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Table of Contents

PHOTOGRAPHY RECONNAISSANCE SATELLITE

Chuang Feng

Photo reconnaissance satellite is the most widely used military reconnaissance satellite in space today. This article introduces the history, the various models and their working principle to the reader.

We all know the saying that one can see far by being at a high place. When we climb to the peak of Hsiang Shan, the "devil's worry," and look around, clearly displayed in front of our eyes are Lake Kunming, the majestic Tien An Men and Hotel Peking, the famous historical White Pagoda, and all the scenery .... , and we can become intoxicated on the beautiful view around the capital of our great country. If you happen to carry a camera, a picture will be your souvenir to keep. It has been over one hundred years since people first photographed large areas of ground by bringing the camera to high mountain tops and into the sky. Because of the overview advantage, aerial photography has been an effective means in military reconnaissance; early in the mid-19th century, people used the balloon for aerial photography, reconnaissance, and the aiming of canons. Some even used kites to carry the camera. The camera moved into airplane cabins shortly after airplanes came into existance in the late 19th century. During World War I, thousands of aerial pictures were taken from airplanes and the number jumped to ten thousand per day in World War II. Objects which were photographed included enemy airports, military harbors, arsenals, military installations, and information was collected on the concentration, transportation, and position of troops. Aerial photography has shown many useful purposes in battles.

Aerophotography entered a new era with the emerging artificial earth satellite. Since the satellites are far superior to airplanes in speed, altitude, and field of view, and they are also vibration-free in their orbiting motion, clear pictures of large ground areas can be taken at high altitude. As a result, great interest is generated in employing satellites for earth observation and research. The two hegemonies, the United States and the Soviet Union are particularly attracted to the satellite's potential in strategic reconnaissance. As soon as World War II concluded, the U.S. Imperialists started the feasibility study of satellite photography and reconnaissance which led to the spy satellite, one of the earliest military oriented satellite. In their struggle for world hegemony, the two super powers made great efforts in developing spy satellites and did all they could to steal military information from China and other nations, and also from each other. Over the years, among the two thousand some space vehicles which they have launched, approximately one fourth were used in photographic reconnaissance. The Soviet Revisionists even reached the madness of launching 34 or 35 such satellites per year. During March 1969, when the Soviet Revisionists violated our holy territory of Chen Pao Isle, they had launched ten photograph reconnaissance satellites in a short two-month period. The sheer number of satellites failed to avert the destined fate of destruction for the Soviet Revisionists and the Chen Pao incident ended with our victory and the Soviet's defeat.

Naturally, satellites are very useful as a means for photography and reconnaissance. The minimum size of a ground object which can be resolved has to do with the orbit altitude and the quality of the image forming system. With today's optical system, objects of 0.3 meter size can be resolved. Such high resolution cannot only accurately detect the position of underground silos for ICBM, but also enables the differentiation of silo sizes. The 0.3 meter resolution is enough to identify airplanes, tanks and vehicles, even single persons can be resolved. The multiple spectrum technique developed in the 1960's has brought new life to the conventional optical photographic reconnaissance in detecting camouflaged targets. Infrared thermal image formation further enabled the satellites to detect enemy activities at night and to detect nuclear submarines cruising underwater. Photographic reconnaissance via satellites is therefore of vital importance militarily.

Basically, there are two types of satellite photographs according to the methods these photographs are acquired. One method is through ground recovery of the films exposed on the satellite, known as the recovery mode. The other mode is via radio transmission which sends the photographic messages to ground known as the radio transmission type of photographic reconnaissance satellite. Brief introductions to both are made below.

<u>The Recovery Type</u> Image transmission is a key question in photograph reconnaissance. From the reconnaissance point of view, one would like to know the detected results as soon as possible and to see the photographed objects as clearly as possible. Naturally, a live television broadcast would be ideal. However, the presently available

technology does not allow real-time reconnaissance. Suppose we carry an ordinary television camera to the satellite altitude of 200 kilometers and suppose 45 degree lens was used; the resolution of the pictures taken by the camera would not be better than 10 kilometers, which obviously is not satisfactory. On the other hand, the higher the resolution, the larger the signal quantity contained in each picture. Take a 23 cm square picture, if the resolution is 100 lines per millimeter, the message data it contains would require about half an hour to transmit on the usual television channel bandwidth. Since a low altitude satellite takes only about ten minutes to fly over a ground station, each pass over will only allow 1/3 of the picture to be transmitted to the ground. Radio transmission of high resolution pictures evidently has its difficulties. In order to solve the problem, one would have to either greatly increase the capability of message transmission, or to lower the signal quantity of the transmitted picture, which means, a lowered resolution. Before the communication technology can reach the kind of high signal transmission rate needed, a compromise method is to recover the satellite film on ground or in the air. The resolution of optical photographs is at least one order of magnitude higher than other image forming techniques; therefore, the recovery method has the advantage of high resolution of the pictures.

The recovery type photo reconnaissance satellites are usually equipped with cameras which have long focal length, large aperture narrow angle lenses. Several cameras can be installed for multiple spectrum photography (see Fig. 1). On top of the destination's target

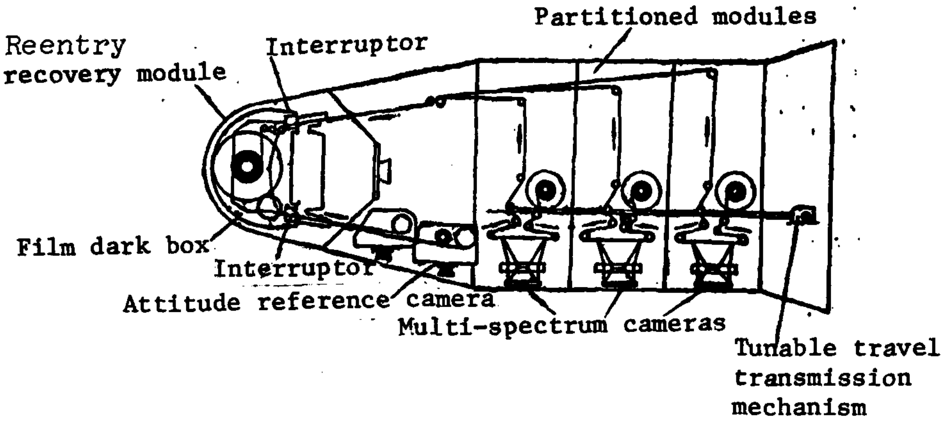

Fig. 1 Schematic diagram of the construction of the recovery type photo reconnaissance satellite.

area, the camera will take pictures according to commands from the ground or according to some automatic procedure. The exposed film is transported to the recovery module for storage. After the picture taking is completed, the recovery module (see Fig. 2) will be ejected from the satellite main body and the reverse thrust rocket will be started at the command of a signal from the ground. After speed reduction, the film recovery module will be spearated from the other parts and enters the re-entry orbit (see Fig. 3).

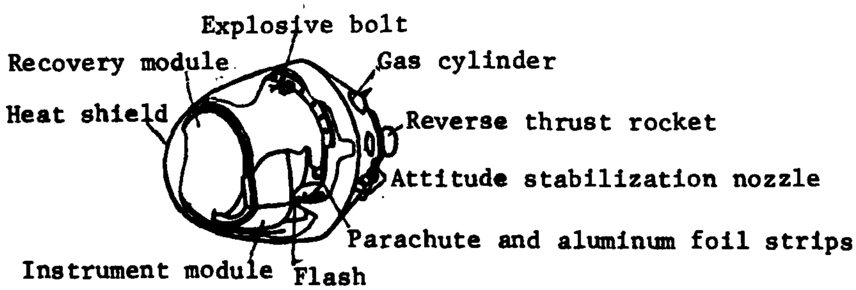

Fig. 2 Schematic of the recovery module

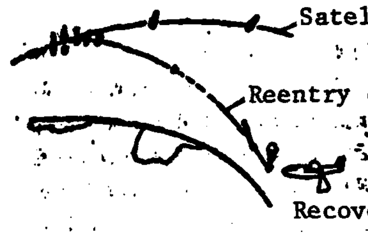

Fig. 3 Schematic of the recovery procedure

The heat shield is discarded after the module passes through the thick atmosphere and, at this point, a radio signal is sent out, or, aluminum foil strips are released to facilitate the discovery and tracking by ground radar. At an altitude of approximately 1500 meters, the chutes are opened to further reduce the speed. Recovery can now be carried out by a circling airplane equipped with recovery equipment. If an air recovery fails, the film recovery module will continue to broadcast radio signals after it falls to the sea or ground surface. Ground personnel can then follow the radio signal in the recovery. In the entire process, the ignition time of the reverse thrust rocket must be critically controlled since an error of 0.1 second will lead to a diviation of several kilometers in the landing point. The films are processed right after recovery and then sent to the section responsible for evaluation and analysis.

The Radio Transmission Type Ordinarily, the recovery type satellites are equipped with narrow angle lens cameras which have a limited field of view and the reconnaissance ability is also limited by the film capacity. Recovery has to wait for the completion of the entire photographic mission, which takes about 10 days. Hence, the recovery type is suitable for looking at a specific area or detailed surveillance of some new target of interest, but not very good for watching a large area. Along with advances in satellite communication techniques, medium resolution can now be achieved by radio transmission of pictures developed right on the satellite. On these radio transmission type of reconnaissance satellites, wide angle lens cameras are usually used to survey a large area. Once suspicious targets are discovered, a recovery type satellite can then be launched for detailed inspection. With the complementary functions of the two types of satellites, the strategic reconnaissance mission can be carried out satisfactorily.

The advantage of the radio transmission scheme is the immediate availability of information and "real-time reconnaissance." The disadvantage is that the high resolution picture suffers substantial degradation in the photoelectric conversion and radio transmission processes. We can see that in the radio transmission scheme the speed of acquiring information is increased at the cost of some sacrifice on the resolution.

Fig. 4 is a schematic diagram of the photography system used in the radio transmission method. In order to avoid blurring of the picture caused by relative motion of the satellite with respect to the earth during the exposure period, the cameras on the satellite (like the ones on airplanes) have compensation systems for the satellite's altitude, drift and attitude. How is the film developed on the satellite after exposure? The method is different from the usual using liquid developer and fixer. The development procedure makes use of an external film plate

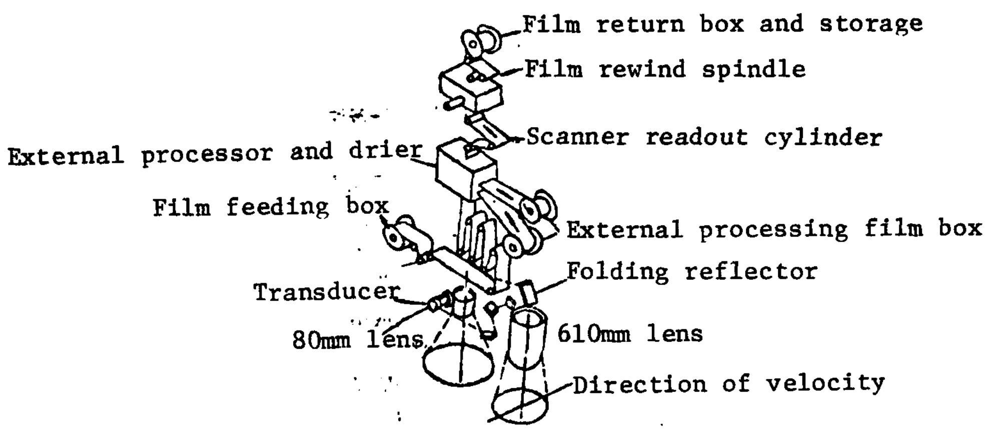

Fig. 4 Schematic diagram of the photography system

containing the developer. The exposed film is brought into close contact with the external film plate for 3-4 minutes and then separated from it. At this time, the exposed film is slightly damp. It is then sent into a drier to be dried at a controlled temperature and the moisture is removed by a drying agent. The developed film is then fed into a readout scanner (see Fig. 5) where the image is converted into video signals and sent to the ground. In the readout scanner, the electron beam from the line scanner hits a fluorescent material (which is movable in the vertical direction) and causes fluorescent light. This light is then focused into a spot of an approximate size 6 micrometer on the film. The line scanner causes the electron beam to move horizontally and the scan lens to move vertically. The scan of a film with a certain width (e.g. 2.661 mm as shown in Fig. 5) is thus accomplished. Together with the horizontal motion of the film, the entire film can be scanned. When the light shines on the film, the transmitted light intensity is modulated by the density of the image on the picture. The transmitted light, after focusing and amplification by a photomultiplier tube, is converted into electrical signals which are again proportional to the intensity of the transmitted light. These signals which contain the information of the image are sent to the earth surface by an antenna. The resolution of pictures transmitted in this fashion is able to distinguish abjects of 0.9 meter size from an altitude of 160 kilometers.

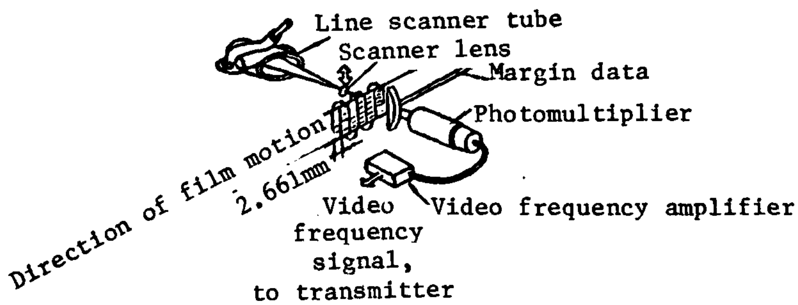

Fig. 5 Schematic diagram of the readout system

Orbit Characteristics The choice of satellite orbit parameters is an important consideration in improving the efficiency of photo reconnaissance. Since high resolution photographs are desired, one has to use cameras with long focal length and aperture. Fine grain films and low altitude are also important in obtaining a high resolution. However, since the air resistance is higher at lower altitudes, the life of the satellite is correspondingly shorter. Satellites used for close inspection are usually orbiting at an altitude of 150 kilometers above the earth surface. In order for the satellite to survive for more than 10 days in orbit without falling into the atmosphere, small rockets are usually installed on the satellite and the orbit parameters are adjusted by periodic starting of the rocket. With the aid of the rocket, the satellite will have the maneuverability to take pictures above certain specified locations during its flight. The consideration for satellites carrying out the mission of general survey of a large area is a longer lifetime. Thus, the altitude of such satellites is slightly higher than the close inspection satellite, and is usually 160 kilometers or greater.

The main instrumentation on a photo reconnaissance satellite is an optical camera. Images are formed on the photographic films via the reflection, absorption and transmission of sunlight by ground objects and the various colors and contrasts as a result of the sunlight. A suitable choice of the incident angle of the sunlight will make the contrast of the objects more favorable for picture identification. The satellite orbit parameters can be adjusted such that the relative position of the sun and the satellite orbit plane is invariant; such orbits are called the solar synchronous orbit. With such orbits, all that is required for the best reconnaissance effects is a proper launching time of the satellite. For example, if multiple spectrum photography is desired, one would launch the satellite at noon when the sun is directly overhead and the shadow is at a minimum. If the satellite is launched at dawn, the area it passes over will be either early morning or late afternoon, and, in these hours, the incident angle of sunlight is small and the long shadow cast by ground objects makes detection very easy.

Photo reconnaissance satellites have gone through substantial improvements in the recent 10 years and have reached the stage that both close inspection and general survey functions are available on the same satellite. Different image forming techniques (multiple spectrum, infrared thermal imaging and sideview radar) are employed simultaneously so that they can complement each other and provide the all weather reconnaissance capability. At present, it takes several days from the launch of the satellite until the photographs become available. The current direction of development is toward "real-time reconnaissance" and the problems to be solved are designing a high resolution television photograph system and a high capacity relay satellite system. Instantaneous transmission of reconnaissance pictures will become a reality once the new developments are accomplished.

PARACHUTE THAT FLIES

Chang Tai Ch'ang

A major development in the history of the parachute was the emergence of the "wing chute" which led to the development of soft wing gliders and attracted increasing attention from people. The development and classification of the wing chute are introduced in this article.

In the celebration of the August First military anniversary, the paratroopers of the Liberation Army staged a wing chute performance for the audience of the capitol. Arriving early at the exhibition field, the enthused crowd was anxious to watch the novel wing chute of the paratroopers. Bright sunlight drove away the red cloud at dawn and started a nice day. Shortly after the test jump, (in the parachuting procedure, there is a jump from the airplane prior to the formal contest to measure the wind speed and direction and correct the parameters of the jump), large transportation planes full of paratroopers were arriving over the field one after the other. A string of small black dots jumped out of the cabins and showly spread out. As usual, the audience is expecting the dots to open up into flower-like parachutes and showly decend in the blue sly; but somehow, today is different. Looking up, one does not see parachutes floating but soaring eagles in the sky. At a closer distance, the audience recognized these are paratroopers with wings above their heads, zooming over the crowd and heading straight to the target in the field. Pulling tight on the control rope, the troopers suddenly stopped and landed on the target. The crowd broke into thundering applause and somebody yelled: "What kind of parachutes are they?" They are what we now call wing chutes, or wing gliders.

Beginning of Wing Chutes We are all familiar with parachutes which have the appearance of an umbrella. Historically, parachutes did have something to do with an umbrella and its predecessor, the bamboo split hat. According to the Five Kings Chronicles in Shih Chi, between 2288 and 2255 B.C., Emperor Shung fell victim to the conspiracy of Ku Sou and was about to be killed by fire on top of a tall barn. The emperor escaped by jumping off the barn while holding onto two bamboo split hats with his hands. Some historical accounts have the umbrella originated in China about the beginning of the Tsing Dynasty or the end of the Ming Dynasty in the form of a "Falling Umbrella." It has been said that during some palace demonstration, one jumped off from a high place while holding one umbrella in each hand. Even the practical parachute emerged two hundred years ago in France and England still has the look of an enlarged umbrella (see Fig. 1). Evolving from bamboo hat and umbrella to parachute, they all have the appearance of an inverted rice bowl since objects of this geometry encounter the maximum air resistance in their fall. A parachute experiences four times the air resistance in its fall as compared to a sphere of the same dimension, or ten times the resistance of a bullet-shaped streamline object. The basic working principle of the parachute is using the spread of the fabric to gain the maximum resistance and reduced falling speed. The development of the parachute in the past one hundred some years is principally on optimum resistance and the safety of the opening procedure.

Fig. 1 Early (1802) parachute of England and France

Because of the compactness of a folded up parachute and the large size when opened up, parachutes are important speed-reducing devices, not only for exercise and paratroop operation, but also essential for emergency ejection in high speed aircraft and the recovery of space modules. With the advances in aerospace technology, there came new challenges and missions for parachutes. In addition to the demands of safe opening and steady descent under certain speed and altitude, a more important requirement is the controllability and gilding ability to correct the shortcoming of drifting with the wind of early models of parachutes. Therefore, various structural design schemes were developed, including unequal chord lengths, vent holes and different shapes, such as triangular, heart-shaped, etc. In the vent hole design, some horizontal speed is obtained by the reaction force of air venting through the holes. This is known as the controllable parachute. In the process of developing controllable parachutes, it was discovered that when the center cord pulls the top down by a certain distance (thus making the shape more closely resemble the wings), and when vent holes on the back half of the chute are used to gain horizontal speed, there existed a lift on the arch-shaped canopy. This was the beginning of a new type of parachutes, the "lift-type gliding parachute" (see Fig. 2), and broke the old belief that parachutes can only reduce their falling speed by air resistance.

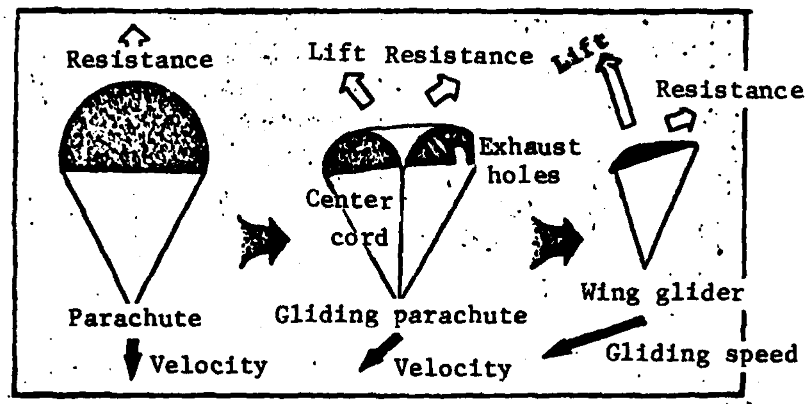

Fig. 2 Evolution of the wing chute from gliding chute and parachute

Although the horizontal speed of the lift-glide parachute is only comparable to its vertical descending speed, that is, it can glide at a 45^{o} angle, both resistance and lift forces are generated in its fall.

The combined action of these two aerodynamic forces greatly reduced the falling speed and improved the performance of the parachute. People are thus attracted to the development of a new model which relies mainly on the lift force in its speed reduction.

Lockheed Company of the United States first proposed the wing-chute principle in 1954 and, after substantial research and testing in the 1960's, produced its first generation rigid frame wing chute (see cover page 3, lower left hand corner). Subsequently, NASA developed a more practical soft wing glider and Notre Dame University in the U.S. presented the impulse wing chute with a better wing profile after they performed systematic study. England and France also did their research work in this area and made the 60's a very important period of wing glider development.

Unique Features of the Wing Glider If parachutes look like an umbrella, then the wing glider looks more like a flying bird. It is probably more understandable to talk about the merits of wings. With their wings spread, soaring eagles can fly tens of miles and when they are diving for a kill they can glide several miles as fast as a gale. Needless to say, the eagle is great in gliding and large lift can be produced by its wings. When we watch the eagle land on a cliff and a fast flying bird stop on a tree branch, they spread their wings and, almost instantly, stop their speed and land lightly. The birds have such delicate controllability in their wings that they can change configuration instantly to vary the resistance and lift and hence the great moves.

Wing gliders have the same advantages. First, it has a much better ability to glide and, with a much smaller area, relatively large lift can support heavier objects. The ordinary sport parachute has an area of 50-60 square meters while the wing glider needs only 20 square meters. Paratroopers can ride the glider to occupy favorable positions at a distance away. In the recovery of flying ships, gliders can be employed to land them at specified recovery sites. If the gliders can only fly at a high speed, people would worry about injuries incurred in a high horizontal speed landing. The second advantage of the glider will set this concern to ease, because it has good maneuverability. Anyone who witnessed the beautiful landing of a glider will be convinced. When the glider is landing, it approaches the target with full speed until it is only 3 to 4 meters from the ground; at this moment, the rider will quickly pull on the control cord with both his hands to lower the rear of the chute. The horizontal speed will be reduced to near zero due to the resistance of the rear of the chute and the vertical descending speed is greatly reduced due to the suddenly increased attack angle and the large lift resulted from it. The rider will take advantage of this favorable moment and land lightly on the ground (this attitude will quickly develop into a stall and drop). Since this landing maneuver is no different from that of a bird, it is also called the "bird landing." By the same token, by pulling on the two sides' control cords, the wing glider can be easily controlled to increase or decrease its speed, to circle or spiral. We will not elaborate on these aspects.

Figure 3 shows the geometric relation among the horizontal speed, vertical speed, lift force and resistance force. The lift-resistance ratio of ordinary wing gliders is usually 3 - 4, that is the lift is three or four times the resistance. From the similarity of the force-triangle and the velocity-triangle shown in the figure, we can deduce, by the similarity theorem in geometry, that the ratio of the horizontal speed to the vertical speed is also 3 - 4. This ratio is known as the gliding ratio. Therefore, the lift-resistance ratio is equal to the gliding ratio for the wing glider (the same is true for the aircraft glider), and this quantity is an important indication of the performance of the wing glider.

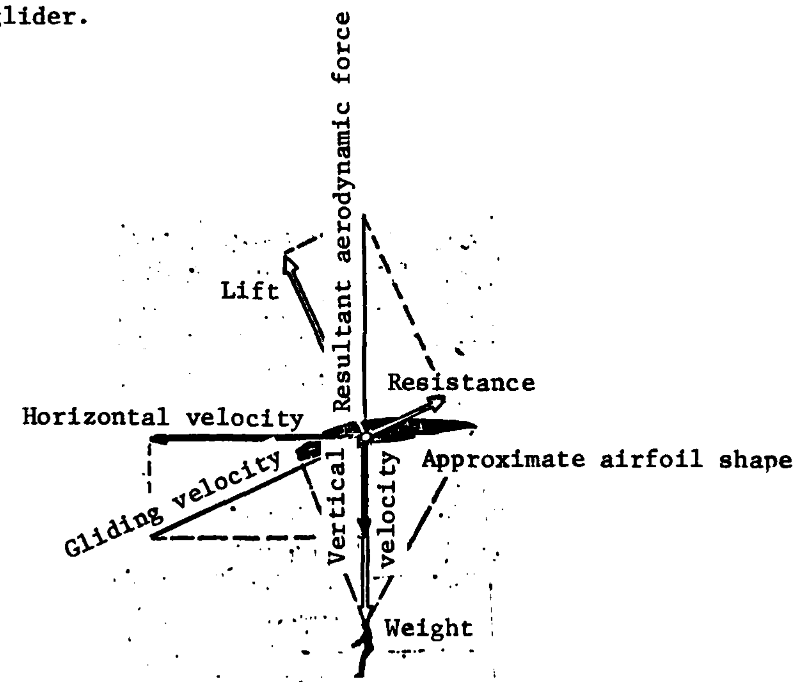

Fig. 3 Lift-resistance ratio and gliding ratio

Nomenclature of the Wing Glider In the West, the wing glider has the name soft wing or extendable wing. In the customary Chinese language, is is more appropriate to call it "wing chute." It is a speed-reducing landing device based on the principle of the airfoil lift. When the device is generalized to one component of flying craft, it is really beyond the realm of a parachute and soft wing may be a better description in that case. According to today's classification, we have:

(1) Parawing (see Fig. 4) -- The canopy has a triangular shape and is made of single knit mercerized nylon silk. There are also the single-keel and double-keel models.

(2) Sailwing (see Fig. 5) -- This is a rectangular glider with triangular outer flaps. Under the rectangular canopy, there are two or three triangular rib plates which has the effect of stabilizing the flight direction. The front edge is pulled and has the appearance of the front edge of an airfoil.

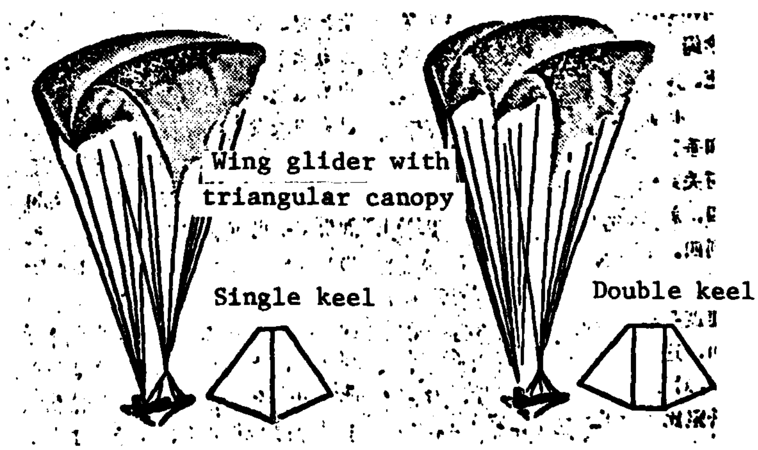

Fig. 4 Triangular wing gliders

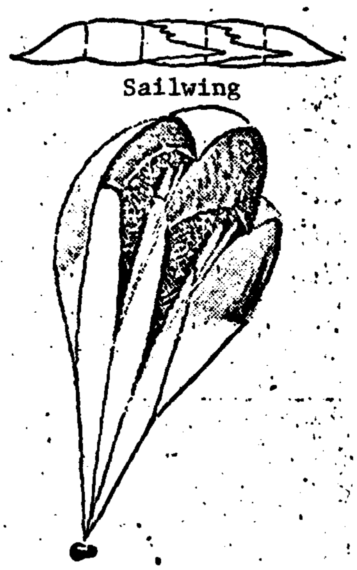

Fig. 5 Sailwing glider

(3) Parafoil (see Fig. 6) -- Parafoil has a double-layered canopy structure with an open front edge which allows air to flow into the space between the layers and, by means of the aerodynamic pressure of this air flow, the canopy takes the shape of an airfoil. This kind of glider has been used widely in sports (see photo of cover page 3). In the thirteenth parachuting championship contest held in Rome, Italy, almost half the contestants used parafoil and had record breaking results. For example, eight out of the first ten places in the 800 meter fixed target jump used parafoil.

The first eight places jumped 64 times and hit the target 47 times, or 75 percent.

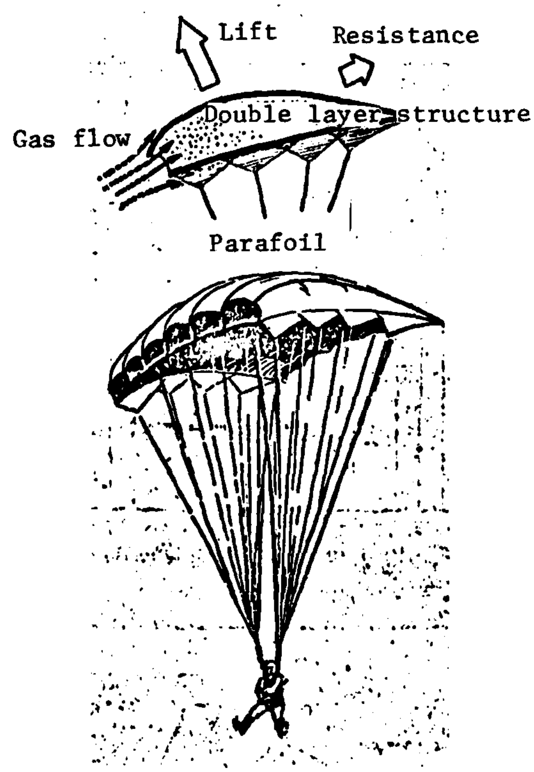

Fig. 6 Parafoil (gas) wing chute

(4) Volpane (see Fig. 7) -- A modified parafoil which kept the airfoil shape in its front half and made the rear half single-layered to reduce the weight and facilitate control.

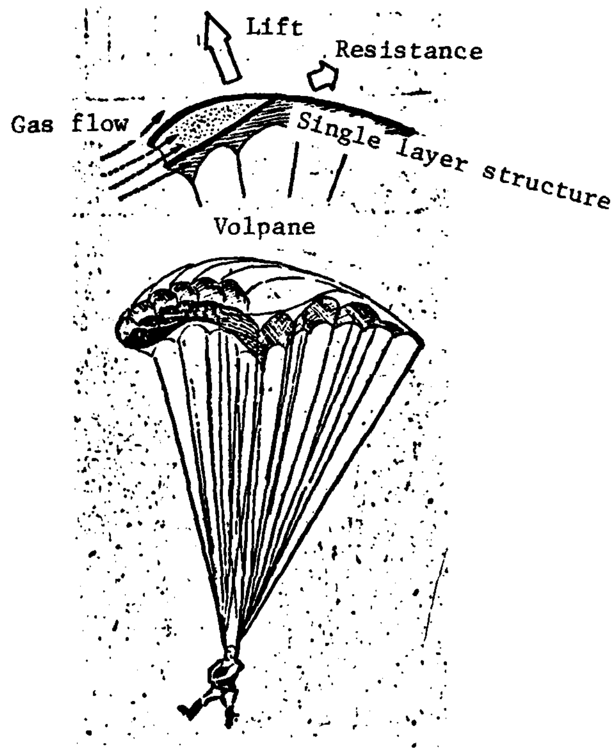

Fig. 7 Volpane (gas) wing chute

<u>Prospects</u> In addition to the four basic models described above, we will simply mention that there are also various modified models such as semi-rigid frame and parafoil frame. It seems that the wing chute is developing into something more than just a parachute. It has been proposed that a sealed double-layered canopy filled with air (or better yet, helium) will maintain the ideal airfoil shape with a certain rigidity. The lift-resistance ratio of the gas filled wing chute can be as high as 10 and only 14 to 15 square meters of area is needed. Equipped with

a small motor of a few horsepower and a small propeller, this device will carry us up into the sky and allow us to roam at will. It would not be too long before mid-size and large models of several tons capacity come into existence.

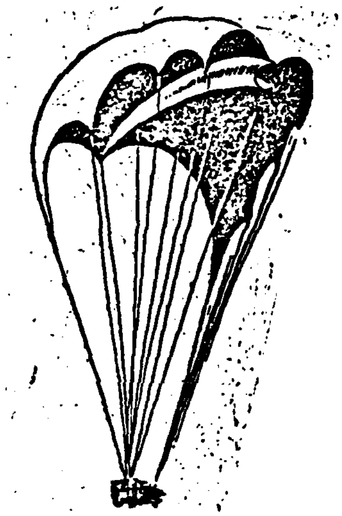

Fig. 8 Wing gliders of parafoil frame

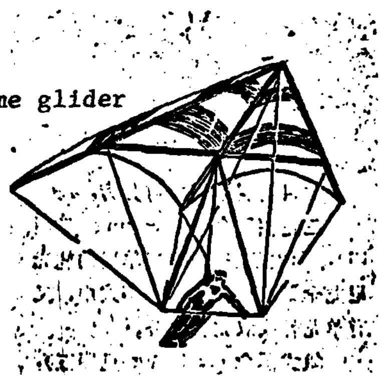

Fig. 9 Wing gliders of rigid frame

Title figure by Yu T'ung Wu
Figures by Chang Tai

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