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AIR FORCE SYSTEMS COMMAND

SPACE SHUTTLE

By

Ling Fu Gen

FOREIGN TECHNOLOGY DIVISION

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SPACE SHUTTLE

by
Ling Fu Gen

The fact that the Space Shuttle, besides being a space vehicle that can be launched vertically to leave the atmosphere and travel in space like a rocket, can also land in an airport like an aircraft, truly combines aviation and spaceflight together, and is therefore quite noteworthy. The struggle between the U.S.S.R. and the U.S. in their efforts to dominate the world has escalated intensively; now, that the U.S. takes the lead by succeeding in their Space Shuttle landing tests is expected to intensify even more the struggle in space between the two giants.

The success of the U.S. Space Shuttle Enterprise in its Manned Landing Flight Test for the first time on August 12 this year has aroused much interest in the public. What kind of a flying vehicle really is the Space Shuttle? What are its characteristics? What are the projections on its future developments? People are anxious to know. The objective of this article basically is to provide answers to these questions.

What Kind of a Flying Vehicle Is the Space Shuttle ?

As advances in science and technology are continually being made, the need for sending more satellites and spacecrafts (which we shall refer to as payloads collectively) arises. This in turn places an increasing demand on the quantity of launch rockets to launch the payloads. However, currently available launch rockets are not re-usable, which means that every time a payload is launched, a launch rocket has to be expended, so that the next time around one or more new launch rockets have to be developed and constructed. This is a situation which seriously impedes progress in the space industry. It therefore becomes imperative to develop a type of re-usable launch vehicle resembling a conventional aircraft so as to reduce the costs on space missions extensively.

The Space Shuttle is a re-usable space transportation vehicle that is proposed in response to this demand.

The Space Shuttle shown in Figure 1 is 37.2 meters long, has a wing span of 23.79 meters, weighs 68 tons, and is similar to a present-day transportation aircraft. However, the Space Shuttle will experience much more adverse flight environments than a conventional aircraft. Besides having to possess an aerodynamic shape suitable for high ultra-sonic, ultra-sonic, and sub-sonic flights, and for horizontal landing, it must also be provided with a heat-protection system to endure the high heat during reentry into the atmosphere. After careful analysis and tests, the Space Shuttle finally assumes the form of a monoplane without a tail section but with a double-delta planform. Different ablative layers are placed on its surface to sustain various degrees of heating.

The Space Shuttle can roughly be divided into three sections: forward, middle, and aft. The forward section consists mainly of a crew module besides a reaction control system. The crew module can ordinarily accomodate 4 to 7 people, and up to as many as 10 people in case of emergency. It is sub-divided into 3 decks. The upper deck is the flight deck. The middle deck constitutes the living area. The lower deck is the equipment deck. Under normal conditions, astronauts responsible for the flight mission and scientists live and work in the crew module. The crew module therefore must be an air-tight vessel having an atmosphere and pressure similar to those on the Earth's surface, so that the crew need only wear ordinary clothing as they do on Earth.

The middle section of the Space Shuttle consists mainly of a large cargo bay 18.6 meters long, 5.2 meters wide, and 3.9 meters long. It has a capacity of about 300 cubic meters, and can carry 29 tons of payloads in one mission. Satellites, space stations, large astronomical telescopes and other instruments for probing space can be put inside this large cargo bay. It is equipped with an automatic retractable manipulator arm and television cameras for deploying payloads that the Space Shuttle carries and for retrieving payloads that are in the orbits.

The aft section of the Space Shuttle is relatively complicated. In addition to the main propulsion engines and the reaction control system which provide propulsion for the Space Shuttle, it also include the elevons, the underbody flap, the vertical tail fin, the rudder, the speed brake, and other components for aerodynamic control. Excellent mobility and stability can be obtained by manipulating these aerodynamic controlling surfaces when the Space Shuttle is travelling in the atmosphere.

Attachments to the Space Shuttle --- External Propellent Tank and Solid-Propellent Rocket Boosters

In order to accomplish its space transportation missions, the Space Shuttle requires an external propellent tank and two solid-propellent rocket boosters, which we shall refer to as attachments to the Space Shuttle. The Space Shuttle (which is also called the Orbiter) together with these attachments constitute the Space Transportation System or the Complete Space Shuttle System. Figure 2 shows the respective positions of the attachments and the Space Shuttle in the complete system. It can be seen from the figure that the Space Shuttle is mounted on the back of the external propellent tank, and that the boosters are situated under the wings of the Orbiter and attached one on each side of the external propellent tank. The complete space transportation system is 56.14 meters long, and weighs about 200 tons at lift-off.

Although the aft end of the Space Shuttle contains three propulsion engines, there is no room for storing propellents. It is so designed to reduce the volume of the Space Shuttle. Thus the purpose of the external propellent tank is to store a large quantity of propellents. The net weight of the external propellent tank is about 30 tons. It can be filled with some 700 tons of propellents. Therefore the external propellent tank is a huge column with a pointed head, measuring 8.38 meters in diameter and 46.84 meters in length and having a total weight of close to 800 tons before lift-off. The three propulsion engines are only capable of providing about 600 tons of thrust, so the two solid-propellent rocket boosters are needed to provide additional thrust.

The structures of the two solid-propellent rocket boosters are identical. Each booster measures 45.46 meters in length and 3.7 meters in diameter, has a net weight of 80 tons, and can carry 500 tons of propellents. The solid-propellent rocket engines are situated at the central portion of the boosters. By utilizing the energy produced from the combustion of the solid propellents, each of them is capable of providing 1200 tons of thrust.

In operation, the Space Shuttle will be launched vertically, with all engines firing in the boosters and the Space Shuttle simultaneously. At 115 seconds after lift-off when the complete system has attained an altitude of about 40 kilometers, the boosters will separate from the system and descend into the sea by parachute for recovery. Each booster can be re-used over 20 times. After jettison of the boosters, the entity now comprising the Space Shuttle and the external propellent tank will continue to increase its speed and altitude by its own engines and propellents. At about 480 seconds after lift-off, the Space Shuttle will jettison the external propellent tank just before attaining orbit at an altitude of about 800 kilometers, and then employ its own propulsion and control systems to enter orbit. The jettisoned external propellent tank will crash to the ground, and is therefore the only expended and unrecoverable item in the Space Transportation System. Upon reentry to Earth after completion of its orbital mission, the Space Shuttle will be the sole member of the System that is left. The orbiting time of the Space Shuttle will normally be seven days, with possible reduction or extension up to 30 days.

Merits of the Space Shuttle

Since the Space Shuttle can be launched vertically like a launch rocket, orbit like existing satellites and spacecrafts, and finally land in an airport by gliding like a conventional aircraft, it is a very novel flying vehicle. The Space Shuttle promises the following advantages over previously available means of performing space missions.

1. Extensive savings in carrying out space missions could be effected. Consider re-usability alone: the Space Shuttle is expected to be re-usable for over 100 times, thereby reducing the costs for launching by 90%. More importantly, though, the use of the Space Shuttle could lead to great simplifications in the design of payloads, and also make possible the retrieval of, and thus the extension of lifetimes of, payloads that were previously considered to be expended, the savings in which would even outweigh the savings obtained from re-usability alone.

2. Safety and reliability of space activities could be greatly improved. During the entire flight, the acceleration overloading value of the Space Shuttle will not exceed 3g, and upon return to the airport, its landing speed will not exceed 300 kilometers/hour. In the history of the space industry, the first time that a product was sent to space was also its last time, and there were no chances for evaluating and assessing the product under actual situations, so that reliability was rather low. On the other hand, equipment on board the Space Shuttle can undergo many tests as the Space Shuttle commutes between space and Earth, thus leading to higher reliability. Besides, in the past, after reentering the atmosphere a manned spacecraft could only land in the sea or in the wilderness, which posed threats to the lives of the crew; whereas as the Space Shuttle reenters the atmosphere, it can utilizes its wings and aerodynamic control surfaces to land in an airport by gliding just like a conventional aircraft. In this way, safety and

reliability of space activities could be made to approach the standards set for the aviation industry, and the space industry would be able to advance from the exploratory phase to a really practical phase.

Owing to the low reliability of conventional spaceflight methods, simulation tests have to be carried out many times carefully for all kinds of equipments on board before lift-off, which means several months have to be spent for preparative work in the launch area, whereas the Space Shuttle is capable of being re-launched two weeks after its previous mission. The fact that it requires simple preparation for launching, and that it makes punctual lift-off possible, is an advantage that promises tremendous military and civilian values. High speed transportation bewteen two arbitrary points on the surface, rescue of astronauts in trouble, interception of nuclear ballistic missiles, detection of enemy reconnaissance satellites, destruction of enemy satellite communication systems, etc., could be realized by the existence of the Space Shuttle.

3. It could help put modern science and technology into service for the space industry. Owing to their peculiar shapes or huge sizes, some equipment used on the ground cannot be sent into space by ordinary launch rockets. For example, for the observation of celestial bodies through a large astronomical telescope in space, the absence of the atmosphere will make the images less distorted and clearer. Unfortunately, because of its huge size, it cannot be launched by currently available launch rockets. At present, many advanced scientific equipment have to be modified before they can be put into space, at the expense of time and quality. By using the huge cargo bay of the Space Shuttle, the best scientific equipments available on Earth could be placed into orbit without modification so that their full potential could be exploited. Moreover, scientists who are not trained astronauts could accompany and conduct their experiments in space to further their research in science.

4. New space activities could be initiated. The Space

Shuttle could basically take the place of existing launch rockets in carrying out current space missions. In addition, it could be used to deploy and retrieve several satellites at one time, to send equipment from Earth orbit to survey distant planets, to periodically rotate shifts of space workers, and to guarantee delivery of services and supplies for space science research through the establishment of regular shuttles. By using the Space Shuttle as a means of transportation between ground and orbit, large space projects such as solar energy stations, hospitals, and factories could be materialized. Thus, conditions of such as vacuum, the absence of gravity, and solar energy could be efficiently utilized to cure diseases, manufacture products, and perform experiments that would otherwise prove impossible on Earth.

Prediction of a Space Army

We mention here in passing that at present some people have already conceived the use of Space Shuttle to form combat forces orbiting in space, suggesting a new military class called the Space Army. Although this prophecy is somewhat premature, we should not fail to remind ourselves that in 1903 when aircrafts made their debut, the prophecy of the appearance of a new military class called the Air Force was considered by the majority of the people to be no more than a joke.

At present the Space Shuttle is still at the Approach and Landing Test phase. Although the advantages mentioned above are rather attractive, they are still but conjectures. It is not until the Space Shuttle has passed the phase in which practicability is demonstrated that its real values will be known.

Approach and Landing Test

In order to assess the aerodynamic properties, flight control characteristics, and landing performance of the Space Shuttle upon reentry without the external propellent tank and the solid-propellent rocket boosters, a large jet-plane (such as a Boeing 747) is needed to carry it to a certain height for atmospheric flight test. This test is called the Space Shuttle Approach and Landing Test or Low Altitude Horizontal Flight Test. The transportation aircraft responsible for carrying the Space Shuttle is called the Shuttle Carrier Aircraft.

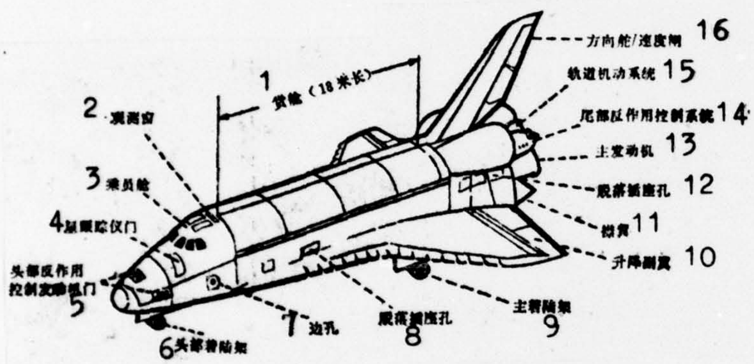
The Approach and Landing Test consists of two phases. In the first phases, the Space Shuttle was unmanned, and was fixed on the Carrier Aircraft throughout lift-off, flight, and landing. A large quantity of instruments were used to test and analyze the performance of each and every system of the Space Shuttle in flight. During the second phase, the Space Shuttle was manned, and it separated from the Carrier Aircraft at a certain height and then returned to the landing area on its own by gliding. For this reason, the second phase of the test is known as the Manned Landing Test. Upon completion of this phase, the aerodynamic properties of the Space Shuttle during sub-sonic flight, the in-flight characteristics of all the systems as a whole, and the performance of its approach and landing by gliding could be determined.

The success obtained on August 12 of this year was in the Manned Landing Flight Test. During this test, the Carrier Aircraft had to incline six degrees downward at an altitude of 13 kilometers so as to achieve separation from the Space Shuttle. In addition, it had to accelerate to provide stability and favorable conditions for gliding for the Space Shuttle. This maneuver is called the Separation Preparative Manoeuvre or Separation Propulsion. The actual height at which separation was achieved was at 6700 meters. After separation, the two vehicles swung to opposite directions in order to obtain necessary lateral separation. At the same time, the Space Shuttle was lifted upward to increase its vertical separation from the Carrier Aircraft to 60 meters in 5 seconds, whereupon the crew began a series of flight manoeuvers to obtain aerodynamic data, flight control data, and system performance data. When these tasks had been completed, the Space Shuttle accelerated downward. At an altitude of about 2000 meters and a distance of 14 kilometers from the touch-down point, it completed two turns for accurate alignment with the runway. At an altitude of about 100 meters, landing gears were lowered, and at an altitude of 30 meters, final levelling manoeuvre for landing was made, whereupon a descending speed of 1 meter per hour was obtained until touch-down. From separation to touch-down, a time of about 5 minutes and 20 seconds elapsed.

The procedures of the Space Shuttle Manned Landing Flight Test were simulated in full accordance with those that would be carried out in actual flight conditions. During the entire flight, the Space Shuttle was unpowered, and depended totally on the control and manipulation of aerodynamic surfaces for landing. However, some systems (e.g. the heat protection system) were only mock-ups. Conditions encountered by the Space Shuttle during reentry will not be known until 1979 when manned orbital flight tests will be performed.

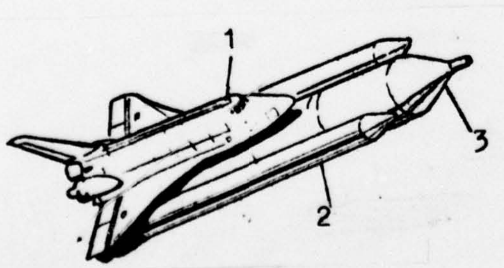
The evolution of mankind transportation from land to sea, from sea to air, and from air to space, is a process made up of continual development and progress (see Figure 4). However, the existing Space Shuttle as a means of space transportation is still not the most satisfactory one. Its attachments are too large, and its flight operations are still somewhat complicated. Moreover, the external propellent tank is not re-usable. Thus, study of a Space Shuttle consisting of a single stage is currently underway, that is to say, a single flying vehicle without the external propellent tank and the solid-propellent rocket boosters is desired. It is not until the achievement of such a vehicle that the space transportation industry will enjoy as much prosperity as its land, sea, and air counterparts.

Figures by: Wen Cheng Cheng



1 cargo bay (18 meters long)
2 observation window
3 crew module
4 star tracker door
5 front end reaction control engine doors
6 nosewheel
7 vent door
8 separation system close-out door
9 main landing gears
10 elevon
11 underbody flap
12 separation system close-out door
13 main engines
14 rear end reaction control system
15 orbit manoeuvring engine system
16 rudder/speed brake

Figure 1 Outer Appearance and Main Components of the Space Shuttle



1 Space Shuttle
2 solid-propellent rocket booster
3 external propellent tank

Figure 2 The Space Transportation System

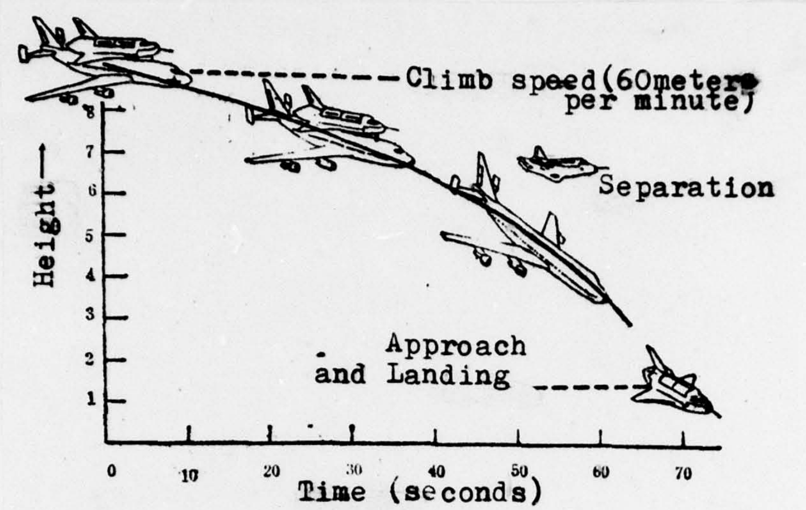


Figure 3 **Space Shuttle Manned Landing Flight Test**

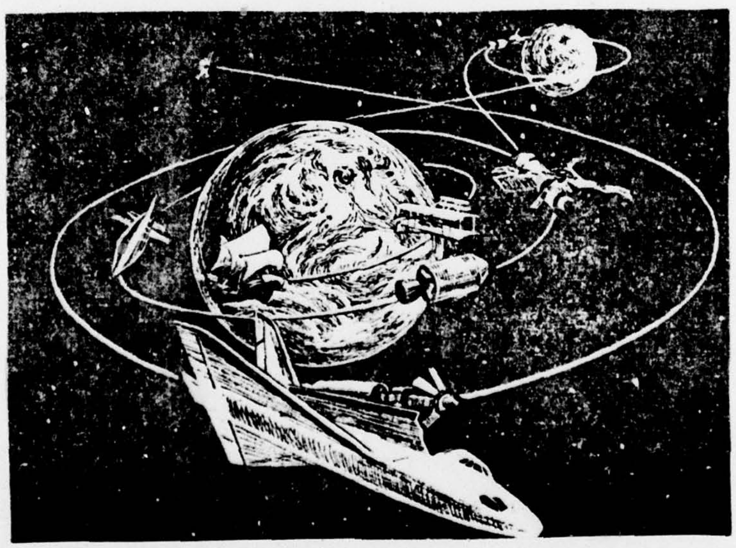


Figure 4 Development of Mankind Transportation

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