

SUMMARY OF DEVELOPMENT PROPOSALS.

C O N T E N T S

INTRODUCTION

SUMMARY OF PREVIOUSLY PROPOSED DEVELOPMENTS

SECTION 1. DESIGN

- 1.1. Extra fuel for 5,000 n.m. range.
 - 1.1.1. Bomb-bay fuel
 - 1.1.2. Revised canopy contours with dorsal fuel tank.
 - 1.1.3. Fuel systems.
 - 1.1.4. Summary.
- 1.2. Installation of larger stand-off missiles.
 - 1.2.1. General.
 - 1.2.2. Vertically retracting nose undercarriage.
 - 1.2.3. Extended forward fuselage.
 - 1.2.4. Installation of a typical 46 ft. stand-off missile.
- 1.3. Integrated missile installation.
 - 1.3.1. Introduction.
 - 1.3.2. Structural alterations.
- 1.4. Weight and centre of gravity considerations.
 - 1.4.1. Present weight and C.G. limits.
 - 1.4.2. Extended aft C.G. limit and revised main undercarriage geometry.
 - 1.4.3. Effect of increasing maximum weight on allowable normal accelerations.
 - 1.4.4. Summary of weight and C.G. cases.
 - 1.4.5. C.G. limits with larger stand-off missiles.

C O N T E N T S

SECTION 2. PERFORMANCE

- 2.1. Introduction.
- 2.2. Engine data.
- 2.3. Performance of standard Vulcan Mk. 2.
- 2.4. Performance with increased tankage.
- 2.5. Carriage of R.A.E. type 'C' missile.
- 2.6. Integrated missile installation.
- 2.7. Summary of performance.

SUMMARY OF DEVELOPMENT PROPOSALS

L I S T O F F I G U R E S

<u>SECTION 1. DESIGN</u>	Fig. No.
Development Diagram.	1
General arrangement of aircraft with vertically retracting nose undercarriage.	2
General arrangement of aircraft with extended fuselage.	3
Arrangement of dorsal fuel tank.	4
Space available for missiles below bomb-bay.	5
Arrangement of vertically retracting nose undercarriage.	6
Installation of 46 ft. long missile (Vertically retracting nose undercarriage).	7
Installation of 46 ft. long missile (Extended fuselage).	8
Integrated missile installation.	9
Structural alterations to produce flat centre section lower wing surface.	10
<u>SECTION 2. PERFORMANCE</u>	
Range performance with Blue Steel (Effect of increased fuel capacity).	11
Range performance (Effect of various missile configurations.)	12

SUMMARY OF DEVELOPEMENT PROPOSALS

INTRODUCTION

The Avro Vulcan will, by the present defence policy, represent the last generation of manned bombers and if Vulcans are to be maintained operationally into the early 1970's then it is essential that the aircraft's potential be developed to its limit. The following proposals outline ways in which the Vulcan can be adapted to carry more sophisticated weapons and also increase the operational range to about 5,000 nautical miles.

This brochure summarises the development proposals of previous brochures, discusses the installation of additional fuel tankage and the installation of stand-off missiles up to 46 ft. in length. The weight and centre of gravity changes involved by these modifications are summarised.

Fig. 1 shows diagrammatically the location of all the proposed modifications, three view general arrangements of the aircraft being given in Figs. 2 and 3.

SUMMARY OF DEVELOPMENT PROPOSALSSUMMARY OF PREVIOUSLY PROPOSED DEVELOPMENTS

The following table summarises the proposals for the development of the Vulcan made in previous Avro brochures and notes where action on these proposals has been taken.

Description	Reference	Date	Remarks
Enlarged engine air intakes.	Avro Brochure I.P.B. 65 Para. 1.2.3.	Nov.'56	To be fitted to the eleventh Mk. 2 aircraft.
Four tyre main undercarriage.	Avro Brochure I.P.B. 65 Para. 2.5.	Nov.'56	Allows for increase in A.U.W. to 225,000 lb. & reduces L.C.N's. Development work is at present proceeding on this scheme.
Outer-wing integral tank.	Avro Brochure I.P.B. 65 Para. 2.6.	Nov.'56	
Installation of R.C.M. in enlarged tail end fuselage structure.	Originally outlined in a letter to M.O.S. (17126/007/R) and Avro Brochure I.P.B. 65 Para. 2.7. (For Mk. 1 Instn. see I.P.B. 69).	Nov.'56 Nov.'56	The enlarged tail will be fitted on the production line to 11th Mk. 2 aircraft. The previous 10 aircraft can be retrospectively modified.
Rear crew ejection.	Avro Brochure I.P.B. 67	Jan.'57	
Installation of Blue Steel Missile on Mk.1 aircraft.	I.P.B. 68	Feb.'57	

SUMMARY OF DEVELOPMENT PROPOSALS

SECTION 1. DESIGN

1.1. Extra fuel for 5,000 n.m. range

1.1.1. Bomb-bay fuel

The Vulcan Mk. 2 will have two alternative sets of bomb-bay fuel tanks which are fitted by special order.

These are:-

(a) Tanks tailored to the installation of the Blue Danube and Yellow Sun stores. The capacity of these tanks is about 1,000 gallons.

(b) Tanks tailored to the installation of the Blue Steel stores; these tanks have a capacity of about 3,300 gallons.

The following should be noted:-

1) Avro Brochure I.P.B. 65 (Nov.'56) also contained proposals for integral tanks in the outer wings. These tanks are considered in conjunction with the bomb-bay and dorsal tanks, (see next para.), when discussing the fuel requirements for a 5,000 n.m. still air range.

2) Tanks compatible with the installation of 46 ft. long missiles could be the same or similar to those for the Blue Steel missile, but until the configuration of the missile and the size of its associated equipment is finalised a more detailed assessment is not possible.

1.1.2. Revised canopy contours with dorsal fuel tank

Wind tunnel and flight tests on the present Vulcan canopy have shown that in its present configuration it is responsible for an undesirable

SUMMARY OF DEVELOPMENT PROPOSALS

drag increment, possibly of the order of $\frac{3}{4}\%$ of the lift/drag ratio. Transonic wind tunnel tests have now produced a revised canopy shape which will materially reduce this drag increment.

In increasing the fuel capacity of the aircraft still further it is desirable to provide fuel forward of the C.G. to counter-balance the extra fuel in the integral wing tanks. Advantage has, therefore, been taken of the proposed canopy alterations to extend it aft and fair it into the existing dorsal fin. The extra volume made available in this way will accommodate some 800 gallons of fuel. The extra fuel is, of course, carried without any increase in the frontal area of the aircraft, with only a slight increase in skin friction drag and with no reduction in critical Mach number and consequently shows considerable advantage over a similar amount carried in external wing mounted tanks.

The proposed canopy alterations could be carried out without re-design of the cockpit rail and without modification to the present D.2 pressure cabin unit. The present dinghy stowage under the canopy could remain unaltered, but some modification would be required if it were to efficiently utilise the space available under the revised canopy. New canopy jettison tests would be required, as the whole of the present canopy is jettisonable, but only part of the revised canopy above the crew and dinghy would be released. The aft portion would be a fixed structure housing

SUMMARY OF DEVELOPMENT PROPOSALS

the extra dorsal tanks. (See Fig. 4).

Alternatively, it would be possible to anticipate a requirement for improved escape for the rear crew members in the event of ditching or a wheels-up landing by increasing the size of the cut-out in the pressure cabin. The dimensions of this cut-out would be similar to those given in the study on rear crew ejection (AVRO Brochure I.P.B. 67) and in fact ejection seats for the rear crew members could be fitted at the same time or at a later date without further structural changes to the pressure shell if required.

Any change in the size and shape of the cut-out in the pressure cabin would necessitate new static strength, pressure and fatigue tests and a revision of the dinghy stowage arrangements.

1.1.3. Fuel Systems

It is not intended to affect the fuel metering of the basic fuel system when the additional fuel tanks are installed. The bomb-bay fuel tanks will form a separate system which will be tapped in to the main fuel supply lines. Similarly the integral outer wing tanks and dorsal tanks together with any extra fuselage tanks available, (see paras. 1.2.2. and 1.2.3.), will form a third separate system. This will avoid the various tanks being interdependent upon one another.

It is desirable to reduce the load on the centre section as soon as possible after take-off

SUMMARY OF DEVELOPMENT PROPOSALS

in order to increase the allowable normal acceleration factors. Consequently the procedure for using fuel will be to take-off with all systems working and then to switch off the main fuel system and the dorsal and integral tanks and to use the bomb-bay fuel. After the bomb-bay fuel is consumed the dorsal and integral tanks will be switched on and then for the remainder of the flight the main system will be used.

1.1.4. Summary

The fuel capacity of a developed Mk. 2 Vulcan can be summarised as follows :-

		<u>Blue Danube or Yellow Sun</u>	<u>Blue Steel</u>
Basic aircraft fuel capacity	- galls	9,290	9,290
Bomb-bay tanks	- galls	1,000	3,300
Integral wing tanks	- galls	1,250	1,250
Dorsal fuel tanks	- galls	800	800
TOTAL	- galls	<u>12,340</u>	<u>14,640</u>
Weight at a specific density of 0.77	- lb.	95,018	112,728

These quantities refer to maximum capacities, for details of quantities for various roles see para. 1.4. Complimentary to the above the capacity of the No. 1 fuel tanks can be increased by 250 gallons each if the fuselage is extended by 4 ft. as outlined in para. 1.2.3. of this brochure, or an additional fuselage tank of 225 gallons capacity can be installed if the vertically retracting nose undercarriage is adopted as outlined in para. 1.2.2.

SUMMARY OF DEVELOPMENT PROPOSALS

(see also Fig. 6).

The performance capabilities of the Vulcan Mk. 2 when utilising the above fuel capacities will be found in Section 2, para. 2.4.

1.2. Installation of larger stand-off missiles

1.2.1. General

Fig. 5 shows the space available beneath the Mk. 2 Vulcan for the installation of stand-off or similar missiles. The Blue Steel missile, which will be fitted to all Mk. 2 Vulcans, is 35 ft. long, but a considerably greater length is available at the expense of only small modifications to secondary structure. The nosewheel unit fitted to the Mk. 2 aircraft is some 14 inches shorter than the Mk. 1 nosewheel unit and also incorporates provision for a pre-retraction mechanism giving a further reduction of 15 inches. The effect of the new nosewheel is to enable the nose of the missile to be extended forwards by about 36 inches, the modifications to the aircraft being confined to the secondary structure in the bottom of the fuselage and the nosewheel doors.

It is also possible to extend the aft end of the bomb bay by about 4' 3", the exact amount depending upon the depth of the bomb relative to the ground clearance. Similar small modifications to secondary structure would be required.

It is therefore possible for the Vulcan Mk. 2 to carry missiles up to 40-42 ft. long without other than minor modifications to light structure.

SUMMARY OF DEVELOPMENT PROPOSALS

The length of the next generation of missiles after Blue Steel is still in doubt, but it would appear that improvements in missile performance may be obtained by increasing the length up to, say, 46 ft. Two alternative schemes are proposed for modifying the Vulcan to accommodate missiles of this length; these schemes are discussed in the following paragraphs.

1.2.2. Vertically retracting nose undercarriage

The present Vulcan nose undercarriage retracts aft and therefore limits the forward extension available for the missile. An alternative means of retraction is proposed for missiles between 38 ft. and 46 ft. in length. A forward retracting undercarriage was originally suggested in Avro brochures I.P.B. 65 and 67; the retracted leg was, however, then housed under the rear crew floor making their present means of entry and exit no longer possible. This meant that the modification also required ejection seats for the rear crew, and alternative normal entry and exit. In order to avoid the complexity of these modifications an alternative method of retracting the nose undercarriage has been developed; this is depicted in Fig. 6.

The main principle of the scheme is to provide a linkage that will retract the wheels in an approximately vertical direction and so avoid the large fore and aft length normally swept by the retracting leg. The main reaction points have been retained but the main reaction point is now disengaged from

SUMMARY OF DEVELOPMENT PROPOSALS

the aircraft on retraction by hydraulically operated pintles. The top of the leg is then rotated aft with the nosewheels trailing and lifting vertically. The retraction path is controlled by radius rods, which only react trimming loads under acceleration and drag conditions and do not react the landing or braking loads; the latter are taken by the main drag struts attached to the pressure bulkhead. The loads on this undercarriage are thus reacted in a similar manner to the present Mk. 2 unit and retrospective fitment can be easily accomplished.

The No. 1 fuel tanks above the undercarriage bay are not affected by the change, but new undercarriage doors and modifications to the structure at the aft end of the nosewheel bay are required to conform to the contours of the missile. In order to facilitate the retraction of the leg, its length has been reduced and the aircraft static incidence reduced to 2° as against $3\frac{3}{4}^{\circ}$ on present Mk. 2 aircraft. The pitching power of the elevons will easily accommodate this change in incidence and the nosewheel raising speed will not be appreciably increased. Furthermore, the shortening of the leg reduces its weight and also improves ground clearance at the rear spar, thereby facilitating the loading procedure for the missile which is offered up to the aircraft from the rear.

This shortened leg also makes it possible to fit an additional fuel tank of approximately 225 galls. below the No. 1 tanks at the aft end of the present nosewheel bay. This tank can be used in

SUMMARY OF DEVELOPMENT PROPOSALS

conjunction with the proposed integral tanks in the outer wing of the aircraft. (See Brochure I.P.B. 65 para. 2.6.)

1.2.3. Extended forward fuselage

An alternative method of providing the required stowage length for missiles of up to 46 ft. in length is to extend the fuselage forward. (See Fig. 8). The required length can be achieved by the introduction of a 4 ft. extension piece of fuselage at the rear pressure bulkhead joint. As this existing joint is forward of the wing/fuselage intersection, the extension piece can easily be introduced both during manufacture of the aircraft or retrospectively if required.

Furthermore, most of the services passing through the pressure bulkhead already have joints at this station, which again facilitates the installation of the extension piece.

A number of advantages, in addition to the extra stowage length, result from this modification. The extra volume can be used to increase the capacity of the No. 1 fuel tanks by 500 gallons which in turn could be used in conjunction with the proposed outer wing integral tanks, and in addition extra space is also available for new equipment. Furthermore, the forward fuselage can be rotated nose-down through some 3° relative to the wing, thus materially improving the pilot's view.

The existing Mk. 2 nose undercarriage can be retained although new drag struts and undercarriage doors will be required.

SUMMARY OF DEVELOPMENT PROPOSALS1.2.4. Installation of a typical 46 ft. stand-off missile

Figures 7 and 8 illustrate the installation of a typical 46 ft. long missile. Figure 7 shows the vertical retracting nose undercarriage and Figure 8 the same missile installation with the extended fuselage. The particular missile illustrated is one designed by the R.A.F. and known as Type 'C', but the versatility of the Vulcan is such that missiles of a variety of configurations with lengths of up to 46 ft. can be installed.

The missile is located on the longitudinal centreline of the aircraft and its fore and aft position is determined by the need to provide retraction clearance for the nose undercarriage, together with adequate tail down incidence. The minimum desirable tail down incidence is 14° with the main undercarriage fully compressed, and this is shown in Figures 7 and 8. A typical missile weight is 25,000 lb. and the centre of gravity relationship between the missile and the aircraft is acceptable, the changes in trim when the missile is released being small and easily controlled by the auto-pilot.

The lower boom of the centre section front spar has already been cranked on the Mk. 2 aircraft to cater for the Blue Steel missile and this structure remains unaltered for the larger missile installations. The cut-out in the secondary fuselage structure forward of this front spar and below the No. 2 fuel tanks will, however, require

SUMMARY OF DEVELOPMENT PROPOSALS

modifying to suit the contours of the missile.

If it is necessary to run the engines of the missile prior to its release then some steel or titanium reinforcing on the underside of the aircraft aft of the rear spar will be required.

The missile will be loaded into the Vulcan from the rear of the aircraft. If upper fins are fitted to the missile it may be necessary to detach these prior to installing the missile below the bomb-bay; the fins can then be re-fitted to the missile from the bomb-bay. Apart from this no special provisions are required to mount the missile underneath the Vulcan.

The wing span of the missile shown here is such that the wings foul the present R.A.T.O.G. units, and a revised location for the rockets would be required if operation with these units is required.

Additional fuel tankage can be installed in the bomb-bay but the number and shape of the tanks cannot be finalised until the equipment required to operate the missile is known. However, unless the dimensions differ considerably from Blue Steel about 3,300 gallons should be available.

1.3. Integrated missile installation

1.3.1. Introduction

The present combination of the "V" bombers and stand-off missiles is not as efficient, aerodynamically, as could have been achieved if the aircraft had been specifically designed for this purpose. Thus in the case of the Vulcan, although

SUMMARY OF DEVELOPMENT PROPOSALS

the large ground clearance enables the Blue Steel and other projected missiles to be loaded without recourse to pits or ramps, the aerodynamic combination gives a higher drag than would have been obtained with a fully integrated installation.

Current research into high Mach number missiles indicates, for instance, that a possible shape is the narrow delta planform with a flat upper surface. An investigation has, therefore, been made into the feasibility of modifying the lower surface of the Vulcan in the region of the bomb-bay and the engine bays and making it capable of carrying this type of very high performance missile with the minimum of installed drag. Figs. 9 and 10 show these modifications and illustrate the mounting of a hypothetical 45 ft. long narrow delta missile.

No quantitative data on the drag of such an integrated installation is at present available, but it is intended to initiate a programme in the Avro wind tunnels to investigate the aerodynamic characteristics of the Vulcan modified in this way and equipped with a range of typical missiles.

1.3.2. Structural alterations

The structural changes required to achieve the flat lower surface are outlined in Fig. 10, the method of modification depending on whether it is to be embodied in the aircraft during manufacture or whether it is to be carried out retrospectively.

The area beneath the bomb-bay will require a new fairing in place of the bomb doors and an external fairing will be required on the lower

SUMMARY OF DEVELOPMENT PROPOSALS

surface of the fuselage forward of the front spar. New engine doors will be required and the engine bay ribs must be deepened to produce the flat surface.

The only fixed portion of the aircraft that requires basic alteration is that in the region of the jet pipe tunnels between the rear edge of the engine access doors and the wing trailing edge. This involves re-design of the formers or the building of a light superstructure upon the existing structure.

The aircraft can still be used as a carrier of ballistic bombs by removing the fixed flat fairing covering the bomb-bay and fitting conventional bomb doors shaped to conform to the new lower surface.

1.4. Weight and centre of gravity considerations

1.4.1. Present weight and C.G. limits

The standard Vulcan Mk. 2 aircraft has been designed to a maximum all-up weight of 195,000 lb. at a normal acceleration factor of 2.7. This weight is made up as follows:-

Basic operational weight, including crew	90,761 lb.
Weight of store (Blue Steel)	15,173 lb.
Normal fuel (9,290 gallons)	71,533 lb.
Bomb-bay fuel (2,280 gallons)	17,533 lb.
	<u>195,000 lb.</u>

The associated C.G. limits are 0.247c to 0.291c (134.8" to 153.8" aft of datum).

Different weights must be quoted for the first 10 and the 11th and subsequent aircraft since the new

SUMMARY OF DEVELOPMENT PROPOSALS.

fuselage D.3 section containing the R.C.M. equipment is first introduced at the 11th aircraft. For simplicity, the weight of Window (1,267 lb.) is included at the same stage, although provision for it is made on all Mk. 2 aircraft.

The basic operational and full load weights when carrying 3,300 gallons of fuel in the bomb bay tanks and a nominal installed store weight of 16,000 lb. now become :-

		Basic operational weight	Weight for full load
1st 10 aircraft	- lb.	91,599	204,542
11th and subsequent aircraft	- lb.	94,038	208,248

1.4.2. Extended aft C.G. limit and revised main undercarriage geometry.

The requirement for a 5,000 n.m. range has necessitated a greater fuel capacity than is given by the normal and bomb-bay tanks, and the general trend is for the centre of gravity of the additional fuel to be aft of the C.G. Thus if the aircraft without R.C.M. and window is loaded with a total of 13,970 gallons of fuel by utilising the integral wing and dorsal tanks, then the C.G. is at 154.3" aft of datum, i.e. 0.5" aft of the present aft C.G. limit (See Table 4). However, this C.G. position is quoted with undercarriage down, as required by R.D.(A) form 13. On retraction a forward shift of approximately 1" in C.G. position will take place at A.U.W.'s in the region of 210,000 lb.

The present limit was based on theoretical estimates of the stability of the Mk. 2 wing and recent wind tunnel, and to some extent, flight tests have indicated that the aircraft is some 2 - 2½% more stable than anticipated. It is, therefore, possible to extend the aft limit by about 2%.

SUMMARY OF DEVELOPMENT PROPOSALS

(8.56") without affecting the flying qualities and this enables more of the additional fuel capacity in the wing integral tanks to be utilised. Thus it is possible to use all the normal bomb-bay, wing integral and dorsal tankage to give a total fuel volume of 14,640 gallons without exceeding the new aft limit; reference to para. 2.4 shows that this gives a range of 5,150 n.m. (see Table 5).-

This extension of the aft C.G. limit must however be accompanied by a modification to the geometry of the mainwheel units to maintain adequate load on the nosewheel. At the present aft limit the percentage load on the nosewheel is about 5% and at the extended limit is reduced to less than 3% which is insufficient to ensure adequate ground handling characteristics.

An investigation into the possibility of rotating the present main unit further aft about its present point of rotation has been made in conjunction with Messrs. Dowty Equipment Limited, and it is found that a further 10 inch rearward movement of the mainwheels can be obtained. This involves the replacement of the drag struts, down-lock mechanism and actuating jacks and also some modification to the bogie geometry to ensure equal loading of the front and rear wheels. This modification could, therefore, be easily introduced by retrospective action..

SUMMARY OF DEVELOPMENT PROPOSALS1.4.3. Effect of increasing maximum all-up weight on allowable normal accelerations.

The following Table 1 shows the values of normal acceleration factors n_1 and n_2 for various all-up weights. The normal acceleration available is dependent upon the portion of the structure which first reaches limit stresses under the particular configuration of loading applied. The values of n_1 are based on the bending stresses in the inboard sections of the outer wing and centre section structure, and those of n_2 on the bending stresses in the wing outboard of the main fuel tanks. In general n_1 is sensitive to loads carried on the centreline of the aircraft and to the total weight of the aircraft, whereas n_2 is almost directly proportional to weight.

It can be seen from Table 1 that n_2 is more critical than n_1 for the extreme loadings considered. Assuming $n = 2.7$ to be met at the present design weight of 195,000 lb., n_2 reduces below the normal overload value of 2.5 to a value of 2.39 when fuel for 5,000 n.m. range is carried; the minimum value of n_2 is 2.34 when all the available tankage is utilised (14,640 galls).

Structural tests will shortly be commenced on the Mk. 2 structural test specimen aircraft, and it seems reasonable to expect that the weight at which a normal acceleration of 2.7 may be applied can be increased from 195,000 lb. to 208,000 lb. with only minor reinforcements to the structure. Table 1 also shows the normal acceleration allowable if the structure is developed to a normal acceleration factor of 2.7 at 208,000 lb., and it can be seen here that n_1 and n_2 are never less than 2.5 for the cases considered.

TABLE 1

OVERLOAD CASES WITH BLUE STEEL MISSILE
LIMITING NORMAL ACCELERATION FACTORS

For details see table.	A.U.W. lb.	Full Factors to Design weight of 195,000 lb.		Full Factors to 208,000 lb.		Remarks
		Limiting Normal Acceleration Factor		Limiting Normal Acceleration Factor		
		n_1	n_2	n_1	n_2	
2	195,000	2.70	2.70	3.02	2.88	Design case
	204,542	2.52	2.57	2.76	2.75	Basic overload case 1st 10 aircraft.
3	208,248	2.44	2.52	2.70	2.70	Basic overload case with enlarged D.3
4	221,097	2.56	2.39	2.98	2.55	5,000 n.m. range case.
4	216,410	2.77	2.43	3.07	2.60	5,000 n.m. range case but no R.C.M. or Window.
5	224,820	2.60	2.34	2.88	2.50	Max. range case. All tanks full.

SUMMARY OF DEVELOPMENT PROPOSALS.

1.4.4. Summary of weight and C.G. cases.

The weight breakdowns and C.G. positions of the 11th and subsequent aircraft are summarised in the following Tables 2 to 5.

The fuel capacity utilised in making up the design maximum weight of 195,000 lb. is 11,292 galls. without R.C.M. and Window, and 10,870 galls. when this equipment is carried. In both conditions the centre of gravity lies within the normal limits (See Table 2).

The breakdown with full bomb-bay fuel tanks (3,300 galls.) is shown in Table 3 and under this loading, with R.C.M. and Window included, the C.G. is outside the normal aft limit. (See para. 1.4.2.)

The weight breakdown for the developed aircraft with increased fuel capacity and carrying a 16,000 lb. Blue Steel weapon is shown in Tables 4 and 5. Table 4 shows the aircraft loaded for a range of 5,000 nautical miles. When R.C.M. and Window are not carried, 13,970 galls. are required at an A.U.W. of 216,410 lb. If this equipment is installed, the tankage increases to 14,150 galls. and the A.U.W. to 221,047 lb. Table 5 shows the aircraft with all available fuel tankage utilised. (14,640 galls.), giving an A.U.W. of 224,820 lb. with R.C.M. and Window installed.

NOTE :

a). All the C.G. positions for the developed aircraft are based on design studies only, and it is therefore advisable to allow a tolerance of some ± 0.5 " when considering any particular configuration.

SUMMARY OF DEVELOPMENT PROPOSALS.

b). All the C.G. positions quoted are with undercarriage down as required by R.D. (A) Form 13. A forward movement of the C.G. of approximately 1" takes place upon retraction of the undercarriage when the A.U.W. is in the region of 210,000 lb.

TABLE 2

<u>ITEM</u>				11th & Subsequent Aircraft		11th & Subsequent Aircraft	
				No R.C.M. or Window		With R.C.M. & Window	
				Wt. (lb)	C.G. in.	Wt. (lb)	C.G. in.
<u>NORMAL CASE</u>							
Basic Operational Weight Store (Blue Steel) Window				92,054 16,000 -	143.65	94,038 16,000 1,267	152.25
		<u>No R.C.M.</u>	<u>With R.C.M.</u>	<u>Galls.</u>			
Fuel normal		9,290	9,290	"	71,533	71,533	
bomb-bay forward tank		1,700	1,580	"	13,090	12,162	
centre tank		302	-	"	2,323	-	
aft tank		-	-	"	-	-	
TOTAL FUEL		<u>11,292</u>	<u>10,870</u>	"			
TAKE-OFF WEIGHT					195,000	195,000	150.76

TABLE 3

<u>ITEM</u>	11th & Subsequent Aircraft		11th & Subsequent Aircraft	
	No R.C.M. or Window		With R.C.M. & Window	
	Wt. (lb)	C.G. in.	Wt. (lb)	C.G. in.
<u>OVERLOAD CASE</u>				
Basic Operational Weight	92,054	143.65	94,038	152.25
Store (Blue Steel)	16,000		16,000	
Window	-		1,267	
		<u>Galls</u>		
Fuel				
normal	9,290	"	71,533	71,533
bomb-bay forward tank	1,700	"	13,090	13,090
centre tank	560	"	4,312	4,312
aft tank	1,040	"	8,008	8,008
	<hr/>			
TOTAL FUEL	12,590	"		
TAKE-OFF WEIGHT	204,997	152.06	208,248	156.67
TAKE-OFF WEIGHT WITH R.A.T.O.G.	212,357	155.74	215,608	160.08

TABLE 4

<u>ITEM</u>				Development Aircraft		Development Aircraft	
				No R.C.M. or Window		With R.C.M. & Window	
				Wt. (lb)	C.G. in.	Wt. (lb)	C.G. in.
<u>OVERLOAD CASE (5,000 N.M. RANGE)</u>							
Basic Operational Weight				92,841	143.63	94,825	152.16
Store (Blue Steel)				16,000		16,000	
Window				-		1,267	
		<u>No</u>	<u>With</u>				
		<u>R.C.M.</u>	<u>R.C.M.</u>	<u>Galls.</u>			
Fuel							
normal		9,290	9,290	"	71,533	71,533	
integral tanks		1,250	1,250	"	9,625	9,625	
canopy tanks		800	800	"	6,160	6,160	
bomb-bay forward tank		1,700	1,700	"	13,090	13,090	
centre tank		560	560	"	4,312	4,312	
aft tank		370	550	"	2,849	4,235	
TOTAL FUEL		<u>13,970</u>	<u>14,150</u>	"			
TAKE-OFF WEIGHT					216,410	221,047	159.36
TAKE-OFF WEIGHT WITH R.A.T.O.G.					223,770	228,407	162.56

TABLE 5

<u>ITEM</u>	Development Aircraft		Development Aircraft	
	No R.C.M. or Window		With R.C.M. & Window	
	Wt.(lb)	C.G. in.	Wt.(lb)	C.G. in.
<u>MAXIMUM INTERNAL FUEL CASE</u>				
Basic Operational Weight				
Store (Blue Steel)				
Window				
			94,825	152.16
	92,841	143.63	16,000	
	16,000		1,267	
	-		76,092	
Fuel				
normal	9,290	"	71,533	71,533
integral tanks	1,250	"	9,625	9,625
canopy tanks	800	"	6,160	6,160
bomb-bay forward tank	1,700	"	13,090	13,090
centre tank	560	"	4,312	4,312
aft tank	1,040	"	8,008	8,008
TOTAL FUEL	14,640	"		
TAKE-OFF WEIGHT			224,820	161.35
TAKE-OFF WEIGHT WITH R.A.T.O.G.			232,180	164.43

SUMMARY OF DEVELOPMENT PROPOSALS.1.4.5. C.G. limits with larger stand-off missiles installed.

The weights of the aircraft are outlined in Tables 6 and 7 for the two alternative modifications required to install missiles of 46 ft. in length. Table 6 shows the aircraft with the vertically retracting nose-wheel and Table 7 the aircraft with an extended forward fuselage. In the former case it would still be desirable to extend the aft limit of the C.G. range, but in the case of the extended forward fuselage, the normal C.G. is forward of the present aft limit. Consequently, it would not then be necessary to move the main wheels aft if the forward fuselage were extended, as the extra four feet between the nosewheel and the C.G. only slightly reduces the percentage nosewheel load.

The above limits are associated with A.U.W.'s in excess of 230,000 lb. and this necessitates reduced normal acceleration factors. It would also be desirable to introduce the four tyre undercarriage originally proposed in Avro Brochure I.P.B. 65 at this stage to maintain the undercarriage strength factors and reduce the L.C.N. values.

TABLE 6

<u>ITEM</u>	Development Aircraft		Development Aircraft	
	No R.C.M. or Window		With R.C.M. & Window	
	Wt. (lb)	C.G. in.	Wt. (lb)	C.G. in.
<u>SUPER OVERLOAD CASE (LARGE STORE R.A.E. MISSILE TYPE C)</u> with vertical retracting nose undercarriage. Extra 250 gall. fuel tank under No. 1 tanks. Basic Operational Weight Store Window	93,161 25,000 -	142.73	95,145 25,000 1,267	151.23
Fuel	<u>Galls.</u>			
normal	9,290	"	71,533	71,533
integral tanks	1,250	"	9,625	9,625
canopy tanks	800	"	6,160	6,160
bomb-bay forward tank	1,700	"	13,090	13,090
centre tank	560	"	4,312	4,312
aft tank	1,040	"	8,008	8,008
Fuel under No. 1 tank	250	"	1,925	1,925
TOTAL FUEL	<u>14,890</u>	"		
TAKE-OFF WEIGHT			232,814	154.23
TAKE-OFF WEIGHT WITH R.A.T.O.G.			240,174	157.43

TABLE 7

<u>ITEM</u>	Development Aircraft		Development Aircraft	
	No R.C.M. or Window		With R.C.M. & Window	
	Wt. (lb)	C.G. in.	Wt. (lb)	C.G. in.
<u>SUPER OVERLOAD CASE (LARGE STORE R.A.E. MISSILE TYPE C)</u> with 4' extension in forward fuselage, and extended No. 1 tanks.				
Basic Operational Weight	93,245	135.59	95,229	144.25
Store	25,000		25,000	
Window	-		1,267	
Fuel				
normal	9,290	"	71,533	71,533
integral tanks	1,250	"	9,625	9,625
canopy tanks	800	"	6,160	6,160
bomb-bay forward tank	1,700	"	13,090	13,090
bomb-bay centre tank	560	"	4,312	4,312
aft tank	1,040	"	8,008	8,008
Ext'd No. 1 tank	500	"	3,850	3,850
	<u>15,140</u>	"		
TOTAL FUEL	15,140	"		
TAKE-OFF WEIGHT	234,824	147.33	238,075	151.37
TAKE-OFF WEIGHT WITH R.A.T.O.G.	242,184	150.71	245,435	154.59

SUMMARY OF DEVELOPMENT PROPOSALSSECTION 2. PERFORMANCE2.1. Introduction

The previous section of this brochure details various lines along which the development of the Vulcan Mk. 2 can proceed. The effect of these proposals on the performance of the aircraft is discussed in the following paragraphs, the range-altitude characteristics of the standard Mk. 2 aircraft carrying Blue Steel being quoted as a datum for comparison.

2.2. Engine data

The Vulcan Mk. 2 production aircraft will be equipped with Bristol Olympus Mk. 200 engines, each giving 17,250 lb. thrust under sea-level static conditions in an I.S.A. atmosphere. (This rating is now referred to as the B.01. 7). The effect of engine development is not discussed here since it has been covered in previous brochures and the incremental changes will be similar in all cases.

2.3. Performance of standard Vulcan Mk. 2

The range/altitude performance quoted in this brochure is based on the following assumptions:-

1. Blue Steel carried all the way.
2. No R.C.M. or window carried, with exception of fixed provision.
3. Engines fitted with con-di nozzles but no infra-red suppression.
4. Take-off with full tanks and climb to cruise climb altitude.
5. Cruise 50% of outward journey at economic cruise conditions at T.M.N. = 0.873.

SUMMARY OF DEVELOPMENT PROPOSALS

6. Open up to maximum continuous rating and cruise-climb at T.M.N. = 0.873 for remaining 50% of outward journey and first 50% of return journey.
7. Throttle back to economic conditions at T.M.N. = 0.873 and cruise-climb for remainder of flight.

NOTE: This flight plan assumes arriving over base with empty tanks, i.e. with no fuel reserves, but no allowance has been made for the distance travelled on the descent.

The normal internal fuel capacity of the Mk. 2 aircraft is 9,290 galls., and a further 3,300 galls. is available in bomb-bay tanks. The take-off weight under these conditions is 204,997 lb. and the still-air range is 4,700 nautical miles with a half range height of 51,250 ft.

2.4. Performance with increased tankage (See Fig. 11)

The Air Staff requirement for a still-air range of 5,000 nautical miles (no allowances) can be met under the assumptions of paragraph 2.3. by an additional 1,170 gallons to the normal and bomb-bay fuel, providing all tankage is internal and causes no increase in drag.

Section 1.1. discusses the various ways which fuel can be located without causing the C.G. to move outside the normal limits; the most convenient arrangement is 2,630 gallons in the bomb-bay (forward tank full), 800 gallons in the extended canopy and dorsal and 1,250 gallons in the outer

SUMMARY OF DEVELOPMENT PROPOSALS

wing integral tanks. This gives a capacity of 13,970 gallons which is 1,380 gallons in excess of normal plus maximum bomb-bay fuel and gives a range of 5,000 n.m. The extra 210 gallons above the figure quoted earlier is due to the increased drag of the extended canopy and dorsal fin. The take-off weight is 216,410 lb. and the half-range height 50,400 ft.

When the tanks are filled completely the range of the aircraft can be further increased beyond 5,000 n.m. In this condition, however, the centre of gravity at take-off is behind the aft limit, (see para. 1.4.2.) but if the full tankage of the aircraft can be utilised, then the range is 5,150 n.m. and the half-range height is 50,200 ft.

Flight plans showing the performance of the Vulcan Mk. 2 with the above increased fuel tankage are shown in Fig. 11 compared to the basic aircraft with normal tankage plus bomb-bay fuel. The results are further summarised in Table 8.

2.5. Carriage of the R.A.E. type 'C' Missile
(see Fig. 12)

The effect of carrying the larger R.A.E. type 'C' missile as an alternative to Blue Steel has been considered. Carriage of the missile in a semi-external position causes an increase in drag from two sources, the basic drag of the missile itself and the unfavourable interference drag of the combination.

Although the profile drag of the missile can be calculated without much difficulty, the interference drag, and hence the total installed drag,

SUMMARY OF DEVELOPMENT PROPOSALS

of the missile is not amenable to calculation.

At the present time no wind tunnel tests are available from which to obtain measurements of the interference drag of the combination; consequently an attempt has been made to establish the drag of the missile installation by using the same interference factors as determined from high speed wind tunnel tests on the Vulcan fitted with the Blue Steel missile.

The still air range of the aircraft when carrying the R.A.E. type 'C' missile is 4,700 n.m. with a corresponding half-range height of 47,900 ft. This performance is achieved with all tanks completely full and the take-off weight is 232,814 lb.

2.6. Integrated missile installation

The combination of missiles such as Blue Steel or R.A.E. type 'C' and the Vulcan Mk. 2 gives rise to large drag increments due to missile/aircraft interference. Consideration of the possible design of new and advanced missiles indicates that their general shape may be very amenable to integration with the Vulcan. For instance, one possible configuration is the narrow delta planform with a flat upper wing surface and, as discussed in para. 1.3, a modification to the lower surface of the Vulcan would enable this type of missile to be attached with no appreciable gaps or other sources of large interference effects.

Such an integrated design would show a considerable reduction in drag when compared to the present Blue Steel installation. No quantitative data on

SUMMARY OF DEVELOPMENT PROPOSALS

the drag of such an installation is yet available but it is intended to initiate a programme in the Avro wind tunnels to investigate the aerodynamic characteristics of the Vulcan modified in this way and equipped with a range of typical missiles.

A provisional assessment of the performance of the Vulcan when fitted with the hypothetical missile shown in Figs. 9 and 10 has been made, assuming that the weight and the profile drag of the missile alone are identical to those of the R.A.E. type 'C' missile. The flight plans for these two cases are shown in Fig. 12, and it is seen that the elimination of interference drag is worth some 300 n.m. range and 1,000 ft. in half range height.

2.7. Summary of performance

The range and altitude performance discussed in the preceding paragraphs is summarised in Table 8 overleaf.

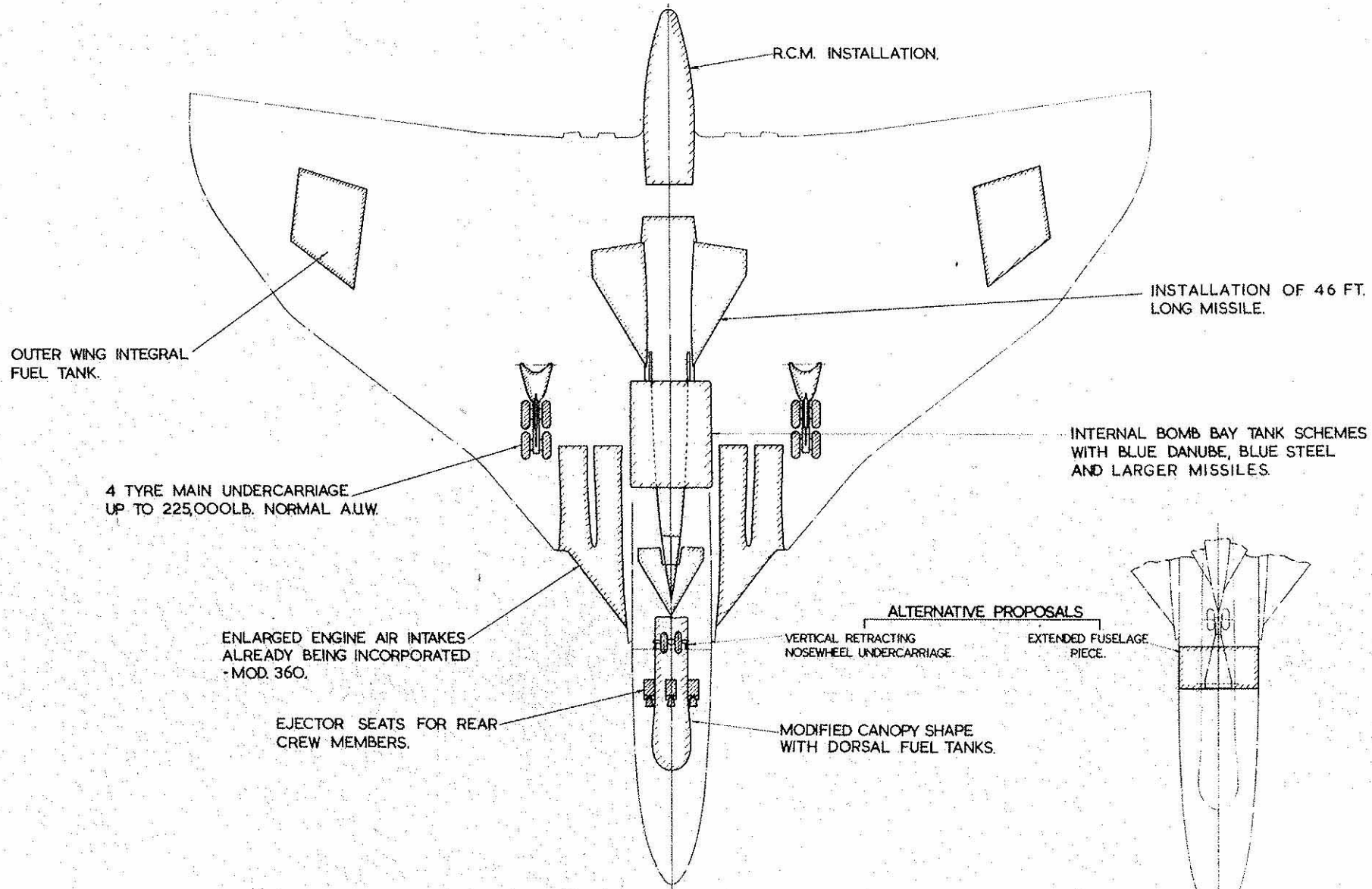
Summary of Performance - 4 Olympus Mk. 200 (B.Ol. 6) engines (17,250 lb. S.L.S.T.).

AVRO VULCAN B. MK. 2

SUMMARY OF DEVELOPMENT PROPOSALS

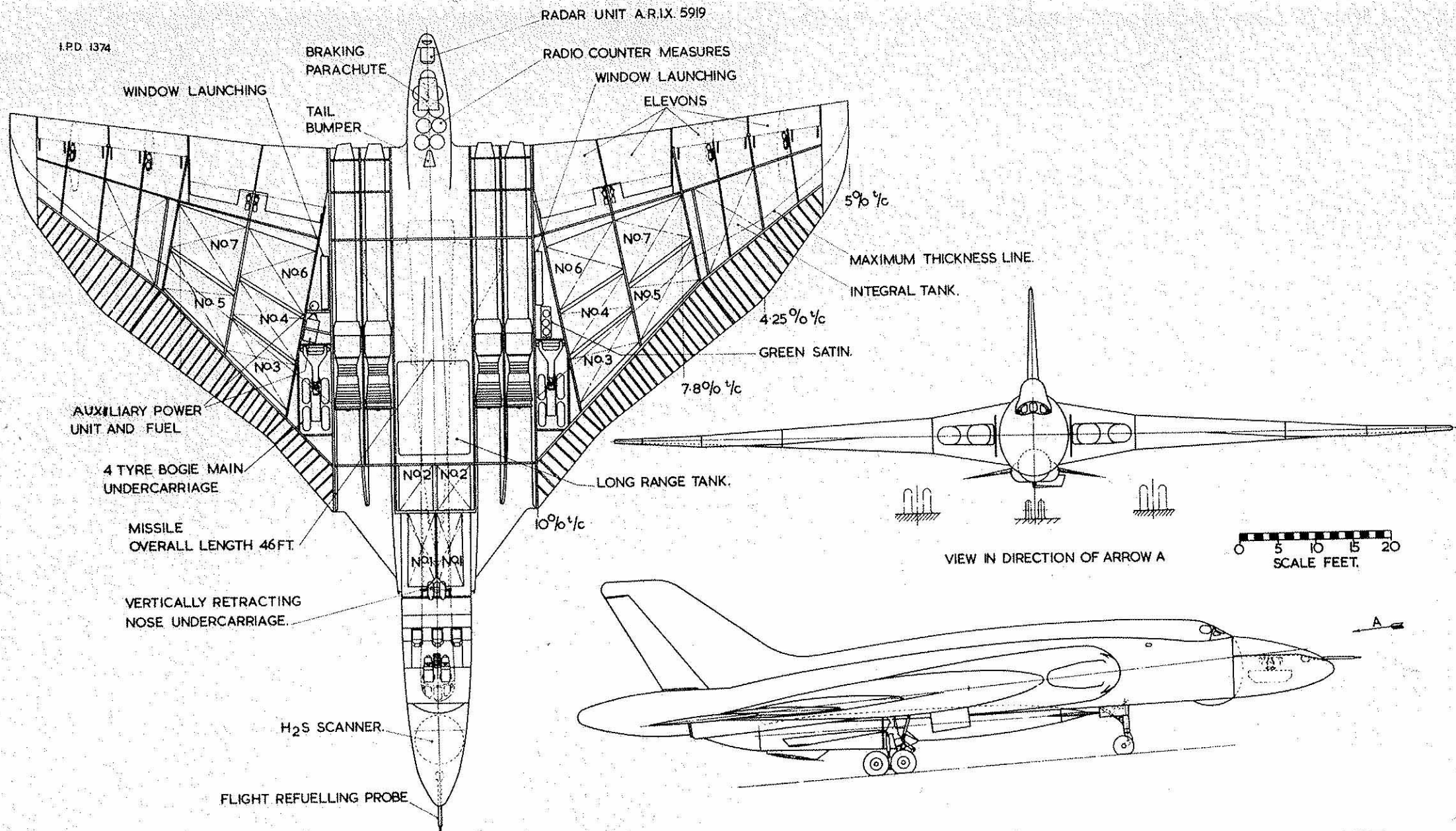
TABLE 8

Configuration		Production Mk. 2	With dorsal tank and		With dorsal tank, wing	
		(11th & subsequent air- craft)	wing integral tanks		integral tanks and for- ward fuselage tank.	
Fuel Capacity Galls.	{ Basic	9,290	9,290	9,290	9,290	9,290
	{ Bomb-bay	3,300	2,630	3,300	3,300	3,300
	{ Dorsal	-	800	800	800	800
	{ Wing integral { Forward fuselage)	-	1,250	1,250	1,250	1,250
					250	250
Fuel weight	-lb.	96,943	107,569	112,728	114,653	114,653
Weight less fuel & store	-lb.	92,054	92,841	92,841	93,161	93,161
Store		Blue Steel	Blue Steel	Blue Steel	R. A. E. 'C' missile	Integrated missile
Store weight	-lb.	16,000	16,000	16,000	25,000	25,000
Hangar weight	-lb.	204,997	216,410	221,569	232,814	232,814
Still air range	-n.m.	4,700	5,000	5,150	4,700	5,000
$\frac{1}{2}$ range height	ft.	51,250	50,400	50,200	47,900	48,800
Remarks		Full tanks and present aft C.G.	Fuel for 5,000 n.m. still-air range, present aft C.G.	Full tanks and extended aft C.G.		



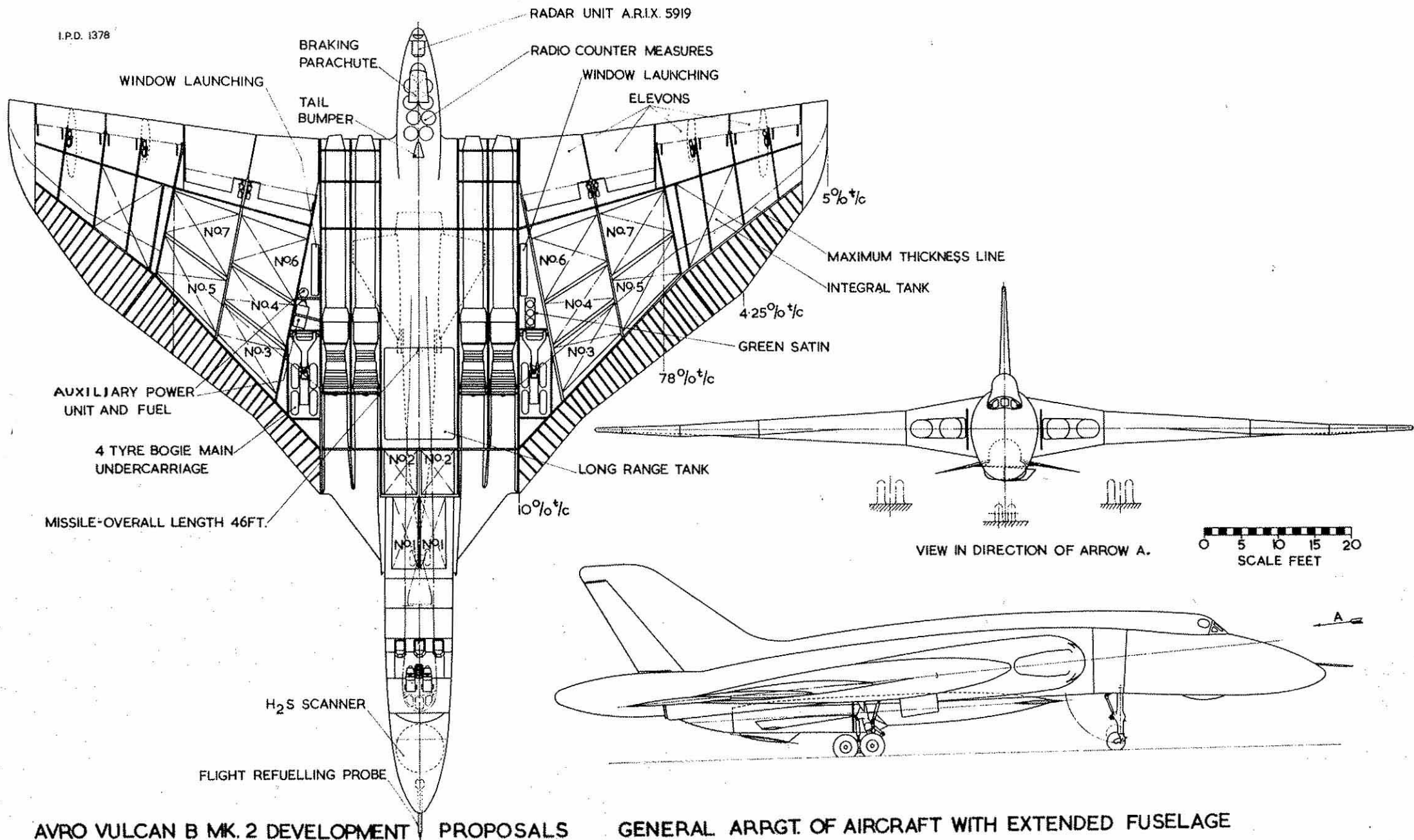
AVRO VULCAN B. MK. 2 DEVELOPMENT PROPOSALS.

KEY DIAGRAM.



AVRO VULCAN B. MK. 2 DEVELOPMENT PROPOSALS

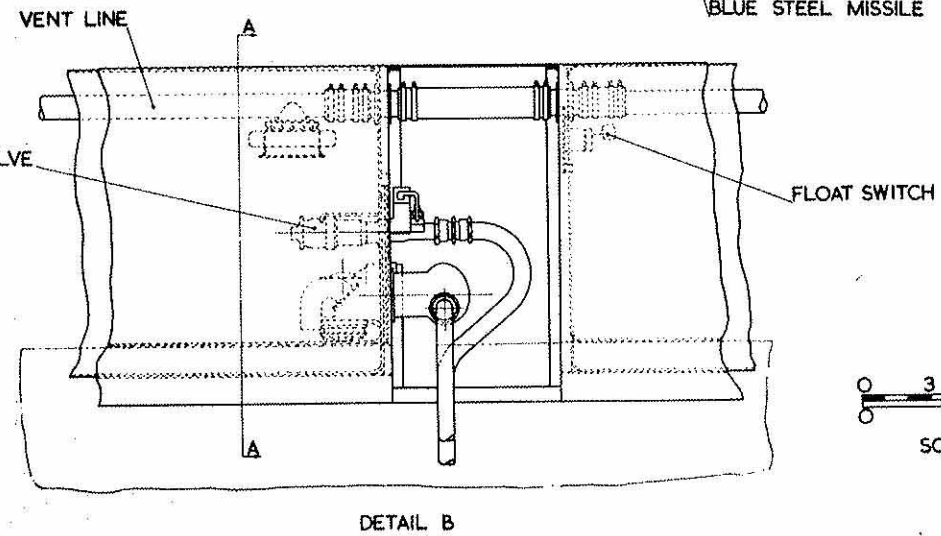
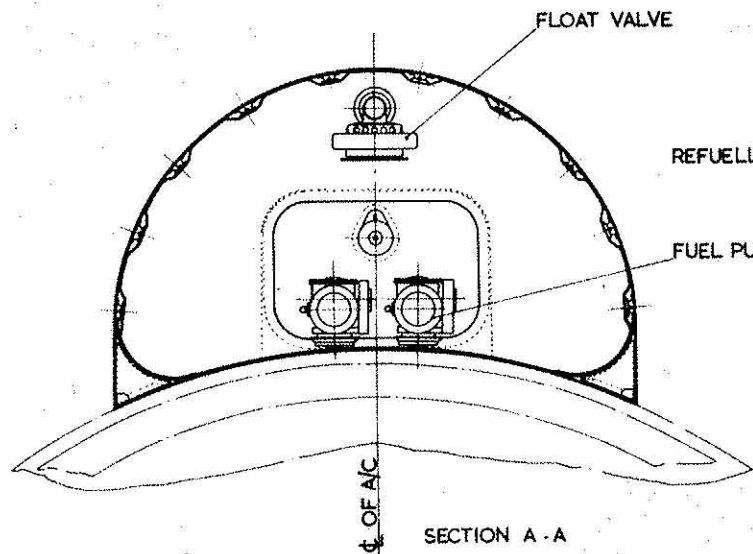
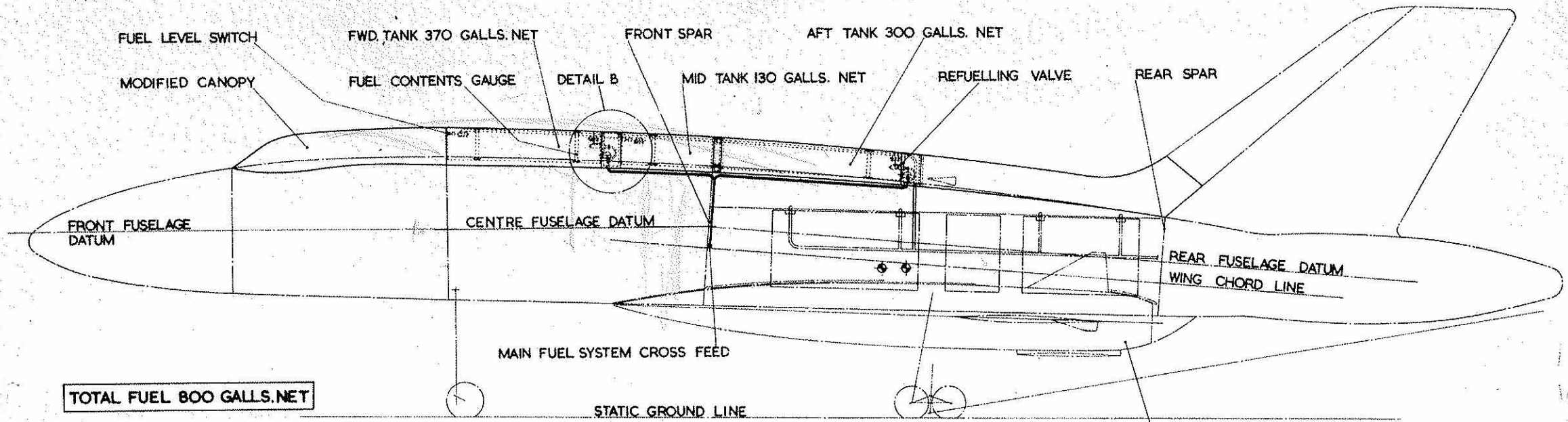
GENERAL ARRGT OF AIRCRAFT WITH VERTICAL RETRACTING NOSEWHEEL.



AVRO VULCAN B MK. 2 DEVELOPMENT PROPOSALS

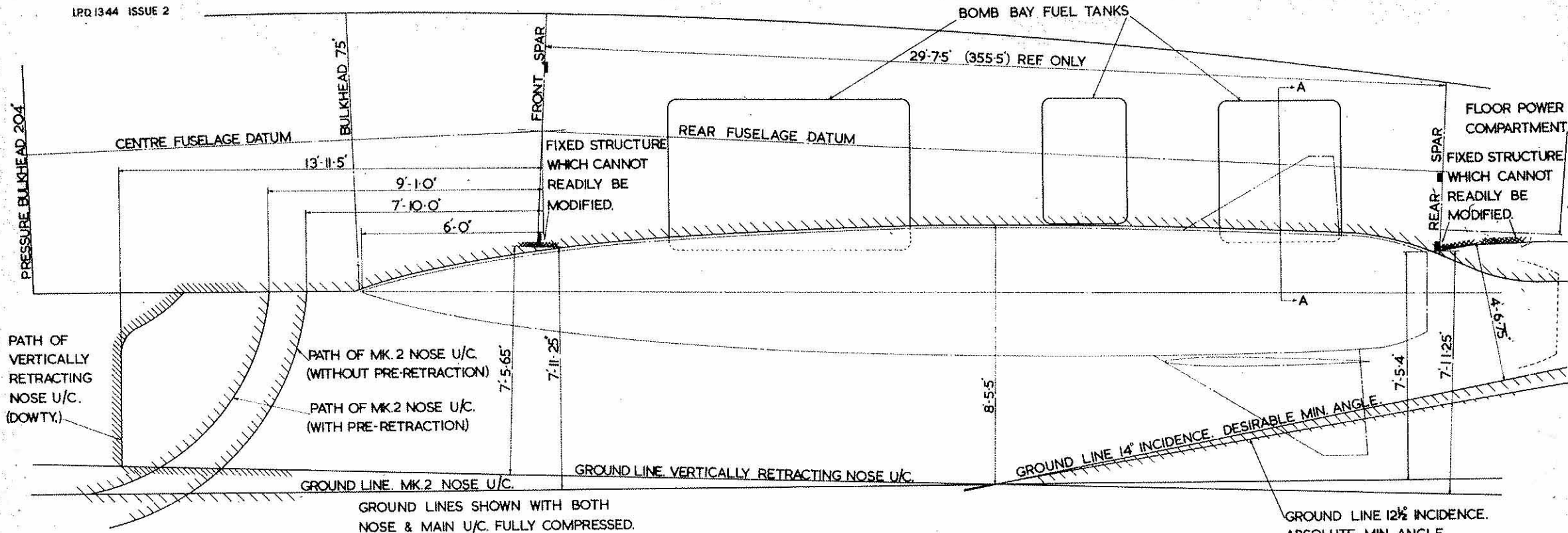
GENERAL ARRGT. OF AIRCRAFT WITH EXTENDED FUSELAGE

I.P.D.1406



AVRO VUCAN B MK.2 DEVELOPMENT PROPOSALS

ARRANGEMENT OF DORSAL FIN FUEL TANKS



PATH OF VERTICALLY RETRACTING NOSE U/C. (DOWTY.)

PATH OF MK.2 NOSE U/C. (WITHOUT PRE-RETRACTION)

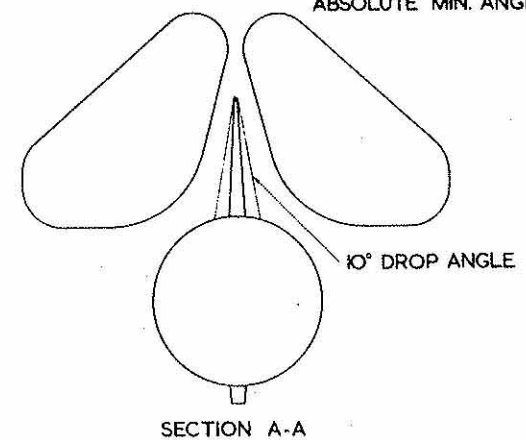
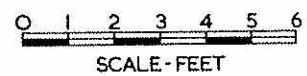
PATH OF MK.2 NOSE U/C. (WITH PRE-RETRACTION)

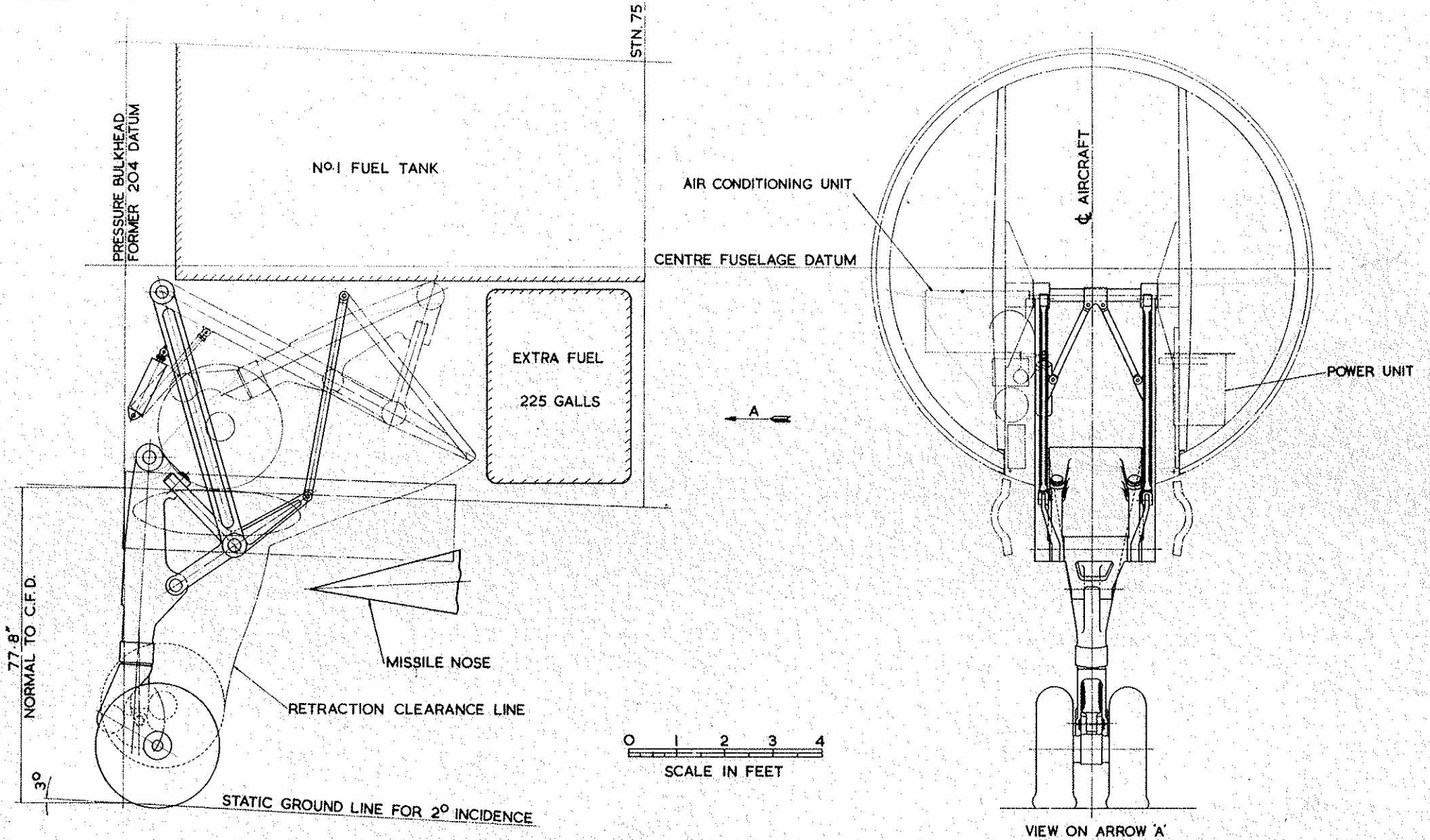
GROUND LINES SHOWN WITH BOTH NOSE & MAIN U/C. FULLY COMPRESSED.

- BASIC BLUE STEEL 7.35' LONG.
 LENGTH CAN BE INCREASED BY:-
1. AIRCRAFT WITH EXISTING MK.1 NOSE U/C.
 2. AIRCRAFT WITH MK.2 NOSE U/C. WITHOUT PRE-RETRACTION
 3. AIRCRAFT WITH MK.2 NOSE U/C. WITH PRE-RETRACTION
 4. AIRCRAFT WITH VERTICALLY RETRACTING NOSE U/C. OR EXTENDED FUSELAGE.

*ENTAILS LOWERING MISSILE BELOW BOTTOM BOOM OF REAR SPAR, DEPENDANT ON MISSILE TAIL DIA. AND REQUIRED GROUND ANGLE.

FWD.	REAR.
BY 6.5' TO 35.6.5"	BY 4.3.0' TO 39.8.5"*
BY 1.2' TO 40.10.5"	
BY 1.3' TO 42.1.5"	
BY 4.6' TO 46.7.5"	





AVRO VULCAN

ARRANGEMENT OF VERTICALLY RETRACTING NOSE UNDERCARRIAGE

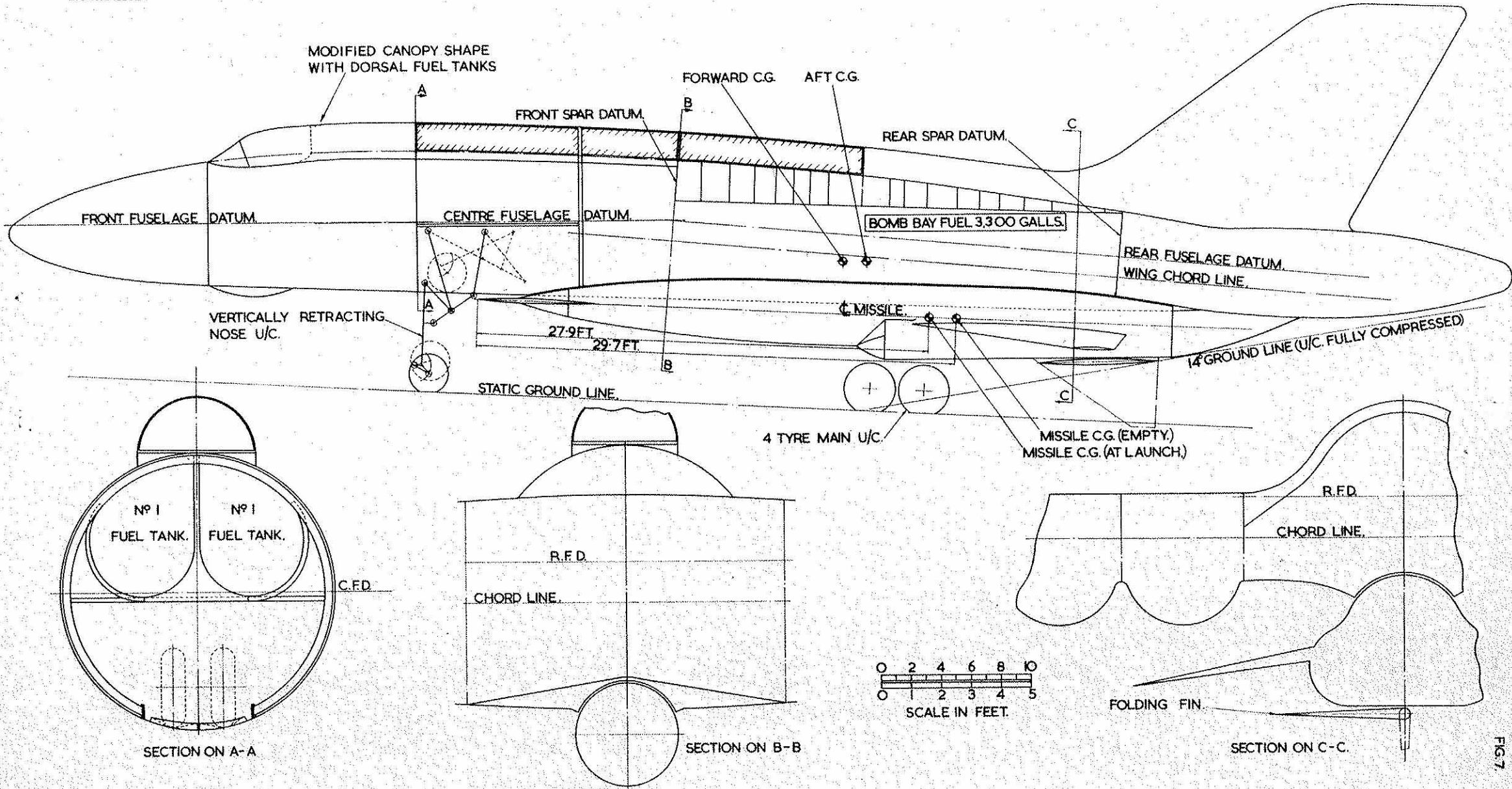


FIG 7

AVRO VULCAN B. MK.2 DEVELOPMENT PROPOSALS

INSTALLATION OF 46FT LONG MISSILE (VERTICALLY RETRACTING NOSE U/C)

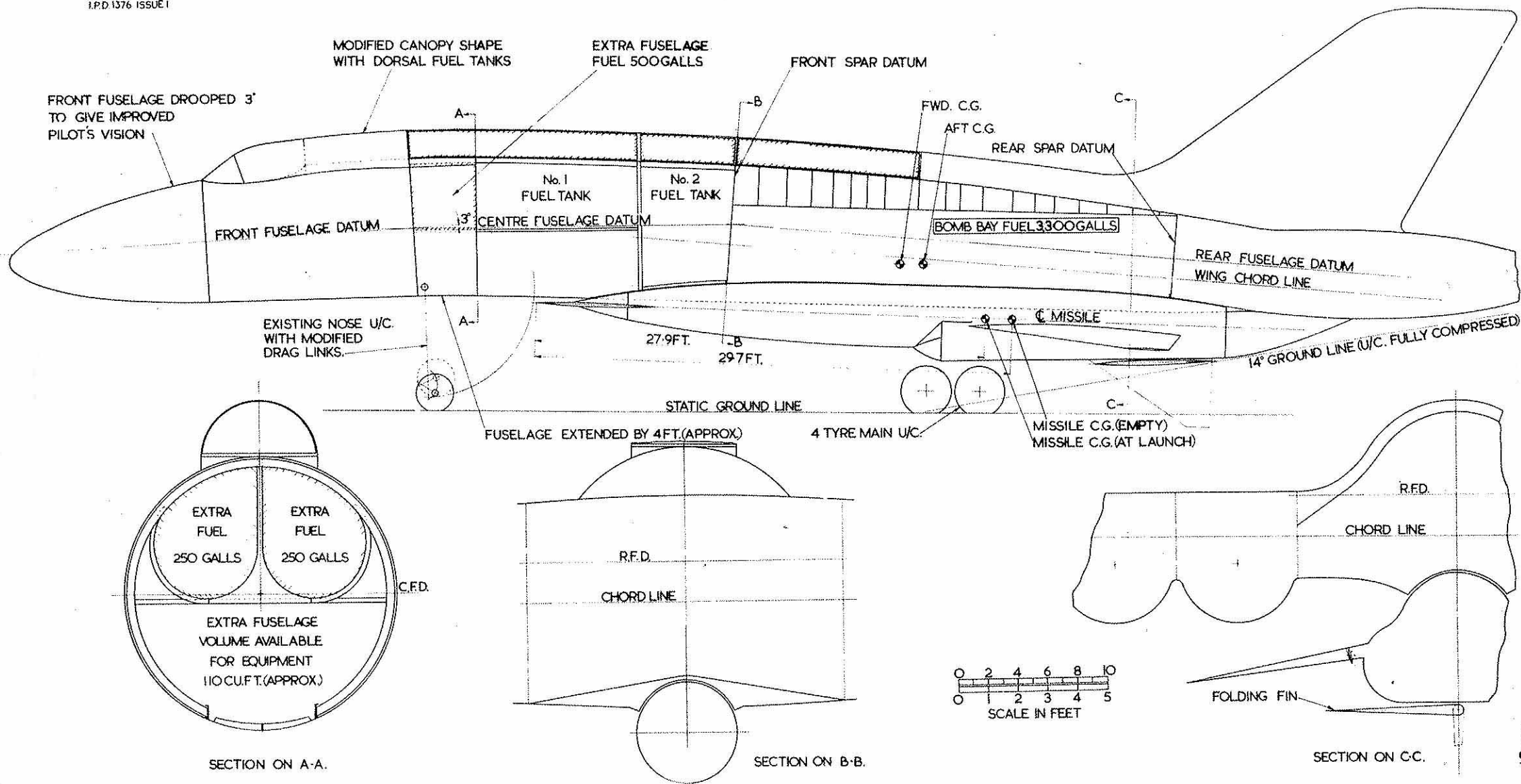
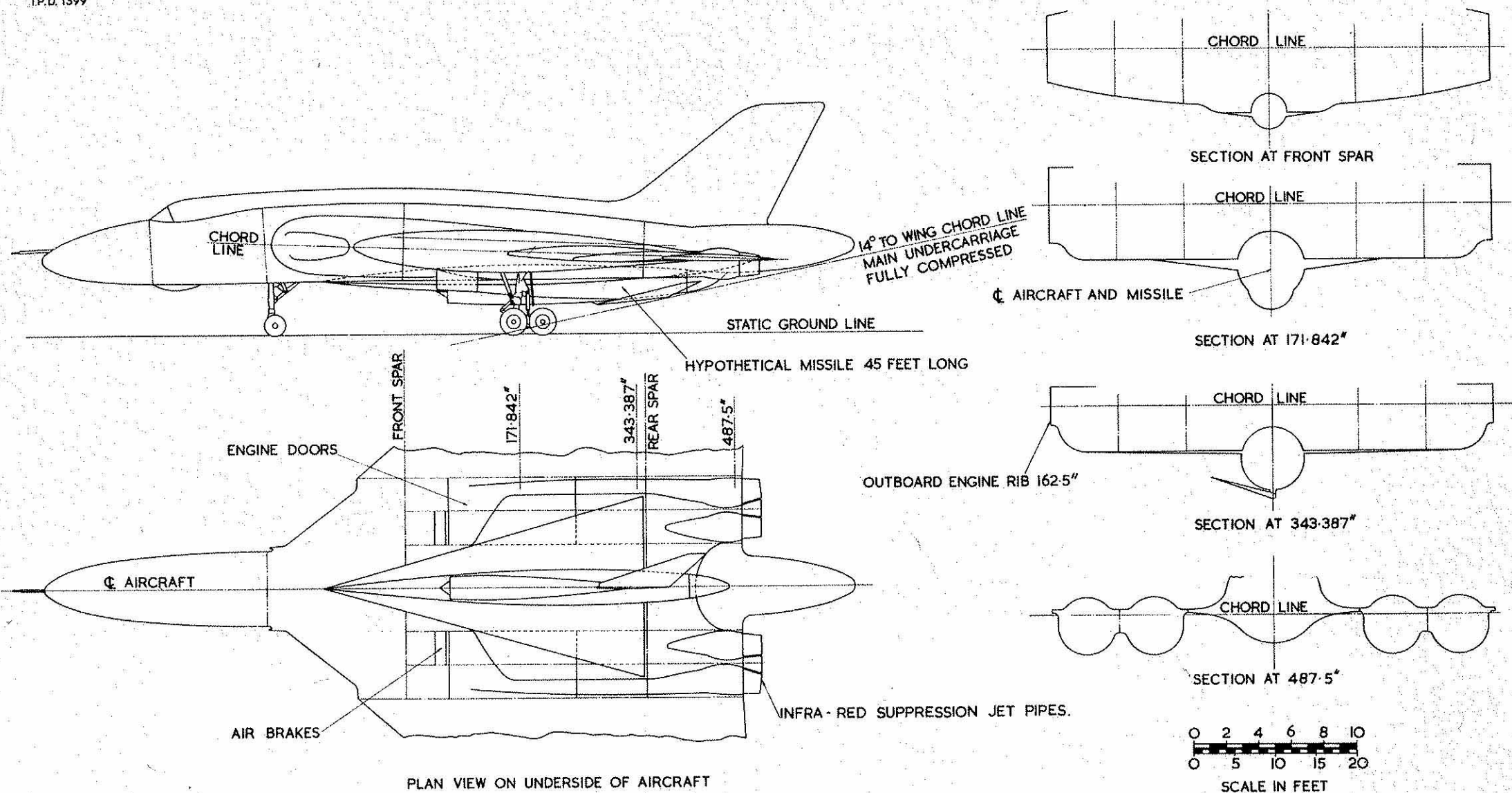
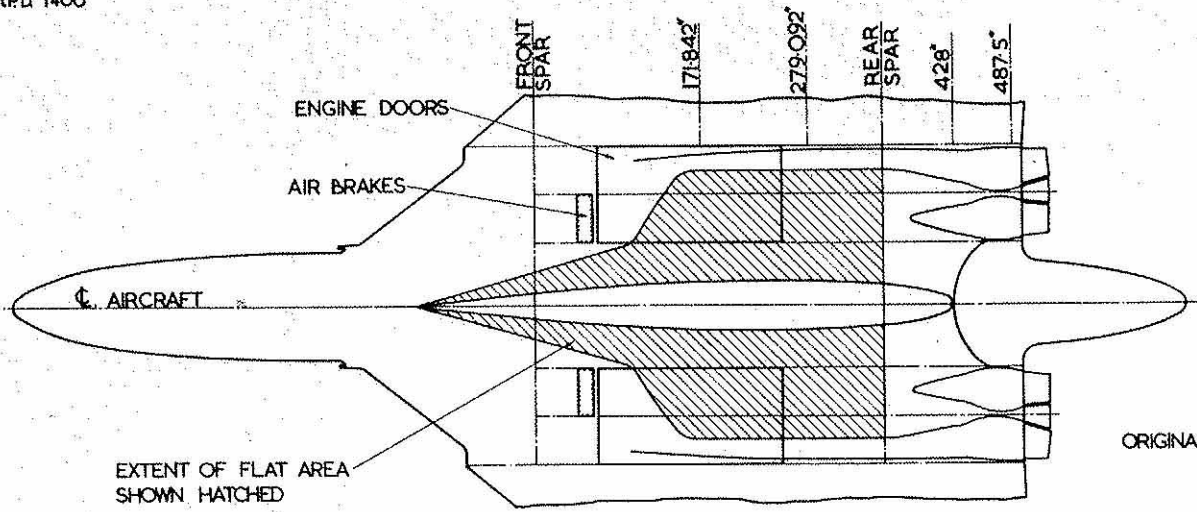
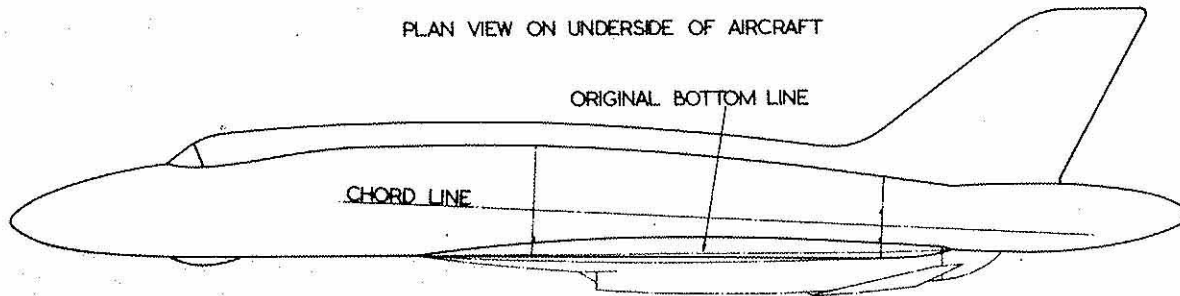


FIG. 8.

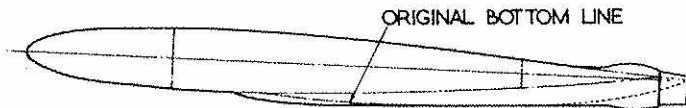




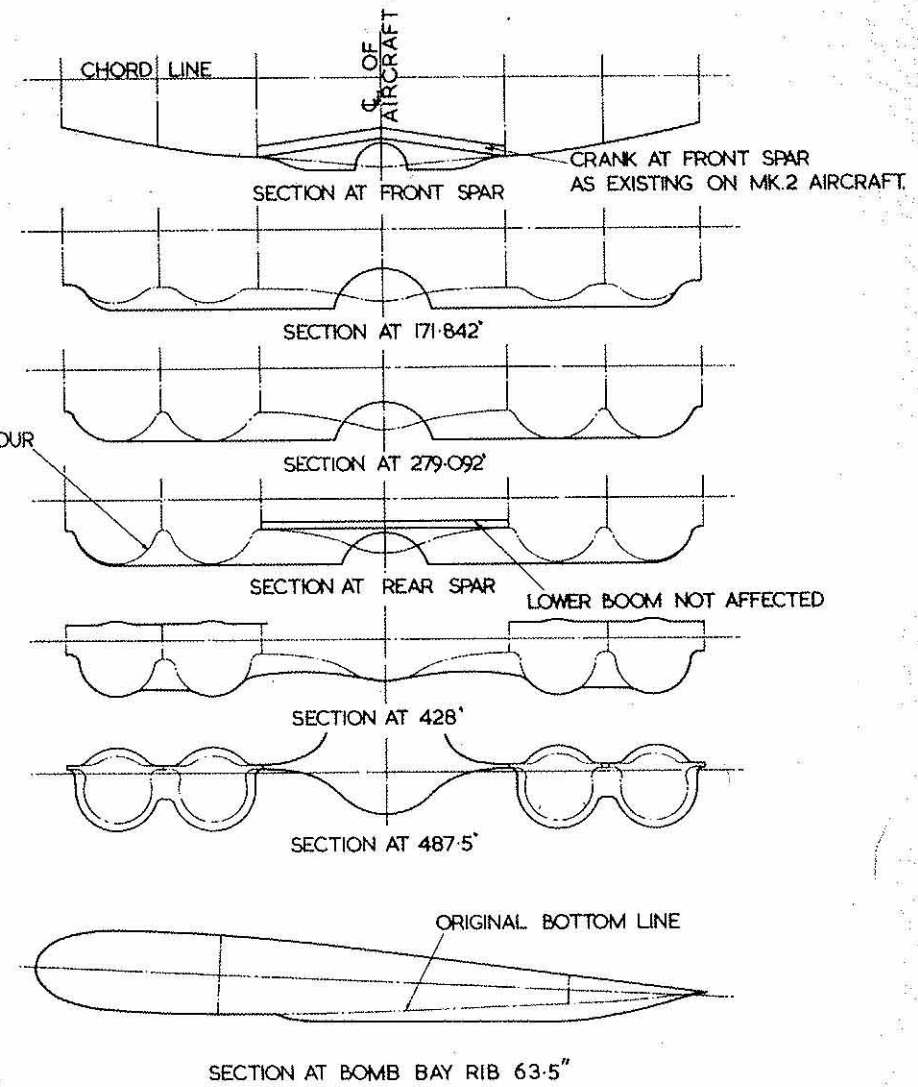
PLAN VIEW ON UNDERSIDE OF AIRCRAFT



SECTION AT CL AIRCRAFT



SECTION AT CL OUTBOARD ENGINE 136.5"

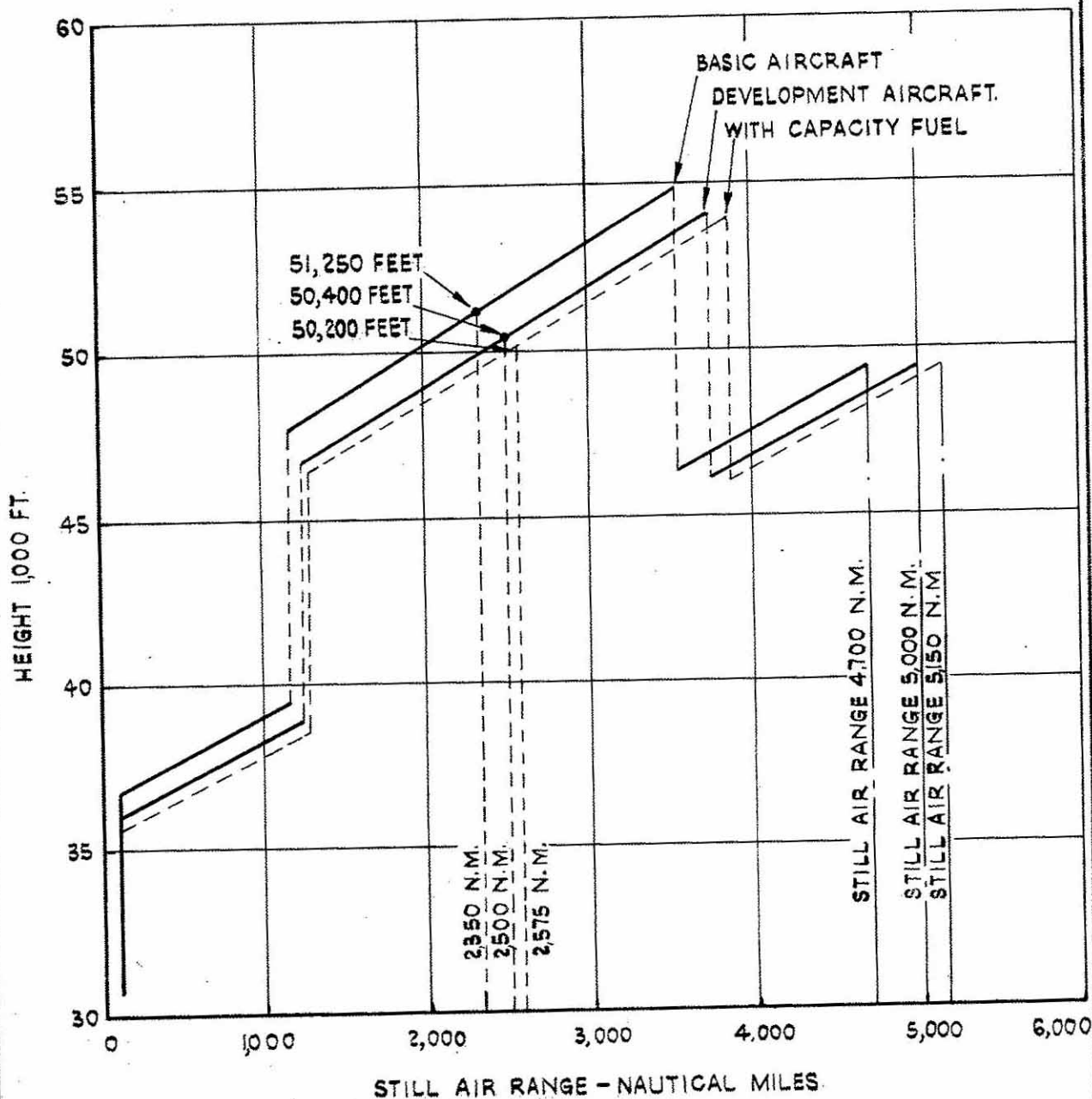


SCALE IN FEET

SUMMARY OF DEVELOPMENT PROPOSALS.

RANGE & ALTITUDE PERFORMANCE WITH BLUE STEEL
 INTERNATIONAL STANDARD ATMOSPHERE
 EFFECT OF INCREASED FUEL CAPACITY
 50% RANGE AT MAXIMUM CONTINUOUS POWER
 50% RANGE AT MAXIMUM ECONOMICAL POWER
 CRUISE AT $M = 0.873$
 NO R.C.M., 'WINDOW' OR I.R. SUPPRESSION EQUIPMENT CARRIED

	BASIC AIRCRAFT	DEVELOPMENT AIRCRAFT.	
		5,000 N.M. RANGE	CAPACITY FUEL.
WEIGHT LESS FUEL & STORE - LB.	92,054	92,841	92,841
WEIGHT OF STORE - LB.	16,000	16,000	16,000
FUEL CAPACITY - GALLONS.	12,590	13,970	14,640
FUEL WEIGHT - LB.	96,943	107,569	112,728
HANGAR WEIGHT - LB.	204,997	216,410	221,569



SUMMARY OF DEVELOPMENT PROPOSALS.

RANGE & ALTITUDE PERFORMANCE.
INTERNATIONAL STANDARD ATMOSPHERE.

EFFECTS OF VARIOUS MISSILE CONFIGURATIONS.

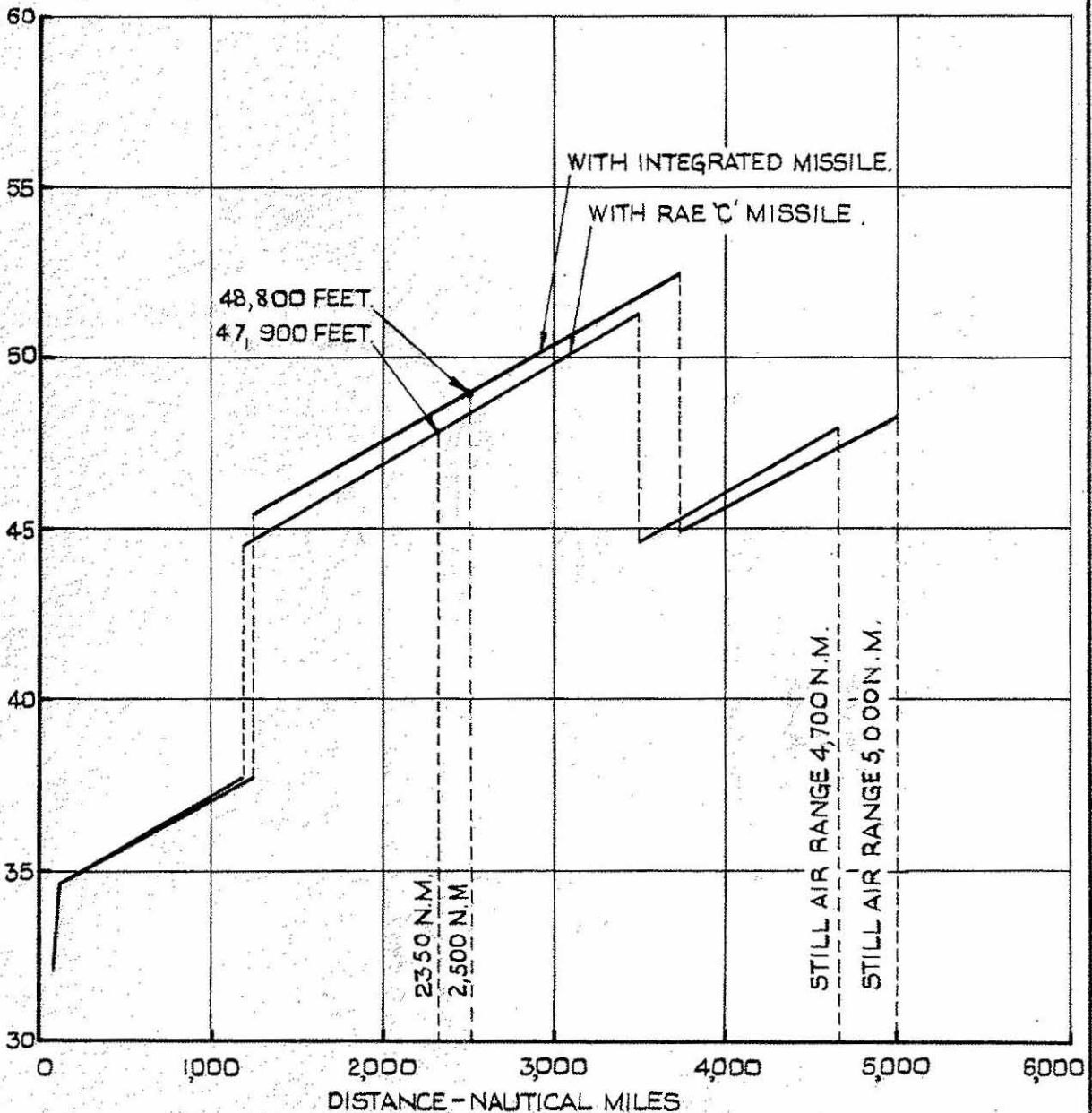
50% RANGE AT MAXIMUM CONTINUOUS POWER.

50% RANGE AT MAXIMUM ECONOMICAL POWER.

CRUISE AT $M = 0.873$.

NO R.C.M, "WINDOW" OR I.R. SUPPRESSION EQUIPMENT CARRIED.

WEIGHT LESS FUEL & STORE	- LB.	93,161
WEIGHT OF STORE	- LB.	25,000
FUEL CAPACITY	- GALLONS	14,890
FUEL WEIGHT	- LB.	114,653
HANGAR WEIGHT	- LB.	232,814





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