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Cockpit Visibility Requirements for Army Liaison-Reconnaissance-Type Airplanes

Part I

Pilot Opinion and Tolerance Study

FOR LIMITED DISTRIBUTION

by

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COCKPIT VISIBILITY REQUIREMENTS FOR ARMY LIAISON-RECONNAISSANCE-TYPE AIRPLANES
PART I - PILOT OPINION AND TOLERANCE STUDY

SUMMARY

A questionnaire concerning cockpit visibility in Army liaison-reconnaissance-type aircraft was distributed to 2,334 Army pilots who fly such aircraft. Three hundred sixty-six of the questionnaires were completed and returned.

It had been determined during initial investigations that the pilots were not cognizant of their actual visibility needs due to the satisfactory quality of visibility provided by the aircraft they fly; namely, the L-19. They were unable to provide quantitative responses to questions concerning minimum visibility requirements with a reasonable degree of consistency. Therefore, the continued use of the questionnaire was limited to the qualitative evaluation of the field of vision provided by the L-19 airplane.

A reduced visibility tolerance study was conducted with 11 pilots to supplement the information on the visibility of the L-19 and to provide a basis for judging the qualitative responses secured through the questionnaire.

Results of the analysis of the questionnaire study and the reduced visibility tolerance study provide a basis for determining specific visibility requirements. These include minimum adequate vision cutoff angles and acceptable post locations. Minimum adequate visual cutoff angles forward are 17° down and 30° up, at 90° to the left or right (symmetrical cockpit assumed), 45° down and 8° up, assuming provision is made for visibility above the high wing obstruction. The minimum adequate azimuth cutoff angle is 130°. The results are not considered to be a final solution to the cockpit visibility problem, but offer a useful guide to the amount and quality of visibility which will be considered acceptable by the pilots.

INTRODUCTION

During recent years, the visual characteristics of aircraft cockpits as determined by window size, type, and location have been receiving increased attention. Such attention has arisen as a result of the increased danger of midair collisions and a desire to establish standards of adequate visibility to be applied to the design of new aircraft.

The CAA Technical Development Center (TDC) has investigated the problem of visibility, as it exists in transport-type aircraft, since 1948. Technical information was obtained through an airline pilot questionnaire study,[1] a pilot

[1]George L. Pigman and Thomas M. Edwards, "Airline Pilot Questionnaire Study on Cockpit Visibility Problems," CAA Technical Development Report No. 123, September 1950.

eye-movement study,[2] a collision-course study,[3] and development of a binocular vision camera for recording cockpit visual angles.[4] The studies culminated in the publication of recommendations for cockpit visibility standards for transport-type aircraft in February 1956.[5] Later, a similar program was undertaken by TDC under the sponsorship of the Department of the Army, Office of the Chief of Army Transportation, to investigate visibility requirements for fixed-wing, liaison-reconnaissance-type aircraft.

Efforts to establish cockpit visibility requirements have been limited due to the complexity of the problem resulting from the great number of interacting variables which, in most cases, cannot be separated. However, it was found possible to translate pilot opinions and their degree of tolerance to reduced visibility into quantitative cockpit visibility requirements.

The pilot questionnaire and reduced visibility tolerance studies covered by this report represent a first approach leading toward the establishment of military standards for windshield size and quality and are considered as supplying contributory data and not a final solution to the problem.

GENERAL BACKGROUND

Aircraft Data.

The Army's fixed-wing, liaison-reconnaissance aircraft presently is typified by the Cessna L-19 "Bird Dog," shown in Fig. 1, which has been operational since 1950. A high-wing monoplane, the L-19 seats a pilot and an observer in tandem. The powerplant consists of a 213-hp, Continental six-cylinder, flat-opposed, air-cooled engine. Further specifications include:

[2]Thomas M. Edwards and Wayne D. Howell, "A Study of Pilots' Eye Movements During Visual Flight Conditions," CAA Technical Development Report No. 179, January 1952.

[3]Wayne D. Howell and Thomas M. Edwards, "Determination of Some Geometric Relationships Pertaining to Collision Flight Paths," CAA Technical Development Report No. 259, June 1955.

[4]Thomas M. Edwards, "Development of an Instrument for Measuring Aircraft Cockpit Visibility Limits," CAA Technical Development Report No. 153, January 1952.

[5]Thomas M. Edwards and Wayne D. Howell, "Recommendations on Cockpit-Visibility Standards for Transport-Type Aircraft," CAA Technical Development Report No. 275, February 1956.

Dimensions:
- Span - 36 feet
- Length - 24 feet, 11 1/2 inches
- Height - 7 feet, 6 inches

Weights and Loading
- Weight empty - 1,498 pounds
- Weight loaded (normal) - 2,200 pounds
- Weight loaded (maximum) - 2,430 pounds
- Wing loading - 12.1 pounds/square foot
- Power loading - 11.05 pounds/horsepower

Performance:
- Maximum speed - 130 mph
- Cruising speed (29 per cent power) - 104 mph at 5,000 feet altitude
- Stalling speed - 54 mph
- Initial rate of climb - 1,485 feet per minute
- Service ceiling - 22,900 feet
- Cruising range - 800 miles
- Takeoff distance over 50-foot obstacle from grass - 560 feet
- Landing distance from 50-foot altitude on grass - 600 feet.

Existing available visibility in the Army L-19 for the average eye location is shown in Fig. 2. The photograph was taken with the TDC binocular vision camera which records the true field of view of a pilot scanning the horizon with simple head rotation. The resulting outline describes cockpit visibility limitations based on eye movement and simple head rotation in a horizontal plane. Figure 2 should not be used to determine absolute limits of foveal vision in any direction, since the pilot's viewpoint and visual cutoff angles will change with vertical head rotation, as shown in Fig. 3. Normally, a pilot can be expected to use eye movement only to 15° in any direction from the centroveal position. Beyond 15°, head movement must be considered. The difference between the true and apparent visual cutoff angles is a function of the elevation angle and the distance from the pilot's viewpoint to the windshield. The true cutoff angle always will be smaller than the angle presented in Fig. 2, the difference between these angles increasing numerically with increasing elevation. When judging areas of visibility, it must be remembered that the spherical limits are projected on a grid similar to a Mercator projection. The area intercepted by the true solid angle therefore decreases with increasing elevation above and below the horizon. A table of solid angles in steridians for each increment of elevation is presented in Fig. 2 to facilitate appreciation of available visibility.

Missions.

The missions of Army aviation are numerous and ever-changing. The present primary missions which liaison-reconnaissance fixed-wing aircraft may be expected to accomplish are:

A. Infantry, Armor, and Artillery.

1. Observation - adjustment of fire.
2. Reconnaissance and survey.
3. Command liaison.
4. Aerial photography.
5. Limited resupply.
6. Wire-laying.
7. Column control.
8. Battlefield illumination.
9. Propaganda distribution.
10. Radio relay.

B. Engineers.

1. Command control and project supervision.
2. Reconnaissance for roads, bridges, and other construction.
3. Survey and mapping.

C. Medical Corps.

1. Medical resupply.

D. Signal Corps.

1. Wire-laying.
2. Aerial photography.
3. Reconnaissance and patrol of wire routes.

E. Transportation Corps.

1. Limited resupply.

There are certain basic flight maneuvers peculiar to Army aviation, such as the short-field, maximum-performance takeoff and landing over a 50-foot barrier; formation flying; high- and low-level landing field reconnaissance, and message pickup and drop.

Cockpit visibility requirements for a particular type of aircraft vary according to the nature of the mission or missions and associated flight maneuvers. All requirements for a given mission or maneuver, however, can be found in one or more of the following basic requirements for cockpit visibility.

1. For ground navigation (taxiing).
2. To break contact with the ground (takeoff).
3. To maintain equilibrium.
4. To prevent midair collisions.
5. For aerial navigation.
6. For observation of ground details at close proximity during flight.

7. To prevent inadvertent contact with the ground and its associated obstructions during low-level flight.
8. To re-establish contact with the ground (landing).

QUESTIONNAIRE STUDY

Procedure.

A tentative questionnaire first was developed from similar questions used previously in the transport aircraft study. A prestudy procedure then was conducted with the questionnaire. This involved completion of progressive revisions of the questionnaire by groups of ten Army pilots picked at random, with each question being discussed, through interview, after each questionnaire was completed. A total of 30 Army pilots took part in the prestudies.

The success of the pilot-opinion study of cockpit visibility in transport-type aircraft had been dependent largely upon the existence of visibility problems which made the pilots cognizant of the over-all visibility characteristics of their aircraft, and on the availability of comparative data from pilots of various aircraft. This enabled control of bias due to dislike or preference for a particular aircraft. Neither of these conditions was existent in this study. The L-19 is the only operational Army liaison-reconnaissance aircraft in its class, and a definite lack of awareness regarding vision needs was noted during the prestudies. Sufficient variation was noted in responses to questions requiring quantitative answers relative to visibility requirements as to negate their usefulness.

The final questionnaire, included as Appendix I, was distributed through the officers of all Army regions within the Continental United States. A preliminary inquiry was made to each region for a listing of the number of qualified, active, fixed-wing aviators. A sufficient quantity of questionnaires was mailed to each regional aviation office. An addressed return envelope was attached to each questionnaire for mailing the completed questionnaire directly to TDC. A total of 2,334 questionnaires were distributed to active Army pilots.

After receipt of 345 completed questionnaires, when return of the questionnaires had slowed to a low rate, a follow-up letter was sent to each regional aviation office urging return of additional questionnaires. The follow-up letter had little effect since no change was reflected in the rate of return. The total return of 366 questionnaires used in this report represents only 15.7 per cent of the total distributed. The data contained in the questionnaires were transferred to punchcards, and tabulation, classification, and totalization of the data were carried out with punchcard machines.

Discussion of Data.

Question 1 - Pilot Height.

Light aircraft seats generally are not adjustable vertically to compensate for variations in pilots' height. This question was used for control purposes to establish the distribution of heights of pilots and determine the effect of height on the pilots' opinions of visibility in the L-19. Both the arithmetical mean and median values of height were 70 inches. The distribution of heights is shown in Fig. 4. The resulting histogram compares favorably with medical studies of thousands of pilots, indicating that the response of this study covers a typical cross section of pilots in respect to height. The effect of height will be discussed with each question where a significant difference is noted.

Question 2 - Pilot Experience.

This question was included for general information and control purposes to permit evaluation of the effect of experience on pilots' opinions. Both total and L-19 flying time were requested, since it was believed that experience in other aircraft might affect a pilot's opinion of the quality of visibility in the L-19. It also was considered desirable to compare opinions of the entire group with pilots having combat experience.

The median values of experience for the entire group were 860 hours of total flying time and 480 hours of L-19 flying time. The distribution of total and L-19 flying experience is shown in Fig. 5. The number of years of flying experience proved of no value, therefore, the results are not presented. Twenty-two per cent of the participating pilots had combat experience in Army aviation. Differences in opinions as a result of varying degrees and types of experience will be discussed with each question where a significant difference is noted.

Question 3 - Quality of Existing Visibility.

The data obtained from the replies to this question are presented in Table I. As specified in the question, Class 1 signifies excellent visibility with a possibility of being reduced without affecting performance; Class 2 signifies satisfactory visibility; Class 3 signifies adequate visibility with desire for improvement; and Class 4 signifies inadequate visibility with a definite need for improvement. Table I also shows the mean rating (M) for each portion of the question. This is the mean value of the four numerical ratings, weighted by the percentage of pilots specifying each rating. These mean values can vary from 1.00 to 4.00. A mean value of 2.00 would be assumed to correspond to satisfactory visibility, and the amount of variation of the mean value from 2.00 corresponds to the degree of superiority or inferiority of visibility compared to satisfactory visibility.

The pilots as a group rate the over-all visibility of the L-19 as satisfactory, with a definite tendency toward excellent. Total and L-19 flying experience had no apparent effect on the distribution of responses. Pilots taller than the 70-inch median rated the quality of upward visibility lower than the entire group, as anticipated. However, tall pilots also rated downward visibility forward lower than the entire group. This lower rating may be attributed to either a general dissatisfaction for over-all visibility due to a specific visibility problem or, because tall pilots must sit farther aft in the cockpit to obtain the necessary leg room, an actual reduction of downward visibility limits.

Combat pilots, whose opinions were given greater weight because of their background experience under true field conditions, distinctly rated the quality of visibility lower than the group average.

The degree of additional experience in other aircraft had no significant effect on the pilots' ratings except that pilots with no flying experience other than in the L-19, comprising 7 per cent of the participating pilots, clearly rated the quality of visibility lower than the group average. The average flying experience for this group was 261 hours. Visibility ratings of pilots with similar experience, who have flown other types of aircraft, compared favorably with the group average. Therefore, lack of flying experience does not appear to be the reason for the variation. A more logical reason is that this group of pilots has not been influenced by the quality of visibility in other types of aircraft. The L-19, because of its intended use, has substantially more visibility than most aircraft. Having flown in aircraft with much less visibility, the average pilot may underrate the true vision needs in reconnaissance-type aircraft.

Question 4 - External Portions of Aircraft Visible from Cockpit.

The detailed results from the replies to this question are shown in Fig. 6. The items listed under "Other" with the number of responses include: bundle or bomb racks (6), leading edge of wing (5), antenna wiring (4), tail wheel (3), taillight, struts, and trim tabs.

The pilots' rate of response to this question was exceedingly high when compared with the responses to a similar question in the transport-type aircraft study. This may be expected, since operations under field conditions are typified by a lack of ground personnel to aid the pilot during ground maneuvers in confined areas, possible damage due to enemy fire or contact with obstructions such as trees and wires must be assessed immediately by the pilot.

Considerable variation existed in the number of external features of the aircraft that the pilots considered necessary to see from the cockpit. Six pilots considered it necessary to see all external features indicated in the questionnaire, while seven pilots considered it unnecessary to see any external features. The response at all intermediate levels is shown in Table II with the distribution of answers at the various levels of response. It can be seen that the distribution remains essentially the same throughout all levels of response, and that the ability to see the flaps and wingtip lights is of the greatest importance to the pilots from an over-all safety standpoint.

Question 5 - Dependence upon Observer.

This question was offered to determine the pilots' degree of dependence upon the observer to aid in his air search duties. Thirty-two per cent of the pilots depend on their observers to assist in preventing midair collisions by searching the sky in their zone of vision, and 54 per cent depend on the observer to look for enemy aircraft. Neither combat nor other flying experience had any effect on the distribution of responses to this question.

Questions 6 and 10 - Permissible Head and Body Movements During Basic Maneuvers and Tactical Missions.

These questions were included to establish an acceptable degree of head and body movements to assist in determining the angular visibility requirements. The list of tactical missions in question 6 was designed to be representative of all missions in Army aviation. The results from the replies to these questions are shown in Table III. Each of the three acceptable degrees of head and body movements was assigned a numerical rating value arbitrarily so that the mean rating (M) for each maneuver and mission could be determined for purposes of comparison. The mean rating is the mean value of the three ratings, weighted by the percentage of pilots specifying each rating. They can vary from 1.00 to 3.00. A mean rating of 2.00 would correspond to the pilots' acceptance of moderate head and body movement to see that which is necessary to be seen during the particular maneuver or mission under consideration. Ratings smaller than 2.00 indicate a desire for less head and body movements while ratings larger than 2.00 indicate a willingness to use more head and body movements.

The acceptable degree of head and body movements appears to be a direct function of the altitude at which the maneuvers for the mission are accomplished. The nearer the ground the maneuver is performed, the greater is the desire to remain fixed in one position. Takeoffs and landings, which actually involve contacts with the ground at high speed, received mean ratings of 1.34 and 1.36, respectively. The rating for final approach which leads to contact with the ground was 1.58, while the low-level landing field reconnaissance, which is flown at extremely low altitudes without actual contact with the ground, received a rating of 1.68. Wire-laying, supply drops, and reconnaissance for roads and bridges, all flown at moderately low altitudes, were grouped closely at 1.62 to 1.85. All other maneuvers and missions rated above 2.

Question 7 - Manuevers for Which Maximum Visibility is Required.

The data obtained from the replies to this question are presented in Fig. 7. It can be seen that pilots believe that good visibility is most urgently required on the final approach, with the climbing turn their next choice, and taxiing placing third in their preference It is noteworthy to reflect again upon the transport-type aircraft study where final approach was the first choice, gliding turns second, and taxiing third. Regard for loss of vision due to the wing obstruction is apparent since liaison-reconnaissance pilots with high-wing aircraft gave the climbing turn as their second choice, whereas transport pilots with low-wing aircraft expressed concern for gliding turns.

Question 8 - Quality of Vision Through Window Material.

Ninety-five per cent of the participating pilots felt that the quality of vision through flat and curved plastic panels is satisfactory for the safe operation of the aircraft during all missions and maneuvers. The greatest percentage of remaining pilots felt that plastic panels are unsatisfactory only where the radius of curvature is small, since the resulting distortion has a detrimental effect on depth perception during critical maneuvers such as final approach.

Though the majority of the pilots rated the quality of vision as acceptable, a number of remarks were added Sixteen pilots complained about distortion as described above. Fourteen pilots disliked the aging characteristics of Plexiglas, since checked and scratched plastic tends to disperse light rays and cause distracting glare points. One pilot indicated that "plastic panels are not satisfactory for missions such as surveillance and fire adjustment when use of binoculars is required."

Question 9 - Window Use in the L-19.

In addition to the normal complement of windows, the L-19 has overhead skylights and observer's windows to the side and rear. This question was included to evaluate the pilot's interest in these secondary windows.

Each window or portion of a window was referred to by number, as shown in Fig. 8. Also, the pilots were offered the opportunity to refer to a window on a particular side of the aircraft by using a subscript "L" or "R," meaning left or right side. The data were condensed subsequently to exclude reference to a particular side of the aircraft since no significant information resulted.

It was requested that responses be limited to windows that the pilots actually used during the maneuver under consideration. Some pilots, however, can be expected to indicate more windows than they actually use while others indicate less. The distribution of responses for each maneuver is shown in Table IV, with the response level containing the median underlined. The distribution of answers at various levels or response is presented in Table V. Assuming that the median of responses indicates the average desires of the pilots accurately, it can be seen from Table V that very few, if any, use the upper or rear windows during takeoff, final approach, or landing. Limited interest was expressed in the use of rear windows during turns and that was centered about window No. 6, which actually forms a continuation of the side window. During cruise, and level and climbing turns, the responses for use of the upper windows actually equalled the responses for the use of the three main areas of vision.

Questions 11 and 12 - Military Branch Association.

A rational analysis of the relative importance of each of the primary missions performed by various military branches within the Army would entail knowledge of the frequency that a particular mission may be expected to be flown. This is governed partly by the number of pilots assigned to accomplish those missions. The predominance of pilots as shown in Fig. 9 are attached to Artillery, with Infantry rating second, and Transportation third. Less than 23 per cent of the pilots have had experience in more than one military branch.

General Comments on Cockpit Visibility.

Fifty-five pilots inserted comments or suggestions influencing cockpit visibility in the space reserved for that purpose. The present location of the magnetic compass, especially on older models of the L-19, was found objectionable by 21 pilots. Fifteen pilots complained about the wing obstruction to vision. Increasing the size of the upper windows to improve visibility was suggested by 12 pilots, while 3 pilots desired the wing to be located further aft. Because of their height, five pilots suggested a vertically adjustable seat to bring their eye levels down below the wing root.

Glare and reflections on the windshield from ground sources during night flights were found objectionable by 12 pilots. Four pilots suggested rear-view mirrors to improve rearward visibility. Two pilots suggested the use of a tricycle landing gear to improve visibility during taxi and takeoff. Finally, three pilots indicated that the L-19 visibility is much greater than actually is necessary.

REDUCED VISIBILITY TOLERANCE STUDY

Procedure.

Eleven pilots with varying degrees of flying experience, from 200 to 11,000 hours of flying time, were selected to serve as subjects in a controlled flight program. The purpose of this program was to provide a basis for judging the qualitative responses secured through the questionnaire study. The program comprised three phases, as follows:

Phase I - The photographic recording of piloting techniques with all available vision.

Phase II - Determination of pilot tolerance in flight to progressive reduction in available visibility through the masking of windshield and windows.

Phase III - The photographic recording of piloting techniques with the windshield and windows masked to minimum tolerance levels.

In Phase I, the pilots' actions and certain associated flight data were recorded photographically as each flew an L-19 through a prescribed set of basic flight and tactical maneuvers under normal conditions for the purpose of establishing the pilot's normal pattern of flight.

The instrumentation for the observation study is shown in Fig. 10. A battery-operated 16 mm movie camera with 9.5 mm wide-angle lens was mounted behind the observer's seat. A secondary instrument panel, including an altimeter, air-speed indicator, magnetic compass, and gyro attitude indicator, was mounted behind the pilot's seat. A sample strip of film showing the resulting field of view is shown in Fig. 11.

Basic flight and tactical maneuvers and missions included in this study were chosen as being representative of current Army aviation operations. The prescribed set of maneuvers included.

1. Taxi on controlled airfield.
2. Normal takeoff from controlled airfield.
3. Normal landing on controlled airfield.
4. Cruise.
5. Turns - 90° and 180°; descending, level, and ascending, normal and maximum performance.
6. Short-strip takeoff (uncontrolled).
7. Short-strip landing (uncontrolled).
8. High-level landing field reconnaissance.
9. Low-level landing field reconnaissance.
10. Message pickup.
11. Road reconnaissance.
12. Artillery spotting.
13. Bridge reconnaissance.

Each maneuver of short duration was performed at least twice to establish an average performance. Continuing maneuvers and missions such as cruise and artillery spotting were recorded for periods of 5 minutes. Each flight, lasting about 2 1/2 hours, provided about 50 minutes of recorded data taken at 8 frames per second.

In Phase II of the program, the participating pilots made five flights during which the windshield and windows of the aircraft were masked off progressively to reduce the available visibility. Preflight discussions determined pilots' opinions of the minimum tolerable vision needed to accomplish safely all maneuvers and missions performed with liaison-reconnaissance-type aircraft. Each discussion period was followed by an orientation flight of approximately 30 minutes' duration, during which the effect of the masking as experienced during the previous flight was determined and the possibility of further masking, as well as other factors, was investigated. Acceptable post location was investigated during the last three inverview periods. The final outlines then were photographed with the binocular vision camera from the subject pilot's true eye position.

In Phase III of the program, the pilots again flew through each of the flight and tactical maneuvers prescribed in the first phase with the aircraft in a maximum tolerable masked condition to record changes, if any, in their normal pattern of flight. In order to obtain data which would be indicative of a pilot's normal flight habits, the subject pilots were provided with only a minimum of information concerning the methodology of the study.

Discussion of Results.

The photographic data obtained in Phases I and III were subjected to frame-by-frame analysis to determine general window use, head and body movements, and the particular techniques of each pilot. Window locations were divided into four sectors for analysis: front, side, upper, and rear. Greater accuracy was not justifiable since the analysis was made through motion pictures of the pilot viewed from the rear. Three degrees of head and body movements were recorded: simple head rotation, head and body movements from 0 to 5 inches in any direction, and head and body movements of more than 5 inches. Data recorded to establish each pilot's normal pattern of flight included aircraft attitude, speed, and altitude. All data concerning window use and head and body movements were converted from frame counts to percentage values for ease of comparison.

Average window use before and after masking is shown in Table VI. Certain maneuvers, such as cruise, permit a greater degree of freedom in the use of available visibility and show a greater variation in the results. However, maneuvers such as landings and takeoffs which require continual concentration exhibit a high degree of consistency.

The pilots' average use of head and body movements before and after masking is shown in Table VII. Head and body movements definitely increased as a result of masking. These increases were sufficient to provoke comments by the pilots that they were "excessive" for normal flights of any great duration and resulted in fatigue. The pilots' patterns of flight did not change appreciably because of masking. The changes noted generally reflected lack of familiarity with the modified visibility and a resulting tendency for less drastic maneuvering.

A single outline representing the average minimum safe visibility estimated by the 15 pilots participating in the reduced visibility tolerance study is illustrated in Fig. 12. The upper windows, though indicated as necessary, are not shown in Fig. 12 because their size or location cannot be specified with a reasonable degree of accuracy. This is attributed to the proximity of the upper windows to the pilot's eyes. This permits considerable variation in the pilot's estimation of their necessary size and location. The upper windows are used primarily during turns. They are in effect a continuation of the side windows which are limited in upward visibility due to the wing obstruction. Being located within 8 inches of the pilot's eyes and although partially masked, they provide visibility for most of the area above the wing with moderate head movement.

VISIBILITY REQUIREMENTS

Estimates of the quality of existing visibility made by the pilots in the questionnaire, together with the minimum tolerable visibility requirements estimated in the reduced visibility tolerance study, were analyzed to determine minimum adequate visibility requirements. The minimum tolerable visibility outline determined in the reduced visibility tolerance study is not adequate for normal use when consideration is given to the pilots' expressed opinions of acceptable head and body movements. Most of the pilots participating in the reduced visibility tolerance study at some time commented on the excessive movement and resulting fatigue. This fact, however, does not reduce the value of the minimum tolerable visibility outline. An outline representing minimum acceptable visibility may, through arbitrary interpretation, be delineated by adjusting the minimum tolerable visibility outline, shown in Fig. 12, in accordance with the opinions expressed on quality of existing visibility replies to question 3 of the questionnaire and acceptable head and body movements expressed qualitatively in replies to questions 6 and 10. Also, due consideration should be given to the increases in head and body movements resulting from the reduction of existing visibility as determined in the observation phase, Phase III, of the reduced visibility tolerance study. Such an outline is shown in Fig. 13.

Windows providing visibility to the rear were excluded from the minimum requirements because their limited use by the pilots, as expressed in replies to question 9 and as shown in the reduced visibility tolerance study, does not justify the design penalties that accompany their inclusion in an aircraft design. The pilots' prime, though limited, interest in the rear windows as expressed in replies to question 9 related to their use in turns. That interest centered about window No. 6 which is, in effect, a continuation of the side window to the rear. The pilot can see anything that may be seen through window No. 6, using window No. 1, with moderate head movement to the side. A willingness to apply such head movement was expressed in replies to questions 6 and 10. The reduced visibility tolerance study showed that the rear windows were used during the takeoff run as well as maximum rate turns. During takeoff, the rear windows were used to "clear" for approaching aircraft at the initiation of ground roll. The time required to turn the head to see in a rearward direction during a flight maneuver could constitute a hazard which might be eliminated through use of a rear-view mirror. As previously discussed, the overhead windows cannot be delineated specifically at this time; however, a note outlining the requirements is included in Fig. 13.

The requirements, as illustrated in Fig. 13 and covered in the previous discussion, are not considered in any sense the final answer to liaison-reconnaissance-type aircraft cockpit visibility requirements. The questionnaire and reduced visibility study methods of investigation have basic limitations in precision. However, their analyses have yielded quantitative conclusions. It is believed that the results of the studies have strong provisional validity and, in particular, show that an aircraft cockpit window arrangement having an outline as shown in Fig. 13 would provide adequate visibility for the majority of Army pilots.

CONCLUSIONS

The data secured from the 366 completed questionnaires and 11 pilot interviews are reasonably consistent, and the following conclusions can be derived:

1. Visibility in a forward and downward direction is critical during taxi, climbing-turn, and landing maneuvers. A minimum downward vision cutoff angle of 17° should provide adequate visibility for taxi and climbing-turn maneuvers with moderate head and body movements, and for landing maneuvers with minimum head movement.

2. Visibility in a forward and upward direction is critical during climbing-turn maneuvers. A minimum upward vision cutoff angle of 30° will provide adequate visibility for climbing turns with moderate head and body movements.

3. Upward visibility to the right and left is critical during all turning maneuvers. A minimum upward vision cutoff angle of 8° at 90° to the side with provision for visibility above the wing obstruction will provide visibility at horizon level during level flight maneuvers, a view of the wingtips with minimum head movement, and a view of the area into which the aircraft will fly during banked turns.

4. Downward visibility to the right and left is critical during tactical maneuvers. A minimum downward vision cutoff angle of 45° at 90° to the side will provide adequate visibility for tactical maneuvers requiring observation of ground details at close proximity with minimum head and body movements.

5. The azimuth cutoff angle is critical during both turns and tactical maneuvers. An azimuth cutoff angle of 130° will provide a full field of view with moderate head and body movements for artillery spotting and general observation, and permit a pilot to clear adequately for turns.

6. The quality of vision provided by plastic window material is adequate in all directions if the curvature of the material is limited to prevent distortion, and if the window is not sloped in a manner which will reflect light from ground sources during night flights.

7. The final approach, climbing-turn, and taxi maneuvers are considered most critical from the standpoint of over-all visibility requirements by the largest number of pilots.

8. A majority of the pilots desire to see the following external portions of the aircraft: engine and propeller, fixed landing gear, pitot tube, wingtips, wingtip lights, flaps, ailerons, and vertical and horizontal tail.

9. The results obtained in this study are not considered to be a complete solution to the problem of visibility requirements. However, application of these results should permit reasonable evaluation of cockpit visibility, and such evaluation is closely related to true adequacy of visibility from the standpoint of safety.

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TABLE I

DISTRIBUTION OF PILOTS' RATINGS OF QUALITY OF L-19 VISIBILITY EXPRESSED AS A PERCENTAGE OF THE TOTAL RESPONSE - QUESTION 3

	All Pilots					Tall Pilots (5 ft, 11 in and above)					Pilots with Combat Experience					Pilots with L-19 Flying Experience Only				
Rating*	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M
Maneuver											Visibility Upward to Front									
Taxi	52	46	3	--	1.50	51	46	3	--	1.52	46	50	3	1	1.59	25	66	9	--	1.84
Takeoff	52	45	3	--	1.51	51	45	4	--	1.53	44	54	1	1	1.59	31	56	13	--	1.82
Cruise	50	46	4	--	1.54	46	49	5	--	1.59	43	53	3	1	1.62	31	60	9	--	1.78
Climb turn	36	51	12	1	1.78	33	52	14	1	1.83	33	49	18	--	1.85	22	50	25	3	2.09
Level turn	41	52	7	--	1.59	37	55	8	--	1.71	34	59	6	1	1.74	25	59	16	--	1.91
Glide turn	42	50	7	1	1.60	38	55	6	1	1.70	37	56	5	2	1.72	25	62	13	--	1.88
Final	50	46	4	--	1.54	49	48	2	1	1.55	43	53	2	2	1.63	25	66	9	--	1.84
Landing	51	46	3	--	1.58	52	46	2	--	1.50	44	51	4	1	1.62	28	66	6	--	1.78
Average	47	48	5		1.58	45	50	6		1.61	41	53	5	1	1.67	27	61	13		1.87
Maneuver											Visibility Downward to Front									
Taxi	15	54	28	3	2.19	14	51	31	4	2.25	19	55	22	4	2.11	--	57	34	9	2.52
Takeoff	32	54	14	--	1.82	32	51	17	--	1.85	32	39	19	--	1.87	3	72	25	--	2.22
Cruise	28	56	16	--	1.88	26	56	18	--	1.92	26	52	29	1	1.97	13	72	16	--	2.05
Climb turn	17	55	25	3	2.14	16	53	28	3	2.18	16	63	19	2	2.07	6	63	28	3	2.43
Level turn	28	57	14	1	1.88	25	58	17	--	1.92	23	68	9	--	1.86	6	69	25	--	1.94
Glide turn	29	57	3	1	1.56	26	55	18	1	1.94	24	66	9	1	1.87	9	75	16	--	2.07
Final	38	50	12	--	1.74	36	49	15	--	1.79	30	51	18	1	1.90	16	68	16	--	2.00
Landing	21	53	25	1	2.06	20	51	28	1	2.10	22	51	26	1	2.06	6	59	32	3	2.32
Average	26	55	17	1	1.91	24	53	21	1	1.99	24	56	19	1	1.96	7	67	24	2	2.19
Maneuver											Visibility Sideward									
Taxi	47	45	8	--	1.61	42	47	11	--	1.69	38	55	7	--	1.69	31	60	9	--	1.78
Takeoff	50	45	5	--	1.55	48	44	8	--	1.60	40	55	5	--	1.65	35	59	6	--	1.71
Cruise	47	46	7	--	1.60	44	47	9	--	1.65	39	51	10	--	1.71	31	60	9	--	1.78
Climb turn	20	48	27	5	2.17	17	45	30	8	2.29	24	49	23	4	2.07	13	63	18	6	2.17
Level turn	22	52	22	4	2.08	22	50	22	6	2.12	24	54	16	6	2.04	16	68	16	--	2.00
Glide turn	25	52	19	4	2.02	21	52	20	7	2.13	26	49	19	6	2.05	9	79	9	3	2.06
Final	42	50	8	--	1.66	36	54	10	--	1.74	35	56	9	--	1.74	21	66	13	--	1.92
Landing	44	50	6	--	1.62	39	53	7	1	1.70	39	58	3	--	1.64	22	72	6	--	1.84
Average	37	49	13	2	1.79	34	49	15	3	1.87	33	52	12	2	1.82	22	66	11	1	1.91

* 1 - Excellent
2 - Satisfactory
3 - Adequate
4 - Inadequate
M - Weighted mean of ratings 1 through 4

TABLE II

DISTRIBUTION OF ANSWERS TO QUESTION 4 CONCERNING EXTERNAL PORTIONS OF AIRCRAFT AT VARIOUS LEVELS OF RESPONSE

Number of External Portions of Aircraft Pilot Desired to See	Total No of Pilots	External Portion of Aircraft										
		Landing Gear Fixed	Landing Gear Retracted	Wing Tips	Wing Tip Lights	Flaps	Ailerons	Pitot Tube	Engine and Propeller	Vertical Tail	Horizontal Tail	Other
1	11	-	1	1	2	5	-	1	1	-	-	-
2	14	1	-	4	8	9	1	2	3	-	-	-
3	18	4	3	7	15	10	7	1	5	-	1	1
4	17	8	1	7	14	12	8	7	7	1	1	1
5	31	14	8	13	28	27	17	16	19	7	8	3
6	12	4	2	11	11	10	9	9	11	2	2	1
7	43	35	5	29	36	41	36	30	30	28	29	-
8	55	35	16	44	50	55	54	40	46	49	49	2
9	102	92	17	99	102	102	101	101	101	101	101	1
10	50	50	44	48	50	50	50	49	50	49	50	10
11	6	6	6	6	6	6	6	6	6	6	6	6

Note 7 pilots indicated no external portions of aircraft

TABLE III

ACCEPTABLE DEGREE OF HEAD AND BODY MOVEMENT DURING VARIOUS MANEUVERS AND MISSIONS EXPRESSED AS A PERCENTAGE OF THE TOTAL RESPONSES - QUESTIONS 6 AND 10

Ratings	1	2	3	M
	Minimum Movement of Head and Body	Moderate Movement of Head and Body	Maximum Possible Movement with Seat Belt Fastened	Weighted Mean of Ratings 1 to 3
Maneuvers				
Takeoff Run	70	26	4	1 34
Landing	70	24	6	1 36
Final Approach	51	40	9	1 58
Cruise	23	52	25	2 02
Level Turns	12	67	21	2 09
Gliding Turns	10	68	22	2 12
Climbing Turns	8	68	24	2 16
Taxi	19	56	25	2 03
Missions				
Low-Level Landing Field Reconnaissance	46	40	14	1 68
Wire-Laying	34	50	16	1 82
Supply Drops	32	54	14	1 82
Reconnaissance of Roads, Bridges, and Wire Routes	27	53	20	1 93
Column Control	19	59	22	2 03
Observation, Adjustment of Fire	21	55	24	2 04
Reconnaissance and Survey, General	17	60	23	2 06
Survey and Mapping	16	58	26	2 10

TABLE IV

DISTRIBUTION OF LEVELS OF RESPONSE TO QUESTION 9 FOR VARIOUS MANEUVERS EXPRESSED AS A PERCENTAGE OF THE TOTAL RESPONSE

Quantity of Windows Indicated in Response	1	2	3	4	5	6	7	8
Maneuver								
Taxi	--	4	56	6	12	14	1	7
Takeoff	--	37	48	3	7	1	--	4
Cruise	--	3	27	6	21	10	8	25
Climb Turn	--	3	13	23	39	9	5	8
Level Turn	--	5	24	21	31	9	4	6
Glide Turn	--	5	36	20	22	9	3	5
Final Approach	--	15	59	6	14	1	--	5
Landing	4	38	52	--	2	1	--	3

Note: Level of response containing median is underlined.

TABLE V

PILOTS' ESTIMATED USE OF VARIOUS L-19 WINDOWS DURING BASIC FLIGHT MANEUVERS - QUESTION 9

Quantity of Windows Indicated in Response	Takeoff								Descending Turns							
Window No	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
5	-	92	120	8	16	1	-	9	-	3	91	47	58	21	8	13
4	-	93	119	7	18	1	-	9	1	10	91	53	60	25	8	13
1	-	3	119	4	17	1	-	9	-	9	93	48	59	26	8	13
2	-	-	1	4	17	1	-	9	-	1	5	30	46	14	8	13
3	-	-	1	8	17	1	-	9	-	-	4	14	47	14	7	13
6	-	-	-	-	1	-	-	9	-	1	3	21	15	20	7	13
7	-	-	-	1	1	1	-	9	-	-	-	2	4	11	6	13
8	-	-	-	-	1	-	-	9	-	-	1	1	11	14	4	13

Quantity of Windows Indicated in Response	Final Approach								Taxi							
Window No	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
5	-	35	149	211	35	3	-	12	-	9	163	19	37	43	3	22
4	1	37	148	197	34	3	-	12	-	7	165	19	37	43	3	22
1	-	4	149	165	34	3	-	12	-	4	165	19	37	43	3	22
2	-	-	-	140	33	1	-	12	-	-	1	1	9	7	3	22
3	-	-	-	114	33	1	-	12	-	-	-	-	11	5	3	22
6	-	-	-	58	2	2	-	12	-	-	1	12	27	42	3	22
7	-	-	-	10	3	2	-	12	-	-	-	2	2	37	1	22
8	-	-	-	10	3	3	-	12	-	-	2	4	25	38	2	22

Quantity of Windows Indicated in Response	Climbing Turns								Cruise							
Window No	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
5	-	4	31	54	97	24	13	19	-	6	69	15	54	26	20	66
4	-	3	22	42	89	21	13	19	-	6	69	13	51	27	19	66
1	-	3	23	36	97	25	13	19	-	2	71	13	54	25	20	66
2	-	2	15	55	94	22	13	19	-	-	1	4	46	18	25	66
3	-	1	11	44	94	19	12	19	-	-	1	6	49	19	20	66
6	-	1	1	5	14	23	11	19	-	-	2	5	8	21	16	66
7	-	-	-	3	8	7	10	19	-	-	-	2	3	6	5	66
8	-	-	-	1	4	9	6	19	-	-	-	2	5	14	20	66

Quantity of Windows Indicated in Response	Level Turns								Landing							
Window No	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
5	-	6	61	53	81	28	12	17	8	99	135	-	4	2	-	8
4	-	7	52	49	76	27	9	17	3	98	135	-	4	2	-	8
1	-	10	53	31	83	28	8	17	-	3	134	-	4	2	-	8
2	-	1	15	43	77	19	11	17	-	-	-	-	4	-	-	8
3	-	-	12	33	71	18	11	17	-	-	-	-	4	-	-	8
6	-	-	2	11	22	25	11	17	-	-	-	-	1	2	-	8
7	-	-	-	2	7	10	8	17	-	-	-	-	2	2	-	8
8	-	-	1	1	7	13	7	17	-	-	-	-	2	2	-	8

Note Median level of response for each maneuver shown in blocked columns For respective window numbers see Fig 8

TABLE VI

AVERAGE WINDOW USE BY ELEVEN PILOTS EXPRESSED AS A PERCENTAGE OF THE TOTAL RECORDED PERIOD

Maneuvers	Windows Not Masked				Windows Masked			
	Front	Side	Upper	Rear	Front	Side	Upper	Rear
Takeoff	77	19	2	2	79	19	2	-
Landing	82	18	½	-	85	15	½	-
Cruise	69	30	1	½	80	19	1	-
Normal Turns	83	15	2	½	83	15	2	-
Maximum Turns	81	14	4	1	82	14	4	-
High Field Drag	48	51	1	½	51	48	1	-
Low Field Drag	78	21	1	½	73	26	1	-
Short-Field Landing	83	17	½	-	84	16	½	-
Short-Field Takeoff	82	16	1	1	86	13	1	-
Artillery Spotting	53	44	3	½	47	52	1	-
Road Reconnaissance	75	25	-	½	75	25	-	-
Bridge Reconnaissance	62	33	5	-	66	33	1	-
Message Pickup	81	18	1	-	84	15	1	-
Taxi	79	20	1	½	81	18	1	-

TABLE VII

AVERAGE HEAD AND BODY MOVEMENT OF ELEVEN PILOTS EXPRESSED AS A PERCENTAGE OF THE TOTAL RECORDED PERIOD

Maneuver	Windows Not Masked Head and Body Movement			Windows Masked Head and Body Movement		
	None (per cent)	0 - 5 In.	5 In.+	None (per cent)	0 - 5 In.	5 In.+
Takeoff	94	2	4	91	1	8
Landing	95	1	4	90	2	8
Cruise	97	1	2	95	2	3
Normal Turns	98	1	1	89	3	8
Maximum Turns	95	2	3	88	4	8
High Field Drag	83	6	11	67	8	25
Low Field Drag	90	5	5	85	5	10
Short-Field Landing	95	2	3	90	3	7
Short-Field Takeoff	94	2	4	84	6	10
Artillery Spotting	93	3	4	73	10	17
Road Reconnaissance	88	5	7	68	12	20
Bridge Reconnaissance	86	4	10	74	8	18
Message Pickup	93	1	6	86	3	11
Taxi	98	1	1	96	1	3

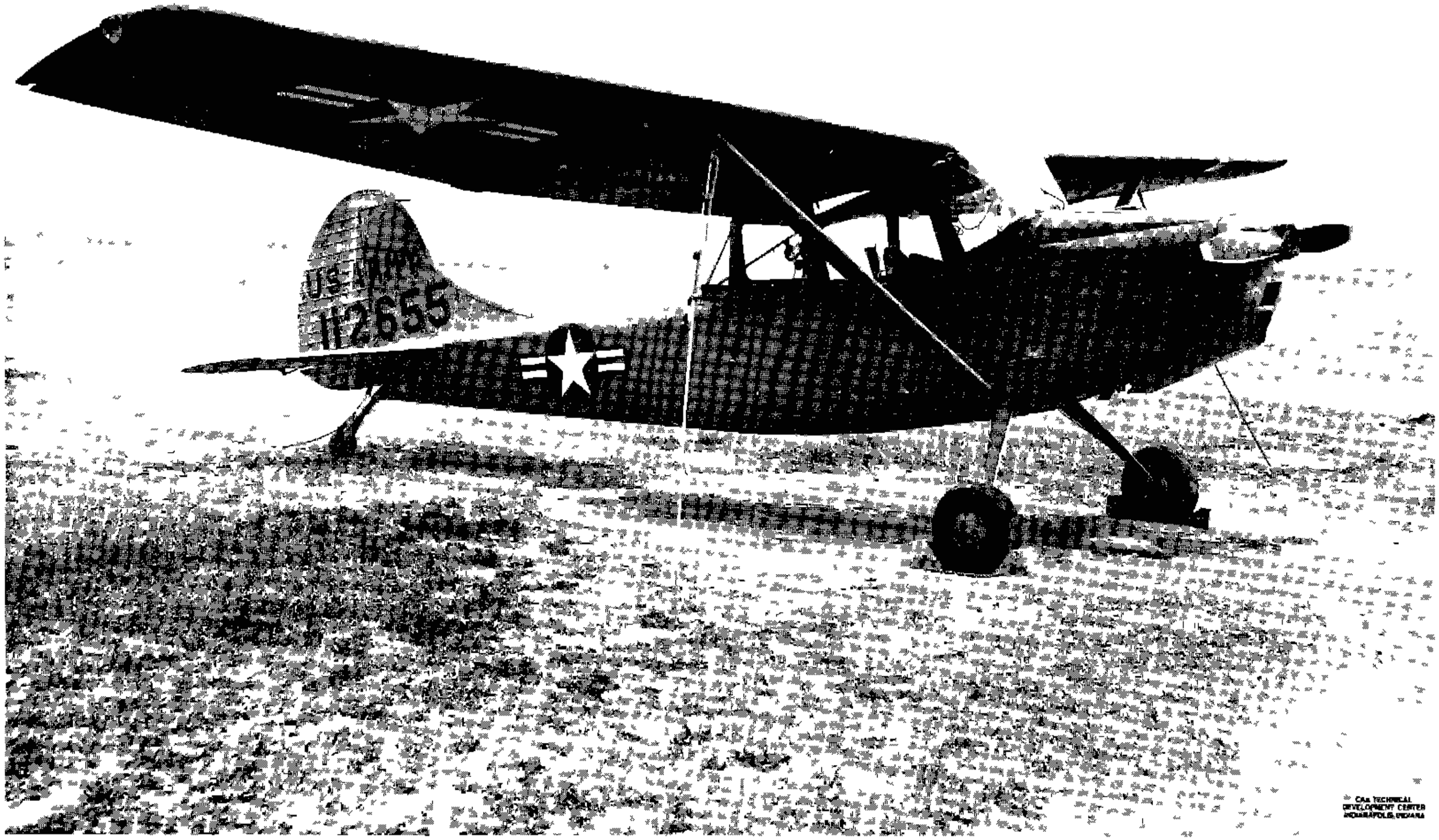

FIG. 1 U. S. ARMY L-19 "BIRD DOG"

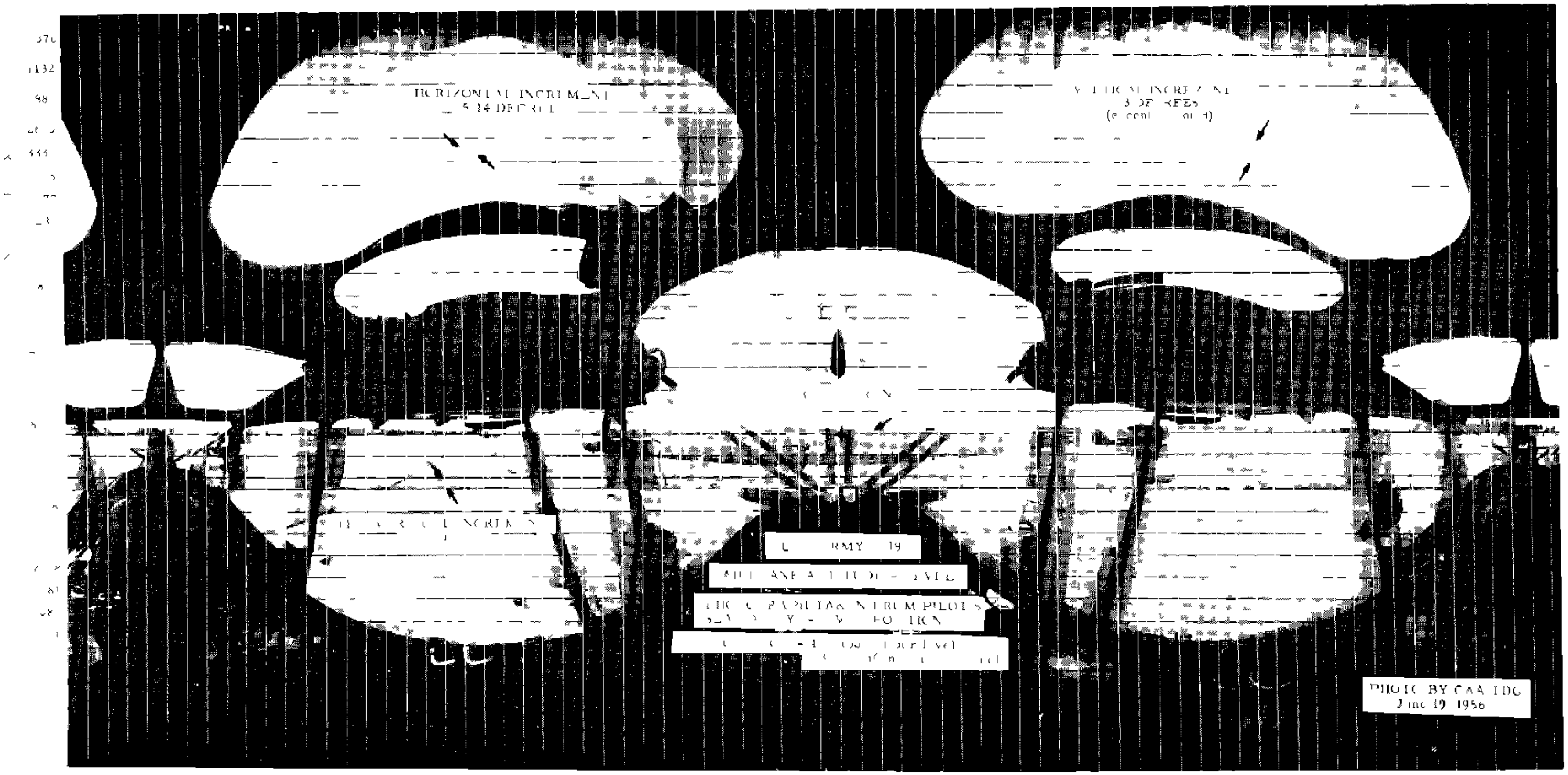

FIG. 2 COCKPIT VISIBILITY OF CESSNA L-19 AS RECORDED WITH BINOCULAR VISION CAMERA

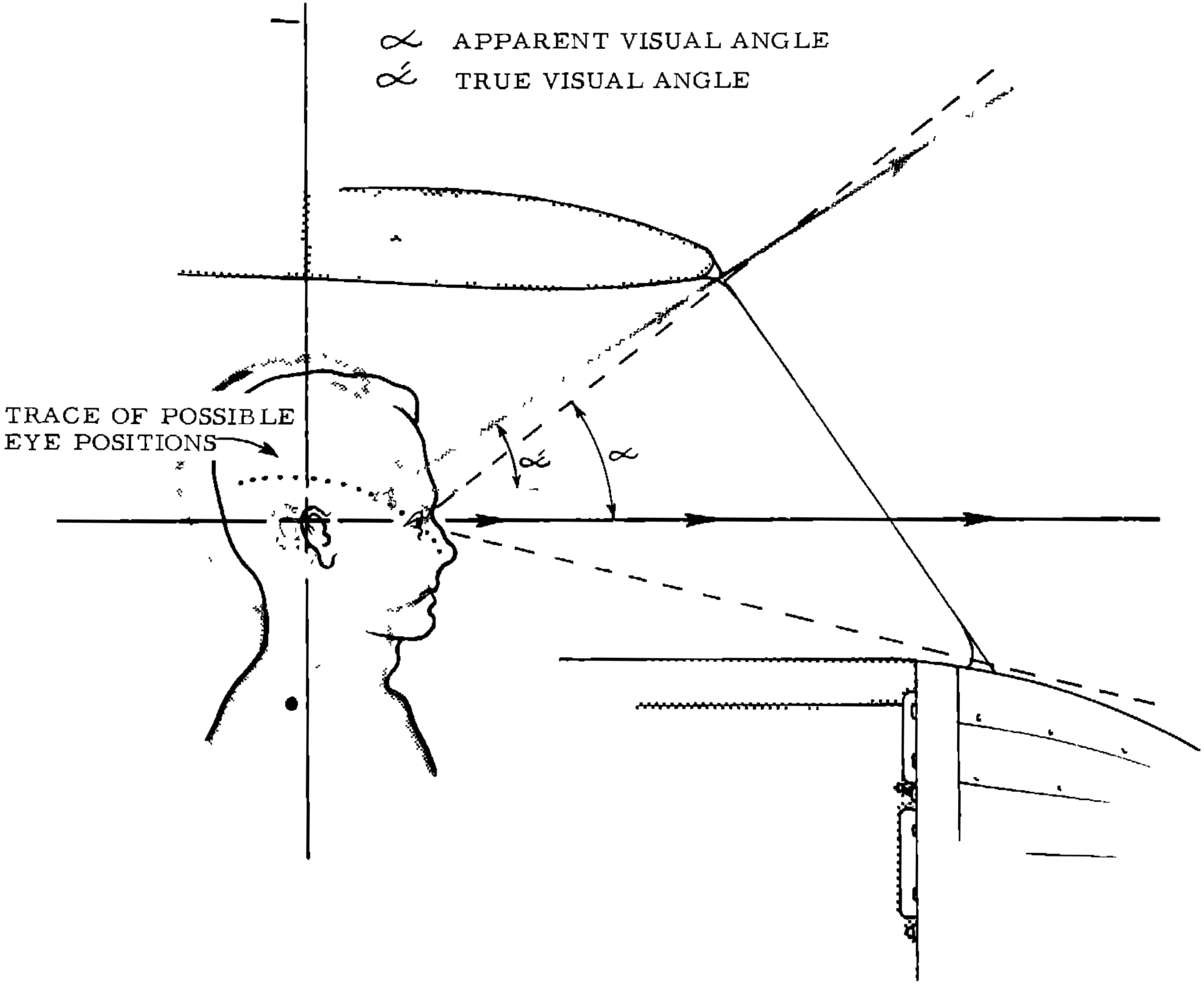

FIG. 3 EFFECT OF HEAD ELEVATION ON ANGULAR VISIBILITY LIMITS

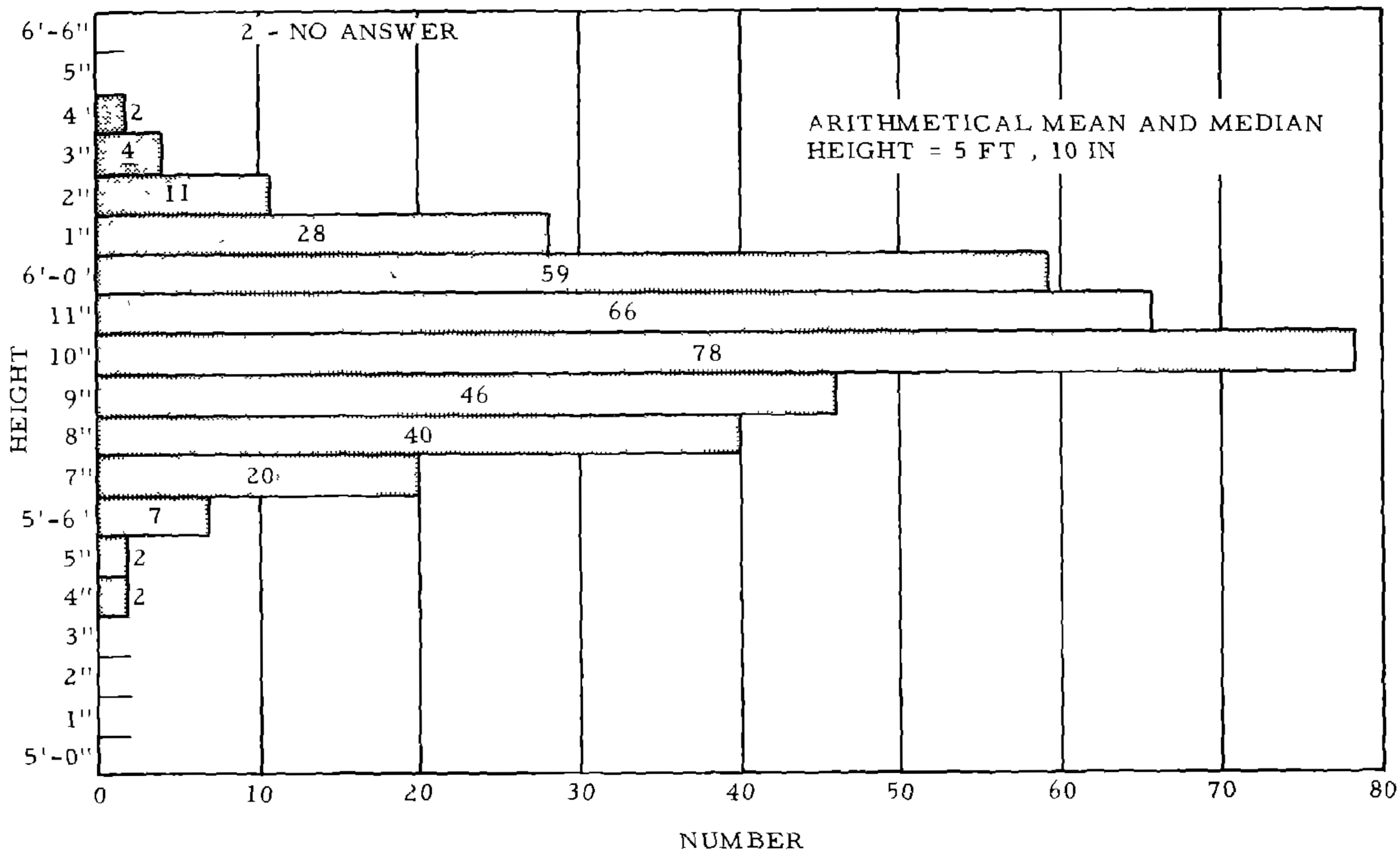

FIG 4 DISTRIBUTION OF TOTAL HEIGHTS OF PILOTS PARTICIPATING IN COCKPIT VISIBILITY QUESTIONNAIRE STUDY

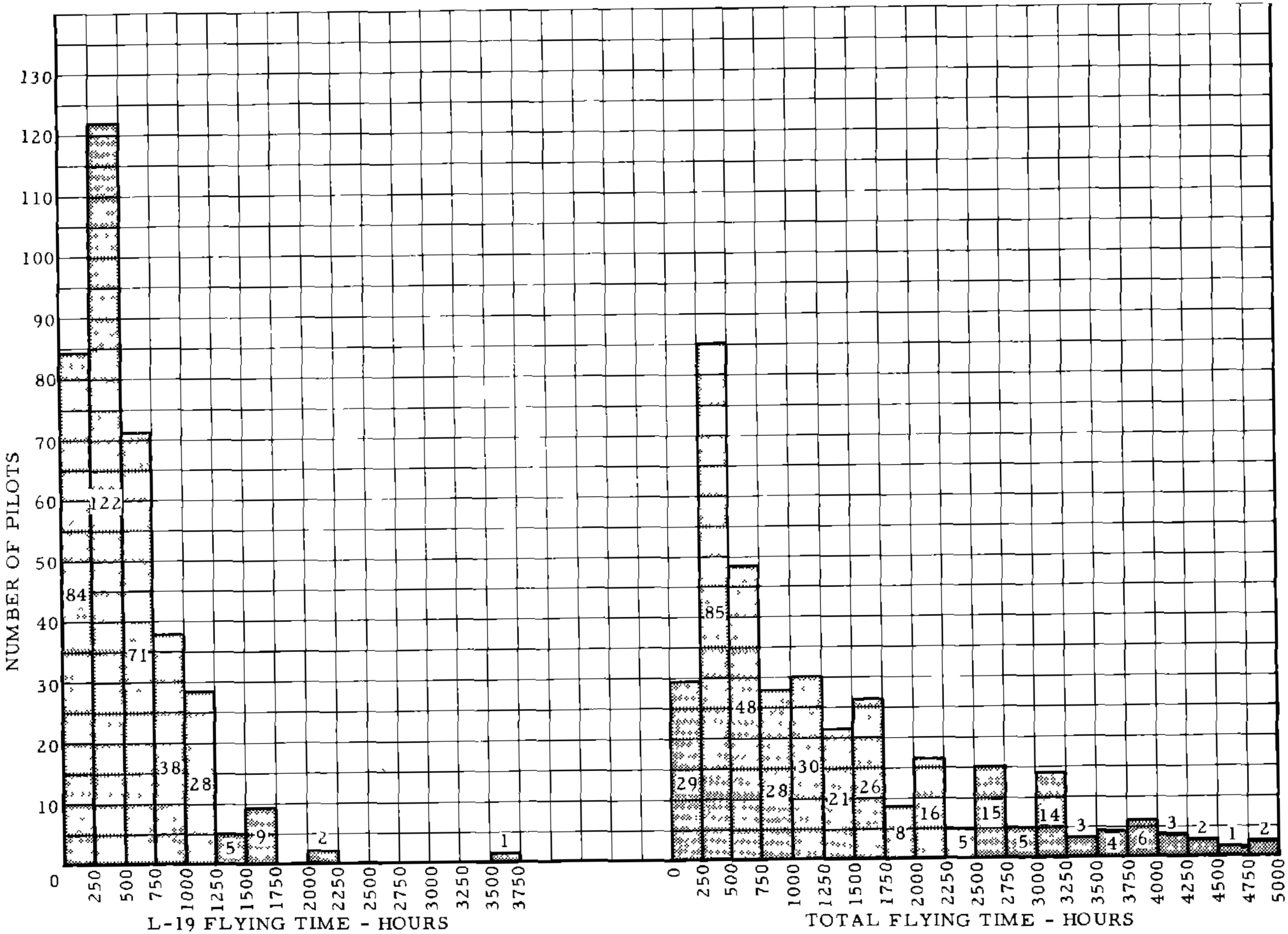

FIG 5 DISTRIBUTION OF FLYING TIME OF PILOTS PARTICIPATING IN COCKPIT VISIBILITY QUESTIONNAIRE STUDY

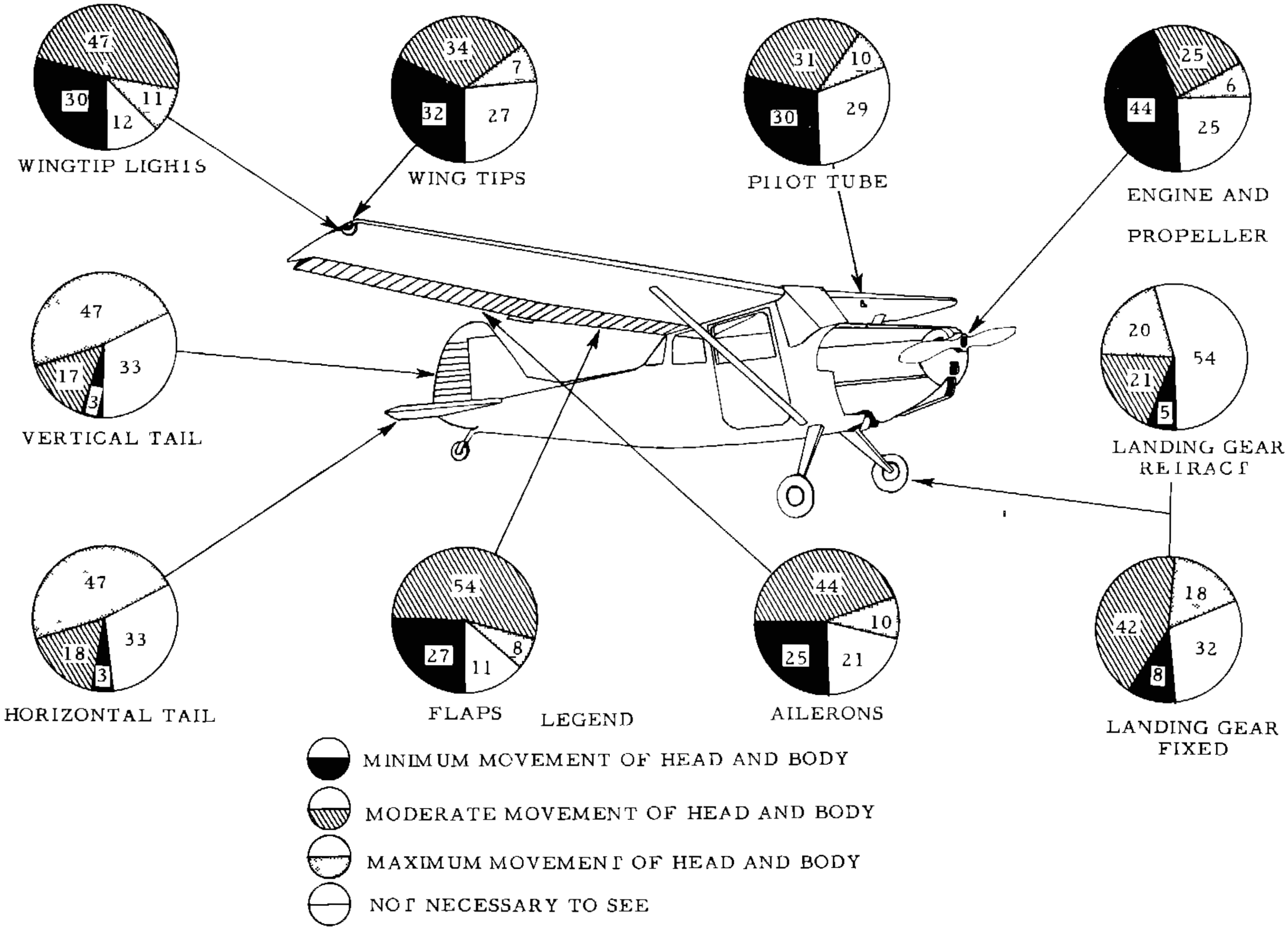

FIG 6 PERCENTAGE OF PILOTS DESIRING TO SEE EXTERNAL PORTIONS OF THE AIRPLANE

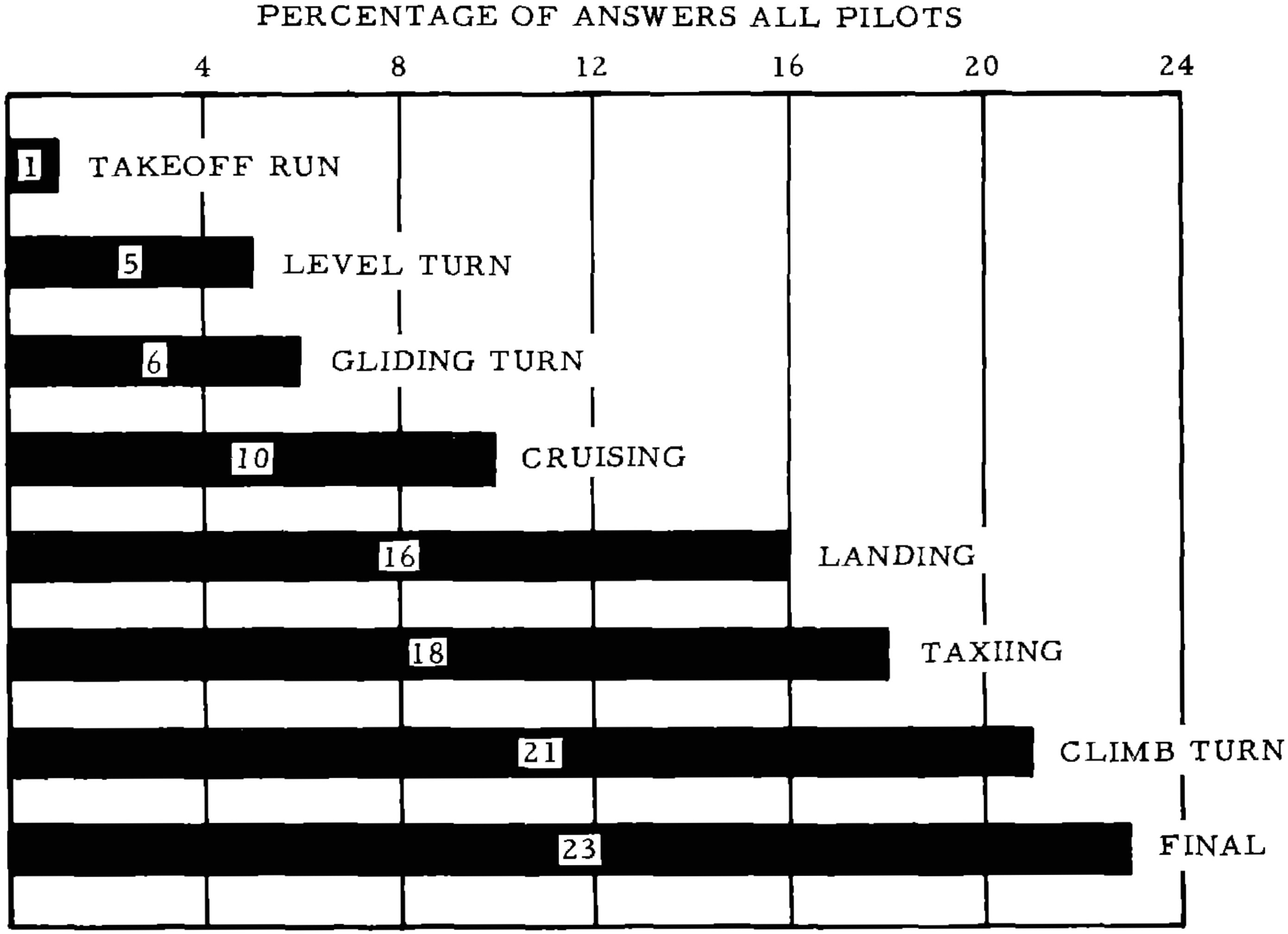

FIG. 7 RELATIVE IMPORTANCE OF VISIBILITY DURING COMMON MANEUVERS SHOWN IN PERCENTAGE OF TOTAL REPLIES FROM PILOTS

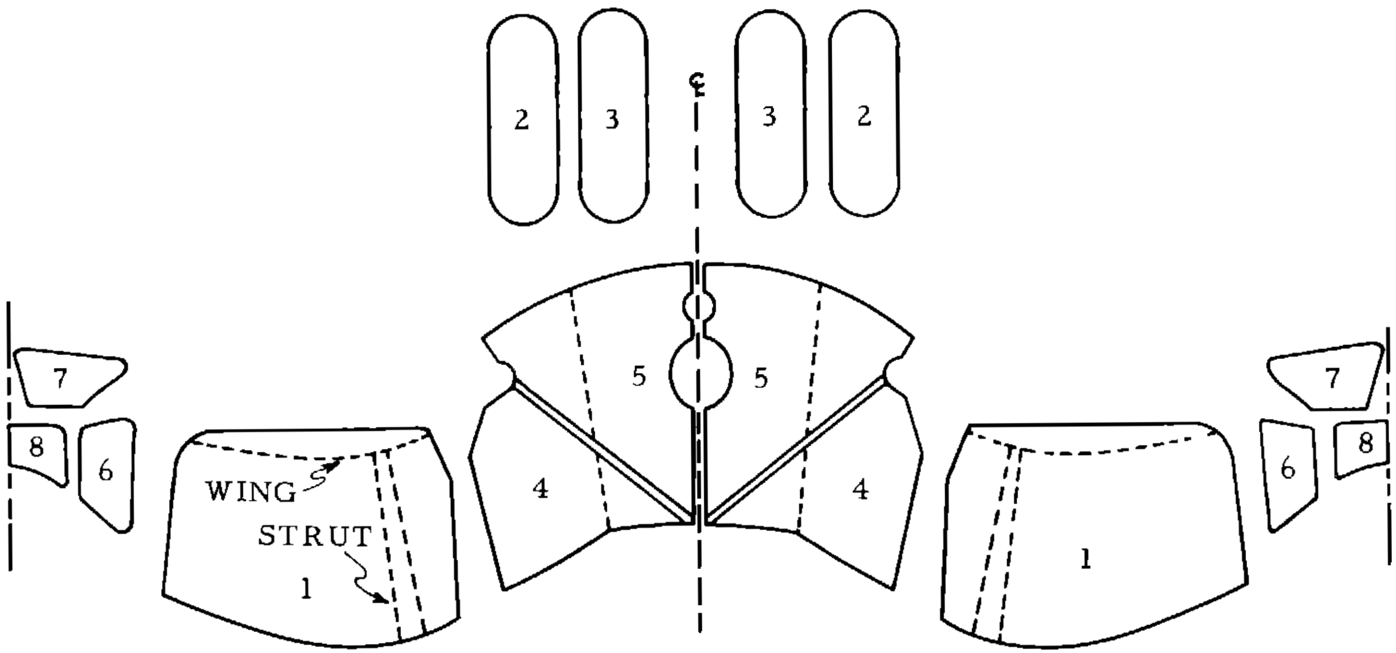

FIG. 8 SKETCH OF WINDSHIELD AND WINDOW OPENINGS IN L-19 WITH CODE NUMBERS USED IN QUESTION NO. 9

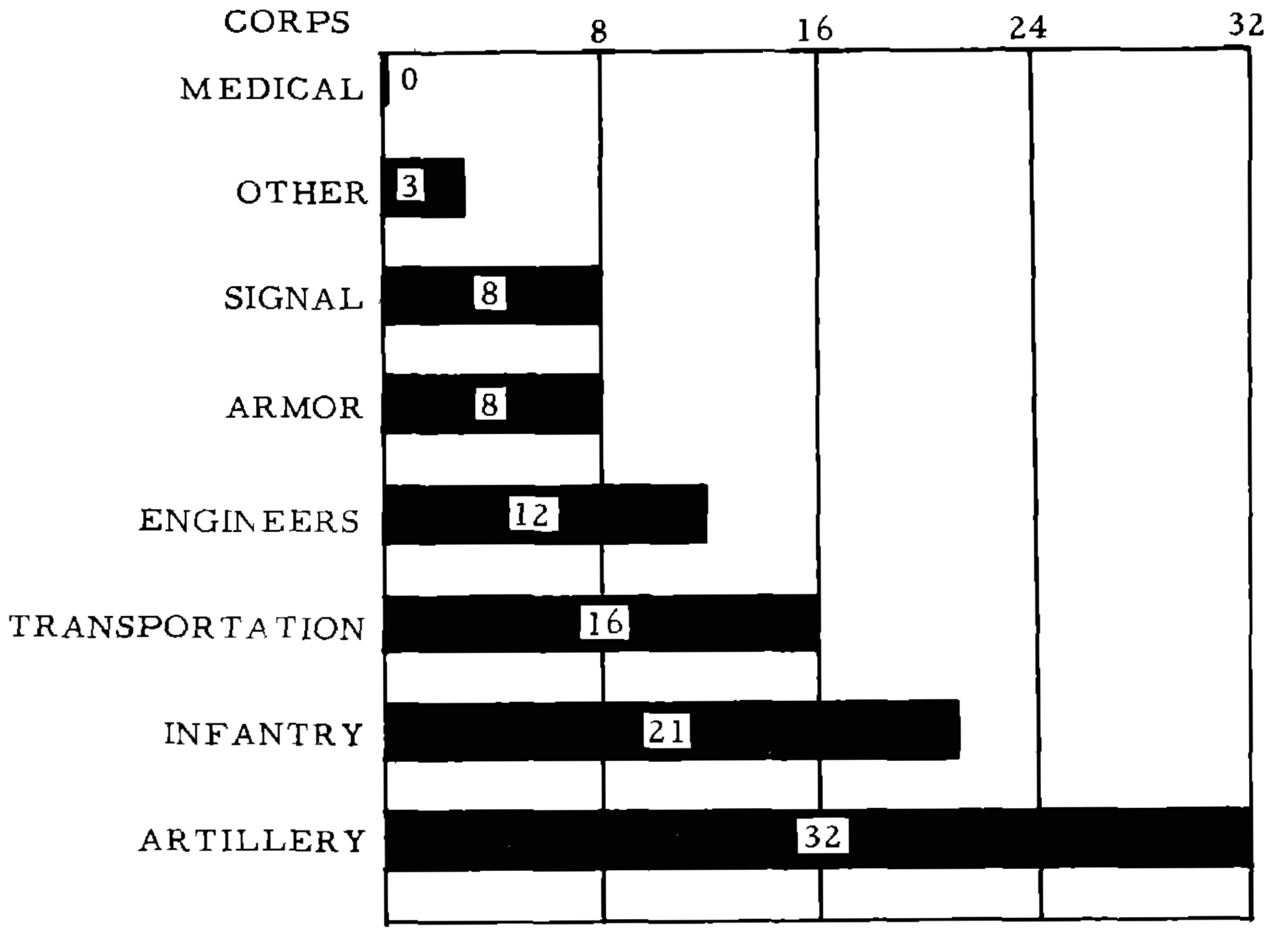

FIG. 9 DISTRIBUTION OF PILOTS IN VARIOUS MILITARY BRANCHES SHOWN IN PERCENTAGE OF TOTAL PARTICIPATING PILOTS

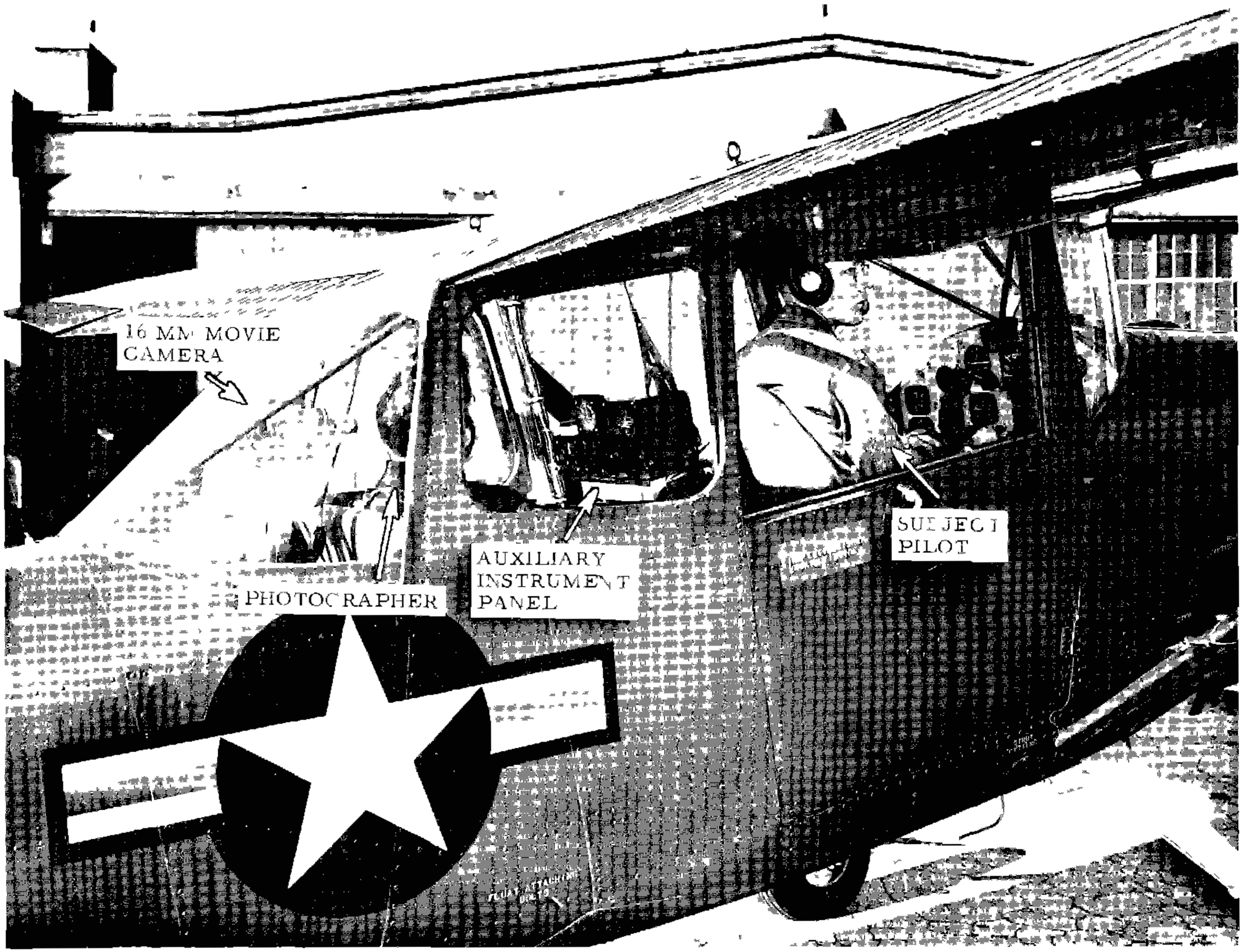

FIG. 10 INSTRUMENTATION FOR PHOTOGRAPHING PILOTS

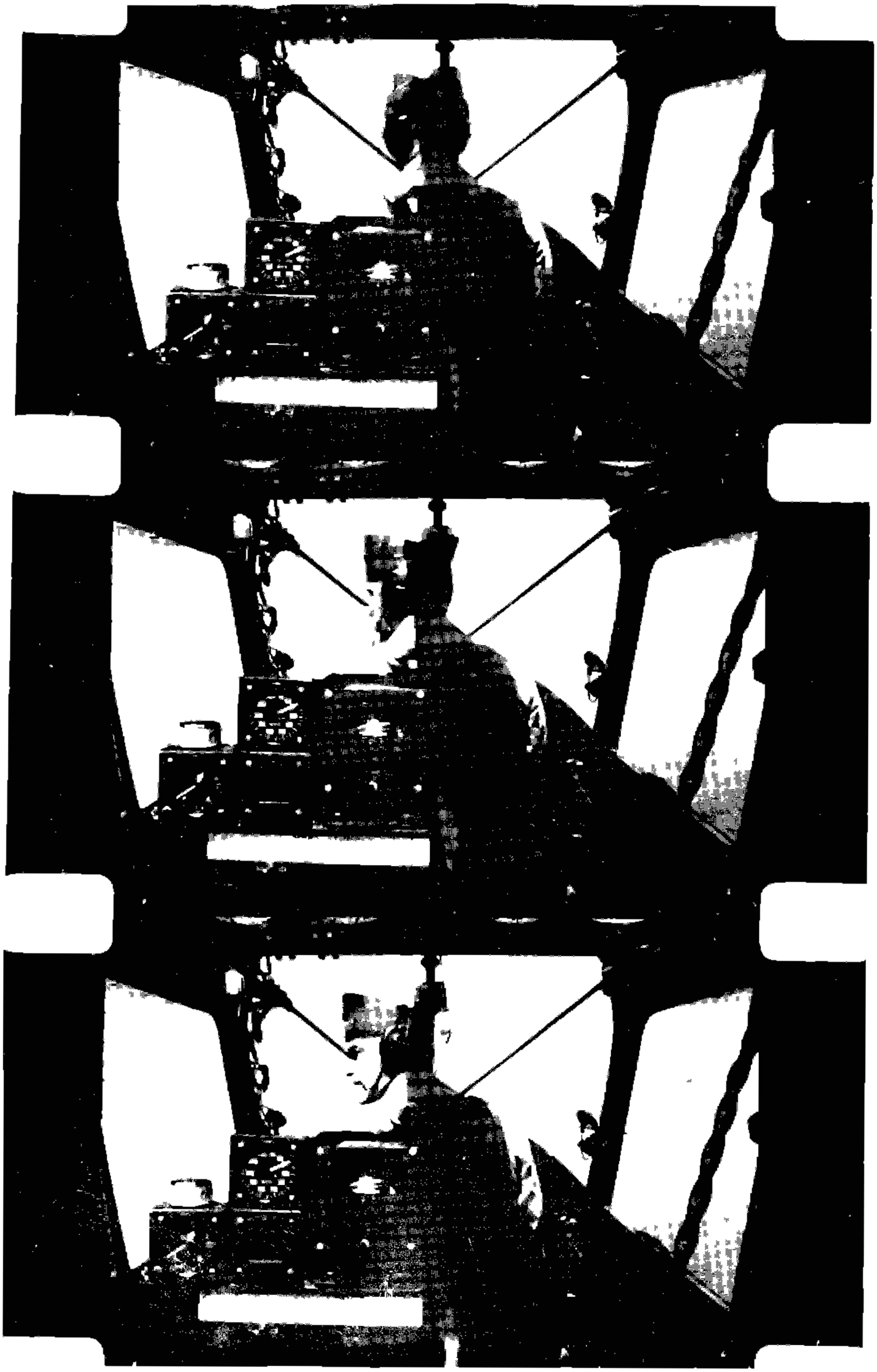

FIG 11 SAMPLE PILOT MOTION RECORD (16 MM FILM STRIP)

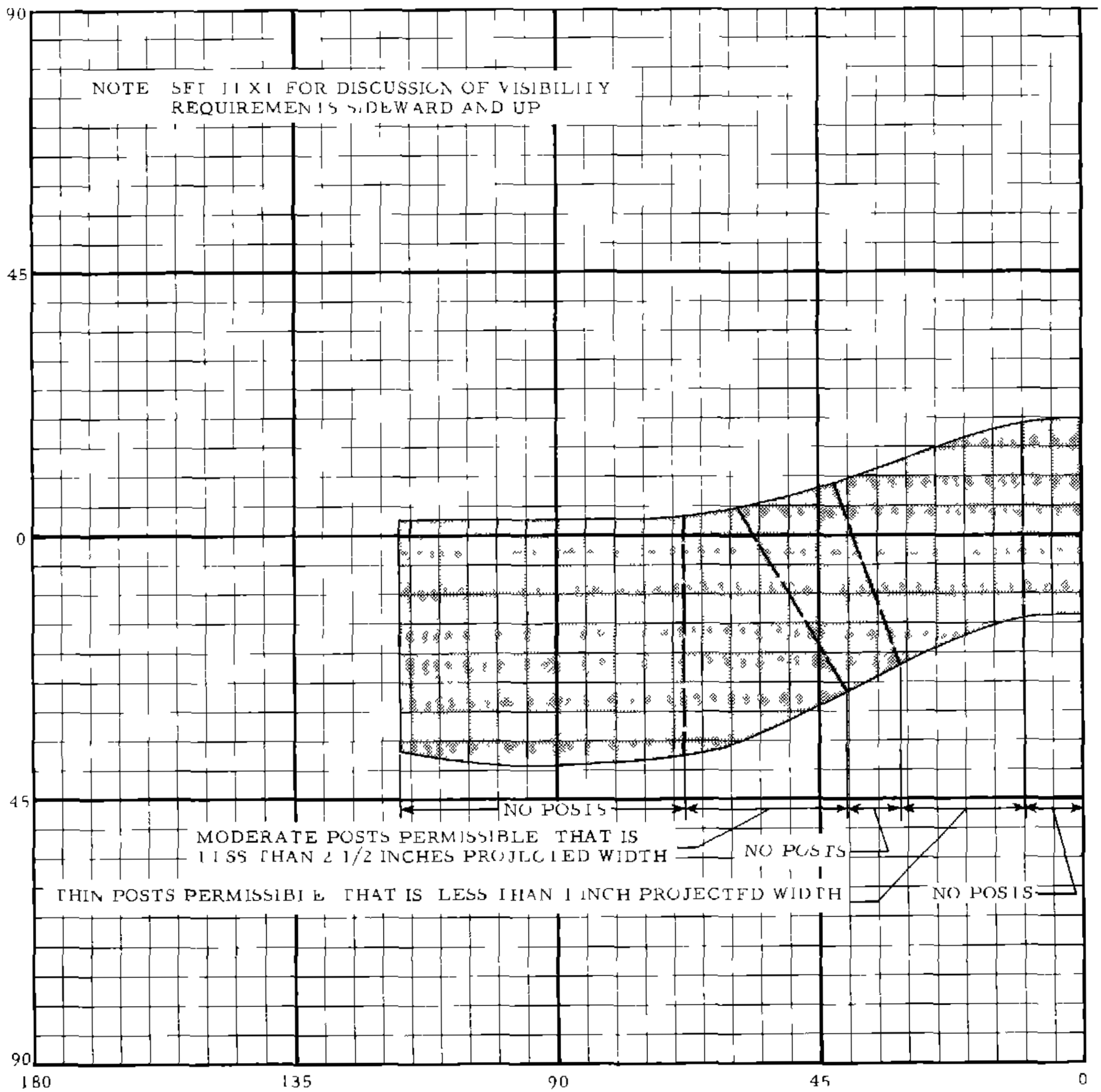

FIG 12 AVERAGE MINIMUM TOLERABLE COCKPIT VISIBILITY REQUIREMENTS BASED ON REDUCED VISIBILITY TOLERANCE STUDY

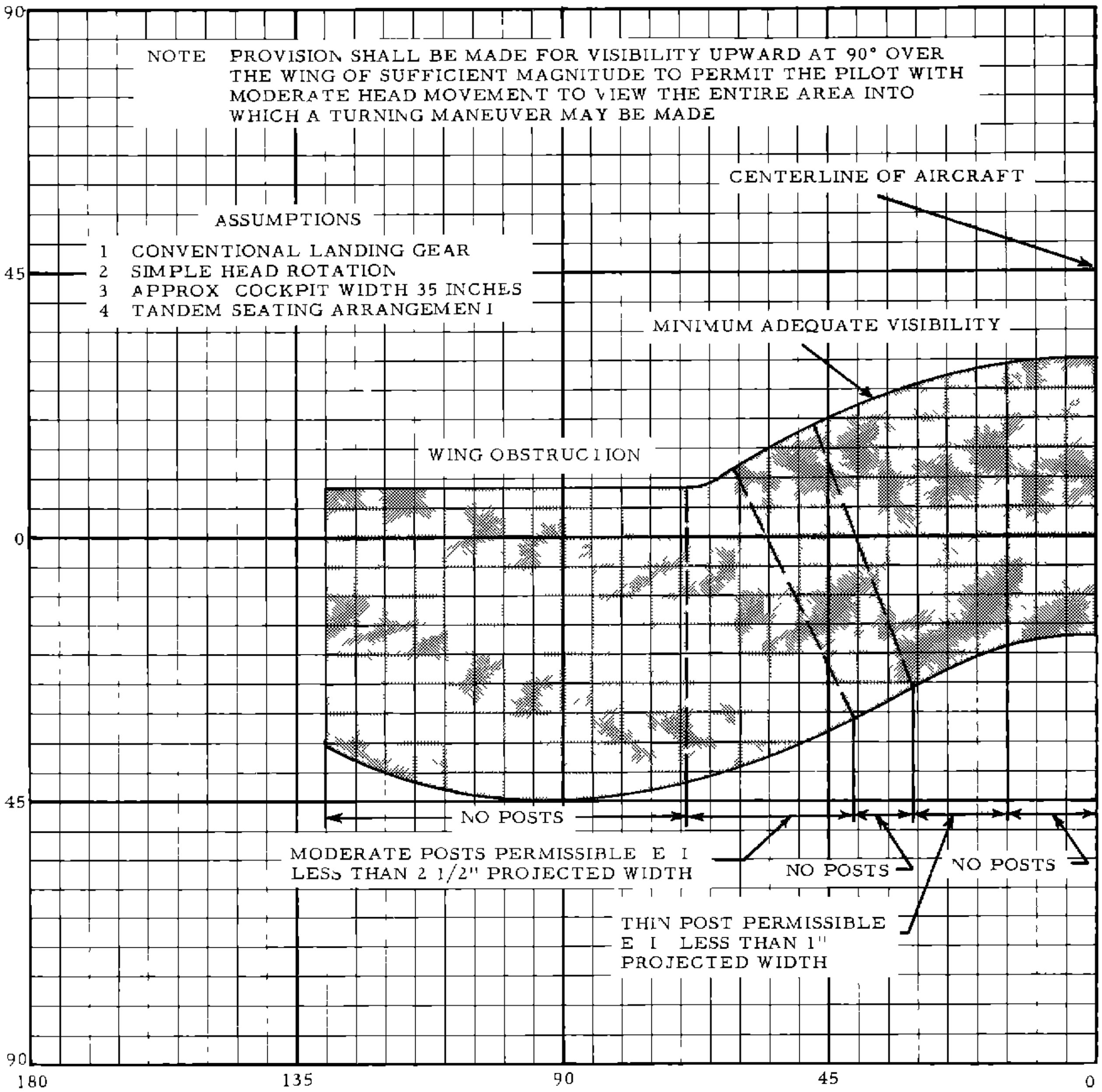

FIG 13 FIXED-WING LIAISON-RECONNAISSANCE-TYPE AIRCRAFT COCKPIT VISIBILITY REQUIREMENTS BASED ON QUESTIONNAIRE AND REDUCED VISIBILITY TOLERANCE STUDY

APPENDIX I

DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT CENTER
P O BOX 5767
INDIANAPOLIS INDIANA

PILOT QUESTIONNAIRE ON COCKPIT VISIBILITY IN FIXED WING RECONNAISSANCE AIRCRAFT

December 1956

DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT CENTER
P O BOX 5767
INDIANAPOLIS, INDIANA

December 1956

PILOT QUESTIONNAIRE ON COCKPIT VISIBILITY IN FIXED WING RECONNAISSANCE AIRCRAFT

The Department of the Army, Office of the Chief of Transportation, is sponsoring a project at the CAA Technical Development Center which has for its objective the development of standards for cockpit visibility in reconnaissance aircraft which will be consistent with adequate operating safety

The principal factor influencing cockpit visibility is considered to be the directions of the angles of sight or field of vision through windshield panels and cockpit windows from the normal pilot-eye position, with consideration of the airplane in different maneuvers

One of the most important aspects of the program consists of evaluating the ideas of the operating pilots concerning these visibility problems Since the best judges of the quality of visibility in cockpits are the pilots themselves, we are calling upon you to supply us with the necessary basic information on which an analysis can be made Such an analysis will permit a quantitative evaluation of the present designs and the establishment of quantitative standards for future designs

The success of this cockpit visibility study is dependent upon an evaluation of your requirements It is requested that you return this questionnaire in the attached envelope as soon as possible with all of the questions completed

Your response will be held confidential and will be used only for analytical purposes by the CAA Your signature is not necessary

NOTE IT IS RECOMMENDED THAT YOU READ THE QUESTIONNAIRE OVER THOROUGHLY, MAKE A FLIGHT WITH THE QUESTIONNAIRE IN MIND, AND THEN FILL IN THE ANSWERS

PILOT QUESTIONNAIRE ON COCKPIT VISIBILITY IN FIXED WING RECONNAISSANCE AIRCRAFT

1. Your height ______ feet ______ inches

2. (a) Total number hours flying time ______ hours

   (b) Total number years flying experience ______ years

   (c) Total number hours flying time in L-19 ______ hours

   (d) Combat experience in Army aviation Yes ☐[1] No ☐[2]

3. Evaluate the cockpit visibility of the L-19 for the maneuvers and directions shown in the following table. The evaluation should be made on the basis of adequacy of windshield area and angles of sight for a pilot flying without observer.

   The numbers of classifications to be used are:

   (1) Visibility excellent, can be reduced without affecting performance

   (2) Visibility satisfactory, no improvement desired but reduction would be detrimental

   (3) Visibility adequate, some improvement desirable but not necessary

   (4) Visibility not adequate, improvement strongly desired

Maneuver	Visibility Upward to Front	Visibility Downward to Front	Visibility Sideward	
(a) Taxiing				
(b) Takeoff Run				
(c) Cruising				
			To Left	To Right
(d) Climbing Turns				
(e) Level Turns				
(f) Chandelle Turns				
(g) Final Approach				
(h) Landing				

4 Do you consider it necessary from an over-all safety standpoint to be able to see any of the following portions of the aircraft from the cockpit while in flight or during takeoff or landing?

Qualify any "yes" answer below by indicating the amount of head and body movement which you feel is permissible in each case

	Minimum Movement of Head and Body	Moderate Movement of Head and Body	Maximum Possible Movement with Seat Belt Fastened	Not Necessary to See
(a) Landing Gear, Fixed	☐ 1	☐ 2	☐ 3	☐ 4
(b) Landing Gear, Retr	☐ 1	☐ 2	☐ 3	☐ 4
(c) Wing Tips	☐ 1	☐ 2	☐ 3	☐ 4
(d) Wing Tip Lights	☐ 1	☐ 2	☐ 3	☐ 4
(e) Flaps	☐ 1	☐ 2	☐ 3	☐ 4
(f) Ailerons	☐ 1	☐ 2	☐ 3	☐ 4
(g) Pitot Tube	☐ 1	☐ 2	☐ 3	☐ 4
(h) Engine and Propeller	☐ 1	☐ 2	☐ 3	☐ 4
(i) Vertical Tail	☐ 1	☐ 2	☐ 3	☐ 4
(j) Horizontal Tail	☐ 1	☐ 2	☐ 3	☐ 4
(k) Other (Specify) ______	☐ 1	☐ 2	☐ 3	☐ 4

5 Do you depend on your observer for searching the sky for other aircraft in his zone of vision in reconnaissance aircraft such as the L-19?

(a) to prevent mid air collisions Yes ☐ 1 No ☐ 2

(b) To avoid enemy aircraft Yes ☐ 1 No ☐ 2

6 Check appropriate boxes below, indicating the amount of permissible head and body movement while accomplishing each of the following missions Consider the necessary search for other aircraft in each case

Mission	Minimum Movement of Head and Body	Moderate Movement of Head and Body	Maximum Possible Movement with Seat Belt Fastened	Have Never Performed
(a) Observation Adjustment of Fire	☐ 1	☐ 2	☐ 3	☐ 4
(b) Reconnaissance and Survey, General	☐ 1	☐ 2	☐ 3	☐ 4
(c) Wire Laying	☐ 1	☐ 2	☐ 3	☐ 4
(d) Supply Drops	☐ 1	☐ 2	☐ 3	☐ 4
(e) Column Control	☐ 1	☐ 2	☐ 3	☐ 4
(f) Low Level Landing Field Reconnaissance	☐ 1	☐ 2	☐ 3	☐ 4
(g) Reconnaissance of Roads Bridges, and Patrol of Wire Routes	☐	☐ 2	☐ 3	☐ 4
(h) Survey and Mapping	☐ 1	☐ 2	☐ 3	☐ 4

7 Place a check mark in one of the boxes below indicating the particular maneuver for which you feel maximum visibility from the cockpit is most urgently required Do not consider limited visibility due to atmospheric conditions

Taxiing	☐ 1	Level Turns	☐ 5
Takeoff Run	☐ 2	Gliding Turns	☐ 6
Cruising	☐ 3	Final Approach	☐ 7
Climbing Turns	☐ 4	Landing	☐ 8

8 Do you feel the quality of vision as provided by flat and curved plastic panels is satisfactory for the safe operation of the aircraft through all maneuvers and missions?

Yes [ ]1 No [ ]2

If your answer to the above question is "no," please indicate below the maneuver or mission for which visibility is unsatisfactory and the window or windows involved Use window numbers in Figure 1 on the following page to indicate unsatisfactory windows

The following space is reserved for any comments or suggestions you may have which influence the problem of cockpit visibility

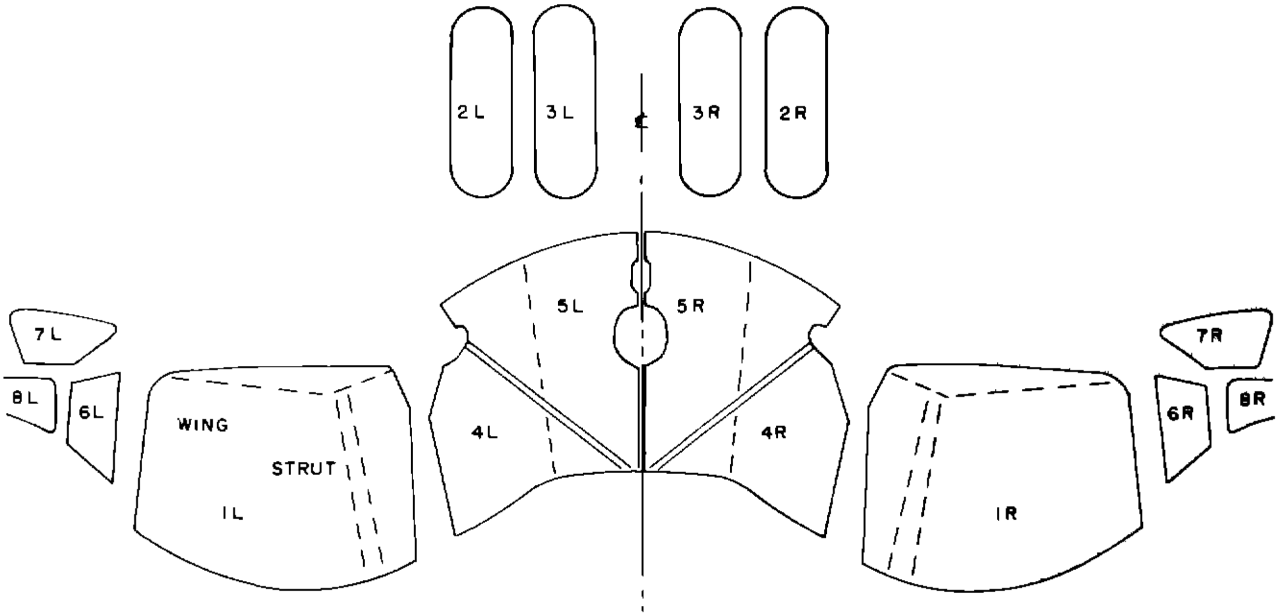

Figure 1 Sketch of Windshield and Window Openings in L-19 Aircraft as Viewed from Pilot's Seat

9 In order to evaluate the adequacy of visibility of an L-19 airplane with regard to minimum visibility that is required for safe operation of the aircraft, a sketch of an L-19 cockpit is shown in Figure 1 above

Evaluate the windows in Figure 1 and indicate them numerically below in the order of their relative importance to you while accomplishing the indicated maneuvers <u>Do not indicate any window that you do not use</u>

If the same window on either side of the aircraft is of equal importance to you, indicate so in the boxes below by omitting the subscript, L or R, which means Left or Right <u>Do not put more than one number in a single box</u>

Window Numbers in Order of Lesser Importance

(a) Taxiing																
(b) Takeoff Run																
(c) Cruising																
(d) Climbing Turn to Left																
(e) Level Turn to Left																
(f) Gliding Turn to Left																
(g) Final Approach																
(h) Landing																

10 Check appropriate boxes below indicating the amount of permissible head and body movement for each of the following maneuvers Consider the necessary search for other aircraft in each case

Maneuver	Minimum Movement of Head and Body	Moderate Movement of Head and Body	Maximum Possible Movement with Seat Belt Fastened
(a) Taxiing	☐ 1	☐ 2	☐ 3
(b) Takeoff Run	☐ 1	☐ 2	☐ 3
(c) Cruising	☐ 1	☐ 2	☐ 3
(c) Climbr Turns	☐ 1	☐ 2	☐ 3
(e) Level Turns	☐ 1	☐ 2	☐ 3
(f) Gliding Turns	☐ 1	☐ 2	☐ 3
(g) Final Approach	☐ 1	☐ 2	☐ 3
(h) Landing	☐ 1	☐ 2	☐ 3

11 Check below the military branch to which you presently are attached

Infantry	☐ 1	Medical Corps	☐ 5
Armor	☐ 2	Signal Corps	☐ 6
Artillery	☐ 3	Transportation	☐ 7
Engineers	☐ 4	Other (Specify)	☐ 8

12 Check below any military branches to which you have been attached as a fixed wing aviator

Infantry	☐ 1	Medical Corps	☐ 5
Armor	☐ 2	Signal Corps	☐ 6
Artillery	☐ 3	Transportation	☐ 7
Engineers	☐ 4	Other (Specify)	☐ 8