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AUGUST 1958

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R.C.A.F. DESIGN STUDY REQUEST

INTRODUCTION OF PRATT AND WHITNEY J.75-P6 ENGINES IN ARROW 2 AIRCRAFT

BROCHURE - SS120

AVRO AIRCRAFT

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AVRO AIRCRAFT LIMITED

MALTON ONTARIO

CONTENTS

1. INTRODUCTION

This study of the ARROW 2 Aircraft with alternative engines has been performed at the request of the RCAF and DDP, ref. letter S 36-38-105-19 (APO) dated June 25, 1958.

It is the result of a preliminary investigation only and contains performance, weights, and changes to the basic airframe, with a statement of work, exclusions, and schedule.

2. SUMMARY

The installation of two Pratt and Whitney J75-P6, JT4B-23 engines into an ARROW 2 airframe involves an estimated weight penalty of approximately 2,600 lbs. to the aircraft basic weight. The comparison with the Iroquois Series 2 powered ARROW 2 from a performance viewpoint shows both versions to be comparable when operating subsonically with afterburners unlit, but at supersonic speeds with afterburner lit it is evident that the JT4B-23 engine has a much greater fuel consumption than the Iroquois.

The JT4B-23 engine installation would require modifications to the air intakes, the inner wing, duct bay, engine bay, rear fuselage, tailcones and stinger structures together with the closely associated engine systems. A number of these modifications could be implemented by using ARROW 1 components, however, a complete reversion to the ARROW 1 configuration is not possible due to the J75-P6 engine requiring increased intake capacity and having a larger afterburner than the J75-P5 currently installed in the ARROW 1. The engine power outputs also require matching with the ARROW 2 systems and installations.

3. PERFORMANCE

This section compares the ARROW 2 performance when fitted with the Pratt and Whitney J75P6 - JT4B-23 engines with the present performance of the Orenda Iroquois powered version.

The time available limited to the accuracy of this comparison in that the JT4B-23 installed performance had to be ratioed from available J75 - JT4A-25 data, i.e.

$$\text{JT4B-23 performance}_{\text{(installed)}} = \text{JT4A-25}_{\text{(installed)}} \times \frac{\text{JT4B-23 Brochure}}{\text{JT4A-25 Brochure}}$$

Thus although the performance of the JT4B-23 version is of the right order, the accuracy of the small differences between it and the Iroquois version cannot be guaranteed.

Both versions of the ARROW are at compatible weights, with suitable allowances being made for the weight changes due to the installation of the JT4B-23 engines. The Iroquois version and the JT4B-23 version are based on the weight breakdowns given in paragraph 4.

3.1 Loading and Performance Under ICAO Standard Atmospheric Conditions

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

Weight		J 75 (P6)	Iroquois
Operational weight empty	lb.	49,239	46,650
Maximum useable internal fuel	lb.	19,443	19,443
Gross Take-off weight (max. internal fuel)	lb.	68,682	66,093
Combat weight (1/2 max. internal fuel wt.)	lb.	58,961	56,372
Maximum external fuel and tank (500 gall. at 7.8 lb/gall. and drop tank)	lb.	4,242	4,242
Maximum gross take-off weight	lb.	72,924	70,335

Weight		J 75(P6)	Iroquois
Normal design landing gross	lb.	52,372	49,783
Maximum landing gross weight	lb.	68,682	66,093
Wing loading at gross take-off weight	lb/sq.ft.	56.1	54.0
Power loading at gross take-off weight	lb/lb thrust	1.62	1.52
Speed			
True airspeed in level flight at combat weight			
Sea Level (i) Maximum thrust, A/B Lit	kts.	700*	700*
(ii) Maximum thrust, A/B Unlit	kts.	648	670
50,000 ft. (i) Maximum thrust, A/B Lit	kts.	1,098	1,147*
* Placard Speed			
Ceiling			
Ceiling at combat weight, rate of climb 500 ft/min. with maximum thrust at optimum Mach number A/B Lit	ft.	55,500 (1.50M)	59,500 (1.80M)
Rate of Climb			
Steady state rate of climb at combat weight			
Sea Level (i) Maximum thrust, A/B Lit, at 0.92M	ft/min.	42,700	42.500
(ii) Maximum thrust, A/B Unlit at 527 kts. TAS	ft/min.	15,700	19,400
50,000 ft. (i) Max Thrust, A/B Lit at 1.80 M	ft/min.	4,260	9,740
Time to Height			
Time to reach 50,000 ft. and 1.5M from engine start at gross take-off weight, maximum thrust A/B lit	min.	5.2	5.3
Manoeuvrability			
Load factor at combat weight			
(1) Maximum thrust A/B lit 1.5M at 50,000 ft.		1.40	1.50
(2) Maximum thrust A/B lit 1.8M at 50,000 ft.		1.19	1.58

		J 75 (P6)	Iroquois
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.	4,120	3,850
(2) Maximum thrust A/B unlit, standard day	ft.	6,350	4,750
(3) Maximum thrust A/B lit, hot day	ft.	5,040	4,640
Landing Distance			
Landing distance over 50 ft. obstacle at sea level at normal design landing gross weight	ft.	4,980	4,800
Stalling Speed			
True stalling speed in landing configuration at combat weight at sea level	kts.	119	117
Missions			
Combat radius of action on internal fuel, see mission profile for detail breakdown			
(1) Supersonic high altitude mission - supersonic combat	n.m.	169	238
(2) Subsonic high altitude mission - supersonic combat	n.m.	310	347
(3) MIL-C-5011A Area Mission - subsonic combat	n.m.	248	277
(a) Ferry Mission (armament carried throughout) - tank jettisoned when empty	Range n.m.	1,310	1,300

3.2 SUPERSONIC HIGH ALTITUDE MISSION - SUPERSONIC COMBAT

ARROW 2 with JT4B-23 Engines.

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	68682
Engine Start	-	.50	100	68582
Take-off to Unstick at S.L. Max Thrust A/B Unlit	-	.38	192	68390
Acc. to M = .92 at S.L. Max Thrust A/B Unlit	7.2	1.02	540	67850
Climb at M = .92 to 30,000' Max Thrust A/B Lit	9.3	1.12	1880	65970
Acc. to M = 1.5 at 30,000' Max Thrust A/B Lit	16.5	1.35	1880	64090
Climb at M = 1.5 to 50,000' Max Thrust A/B Lit	22.5	1.58	1650	62440
Cruise Out at M = 1.5 at 50,000' with Partial Afterburning	113.5	7.93	4550	57890
Combat at M = 1.5 at 50,000' Max Thrust A/B Lit	-	5.00	3800	52362 *
Descent to 34,000' at Idle Thrust	-	2.82	213	52149
Cruise Back at M = .90 at Optimum Cruise Altitude (34,000')	169.0	19.50	2034	50115
Loiter Over Base at 34,000' at Max Endurance Speed	-	15.00	1515	48600
Descent to S.L. at Idle Thrust	-	5.90	307	48293
Land with Fuel Reserves for 5 min Loiter at S.L. at max. Endurance	-	5.00	782	47511
TOTAL	338.0	67.10	19443	

ARROW 2 with Iroquois Engines

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	66093
Engine Start	-	.50	100	65993
Take-off to unstick at S.L. Max Thrust A/B Unlit	-	.30	185	65808
Acc. to M = .92 at S.L. Max Thrust A/B Unlit	7.0	1.10	810	64998
Climb at M = .92 to 30,000' Max Thrust A/B Lit	9.4	1.12	1560	63438
Acc. to M = 1.5 at 30,000' Max Thrust A/B Lit	17.8	1.48	1680	61758
Climb at M = 1.5 to 50,000' Max Thrust A/B Lit	21.5	1.53	1360	60398

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Cruise out at M = 1.5 at 50,000'	182.15	12.67	5068	55330
Combat at M = 1.5 at 50,000' Max Thrust A/B Lit	-	5.00	3042	50560 *
Descent to 36,000' at idle thrust		2.80	210	50350
Cruise back at M = .91 at optimum Alt.	237.85	27.20	2834	47516
Loiter over Base at 36,000' at Max Endurance Speed		15.00	1530	45986
Descent to S.L. at Idle Thrust		6.20	324	45662
Land with reserves for 5 min Loiter at Max Endurance Speed		5.00	740	44922
TOTAL	475.7	79.9	19443	

* 1728 lb. of Missiles fired during combat

Fuel Density 7.8 lb/gal.

3.3 SUBSONIC HIGH ALTITUDE MISSION - SUPERSONIC COMBAT

ARROW 2 with JT4B-23 Engines

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	68682
Engine Start	-	.50	100	68582
Take-off to Unstick at S.L. Max Thrust A/B Unlit	-	.38	192	68390
Acc. to 527 Kts at S.L. Max Thrust A/B Unlit	4.16	.70	351	68039
Climb at 527 Kts to 28,000' Max Thrust A/B Unlit	32.40	3.75	1360	66679
Cruise Out at M = .90 at Optimum Cruise Altitude (28,000')	238.34	26.70	3721	62958
Acc. to M = 1.5 at 28,000' Max Thrust A/B Lit	14.40	1.18	1774	61184
Climb at M = 1.5 to 50,000' Max Thrust A/B Lit	20.40	1.48	1540	59644
Combat at M = 1.5 at 50,000 Max Thrust A/B Lit	-	5.00	3800	54116 *
Descent to 34,000' at Idle Thrust	-	2.82	213	53903
Cruise Back at M = .90 at Optimum Cruise Altitude (34,000')	310.00	35.60	3788	50115
Loiter Over Base at 34,000' at Max Endurance Speed	-	15.00	1515	48600
Descent to S.L. at Idle Thrust	-	5.90	307	48293
Loiter at S.L. at Max Endurance Speed	-	5.00	782	47511
TOTAL	620.0	104.01	19443	

ARROW 2 with Iroquois engines

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	66093
Engine Start	-	.5	100	65993
Take-off to Unstick at S.L. Max Thrust A/B Unlit	-	.3	185	65808
Acc. to 527 kts at S.L. Max Thrust A/B Unlit	5.0	.88	634	65174
Climb at 527 kts to 34,000' Max Thrust A/B Unlit	35.5	4.1	1765	63409
Cruise Out at M = .91 at 34,000'	269.5	30.68	4055	59354
Acc. to M = 1.5 at 34,000' Max Thrust A/B Lit	19.0	1.65	1560	57794
Climb to 50,000' at M = 1.5 Max Thrust A/B Lit	18.0	1.25	1080	56714

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Combat at M = 1.5 at 50,000' Max Thrust A/B Lit	-	5.0	3042	51944 *
Descent to 36,000' at Idle Thrust	-	2.8	210	51734
Cruise Back at M = .91 at Optimum Alt.	347.0	39.62	4218	47516
Loiter Over Base at 36,000' at Max Endurance Speed	-	15.0	1530	45986
Descent to S. L. at Idle Thrust	-	6.2	324	45662
Land with Reserves for 5 min Loiter at S. L. at Max Endurance Speed	-	5.0	740	44922
TOTAL	694.0	112.98	19443	

Fuel Density 7.8 lb/gallon.

* 1728 lb. of missiles fired during combat.

3.4 MIL - C-5011A AREA MISSION - SUBSONIC COMBAT

ARROW 2 with JT4B-23 Engines

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	68682
Allowance for Engine Start, Take-off and Accelerate to 527 kts at S. L. (a) 2 min. with Normal Power (max Continuous) at S. L. Static plus (b) 1 min. Max Power (A/B Lit) at S. L. Static		3.0	2686	65996
Climb to Cruising ceiling (35,000 ft) at 527 kts Max Thrust A/B Unlit	60.0	7.0	2153	63843
Cruise at M = .915 at Cruise Ceiling	163.0	18.6	2820	61023
Climb to Combat Ceiling at M = .92 Max Thrust A/B Lit	25.4	2.92	1607	59416
Combat at M = .92 at 50,000' Max Thrust A/B Lit		5.0	2100	57316
Cruise Back at M = .90 at optimum altitude (32,000 ft.)	248.4	28.30	3782	53534
Land with 5% of Initial Fuel + 20 mins. Loiter at Max Endurance Speed at S. L.		20.0	4295	49239
TOTAL	496.8	84.82	19443	

ARROW 2 with Iroquois Engines

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	66093
Allowance for Engine Start, Take-off and Accelerate to 527 kts. at Sea Level (a) 2 min. with Normal Power (Max Continuous) at S. L. Static plus (b) 1 min. Max Power (A/B Lit) at S. L. Static	-	3.0	2790	63303
Climb to Cruising Ceiling (41,000 ft.) at 527 kts. Max Thrust A/B Unlit	67.5	7.27	2457	60846
Cruise at M = .93 at Cruise Ceiling	192.0	21.60	3190	57605
Climb to Combat Ceiling at M = .92 Max Thrust A/B Lit	17.0	1.82	903	56702
Combat at M = .92 at 50,000' Max Thrust A/B Lit	-	5.0	1922	53052
Cruise Back at M = .91 at Optimum Cruise Altitude (36,000 ft.)	276.5	31.7	4081	50750

CONDITION	DISTANCE N. M.	TIME MIN.	FUEL LB	A/C WT. LB
Land with 5% of Initial Fuel + 20 mins. Loiter at Max Endurance Speed at S. L.	-	20.0	4100	46650
TOTAL	553.0	90.39	19443	

1728 lb. missiles carried throughout flight

Fuel density 7.8 lb/gallon.

All fuel allowances increased by 5%

3.5 FERRY MISSION (ARMAMENT CARRIED THROUGHOUT)

EXTERNAL TANK JETTISONED WHEN EMPTY

ARROW 2 with JT4B-23 engines

CONDITION	DISTANCE N.M.	TIME MIN.	FUEL LB	A/C WT. LB
Start Weight	-	-	-	72924
Engine Start	-	.5	100	72824
Take-off to Unstick Max Thrust A/B Unlit	-	.44	193	72631
Acc. to 527 kts. at S.L. Max Thrust A/B Unlit	4.61	.76	383	72248
Climb to 27,500' Max Thrust A/B Unlit at 527 kts. T.A.S.	38.50	4.45	1610	70638
Cruise Climb to 34,500'at M = .90	1267.3	145.0	18347	51949
Loiter Over Base at 34,500'at Max Endurance Speed	-	15.0	1620	50329
Descent to S.L. at idle thrust	-	5.95	310	50019
Land with Reserves for 5 min. Loiter at S.L.	-	5.0	780	49239
TOTAL	1310.4	176.6	23343	
ARROW 2 with Iroquois engines				
Start Weight	-	-	-	70335
Engine Start	-	.50	100	70235
Take-off to Unstick Max Thrust A/B Unlit	-	.34	209	70026
Acc. to 527 kts. Max Thrust A/B Unlit	5.4	.94	677	69349
Climb to 30,000' Max Thrust A/B Unlit 527 kts. T.A.S.	30.1	3.48	1690	67659
Cruise Climb to 36,000' at M = .91	1265.	144.0	18098	49219
Loiter Over Base 15 mins. at 36,000'	-	15.0	1485	47734
Descent to S.L. at Idling Thrust	-	6.2	324	47410
Land with reserves for 5 min. Loiter at S.L. at Max Endurance Speed	-	5.0	760	46650
TOTAL	1300.5	175.46	23343	

Missiles carried throughout mission.

Fuel density 7.8 lb/gallon.

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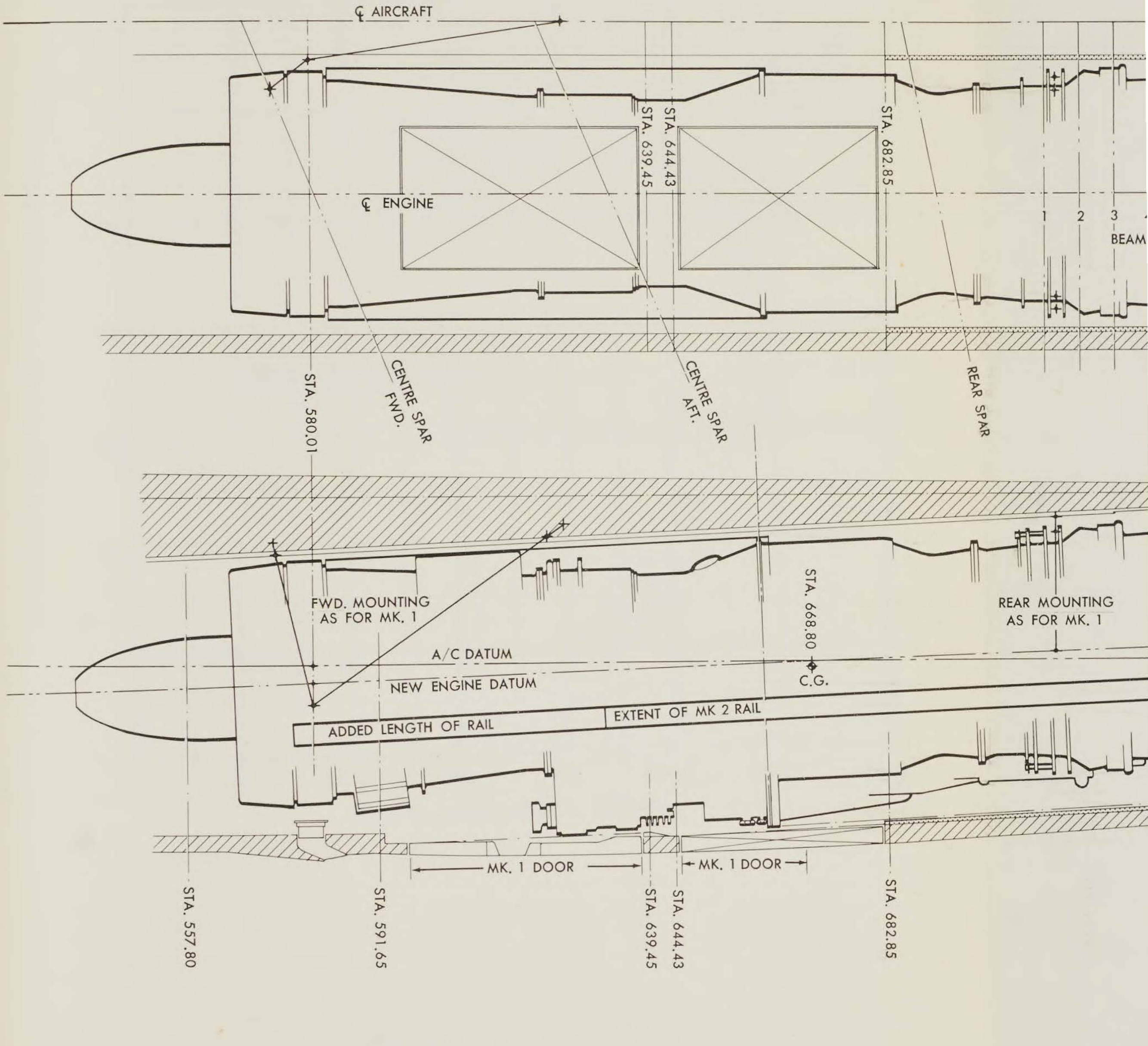
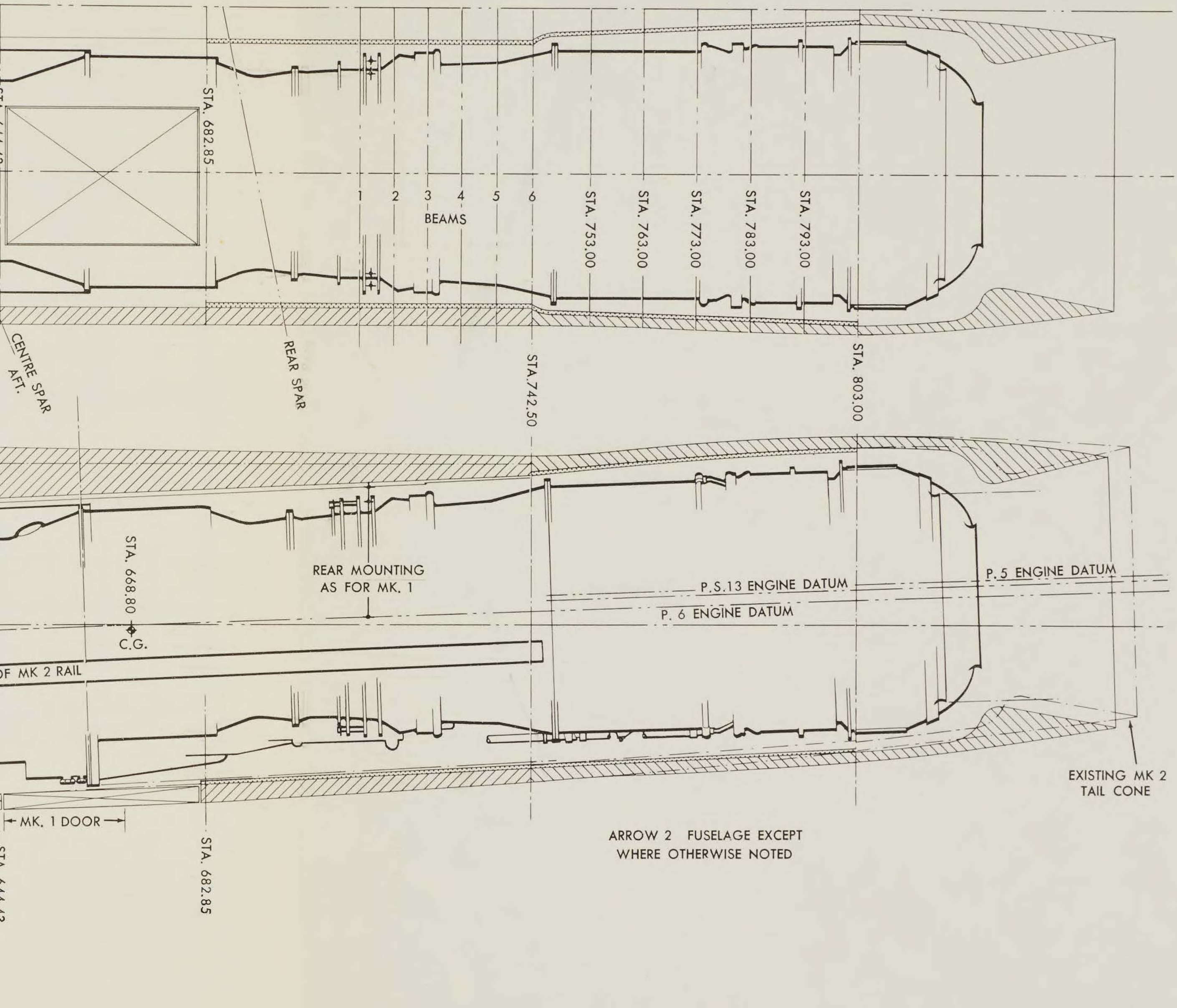
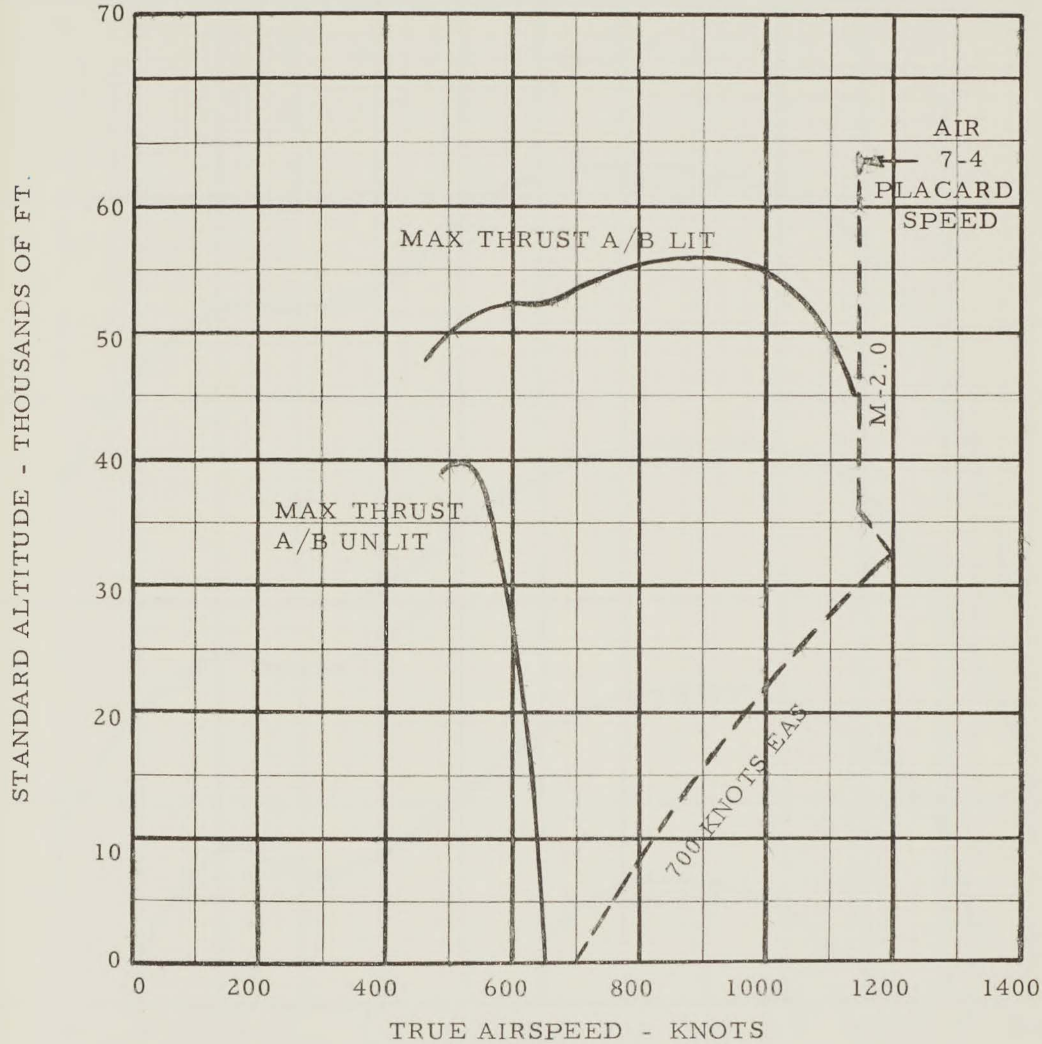


J75-P6 ENGINE INSTALLATION IN ARROW 2

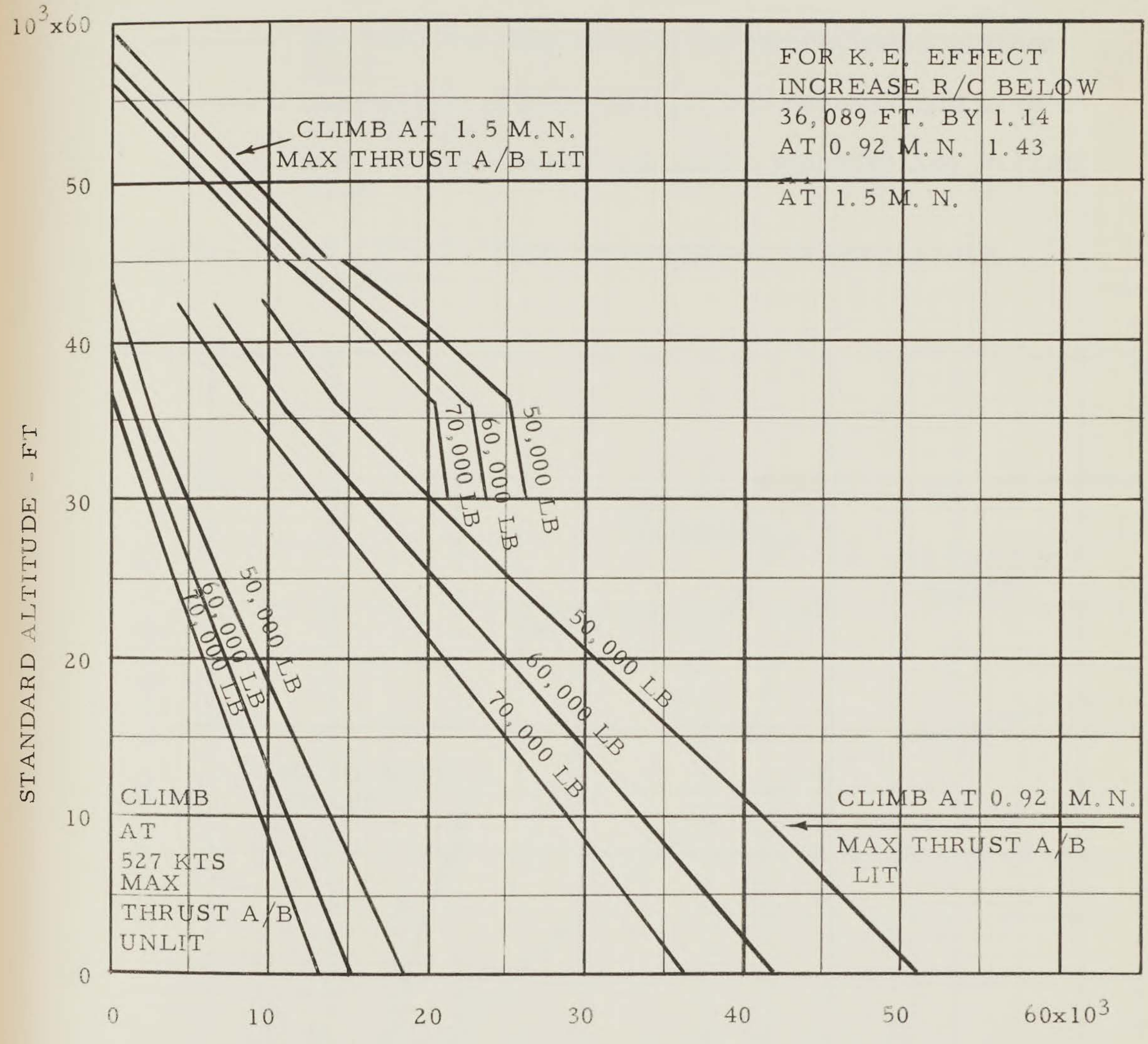


P6 ENGINE INSTALLATION IN ARROW 2 FUSELAGE



ARROW 2 - J75-P6 ENGINES

MAXIMUM LEVEL SPEED AT COMBAT WEIGHT - 58,961 LB



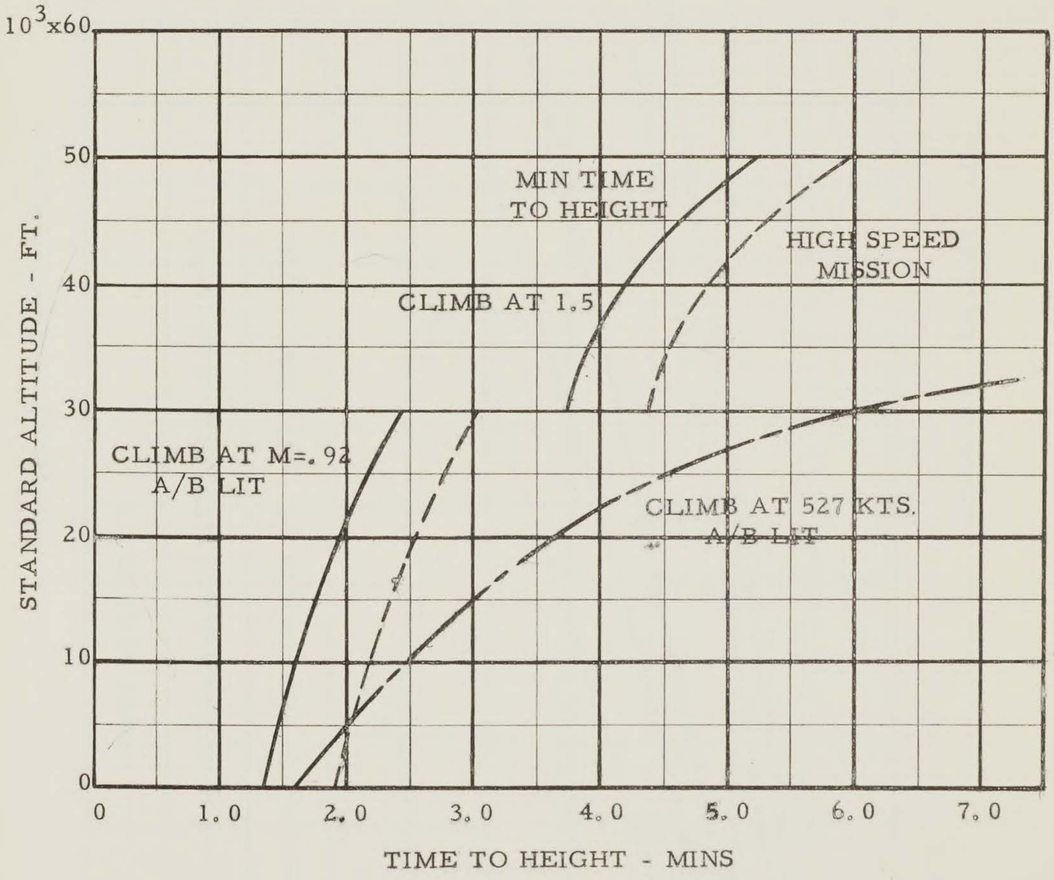
ARROW 2

J75-P6 ENGINE

STEADY STATE RATE OF CLIMB

——— MIN TIME TO HEIGHT A/B LIT THROUGHOUT FLIGHT PLAN
– – – – HIGH SPEED MISSION A/B LIT AT THE BEGINNING OF M = .92 CLIMB
—-— MAX RANGE MISSION A/B UNLIT THROUGHOUT FLIGHT PLAN

NOTE: 1/2 MIN ALLOWED FROM ENGINE START TO MAX THRUST

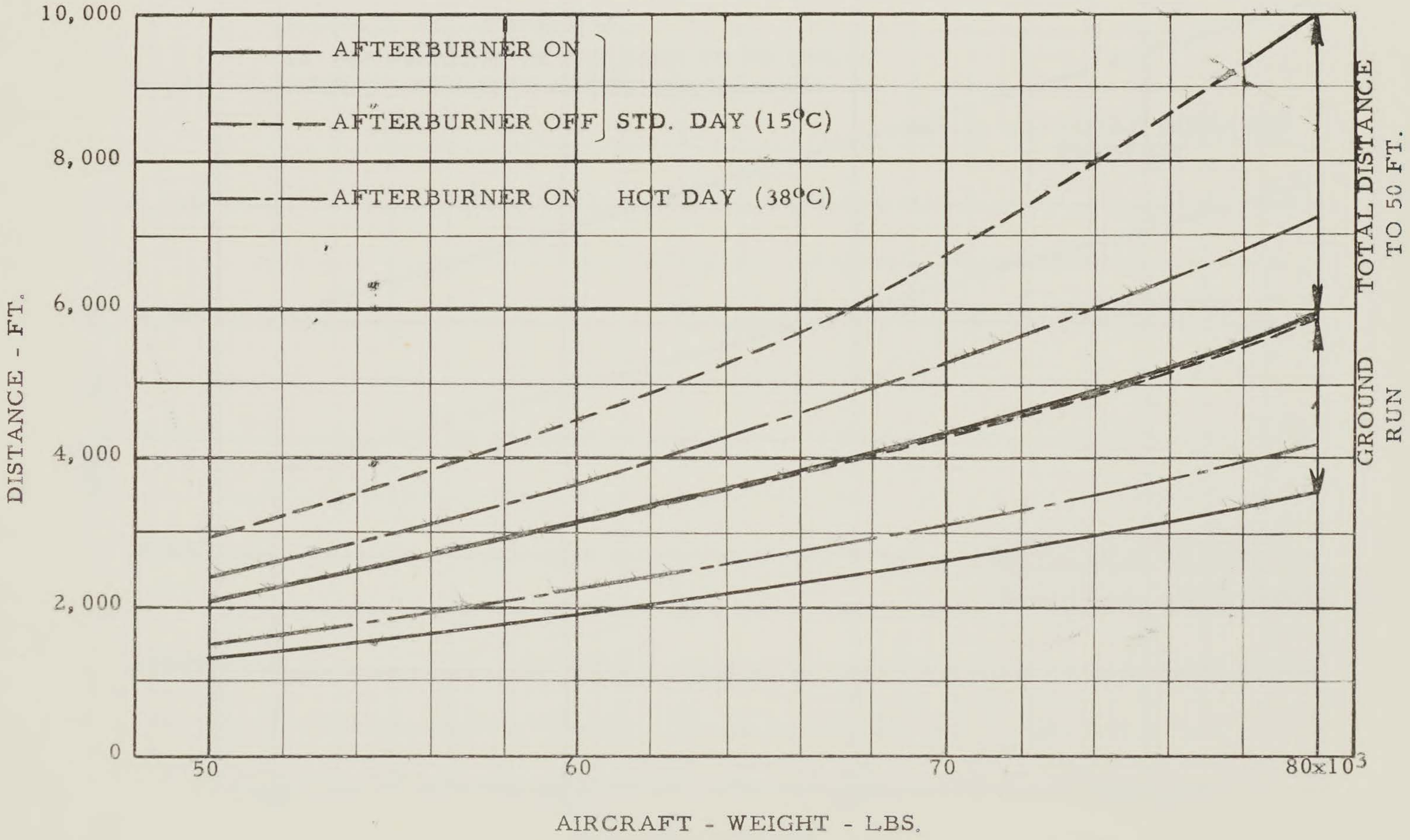


ARROW 2 J75-P6 ENGINE

TIME TO HEIGHT

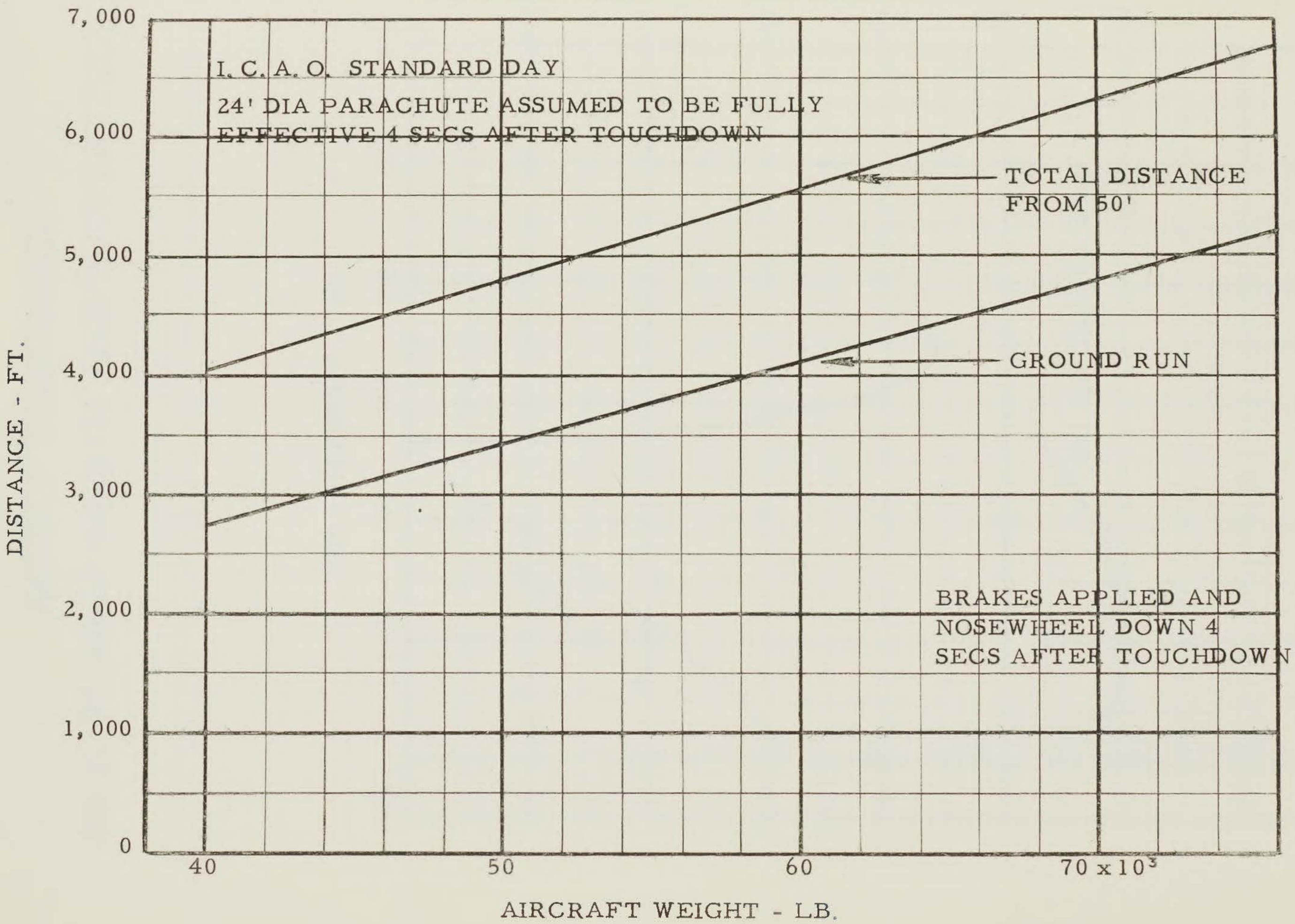
ARROW 2 J75-P6 ENGINE

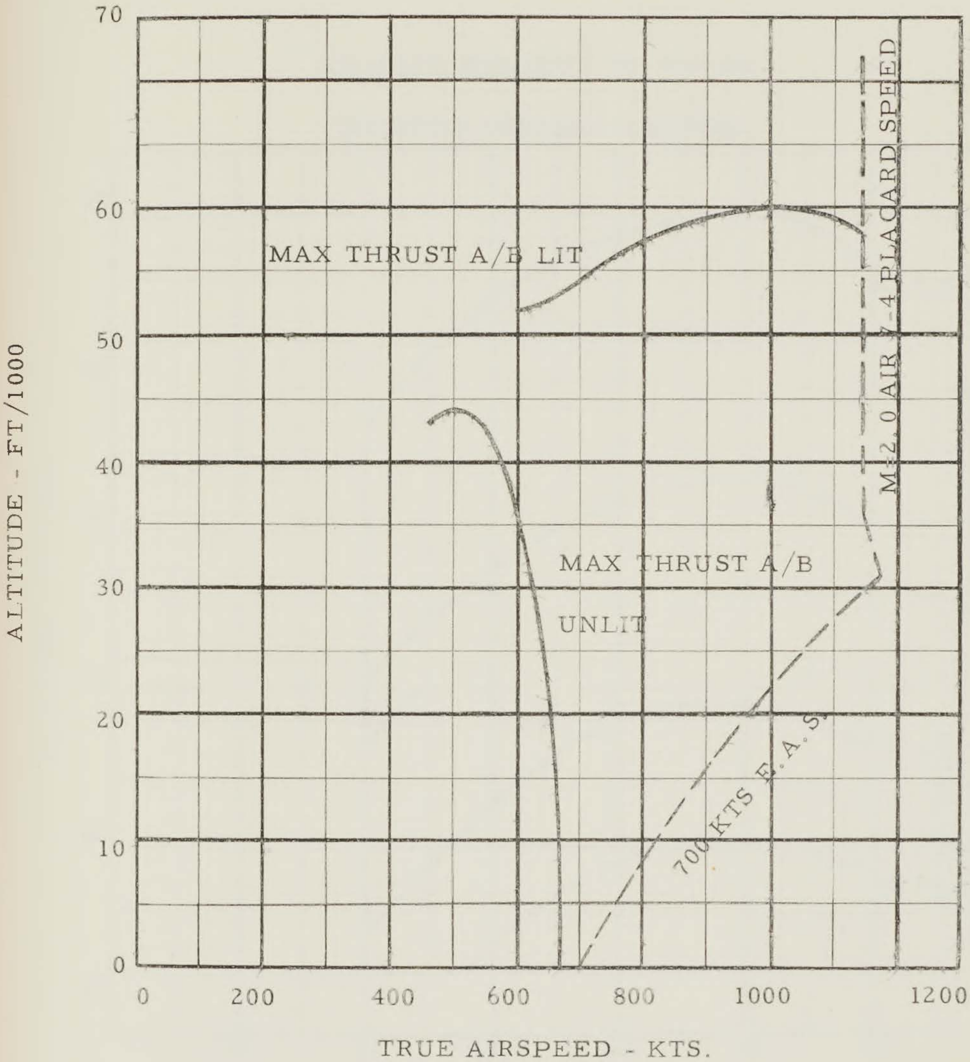
TAKE-OFF DISTANCE AT S. L.



ARROW 2 J75-P6 ENGINE

LANDING DISTANCE AT SEA LEVEL



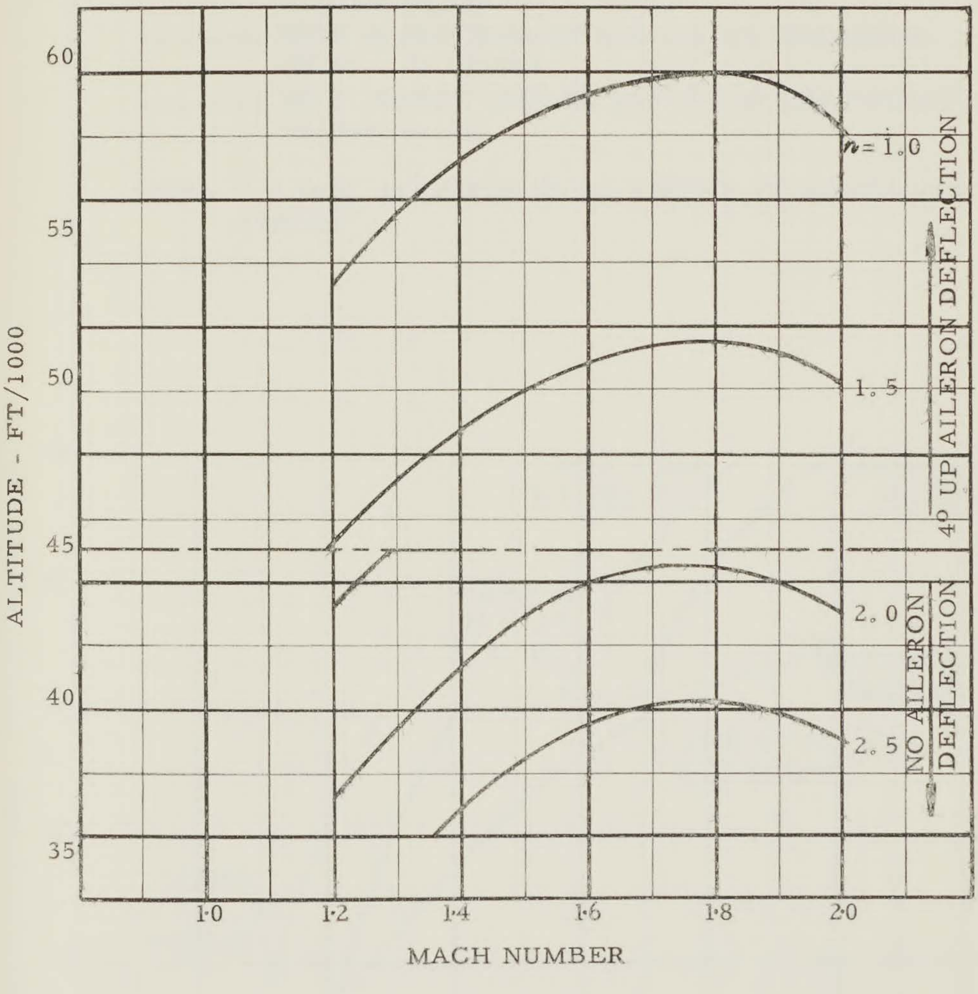


ARROW 2 MAX LEVEL SPEED AT COMBAT WEIGHT (56,372 LB)

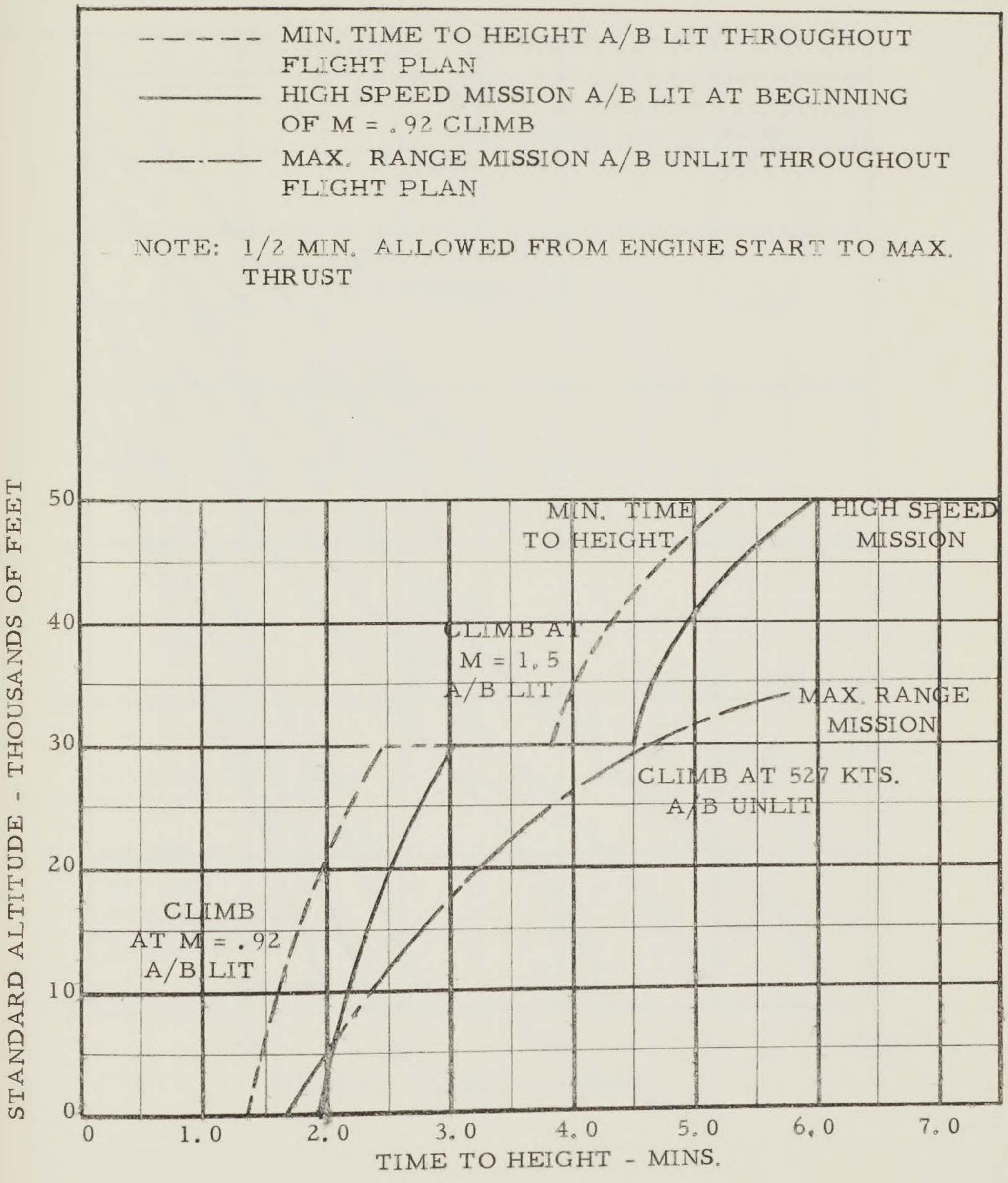
IROQUOIS SERIES 2 ENGINES

COMBAT WEIGHT = 56,372 LB.

IROQUOIS SERIES 2 ENGINES

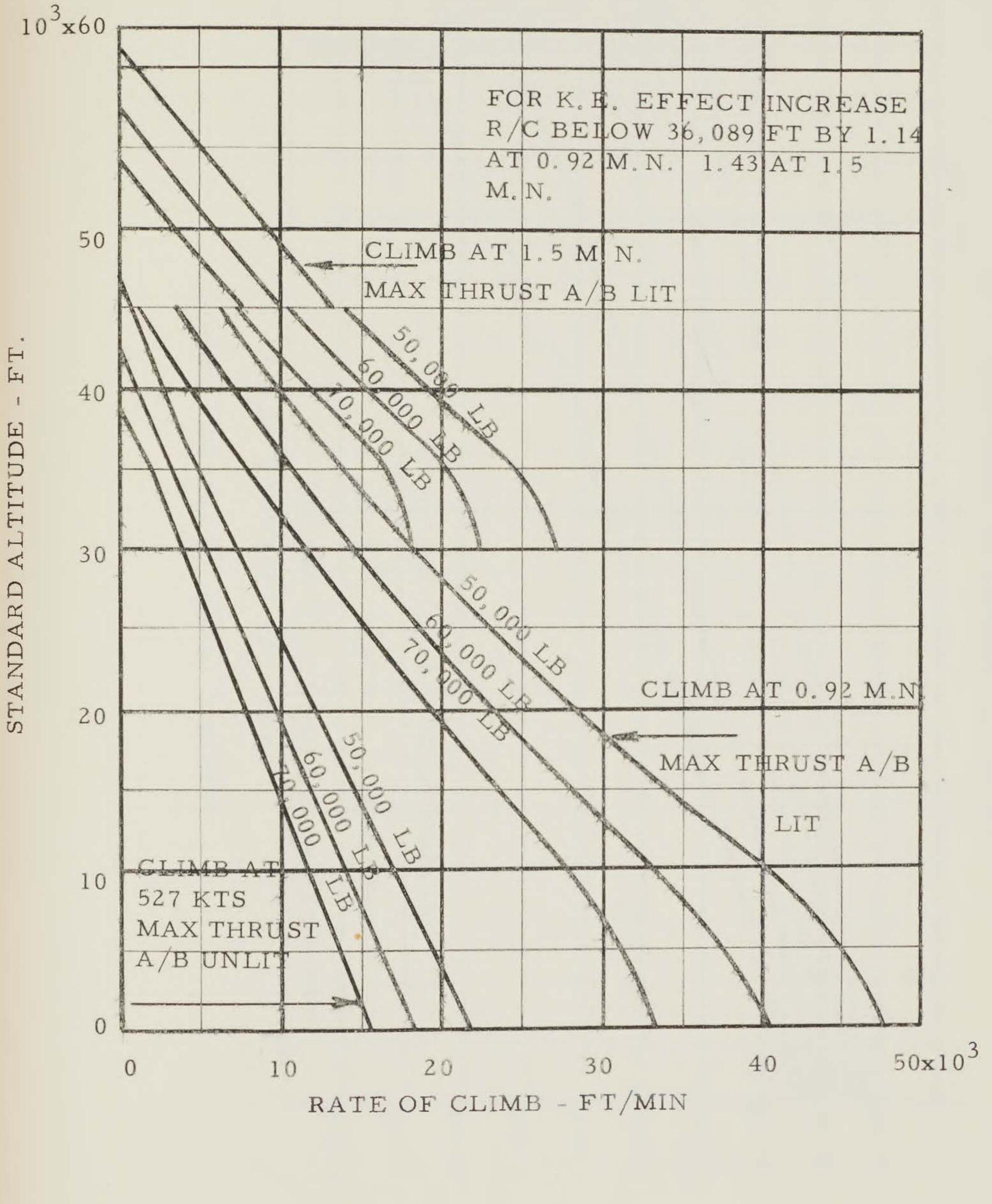


ARROW 2 MANOEUVRABILITY - STEADY G'S AVAILABLE AT COMBAT WEIGHT MAX THRUST A/B LIT



ARROW 2 - IROQUOIS SERIES 2 ENGINES

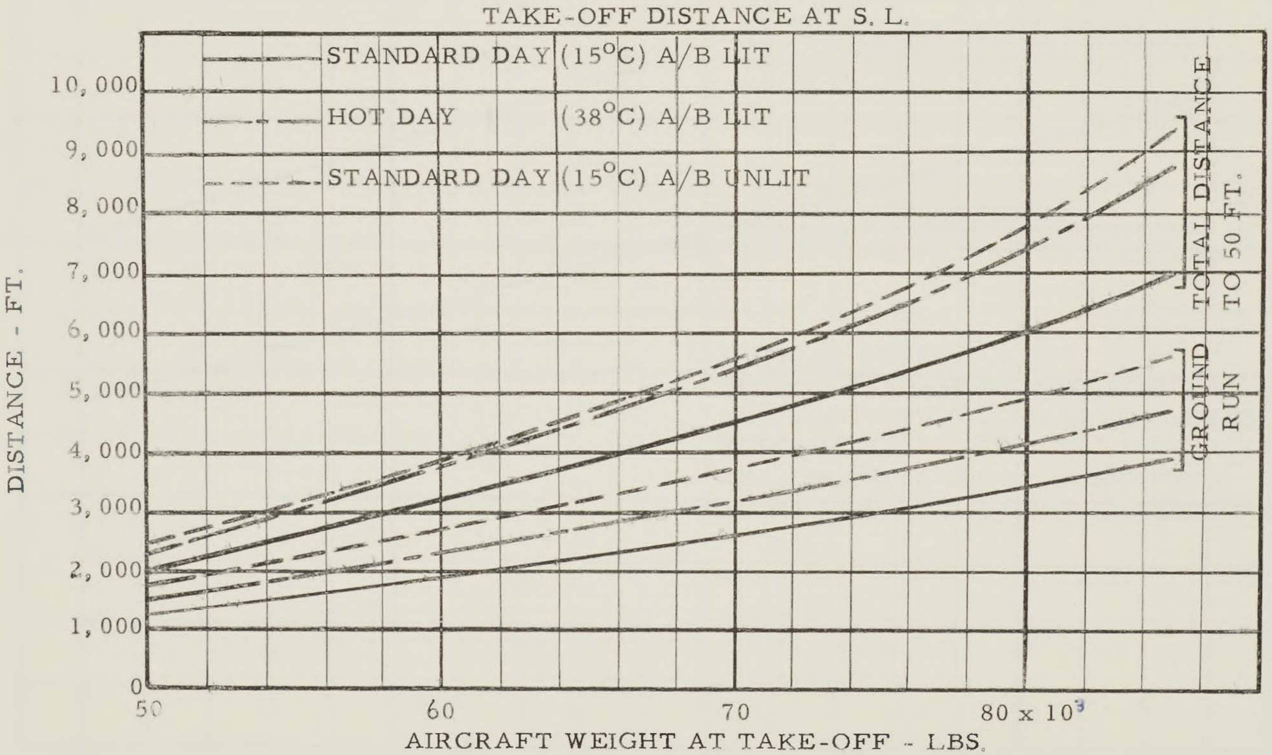
TIME TO HEIGHT



ARROW 2 IROQUOIS SERIES 2 ENGINE

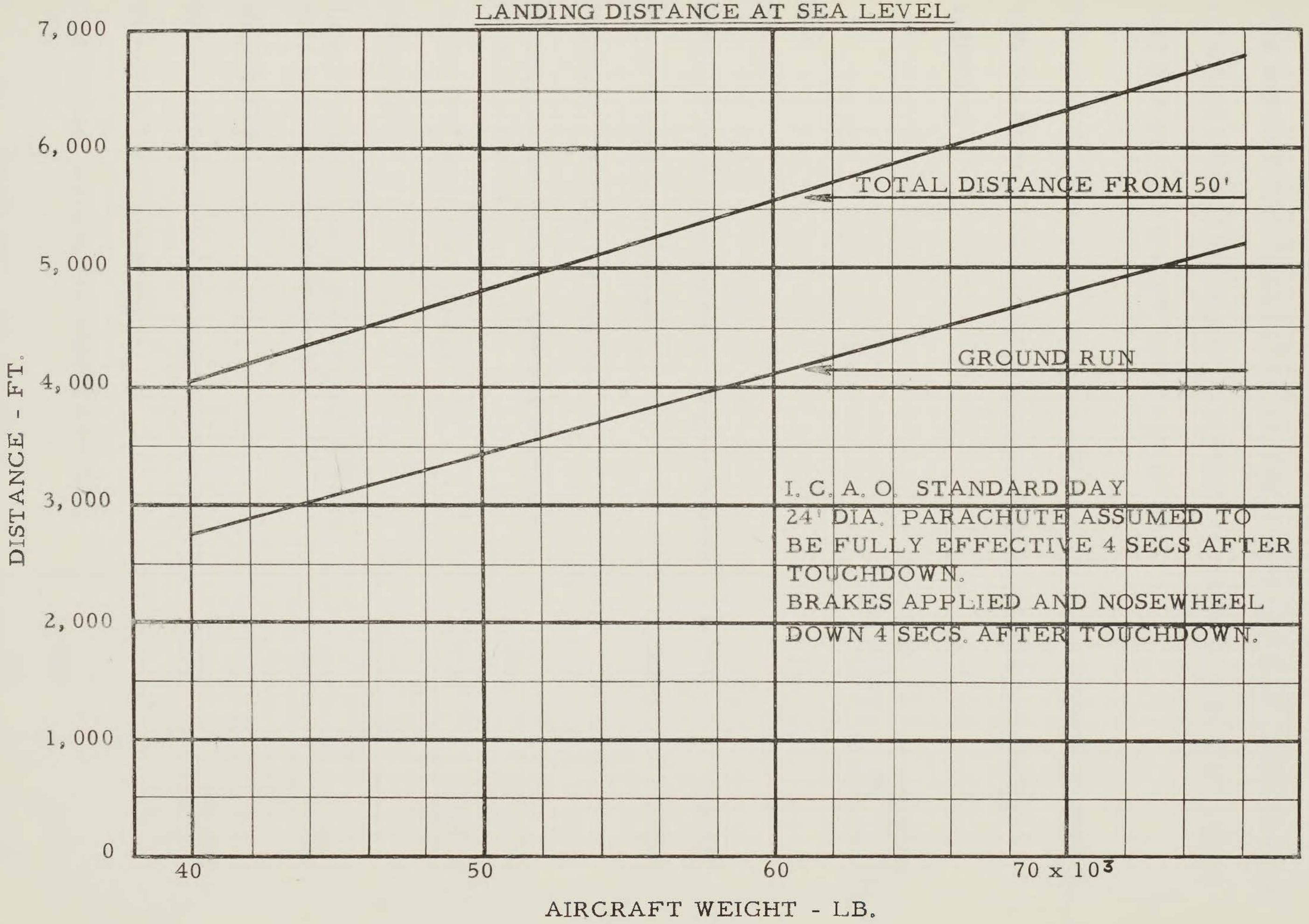
STEADY STATE RATE OF CLIMB

ARROW 2 IROQUOIS SERIES 2 ENGINE



ARROW 2 IROQUOIS SERIES 2 ENGINE

LANDING DISTANCE AT SEA LEVEL



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4. WEIGHTS AND LOAD FACTORS

It is assumed that there will be no change in the strength of the aircraft structure and that the increase in weight is met by a reduction in limit load factors such that nW remains constant.

The following breakdown compares the weight of the ARROW 2 JT4B-23 with the ARROW 2 Iroquois assuming an Iroquois engine weight of 4,500 lbs.

		JT4B-23 Wt. in lbs.	Iroquois Wt. in lbs.
Structure			
(a)	Wings		
	Modification to inner wing for engine mounts	10,012	10,021
(b)	Fin & Rudder - no change	1,042	1,042
(c)	Fuselage - Forward of sta 255		
	Redesigned air intake - however no weight penalty involved	2,590	2,590
(d)	Centre Fuselage - no change	1,712	1,712
(e)	Duct Bay		
	Less articulated duct, redesigned floating duct and heat exchanger area.	1,022	1,161
(f)	Engine Bay		
	Extensively modified for engine installations	1,543	1,574
(g)	Fuselage - Aft of sta 742.5		
	Redesigned, however no weight penalty involved	1,019	1,019
(h)	Fuselage "marry up" - no change	43	43
	TOTAL STRUCTURAL WEIGHT	18,983	19,162

	JT4B-23 Wt. in lbs.	Iroquois Wt. in lbs.
Landing Gear		
(a) Nose Gear - no change	334	334
(b) Nose Gear doors and fairings - no change	28	28
(c) Main Gear doors and fairings - no change	288	288
(d) Main Gear - no change	2,039	2,039
TOTAL LANDING GEAR WEIGHT	2,689	2,689
Power Plant and Services		
(a) Engines and Accessories	11,844	9,187
(b) Nose bullets	76	70
(c) Engine Controls - no change	33	33
(d) Fire Extinguisher - no change	73	73
(e) Engine Mounts	206	132
(f) Auxiliary Gear Boxes, starters and drives	602	602
(g) Fuel System	749	717
TOTAL POWER PLANT WEIGHT	13,583	10,815
Flying Control Group		
No weight change	1,932	1,932
Equipment Group		
No significant weight changes	9,258	9,258
AIRCRAFT BASIC WEIGHT	46,445	43,856
Missiles	1,728	1,728
Operational Load	852	852
Trapped Fuel	214	214

	JT4B-23 Wt. in lbs.	Iroquois Wt. in lbs.
OPERATIONAL WEIGHT EMPTY	49,239	46,650
Max. Internal Fuel	19,443	19,443
GROSS WEIGHT (Max. Internal Fuel)	68,688	66,093
Operational Weight Empty (less missiles)	47,511	44,922
25% Maximum Internal Fuel	4,861	4,861
LANDING WEIGHT (25% Max. Internal Fuel)	52,372	49,783
Half Maximum Internal Fuel	9,722	9,722
COMBAT WEIGHT (Half Max. Int. Fuel)	58,961	56,372

The following limit loads are given for the Combat Weight Condition quoted above:	JT4B-23	Iroquois
(a) For room temperature cases	5.8g.	6.1g.
(b) For 250°F cases	4.8g.	5.0g.
The allowable sinking speed at the landing weight quoted above are:	8 f.p.s.	8 f.p.s.

5. ENGINE INSTALLATION

From preliminary layouts the optimum position of the engine was determined, based on minimum structural changes, as follows:

(a) Fore and aft location would be identical to ARROW 1, thus allowing the use of the ARROW 1 front engine mountings and local wing structure design.

(b) Vertical location would be identified to the ARROW 1 at the front engine mounts, but lower by approximately 3.0'' at the trailing edge of the airframe ejector. The aft end of the engine is lowered in order to preserve the rear wing structure and former 742.5 since the JT4B-23 afterburner front flange, which occurs at this stn. is 4.5 in. larger in diameter.

(c) The center line in plan view is the same as for the ARROW 2, i.e. 30.7'' from ℄ of aircraft. This installation improves clearance between engine and shroud.

The front engine mounts would be the same as for the ARROW 1. However, the rear mounts would be redesigned. The engine installation and withdrawal procedure, would be similar to that used on the ARROW 2 with one rail built into the outboard side of the fuselage from stn. 576 to 743 . It is impossible to remove this rail as is done on the ARROW 1 because of the larger afterburners.

New ground handling equipment would be required for engine change.

The blanket insulation would be the same as for the ARROW 2 from stn. 682 aft, i.e. partial coverage to stn. 742.5 and complete coverage from stn. 742.5 to stn. 803.

Fire zoning, similar to the ARROW 1 installation, would be provided using new longitudinal and vertical fire seals.

Other small modifications required by this engine installation include; an Air Ejector and its Control Valve to provide ventilation of Zone 1, provision for overboard venting of the inter-compressor bleed valves and for ducting engine bleed air overboard.

6. AIRFRAME MODIFICATIONS

The structural and system changes required for the JT4B-23 engine installation are discussed in detail by component and system in subsequent paragraphs.

6.1 STRUCTURES

6.1.1 Front Fuselage

The pilots' left hand console would be modified to suit the revised Throttle Control Box, see para. 6.2.3. Other minor changes may be required to suit engine monitoring displays.

6.1.2 Air Intakes

The intake throat area required by the JT4B-23 engine would be between that used on the ARROW 1 and the ARROW 2 aircraft, and would require a modification to the inboard intake lines.

6.1.3 Duct Bay

The existing ARROW 2 articulating duct would not be required, and a redesigned floating duct incorporating a gill door structure similar to the ARROW 1 arrangement would be introduced. The attachment to the wing structure would be as for the ARROW 2, provided the redesigned gill structure did not affect the geometry of the aft portion of the duct.

Redesign of the structure in the heat exchanger area would be required in order to accommodate a 4 unit heat exchanger similar to that used on the ARROW 1.

6.1.4 Engine Bay

The engine bay formers at stns 729 and 735 would be relocated to stns. 712 & 717 respectively, a post added and the wing - fuselage joint revised for these changes. The upper shroud would be changed from titanium to aluminum, because of the titanium can on the engine.

Some local changes in the lower shroud and inside engine door lines would be required to give clearance for engine withdrawal.

Other changes to the shrouds would be required to suit the revised gear box drive, relocated engine mounts, relocated restrictor, relocated air conditioning bleed pick off and engine controls.

Repositioning and lengthening of the engine removal rail with modified and additional bracketry would be required. No. 1 and 2 engine access doors size and position would remain as for the ARROW 2, however the doors would be modified for engine starter access, added ejector tube and relocated fire seals.

The access panels for air conditioning bleed line, engine mounts and fire extinguisher and the pressure vent doors would be relocated.

6.1.5 Rear Fuselage, Tailcones and Stinger

Because of the larger engine diameter in this area the lines of the fuselage aft of stn. 742.5 would be revised resulting in the redesign of these components.

6.1.6 Inner Wing

The structure of the inner wing torque box, centre trailing edge and centre box would be modified to reintroduce the ARROW 1 engine mounting provisions. Further modification would be required at the fuselage-wing attachments to suit the revised engine bay and rear fuselage.

6.1.7 Miscellaneous Changes

Further minor changes to structural components, throughout the aircraft may be necessary due to modifications to systems which affect bracketry clipping etc.

The ARROW 2 landing gear will meet the requirements of the revised aircraft and no changes should be required.

6.2 SYSTEMS

Systems that are closely associated with the engine require considerable changes and these are discussed in subsequent paragraphs. Other systems will be affected by structural changes and the engine installation and mountings. Typical examples of changes that could be expected are remounting utility hydraulic system compensator and the 200 cut. in. brake accumulator due to front engine mounts, and re-routing of pipes and systems due to engine mounts and controls and posted structure at stn. 712.

6.2.1 Fuel System

No changes required except for minor modifications at engine connection.

6.2.2 Air Conditioning System

Ducting upstream of the Pressure Reducing Valve would be changed in size. and the Engine Bleed Shut Off Falves and the Pressure Reducing Valve would revert to modified ARROW 1 units, the latter being reset to control to 60 p.s.i.g.

6.2.3 Engine Controls

At the engine and through the shrouds the throttle connections would revert to the ARROW 1 system and in the cockpit the throttle box would be replaced by the ARROW 1 unit to provide the applicable "OFF - IDLE - MILITARY and AFTERBURNER" settings.

6.2.4 Engine Performance Indicating System

The present system as used with the Iroquois would be adapted to suit the JT4B-23 engine by suitable probes, and other modifications to suit the two position afterburner.

6.2.5 Engine Starting System

This would be a direct reversion to the pneumatic ARROW 1 system due to engine starting characteristics and the engine/airframe geometry.

6.2.6 Engine Oil Sub-System

The JT4B-23 requires additional cooling which would mean enlarging the Air/Oil and Fuel/Oil Heat Exchangers due to lower fuel flows at the design case, plus other minor changes.

6.2.7 Accessories Gearbox System

The changes required to this system would mainly constitute the reintroduction of the ARROW 1 power take off units except where specific ARROW 2 power requirements necessitate new units. Due to the reverse operating rotations of the engines the hydraulic pumps for the Flying Control and Utility Systems would revert to ARROW 1 units.

6.2.8 Fire Extinguisher and Detection System

The existing ARROW 2 system would be retained, suitably modified for the revised JT4B-23 fire zone arrangement.

6.2.9 Constant Speed Unit

Due to the different speed ranges and direction of rotation on the two engines the Constand Speed Drive would require some detail redesign and repackaging resulting in a new unit which would require full qualification testing.

6.2.10 Alternator

Minor changes would be required to reverse the direction of rotation.

7. GROUND AND FLIGHT TESTING

7.1 Ground Tests

No specific ground test program has been established, but it is anticipated that Ad Hoc systems and structure tests will be required.

7.2 Flight Tests

Performance, structural integrity and systems flight tests using one ARROW 2 for up to 50 flying hours are anticipated.

It is estimated that approximately 30 parameters require instrumentation and it is assumed the data recording system would be accommodated in an existing ARROW 2 instrument or wpn. /instrument pack.

8. STATEMENT OF WORK, EXCLUSIONS AND SCHEDULE

8.1 STATEMENT OF WORK

Avro Aircraft Limited will carry out the following items of work to produce a version of the ARROW 2 aircraft powered by two Pratt & Whitney J75-P6, (JT4B-23) engines.

8.1.1 Provide services and materials, to redesign airframe structural components.

(a) air intakes in the front fuselage.

(b) floating duct in the duct bay, incorporating a gill door structure.

(c) structure in the heat exchanger area of the duct bay to accommodate a 4 unit heat exchanger.

(d) engine formers at stns. 729 and 735, which will be moved to stns. 712 and 717 respectively, including the addition of a post, in the engine bay.

(e) engine shrouds and engine access doors.

(f) engine rails and bracketry.

(g) complete rear fuselage including tailcones and stinger.

(h) forward and aft engine mounts.

(i) inner wing torque box.

(j) centre trailing edge (wing).

(k) centre box (wing).

(l) other structural changes necessitated by systems revisions.

8.1.2 Provide services and materials, to design and/or specify modifications to airframe systems.

(a) engine controls, including the throttle box in the cockpit.

(b) air-conditioning system.

(c) engine performance indicating system.

(d) engine oil sub-system.

(e) accessories gear box system.

(f) fire extinguisher system.

(g) constant speed unit and alternator.

(h) other airframe systems affected by structural changes.

8.1.3 Provide services and materials, to conduct such studies related to the J75 - P6 engine installation as are agreed to between the RCAF and the company. (To be funded by ARROW Product Improvement Contract).

8.1.4 Provide services and materials, to design modifications to engine G.S.E., including engine starter and engine change equipment.

8.1.5 Provide services and materials, to prepare a model specification for the J75 - P6 ARROW aircraft.

8.1.6 Provide services and materials, to conduct ground tests of redesigned structural components and systems as necessary, including the design and construction and/or modification of required test rig.

8.1.7 Provide services and materials for a ground check-out of the first J75 - P6/ ARROW aircraft.

8.1.8 Provide services and materials to conduct a flight test program for the first ARROW aircraft with the J75 - P6 engine installation, including:

(a) Planning flight test program.

(b) Specification of, maintenance of, and design of the installation of airframe and engine sensing and recording instrumentation.

(c) Manufacture and/or purchase and installation of recording instrumentation.

(d) Flight test data processing and analysis of results.

(e) Fuel, oil and other consumable stores.

(f) Inspections, as required.

(g) Maintenance of the aircraft.

(h) Services of a flight observer.

(i) Completion of the aircraft, after RCAF acceptance, to a suitable condition to permit commencement of the flight test program.

(j) Incorporation of mandatory modifications.

NOTE: For estimating purposes a flight test program of 50 flying hours and twelve months duration has been assumed.

8.1.9 Provide liaison services, as required, with:

(a) The RCAF and other Government agencies.

(b) Pratt and Whitney.

(c) Other contractors and sub-contractors.

8.2 EXCLUSIONS

The following are not included in this Statement of Work:-

8.2.1 Wind Tunnel Program. (It is not anticipated that such a program will be required.)

8.2.2 Manufacture of a Pack. (It is expected that an existing pack will be utilized and that some minor changes will be required. The cost of these changes has been estimated and included in the forecast contained in our letter to the RCAF T.S.D. Ref. SO4975/20-14/9794 dated 31st July, 1958.

8.2.3 Work on the Structural Test Aircraft.

Work on the Air Conditioning Rig.

Testing of the aircraft landing gear.

8.2.4 Modification kits and/or parts which are available from the Manufacturing Division before and after first flight.

8.2.5 All services up to and including first flight.

8.2.6 Manufacture of changes to GSE items.

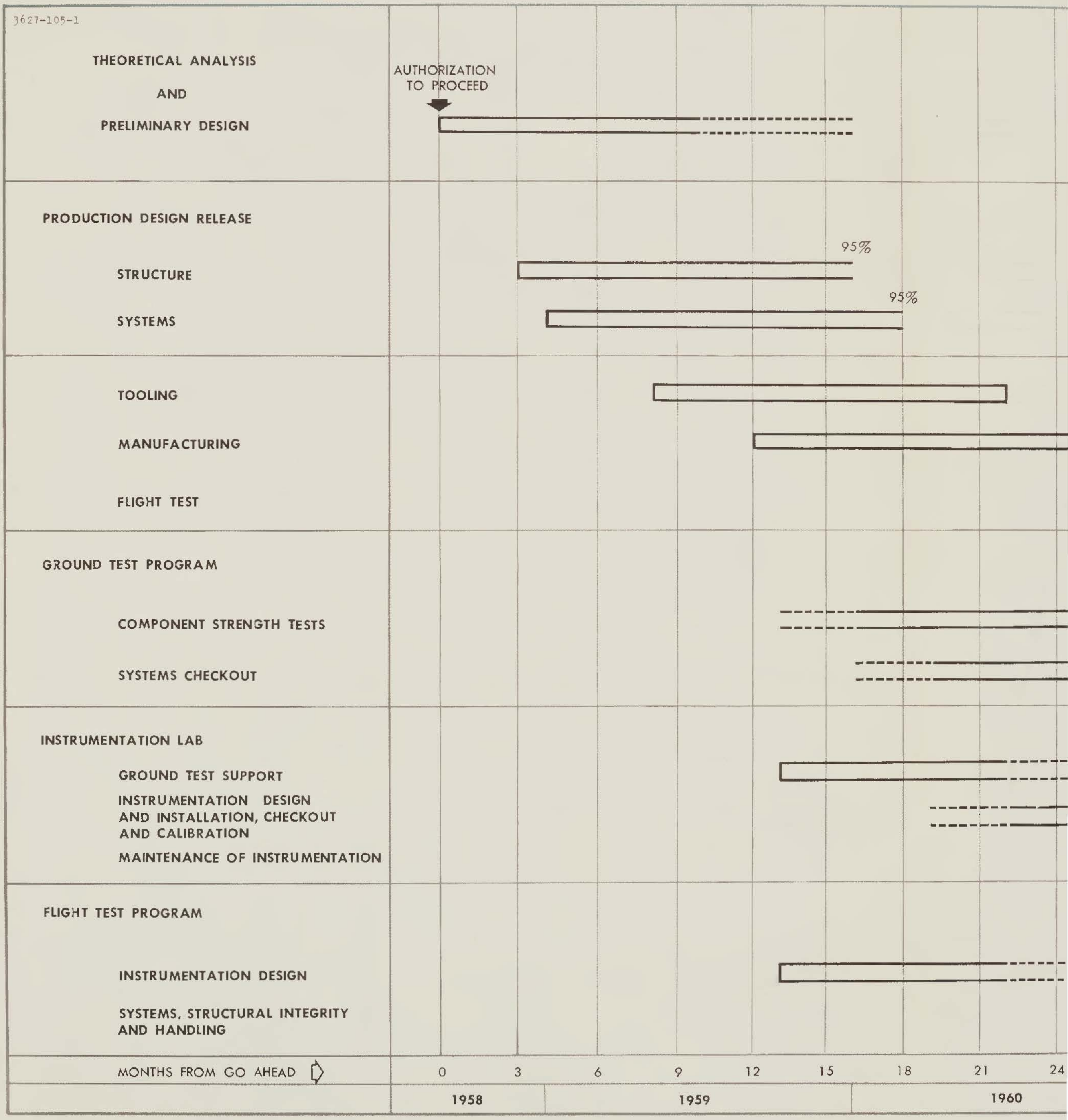
8.2.7 Airframe and GSE spares.

8.2.8 Pilots (Flight Operations Division)

8.2.9 Repair and Overhaul of the airframe and GSE, including instrumentation repairs in excess of normal maintenance (ref. 8(b)).

8.2.10 Test Specimens or components.

8.2.11 Purchase of airframe sensing instrumentation.



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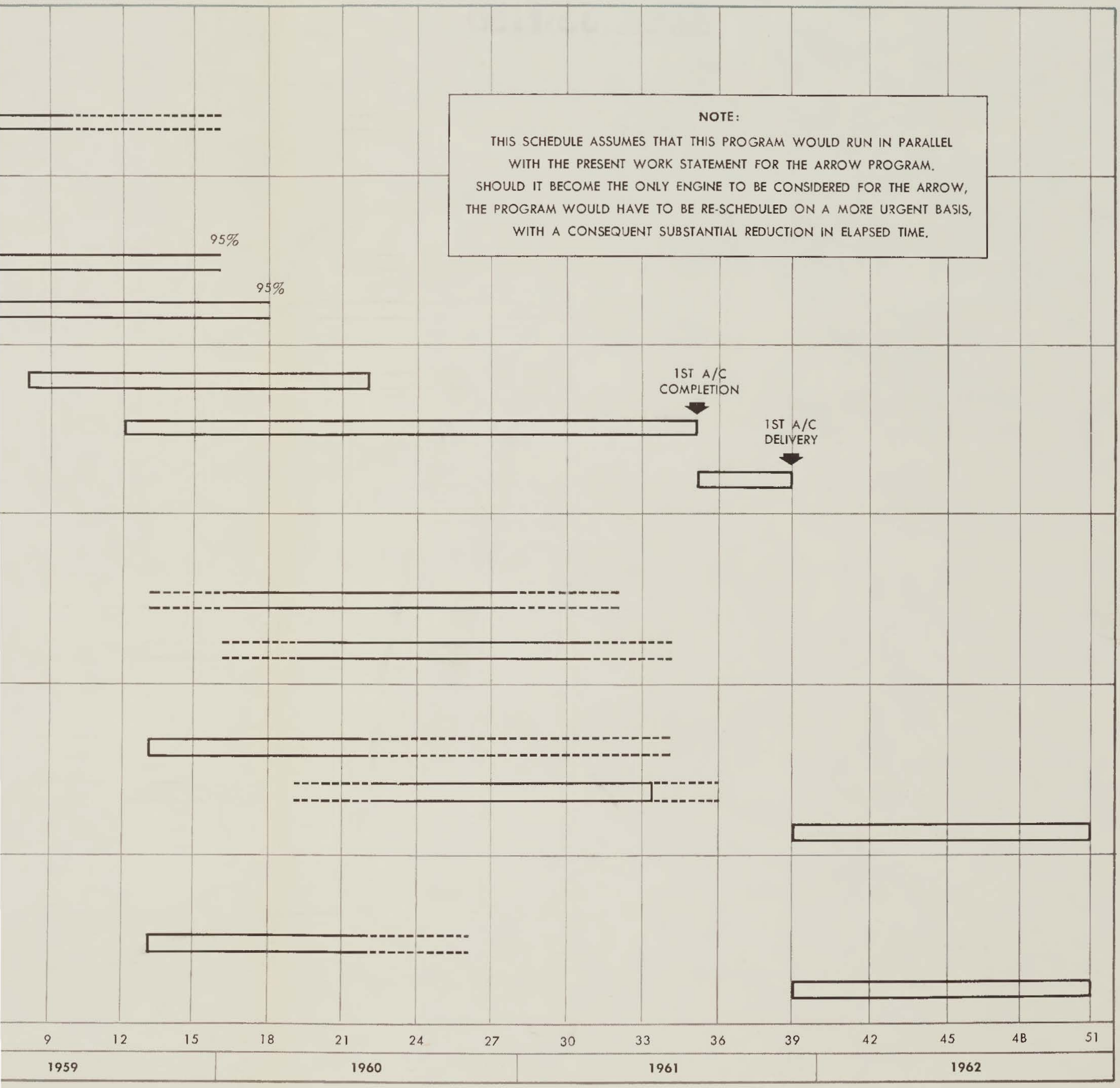

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