LONG RANGE ARROW

P.R.7-1 Appendix 2

PROJECT RESEARCH GROUP

Prepared by W. Knight (signature) Approved by [signature]

Date SEPT 9/57 Date SEPT 9/57

INDEX

LONG RANGE ARROW PROPOSAL

INTRODUCTION

The potentiality of an airplane lies in its flexibility, i.e. being capable of fulfilling a variety of mission profiles. If we are to be able to develop the Avro Arrow to its fullest extent we must:

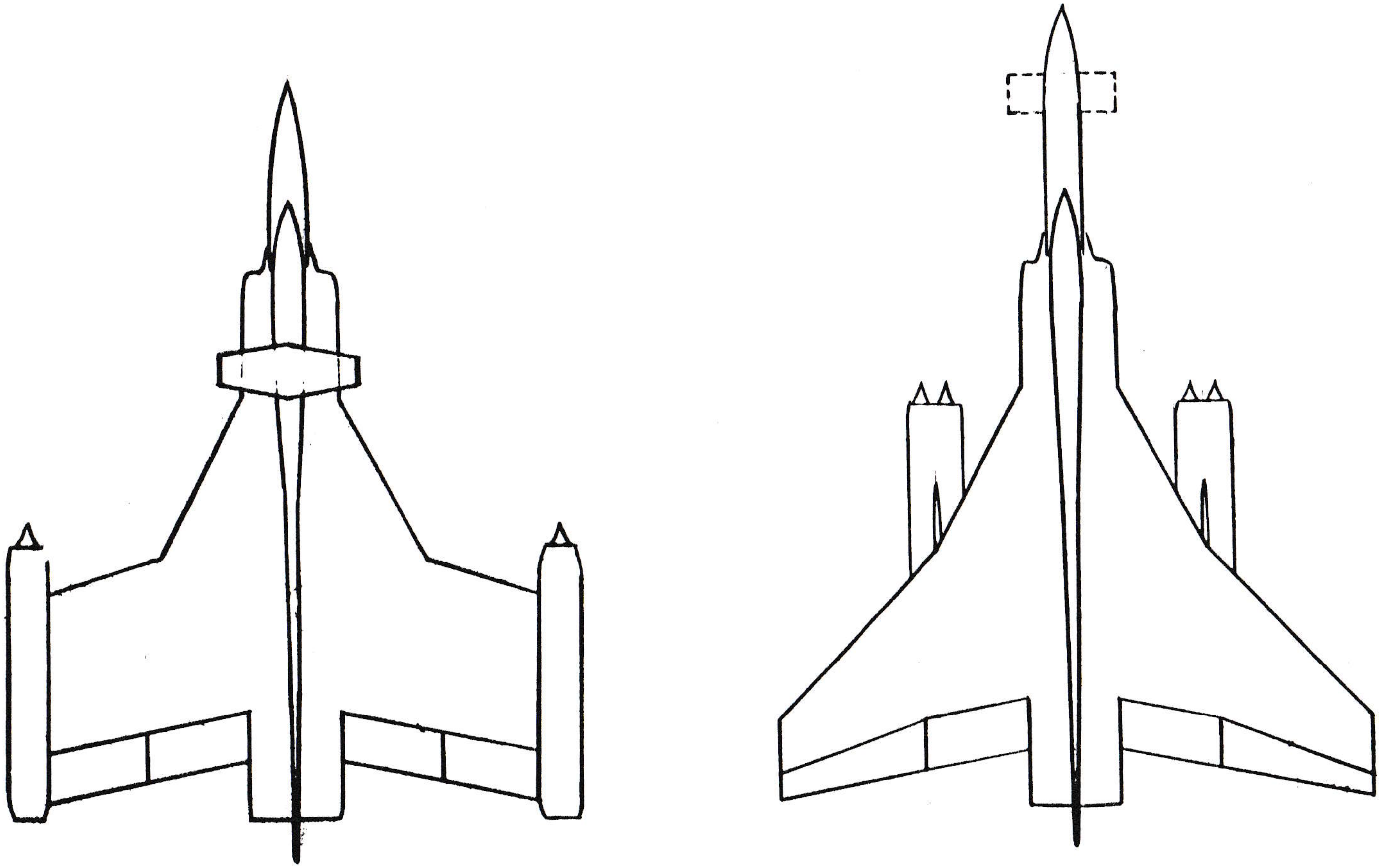
(1) Arrange for more power to increase Mach number and altitude.

(2) Arrange for an increased fuel load for increased range.

(3) Arrange for a higher take-off weight to accommodate (1) and (2).

In fulfilment of the above conditions a carefully proposed configuration is shown in Figure 2. The changes are more than minor modifications, but it is felt that the increased potential of such an Arrow will be well worth the effort.

EVOLUTION



STUDY 1 -
ADVERSE C.G., C.P., & MAIN U/C
CONDITIONS

STUDY 2 -
STATIC MARGIN MAINTAINED
AND MAIN UNDERCARRIAGE
ACCOMODATING

FIG. 1

EVOLUTION

Prior to exposing the Long Range Arrow features a brief summary on the evolution of studies is presented:

Study 1

The placement of the ramjet wing tip pods and additional wing area created an adverse CG-CP-U/C combination. This necessitated relocating the main undercarriage. Further it was felt (by the Stress Office) that the present design could never cope with a take-off weight in excess of 75 - 80,000 lb.

Careful consideration of the above and other problems prompted an evolution to Study 2, which represents the Long Range Arrow Proposal.

Study 2

The placement of the ramjet pods and additional wing area maintained the static margin the same, and the relocation and combination of the main undercarriage with the ramjet pylons resulted in the removal of the main disadvantages of Study 1. Thus we now have the same relative CG-CP-U/C placements as on the Arrow 2.

BASIC MODIFICATIONS FOR LONG RANGE ARROW

ITEM	REMARKS
UNDERCARRIAGE	(1) UNDERCARRIAGE REMOVED AND SPACE USED FOR FUEL ~2000 LBS (2) UNDERCARRIAGE INTEGRATED WITH RAMJET PYLONS, AND RELOCATED TO THE INNER AND OUTER WING TRANSPORT JOINT.
MIXED POWER	COMBINATION OF TURBOJET AND RAMJET POWER PROVIDES A LIGHT AND EFFICIENT SYSTEM CAPABLE OF EXTREMELY HIGH PERFORMANCE
INCREASED FUEL	RAMJET PODS SERVE AS FUEL PODS DURING CRUISE - OUT.
DRAG REDUCTION	(1) ADDITION OF CANARD (2) INCREASED WING AREA (3) INCREASED ASPECT RATIO

INCREASED FUEL

Additional fuel can be carried in:

(1) Ramjet pods 29,200 lb.

(2) Outer wings 6,000 lb.

(3) Former wheel well 2,000 lb.

thus increasing the fuel load to at least 19,438 + 37,200 = 56,638 lb. It is noteworthy that the Long Range Arrow mission profiles to be shown later are based on a 54,600 lb. fuel load and a 105,000 lb. take-off weight.

DRAG REDUCTION

A drag estimate of the Avro Arrow 2 showed that at M 2.5, 90,000 ft. altitude and W/P = 250,000 sq.in. the drag components to be:

Profile Drag - 4,080 lb.

Induced Drag - 11,080 lb.

Trim Drag - 6,960 lb., totalling 22,120 lb.

Profile drag is relatively a 'fixed item' and any large improvement of it was unlikely. Therefore the reduction is more probable in the induced and trim drags. Consequently it is recommended that:

(1) A canard be added to provide supersonic trim, 32 sq.ft., L.E. at station 0.

(2) The wing area be increased from 1225 to 1410 sq.ft. (outer wing increased).

(3) The aspect ratio be increased from 2.04 to 2.55.

The preceding three basic modifications would in effect reduce the drag at M 2.5, 90,000 ft. al...

to:

Profile Drag - 4900 lb.

Induced Drag - 6950 lb.

Trim Drag - 1230 lb., totalling 13,080 lb. and reduction of over 9,000 lb.

It should be noted, however, that the subsonic drag, at M = .92, 40,000 ft. and $\frac{W}{P}$ = 22,000, increases approximately from 6,660 to 7,000 lb., a small subsonic penalty to pay for attainment of a 90,000 ft. ceiling.

(1) CANARD

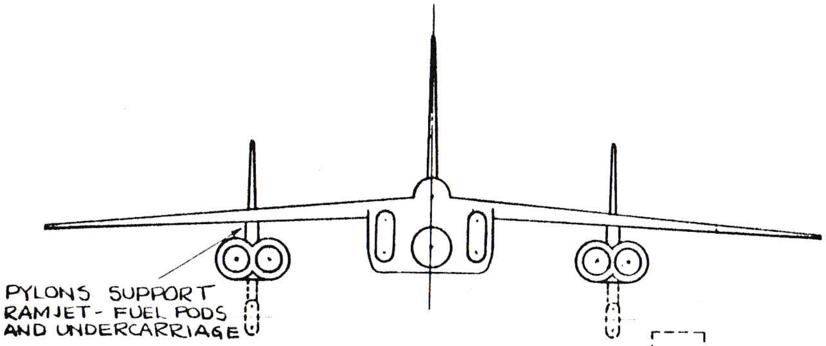
It is intended that the canard be used as an additional trim control at supersonic speeds only. At subsonic speeds it would be retracted into the 4 ft. nose extension. The aircraft controls in all other respects could function essentially the same. It is felt that the additional canard air loads induced into the fuselage can be adequately catered for by increasing the skin thickness.

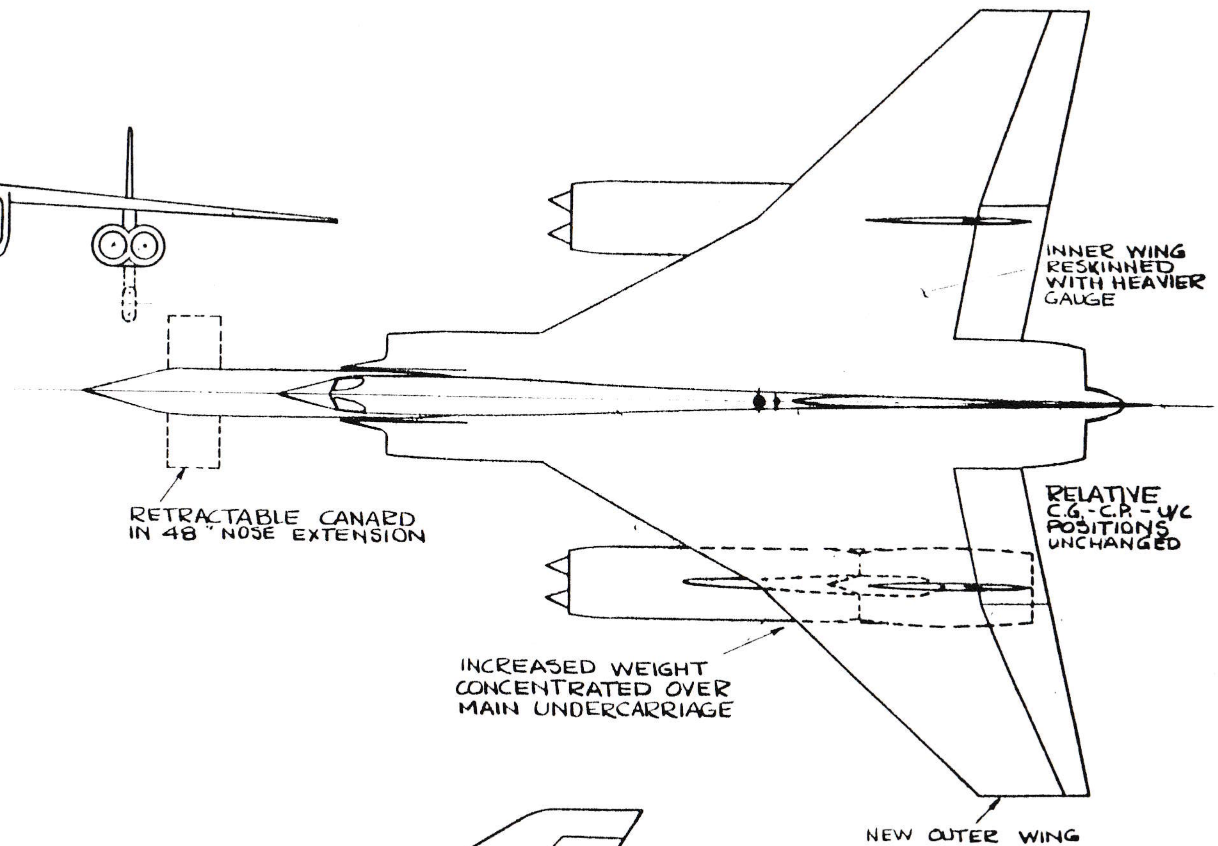
(2) WING AREA

The increased wing area may be obtained by utilizing an entirely new outer wing of a lesser sweepback angle. The resulting increased tip chord (from 52.085 to 102 in.) also provides for a much stiffer wing. It is however anticipated that some re-vamping of the aileron and aileron control may be necessary.

(3) The addition of 10 ft. to the existing span increases the aspect ratio from 2.04 to 2.55 thereby resulting in a substantial reduction in induced drag.

LONG RANGE ARROW PROPOSAL





	LONG RANGE ARROW
WING AREA	1410 FT²
CANARD AREA	32 FT²
ELEVATOR AREA	106 FT²
AILERON AREA	88 FT²
FIN AREA	172 FT²
RUDDER AREA	50 FT²
SIDE FIN AREA	90 FT²
ASPECT RATIO	2.55
SPAN	60 FT
LENGTH	4' ADDED TO NOSE
ESTIMATED -	
ZERO FUEL WEIGHT	50,500 LBS.
INTERNAL FUEL	27,438 LBS.
PODDED FUEL	29,200 LBS.
TO WEIGHT	107,000 LBS.

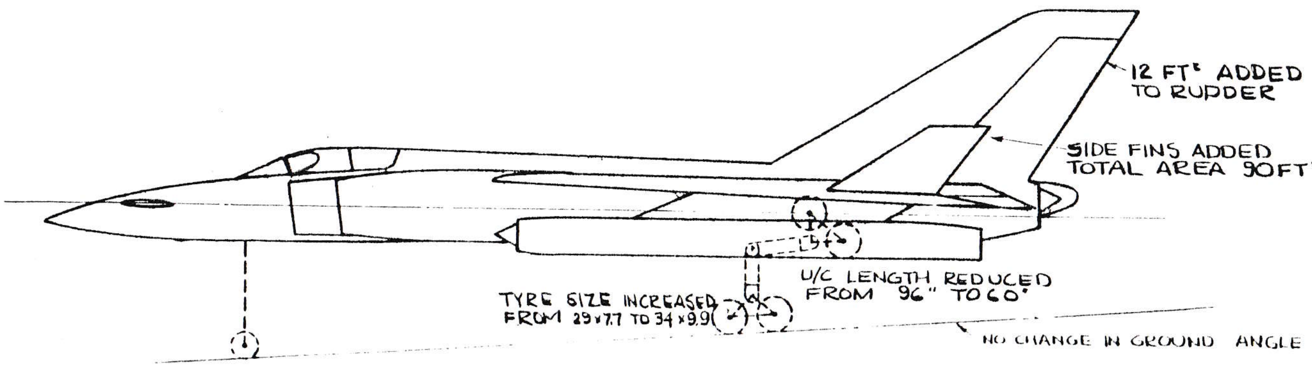


FIG. 2

LONG RANGE AVRO ARROW PROPOSAL

TABLE 1

	ARROW 2	LONG RANGE ARROW
WING AREA	1225 SQ FT.	1410 SQ. FT
CANARD AREA	NIL	32 SQ. FT
ELEVATOR AREA	106 SQ. FT.	106 SQ. FT
AILERON AREA	66 SQ. FT.	88 SQ. FT
FIN AREA	170 SQ. FT	172 SQ. FT
SIDE FIN AREA	NIL	90 SQ. FT
RUDDER AREA	38 SQ. FT.	50 SQ. FT
ASPECT RATIO	2.04	2.55
SPAN	50 FT.	60 FT
LENGTH		4 FT. ADDED TO NOSE
ESTIMATED:-		
ZERO FUEL WEIGHT	44,516 LBS.	50,500 LBS.
INTERNAL FUEL	19,438 LBS	27,500 LBS
PODDED FUEL		29,200 LBS
T.O. WEIGHT		107,000 LBS

LONG RANGE AVRO ARROW

PRELIMINARY PERFORMANCE ESTIMATES

TABLE 2

1. ASSUMPTIONS $\Sigma C_{D_o} = C_{D_o\,ARROW} + \Delta C_{D_o\,PODS} = .023 + .00338$

2. CLIMB DATA

ALTITUDE	WEIGHT	M_c	R/C FT/MIN	POWER	ΔX_N - LB
41,000	78,520	1.5	20,000	TJ+AB+RJ	17,450
50,000	77,650	1.5	10,000	"	8,770
60,000	79,650	1.5	7,300	"	6,670
41,000	80,000	2.5	130,500	"	70,400
50,000	79,000	2.5	105,300	"	56,400
60,000	79,000	2.5	42,500	"	22,800
70,000	79,000	2.5	27,300	"	14,600
80,000	79,000	2.5	6,400	"	3,430

3. CRUISE DATA

ALTITUDE	WEIGHT	M	G	NOTE
70,000	79,000	2.5	1	
70,000	70,000	2.5	1.5	SUSTAINED
80,000	80,000	2.5	1	
80,000	70,000	3.0	1.5	SUSTAINED
90,000	60,000	3.0	1	

LONG RANGE ARROW

The Long Range Arrow lends itself to a variety of roles:-

(a) Long Range Supersonic Interceptor - could be a threat to the Mach 2, high altitude bomber.

(b) Reconnaissance Arrow - which with greatly improved performance is provided with a very useful Mach 2.5, 90,000 ft. altitude dash for evading potential enemies and positioning prior to the observance and photographing of target areas.

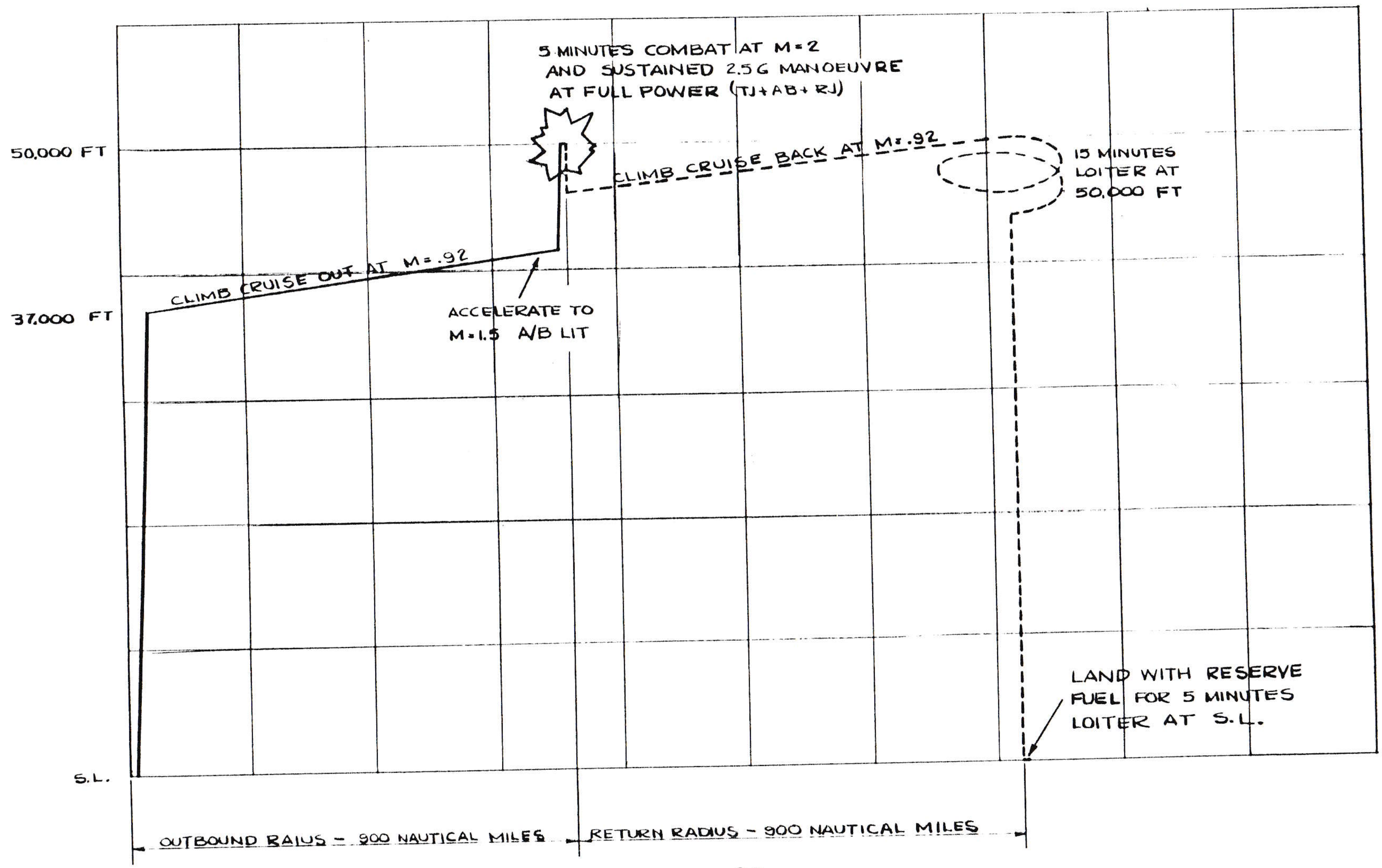
(c) Tactical bomber should the need arrive.

A variety of missions demonstrating the flexibility of this Long Range Arrow is shown in the Long Range Arrow Missions 1 to 7, following.

LONG RANGE ARROW MISSION #1

SUBSONIC CRUISE OUT

INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS



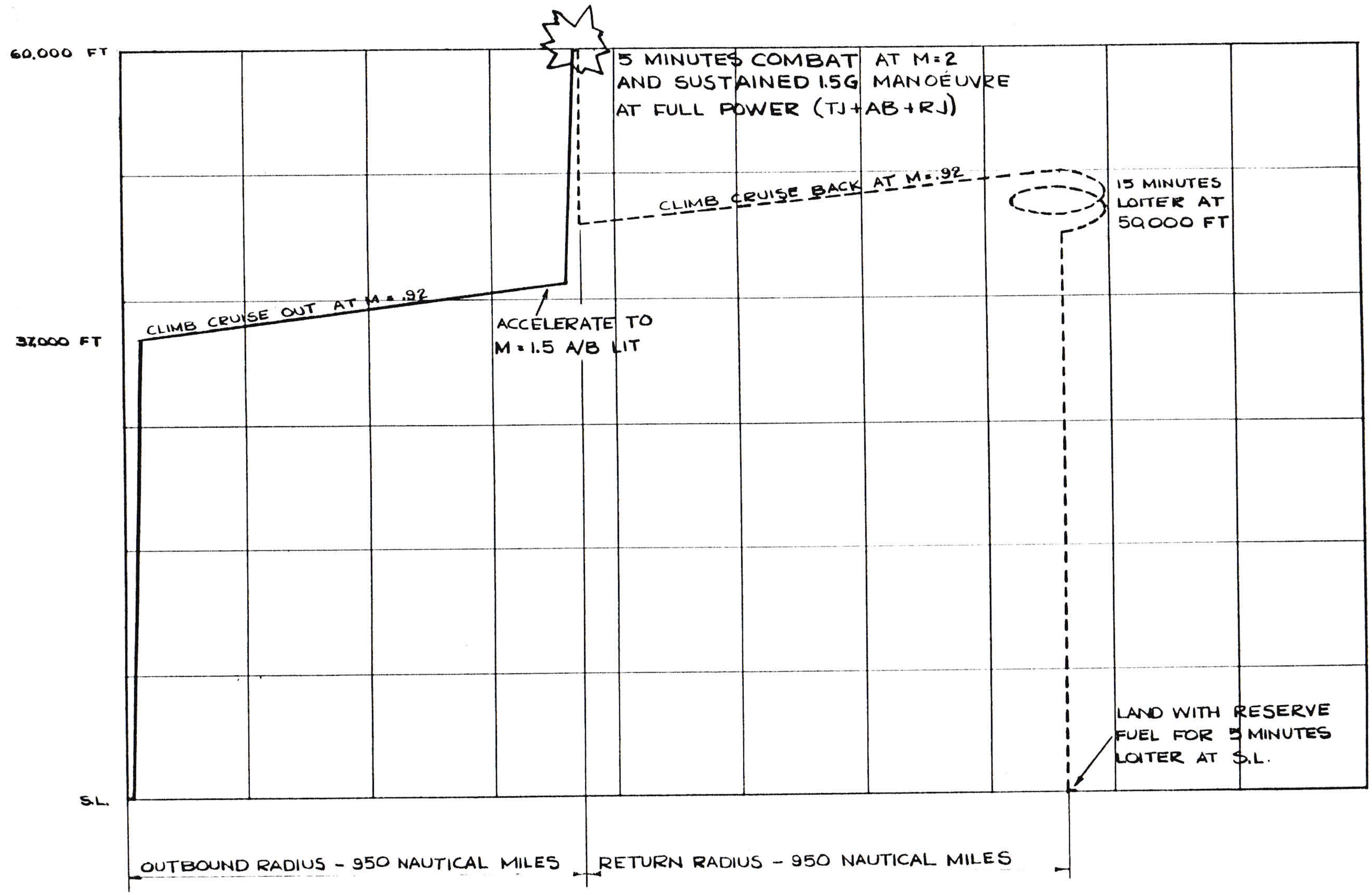
MISSION NO. 1 - LONG RANGE INTERCEPTION

This constitutes a subsonic cruise-out followed by 5 minutes combat at Mach 2, 50,000 ft. altitude, and sustained 2.5 g manoeuvre at full power. The return radius consists of a Mach .92 climb cruise, 15 minutes loiter at 50,000 ft. altitude and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 900 nautical miles.

LONG RANGE ARROW MISSION #2

SUBSONIC CRUISE OUT

INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS



MISSION NO. 2 - LONG RANGE INTERCEPTION

This mission constitutes a subsonic cruise-out, followed by 5 minutes combat at Mach 2, 60,000 ft. altitude and 1.5 g sustained manoeuvre at full power. The return radius consists of a Mach .92 climb cruise, 15 minutes loiter at 50,000 ft. altitude and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 950 nautical miles - somewhat more than on Mission 1, because of 5 minutes combat at a higher altitude.

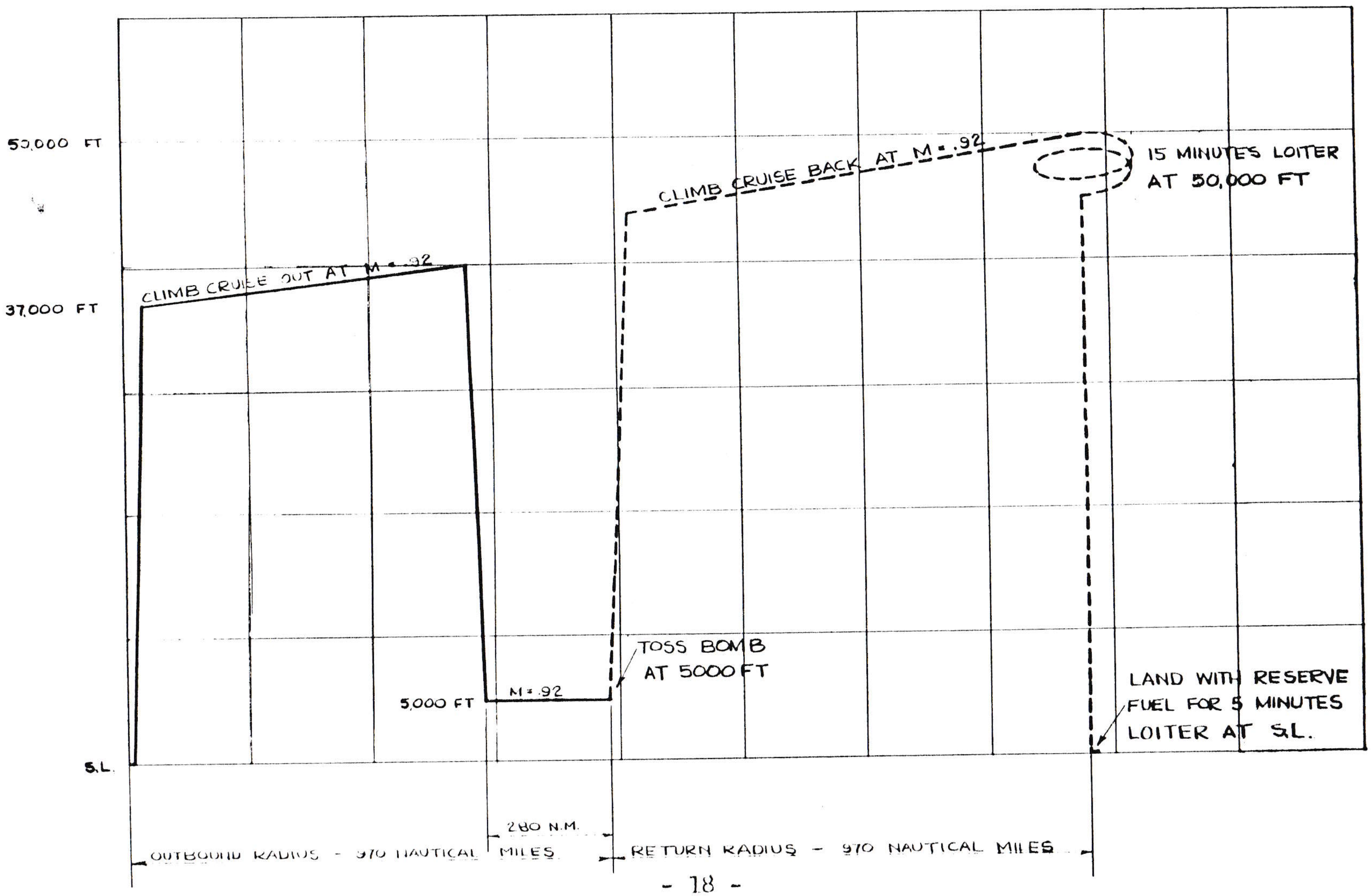
MISSION NO. 3 - LOW ALTITUDE TOSS BOMB

This mission consists of a 640 nautical mile climb cruise at Mach .92 followed by a descent to 500 ft. altitude and a cruise for 280 nautical miles immediately after which the bomb is tossed. The return radius consists of a climb to economical altitude, a Mach .92 climb cruise, 15 minutes loiter at 50,000 ft. and a landing with fuel reserves for 5 minutes loiter at sea level. The operational radius of this mission is 920 nautical miles.

LONG RANGE ARROW MISSION # 4

SUBSONIC CRUISE OUT

INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS



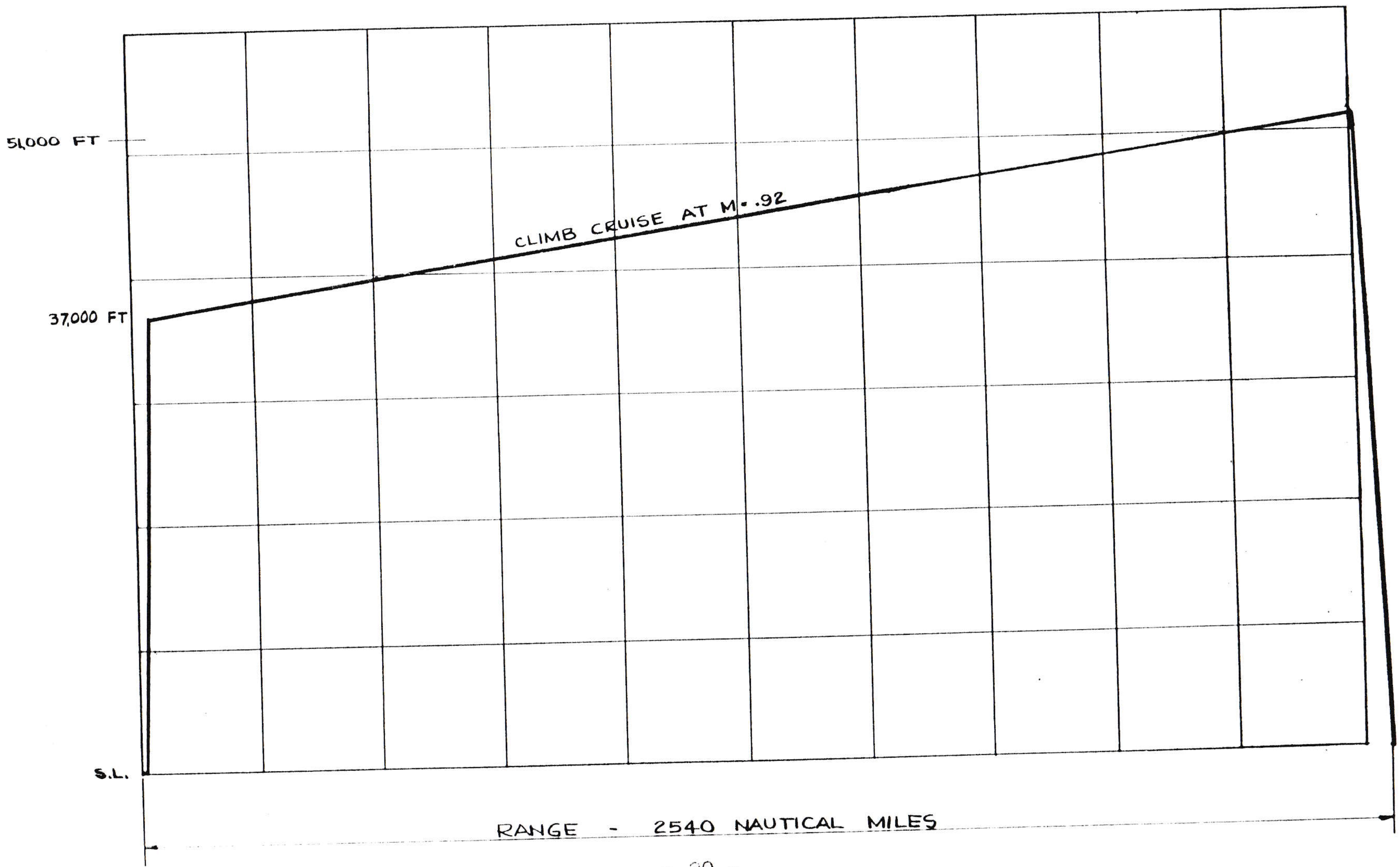
MISSION NO. 4 - HIGH ALTITUDE TOSS BOMB

This mission consists of a 690 nautical mile climb cruise at Mach .92 followed by a descent to 5000 ft. altitude and a cruise for 280 nautical miles, immediately after which the bomb is tossed. The return radius consists of a climb to economical altitude, a Mach .92 climb cruise, 15 minutes loiter at 50,000 ft. and a landing with fuel reserves for 5 minutes loiter at sea level. The operational radius of this mission is 970 nautical miles.

LONG RANGE ARROW MISSION # 5

SUBSONIC CRUISE

INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS

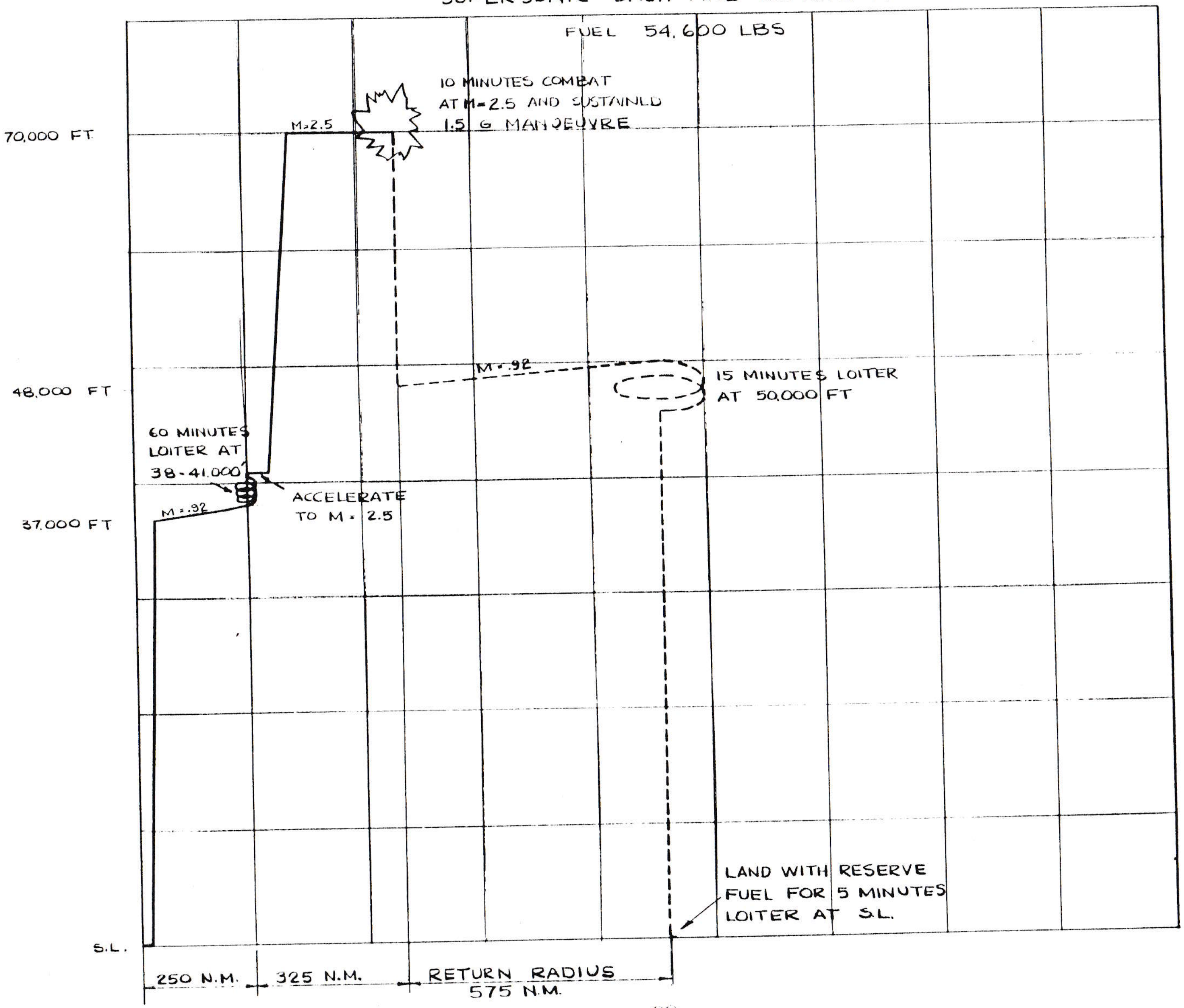


MISSION NO. 5 - LONG RANGE FERRY

This mission consists of an economical Mach .92 climb cruise between 37,000 and 51,000 ft. altitude, and represents the ultimate range with no reserves on landing. The ultimate ferry range, based on 54,600 lb. of fuel is 2540 nautical miles.

LONG RANGE ARROW MISSION # 6

SUPERSONIC DASH AND COMBAT AT M = 2.5

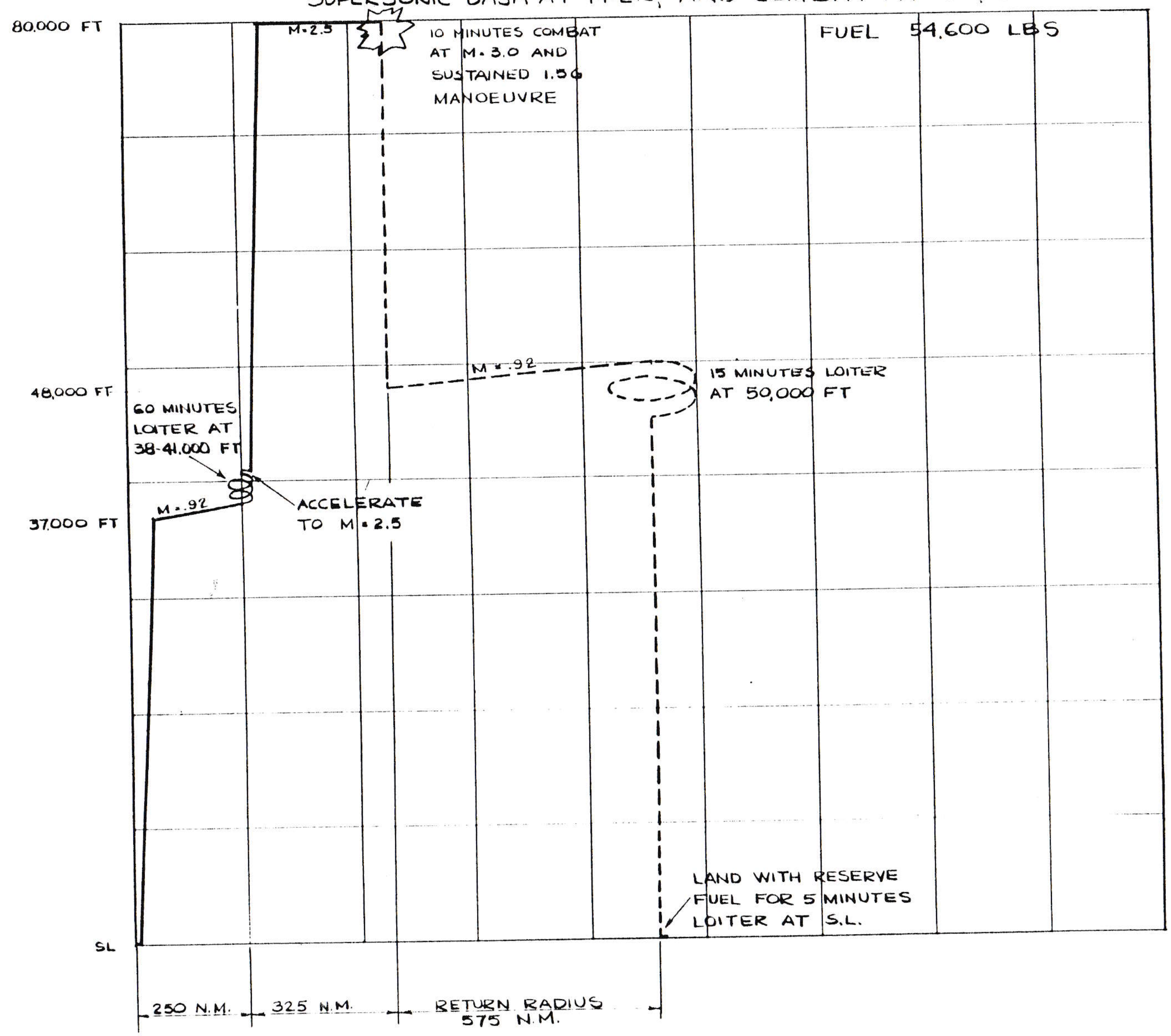


MISSION NO. 6 - U.S.A.F. LONG RANGE INTERCEPT MISSION MODIFIED

This mission consists of an economical climb cruise for 250 nautical miles followed by a 60 minute loiter at 38 - 41,000 ft. The aircraft is then accelerated to Mach 2.5 and climbed to 70,000 ft. at which altitude an approximately 280 nautical mile, Mach 2.5 dash is executed, bringing the out-bound radius to 525 nautical miles. This is followed by 10 minutes combat at 70,000 ft. altitude, Mach 2.5 and sustained 1.5 g manoeuvre. The return radius consists of a descent to 48,000 ft. altitude, a Mach .92 climb cruise followed by 15 minutes loiter at 50,000 ft., and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 575 nautical miles. The deviation of this mission from the requirement is dash and combat at Mach 2.5 in lieu of Mach 3.

LONG RANGE ARROW MISSION #7

SUPERSONIC DASH AT M-2.5, AND COMBAT AT M-3.0



MISSION NO. 7 - U.S.A.F. LONG RANGE INTERCEPT MISSION MODIFIED

This mission consists of an economical climb cruise for 250 nautical miles followed by a 60 minute loiter at 38 - 41,000 ft. The aircraft is then accelerated to Mach 2.5 and climbed to 80,000 ft. at which altitude an approximately 280 nautical mile, Mach 2.5 dash is executed, bringing the out-bound radius to 575 nautical miles. This is followed by 10 minutes combat at 80,000 ft., Mach 3 and sustained 1.5 g manoeuvre. The return radius consists of a descent to 48,000 ft. altitude, a Mach .92 climb cruise followed by 15 minutes loiter at 50,000 ft., and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 575 nautical miles. The deviation of this mission from the requirement is dash at Mach 2.5 in lieu of Mach 3, and combat at 80,000 ft. in lieu of 70,000 ft. altitude.

SUMMARY

The philosophy behind this proposal is to make every possible use of the engineering that has gone into the Avro Arrow I, II and III. One might argue that the proposal calls for substantial redesign and it would be better to start at the beginning and design a new aeroplane. However, in the consideration of overall economy and time, it is felt that utilization of the present engineering systems and airframe center portions would indeed be worthwhile.

In conclusion, some of the highlights of this study are listed below,

(a) Avro Arrow hardware and systems used with minimum modification commensurate with $M = 3$ capability.

(b) Most of Mk. III development would be utilized.

(c) Provision for installing mixed fuel operation.

(d) Most of added weight concentrated over redesigned and relocated main undercarriage capable of development for higher T.O. weights.

(e) Jet pods capable of containing much more than 29,200 lb. of fuel.

(f) Area rule application could reduce parasitic drag.

and finally,

(g) The Long Range Arrow is a means of prolonging the life of the Avro Arrow and extracting the maximum amount of return from the current and immediate future Arrow investment.