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SS119

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JULY 1958 SECRET

R.C.A.F. DESIGN STUDY REQUEST

INCREASED COMBAT RADIUS

ARROW 2

BROCHURE - SS119

AVRO AIRCRAFT LIMITED

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RCAF ENGINEERING STUDY REQUEST

ON

ARROW 2

INCREASED COMBAT RADIUS

SS. 119

JULY 1958

Ref: Avro Aircraft Ltd.,
Engineering Division,
Report No. 72/Proj. 7/11
dated 27th June 1958

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AVRO AIRCRAFT LTD.
MALTON, ONT.

TABLE OF CONTENTS

INTRODUCTION

SUMMARY

Part 1 - INCREASED FUEL CAPACITY AND ASSOCIATED STRUCTURE AND SYSTEMS CHANGES

1.1 Performance

1.2 Weights and Load Factors

1.3 Airframe Modifications

1.4 Test Program

1.5 Statement of Work

1.6 Phasing Chart

Part 2 - VARIABLE NOZZLE

2.1 Performance

2.2 Weights and Load Factors

2.3 Structure and Systems

2.4 Ground and Flight Testing

2.5 Statement of Work

2.6 Phasing Chart

Part 3 - WING LEADING EDGE

3.1 Performance

3.2 Test Program (Wing Tunnel only)

3.3 Statement of Work

Part 4 - PRELIMINARY ENGINEERING

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SUMMARY.

The addition of about 9300 lbs. of fuel internally, as described in Part 1, shows an increase in combat radius up to approx. 90% over the basic ARROW 2. The incorporation of the necessary modifications can be accomplished without major system or equipment changes, and the necessary structural redesign would utilize existing engineering and manufacturing techniques. This capability could be made available during 1961 provided authority to proceed with Parts 1 and 4 is granted by December 1st, 1958 and September 1st, 1958 respectively.

Further extensions to the ARROW 2 combat radius may be obtained by the introduction of variable ejectors and a moveable wing leading edge. However, further study and development testing will be required to determine the degree of improvement achievable. Parts 2 and 3 of this proposal indicate the programs recommended to establish the capability available with the objective of including either or both features into service aircraft during 1961.

The portions of the aircraft where changes are proposed are illustrated on the following page.

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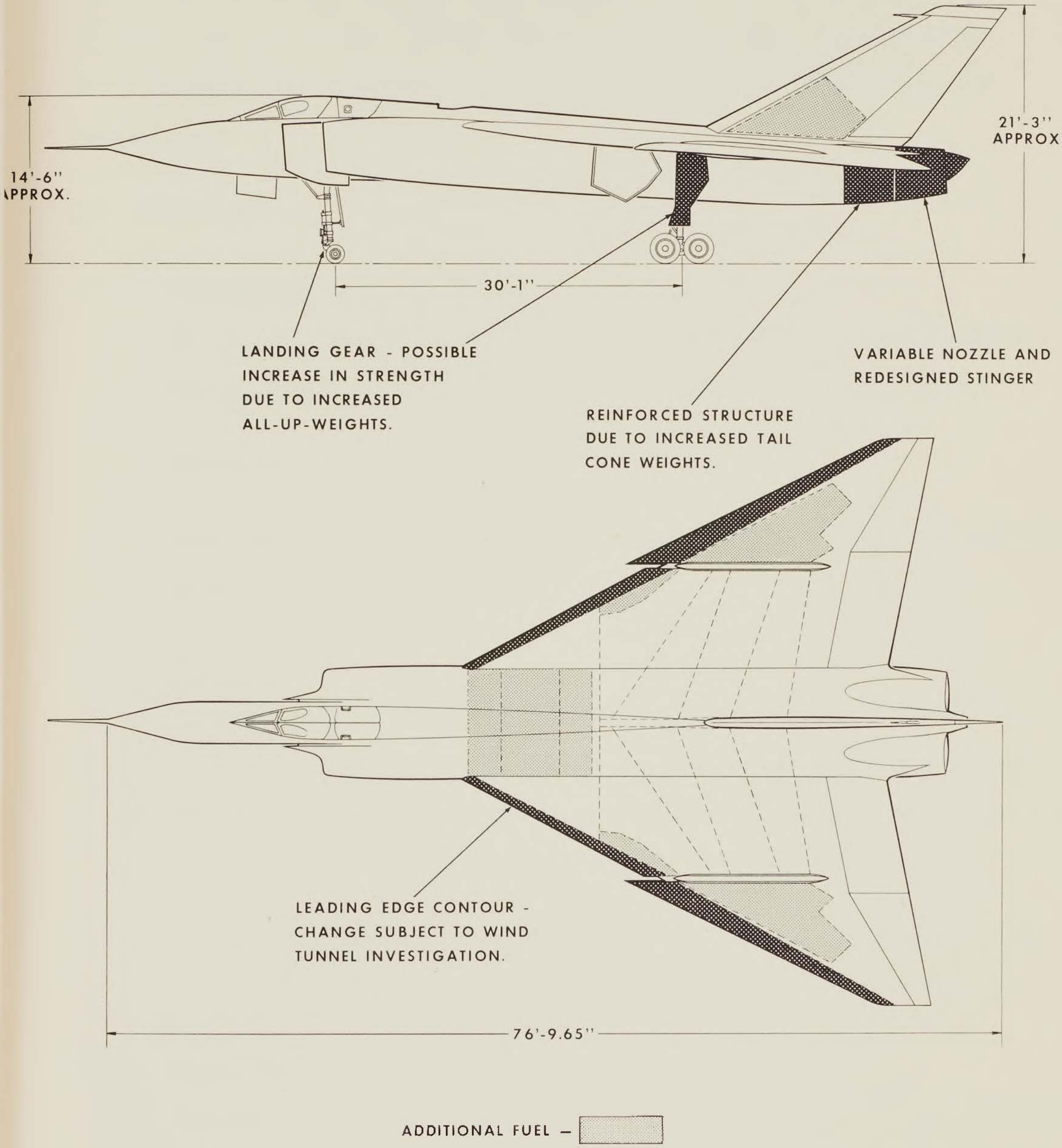


CHANGES TO ARROW 2

PART 1 - INCREASED FUEL CAPACITY AND ASSOCIATED STRUCTURE AND SYSTEM CHANGES

This part describes the increased combat radius achievable by the addition of approximately 9,300 lbs. of internal fuel, the changes necessary to the structure and systems and the associated ground and flight test programs. It is intended that this capability will be available in ARROW 2 aircraft during 1961.

1.1 PERFORMANCE

1.1.1 Introduction

The aircraft considered consists of the basic ARROW 2 airframe, from a drag viewpoint, with 4° up aileron again assumed above 45,000 ft.

The powerplant consists of two Orenda Iroquois.

Basic loading and performance details are given in Table 1, and relevant performance curves shown in figures A to F.

1.1.2 Fuel

An extra 9,300 lb. of usable internal fuel has been accommodated, compared with the ARROW 2, and the total internal fuel has been sequenced such that the mean c.g. position can be regarded as being at 29.5% M.A.C. prior to combat, and at 31% M.A.C. after the missiles are fired.

The external fuel for the maximum range and overload range missions is carried in the 500 gallon ventral tank of the basic ARROW 2 aircraft.

1.1.3 Weight

Compared to the basic ARROW 2, the operational weight empty has increased by 1,569 lb., and combined with the extra usable internal fuel of 9,300 lb., this represents an increase in gross weight with maximum internal fuel of 10,869 lb.

1.1.4 Power Plant

The power plant assumed consists of two Orenda Iroquois (to EMS 8 Issue 2) with infinitely variable afterburners.

The same fixed ejectors (40 - 49 in.) and after-body shapes as used on the ARROW 2 have been assumed.

1.1.5 Mission Details

The details of the missions quoted in Table 1 are:

(a) High Speed Mission (with full internal fuel)

(i) Start engines

(ii) Take-off to unstick at sea level, maximum thrust A/B unlit

(iii) Accelerate to 0.92M at S.L., maximum thrust, A/B unlit

(iv) Climb at 0.92 to 30,000 ft., maximum thrust A/B lit

(v) Accelerate to 1.5M at 30,000 ft., maximum thrust A/B lit

(vi) Climb at 1.5M to 50,000 ft., maximum thrust A/B lit

(vii) Cruise out at 1.5M at 50,000 ft., partial afterburner

(viii) 5 min. combat at 1.5M at 50,000 ft., maximum thrust A/B lit (no distance credit) missiles fired during combat

(ix) Descend to optimum cruise altitude at idle thrust (no distance credit)

(x) Cruise back at 0.91M at optimum altitude

(xi) 15 min. loiter over base at maximum endurance speed

(xii) Descend to S.L. at idle thrust (no distance credit)

(xiii) Land with reserves for 5 min. loiter at S.L. at maximum endurance speed

Radius of action = 439 n. miles

(b) Maximum Range Mission (full internal fuel)

(i) Start Engines

(ii) Take-off to unstick at sea level, maximum thrust A/B unlit

(iii) Accelerate to 527 knots at S.L., maximum thrust A/B unlit

(iv) Climb at 527 knots TAS to optimum altitude, maximum thrust A/B unlit

(v) Cruise out at 0.91M at optimum altitude

(vi) Accelerate to 1.5M at optimum altitude, maximum thrust A/B lit

(vii) Climb at 1.5M to 50,000 ft., maximum thrust A/B lit

(viii) 5 min. combat at 1.5M at 50,000 ft., maximum thrust A/B lit (no distance credit) Missiles fired during combat.

(ix) Descend to optimum cruise altitude at idle thrust (no distance credit)

(x) Cruise back at 0.91M at optimum altitude

(xi) 15 min. loiter over base at maximum endurance speed

(xii) Descend to S.L. at idle thrust (no distance credit)

(xiii) Land with reserves for 5 min. loiter at S.L. at maximum endurance speed

Radius of action = 639 n. miles

(c) Maximum Range Mission (full internal and external fuel)

As detailed for (b) above, with ventral tank jettisoned at fuel exhaustion.

Radius of action = 743 n. miles

(d) Overload Range Mission (full internal and external fuel)

Missiles carried throughout flight. Ventral tank jettisoned when empty.

(i) Start engines

(ii) Take-off to unstick, maximum thrust A/B unlit

(iii) Accelerate to 527 knots at S.L., maximum thrust A/B unlit

(iv) Climb to optimum altitude at 527 knots T.A.S., maximum thrust A/B unlit

(v) Cruise climb at optimum conditions

(vi) Loiter over base at maximum endurance speed

(vii) Descend to S.L. at idle thrust (no distance credit)

(viii) Land with reserves for 5 min. loiter at S.L. at maximum endurance speed

Range = 1,820 n. miles

(e) Overload Range Mission (full internal and external fuel)

As detailed for (d) above, but with ventral tank retained throughout mission.

Range = 1,773 n. miles

Compared to the basic ARROW 2, these mission distances represent the following approximate improvements due to the extra internal fuel:

For a)	the High Speed Mission	90%
b)	the Maximum Range Mission (full internal fuel)	80%
c)	the Maximum Range Mission (full internal and external fuel ventral tank jettisoned)	55%
d)	the Overload Range Mission (ventral tank jettisoned)	40%
e)	the Overload Range Mission (ventral tank retained)	40%

Thus, for take-off and landing distances still compatible with existing runways, the mission distances of the ARROW could be boosted by a

EXTENDED COMBAT RADIUS - ARROW 2

MAX. LEVEL SPEED AT COMBAT WEIGHT
62,291 lb.

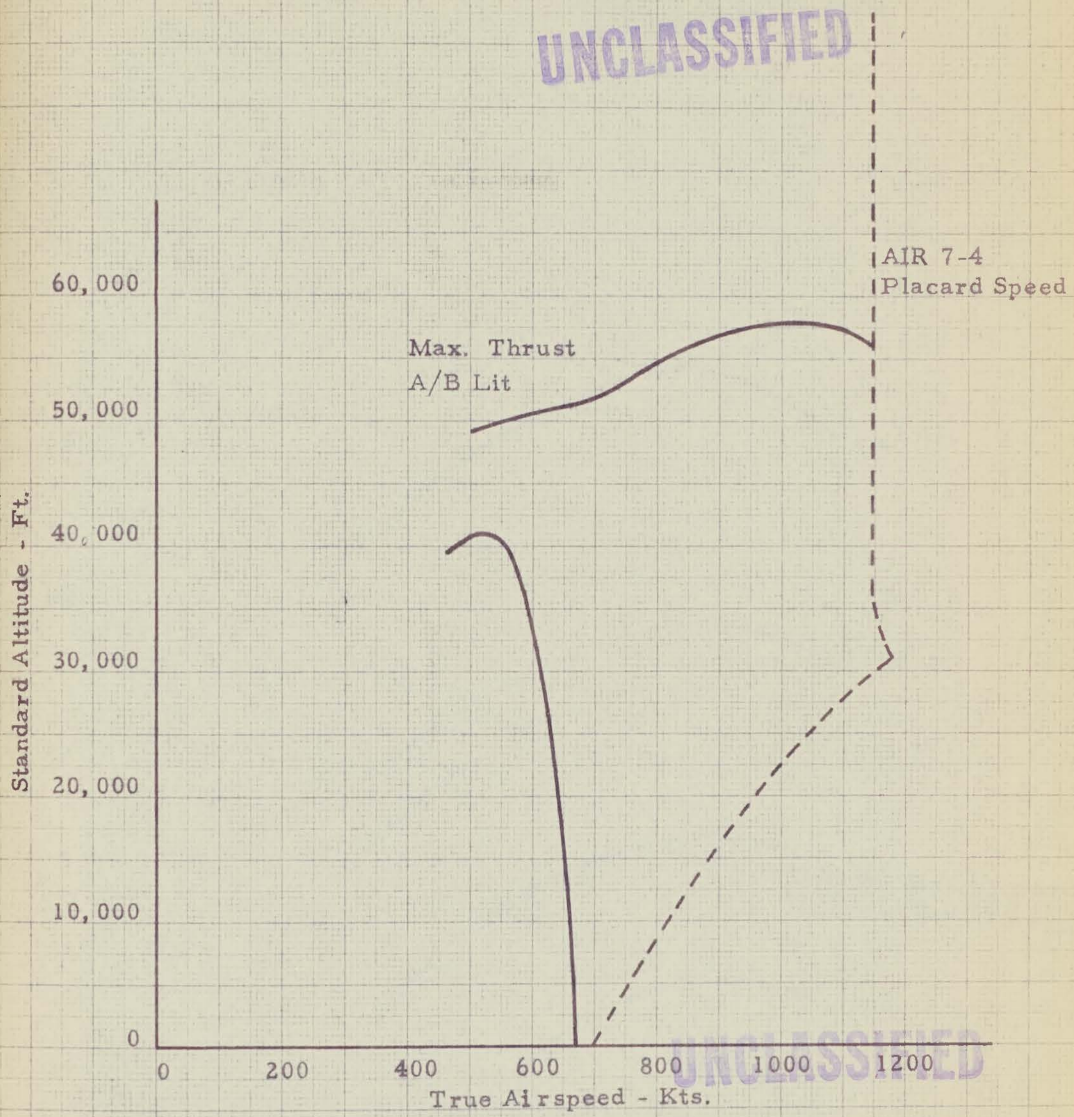


FIG. A

Available Steady G's at

Combat Weight - 62,291 Lb.

Max Thrust - A/B Lit

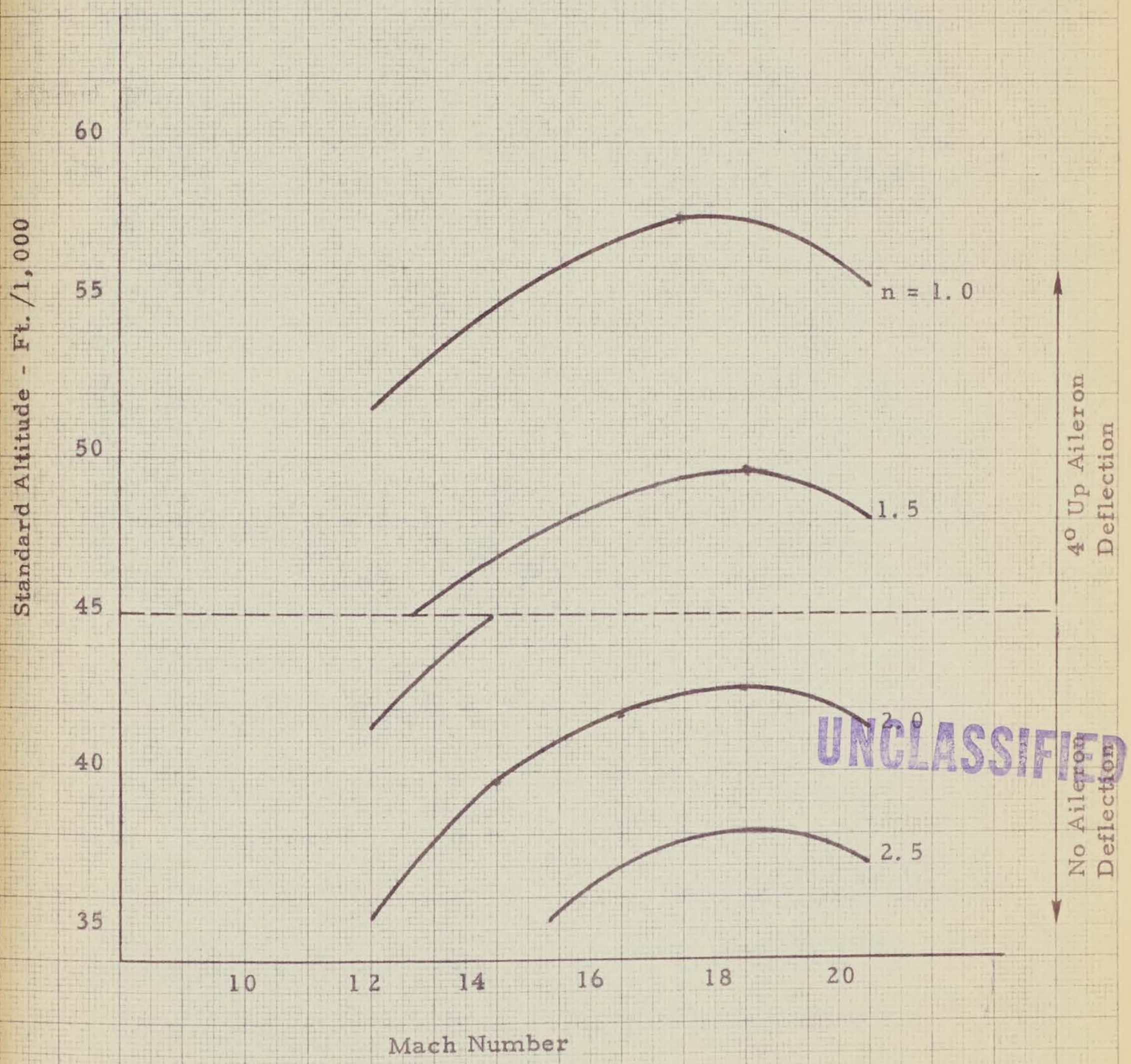
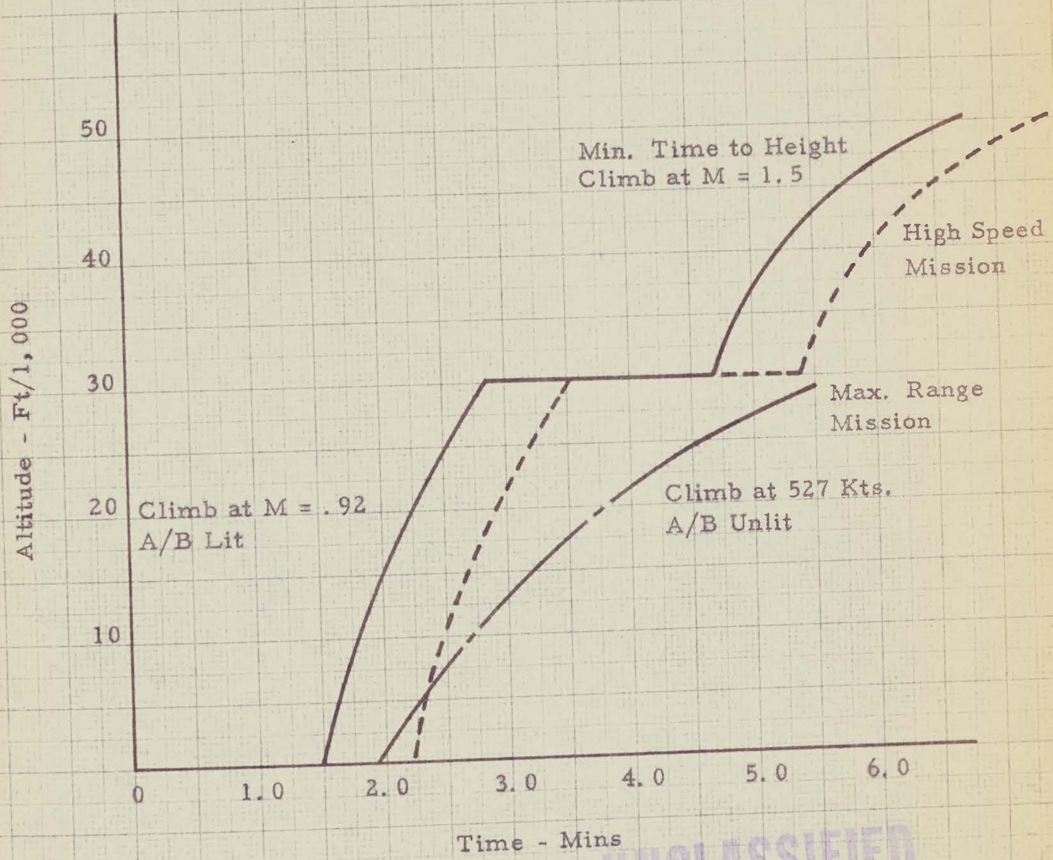


FIG. B

EXTENDED COMBAT RADIUS - ARROW 2

TIME TO HEIGHT



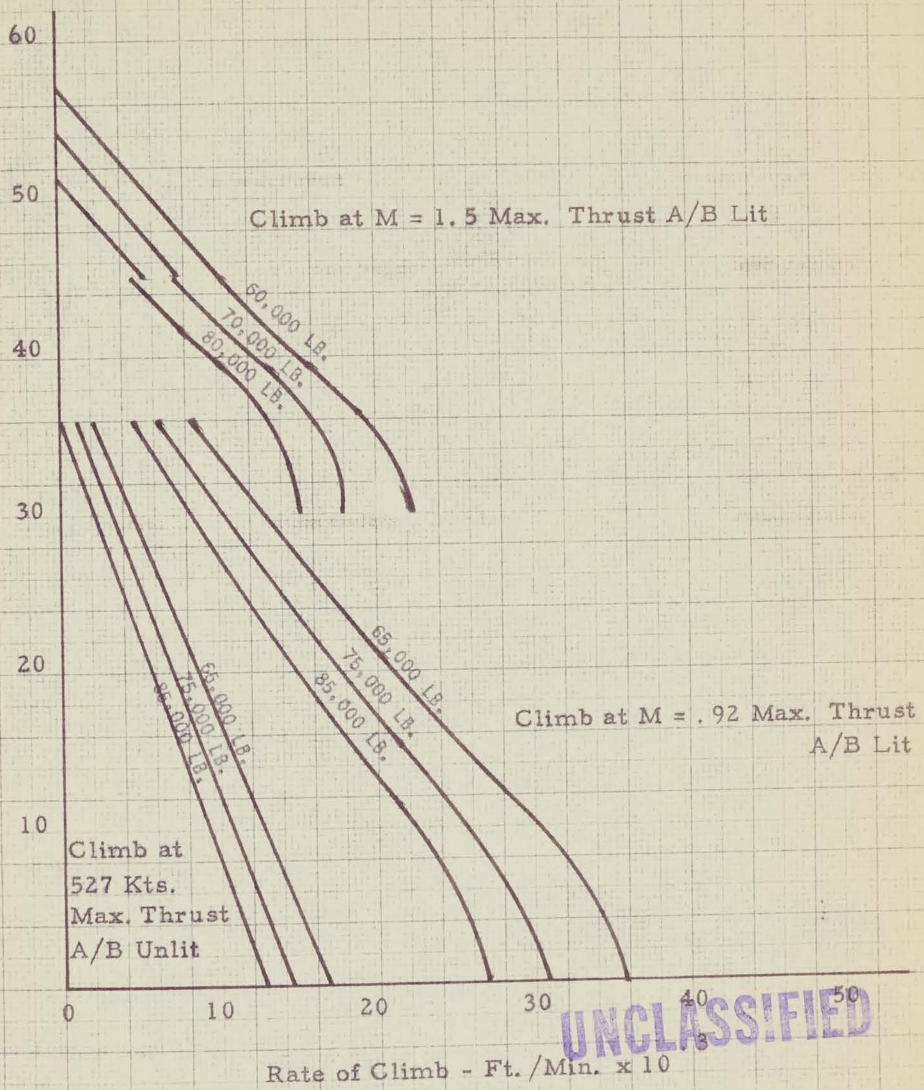
Min. Time to Height - A/B Lit throughout the Flight Plan

High Speed Mission A/B Lit at the Beginning of M = .92 Climb

Max. Range Mission A/B Not Lit

NOTE:- 1/2 Min Allowed from Engine Start to Max. Thrust

Steady State Rate of Climb



* For K.E. Effect Increase R.O.C. Below 36,089 Ft. By:-

1.14 at M = .92

1.43 at M = 1.5

FIG. D

EXTENDED COMBAT RADIUS ARROW 2

TAKE-OFF DISTANCE AT S.L.

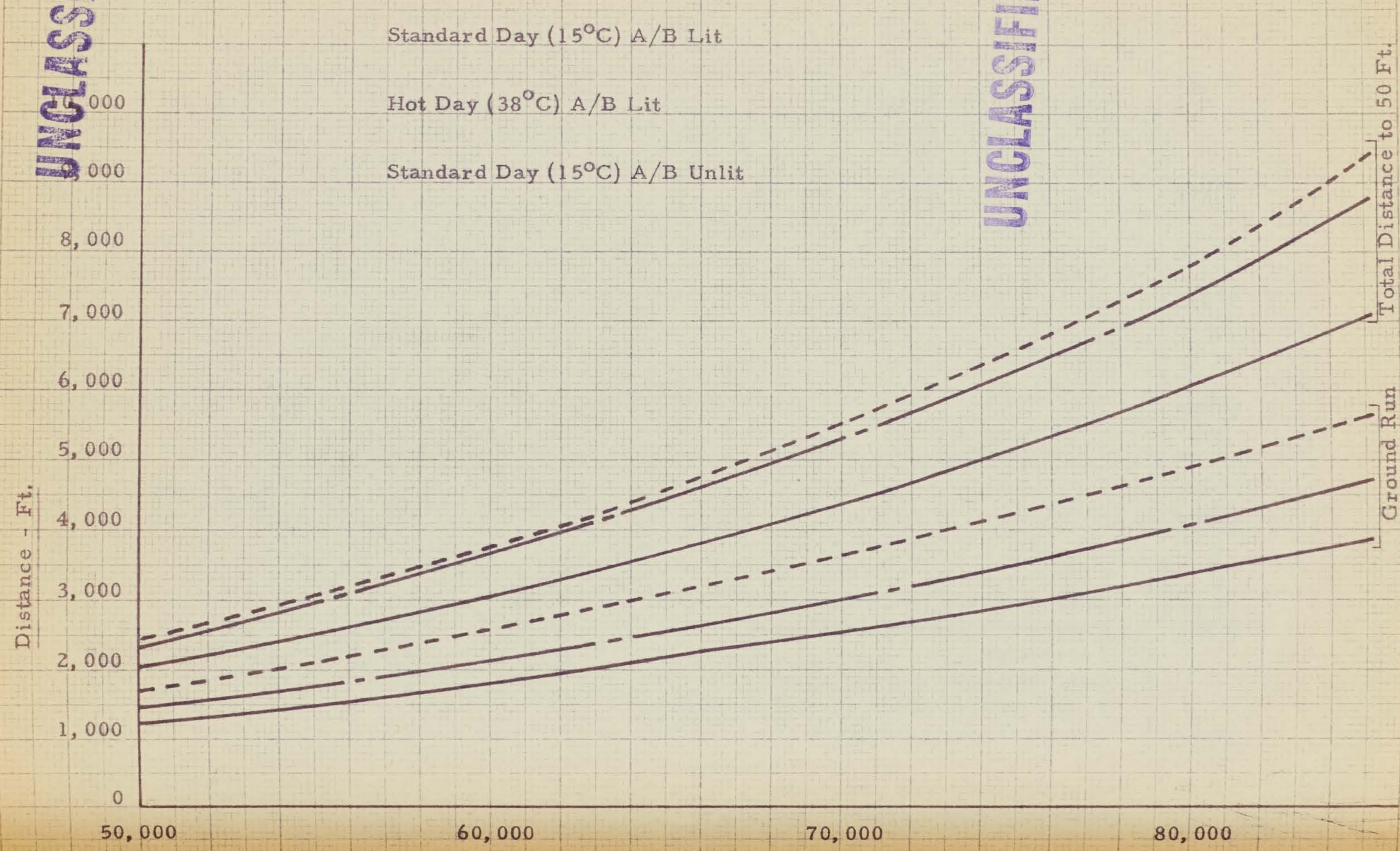
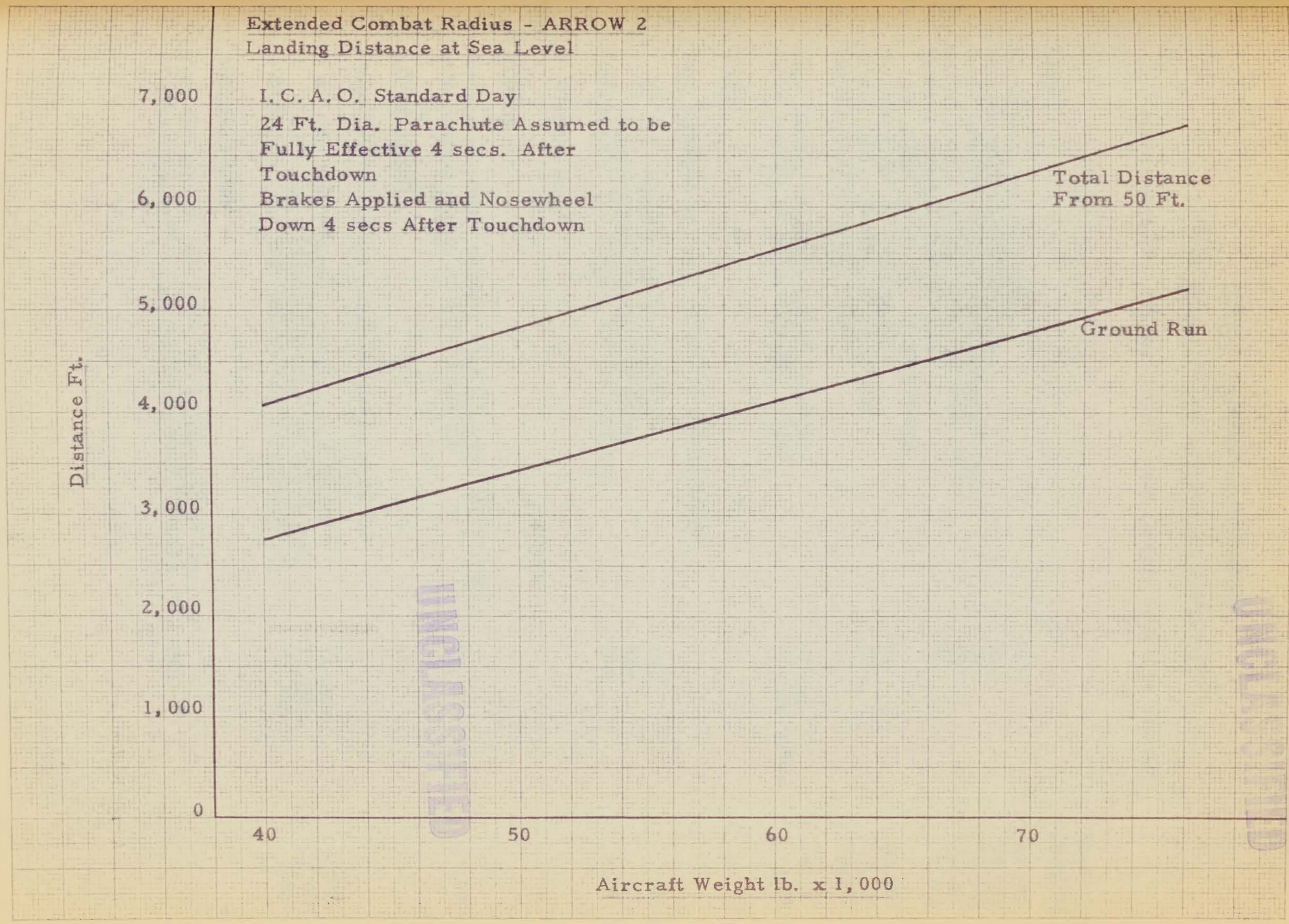


FIG. E



Extended Combat Radius - ARROW 2
Landing Distance at Sea Level
I. C. A. O. Standard Day
24 Ft. Dia. Parachute Assumed to be Fully Effective 4 secs. After Touchdown
Brakes Applied and Nosewheel Down 4 secs After Touchdown
Total Distance From 50 Ft.
Ground Run
Distance Ft.
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
40
50
60
70
Aircraft Weight lb. x 1,000

FIG. F

TABLE 1 - LOADING & PERFORMANCE

UNDER ICAO STANDARD ATMOSPHERIC CONDITIONS

(Clean aircraft i.e. no ventral tank, unless otherwise stated)

		40-49 ins. Ejector
Weight		
Operational weight empty	lb.	47,922
Maximum usable internal fuel	lb.	28,738
Gross take-off weight (max. internal fuel)	lb.	76,660
Combat weight ($\frac{1}{2}$ max. internal fuel wt.)	lb.	62,291
Maximum external fuel + tank (500 gal @ 7.8 lb./gal. + drop tank)	lb.	4,248
Maximum gross take-off weight	lb.	80,908
Normal design landing gross weight	lb.	53,379
Maximum landing gross weight	lb.	76,660
Wing loading at gross take-off weight	lb./sq. ft.	62.5
Power loading at gross take-off weight	lb./lb. thrust	1.76
Speed		
True airspeed in level flight at combat weight		
SL (i) Maximum thrust, A/B lit	Kts.	700 *
(ii) Maximum thrust, A/B unlit	Kts.	675
50,000 ft. (i) Maximum thrust, A/B lit	Kts.	1,147 *
* Placard Speed		
Ceiling		
Ceiling at combat weight, rate of climb 500 ft./min. with maximum thrust at 1.80 M A/B lit	ft.	57,100
Rate of Climb		
Steady state rate of climb at combat weight		
SL (i) Max. thrust, A/B lit. at 0.92 M	ft./min.	38,000
(ii) Max. thrust, A/B unlit at 527 knots	ft./min.	17,650
50,000 ft. (i) Max. thrust A/B lit. at 1.80 M	ft./min.	7,850
Time to Height		
Time to reach 50,000 ft. & 1.5 M from engine start at gross take-off weight maximum thrust, A/B lit.	min.	6.7

Manoeuvrability		40-49 ins. Ejector
Load factor at combat weight		
1) Maximum thrust A/B lit. 1.5M 50,000 ft.		1.36
2) Maximum thrust A/B lit. 1.8M 50,000 ft.		1.47
Take-Off Distance		
Take-off distance over 50 ft. obstacle at sea level at gross take-off weight		
1) Maximum thrust A/B lit standard day	ft.	5,470
2) Maximum thrust A/B unlit standard day	ft.	7,000
3) Maximum thrust A/B lit hot day	ft.	6,630
Landing Distance		
Landing distance over 50 ft. obstacle at sea level at normal design landing gross weight	ft.	5,070
Stalling Speed		
True stalling speed in landing configuration at combat weight at Sea Level	Kts.	123
Missions		
Combat radius of action, see mission profile for detail breakdown		
1) High speed mission with full internal fuel	N.M.	439
2) Maximum range mission with full internal fuel	N.M.	639
3) Maximum range mission with full internal fuel plus 500 gallon external tank (Tank jettisoned when empty)	N.M.	743
(a) Overload range mission with full internal fuel plus 500 gallon external tank (tank jettisoned when empty)	N.M.	1,820
(b) As (a) but external tank retained throughout mission	N.M.	1,773

1.2 WEIGHT AND LOAD FACTORS

1.2.1 General

For weight estimation, it is assumed that there will be no major weight increase due to maintaining the airframe structure to suit the recommended 6g min. load factor.

The main structural change will be on the centre fuselage, and this has been examined in detail. All other structural changes are considered to be minor, and the associated weight changes have been estimated.

The following weights are those used for performance calculations, and include all changes associated with the extra fuel capacity.

1.2.2 Structure Weight

From preliminary stress calculations the following are the weight estimates for the structural provisions of the extended range ARROW.

		Wt. Lbs.
Centre Fuselage	Redesigned tanks and air ducts	500
Duct Bay	Local Strengthening	30
Outer Wing	Redesigned for tank structure	110
Inner Wing	Revised for additional tank structure	44
Fin	Redesigned for tank structure	60
Miscellaneous	Structural changes for local strengthening	100
	TOTAL	844

1.2.3 Landing Gear

The following is an estimate of weight increases to the landing gear:

		Wt. Lbs.
Brakes and tires		100
Main leg and bogey		90
Nose leg		25
	TOTAL	215

1.2.4 Equipment

From preliminary estimates the weight increase for fuel piping will be approximately 150 lb.

		Wt. Lbs.
Fuel piping		150
Trapped fuel (in piping)		200
	TOTAL	350

1.2.5 Residual Fuel

The existing weight of residual fuel in the ARROW 2 is to be increased and there will be an additional increase due to the enlarged fuel capacity.

	Wt. Lbs.
Extended range ARROW increase	160

1.2.6 Weight Summary

Description	ARROW 2 Weight (June /58) Lb.	Weight Increase Lb.	Extended Range ARROW Weight Lb.
Structure	19,154	844	19,998
Landing Gear	2,638	215	2,853
Power Plant	10,801	-	10,801
Flying Controls	1,927	-	1,927
Equipment (including trapped fuel)	9,034	350	9,384
AIRCRAFT BASIC WEIGHT	43,554	1,409	44,963
Residual Fuel	218	160	-
Missiles	1,728	-	1,728
Crew & Miscellaneous	853	-	853
Operational Weight Empty	46,353	1,569	47,922
Maximum Internal Fuel	19,438	9 300	28,738
GROSS WEIGHT			
(Maximum Internal Fuel)	65,791	10,869	76,660
(Maximum Internal Fuel + External Tank)	70,039	-	80,908
Existing Half Combat Mission Fuel (1,127) (gals.)	8,790	-	
Stressing Weight (Existing Half Combat Mission Fuel)	55,143	1,569	56,712
Operational Weight Empty	46,353	1,569	47,922
25% Combat Mission Fuel (564 gals.)	4,395	-	
Normal Landing Weight (25% Combat Mission Fuel)	49,020		
Half Maximum Internal Fuel			14,369
Combat Weight (Half Maximum Internal Fuel)			62,291
25% Maximum Internal Fuel			7,185
Revised Landing Weight (25% Maximum Internal Fuel)			53,379

1.2.7 Load Factors

It is intended that the airframe shall be upgraded so that the limit load factors are not less than 6.0g for room temperature cases based on the half maximum internal fuel weight.

1.3 AIRFRAME MODIFICATIONS

1.3.1 Systems

Systems revisions will be kept to a minimum and will involve only those changes necessary to achieve the extended range.

1.3.1.1 Fuel System

The fuel system will function in the same manner as the present ARROW 2 system, but will be extended to include the additional and revised tankage. This will mean a revision to most of the pipe runs and the addition of some items of equipment.

1.3.1.2 Electrical System

Minor changes will be required to adapt the electrical system to the revised fuel system.

1.3.1.3 Miscellaneous Changes

Due to changes in the geometry of the armament bay roof, some minor revisions will be necessary to systems installations in this area (e.g. control and hydraulic runs, piping, etc.). Some minor changes in the installations in the air conditioning equipment bay may result from the longer range provisions and the consequent changes to the centre fuselage structure.

1.3.2 Structure

1.3.2.1 General

The major structural revisions will be caused by the addition of extra tankage, structural modifications to provide passage for additional fuel pipes, and some local reinforcements due to increase in all-up-weight. The latter revisions cannot be described in any detail in this proposal.

1.3.2.2 Centre Fuselage

This component will be redesigned to remove the existing bladder tanks, and to increase the present fuel capacity. This involves converting the area between station 337 and station 469 into an integral fuel tank. This tank will extend right across the fuselage and will envelope the intake ducts. To facilitate sealing, all skins in this area, including duct skins, will be integrally machined, and bulkheads forming tank boundaries will be machined from the solid. To relieve machine shop loading, as much tank structure as possible will be made from sheet material and the structure from station 337 to station 255 will include as many of the present components as possible.

1.3.2.3 Outer Wing

The fuel tank changes will be confined to the inboard end of the outer wing torque box area. The root rib and front and rear spars in this area are at present solid machined items and the major changes will therefore be confined to the skins. It is proposed to change to machined skins over the complete span for structural economy reasons, and to add a machined rib at the outboard end of the fuel tank area. The remaining internal structure of the torque box will be changed as little as possible.

1.3.2.4 Fin

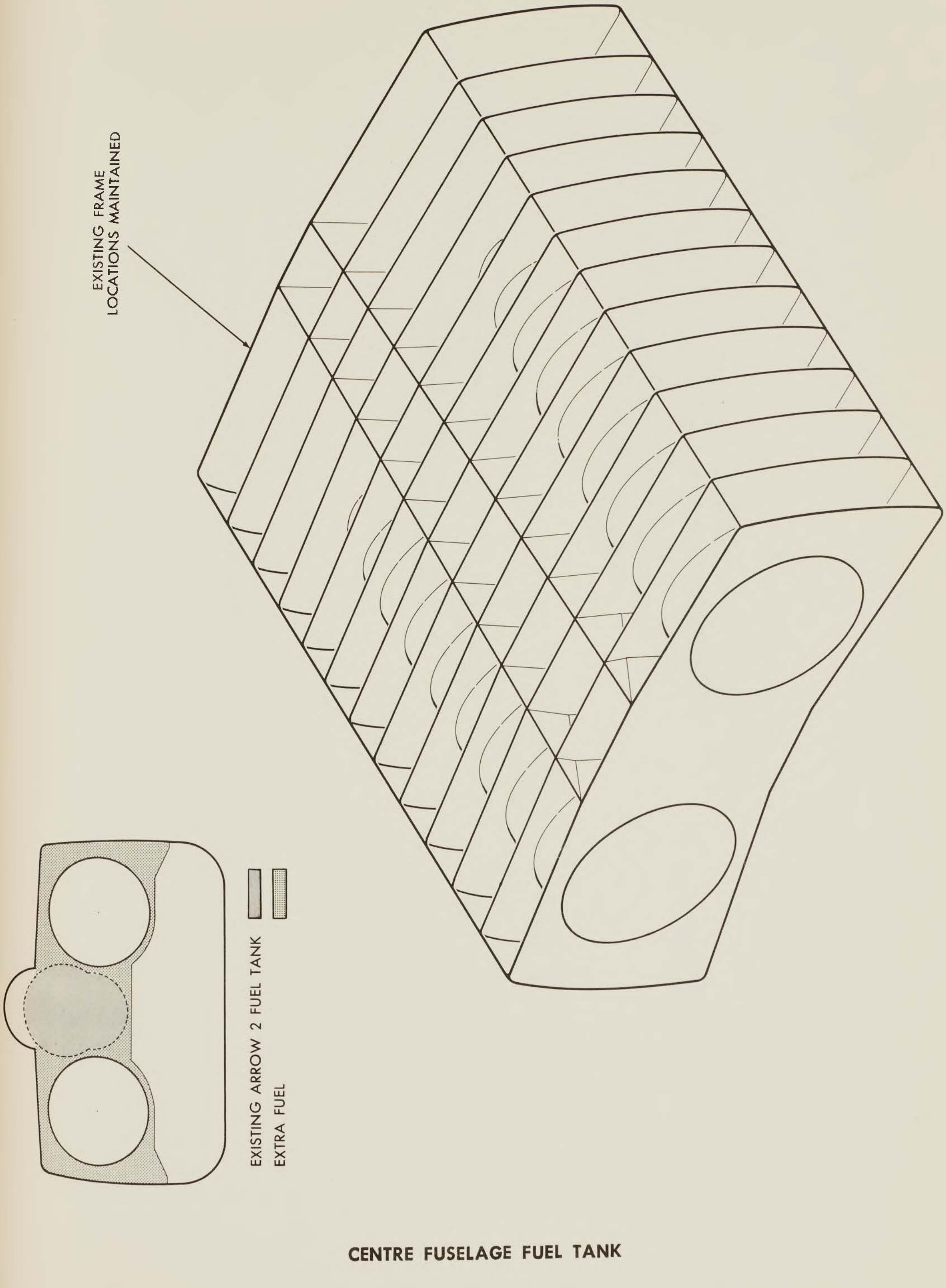
The proposed changes to the fin are very similar to those proposed for the outer wing. However, in addition, the root rib and front and rear spars will require changing from riveted components to solid machined items.

1.3.2.5 Inner Wing

The small fuel cell added in the inner wing will constitute a fairly simple change. The spar forming the forward boundary is a machined item and any changes will therefore be confined to the skins and rear boundary structure to facilitate sealing.

1.3.2.6 Landing Gear

The increased aircraft all-up-weight, may necessitate strengthening the landing gear legs, bogeys and associated wing and fuselage structure depending on wheel, brake and tire weights and also on minimum sinking speeds allowable. Development of the main landing gear shock absorbers to prevent bottoming, and improvements to the nose gear due to brake/taxi cases will be required.



CENTRE FUSELAGE FUEL TANK

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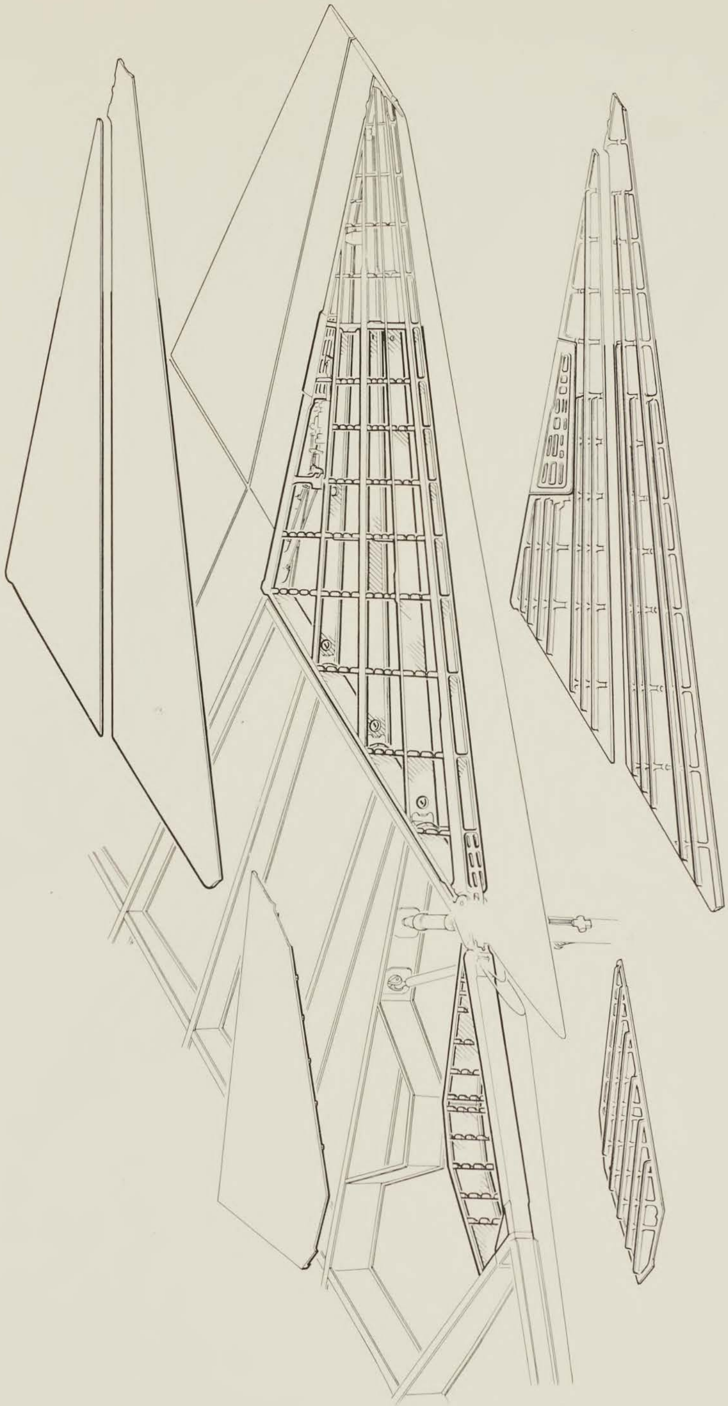

MODIFIED STRUCTURE TO USE WING SPACE FOR EXTRA FUEL

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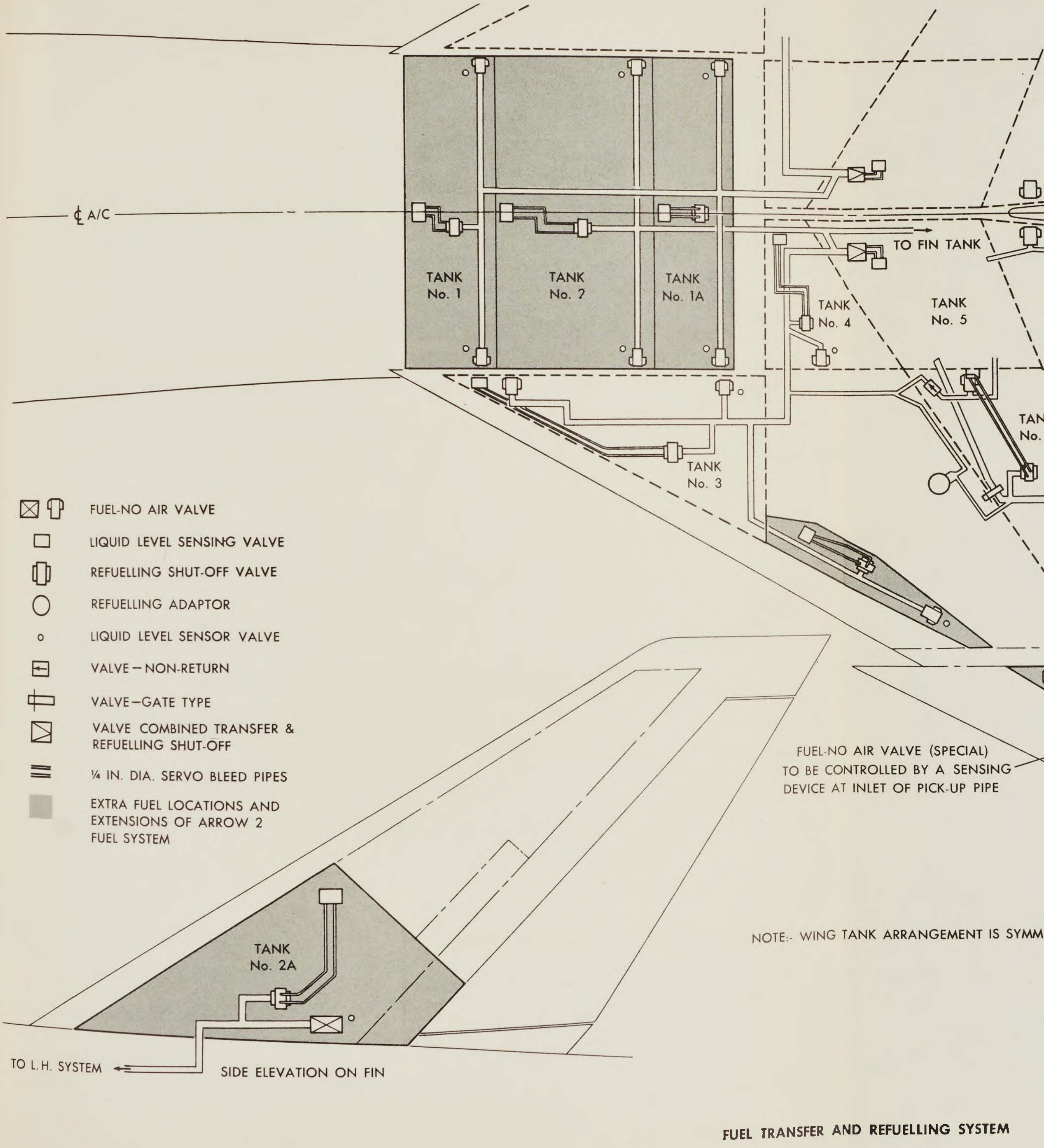
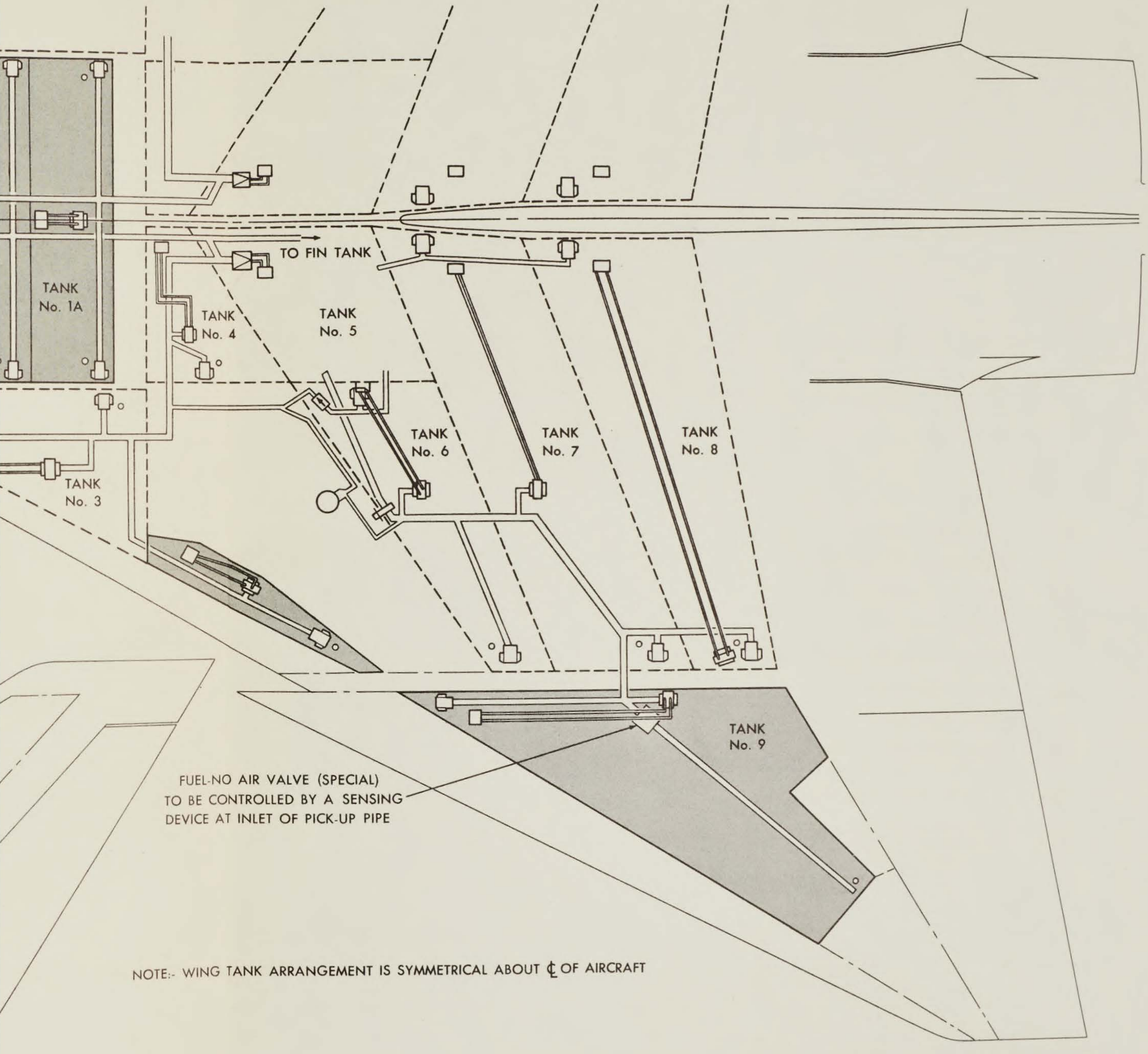


FUEL TRANSFER AND REFUELLING SYSTEM



FUEL TRANSFER AND REFUELLING SYSTEM

1.4 TEST PROGRAM

1.4.1 Ground Test Program

The ground test program is partly an extension to the basic ARROW 2 program, and partly a series of tests on new components.

The present static test aircraft program will be extended by increasing the limit load by about 20% in two test cases. To accomplish this it is expected that load distribution linkages will require some redesign. The increased loading will probably cause partial failure of the structure, and some rework will therefore be necessary.

An outer wing fuel tank sloshing rig will be required. The design and operation of this rig will be similar in concept to the inner wing rig used for the basic ARROW 2.

The addition of fuel in the outer wing may necessitate shear, bending, torsion and pressure tests on an outer wing posted box.

A modest program will be required to investigate the fuel tightness of joints in the structure. This will be conducted under environmental and repeated deformation conditions.

Other ground tests will be conducted on a typical redesigned centre fuselage frame, a typical redesigned outer wing rib, and a small number of small-element static and fatigue tests.

1.4.2 Flight Test Program

Two extended range ARROW 2 aircraft will be required to conduct the necessary flight tests. Aircraft 'A' will be used for testing the fuel system and other systems affected by the additional fuel tankage. This will require approximately 20 flying hours, and will include fuel sequencing tests, fuel temperature tests, air conditioning system tests and so on.

Aircraft 'B' will be used for handling and structural integrity tests, and this also will require about 20 flying hours. It will be necessary to check the handling characteristics with the revised aircraft weight, and in particular to check handling at take-off with a forward c.g.

S/Lrd. Crosby

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July 18, 1958

Group Captain H.R. Foottit,
CAE/AAWS,
Royal Canadian Air Force,
OTTAWA, Ontario.

Dear Sir:

Re: Brochure SS-119 - RCAF Design Study Request, Increased Combat Radius Arrow 2 Aircraft.

In accordance with DDP direction on your behalf under Item 7.9 of the Arrow Programme Statement of Work, we have undertaken a study on the modification of Arrow Mark 2 aircraft for increased combat radius, and enclosed are ten copies of Avro Aircraft Brochure SS-119 containing this information.

Preliminary estimates are shown below for the engineering and manufacturing costs for effectivity of the 79th aircraft - that is, for incorporation in the last 126 aircraft of the proposed 164 Arrow Aircraft Programme. All figures shown include fee and Sales Tax where applicable; manufacturing figures are shown as the increased costs over and above the estimates given for the 164 Arrow Aircraft Programme in our estimates of May 5, 1958. The engineering figures shown assume the existence of a separate continuing engineering contract following up the development work covered in the 37 Aircraft Programme.

Engineering

(1)	Structure and Systems modifications	$4,830,000
(2)	Associated Variable Nozzle and Ejector Development	$3,675,000
(3)	Wing Leading Edge modification,	$ 270,000
	Sub-total	$8,775,000

Manufacturing

(1)	Additional manufacturing,	$55,000,000
(2)	Additional tooling	$ 9,650,000
	Sub-total	$64,650,000
	GRAND TOTAL	$73,425,000

We are continuing our engineering investigations with a view to reducing the work involved thereby obtaining an overall cost reduction and at the same time achieving an earlier effectivity.

As soon as these further studies are completed, we will advise you of the results.

Yours very truly,
AVRO AIRCRAFT LIMITED.

J.A. Morley
Vice President Sales and Service

JAM/M
cc: Detachment Commander, 1202 Technical Services Detachment
Mr. D.L. Thompson
Mr. C.A. Hore
Mr. E.G. Mahoney

sc: Group Captain E.R. Emond
W/Cdr. G.T. Doucet
Mr. J.L. Plant
Mr. J.C. Floyd Mr. J. Turner Mr. W.H. Riggs

1.5 <u>STATEMENT OF WORK AND FINANCIAL FORECAST.</u>

Engineering material and services necessary for the development, manufacture and installation of modifications to the ARROW 2 to provide increased fuel capacity.

1. Systems analysis, performance and technical support as necessary.
2. Redesign of the centre fuselage to provide additional fuel capacity.
3. The design of modifications to other components and systems as necessary to provide for additional fuel and increased aircraft weight.
4. Structure, Systems and flight testing as follows:
   (a) Design and/or specification of test specimens.
   (b) Rig design and manufacture.
   (c) Design and/or specification of airborne instrumentation.
   (d) Design of the installation of airborne instrumentation.
   (e) Installation and calibration of recording instrumentation.
   (f) Fuel and oil.
   (g) Maintenance of 2 modified ARROW 2 aircraft for a period of four months.
   (h) Data reduction facilities and services.
   (i) Experimental Manufacturing support.

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EXCLUSIONS AND LIMITATIONS.

Supply of test specimens (Mfr. Div.)

Supply of airborne test instrumentation (Mfr. Div.)

Ground Support Equipment and hangar facilities.

Any additional ground station and data handling facilities, (if required).

Repair and Overhaul.

Modifications to Aircraft Systems Trainer.

Provision of airframe and GSE spares.

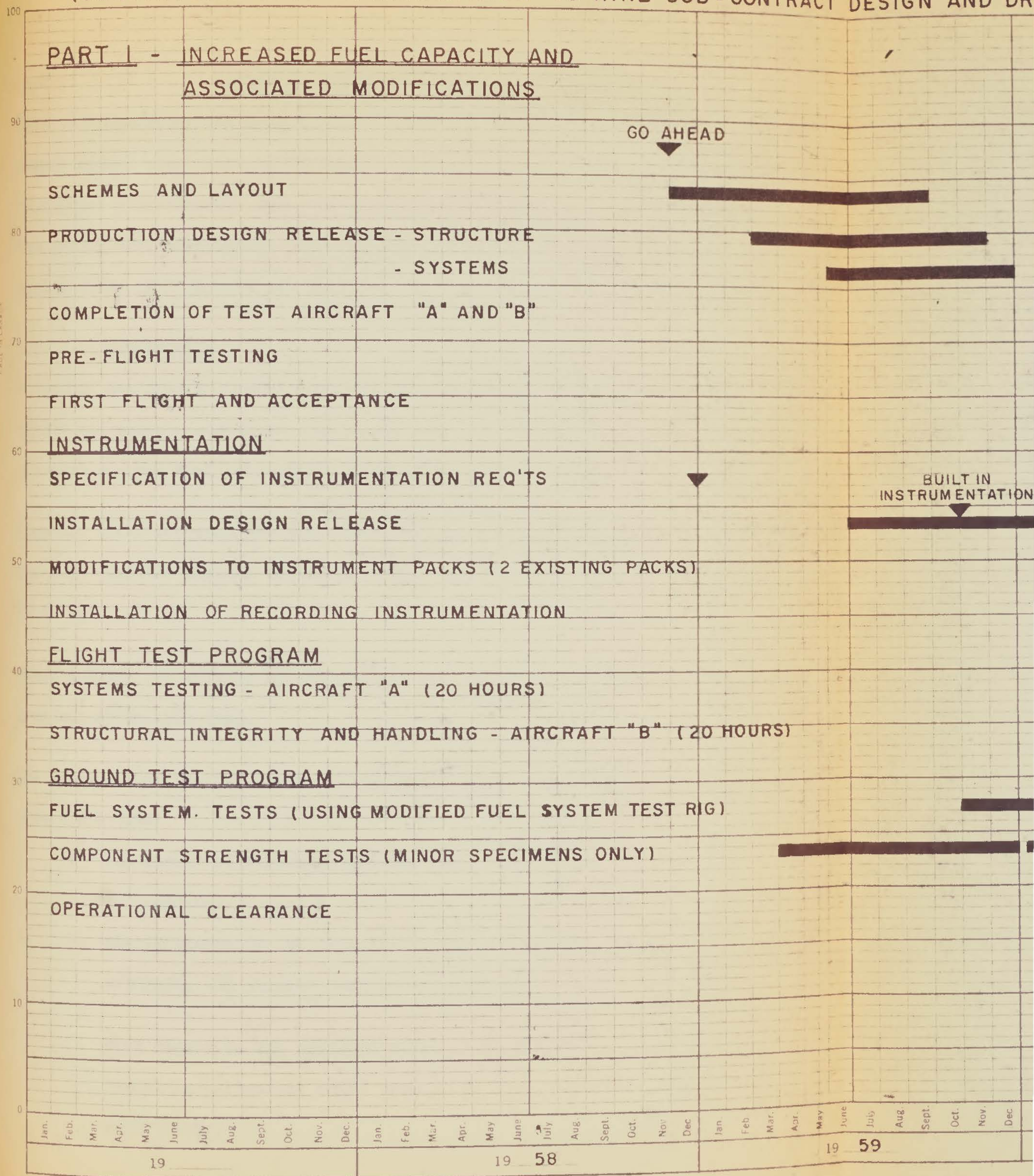
This program is based on the assumption of a go ahead by Dec. 1st/1958, for this Part and a go ahead by September 1st/1958 for Part 4.

Flight testing of a maximum of 50 total flying hours.

Qualification testing of new or revised equipment is not included.

ENGINEERING PHASING CHART - SHEET I

(CONTINGENT UPON AUTHORIZATION TO HIRE SUB-CONTRACT DESIGN AND DR



HEET I

E SUB-CONTRACT DESIGN AND DRAFTING LABOR)

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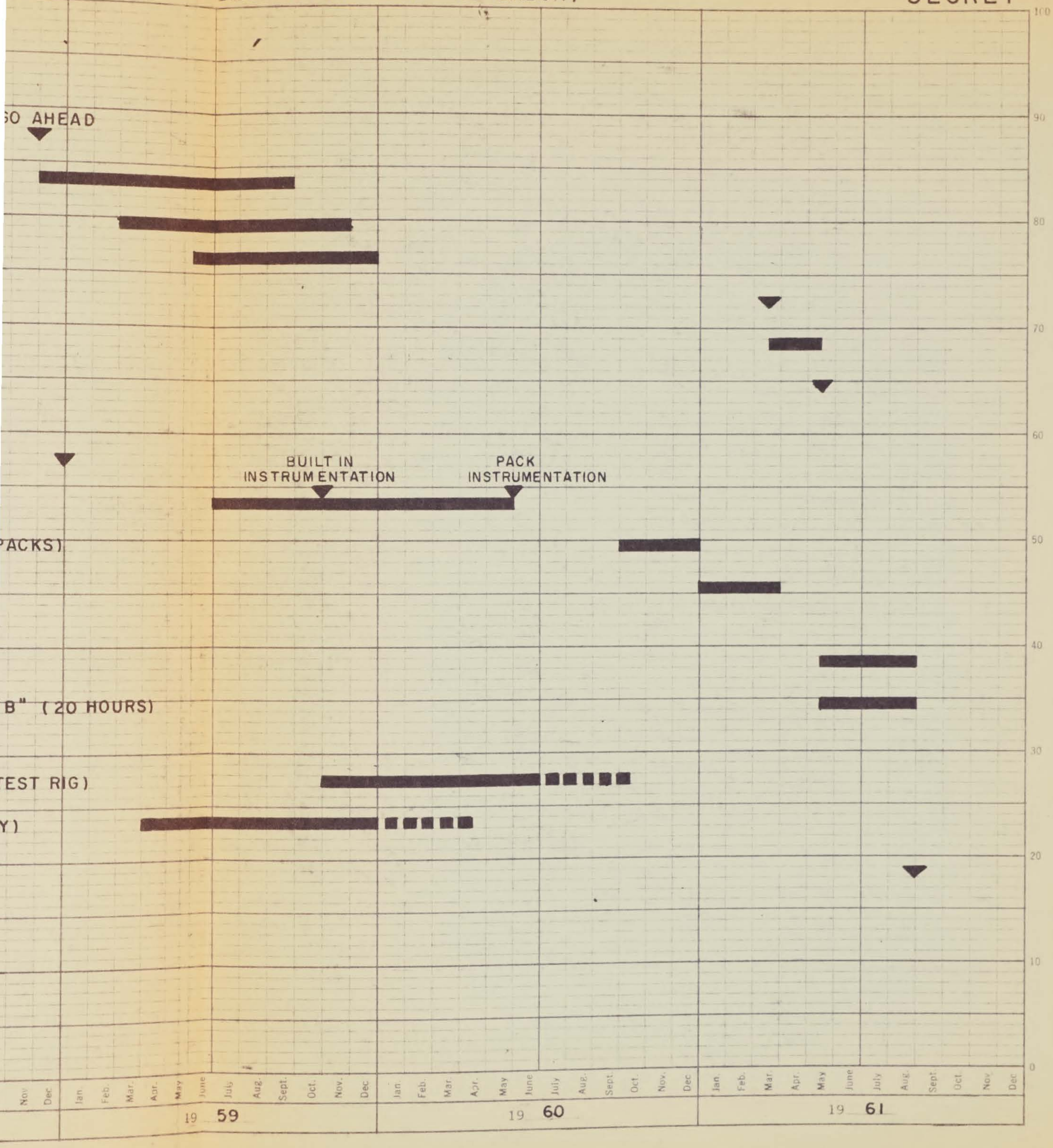

PART 2 VARIABLE NOZZLE AND EJECTOR DEVELOPMENT

This part describes the program recommended to establish a possible increase in combat radius capability additional to that shown in Part 1. It is proposed to conduct a development and test program on a variable ejector to determine the improvement achievable. The results of this program will establish the desirability of incorporating this feature into ARROW 2 production aircraft.

2.1 PERFORMANCE

A further increase in combat radius may be achieved by incorporating a variable nozzle and ejector system to obtain maximum thrust for accelerations and climbs and also minimum fuel consumption for cruising at all mach numbers and altitudes.

Although there are inherent practical difficulties in mechanizing such a system, the gain over the mission distances quoted in Part 1 could be of the order of 7% to 10%.

This includes the effects of aerodynamic influences such as subsonic spillage drag and after-body drag.

The areas of uncertainty which influence the final values associated with this system are then:

(1) The amount of subsonic spillage drag present when the intake is unchoked.

(2) The influence of the flow from a variable nozzle and ejector on the afterbody and stinger drag at subsonic and supersonic speeds.

With regard to the spillage drag, it is felt that a suitable wind tunnel investigation could result in a reduction in the degree of uncertainty.

For afterbody and stinger drag, the situation is less hopeful,

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in that, with present techniques and wind tunnels available, it would appear that the order of accuracy of the experimental results would be much the same as the actual percentage gain being looked for from the optimum nozzle and ejector system.

Therefore it is felt that adequate performance evaluation will be obtained only by building and flight testing a prototype installation.

2.2 WEIGHTS AND LOAD FACTOR

Estimated weight increase is as follows:

2 Ejectors and systems	1000 lbs.
Rear Fuselage	50 lbs.
Total	1050 lbs.

The affect of this weight increase on load factors will be catered for by the structural revisions included in para. 1.2.7.

2.3 STRUCTURE AND SYSTEMS

2.3.1 REAR FUSELAGE

The structure aft of station 803 will be redesigned due to the incorporation of a variable ejector and nozzle. The ejectors will be separate units with variable geometry mechanisms, and may possibly be supplied as part of the engine assembly. The drag chute box and stinger assembly will require redesign in order to fit into the area between the ejectors.

The structure between stations 742 and 803 will require reinforcement to withstand the increased ejector weights and increased aerodynamic loads from the variable ejector. The repositioning of the drag chute box may also cause changes in this area.

2.3.2 VARIABLE NOZZLE AND EJECTOR

The convergent divergent variable nozzle and ejector would consist of the following items:

(a) A convergent primary nozzle of similar design to the existing Iroquois variable nozzle and operated by the present engine control and hydraulic system.

(b) A divergent ejector plus external fairing leaves interconnected

at the trailing edge, and operated by the aircraft utility hydraulic system.

The two systems are independent and provide an annulus between the convergent and divergent systems to obtain optimum ejector performance.

2.4 GROUND AND FLIGHT TESTING

2.4.1 GROUND TESTING

Mechanical tests on individual mechanical components and the ejector controls plus testing of the complete system in engine test cells, including altitude testing.

2.4.2 FLIGHT TESTING

Preliminary flight testing to establish final control settings and mechanical reliability followed by performance testing. Airborne instrumentation will be required to provide approximately 30 parameters. Data extracted will be directly applicable to the increased range ARROW 2.

2.5 STATEMENT OF WORK AND FINANCIAL FORECAST.

Engineering and Experimental materials and services necessary for the design, manufacture and test of a variable ejector installation in one ARROW 2 aircraft.

1. Design and manufacture of components and systems as follows:

   (a) Design, experimental manufacture and installation of modifications to one rear fuselage to accommodate a variable ejector/nozzle and associated operating systems.

   (b) Design, including necessary development follow up, of a variable ejector/nozzle for test purposes and necessary development tooling to permit manufacture of a limited quantity of test units.

   (c) Manufacture of 4 units and installation of one Aircraft set in one ARROW 2 Aircraft.

   (d) Design, experimental manufacture and installation of one stinger.

2. Conduct ground and flight testing necessary to evaluate the operation and performance of the variable ejector installation as follows:

   (a) Test bed operation, including altitude chamber testing.

   (b) Flight testing to establish satisfactory mechanical functioning and to determine resultant affect on aircraft performance.

   (c) Ad Hoc structural and mechanical ground testing.

   (d) Fuel and oil.

   (e) Maintenance of one ARROW 2 Aircraft for a 12 month period.

(f) Design and/or specification, provision and installation of airborne instrumentation.

(f) Facilities and services for data reduction and analysis.

(g) Preparation and submission of a final report.

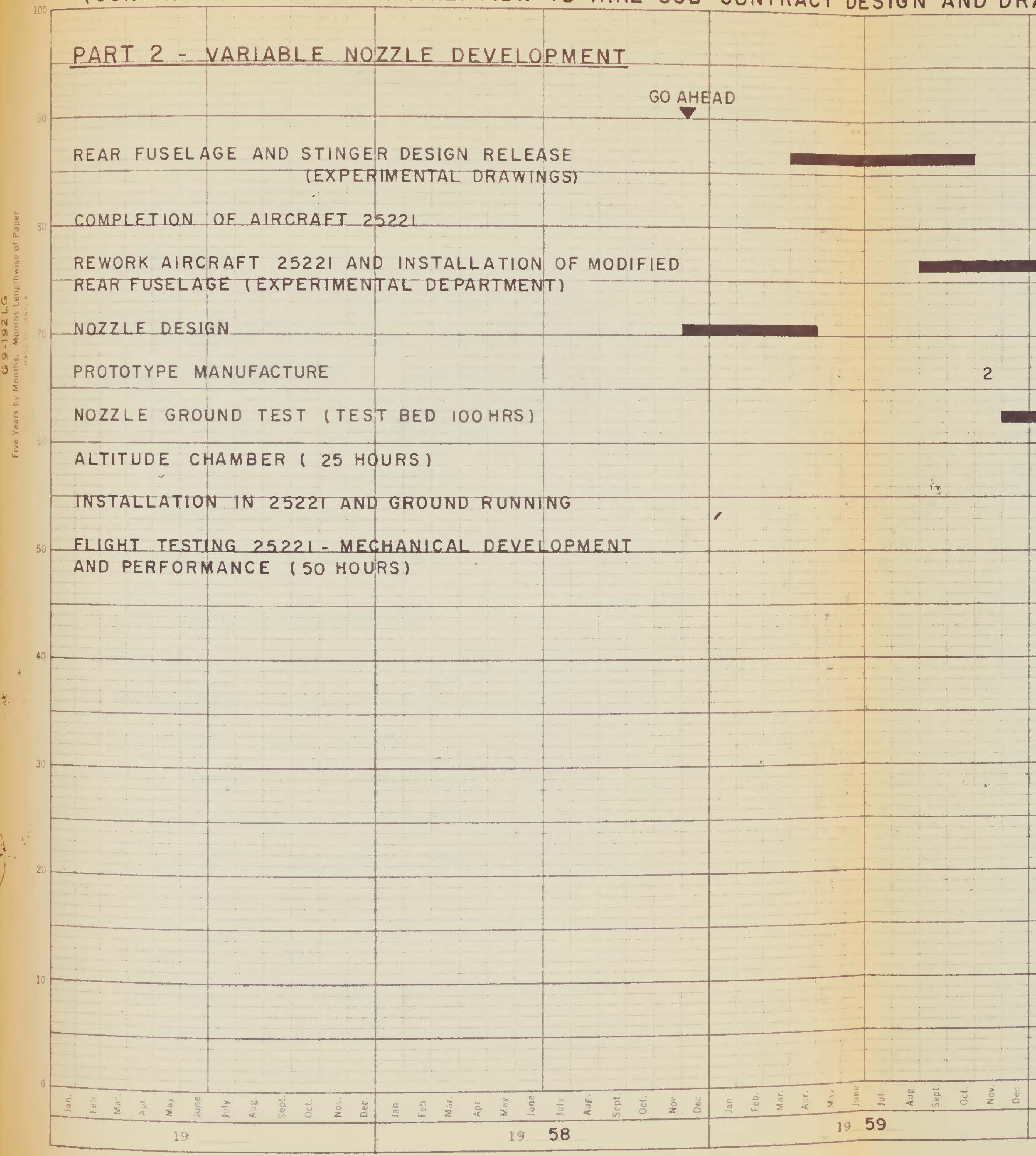
EXCLUSIONS.

This program is based on the assumption of a go ahead by December 1st/1958 for this part and a go ahead by September 1st/1958 for Part 4.

- Repair and Overhaul of the Aircraft or Ground Support Equipment.
- Aircraft or Ground Support Equipment Spares.
- Design and manufacture of Ground Support Equipment.
- Flight testing is limited to a maximum of 50 flying hours.
- Engineering for production manufacture.

ENGINEERING PHASING CHART -SHEET 2

(CONTINGENT UPON AUTHORIZATION TO HIRE SUB-CONTRACT DESIGN AND DRA



HEET 2

(SUB-CONTRACT DESIGN AND DRAFTING LABOR)

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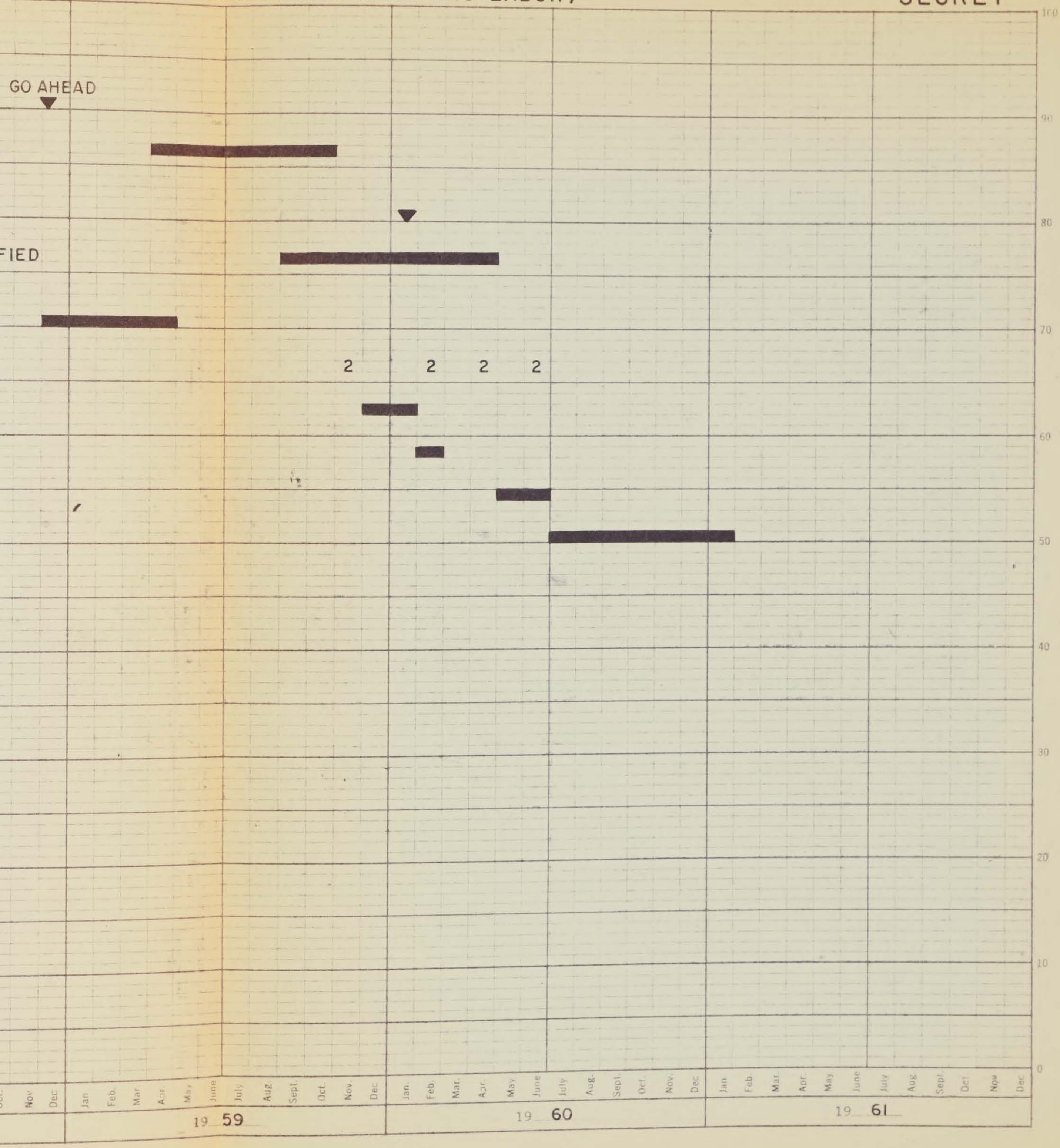

PART 3 WING LEADING EDGE

Some improvement to the combat radius of action appears possible by providing a moveable wing leading edge. A study and wind tunnel program is recommended to establish the value of such a modification.

3.1 PERFORMANCE

A further manner in which the mission distances of Part 1 might be improved is to modify the basic wing section. The maximum theoretical gain possible from such redesign is estimated to be of the order of 10% for any one cruise condition.

Three alternative methods of accomplishing this gain have been considered, namely,

1. Fixed leading edge modification.
2. Variable leading edge.
3. Complete wing section change.

3.1.1 FIXED LEADING EDGE MODIFICATION

This modification would be confined to a region forward of the front spar. Initial investigations indicate that there may well be a reasonable gain available on subsonic cruise, although this would require confirmation by wind tunnel tests. However from the overall point of view there may not be much advantage from a modification of this nature, since the present fixed leading edge droop on the ARROW 2 represents a reasonable compromise between optimum subsonic and supersonic cruise performance.

3.1.2 VARIABLE LEADING EDGE

This is considered to be the optimum modification that could be made. It is contemplated that the forward 10% of the wing would be made movable. The nose droop would be split into spanwise sections, with the possibility of a fixed portion on the centre section to improve stability characteristics. There would be an optimum setting of the sections for subsonic cruise, and another setting which would be optimum for supersonic cruise.

The mission gains due to this variable leading edge droop may be of the order of 7%, and represents the maximum amount of the theoretical 10% available that could be achieved by any of the alternatives considered.

Thus, variable leading edge droop would seem to be a practical modification which could result in a worthwhile gain in mission distance.

A suitable wind tunnel program would be required to ascertain the optimum nose droop configuration and settings.

3.1.3 COMPLETE WING SECTION CHANGE

Here it was envisaged that true conical camber would be applied to the whole wing. The gain in mission distance would not be more than about 5% since a compromise would again have to be made between subsonic and supersonic performance. In addition, there might be some sacrifice of the longitudinal and directional stability. It would entail a complete wing redesign.

It is felt that the relatively small gains attainable are not worth the enormous financial outlay and design effort required, nor the considerable delay to production schedules which this change would entail.

3.2 TEST PROGRAM (TUNNEL ONLY) - (VARIABLE L.E.)

3.2.1 SUBSONIC AND TRANSONIC TESTS

These tests would be carried out at Cornell Aeronautical Laboratories using the .04 scale model (modified) to test the effects of high Reynolds numbers. Approximately 200 to 250 runs would be required.

3.2.2 SUPERSONIC TESTS

These tests could be carried out at the Langley Unitary Tunnel using the .03 model.

Approximately 40 runs would be required.

3.3 STATEMENT OF WORK

Engineering material and services necessary for the following:

(a) Theoretical study of optimum shape and geometry of leading edge configurations.

(b) Design of modifications to existing wind tunnel models.

(c) Procurement of services for rework of existing wind tunnel models.

(d) Procurement of wind tunnel time and services to the extent indicated in 3.2.1 and 3.2.2.

(e) Preparation and submission of final report.

PART 4 PRELIMINARY ENGINEERING

To expedite the introduction of the features described in Parts 1, 2 and 3 it is recommended that authority be granted to proceed with preliminary engineering for a period of ninety days. This will permit scheming, layouts and establishment of test programs to get underway and will enable the Company to prepare and submit ECP's to cover Parts 1, 2 and 3 within approximately sixty days of the go ahead for Part 4.

STATEMENT OF WORK

Provide Engineering services necessary to conduct investigation of and preliminary design of the recommended changes to increase the combat radius of the ARROW 2. This shall include the establishment of wind tunnel, ground and flight test programs, instrumentation requirements and design schemes. The duration of this item shall be ninety days after approval.