DEVELOPMENT PROGRAM FOR THE ARROW

ESCAPE SYSTE[redacted]

June 1958 72/SYSTEMS 24/205

AVRO AIRCRAFT LIMITED

MALTON – ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

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DEVELOPMENT PROGRAM FOR THE ARROW ESCAPE SYSTEM

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TECHNICAL DEPARTMENT

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AIRCRAFT: ARROW 2

DEVELOPMENT PROGRAM FOR THE ARROW ESCAPE SYSTEM

1. INTRODUCTION

1.1 It is suspected that the present emergency escape system may not be satisfactory over the full flight envelope of the Arrow. Fig. 1 shows the expected capabilities of the present system using a Martin-Baker C5 seat. A development program to establish and improve the systems performance is therefore essential.

1.2 Investigations have shown that a system, in which both crewman eject themselves independently, is unsatisfactory in some flight conditions. Therefore, a system, in which escape is 'linked' * for both crewman, will be utilized. For a discussion of the reason for this choice reference should be made to Appendix 2 of this report.

1.3 This report presents a development program for such a system and outlines the required tests.

2. GENERAL PROGRAM

The program shall consist of the following phases:-

2.1 Preparation of Requirements.

2.2 Design and Development of the System.

2.3 Test Program.

2.4 System Evaluation.

* A 'linked' escape system is one employing automatic sequencing whereby a single operation of the pilot's firing control will eject the observer first and then the pilot.

3. PREPARATION OF REQUIREMENTS

3.1 Avro shall prepare the detailed requirements for an Escape System, which is to operate satisfactorily over the full flight envelope of the Arrow, as far as the state of the art and sciences will allow.

3.2 This shall include a requirement for a 'linked' system, with a provision, however, for the observer to eject himself independently. This system will utilize the sequenced canopy actuation as proposed for the Arrow 1.

3.3 The detailed requirements for the seat are contained in Appendix 1 of this report.

4. DEVELOPMENT OF THE SYSTEM

4.1 The responsibility for developing the system to Avro's requirements will, if practicable, be given to a sub-contractor experienced in this field.

4.2 Provided that sub contract, as in 4.1, is effected Avro shall provide Technical assistance and liaison with the sub contractor as required to ensure a vigorous and effective program.

5. TEST PROGRAM

5.1 In order to ensure that the Escape System will meet the requirements of paragraph 3.1 and to determine its capabilities within the accuracy, obtainable from established techniques, a series of tests will have to be carried out. The methods of testing employed shall be:

Tower Tests
Ground and Rig Tests
Wind Tunnel Tests
Static Ejection
Sled Ejection Tests
Flight Ejection Tests

5.2 Tower Tests

5.2.1 An ejection seat and all its allied equipment will be fired up a test tower. Two mock-up cockpits, a pilot's and an observer's, will be constructed so that they can be assembled and fixed individually in the correct position relative to the tower mechanism.

5.2.2 The object of these tests will be as follows:

To test the structural integrity of the seat equipped with the R.C.A.F. survival pack and container and effect of the pack and container on the spinal accelerations and on the cockpit clearances.

To test the operation of the restraints for head, shoulders, arms and legs. In a 'linked' system, it is of the utmost importance that the crewman can be safely ejected with no prepositioning of any part of his body.

To make preliminary tests of the cockpit clearances of various sizes of anthropomorphic/metric dummies and live subjects having due regard to the fact that these are static tests with a simplified and constrained trajectory.

To test the performance of the ejection gun with respect to variations in ejected weights, cartridge temperature and aircraft load factor.

5.2.3 The following tests shall be done.

NO OF SHOTS	GUN CARTRIDGE TEMPERATURE	SIZE OF DUMMY		AIRCRAFT LOAD FACTOR	COCKPIT
2	-65°F	95%		1	Pilot
2	60°F	95%		1	Pilot
2	160°F	95%		1	Pilot
2	60°F	5%		1	Pilot
2	60°F	95%		1	Obs.
2	60°F	5%		1	Obs.
2	60°F	95%		4	Pilot
2	60°F	95%		8	Pilot
1	60°F	95%	*	1	Pilot
1	60°F	5%	*	1	Pilot
1	60°F	95%	*	1	Obs.
1	60°F	5%	*	1	Obs.

* Live Subject.

5.2.4 The following data will be acquired:

Inspection of the seat, dummy and mock-up cockpit prior to, and after, ejection to assess damage, if any. Film presentation of the movement of the dummy during ejection from the cockpit.

Continuous traces of the vertical and horizontal accelerations of the dummies chest, head and limbs.

Continuous readings of the seat velocity, loads on the seat pan, seat back and gun attachment points.

These traces will be taken on a time base with the point of initiation clearly recorded.

5.3 <u>Ground and Rig Tests</u>

5.3.1 Adequate rig testing of the canopy emergency actuation system has all ready been carried out, reference: Canopy Functioning TestsAvro, ATR No. 2472/1 etc. A series of firings, however, shall be carried out to check the performance of the ballistic-delayed Pilot's Gas Generator cartridge, over the temperature range -65°F to 160°F.

5.3.2 A seat shall be placed in a rig and shall withstand, without permanent set, the loads derived from paragraph 29.1 of Appendix 1 using a 95 th. percentile man, and without structural failure, the ultimate loads similarly derived from paragraph 29.2 of Appendix 1.

5.3.3 A seat will be placed in an aircraft cockpit, the gun will be replaced by a tube. With a 95th percentile man in the seat, it will be drawn slowly up the tube. The operation of the head, shoulder, arm and leg restraints will be checked and, with all these restraints fully operative, a check will be made that the crewman is able to operate the firing control and the restraint manual release. The operation of Composite Leads Disconnect, the Distress Signal Device and any other relevant mechanism, sequences and clearances shall be checked.

5.3.4 The tests of paragraph 5.3.3 will be repeated with a 5th percentile man and conducted in both the Pilot's and Observer's cockpit.

5.3.5 All the components of the system will undergo qualification test procedure.

5.4 Wind Tunnel Test

Dynamic wind tunnel test techniques will be used to evaluate the stability, trajectory and altitude versus time relationship of the seat-man combination in free flight, after ejection from the aircraft under various flight conditions. Two model seats will be ejected from a model of the Arrow 2, at points in the escape envelope considered typical of the areas which will not be covered by the sled tests or possible flight tests proposed in paragraphs 5.6 and 5.7. Filmed records of the movements of the seat after ejection will be obtained. The following tests will be conducted:

MACH NO.	ANGLE OF YAW	ALTITUDE
1.2	0	Sea Level
1.2	5°	Sea Level
2.25	0	35,000 feet
2.25	15°	35,000 feet
2.25	0	70,000 feet
2.25	15°	70,000 feet

5.4 (continued)

This type of test will not yield the fundamental information required to correct the seat characteristics if they should be unsatisfactory. In order to determine all the relevant aerodynamic coefficients and to compute the trajectories and rotations of the seat man combination and the pressure forces acting on the crewman, something in excess of 500 runs in the wind tunnel and a formidable computation program would be required to cover the basic minimum of cases. On account of the time and cost involved only dynamic tests will be conducted, unless the results indicate that the stability of the seat has to be improved, when an investigation will have to be carried out into the best method of testing during such a development program.

5.5 Static Ejection

5.5.1 This test shall consist of ejecting both seats from an aircraft at rest by initiating the escape sequence by remote control. The object of the test will be to test the ejection sequence and cockpit clearance in an actual aircraft and to prove escape capability on the runway.

5.5.2 The following data will be acquired:

Inspection of the dummies and cockpits prior to, and after, ejection to assess damages, if any.

Film presentation of the movements of the dummies during ejection from the aircraft and of the proximity of the men and the seats during the complete ejection operation. A measurement of all the time intervals in the ejection sequence of the seats.

5.6 Sled Tests

A two-phase rocket sled program will be carried out. The first phase will be carried out using an existing type of standard sled and the second phase will involve the use of an Arrow 2 sled.

5.6.1 Phase 1:-

This will consist of single seat ejection from an existing type of standard sled. The object of this test will be to obtain information on the dynamic performance of the seat and the R.C.A.F. personal equipment.

Runs will be made at: 500, 600, 700 and 750 knots. 95th percentile dummies will be used.

The data to be obtained from this test will be:

Film presentation of the seat and dummy during and after ejection. This should cover the operation of the restraints, free flight of the seat, operation of the drogue gun, seat-man separation, deployment of the main parachute and descent to the ground.

Longitudinal and vertical accelerations of the test vehicle, and also, a record of distance of the sled versus time will be taken.

Continuous recording of the following will be made:

Lateral accelerations at the heart location and at the head; Vertical accelerations at the heart; sideways accelerations at the heart; pitch and roll rates; and the total dynamic pressure on the dummy's chest.

5.6.2 Phase 2:-

These tests will be run on an aerodynamically, but not necessarily structurally, representative sled fitted with a complete aircraft canopy system and with a representative opening in the pilot's bulkhead. These will provide a check of the entire system over the range indicated in Fig. 2.

5.6.2 (continued)

The conditions for the runs will be as follows:-

TEST	MACH NO.	GROUND SPEED M.P.H.	COCKPIT DIFFERENTIAL PRESSURE - P.S.I.	SEQUENCE
1	0.135	100.1	0	Obs.-Pilot
2	0.5	373.7	+5.89	Obs.-Pilot
3	1.16	867.1	0	Obs.-Pilot
4	1.16	867.1	+4.15	Obs.-Pilot
5	1.16	867.1	+4.15	Pilot Alone
6	1.20	897.0	0	Obs.-Pilot

This assumes that the tests will be made at one altitude of 5,300 ft. Test number 5 is to be made with the pilot alone ejecting and is intended as a check of the loads and performance of the Pilot's canopy and seat should the sequencing fail.

All these tests will be made with 95th percentile dummies.

The instrumentation for the motion of the sled and the dummies and seat shall be the same as in paragraph 5.6.1

The instrumentation for canopies shall be as follows; signals showing the instants of initiation of both sets of canopies; continuous records of the loads in all four canopy operating links; continuous records of the gas pressures in both canopy systems; continuous records of the strains at about 12 locations on the canopy and cockpit structure; continuous records of pressures in both cockpits; continuous records of the angular displacements of the four canopies; film presentation of the latch and opening mechanism action for each cockpit.

5.7 Flight Tests

In order to obtain data on the performance of the system at different altitudes, and higher Mach numbers some ejections will be made from the rear cockpit of the Arrow 2, if feasible points in the flight envelope can be established from data acquired during the Arrow 1, Flight Test Program. An approximate total of 3 tests one low speed and one high speed at 30,000 ft. and 1 at 50,000 feet, are expected to be sufficient to give the required check points.

The instrumentation for this test will be the same as in Phase 2 of the Sled Test Program but the trajectory of the dummy after ejection will not be measured, Film presentation of the free-fall, seatman separation and parachute descent will be made from an accompanying aircraft. Facility for closing the rear cockpit canopy after ejection of the dummy will be made available to the pilot.

5.8 Number of Seats Required

The number of seats required for the Test Program is shown, broken down for the various test.

Tower test	4 seats
Ground and Rig Tests	2 seats
Wind tunnel test	0 seats
Static Ejection	2 seats
Sled Test - Phase 1	4 seats
Sled Test - Phase 2	11 seats
Flight Test	3 seats
Spares	8 seats
TOTAL NO.	34 seats

6. SYSTEM EVALUATION

The result of all the tests in section 5 will be reviewed and extrapolation and interpolation will be used to define by analysis the capabilities of the Escape System throughout the full flight envelope of the Arrow 2.

6. SYSTEM EVALUATION (continued)

The presentation of the results of this test program shall take the form of two envelopes: one in which the structural integrity of the escape system shall be maintained; and one in which the crewman shall not be subjected to conditions more severe for aircrew during escape than the R.C.A.F. physiological tolerances.

7. PROGRAM

A tentative schedule for this development program is shown in Fig. 3.

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PERFORMANCE LIMITATIONS OF EXISTING MARTIN BAKER MK C5 EJECTION SEAT

AREA ① = AREA ACCEPTED AS SAFE ON BASIS OF AVAILABLE DATA.
AREA ② = AREA EXPECTED TO BE SAFE
AREA ③ = AREA BELIEVED TO BE UNSAFE

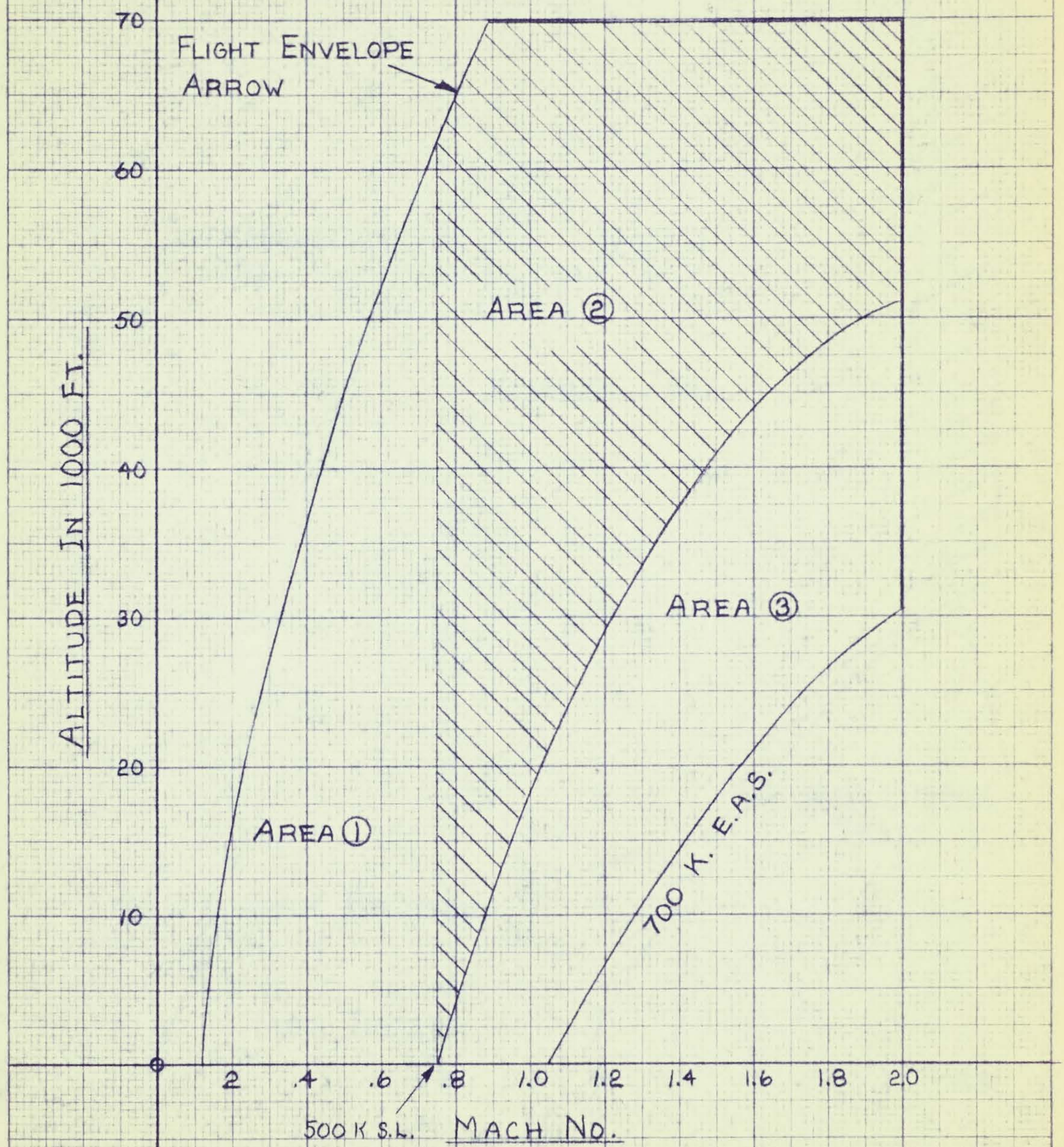

FIG. 1

Methods Of Investigating Areas In The Escape Envelope

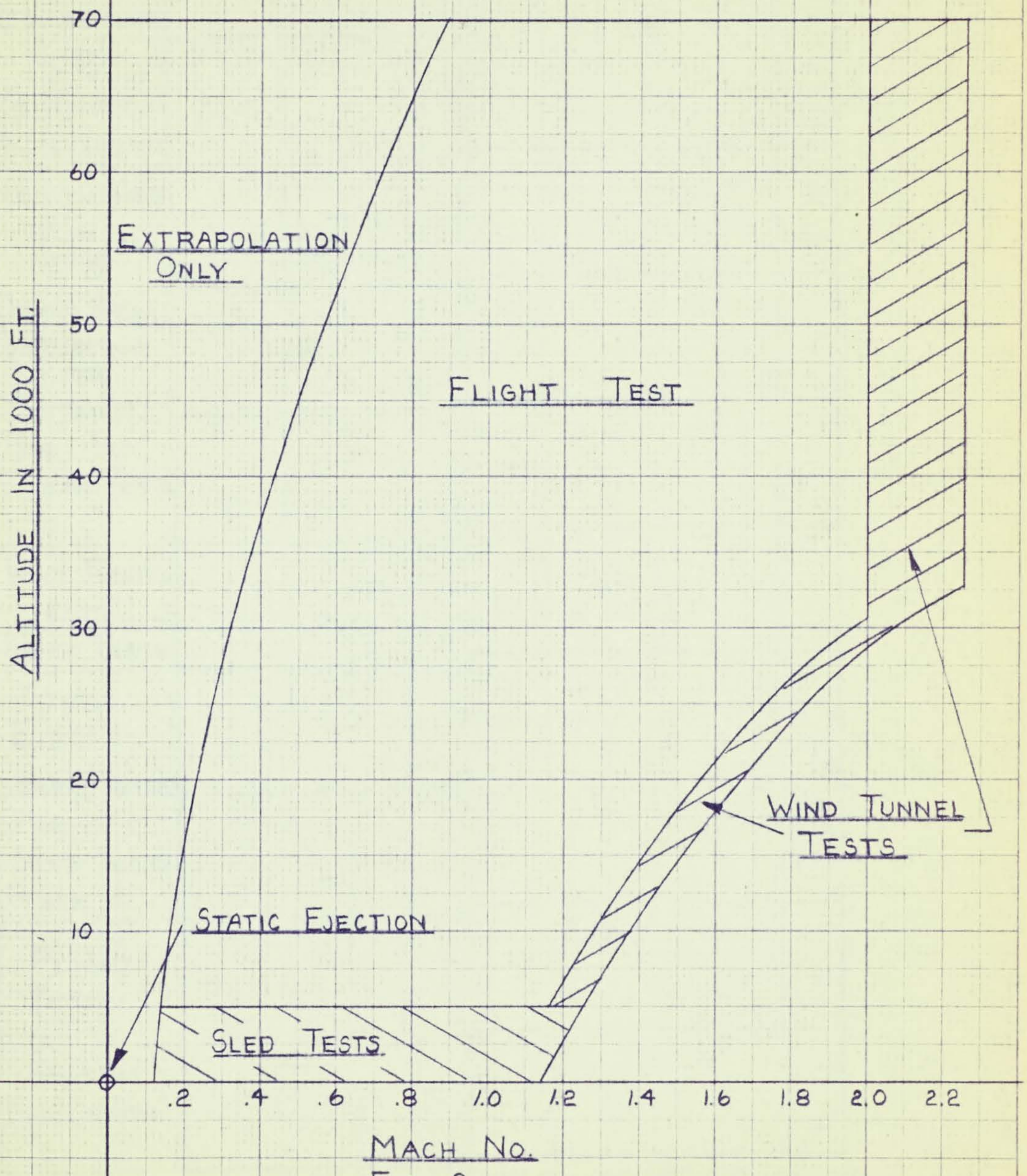

Fig. 2

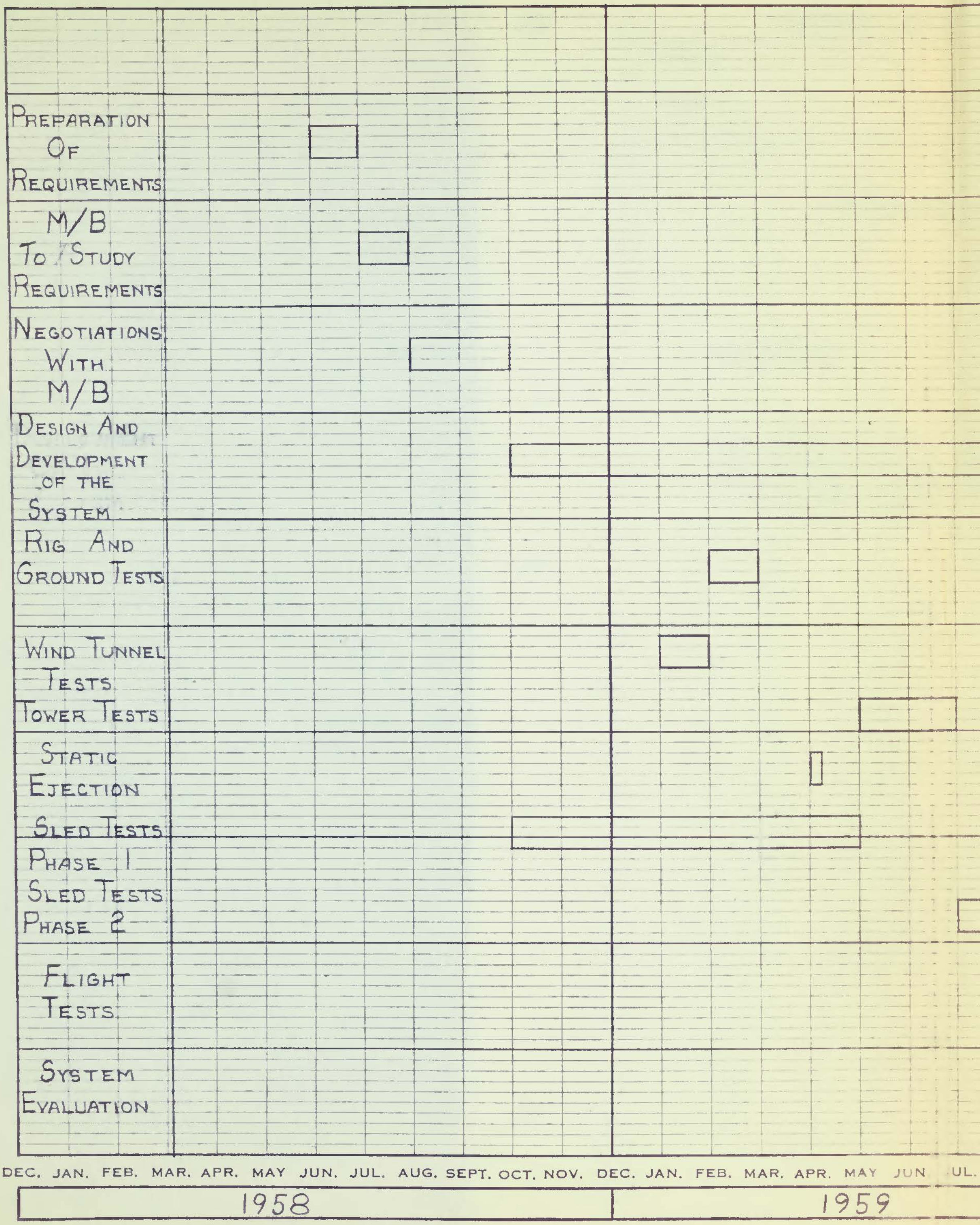
Preparation Of Requirements
M/B To Study Requirements
Negotiations With M/B
Design And Development of the System
Rig And Ground Tests
Wind Tunnel Tests
Tower Tests
Static Ejection
Sled Tests Phase 1
Sled Tests Phase 2
Flight Tests
System Evaluation
DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN JUL.
1958
1959

Fig. 3

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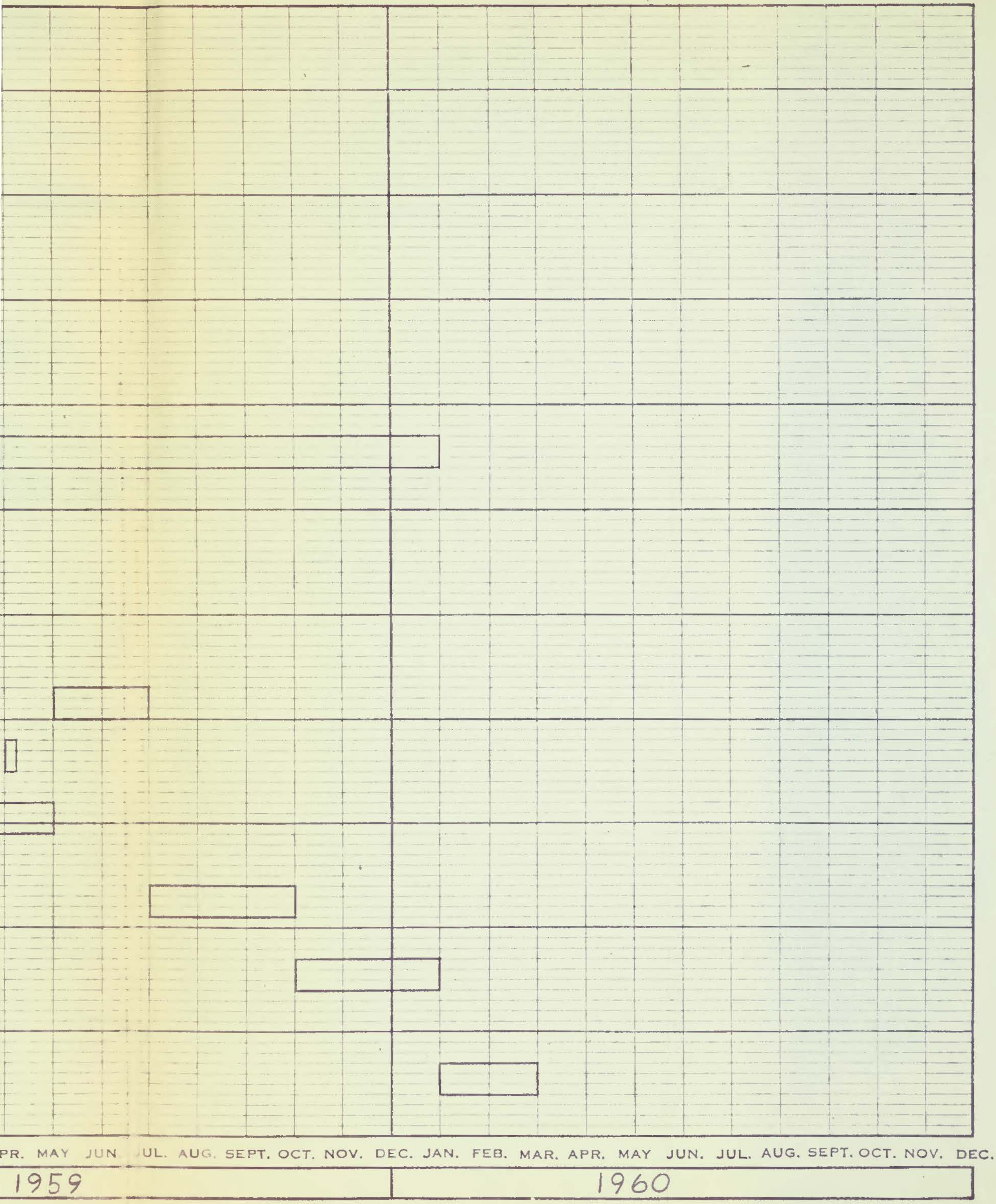

FIG. 3

AIRCRAFT:		PREPARED BY	DATE
ARROW 2	APPENDIX 1	M. Davis, K. Korsak	
		CHECKED BY	DATE

REQUIREMENTS FOR AN UPWARD EJECTION SEAT FOR THE

ARROW 2

Introduction

This section presents the detailed requirements for an ejection seat for the Arrow 2 designed for operation as part of a 'Linked' system. These requirements are subject to paragraph 3.1 of Report No. 72/SYSTEMS 24/205.

AVRO AIRCRAFT LIMITED
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REQUIREMENTS FOR AN UPWARD EJECTION SEAT FOR THE ARROW 2

1. GENERAL REQUIREMENTS

1.1 Normal Use

In normal use, the seat shall be as comfortable for the crewman as possible and it shall be adjustable to suit a range of size as defined in paragraph 14.

1.2 Seat Geometry

The seat geometry and attachments to the aircraft shall conform to the requirements of paragraph 11.

1.3 Seat Harness

The seat shall be equipped with an integrated harness as defined in paragraph 4.1

1.4 Crash Landing

In the case of a crash landing the seat shall conform to the requirements of paragraph 12.

1.5 Emergency Escape

For an emergency escape from the aircraft, the seat shall provide safe egress under the full escape envelope of the aircraft, as defined in paragraph 16 and the ejection space envelope of paragraph 13.

1.6 In normal use and for emergency escape, the seat shall fulfill all the requirements considering a most adverse combination of weight, dimension and equipment, defined in paragraph 14 & 15.

1.7 Descent

After ejection from an aircraft, flying at any speed and altitude within the flight envelope, in any position with respect to the horizon, and experiencing any accelerations, resulting from maneuvering as defined in paragraph 17, the crewman shall not be permitted to exceed the human tolerances, as defined in paragraph 18, shall safely sep rate from the seat; and shall be able to land safely on a hard, unobstructed land surface or in the water.

At very low altitude, safe egress from the aircraft shall be expected over as large as possible a range of aircraft position, with respect to the horizon.

1.8 The seat shall be designed to be ejected by means of energy derived from burning of a solid propellant fuel.

2. ENVIRONMENTAL CONDITIONS

The seat shall operate satisfactorily when subjected to a most adverse combination of the following conditions:

2.1 Prolonged soaking at temperatures ranging from -65°F to 160°F.

2.2 In relative humidity up to 100 percent, including conditions wherein condensation takes place in the form of both water and frost.

2.3 Exposure to salt laden atmosphere.

2.4 Induced vibrations of frequencies and amplitudes, defined in paragraph 19, and applied to the seat through the attachment points, defined in paragraph 11.

2.5 With sand and dust particles as may be encountered in desert areas.

2.6 Exposure to sea water and to conditions favouring fungus growth.

3. OPERATION OF THE SEAT ON EJECTION

The seat shall be designed as part of a system in which the Pilot operates one firing control to eject the Observer and then himself in automatic sequence; the Observer, however, shall be able to eject himself independently. This sequence shall be achieved in the following manner:

3. OPERATION OF THE SEAT ON EJECTION (continued)

(1) When the Pilot operates his firing control, he shall simultaneously remove the sears from both his own and the Observer's emergency canopy opening system.

(2) The Pilot's canopy cartridge shall have a 0.5 second ballistic delay incorporated into it to sequence the ejection of the two seats.

(3) The seat design shall permit the initiation of ejection either with, or without, the use of its own ejection handle. Thus the Pilot's and Observer's seat shall be interchangeable

The detailed operation of the seat in both firing modes will be as described below:

3.1 Operation Through the Use of The Pilot's Seat Ejection Handle

Operation of the Pilot's handle defined in paragraph 2.4 shall simultaneously remove the sear from both the canopy systems; remove the safety catch of both seat ejection cartridges and initiate the operation of both sets of head and shoulder restraints, defined in paragraph 4.2.

The Observers canopy will commence to open immediately but there shall be a 0.5 second delay before the Pilot's canopy commences to open. Both systems will operate independently for the rest of the sequence, as described below.

The movement of the seat relative to the guiding rails, which stay with the aircraft, shall be used to operate the leg and arm restraints, defined in paragraphs 4.3 and also operate a quick disconnect for the personal leads and bring the emergency oxygen into operation.

3.1 Operation Through the Use of The Pilot's Seat Ejection Handle (continued)

A stabilizing device will be deployed during or immediately after ejection of the seat from the aircraft. The time of deployment of this device shall be regulated to assure that the seat with the device deployed shall not interfere with the ejection path of the seat and that no excessive accelerations occur during and after its deployment.

Automatic Man-seat separation shall immediately follow the deployment of the stabilizing device, except for a delay which shall be provided, as defined in paragraph 20, to prevent this separation occuring at too high an altitude and at too high a forward speed.

3.2 Operation through the Use of The Observer's Seat Ejection Handle

Operation of the Observer's handle, defined in paragraph 24, shall remove the sear from the Observer's canopy system, remove the safety catch from his seat and initiate the operation of the head and shoulder restraints, defined in paragraph 4.2. The Observer's seat will then be ejected from the aircraft as described above, in paragraph 3.1.

4. RESTRAINTS

The restraints shall be designed to protect the crewman during normal flights, crash landing and during and after ejection from the aircraft.

4.1 Harness

The harness shall be of the integral type, i.e. it shall combine the personnal parachute harness with the seat harness.

During normal aircraft operations the harness shall provide adequate adjustment allowing it to be tightened according the the dimensions of the seat occupant, as defined in paragraph 14. As a design objective, the harness should be partly incorporated into the crewman's clothing and attached to the seat by four plug-in connectors. This harness shall be so designed that operation of a single control shall free the crewman from his personal parachute.

4.1 Harness (continued)

A conventional set of straps, with a central locking point would also be acceptable. If used, the strap locking device shall be simple and fool-proof in operation. It shall embody a quick release mechanism lock, to prevent inadvertant release. The design shall exclude the possibility of the quick release being unlocked after the belts are in place, i.e. it shall not be possible to engage the belts when the quick release mechanism is unlocked.

The harness shall upon the manual operation of a release control allow the seat occupant to lean forward when required. This mechanism shall be so arranged that upon the occupant's partial, or complete, return to the ejection position, he will be restrained.

The harness shall retain its normal flexibility throughout the operating conditions of paragraph 2.

The survival pack shall be attached to the crewman by this harness and shall remain with him after man-seat separation.

The harness shall be able to retain the crewman, except his limbs, within the following space envelopes:

1) In crash landings within the envelope of paragraph 12.

2) During emergency escape within the envelope of para. 13.

4.2 Head and ShoulderRestraints

These restraints shall supplement the harness in assuring that during ejection, the crewman's torso is kept in the ejection position, with the head, neck and the vertebrae in a straight line parallel to the direction of ejection.

These restraints shall in no way hinder the crewman during performance of his normal duties.

4.2 Head and Shoulder Restraints (continued)

The head restraint will provide protection against flailing and other effects of windblast.

The shoulder restraints shall prevent the shoulders moving forward during ejection. As a design objective, the shoulder restraint shall partially support the weight of the upper portion of the crewman's torso, thus preventing high compression loads on the vertebrae of the pelvis region.

The head and shoulders restraints shall become fully effective prior to the onset of any high accelerations, caused by the ejection, on the crewman.

4.3 Leg and Arm Restraints

These restraints shall prevent the legs and arms from flailing during and after ejection.

The leg and arm restraints shall be operative before the crewman is exposed to windblasd, and shall prevent the crewman, or his personal equipment, from fouling any part of the cockpit during ejection.

The arm restraints shall not prevent the crewman operating the firing mechanism or a manual release to free himself of the restraints. As a design objective, the arm restraints shall assist in taking compression loads as in paragraph 4.2.

5. SURVIVAL PACK STOWAGE

Space shall be provided in the seat pan for a survival pack, defined in paragraph 6.

This pack shall be located beneath the seat cushion and shall be connected to the harness as described in paragraph 4.1.

6. SURVIVAL PACK

The survival pack shall be an R.C.A.F. supply item. It shall consist of a rigid outer shell, containing survival equipment, which shall be designed to prevent the crewman submarining during ejection. The weight of the survival pack shall not exceed 30 lb.

The seat pan shall be designed to accomodate this pack. The pack dimensions shall be supplied by the R.C.A.F.

7. SEAT CUSHION

A cushion shall be provided to make the seat comfortable and reduce fatigue of the crewman. The elastic properties of this cushion shall be designed to avoid detrimental effects on man-seat dynamics.

8. HEAD REST

An adequate head rest shall be provided.

9. LEG AND FEET SUPPORTS

Supports for the crewman's legs and feet shall be provided.

These supports shall be so designed as to prevent the legs and feet being bent backwards by the Windblast during and after ejection.

10. SEAT VERTICAL ADJUSTMENT

A seat adjustment mechanism shall be mounted on the seat to provide a vertical adjustment of the seat pan so that a 50th percentile man shall, with his eye at the normal eye level for the aircraft, as shown in Avro drawing no. 7-4452-7, have available an adjustment of vertical seat pan movement through ± 3 inches. The seat adjustment control shall be so designed that it cannot be inadvertantly operated, but shall be operable with a minimum of effort by the crewman.

11. SEAT GEOMETRY AND ATTACHMENT FITTINGS

The dimensions and configuration of the seat shall be within the envelope of Avro Drawing No. 7-2852-83.

The attachment fittings shall be as shown in Avro Drawing No. 7-1052-15113.

12. CRASH LANDING CASE SPACE ENVELOPE

The seat and harness shall be so designed that under the applied crash loads, as defined in paragraph 28, the crewmans torso and head should remain within the envelope of Avro Dwg. No. (to be issued).

13. EJECTION SPACE ENVELOPE

During ejection the crewmans head, torso and limbs will be kept within the envelope as shown on Avro Dwg. No. 7-4452-7

14. DIMENSIONS AND WEIGHT OF CREWMEN

The crewman will have the following range of dimensions and weights (clothed):

To be supplied.

15. PERSONAL EQUIPMENT

The crewman's personal equipment shall be the responsibility of the R.C.A.F. and shall be compatable with the escape system requirements.

16. ESCAPE ENVELOPE

The Escape Envelope of the Arrow 2 for which the seat shall be designed will be as shown in Figure 1., including zero speed at zero altitude.

17. MANOUVERING ENVELOPE

During manouvering the aircraft will be subjected to the following maximum accelerations:

1) Normal upwards accelerations of 7.33 G.

2) Normal downward accelerations of 3.0G.

3) Normal side accelerations of 2.0 G.

4) Forward accelerations of 11 G.

18 HUMAN TOLERANCES

The acceptable human tolerances will be agreed upon, in detail, by Avro and the R.C.A.F. and supplied to the seat manufacturer. However, the following values shall be used as design criteria:

18.1 Acceleration up the seat rails: The seat-man combination shall not be subjected to an acceleration greater than 25 G and a rate of rise of acceleration greater than 300 G/sec.

18.2 Transverse deceleration: During free flight the seat-man combination shall not be subjected to an acceleration-time relationship which exceeds the "Zone of Safety" in Fig. 2.

19. INDUCED VIBRATIONS

The seat will be subjected to vibrations applied to its attachment fittings, of the frequencies and amplitudes as specified in Avrocan Specification No. 266.

20 ALTITUDE AND DECELERATION DELAY MECHANISM

20.1 High Speed Override

In the case of an ejection at high speed of the aircraft, the seat shall be fitted with a device which will ensure that the personal parachute can be deployed, at the earliest moment, without suffering structural damage.

20.2 Altitude Override

In the case of an ejection above an altitude of 5000 metres, a device will be fitted to the seat which will ensure that seat man separation and parachute deployment does not occur until the seat has descended to an altitude of 5000 metres.

In the case of an ejection below the altitude of 5000 metres man-seat separation shall be allowed to occur immediately.

The tolerances on this device shall be + 300 metres with no downward tolerance.

21. MANUAL OVERRIDE

A manual override control shall be provided which shall enable the crewman to release himself manually from the seat as an alternative to the automatic release. A simple warning system should be fitted to the seat to ensure that, when the seat is below 5000 metres, should a failure of the automatic release mechanism occur the crewman himself may operate the manual release.

The release shall be designed for easy operation by the crewman with all the restraints in operation.

22. AUTOMATIC RESTRAINT RELEASE MECHANISM

The seat will be fitted with a device which will simaltaneously release all the restraints, the composite leads disconnect and the drogue chute, if fitted, from the seat.

23. COMPOSITE LEADS DISCONNECT

Provision shall be made for mounting a composite leads disconnect.

The disconnect shall be provided with a release mechanism which will operate in conjunction with the automatic release or manual release in the case of seat-man separation after ejection, or during normal exit from the cockpit.

23. COMPOSITE LEADS DISCONNECT (continued)

The installation of the disconnect and its allied equipment shall be so designed that it will not foul any of the crewmans restraints during ejection and shall not flail after seat-man separation.

24. EJECTION HANDLE

The ejection handle shall be so designed that a single operation of it will initiate the ejection sequence, as defined in paragraph 3. It shall be so positioned on the seat that the minimum movement of the crewman will be required to grasp it from the position of his hands during his normal duties. Operation of the control should require the minimum effort of the crewman, when subjected to the accelerations of paragraph 17, and should be so designed that it cannot be inadvertantly operated.

The design of this control shall be such that it can be operated by the crewman with either one or both gloved hands.

25. SAFETY DEVICES

Safety devices shall be provided to prevent inadvertant firing of the seat under the following conditions:

25.1 For normal ground servicing.

25.2 When operating the emergency canopy control. This safety device shall be encorporated in the seat-firing sequencing of paragraph 3.

26. EJECTION RAILS

A set of ejection guides shall be supplied with the seat to be attached to the aircraft structure as defined in paragraph 11. They shall be sufficiently rigid to prevent excessive deflections, such as would cause binding of the rollers or slide blocks, or allow the rollers to jump the rails, under loads implied by aircraft maneuvres or due to wind blast. The rails will provide the maximum length of guided stroke as is practicable in the cockpit.

30. EMERGENCY OXYGEN SUPPLY

The seat will be fitted with an emergency oxygen supply which will be switched automatically into operation when the seat is ejected. This supply will contain at least 20 minutes supply of oxygen.

31. GEAR UP LANDING DEVICE

As a design aim the seat shall be provided with a device to prevent injury to the crewman's spine, due to impact of the aircraft on the ground, during a 'gear-up' landing. This device need not be in operation during normal use and during ejection; but may be engaged by the crewman prior to such a landing. The exact requirements for this device will be issued at a later date.

SECRET

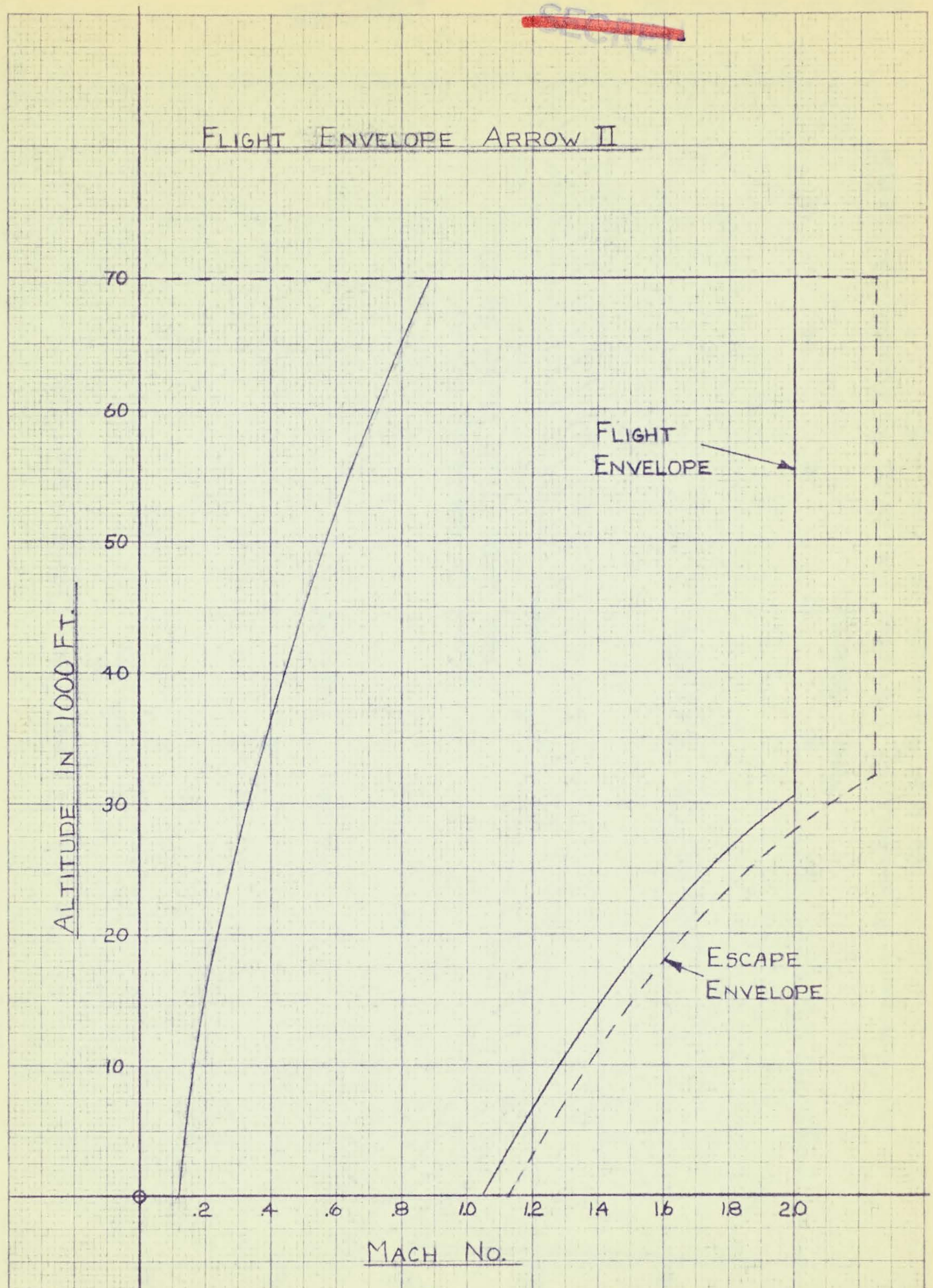
FLIGHT ENVELOPE ARROW II
ALTITUDE IN 1000 FT.
70
60
50
40
30
20
10
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
FLIGHT ENVELOPE
ESCAPE ENVELOPE
MACH NO.

FIG. 1.

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TECHNICAL DEPARTMENT

SECRET

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AIRCRAFT: ARROW 2	APPENDIX 2	PREPARED BY: R.E.F. Lewis	DATE
		CHECKED BY	DATE

HUMAN FACTORS NOTE

THE REQUIREMENT FOR "LINKED" CREW ESCAPE FROM THE ARROW

This was originally issued as Report No. 72/SYSTEMS 24/210

THE REQUIREMENT FOR "LINKED" CREW ESCAPE FROM THE ARROW

INTRODUCTION

When a single place high perfromance aircraft must be abandoned, the pilot need make only one major decision - to escape. To execute this decision he simply operates a firing handle which initiates an automatic ejection sequence. Once this decision has been made there is very little further delay. The entire escape sequence for the single place aircraft pilot should take only one second approximately from the time at which the pilot reaches for the firing handle to the time at which he is clear of the fuselage.

The pilot of a tandem-crewed aircraft faces a more complex situation however. When his aircraft must be abandoned he has first to order his observer to escape, and as captain of the aircraft, waits until the observer has ejected before ejecting himself.

The events occuring within the Arrow tandem-crew escape sequence take an average of eight seconds approximately * to complete from the time at which the pilot commences to order the observer to escape, to the point in time at which both men are clear of the aircraft fuselage. However, this figure (8 seconds) can only be regarded as a best possible average, for it was obtained under ideal conditions. In actual escape the time may well be

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* This average time for escape was obtain in a study of crew behaviour during simulated escape sequences [1] in the Arrow Mock-up. Rather better times were shown in some of the sequences measured, but, more important, considerably longer times were shown on others - the longest time measured was almost 13 seconds.

extended for the following reasons.

(a) The observer may not understand the escape order. This could be because of the unexpected nature of the message [2]. Also, the spoken order may lose intelligibility [3] according to the stress conditions experienced by the pilot. In these circumstances the observer may ask for the message to be repeated.

(b) The observer may not agree with the pilot's order to escape and may debate the issue.

(c) The observer may refuse to eject.

These reasons are valid. Incidents have occured in which pilots have met this type of response to their order to eject. This is understandable when one considers that escape by ejection is not without hazard and whereas some observers may be poised waiting to eject with alacrity, others may quite understandably hesitate before resorting to ejection. Perhaps the important difference between pilot and observer attitude to escape is that the pilot is constantly checking for malfunctions or conditions that may lead to escape and also is the only man properly able to assess these conditions. On the other hand the observer is really a passenger in this respect. Whereas he does a most important job as navigator and radar operator, he is not concerned with the functioning of flying controls, engine etc., and almost certainly is often quite unprepared for the escape order.

<u>The Significance of Short Periods of Time in Escape with Respect to the Arrow</u>

There are two clear reasons why delay in escape from the Arrow should be reduced as much as possible.

(a) The Aerodynamic reason.

It has been predicted, that in a small high EAS portion of the Arrow flight envelope, should a double failure occur in the flying control or damping system, the aircraft will commence a yaw divergence which will build up very rapidly. In these circumstances crew escape (ejection of both occupants) must be executed within a period of approximately three seconds from the onset of the divergence. Beyond this point in time the aircraft may suffer structural failure.

(b) The low level reason.

There is ample evidence that aircraft have at times to be abandoned quite near to the ground.[4] The majority of accidents occur during landing and take-off. The reasons for escape near the ground vary, as they do at altitude e.g. loss of power, loss of control, structural failure, control system failure, fuel shortage etc., but the important difference is that when these incidents occur near to the ground it is probable that very little time is available for the escape. This point is best illustrated by two accidents to CF100 aircraft.

(1) The first incident concerns the aircraft which, during a low level high speed run at an air show, exceeded the G. limitation for that altitude. From the time at which the aircraft wing tips failed structurally, to the time at which the aircraft struck the ground, some ten seconds elapsed. After five seconds the pilot ejected, but because of incorrect personnal harness adjustment, stayed attached to the seat and was killed. The observer was killed because he did not eject.

(2) The second incident concerns the aircraft which was lost at the 1957 C.N.E. waterfront rehearsal. This aircraft, flown by an experienced CF-100 pilot, fell in an inverted spin from a height of approximately 5,000 feet above the ground. It has been calculated that the crew had some twenty-five seconds in which to escape (assuming that no spin recovery should be attempted at that low altitude). Shortly before the aircraft struck the water one man ejected. The other occupant did not eject. Both were killed.

It seems reasonable to assume that in both of these accidents, at some point in time beyond that at which the condition demanding escape occurred, the pilot ordered his observer to escape. This order must (as has been demonstrated) have taken time to execute.

It is the purpose of this note to point out that had a "linked" escape system been installed in these aircraft:-

(a) All four men would certainly have been ejected.

(b) All four men would probably have been ejected sooner, with a better chance of survival for three of them - the exception being the pilot whose personal harness was improperly connected.

(c) Both pilots would only have been required to make the decision to escape - no order to escape to the observer would have been necessary.

A "linked" escape system would be such that the pilot, by operating one control, would eject both the observer and in turn, himself. Such a "linked" system could reduce total crew escape time to 2.5 seconds. It would, however, be necessary to provide complete automatic restraint prior to ejection for the observer, and in addition an override permitting independent observer escape.

Several lives have almost certainly been lost in tandem-place, high performance aircraft in the past because total time for two men to escape is unduly long. This is particularly true with respect to incidents occuring near to the ground. Arrow crews face precisely the same escape situation, plus the high speed problem mentioned above. One solution is to incorporate a "linked" system. This will

(a) Reduce total crew escape time to 2.5 seconds.

(b) Permit the pilot to initiate crew escape by operating one control.

(c) Eliminate observer hesitation or refusal.

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Classification cancelled / changed to Unclassified
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Signature Bdubray, Co-Chairperson
Unit / Rank / Appointment DSIS 3