

Space Travel

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TODAY'S CHALLENGE:
SATELLITES TO A
SPACE
STATION



★ DENOTES SPECIAL
FEATURE ARTICLE

JULY 1958

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FACT & FICTION

- ★ TODAY'S CHALLENGE—SPACE STATION 6
Special science feature by Henry Bott, Research Engineer
- ★ SURVIVAL PROBLEMS FACING—MAN IN SPACE 18
Special science feature by Guenther Schmidt, Ph.D.
- PLANET OF EXILE 30
Interplanetary science fiction novel by Edmond Hamilton
- BLIZZARD-BRAIN 86
Science fiction short story by Darius John Granger
- THE ULTIMATE VICE 100
Science fiction short story by A. Bertram Chandler
- TO PLEASE THE MASTER 110
Science fiction short story by Margaret St. Clair

FEATURES

- THE EDITORIAL 4 REMAKING THE EARTH 116
- MAGNETISM 28 SCIENTIFILM MARQUEE 118
- ROBOT TRANSLATORS 99 THE COSMIC PEN CLUB 123

Front cover painting by Malcolm Smith, depicting coming Space Station

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SPECIAL SCIENCE FEATURE

**Today's Challenge:
From Satellites to a**

SPACE STATION

by

Henry Bott

Research Engineer

THE SKY HAS NOT changed greatly over the few thousand years that men have observed it. It has not altered much until this past year. In that year men looked into the sky with mingled awe and fear; for the first time in their history they were seeing something which had not been there before, which was man-made, and which, for better or for worse, was to alter their role in the universe. Like the discovery of fire, agriculture, the wheel, the steam engine, and atomic energy—satellites are the precursors of men into space.

We have previously discussed the fantastic power of the gravitational chain which binds us to this planet and the equally astonishing power

of the rocket engines which will liberate us. This article proposes to consider the first faltering but positive uses which will be made of the rocket to construct a stepping stone from which astronauts will go to the Moon, the planets of the Solar System and ultimately—the stars.

The first question is: "What is a satellite? To what in our experience does a satellite conform?"

Hitherto a satellite has meant, "a planetary body which orbits around another planetary body, the Moon around the Earth, the Earth around the Sun." October 4, 1957 changed that however. It is likely that to most of us, the word "satellite" will stand exclusively for an artificial object designed to circle



Figure 1

Scientists agree first Space Station will be "wheel-shaped" as above.

the Earth and which will be thrown into that position by rocket motors.

In principle the establishment of a satellite is simple. The satellite, whether it weighs ten or ten thou-

sand pounds, is mounted in the nose of a rocket. The rocket carries it to the desired altitude. At that altitude the rocket tips into a tangential position with respect to

a circle of the radius of its height, accelerates the satellite to a pre-ordained velocity and then releases it to course around the Earth while it, the rocket, returns to Earth.

"In principle" the words had it. Actually this is an exceedingly difficult thing to do. Nevertheless it has been done.

We shall assume only circular orbits in this article although they are the most difficult to establish. They also are the most desirable, and as we become more sophisticated in the techniques of rocketry, they will be the orbits actually used.

It has been established that for any altitude above the Earth's surface outside the Earth's atmosphere there is a specific tangential velocity which a body must have to remain in a circular orbit precisely as a stone swung at the end of a string remains in a circular orbit about the swinger provided he sustains its motion at a certain and requisite velocity.

Figure II shows the relationship between velocity and altitude above the Earth's surface for circular orbits. It is merely a plot of v against r from the formula previously derived, which equates gravitational force to centrifugal force.

The mechanics of orbits in gravitational fields have been considered. All we require to know is the rela-

tionship described in Figure II. The weight of the satellite which can be placed in a circular orbit is dependent upon the size and power of the step-rockets which launch it. Given these instruments, satellites of any physical size can be constructed, piece by piece if necessary. We shall see later that an inhabited satellite undoubtedly will be built in this manner. It is much less costly in terms of rockets and fuel.

The satellites already established are modest affairs compared with what ultimately will be set up, although Sputnik II was astonishingly sophisticated for the time in which it kept its canine passenger alive.

The main reason for establishing a satellite of any magnitude—and manned—is to use it as a central core for the construction of a space station which in turn will be used as a jumping-off point for rockets to the Moon and to the planets. But before we consider the space station, let us examine the sequence of events which will lead to it.

The series of satellites now existing in their temporary orbits about the Earth have—and will continue—sent invaluable information on the shape of the Earth, the variation of air density with altitude, the intensity of cosmic radiation, the density of meteoric dust, and innumerable vital other intelli-

height above Earth's surface	tangential velocity re- quired for circular orbit
200 miles	16700 miles/hour
4200 "	11850 "
8200 "	9600 "
12200 "	8450 "
16200 "	7500 "
26200 "	6080 "
46200 "	4750 "

This table is computed from the formula

$$v \text{ tangential} = \sqrt{g \frac{R^2}{r}}$$

which is found by equating the centrifugal force on a satellite with the gravitational force on it.

Figure 2

gences.

It requires very little more power and skill to send up a satellite equipped with a television transmitter, powered by solar cells, into a permanent and more nearly circular orbit than were the original sputniks. Satellites of this type will be sent up to various altitudes in-

cluding undoubtedly the altitude of 22,000 miles above the Earth. The characteristic of this altitude is that it provides a twenty-four hour orbit, coinciding with the period of the Earth so that the satellite would remain at one point fixed with respect to a point on the Earth. To an observer on the Earth

it would be fixed in the sky. Arthur Clarke points out that a chain of such satellites could serve as television and radio relays capable of blanketing the Earth—and only a few would be needed.

Remember that we are still speaking of *un-manned* satellites.

The military aspects of such satellites are obvious, although it seems hardly necessary to point out that the capability of establishing such a satellite automatically includes the capability using un-stoppable intercontinental ballistic missiles. In the view of many observers, military considerations of satellites are not worth discussing simply because the present state of rocketry, aircraft and hydrogen bombs have already made the concept of war as an instrument of national policy absurd—such a thing as a war of the World War II character can mean only the destruction of most living things on Earth—victor and vanquished. Nevertheless, we can think of rockets and satellites in terms of “massive deterrents” if we like, although it is hard to imagine the irrationality of war at all in an age of current weapons.

Un-manned satellites in permanent orbits, equipped with communicating devices will be then the nuclei for the establishment of the space station. Prior to this there

will be short-lived flights of human beings in semi-permanent satellites, perhaps for days or weeks. The animal-carrying satellites will have already supplied all the necessary information about the environment that must be sustained in order to accommodate other living things.

THE STATE of rocketry is progressing so rapidly that by the time this article appears in print, many of the aspects of satellites we have been discussing, likely will be established fact.

A project longer of attainment but just as certain, is the space station. This conception which has a history as old as rocketry, is the most important idea of all, after the rocket itself. The reason for its importance is that it breaks down the jump into space into steps. Great stress is laid on the fact that to shoot a rocket to the Moon or to Mars, even a multi-step rocket, is an incredibly difficult undertaking because the gravitational chain is so powerful. The space station breaks this chain.

It will be remembered that gravitational force falls off as the square of the distance. Imagine a satellite set into an orbit at ten times the radius of the Earth. With respect to the Earth's gravitational field, gravity has one one-hundredth its value here of its value at the sur-

face of the Earth. To project an object—say a space-ship—into escape velocity to the Moon or to another planet—say Mars—requires only a trivial additional velocity because the Earth's gravitational field here is essentially nothing. Of course nothing has been gotten without cost. It still takes enormous energies and velocities to lift objects to the space station. The law of conservation of energy does not permit us to get something for nothing. How then does the space station aid us?

To raise tons and tons of space-ship in one jump is incredibly difficult, but if we break down the space-ship into small packages, raise them one at a time and then assemble them at some central point—the space station—the job is infinitely easier. It is the purpose of the space station to be this rallying point.

Every bit of mass that is put into space, either in an orbit or in escape, must be paid for with fuel—that fact is inescapable.

Doing this piece-meal is many times easier than doing it in one effort. It is precisely the reason for the step-rocket. A single-stage rocket for massive satellite work would be gigantic. A three-step rocket becomes manageable. Similarly a single jump to the Moon is very hard. But a jump to the

Moon in two steps, first from the Earth to an orbiting satellite and then from the satellite to the Moon is a reasonable endeavor.

Let us then consider the establishment of a manned satellite, a space station.

To begin with let us assume that a twenty-four hour satellite (height 22,000 miles) has already been located in orbit. This fixed dot in the sky, undoubtedly lighted, would be the star toward which we would aim our efforts. We can regard this as being located at a suitable height for a space station. Escape velocity for an object from this altitude would be about 2 miles per second, a modest speed considering that escape velocity from the Earth's surface is about 7 miles per second.

This unmanned satellite which will serve as a focal point of the space station effort would be as large as it conveniently could be made since it would eventually be cannibalized for metal and parts as the space station evolved. The object now would be to send up rocket after rocket, the first few manned, to intersect the orbit of the unmanned satellite. Intersection of course is not enough. The ascending rockets must match direction and velocity with the satellite. The technicians sent up with the first rockets would easily be

able to accomplish this operation for the accuracies needed are not insuperable. They could "home" either on the satellite's light or its radio beacon. It is assumed of course that the state of rocketry would enable the ascending rockets to be placed reasonably close to the satellite. Subsequent manueverings to match velocity and direction would not be difficult.

Every bit of material sent up to this focal point would be used. Except for the one or two ferry rockets that might return to Earth, everything ascending skyward—except the technicians—would be going one way—spacewards.

In the beginning, the construction of a space station would remind one of a cosmic junkyard or a stellar autowrecker's. Once directions and velocities of cargo rockets had been matched with the satellite, the "junkpile" would be a super-satellite.

Naturally everything related to this operation would have been very carefully planned. In principle again this sounds easy and from one point of view, would be. But there would be a myriad of details to be watched. Every bolt and nut, every scrap of wire, every can of food and water would require the expenditure of an enormous amount of fuel. Hence, careful planning.

Everyone has seen innummer-

able pictures of this hypothetical space station. Imaginative planners have given it the form of a gigantic bicycle wheel (von Braun) or the shape of a huge umbrella. Opinions for the requirements dictating shape may change with time. There is good reason for considering the shape of a wheel since rotation—and hence artificial gravity—could easily be arranged with this form. Whatever its initial form, it is not hard to imagine its growth by a process of accretion. Since nothing sent up would be thrown away, after a time the space station might look like "nothing on the Earth—or of it."

The materials from which it would be constructed as well as its mechanical structure might strike one, accustomed to conventional engineering practice, as peculiar. Because gravity need not be contended with, materials could be flimsy by Earth standards. Wire, thin sheet metal, impregnated fiber-glass, plastic-film, and materials of the sort which are good in tension but not in compression, would be used. Living quarters might be distended balloons.

The outlines though, of structure of this kind are not dim. We can think of the space station as a large torus, a spacial doughnut, compartmented, delicate in structure, but adequate. A new-comer

to such a place might be struck by the abundance of wire, the use of nets, the ubiquitous antennae. (See figure I)

The purpose of the satellite is to serve as a rallying point, a way station, a depot, a housing project, for men and space-ships on their way to the Moon and eventually to the planets. It would have fuel storage tanks as well as rooms for food. It would have elaborate transmitting and receiving equipment for all radio bands as well as for television. It would eventually house a telescope, (infinitely superior to any on Earth by virtue of its operation in space, not air) and of course in time there would be laboratories of all kinds, for physical, chemical, biological and medical research.

An extravagant development like this would not take place overnight. Rather its growth would be over a course of years. Undoubtedly more than one such space station would be erected.

Remembering that each kilogram of mass in the satellite represents thousands of kilograms of chemical fuel supplied by Earth, it is not hard to realize what a costly undertaking this would be. But it will be done whatever the cost.

All of this activity is predicted, as was the story of the rocket, on the use of chemical fuels. But

technology has a way of coming up with turning points—I'm thinking of developments in atomic energy and hydrogen fusion—which might ease the costs considerably.

With the exception of the personnel of the space station and the ferry rockets, we think of the traffic between the Earth and the space station as one-way, at least until men intend to bring with them samples from the Moon and planets.

LET US LOOK a little more closely into the basic needs of the space station. First, there is the matter of food, oxygen, and water. Arthur C. Clarke has pointed out that for a crew of twenty-four men, for a period of one year, these three vital requirements would total little more than seventy tons, a quite reasonable figure. The techniques provided by the various "space-medicine" groups assure us that men could live comfortably in a "closed-system" given these supplies. Absorption of carbon dioxide from the air, provision of oxygen by growing plants or by actual supply from Earth, re-cycling of body wastes—all these things are done today on a laboratory scale or simulated in submarines.

The question of heat of course has so often been discussed that it needs no more than mention here.

A space-ship or space station can be regarded as a superior vacuum bottle—temperature control is a trivial problem.

The other major requirement for a space station is, naturally, power—power for communication, lighting, perhaps subsidiary heating, welding, and in general for the multiplicity of tools and machines which would be in use, from cigarette lighters to machine tools.

We can imagine that this need will be met in any of a number of ways. Until recently, the favored method suggested was the use of a solar mirror of large but flimsy construction which would supply the heat energy by focusing the rays of the Sun on a mercury vapor boiler which in turn would be used to drive a turbine to power an electric generator. Theoretically there is nothing wrong with this idea, but as has been mentioned, advances in science come at such a furious pace, that the idea seems outdated already.

Photo-electric cells of remarkable power and efficiency already are available. By the time the space station is a reality, these direct convertors of sunlight to electric power will have been so well developed that intermediate methods will be unnecessary.

It is also perfectly feasible that a small atomic power package

might then be developed, and of course there is the encouraging possibility that hydrogen fusion will be well out of the laboratory stage.

In a phrase, power for the space station is no problem at all.

A number of potential dangers to space station crews must be considered. Cosmic radiation still remains somewhat of an unknown quantity about which satellites are providing information. It is reasonable to expect that cosmic radiation however will not be an insurmountable obstacle.

The statistical study of meteoric impact has assured us that the danger of a space station being struck by a meteor capable of injuring the "place" or its crew is negligibly remote.

While we do not yet know the full story of "Laika" the inhabitant of Sputnik II, everything that so far has been learned leads us to believe that not only can man endure the state of "free-fall" or weightlessness, but he can operate most effectively in it. Air Force tests have confirmed this also. Our physiology has nothing inherently in it which forbids the human body from functioning without gravity.

A space station set into its orbit cannot expect to remain there permanently. Perturbations caused by

the asymmetry of the Earth and presence of the Moon can be expected to shift the orbit. Corrections for these effects can easily be taken care of with small rocket impulses of the correct thrust, direction and duration. In fact an automatic system for this purpose can be devised.

The purely mechanical problems of matching the velocities and directions of arriving space-ships and ferry rockets to that of the satellite, the transfer of men and goods, and other matters of a similar kind, can be regarded as relatively simple. While it is true that the velocity of the satellite will be measured in thousands of miles per hour, all that really concerns the pilot of the arriving space-craft is the *relative* velocity between his vessel and the satellite. In some respects, because of the large margin for error provided by the very vastness of space, attaching to a satellite is simpler than the case of one jet plane re-fueling another.

Communications between space-ships and satellites, over the distances we are speaking of—thousands, tens of thousands, and hundreds of thousands of miles—is a straight-forward problem in applied radio and radar techniques. The power of ordinary present-day transmitters and the sensitivity of familiar receivers such as are used

in communications on Earth, are adequate for the purpose suggested. The send-reflect of the radar system used to make contact with the Moon is orders of magnitude more difficult.

WITH A MANNED satellite in position, the trip to the Moon and back—and even the Martian and Venusian round trips—assume less frightening proportions. Ferry rockets will carry small quantities of fuel to the satellite, making many trips until the satellite takes on its major characteristic, that of an orbiting “fuel dump”.

Because a ship attached to the satellite already has acquired most of the necessary potential energy to reach escape velocity, a small increase in velocity will then be the ship's escape velocity from the altitude of the satellite. In fact the tangential velocity of the satellite in its circular orbit, multiplied by the square root of two is “escape” velocity for the rocket.

As rocketry and astronautics develop we can also expect to see the satellite or artificial “space island” idea carried out for the Moon and for Venus. Mars has an excellent set of satellites in the form of its moons, Deimos and Phobos, orbiting around the planet at useful distances.

It cannot be emphasized too often that the use of satellites lies in making the "steps" to space, smaller. No matter how you do it, just as much work must be done to pass through a gravitational field in steps as must be done to do so in one jump. But with the limitations Nature has imposed on us in the form of chemical fuels, the step method enables us to supply the necessary energy to do work in this gravitational field in increments which are small enough not to require the construction of rockets, the mass-ratio of which, is almost unrealizable.

Perhaps one of the most useful, if somewhat prosaic aspects of satellite building, is given by their suitability as telescope platforms. Any astronomer would be delighted to eliminate the gigantic column of air through which his telescope must probe. The major limitation on the modern telescope is that the light which reaches it must penetrate the Earth's dense atmospheric blanket, a shimmering haze which plays hob with incident light. In the superb vacuum of space a telescope which would be regarded as modest on Earth, would be as effective as the Palomar giant.

The emphasis given to the telescope located on a satellite comes from understanding that it is our primary tool for discovering ma-

crocosmic knowledge of the Universe. The other end of the scale can be probed in the microcosmic laboratories of the nuclear physicist. But study of the Universe requires that light from the depths of space reach us.

As for the Earth-bound science of meteorology which is so important to each of us, the satellite will enable that subject to become more than the scientific guessing game it is today. Imagine the weatherman who can study the complete pattern of cloud formations on the entire globe spread out before him as he sits in his comfortable niche in the Earth-girdling satellite.

The usefulness of the satellite to the sciences cannot be exaggerated and we are probably just touching the fringes of the effects it will have in those fields.

Studies conducted in satellites may yield important clues to basic questions such as "what is life?" and "what is the nature of the atom?" We can only speculate on these potentialities.

It is not inconceivable that the arts and the humanities will receive fresh impetus from the satellites. Certainly the human spirit has never been released so dramatically. What new art forms can originate with a person whose viewpoint has been so strikingly refurbished through a visit to a satellite?

Dare we imagine a second Renaissance?

But no apology is needed for suggesting that satellites must come. They are as inevitable as technological advance itself. What is hard for many persons to realize is that unlike any other adventure of the human spirit, the development of these stepping-stones to interplanetary—and interstellar—

space, is a step forward in human progress. It is comparable only to the greatest landmarks in human history—the discovery of fire, the city, agriculture, Grecian mathematics and philosophy, the Renaissance, the concept of freedom, the Industrial Revolution, or the Ages of Iron and Atoms. . .

Our conquest of space will reshape life on Earth as we know it.
