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CIVIL AVIATION AUTHORITY

CAA PAPER 95014

# HELICOPTER PILOT VIEW

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# HELICOPTER PILOT VIEW

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**Abstract**

The results of a study into the field of view available to civilian helicopter pilots are presented. The influence of weather conditions is addressed.

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# Foreword

The research reported in this paper was funded by the Safety Regulation Group of the UK Civil Aviation Authority, the UK Department of Transport, and UK Health and Safety Executive. The work was instigated at the Defence Research Agency's All Weather Operations Department in response to the findings of the Helicopter Human Factors Working Group, reported in CAA Paper 87007 (recommendation 4.1.9). The Helicopter Human Factors Working Group was formed in response to Recommendation 1 of the Report of the Helicopter Airworthiness Review Panel (CAP 491).

The CAA concurs with the conclusions of this work. At the time of publication, the Authority is planning a proof of concept trial for Differential GPS-based approaches to offshore platforms, and a series of offshore trials of improved helideck lighting schemes. It is anticipated that the recommendations contained in this paper will be addressed during the course of these activities.

Safety Regulation Group

## Executive Summary


The maintenance of high levels of safety and regularity of operations in the civil helicopter environment requires that all aspects of the operations are constantly reviewed and research initiated where enhancements are considered necessary.

The importance of adequate visual cueing for helicopter pilots was highlighted during a recent CAA research programme investigating helicopter handling qualities. There are two main elements to the visual scene; size (field of view) and content (visual cueing). This report investigates field of view issues. The visual scene is increasingly important as industry requirements for low visibility operations increase.

There are three areas of investigation within this study, these are:

- The extent of previous research in the area of visual cues for helicopter approach and landing.
- Collation of field of view data for a number of helicopters representative of the main types used in the U.K.
- Review and comparison of civil and military requirements.

The conclusions reached as a result of an extensive literature search and practical investigations include:

(a) The basic field of view provided by the civil helicopters examined does not seriously affect operations in good visibility conditions.

(b) In many instances the available field of view is eroded by additional instruments/displays fitted in the cockpit (satellite navigation receivers, map displays etc.).

(c) There are no minimum specifications for cockpit field of view in the civil industry, only advisory circulars showing acceptable methods for compliance with visual specifications (FAR, BCAR etc.). If these methods of compliance were to be developed into a minimum specification and enforced then some of the associated visual scene problems would be solved.

(d) During precipitation, or in the presence of other contaminants, the wiper swept area becomes the only useable segment of the windscreen thereby significantly reducing the available field of view.

(e) During low visibility conditions, normal operating procedures for the aircraft can significantly reduce the effectiveness of the available field of view.

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# 1 INTRODUCTION

1.1 The maintenance of high levels of safety and regularity of operations in the civil helicopter environment requires that all aspects of the operations are constantly reviewed and research initiated where enhancements are considered necessary.

1.2 The importance of adequate visual cueing for helicopter pilots was highlighted during a recent CAA research programme investigating helicopter handling qualities. There are two main elements to the visual scene; size (field of view) and content (visual cueing). This report investigates field of view issues. The visual scene is increasingly important as industry requirements for low visibility operations increase.

1.3 Before initiating a major project on this subject, the CAA tasked the DRA (All Weather Operations) with the conduct of a study having the following objectives:

- A literature search to ascertain the extent of previous research into the subject of visual cues for helicopter approach and landing.
- The collation of field-of-view data for a number of helicopters representative of the main types used in the U.K.
- Review and comparison of civil and military requirements.

1.4 This paper presents the results of this study and identifies potential areas for further research.

# 2 LITERATURE SEARCH

2.1 A literature search was initiated at DRA Bedford using the key words: *helicopter, approach, landing, takeoff, take-off, take off, visual cues, visual approach, instrument approach.* Of the 25 papers thus identified those whose abstract suggested some degree of relevance to the topic were obtained for detailed review. Also included for reference were specifications in FAR Part 27, BCAR 29 together with Advisory Circulars 27–1 Chapter 2 and 29–2a Chapter 2. The twelve papers are listed in Appendix A.

2.2 The research reported was heavily biased towards military operations but, since many of the landing problems are common to all helicopter operations, the data is of relevance to civil operations. The only material specifically targeted at civil helicopter operations was found in a CAA paper which reported a fog flying experiment conducted with DRA Bedford.

2.3 The results from a questionnaire given to military rotorcraft pilots are detailed in Reference 1. The authors concluded that:

(a) Field-of-view (FOV) requirements are not significantly influenced by pilot experience.

(b) The downward FOV of the helicopter is assessed as adequate for all landing manoeuvres if it extends 29° below the horizon.

(c) The forward and upward FOV is of significance only for take-off manoeuvres.

(d) Visibility to the side is critical in confined areas; to be rated adequate the azimuth FOV must be at least 90°.

2.4 In Reference 2 the results of flight trials that used an eye mark recorder to determine the scan used by pilots in various manoeuvres are presented. With regard to the landing phase it was concluded that:

(a) With the pilot in the right hand seat the visual cues to the left of the pilot were used infrequently.

(b) The chin bubble windows were used infrequently.

2.5 The trials reported in Reference 3 were carried out to determine the size of the delivery envelope required for instrument approaches to a visual deceleration phase commencing at the decision height. The data is nearly all related to helicopter performance and handling limits at low speed. Only in the case of low approaches, when obstacles became a significant concern, was there any consideration of visual cueing. No quantitative data is presented. There is an indication that in a poor visual scene environment increased demands may be put on helicopter performance capabilities.

2.6 The data in Reference 4 relates to an analysis of the problems associated with landing a helicopter on a moving ship. The authors noted that the main problem in the task arose from the lack of inertially stable visual references. This absence of useable cues is important because *'the pilot's main source of information originates from the visual field'*. The authors of the present paper are familiar with these problems and their potential solution but, due to the nature of civil operations (even those offshore), this particular area of research is not of prime importance.

2.7 Reference 5 presents data largely related to a review of non-visual guidance aids. The data presented describes the characteristics and performance of hardware under development for use on board ships. Some of the hardware is directed towards improving the visual task. Since this report is devoted to the ship landing problem it again contains little of particular relevance to the present study, although it does identify the need for research into hover and landing aids.

2.8 In Reference 6 work is described to develop a mathematical model of the pilot task in visual flight. This paper was published in 1982 and comments that *'the weakest link in applying a model based approach lies in not being able to define what a pilot actually does with the information provided by visual cues'*. However, there is some discussion of what are called *'plausible descriptive mechanisms'*. This paper concludes that flight simulation trials are required together with flight trials.

2.9 The results from a simulator trial using three approach lighting configurations is reported in Reference 7. The authors do not seem to be aware of some basic aspects of visual cueing during an approach to land and the paper therefore contains no useful new data.

2.10 Reference 8 is primarily targeted at simulator issues. Although not directly related to the present study the investigation did raise some issues of relevance. The simulation utilised military and civil pilots. The approach to land procedure is significantly different between the two sets such that the civil pilot has greater access to the visual scene compared to the military pilot. This is due to the procedure adopted, particularly during the deceleration.

2.11 In Reference 9 the relevance of pitch attitude profiles during the final phase of approach is highlighted. In visual conditions, high pitch attitude control activity, maximum deceleration and pitch attitude changes all occurred within 120m range from the helideck. Attitude changes of up to 11·5° were recorded.

2.12 Reference 10 reports on a research project investigating the all weather operations capabilities of helicopters looking specifically at reduced visibility approach/landing tasks. The investigation was an attempt to quantify the special considerations given to helicopters for their unique operational capability. Standard fixed-wing visual aids were utilised. The trials were carried out by the CAA and the DRA at Bedford using simulation and flight test. These trials demonstrated that:

(a) Helicopters can land from large lateral offsets in clear conditions.

(b) This manoeuvrability cannot be utilised for low visibility operations due to the restricted visual cues.

(c) Helicopters could operate in more restricted Runway Visual Range (RVR) conditions if helicopter specific cues and lighting patterns were provided.

(d) Size of the visual segment (amount of approach lighting visible to pilot) is strongly dependant on cockpit cut-off angles, including side and chin windows.

(e) In low visibility conditions the visual segment determines the minimum RVR allowable for each type of helicopter.

(f) The landing decision is affected by the offset due to visual cue acquisition positions.

(g) In low visibilities the nose can only be raised by a maximum 5° in pitch before the visual cues are reduced significantly.

2.13 Reference 11 deals mainly with the handling qualities of helicopters at the high altitude/high temperature end of operations. Very little new and useful information relevant to the study was available in this report.

2.14 Reference 12 is a report based on a military research programme to investigate the recovery to ship operation of helicopters and is not of direct relevance to the civil industry. However, some of the conclusions reached are relevant and include:

(a) *'all pilots have a tendency to rely on eyesight above and beyond all else'.*

(b) The more important visual cues during the approach to hover are artificial.

(c) Chin windows play a significant part in the hover phase and cues on the deck are utilised to maintain the position relative to the deck.

2.15 In summary, in the papers studied in detail, one thing is clear: cues in the visual scene are a key factor in the approach and landing task of helicopter operations, particularly under low visibility conditions.

## 3 HELICOPTER FIELD OF VIEW

3.1 Evidence from the literature search suggests a strong link between available FOV and a pilot's ability to perform certain tasks such as take-off, approach and landing. While this connection has been recognised in military aircraft design, there is a lack of evidence that the importance of the relationship is acknowledged in the civil industry. Guidelines exist (Advisory Circulars AC 27 and 29) for defining an acceptable visual window, but these are only guidelines and are not enforceable. Most military helicopters will, in future, have a known and diagrammatically represented visual envelope (see Figure 5). In order to develop a database of fields of view currently available in the civil industry an empirical method to derive helicopter cockpit FOV was developed for this project. The method relies on measurement techniques and trigonometric analysis of the data and comprises the following steps:

(a) Derive the pilot's eye position in plan view and mark it. This is achieved by the viewer (pilot) lining up two markers (the further apart the markers the greater the accuracy) in the dead ahead direction and two markers in a direction not less than 60° from dead ahead. The two lines thus defined should intersect at a point below the pilot and coincident with the eye position.

(b) Measure the pilot's eye height relative to the ground.

(c) The pilot then indicates points on the ground around the helicopter, coinciding with cut-offs caused by the helicopter structure. These points would ideally be corners at the intersection of elements of cockpit structure. A number of positions are marked in this way.

(d) The marker position is then defined by an angle from dead ahead and a distance from the plan eye position.

(e) This then gives the azimuth extent of the point and the elevation angle can be derived from trigonometry.

3.2 These steps work well for the areas where the pilot can locate a ground based marker. When the overhead windows are also considered then a second technique is adopted which is based on angular measurements relative to data points defined above.

3.3 An assessment of S-61 and S-76 helicopters was conducted using the above method. The data derived for the S-76 is detailed in Figure 4, data obtained for the S-61 was not usable in this instance but Appendix B does contain data derived from a Sea King which is a derivative of the S-61. Appendix B contains examples of FOV from other helicopters and demonstrates the different techniques used for presenting this data.

## 4 DISCUSSION

4.1 This paper forms part of a research programme the purpose of which is to establish the means to specify and achieve an adequate visual scene for helicopter approach and landing operations. There are three basic areas to be addressed:

(a) What is the pilot's task? i.e. what operations are to be carried out using external visual references?

(b) How does the FOV as defined by the shape, size and disposition of the helicopter windows influence task achievement as the pilot manoeuvres the aircraft?

(c) What visual cues does the pilot require to perform the specified operations safely and routinely, and how can these be provided?

4.2 The third area is the main focus of the research reported in this paper. The two remaining areas have a direct influence on the work due to the link between task difficulty and quantity/quality of information provided to the pilot for performing the task. The literature search provided a limited amount of information on the pilot task, the influence of the FOV and the rôle of the visual scene content. The most comprehensive and relevant data was identified in the fog flying trials work conducted by the CAA and the DRA reported in Reference 10.

4.3 In good visibility conditions, helicopters have an adequate FOV for most operations. There are strong similarities between rotorcraft and fixed wing initial approach phase requirements under all weather conditions. In both cases the pilot requires good cues in the sector immediately ahead of the aircraft. Cues in other directions are of limited value because, during the initial approach, the pilot is primarily trying to assess the degree of disparity between the velocity vector and the desired aiming/landing point in order to take necessary corrective action to make them coincide. Thus for the initial phase of the approach the FOV over the nose and the visual aid requirements are generally well understood and provided for. Practical difficulties arise when it is not possible to display conventional aerodrome lighting patterns due to facility size or when visibility conditions limit the forward view.

4.4 The helicopter/fixed wing requirements alter significantly when the helicopter enters the deceleration segment of the approach. During this manoeuvre, which is unique to helicopters, pitch attitude changes are much larger than those applied to control a steady speed fixed wing approach. In addition, as the helicopter decelerates it becomes increasingly susceptible to the effects of cross winds. The overall effect is to increase the visual area around the helicopter which can be detrimentally obscured either continuously or on an intermittent basis by these attitude changes.

4.5 As the helicopter enters the hover and landing phase, the FOV that the pilot needs to scan is further increased. At restricted sites such as helipads on oil rigs, the aircraft may have to come very close to obstacles which may be difficult to see from the cockpit. Thus, FOV requirements are of greatest importance at the end of the landing sequence. The inter-relationship between task, FOV and visual cues is summarised in Table 1.

**Table 1: Task, Field Of View and Visual Cue Relationships**

| *Task* | *FOV currently provided* | *Visual Cues Environment* |
|---|---|---|
| Initial approach | Adequate. | Adequate cues for line-up and glide slope can be provided by conventional lighting at large heliports. For smaller heliports, lack of space to deploy conventional lighting patterns can cause limitations, particularly for low visibility operations. |
| Deceleration | Adequate in good visibility, benign conditions. Inadequate in bad weather conditions. | Adequate ground based cues become increasingly difficult to provide due to large areas of obscuration caused by helicopter pitch attitude changes. Requires cues over a large area ahead and around the helicopter to make best use of available fields-of-view. |
| Hover and landing | May be inadequate in all visibility conditions. | Primary areas of interest are close to the helicopter and may include obstructions. Adequate cues, particularly at small heliports may only be available from visual aids mounted in the vertical plane. |

4.6 Appendix B contains examples of FOV gathered for seven other aircraft. All diagrams are representative of a clean aircraft with no retrofitted equipment such as satellite navigation receivers, map displays and weather radar. Of these diagrams the Sea King is similar to the S-61 which was evaluated (data not shown), the Super Puma is similar to the S-76 also evaluated with derived data shown in Figure 4.

4.7 Figures 1 to 3 show photographic views from two helicopter types commonly used for offshore operations. Figure 1 shows the windscreen area of an S-61. Figures 2 and 3 show the windscreen area of an S-76 which is a purely civil aircraft. It can be seen that the S-61 has a far greater windscreen area available to the pilot, indeed the wiper swept area of the windscreen is also comparatively large, compared to the S-76. The S-61 is the airframe on which the Sea King military aircraft is based. The problems associated with available FOV have already been addressed and solutions found. These solutions have been enforced, for operational reasons, in the military industry (MIL Standard 850B) but exist only as guidelines for civil designers. The purpose of MIL Standard 850B is to establish criteria for providing adequate external vision for the aircrew stations of all military aircraft. Criteria are defined for minimum acceptable external vision based on the datum eye position for each crew member. The extent of external vision is dependant on normal operations and typical mission scenarios, but basic criteria exist for all classes of aircraft during the approach and landing phases of operation. Downward and forward vision, enabling the pilot to use all available and relevant landing aids, is to be provided in all aircraft. The standard specifies:

(a) The transparent area in azimuth and elevation for a range of aircraft types, missions and aircrew positions.

(b) A maximum width for structural obstructions within the transparent area.

(c) The clear vision area which is defined as the area of transparent material free of structure, edge bonding and any other material causing obstruction to the external vision, and that area which is also kept free of ambient effects such as rusting, precipitation, ice and insects.

(d) The quality of the external vision provided such that radii of curvature and angle of incidence of transparent components in the cockpit be consistent with aerodynamic, structural and fabrication conditions but reduce/minimise reflections and optical distortions which would interfere with pilot vision.

4.8 MIL Standard 850B as applied to two pilot, side-by-side arrangement rotorcraft includes:

(a) Controls, consoles and instrument panels to be located such that visibility, particularly that over-the-nose, is not restricted.

(b) Mounting or reinforcing frames or strips which divide transparent areas and cause obstruction be not greater than 2 inches wide when projected onto a plane perpendicular to a line between the structure and the pilot's eye at the datum eye position. Such obstructions should be distributed so as to avoid critical vision areas.

(c) Minimum angles of unimpaired vision designated with respect to the main pilot. Figure 5 shows the minimum angles of unimpaired vision recommended for helicopters with two pilots seated side by side. The main pilot is assumed to be in the right hand seat. In addition, the following is also stipulated:

(i) There is to be no vertical obstruction between 20° right and 20° left of the longitudinal axis relative to the datum eye position.

(ii) There is to be no horizontal obstruction in the area extending 15° above the horizon from 135° right to 40° left and decreasing to a point 10° above the horizon at 100°left. If necessary then the number of obstructions are restricted to one above and one below the horizon with a width of not greater than 4 inches.

Equivalent vision angles are provided for the co-pilot (left hand side).

4.9 The angular limitations are dependant on the mission, the aircrew arrangements and the aircraft type. MIL Standard 850B covers all aircraft procured by the military inclusive of fixed wing, Vertical/Short Take-Off and Landing (VSTOL) and rotorcraft. Also shown in Figure 5 (dotted line) is the only difference between MIL Standard 850B and the guidelines indicated in the Advisory Circulars 27 and 29. It can be seen that if the guidelines are followed, military and civil aircraft should have similar visual windows.

4.10 Figure 6 presents typical data indicating the track of a helideck superimposed on the FOV of a helicopter (S-76) during the approach to land phase of operation. The diagram illustrates the adverse effects of helicopter attitude changes during the deceleration phase. From this diagram, it can be seen that an offset approach makes better use of the available FOV, particularly during the latter stages.

4.11 In good visibility conditions the available FOV is generally not a major constraint on landing operations with current civil helicopter types. However, there are two significant conditions where deficiencies exist. The first of these is illustrated in Figure 2 which shows the view available to a pilot when there is rain on the windscreen. It can be seen that the FOV is, in effect, substantially reduced since the only area that is useable, particularly at night in the presence of external lighting, is that which is swept by the screen wiper system. Since the wipers are only fitted to the forward windscreen the FOV becomes inadequate as the deceleration phase commences, an effect that is exacerbated in the presence of cross winds.

4.12 The second area of deficiency was highlighted during the fog flying trials reported in Reference 10. In low visibility conditions current operational techniques require the pilot to perform the deceleration and landing phases using external visual references. In practice this results in the pilot deriving cues from the view ahead of the helicopter. For landings at aerodromes the cues may include approach and runway lighting. At other sites, particularly offshore, the cues will be those provided by the helideck and any adjacent structures. In all cases, the pilot needs to see cues ahead of the aircraft in order to acquire positional, attitude and rate cues and to estimate the instantaneous location of the helicopter velocity vector in relation to the desired aiming point. Since the deceleration requires a nose up attitude change the pilot is presented with the dilemma of either using normal attitude changes (at least 10 degrees) and thereby losing sight of the aiming point, or using smaller attitude changes that result in deceleration distances which are in excess of the visual range available i.e. if the visibility is 300 metres but the deceleration distance is 400 metres the pilot cannot stop the helicopter in the distance known to be available and retain sight of the helideck. This problem is made more severe if the final glide path angle is large since in this case the datum position of the aiming point is closer to the cockpit coaming. From this point of view a level approach is preferred.

4.13 For future helicopter operations, avionics enhancements offer a practical solution to the problem of providing adequate visual cues ahead of the helicopter since it is feasible to conduct the deceleration to the hover by reference to cockpit instrumentation alone. However, unless means are devised for clearing the windscreen over a much wider area than is done at present the problem of FOV deficiencies in conditions of precipitation will remain for the hover and landing tasks.

4.14 The data presented in this study would suggest that, in the longer term, there is a need to develop and enforce a civil specification for helicopter FOV. Such a specification would need to include provision of adequate screen clearing and guidance on retrofitting cockpit equipment. In the short term, operations will continue to be constrained by these design short comings, however the optimum use of available FOV could be the subject of further studies. For example, the development of new visual aids including those that can be viewed through contaminated screen areas is feasible. Alternative deceleration techniques could also have a beneficial impact on current operational limitations.

## 5 CONCLUSIONS

On the basis of the literature search and the practical measurements made within this study it is concluded that:

(a) In good visibility conditions the basic FOV provided in helicopters does not seriously affect operational capability.

(b) In many instances the actual FOV available to pilots is eroded by the retrofitting of additional equipment in the cockpit.

(c) There are no minimum specifications for cockpit field of view in the civil industry, only advisory circulars showing acceptable methods for compliance with visual specifications (FAR, BCAR etc.). If these methods of compliance were to be developed into a minimum specification and enforced, then some of the associated visual scene problems would be solved.

(d) When there is any form of precipitation or contamination on the windscreen the FOV is substantially reduced. This is particularly significant during the deceleration, hover and landing phases. At night the problem is exacerbated by excess lighting in and around the heliport producing disabling illumination of the water droplets on the large unswept screen areas, including the chin windows which would otherwise provide a useful source of cues in the hover and landing phase.

(e) In low visibility situations, the view ahead of the helicopter becomes inadequate as pitch attitude changes are applied to perform the deceleration manoeuvre. Final approach patterns flown at shallow glidepath angles would optimise use of the available FOV.

## 6 RECOMMENDATIONS

It is recommended that:

(a) Further investigation into the guidelines defined in Advisory Circulars 27 & 29 and development of these guidelines into an enforceable specification for civil helicopters be conducted.

(b) Investigation into the effects of developing approach profiles which would minimise the adverse FOV effects especially during low/poor visibility operations be conducted.

(c) Visual aids that are usable with contaminated windscreens should be researched and developed.

(d) The short/medium term benefits and feasibility of instrument deceleration techniques should be investigated.

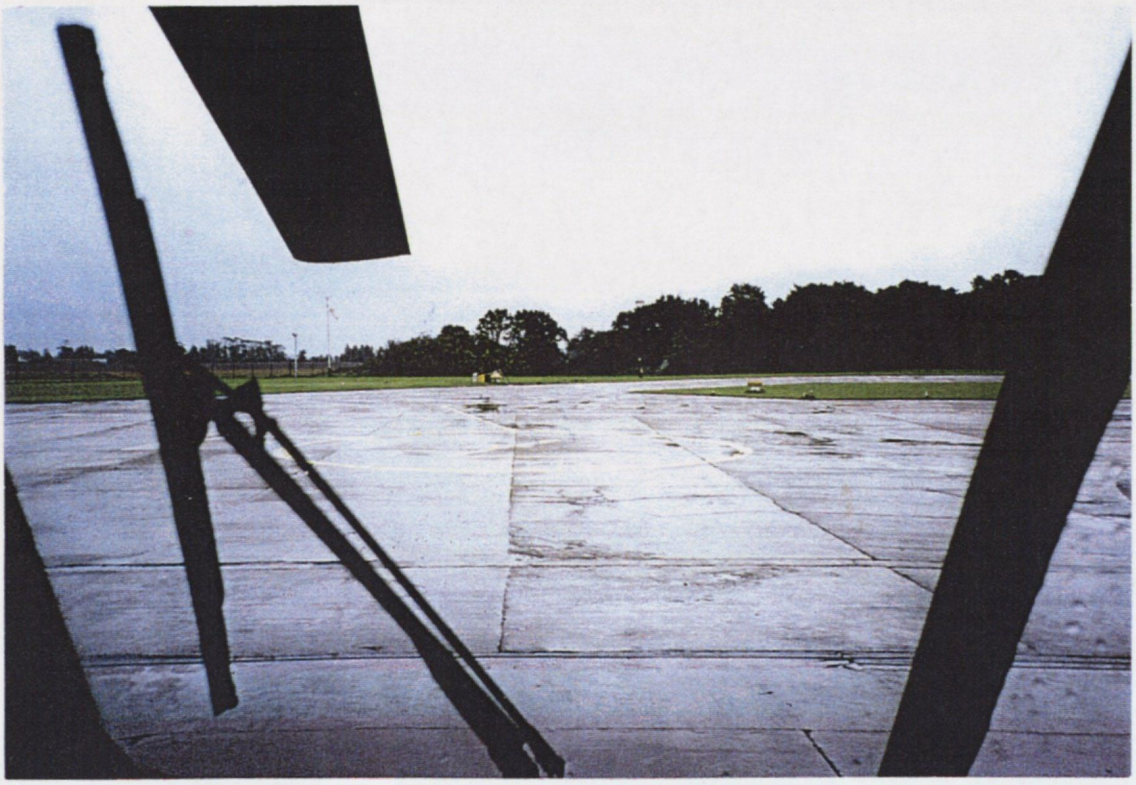

**Figure 1 View from S-61 Left Hand Seat**

**Figure 2 View from S-76 Right Hand Seat**

**Figure 3 Cross Cockpit View from S-76 Right Hand Seat**

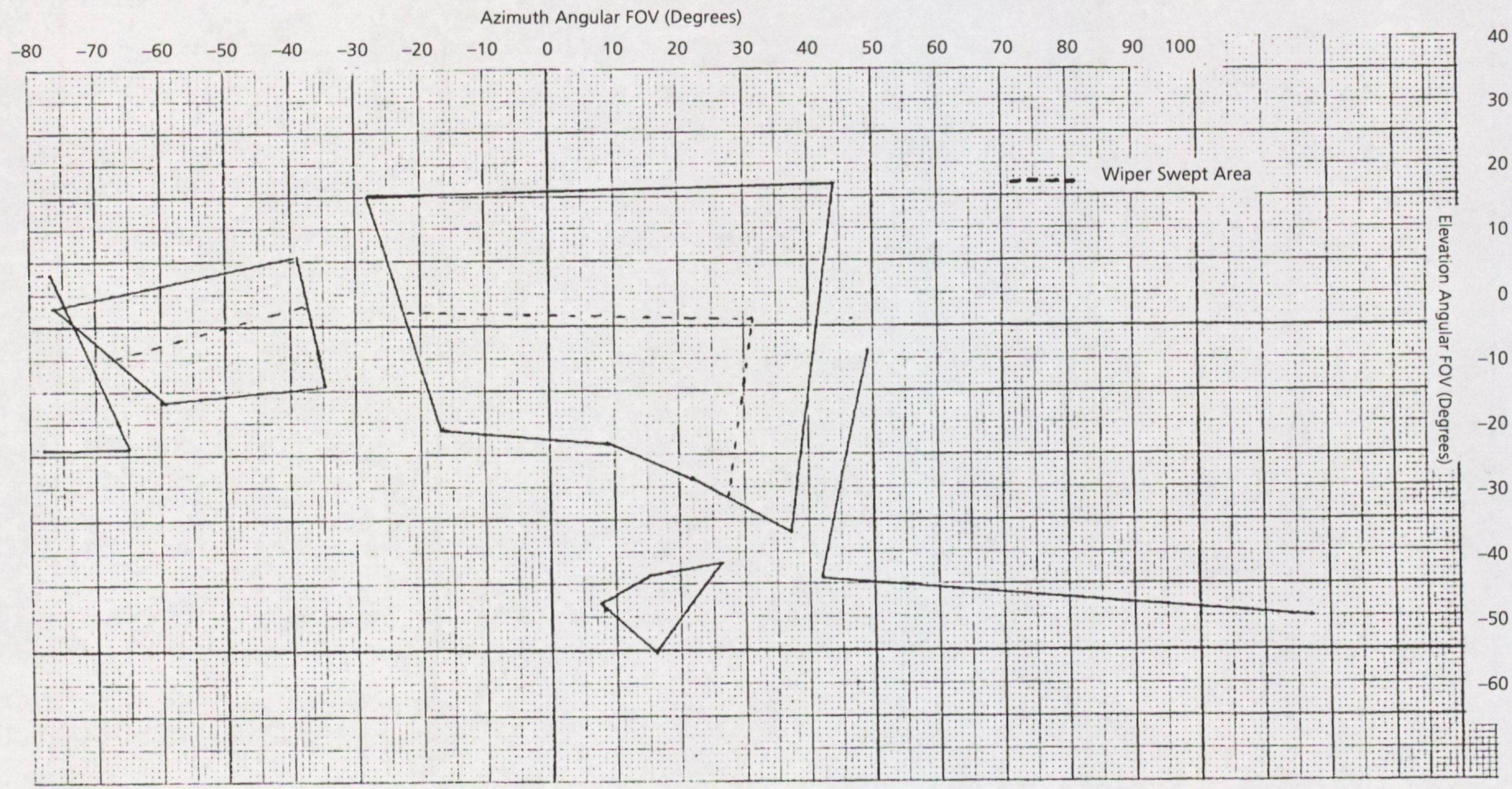


**Figure 4 Experimentally Defined Field Of View For S–76**

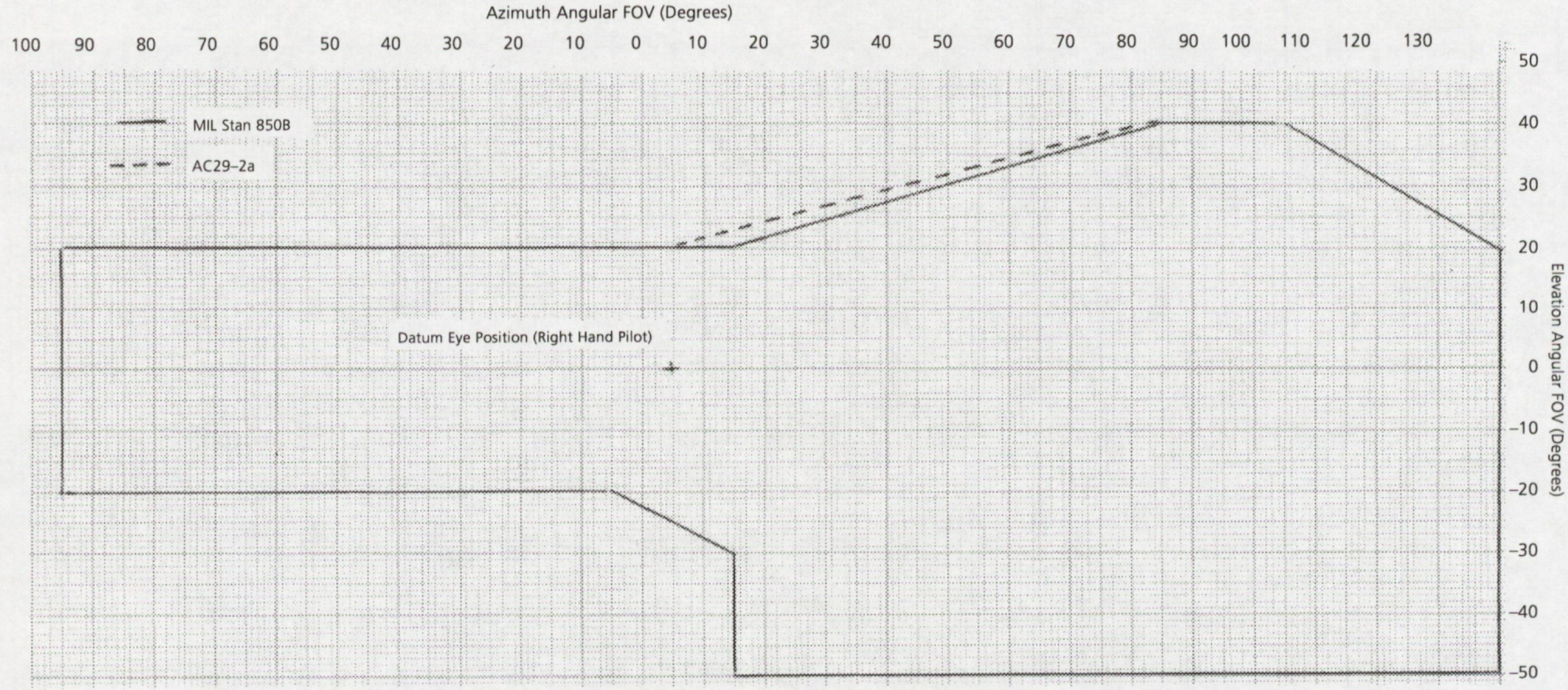


**Figure 5 Diagrammatic Representation Of MIL Standard 850B for Side by Side Helicopter**

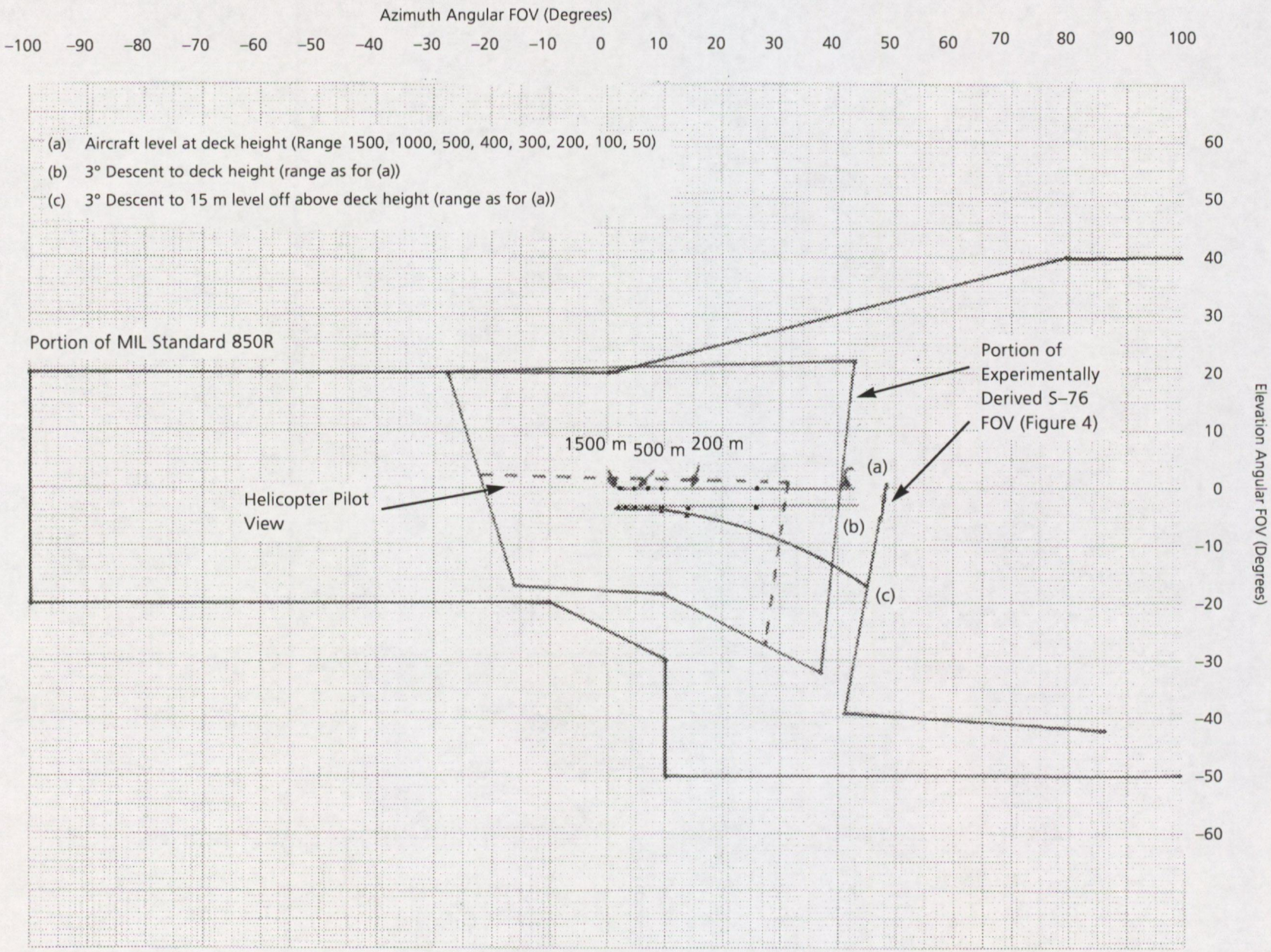


**Figure 6 Movement Of Helideck Through Windscreen Of S–76**

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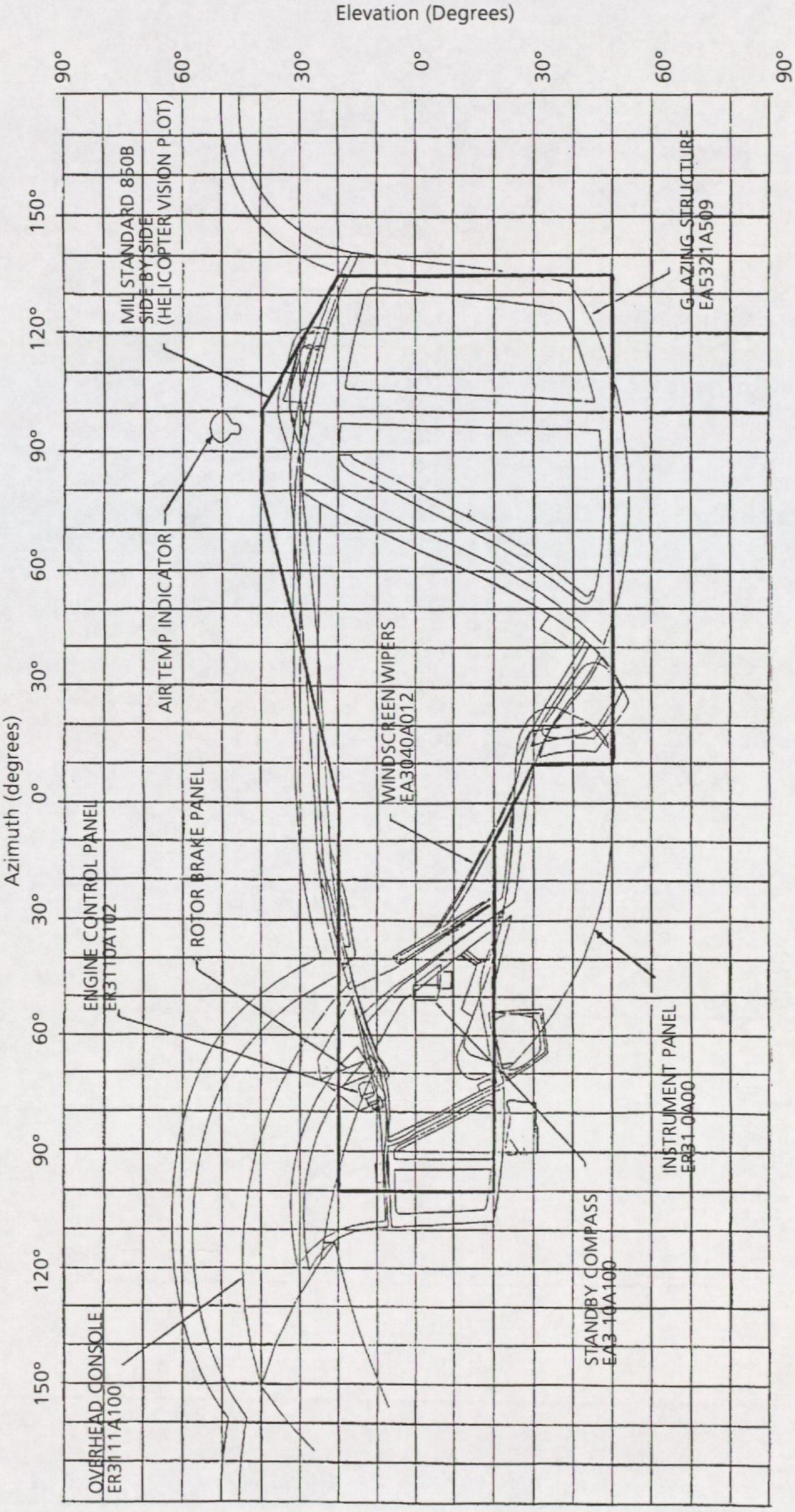
# Appendix B Helicopter Field Of View Diagrams

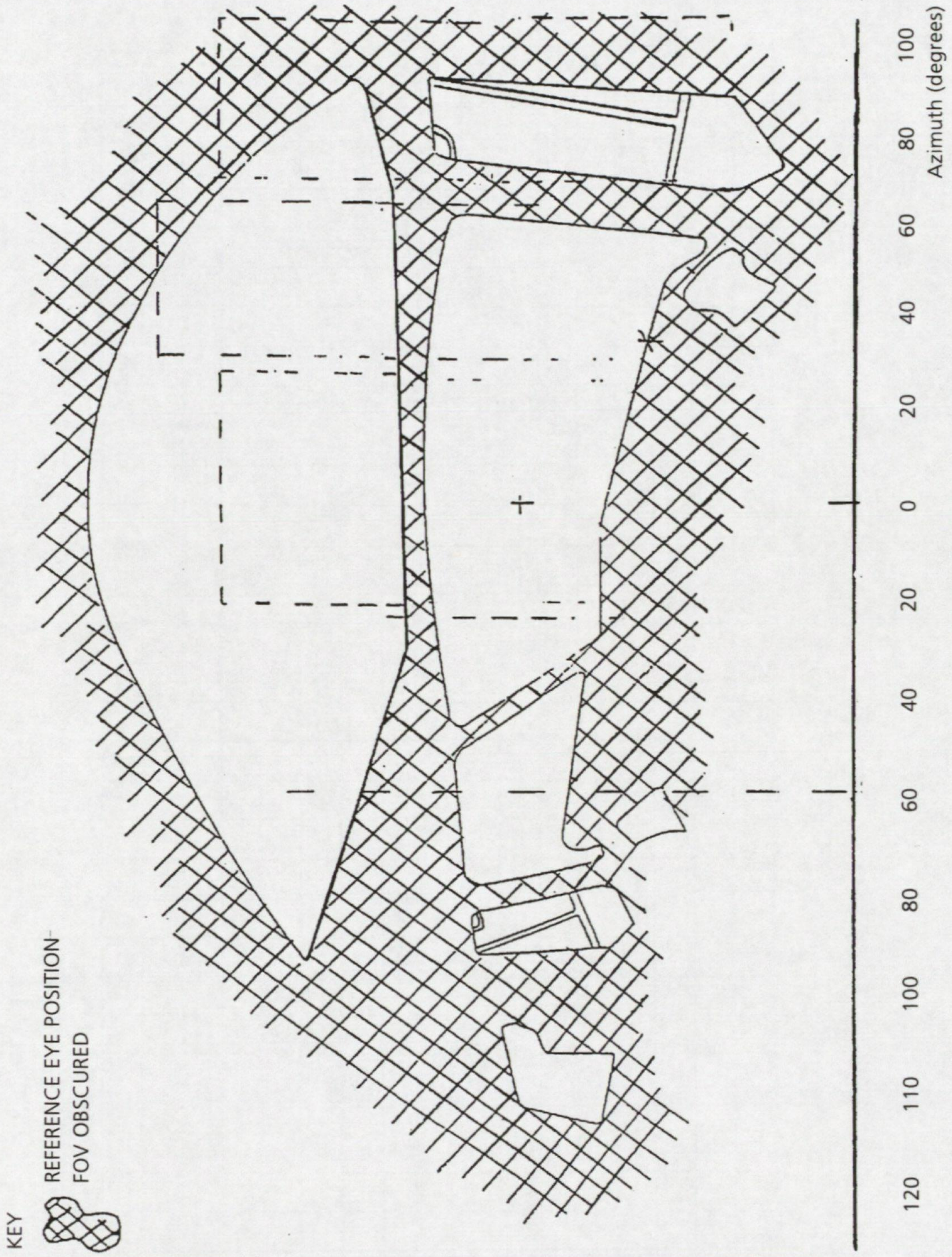
## EH101 – Naval



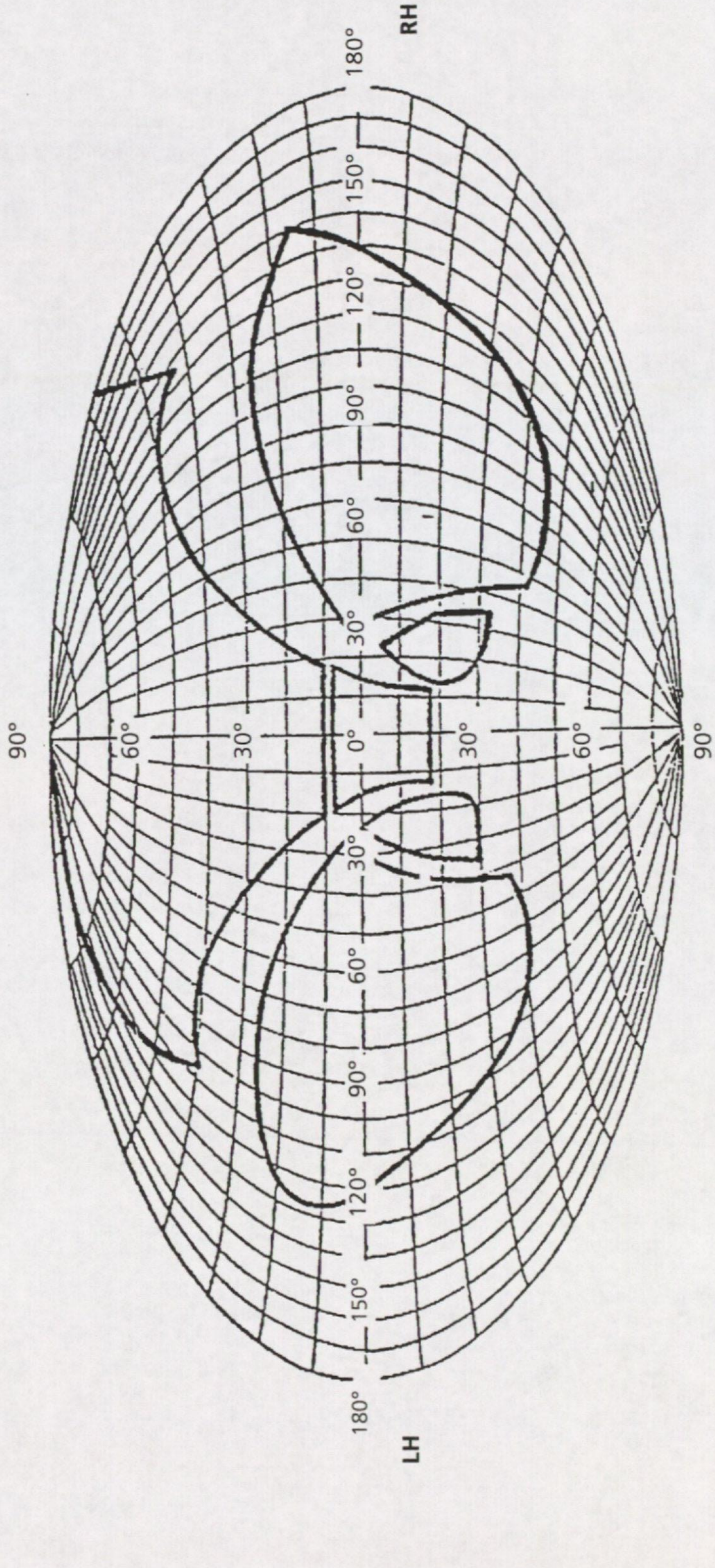

**Pilot Vision Diagram (Eye Centre x3495, y600, z2875)**

**Lynx AM Mk7**

Elevation (Degrees)



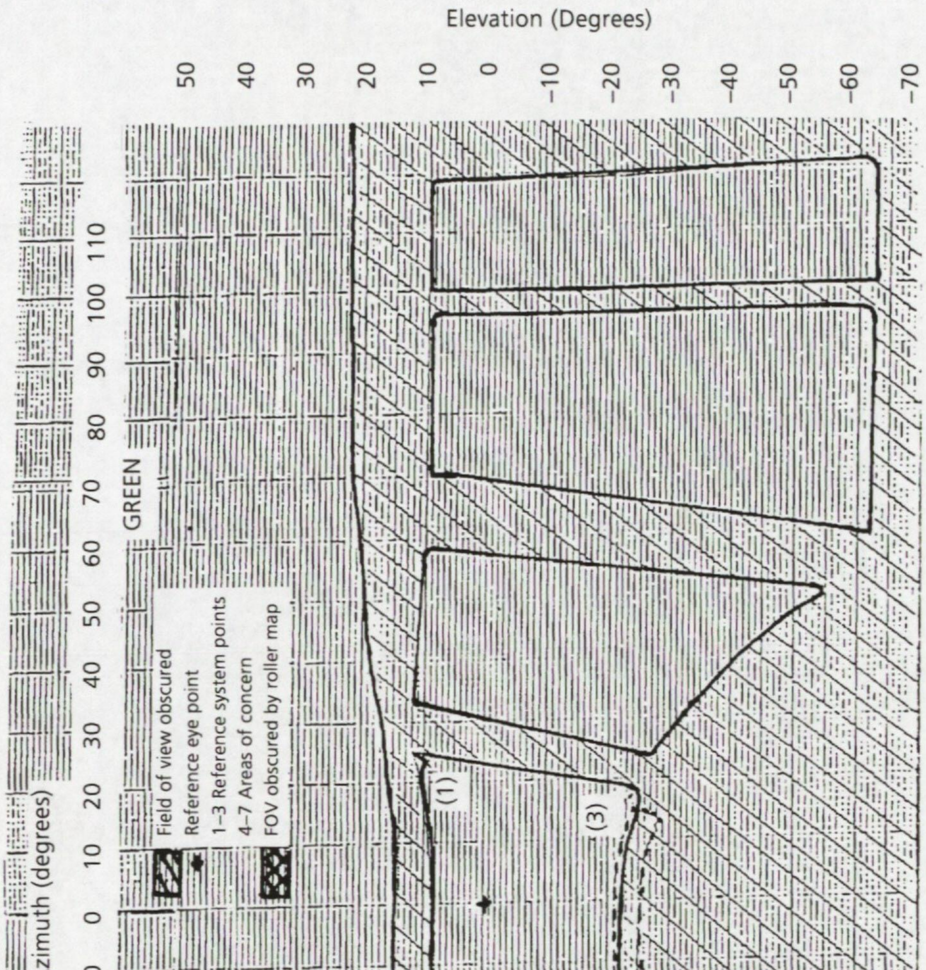

**Cockpit Field Of Vidw**




**Pilot Vision Plot (Rear Seat)**

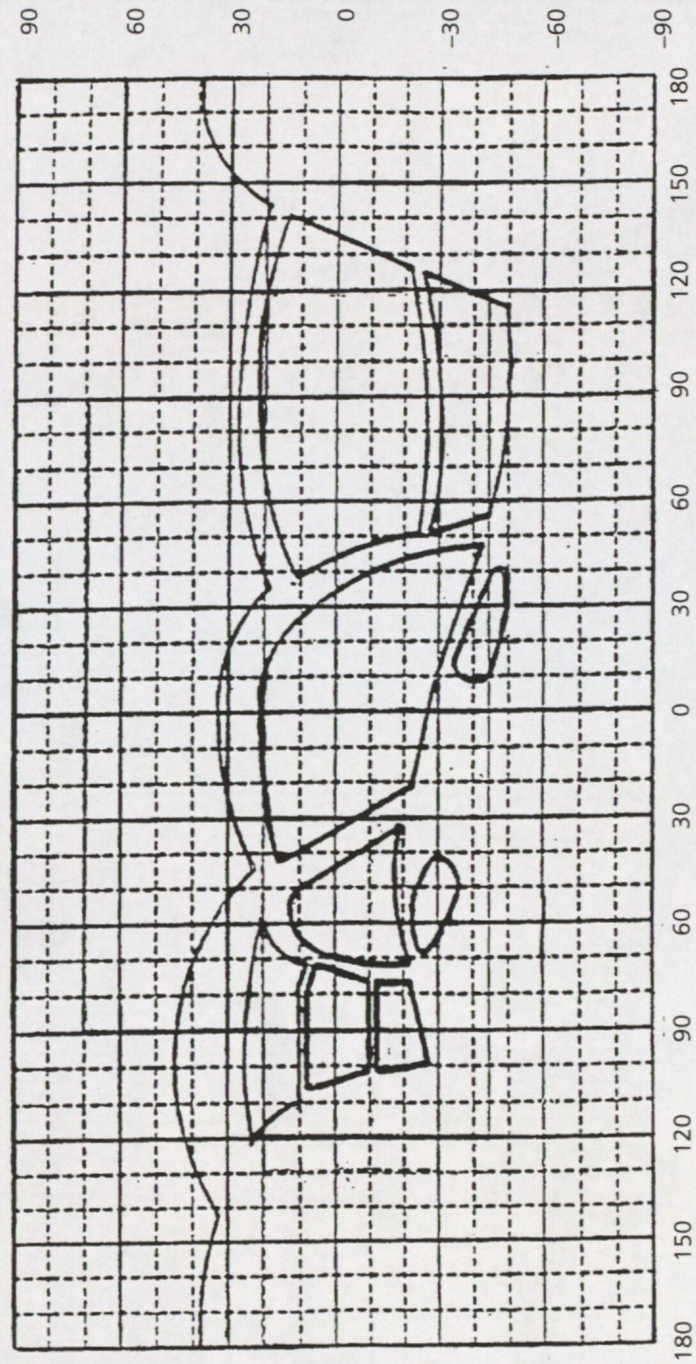
**AITOFF'S Equal Area Projection Of The Sphere**
**(Radius Of Projected Sphere Equals One Decimeter)**

## Sea King Mk 1/2



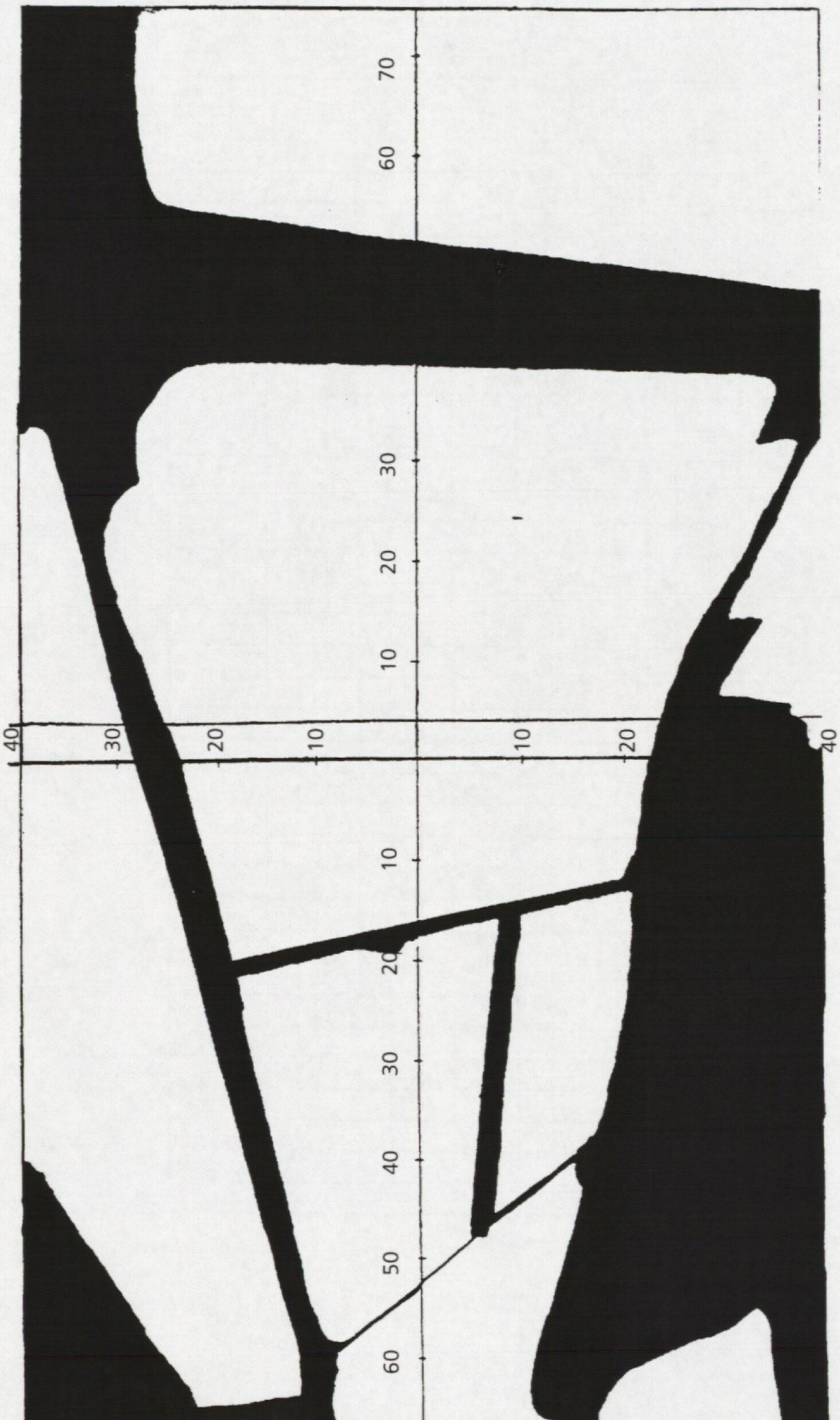

Cockpit Field Of View

**Bell Boeing MV–22A**




Rectilinear Vision Plot (Pilot)

**Super Puma**




**Cockpit Field Of View (Pilot)**