-hot lava spreads over a huge land mass, as happened in what are now called the Siberian Traps. Geologists believe such eruptions have happened about a dozen times in the last several hundred million years. The most destructive explosion in the last 10,000 years happened at Mount Tambora in Indonesia in 1815. The eruption shot twelve cubic miles of gas, dust and hot rocks into the atmosphere, severely polluting the surrounding area and killing about 10,000 locals. Typically, the effects of the blast were far-flung. Parts of Earth were chilled for many months because of lingering clouds of thick atmospheric debris that contributed to epidemics in Europe and widespread crop failure in North America. Massive earthquakes have taken their toll, too. As Bob Shapiro, my colleague in the Chemistry Department at NYU, has said: Contrary to what tree-huggers think, nature is not purely benevolent. To the contrary, it can be terrifyingly violent and deadly, as those caught in the path of furious rain and wind from Bangladesh to the Caribbean know so well. And you know as much as you want to know about global warming.

And certainly technology can bite back. A worldwide electronic meltdown would create horrific communication and transportation problems in computer-dependent societies all over the globe. The internet, which is connected by a vast number of nodes, is highly resistant to random failure, as is the complex global society it serves. But, also like society as a whole, the internet is very vulnerable to targeted disruption of the most highly connected nodes. As we know, the new breed of terrorist is computer literate, and therefore has the capacity to paralyze the systems that keep our society functioning.

All that having been said, I am very optimistic about the fate of the Earth. The litany of catastrophes I just rattled off is loaded with very low probability occurrences. I mentioned them because I am an unabashed alarmist. And I am trying to play doctor. Physicians are trained to think in terms of the worst case scenario first, and then work backwards, eliminating the most serious dangers in descending order. When you tell your physician you have chest pains, for example, he or she first thinks of the possibility of a heart attack, not heart burn. Only after a heart attack has been categorically eliminated does the next, less threatening, possibility get attention.

I agree with one scientist who was quoted in *The New York Times* a few years ago as saying that Earth is a very seaworthy craft sailing through space. But no matter how seaworthy a ship is, no skipper in his or her right mind would go to sea without a lifeboat and insurance. Planetary defense is both. Put another way, like everything else in the cosmos, the inhabitants of Earth and the planet itself have life cycles that start with birth and end with death. Between the two there are opportunities to be seized, pleasures to be had, and dangers to be avoided. I increase my chance for survival by not smoking, staying out of dangerous neighborhoods in the middle of the night, having routine medical examinations, and seeing a physician when I am ill. It's the same with Earth. Its chance for survival improves when pollution and other assaults on the environment are reduced, threats in the bad neighborhood are anticipated and either avoided or countered, and potentially debilitating afflictions are treated and cured.

Now to move closer to the problem haunting NASA and much of the rest of the space community. To the list of nautical metaphors that have symbolized this nation's space program since its inception – rocketship, spaceship, starship, spaceport, life boat, new ocean, Mariner, Magellan, Viking, Delta Clipper, Atlantis, Columbia, Discovery, Endeavour, and Enterprise – add becalmed.

In October 1951, with the cold war underway, the military situation looking bleak in Korea and exceedingly dangerous in Europe, and Mikhail Tikhonravov claiming that the Soviet Union was probably going to build a space station – this is six years before Sputnik – Wernher von Braun presided over the First Annual Symposium on Space Travel at the Hayden Planetarium in New York. There, a galaxy of visionaries including Willy Ley, Heinz Haber, and Fred Whipple, the Harvard astronomer, laid out what was supposed to be a richly detailed blueprint for the coming age of space. Its heart was the "conquest" of space by men who were supposed to successively use shuttles to build a revolving doughnut-shaped station in permanent orbit that would itself be the embarkation point for a rocket-propelled expedition to Mars. The Red Planet would in turn be settled and colonized in what true believers everywhere took to be another expression of the human race's innate manifest destiny. The phenomenally ambitious plan was serialized in eight installments in *Collier's* magazine from 1952 to 1954. For 15 cents apiece, or $1.20 in all, the plan for mankind's role in space, right down to the physiological challenge, all nicely illustrated, could be had by anyone.

It was a fantastic dream that was further shaped by the likes of Jules Verne, Konstantin E. Tsiolkovsky, Arthur C. Clarke, Isaac Asimov, Gerard K. O'Neill, Carl Sagan, and many others. The immensely gifted and charismatic von Braun was soon recruited by Walt Disney to appear in a specially designed television series called Tomorrowland that was part of a larger series called The Wonderful World of Disney. There, an earnest-looking von Braun, shirtsleeves rolled up, gamely used models of his shuttle and Mars expedition ships to preach the revealed gospel.

The dream was brought to an abrupt halt in May 1961 when President Kennedy challenged the country to send astronauts to the Moon within the decade. Apollo was an

unparalleled managerial and technological tour de force, the greatest feat of human exploration in history, a cohesive patriotic force in the United States and the West, and what Kennedy wanted most: a sensational propaganda triumph.

But Apollo also created a conundrum that haunts the space agency and the broader community to this day. By short circuiting the gradual, measured, progressive move to space in a careful sequence by launching capsules on top of colossal ballistic missiles, NASA achieved a level of drama that was virtually impossible to repeat. For sheer excitement and adventure, only an expedition to Mars stood a chance of equaling the Moon landings, and even that was dubious because of the time required to get there and return.

But in any case the Mars mission was moot. There was no appetite for the exploration of Mars after the near-instant gratification that came with

Buzz Aldrin's, Neil Armstrong's and Michael Collins's nine-day round trip to the Sea of Tranquility. The end of the cold war and the attendant collapse of our main rival in space only contributed to the public's ennui. Send people back to the Moon or to Mars for fun and adventure? Been there. Done that.

NASA's response was to abandon the get-their-attention-with-death-defying-thrills strategy and instead claim that its objective was to make access to space as steady, safe and dependable as airline service. That was a commendable goal and it was achieved. There are obvious parallels between the development of aviation and spacefaring. But it created another conundrum. People haven't gone to airports to watch planes takeoff and land since the 1940s.

The space program was increasingly taken to be wasteful by ordinary citizens who were preoccupied with challenges on *terra firma* such as quality of life, including the eradication of dread disease, better education, and equitable opportunities for all citizens. Justified or not, images of astronauts floating in near-zero gravity or bolting together station modules are considered by most people I know, including university professors, administrators, and both undergraduate and graduate students, to be frivolous and irrelevant to their lives, liberty, and the pursuit of happiness.

The grand scheme for the conquest of space, and the Apollo program that derailed it, were profoundly contentious. Yet they shared one crucial characteristic: both had a clearly delineated goal on which to focus. An overarching goal in space is now long gone. The space program began to go out of focus on December 14, 1972, when Gene Cernan, the last man of the Moon, packed up and went home.

The intervening years have seen a number of triumphs, notably space science programs such as Voyager's Grand Tour of the outer planets, Galileo's extraordinary close inspection of the jovian system, the Viking and Mars Pathfinder missions, and of course, the incomparable Hubble Space Telescope. It has also seen singularly impressive shuttle flights as, for example, when the first Hubble servicing mission corrected the telescope's severely impaired vision over the course of eleven days in December 1993.

The flights to *Mir* with seven American occupants also stand out for demonstrating that cooperation between the two old rivals, however tentative, was at least possible in space. What happened behind the scenes on the ground, however, is another story. The degree of hubris each side brought to Phase 1, as Shuttle-*Mir* was also called, was intense.

But the manned program has essentially drifted into the doldrums. The shuttle's main mission is to build an *International Space Station* whose own tortured history, going back to President Reagan's *Freedom* project, epitomizes the quagmire. The Russians can't afford to participate without laundered U.S. funds; the administration has unilaterally reduced the station's crew size (infuriating ESA and sending a message on the thing's priority, or lack of it, to an equally indifferent public); the science community despises it; and no one is really certain what it's mission is. Its mission, most basically, is to be there. That is, it is there to establishment the fact that there can be a continuous human presence off the planet. That is important. But it is not compelling.

What is lacking is a single, very long term, compelling goal in space that the community can use to sharply focus its various resources and disparate programs. And that goal exists. It is called planetary defense for the survival of this civilization. Access to space has given the inhabitants of Earth the means to protect themselves from potentially catastrophic destruction for the first time.

Planetary defense should be a very focused program with several facets that come together with the single, specific goal of protecting Earth from danger and providing a rescue capability if a catastrophe occurs despite the protection.

Locating and staving off Earth-threatening objects is the most apparent mission for planetary defense. But it is far from the only one. And that is where people in space, and especially on a lunar base, come in. We see the Moon not primarily as a source of raw materials to help Earth, nor as a tourist mecca, nor as a scientific outpost. We see it essentially as a life boat from which raw materials will indeed be extracted to supplement finite supplies on Earth, where tourists will visit and hopefully settle into the colony, and where science will be undertaken, at least in part to keep still another eye on the universe. Each of those endeavors is therefore itself a facet of planetary defense: new raw materials will be vital to our civilization in the long term; tourists will be in the forefront of lunar colonization, and science will serve our world's vital knowledge base. But they will need to be pursued, not as distinct programs, but as integral parts of the larger system of planetary defense.

And each of them in turn will require thoroughly dependable, reusable, spacecraft – preferably single stage to orbit or, failing that, two stages to orbit – that can be overhauled and serviced like airliners. The frequent access to space they will provide is imperative and necessarily precedes a return to the Moon. They will be an extension of the shuttle envisioned by von Braun and the others, later preliminarily tested on the X-15's 199 flights, that were eclipsed by Apollo's cannon balls.

But I must emphasize again that the components of planetary defense are not the drivers. It is multiple drivers, most of them competing for funding, that have gotten us stalled in the first place. And so has the ancient, maddeningly parochial, manned versus unmanned war. The single imperative is survival and doing whatever is required to assure it. That means people and machines doing what they best as mutually supportive entities. The water ice on Mars that will one day sustain manned missions there was discovered by a succession of machines, starting with ground based telescopes and going through exploring robots that went there and confirmed what astronomers saw from afar. Just this March, Mars Odyssey turned up a vast subsurface ocean of frozen water that could be used for drinking and as a fuel source for the trip back to Earth. And, of course, it holds the tantalizing possibility of life or its remnant.

The main instrument by which a lunar base and then a large colony could help Earth by mitigating the effects of any of the calamities, individually or in combination, is called ARC, as in ARChive, for the Alliance to Rescue Civilization. ARC is best thought of as backing up the planet's essence for the same reason discs are used to back up a computer's hard drive.

In a sense, all of us are already doing on a personal basis what we are proposing for the planet as a whole. If you use a safe deposit box to protect family jewels, the deed to your house, marriage and birth certificates, and other valuable documents from fire or other damage, adding them as they appear, you are already practicing what we are advocating on an infinitely larger scale. As Dave Morrison, a NASA astronomer who is working on both Spaceguard and astrobiology recently pointed out, most homes don't catch fire but people have fire insurance as a precaution anyway.

The idea is to continuously copy Earth's overall civilization and nature – most or all of what we are – and send it elsewhere for safekeeping. By this we mean the near-totality of the history, politics, science, technology, art and literature of any nation or society that wants to participate. In addition, the preserved DNA of life forms, plants and animals, would also be archived.

The idea is emphatically not to create a time capsule. The reason is apparent. If ARC had been created as a time capsule only 100 years ago, it would contain nothing about the airplane, atomic energy, abstract expressionism, relativity, quantum electrodynamics, Ernest Hemingway, Jean Paul Sartre, Dmitri Shostakovich, the Bauhaus, solar system exploration, the manned Moon landings, DNA, the human genome project, Salk vaccine, all of the other scientific and medical advances, two world wars and the holocaust, and the birth and death of Soviet communism, not to mention three of the most sacred and enduring twentieth century American icons: Coke, Big Mac, and Elvis. Rather, we see ARC as a continuously and indefinitely updated record of life on Earth in its multiple forms.

The idea of a comprehensive record is not new. Asimov made reference to an *Encyclopedia Galactica* in his Foundation series: a thorough record of that civilization. And in very rudimentary form, the bronze plaques carried by Pioneers 1 and 2 that describe where they come from and the race that made them, and the far more detailed

collection of sights and sounds of Earth carried by Voyagers 10 and 11, are basically repositories of information about Earth. Besides ARC being infinitely more comprehensive than the plaques, it is not for use by other civilizations, but by our own.

There is a well-known precedent for the consequences of not backing up, or storing in more than one place, accumulated knowledge. It was the destruction of the great library, museum and zoological park at Alexandria two millennia ago. As Sagan noted in *Cosmos*, the library was the first true research institute in history, where humanity "first collected, seriously and systematically, the knowledge of the world." It was there that Herophilus identified the brain rather than the heart as the site of intelligence; that Euclid devised geometry; Hipparchus invented longitude and latitude, mapped the constellations, and measured the brightness of the Sun; Archimedes created his mechanical wonders; and where Dionysius of Thrace brought logic and form to the study of language. And among the many hundreds of other tablets and papyrus scrolls that were forever lost in the fire (if that's what it was) was one or more written by Aristarchus of Samos, who had the unmitigated gall to argue that this planet is merely one of several, that they all circle the Sun, and that the stars are enormously far away. For devising the heliocentric theory of the solar system, Aristarchus was accused by another library scholar, the Stoic Cleanthus, of blatant impiety. Because the scrolls were lost, it took almost 2,000 years before Kepler, Copernicus, and Galileo picked up the scent and repostulated the theory. Galileo was also charged with impiety – that is, with daring to shed light in a politically very dark place – and was put under house arrest to keep him from making more trouble. Giordano Bruno, a Dominican friar and eclectic philosopher, fared worse for holding the same "monstrous" thoughts. On February 19, 1600, insisting he had nothing to repent, Bruno was taken from his cell in Rome, striped naked, gagged, and burned at the stake.

And there is another lesson in the fate of the library, this one having implications for globalization. Where there was diversity of knowledge in many places and among many cultures, the loss of one body of knowledge – the destruction of Pompeii by an act of God or part of the Parthenon by an act of war, to take only two examples – could to a great extent be ameliorated. But the loss of the library, where so much knowledge was concentrated, was infinitely worse. It will become even more so if the global system that is the repository for all our scientific, medical, and other vital information – the greatest aggregation of knowledge in history – takes a major hit.

But in that vulnerability lies considerable advantage. Fortunately, we are not dealing with individual, flammable, papyrus scrolls, but with digitized information that can be carried or transmitted to multiple locations, including one off the planet.

ARC could have multiple repositories, including various places on Earth. But limiting it to Earth would be self-defeating in the event of widespread devastation. The logical place to store all that information is on a large space station that is close enough to Earth so as to be readily accessible in an emergency, but far enough away so as not to get caught in whatever calamity befalls this planet. Those two requirements rule out a station in low Earth orbit, which could get clobbered directly or by residual debris from whatever hits Earth. It also rules out Mars. The Red Planet invites manned exploration,

but the fact that it is a year away by chemical rocket makes it virtually useless as a base that could be used for a quick response to horrendous devastation. The perfect station already exists, of course, and it is called the Moon.

Since ARC would take many years to start and then operate continuously, a permanent, standard computation system, or more likely one that is infinitely adaptive, would be necessary. As someone who owns long playing records I can no longer play, home movies I can no longer watch, and has acquired a DVD player because even VCRs seem to be on the way out, I understand that technological advances can quickly make data unusable. Yet the creation of a permanently adaptable storage and retrieval system is not beyond the capability of those who are now conceptualizing the mating of humans and computers. Only last month, I.B.M. scientists announced they had created data storage technology that can store the equivalent of 200 CD-ROMS on a surface the size of a postage stamp. So the possibilities are literally infinite.

There is also an implicit political advantage to ARC. Since it would by definition be a highly cooperative international effort it could be expected to foster international stability and the beginning of the planetary civilization that will be required to colonize other worlds, including the Moon. Less obviously, cooperation in an international space venture is ultimately crucial for the spacefarers themselves. If there was one enduring lesson that came out of *Mir's* year-long spate of awful mishaps, it was the realization that its crew had to work together or die. That lesson holds for the occupants of the larger spaceship we are on right now. ARC would be another force for peace and cooperation.

Now for a caveat. Since ARC is designed to extend into the indefinite future, meaning centuries, it cannot be held hostage to the vagaries of whatever political administration or even system of government is in power at any given time. So while NASA, ESA, and other governmental institutions have a role to play in launching ARC and supporting it in ancillary ways, its core funding has to come from the private sector, perhaps from a partnership between corporations and foundations. Only that way will it have the independence, flexibility, and efficiency to function as it needs to function. It is conceivable that ARC could be managed as a permanent, integral, constituent part of the United Nations, as is the World Health Organization or UNICEF, for example, or as a free-standing institution in the United States or elsewhere. What is crucial is that it never be dependent on politicians of any stripe for its existence.

And funding ARC will bring a benefit that is not readily apparent: immortality. The names of individuals, corporations, and foundations that finance college dormitories, libraries, and classrooms disappear when the structures are demolished and replaced fifty or seventy-five years later. But the names of ARC donors will be cut on the Moon and will therefore last quite a bit longer.

Using ARC, the inhabitants of the lunar colony could organize a relatively quick response to help the home planet. If massive tragedy does strike, the colony would not only be able to use the archive to reconstitute whatever cultural assets were lost, but it would be able to perform social and engineering rescue work as well.

Seen from the perspective of the very long range big picture, most of the space agency's programs are, or could be, enlisted for planetary defense. While it is not thought of in those terms, the remote sensing program, which started thirty years ago with Earth Resources Technology Satellites – subsequently called Landsats – is in fact another facet of planetary defense. Landsat's mission, as you know, is to monitor natural and cultivated resources, including forests, potential farmlands, wetlands, and other places that can be enlisted to help feed the planet; identify pollution and its sources, and provide warning of surface and subsurface degradation. The most dramatic example of the last shows a dramatic shrinkage of the Aral Sea as photographed over the years by both Landsats and Corona reconnaissance satellites. The start of the disintegration of both polar ice caps, and of the southern one in particular, has also been depicted in imagery for which space remote sensing is uniquely qualified, as it also is with our massive forest fires. As is the case with imagery collected by the National Reconnaissance Office's array of intelligence collecting satellites, the technology is assigned the task of providing evidence for decision making.

Closer to home where ARC is concerned, remote sensing could be used to monitor UNESCO's World Heritage Sites. As explained by Derrold Holcomb of Leica-Geosystems at the American Association for the Advancement of Science annual meeting in Boston in February, an image processing and data handling facility would archive data on four kinds of sites to protect them from natural and man-made encroachment and destruction: vast natural areas, remote archaeological sites, sites surrounded by urban development, and historic districts. Holcomb made the excellent point that an underlying thesis of the World Heritage Sites program is that they are everyone's heritage and responsibility. We believe as much can be said of the planet as a whole. And the great value of using spacecraft to do this is that they can collect huge amounts of data regardless of the political situation on the ground.

Solar system exploration is (pardon the expression) looking through the other end of the telescope. Having been cognizant of the whole, wonderful, process as it unfolded – certainly including Mariner 4's initial flyby of Mars in 1964, to Mariner 9's sensational imagery of the planet and both of its moons, to the Viking landings to Pathfinder to Mars Odyssey's recent confirmation that there is a huge amount of water ice on the planet, meaning the possibility of life – I have relished the string of discoveries as they progressed as if in a page-turning novel. Likewise with the Voyagers' initial reconnoitering of Jupiter and its moons, followed by Galileo's return for a close-up, detailed, inspection of what amounts to a miniature solar system.

But certainly in the case of Mars, the ever more detailed information – now enough to stock a small library – is leading to an eventual expedition and then to an outpost and a large habitation. This long process, too, is not being done – or should not be done – for the same reason Annapurna, K-2, and Everest were climbed: as an adventurous lark or, in Sir Edmund Hillary's famous words, "Because it is there." There are infinitely more compelling reasons to climb into space than to climb mountains. The eventual move to Mars, like the colonization of the Moon, should be to spread the seed in

defense of all humanity. And we like to think that planets picked up in very distant solar systems – about 100 at last count – may include some that are potentially habitable by our distant descendents who go on multi-generational interstellar missions.

This brings to mind an anecdote from the Pathway to the Planets conference that was held in Washington in the late spring of 1989. Lennard Fisk, who was then the head of NASA's Office of Science and Applications – the "practical" operation – good naturedly chided Frank Martin, who headed what was then the Office of Exploration, about the lack of practicality in solar system exploration. Finally, Frank responded:

"Lenny, your job is to save Earth," he said. "Our job is to find a place to go if you screw up."

On that note, I would like to end in the most dangerous of realms: the philosophical.

The July 1st issue of *Time* had a cover that showed a cross rising out of flames and bearing this stark message: "The Bible & the Apocalypse: Why more Americans are reading and talking about the end of the world."

In a nutshell, according to the cover story, a sharply increasing number of Americans are interpreting the holocaust, the dropping of two atomic bombs on Japan, the arrival of the millennium, the attacks on September 11th, the spread of terrorism, and many of the ugly and dangerous facets of life on this planet as clear indicators that history is speeding up and that the final battle between Christ and the AntiChrist – Armageddon – as foretold in *Revelation*, the last book of the New Testament, is almost at hand. A Time/CNN poll found that more than a third of Americans claim to be paying more attention now to how the news might relate to the end of the world and have talked about what the Bible has to say on the subject. And fifty-nine percent say they believe the events in *Revelation* are going to come true. Walter Russell Mead, a scholar in residence at the Council on Foreign Relations in New York, is researching a book on what he calls the Age of Apocalypse. That is not to say Mead thinks the end is near, but that a growing number of people do think so because as history allegedly accelerates, the ancient prophesies are coming true in real time.

No matter that masses of people thought the end was near when Rome was sacked in 410, when the plague wiped out a third of the population of Europe in the fourteenth century, when tectonic shudders from the earthquake in Lisbon in 1755 caused church bells to ring in England, and after August 1945, when many thousands of hapless Japanese were incinerated by the forerunners of the thousands of nuclear weapons now spread around the world, many of them targeted. For our resident doomsdayers, technology is almost uniformly evil and paves the way to the Apocalypse. I say "almost" because the *Time* article said one woman in the Midwest quoted *Revelation* as saying: "When Christ returns, every eye shall see Him." That, she reasoned, is why God gave us CNN and the Internet. For her, there is at least some good in high-tech.

We believe that a battle of profound importance is, indeed, underway.

But it is not a simplistic contest between good and evil. Rather, it is a battle between the rational and the irrational: between those who believe human beings have the capacity to shape their own destiny, certainly with science and technology, and those who think they are the helpless slaves of predestination.

To the multiple physical and political benefits of planetary defense, then, add one that is philosophical. It is a supremely dignified – I will say noble – endeavor because it empowers us to shape our own destiny rather than relinquish it to fate and therefore become fate's willing victims. Planetary defense, certainly including the ARC, is therefore a statement of belief in the fundamental worth of human intelligence, imagination, and the ability to make decisions based on reason and enlightened self-interest, not on unsubstantiated dogma. It is the apocalyptics' right to go down with the ship if they believe that is God's will. The rest of us think God wants us to save the ship, sail to safety, and prevail.

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