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THE SAFETY AND RESCUE TECHNIQUES OF MANNED SPACE FLIGHTS. (U)
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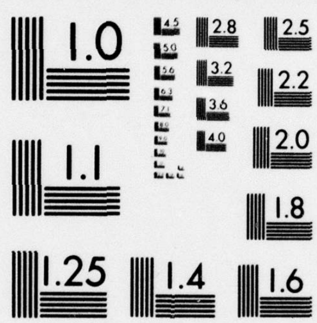

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FOREIGN TECHNOLOGY DIVISION

THE SAFETY AND RESCUE TECHNIQUES
OF MANNED SPACE FLIGHTS

by

Hwa Po

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EDITED TRANSLATION

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THE SAFETY AND RESCUE TECHNIQUES OF MANNED SPACE FLIGHTS

Hwa Po

Abstract

Starting with a story of manned space flight, this article discusses the importance of safety in space flights and the necessity of developing rescue techniques. Safety and rescue methods in various stages of space flight are described. The reader can gain some understanding about the space flight operation and various components of spaceships. This article will appear as two installments.

Man has always been fascinated by the deep space; this is reflected by such wide spread myths and folklore as the Ch'ang O's flight to the moon and the wonder Monkey's upsetting of the palace in the sky. Today, with the highly developed modern science and technology, man's dream of roving in space and exploring the secrets of the universe have become reality. However, the realization of space travel has yet to go through objective and repeated practice to achieve perfection and thus people still consider space travel as some sort of expedition and feel nervous about the safety of astronauts.

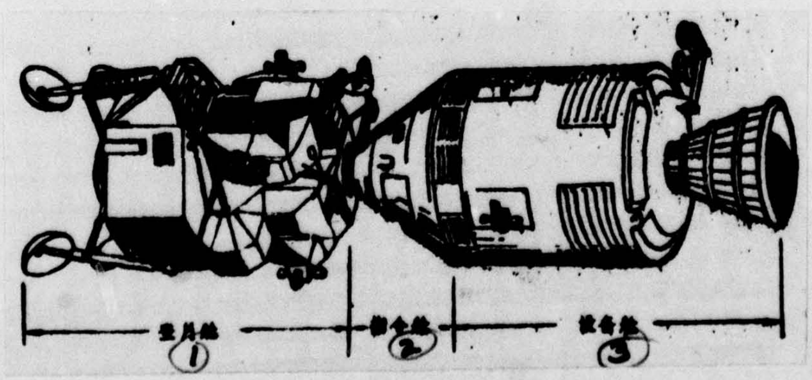
Currently, Russia and the United States are vigorously struggling to gain domination of the world and the space launches they made are primarily for political reasons: fighting for the so called "leading position" and going after "the first" at high costs of risk. For example, the United States launched their first generation spaceship Mercury and anxiously sent man to space before its carrier rocket Atlas even reached eighty percent reliability. In order to beat the U.S. Gemini and send three men to space, the Soviets hastily converted their one-man spaceship to accommodate three men and renamed it Troika. In the crowded cockpit on this spaceship, they did away with the ejection seat emergency system and sacrificed the safety of the astronauts. Under such circumstances, the manned space flights of Russia and the U.S. verged on chances, and, as a result, major flight accidents and loss of astronauts repeatedly happened.

Along with the development of aerospace technology, both the number and duration of space flights have increased considerably. Men have not only landed on the moon, but are also exploring the possibility of travelling to other planets such as Mars. The problem of emergency rescue in space flights has become one item on the agenda for serious consideration. Among the rescue plans proposed for various emergency conditions, most of them are hypothetical and exploratory in nature and certainly a long way from engineering feasibility. In order for the reader to grasp the problem we are discussing, let us begin with a story of the narrow escape of the Apollo 13 astronauts.

Survival Story of the Apollo 13 Astronauts

Noon, April 4, 1970, spaceship Apollo 13 finally took off on the Saturn 5 carrier rocket after a month of delay. The mission of this flight was to send three astronauts to the moon and then return them to earth. The spaceship consists of the rescue tower, the command module, the service module and the lunar lander, see Fig. 1. The rescue tower is an emergency device for the spaceship below an altitude of 60 kilometers and is normally discarded after the spaceship has reached an altitude of

80 kilometers. The command module is the main body of the spaceship and the three astronauts work and rest in the command module, also known as the cockpit, during the entire flight except the lunar landing stage. Service module, also known as the equipment module, is equipped with environment control, electric power source, communication, tracking, and guiding systems, and the engine for position control and orbit change. The service module thus is the main supply tender of the ship. It uses three batteries of oxygen-hydrogen fuel as the main electric power source for the ship. The lunar landing module has two stages: the descending section and the ascending section. The descending stage has an engine of four and one-half tons thrust to ensure the landing speed on the surface of the moon is not greater than one meter per second. The ascending stage has two seats for the astronauts and the necessary life-support, electric power, communication control, and the ascending engine. A tunnel connects the joint between the command module and the landing module for the passage of the astronauts.



Key: 1 - Landing module; 2 - Command module; 3 - Service module.

Fig. 1 Components of the Apollo spaceship.

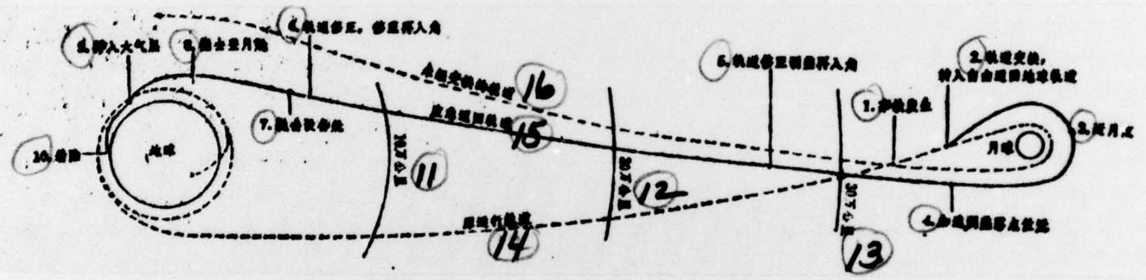
Saturn 5 is a three stage rocket. Its first stage worked normally, the second stage, consisting of five engines, then had ignition and the flight continued. Suddenly, large amplitude vibrations developed near the center engine and, as a result, the fuel flow and combustion chamber pressure of the center engine dropped and the center engine stalled 132 seconds ahead of schedule. The heart beats of the three shocked astronauts reached one hundred and ten per minute. In order to compensate for the shortened working time of the center engine, the other four engines were prolonged for thirty four seconds and the third stage engine also worked ten seconds extra time and the ship was sent into the transfer orbit of an altitude of 190 kilometers. Two and one-half hours later, the ship left its orbit around the earth and took off in the direction of the moon.

Evening of April 13, the ship was 330,000 kilometers from earth and 61,000 kilometers from the moon. The astronauts suddenly heard a big "bang!" and yelled to the ground station, "We have a problem here!" What happened was that the No. 2 liquid oxygen storage tank in the service module exploded and blew a big hole in the service module. Immediately, the voltage of the main electric power system was rapidly dropping and the leaking service module was losing pressure. The weakened thrust caused the ship to tumble in space. Two of the three sets of fuel cells were destroyed and in the third set, voltage was dropping. Before long, the oxygen water, air and electricity supply to the command module terminated.

The command module carried only limited amounts of electricity and supply which were intended only for the final re-entry into the atmosphere. Following orders from the ground, two of the astronauts crawled through the tunnel into the landing module, leaving one man in the command module. It was now four days before the ship could return to earth and the astronauts had only the limited electricity and supply in the landing module to sustain their life and to operate the ship. With the service module engine out of commission, the ship orbit can only be adjusted using the descending engine of the landing module. The landing module has now become the life boat for survivial.

The life of the three astronauts was in serious jeopardy. The American Congress pleaded with the nation to pray to God for the safety of the astronauts. The ground control center was in a shambles. The landing plan was hastily cancelled and personnel urgently mobilized to work on emergency rescue plans. The ship was now far away from earth and can only return to earth after revolving around the moon. Since the orbit adjustment can only be done with the power of the landing module, the weight distribution and working conditions of the system were quite different from the original design, so was the consumption of oxygen, water and electricity. A series of experiments were carried out on the ground to simulate the operation of the landing module. Based on the test results and after elaborate computation, an emergency return orbit, revolving around the moon before return to earth, was devised.

Early morning of April 14, the astronauts followed instructions sent from earth and operated the landing module descending engine for 35 seconds and shifted the ship into the free return orbit around the moon (Fig. 2). If this change of orbit failed, the ship would still head for earth after it revolved around the moon, but it would have missed the earth by 32,000 kilometers and disappeared into the vast universe forever. Two hours after passing the perigee, the astronauts operated the landing descending engine again and increased the ship speed by 263 meters per second, thus shortened the flight time by nine hours, and also changed the landing point from south of the Indian Ocean to the vicinity of Samoa in the Pacific Ocean, which was the original planned recovery zone.



Key: 1 - Accident occurred; 2 - Change of orbit, into free return orbit; 3 - Perigee; 4 - Acceleration, adjust landing location; 5 - orbit adjustment, adjust re-entry angle; 6 - Orbit correction, adjust re-entry angle; 7 - Drop service module; 8 - Drop landing module; 9 - Enter atmosphere; 10 - Splashdown 11 - 100,000 km; 12 - 200,000 km; 13 - 300,000 km; 14 - Original planned orbit of return; 15 - Emergency return orbit; 16 - Orbit without midcourse corrections

Fig. 2 Flight orbits of Apollo 13

Midnight of April 16, the astronauts followed orders and carried out one more orbit correction using the landing module engine so that the ship could enter the asmosphere with a re-entry angle of negative 6.5 degrees. Without this correction, the ship would have skimmed over the earth's atmosphere and disappeared into deep space with no chance of returning.

The supply carried by the ship was getting low and the temperature control system of the command module was turned off to save electricity. Temperature in the module dropped down to two degrees below zero Celsius. The air purification circuit stopped working and carbon dioxide concentrations in the module were rising. An emergency air purifier system was temporarily installed, following the instructions from the ground, the air purifier of the landing module was connected to the command module using tubes from the space suit and tape. The astronauts listened to the instructions sent from earth very carefully and tensely attended and watched various equipment on the ship. In the dark, cold, and horrified spaceship, three exhausted astronauts felt time had stopped. Relying on drugs, they survived until April 17 and returned to the earth surface, narrowly escaping death.

Investigations after the accident concluded that malfunctions started on the two switches of the temperature control in the liquid oxygen storage tank heating system in the service module. This type of switch used 28 volts according to the 1962 design and a design modification in 1965 changed the voltage to 65 volts. The manufacturer for this switch, however, did not conform to the new specification and still supplied 28 volt switches. Under certain conditions, these 28 volt switches could withstand 65 volts of voltage, but the overload resulted in electric sparks and short circuit. Without the protection of the constant temperature control circuit, the temperature of the heating system pipes reached 532° C and seriously damaged the tetrafluorethylene insulation of the nearby motor circuit, and finally led to the explosion of the liquid oxygen storage tank.

From the fact that such unacceptable elements did pass the receiving inspection, was assembled and escaped the notice of many reported pre-launch preparation tests, it is obvious that technology was not at fault, but the profit-first syndrome of capitalism is to be blamed.

The Vital Importance of Space Flight Rescue Problems

The Apollo 13 story demonstrated that small faulty switches could cause the abortion of a mission costing 375 million dollars and almost killed three astronauts. The reliability of manufactured products is therefore the primary insurance of space flight safety.

Since the incident was totally unexpected, once happened, ground personnel had to be mobilized in an emergency to carry out simulation tests, computations and the design of emergency rescue plans. Fortunately the ship had a landing module to provide some energy source and equipment needed in the emergency return for life support, orbit correction and communication and communication, and a disaster was avoided. Had the explosion spread to the command module and damaged the heat shield, or had the accident occurred in the Apollo flight of 1968 (without a landing module), the results would have been disastrous. The narrow escape from death of the Apollo 13 astronauts was therefore accidental.

One should also realize that malfunction could happen to any of the engine, control and power source systems on the carrier rocket and the spaceship. Furthermore, the malfunction of one component often causes problems of the entire system since all the components are interrelated. Therefore, in the design of the spaceship, various emergency situations should be carefully studied and rescue plans devised. Escape or remedial devices should be installed before hand to avoid a helpless situation in emergency.

In designing the rescue operation porposals, the following aspects should be taken into consideration: An exhaustive analysis of the possible malfunctions of various systems and components from take-off to return, results of each possible malfunction and regions it will affect, monitoring method by ground or ship stations, tolerable error range of various parameters, criteria for judgement of emergency situations and warning method, design and manufacture of rescue devices, device of operation procedures for emergency return and instructions to astronauts. In the meantime, the effects on human body in an emergency return operation should be studied from the medical point of view. Emergency oxygen, medicine and food supply, communication gear should be provided. Obviously this is a very involved subject calling for extensive theoretical design and analysis and experimental simulation and testing on the ground. In view of the past accidents in space flights, where a majority occurred totally unexpectedly and were unprepared for, it is evident that the rescue method in space flight is yet to mature and achieve perfection.

Of the six manned spaceships of the Soviet Union and the United States, more attention was given to the emergency rescue operation for accidents involving the carrier rocket, with special escape devices installed. In case an accident happened to the spaceship itself, there is no choice other than an early return using the power device on the ship, see Table 1.

Recently, considerations have been given to equipping the spaceship with a special life-module, the equivalent of life boats on the ocean ships, in which the astronauts can return to earth in case of danger. This seems to be a viable scheme in today's opinion. Since the techniques of orbit interception, spaceship docking and linkage have had substantial development, the idea of an ambulance spaceship has also been proposed, that is, a rescue operation from the outside of the spaceship in trouble. The ambulance ship can be launched from the earth surface or from the space station. Another proposal is to equip the spaceship with a refuge ship. In the emergency, the astronauts could be harbored in the refuge ship and disengage with the mother ship, waiting for rescue from an ambulance ship. In the future, maybe an ambulance station could be established in space to serve as a space hospital. For now, at least, these are merely proposals to be engineered into reality.

Table 1. Safety measures in various Flight Stages of Present Space Ships.

Flight Stage \ Ship Name	U. S.		
	Mercury	Gemini	Apollo
Launching Pad, Low altitude flight	Rescue Tower	Seat ejector	Rescue Tower
high altitude	Retainer rocket separates ship from carrier rocket, ship return to earth surface.	Retainer rocket separates ship from carrier rocket, ship returns to earth surface.	orbit correction rocket separates ship from carrier rocket, ship returns to earth surface.
orbit flight	early return	early return	early return
retainer rocket operation stage	1. Limit on perigee altitude 2. retainer rocket has three engines, return with one out of order	Retainer rocket has three engines, will return with one out of order.	Landing module engine is used as a spare engine in the flight to the moon.
Reentry	None	None	None
Landing stage	Spare main chute	Seat ejector	Three main chutes, safe landing with two

Table 1. Continued.

U. S. S. R.		
Seat ejector	none	escape rocket
orbit correction rocket separates ship from carrier rocket, ship returns to earth surface.	orbit correction rocket separates ship from carrier rocket, ship returns to earth surface.	orbit correction rocket separates ship from carrier rocket, ship returns to earth surface.
early return	early return	early return
Limit of altitude of perigee, ship returns in a few day if retainer rocket out of order	Limit of altitude of perigee, ship returns in a few days if retainer rocket out of order.	Two orbit correction engines (also used as retainer rocket), one as a spare
None	None	None
Seat ejector	None	spare main chute

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