Astronautics and the Future

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A few years ago, space flight was only a gleam in the eyes of a few rocket enthusiasts; and now Mr. Edson, who is Assistant to the Director of Research and Development of the Department of the Army, feels secure enough to extrapolate the schedule of man's travel to the moon and the planets over the next few decades. That in doing so he projects into the era of space conquest the power conflicts among the nations of the earth is, unfortunately, not illogical in view of the continuation of these conflicts in the atomic age.

The Bulletin *is dedicated to the idea that armed conflicts between fractions of humanity must (and can) be stopped before they lead to the suicide of the human race on earth. Mr. Edson puts his hope instead in the colonization of the moon and other cosmic bodies, where he believes man can become self-sustaining (despite the radical difference of physical and chemical—and perhaps a complete absence of biological—background), and survive the extermination of the human race on earth.*

BECAUSE in earlier days the Queen of an obscure realm made sacrifice of her gems to the brighter gleam of Columbus' vision, her nation came to greatness, wealth, and power. European, then worldwide affairs took a turn literally unimaginable to the statesmen of that time. So will it be with astronautics, and soon. From *Nina* to *Nautilus* was a little less than thirty decades. The transition from sputnik to space cruiser will assuredly be less than thirty years. Indeed, it is already proceeding ahead of earlier estimates.

Astronautic Technology

Artificial Earth satellites must be raised above the substantial Earth atmosphere (say 150 miles or more altitude) and given a tangential velocity around the Earth. This tangential, or circular orbital, velocity is about five miles per second for orbits near the Earth such as the paths of the U.S. IGY *Explorer*, the *Sputniks*, and of the contemplated Vanguard satellites. At this speed, objects within a few hundred miles of the Earth fly sidewise so fast that the Earth curves away beneath them as they fall and they never strike the atmosphere. Or you can say that centrifugal force just balances gravitational force. If the tangential launching speed of such an object is greater than the circular orbital velocity but less than about seven miles per second, it will swing away from the Earth in an elliptical orbit, returning at the end of each orbit period to the point near the Earth where its last rocket burned out. If its speed is greater than about seven miles per second it flies away from the Earth, receding forever.

For more distant Earth satellites, the rockets have to lift farther, but they don't have to give the payload so much tangential speed in orbit, because Earth gravity falls off with the square of the distance from Earth center. For instance, a body in a circular orbit about 22,000 miles above Earth surface would require an orbit speed of about 1.9 miles per second and go around the Earth in exactly 24 hours. If the satellite orbit were in the equatorial plane, it would seem to remain suspended motionless above one point on the Earth's surface.

The path of a satellite object through space does not depend upon the weight, shape, or size of the object. Thus satellite packages such as *Sputnik I* or the contemplated Vanguard payloads will fly along for some time close to their burned-out last stage rocket motors. Finally the slow drift of the separation velocity, plus minute tidal accelerations, will cause them to move apart. The pieces of a large satellite can be delivered successively into the same orbit, thus to fly along together while men in space armor assemble them into the completed vehicle. But if a large, light object like a hollow sphere and a heavy dense object like a cannon ball fly along together through even a thin atmosphere, air drag will soon separate them, identifying their own characteristics, or, if these are known, the density of the outer atmosphere. One of the *Explorer* experiments will use this method to measure the density of the high atmosphere.

Specific Impulse

Key parameter of the space rocket art is "specific impulse." This may be defined as the thrust produced by consuming the propellants at the rate of one pound per second. It is theoretically a characteristic of the propellants (in rockets using the chemical energy of propellant reaction; nuclear or electric rockets are different). In practice, it depends considerably on rocket motor design and other circumstances. Many of today's better conventional rockets have specific impulse in the range of 250–275 pound seconds per pound. That is, a rocket burning one pound of propellant per second will produce 250–275 pounds of thrust. (See R. Rollefson's article, "Why So Many Missiles?" in the October 1957 *Bulletin.*) Another important parameter is "mass ratio," the ratio of the rocket weight at take-off to the weight of remaining mechanism plus payload at burn-out. This is set by the state of the rocket engineering art. With present propellants and rocket art, three or four rocket "stages," burning successively and in turn discarded, are necessary to put payloads of a few tens to a few hundreds of pounds into orbit near the Earth. An extra rocket stage will enable rocket systems to put about a tenth as much payload on or around the Moon as they can put in orbit near the Earth.

"Planetfall" is the act of coming down out of space to land on the surface of a planet. On an airless world, such as our Moon, planetfall must be controlled and the velocity of fall eliminated by means of downward-firing rockets. Where there is an atmosphere, as on Earth, Mars, or Venus, the excess velocity can be eliminated by skillful use of friction with the outer atmosphere, in a "braking orbit." The vehicle then glides to the surface as an aircraft or perhaps descends by parachute. The braking maneuver must be executed precisely and with accurate knowledge of the atmospheric structure. To this end the astronauts have made a considerable study of the atmospheres of Mars and Venus. Use of braking orbit makes a very important saving in the rocket fuel required for a round trip from the Earth. For this reason, an expedition to Mars is, rocketwise, not greatly more difficult than one to the Moon. Planetfall on the Earth goes by the name of "re-entry" (into our own atmosphere). The heating and other problems of re-entry have to be solved in the design of long-range ballistic missiles. The strain placed on human anatomy by abrupt deceleration will make necessary for manned spacecraft a less sudden plunge into the denser layers of the atmosphere than for unmanned missiles.

"Space medicine" is the study of the requirements of humans living and working aboard spacecraft. Active research in this field is about ten years old. The art may be expected, within the next two or three years, to advance to the point where suitably selected, physically conditioned, and mentally trained men can confidently embark on space trips of many days' duration.

Navigation

Space navigation includes the theory, calculating techniques and instruments for guiding a spacecraft from the moment of "up ship," across interplanetary space, through planetfall at destination. It is well developed. A course of instruction in it has been given at the University of California at Los Angeles for the past ten years. Guided missile research and development has gone far toward the automation of this entire field. The navigators of the first manned space vessels will surely have much to learn from their own experiences, but they will have the benefit of an advanced art and the backup of ground-based observing and computing centers. The longest possible time for each trip, using conventional rockets, can be accurately stated. Such rockets burn for only a few minutes, then coast on an orbit to their destination. A slower trip would not attain the destination; the ship, checked by terrestrial and solar gravitation, would fall short of its goal. Such trip times are as follows:

Earth to:	Moon	4¾ days
	Venus	146 days
	Mars	260 days
	Asteroids	1½ to 2 years
	Jupiter and its satellites	2¾ years

These times will probably be needed for the first few voyages. They will become much shorter as astronautic propulsion technology advances.

Space rocket capabilities increase very fast with increasing specific impulse. A specific impulse of 400 to 600 pound seconds per pound will make permanent, manned Earth satellites relatively easy, and will increase the practicability of travel between the Earth and lunar bases. The lower part of this specific impulse range might be attained by "chemical" propellants; the "frozen atom" or "frozen free radical" reactions offer promise here. This range will also be attainable with "thermal nuclear" rockets in which the exhaust gases are preheated to high temperatures by flow through a nuclear fission reactor and thence through a rocket nozzle. This involves radiation shielding and some other problems.

Interplanetary cruising is possible but difficult with present techniques, but will become fairly easy at specific impulses of the order of 10,000 pound seconds per pound. These can be attained by ionic jets, in which atomic particles are accelerated to very high velocities by means of electromagnetic fields. The electric power must be produced by a generator, presumably nuclear powered, in the ship. The principle is an old one, but extensive engineering development will be required. The first practical engines of this type will probably be low-thrust "sustainers," which will gently but steadily push the ship to very high velocities after it is well started on its journey through interplanetary space.

What Next?

Having reviewed some astronautic concepts, let us now forecast the development of the art over the next couple of decades. Let us base our estimates on normal rate of engineering development progress, making no allowance for unpredictable creative "breakthroughs." The actual events will then tend to occur earlier, rather than later, than predicted. The events are listed in the most probable chronological order of their occurrence. To each event is assigned a five-year interval within which it is most likely to occur. These predictions are, of course, estimates of the same kind that must guide the planning of any extended research and development program. If your estimate differs from that given, you are invited to record your own predictions in the table below. You might also write down, if you like, what nation will in your own opinion first make the indicated achievement. We will then wait and see how it turns out!

Event	Potential Use or Significance	Time Scale
First primitive satellite.	Investigate satellite environment. Precision geodesy. Show capability.	Occurred October 4, 1957
Satellite of payload 100 to 1,000 lbs.	Sophisticated and detailed research observations. "Applied" use in communications, meteorological forecasting, and surveillance. Possible weapons carrier.	Occurred November 2, 1957
Unmanned vehicle around hidden far side of Moon and back to vicinity of Earth.	Pictures and other observations of hidden far side of the Moon. Keen interest by scientists and laymen. Propaganda with emphasis on curiosity and exploration; "peaceful purposes."	Interval between now and 1962.
Unmanned vehicle crash against visible face of the Moon. (Possibly with atomic bomb to make a permanent mark.)	Spectrum of volatilized lunar surface. Cratering to measure properties of lunar rock. Propaganda with emphasis on threat and power.	"
Re-entry and recovery of satellite equipment and biological specimens.	Recovery of photographs and other records. Examination of recovered biological and other material.	"
Biological readiness to put man in space; selection and training of men for space duty.	Assurance that manned spacecraft are feasible, and that their advantages can be realized.	"
Satellites of 5,000 lb. payload class, probably using rocket motors, in 400 to 600 lb. sec. impulse range.	Advanced astronomical and other research. Regular commercial use in communications, meteorology, navigation, surveying, etc. Routine and detailed surveillance for both nonmilitary and military purposes. Can carry armaments.	Interval between 1963 and 1967.
Engineering readiness to put man in space; order of 10,000 lbs. payload in orbit; re-entry with human survival.	Major increase in reliability and versatility of most satellite uses due to human operator. Technical capability to extend range of human habitat to extra-terrestrial bodies.	"
Permanent, manned satellite stations; crew regularly "rotated."	Diverse uses, including scientific, military. Staging point for lunar, and interplanetary travel.	"
First manned lunar landing.	Competition for military (and commercial) lunar possessions.	Interval between 1968 and 1973.
First permanent lunar base.	Lunar military and commercial power established.	"
First Martian landing.	Exploration of the Solar System actively under way. Human habitat continuously being extended.	"
To the stars.	True racial immortality achieved by making man's survival independent from his fate on any cosmic body? Or will we meet our match out there?	Theoretically possible using nuclear-powered ion jets.

Spies in Space

First, the skies of the world are irretrievably open. The Soviet leaders have been coy about our "open skies" proposal; and we ourselves may not have been quite ready to peel open the skies of all the world, as the Russian astronauts have now in fact done. A satellite of "muttnik" payload capabilities, suitably equipped, can be a potent surveillance device. It could (so crystal clear is empty space) gaze down into your yard, and send back to its master a picture of your car standing in your driveway. Within the next year or two, we should expect the beginnings of such surveillance.

The owners of such devices can watch in some detail the shipping, building, industrial, and military activities of the world by optical and electronic means.

What will it be like to live thus always under alien eyes? People everywhere may come to welcome the friendly shelter of the clouds. Perhaps the world will prefer to keep these eyes in the sky under international sponsorship, passing from an IGY scientific phase to a U.N. surveillance satellite era. At any rate, so far as open skies can do it, the world will soon be forever nakedly innocent of secrecy—or privacy, for that matter!

A surveillance satellite is a spy in the sky. Every nation is now a potential producer of anti-satellite weapons. Their use will be affected by two conflicting factors: On the one hand, nations will want to control in fact (and in law) the space above them; for this, they must able (and willing) to destroy intruding satellites. But, if they burn out their rival's satellite eyes, he may launch a "preventive" attack.

Of course, if satellites come under attack they will get defensive arms and armor. It is not clear whether armed satellites will become important strategic bombardment weapons; but, equipped with appropriate surveillance means and weapons, they will be able to detect and destroy hostile ICBMs, or new satellites, while these are still rising under power above their launching bases. (This would be a very punishing experience for the countryside around the bases!) Such an anti-ICBM satellite system can and may be a reality within a decade.

A New Army

Meanwhile, a spaceborne army may appear. Crack divisions will embark in rocket gliders. They will rise like flying fish above the atmosphere, re-enter, and glide to their destination. They can be in action half the world away within two or three hours after the action order comes. Spaceborne warriors may appear later in other places: satellites, lunar bases, other planets.

As satellites demonstrate their unique advantages for research, communications, meteorology, surveillance—both military and civil—and other yet unidentified employments, a contest may arise for control of cis-lunar space. Domination of the space between the Earth and the Moon may well, in time, become decisive for domination of the Earth.

The delivery and return of a small lunar expedition could, as shown by the studies of von Braun and others, be accomplished with present technology. Advances in prospect within the next five years will make this task far simpler. Within a very few years, the first manned expedition will be followed by the beginnings of the first permanent lunar base. That base will probably begin with a hole in the ground. It may be a natural cave or fissure; providing protection from hot sun, cold nights, cosmic rays, and meteors. It should grow into sealed caverns, in which pressure will be maintained just high enough to keep the blood from boiling. But the Moon pioneers may not need oxygen. The "space medicine" people are working toward the development of a synthetic nutrient which could be injected into the bloodstream; making breathing as well as eating and drinking unnecessary. It may, however, prove necessary to breathe at least a little, so as not to get out of the habit, and to provide speech.

Why Occupy the Moon?

The occupation of the Moon may offer, aside from the prestige of its accomplishment, two rewards. One of these depends upon the theory, yet unproved, that the lunar craters are scars of giant meteors, left from the days of the Moon's formation. If this is so, great amounts of nickel, steel, and other valuable minerals may exist on and under the surface. The other is a military one. If one great power should establish a base on the Moon, and hold it for a time against intruders, it might build a lunar fortress almost impregnable to Earth-launched attacks, and thus decide the outcome of a terrestrial power contest. Prevention of exclusive lunar occupation by another power may some day become a major objective of U.S. foreign policy and of our technologic effort. One can even imagine the Moon becoming the agreed arena of conflict for the settlement of terrestrial power disputes, terrestrial damage thus being avoided by both sides and the winner emerging in a position to impose his will upon the earth!

The course and consequences of lunar occupation must for a time remain speculative; but speculation does point up what seems quite likely—that the Moon may, within the next two decades, assume a major role in the terrestrial power contest. Self-sufficient lunar bases may provide an important extension of the human habitat; and thus decrease the risk of self-extermination of the human race in a terrestrial conflict.

And, once Mars has human colonies independent of the Earth, a trend may be set. The expanding range of human habitat may forever be wider than the area that can be depopulated in a violent power contest! We can imagine a time when the destruction of mankind on any single planet will be like the loss, in earlier times, of a city or a culture—a tragedy, but not the end of everything. We, as scientists, may now, in our several ways, strive the more vigorously to stave off a terrestrial holocaust. If, at the same time, we vigorously pursue the development of astronautics, an advance across a truly endless frontier may be inaugurated, ending effectively the peril of racial suicide of man on Earth.