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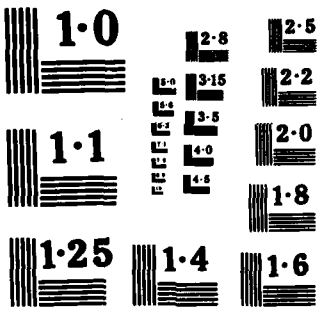
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Systems Technical Memorandum 75

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K.W. ANDERSON and K.C. HENDY

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PROPOSED MODIFICATIONS FOR THE RAAF AIRTRAINER CT-4A COCKPIT

by

K.W. Anderson and K.C. Hendy

SUMMARY

The design of the CT-4A Airtrainer cockpit is known to breach numerous ergonomics principles and several ASCC Air Standards. As a result, pilots report problems such as inadequate reach envelopes and obstruction of the control column by the left pilot's left knee. Consequently, the RAAF asked ARL to study the cockpit design and recommend simple changes. An anthropometric model was developed and used to evaluate several patterns of seat adjustment. The best of these (a ramp at 40 degrees to the fuselage reference line) was evaluated in practical trials with an experimental seat in a CT-4A fuselage. For each of the thirty pilot subjects, a sitting position with acceptable view, reach and clearance was found with the experimental arrangement.

The ARL recommendations for cockpit modifications include:

a smaller left side throttle quadrant with external pushrods, a seat adjustable along a 40 degree ramp, improved instrument lighting, pedals moved forwards, control column modifications, lowered lap belt anchor points, dual fuel gauges and a centre transponder location.

Incorporation of these recommendations is expected to enhance training effectiveness and improve flying safety.

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FIGURES

1. INTRODUCTION

The CT-4A Airtrainer was introduced for RAAF flying training in 1975/76. The aircraft, manufactured by New Zealand Aerospace Industries (NZAIL), is a derivative of Henry Millicer's designs for a low-cost light civilian aircraft, i.e. the Victa Aircruiser/Airtourer series. In 1975, members of Cybernetics Group (now Human Factors Group) at Aeronautical Research Laboratories (ARL) conducted a brief cockpit evaluation of a CT-4A aircraft which was at the RAAF Aircraft Research and Development Unit (ARDU) for flight evaluation. From this brief examination came a number of recommendations for remedial action in areas of major ergonomics deficiency. Following criticisms from the RAAF Institute of Aviation Medicine (IAM) and the aircraft operators at Number 1 Flying Training School (1FTS), Point Cook, ARDU performed a detailed cockpit assessment of the aircraft. The ARDU report (Ref. 2) reiterated the criticisms made in the ARL assessment and added to the list of human factors deficiencies. Meanwhile the Royal New Zealand Air Force (RNZAF) had expressed some dissatisfication with aspects of the cockpit and instrumentation layout in their version (CT-4B) of the aircraft. This led to a detailed study of the CT-4B cockpit by the NZ Defence Environmental Medicine Unit (DEMU). The DEMU study (Ref. 3) placed emphasis on the need for an adjustable crew seat.

In 1979, RAAF Support Command (HQSC) asked ARL to study the layout and facilities of the CT-4A cockpit and recommend improvements aimed at correcting the widely recognised deficiencies of the original arrangement. It was emphasised that modifications would not be implemented unless the improvement in cockpit ergonomics was great, the cost was modest, and aircraft performance decrement due to increases in the aircraft mass or form drag was minor.

The fuselage of a damaged CT-4A (A19-057) was made available to ARL for use during the design and evaluation of various proposed modifications to the cockpit area. Mock-ups of the proposed modifications were assessed using the fuselage structure of A19-057 and recommendations were presented to the RAAF at a meeting in September 1980. The proposals generated considerable discussion from ARDU (Ref. 4), 1FTS (Ref. 5) and HQSC (Ref. 6), but during 1981 the RAAF decided not to proceed with the proposals as the expenditure was not considered to be justified. Subsequently, publication of this document was given reduced priority because of staff changes and pressure of other tasks. Its belated publication in 1984 fulfils the following purposes:

(i) provision of an archival record of work done; and

(ii) provision of a reminder of the need for adequate specification of the man-machine interface in defence equipment purchases.

An offshoot of the CT-4A study was the development of a graphic anthropometric design aid (Ref. 7). The aid was used to assess various proposals for crew seat adjustment in the CT-4A programme and subsequently has been used to assist in the geometrical layout of the Australian Aircraft Consortium's WAMIRA aircraft which is a contender for the CT-4A replacement.

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2. CT-4A COCKPIT PROBLEMS

The CT-4A cockpit is narrow: two pilots of moderate size sit elbow to elbow when wearing their usual bulky military flying equipment. Many pilots cannot reach the panel from the fixed seat if the harness is locked. The only seat adjustment is by the use of polyethylene foam spacers to raise the effective seat reference point (SRP) and hence the eye position. For many pilots the pedals are uncomfortably close to the seat even when the pedals are adjusted fully forwards. Full aileron deflection cannot always be achieved because knees and thighs obstruct lateral movement of the control column especially near the left side throttle quadrant.

The CT-4A was derived from a small light civilian aircraft with a single centre quadrant for engine controls and no centre console. Therefore some space problems were inevitable when a centre console was added in adapting the aircraft for military use. However, many of the space difficulties appear to be the result of inadequate consideration of anthropometry in the design. For example the arrangement of the seat and pedals is poor because inadequate adjustment was provided.

The cockpit of the CT-4A Airtrainer fails to conform with several ASCC Air Standards. Important examples include:-

a. external view forwards (Air Standard 10/53)
b. seat adjustment (10/55)
c. helmet to canopy clearance (10/55)
d. body to airframe clearance (10/55)
e. controls clearance (10/55)
f. pedal position (10/55)
g. reach envelopes (10/13, 10/55)
h. switch and control locations (10/13, 10/14, 10/15)
i. harness geometry (61/2).

3. USE OF AUSTRALIAN ANTHROPOMETRIC DATA

Quarter-scale US manikins and percentile tables of Australian anthropometric data were used to confirm the user-reported space problems and to evaluate some possible alternative seat-pedal-panel arrangements. This conventional approach proved inconclusive so an alternative technique was developed: an anthropometric model was devised to estimate each individual's sitting position using his actual body measurements. For each of the 456 aircrew entries in the ARL Anthropometric Data File, a sitting position (eye and limb points) could be estimated from any given seat reference point. Details of the model development and validation are reported separately (Ref. 7).

The model was used to investigate different seat positions and several techniques for seat adjustment. A uni-dimensional adjustment was investigated as a possibility because of the potential advantages of simplicity, low cost, light weight and crashworthiness by comparison with the two-dimensional types which are common in military aircraft. The results indicated the feasibility of having the whole seat adjustable in position along a ramp inclined at 40 degrees to the fuselage reference line; the occasional use of spacers would allow a little more freedom for the pilot to adjust his eye position and reach envelopes.

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4. EXPERIMENTAL EVALUATION OF THE REVISED COCKPIT

The fuselage of the salvaged CT-4A was used as a mock-up for the proposed modifications, including:

(i) a seat adjustable along a ramp at 40 degrees to the fuselage reference line;

(ii) a thin, contoured, polystyrene cushion with extended thigh support;

(iii) a smaller left-side engine controls quadrant;

(iv) a recessed flap lever on the left fuselage wall;

(v) a pedal position 70 mm forward of the standard CT-4A pedal position;

(vi) separate gauges for left and right wing fuel tanks.

Photographs of the mock-up are shown in Figures 1 to 6.

Thirty-one flying instructors from RAAF Base Point Cook participated in the anthropometric study and graphic design aid validation (Ref. 7). Of these, 23 were available for the experimental evaluation of the cockpit mock-up. A seat position for each subject was precomputed using his individual data and the validated graphic design aid cited above. Subjective measures of reach envelopes, external view, body clearances and control interference were recorded both for the precomputed seat position and for a separate seat position chosen independently by the subject. Head and eye locations were recorded photographically for both seat positions; an example is shown in Figure 7. A total of 30 flying instructors participated in the mock-up evaluation. These subjects comprised the 23 cited above and a further 7 flying instructors who had not been available at the time of the earlier study. Because no anthropometric data were available for these 7 subjects, no seating position was precomputed; only the position chosen by the subject was evaluated.

The results were generally favourable. For only one of the 23 subjects was the precomputed position quite unlike the selected position: the subject's buttock to knee length was disproportionately long with respect to his arm and trunk dimensions and, as a result, the solution chosen by the design aid did not accord with the subject's chosen compromise. For each of the 30 subjects an acceptable seat position was found although five would have preferred to be further forward but for control column interference.

Subjects were generally enthusiastic about the proposed changes. One exception was the proposed recessed flap lever which was generally considered acceptable but not ideal.

It was found that most subjects chose a seating position a little lower and a little further aft than the precomputed position. This would suggest that subjects placed a little more emphasis on the need for helmet/canopy clearance at the expense of view over the nose. Consequently, it was concluded that the seat ramp height should be a little lower than in the mock-up and also that the pedals should not be so far forwards in order to suit the greatest number of potential users.

.../4.

5. PROPOSED MODIFICATIONS

This section presents a list of proposed modifications for improving the ergonomics of the CT-4A cockpit. They are classified as essential, highly desirable and desirable according to the importance of the existing problem and the degree of improvement expected. The recommendations are based on:

(i) in-flight and ground observations and demonstrations of existing ergonomic problems;

(ii) the opinions of experienced CT-4A pilots on present problems and some possible alternatives;

(iii) the conclusions drawn from the practical trials described above; and

(iv) ARL's experience with anthropometry and cockpit layout problems in several other aircraft.

5.1 Essential

The proposed modifications are central to the ergonomic improvement of the CT-4A cockpit. They are aimed at alleviating the major anthropometric deficiencies present in the original geometric layout of the CT-4A cockpit. The proposed modifications are complementary and should be implemented together. If the adjustable seat is adopted the revised left-side engine control quadrant must be used to prevent new problems being introduced for those smaller subjects who will, with the proposed arrangement, be sitting further forward.

5.1.1 Left Quadrant and Flap Selector

The existing left-side engine controls and flap selector should be replaced by a less bulky arrangement with the push-rods in a fairing outside the airframe (see Figure 5). The revised system should have the control levers closer together both at the handgrips and on their axis of rotation. A smaller friction-adjustment lever should be used and the revised system should protrude no further than 40 mm inboard from the inner fuselage skin. A guarded flap selector for the left pilot should be located just aft of the new quadrant partly in a recess in the fuselage skin.

This modification provides some much-needed knee room for the left pilot. Other ARL cockpit proposals (notably for the seat and pedals) would not be practical with the existing quadrant and internal push-rods. It seems likely that the drag associated with the small fairing would have a very small effect on climb and cruise performance, and this should be tolerated because of the major improvements gained in cockpit safety and comfort.

5.1.2 Seat and Cushion

An adjustable seat should allow the seat reference point to be selected in side elevation along a line from (1188 mm, -332 mm) to (1093 mm, -252 mm) with respect to the aircraft datum. Discrete fixing points at approximately 10 mm intervals along that line would be appropriate. A mechanism which does not allow in-flight adjustment might be necessary to remain within the small mass increase allowed by the RAAF.

.../5.

The considerable advantages of standardising eye position and improving panel and pedal reach distances were verified in the practical ground trials with an experimental adjustable seat. Further, an improvement in crashworthiness will be possible because of the increased vertical stroke available in most positions of the proposed seat.

The seat should be supported by a rail on each side (see Figures 1, 2 and 3). The space below the seat should be filled with a structure designed to crush at a uniform rate under survivable crash loading in order to obtain full advantage of the available stroke. The front edge of the seat should have a cut-out approximately 30 mm longitudinally and 120 mm laterally to allow clearance for the control column and harness crotch strap in accordance with ASCC Standard 61/2.

A glass reinforced plastic contoured seat pan is recommended. It should be moulded to an approximate buttock shape and be covered with a thin layer of flexible polyurethane foam and woolled sheepskin for comfort. The sheepskin also enhances safety in the event of fire. It should be available in two thicknesses: 30 mm and 60 mm. The front edge should have a cut-out to match the seat.

5.2 Highly Desirable

These proposed modifications represent, with the exception of the pedal position, a series of improvements which could be implemented in consort or as independent improvements to the cockpit ergonomics. They represent items which are believed to compromise aircrew safety as presently implemented or contribute to improved aircraft operability.

5.2.1 Lighting

White, dimmable lighting, balanced for brightness should be provided for all instruments, including the G-meter and the RMI. Eyebrow lighting should be replaced by pillar lighting where possible, in order to avoid masking of the upper part of the instrument face.

5.2.2 Pedals

The pedals should be placed 35 mm forwards of their existing CT-4A position (cf. 50 mm for the NZAIL modification). They should retain their present adjustment range and orientation. This modification should not be implemented in the absence of seat adjustment as described in Section 5.1.2 above.

5.2.3 Control Column

A crank should be placed in the control column in order to place the hand grip 20 mm forwards and 10 mm outboard of its present position. The handgrip should be rotated about 20 degrees anti-clockwise. A handgrip height adjustment should be provided.

5.2.4 Harness Geometry

The crotch strap should assume a near vertical orientation with the revised seat arrangement. The lap belt anchor points should be lowered by about 150 mm, and the shoulder harness guide should be relocated on the rollover structure about 400 mm above the fuselage reference line and in line with the centre of the seat.

.../6.

ASCC Air Standard 61/2 indicates that the guide for the shoulder harness should be (i) attached to the seat back; and (ii) located above the shoulders. The proposed ARL adjustable seat is of minimum additional mass to conform with RAAF requirements and is probably therefore insufficiently strong for the harness guide requirements specified in the Air Standard (which is directed at combat aircraft). Consequently a guide mounted on the rollover structure (as is the present CT-4A shoulder harness guide) is proposed as a compromise which satisfies the geometrical aspects of the Air Standard.

5.2.5 Fuel Gauge

The fuel gauge should be replaced by a two-dial arrangement (see Figure 4) to display the contents of both tanks at all times. A single instrument case with adjacent scales no smaller than 25 mm diameter would be satisfactory.

5.2.6 Transponder

The IFF transponder should be fitted into the instrument panel below the UHF radio set, and the displaced ICS should then be located under the instructor's flight instruments. If the ICS is not to be shifted, an extra radio mute switch for the instructor should be provided on the centre console near the flap selector.

At present the transponder control box has been fitted on the extreme right side of the instrument panel. This position is considered ergonomically poor for the following reasons:

(a) The controls would be out of reach of a left side pilot wearing a locked harness.

(b) Disorientation would be a significant hazard should a left side pilot have to unlock his shoulder harness and reach across to select a channel change (e.g. to emergency) when flying solo during instrument meteorological conditions.

5.3 Desirable

These remaining recommendations represent items which contravene good ergonomic practice, either through their current implementation in the CT-4A or through their absence. They fall into this last category because their contribution to flight safety and aircraft operability is less obvious than for the items in the two previous categories.

5.3.1 Rudder Trim

The rudder trim switch should be mounted on a small block in order to place the switch about 20 mm further aft. A plastic guard should replace the existing sheet metal fitting.

5.3.2 Volt-Ammeter

An instrument with separate pointers and scales to display both voltage and current simultaneously is recommended in place of the existing volt-ammeter.

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5.3.3 Park Brake Handle

A replacement park brake lever using an over-centre toggle mechanism (originally suggested by 1 FTS to avoid awkward arm movements associated with the original park brake handle) would be satisfactory if located in a recess in the centre console. The shape of the lever should be distinctly different from the flap lever.

5.3.4 Dinghy

The proposed inflatable mini-boat should be lightly packaged and attached with "Velcro" to the inner fuselage skin close to the seat front (i.e. under a pilot's outboard knee). An adjustment to the position of the control column lock may be necessary. During flight, the package could be attached to a pilot's life preserver vest by a short lanyard of limited strength. This arrangement represents a compromise between the preferred arrangement (i.e. seat mounted dinghy) and the already unsatisfactory seat-canopy distance.

5.3.5. Magneto Switch

The rotary magneto switch should be retained in its present position. To prevent inadvertent selecting of the "start" position, a spring-loaded mechanical stop should be fitted.

5.3.6 Map Cases

Small map cases (similar to that existing on the right side fuselage wall) could be provided on the walls of the centre console (i.e. under a pilot's inboard knee).

5.3.7 Strobe Switch

The proposed strobe lights should be selected by a toggle switch independent of the navigation lights and beacons. By connecting the two beacon lights into one switch, a suitable switch position for the strobe lights would be available.

6. CONCLUSIONS

Some of the CT-4A Airtrainer's present cockpit difficulties result from inadequate design attention to basic ergonomics principles, and especially to anthropometry. Obstruction of the control column by the left pilot's left knee and inadequate reach envelopes are common problems in the CT-4A at present. An anthropometric model was developed and used to evaluate several patterns of seat adjustment. The best of these (a ramp at 40 degrees to the fuselage reference line) was evaluated in practical trials with an experimental seat in a CT-4A fuselage. For each ot the thirty pilot subjects, a sitting position with acceptable view, reach and clearance was found with the experimental arrangement.

The ARL recommendations for cockpit modifications include:

.../8.

a. a smaller left side throttle quadrant with external pushrods,

b. a seat adjustable along a 40 degree ramp,

c. improved instrument lighting,

d. pedals moved forwards,

e. control column crank and twist,

f. lowered lap belt anchor points,

g. dual fuel gauges and

h. a centre transponder location.

Incorporation of these recommendations is expected to enhance training effectiveness and improve flying safety.

.../9.

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FIG. 1 LEFT-SIDE EXPERIMENTAL SEAT ADJUSTED FORWARDS ON THE INCLINED TRACKS

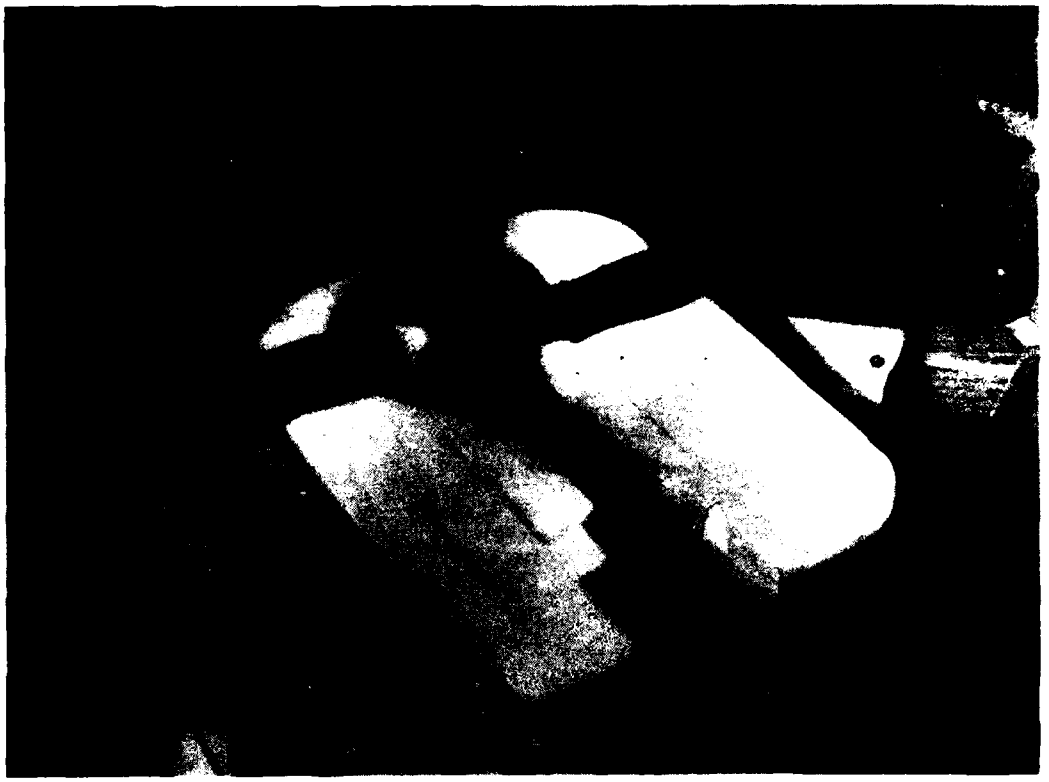

FIG. 2 LEFT-SIDE EXPERIMENTAL SEAT ADJUSTED REARWARDS ON THE INCLINED TRACKS

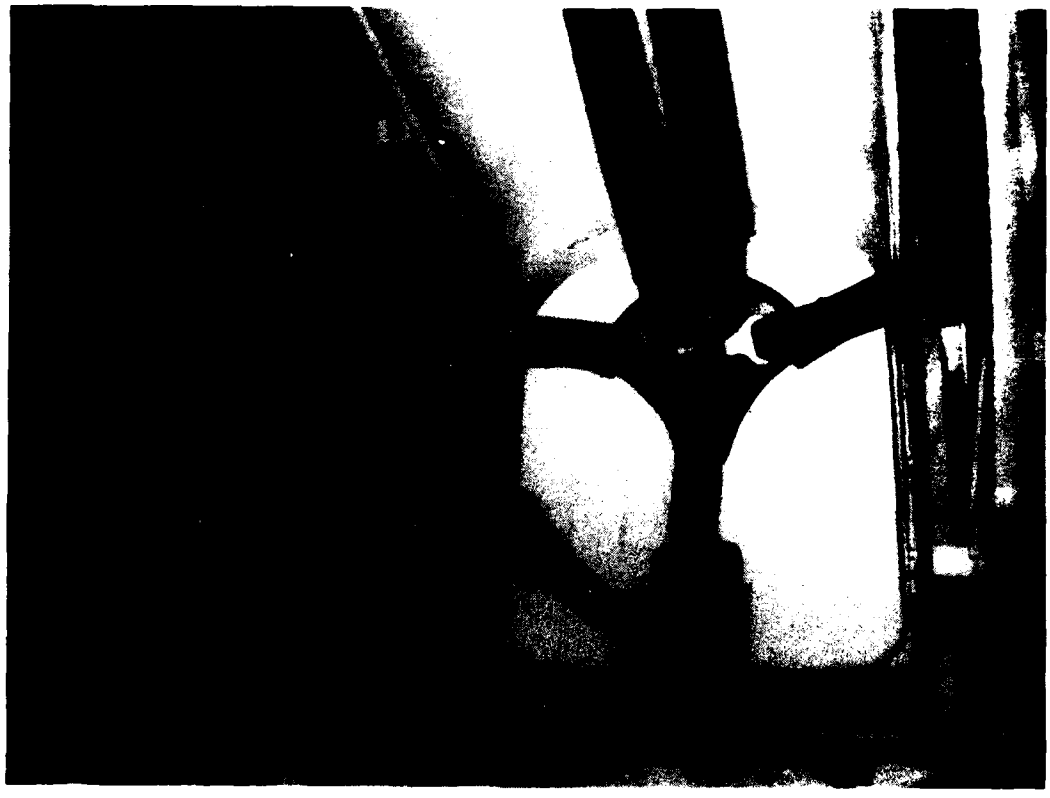

FIG. 3 PLAN VIEW OF LEFT-SIDE EXPERIMENTAL SEAT SHOWING SEAT CUT-OUT FOR CROTCH STRAP AND CONTROL COLUMN

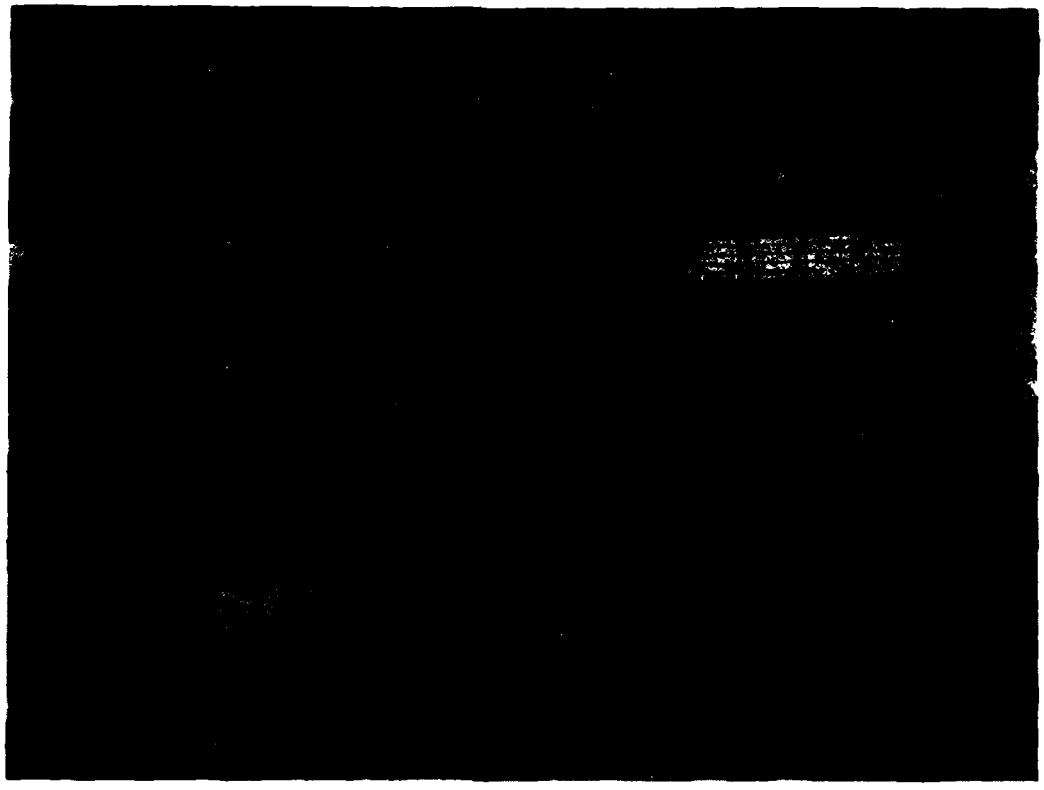

FIG. 4 SIDE-BY-SIDE FUEL GAUGES

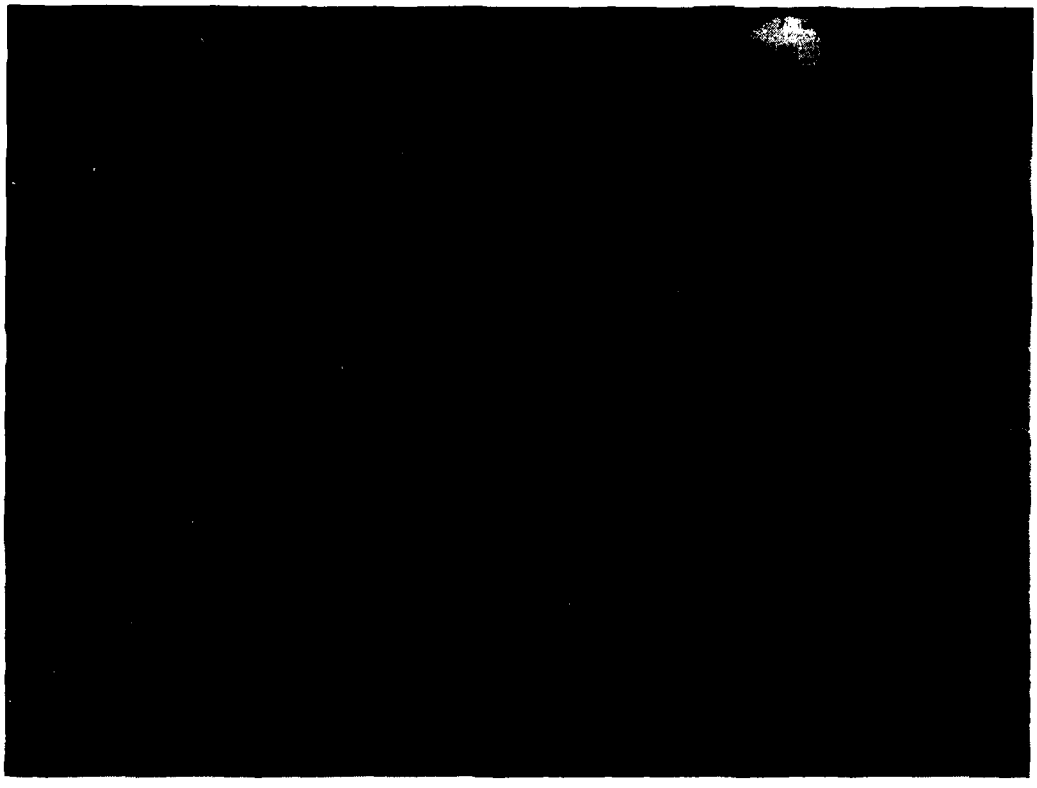

FIG. 5 MODIFIED LEFT-SIDE THROTTLE QUADRANT AND FLAP CONTROL

FIG. 6 EXPERIMENTAL PEDAL ASSEMBLY WITHOUT BRAKE MASTER CYLINDERS

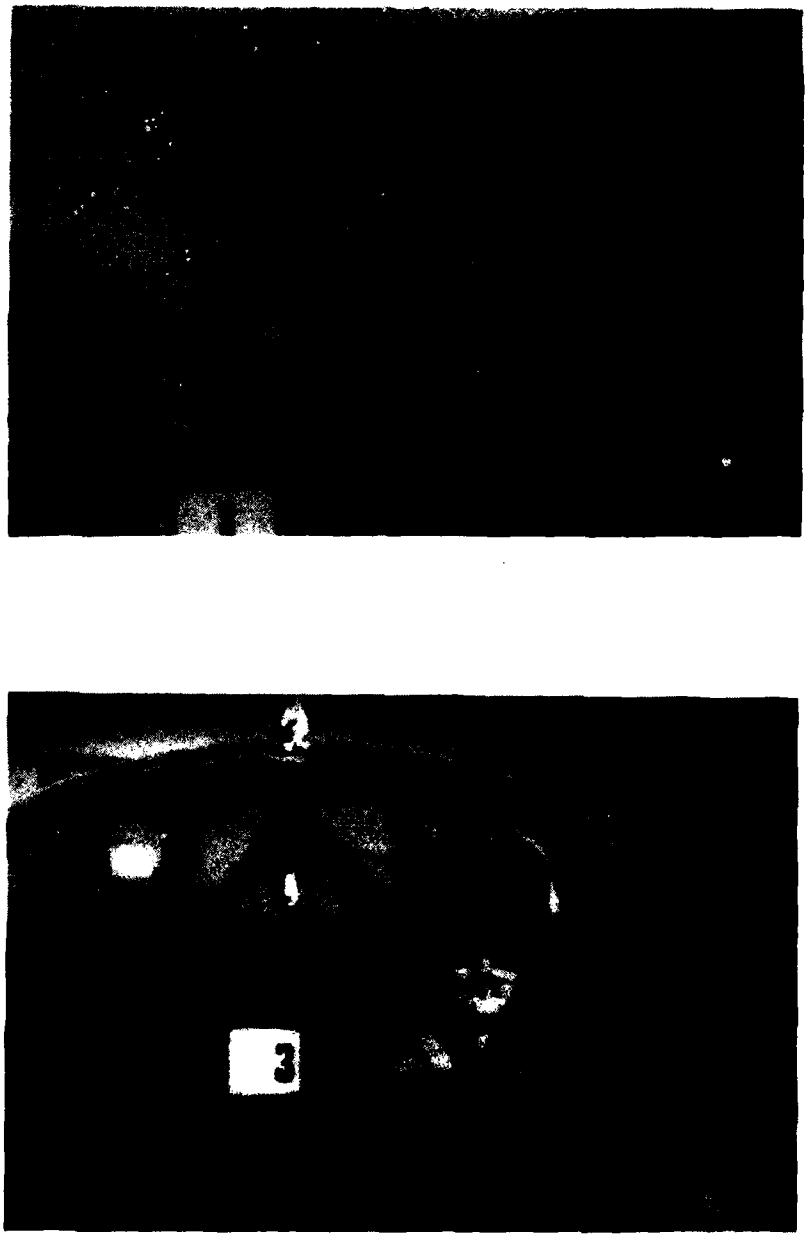

FIG. 7 SIDE AND FRONT VIEWS OF A FLYING INSTRUCTOR SUBJECT SITTING IN THE MOCK-UP WITH THE SEAT ADJUSTED TO HIS PREFERRED POSITION

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16. Abstract

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16 Abstract (Cont'd)

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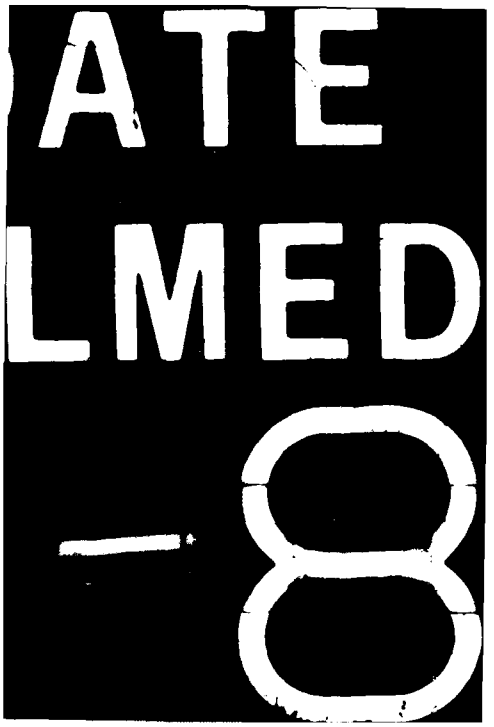
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