

Version 1.0 dtd 032800

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The Future of Science:

Prometheus, Apollo,

Athena

Where is science heading? Is it taking us on a one-way ride to oblivion, or leading the human spirit upward to the stars? Science fiction writers have been predicting both, for centuries.

"I have but one lamp by which my feet are guided," Patrick Henry said, "and that is the lamp of experience. I know of no way of judging of the future but by the past."

Look at the past, at the way science and technology have affected the human race. Look far back. Picture all of humanity from the earliest Homo erectus of a half-million years ago as a single human being. Now picture science as a genie that will grant that person the traditional three wishes of every good fable.

We have already used up one of those wishes. We are working on the second one of them now. And the future of humankind, the difference between oblivion and infinity, lies in our choice of the third wish.

Our three wishes can be given classical names: Prometheus, Apollo, and Athena.

Prometheus

Long before there was science, perhaps even before there was speech, our primitive ancestors discovered technology. Modern man thinks of technology as the stepson of scientific research, but that is only a very recent reversal of a half-million-year-long situation. Technology-toolmaking-came first. Science understanding-came a long time later.

Look at the Prometheus legend. It speaks the truth as clearly as any modern science fiction story. It speaks of the first of our three wishes.

Prometheus brought the gift of fire. He saw from his Olympian height that man was a weak, cold, hungry, miserable creature, little better than the animals of the fields. At enormous cost to himself, Prometheus stole fire from the heavens and gave it to man. With fire, man became almost godlike in his domination of all the rest of the world.

Like most myths, the legend of the fire-bringer is fantastic in detail and absolutely correct in spirit. Anthropologists who have sifted through the fossil remains of early man have drawn a picture that is much less romantic, yet startlingly close to the essence of the Prometheus legend.

The first evidence of man's use of fire dates back some half million years. The hero of the story is hardly godlike in appearance. He is *Homo erectus*, an ancestor of ours who lived in Africa, Asia, and possibly Europe during the warm millennia between the second and third glaciations of the Ice Age. *Homo erectus* was scarcely five feet tall. His skull was rather halfway between the shape of an ape's and our own. His brain case was only two-thirds of our size. But his body was fully human: he walked erect and had human, grasping hands.

And he was dying. The titanic climate shifts of the Ice Age caused drought even in tropical Africa, his most likely home territory. Forests dwindled. Anthropologists have found many *H. erectus* skulls scratched by leopard's teeth. Our ancestors were not well equipped to protect themselves. Picture Moon Watcher and his tribe from Arthur C. Clarke's 2001.

It was a gift from the skies that saved *Homo erectus* from oblivion. Not an extraterrestrial visitor, but a blast of lightning that set a bush afire. An especially curious and courageous member of the *erectus* clan overcame his very natural fear to reach out for the bright warm promise of the flames. No telling how many times our ancestors got nothing for their curiosity and courage except a set of burnt fingers and a yowl of pain. But eventually they learned to handle fire safely, and to use it.

With fire, humankind's technology was born.

Fire, the gift of Prometheus, satisfied our first wish, which was: Feed me, warm me, protect me.

Fire not only frightened away the night-stalking beasts and gave our ancestors a source of warmth, it helped to change the very shape of their faces and their society.

Homo erectus was the world's first cook. He used fire to cook the food that had always been eaten raw previously. Cooked food is softer and juicier than raw food. Cooking cuts down greatly on the amount of chewing that must be done. Our ancestors found that they could spend less time actually eating and have more time available for hunting or traveling or making better spear points.

More important, the apelike muzzle of *Homo erectus*, with its powerful jaw muscles, was no longer needed. Faces became more human. The brain case grew as the jaw shortened. No one can definitely say that these two face changes are related. But they happened at the same time. The apelike face of the early hominids changed into the present small-jawed, big domed head of *Homo sapiens sapiens*.

Beyond that, fire was the first source of energy for any animal outside its own muscles. Fire liberated us

from physical labor and unleashed forces that have made us masters of the world. Fire is the basis of all technology. Without fire we would have no metals, no steam, no electricity, no books, no cities, no agriculture, nothing that we would recognize as civilization.

The gift of Prometheus satisfied our first wish. It has fed us, kept us warm, protected us from our enemies. Too well. It has led to the development of a technology that is now itself a threat to our survival on this planet.

The price Prometheus paid for giving fire to us was to be chained eternally to a rock and suffer daily torture. Again, the myth is truer than it sounds. The technology that we have developed over the past half-million years is gutting the Earth. Forests have been stripped away, mountains leveled, our air and water fouled with the wastes of modern industry.

For our first wish, the wish that Prometheus answered, was actually: Feed me, warm me, protect me, regardless of the consequences. Our leopard-stalked ancestors gave no thought to the air pollution arising from their primitive fires. And our waist coated entrepreneurs of the Industrial Revolution did not care if their factories turned the millstream into an open sewer.

But today, when the air we breathe can kill us and the water is often unfit to drink, we care deeply about the consequences of technology.

The gift of Prometheus was a first-generation technology. It bought the survival of the human race at the price of eventual ecological danger. Now we seek a second-generation technology, one that can give us all the benefits of Prometheus's gift without the harmful by-products.

This is our second wish. We have already asked it, and if it is truly answered, it will be answered by Apollo.

The sun god. The symbol of brilliance and clarity and music and poetry. The beautiful one.

* * *

Apollo

Although our first-generation technology predated actual science by some half-million years, the second generation technology of Apollo cannot come about without the deep understandings that only science can bring us. To go beyond the ills of first-generation technology, we must turn to science, to the quality of mind that sees beyond the immediate and makes the desire to know, to understand, the central theme of human activity.

Science is something very new in human history. As new, actually, as the founding of America. In the year 1620, when the Puritans were stepping on Plymouth Rock, Francis Bacon published the book that signaled the opening of the scientific age: *Novum Organum*.

Men had pursued a quest for knowledge for ages before that date. Ancients had mapped the heavens, tribal shamans had started the study of medicine, mystics had developed some rudimentary understandings of the human mind, philosophers had argued about causes and origins. But it was not until the first few decades of the seventeenth century that the deliberate, organized method of thinking that we now call science was created.

It was in those decades, some 350 years ago, that Galileo began settling arguments about physical phenomena by setting up experiments and measuring the results. Kepler was deducing the laws that govern planetary motion. Bacon was writing about a new method of thinking and investigating the secrets of nature: the technique of inductive reasoning, a technique that requires a careful interplay of observation, measurement, and logic.

Bacon's landmark book, *Novum Organum*, was written and titled in reaction to Aristotle's *De*

Organum, written some fifteen hundred years earlier as a summarization of all that was known about the physi

cal universe. For fifteen hundred years, Aristotle's word was the last one on any subject dealing with "natural philosophy," or what we today call the physical sciences. For fifteen hundred years it was blindly accepted that a heavy body falls faster than a light one, that the Earth is the center of the universe, that the heart is the seat of human emotion. (And when have you seen a Valentine card bearing a picture of the brain or an adrenal gland?)

For fifteen hundred years, human knowledge and understanding advanced so little that the peasant of Aristotle's day and that of Bacon's would scarcely seem different to each other. This was not due to a Dark Age that blotted out ancient knowledge and prevented progress. For this fifteen-hundred-year stasis affected not only Europe, but the Middle East, Asia, Africa, and the Americas as well.

The lack of advancement during this long millennium and a half was due, more than anything else, to the limits of the ancient method of thought. Only incremental gains in technology could be made by people who accepted ancient authority as the answer to every question, who believed that the Earth was flat and placed at the exact center of the universe, who "knew" that empirical evidence was not to be trusted because it could be a trick played upon the senses by the forces of evil.

In the 350 years since the scientific method of thought has become established, human life has changed so enormously that a peasant of Bacon's time (or a nobleman, for that matter!) would be lost and bewildered in today's society. Today the poorest American controls more energy, at the touch of a button or the turn of an ignition key, than most of the high-born nobles of all time ever commanded. We can see and hear the world's history, current news, the finest artists, whenever we choose to. We live longer, grow taller and stronger, and can blithely disregard diseases that scourged civilization, generation after generation.

This is what science-based technology has done for us. Yet this is almost trivial, compared to what the scientific method of thinking has accomplished.

For the basic theme of scientific thought is that the universe is knowable. Man is not a helpless pawn of forces beyond his own ken. Order can be brought out of chaos. Albert Einstein said it best: "The eternal mystery of the world is its comprehensibility."

Faced, then, with a first-generation technology that threatens to strangle us in its effluvia, we have already turned to science for the basis of a second-generation technology. We have turned to Apollo.

We recognize that it is Apollo's symbol-the dazzling sun-that will be the key to our second-generation technology. The touchstone of all our history has been our ability to command constantly richer sources of energy. Homo erectus's burning bush gave way to fires fueled by coal, oil, natural gas-the fossils of antediluvian creatures. Today we take energy from the fission of uranium atoms.

Tomorrow our energy will come from the sun. Either we will tap the sunlight streaming down on us and convert it into the forms of energy that we need, such as electricity or heat, or we will create miniature suns here on Earth and draw energy directly from them. This is thermonuclear fusion, the energy of the H-bomb. In thermonuclear fusion, the nuclei of light atoms such as hydrogen isotopes are forced together to create heavier nuclei and give off energy. This is the energy source of the sun itself, and the stars. It promises clean, inexpensive, inexhaustible energy for all the rest of human history.

The fuel for fusion is deuterium, the isotope of hydrogen that is in "heavy water." For every six

thousand atoms of ordinary hydrogen in the world's oceans,, there is one atom of deuterium. The fusion process is

energetic enough so that the deuterium in one cubic meter of water (about 225 gallons) can yield 450,000 kilowatt-hours of energy. That means that a single cubic kilometer of seawater has the energy equivalent of all the known oil reserves-on Earth. And that is using only one six-thousandth of the hydrogen in the water.

Fusion power will be cheap and abundant enough to be the driving force of our second-generation technology. The gift of Apollo can provide all our energy needs for millions of years into the future.

There will eventually be no further need for fossil fuels or even fissionables. Which in turn means there will be no need to gut our world for coal, oil, gas, uranium. No oil wells. No black lung disease. No problems of disposing of highly radioactive wastes.

The waste products of the fusion process are clean, inert helium and highly energetic neutrons. The neutrons could be a radiation danger if they escape the fusion reactor, but they are far too valuable to let loose, for energetic neutrons are the philosopher's stone of the modern alchemists. They can transform the atoms of one element into atoms of another.

Instead of changing lead into gold, however, the neutrons will be used to transmute light metals such as lithium into the hydrogen isotopes that fuel the fusion reactors. They can also transmute the radioactive wastes of fission power plants into safely inert substances.

The energy from fusion can also be used to make the ultimate recycling system. Fusion "torches" will be able to vaporize anything. An automobile, for example, could be flashed into a cloud of its component atoms iron, carbon, chromium, oxygen, etc. Using apparatus that already exists today, it is possible to separate these elements and collect them, in ultra pure form, for reuse. With effective and efficient recycling, the need for fresh raw materials will go down drastically. The mining and

lumbering industries will dwindle; the scars on the face of the Earth will begin to heal.

Fusion energy will produce abundant electricity without significant pollution, and with thousands of times less radiation hazard than modern power plants. With cheap and abundant energy there need be no such thing as a "have-not" nation. Seawater can be desalted and piped a thousand kilometers inland, if necessary. The energy to do it will be cheap enough. All forms of transportation-from automobiles to spacecraft-will either use fusion power directly or the electricity derived from fusion.

The gift of Apollo, then, can mark as great a turning point in human history as the gift of Prometheus. Like the taming of fire, the taming of fusion will so change our way of life that our descendants a scarce century from now will be hard put to imagine how we could have lived without this ultimate energy source.

Apollo is a significant name for humankind's second wish for another reason, too. Apollo was the title given to humanity's most ambitious exploration program. In the name of the sun-god we reached the moon. Not very consistent nomenclature or mythology, perhaps, but extremely significant for the future of science and the human race.

For to truly fulfill our second wish, we must and will expand the habitat of the human race into space.

We live on a finite planet. We are already beginning, to see the consequences of overpopulation and over consumption of this planet's natural resources. Sooner or later, we must begin to draw our resources from other worlds.

We have already "imported" some minerals from the moon. The cost for a few hundred pounds of rocks was astronomically high: more than \$20 billion. Clearly, more efficient modes of transportation must be found, and scientists and engineers are at work on them now.

It is interesting to realize that the actual cost of the

energy it takes to send an average-sized man to the moon and back-if you bought the energy from your local electric utility-is less than \$200. There is much room for improvement in our space transportation systems.

Improvements are coming. Engineers are now building the Space Shuttle, which will be a reusable "bus" for shuttling cargo and people into orbit. Fusion energy itself will someday propel spacecraft. Scientists are working on very high-powered lasers that could boost spacecraft into orbit. And the eventual payoff of the esoteric investigations into subatomic physics might well be an insight into the basic forces of nature, an insight that may someday give us some control over gravity.

There is an entire solar system of natural resources waiting for us, once we have achieved economical means of operating in deep space. Many science fiction stories have speculated on the possibilities of "mining" the asteroids, that belt of stone and metal fragments in orbit between Mars and Jupiter.

There are thousands upon thousands of asteroids out there. A single 10-kilometer chunk of the nickel iron variety (which is common) would contain approximately 20 million million tons of high-grade iron. That's 2×10^3 tons. Considering that world steel production in 1973 was a bit less than a thousand million tons (109), this one asteroid could satisfy our need for steel for about ten thousand years!

The resources are there. And eventually much of our industrial operations will themselves move into space: into orbit around Earth initially, and then farther out, to the areas where the resources are.

There are excellent reasons for doing so. Industrial operations have traditionally been sited as close as possible to the source of raw material. This is why Pittsburgh is near the Pennsylvania coal fields, and not far from the iron-ore deposits further west. It is cheaper to

transport finished manufactured products than haul bulky raw materials.

The very nature of space offers advantages for many industrial processes. The high vacuum, low gravity, and virtually free solar energy of the space environment will be irresistible attractions to designers of future industrial operations. Also, the problems of handling waste products and pollution emissions will be easier in space than on Earth.

The pressures of social history will push industry off-planet. We cannot afford to cover the Earth with factories. Yet the alternative is a cessation of economic growth-as long as industrial operations are limited to our finite planet.

Although studies such as the MIT/Club of Rome's "Limits to Growth" have urged a stabilized society,

human nature usually wants to have its cake and eat it, too. It should be possible to maintain economic growth by expanding off-planet, and thereby avoid the catastrophic effects of polluting our world to death.

What about the ultimate pollution: overpopulation? Will our expansion into space simply allow the human race to continue its population explosion until civilization collapses under the sheer groaning weight of human flesh?

Many science fiction stories have depicted a rigidly stabilized future society, where vocation, recreation, and even procreation are strictly controlled by -the state. Given modern techniques of behavior modification and genetic manipulation, this might someday be possible. Indeed, this is the world that "The Limits to Growth" inevitably leads to.

There is an alternative. In all of human history, the only sure technique for leveling off an expanding population has been to increase the people's standard of living. War, famine, pestilence inevitably lead to a higher birthrate. Modern science has reduced the death rate to the point where even a moderately rising birthrate is a threat to society.

If economic growth can be maintained or even accelerated by expanding the economy into space-and this growth is shared by all people everywhere on Earth-we may have the means for leveling off the population explosion without the repressions that most science fiction writers are haunted by.

Eventually, people will go into space to live. There will be no large-scale migrations-not for a century, at least. But within a few decades, we may see self-sufficient communities in orbit around the Earth, on the moon, and eventually farther out in space.

For the first time since the settling of the Americas, humankind will have an opportunity to develop new social codes. In the strange and harsh environments we will encounter in space, we will perforce evolve new ways of life. Old manners and customs will wither; new ones will arise.

Scientists such as astronomer Carl Sagan look forward to these "experimental communities." They point out that social evolution on Earth is stultified by the success of Western technological civilization. Nearly every human society on this planet lives in a Westernized culture. Variety among human cultures is being homogenized away. The new environment. of space offers an opportunity to produce new types of societies, new ways of life that might teach those who remain on Earth how to live better, more fully, more humanly.

Which brings us to the last of humankind's three wishes, the most important one of all, the wish for the gift of Athena. ,

Athena

The gray-eyed goddess of civilization and wisdom. The warrior-goddess who was born with shield and spear in her hands, but who evolved from Homer's time to Pericles' into a goddess of counsel, of arts and industries, the protectress of cities, the patron deity of Athens.

It is to Athena that we must turn if we are to succeed in our long struggle against the darkness. For

human history can be viewed as an attempt to countervene the inevitable chaos of entropy. We succeed as individuals, as a society, as a species, when we are able to bring order out of confusion, understanding out of mystery. Athena, whose symbol is the owl, represents the wisdom and self-knowledge that we so desperately need.

Knowledge we have. And we are acquiring more, so rapidly that people suffer "future shock" from their inability to digest the swift changes flowing across our lives. Wisdom is what we need; the gift of Athena. Self-understanding.

Human beings are understanding-seeking creatures. But when we seek understanding from authorities-in ivied towers of learning, or marbled halls of government, or dark caves of mysticism-we fall short of our goal. Proclamations from authorities are not understanding. When we as individuals give up our quest for understanding and allow others to think and decide for us, we allow the inevitable darkness to gather closer. The brilliant Aegean sunlight is what we seek, and we must turn to Athena's gift of wisdom to find it.

Science will be the crucial factor in finding Athena's gift. As a mode of thinking, a technique for learning and understanding, it is central to our search for self-knowledge.

Our first two wishes were largely focused outside ourselves. They were aimed at manipulating the world outside our skins. Our third and final wish concerns the universe within us: our bodies, our brains, our minds. Until now, scientific research has been mainly concerned with the physical world around us. Physics, chemistry, astronomy, engineering-all deal with the universe that we lay hands on. Even biology and sociology have dealt mainly with matters external to the individual human being. Medical research has been confined to chemistry, mysticism, and sharper surgical tools, until very recently.

But starting with psychology, the major thrust of scientific research has been slowly turning over the past century or so toward the universe inside our flesh.

Molecular biology is delving into the basic mechanics of what makes us what we are: the chemistry of genetic inheritance. Ethnology and psychology are probing the fundamentals of why we behave the way we do: the essence of learning and behavior. Neurophysiology is examining the basic structure and workings of the brain itself: the electrochemistry of memory and thought.

Many view this research with horror. From Mary Wollstonecraft Shelley's vision of Frankenstein, generations of writers and readers have feared scientists' attempts to tamper with the human mind and body. "There are some things that man was not meant to know," has become not only a cliché, but a rallying cry for the fearful and the ignorant.

Genetic manipulation could someday create an elite of geniuses who rule a race of zombies. Behavior modification techniques can turn every jailbird into a model prisoner, and make prisoners of us all. Psychosurgery is performed on the poor, the uninformed, the helpless.

Yet molecular biology may erase the scourge of cancer and genetic diseases, bringing the human race to a pinnacle of physical perfection. Behavior modification techniques will someday unravel the tangled engrams of hopeless psychotics and restore them to the light of healthy adulthood. Brain research could bring quantum leaps in our abilities to understand and learn.

Human societies have developed in such a way that new ideas and new capabilities are acquired by the rulers long before the ruled ever hear of them. All societies are ruled by elites. But the eventual effect of new knowledge is to destroy the elite, to spread the new capabilities among all the people. Far from

fearing new knowledge, or shunning it, we must seek it out and embrace it wholeheartedly. For only out of the new knowledge that scientists are acquiring will we derive

the understanding that we need to survive as individuals and as a species.

The gift of Athena is what we must have. And it must be shared by all of us, not merely an elite at the top of society. The gift of Prometheus gave us mastery of this world. The gift of Apollo is bringing us powers so vast that we can turn this planet into a paradise or a barren lifeless wasteland.

Only the wisdom of Athena can control the powers of modern science and technology. Only when all the people know what is possible will it be possible to know what to do. As long as an elite controls the power of science and technology, the masses will be manipulated. And such manipulation will inevitably lead to collapse and destruction.

We stand poised on the brink of godhood. The knowledge and wisdom that modern scientific research offers can help us to take the next evolutionary step, and transform ourselves into a race of intelligent beings who truly understand themselves and the universe around them. It is possible, by our own efforts, to climb as far above our present condition as we today are above primitive little Homo erectus.

The anthropologist Carleton Coon painted the prospect twenty years ago, in his book, *The Story of Man*:

A half-million years of experience in outwitting beasts on mountains and plains, in heat and cold, in light and darkness, gave our ancestors the equipment that we still desperately need if we are to slay the dragon that roams the earth today, marry the princess of outer space, and live happily ever after in the deer filled glades of a world in which everyone is young and beautiful forever.

We have the means within our grasp. The gift of Athena, like our first two gifts, actually comes from no one but ourselves.