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ARROW 2 READINESS FACILITY

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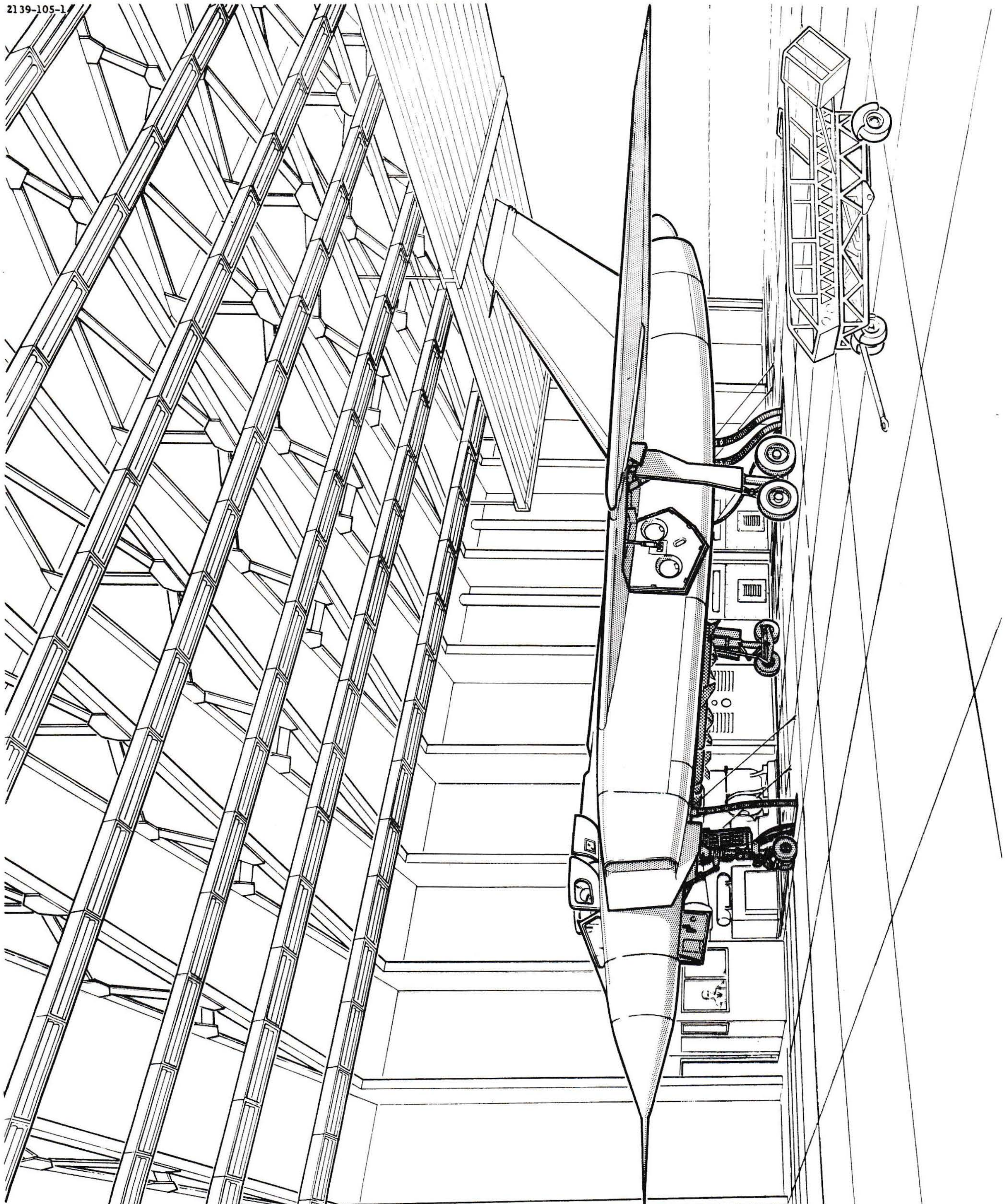

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1. Abstract

1.1 Introduction

In October, 1955 the R.C.A.F. requested Avro Aircraft Limited to conduct certain engineering studies in order to ensure that the R.C.A.F. would be adequately prepared to support and maintain Arrow 2 aircraft in the field. One of these studies was to cover the mobile equipment and stationary ground facilities that would be required to maintain the Arrow 2 aircraft at readiness.

1.2 Purpose of Report

The purpose of this report is twofold:

(a) To outline the requirements for facilities and equipment which will be needed in order to maintain the Arrow 2 aircraft at various states of readiness.

(b) To make recommendations concerning the facilities and to specify equipment.

1.3 Discussion

It was intended originally to have this report compare detailed design proposals for ground support equipment for use in the readiness hangars and to make recommendations concerning specific items of equipment. However, this has not been possible since some of the fundamental requirements for the Arrow 2 are not yet firm and, in addition, others will require consideration and acceptance by the R. C. A. F. before detailed specifications for ground support equipment can be prepared. For these reasons, this report has reviewed the design requirements for the Arrow 2 aircraft and has outlined the factors which will determine or affect its states of readiness based on present knowledge. It remains then for these other factors to be resolved so that the requirements for the ground support equipment and readiness hangars can be specified in detail. Specifically, the following items need clarification:-

(a) Readiness capabilities of Astra 1 integrated electronic system. On the one hand it is hoped that the system can be left "off" and be considered serviceable and operational within 5 minutes at any time. On the other hand a large amount of high-quality electrical power and cooling air may be required continuously, with periodic breaks in the aircraft's readiness status to permit serviceability checks. Primarily, this will affect the requirements for emergency power and possibly for equipment to cool the readiness hangars to overcome the temperature rise if the Astra system is in operation for long periods of time. Primary power for the electrical and cooling air supplies will be required in any case, since it is desirable to be able to warm and operate the electronic system just prior to starting a mission.

(b) Design combat mission for the aircraft. The maximum fuel temperature at the start of a mission should be 70°F. If the mission involves 10 minutes flying at Mach 2, but may be up to 110°F, if Mach 1.5 is not exceeded. A limit of 70°F. (maximum) would create a need for equipment to cool the readiness hangars, or would limit the duration of high states of readiness during very hot weather.

(c) Ambient conditions for the design of the cooling air supplies. Limiting temperatures and dew points for the design of the cooling air supplies have been suggested in the report. These must be accepted, or alternatives stated by the R. C. A. F., before equipment can be specified. The design proposal presented in App. 1 of this report has been based on the figures suggested in this report.

1.4 Conclusions and Recommendations

1. The use of readiness hangars will be necessary with the Arrow 2 in order to meet the scramble and mission requirements for this aircraft under all conditions of weather. These hangars are required in order to shade the fuel tanks and cockpits during hot weather, to protect the aircraft from deposits of snow and freezing rain during bad weather, and to heat the hydraulic systems to at least 0°F. during

cold weather. The R.C.A.F. standard readiness hangars will be suitable for use with Arrow 2 aircraft, but some alterations will be required to accommodate ground support equipment and services to the aircraft.

2. It is noted that the R.C.A.F. standard readiness hangars are sited to provide a lateral clearance of 1000' from the main runway. With this siting arrangement at least 20 seconds will be required to taxi from the readiness hangars to the runway with the Arrow 2 aircraft.

3. A taxi strip from the maintenance area to the rear of the readiness hangars is recommended because with the present arrangement the main approach to the runway can be blocked for periods of up to 1 minute while aircraft are being towed to and from the readiness hangars.

4. The present layout for readiness hangars and crew rooms is considered satisfactory for use with the Arrow 2 aircraft.

5. It is recommended that the hangar doors be capable of being opened fully within 20 seconds in order to be compatible with the Arrow 2 engine starting time.

6. For meeting the "Scramble" and "Standby" requirements the Arrow 2 aircraft will have provision for accepting the following services from ground support equipment:

(a) Hot, medium pressure air for starting the two jet engines as noted below for sea level standard conditions:

Flow - 112 lb./minute (minimum) per engine

Pressure - 50 p.s.i. absolute (minimum)

Temperature - 360 to 500°F.

Simultaneous starting of both engines is required in order to meet the scramble requirement.

(b) Up to 40 K.V.A. of 208/120V, 400 C.P.S. 3 phase A.C. power. All of the aircraft electrical and electronic systems may be energized from a ground supply through this receptacle.

(c) 5 amperes at 275V. D.C. with the main A.C. cable. This power is used to operate the A.C. line relays in the aircraft.

(d) Cooling air. Whenever A.C. power is being supplied to the aircraft, cooling air should also be supplied as below:

Flow - 150 Lb. /minute (maximum)

Temperature - 55°F. to 80°F.

Pressure - 4.5 p.s.i. gauge at the aircraft connector.

(e) Ground wire.

(f) Nose undercarriage cable. A quick-disconnect receptacle on the nose undercarriage leg has provision for

(1) 50 amperes current at 27.5 V. D.C. for operating essential D.C. services if the main A.C. systems are not being energized.

(2) 27.5 V. D.C. signals so that the flow of engine starting air can be initiated by the pilot and stopped automatically when the engines reach a pre-set speed.

(3) Approximately 250 V.A. of 400 C.P.S., single phase, 115V. power per engine for warming the electronic components in the fuel flow control units.

(4) Audio signals for intercommunication with ground crew personnel.

(5) Audio signals for two-way communication with an Operations Controller via land telephone line (Telescramble).

It is recommended that provision be made in the R. C. A. F. standard readiness hangars for running these services under the floor to suitable points below the aircraft. A layout for ducting the services is presented in Fig. 7 of this report.

7. Although the readiness characteristics of the Astra 1 integrated electronic system are not known at present, it is considered desirable to be able to warm and operate the fire control system prior to take-off for a combat mission. On this basis the following services will be required for each Arrow 2 aircraft at "Standby":

(a) Hot, medium pressure air must be immediately available for starting both engines simultaneously.

(b) Electrical power (208/120V., 400 c. p. s., 3-phase A. C.). Up to 30 K.V.A. at 0. 75 power factor will be required. In addition, 5 amperes at 27. 5V. D. C. will be required for operating the main A. C. relays in the aircraft.

(c) Cooling air. 150 lb. /minute of air at a temperature between 55 and 80°F. and a pressure of 4. 5 p. s. i. gauge will be required.

(d) Services through the nose-undercarriage receptacle:

(i) 27. 5V. D. C. signal wires for controlling engine starting.

(ii) Intercommunication with ground crew.

(iii) Telescramble.

(e) Ground wire.

8. For engine starting only, without supplying power and cooling air for the Astra 1 system, the following services will be required:

(a) Hot, medium pressure air for starting the engines simultaneously or in sequence as desired.

(b) Services through the nose-undercarriage receptacle:

(i) 50 amperes at 27.5 V. D.C.

(ii) 27.5 V. D.C. control wire.

(iii) 27.5 V. D.C. signal wires for controlling engine starting.

(iv) 500V.A., 400 c.p.s., 1-phase A.C. power for warming the amplifiers in the fuel flow control units.

(v) Intercommunication with ground crew.

The aircraft might be operated with only these services for training and ferry flights or when A.C. electrical power is not available. In the readiness hangars these services should not be dependent solely on the hangar main electrical supply.

9. Gas turbine compressors are recommended for supplying the hot, medium pressure air for engine starting for the reasons noted below:

(a) They are well suited to the intermittent duty cycle that is anticipated because of their ability to start and to take full load quickly under all temperature conditions.

(b) They are self-contained and therefore are not dependent on an external power supply.

(c) Suitable units are qualified and are in production now and others will be available in time to meet Arrow 2 Squadron requirements.

(d) They are reliable and simple to maintain.

(e) They compare with other types of equipment in initial cost and also in operating costs because of the intermittent duty cycle.

(f) They use JP-4 fuel which will be available at all Arrow 2 bases.

(g) They will be used for mobile starting equipment because they are light and compact. It would therefore be advantageous to use the same equipment in the readiness hangars since ground crew training and logistic support would be simplified.

(h) Although other types of equipment have been designed for this purpose, none are qualified and in production at the present time.

Pending further information concerning the availability of suitable engines and facilities for overhaul, no specific gas turbine is recommended.

10. It is recommended that the 3-phase, 400 C. P. S. A. C power for "Standby" be obtained from a Arrow 2 generator driven by a 50 H. P. synchronous motor through gearing. This unit should also provide 5 amperes at 28 V. D. C. for operating the main A. C. relays in the aircraft. The aircraft generator is defined by Avrocan Specification E-500 but a detailed specification has not been prepared for a ground power unit at the present time.

11. For providing cooling air to the aircraft, an electrically driven compressor and a freon refrigeration system with an air cooled condenser is recommended. A detailed specification for this equipment cannot be prepared until the ambient operating conditions for the system have been considered and stated by the R. C. A. F.

12. Although not needed when the aircraft electrical systems are being energized, a 500 V. A. inverter is recommended for supplying 115V., single phase A. C. power to each aircraft under emergency conditions. It should be powered from the emergency 28V. D. C. power supplies.

13. Existing types of R. C. A. F. equipment will be suitable for supplying 28V. D. C. power for 2 Arrow 2 aircraft. Typical units are:

Normal supply - 100 ampere rectifier (Sect.5P, Ref. #47)

or 500 amp. motor-generator (Sect. 5P, Ref. #60)

Emergency Supply - 3000 watt gasoline-driven generator (Sect. 42, Ref. #1093)

14. The AN/AIC-17 ground intercommunication system is recommended for use in the readiness hangars. Power should be obtained from the 275V. D.C. power supply in the hangar.

15. The mobile retractable stairs designed by Avro Aircraft Limited are recommended for access to the cockpits of the Arrow 2 in the readiness hangars, pending evaluation by the R.C.A.F..

16. It is recommended that all of the controls for the ground support equipment for two aircraft be brought to one control panel and that this be in a room near the front of the readiness hangar. This room should be designed to protect the ground crew from the noise and wake from the Iroquois engines and should have provisions for communication with the aircrew, the operations control officer and the maintenance control officer.

17. The main electrical supply to the readiness hangars should cater for at least 838 K.V.A. in order to maintain 4 Arrow 2 aircraft at "Standby", assuming that the

compressors for engine starting are not powered by electricity.

18. If the electrical supply to the air base should fail, emergency electrical power and cooling air for aircraft at "Standby" should be obtained from mobile power/air conditioning units. While these vehicles are being obtained from the flight line, power would have to be supplied from the air base emergency electrical system. If this system is not capable of supplying the power to the readiness hangars during this period, a 450 K.V.A. diesel-generator set, complete with controls and automatic quick-starting features, should be installed at the readiness hangars to serve each pair of Arrow 2 aircraft at "Standby". Without A.C. electrical power and cooling air being supplied to the aircraft, the Arrow 2 could be started in the normal time, but it should not be taxied until the gyroscopes in the vertical and heading reference system have been erected and oriented. This will require 3 minutes at normal temperatures.

19. Mobile ground support equipment will be developed by Avro Aircraft Limited for the R.C.A.F. in the form of two vehicles; one to provide all of the services related to starting the aircraft, the other to provide electrical power and cooling air for "Standby" and for maintenance work. The

starter will be a self-contained package that will provide:

(a) Hot medium pressure air for starting one engine at a time.

(b) D.C. power - at least 50 amperes at 28V. D.C.

(c) Single phase A.C. power - 500 V.A. at 115 V., 400 c.p.s.

(d) Provision for control of starting air from the aircraft cockpit.

(e) Intercommunication.

The power/air conditioning vehicle will provide:

(a) A.C. Power. Up to 40 K.V.A. of 3-phase, 208/120V., 400 c.p.s. will be available. An aircraft generator and constant-speed drive unit probably will be fitted for supplying this power.

(b) D.C. Power. 5 amperes at 28 V. D.C. will be supplied for energizing the main A.C. relays in the aircraft.

(c) Cooling air. A flow of 150 lb./minute at a pressure of 4.5 p.s.i. (gauge) and a temperature between 55°F. and 80°F. will be available. A gas-turbine compressor with an air-cycle refrigeration system is proposed.

20. At each Arrow 2 base there should be towing vehicles available that are capable of providing a drawbar pull of 7000 lb. under all surface conditions that are likely to be encountered.

2. Introduction

2.1 Authority for Study

On September 27, 1955 a letter (AMC 1038 CN-100 (Act-2-1)) was sent from Air Materiel Command to the Chief of the Air Staff recommending that certain engineering studies be prepared by Avro Aircraft Limited in order to ensure that the R.C.A.F. would be adequately prepared to support and maintain Arrow 2 aircraft in the field.

On October 4, 1955, R.C.A.F. letter S1038-105-11 (ACE-1) from T.S.D.'s/A.V. Roe Canada Limited to the Company set out in detail the sum total of Avro Aircraft Ltd's development responsibility with regard to Arrow 2 Ground Support Equipment. List 2, appended to that letter called up specific engineering studies which the Company was to carry out for the R.C.A.F. One of these studies was to cover the mobile equipment and stationary ground facilities that would be required to maintain the Arrow 2 aircraft at readiness.

2.2 Scope of Study

The purpose of this report is two-fold:

(a) To outline the requirements for facilities and equipment which will be needed in order to maintain the Arrow 2 aircraft at various states of readiness, and

(b) To make recommendations concerning the facilities and to specify equipment.

The report is based primarily upon the aircraft specification (R. C. A. F. specification AIR-7-4, Issue 3) and on an R. C. A. F. report which outlines basic date for maintenance planning for the Arrow 2 aircraft. Pertinent extracts from these documents are presented in Chapter 3 of this report.

3. General Requirements

3.1 Aircraft Requirements

In order that the requirements for Arrow 2 readiness facilities and ground support equipment may be appreciated, the following paragraphs, which contain the design requirements for the Arrow 2 with respect to readiness, have been extracted from R.C.A.F. specification AIR-7-4, Issue 3:

"Para. 3.4 Scramble Time

3.4.1 With the aircraft at normal gross weight and positioned at the end of the runway, the elapsed time from the initiation of engine starting, until the aircraft becomes airborne shall not be more than one minute.

Para. 4.7.3 Readiness

4.7.3.1 The aircraft shall be designed such that, once having been certified operationally serviceable, it shall be capable of remaining serviceable at the highest state of readiness for a period of at least 24 hours.

4.7.3.2 The aircraft shall be capable of meeting the scramble requirement of para. 3.4.1 under all climatic conditions when housed in a readiness hangar. Details of the facilities required in the readiness hangar shall be provided by the Contractor and shall be subject to the approval of the Department (of National Defence).

4.7.3.3 The aircraft shall be capable of meeting the scramble requirement of para. 3.4.1 with a delay of not more than one minute, when dispersed in the open. Details of the environmental conditions involved in this case will be provided by the Department.

4.7.3.4 Special ground handling equipment peculiar to the aircraft which is necessary to meet the scramble requirements detailed above shall, subject to the approval of the Department, be developed by the Contractor and delivered as specified by the Department.

4.7.4 Automatic Disconnect Couplings. All external connections from the aircraft to ground equipment shall be made through automatic disconnect couplings preferably located in an adjacent area. The automatic couplers shall be positioned such that they will be disconnected by the aircraft taxiing straight away.

Para. 6.7 Engine Starting

6.7.1 The engine starting shall be under the control of the occupant of the front cockpit, and shall be such as to meet the one minute scramble time detailed in paragraph 3.4."

3.2 Concept of Base Operations

An R.C.A.F. report "CF-105 Aircraft - Basic Data for Maintenance Planning" was presented at the 32nd Meeting of the Arrow Co-ordinating Committee, and was published as Appendix "A" to the minutes of that meeting. Extracts from this document which pertain to readiness are presented below:

"Para. 4 The AWX squadron will have a UE of 12 fighter and 2 trainer aircraft. Full logistic support will be provided on the base in the form of a single support organization, and the squadron will not normally be required to operate from any other base unless similar support is supplied.

Para. 5 In exceptional circumstances, the squadron may be required to operate from a forward readiness base to which aircraft will be flown in a fully operational state. They will be serviced and made available for readiness on arrival, but normally will return to their main base after being scrambled. If they should land back at a forward base, only sufficient facility to prepare them for return to the main base is required. This is a detachment operation and the main base is to be capable of supporting such an operation up to a maximum of 50% UE. The support equipment required is to be air transportable in a C119 aircraft. Individual aircraft will not normally remain on the forward base longer than the time between primary inspections.

Para. 6 At the main base, 2 fighter aircraft will be at operational readiness at all times, and two readiness hangars will be provided which will be sited at one end of the principal runway. These aircraft are to be capable of becoming airborne within one minute from the time at which starting is initiated, excluding time taken to taxi from the readiness hangar to the runway end.

Para. 7 Ground support equipment in the readiness hangars is to be capable of maintaining aircraft "available" (15 minutes) indefinitely, and to provide for random periods of not more than 30 minutes at "standby" (2 minutes).

Para. 8 A time of 15 minutes is allowed in which an aircraft scrambled from or becoming unserviceable in an alert shelter is to be replaced. This taken into consideration a state of airborne readiness whereby aircraft scrambled on training exercises are considered at readiness for a similar period.

Para. 10 The minimum training requirement involves a utilization of 20 hours per UE aircraft per month, but the desirable requirement involves raising that figure to 25.

NOTE: The calculation (supporting this utilization) is as follows:

Squadron U.E.	- 12 fighter and 2 trainer aircraft.
Minimum average training requirement	- 20 hours per crew per month.
Planned utilization	- 20 hours per aircraft per month.
Average sortie duration	- 1 hour 25 minutes. This includes a factor to cover aborted sorties.
Therefore, training requirement	- 200 sorties per month.
Maximum flying rate	- 10 sorties per day on the basis of a 4-week month with 20 working days."

3.3 States of Readiness

The R.C.A.F., through the Arrow Sub-committee for Readiness

Equipment, has defined various states of readiness for its interceptor aircraft. These terms and definitions have been extracted from the minutes of the fifth meeting of this sub-committee and are given below:

"Condition 1 (Standby)

'Standby' means that an aircraft is ready for immediate (maximum two (2) minutes) take-off. The aircraft, with the engine not running (starter batteries plugged in), is to be positioned for take-off. The pilot is to be in the cockpit and the ground crew are to be on the alert.

Condition 2 (Readiness)

An aircraft on 'Readiness' is to be capable of becoming airborne within five (5) minutes. The aircraft engine is not to be running, however, starter batteries are to be plugged in. The pilot is to be close to the aircraft and the groundcrew are to be standing by.

Condition 3 (Available)

An aircraft on 'Available' is to be capable of becoming airborne within fifteen (15) minutes. Groundcrew are to be standing by; however, they may carry on maintenance work provided that the aircraft can be available for take-off within 15 minutes.

Condition 4 (At Ease)

An aircraft on 'At Ease' is to be capable of becoming airborne within 30 minutes.

Condition 5 (Released)

Aircraft and pilots which have been 'Released' will not be available until the time specified."

4. CF-105 Technical Considerations

4.1 General

During the design of the Arrow 2 aircraft, the scramble and readiness requirements from specification AIR-7-4 have been considered in detail for operations under all conditions of weather. However, for certain extreme and rarely-met conditions, compliance with these requirements would have imposed severe weight or space penalties on the aircraft which, in turn, would have had an adverse effects on its performance. For these cases some compromise was necessary and, since the all-weather mission capability could be attained by providing adequate ground support facilities, the aircraft has been designed to give maximum performance in the air. The effects of various weather conditions on the readiness states of the Arrow 2 aircraft are discussed in detail in the following paragraphs and are presented graphically in Figures 11, 12, 13.

4.2 Airframe

Although the Arrow 2 aircraft is required to be held at readiness and to be operated under all conditions of weather, no provision is made for de-icing the airframe while the aircraft is on the ground. De-icing equipment for the wings and fin would have imposed a severe weight penalty on the aircraft, and the readiness requirements can be met by using a shelter for the aircraft when snow or freezing rain is falling. During taxiing, take-off, and landing the engines are protected by hot air anti-icing systems and the windscreen and engine air intakes will be kept clear of ice by electrically heated panels. Also an alcohol spray system is installed to de-ice the radome when the aircraft is airborne, and an air blast system is fitted for clearing rain from the windscreen. Adequate drain holes will be provided to prevent trapping any water which may enter the airframe during heavy rain or during operations from wet runways. With these provisions a complete all-weather operating capability is anticipated.

4.3 Engines

Arrow Mk. 1 aircraft will be fitted with Pratt & Whitney engines, but Service aircraft will have the Orenda 'Iroquois' engines installed instead. At the present time no data is available concerning the starting times and characteristics of the Iroquois engines throughout the temperature range. However, it should be noted that at temperatures below -35°F, the Pratt & Whitney J-75 engines (and presumably the Iroquois) will require 2 minutes running at idling power before being operated at military or maximum power. Thus the engines will have to be heated if the scramble requirement is to be met during very cold weather.

As with many other new jet aircraft, the Arrow 2 uses air turbine systems for starting the jet engines because of their low installed weight and reliability. These systems require a large supply of hot, medium pressure air which, on the CF-105, is fed to the starters through two automatic quick-disconnect couplings as shown in Figure 2. The flow of air to the engine starting motors is controlled electrically by valves on the ground air supply unit. These valves may be opened by selecting "Start" or "Motor" on the engine starting switches in the front cockpit and will be closed automatically by centrifugal switches when the engines reach a pre-set speed. Two 28 V. D.C. signal wires are brought to an automatic quick-disconnect coupling on the nose undercarriage leg for this purpose.

In order to meet the "Scramble" requirement, both engines must be started simultaneously and must reach idling speed within 25 seconds, since engine acceleration from idling to maximum power will take 7 seconds and the take-off time (to 50' altitude) will be 28 seconds under the worst practical environmental condition (3500' altitude, 100^{o}F ambient temperature). Starting times of less than 15 seconds are not feasible with 2-spool engines since the low-pressure spools are not driven from the starting motors, and therefore tend to lag and restrict the flow of air through the engine. In tests at normal temperatures, starting times of less than 20 seconds have been attained on the Iroquois engine using air bled from an AiResearch

GTC 85-20 gas turbine compressor. Under standard, sea level conditions this unit supplies 118 lb/minute of air at 51 p.s.i. absolute pressure and 380°F. However, the engine starting motor can accept air at up to 60 p.s.i. absolute pressure and 500°F.

An engine acceleration time of less than 10 seconds from idling to full power is feasible for the Iroquois engine provided that the electronic components in the fuel flow control units are warm prior to starting the engines. Provision is made in the aircraft to supply power for this (250 VA, 115V, 1 phase, 400 c.p.s.) either from the aircraft A.C. electrical system if this is energized from an external source, or through the connector on the nose undercarriage leg if external power is not available for energizing the aircraft A.C. electrical system.

4.4 Fuel System

In the Arrow 2 aircraft, the fuel flows from the tanks through a heat exchanger as a cooling medium for hydraulic fluid and engine oil before it is delivered to the engines. The limiting fuel temperature at the engine inlet is 160°F, and since the fuel will also absorb heat from the aircraft skins during high-speed flight, the fuel temperature at the start of a flight should not exceed 110°F for a Mach 1.5 combat mission, or 70°F for a combat mission involving 10 minutes flying at Mach 2.0.

Fuel temperatures in the tanks of various types of R.C.A.F. aircraft have been measured by the Central Experimental and Proving Establishment at Station Rockcliffe and a high of 104°F was noted for a CF-100 aircraft sitting in the sun when the ambient temperature was 92°F. This fuel temperature would be exceeded for the Arrow 2 under similar conditions because of the thin, flat integral tanks in the delta wing. Thus, it is anticipated that shade will be required in order to limit the fuel temperature to 110°F for aircraft at readiness whenever the ambient temperatures exceed 90°F.

Although a Mach 2 combat mission is not a current R.C.A.F. requirement, it is within the capability of the Arrow 2 aircraft. If such a mission were contemplated, it would be desirable to pre-cool the fuel during hot weather in order to keep the fuel temperature below 70°F at engine start. In addition, the length of time at which an aircraft could be held at readiness for this mission might be limited during hot weather. This would depend on the initial fuel temperature, ambient conditions, and the rate of transfer of heat into the various fuel cells. These aspects cannot be investigated fully until an aircraft becomes available.

4.5 Hydraulic Systems

Three independent 4000 p.s.i. hydraulic systems are fitted in the Arrow 2 aircraft - two for operating the fully-powered flying controls, and a utility system to extend and retract the missiles, dive brakes, undercarriage, and to operate the brakes and the nosewheel steering system. In the design of the flying control systems the pipes have been sized to permit operation of the flying controls at full rate from 0^{o}F to 250^{o}F and adequate control with limited manoeuvrability down to -20^{o}F. At temperatures below -20^{o}F, a significant delay will be required after starting the engines in order to work the flying controls and thereby circulate the oil and warm it up to -20^{o}F. At -65^{o}F this delay is estimated to be approximately 5 minutes. In the undercarriage retraction sub-system the hydraulic lines have been designed to permit a retraction time of 5 seconds at temperatures down to -20^{o}F and 30 seconds at -65^{o}F. Thus, in order to meet the specified scramble requirements it is recommended that the Arrow 2 be kept in shelters heated to at least 0^{o}F when the outside temperature approaches -65^{o}F.

4.6 Electronics

Readiness states for the Astra I integrated electronic system have not yet been determined, but it appears that two items will limit the aircraft with respect to immediate operating capability when power is applied. These items are the magnetron, which will require approximately 5 minutes for warm-up regardless of ambient temperature, and the stable platform in the navigation system, which will require approximately 5 minutes for erection and orientation at $-65^{\circ}F$, 3 minutes at $72^{\circ}F$, and 2 minutes at $+160^{\circ}F$. Because of these items, external power and, as a result, cooling air will be required for approximately 5 minutes before take-off, since it will be desirable to have the system fully warm and operable prior to take-off.

Prior to flight the vertical and heading reference system will require orientation with respect to the earth's axes. For this the heading of the aircraft must be determined to within $\pm\frac{1}{4}^{\circ}$ and the reference system will then be locked or slaved to this heading until the aircraft is moved. At the present time the techniques and equipment for orienting the system have not been established, and although the process may be self-contained and automatic within the aircraft, it is assumed for this report that an optical check will be required and that this will be done by 2 men in 5 minutes when the aircraft is placed in the readiness hangar.

At the present time it is hoped that no testing or maintenance work will be required on the electronic equipment during any of the aircraft states of readiness. If this should be the case then, once an aircraft has been declared serviceable, it could be left with power off and would be capable of becoming airborne at any time within 5 minutes. On the other hand, studies that are being conducted at the present time by the Radio Corporation of America (R.C.A.) may indicate that reliability can be improved by keeping the electronic system in either a "Warm" or a "Standby" condition at all times. In that case external power and cooling air would be needed continuously and the electronic system would be ready for take-off at any time without delay. However, if this is done, periodic serviceability tests of a "go - no go" nature might be required at intervals of, say, 4 hours. During these checks, which would take approximately 10 minutes, the aircraft would have to be derated to readiness condition 3 "Available" since it would take from 5 to 15 minutes to restore an aircraft to operational condition and to start it and take off. The "go - no go" test equipment, if used, would be mounted on a dolly and would require approximately 6 KW of power at 115/220 V. and between 50 and 1000 c.p.s.

4.7 Electrics

4.7.1 Alternating Current Power Requirements

The Arrow 2 aircraft will be equipped with two completely independent and self-contained electrical systems, one being powered from each aircraft engine. Each system will obtain its power from a 40 K.V.A., 208/120V., 3 phase, 400 c.p.s. alternator which will be driven by its aircraft engine through a constant-speed drive unit. Under steady conditions of load and engine speed the frequency will be controlled to 400 c.p.s. ± 1% (maximum), and during a no-load to rated-load transient the frequency deviation will not exceed ± 5% with recovery to 63% of its initial value within 0.5 seconds. Direct current at 27.5V. is obtained from two 4.5 K.W. transformer-rectifier units, each supplied from one of the A.C. systems. These D.C. outputs are paralleled to feed all of the aircraft D.C. services.

To operate the electrical systems without having the aircraft engines running, external A.C. power may be supplied to the aircraft through an AN-3114 automatic quick-disconnect coupling which is located under the fuselage just behind the armament bay as shown in Fig.2. When 28V. D.C. is applied to pin "E" of this connector and the aircraft "Master" switch is turned "On", two 3-phase line relays will close and both A.C. busses will be energized. At the same time a slave relay opens to prevent the main A.C. line relays from closing, thereby preventing the feedback to the aircraft alternators. Direct current is obtained from the transformer rectifier units as in flight and there is no provision for energizing the main D.C. busses directly from an external D.C. supply.

Whenever an A.C. ground supply is plugged into the aircraft, cooling air must also be supplied since considerable heat may be generated by some items of electrical and electronic equipment which are mounted in confined spaces in the aircraft.

At high states of readiness and during engine start the electrical load is expected to be less than 30 K.V.A. at .75 power factor, but a detailed analysis of the electrical loads is not available at the present time.

Frequency response, wave form, and harmonic content of the external A.C. power supply are all critical for some items of electronic equipment in the aircraft, and should meet the performance requirements of Avrocan specifications E500 (40 K.V.A. A.C. Generator) and E501 (Constant Speed Drive Unit for 40 K.V.A. A.C. Generator).

4.7.2 Direct Current Power Requirements

As outlined in paragraph 4.7.1, all electrical power on the CF-105 aircraft is generated as A.C., and direct current (D.C.) at 27.5 V is obtained from transformer rectifier units in the aircraft. In addition, a 15 ampere-hour battery is fitted to operate the essential D.C. services during emergency conditions. To permit ground operation when A.C. power is not being supplied to the aircraft, external D.C. power can be supplied to the battery and emergency D.C. busses through a receptacle which is fitted on the nose undercarriage leg as shown in Fig. 2. From this D.C. connection the following services may be operated during standby and engine starting:

SERVICE	LOAD		
Battery isolation relay	.26	Amp.	Continuous
U/C indication	0.5	"	"
Fire detection	1.00	"	"
Master warning box	1.35	"	"
Emergency cockpit lights	.60	"	"
Turn and bank indicator	.20	"	"
AN/A.R.C. 52 U.H.F.	5.6	"	"
AN/AIC 10 Intercommunication	2.90	"	"
Canopy actuation	16.8	"	(for 8 seconds)
Fire extinguishing	8.0	"	(momentary)
L.P. fuel cocks	12.8	"	(for 1 second)
Ignition for engine starting	31.0	"	(for 30 seconds maximum)
Total connected load	80.6	Amp.	

Since the continuous load is only 12.4 amperes and since the intermittent loads are not likely to be encountered simultaneously, a nominal 50 ampere ground supply is considered adequate.

Normally when an aircraft is being maintained at a high state of readiness the power for these services will be obtained from the transformer rectifiers in the aircraft. Since these will be energized from the main external A.C. supply, only 5 amperes at 27.5 V D.C. for operating the main A.C. relays as outlined in para. 4.7.1 will normally be required. The D.C. loads noted above will be required only when external A.C. power is not available.

In addition to D.C. power leads, the nosewheel connector has provisions for the following services:

1. Signals from switches in the pilot's cockpit to flow control valves on the engine starting units to permit the pilot to

initiate engine starting. When the aircraft engines reach a pre-set speed, these signals are removed by the action of centrifugal switches on the engine starting motors so that the valves will close automatically.

2. Audio signals from a landline "telescramble" system to provide two-way communication between the cockpits and an operations controller.

3. Audio signals between the cockpits and ground crew.

4. D.C. power to control the external D.C. supply to the aircraft and to energize the aircraft interphone system from a towing vehicle, thereby permitting intercommunication between the crew in the cockpit and the driver of the towing vehicle. This power lead permits use of the interphone system with all other aircraft services turned off.

5. A.C. single phase power to warm the amplifiers in the engine flow control units.

4.8 Cooling Air

In the Arrow 2 aircraft, many items of electrical and electronic equipment are mounted in confined spaces so that a continuous flow of cooling air is required in order to maintain the temperatures of the components at an acceptable value. In flight, this cooling air is obtained from the aircraft air conditioning system which uses air that is bled from the engine compressors and cooled through a heat exchanger, a water boiler, and an expansion turbine. For ground operation, air can be supplied through two automatic quick-release connectors which are located on the bottom of the fuselage, just forward of the armament package, as shown in Fig. 2. Since there is no provision for adjusting the distribution of air within the aircraft as various loads are switched on or off, sufficient air must be supplied to ensure that all components receive adequate cooling.

In determining the supply of air that will be required for an Arrow 2 aircraft that is being maintained at a high state of readiness, the following conditions have been considered:

1. The maximum average temperature of air exhausted from the aircraft should not exceed 140°F. This infers that some compartments may operate at temperatures higher than 140°F, but that, for the purpose of determining the total airflow that is required, the average temperature of the exhaust air should not exceed 140°F.
2. The maximum temperature of the air entering the aircraft should not exceed 80°F, limited for the comfort of the aircrew in the cockpits.
3. The minimum temperature of air entering the aircraft should be 55°F, limited for the comfort of the aircrew in the cockpits.

4. Maximum humidity of air entering the aircraft may be 100%. It is noted that in the aircraft air conditioning system no provision is made for water separation or water removal during taxiing or in flight. However, hot air may be directed to the cockpits for defogging the cockpit or demisting the windscreen under adverse conditions.

5. Pressure of air entering the aircraft should be 4.5 lbs. per sq. in. (gauge) to ensure adequate distribution of air within the aircraft.

6. For a temperature rise of 60°F as the air passes through the aircraft (140° - 80°F), the quantity of air required is approximately 4 lb. per minute for each kilowatt of power used, or 120 lb./minute total for equipment cooling. In addition, 28 lb. per minute will be directed to the cockpits because of the distribution system within the aircraft so that the total flow required is approximately 150 lb. per minute.

4.9 Intercommunication

The Arrow 2 aircraft will use the AN/AIC 10 interphone system for communication between the two cockpits. This system may also be used, through the nosewheel connector, for

(a) two-way "hot-mic" communication between the cockpits and ground personnel.

(b) "Telescramble" - i.e. two-way "press-to-talk" communication with an operations control center by land telephone line. The present wiring design includes provision for a four-wire telescramble system and will require a signal level of one milliwatt in 150 ohms at the aircraft connection.

4.10 Towing

Since the need for readiness shelters is evident in order to obtain an all-weather capability with the Arrow 2 aircraft, towing and manoeuvering the aircraft on the ground should be considered as functions affecting readiness. The weight of the Arrow 2 aircraft will be approximately 60,000 lb. when loaded for its primary combat mission, and the maximum take-off weight will be 67,850 lb. The aircraft is designed to be towed by the nose undercarriage with drawbar loads up to $\pm$ 10,000 lb. and with nosewheel castoring angles up to $\pm 55^{\circ}$. Since the towing tactor will not be visible from the cockpit, an intercommunication system will be fitted to the tractor and suitable connectors will be fitted to the towbar and to the nose undercarriage. In addition, an audio warning system will be fitted to warn

(a) the tractor driver and cockpit occupant if a shear pin fails in the towbar.

(b) the tractor driver whenever the nosewheel angle exceeds approximately 45°.

The geometry of the undercarriage and the minimum radius of turn will be as shown on Fig. 1. The towing loads will be approximately 3000 - 4000 lb. on hard, level surfaces but will, of course, be higher during starting, on grades, or in snow. Each air base should have available some towing equipment capable of providing at least 7000 lb. drawbar pull under all surface conditions that are likely to be encountered.

4.11 Aircrew Factors

Because of the high-speed, high-altitude role of the CF-105 aircraft, aircrew will require special flying equipment, probably consisting of the following:

1. Pressure helmet for protection in case cabin pressurization should be lost at high altitude. Since these helmets restrict downward peripheral vision, they would probably not be put on until the crew members were settled in the cockpits. Connections must be made from the helmet to the aircraft systems for oxygen supply, and two-way communications.
2. Pressure vest for protection as in (1) and for improving the crew's tolerance to "G". This vest is inflated from the aircraft oxygen system as required.
3. "G" pants for improving the crew's tolerance to "G", inflated from the aircraft low pressure air system.
4. Leg restraints to prevent the legs from flailing if ejection is required at high speeds.

5. Parachute attachments and ejection seat harness.

The final equipment is not available at the present time, but preliminary checks using current equipment and allowing for known changes indicate that approximately 2 minutes will be needed for the crew to enter the cockpits and to prepare to start the engines for take-off. This time is based on the following routine:

(a) Enter cockpits (from top of access stairs) - 10 seconds.

(b) Preliminary cockpit check. Switch electronic equipment to "Standby"; check cockpit switches, warning lights, fuel contents, oxygen contents. - 20 seconds.

(c) Connect leg restraints, parachute and seat harness, oxygen supply, low pressure air supply, and intercommunications plug. - 1 minute

(d) Put on helmet, check oxygen flow, check communications with other cockpit and with ground crew. - 30 seconds

(e) Wait for order to "Scramble".

(f) Start engines and take off as required.

Thus, for aircraft at readiness condition 1 ('Standby', capable of being within 2 minutes) the crews would be in the cockpits and ready for take-off, but for readiness conditions 2 ('Readiness", capable of being airborne within 5 minutes) the crews could be in the crew rooms, but should be dressed for flight except for the pressure helmet.

At the present time it is not clear whether or not the aircrews should breathe pure oxygen while at "Standby". This may prove to be desirable in order to prevent "bends" due to nitrogen escaping from the blood as the cabin altitude is increased rapidly, since the aircraft will be capable of reaching 50,000' altitude (20,500' cabin altitude) within 4.2 minutes after engine starting is initiated. With this degree of cabin pressurization, "bends" should not be encountered under normal conditions. However, should cabin pressurization be lost early in a flight, it is unlikely that the crew would be able to maintain flight at 50,000' altitude. Tests will be undertaken shortly by the R.C.A.F. Institute of Aviation Medicine to assess this problem.

If oxygen is required during "Standby", the duration of the readiness period will be limited as noted below (unless a ground source of oxygen is provided):

Oxygen supply (5 litre liquid oxygen converter)

= 4.606 litres after standing for 24 hours

= 3960 litres of gaseous oxygen at normal temperature and pressure (N.T.P.).

Requirement for high-speed combat mission = 910 litres N.T.P.

Consumption at "Standby" at sea level - 730 litres N.T.P. per hour per man

$$\therefore \text{ Duration of "Standby"} = \frac{3960 - 910}{2 \times 730} = 2.14 \text{ hours}$$

= 2 hours (approx.)

If the oxygen supply should need replenishing, this is done by replacing the liquid oxygen converter which is mounted in the dorsal fairing behind the rear cockpit. This would take approximately 3 minutes, and the aircraft would be derated to readiness condition 2, "Readiness" during that time.

5. Ground Support Equipment

5.1 Engine Starting Air

In order to meet the scramble requirement outlined in R.C.A.F. Specification Air 7-4, both engines of the Arrow 2 must be started simultaneously and must reach idling speed within 25 seconds under all ambient conditions. This will require a large supply of hot, medium pressure air to each engine as detailed below:

Altitude	Sea level	Sea level	Sea level
Temperature	-65°F.	± 59°F	± 100°F.
Flow(minimum)	145 lb. /min.	112 lb/min.	101 lb/min.
Pressure(minimum)	60 p. s. i. abs.	50 p. s. i. abs.	47 p. s. i. abs.
Temperature	240 to 500°F	360 to 500°F.	390 to 500°F.

Assuming 70% adiabatic efficiency for the compressor and allowing for losses in the ducts or hoses leading to the aircraft, this air supply represents a power input of approximately 250 H. P. for starting each aircraft engine.

The duty cycle for the starting equipment will be of an intermittent nature since normally the flow of air will be required for about 20 seconds, followed by a 15-minute wait while another aircraft is placed in the readiness hangar. Even allowing for a false start, a motoring run and then a successful start the load is required for less than 2 out of every 15 minutes. and in peacetime the average utilization of the equipment will be far less than that indicated above.

In the R. C. A. F. Basic Data for Maintenance Planning, it is noted a squadron may fly an average of 10 sorties per day. Assuming that all flights originate from the readiness hangars, the average utilization of the starting equipment is not likely to exceed 5 starts per day.

The prime requirement in the design of equipment for supplying this air is reliability, since the ability to start engines under all conditions and thereby enable aircraft to take off is vital. Various methods of supplying the air have been considered and are outlined below:

1. Air bled from the compressors of gas turbine units such as the Air Research GTCH 85-20, AiResearch GTCP100-50, (capable of starting both aircraft engines simultaneously). Blackburn Palouste 500, Continental TC 106, or Solar T300 J2. These units are lightest and most compact and are therefore more suitable than other types of equipment for use as mobile starters, as concluded in Avro Aircraft Limited Report Log/105/24 "CF-105 Evaluation Study of Mobile Ground Power Equipment". Since a requirement exists for starting Arrow 2 aircraft on a flight line or at an advanced base, it would seem advantageous to use the same equipment in readiness hangars, since ground crew training and logistic support would thereby be simplified.

For this application gas turbine compressor units have the following advantages:

(a) They are able to start and to take full load quickly under all temperature conditions provided that the battery is maintained at 0°F. or warmer. Thus the units need only be started when an aircraft is to be brought to "Standby" (2 minutes to take-off), and they could be shut down at all other times. This characteristic is well suited to the duty cycle that was outlined.

(b) The units are self-contained and require no external or emergency source of power provided that the battery is maintained at 0°F. or warmer.

(c) They use JP-4 fuel which will be readily available at all bases.

(d) They are reliable and simple to maintain because of the small number of moving parts. Also, because of their small size and low weight, it will be possible to replace them readily for overhaul purposes without hindering activities in the readiness hangar.

(e) They will compare favourably from the point of view of initial, operating, and maintenance costs.

(f) Some suitable units are fully developed and are in production; others will be available in time for Arrow 2 squadron requirements.

2. Air supplied directly from industrial - type compressors driven by electric motors or by gasoline or diesel engines. Commercial equipment is not readily available to supply air for engine starting at the temperatures and pressures that are required. However, suitable equipment could be designed and built and would likely consist of a 2-stage centrifugal compressor with an intercooler in order to improve the efficiency and to limit the temperature during the second stage of compression to a value which the compressor can tolerate. The air would then have to be heated prior to delivery to the aircraft. In the sizes required (approximately 250 H. P.) for starting each jet engine) the initial cost of such equipment, including installation, will exceed that of gas turbine units, and the operating and maintenance costs will be high because of the complexity of the equipment and controls. Also, if these compressors were to be driven by electric motors, an adequate emergency power supply would be required, and the cost of this equipment must be considered.

Because of the design and development work that would be required, and since suitable qualified gas turbine units will be available, commercial equipment is not recommended for supplying air to start the engines in the Arrow 2.

3. Air supplied from high pressure air storage bottles which, in turn, would be charged by electrically driven compressors. This system might prove cheaper because smaller compressors could be used, since the flow of air is required for only 20 seconds, followed by a period of 12 to 15 minutes while another aircraft is place in the hangar. However, several factors must be considered:

   (a) Because the compressor capacity would not be sufficient to sustain repeated starts, the supply of stored air would have to be capable of providing more than one start per engine. As a minimum the system should be capable of handling a false start and a motoring run, followed by a successful start.

   Although the size and cost of the compressors would be less than in Case 2, the overall gain would be very small when adequate reserve air storage is provided. The inability of the system to sustain repeated starts is considered a serious operational limitation.

   (b) Since the air turbine starter requires hot air, heat would have to be added to the air either at the storage bottles or at the delivery lines to the aircraft. The saving in compressor cost would be partly offset by the cost of air storage bottles rated at, 500°F say, or by the cost of heaters to warm the air during delivery to the aircraft.

(c) The system could be designed to supply a uniform flow of air to the engine starters regardless of ambient temperatures and pressure.

(d) A system of this type has not been developed and therefore no experience is available.

4. Hot gas from a fuel-air system. This is an adaptation of the previous system in which the air is heated by burning JP-4 fuel in a combustor mounted in the delivery line. A mixture of water and methyl-alcohol may also be added as a means of controlling the temperature and increasing the mass flow. Although the system would be more complicated than a hot air system, it might prove cheaper than other methods because less compressed air is used. In other respects it is similar to the stored air system.

On the basis of this analysis, gas turbine compressor units are recommended for supplying hot, medium pressure air for starting the engines in the Arrow 2, both in the field and in readiness hangars. Pending further information concerning the availability of suitable engines and provisions for overhaul, no specific engine is recommended. For the time and motion studies in Chapter 7, however, the performance characteristics of the AiResearch GTC85-20 compressor have been used.

While the starting requirements can be satisfied by using one compressor for each jet engine, the possibility of using only two compressors for each pair of aircraft also warrants study. With the readiness hangars and taxi strips laid out as shown in Fig. 4, four aircraft could not taxi out and take off simultaneously, so that if one aircraft was started and taxied out from each pair of readiness hangars, followed 25 seconds later by the other two aircraft, then all four aircraft could still be airborne within 1 minute and 40 seconds after a scramble order as shown on Fig. 10. Such an arrangement would require a "Y" connection, and two load valves for each compressor package so that air could be directed first to an engine of one aircraft and then switched to an engine of the other aircraft. For this the two compressors would have to be located centrally between the two aircraft as shown in Fig. 6. In order to keep the pressure drop and heat losses to a minimum with this scheme, the air should be ducted through smooth insulated ducts of 5" inside diameter, preferably under the floor. Short, flexible hoses would be needed to connect to the compressors and to each aircraft. This scheme would be cheaper than using four compressors, but some flexibility would be lost because a false start on one aircraft engine or a malfunction of one compressor unit would delay the take-off of two aircraft.

The following quantities of starting equipment are recommended for each aircraft at "Standby":

two gas turbine compressor units, each capable of starting one jet engine.

or

one gas turbine compressor unit capable of starting both engines simultaneously.

5.2 A. C. Power (400 C.P.S., 208/120V, 3 phase, 4 wire) for each aircraft that is being maintained at a high state of readiness, the electrical load may be up to 30 K.V.A. at .75 power factor. Frequency, wave form and harmonic content of the supply are all critical for the electronic equipment in the aircraft so that, at present, it is recommended that an aircraft generator, complete with voltage regulator and control panel, be used to provide this ground power. The aircraft generator is defined by Avrocan Specification E-500, but a ground power unit incorporating this generator has not yet been designed. However, it may be stated that a 50 H.P. synchronous motor and a gearbox will be required to drive each generator. The unit should also incorporate a small 27.5 V. D.C. supply for energizing the main A.C. relays in the aircraft.

As A.C. systems become more widespread in aircraft, new motor-generator sets will be designed for ground support and suitable direct-coupled units may become available in time for use with the CF-105 aircraft. This field should not be overlooked since simpler, more robust equipment could result, provided that the power characteristics are satisfactory.

5.3 D.C. Power Supply

For standby conditions when A.C. power is available, the only continuous D.C. load is 5 amperes per aircraft at 27.5V for energizing the A.C relays in the aircraft. If the A.C. supply should fail, then D.C. is required for the services outlined in para. 4.7.2, giving a total of 3.2 amp. continuous load and 47.6 amp. intermittent or emergency load. Thus, the D.C. requirements are best satisfied by a small rectifier or motor generator set and a battery cart or a gasoline - powered auxiliary power unit for emergency power. Suitable units are available in the R.C.A.F. at present as noted below:

- Power supply, rectifier, metallic
  Sect. 5P, Ref. #47 (Mallory #VA 3000)
  20/32V, 100 Amp. output
  220V, 60 C.P.S., 3-phase input
- Motor Generator Set

Sect. 5P, Ref. #60

Output 23/33V, 500 mp. continuous, 1000 Amp. intermittent

Input 500V, 50/60 C. P. S., 3 phase

- Generator Set, gasoline electric, direct current

Sect. 42, Ref. #1093

Output 28V, 3000 watts

If gas turbine compressors are used for supplying the air to start the jet engines in the CF-105, the D. C. supply should also be capable of assisting the batteries in these units during their own starting cycle. This load will be approximately 45 Amp. for 30 seconds for each compressor.

5.4 A. C. Power (400 C. P. S., 115V., 1 Phase)

In order to warm the amplifiers in the engine fuel flow control units approximately 250 V. A. of 400 C. P. S. single phase power will be required. Normally this is obtained from the main A. C. supply in the aircraft, but a 500 V. A. inverter powered from the emergency 28V. D. C. supply is recommended for emergency use.

5.5 Cooling Air Supply

The requirements for the air to be supplied to the aircraft were presented in paragraph 4. 8 of this report and are, briefly:

Quantity	-	150 lb. per minute
Temperature	-	55 -80°F at the aircraft coupling
Pressure	-	4.5 p.s.i. gauge at the aircraft coupling
Humidity	-	up to 100%

In addition to these factors, the design of the equipment depends on the ambient conditions which might be encountered. Mobile equipment, for example, should be capable of meeting these requirements throughout the complete temperature range in which the aircraft can be operated (-65°F to -130°F). However, for fixed equipment which is to be used at air bases in Canada, it is felt that some relaxation is permissible, as noted below:

1. High Temperature: +95°F.

   Avro report LOG/105/13, "Environmental Requirements for CF 105 Mobile Ground Power Units", outlines the average and extreme temperatures that have been recorded at various air bases in Canada. It is noted that +95°F has been exceeded at some bases, but these instances are rare and of short duration. It is recommended that the cooling air equipment be designed to supply air at 80°F when the ambient temperature is +95°F. Slightly higher delivery temperatures would be permitted when the temperature exceeds +95°F.

2. Dewpoint: 75°F (maximum)

From Avro report LOG 105/13, a maximum dewpoint of 75°F would seem acceptable, since this is rarely exceeded in Canada. Again, the delivery temperature could be increased to 80°F or slightly higher to eliminate free moisture if the dewpoint should exceed 75°F.

3. Minimum Ambient Temperature: 0°F

It has been shown that 0°F is the minimum temperature at which full readiness capability is maintained for the Arrow 2 aircraft and that below 0°F heated shelters are required. Thus, by drawing the "cooling" air from within the readiness hangars, 0°F is a reasonable minimum temperature for design purposes. It is recognized that lower temperatures would be encountered for short periods of time after the hangar doors have been opened, as when placing aircraft in the hangars. During these periods the delivery temperature of the air would be less than 55°F at the aircraft.

An engineering proposal for equipment to supply cooling air, based on the above considerations, has been submitted to Avro Aircraft Ltd., by the John Inglis Co. Ltd., of Toronto and is included in Appendix 1 of this report. This proposal also outlines equipment for supplying 300 lb. of air per minute, which could be used for maintaining two aircraft at readiness and for use in first and second line maintenance hangars. Either size of unit would be suitable for the job, but separate units for each aircraft are recommended since they would be more efficient when only one aircraft is being supplied with air and both hangars would not be affected if one machine was shut down for maintenance.

Three types of condensers have been proposed for the refrigeration system, but only the air cooled type is suitable, since an adequate supply of water for the other types may not be available at all bases. The condensers must be mounted outside the readiness hangars and in Fig. 6 they are shown mounted above the roof.

5.6 Communications Equipment

As noted in paragraph 4. 9., the Arrow 2 aircraft has provisions for "Telescramble" and for communiction with the ground crew though a connector on the nose undercarriage leg. The requirements for the ground equipment for these services are detailed in Avro report C-105-R-0016 "Ground Intercommunication System", and are summarized below.

For each headset used by the ground crew, a portable 2-channel audio amplifier operated from a 27.5V. D.C. power supply is required. In the starting and towing vehicles these units will be permanently mounted, but for maintenance personnel they would be plugged into a junction box on a ground power supply. These amplifiers will weigh approximately 1 lb. each and will be fitted with a shoulder harness.

In the readiness shelters, it is recommended that the controls and switches for all of the ground support equipment for a pair of aircraft be brought to one control panel. This panel should be in a room which would provide protection for personnel against jet engine exhaust and against noise from the jet engines and ground equipment.

Communication equipment at this point should consist of

(a) AN/AIC17 ground intercommunication system for two-way communications with the two aircraft being served and for "Telescramble" message receiving.

(b) Telephone for contacting the aircraft Maintenance Control Officer.

In addition receptacles for headsets should be located at points convenient to the hangar door release handles, so that personnel could open the doors without delay after a "Scramble" order is received.

5.7 Cockpit Access

As shown on Fig. 1 and 3, the cockpits of the CF-105 are entered from above, and at a level approximately 13-1/2 feet above the floor. To permit rapid scrambling of the aircraft, cockpit access equipment should permit safe, quick entry to both cockpits, and also rapid clearance of the taxi path of the aircraft after the crew members are aboard. Various schemes have been considered, including mobile stairs, "hang on" types of ladders, and catwalks which could be built into the readiness hangars. These are discussed below.

5.7.1 Mobile Stairs

A retractable, mobile set of stairs as shown in Fig. 3(a) has been designed (Avro drawing 7-2700-8) and is recommended for use with the CF-105 aircraft. This unit is mounted on castors and can be retracted hydraulically to give an overall height of 53". It will weigh about 800 lb. and could be moved clear of the aircraft taxi path by two men and retracted in approximately 10 seconds. The unit could also be used outdoors on the flight line or be transported by air to other bases.

5.7.2 Ladder Attached to Aircraft

An aluminum alloy ladder has been considered, similar to that shown in Fig. 3(b). It is attached to the aircraft by means of a padded lug wedged between the fuselage and the engine air intake ramp and a platform at the top permits access to front and rear cockpits. This type of ladder is lighter, less bulky, and does not require precise positioning of the aircraft or ground equipment, but is awkward to handle and might prove awkward for use by aircrew dressed in flying clothing. Its main use should be for ground crew when aircraft are being moved about, since the aircraft could be towed with the ladder attached.

5.7.3 Retractable Catwalk

A basic scheme for a catwalk which might be fitted to the standard R. C. A. F. readiness hangars is shown in Fig. 3(c). A fixed portion would be suspended and braced from the roof trusses and at its end a short portion would be hinged to clear the path of the aircraft as it taxis out of the hangar. Such a scheme necessitates accurate positioning of the aircraft inside the hangar, but otherwise it could be made simple to operate and relatively inexpensive. The catwalk and bracing would weigh approximately 800 lb. and would be designed to carry a live load of 800 lb. This scheme however has little merit for use with the standard R. C. A. F. readiness hangars and crew rooms as they are laid out at present but if the buildings were rearranged with the crew rooms upstairs and between two aircraft, as shown in Fig. 3(c) 8, catwalks would be recommended.

5.8 Mobile Readiness Equipment

In order to support CF-105 aircraft on a flight line or at an advanced base, mobile equipment is proposed in the form of two vehicles - one to supply all of the requirements for engine starting; the other to supply A. C. electrical power and cooling air. These are described briefly below:

5.8.1 Starter Vehicle

This unit would consist essentially of a single gas-turbine compressor package mounted on a suitable truck or trailer. In addition to supplying the air for starting the jet engines, it would provide electrical power (up to 75 amperes at 27.5 V. D. C.) for operating the aircraft canopies, interphone system, and the other services noted in paragraph 4.7.2 as required. An interphone amplifier on the starter vehicle would also be energized from this D. C. supply, as would a 500 V. A., 400 c. p. s., 1 phase A. C. inverter. This inverter would be used to provide power to warm the amplifiers of the flow control units on the Iroquois engines as noted in paragraph 4.3. The flow of air to the engine starting motors would be controlled from the pilot's cockpit through signal wires which, along with the electrical and interphone wires, would be in one cable that would plug into the receptacle on the nose undercarriage leg.

5.8.2 Power/Air Conditioning Vehicle

An interim vehicle has been ordered to supply A. C. electrical power and cooling air for Arrow 1 aircraft. It consists of a 3-ton truck chassis with a 400 C. P. S. A. C. generator (industrial type) and a 27.5V. D. C. generator driven by enclosed chains from the truck engine. The cooling air supply is obtained from an AiResearch GTC85-20 gas turbine compressor and an air-cycle refrigeration system, both mounted on the truck. In addition the vehicle is capable of towing ground support equipment and has provisions for intercommunication with the aircraft being served. . Also, it carries distilled water for filling the boiler in the CF-105 air conditioning system and alcohol for filling the tank in the radome de-icing system.

It is anticipated that the power/air conditioning vehicle for supporting Arrow 2 aircraft will be similar, although an aircraft type generator with tight frequency control and a larger supply of cooling air will be required. A specification for this vehicle is being prepared by the Company.

6. Suitability of Standard R. C. A. F. Readiness Hangars

6.1 General

Readiness shelters have been designed for the R. C. A. F. to meet Operational Requirement OCH 1/20-11, and are being built currently for use with CF-100 aircraft. Drawings of these hangars have been made available to the Company and their suitability for use with Arrow 2 aircraft is discussed in this chapter.

6.2 Siting

These readiness hangars are being located at the end of a taxi strip which is 75' wide and which is at an angle of 45° to the principal runway as shown in Fig. 4. The length of this taxi strip is governed by a Department of Transport requirement for 1000' minimum lateral clearance between the hangars and the center line of the runway (extended), so that the aircraft must taxi approximately 1700 feet to reach the runway.

In order to determine the effect of this on the "Scramble" time, it is assumed that aircraft would taxi as fast as possible from the readiness shelters to the runway and would take off without slowing down. A practical radius for the turn on to the runway is 600 ft., for which the speed must be less than 75 mph (110 feet/sec) with the Arrow 2 in order to prevent tipping. The effect on take-off time is calculated below:

Assume that the aircraft weighs 60,000 lb., and accelerates to 75 mph using half military thrust (20,000 lb.).

$$\text{Acceleration} = \frac{20,000}{60,000} \times 32.2 = 10.7 \text{ ft/sec.}^2$$

$$\text{Time to accelerate to 75 mph} = \frac{110}{10.7} = 10.3 \text{ seconds}$$

$$\text{Distance to accelerate to 75 mph} = 1/2 \times 10.7 \times 10.3^2 = 545 \text{ ft.}$$

$$\text{Time to taxi to runway} = 10.3 + \frac{(1700 - 545)}{110} = 20.8 \text{ secs}$$

Had the aircraft been parked at the runway and accelerated using maximum thrust (50000 lb.) the acceleration would have been $\frac{50000}{60000} \times 32.2 = 26.8 \text{ ft/sec.}^2$

$$\text{Time to accelerate to 75 mph} = \frac{110}{26.8} = 4.1 \text{ sec.}$$

Thus the additional time required from "Scramble" to "Wheels Off" of the readiness hangars is a minimum of 20.8 - 4.1 = 16.7 seconds.

6.3 Approaches

On the plans of existing sites which were made available to the Company, the only approach to the readiness hangars is via the taxi strip which leads from the readiness hangars to the main runway. Thus whenever an aircraft is being towed to or from the readiness hangars, the taxi strip may be blocked for periods up to one minute. In addition, the aircraft has to be turned around and manoeuvred backwards into the hangars, and although the tarmac in front of the hangars has adequate space for this, as shown in Fig. 4 and 5, it apparently slopes down from the readiness hangars. Under wet or slippery conditions difficulty may therefore be experienced, unless the towing vehicles are sufficiently heavy or are equipped to spead hot sand under the driving wheels.

The Standard Readiness Hangars have doors 75' wide & 24' high at both front and back so that a taxi strip could be built from the maintenance area to the rear of the readiness hangars. Such a taxi strip is shown on the typical airbase layout in Fig. 4 and would eliminate the difficulties noted above.

6.4 Hangar Struture

The Standard Readiness Hangars are 80' wide, 100' long, and are fitted with doors 75' wide and 24' high at each end. The Arrow 2 aircraft has a wing span of 50', an overall length of 82' (approximate) and a height of 21' - 2". Thus clearance is adequate and, since a steerable nosewheel will be fitted in the Arrow 2 aircraft, no difficulty is anticipated in taxing this aircraft from these hangars.

Operational Characteristic OCH-1/20-11 specifies that the doors should be capable of being opened fully within 30 seconds under all conditions of weather and without powered operation. This is accomplished by using counterweights to open the doors automatically once mechanical latches have been released. The door mechanism will have been used and proven with the CF-100, and should be satisfactory for use with the Arrow 2. However, the opening time should be 20 seconds maximum in order to match the Arrow 2 engine starting time.

The hangars are constructed with steel frames placed 10' apart and are braced to withstand severe wind and snow loads. They are covered with aluminum sheathing and are lined with a blanket type insulation 1" thick which has an aluminum foil protective facing. The durability of this insulation and its attachment to the structure might be queried, and should be checked during use with CF-100 aircraft at maximum thrust since the noise levels and jet echaust patterns thus experienced would be similar to those with the Arrow 2 at approximately half of its military thrust. Because of the high thrust to weight ratio of the Arrow 2 aircraft, it is assumed that not more than half of its military thrust would be used until the aircraft had reached the runway. Jet exhaust patterns for the Arrow 1 aircraft (J-75 engine) at military thrust are shown in Fig. 14.

Although these readiness hangars are being erected in pairs, with crew rooms between two pairs of hangars as shown in Fig. 6, they are capable of being erected and used singly if required. If the aircrews are to be in the crew rooms at readiness condition 2 "Readiness", it must be possible for them to enter the aircraft and to prepare for take-off in 3 minutes. This is feasible with the Arrow 2 and the existing layout for the existing readiness hangars and crew rooms. However, an alternate arrangement of buildings, such as in Fig. 7, could reduce the time and physical effort required in entering the aircraft. In this layout the two readiness hangars are separated to allow space for a ground support equipment building with crew rooms upstairs and a "catwalk" leading to each aircraft.

6.5 Heating

It was recommended in Chapter 4 that the Arrow 2 be kept at 0°F. or warmer in order to meet the scramble requirements. The R. C. A. F. standard readiness hangars should achieve this for outside temperatures down to -65° F., since the heating units have been designed to maintain 0°C. (32°F), in the shelters down to an outside temperature of -40°C, (-40°F).

When aircraft are being maintained at readiness condition 1 (Standby), heat is also being supplied to the hangars through the cooling air which is being exhausted from the aircraft.

The effect of this additional heat on the temperature inside closed readiness hangars is estimated below:-

Quantity of air	-	150 lb. /minute.
Temperature of air from a/c	-	115°F to 140°F.
Heat loss from hangar (est).	-	4630 B. T. U. /hr/°F.
Specific heat of air	-	.24.

At an ambient temperature of 95°F., heat supplied from aircraft

$= 150 \times (140-95) \times .24 \times 60 \quad = 97000$ B.T.U./hr.

Temperature rise $= \frac{97000}{4630} \quad = 21F^{\circ}$.

Stabilized temperature $= 95 + 21 = 116^{\circ}$F.

At an ambient temperature of 32°F., heat from aircraft

$= 150 \times (115 - 32) \times .24 \times 60 \quad = 179,000$ B. T. U. /hr.

For this, the temperature rise should be approximately 40°F., giving a stabilized temperature of 72°F. in the hangars. In addition some heat would be dissipated from the ground support equipment but has not been considered since, in any case, the temperature in the hangars could be reduced by opening the doors from time to time. Hangar cooling equipment is not proposed at the present time, but should be considered as a means of keeping the fuel cool in very hot weather if Mach 2.0 combat missions are contemplated.

6.6 Lighting

No new requirements for lighting would be introduced as a result of using the Arrow 2 aircraft.

6.7 Equipment Installation

The major items of ground support equipment would be mounted on skids or castors for use on the hangar floors without special foundations. However, anti-vibration pads and tie-down points would be required and it would be desirable to duct the electrical and air supplies under the floor to each aircraft. Layouts for these services are shown in Fig. 6 & 7. The air ducts should be insulated and of the sizes shown in order to minimize pressure and heat transfer losses. Fittings should be provided at each end so that short, flexible hoses could be used to connect to the aircraft and to the air supply equipment, the installation of these ducts in the trenches should permit ready expansion and contraction, since the ducts would be heated and cooled over a wide temperature range during normal use. In addition, the exhaust gases from the gas-turbine starter units should be ducted outside the hangars. In Fig. 6, these exhaust ducts are shown as going up through the roof. Since the starters will be drawing air from inside the hangars and exhausting it outside, a means of preventing the pressure from decreasing excessively in the hangars must be provided.

It is recommended that the controls for all of the ground equipment required to support a pair of aircraft be brought to one control panel as shown schematically in Fig. 8. This could be installed in a room near the front of the hangar which would also provide protection for the ground crew against noise and against the exhaust from the jet engines. In this way one man could control and check the operation of all of the ground equipment and could communicate quickly with both air crews, the maintenance control office, and the operations controller, through the aircraft interphone, air base telephone, and 'Telescramble' systems.

6.8 Power

At present a 100 K.V.A. transformer is being installed to supply electrical power for each group of 4 standard readiness hangars. If electrically-driven equipment is used for maintaining the Arrow 2 aircraft at high states of readiness, as outlined in Chapter 5, this transformer will be inadequate. Its capacity would have to be increased to cater for the operating loads noted below for 4 aircraft:

	Motor Size	Electrical Equivalent	No. of Units	Total Power Required
400 C.P.S. Generator	50 H.P. (Synchronous)	45 KVA	4	180 KVA
100 Amp. D.C. Supply	Rectifier	3.5KVA	2	7 KVA
Cooling Air Blower	100 H.P. (Induction)	93 KVA	4	372 KVA
Refrigeration Compressor	40 H.P. (Induction)	37.5 KVA	4	150 KVA
Condenser Fan	4.5 H.P.	4.2 KVA	4	17 KVA
"Astra 1" Test Equipment	-	6.0 KVA	2	12 KVA
Hangar Services	-	-	-	100 KVA
Total				838 KVA

6.9 Emergency Power

The power requirements shown in paragraph 6.8 do not include any power for starting the jet engines in the Arrow 2, since it was recommended that air for this service be obtained from gas turbine compressor units. Thus, the ability to start and to fly aircraft would not be impaired if the hangar hydro supply failed, although the state of readiness could be affected, depending on the final requirements from the Astra 1 system and on the ambient temperature conditions. If it proves feasible to leave the Astra 1 system turned off for the 5- and 15 - minute readiness conditions, emergency power should be provided as below:-

1. Hangar services, including heating for a group of four hangars - 100 K. V. A.

2. Standby D. C. power at 27.5 V
   Batteries or a gasoline-driven generator set (eg. R. C. A. F. Sec. 42, Ref #1093) would be needed for each pair of readiness hangars.

With these power supplies, aircraft could be started in the normal manner, but a period of 5 minutes would be required to warm the Astra I system. During the first 3 minutes the aircraft should be stationary while the gyroscopes are being erected and oriented, but following this period the aircraft could taxi and take off. Thus, an aircraft could be airborne within 4 minutes and 15 seconds after an order to scramble, although the fire control system would not be fully operative for about 1 minute after take off.

To maintain aircraft at a higher state of readiness after the normal power supply had failed, mobile power/air conditioning units could be brought into the readiness hangars and used in place of the electrically driven hangar equipment. There would, however, be a period of about 5 minutes while the vehicles were being obtained from the flight line, during which time power might be obtained from the station emergency system, provided that it can be started immediately following any power failure. If the station emergency system is not capable of supplying this power immediately following a hydro failure and if the 5 minutes to obtain mobile equipment cannot be tolerated, a diesel-generator set rated at 450 K. V. A., complete with controls and automatic starting features, should be installed to serve each pair of Arrow 2 aircraft at "Standby". These emergency power systems are portrayed in Fig. 9.

7. Arrow 2 Scramble and Readiness States

Preliminary time and motion studies have been prepared for the air-crew and ground crew operations during preparation for "Standby" and during a "Scramble" and are shown in Fig. 10 of this report. These studies are based on the standard arrangement for R.C.A.F. readiness hangars and the times were obtained using the wooden mock-up of the Arrow 2 aircraft and making allowances for known changes in flying equipment. From Fig. 10 it will be noted that 5 ground crew personnel are required for each pair of aircraft - one man to control the ground support equipment and two men per air-craft to assist the aircrew, remove the cockpit access stairs, and open the hangar doors. However, should the Astra 1 electronic system require periodic serviceability checks, additional personnel would be needed.

The 2, 5 and 15-minute readiness states for the Arrow 2 aircraft are portrayed in Fig. 11 (Standby), Fig. 12 (Readiness) and Fig. 13 (Available). These diagrams indicate the factors which affect the Arrow 2 in each readiness state and also describe the ground support equipment that is required.

8. Discussion

It was intended originally to have this report compare detailed design proposals for ground support equipment for use in the readiness hangars and to make recommendations concerning specific items of equipment. However, this has not been possible since some of the fundamental requirements for the Arrow 2 are not yet firm and, in addition, others will require consideration and acceptance by the R.C.A.F. before detailed specifications for ground support equipment can be prepared. For these reasons this report has reviewed the design requirements for the Arrow 2 aircraft and has outlined the factors which will determine or affect its states of readiness based on present knowledge. It remains then for these other factors to be resolved so that the requirements for the ground support equipment and readiness hangars can be specified in detail. Specifically, the following items need clarification:-

1. Readiness capabilities of Astra I integrated electronic system. On the one hand it is hoped that the system can be left "off" and be considered serviceable and operational within 5 minutes at any time. On the other hand a large amount of high-quality electrical power and cooling air may be required continuously, with periodic breaks in the aircrafts readiness status to permit serviceability checks. Primarily, this will affect the requirements for emergency power and possibly for equipment to cool the readiness hangars to overcome the temperature rise if the

Astra system is in operation for long periods of time. Primary power for the aircraft electrical and cooling air supplies will be required in any case, since it is desirable to be able to warm and operate the electronic system just prior to starting a mission.

2. Design combat mission for the aircraft. It was noted in paragraph 4.4 that the fuel temperature at the start of a mission should not exceed 70°F. if the mission involves 10 minutes flying at Mach 2, but may be up to 110°F. if Mach 1.5 is not exceeded. A limit of 70°F. (maximum) would create a need for equipment to cool the readiness hangars, or would limit the duration of high states of readiness during very hot weather.

3. Ambient conditions for the design of the cooling air supplies. Limiting temperatures and dew points for the design of the cooling air supplies have been suggested in the report. These must be accepted, or alternatives stated by the R.C.A.F., before equipment can be specified. The design proposal presented in App. 1 of this report has been based on the figures suggested in this report.

9. Conclusions and Recommendations

1. The use of readiness hangars will be necessary with the Arrow 2 in order to meet the scramble and mission requirements for this aircraft under all conditions of weather. These hangars are required in order to shade the fuel tanks and cockpits during hot weather, to protect the aircraft from deposits of snow and freezing rain during bad weather, and to heat the hydraulic systems up to at least 0°F. during cold weather. The R.C.A.F. standard readiness hangars will be suitable for use with Arrow 2 aircraft, but some alterations will be required to accommodate ground support equipment and services to the aircraft.
2. It is noted that the R.C.A.F. standard readiness hangars are sited to provide a 1000' lateral clearance from the main runway. With the present siting arrangement at least 20 seconds will be required to taxi to the runway with the Arrow 2 aircraft.
3. A taxi strip from the maintenance area to the rear of the readiness hangars is recommended because with the present arrangement the main approach to the runway can be blocked for periods of up to 1 minute while aircraft are being towed to and from the readiness hangars.
4. The present layout for readiness hangars and crew rooms is considered satisfactory for use with the Arrow 2 aircraft.
5. It is recommended that the hangar doors be capable of being opened fully within 20 seconds in order to be compatible with the

Arrow 2 engine starting time.

6. For meeting the "Scramble" and "Standby" requirements the Arrow 2 aircraft will have provision for accepting the following services from ground support equipment:

(a) Hot, medium pressure air for starting the two jet engines as noted below for sea level standard conditions:

Flow - 112 lb./minute (minimum) per engine

Pressure - 50 p.s.i. absolute (minimum)

Temperature - 360 to 500^{o}F.

Simultaneous starting of both engines is required in order to meet the scramble requirement.

(b) Up to 40 K.V.A. of 208/120V., 400 C.P.S., 3 phase A.C. power. All of the aircraft electrical and electronic systems may be energized from a ground supply through this receptacle.

(c) 5 amperes at 27.5V. D.C. with the main A.C. cable. This power is used to operate the A.C. line relays in the aircraft.

(d) Cooling Air. Whenever A.C. power is being supplied to the aircraft, cooling air should also be supplied as below:

Flow - 150 Lb./minute (maximum)

Temperature - 55^{o}F. to 80^{o}F.

Pressure - 4.5 p.s.i. gauge at the aircraft connector.

(e) Ground wire.

(f) Nose undercarriage cable. A quick-disconnect receptacle on the nose undercarriage leg has provision for:

(I) 50 amperes current at 27.5V. D.C. for operating essential D.C. services if the main A.C. systems are not being energized.

(II) 27.5 V. D.C. signals so that the flow of engine starting air can be initiated by the pilot and stopped automatically when the engines reach a pre-set speed.

(III) Approximately 250 V.A. of 400 C.P.S., single phase, 115V. power per engine for warming the electronic components in the fuel flow control units.

(IV) Audio signals for intercommunication with ground crew personnel.

(V) Audio signals for two-way communication with an Operations Controller via land telephone line (Telescramble).

(VI) 27.5V. D.C. for controlling 27.5V. D.C. external supply to aircraft and for energizing the interphone system with all other aircraft services turned off.

It is recommended that provision be made in the R.C.A.F. standard readiness hangars for running these services under the floor to suitable points below the aircraft. A layout for ducting the services is presented in Fig. 7 of this report.

7. Although the readiness characteristics of the Astra I integrated electronic system are not known at present, it is considered desirable to be able to warm and operate the fire control system prior to take-off for a combat mission. On this basis the

following services will be required for each Arrow 2 aircraft at "Standby":

(a) Hot, medium pressure air immediately available for starting both engines simultaneously.

(b) Electrical Power. (208/120V., 400 C.P.S., 3-phase A.C.) Up to 30 K.V.A. at 0.75 power factor will be required. In addition, 5 amperes at 27.5V. D.C. will also be required for operating the main A.C. relays in the aircraft.

(c) Cooling air. 150 lb./minute of air at a temperature between 55 and 80°F. and a pressure of 4.5 p.s.i. gauge will be required.

(d) Services through the nose-undercarriage receptacle:

(i) 27.5V. D.C. signal wires for controlling engine starting.

(ii) Intercommunication with ground crew.

(iii) 'Telescramble'.

(e) Ground wire.

8. For engine starting only, without supplying power and cooling air for the Astra I system, the following services will be required:

(a) Hot, medium pressure air for starting the engines simultaneously or in sequence as desired.

(b) Services through the nose-undercarriage receptacle:

(i) 50 amperes at 27.5V. D.C.

(ii) 27.5V. D.C. control wire.

(iii) 27.5V. D.C. signal wires for controlling engine starting.

(iv) 500 V.A., 400 C.P.S., 1-phase A.C. power for warming the amplifiers in the fuel flow control units.

(v) Intercommunication with ground crew.

The aircraft might be operated with only these services for training and ferry flights or when A.C. electrical power is not available. In the readiness hangars these services should not be dependent solely on the hangar main electrical supply.

9. Gas turbine compressors are recommended for supplying the hot, medium pressure air for engine starting for the reasons noted below:

(a) They are well suited to the intermittent duty cycle that is anticipated because of their ability to start and to take full load quickly under all temperature conditions.

(b) They are self-contained and therefore are not dependent on an external power supply.

(c) Suitable units are qualified and are in production now and others will be available in time to meet Arrow 2 squadron requirements.

(d) They are reliable and simple to maintain.

(e) They compare with other types of equipment in initial cost and also in operating costs because of the intermittent duty cycle.

(f) They use JP-4 fuel which will be available at all Arrow 2 bases.

(g) They will be used for mobile starting equipment because they are light and compact. It would therefore be advantageous to use the same equipment in the readiness hangars since ground crew training and logistic support would be simplified.

(h) Although other types of equipment have been designed for this purpose, none are qualified and in production at the present time.

Pending further information concerning the availability of suitable engines and facilities for overhaul, no specific gas turbine is recommended.

10. It is recommended that the 3-phase, 400 C.P.S. A.C. power for "Standby" be obtained from an Arrow 2 generator driven by a 50 H.P. synchronous motor through gearing. This unit should also provide 5 amperes at 28V. D.C. for operating the main A.C. relays in the aircraft. The aircraft generator is defined by Avrocan Specification E-500 but a detailed specification has not been prepared for a ground power unit at the present time.

11. For providing cooling air to the aircraft, an electrically driven compressor and a freon refrigeration system with an air cooled condenser is recommended. A detailed specification for this equipment cannot be prepared until the ambient operating conditions for the system have been considered and stated by the R.C.A.F.

12. Although not needed when the aircraft electrical systems are being

energized, a 500 V.A. inverter is recommended for supplying 115V., single phase A.C. power to each aircraft under emergency conditions. It should be powered from the emergency 28V. D.C. power supplies.

13. Existing types of R.C.A.F. equipment will be suitable for supplying 28V. D.C. power for two Arrow 2 aircraft. Typical units are:

Normal supply	- 100 ampere rectifier (Sect. 5P, Ref. No. 47) or 500 amp. motor-generator (Sect. 5P, Ref. No. 60)
Emergency Supply	- 3000 watt Gasoline-driven generator (Sect. 42, Ref. No. 1093)

14. The AN/AIC-17 ground intercommunication system is recommended for use in the readiness hangars. Power should be obtained from the 28V. D.C. power supply in the hangar.

15. The mobile, retractable stairs designed by Avro Aircraft Limited are recommended for access to the cockpits of the Arrow 2 in the readiness hangars, pending evaluation by the R.C.A.F.

16. It is recommended that all of the controls for the ground support equipment for two aircraft be brought to one control panel and that this be in a room near the front of the readiness hangar. This room should be designed to protect the ground crew from the noise and wake from the Iroquois engines and should have provision for communication with the aircrew, the operations control

officer and the maintenance control officer.

17. The main electrical supply to the readiness hangars should cater for at least 838 K.V.A. in order to maintain 4 CF-105 aircraft at "Standby", assuming that the compressors for engine starting are not powered by electricity.

18. If the electrical supply to the air base should fail, emergency electrical power and cooling air for aircraft at "Standby" should be obtained from mobile power/air conditioning units. While these were being obtained from the flight line, power would have to be supplied from the air base emergency electrical system. If the air base emergency power system is not capable of supplying this power to the readiness hangars during this time, a 450 K.V.A. diesel-generator set, complete with controls and automatic quick-starting features, should be installed at the readiness hangars to serve each pair of Arrow 2 aircraft at "Standby". Without A.C. electrical power and cooling air being supplied to the aircraft, the Arrow 2 could be started in the normal time but it should not be taxied until the gyroscopes in the vertical and heading reference system have been erected and oriented. This will require 3 minutes at normal temperatures.

19. Mobile ground support equipment will be developed by Avro Aircraft Limited for the R.C.A.F. in the form of two vehicles; one to provide all of the services related to starting the aircraft, the other to provide electrical power and cooling air for "Standby"

and for maintenance work. The starter will be a self-contained package that will provide:

(a) Hot, medium pressure air for starting one engine at a time.

(b) D.C. power - at least 50 amperes at 28V. D.C.

(c) Single phase A.C. power - 500 V.A. at 115V., 400 C.P.S.

(d) Provision for control of starting air from the aircraft cockpit.

(e) Intercommunications.

The power/air conditioning vehicle will provide:

(a) A.C. Power. Up to 40 K.V.A. of 3-phase, 208/120V., 400 C.P.S. will be available. An aircraft generator and constant-speed drive unit probably will be fitted for supplying this power.

(b) D.C. Power. 5 amperes at 28V. D.C. will be required for the A.C. cable.

(c) Cooling air. A flow of 150 lb./minute at a pressure of 4.5 p.s.i. (gauge) and a temperature between 55°F. and 80°F. will be required. A gas-turbine compressor with an air-cycle refrigeration system is proposed.

20. At each Arrow 2 base there should be towing vehicles available that are capable of providing a drawbar pull of 7000 lb. under all surface conditions that are likely to be encountered.

10. References

1. AIR 7-4, Issue 3. R.C.A.F. Specification for Supersonic All-Weather Interceptor Aircraft Type CF-105.

2. R.C.A.F. Report "Concept of Base Operation for CF-105 Aircraft" S 1038 CN-180 (AMTS/DMEng.), dated April 30, 1956

3. R.C.A.F. Report "CF-105 Aircraft - Maintenance Concept (1038 CH-100, dated December 1956).

4. R.C.A.F. Report "CF-105 Aircraft - Basic Data for Maintenance Planning" (Appendix "A" to the minutes of the 32nd meeting of the Arrow Co-ordinating Committee).

5. R.C.A.F. Operational Requirement 1/15-31 - Aircraft Telescramble System.

6. R.C.A.F. Operational Characteristic OCH 1/20-11. Operational Characteristics for an Alert Shelter for All-Weather Fighters.

7. R.C.A.F. Supplementary Specification to R.C.A.F. General Specification No. 1 for Standard Readiness Hangars.

8. Minutes of the 18th meeting of the Arrow Co-ordinating Committee.

9. Minutes of the 25th meeting of the Arrow Co-ordinating Committee.

10. AAMS-105/2 Issue 1. Model Specification for Arrow 2 Supersonic Interceptor Aircraft.

11. Avro Aircraft Limited Report Log/105/13 - Environmental Requirements for CF-105 Mobile Ground Power Units.

12. Avro Aircraft Limited Report C-105-R-0022 - A Proposal for Cables and Junction Boxes in the Readiness Hangar.

13. Avro Aircraft Limited Report Log/105/4. Automatic Disconnect Couplings.

14. Avro Aircraft Limited Report Log/105/24. Evaluation Study of Proposed Mobile Ground Power Equipment.

15. Avro Aircraft Limited Report P/Systems/8R - Load Analysis and Power System for Arrow 2 Aircraft.

16. R.C.A.F. Drawings

S-10-1020-1	Alert Hangar Unit; Hangar Plan, Site Plan, Elevation.
S-10-1020-2	Alert Hangar Unit; Crew Building.
SK-1075	Siting Sketch; Rocket & Missile Area.

APPENDIX A

ARROW 2 - GROUND COOLING OF ELECTRONIC EQUIPMENT
(Proposal submitted by John Inglis Co., Toronto)

SUBJECT

To establish the practicability of supplying conditioned air to electronic compartment and cockpit for stationary aircraft.

REQUESTED

Supply conditioned air at the rate of 150 lb./minute per aircraft at a pressure of $4\frac{1}{2}$ psig at the aircraft.

Air to be delivered at the aircraft within a temperature range of 55 to 80^{o}F. when ambient air has a temperature of 0 to 95^{o}F.

Equipment for supplying the air to be sized to deliver 150, 300 and 600 lb. air/minute for 1, 2 and 4 aircraft respectively with the larger sizes of equipment capable of supplying air at the necessary rate from 150 lb. to maximum capacity.

INITIAL SURVEY - The essential pieces of equipment were quickly established.

1. Filters to remove foreign particles from the incoming air.
2. Air compressor to compress the air to 6 psig to allow for air duct and equipment losses due to friction and to give 4.5 psig at the aircraft.
3. Cooling equipment to maintain air temperature to the aircraft within the desired limits.
4. Air ducts to feed the conditioned air to the aircraft.

EQUIPMENT SELECTION

This selection is broken down into 4 main sections dealing with the equipment shown in the Initial Survey.

1. Filters

This requirement for filters poses literally no problem as there is a wide range of material and sizes available for all purposes. We have shown on the following pages sizes of filters which will do the necessary work. The main essential is that these filters should be readily cleanable and efficiently screen out unwanted foreign matter. Electrostatic filtering is not considered necessary.

2. Air Compressor

It was imperative that this machine be capable, under continuous operation, of maintaining maximum dependability. The machine also had to be capable of delivering variations in volume whilst maintaining the air at a uniform pressure. A selection was, therefore, made of multi-stage centrifugal blower directly connected to a 3600 R.P.M. motor.

Note: - It was found that a blower selected for 600 lb. air/min. would surge when called upon to supply 150 or 300 lb. air/min. Also, due to large load variation in the cooling cycle such a large variation in air delivery would tend to complicate the necessary cooling controls. It was therefore decided at this point only to select equipment suitable for supplying 150 and 300 lb. air/min. It will be a simple matter to interconnect the duct-work so that 600 lb. air/min. can be maintained for distribution purposes by using two sets of air conditioning equipment.

3. Cooling Equipment

Essentially, this equipment can be broken into four parts:-

(a) Cooling coil, containing liquid refrigerant, over which the air to be cooled is passed. Heat from the air will vaporize the liquid refrigerant with the vapor being returned to the compressor by the suction piping.

(b) Refrigerant compressor to maintain a pressure differential between the suction and discharge lines in order that refrigerant flow through the evaporator may be achieved.

(c) Condenser to provide a continuous supply of liquid refrigerant to the cooling coil by removing the heat of compression and latent heat of vaporization from the refrigerant gas delivered by the compressor discharge.

(d) Controls to adjust automatically the refrigeration system capacity to match the cooling load.

These four parts are further amplified thus:-

(a) The cooling coil should be finned to provide the necessary heat transfer resulting in a smaller size than for plain tube. The sizing of the coil has been shown on the following pages. The refrigerant inside the tubes should be maintained at a minimum temperature of 35°F to prevent the formation of ice on the finned tubes.

(b) The refrigerant compressor, V-belt driven by an electric motor, to be capable of adjusting its capacity automatically as the cooling load varies, and running without requiring any attention beyond normal maintenance.

(c) The condenser could be either -

(i) Water Cooled Condenser which, as its name implies, uses water passed through tubes to cool the refrigerant gas encased in the condenser shell.

(ii) Evaporative Condenser which sprays water over coils containing the refrigerant whilst at the same time blowing air across the tubes. The prime consideration here is that less water is used than with the water cooled condenser. However, the evaporative condenser is larger than the water cooled condenser and precautions should be taken during the cold season due to the danger of the water freezing.

(iii) Air Cooled Condenser. This condenser is purely large areas of finned tube, containing the refrigerant over which air is blown. The disadvantage of price and large areas of finned tube is compensated by the fact that no water supply is required for this type of condenser. Multi-staging of the fans blowing the air will help to maintain constant head pressure at all ambients.

Dimensions of condensers with necessary water requirements are listed on the following pages.

(d) The main controls should consist of:

(i) Thermostat to ring alarm bell if air delivered to aircraft is above 80°F.

(ii) Suction Pressure Regulator to maintain a minimum refrigerant temperature in the cooling coil at 35°F.

(iii) Low Pressure Switches to reduce the capacity of the refrigerant compressor to coincide with the cooling coil load.

4. Air Ducts

The air after passing the filters will be fed via transition pieces to the blower, thence to the cooling coil. After the cooling coil a transition piece will feed the air into the main delivery ducts. The main delivery ducts of each set of equipment will be joined into a common distribution header system capable of handling a total of 600 lb. air/min. From the header duct, branches will lead to the various aircraft stations. It is understood that the aircraft stations will be fixed as to position. It is therefore possible for the header and branch ducts to be led around the wall of the hangars or embedded in the floor. From the end of each air branch a flexible pipe will feed, via quick-release connection, to the 3" dia. opening in the plane. It is also understood that this 3" opening will be actually a streamlined orifice, otherwise a higher air pressure would be needed to supply this volume of air than the 6 psig allowed.

OPERATION

The air blower and refrigerant compressor would be started manually by means of electrical switches. Air would then be automatically conditioned and fed into the main delivery duct. No other action would be required to start or continue the delivery of conditioned air by the personnel. Connecting of the quick-release connection to the aircraft and manual operation of an air valve would allow the feeding of conditioned air to that aircraft. Regardless of the size of the equipment, if air is not required for a considerable time, say 12 hours or more, it would not be necessary to shut down the equipment manually by means of the electrical switches. No harm will be done to the air blower or refrigerant compressor if air is not required for sometime. The air blower will continue to run but its performance characteristics are such that only a very slight increase in air pressure would result in the ducting system. The refrigerant compressor would automatically stop if there was no cooling load. If equipment were selected for delivery of 300 lb. air/min. per set, then if only one aircraft required cooling the duct friction would be such that only slightly over half the requirement, that is, 150 lb. air/min. would be fed to the one aircraft. No problem is envisaged if more than 150 lb./min. is fed to the one aircraft and, therefore, no special steps have been taken to control the delivery to a maximum of 150 lb. air/min.

We believe that, as outlined above, equipment can be selected to give the necessary conditioned air in the quantities desired and maintain maximum dependability of operation.

It is felt that equipment as outlined above could be supplied f.o.b. Toronto, taxes extra, for the approximate sum of:-

For 150 lb. air per minute, using	Water Cooled Condenser	....	$ 29,300.00
	" Evaporative Condenser	....	30,500.00
	" Air Cooled Condenser	....	31,000.00
For 300 lb. air per minute, using	Water Cooled Condenser	....	$ 41,100.00
	" Evaporative Condenser	....	42,700.00
	" Air Cooled Condenser	....	44,600.00

Not included in the above costs are:

(a) Installation of equipment.

(b) Flexible duct and quick-release connection to aircraft.

DIMENSIONS

The following data shows size and other pertinent detail for the major components on the system.

	For 150 lb. Air/Min.	For 300 lb. Air/Min.
1. FILTERS		
Overall size	32" x 20" x 2" th.	32" x 40" x 2" th.
2. AIR BLOWER	L W H	L W H
Overall size with motor	79" x 38" x 48"	110" x 41" x 54"
Discharge Pressure psig	6	6
H. P. input	95	173
Motor H. P. req'd.	100	200
Discharge temp. at 0°F ambient	85	77
Discharge temp. at 95°F ambient	198	188
3. (a) COOLING COIL	H W D	H W D
Overall size	27" x 33" x 15"	27" x 57" x 15"
(b) REFRIGERANT COMPRESSOR	L W H	L W H
Overall size with motor	70" x 36" x 36"	70" x 36" x 40"
Cooling capacity at 35°F refrigerant temp.	27 tons	55 tons
H. P. input	36.5	71 H. P.
Motor req'd. H. P.	40	75
Condensing Temp.	115°	115°
Heat rejection BTU/hr.	410,000	830,000
(c)(i) WATER COOLED CONDENSER (mounted over compr.)		
Overal size	72" L x 12" dia.	18" dia. x 84" L
Max. water req'd. U.S. g.p.m. at 80° temp. eater on temp.	50	75

(ii) EVAP. CONDENSER (stationed outside bldgs.)

	For 150 lb.Air/Min. H L W	For 300 lb.Air/Min. H L W
Overall size	84" x 54" x 62"	90" x 72" x 84"
Fan H.P.	1-1/2	3
Approx. max. water req'd. U.S. g.p.m.	3	6
Pump H.P.	1/3	1/2

(iii) AIR COOLED CONDENSER (stationed outside bldgs.)

	H W D	H W D
Overall size	90" x 90" x 36"	2 x 90" x 90" x 36"
Fan H.P.	4 - 1/2 H.P.	8 - 1/2 H.P.

3. Main delivery duct size dia. - Max.length 100'	10"	12"
Common header duct size - 600 lb./min., max.length 100'	14"	14"
branch duct size 300 lb./min., max.length 100'	10"	10"
flexible duct size 150 lb.min., max.length 50'	6"	6"

Note: (a) Flexible duct to taper to 3" dia. for entry to aircraft.

(b) Duct lengths above are to show approximate allowance in cost figures and do not represent maximum lengths of ducts which could be used if so desired and any necessary increase in duct size allowed.

(c) Weight of equipment, less ductwork, for the supply of 150 lb. air/min. is estimated to be in the region of 12,000 lb.

(d) Weight of equipment, less ductwork, for the supply of 300 lb./ min. is estimated to be in the region of 18,000 lb.

(e) Above weights are based on air-cooled condensers will be reduced somewhat with water cooled condensers.

2140-105-1

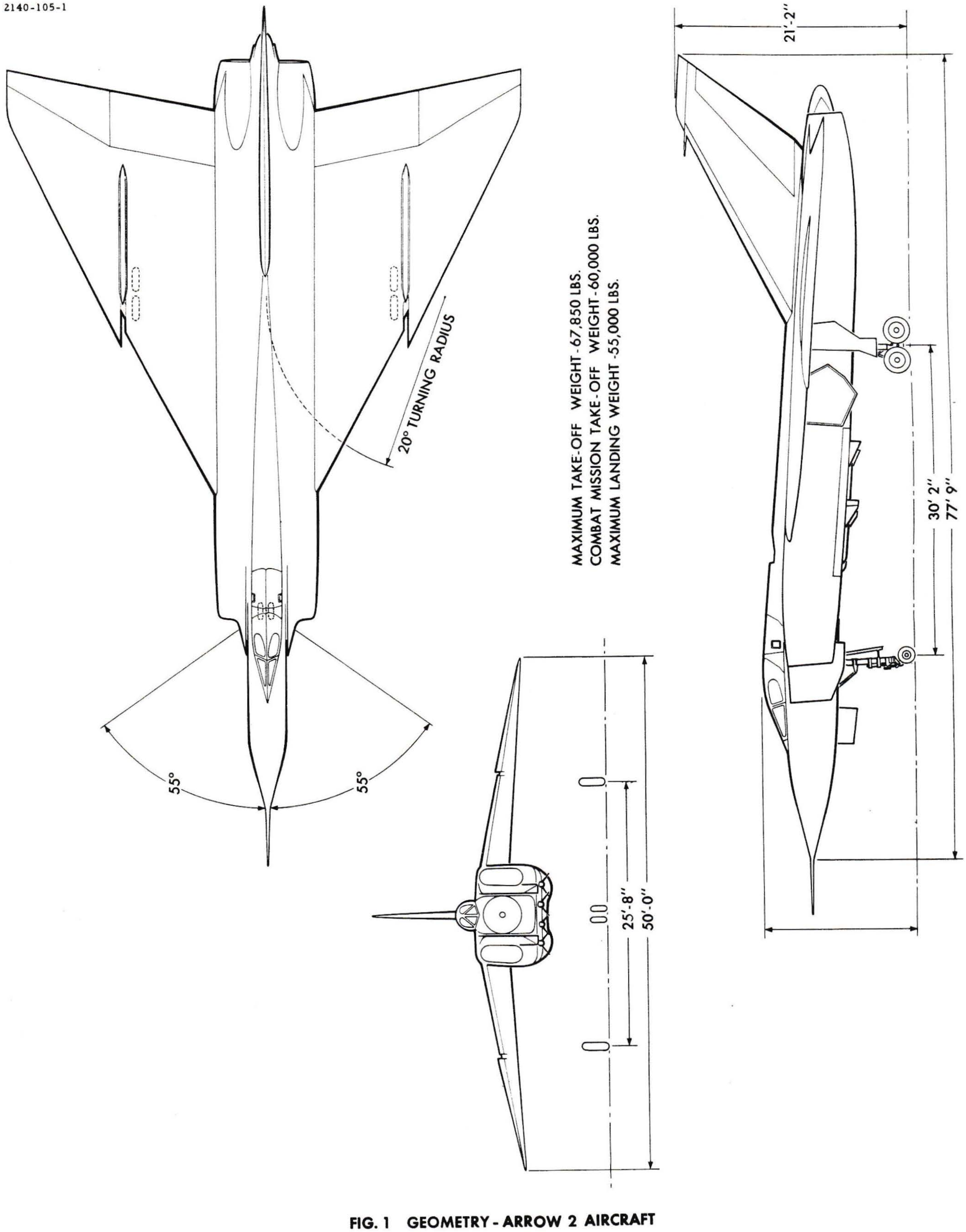


FIG. 1 GEOMETRY - ARROW 2 AIRCRAFT

3141-105-1

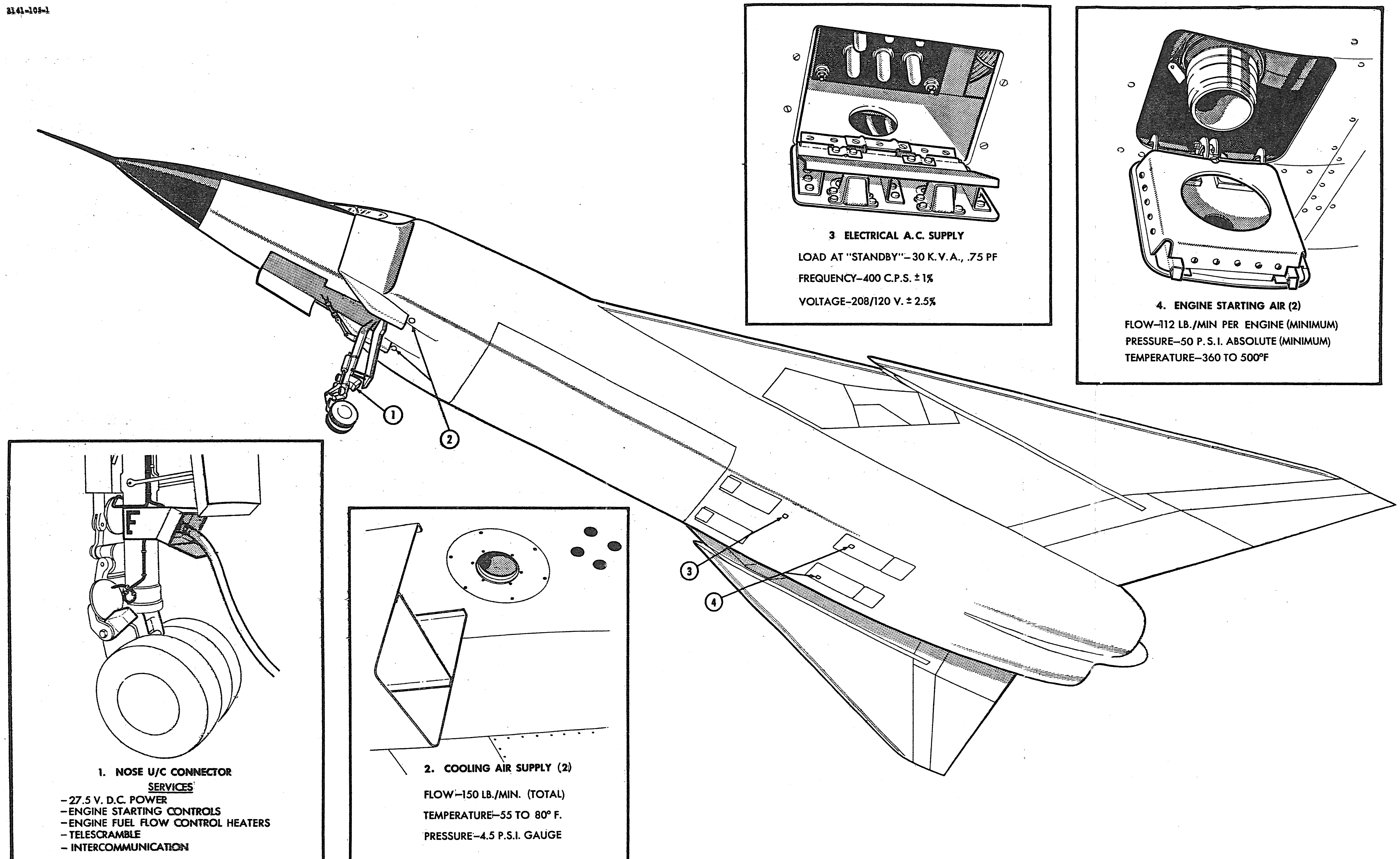


FIG. 2 ARROW 2 CONNECTIONS FOR GROUND SUPPORT SERVICES

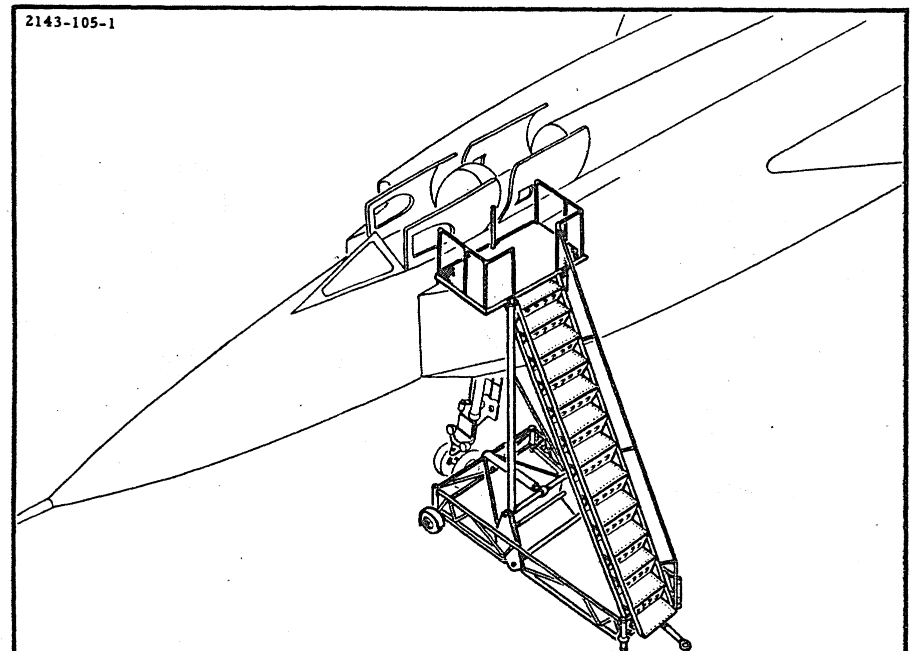


FIG. 3A COCKPIT ACCESS-MOBILE LADDER

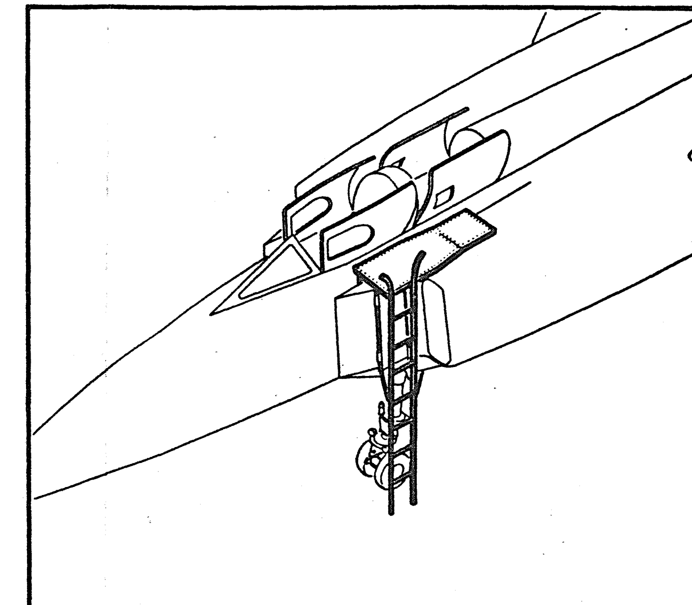
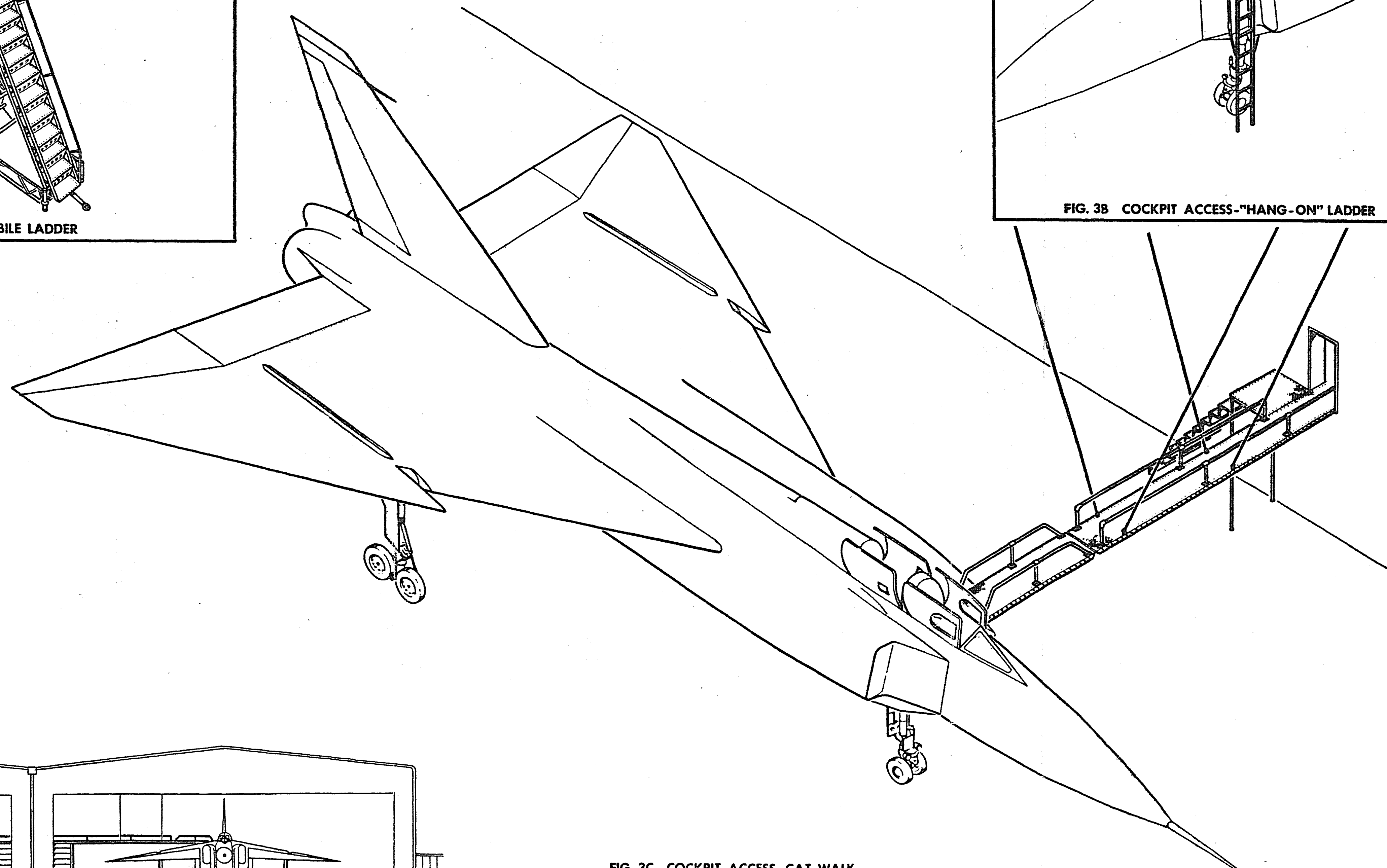


FIG. 3B COCKPIT ACCESS-"HANG-ON" LADDER



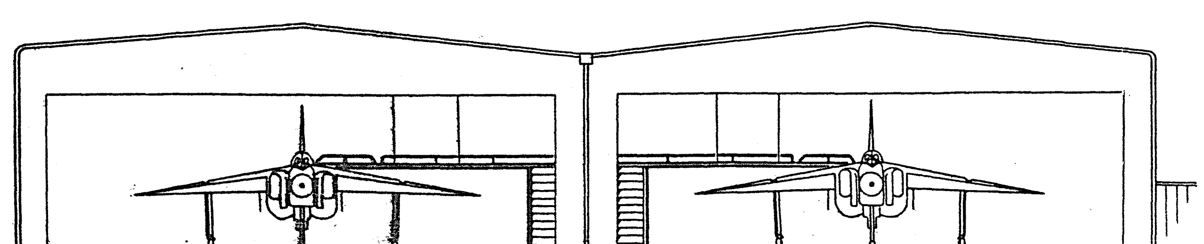


FIG. 3C COCKPIT ACCESS-CAT WALK

FIG. 3 ARROW 2 COCKPIT ACCESS EQUIPMENT

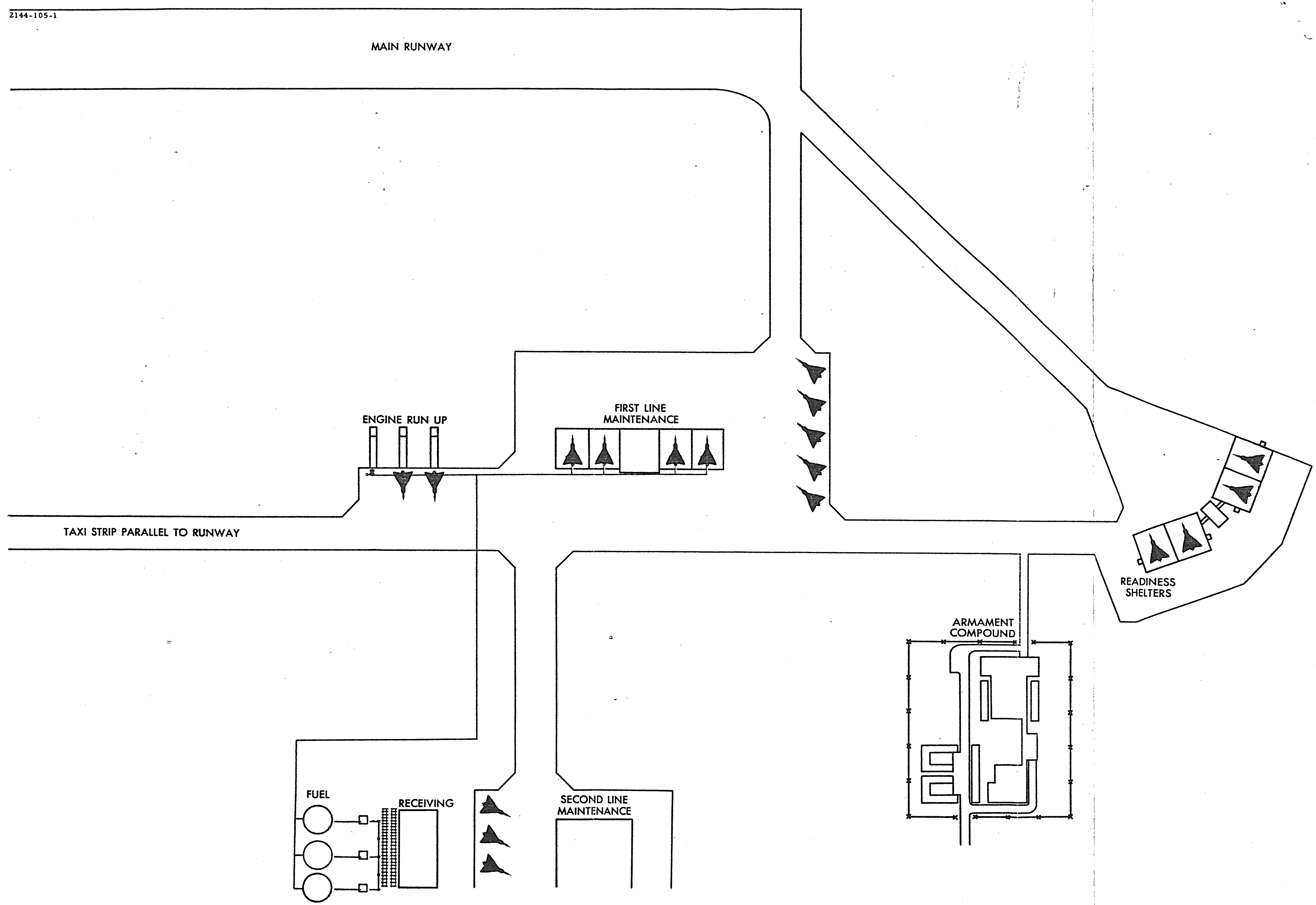


FIG. 4 TYPICAL AIR BASE LAYOUT

2145-105-1

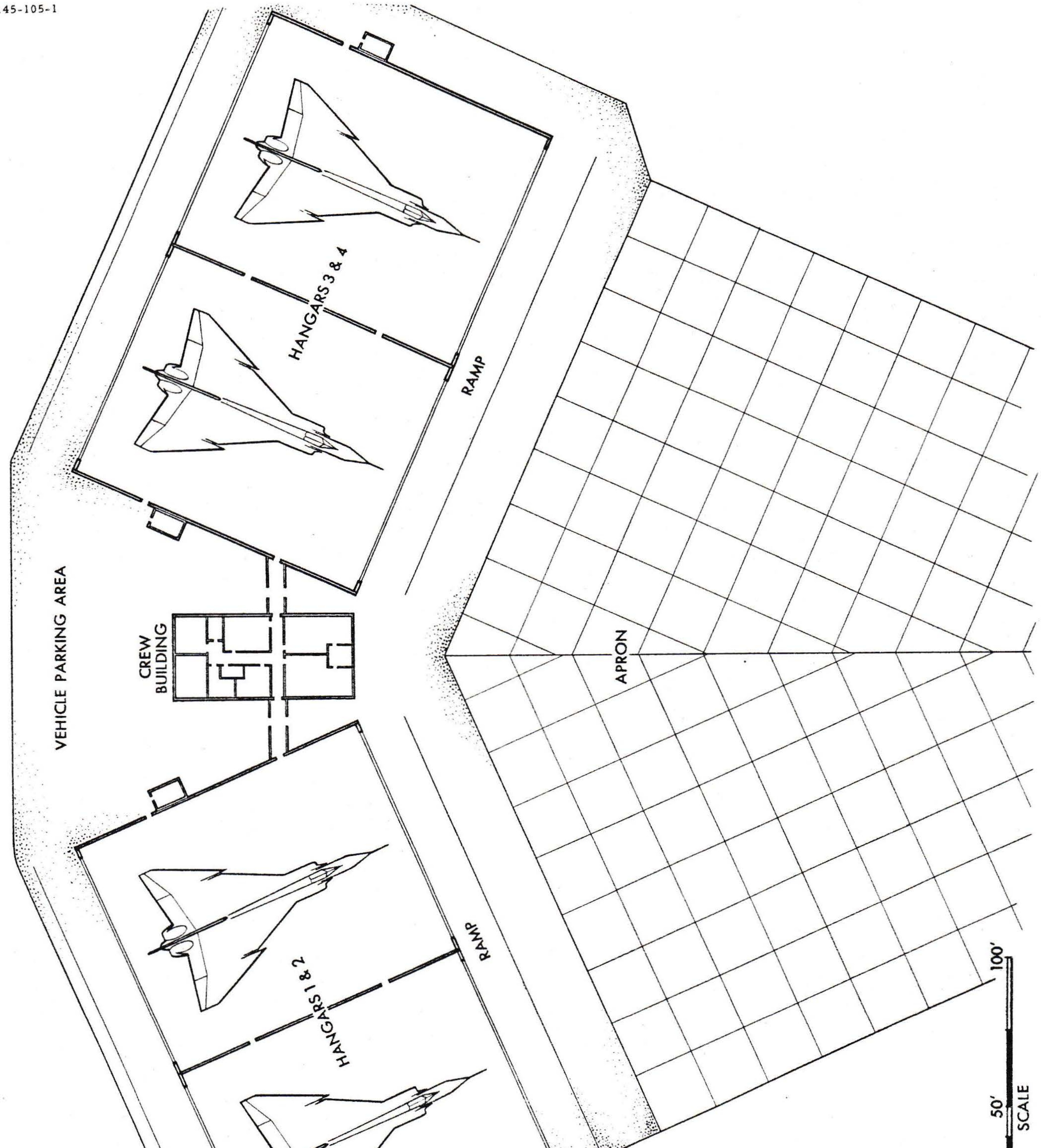


FIG. 5 LAYOUT - R.C.A.F. STANDARD READINESS HANGARS

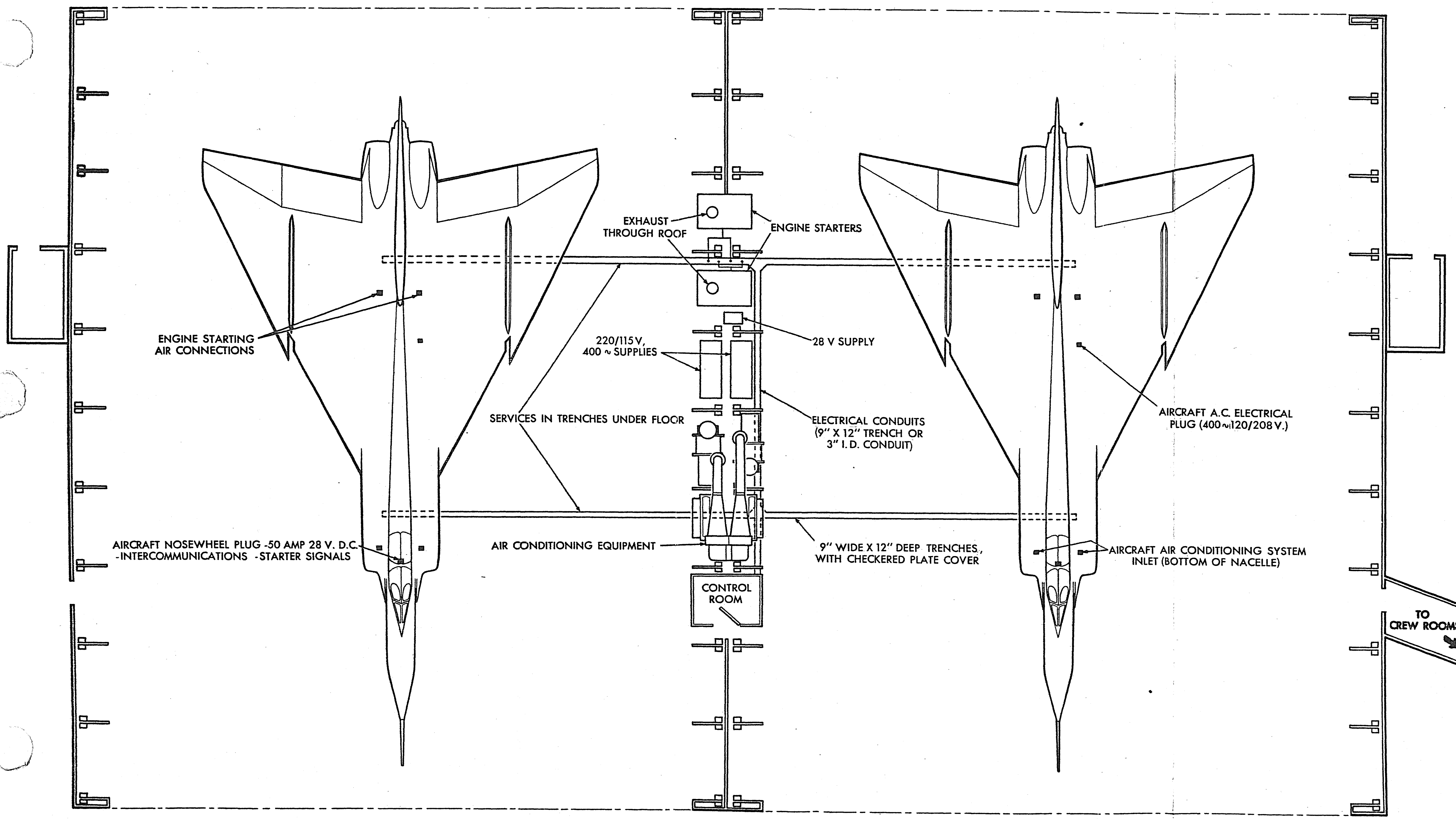


FIG.6 LAYOUT OF GROUND SUPPORT EQUIPMENT & SERVICES IN R.C.A.F. STANDARD READINESS HANGARS

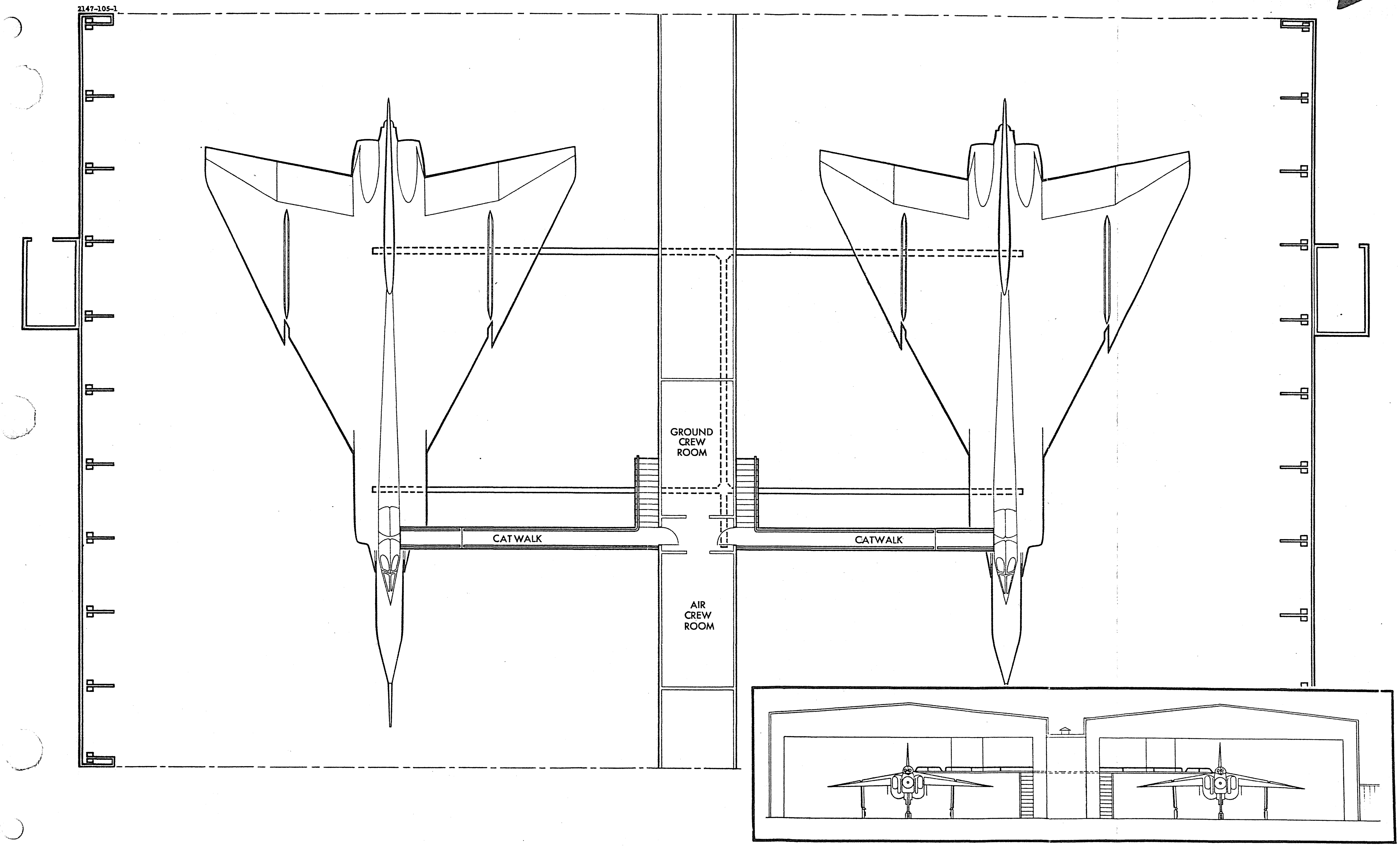


FIG. 7 ALTERNATIVE LAYOUT FOR READINESS HANGARS

2148-105-1

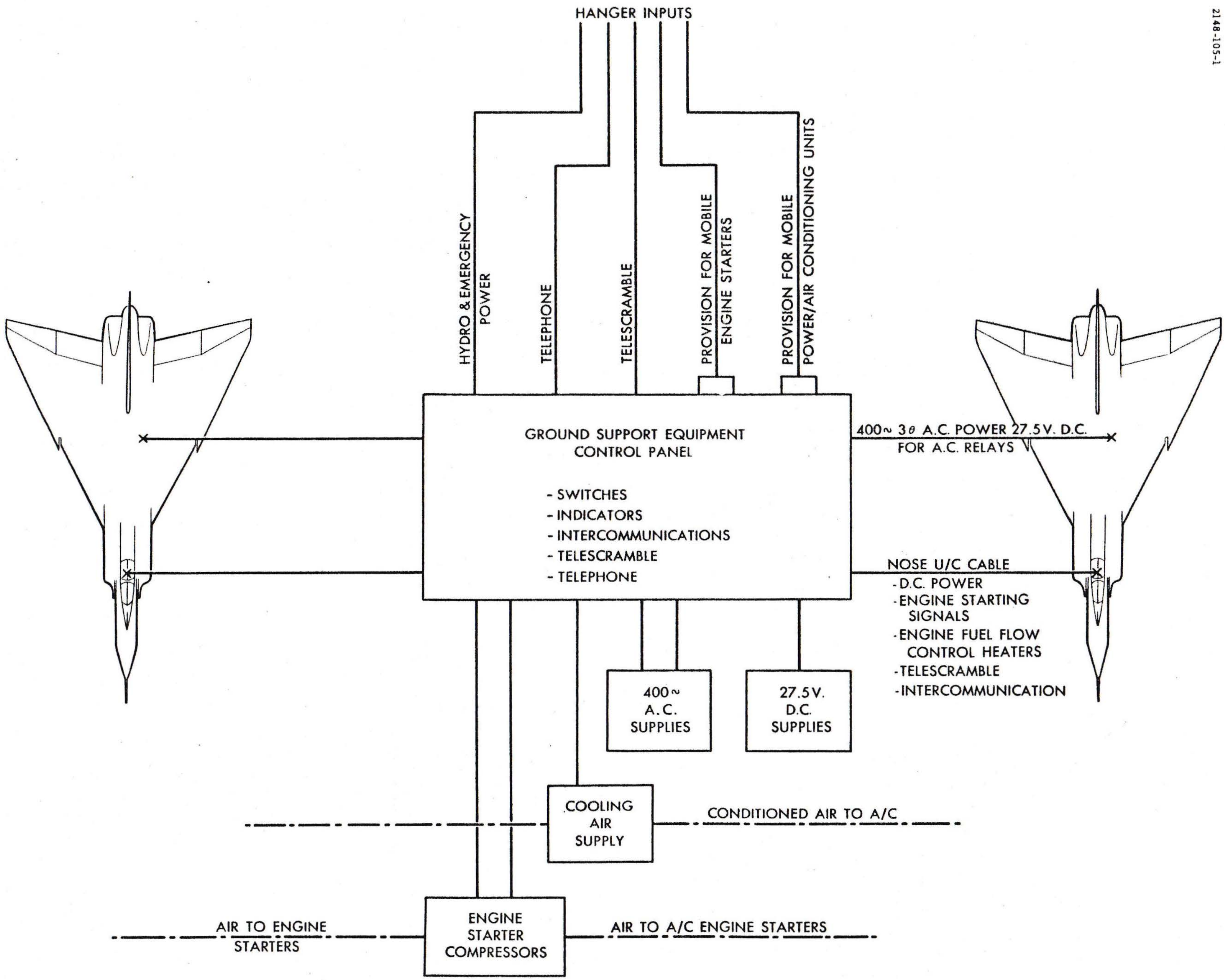


FIG. 8 SCHEMATIC DIAGRAM - ARROW 2 READINESS SERVICES

2414-105-1

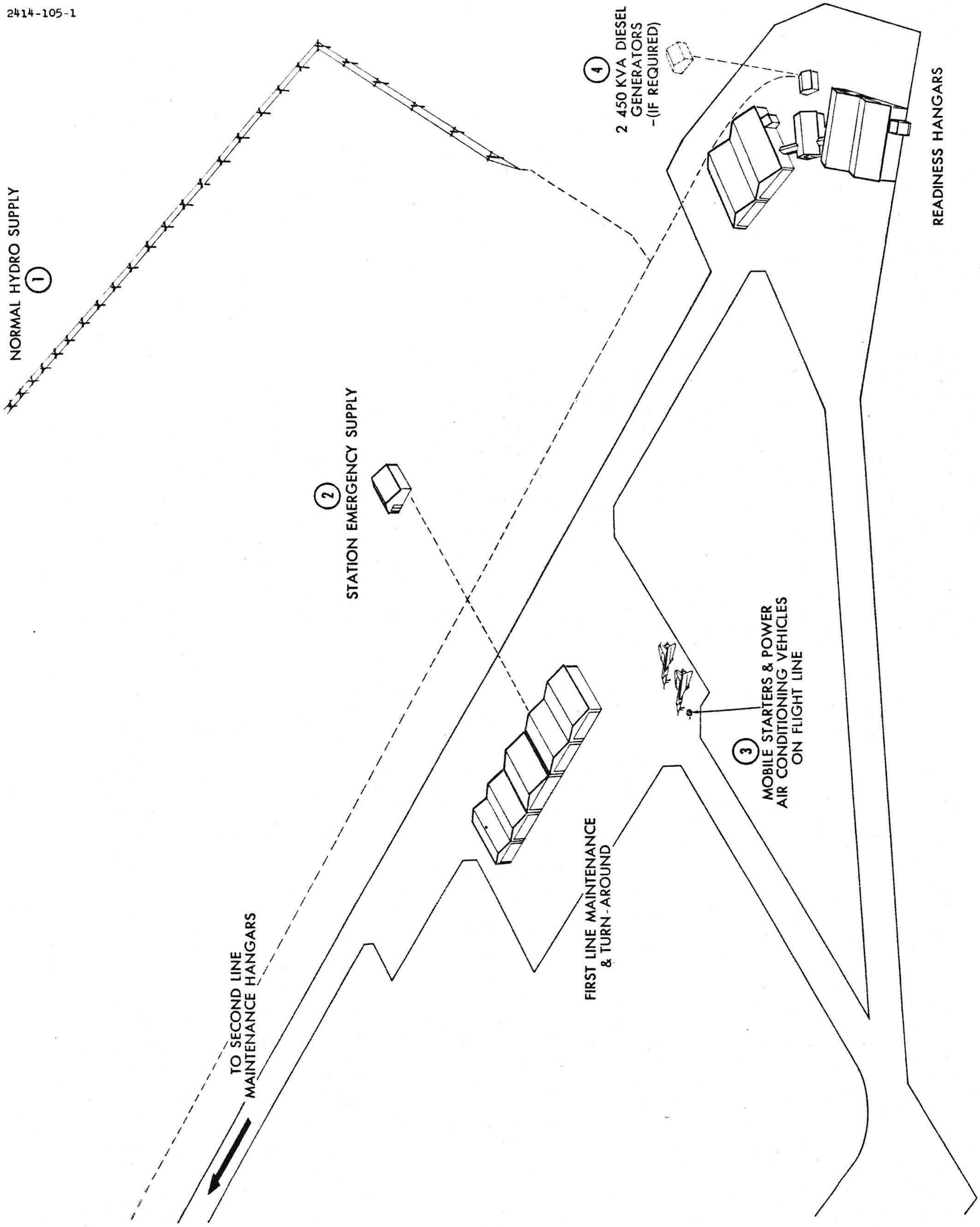


FIG. 9 EMERGENCY POWER SUPPLIES

2149-105-1

AIR CREWS

1. LEAVE CREW ROOM, GO TO #1 A/C
2. LEAVE CREW ROOM, GO TO #2 A/C
3. ENTER & CHECK COCKPITS #1 A/C
4. ENTER & CHECK COCKPITS #2 A/C
5. CONNECT HARNESS, SERVICES #1 A/C
6. CONNECT HARNESS, SERVICES #2 A/C
7. WAIT FOR SCRAMBLE ORDER #1 A/C
8. WAIT FOR SCRAMBLE ORDER #2 A/C
9. START ENGINES #1 A/C
10. START ENGINES #2 A/C
11. ACCELERATE ENGINES & TAXI #1 A/C
12. ACCELERATE ENGINES & TAXI #2 A/C
13. TAKE-OFF #1 A/C
14. TAKE-OFF #2 A/C

GROUND CREW #1

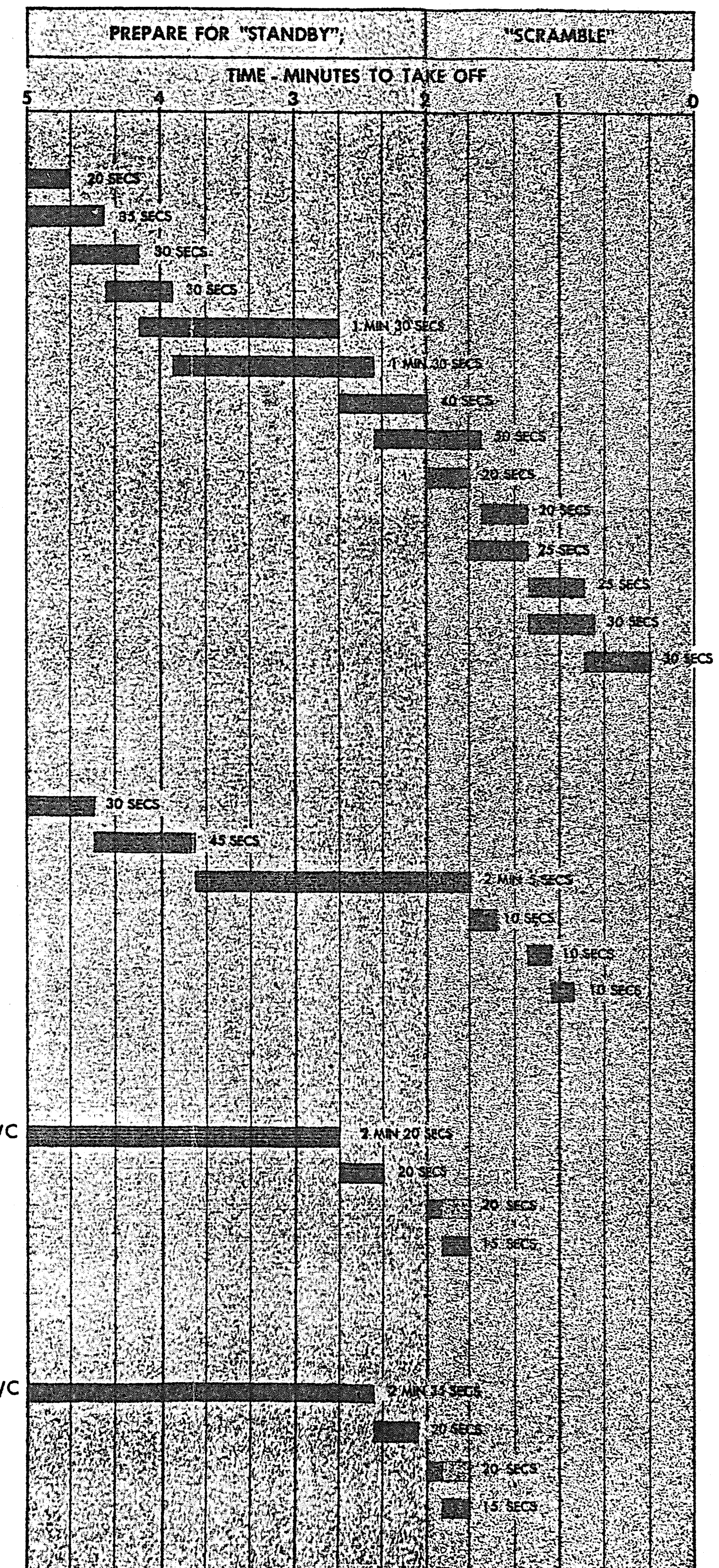
1. PROCEED TO CONTROL ROOM
2. START COOLING AIR SUPPLY, ENGINE STARTERS
3. MONITOR GROUND SUPPORT EQUIPMENT
4. CHECK RELEASE OF COUPLINGS #1 A/C
5. CHECK RELEASE OF COUPLINGS #2 A/C
6. TURN OFF EQUIPMENT

GROUND CREW #2 & 3

1. REMOVE GROUND LOCKS ASSIST AIRCREW #1 A/C
2. REMOVE ACCESS STAIRS
3. OPEN HANGAR DOORS
4. PROCEED TO CREW ROOMS

GROUND CREW #4 & 5

1. REMOVE GROUND LOCKS ASSIST AIRCREW #2 A/C
2. REMOVE ACCESS STAIRS
3. OPEN HANGAR DOORS
4. PROCEED TO CONTROL ROOM



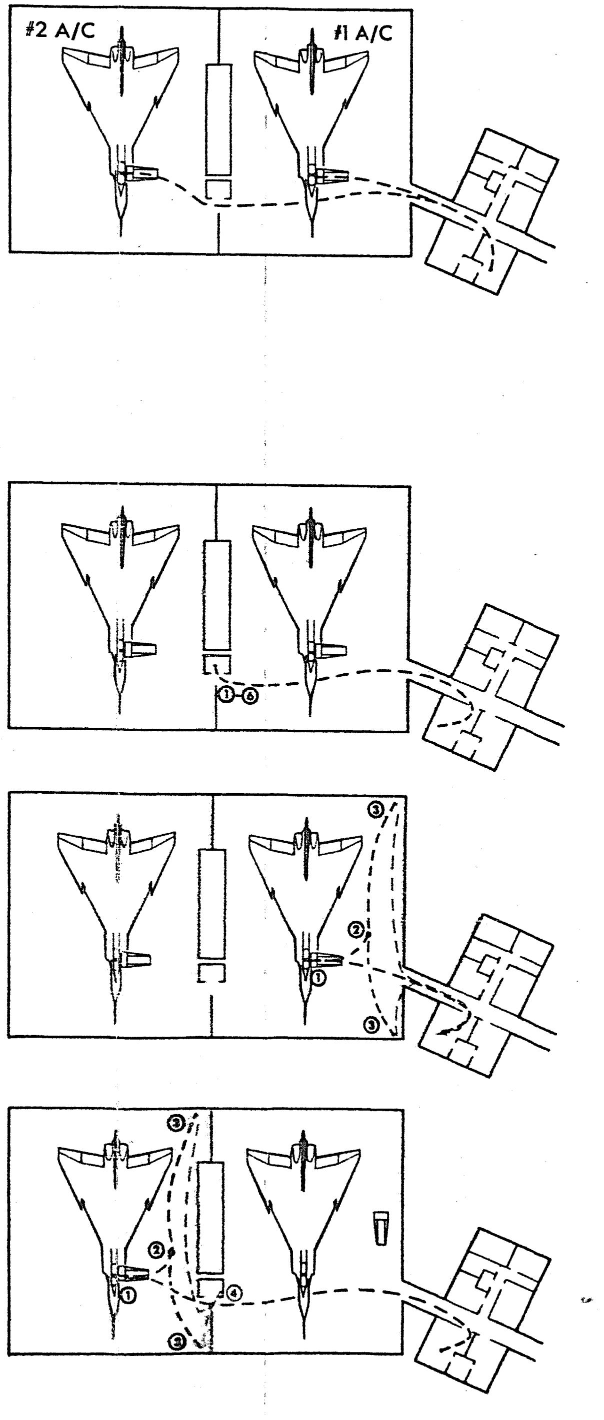
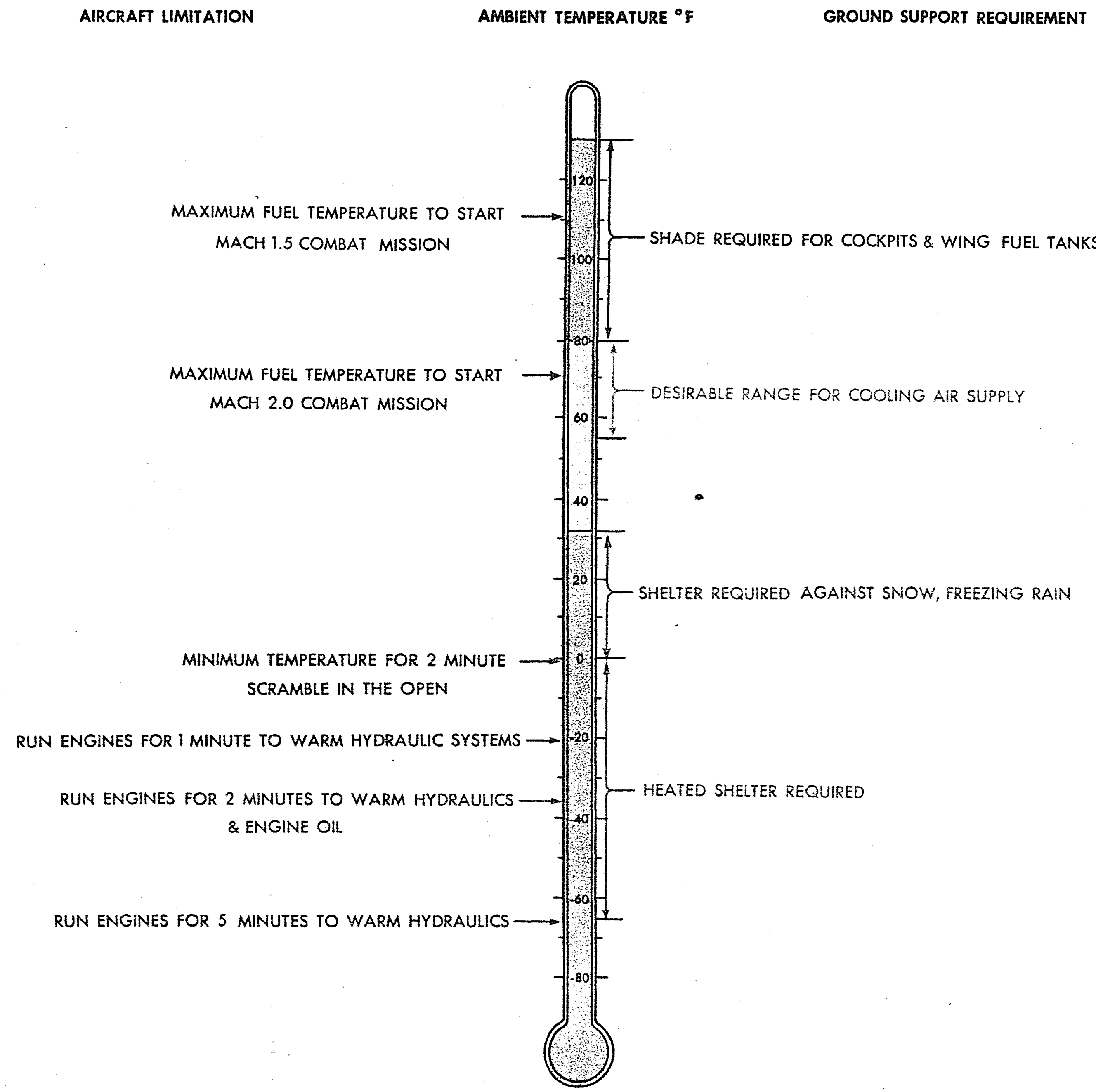
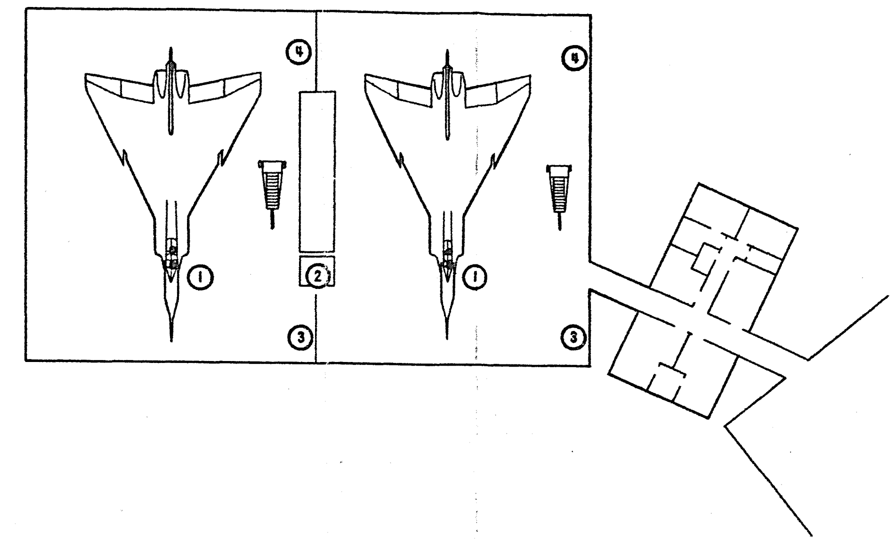


FIG. 10 TIMES & MOTIONS - PREPARATION FOR "STANDBY"; "SCRAMBLE".

2150-105-1





CREW POSITIONS

1. AIRCREW–IN COCKPIT & READY FOR SCRAMBLE
2. GROUND SUPPORT EQUIPMENT OPERATOR–IN EQUIPMENT CONTROL ROOM

3,4. GROUNDCREW–AT HANGAR DOOR RELEASE HANDLES

EQUIPMENT STATUS

1. ELECTRICS–"ON" POWER FROM GROUND SOURCE
2. ELECTRONICS–"STAND-BY"
3. COOLING AIR–SUPPLIED FROM GROUND SOURCE
4. COMMUNICATIONS EQUIPMENT–"ON" NOSE U/C CONNECTOR PLUGGED IN.
5. ENGINES–"OFF"
6. ENGINE STARTING UNITS-RUNNING; HOSES CONNECTED TO A/C; FLOW CONTROL VALVES CLOSED
7. UNDERCARRIAGE LOCKS, EJECTOR SEAT SAFETY PINS REMOVED
8. COCKPIT ACCESS STAIRS CLEAR OF TAXIING PATH
9. HANGAR DOORS–CLOSED IF TEMPERATURE IS BELOW 0°F

GROUND SUPPORT SERVICES FOR EACH AIRCRAFT

1. A.C. POWER–400 C.P.S. ± 1%, 3 PHASE, 4 WIRE, 220/108 V., 30 K.V.A. AT .75 POWER FACTOR
2. D.C. POWER–27.5 V. 5 AMP. AT A.C. PLUG FOR A.C. RELAYS.
   –APPROX. 40 AMP. INTERMITTENT OR EMERGENCY AT NOSE UNDERCARRIAGE PLUG.
3. COOLING AIR–4.5 P.S.I. GAUGE, 55-80°F., 150 LB./MIN. THROUGH 2 HOSES
4. ENGINE STARTING AIR–50 P.S.I. ABSOLUTE (MINIMUM), 112 LB./MIN PER ENGINE (MINIMUM); 360 TO 500°F
5. NOSE UNDERCARRIAGE CONNECTOR –TELESCRAMBLE
   –INTERPHONE
   –ENGINE STARTING SIGNALS
   –EMERGENCY D.C. POWER
   –400 C.P.S., 1 PHASE AC POWER-500 V.A.

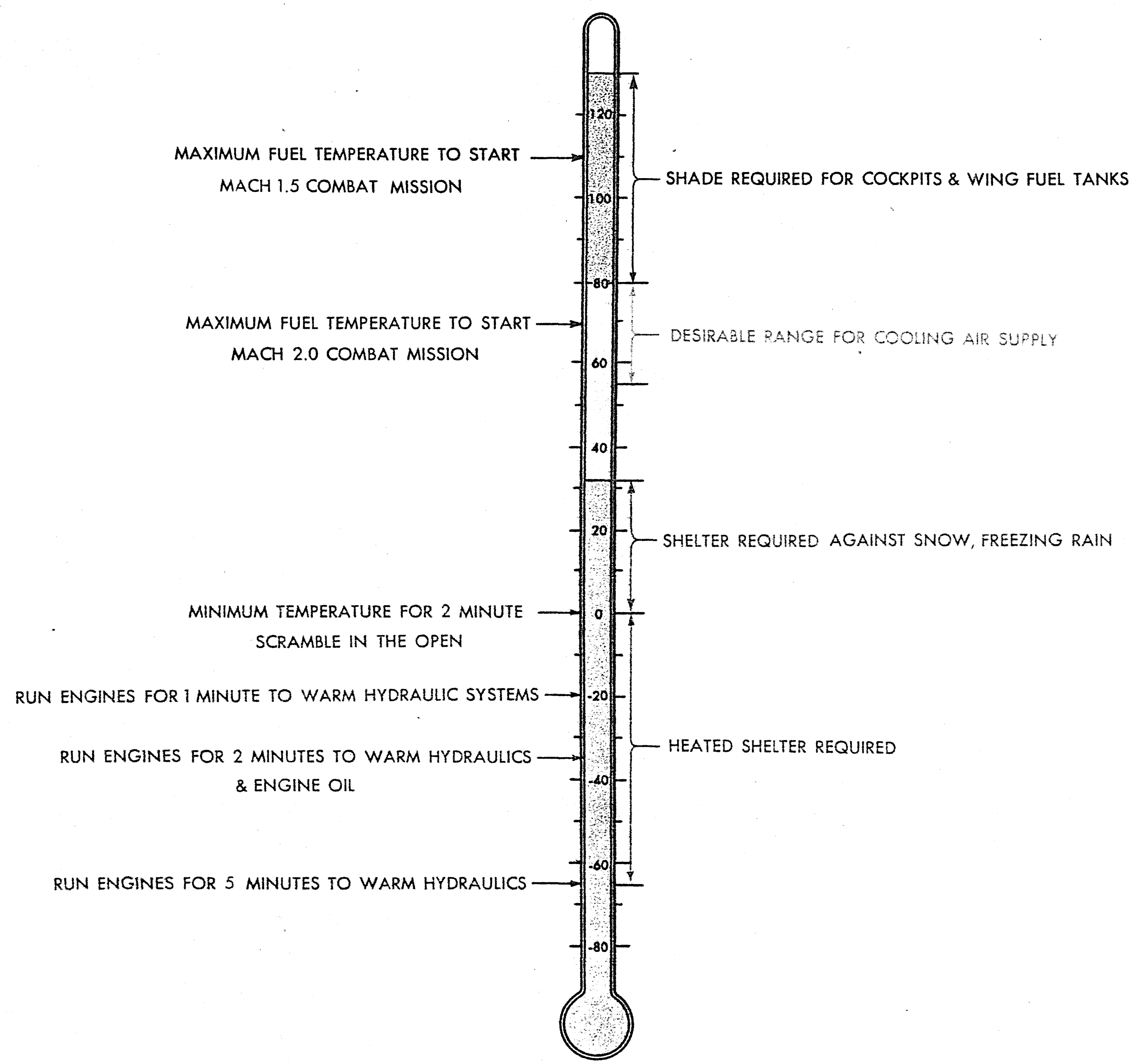
FACTORS LIMITING DURATION OF "STANDBY"

1. MAXIMUM FUEL TEMPERATURE-FUNCTION OF INITIAL FUEL TEMPERATURE, AMBIENT CONDITIONS, MISSION. TIMES NOT AVAILABLE
2. AIRCRAFT OXYGEN SUPPLY–2 HOURS IF USED BY AIRCREW AT STANDBY
3. ASTRA 1 SYSTEM-DATA NOT AVAILABLE. "GO-NO-GO" CHECK MAY BE DESIRABLE EVERY 4 HOURS
4. AIRCREW

FIG. 11 ARROW 2 READINESS CONDITION 1 "STANDBY"
(AIRCRAFT CAPABLE OF BEING AIRBORNE WITHIN 2 MINUTES)

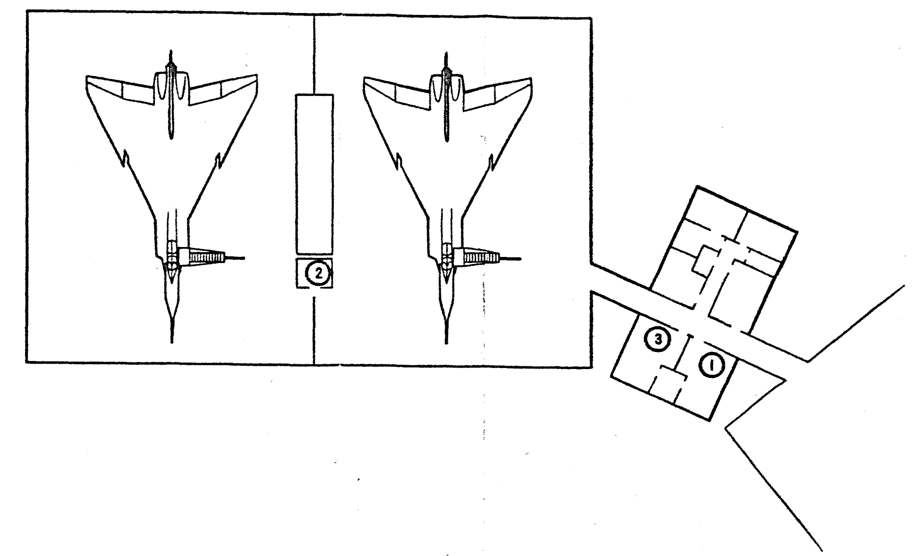
2151-105-1

AIRCRAFT LIMITATION | AMBIENT TEMPERATURE °F | GROUND SUPPORT REQUIREMENT



FACTORS LIMITING DURATION OF "READINESS"

1. MAXIMUM FUEL TEMPERATURE-FUNCTION OF INITIAL FUEL TEMPERATURE, AMBIENT CONDITIONS, MISSION. TIMES NOT AVAILABLE
2. ASTRA I SYSTEM – DATA NOT AVAILABLE. "GO-NO-GO" CHECK MAY BE DESIRABLE EVERY 4 HOURS



CREW POSITIONS

1. AIRCREW-IN CREW ROOMS
2. GROUND SUPPORT EQUIPMENT OPERATOR-IN EQUIPMENT CONTROL ROOM
3. GROUND CREW-IN CREW ROOMS

EQUIPMENT STATUS

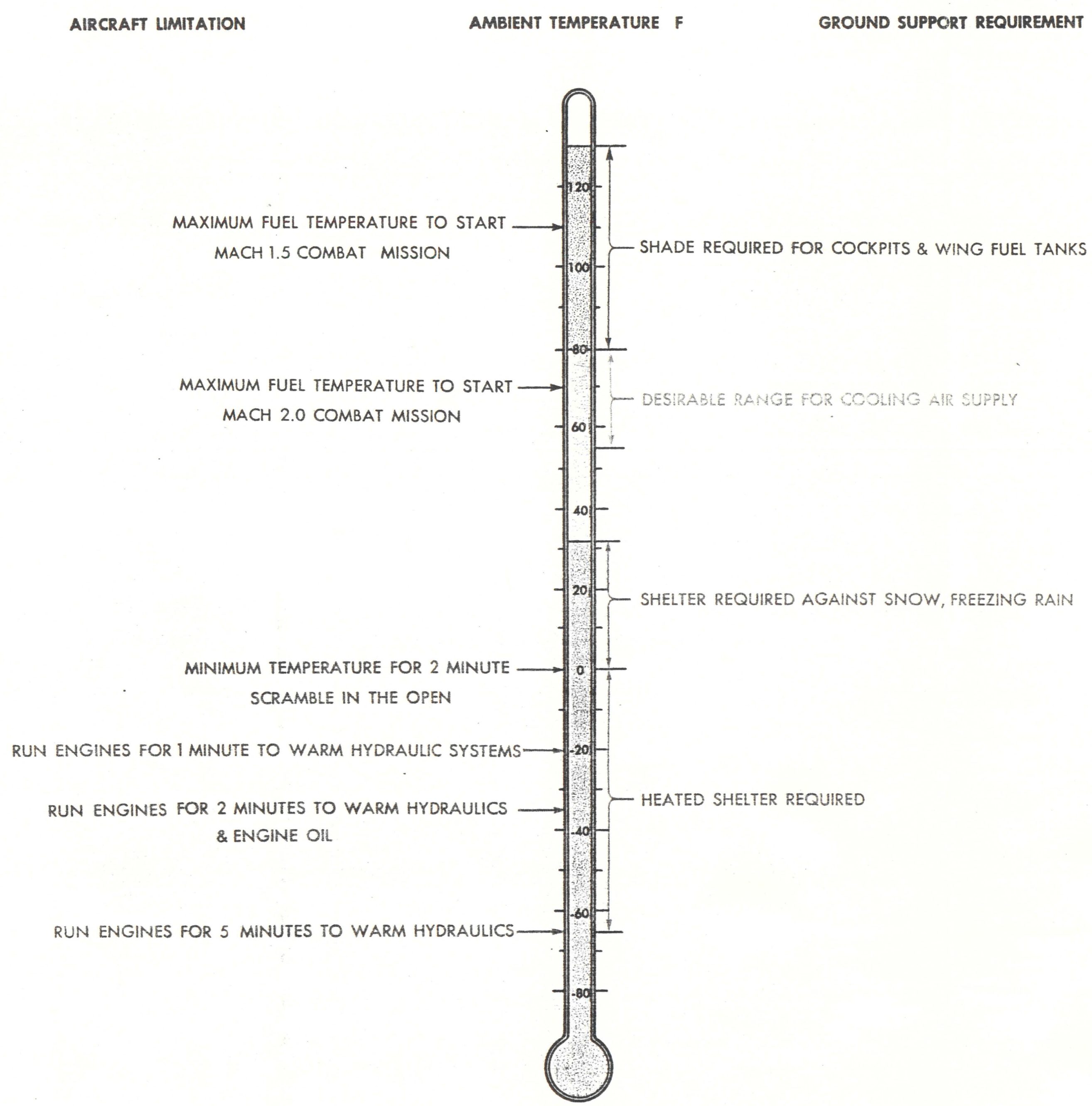
1. ELECTRICS-"ON" POWER FROM GROUND SOURCE
2. ELECTRONICS- GYRO HEATERS ON. ASTRA SYSTEM POSSIBLY ON "STAND-BY"
3. NOSE UNDERCARRIAGE CONNECTOR-PLUGGED IN; POWER, INTERCOMMUNICATIONS & TELESCRAMBLE ON
4. COOLING AIR– SUPPLIED FROM GROUND SOURCE
5. ENGINE STARTING UNITS-"OFF" HOSES CONNECTED TO AIRCRAFT
6. UNDERCARRIAGE GROUND LOCKS INSTALLED, EJECTOR SEAT SAFETY PINS FITTED
7. COCKPIT ACCESS STAIRS IN POSITION
8. HANGAR DOORS-CLOSED IF TEMPERATURE IS BELOW 0°F

GROUND SUPPORT SERVICES FOR EACH AIRCRAFT

1. A.C. POWER-400 C.P.S. ± 1%, 3 PHASE, 4 WIRE, 220/108 V., –30 K.V.A. AT .75 POWER FACTOR
2. D.C. POWER-27.5 V. 5 AMP. AT A.C. PLUG FOR A.C. RELAYS.
   APPROX. 40 AMP. INTERMITTENT OR EMERGENCY AT NOSE UNDERCARRIAGE PLUG.
3. COOLING AIR-4.5 P.S.I. GAUGE, 55-80°F., 150 LB./MIN.
4. ENGINE STARTING AIR-50-60 P.S.I. ABSOLUTE, 200-500°F., 120 LB./MIN. PER ENGINE
5. NOSE UNDERCARRIAGE CONNECTOR-TELESCRAMBLE
   - INTERPHONE
   - ENGINE STARTING SIGNALS
   - EMERGENCY D.C. POWER
   - 400 C.P.S., 1 PHASE AC POWER-500 V.A.

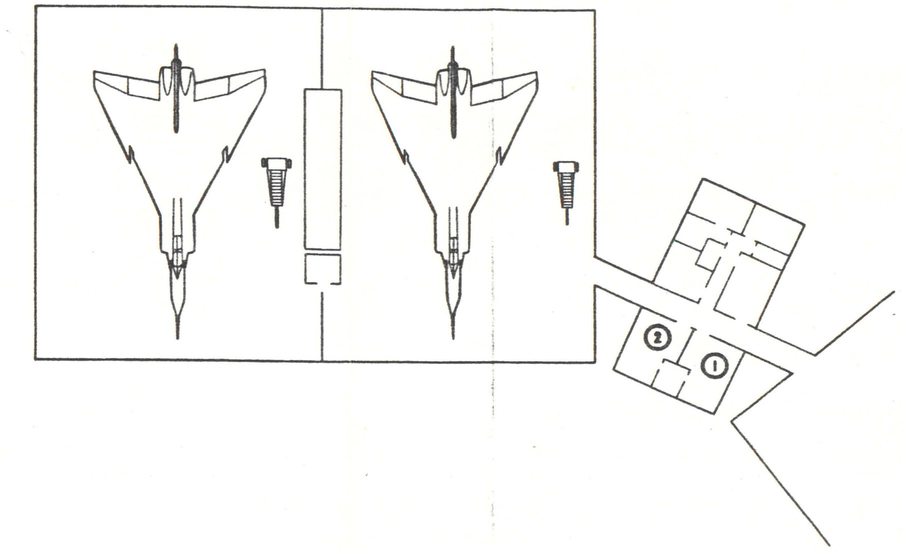
FIG. 12 ARROW 2 READINESS CONDITION 2 "READINESS"
(AIRCRAFT CAPABLE OF BEING AIRBORNE WITHIN 5 MINUTES)

2152-105-1



FACTORS LIMITING DURATION OF "AVAILABLE"

1. **MAXIMUM FUEL TEMPERATURE - FUNCTION OF INITIAL FUEL TEMPERATURE, AMBIENT CONDITIONS, MISSION. TIMES NOT AVAILABLE**
2. **ASTRA 1 SYSTEM - DATA NOT AVAILABLE.** "GO-NO-GO" CHECK MAY BE DESIRABLE EVERY 4 HOURS



CREW POSITIONS

1. AIRCREW-IN CREW ROOMS
2. GROUNDCREW-IN CREW ROOMS OR DOING MINOR SERVICING JOBS-REPLACE LIQUID OXYGEN CONVERTER -REPLACE AIRCRAFT IN HANGARS -REFUELLING ENGINE STARTERS - ALIGN VERTICAL & HEADING REFERENCE SYSTEM "GO-NO GO" CHECK ON ASTRA 1 ELECTRONIC SYSTEM

EQUIPMENT STATUS

1. ELECTRICS-"OFF"
2. COOLING AIR-"OFF"

] "ON" IF ASTRA 1 SYSTEM IS UNDER TEST OR KEPT ON "STANDBY"

3. ENGINE STARTING UNITS-"OFF"
4. UNDERCARRIAGE GROUND LOCKS INSTALLED; EJECTOR SEAT SAFETY PINS FITTED
5. HANGAR DOORS-CLOSED IF TEMPERATURE BELOW 0°F

GROUND SUPPORT SERVICES FOR EACH AIRCRAFT

1. A.C. POWER–400 C.P.S. ± 1%, 3 PHASE, 4 WIRE, 220/108 V., 30 K.V.A. AT .75 POWER FACTOR
2. D.C. POWER–27.5 V 5 AMP AT A.C. PLUG FOR A.C. RELAYS.
   –APPROX. 40 AMP. INTERMITTENT OR EMERGENCY AT NOSE UNDERCARRIAGE PLUG.
3. COOLING AIR–4.5 P.S.I. GAUGE, 55-80°F., 150 LB./MIN. THROUGH 2 HOSES
4. ENGINE STARTING AIR– 50 P.S.I. ABSOLUTE (MINIMUM), 112 LB./MIN PER ENGINE (MINIMUM); 360 TO 500°F
5. NOSE UNDERCARRIAGE CONNECTOR - TELESCRAMBLE
   –INTERPHONE
   –ENGINE STARTING SIGNALS
   –EMERGENCY D.C. POWER
   –400 C.P.S., 1 PHASE AC POWER - 500 V.A.
6. ASTRA 1 "GO-NO GO" TEST EQUIPMENT (POSSIBLY)

FIG. 13 ARROW 2 READINESS CONDITION 3 "AVAILABLE"
(AIRCRAFT CAPABLE OF BEING AIRBORNE WITHIN 15 MINUTES)

2153-105-1

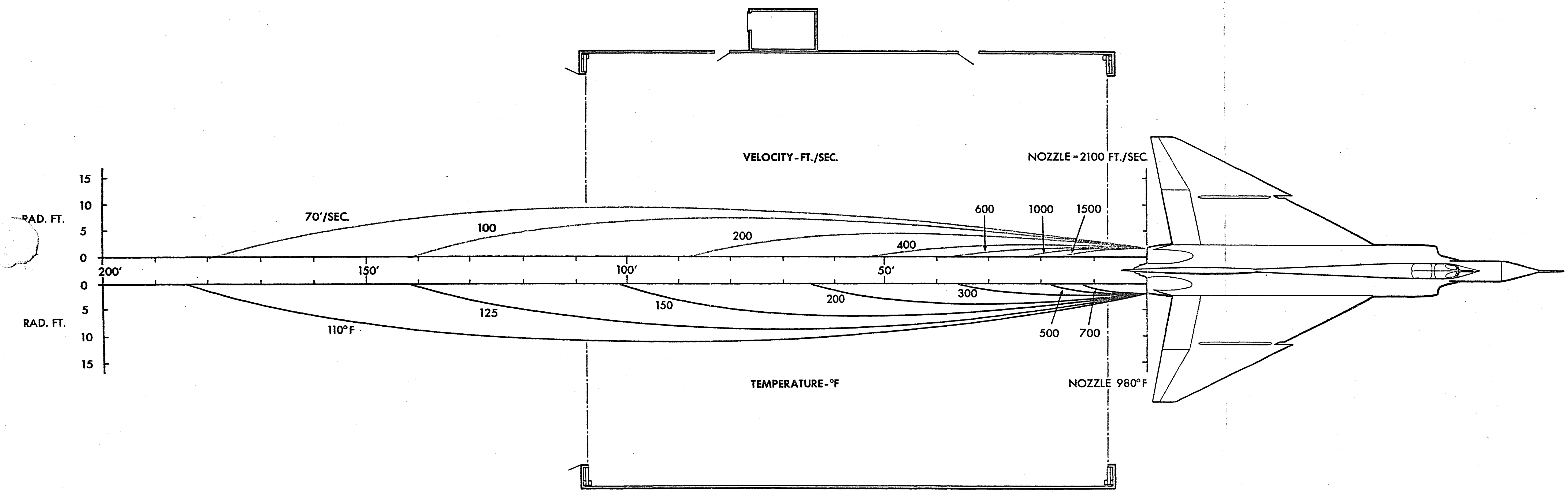


FIG. 14 ESTIMATED ARROW 2 JET EXHAUST PATTERNS BASED ON J-75 MILITARY THRUST