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FOREIGN TECHNOLOGY DIVISION

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AERONAUTICAL KNOWLEDGE
(Selected Articles)

FOREIGN TECHNOLOGY DIVISION

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SATELLITE DETECTION OF NUCLEAR EXPLOSIONS

Ch'un Feng

Abstract: Nuclear explosion testings constitute an important stage in the research and development of nuclear weapons. Based on nuclear test detections, the development situation of enemy's nuclear weapons can be assessed and appropriate defense measures can then be taken. One of the important detection methods for nuclear explosions tests is via satellite. This article is an introduction to the operation method and necessary equipments used in the satellite monitor of nuclear tests.

* * *

Since the grotesque mushroom cloud appeared above Hiroshima on August 6, 1945, the history of nuclear weapons has spanned over thirty years. Since then, the Soviet Union and the United States, two superpowers of the world, have been threatening people of the world. But, "Nuclear blackmail will not scare the people of China." Under the greater leader and teacher Chairman Mao and the outstanding guidance of Chairman Hua, China has successfully carried out many nuclear tests and developed the nuclear force of our own. This is a serious blow to the hegemony and nuclear monopoly, nuclear blackmail policies of the two superpowers. Attempting to steal the nuclear development information of other nations, the Soviets and the U.S. have been discussion methods of detecting nuclear explosions ever since 1958.

As we all know, nuclear tests are vital to nuclear weapon development, and thus, the detection of nuclear tests provided a handle on the weapon ability and development activities of other nations. By monitoring nuclear tests, we also learn the killing and destruction ability of the nuclear weapons and their impacts on human life, facilities, and the natural environment, and gain valuable offense and defense experiences under the conditions of an atomic war. In a nuclear war, the detection of nuclear explosion provides timely information on the time, location and power of the explosion and appropriate reactions can be rapidly implemented. Because of the above stated reasons, the detection technology of nuclear explosions has attracted general attention and effort of various nations.

Effects of a Nuclear Explosion: How can one effectively detect a nuclear explosion? First we have to understand the effects produced by an explosion and the differences and characteristics of various explosion conditions, such as underground, underwater, surface, and atmosphere. By recording the effects produced and analyzing the intensity and variations, one can obtain an overall understanding of the explosion situation. Nuclear explosions have direct and indirect effects which can be catagorized roughly as the following:

Shockwaves -- When a nuclear weapon explodes in the atmosphere, the temperature may reach a few million degrees. The matter in the bomb will rapidly vaporize under such high temperatures and the pressure produced will reach several tens of thousands atmosphere (i.e., tens of thousands kilograms per square centimeter). The rapid expansion of the gas creates shock waves. In their propagation, the intensity and the speed of the shock waves will be attenuated and they become sound waves. After the high frequency components of the sound wave gradually are absorbed by the atmosphere, the remaining low frequency or subsonic waves have a long range of propagation. Using a micromanometer, the acoustic pressure pulse produced by a kiloton nuclear explosion can be detected as far away as 1300 kilometers from the site.

Light Radiation -- At the moment of the nuclear explosion, huge amounts of energy are released in the form of X-rays. If the explosion is in the atmosphere, the X-rays will be absorbed quickly by the surrounding air and a giant fire ball is formed which then radiates ultraviolet, visible light and infrared radiation. Ninety-nine percent of the light energy is in the visible light and infrared region. This radiation process may continue for several seconds to a minute. Without the impedance of clouds and earth curvature, such visible light can be detected at a distance of 300,000 meters during the day from the explosion site of a megaton nuclear bomb, and the distance can be ten times larger at night. If the explosion is in the upper atmosphere where air is thin, the X-ray radiation will exciet the nitrogen molecules and produce fluorescence which can be detected at a distance of several hundred kilometers at night from a megaton nuclear explosion.

Nuclear Radiation -- There are two kinds of nuclear radiation produced in an explosion. The first kind is the instantaneous radiation which, like the X-rays, are quickly absorbed by the air molecules in the surroundings. It may be alpha radiation or neutrons. However, such radiation can propagate great distances in outerspace. In the intermediate altitude, this radiation into the surrounding space is not as strong as the X-ray, but, in the decay process, indirect ionization effect can be produced. The second kind of radiation is prolonged radiation fallout, produced by the radioactive fragments and precipitates. The effects and movements of such fragments vary with the altitude; it may produce ionization or it may drift for long distances with the wind. If the explosion is near the ground level, we will see the characteristic mushroom cloud column. The radioactive dust carries in the cloud column may be washed to the ground by rain or it may spread like smoke and dust.

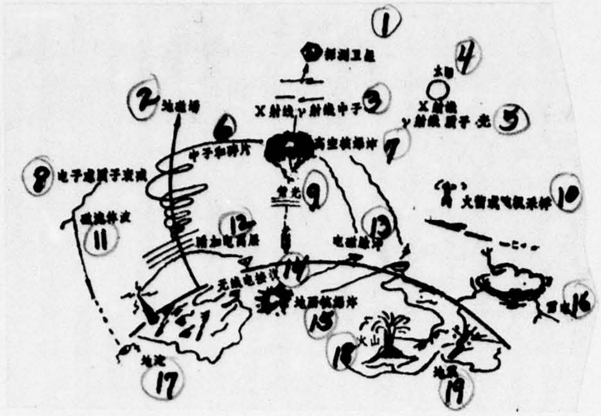
Electromagnetic Pulse -- The fourth effect generated by a nuclear explosion is the electromagnetic pulse. It is generated by the interaction of the atmospheric molecules and the gamma and neutron radiation. Although the electromagnetic pulse occupies a very fraction of the released total energy, it has a very wide frequency bandwidth, from several thousand Hertz to one megahertz. Most of the high frequency portions are absorbed by the atmosphere although some may escape to outer space. In the atmosphere, the low frequency radiation can be detected thousands of kilometers from the explosion.

Most of the effects described above are not observable in underground nuclear tests, but nevertheless, the shock wave propagates out as an elastic wave and produces an earthquake type of effect. A thousand ton nuclear explosion underground is equivalent to a fourth grade earthquake. Of course, there are other effects, such as the collapse of the explosion location, the flying dust and delayed damages to surrounding vegetation.

Satellite Detection Techniques

Through the understanding of nuclear explosion aftermath, we can see that there are many different detection techniques, such as subsonic, seismic, flourescent, ionosphere phenomena, electromagnetic pulse, and fallout sample radioactivity analysis, see Fig. 1.

Satellite monitoring of nuclear tests is a spin-off of the space technology development. The advantages are: it can detect and monitor



Key: 1 - detecting satellite; 2 - Earth magnetic field; 3 - x-ray; gamma ray, neutrons; 4 - Sun; 5 - x-ray, gammaray, protons, light; 6 - Neutron and fragments; 7 - High altitude nuclear explosion; 8 - Neutron or electron decay; 9 - Fluorescence; 10 - Rocket or aircraft taking samples; 11 - Magnetohydrodynamic waves; 12 - Induced ionosphere; 13 - Electromagnetic pulse; 14 - Antenna receiver 15 - Surface nuclear explosion; 16 - Storm and lightning; 17 - Ground current; 18 - Volcano; 19 - Earthquake.

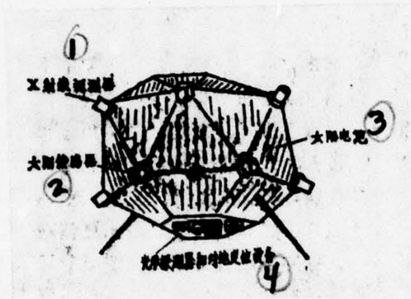
Fig. 1 Schematic diagram of nuclear explosion aftermath and detection methods

activities in a wide region and it takes only a very short time for information gathering. The reliability of information can be substantially increased by having several different detectors on the satellite. Because of these attractive features, the technique of satellite detection is developing rapidly.

Satellite orbit -- What kind of satellite orbits are suitable for such detection missions? Although low altitude orbits are favorable in view of carrier vehicle, remote monitoring and control, the low orbits have two problems. First, many such low orbit satellites would have to be working simultaneously due to the limited field of view in individual ones; secondly if orbits are in the radiation belts of the earth, strong flux of electrons and protons will saturate the radiation detectors on the satellite, or at least reduce their sensitivity. Due to these problems, the satellite orbit is usually chosen to be high altitude, over one hundred thousand kilometers from earth surface, or use synchronous satellites. At such high altitudes, two satellites in the same orbit and 180° apart will carry out the duty of monitoring the entire earth surface. With two satellites confirming each other, the chance for accidental false alarm due to natural phenomena is reduced.

Detection Ability -- The ability to detect nuclear explosions depends upon the method of explosion because different explosion modes produce different effects. For explosions above an altitude of 20 kilometers, the satellite can measure the explosion time, altitude, location and tonage equivalent by using the X-ray, alpha radiation and neutron detectors it carries. But it is not possible for the satellite to detect surface explosions below 20 kilometers. To detect ground surface explosions, it needs the aid of optical flash detectors, infrared detectors and electromagnetic pulse receivers. As far as underground testing, the ground breaking and well drilling before the test and crater formation and environmental changes after the test can be detected by photographic surveillance satellites. Thus, various detection schemes allow us to find out nuclear explosions from underground, surface to outer atmosphere.

Since X-ray cannot penetrate the shell of the satellite, X-ray detectors are mounted on the outside, Fig. 2. Neutron and alpha particle detectors are on the inside because these two radiations are highly penetrating. In order to aim the optical infrared and electromagnetic pulse detectors to the earth for surface nuclear explosions, the satellite is equipped with sun-position-sensor and nozzles for satellite to earth location and orientation adjustments.



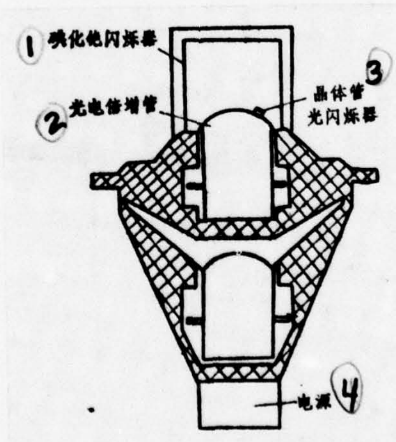
Key: 1 - X-ray detector; 2 - Solar transducer; 3 - Solar cell panels; 4 - Optical detectors and satellite to ground positioning apparatus

Fig. 2 Nuclear explosion detection satellite

Background radiation and false alarm problems -- As the satellite moves through space, its high sensitivity radiation detectors can equally well respond to natural radiation phenomena, or background radiation, such as X-ray emitted by the sun and protons, alpha particles, electrons, and other heavy particles brought by sun spots and solar winds. The intnesity of such radiations fluctuates with the eleven year cycle of the sun. Occasionally, bursts of high energy cosmic rays can also happen. All these contribute to the difficulties of detectors' operation, from jeopardizing their sensitivity to totally impeding the detection ability. Accidental natural radiation bursts can be mistaken as nuclear explosion. The solution to this problem is to install special detectors explicitly designed for background level measurement. The periodicity of natural radiation is recorded and studied, in the meantime, these special detectors work with the nuclear explosion detectors. When an explosion is detected, the signals from all the different types of detectors are sent to special logic circuits for comparison and identification to distinguish real nuclear explosions from cosmic rays or solar radiation phenomena.

Radiation Detectors

What are the mechanisms of X-ray detectors and neutron detectors? Fig. 3 shows the construction of an X-ray detector. It consists of a thin scintillator made of cesium iodide and a photomultiplier.



Key: 1 - Cesium iodide scintillator; 2 - Photomultiplier; 3 - Crystal scintillator; 4 - Power source

Fig. 3 Schematic diagram of a X-ray detector

Cesium iodide absorbs the X-rays emitted in an explosion and re-emits light with an intensity proportional to the X-ray intensity. This light pulse goes through photoelectric conversion and amplification in the photomultiplier. The output voltage is proportional to the scintillation intensity. The signal from the photomultiplier then enters a pulse height analyzer system which has three amplifiers, with two of them being of fixed gain equal to 10, and several threshold value discriminators which allow only signals greater than a certain threshold value to pass through. The passed signals are coded, recorded, and stored, in the meantime, they enter a conincidence circuit. The ground station controls which threshold signals are being fed into the coincidence circuit. To ensure that the radiation pulse is indeed due to a nuclear explosion, there are usually several transducers of the same kind on the satellite and their signals are simultaneously fed into the curcuit to determine how many transducers are receiving pulses of the same level. For example, coincident signals from at least three X-ray transducers are able to trigger the logic circuit and send alarm to the ground station.

Due to the long lifetime of a satellite in orbit, the operation of the detector must be tested for normal function. To perform this test, artificial light pulse is induced in a crystal scintillator mounted on the photomultiplier at the command from the ground station. The output signal from this testing light pulse is then analyzed to check the function condition of the system.

The alpha radiation detector has similar construction and works on the same principles as the X-ray detector. The neutron detector (Fig. 4) consists of two proportion counter tubes which are filled with He 3 gas and located in polyethylene moderators. The neutrons generated in an explosion enter the counter tubes after going through the moderator and cause the ionization of the gas. Under the electric field between the two electrodes, an electric pulse is produced. The pulse height is proportional to the number of ions produced in the tube and the associated

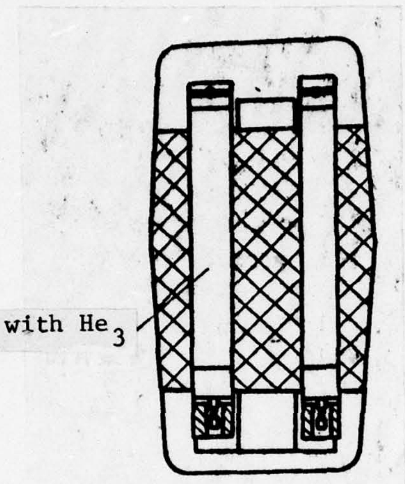


Fig. 4 Neutron detector

circuitry is similar to the X-ray detector system described above.

Signals received by various transducers on the satellite are binary coded and stored in the memory device. Data are then transmitted to the ground in real time.

IMPRESSIONS OF THE PARIS AIR SHOW

Chu Hsiao Yun

The 32nd biannual World Aeronautic Exposition was held at the Le Bourget airport in Paris, June 3 to 12, 1977. More than twenty countries and 760 manufacturers from the United States, the Soviet Union, France, England, West Germany, Sweden, Japan and other nations with advanced aeronautic industiy participated in the large exhibition lasting for 10 days. Some Third World countries such as Argentina also displayed their aeronautic products. At the invitation of the French government, the visiting Chinese Delegation visited the Exposition and some units of the French aviation industry. In addition, a number of well known research institutes participated in the exhibition, such as NASA of the United States, the French Aerospace Research Institute, and the Germany Aerospace Research Institute. Items on display are specialized and of great variety: aircraft, engines, components, special equipment, tactic guided missiles, electronic equipment, metal and non-metallic materials and other space equipment. Host country France has the largest number of exhibition items and the United States and England come next, while the Soviet Union showed only 7 transport planes. Among the exhibits, special aeronautic products constitute the majority, and space products included the U.S. space lab, the Soviet Soyuz and some civilian satellites (mock-ups) of France and other European nations.

Aircraft exhibitions

Approximlately 200 aircraft were among the dispalys, including fighters, attack aircraft, transport, helicopters, early warning planes, anti-submarine aircraft, executive airplanes and sport planes. In the fighter category, there were F-15, F-16, YF-17, "Tornado" (Panavia 200), Saab 37, Mirage F-1, and other newly developed fighters. France displayed the full-scale model of the Mirage 2000. This is the new Mirage which will replace the old models in the 1980's. Ground-attack aircraft include A-10, Tiger, "Super Etendard", and "Alpha Jet." Transport planes are the "Concord," TU-144, IL-86, Yak-42, A300B, "Falcon" 50, YC-14, YC-15 and so on. Military and civilian helicopters are mostly medium or small size aircraft of European nations. Early warning aircraft are the E-2C and E-3A of the United States. The French "Atlantic" was amont the anti-submarine aircraft displayed. A dozen models are making their debut: Mirage 2000, YF-17, A-10, IL-86, E-2C, E-3A, etc. However in the first day of the flight demonstrations, the A-10 pilot attempting an astounding maneuver, made a control error which led to the crash of the aircraft and killed the people onboard. The flight demonstrations are an important activity on the agenda of the Exhibition, and many aircraft participated in them each day. June 11, however, had the most activity and can be called the "flight demonstration day". About 94 different kinds of aircraft went through flight demonstrations and all the fighter planes at the Exhibition went through repeated flight shows. Some of them showed their take-off and landing performance and others went complicated maneuvers such as loop, vertical climb, vertical dive low speed spiral and so on, all in all, to show that their aircraft performance in an air battle is first rate.

From the aircraft on display and the flight demonstrations, one can see that most fighters are emphasizing the subsonic meneuver ability and the take-off and landing performance, that is, they emphasized good maneuverability and short take-off and landing distances. The chief means of achieving those characteristics is to increase the thrust weight ratio and reduce the wing load. The following design considerations are usually taken into account.

(a) Increasing the maneuverability from aerodynamic design, such as by using wings with large slats, leading edge flaps, leading edge slots or by tapering and twisting them. The wing load can be as small as 320 kg/m^2. Due to the large attack angle, the landing speed is low, gener lly 210 km/hr, and the take-off and landing distances are in the neighborhood of 500 meters.

(b) Emphasizing the usage of light weight and high rigidity material. Composite materials are widely in use, for example, the F-15 uses boron fiber composite material with a strength approaching that of carbon steel and steel alloy, but a specific gravity comparable to wood.

(c) Employing electronic control systems and lowering the static stability requirements. It has been reported that, after the F-16 employed such systems, the maneuverability was improved and the weight was reduced by 180 kg. Application of such systems indicate that the reliability and performance of the electronic components and servo motors have reached the level capable of ensuring safety.

(d) Increasing the engine thrust to weight ratio. The large amplitude increase of maneuverability was mainly due to the high performance engine. The thrust-weight ratio of most U.S. fighters is close to 8, and in Europe it is about 6.

(e) Select hight quality electronic equipment to ensure the efficiency in battle. Modern fighters are designed as an entire weapon system with remote control radar, plain view scope, and associated electronics. The average period between malfunctions of this equipment is long enough for the aircraft to carry out their missions successfully. The malfunction-free time period for radar has reached 60 - 90 hours.

The notable character of the air-to-ground attack aircraft is their strong fire power, mostly against tanks. Although A-10 had the accident, its strong fire power was still very impressive. ¶ As far as helicopters go, mostly are medium or small size, and the notable feature of the armed helicopters is their ~~dynamic~~ maneuverability, such as reverse, spiral at a large inclination angle, and so on. This maneuverability allows the helicopter to avoid ground fire while attacking the ground force. For small helicopters, the current trend is using [redacted] fiber glass and carbon fiber composite material ~~as~~ for the blades; their usage life, it has been claimed, is indefinitly long.

In the area of military transport~~ation~~ planes, the United States exhibited two new models of [redacted] tactical transport~~ation~~ planes, the YC-14 and YC-15, both are large aircraft, over 100 tons, with supercritical wings. The engines are mounted above and below the wings and the rear edges of the wings have double gap flaps. With the engines' jet flows aimed at the flaps, the maximum ~~ascending~~ coefficient of lift is claimed to have reached 8. The landing speed is 150 km/hr and the landing distance is estimated to be less than 300 meters. After take-off, they can ascend with an elevation angle of 30 to 40 degrees and sprial at a 45 degree banking. The YC-14 engine also has a reverse thrust facility, which not only stops the aircraft very quickly on landing, but also moves the aircraft backward.

Under the category of **fighter bombers**, no exhibitions were presented this time. However, judging from the displayed fighters, they all have relatively large thrust to spare, and all can carry bombs and rockets, some with slight modifications (to the electronic equipment), and assume the role of ground attack planes.

Regarding passenger planes, all the new models emphasize rigorous calculation of the costs and the aerodynamic design. The "Falcon" 50 of the French Dassault Company employed supercritical wing shape with a relative thickness of 9-14% and a maximum M number of 0.93. Using the regular wing shape, the relative thickness can only be 7-9% and the maximum M value is 0.85.

<u>Engine exhibitions</u>

Thirty-three engines and engine models were on display by 8 countries, with most of the exhibits from France, England and the United States. France displayed their M53, (Atar) [redacted] $9K^{50}$, CFM-56, "Larzac" and seven other kinds of engines. England had 10 engines on display, including RB 199, RB 211, and M45H. The United States exhibited seven models including F100, F404, TF34, CF6-32 and so on. First appearances are the CFM56, F404 (mock-up) [redacted] and the French ("Astafan".) [redacted] More advanced engines are F100, F404, F40, M53 and RB199. The thrust weight ratio of M53 is approximately 6, and all the other advanced engines have a ratio above 7.5.

Among the small engines of turbojet, turbofan, turbo-shaft and turbo (prop type) [redacted] France had the most and prominent displays with England coming next. The variable torque turbofan engine "Astafan"

~~*Transliterate~~

of the Turboméca company, France has some unique features: the blades of the fan are rotatable and reverse thrust can be realized under the condition of constant angular speed.

The wide application of the turbofan engine is evident in the exhibition. They are employed not only in fighter planes but also in military transport planes, passenger planes and bombers. The turbofan engine proves to be an important step in improving the performance of aircraft, and of fighters in particulary. The R and D of turbofan engines are therefore among the mainstream of the endeavor of the major aviation engine manufacturers of the world. The relatively large thrust to weight ratio of the turbofan engine is a result of some technical features in its design, among which are:

(a) Improved component design -- Increased load or compression ratio of the compressor is the main feature. Supersonic design is employed. The 11 stage compressor of the F101 engine has a total compression ratio of 26.5. The combustion chambers of most engines are cylindrical in shape and the lengths are greatly reduced by using the pre-mist type fuel nozzle and improved design. Improvements in the turbine consist of raising the pre-entry temperature (1371^{o} C has been reached to date), reducing the number of stages and using air cooled turbine with cast blades.

(b) Wide applications of titanium alloys -- In most of the advanced engines, titanium alloys are used more and more in high temperature components, as well as in the low temperature components. The thrust-weight ratio is increased.

(c) Employing advanced engineering -- Vacuum electron-beam welding, electron bombardment of cylindar pin holes and honeycomb layer structure are examples.

(d) Wide use of new technology -- In addition to the engines employing modular design their fuel control systems, such as on the M53 engine employ electronic computers. The system provides reliable performance in the temperature range of -40° to 210° C. The F101 engine has an infrared pyrometer which samples the average temperature of the 72 working blades of the high pressure turbine and adjusts the fuel supply to the engine.

Special equipment and aviation electronics

A great variety of products are exhibited in this category, with applications extending into almost every stage of the R and D of aircraft and engines. Products along this line made up a good proportion of the indoor exhibitions, even more so in the American building. According to an unofficial count, special and electronic equipment **constitute about** one-half of the total U.S. displays.

Among the electronic instrumentations on display, there are aircraft instruments and displays, automatic flight control systems, automatic landing systems, inertial guidance systems, flight simulators, integrated data collection and processing systems, and so forth. Also on public display are weather radar, air traffic control radar, communication and radio guidance systems, and laser distance meters. Airborne radars, computers and electronic interference equipment, however, are kept secret and omitted from the displays. Generally, there is no obvious break-through in this equipment other than the consolidation, digitization, miniaturization, and new developments in the solid state electronics technology. The U.S. F-16 fighter's fire control radar has reached an average malfunction-free period of 90 hours. The French Celano N radar operates 60 hours trouble-free and the operation periods for airborne computer and plain viewers are 360 hours and 500 hours, respectively. Various electronic components have mostly systemized, standardized, miniaturized, and ultra-miniatruized. Their stability, reliability and ability to work under harsh environments have been improved.

Tactic guided missiles and ejection rescue

In the area of tactic missiles, more than 70 different products are on display if one counts rocket missiles in this category. Tactic missiles number about 20, mostly airborne and almost none of the ground-to-air variety. France has the most products on display — about 36 different kinds. Technologically, display items are mostly 10 year-old products already equipped in armed forces; new products are mostly mock-ups and not much discription was given on the display stands.

Regarding ejection rescue facilities, Great Britain, the United States, France and Canada have all exhibited their new products. The British Martin-Baker Company displayed their MK-10 series ejection seats and Stantzer of the United States showed its SIIIS-3 seat. The French company Raer-de Boir displayed tracking rescue system. The exhibition of rescue systems indicated that, after the 0-0 (that is, zero altitude and zero velocity) rescue problem solved by the ejection rescue system, the emphasis of design has been placed on the safe rescue under various altitude and under a high sinking speed of the aircraft.

Figures by Li Chia

SATELLITE NOSE FAIRING

Chi Teng

Abstract

Satellite nose fairing is one constituent of the carrier, and although not very complicated, its safe and reliable operation is indispensible to a successful launching. This article is a discussion of the nose fairing's function, separation mechanism, choice of material and its profile determination.

* * *

In outer space, there are satellites of all different sizes, shapes and functions. When these satellites are launched, most of them are covered with a nose fairing to protect them from severe aerodynamic pressure and heating in their ascents. After they are above the dense atmosphere, the nose fairing is jettisoned from the carrier rocket to reduce the load and conserve energy. In the jettison process, explosion fragments and contaminating gas should be contained and the disturbance due to separation kept at a minimum. Since the successful launching of a satellite relies on the protection and the separation of the nose fairing, both must be guaranteed to be highly reliable. Therefore, the nose fairing, seemingly a simple device, must meet the requirements on both the aerodynamic profile and a responsive and reliable separation mechanism. Extensive ground testings are needed to ensure the flight's success. In general, the protection structure is easier to design than the separation structure. As a matter of fact, the design of the separation mechanism has become the main concern of the nose fairing.

Modes of Separation

Generally, there are two methods to jettison the nose fairing. The first method is the overhead separation, that is the fairing is pushed out to the front of the satellite. In removing the cap of a fountain pen, the cap must move forward along the axis of the pen and any tilting would cause it to rub against the pen tip. In the short moment after the separation, with the nose fairing in the vicinity of the satellite and the carrier, there remains the danger of a collision. Therefore, either the fairing or the carrier would have to take a dynamic movement in order to create a distance between them. This brings up some control problems to the separation.

When the separation takes place with both the fairing and the carrier undergoing acceleration, the overhead jettison would require relatively large spearation and control forces to avoid collision. Under such circumstances, the jettison is often delayed until the carrier engine is turned off and the acceleration drops down to zero in order to avoid collision. As a result, the carrier vehicle would have to spend extra energy in the acceleration of the fairing. The advantage of this method is a simple unibody structure of relatively light weight, suitable for early models of small satellites.

The second separation method is the pedal style where the fairing separates into two halves along its longitudinal axis much like the two halves of a clam shell. The two half shells are held together with an explosive bolt or quill with the base of the pedals hinged on the carrier vehicle and fixed with explosive bolts along its circumference.

To separate, the bolt or quill is exploded to open the locking mechanism, and under the influence of the separating force (due to spring, powder or small gas nozzle) the two pedals will rotate around their hinge to a certain angle where the hinge connectors disengage and the fairings are thrown out by its own rotational inertia. Almost all large satellites and space explorers are equipped with this type of nose fairing, see Fig. 1.

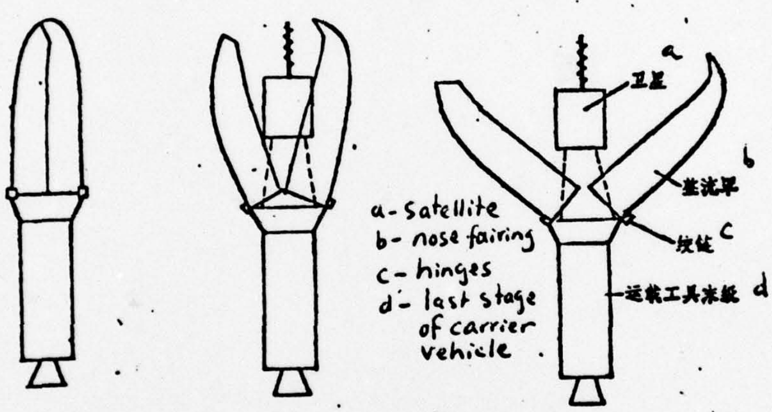


Fig. 1 Schematic diagram showing the three stages of the pedal-type separation: 1. Bolt (or quill) explodes, unlock; 2. Pedals rotate under separating force; 3. Rotation continues until hinges disengage.

Selection of Material

Aluminum alloy and magnesium alloy are widely used as nose fairing matererials. Magnesium frame has good high temperature properties but requires complex heat treatment. Aluminium alloy is easier to form although both alloys are heavier than glass steel. At one time there seemed to be a tendency that glass steel will replace aluminium and magnesium alloys. After the new technique of chemical or mechanical milling of grilled tile, excessive weight of metal fairings can be easily milled away, aluminium and magensium alloys are coming back again.

The mechanical properties of glass steel are close to those of magnesium alloy, which makes it a good light structure material and its forming procedure is relatively simple. Glass cloth soaked with organic resin is first laid on the mold in a vacuum bag. The resin is then hardened by heating it to form the shell body. The thickness is easily controlled by laying different numbers of glass cloth, a distinct advantage of form glass steel. In addition, since the resin reflects negligible amounts of electromagnetic waves, no windows need to be opened on the nose fairing for the passage of waves. One shortcoming of the glass steel is that, at temperatures over 100° C, the yellow residue from the evaporated resin may contaminate the satellite. Although the precipitation of the evaporated resin is relatively slow, this material is often ruled out on satellites requiring strictly contamination free. In any case, the good heat resistance of the glass steel makes it a suitable material for heat protection of the nose cone.

The honeycomb triplex structured glass steel has been used in satellite nose fairing since it has relatively large rigitity and strength to weight ratios. However, there are still some problems to be solved. The major fault is that the honeycomb cannot always be firmly attached, and separation between layers may occur. Another problem is to get rid of the air trapped in the honeycomb spaces between the sandwiching layers of glass cloth. The overhead jettison type nose fairing on the early interstellar explorer "Mariner" has this honeycomb layered structure.

The trapped air did cause one flight to fail: signals from the remote monitor indicated that the Mariner did not get rid of its nose cap after the fairing separation command was transmitted. What caused this failure? It turns out that, when the satellite was on the ground, the pressure of the trapped air was equal to the exterior atmospheric pressure. The exterior pressure dropped rapidly as the carrier rocket was climbing and the trapped air pressure soon exceeded the ourside pressure and the expanding air ripped off the glass cloth, which happened to tangle with the satellite. Thus, after loosening the release spring, the fairing only moved forward slightly before it got caught and the separation failed.

Peculiar Profile

The profile or early Mariner nose cone has a sharp and smooth tip which reduces shockwaves by attenuating the aerodynamic pressure smoothly. But not many nose fairings have good streamlined profiles since the size and shape of the fairing are largely determined by the size and shape of the satellite. For example, if the cross section of the satellite is larger than that of the last stage carrier rocket, the satellite may have a peculiar plummet or light bulb shaped nose fairing. With this kind of profile, there will abviously be serious aerodynamic vibration problems if the fairing is not made correctly. Hence, extensive wind tunnel experiments are required in determing the geometric parameters of the profile. Fig. 2 shows several external shapes of nose fairings.

In determining the nose cone shape, considerations are often given to the requirements of the satellite and the heat resistant characteristics of the material used. The light bulb shape nose cone may reach a

Fig. 2 Several different shpaes of nose fairings. Left: overhead fairing; right: clam shell type fairing.

temperature as high as 1000° C at its tip, glass steel or other heat resistant materials are used in making the cone. Obtuse nose cones have greater surface area at their front end, aerodynamic heating will therefore raise a greater area to a high temperature. Pointed nose cones may reach a higher temperature but the heating is more localized. Narrow and pointed cones also increase the length of the cone and reduce the usable space in the cone.

Simulation Tests on the Ground

People have learned from the experience of designing and producing satellite nose fairings that separation tests must be carrier out under simulated high altitude conditions to ensure safe and reliable jettison in space. One example is the "Aber" carrier vehicle's pedal type nose fairing. The two half conic shells are designed to be activated by springs and to rotate around the base before they are thrown out. Although the design passed ground tests, remote data showed malfunction and jettison failure. After extensive experiments, the source of malfunction was located. Since the tests were performed under atmospheric pressure, the interior and exterior pressures of the cone are equal and the atmosphere also exerts damping effect on the rotating pedals. At high altitude, however, the extremely thin air exerts no damping effect, and as a result, the unimpeded impact locally deformed and jammed the structure, and prevented the shells from separation. This episode testifies to the importance of the simulation tests. Only after a series of simulation tests on the ground to verify the performances of the nose fairing and its separation mechanism, can a successful flight be ensured.

Figures by Yen Ho

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