HARPER'S

MONTHLY MAGAZINE

VOLUME 171

JUNE, 1935 — NOVEMBER, 1935

NEW YORK AND LONDON
HARPER AND BROTHERS, PUBLISHERS
1935

THE CONQUEST OF OUTER SPACE

AN APPROACH TO ASTRONAUTICS

BY PETER van DRESSER

THE world is small and getting smaller. Sailors in steam are apt to refer sarcastically to themselves as seagoing conductors; even the air, though it still holds a deal of romantic promise, is being invaded by the worldly and the commercial. The discarded razor blades and empty film containers of exploring parties before very long will have littered all the trails of distant romance still left; air travel—safely, on schedule, anywhere—will become commonplace, and bathysphere excursions to the sea-bottom will furnish amusement for week-enders. What then will be left for the "lunatic fringe" of eternal adventurers, the men who were willing to gamble that the ocean did not end somewhere in a bottomless abyss, the men to whom unknown lands, unconquered elements, have been challenges and lures not to be resisted? Will they cease to exist? Will they sublimate their desires to other fields, scientific, economic, or technical? Or will they settle back in their armchairs and at last become rational, admit that, having reached the sky, man has encountered his ordained limits?

Not, one suspects, while there is an instrument available with which they can pry their way into any new chambers of the cosmos. To the earlier, more naïve mind the flying machine appeared to be such an instrument. With it one might wing to distant spheres, might track the angels in their courses. Now that we can outfly the celestial beings themselves (a fact which any aeronautical engineer can demonstrate; weight/horsepower ratio, coefficient of resistance—these do not harmonize with the idea of an angel) increased knowledge shrinks our limits still farther. We realize more clearly each day that the highest flights of aircraft are mere microscopic punctures of the thin peel of atmosphere surrounding our earth, and the astronomers are at considerable ingenious pains to inform us just how insignificant that globe itself is.

At ten or fifteen miles high wing and propeller bite futilely into near-nothingness; a few miles farther, and the lightest sphere of gas we can create floats at the limit of its buoyancy. Beyond for a hundred miles or more stretches a zone of mystery, a zone where rarefied gases react in obscure ways to radiations from the sun, moon, and stars, where streams of ions weave in patterns almost astrological, where meteorites from outermost space strike and burn themselves to dazzling lances of white-hot vapor, and the eerie glow of the aurora shifts and flickers. Incalculably rich in significance to the life far below are the enigmatic processes of this region. Here are set up the balances, the interplays of forces and elements which, as they flow about the atmospheric globe and work downward through its various strata, condition the weather for the day, the year, the decade. Here occur the great electronic tides controlled by radiation from bodies in the solar system and beyond, whose pulses are reflected in the operation of our radio network. Here begins the strange catenation of influences which links sunspot cycles ninety million miles away with the yearly thickness of fur worn by animals in North America, with the level of Lake Nyasa in Africa, and with environmental changes affecting our destinies with unknown profundity.

A world such as this calls as imperiously for exploration as an unknown continent bearing broad forests, deep rivers, and mountains inhabited by strange races. Its appeal is of impalpables, its significance is only for minds saturated with the scientific animism of this age. It possesses the quality of *endlessness*, that feeling of receding vistas that has attracted the Western mind across oceans, above the clouds, into the depths of space and matter. Tier on tier withdrawing from us stretch the chambers of the universe; we give them resounding names. Beyond the sky is the stratosphere, and above that the ionosphere, and beyond that Störmer's toroid reaches out into space three hundred thousand miles or more. And all this is but an antechamber to the vastness of the solar system, wherein the nine planets with their moons wheel and circle miraculously, and a thousand wanderers swing through their complex cycles, and through all, the tides of radiation ebb and flow from the farthermost ends of all things, and the cunning invisible fingers of gravitation reach and balance and direct.

We have learned a little of these worlds in the generations since we guessed their existence. We want to learn more. And it is in our blood to demand: Will the ship be built to take us to them?

Down the ages drift echoes of the disgusted grunts of the adventurous caveman's mates as he lashes his log contraption together; the contemptuous head-tappings as Columbus' three caravels stand out to the west; the merciless witticisms as Langley and the Wrights tinker with their queer machines. And this is perhaps just as well, for humanity has always had ample share of crackbrains, and a robust skepticism is its necessary defense.

And yet . . . *will the ship be built to take us to them?* And how will she be built . . . of what material . . . and how powered and directed?

Vaguely in answer to these questions looms the astroplane of the future, the ship of space, its form limned in by the men who are laying the foundations of the coming science of astronautics. Yet to visualize it is difficult, for one must adjust oneself to a mode of operation entirely new. Aeronautics, ballistics, and celestial mechanics will be combined in its design. A little of the airplane, more of the projectile, and a great deal of the asteroid, the star-ship will be quite literally like nothing on earth. First of all its propelling principle must be completely independent of air or even of gravitation, and—because "astronautics is primarily a problem of quantities of motion"—it must be capable of driving it to speeds vastly greater than any we are used to, aircraft or even cannon shot not excepted. This is an absolute necessity. Can we conceivably meet it? Conceivably, yes.

II

There is one instrument in existence which in theory is able to deliver velocity in the required amounts and under the required conditions. That instrument is the reaction motor or rocket.

Perhaps the oldest of all prime movers, barring muscle, wind, and water, the rocket has never been seriously put to work. A signal, to some extent a weapon of war, and a life-saving device—these three uses complete the catalogue of its services. The reason is plain: the rocket is in essence an engine of high velocity, and at ordinary speeds is woefully inefficient. Two factors combine to make this so. One is that, like the air propeller, it derives its forward "kick" or thrust by shoving back on a column of gas (though, unlike the propeller, it carries and generates its own gas). Now the magnitude of the thrust depends on the speed with which the relatively light gas is shoved back, and in order to develop a usable force it must be moved very rapidly—in fact with explosive violence. In the past this has been accomplished by using gunpowder as a fuel; and gunpowder is actually a very inferior kind of fuel, not only because of cost but also because, weight for weight, it has nowhere near the energy of ordinary coal. It merely *seems* to have more because of the speed with which it liberates it. The second cause of inefficiency is that even if a "velocity of ejection" of gases high enough to build up a sizable thrust is reached the rocket is still in danger of using most of its energy to shoot these gases back instead of itself ahead. In fact, a rocket is quite capable of burning all its charge at zero efficiency if it happens to be too heavy to lift itself. Not until it is traveling forward somewhere near as fast as its gases shoot backward is it getting the proper power out of its charge. And by the time this high speed is reached the charge is practically exhausted, so that the over-all efficiency of the flight is extremely low—perhaps one or two per cent.

A kind of machine which does not begin to work well until it is traveling a thousand feet a second, and which must burn a fuel as costly and uncontrollable as gunpowder, has naturally found few uses. Yet the very deficiencies of the rocket, viewed from the point of view of the astronaut, proclaim it the only engine suitable for the new and splendid task. Ultra-high velocities are the *sine qua non* of astronautics.

Just what does the rocket motor offer in this direction? This question has been carefully examined by such noted engineers and physicists as Professor Robert H. Goddard, Director of the Physics Laboratory at Clark University, Dr. Hermann Oberth of Rumania, and Robert Esnault-Pelterie, French aeronautical engineer. In the light of such analysis the gunpowder rocket departs completely from the scene, having served its only important purpose of germinating an idea. The low-energy content of its available fuels and the difficulty of controlling them make this inevitable. The power plant of the hypothetical astroplane must bear the same relation to the Fourth of July skyrocket as the turbines of the *Normandie* do to the steam-driven toy described by Hero of Alexandria.

It must make use of the most violent possible controlled combustion of the most highly concentrated fuels we can produce. Explosives such as nitroglycerine or TNT do not answer the requirements. Any of various hydrocarbons do—gasoline, alcohol, or acetylene, combining with pure liquid oxygen. Gasoline, for instance, contains energy to the extent of 20,000 British thermal units per pound, or, expressed in mechanical terms, about fifteen and a half million foot pounds. Theoretically then, a pound of gasoline can generate enough power to lift its own weight fifteen and a half million feet—or almost three thousand miles—above the earth's surface (that is, assuming the force of gravity to remain constant, though actually at that distance it would diminish to a ninth the value at the earth's surface). Here in common use we seem to have a fuel powerful enough to command the interest, if not the respect, of the ambitious astronaut.

Of course such an estimate is only the crudest sort of approximation. The pound of gasoline must lift not only its own weight, but three and a half pounds of oxygen for combustion as well as the weight of the apparatus which it drives. Furthermore, only a fraction of its power is liberated usefully, depending on the efficiency of the engine in which it is burned. This efficiency in the case of the rocket is conditioned by the two factors previously mentioned—one, its ability to turn the potential energy of fuel into the kinetic energy of its jet of exhaust gases; and the other, its ability to translate the resulting thrust or reaction into forward motion. Rocket engineers name the first factor "thermal efficiency," the second, "ballistic efficiency."

Thermal efficiency is determined by the design of the rocket motor—the shape of the "combustion chamber" in which the fuel is burned, the shape of the exhaust nozzle, the way the fuels are injected, and the pressure behind them. Experiments and calculations indicate it can be brought up to about ninety per cent. This high figure is due to the fact that the reaction motor is by far the simplest known—a combustion chamber and nozzle being its only parts.

The ballistic efficiency varies from zero when the rocket is standing still to one hundred per cent when it is moving forward as fast as its exhaust gases do backward. Naturally the final figure, which heretofore has been low, depends upon how long the rocket takes to reach its optimum velocity, and this in turn depends on the ratio of its weight to its thrust, on its air resistance, and on whether it is launched under its own power or given an initial velocity by external means.

A vast field for experimental research, bristling with technical problems, surrounds these various factors. The forces involved, even on a small scale, are quite awe-inspiring. For instance, the mixture of liquid oxygen and gasoline, most commonly used by experimenters, possesses ten times the explosive energy of TNT, and the heat developed is of the order of 2000° Centigrade. The mere bringing together of these fuels, the burning of them in a chamber which will not melt or explode, the directing of the exhaust gases and the measuring of their forces require long and patient practical work guided by engineering ingenuity. Even the *sound* of a liquid-fuel rocket in operation is a new thing on earth, a warning signal of inexpressible and deadly potency. There is something about it as elementally fearful as the whirr of a rattler, and it has been compared to the satanic howl of the wind during a tropical hurricane.

III

Playing with toys of this sort has not been a very common occupation. Professor Goddard, under a grant from the Smithsonian Institute, and later from Simon Guggenheim, executed the first scientific investigations of the rocket motor. A quite extensive series of experiments have been carried on by the German society called the *Verein für Raumschiffahrt*. This society was able to expend upward of twenty thousand dollars in research during its most prosperous year. A handful of individuals scattered about the globe have carried on investigations, some of them systematic and scientific, some of them merely spectacular. Probably the most active center of rocketry is now the American Rocket Society in New York, and there is a Cleveland society. There are also organizations in Germany, Holland, Austria, England, Russia, and Japan.

Slowly, even painfully, these various experimenters are working toward the realization of the theoretical possibilities of the reaction motor. What can be done when certain stages of mastery are reached has been calculated many times. Given a velocity of ejection of so-and-so, a ratio of fuel weight to rocket weight of such-and-such, a certain altitude can be reached. Principles long in use in ballistics and celestial mechanics govern these calculations. They are not speculative. Beginning with trajectories comparable to those of the shells of some of our great guns, the rocket, as its power and efficiency increases, blasts its way farther and farther into the sky. With velocities of ejection already reached in ground tests—about 2500 meters a second—the way well up into the stratosphere, miles above the ultimate ceiling of any aircraft, is open. As the latent energies of the fuel are released more and more efficiently, successive chambers of the cosmos are thrown open to exploration.

If a motor can be built able to hurl its incandescent gases backward at 4000 meters a second and large enough to thrust with a force five times the weight of the projectile it drives, and if this projectile consists by weight of twenty-eight parts of fuel to one part of structure, then the magical "velocity of liberation" can be reached.

This velocity, the holy grail of the astronaut, is the speed at which a body moving in the earth's gravitational field ceases to travel in closed ellipses and follows a parabolic path. It is the speed which, once attained, carries a projectile completely and forever away from the earth. It is the point of transition from the terrestrial to the cosmic, from the earth-bound to the infinite. Its value at the earth's surface is about seven miles a second, or over twenty-five thousand miles an hour. At speeds of this order and greater the true science of astronautics begins. A vehicle reaching them would become in fact an astroplane, able to leave the earth and plunge into outer space, its destination the moon or even a planet. Here again the mathematicians have pursued their indefatigable investigations and have calculated to the last decimal place the possible course of such a projectile, the forces to which it would be subject. They have plotted orbits and trajectories requiring the least amount of time or of energy for a passage from the earth to the nearer heavenly bodies. (They are not wholly inconceivable; that to the moon, for instance, occupies 2 days, to Venus 48 days, and to Mars 90 days.) They have computed the temperatures such a vehicle would attain in free space. (By polishing one half of the hull and coating the other half with black, and thus either absorbing or reflecting the sun's rays as the case demands, livable temperatures could be maintained as near to the sun as Mercury or as far away as Mars.) They have examined the possibility of keeping a breathable atmosphere in an airtight hull over long periods. (Submarine engineering offers a starting point for the development of this technic.) They have discussed the effect on the human body of accelerations five times that of gravity, or entire absence of gravity. (Pilots of racing airplanes and stunt drivers of motorcycles in bowls at fairs are subject to the first condition, and long parachute falls approximate the latter —at least for a short time.) They have worked out satisfactory methods of navigation, based on celestial observations and the use of gyroscopic instruments.

The greatest difficulty so far discovered in this theoretical study is not leaving the earth, but returning to it. It is schoolboy knowledge that an object falls to the ground just as hard as it is thrown up. An astroplane in this sense would behave exactly like a baseball. Leaving the vicinity of the earth at seven miles or so a second, it would return with practically the same speed—a speed at which even the cold, rarefied air of the high stratosphere would be heated far above the melting point of any metal, and the vehicle would flash into white-hot vapor like any of the thousands of meteorites which strike our atmosphere daily. (The same danger would not be present during the outbound trip, because the acceleration to the maximum speed would take place outside the atmosphere.) Two methods have been suggested for avoiding this unpleasant termination to an interplanetary voyage. The first is to use the rocket motor itself to slow down the ship. This, unfortunately, requires the release of atomic power; because no known fuel, in reasonable quantities, contains enough energy to drive a ship away from the earth, laden with enough of the same fuel to stop itself on the way back. The second scheme is to guide the returning ship so as to strike the outer curve of the atmosphere a "glancing blow"—that is, just so as to pass through a comparatively thin bulge of air. The ship would then be slowed somewhat by air resistance, but its line of flight would carry it on out again to airless space before it became dangerously heated. Having then fallen below the "velocity of liberation," it would eventually be drawn back to earth on an elliptic orbit and would reënter the atmosphere to repeat the maneuver. After an adequate number of these "braking ellipses" had been performed the astroplane would have transformed enough of its kinetic energy to heat—in other words would have slowed down sufficiently—to volplane to earth.

This last method is the only one which even remotely indicates a means of making a round trip to our nearest neighbor, the moon. (At least without the aid of complex auxiliary systems to increase the range of a given rocket. These systems are comparable to the re-fueling of an airplane in flight, but of course under entirely different circumstances, and on a vastly greater scale.) Using at high efficiency the most powerful of all fuel mixtures known, which is liquid hydrogen plus liquid oxygen, it is not altogether impossible that a projectile be shot from the earth at exactly the right angle and speed to coast within the moon's field of gravity, encircle her, and fall back to earth in the right direction to land by means of "braking ellipses."

IV

However interesting they may be, it must be emphasized that calculations concerning the possibility of voyages to other planets are now about as valid as calculations for a transoceanic flight based on the performance of Langley's aerodrome. They serve principally to bring home the almost unthinkable difficulties to overcome—difficulties so vast that many learned men have pronounced an interplanetary trip an utter impossibility short of the release of atomic energy or some other god from the machine. Yet it is well to remember that not so many years ago similar pronouncements were made by equally learned men concerning the bare possibility of mechanical flight, even though the gasoline motor had already been invented, the airscrew was known, and aluminum was available. It is now impossible to foresee what new principle or method of attack will be brought to bear on this problem.

Over-enthusiastic speculation and "fictionizing" launched by conjectures of this sort have thrown the whole subject into the domain of the fantastic so far as most people are concerned. And this applies even to rocketry, little sister to astronautics. Yet the art of rocketry, even in its present stage of development, offers the base for a sound program of research leading to immensely valuable results. There is no physical reason why our technic cannot be perfected to such an extent that we can send exploring rockets equipped with instruments twenty-five, fifty, or a hundred miles into the stratosphere. The increasingly important science of meteorology would probably receive the greatest immediate benefit from such an achievement. With hundreds of weather stations about the globe, each one equipped to probe quickly and accurately into atmospheric conditions scores of miles above it, the "three-dimensional weather map" would become a vital reality, and long-range forecasting would influence our economics and sociology. Accurate knowledge of what goes on in the outermost regions of the sky would lead to the development of a science of a kind now hardly conceivable—a science of the cosmic factors affecting terrestrial life and activity.

The next logical field for development is in the fast transport of mail by rockets traveling in trajectories between the great cities of the world. Though somewhat more ambitious than the high-altitude exploration, the making and controlling of rockets for this purpose is not at all beyond the development we have a right to expect in the fairly near future. Transportation of this sort would be about the ultimate in speed: a rocket mail projectile operating between New York and Paris, for example, would cover the distance in about twenty-five minutes. The economic value of such a service in this age ought certainly to be high.

As for man-carrying rockets, they will probably be evolved by judicious crossbreeding with the airplane. Projects for high speed stratosphere planes point toward evolution of this kind; for these aircraft will probably reach velocities at which the reaction motor begins to be efficient. At first merely an experimental auxiliary, the rocket motor may develop a type of extremely fast high-altitude craft which as its power and range increase will gradually merge into something worthy of the name astroplane. This would seem to be the safest way for working out a technic for the use of the new motive power in manned craft.

Why has an instrument of such potentialities not already been brought to some degree of perfection? This question is answered very well by a paragraph from an article on "aerial navigation" which appeared in the February, 1879, issue of *Scribner's Magazine*, long before any successful airship ever flew. I quote the anonymous author:

"Have any commensurate efforts yet been made to achieve this result? [The mastery of the air] Has it been considered otherwise than as a fantastic dream? Have any, save a few enthusiasts, mostly poor . . . attempted to realize it? Is it not left, even now, to the accidents of time? Still, there is nothing yet undone but man desires to do it. His unrest, his eager insatiate daring, penetrates the heart of Africa, the depths of the seas. Visionary speculators waste fortunes upon impossible motors, upon luckless wells and mining shafts, while here is the most tempting of all material achievements demonstrably within the capacities of force and matter already under our control. The determined effort, the liberal expenditure of a single government, even of one of our thousand moneyed corporations, can solve the problem. It is strange that a score of such efforts, of such expenditures are not making; that the princeliest appropriations, the deftest intellects, are not devoted to the attainment of this end. But with or without them, I repeat, the end is near at hand."

Fifty years have passed since this was written, and the situation has repeated itself. As a matter of course money has little taste for such projects as these, for they are profoundly impractical—as impractical as a work of great music, or as Columbus' first voyage across the western ocean. Society can get along perfectly well, in a material sense, without such gestures. It is, perhaps justly, hard to interest capital in making them; and rocket experiments are quite expensive gestures. Fulton was able to work out the principles of his steamboat with small clockwork models—but even model liquid-fuel rockets are formidable and costly contrivances. What work has so far been done has been with limited or erratic financial resources. A great many mistakes have been made, and a great deal of duplication of effort. The majority of rockets so far built—and there have been some ambitious ones—seem to have exploded in mid-air, and none of them has set an altitude record.

But the work goes on and must sooner or later blaze a new trail through and beyond the skies. And this is true above all because the idea has gripped our imaginations—because it speaks imperiously to the presiding genius of our race. We must bring into hard reality the promise of this vision, and affirm once more our unique and all-important creative mastery of matter and space and time.