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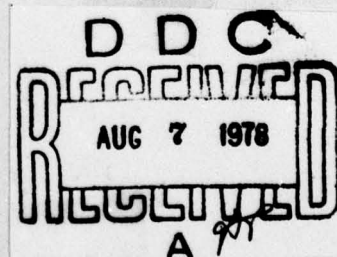
# FOREIGN TECHNOLOGY DIVISION



CARRIER OF SATELLITE AND SPACESHIP - PART II

by

Ch'i Teng



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CARRIER OF SATELLITE AND SPACESHIP  
- PART II

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## CARRIER OF SATELLITE AND SPACESHIP -- PART II

Ch'i Teng

This is Part II of an introductory article on space carrier vehicles. Part I was published in No. 1 January 1977 of this Journal. Part II continues the discussion of the dimension, orbit, mission and future prospectives of launching carriers of satellites and spaceships. The readers are referred to the informative drawings on the back cover.

In order to minimize the energy consumption and to satisfy the orbit requirements, the last stage of the rocket engine needs to be ignited twice. When the engine is cut off after the first ignition, the thrust reduces to zero and the carrier rocket changes from accelerated flight to inertial flight (coasting); at this time, the residual propellant in the pipe below the combustion chamber and the main valve will evaporate and be exhausted under the action of the external high vacuum. Under the influence of such factors as the ambient pressure, propellant and structure temperature, the inertial flight time, the evaporating propellant absorbs heat from its surroundings and rapidly reduces the propellant temperature, causing portions of it to freeze. These frozen portions of propellant are likely to impede the exhaust nozzles and cause malfunction when the engine is reignited after the inertial flight.

The last stage of the carrier is under a weightless condition in the orbital flight (either circular or elliptical orbit). Under such

conditions, the spreading of surface cohesive force in the liquid propellant causes the propellant to crawl along the tank wall, to such an extent that the propellant moves away from the tank bottom toward the front end and mixes with the pressurized gas if the flight time is long enough. Thus, one cannot be sure that the propellant will enter the pump without trapped gas bubbles during the reignition. One solution to the problem is to impart some positive acceleration to the last stage by igniting a small positive thrust solid propellant rocket before igniting the engine. This causes the propellant to sink toward the tank bottom outlet and the trapped gas bubbles to be buoyed to the surface. Another way is to use the type of propellant reservoir with capillary action which allows part of the propellant to stay in its loaded position, and bubble free, even under weightlessness.

The dimension of the carrier vehicle is determined by the payload and flight orbit of a particular flight mission. For the same orbit, the greater the payload, the greater the weight at takeoff; and for equal payload, the higher the orbit, the more the weight at takeoff. The payload and the weight at takeoff of several different flight missions are listed in the table below:

Flight Mission	Wt. at takeoff (tons)	Carrier No. of stages	Payload (tons)	Remarks
Low orbit satellite, altitude 500 km	55	2~3	0.25~0.5	Carrier based on ICBM
Low orbit satellite, altitude 500 km	110	2~3	0.9~2	Carrier based on ICBM
Synchronous orbit satellite altitude 35,860 km	130~120	3	0.7~1	ICBM & 1 stage liquid O <sub>2</sub> /liquid H <sub>2</sub> rocket engine
Manned moon landing and return	2,800	4 including power of spaceship	6.5	see text below

Currently the largest spaceship carrier used by a foreign country is the Saturn V multistage rocket (see Fig. 6). Its first stage has five large liquid oxygen/kerosene liquid fuel engines of a combined thrust approximately 3,400 tons. The second stage has five liquid oxygen/liquid hydrogen engines with a total thrust of 520 tons and the third stage is a liquid oxygen/liquid hydrogen engine of 104 tons thrust. The range and load ability of Saturn V rocket is a payload of 118 tons for launching a 180 km orbit satellite and a payload of 28 tons for an equatorial fixed-point orbit (earth synchronous orbit) satellite.

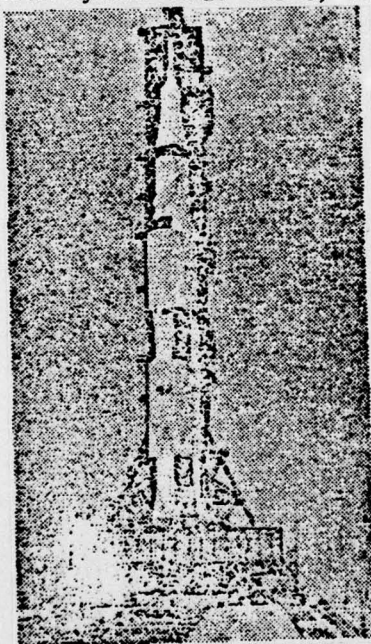


Fig 6. Saturn V rocket on the launching pad

The manned moon landing carrier consisting of Apollo and Saturn V has 2,812 tons of weight at takeoff, a launching thrust of 3,400 tons and 2,600 tons of propellant. The spaceship consists of three parts: the service module, the control module and the landing module, with a total weight of 45.3 tons. The lunar lander weighs about 6.5 tons. The spaceship has a maximum diameter of 10.3 m and is 110 m long. Fig. 7 shows

one of the manned carrier rocket used by a foreign country.



Fig. 7 Manned carrier rocket used by another country

The first two launches of Saturn V were unmanned and the rest were manned flights. Vibration damage to a small flexible tube caused engine malfunction during its second flight which eventually resulted in the redesigning of the tube. There is the future possibility that an atomic rocket may be used as its last stage to power interstellar flights to Mars.

It can be seen from the Table that the weight at takeoff varies rather widely in different flight missions, together with the fact that as current rockets are one-time-only carriers, the designing is done specifically for the mission in mind. One also realizes that for space carriers, the ratio of payload to the weight at takeoff is far less than that of ordinary transportation vehicles. A subsonic jet such as Boeing 707

can carry a payload which amounts to 16% of its maximum weight at the takeoff; the value drops to 8% for the supersonic Concorde. However, when launching a low orbit satellite with a rocket using conventional propellant, the payload is generally 1 to 2% of the takeoff weight. In launching a synchronous satellite, using a liquid oxygen/liquid hydrogen rocket engine as the last stage, the ratio is only about 0.5% and in the launching of a manned spaceship for lunar landing and return, the ratio has dropped further to about 0.2%. All these exemplified the fact that space carriers have a much lower efficiency than other types of vehicles.

#### Orbit of a Carrier Launched from the Earth's Surface

The proper orbit of a carrier launched from the earth's surface (Fig. 8) can be divided into three stages: accelerated flight (powered flight), coasting (inertial flight) and final acceleration stage. In the accelerated flight, the carrier is launched vertically, and, under the thrust of the engine, goes through the dense atmosphere and reaches a predetermined speed before the engine is cut off. After that, the thrust reduces to zero and the acquired energy allows it to undergo inertial flight

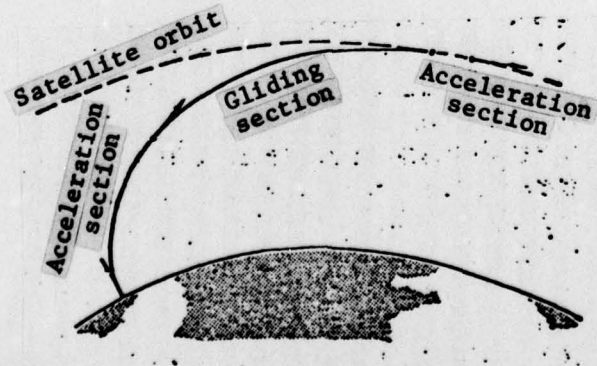


Fig. 8 The proper orbit for satellite launching

under the influence of the earth's gravity and reach a point tangent to the satellite orbit. At this point, the rocket is reignited (usually by the work of a small solid fuel engine) to give the satellite a slight gain of speed before entering its orbit.

One might wonder why the division between accelerated flight and inertial flight? Any why there is the reignition and final acceleration after the inertial flight? Why can't it be accelerated flight all the way? It turns out that there are two reasons: one is to satisfy the altitude of satellite orbit and the other is to minimize the energy consumption while meeting the orbit requirements.

As we all know, space carriers launched from earth are unlike shells from a cannon. The shell burns up the powder in a flash and gains its muzzle velocity right away. For the rocket, however, the propellant is being burned in the combustion chamber at a fixed rate, and the thrust resulting from the exhaust jet makes the carrier ascend slowly and accelerate to a predetermined height before cutoff. Therefore, part of the propellant in the storage tank must be used to carry the unburnt propellant and consequently reduces the load capacity. The higher the cutoff point, the more energy will be consumed. The altitude of a satellite orbit can vary from several hundred kilometers to ten thousand kilometers, thus the usual cutoff point of several tens of kilometers falls short of the satellite orbit requirement. This is the reason for having the inertial flight to utilize the already acquired kinetic energy until the trajectory is tangent to the satellite orbit. Then, the rocket is reignited for the final acceleration to put the satellite into its orbit. Without the final acceleration, the satellite will continue along

its elliptical trajectory under the influence of inertia and gravitation until it falls back into the earth's atmosphere where it burns up. The three flight stages of a proper launching orbit are therefore essential and interrelated.

The orbits are even more complicated for launching synchronous satellites, manned lunar landing and interstellar rockets, although based on the same principles. The reignition of the engine mentioned earlier is to minimize energy consumption and to satisfy orbit conditions. Naturally, one could skip the coasting stage and put the satellite into orbit with accelerated flight only, but this would consume more energy.

#### Future Prospectives

Chairman Mao pointed out that: "In the realm of production struggle and scientific experimentation, the human race will keep on developing, so will nature. Neither will ever stop at one level." Today's space carriers seem to be complicated enough, but like early models of aircraft compared to the modern day airplane, so will today's space vehicles appear against interstellar space transports of the future. It can be seen from foreign journals, the main development directions of space vehicles are: (1) to replace one-time-use by multiple-use rockets, (2) to extend the present chemical propellant rockets by developing newer propulsion systems to further increase their carrying ability and (3) to reduce structure weight and to increase reliability.

To the two superpowers, America and the Soviet Union, space technology is primarily used as a military weapon, in such areas as military surveillance, information collection and transmission. Secondary are

civilian applications, including global television transmission, communication, weather, navigation and space science research. The satellite style interplanetary space station, which may be built sometime in the future, would be like a huge earth satellite from which rockets and spaceships heading for other planets can be launched; interplanetary flights can then be established and the space industry developed. For the numerous launchings expected in the future, it would be a great waste if rockets can be used only once. Therefore, other countries have been developing repeatedly usable space shuttles (see Fig. 9), since the early seventies. Space shuttles can make frequent travels between earth and space stations to carry people and material; they can also be used to put satellites into orbits around the earth, and for satellite maintenance and recovery.

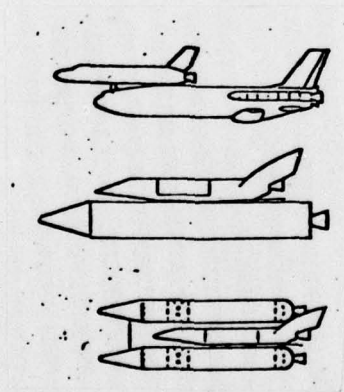


Fig. 9 Three types of space shuttles currently developed by foreign countries

The size of future space vehicles will not be much larger than the present ones since excessive weight and size will cause difficulties in manufacturing, assembling, and transportation. The main obstacle is finding a solution to the power problem of interstellar flights. All present spaceships use chemical propellant rocket engines which have rather limited exhaust

velocity. New propulsion systems such as an atomic rocket and an electronic rocket are being developed. In the atomic power rocket engine, the heat from the nuclear fission is used directly to heat up a propellant substance which is then ejected through the nozzle to produce thrust. In the electron propulsion engine, the fission heat is first used to produce a gaseous working substance of high temperature and pressure which drives the turbine. The turbine turns an electric generator to convert mechanical energy to electrical energy, which in turn accelerates a small amount of propellant to an extremely high exhaust speed. The exhaust speed can reach several tens to two hundred kilometers per second. The exhaust speed of the chemical propellant rocket engine is only 3 to 5 km/sec; even for the atomic power engine, the exhaust speed cannot exceed 8 to 10 km/sec. However, the electron propulsion rocket engine is virtually equivalent to moving a nuclear power plant and an ion accelerator onto the rocket. Its structure will be bulky and complex and only a small portion of the energy results in thrust. For the above reasons, electron propulsion rocket engines cannot be launched from the ground and can only be used in space.

Rocket engines using chemical propellant have adequate carrying capacity for terrestrial space and flights to the moon and nearby planets. For flights to Jupiter and farther, or beyond the solar system, high performance rocket engines such as the electron propulsion engine are needed. In all likelihood, the liquid propellant engine will continue its domination in the realm of space carriers in view of its intrinsic merits even after more advanced atomic or electronic rocket engines are put into practical use.

There have been other proposals concerning the power problem of interstellar flight carriers, such as a turbojet engine using air as the oxidizer, and a ram pressure type engine for launching thrust. Another

possibility is the combination of interstellar and terrestrial flights, namely, by installing an air liquifier on board the vehicle, liquid oxygen and liquid nitrogen can be obtained in flight. The liquid oxygen is then used as the oxidizer and liquid nitrogen as the working substance of the rocket. All of the above options are complex problems requiring further technical and economic studies.

Weight minimization is the main consideration of vehicle structure. This also involves the manufacture of large propellant storage tanks, prevention of meteor puncture and radiation shielding for astronauts. The structure must also be capable of enduring various loads and thermal cycling effects. In addition, there are long term problems awaiting further investigation: How to solve the supply and maintenance problems of a vehicle in satellite orbit? Can the vehicle structure endure the outer space environment for years? Can we assemble a space station during the orbital flight using components from the rocket?

It should be pointed out that the United States and the Soviet Union, the two super powers, are using space technology to serve their military and political purposes. In 1975, under the name of "detente," U.S. and the Soviets staged the Apollo-Soyuz space linkup in attempts to deceive the people of the world. But the reality of "shake your hand in the sky, kick your feet on the ground" exposed their hanky panky.

In the seventies, China has successfully launched seven earth satellites and carried out recovery on the fourth and the seventh. The success of satellite launching and recovery not only signifies the great strides of China's industrial and scientific technology but also broke the monopoly on space technology by the two super powers and greatly

elevated the morale of the revolutionary people. It is the triumph of Chairman Mao's revolutionary lines and the fruit of the Great Proletarian Culture Revolution. It is also another one of the copious accomplishments in smashing the Wang-Chang-Chiang-Yao "Gang of Four" antiparty cluster.

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