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FOREIGN TECHNOLOGY DIVISION



COCKPIT DESIGN IN THE MILITARY AIRCRAFT OF THE FUTURE

by

Mei Guoying

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AUG 9 1991
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91-07202



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HUMAN TRANSLATION

FTD-ID(RS)T-0244-91

23 July 1991

MICROFICHE NR: .

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English pages: 13

Source: Guoji Hangkong, Nr. 11, 1982, pp. 38-40, 17

Country of origin: China

Translated by: SCITRAN

F33657-84-D-0165

Requester: FTD/TTTRL/Lisa A. Tidd

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TITLE: COCKPIT DESIGN IN THE MILITARY AIRCRAFT
OF THE FUTURE

AUTHOR: Mei Guoying

It goes without saying that, in aerial dogfighting or in evading the opposite side's missiles, fighter planes must all maneuver abruptly. Because of this, speaking in terms of the next generation of fighter aircraft, how to increase their conventional and nonconventional maneuverability is still a key direction for development.

The maneuver capabilities of fighter aircraft, which are improving everyday, cause pilots to be put under ever increasing loads. On the basis of estimates, the next generation of fighter aircraft, during low altitude maneuver flights, can, within a few minutes, subject pilots to 8g or even higher loads. In order to make pilots capable of operating under loads this great, it is necessary to supply them with various types of protective measures, such as the use of anti-load suits to protect their four extremities. One must opt for the use of adding additional pressurization to the oxygen supplied in order to maintain respiration in their lungs, as well as opting for the use of rear slanting cockpit seats in order to reduce hydrostatic pressures between the aorta and the retina. In summary, cockpit equipment must go through a series of revolutionary changes in order to make pilots capable of going through the experiencing of great loads. In conjunction with this, we must exert every effort to reduce and lighten their operational responsibilities in order to make them capable of responding to the combat requirements of future military aircraft.

SEAT DESIGN

The science of making measurements and determinations about the human body or anthropometry is capable of being used in order to study pilot seat postures and the relationships between them and being able to accept excessive loads. In the last few years, a good number of cockpit design personnel have gathered together and studied rearward slanted seats in order to improve capabilities of the pilots of future fighter planes to accept excessive loads during periods of great flight maneuver. The basic principle is that one takes the aorta exit from the heart and moves it a distance upward causing the vertical

distance between it and the retina to be even closer. In this way, the amount of work which the heart must correspondingly do during periods when it must both support vision and carry out blood circulation is reduced. This, in turn, reduces the possibility of the occurrence of a cut-off of blood circulation. As a result of this, the pilots ability to fight excessive loads increases. Although pilots are able, during extremely short periods of time, to accept high overloads without obvious feelings of discomfort, it is true, however, that, under conditions with excessive loads of 8 g or higher than 8 g, when one stays in the deadening conditions for a few minutes, people then experience great fatigue. When one opts for the use of back slanting seats as well as other ancilliary equipment--for example, anti-load suits, increased pressurization of oxygen, and so on, and so on--it is possible to greatly reduce heart speed. As a result of this, it is possible to reduce the fatigue of the pilots.

Rear slanting seats, which have already been designed, come in four types--fixed, half-reclining types; fixed with great angles of installation; fully moveable types; and, hinged or articulated types. The fixed type of rear angle seat structures are relatively simple. However, the design fields of vision are relatively small, and it is also relatively difficult to fire for ejection. The fully moveable types are difficult to control. Also, the cockpit space is not adequate for the use of them. Articulated types of seats are relatively appropriate. Design personnel, after doing detailed studies of the various types of factors, finally selected the angle of rear slant as 35° . The seats' base plate movement angle is 20° . Its design schematic is as shown in Fig.1. The seats' base track is the same as that of the conventional one. The newly designed seat base plate opts for the use of shoulder axis and bilateral connections. Going through the shoulder axis and a simple linear motion operation, it is easy to adjust the angle of backward slant.

This kind of seat is capable of being used for escaping with the pilot's life. Its ejection process is such that, if the seat is put into a general, normal position. the ejection process and that for the current ejection seat is the same, that is, one first pulls the

ejection handle. A small charge breaks open the cockpit cover. 0.3 seconds later, the seat slides up along rails, the pilot goes through the cockpit opening, and ejects out. If the seat is placed in a back slanted position, one, by contrast, pulls the handle, and, at the same time as the small charge breaks open the cockpit cover, the seat base plate returns to the normal position. After that, it ejects out. In this way, the new seat arrangement will not cause added delay. On the basis of this design plan for seats, the system has already been through evaluation tests in model cockpits. Another design of seat is just in preparation for centrifuge tests.

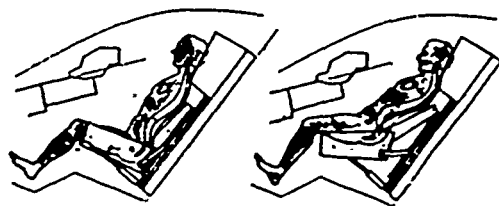


Fig.1 (Left) Normal Flight Position (Back Slant Angle 35°)
 (Right) Back Slant Combat Position (Back Slant Angle 35°)
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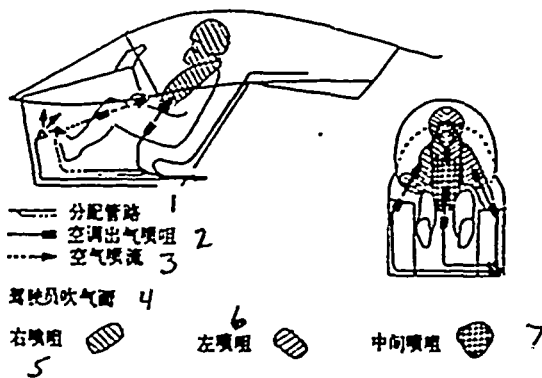


图 2 空调空气分配系统

Fig.2 Air Regulation and Air Distribution System (1) Distribution Tubing (2) Air Regulation Output Jet Nozzle (3) Air Spray Flow (4) Pilot Air Face Mask (5) Right Spray Nozzle (6) Left Spray Nozzle (7) Middle Spray Nozzle

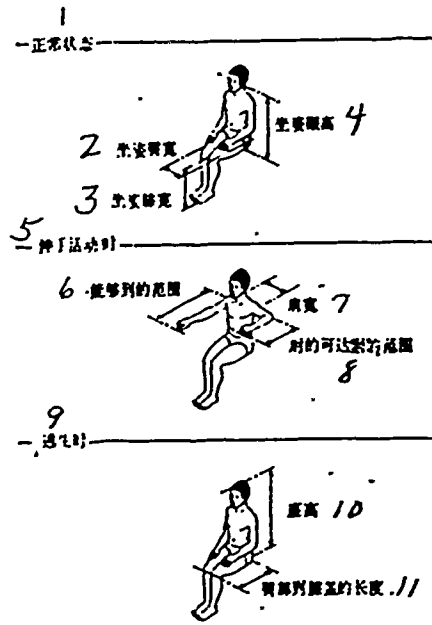


Fig.3 Key Dimensions for the Evaluation of Human Bodies in Different Configurations (1) Normal Configuration (2) Sitting Buttocks Width (3) Sitting Knee Width (4) Sitting Eye Height (5) When Hands Are Extended in Activity (6) Capability Range (7) Shoulder Width (8) Range that Can Be Reached (illegible) (9) When Ejecting (10) Sitting Height (11) Length from Buttocks to Kneecap

Other structural considerations of cockpit design which still remain are cockpit cover or canopy design, air regulation, as well as the noise problems which are caused by these. Cockpit cover design is tending toward an option for using single layer cylindrical form or conic forms of windshields and single layer cockpit covers. The reason is because, in this way, it is possible to improve fields of vision in all directions. In recent years, design has tended toward options for the use of polycarbonate materials. The reason for this is that they are easy to form. Their disadvantages are that they are easily abraded and are affected by bird collisions. Besides this, the explosive effects of small models of detonation cord on polycarbonate have yet to be studied. The most recent trend is to opt for the use of polycarbonate which has thin polypropylene pressure layers. This type of material is capable of solving the abrasion problem relatively well. However, the explosive effects of small model detonation chord on it still await a more thorough decision.

At the present time, there are a number of technologies which are capable of being used in order to lower the noise from cockpit air regulation equipment. Before, the air regulation spray nozzles were always designed to be the organ pipe type. In recent years, due to opting for the use of new principles, the "organ pipe" effect has been very greatly reduced. If one takes the new principles and uses them on the early period cockpits, it is possible to at least reduce the noise by 10 decibels. Besides this, if the air regulator spray nozzles are positioned in the vicinity of the plate around the mouth of the cockpit, and, in conjunction with this, the air jets spray through the area of the displays, the air regulation gases are also capable of being used in order to cool the equipment inside the cockpit.

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CONSIDERATIONS ASSOCIATED WITH COCKPIT FIELDS OF VISION

The basic problem in the design of arrangements for cockpit instruments is to do precise evaluations of the pilot's body as well as his line of sight and required working ranges. Fig. 3 shows the key physical dimensions influencing the design of cockpits. From the

Fig., it is possible to see that, as far as different configurations are concerned, the dimensions created as requirements for cockpit design are also different. For example, back slanted seats put strong emphasis on the height from the buttocks to the eye position and the length from the buttocks to the knee cap. Speaking in terms of fighter aircraft, the exterior field of vision is extremely important. The reason for this is that, when designing cockpits, the most important thing is the need to set up a design datum point. Moreover, the eye position is unusually important for the precise determination of this datum position. This is because it will be taken to decide the position of the cockpit's surrounding plate. Moreover, the requirements of seat ejection are also related to the volume of the cockpit and the location of the display devices. The back slanted seat is also limited by the depth of the instrument panel. The upper limit of the line of the surrounding plate of the cockpit generally requires guaranteeing that the angle of the field of vision to the front of the nose of the aircraft and down be 15°. The downward limit is determined by the space between the pilot's kneecap and the surrounding plate when he is seated in the back slanted seat. The distance from the pilot's eye to the instrument panel primarily determines the ejection space. When designing fighter aircraft, exterior fields of vision are exceptionally important. At the present time, there is a military standard. It mandates the requirements for cockpit fields of vision (See Table 4). Table 5 is the actual cockpit fields of vision measured for cockpit models by Britain's BAe Company on its own. From the Fig., it is possible to see that most of the requirements of the military standard can be satisfied. However, the field of vision angle forward and down from the front of the aircraft, speaking in terms of the back slanted seat, is capable of being relatively difficult to guarantee. However, the model cockpit, when entering the field, had a downward angle of vision which was capable of reaching 15°. As far as the rear field of vision is concerned, if the back slant angle of the seat allows both the pilot's shoulders to turn, then, it is only limited by the head of the ejection seat.

Other factors affecting the line of vision also include the arch form framework of the cockpit cover and the windshield installation columns. The former must be selected with great care. One must exert every effort to avoid creating, in aerial combat, a loss of the aiming target. The latter has an effect on air to ground fields of vision.

The method for deciding it is to opt for the use of a cylindrical or conical form of windshield cross section. However, they must maintain clarity and cleanliness. In conjunction with that, they must possess a definite capability to rebound from bird collisions.

Inside the cockpit, the pilot must be able to clearly see and read all the displays and instruments. Within the scope of the forward field of vision, it is necessary to exert every effort to avoid positioning control devices. The reason for this is that, in that way, one not only takes up usable space, but the effects are extremely slight. Control devices should be positioned on the cockpit control platform, within easy reach. Moreover, they should also, within practical limits, be put in places where they can be seen, if at all possible. The conversion of displays should, at all times, as much as possible, allow the maintaining of the head up instruments. When controls are changed, it is also necessary to display that on the instruments. In this way, when looking down, it is then possible to see the appearance of dangers from navigational errors.

When pilots fly aircraft, they go through visual indications or clues in order to control the airplane. In actuality, he has already taken himself and included it inside the control circuits. The aircraft movements supply changes in the optical input information. Pilots, on the basis of these changes, continually select appropriate control operations. Here the pilot's work responsibilities are determined by the aircraft's dynamic characteristics, the precision of tracking requirements, as well as the degree of familiarity of the pilot.

Large amounts of test results prove that, in order to match an optimized principle or accepted standard, for example, making control errors as small as possible, the pilot is capable of using period sampling methods to carry out scanning between various types of tasks. The ideal sampling period is selected as a characteristic of changes in the duration of tasks. The time for the completion of the mission or task is determined by the content of information, and also by the difficulty of the task.

In order to simplify the explanation, Fig.6 shows, in a designed cockpit, the "up to" or end times obtained for tests carried out. In the Fig., the left side control platform is divided into a number of end regions. The end times are displayed by means of a matrix form. Besides this, pilots ability to transmit data is approximately 9.3 bits/second. On the basis of the difficulty index of the tasks, a comparison is made with other similar tasks which had adequate prediction. The results were not bad. Speaking in terms of classical tracking tasks, pilots must, in unpredicted situations, make reactions to input. The classical processing rate is predicted at 5 bits/second more or less.

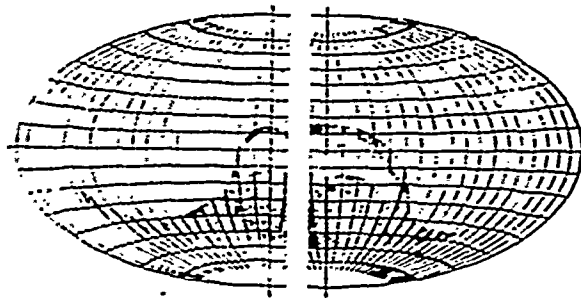


Fig.4 (Left) Military Standard Cockpit Field of Vision
Fig.5 (Right) Actual Cockpit Field of Vision

In complicated flight situations, pilots are busy using the control handle or stick to carry out control. However, the aircraft systems that require operating are very numerous, causing the pilot to be unable to use the hand controls. One type of possible method for resolving this is to use sound for control. In this way, delays created by the operation of the four appendages are reduced. As a result of this, it is possible to save time. Equipment which is capable of distinguishing sounds has already been successfully test manufactured. It has gone through training and is capable of distinguishing limited numbers of characters (for example, 32 characters). This is already adequate for the insertion of numbers.

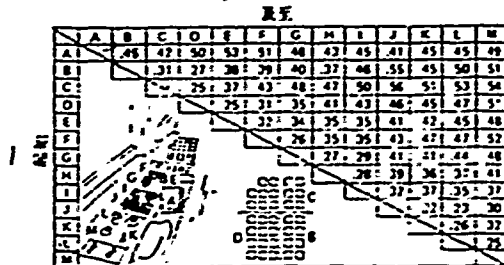


Fig.6 End Times for Various Equipment in the Cockpit (1) Initiation (2) End In the chart, A, Fuel Valve; B, Throttle; C, System Keys; D, Number Keys; E, Display/Weapons Select; F, Weapon Select; G, Attack Cross Section Select; H, Communications Select; I, Frequency Select; J, Control Stabilization Select; K, Operating Method Select; L, Target Select; M, Display Select

COCKPIT DISPLAYS

The cockpit displays in the fighter planes of the future will, undoubtedly, opt for the use of electronic displays. This is principally in order to lighten the pilot's work responsibilities and respond appropriately to the objective situation in which opting for the use of the back slanted seat makes the pilot's field of vision relatively small.

Opting for the use of electronic display equipment makes it possible to display information according to flight modes in order to do arrangements such as take offs, landings, cruising, air to air combat, and so on, and so on. In this way, one only has information displayed which is related to the flight phase in question. As a result, it is possible to make even more effective utilization of display space. If there is a requirement to display other information, it is possible to go through the keyboard in order to bring up the request.

Opting for the use of this type of operating method is the key to transferring files and is necessary to guarantee that key flight data is displayed on the screens all the time. In this way, flight personnel are then capable of knowing at all times the attitude, direction of flight, speed, and other similar basic parameters. Information display requires making the pilot see the data when his head is up. Information transfer and switching is mostly controlled by hand by the pilot on the control panel. The number of display devices is determined by the need to have an appropriate display surface area in order to be able to facilitate being capable of containing the required display forms and providing a stand-alone display device which possesses the capability to present an appropriate, comprehensive display.

In the arena of displaying flight information, there is a tendency more and more to opt for the use of predictive type displays, including iterative additions of velocity vector information, attack data, flight limit data, as well as energy data, and other similar information onto ideal flight line data. Appropriate displays of these parameters are capable of very greatly lightening the pilot's operating responsibilities.

The newest designs of cockpits are as shown in Fig.7. They opt for the use of back slant seats. The size of the cockpit is just about the same as that of Harrier type aircraft. However, the design plans have very large changes. The new cockpit opts for the use of fully electronic display equipment and head up instruments which are the newest generation of multi-dimensional, composite, multiple-unit equipment. Installed underneath it is a head level display device. Its display depth is very shallow, and it is capable of executing displays at the level of the pilots normal head level. This type of display device is capable of showing moving maps. On the top of them, it is also capable of superposing alphanumeric information. In conjunction with this, it is capable of displaying written charts and tables as well as general real time visual frequency information.

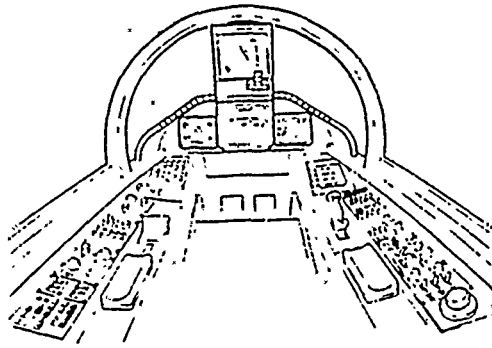


Fig.7 Advance Fighter Cockpit Design

There are also two cockpit display devices positioned above the knees of the pilot. They are called multiple function or power displays--MPD1 and MPD2. They are normally used in order to display aircraft system data, engine data, guidance data, and weapons system data. On the plate surrounding the cockpit, there is a group of warning indicator lights. When one gets the appearance of red or amber indications, the pilot must pay attention to the displays on the multifunction display devices which correspond to the warning lights. In conjunction with this, he carries out control according to the displays. When the various task items are complete, the order then automatically cancels itself. There are two other ancillary display devices. These include the small attitude indicator device on the left side instrument panel and the auxiliary altitude and speed information displayed on it. These are used in order to supply attitude data when the pilot control keyboard is used. The reason for this is that, at this time, the pilot, for several seconds, is only looking at the inside of the cockpit. They also include the display devices of the right side control panel. These supply various types of selected items to the pilot.

The display information which is supplied by the four key display devices in the cruising stage is generally as follows. The head up display instruments supply aircraft symbols, flight line deviations, direction of flight, pitch, precise flight line control vectors, and radar information on distance to target. Head level display instruments are used for short periods of guidance, supply flight route point maps, data on known threats, targets, immediate location, distance waiting to be flown, time waiting to be flown, flight direction, altitude, and other similar items. The No.1 multiple function display device is used for long duration guidance, to provide projected flight plans, flight route points, renew points, targets, bases, immediate locations, required course direction, actual course direction, guidance system operating mode, flight speed, altitude, duration, as well as the time to reach the next characteristic or indication point, and other similar items. The No.2 multifunction display device shows flight system information, including flight speed, altitude, direction, immediate position, amount of fuel, communications status, throttle rod position, Greenwich time and ephemeris or sidereal time, as well as warnings and other similar items. (Note: Head up display devices are placed on the pilot's instrument level line of sight. The current head up displays are generally positioned along the level vision line of sight.)

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Flight control rods are positioned on the control platforms. Due to the option for the use of the articulated type of seat, it is not possible to make use of the intermediately positioned control stick. As a result of this, a choice was made to make use of small control rods installed on the lateral surfaces. Because of the utilization of a driven control system, the control rods or sticks and the control surfaces are connected by electricity. The throttle rod is also connected by electricity. It is still positioned on the control platform, in the normal location.

Opting for the use of general data line makes it possible to very greatly improve and transform the design of the control panel. Due to the fact that a choice was made to use computers to carry out

sampling tests of exchanged locations, the result was that there was an important consolidation of hand control operations. In this way, it was possible to reduce approach or entry times and the operational responsibilities of the pilot. In principle, the right control platform manages operational form or mode transfers, and the left operational platform manages control transformations or switchings in flight.

In the area of aiming, it is possible to opt for the use of helmet sights. Helmet sights have already gone through air to air and air to ground combat tests. The results were good. Due to the fact that course errors can be easily caused by the confusion of flight data and display signals from outside, the result is that helmet aiming devices are only limited to use in aiming and warning. Because, when one is aiming, he normally uses his eyes in the direction of the target, the result is that it is also possible to opt for the use of eye-activated search devices in order to aim. For example, it is possible to opt for the use of infrared equipment related to corneal side slant pressure in order to carry out searches. When the eyes look at a slant, due to the fact that the position of the eyeball changes, it will cause the search or probe equipment pressure to change. After the technological problems with this type of equipment are solved, it is approved for relatively practical use.

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