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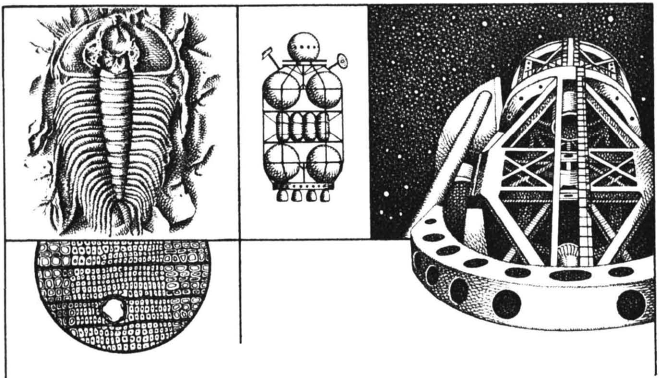
ORBITAL ROCKET LAUNCHING FROM FLYING WING! by WILLY LEY



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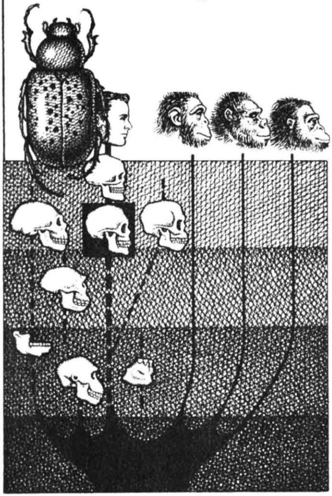

By WILLY LEY

THE ORBITAL (Unmanned) SATELLITE VEHICLE

THE TIME has come when humanity is capable of throwing its first artificial satellite into the sky, and our cover shows Mel Hunter's idea of how it might be done. It is a rather startling idea, combining some elements one would not normally combine that way. But there is at least one good reason for this combination, though it may not be a decisive reason. However, before I go into this with some more detail, the problem itself needs some explaining and clarifying.

As I told some time ago in another column in GALAXY, the idea of the artificial satellite grew slowly, even though its total age is not much over a generation.

When Prof. Hermann Oberth first published his rocket theory in 1923 and 1925, he mentioned that it might be worthwhile to put a manned rocketship in an orbit around Earth in order to pursue a few interesting research projects. He went on to say that a very large rocketship might be left in such an orbit while the pilot returned to the ground by means of a smaller landing rocket. It was on the basis of this suggestion that the concept of the manned space station was developed through the years, culminating in Wernher von Braun's space station project, which was published for the first time several years ago.

INTERESTINGLY enough, nobody, for a long time, thought of an unmanned satellite. Otherwise the rocket pioneers had rather definite ideas on how "the art" would progress. It would begin with small liquid fuel rockets of which nothing was expected except that they functioned at all.

Once one had functioning liquid fuel rockets, one could study them for improvements and one would, in time, arrive at the first useful item: the instrument-carrying high-altitude research rocket. The high-altitude rocket, in turn, would be the foundation for the long-range rocket (either as a military weapon or a mail carrier or both) and then, when the long-range rocket had grown big enough, it would turn into a piloted rocketship which could rise beyond the atmosphere and, if desired, take up an orbit around Earth.

These phophecies of thirty years ago have not only largely come true — they even came true in just about the manner and the order foreseen. The item missing in the early forecasts was, as has been mentioned, the unmanned satellite. I can, in retrospect, think of a few reasons why nobody thought of it.

At the time when Oberth and others talked about high-altitude research rockets, the idea was still that the rocket and its instruments would return to the ground by means of a parachute, or by separate parachutes if this should turn out to be more practicable. Then the instruments would be picked up and their records examined. In reality — even though some of the smaller types of liquid fuel rockets have been recovered by parachute in the meantime — this is not the method generally followed.

During the time needed by the liquid fuel rockets to grow to the necessary size to become high-altitude research rockets, another technique grew up, too, the one now called "telemetering." In principle, it consists of hooking up the instruments with an automatic radio transmitter so that the instrument readings are broadcast and received and recorded on the ground while the rocket is still climbing.

Without such telemetering, an unmanned artificial satellite would have seemed useless. What would have been the use of throwing a package of instruments into an orbit around Earth if the only way of recovery would have been by manned rocketship? If you had to build a manned rocketship for this purpose, it was far more logical to expect the manned ship to take the readings in the first place.

BUT now we do have telemetering and that changes the whole picture. A package of instruments circling Earth could report to what extent it was warmed by the Sun and how much (and how fast) it would cool off when in the shadow of Earth. Such a package could count the number of cosmic rays encountered and report it to the ground station. It could count, and report, the number of impacts of cosmic dust particles and one could even go so far as to divide the outer skin into a number of "reporting areas" so that one could get a good idea of the distribution of cosmic dust impacts.

It has also been suggested to make a small pressurized cabin with an experimental animal in it a part of the instrument package, for the behavior and reactions of the animal over a period of several days of apparent weightlessness would be very worth while knowing. (At the end of the observation period, the animal could be killed instantly and painlessly by having a timing device release hydrocyanic acid into the compartment.)

In addition to these general problems, an artificial satellite could be used with probable success to attack a few special problems. If the artificial satellite did not circle Earth over its equator, but had been placed into an orbit cutting across at a slant, its whole orbit would slowly be turned around. This is technically known as the progression of the nodes and the rate of this progression would furnish us with rather precise information about the volume of Earth's equatorial bulge.

An artificial satellite placed into an orbit which leads over both magnetic poles could be specially equipped to tell us more about

Earth's magnetic field. Incidentally, it would also provide a great deal of useful knowledge about the cosmic rays and their distribution in Earth's magnetic field.

If we had one artificial satellite moving at a certain height over the equator and equipped to report cosmic dust particle impact, and another artificial satellite, equipped in the same way but moving in an orbit which passes over both geographical poles, we would quickly find out whether there is a higher accumulation of cosmic dust over the equator (or in the plane of the ecliptic), which is a theoretical possibility.

Another and rather obvious job for an artificial satellite would be to demonstrate how much drag is caused at a given height by the air molecules — one can't very well call it atmosphere — still present. Right now, you won't find anybody who'll be willing to give definite figures for residual drag at, say, 180 miles. But you'll find a large number of people who would part with a month's pay, if necessary, to find out.

The method of finding out would be simplicity itself — put an artificial satellite into an orbit 180 miles above the ground and watch it carefully. Residual drag will make its orbit shrink — and cause it to burn up in the atmosphere like a meteorite in the end — and the rate of shrinkage will provide the figure for the drag. Of course, once this has been solved for the 180 miles mentioned, the experiment might be repeated for 250 or 300 miles. The goal is still the manned space station and engineers want to be very sure that there is no observable residual drag at the height where *that* is going to be built.

IF YOU have followed carefully, you'll have noticed that quite a number of the problems to be solved do not require reporting instruments. In various cases, the answer can be found by observation of the orbit assumed by the satellite; the instrumentation would report on something else. This means that the first artificial satellite — or possibly the first two or three — do not need to be instrumented. Their very existence would do the job.

Hence the fairly recent concept of the *un*-instrumented artificial satellite. We would learn something (something, I wish to stress, that cannot be learned any other way) if we merely threw a bale of cotton into an orbit around Earth. Obviously such a "bale of cotton" would be cheaper by far than a complicated instrument package and in all probability it will cost less fuel to throw it into an orbit.

All that is really required of the first one is that it can be observed from the ground visually and photographically and that it will give a radar echo.

How large would it have to be for this purpose?

I know from lecture experience that the size thought to be necessary for observation is always wildly overestimated. Recently a reader sent me a newspaper clipping about an amateur astronomer who said that he believed that he had discovered a second moon of Earth. The clipping went on to tell that the distance estimated was 400 miles above the ground and that the amateur astronomer stated that it was quite small, "possibly less than a hundred feet in diameter." I have put this sentence in quotation marks because it is not clear from the article whether this was a verbatim quote or a remark by the newspaper reporter himself.

The answer to the whole story is that a second moon of Earth, moving at a distance of 400 miles and about 100 feet in diameter, would have been discovered a long time ago because under favorable conditions, at dawn and at dusk, it would be a naked-eye object which might be faint but would be conspicuous because of its visible movement.

What is really possible with modern instrumentation (and you don't have to think of the 200-inch reflector or the 48-inch Schmidt camera) has recently been told by Clyde Tombaugh, who is hunting for moonlets of Earth. He could detect a V-2 rocket at the distance of the Moon (240,000 miles) or a tennis ball at a distance of 1000 miles, provided only that both were painted white. This refers to photographic rather than visual detection, but it shows what can be done. It also shows that the un-instrumented artificial satellite would not have to be very large.

ONE suggestion made is to use an inelastic plastic balloon, white in color and radar-reflective and pack it into the nose of a rocket. The nose compartment would be in sections, held together by explosive bolts so that it can be made to fall part either by means of a timing device or by radio command from the ground.

The same timing device would open the valve of a tiny pressure cartridge inflating the balloon. Since the outside pressure is zero, the pressure required for inflating the balloon is very small; an ounce per square inch would be fully sufficient. Because of the lack of pressure from the outside, this balloon would keep its shape even if punctured by a meteorite, which is why I stated that it should be an inelastic balloon that is not stretched during inflation but is inflated merely to establish its shape.

Another suggestion for a very simple un-instrumented artificial satellite is to carry a pressure cartridge containing a plastic foam, similar to the aerosol shaving cream bombs. Here nothing is needed but a timing device operating the valve at the right time, after the rocket has settled in the orbit. The total weight of such an un-instrumented satellite would be ridiculously small, six or eight pounds, but the bubble would be large enough for easy observation with small instruments, for radar echoes and even for naked-eye visibility at dawn or dusk, when the observer is still (or already) in the shadow of Earth but the artificial satellite is still in sunlight.

Now let us see how difficult it would be to get it into space. The so-called circular velocity for Earth, the velocity with which a body must move to stay always at the same distance from the ground, is given by the square root of $g(r + h)$ where g means gravity, as usual, r means the radius of Earth and h refers to the distance above the ground. If h is zero, the value for the circular velocity is 4.943 miles per second. That is the speed a satellite would have if it were racing around Earth at ten feet above sea level.

Obviously this cannot be done because of air resistance. At a distance of 1000 miles, the necessary speed is 4.4 miles per second; a quarter of a million miles away, it is only 0.64 miles per second.

But these figures are deceptive in a certain way. True, the farther the satellite is from Earth, the smaller its orbital velocity, but that does not mean that it would be easier to establish a satellite at 10,000 miles than at 500 miles. It needs extra fuel to lift it to that distance, so the cheapest satellite, in terms of fuel expenditure, is the one closest to Earth that the presence of the atmosphere will permit.

LET us say, for the sake of round figures, that the artificial satellite will require an orbital velocity of 4.5 miles per second. The rocket must be capable of attaining this velocity, parallel to the ground. And in the process of attaining this velocity, it must climb out of the atmosphere against Earth's gravity and against atmospheric drag for part of the way.

If the rocket climbed on a near-vertical path all the way, it would, of course, traverse the atmosphere along the shortest route, but its "heading" would be wrong. The solution is the one which has been in use for a long time for long-range rockets: vertical takeoff and a vertical, or very nearly so, path for the first eight or ten miles. Then a gradual tilt in the proper direction, assuming shallower and shallower angles to the horizontal. For long-range rockets, the tilt is usually stopped when the angle is near 45°, since this results in the longest range for a given velocity. For establishing an artificial satellite, the angle would be still shallower.

Of course it cannot be a single rocket. If we wanted a single rocket to go into such an orbit, it would need so much fuel that it would have to have a mass-ratio of about 40:1, which means that its takeoff weight should be 40 times as high as the weight of what finally gets into space. Such a rocket obviously cannot be built. The answer is the step principle, a rocket carrying another rocket as its payload, and the payload of the second rocket being a third rocket. That way, you get rid of unnecessary dead weight just about as soon as it can be done.

Now the general rule for the velocity a rocket will attain is that the velocity of the rocket becomes equal to the exhaust velocity if the mass-ratio is equal to 2.72. This, however, does not include the fuel that is expended in fighting gravity and that required to overcome air resistance. An extra allowance has to be made for that.

If we assume that our fuel will produce an exhaust velocity of 1.5 miles per second — a little high for present-day fuels, but I am not advocating a special design, only to demonstrate the principle — such a mass-ratio of 2.72:1 would produce a rocket velocity of 1.5 miles per second. If we take the mass-ratio a bit higher, namely 3.5:1, the rocket velocity would be 5/4 of the exhaust velocity or 1.87 miles per second. Since the establishment of the artificial satellite needs 4.5 miles per second plus allowance for the climb and some air resistance, and since 3 times 1.87 is 5.61, the rocket needed for the job would be a three-stage rocket.

WE'LL run quickly through a rough weight calculation for the whole. If the payload weighs 8 pounds and the empty rocket of Stage III weighs 60 pounds, the third stage would need 170 pounds of fuel, so that its total weight would be 238 pounds. This is the "payload" for the second stage, which we'll assume to weigh 812 pounds empty. It would need 2625 pounds of fuel, so that the "payload" for the first stage would work out to 3675 pounds. If the empty rocket of the first stage weighs 6125 pounds, the fuel for the first stage would be 24,500 pounds, so that the total takeoff weight for the whole three-stage job would be 34,300 pounds or about 15½ tons. That wouldn't be much bigger than the 12-ton V-2.

But a rocket engineer entrusted with the job of designing a three-stage rocket for an uninstrumented artificial satellite would not start from scratch in this manner. He would look around for existing rockets which could be fitted into a three-stage assembly with only minor modifications.

When the two-stage rockets of Project Bumper were designed, two existing and then available types were used: V-2s for the first stages and WAC Corporals for the second stages (even though everybody, including the designer, of course, knew that a specially developed second stage would produce much better results). For the satellite-carrying three-stager, the engineer might hope for three different available rockets which, in combination, would produce the required ultimate velocity. Naturally, it may happen that he has to settle for two and design a stage between them to do the job.

An interesting example of such thinking, with an additional idea thrown in, was a paper read at the Ninth Annual Meeting of the American Rocket Society in December, 1954. During the past few years, Dr. Van Allen had obtained very satisfactory results by launching the solid-fuel "Deacon" rockets from high-flying plastic balloons. Because the balloon carried the rocket to regions where air resistance has become almost negligible, the rockets operated under near-ideal conditions: they could move under high accelerations.

The two authors of the paper (K. Stehling of Bell Aircraft Co. and R. M. Missert of the University of Iowa) advocated the launching of the artificial satellite by means of a balloon-borne rocket. Their first stage was to consist of four solid-fuel booster units with a total weight of 12,000 pounds. The second stage was to be a 1300 pound liquid fuel rocket and the third stage a 200 pound liquid fuel rocket with a thrust of 2000 pounds and a payload (satellite) of 30 pounds.

All these figures sound "reasonable" in the sense that rockets of about these specifications are likely to exist. The solid-fuel boosters resemble a British type which has been discussed in aviation magazines, the second stage corresponds approximately to the Aerobee rocket and the third stage might be built around a liquid fuel booster.

TO SUBSTITUTE a fast jet plane for the balloon would have a number of advantages. The jet plane probably could not carry the rocket to quite the height reached by a plastic balloon, but it could go high enough so that more than half of the total mass of the atmosphere would be below the rocket.

To make up for the comparative lack of height, the jet plane would provide an initial velocity of ¼ mile per second. If it flew in an easterly direction near the equator, Earth's rotation would have added another ¼ mile per second before the plane even took off. This would leave slightly more than 4 miles per second to be added by the rocket assembly, which might be done even by a two-stage rocket, especially since the plane would provide direction and elevation (by pulling out of a shallow dive) so that the guidance equipment of the rocket could be kept to a minimum. All it would have to do is to go where aimed.

Again, somebody toying with this possibility would have to look around for two suitable rockets plus a suitable jet plane. But whether air-launched or ground-launched, the combination of rockets required to throw a small uninstrumented satellite into an orbit should be achievable in the near future.

ANY QUESTIONS?

Just what is the internal constitution of Jupiter? In the book "Earth, Moon and Planets" by Fred L. Whipple, Jupiter is shown as consisting of a metallic core overlaid by a thick shell of ice and a deep hydrogen atmosphere. The diameter of the metallic core is shown to be about half the total diameter. In a more recent book by George Gamow, the same scheme is followed, but the metallic core is at best 10 per cent of the total diameter. Which one is right?

Charles B. Hoffmeister
Montclair, New Jersey

To answer the last sentence first: I don't know which is right and if anybody else does, he has kept quiet so far. Naturally we don't know the internal constitution of Jupiter; these are various "educated guesses" to make the mass come out right for the observed dimensions and to account, simultaneously, for the measured temperatures.

In a still more recent book, Robert S. Richardson's *Exploring Mars*, you can find a cross section of Jupiter according to the ideas of W. H. Ramsay of Manchester University, England. Professor Ramsay's fundamental proposition is that Jupiter consists mostly of hy-

drogen, all other elements being present in such small amounts (comparatively speaking) that they can be regarded as mere impurities of the hydrogen. In this concept, the surface of the planet consists of cold gases in violent motion, which is what we see in the telescope.

The pressure below this surface builds up rapidly and at a depth of, say, 500 miles, the planet's crust would consist mostly of solid hydrogen. At a depth of 2000 miles, the solid hydrogen is calculated to be under a pressure of 200,000 atmospheres. At a depth of 5000 miles, the pressure would approach 800,000 atmospheres.

The solid hydrogen would have a density of 0.3 of that of water at 2000 miles and of 0.4 at 5000 miles. At a pressure of 800,000 atmospheres, solid hydrogen changes to metallic hydrogen, which is far more compressible than solid hydrogen.

Ramsay's picture of Jupiter then consists of a solid hydrogen shell 5500 miles thick covering a sphere of metallic hydrogen 75,800 miles in diameter. The density of the solid hydrogen is supposed to lie between 0.3 and 0.4; the density of the metallic hydrogen is calculated as being 0.9 near the surface of the metallic hydrogen sphere and 3.7 at its center.

This, too, makes the overall density come out correctly, but whether this picture corresponds to reality is something that only future research can tell.

What is the escape velocity for each planet of the Solar System and how is it found?

Earl Dawney
Route No. 2
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The escape velocities of the various planets, expressed in miles per second and rounded off to the nearest 1/10th of a mile, are as follows:

Mercury	2.2
Venus	6.3
Earth	7.0
Mars	3.1
Jupiter	37.0
Saturn	22.0
Uranus	13.0
Neptune	14.0
Pluto	6.0??
Moon	1.5

In order to find the escape velocity for any planet, it is necessary to know its surface gravity. The escape velocity corresponds to the impact velocity of a body which fell to the planet from infinity; this happens to be equal to a fall through a field of constant sur-

face gravity for the distance of one planet radius. The formula is the square root of 2 g multiplied by the planet radius; the "g" refers to the surface gravity of the planet.

I wish to take exception to your statement in GALAXY *for February, 1955, page 82, where you say "1* A.D. *immediately followed after 1* B.C.*, though logically one should expect a year zero (namely the year of the birth of Christ) between them." Most scholars are now agreed that Christ was born in 6* B.C.

"Student"
University of Chicago
Chicago, Ill.

Normally I do not answer anonymous letters — names are withheld on request — but I'll make an exception in this case since a personal acquaintance brought up the very same question. Of course I know that historians think that Christ was born several years earlier than first believed — the dates mentioned are 4 B.C., 6 B.C., and 8 B.C. But when I wrote this reply, that problem was not under discussion; no matter what the actual year of the birth of Christ happened to be, my point remains: logically, the year of the birth of Christ should be zero between 1 Before Christ and 1 Anno Domini.

—WILLY LEY