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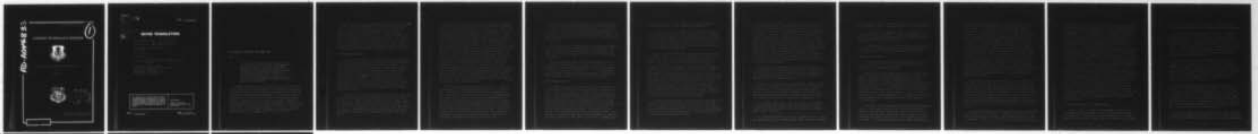
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by

Hwa Pao



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THE RETURN OF SATELLITE AND SPACE SHIP

Hwa Pao

The problem of returning a satellite and space ship to the ground is a rather important and complex problem in space technology at present. In order to let the readers have a preliminary understanding, this article simply introduces the principles, methods, and returning procedures of the satellite and space ship based on the materials published in foreign books and magazines. Since the entire article is rather long, it is divided into two parts for publication.

Chairman Mao personally started and led the Great Proletarian Cultural Revolution and the Movement of Criticizing Lin Piao and Criticizing Confucius which pushed the development of science and technology in our country by thoroughly criticizing the course of Revisionism of Liu Shao Chi and Lin Piao. The artificial earth satellite launched on Nov. 26, 1975 by our country returned to ground according to plans after normal performance. This is another achievement of science and technology in our country. This labels a new horizon of science and technology in our country, and is a powerful blow to the rightist case - reopening agitation.

"There is no difficulty in this world, only if you are willing to climb." Under the exceedingly favorable foreign and domestic situation, and under Chairman Mao's direction of revolutionary lines as outlined by the class struggle, the large masses of workers, peasants and soldiers, and the scientists and engineers, firmly remembering "A satellite goes up to the sky, a red banner falls to the ground" and the historical lesson of Soviet revisionism, have the ambition and the ability, certainly will overcome any difficulties, and will climb lofty peaks one after another to contribute much more to Chinese revolution and world's revolution.

THE RETURNABLE SPACE CRAFT

Space craft, including the artificial satellites, space ships, and all other space probes may be divided into two big categories "non-returnable" and "returnable" depending upon whether it is necessary to return to ground safely after completing a predetermined flight mission in space. For example, the communication satellite, weather satellite and navigation satellite, which operate in orbit year after year and have no need to return to ground, belong to the former. But manned space ships and photo reconnaissance satellites and some other experimental satellites, which need to return to ground and land at a safe speed at the predetermined recovery area after completing the work in orbit, belong to the later.

Looking at the present foreign-launched space craft, there are more than a dozen types of non-returnable craft, but only few in each type. The types of returnable craft are few. Mainly, there are manned space ships and photo reconnaissance satellites. There are also some satellites with animals on board and some experimental satellites. Large quantities of photo reconnaissance satellites are launched every year by two tyrants, Soviet Union and United States.

Following the intensification of the struggle for seizing the world's tyranny by Soviet Union and United States, their espionage warfare in the space becomes more and more impetuous. The returnable photo reconnaissance satellite is the main weapon used in the espionage warfare between Soviet Union and United States. After the launching of the first artificial satellite in 1957, Soviet revisionists waved the guided nuclear weapon everywhere to put on airs and insult others and to swagger like a conquering hero. American imperialist authorities are all in a bustle, trembling with nervous agitation in facing the Soviet revisionists' erroneous nuclear threat. A large increase in military funds was appropriated in a big hurry. One of the important arrangements is to expedite the research and manufacture of the photo reconnaissance satellite. In three years from Feb. 1959, the American imperialists launched consecutively 38 "Discoverer" test satellites, averaging two launchings a month. One of the test purposes is to test the returning techniques for the photo reconnaissance satellite. After twelve consecutive flight-test failures (among which five flights were not in orbit due to malfunctioning of the carrier rocket), "Discoverer 13" launched on Aug. 10, 1960 returned successfully for the first time and brought back pictures of the earth taken by the satellite while it was on orbit.

The Soviet revisionists started experiments of launching returnable photo reconnaissance satellites since 1962. About 30 photo reconnaissance satellites were launched every year since 1968. From 1957 to the end of 1975, the Soviet revisionists had 880 launches of all kinds of space craft (multiple satellites launched by one carrier rocket is counted as one launch), among which there are 331 photo reconnaissance satellites. Each time that an important international affair takes place, the activities of this kind of reconnaissance satellites increase. Take as an example, the case of the Mid East War in Oct. 1973, the Soviet revisionists launched consecutively six photo reconnaissance satellites, averaging one launching every three days.

As for the manned space ship, there is a space race between Soviet Union and United States and this race is an important means to demonstrate their power. In the recent years, the authorities of the Soviet Union and United States racked their brains and invented a new application --- Using the space ships to make a show "Hand shaking in space", to put a few repairs on the broken curtain of "moderation".

It is obvious that returnable space craft hold rather important positions in the space activities between Soviet Union and United States. They are used as an important means of spying on each other for strategic intelligence in order to extend expansionism and tyranny.

From the long-range point of view, the consequence of the development of space technology is to put the discussion of re-utilization of the carrier rocket and space craft on the agenda. To solve the problems in reutilization , the problems of safe return and landing must first be addressed. Therefore, the return technique of space craft will have new developments.

THE RETURNING PROCESS

Launching a space craft (simply called craft subsequently) is an acceleration process; it is accelerated by the carrier rocket from a steady state gradually to a speed about 8 kilometers per second. The returning the craft is then a deceleration process; from the orbital speed it is gradually decelerated to a dozen of meters even several meters per second when the craft is getting close to the ground. Theoretically speaking, for the returning of a satellite, a rocket could be fired in a direction opposite to that of launching to reduce the speed. The procedure is the reverse of the launching process along the launching orbit. But it requires a fairly large power plant and large amount of propellant which is the payload of the carrier rocket during launching, thus

greatly increasing the flight weight of the launched satellite; therefore, this method is not economical nor practical.

The craft enters the atmosphere with a very high velocity; thus, a large drag force is produced on it due to the aerodynamic effect. During the design of the returning portion of the craft, if the suitable aerodynamic configuration is chosen and the return orbit is reasonably designed, the speed of the craft could be reduced rapidly by utilizing the air drag which is produced when the craft moves in the atmosphere.

Why does the craft fall slower and slower after entered the atmosphere? This is due to the air drag which acts upon an object that moves in air. The air drag is proportional to the air density, the cross section of the object and the square of the speed. The speed of the craft is very high when it enters the atmosphere, the drag coefficient is made very high when designing the configuration of the craft, that is to say it is not made streamlined. Thus, the air drag which acts upon the craft is very large and reaches a maximum of several time or a dozen of times its own weight, so the craft decelerates several-fold to a dozen times the gravitational acceleration. Under the effect of the air drag, the speed of the craft decreases from the cosmic speed at the entering of atmosphere to subsonic speed at an altitude of a dozen kilometers, that is about 200 meters per second. Finally, a parachute which produces a large drag area is utilized to further reduce the speed of the craft to a safety landing.

By using this method, only a retrorocket with some energy is needed to act in a short period of time so that the craft will leave its original orbit and change its direction to the atmospheric orbit; then it does not use rocket power to reduce the speed. Until now, all foreign returnable space vehicles use this method to return to ground without any exception.

The so-called returnable craft does not mean that the entire craft returns to ground. In order to reduce the weight of heat protection and the parachute landing system, that is, to reduce the weight of the entire craft, the necessary returnable items and the facilities that have to work during the returning process are purposely put together in a capsule which is called the reentry capsule, and items which need not be returned to ground, such as the facility cabin and orbiting module, are put in another capsule during design. Before the craft returns to the atmosphere, it discards the whole module that need not be returned, and only the reentry capsule passing through the thick atmosphere returns to ground (Fig. 1). After the parachute opens, some craft eject the heat protection shield, only the container with the returnable items lands by parachute. This container is called the recovery container or recovery cabin.

The aerodynamic configuration, the return orbit, and the structural design of the returnable cabin, etc., are mainly determined according to the working characteristics and requirements of the atmospheric layer reentry process. In flight dynamics, the returnable cabin is called reentry craft.

Based on the amount of lift produced by the returnable cabin moving in the atmosphere, the returnable cabins are divided into two categories, the ballistic-type and aircraft-type reentry vehicle. Up to now, all foreign returnable craft belong to the ballistic reentry vehicles; they go through roughly the following four stages from circling the earth orbit to ground (Fig. 2).

1. Braking flight stage. Under the action of retrorocket, the vehicle leaves the original orbit and transfers to another transitional orbit that will let the vehicle enter the atmospheric layer (point A in Fig. 2).

2. Free-falling stage in the outer atmospheric layer. After the vehicle has left the original orbit, under the force of gravity

it falls freely along the transitional orbit. It starts to enter the atmospheric layer at an altitude of about 100 km (AB section).

3. Reentering the atmospheric layer. The speed of the vehicle is rapidly reduced after entering the atmosphere. At the same time the vehicle is receiving severe aerodynamic heating and braking overload (after passing point B).

4. Landing stage. At an altitude under 15 km, the speed of the vehicle is further reduced by a parachute from subsonic to safe landing speed (from an altitude under 15 km to point C).

LEAVING OPERATING ORBIT

For the return of vehicle, the first step is to leave the original operating orbit and to change to a new interim orbit which leads to entering the atmosphere.

Assume that the speed of the vehicle is V_1 at point A on the orbit. The thrust of the braking rocket acts for a short time along the direction of angle θ with the horizon to obtain a velocity increment ΔV of several hundred meters per minute; the vehicle now flies at a velocity V_2 which is the compound velocity of V_1 and ΔV (Fig. 2). In a comparison of V_1 and V_2 , not only the velocities are different, but the direction also turned a small angle toward earth (only several degrees). Thus, the vehicle entered a new elliptical interim orbit. This new orbit must enter the atmospheric layer, otherwise the vehicle will continue to orbit the earth.

The vehicle left the original orbit entering the atmospheric layer at an altitude of about 100 km. The angle between the vehicle's entering direction and the horizon at the point is called reentry angle γ_E . The reentry angle cannot be too small; otherwise, the vehicle may only touch the atmosphere and could not enter. The reentry angle cannot be too large, otherwise the

deceleration (braking acceleration) of the vehicle is too large or the aerodynamic heating is too serious due to the air drag in the atmosphere. For instance, the allowable maximum braking acceleration of a manned ship should not exceed what an astronaut can bear, that is should not exceed 10 g (ten times the gravitational acceleration) under normal conditions. Therefore, the vehicle can only enter the atmosphere rather horizontally within a range of 1 to 3 degrees of reentry angle and not any steeper. At this point, the flight range of the vehicle from the ignition of the braking rocket to landing is more than 4 to 5 thousand kilometers. For the unmanned vehicles, the limit of the braking acceleration could be a little less rigid and could reach to ten to twenty g, and the reentry angle does not exceed ten degrees. Thus, the flight range of the vehicle is a little shorter, about 2 to 3 thousand kilometers. According to the factors of the original orbit parameters of the vehicle the range of allowable reentry angle, the location of the recovery area, the total impulse of the braking rocket, the direction of action, and the time of ignition can be determined, and have to be controlled exactly within a certain range.

On the facility cabin of the vehicle there is an installation that adjusts the attitude, and it is called the attitude control system. The so called attitude of the vehicle is the showing of the positions of its three axes whether its head is upward, downward, horizontal or inclined at some angle. Before returning, first the center axis of the vehicle is adjusted (that is, the direction of the thrust of the braking rocket) to the necessary direction when the braking rocket is working, then the reentry cabin separates from the facility cabin, and the braking rocket start to function (Fig. 3).

The center of gravity of the reentry cabin should be controlled strictly within a certain range to guarantee the stability of the reentry cabin when it is moving in the atmosphere, that is to say, no tumbling. If there is an attitude control device in the reentry

cabin, then let the device guarantee the attitude during the retro-rocket working stage and the process of reentering atmosphere, but if there is no attitude control device in the cabin, in order that the **direction** of the thrust remains the same when the retrorocket works and is not affected by the factors of deviated thrust and center of gravity, it is necessary to rotate reentry cabin along its own center axis with a rotating speed of one to two turns per second before igniting the retrorocket. This is called spin stabilization. After the retrorocket has complete its work, the despinning function starts, and the reentry cabin loses the ability of spin stabilization. Thus, after the reentry cabin enters the atmosphere, under the aerodynamic action the head will turn rapidly toward the front. Whether the attitude control device can accurately adjust the attitude of the vehicle to the required direction at which the retrorocket starts to work and maintain this attitude until its work is completed is the key problem for the vehicle to return properly. On 13 Aug. 1959, during the return of the American satellite "Discoverer 5" after the ignition of the retro-rocket, it disappeared. In February next year, U. S. DOD announced that a new artificial satellite was found and believed to be a secret satellite of some country. But after being checked out, it was the same "Discoverer 5" which disappeared half a year ago because a wrong direction was set when the return attitude was adjusted. As a result, the retrorocket became an acceleration rocket, and pushed the satellite to a higher orbit. On 15 May 1960, the USSR test spaceship "Sputnik 4" made same mistake as did the "Discoverer 5". There are examples like this, and they are too many to mention.

BALLISTIC AND SEMIBALLISTIC REENTRY VEHICLE

When a vehicle is moving in the atmosphere, there is an aerodynamic action in addition to the gravitational force (Fig. 4). The aerodynamic force which acts upon the vehicle can be broken down into drag and lift. Based on the lift produced by the vehicle

moving in the atmosphere, the vehicle can be divided into two categories, the ballistic- and the aircraft-type reentry vehicles.

When a ballistic reentry vehicle moves in the atmosphere, drag is produced on it, but not any lift; that is, the lift to drag ratio is equal to zero. For example, the reentry cabin of the USSR "Vostok" or "Voskhod" is a ball with a diameter of 2.3 meters. The profile of the American "Mercury" looks like a cone (Fig. 5). Once the vehicle has left the original orbit, it returns to ground along a certain trajectory without control, moves similarly as the warhead of ballistic guided missile, and is a so-called ballistic reentry vehicle.

Due to the lack of lift, the aerodynamic profile of the vehicle is rather simple, and the time during which it passes through the atmosphere is rather short, generally not more than 400 seconds; therefore, the total quantity of heat from the aerodynamic heating is relatively small and the structure of the heat protection is rather simple. Therefore, the ballistic reentry vehicle is one of the simplest of the returnable vehicles, technically simple to put to practice.

The main drawback of this type of vehicle is that there is no control over its movement in the atmosphere. Whether the vehicle can land at a predetermined recovery area or not depends on the working attitude and total impulse of the retrorocket of the vehicle. Once the work of the retrorocket is finished, the vehicle will return to the ground along a certain trajectory. The landing position is also correspondingly determined. If there is any deviation during the operation of the retrorocket, there is no way to adjust it during the descending process.

On May 24, 1960, the second American manned orbital flight by a "Mercury" spaceship had a malfunction in the automatic-controlled attitude control system before returning. The astronaut immediately

changed to manual control. The ignition time of the retrorocket was still three seconds late, the drift angle of the spaceship was drifted to the right about 27 degrees, and the total impulse of the retrorocket was 3% less than normal. By these few combined factors the spaceship landed far beyond the predetermined descending point by 480 km, which was very dangerous thing. It is obvious that lack of control of the reentry process is really a serious defect of the ballistic reentry vehicle.

Its other defect is that the braking overload during the reentry is rather large. Even though the reentry angle of the manned spaceship is limited to a very small angle, the maximum overload still could reach to 8 to 10 g. Thus the astronaut feels a very high pressure during the reentry at such large braking overloads.

In order to compensate for the above-mentioned defect of ballistic reentry, the easier method is to control the lift. When installing the returning cabin, the position of the center of gravity is arranged a small distance from the central axis. Thus, the returning cabin (besides the ball shape) will produce an angle of attack, called trim angle, which produces a certain lift correspondingly. Of course, this lift is limited, not more than half of the drag. If the returning cabin is rotated by an angle ϕ along its own central axis, the lift produced due to the trim angle can be broken down into vertical component (upward force) and horizontal component (sideward force). In the reentry process, the rotating angle is controlled by a certain logical sequence, the vertical and horizontal components of the lift which control the orbit of the reentry cabin in the atmosphere and control the descending point of the vehicle within a certain range vary. On the basis of this type of ballistic reentry vehicle, the limited controllable lift is called semiballistic lift -- a ballistic reentry vehicle. This type of controlled lift technique was used on the "Apollo" and "Soyuz" spaceships which were used in the Soviet Union and United States joint show "space handshake."

Problems about the aerodynamic heating and heat prevention structure of the satellite and spaceship at reentry, landing, and the aircraft-type reentry vehicle shall be continued in the next issue.

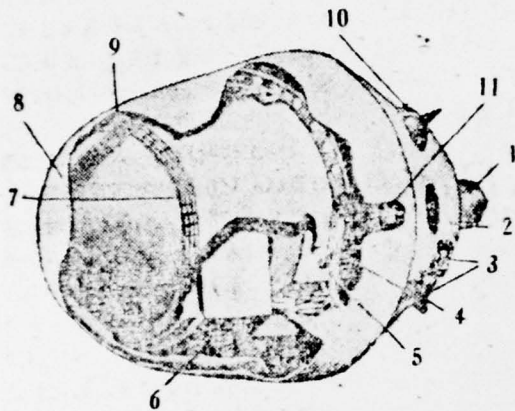


Fig. 1. An earliest foreign model of the reentry cabin. 1 - Retro-rocket; 2 - Thrust cone; 3 - Spin-up rocket and despin nozzle; 4 - Parachute and chaff cabin; 5 - Parachute cabin cover; 6 - Instrument casing; 7 - Sea water dye; 8 - Ablative shield; 9 - Recovery capsule; 10 - Cooler; 11 - Explosive bolt.

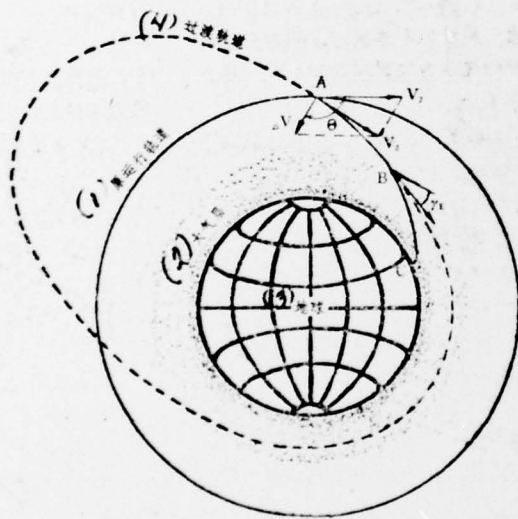


Fig. 2. Diagram of reentry orbit. 1 - Original orbit; 2 - Atmosphere; 3 - Earth; 4 - Interim orbit; Point A: Retrorocket functioning; Point B: Reentering the atmosphere; Point C: Landing.

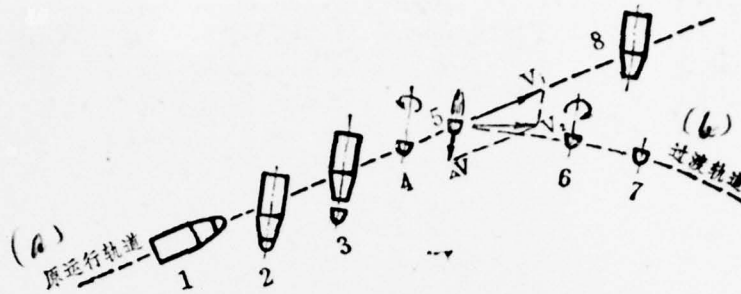


Fig. 3. Diagram of the reentry cabin leaving orbit (condition of self-spinning stabilization). 1 - Moving in the orbit; 2 - Adjusting returning attitude; 3 - Separation of reentry cabin and facility cabin; 4 - Self-spinning; 5 - Ignition of retrorocket; 6 - Despin; 7 - Returning cabin descending along interim orbit; 8 - Facility cabin moves in the orbit continuously: a) Original orbit; b) Interim orbit.

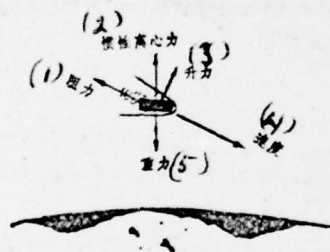


Fig. 4. Forces act on the vehicle. 1 - Drag; 2 - Inertia centrifugal force; 3 - Lift; 4 - Velocity; 5 - Gravity.

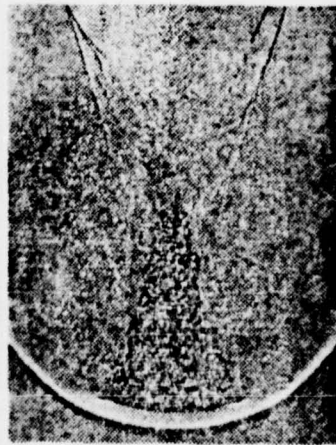


Fig. 5. Model of "Mercury" spaceship in super-sonic airstream (wind tunnel test).

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