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INITIAL OPERATIONAL ARROW
WEAPON SYSTEM
Report No. 1
DEFINITION AND DEVELOPMENT
PROGRAM
UNLIMITED



AVRO AIRCRAFT LIMITED

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BRANCH

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ARROW WEAPON SYSTEM
CO-ORDINATING CONTRACTOR

REPORT NO. 1

1st APRIL 1958

INITIAL OPERATIONAL ARROW
WEAPON SYSTEM

DEFINITION AND DEVELOPMENT PROGRAM

ISSUED: William R. Stephens
Arrow Weapon System
Co-ordinator

APPROVED: J. A. Morley
Vice-President
Sales & Service



AVRO AIRCRAFT LIMITED



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PROLOGUE

As set forth in paras. 5b and 16 a of the minutes of the 28th January 1958 meeting of the Arrow Weapon System and Co-ordinated Projects Programming Committee, the Arrow Weapon System Co-ordinating Contractor and Associate Contractors met on 26th March 1958 at Avro Aircraft Limited, Malton, Ontario to:

- (1) define the Arrow Weapon System which can be introduced into squadron service in January 1961.
- (2) compile a master schedule chart to reflect component delivery requirements for the system defined in (1) above.
- (3) establish an integrated flight test program for the development and demonstration of the weapon system.

Contractors' representatives participating in the 26th March meeting were as follows:

AVRO AIRCRAFT LIMITED

W.R. Stephens
C.V. Lindow
I.M. Liss
I.R. Craig

RADIO CORP. OF AMERICA

T.O. McClure
H.C. Lawrence
E.A. Williams
E.W. Sheridan
D.E. Shumaker

PROLOGUE (Cont'd.)CANADAIR LTD.

R. D. Richmond

R. Raven

D. Bogdanoff

ORENDA ENGINES LTD.

H. Keast

D. J. Caple

The following document presents the agreed conclusions and recommendations resulting from the first meeting (26th March 1958) of the Arrow Weapon System Associate Contractor Co-ordinating Committee.

A handwritten signature in cursive script, reading "William R. Stephens".

William R. Stephens
Arrow Weapon System Co-ordinator
Chairman



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S U M M A R Y

It is considered that an Arrow Weapon system having the following capability can be delivered for squadron service in January 1961:-

- (a) An aircraft capability which is substantially in agreement with the interim performance required by the Air Staff and expressed in RCAF letter S36-38-105 (APO).
- (b) A basic fire control capability in conjunction with Sparrow 2 Mk 1 missiles using manual attack methods.
- (c) A dead reckoning navigation computer, with manual inputs, together with UHF communication and homing, intercomm, air to ground IFF and radio compass.

Additional capability may well be available at that time, but it can not be guaranteed. The capability of subsequent systems should improve rapidly with time, as flight experience builds up through continuation of the contractors' development programs and the RCAF flight evaluation.

The above capability can be developed and demonstrated by January 1961, only if:-

- (a) Deliveries quoted in the Master Schedule Chart are met.
- (b) There is no attrition of aircraft early in the program
- (c) The Astra system development is reinforced early in the program by additional flying test beds, such as F101B aircraft.

S U M M A R Y (Cont'd.)

- (d) Additional development Astra Systems are made available for installation in the additional test beds and in aircraft 10.

Arrow Weapon System capability in terms of kill probability (Pk) can not be "guaranteed" by the contractors. Contractors should be required only to establish the weapon system potential and to assist the RCAF in weapon system evaluation.

Demonstration of compliance with specification provisions would be a part of each associate contractors development program, except where it is more convenient to prove as part of the Weapon System Program. A procedure to concur that "proof of compliance" has been presented should be set up.

The weapon system development and demonstration program would be carried out on aircraft 13 and 14 and consist of flying agreed missions against drone or towed targets. The aircraft will be instrumented to measure significant parameters so that mission performance can be compared with predictions based on a mathematical model. The main objective of the program will be to demonstrate qualitatively that the components are working together as a system.



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INITIAL OPERATIONAL ARROW WEAPON SYSTEM DEFINITION AND DEVELOPMENT PROGRAM

1.0 INTRODUCTION

1.1 Objectives

Paragraphs 5B and 16A of the Minutes of the First Arrow Weapon System and Co-ordinated Projects Programming Committee, held in Ottawa on 28th January 1958, directed the Co-ordinating Contractor, in conjunction with the Associate Contractors, to:-

- (1) Decide upon the weapon system that can be developed and proven by the first squadron aircraft to be delivered in January 1961 and amend the Master Schedule Chart to reflect the component delivery requirements.
- (2) Plan the integrated flight test program to ensure sufficient flight test time is available for proper development and proving of the associate contractors' equipment.

Because of their interdependence, action on these two directives has been integrated into this document.

1.2 Basis of Proposed Program

This document is based on entry of the Arrow Weapon System into squadron service in January 1961.

The need to achieve a higher capability as soon as possible after January 1961 has been recognized by the inclusion of programs in the Integrated Flight Test Program, the results of which will not be reflected



1.2 (Cont'd.)

in system capability until some time after initial squadron introduction.

1.3 Factors Considered

The factors that have been considered in arriving at this proposed program include:-

- (1) Current status of Associate Contractors' programs.
- (2) Adequacy of basic preliminary programs and availability of specimens and test beds.
- (3) Availability and timing of Arrow test vehicles.
- (4) Availability of Associate Contractors' products for installation in Arrow test vehicles.
- (5) Lead time required to introduce modifications.

2.0 DEVELOPMENT PROGRAMS

2.1 Stages of Development of the Arrow Weapon System

The attached Figure 1 illustrates diagrammatically the various stages of development which must be carried out to achieve a weapon system capability by January 1961. Each of these stages must be carried out sequentially although it is not always necessary to complete one stage before commencing the next and for this reason subsequent charts show the timing of the various stages.

2.2 Arrow Flight Time Available

To estimate the amount of development that could be carried out in Arrow aircraft, it was necessary to estimate the available flying hours that can be anticipated in the program. Based on experience in other programs,



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2.2 (Cont'd.)

utilization rates of 5 1/4 hrs. /aircraft/month for non electronic testing or 3 3/4 hrs. /aircraft/month for electronic testing on the Arrow have been adopted. These rates will give approximately 1,000 hrs. of Arrow development flying prior to January 1961 and approximately 300 hrs. prior to the major modification deadline.

2.3 Aircraft Allocation to Programs

The scheduled aircraft acceptance dates for the fifteen Arrow aircraft allocated to Contractors for development purposes are shown in Figure 2.

Engine delivery schedules are compatible with those of the airframes, but deliveries of pre-production Astra systems are not. In fact the first pre-production Astra System is scheduled for delivery six months later than it should be for production incorporation in aircraft 10.

While development of the basic airframe and engine does not require Astra systems to be fitted, such programs as Astra/airframe compatibility, missile development and the weapon system development program do require Astra systems. RCA states that there is no reasonable way to improve upon the delivery dates shown in this report and, in fact, some relaxation of inspection and procurement procedures, and even of system content, will be necessary to meet them. It should be noted that the schedule of Astra deliveries shown in Fig.5 is one that RCA considers could be met if they were to be so instructed and funded. The schedule is not one that they are currently working to. Governmental action to negotiate the improved deliveries should be regarded as urgent. Any



2, 3 (Cont'd.)

further action that the Government can take to attempt to make the Astra delivery schedule more compatible with the airframe build schedule should be taken. The possibility of obtaining laboratory built systems in place of the factory built systems has been examined. The building of additional systems in the laboratory will put a strain on RCA's engineering effort which will adversely affect pre-production systems. It has therefore been decided that the use of laboratory built systems shall be kept to an absolute minimum.

Because Astra deliveries are out of phase with aircraft availability, development time on Astra equipped Arrow aircraft will be at a premium. To maximize this flying time it is proposed to process the early aircraft, minus Astra, through manufacture and flight acceptance and to install the Astra system after the aircraft have flown and have had airframe and engine snags cleared. It is believed that even with this expedient the first aircraft which can be made available will be too late to conduct Astra/airframe compatibility and missile captive seeker tests and still meet the January 1961 date for weapon system delivery. It is therefore considered necessary to have one pre-production system available earlier than it can be if it is built in the factory.

The aircraft availability chart has therefore been based on the assumptions that:-

- (1) A laboratory built Astra system is made available for production line incorporation in aircraft 25210.
- (2) The early pre-production Astra systems will be retrofitted to aircraft 25211 through 25214 after flight acceptance.



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2.3 (Cont'd.)

Using the staging chart (Figure 1) programs were then allocated to aircraft as shown in Figure 3. It is believed that this allocation is the optimum one within the limitations imposed by the various factors involved. Maximum use has been made of combined programs on aircraft where these programs involve the same type of flying.

Basic airworthiness is to be established on aircraft 1, 2 and 3. As soon as safety of flight over an appreciable portion of the flight envelope is established, aircraft 3 will be switched to weapon pack development in order to have this item in working condition for marriage with the Astra system on aircraft 9. During the weapon pack program, vibration and temperature environmental test missiles will be carried to investigate missile/airframe compatibility.

While engaged in its Phase 1 program, aircraft 2 will conduct a first order check on antenna coverage, will examine air data sources and during flight testing of these sources will record air data computer outputs. This testing will enable aircraft 4 and 5 to make an immediate start on basic Astra development as soon as they are available.

Aircraft 4 and 5 are flying test beds for Astra development. In addition to the necessary communication equipment, they will be equipped with fire control and navigation subsystems. Importance is attached to the need for infra red tracking capability in the weapon system at the earliest possible moment. These aircraft will therefore include as much provision as



2.3 (Cont'd.)

possible for installation of the infra red system, without extending the grounding period during which the Astra systems are installed. The program to be conducted on aircraft 4 and 5 is one of getting the system sufficiently developed to commence programs on Arrow 2 aircraft and for mating with the missile installation. At the same time, significant parameters will be established and dry run miss distance evaluation can be carried out. Until late 1960 all flying will be in the manual mode.

Aircraft 6 is the first Arrow 2 and will commence its program with airworthiness flights and engine/airframe compatibility trials. Aircraft 7 will take over engine/airframe compatibility work and engine development.

Meanwhile, aircraft 6 will engage in an airframe systems development program in which it will be joined by aircraft 8.

Integration of Astra, the missile installation and the missile, will be carried out on aircraft 9. Canadair will join with RCA in conducting Astra/missile compatibility tests on this aircraft.

Compatibility of the Arrow 2 airframe and the Astra system will be established in aircraft 10 and 13. Avro will provide Canadair with data from this program to enable the performance of the missile seeker to be determined. Parameters such as the influence of geometry and the influence of adjacent missiles on missile seeker performance will be established.

Prior to commencing the firing of homing test missiles (HTVs) a check on the missile control system at high altitudes will be conducted by firing controlled



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2.3 (Cont'd.)

test vehicles (CTVs) from aircraft 3.

Because of the short time available between the availability of aircraft for HTV firing and January 1961 it is considered essential that two aircraft be made available for missile firing tests. Aircraft 11 and 12 have been allocated.

Aircraft 13 has been allocated to work with aircraft 10 until the last quarter of 1960 when it will join aircraft 14 in the weapon system development and demonstration program.

Aircraft 15 is allocated for airframe structural integrity work.

As soon as aircraft 1 and 2 have completed their Phase 1 program, it is considered necessary to use them for component development and to transfer airframe development to Arrow 2 aircraft. To this end it is proposed that aircraft 1 should be used for trials of such features as anti-skid and for a rigorous investigation into antenna patterns. More importance is attached to automatic modes of operation in the Arrow, by RCA, than to these modes in a lower performance aircraft and it is anticipated that aircraft 4, 5 and 9 will be ready to commence development of the automatic modes of Astra towards the end of 1960. In preparation for this stage it is proposed that aircraft 2 should be utilized in an AFCS program limited to pilot assist features.



2.3 (Cont'd.)

The phasing of these various programs is shown in Figure 4. Required deliveries of components to carry out those programs are shown on the Master Schedule Chart, Figure 5.

2.4 Modification Status of the Arrow Weapon System in January 1961

It is evident that a higher system capability will be demonstrated late in 1960 than can be delivered in January 1961, because of the difference in lead times involved in incorporation of modifications into development aircraft and into the production line. During development programs, trials of modifications can often be accomplished by retrofit means with relatively short lead times.

To introduce a modification into a production article involves considerably longer lead time. In the case of the airframe or the electronics system for instance, approximately 12 - 14 months must elapse between the engineering of a fairly complex modification and aircraft acceptance. Aircraft 25238 in January 1961 will therefore incorporate necessary and desirable modifications which can be released to production before the end of 1959. The stage of development which will have been reached by that time is indicated by the green line on Figure 1. Development work accomplished after the deadline will probably indicate the need for further modifications and these may not be incorporated into production until aircraft subsequent to number 38. Minor modifications will have a shorter lead time and these, and "safety of flight" modifications, will of course be incorporated.



3.0 ANTICIPATED ADEQUACY OF COMPONENT DEVELOPMENT PROGRAMS

3.1 Airframe

Prior to the commencement of airframe flight testing, a ground test program has been carried out to permit flight testing to be undertaken with the acceptance of reasonable risks. By late 1959 basic airworthiness trials will have been conducted, weapon pack functioning and satisfactory missile launch will have been proved, antenna coverage will have been shown to be adequate and some airframe systems testing will have been done. In addition the compatibility of the airframe and the engine will have been proved.

In January 1961, airframe performance will be substantially as quoted in current performance reports. The airframe will be equipped with a useable Sparrow 2 installation and will have adequate antenna coverage.

3.2 Engine

A satisfactory ground, tunnel and flying test bed program precedes flight of the Iroquois engine in the Arrow 2.

The factors affecting compatibility of the engine with the airframe are: engine environment, effect of flow distortion and functioning of the engine controls. Full compatibility will be achieved by January 1961. Should trouble be encountered, say from vibration induced by flow distortion, a possible fix is a resetting of the engine to a lower rating. Thus it may be anticipated that although the optimum integration of engine and airframe may not have been realized by January 1961 a satisfactory



3.2 (Cont'd.)

engine installation for the restricted flight envelope previously described can be provided.

At this time the engines will be cleared by a 150 hour type test to the model specification.

3.3 Electronics System

Because of the time phasing of the design of the Astra system, it is considered to be the limiting component with respect to the Arrow Weapon System schedule. The YC131 is expected to fly with breadboard Astra fire control subsystem installed in July of 1958. Four months later, installation of a large portion of the final configuration system is scheduled to commence in an Arrow aircraft. Even optimistically, only 50 hours of Arrow/Astra flying will have been done by the Dec. '59 modification deadline. The introduction of more Arrow aircraft into the program will not assist because of the lateness of their availability. RCA states that it is therefore imperative that two additional flying test beds be added to the Astra program. If at all possible these test beds must have performance more closely approximating that of the Arrow than the YC131.

F101B aircraft are considered by RCA to be the most suitable vehicles for this purpose. Two additional fire control and navigation subsystems to install in them are required. These additional test vehicles will only achieve their purpose if they are available by June 1958. Immediate action to make these aircraft available to the program is mandatory.



3.3 (Cont'd.)

The Astra system proven capability in January 1961 will consist of the following:-

- (1) Fire control subsystem capable of manual attack with Sparrow 2 less the following:- I.R., Genie capability, full power (675 KWmin) and certain ECCM capabilities.
- (2) UHF Communication and homing
- (3) Radio compass
- (4) Intercomm
- (5) Air to ground IFF
- (6) D.R. Navigation computer (Manual inputs)

3.4 Missile

The Sparrow 2 missile will have a good development background on the CF-100, prior to commencing its development program on the Arrow. Apart from environmental testing and controlled test vehicle firings, which do not require electronic systems to be fitted to the test aircraft, the remainder of the program on the Arrow is paced by progress of the Astra system.

It is important to note that the missile program takes place almost exclusively in 1960, the firings in the latter half, and that the program can not tolerate any slippages in commencement dates.

If planned progress is realised, and systems are available on the scheduled dates, it is anticipated that there will be no serious incompatibilities between the missile, the airframe and the Astra system in



3.4 (Cont'd.)

January 1961 over the flight envelope previously described. The firings which will be conducted on aircraft 11 and 12 will expand knowledge of missile performance at higher altitudes and launch speeds. The missile capability at these altitudes and launch speeds will of course be that inherent in the basic design.

4.0 ANTICIPATED CAPABILITY OF THE ARROW WEAPON SYSTEM AT THE TIME OF INITIAL SQUADRON INTRODUCTION

4.1 Minimum Weapon System

In January 1961 it can be expected that the Arrow Weapon System will have a capability not less than outlined below:-

- (1) The aircraft component of the system is expected to have a performance not less than as follows:- The speed and height potential, the manoeuvre-ability, the radius of action, and take off and landing characteristics are likely to be as shown in Avro Periodic Performance Report #13. The sustained maximum speed is likely to be limited to correspond to a kinetic recovery temperature of 160°F. Excursions of limited duration at speeds corresponding to 250°F may be made, excepting that the speed shall never exceed 700 knots EAS.
- (2) A basic fire control capability with Sparrow 2 Mk 1 missiles using manual attack methods.
- (3) UHF communication and homing, intercomm, air to ground IFF and radio compass.



4.2 Prospects

Assessment of minimum weapon system capability took into account realistic minimal time allowances for development problems. It is quite possible that the program will progress more favourably and in fact the Arrow in January 1961 may have improved capabilities over those predicted. Conversely, the contingencies do not provide for catastrophies such as attrition of development aircraft which would obviously affect rate of progress.

5.0 ARROW WEAPON SYSTEM POTENTIAL (PK) AT THE TIME OF INITIAL SQUADRON INTRODUCTION

It is not considered feasible for the contractors to guarantee a specific system capability in terms of (PK) or similar parameter. It is suggested that the contractors should establish the potential of the weapon system and assist the RCAF in their evaluation of the weapon system.

The method of establishing system potential is well known, and consists of establishing a mathematical model of the system. This model is then matched with a corresponding model of the target on a simulator and potential figures are obtained. The accuracy limits of this process are of course determined by the accuracy of the assumptions made and the coefficients used.



5.0 (Cont'd.)

It is proposed that the Co-ordinating Contractor, in conjunction with the Associate Contractors, make a study of the Arrow Weapon System potential by use of mathematical models, and that the assumptions made and coefficients used be validated by data obtained during development test programs.

The data required to establish system potential is a series of numbers which specify performance of the components. Airframe parameters will be available based on data correlated with flight test results on aircraft 1, 2 3, 6 and 8. Engine performance will be determined on aircraft 7. Astra performance parameters will be established on aircraft 4, 5 and 9. Missile performance will be described by tests on aircraft 3, 10, 11 and 12. The remaining performance, which will not have been determined in the contractors component development programs, will therefore be the airframe thrust/drag type parameters. It is proposed that these parameters should be checked by CEPE on aircraft 16 and 17. The methods used by CEPE should have the concurrence of the airframe contractor.

In summary, it is proposed that contractors not be called upon to guarantee weapon system performance. They should however establish potential by use of mathematical models and flight test data, and assist the RCAF in evaluation of the weapon system.



6.0 WEAPON SYSTEM DEVELOPMENT AND DEMONSTRATION

Weapon System Demonstration has been much discussed but not clearly defined. A proposed approach is outlined in this section.

In general, Associate Contractors will prove compliance with provisions of their specifications during component development programs, however some requirements such as states of readiness, aircraft turnaround and mission performance can not be readily proved in component programs.

The Weapon System Demonstration should not in general be used to obtain "proof of compliance" except for items, such as those already mentioned, which can not be readily proved in other programs.

System potential will be established using the mathematical model and data obtained during component development and RCAF Phase 4. The Weapon System Demonstration should not in general be used to gather data for system evaluation.

It is proposed that the aircraft 13 and 14 allocated to this program be operated in a fashion similar to that in which squadron aircraft will be operated. After due allowance of time for correction of minor inconsistencies and incompatibilities, it is proposed that these aircraft engage in a demonstration program. This program will consist of flying simulated missions against drone or towed targets. The principal purpose of the program will be to demonstrate in a qualitative fashion that the various major components are



6.0 (Cont'd.)

working together as a system. A quantitative aspect could be given to this program by the method adopted by the U.S. Navy for such programs. In their case up to twenty-eight missions are flown, to cover seven different interceptor / target configurations. At least two successful attacks are required in each configuration.

In the course of carrying out this program, proof of compliance will be obtained for such things as states of readiness and turnaround. It is proposed that the program be under the direction of the Arrow Weapon System Co-ordinator and be fully staffed by associate contractors' engineering, flight testing and servicing personnel. A limited quantity of instrumentation to record major interception and attack parameters could be fitted so that results can be compared with the results predicted by the mathematical model.

7.0 CONCLUSIONS

7.1 It was concluded that the probability of successful development of an Arrow Weapon System having a useful mission capability (as defined in Item 4.0) for squadron introduction in January 1961 is high.

7.2 It is quite possible that the Arrow delivered in January 1961 will have a greater capability than that specified by Item 4.0 and it is apparent that system capability will improve rapidly during the subsequent 6-12 month period.



- 7.3 The development program required to achieve the January 1961 objective is very stringent and will tolerate no extended administrative delays nor accommodate any major technical set backs.
- 7.4 Provision of additional flying test beds for the Astra system development is essential.
- 7.5 The contractors can not guarantee a capability for the Arrow Weapon System in terms of kill probability. System potential should be established by the contractors through a mathematical model plus substantiating data derived from the test programs.

8.0 RECOMMENDATIONS

- 8.1 It is recommended that this report be approved and that the contractors and government agencies involved be instructed to take immediate action within scope of existing authority to implement its provisions.
- 8.2 It is recommended that negotiations be initiated at once to provide additional flying test beds for Astra development.
- 8.3 It is recommended that immediate action be taken to provide the Astra systems for installation in the test beds of 8.2 above and in Arrow Aircraft No. 25210.

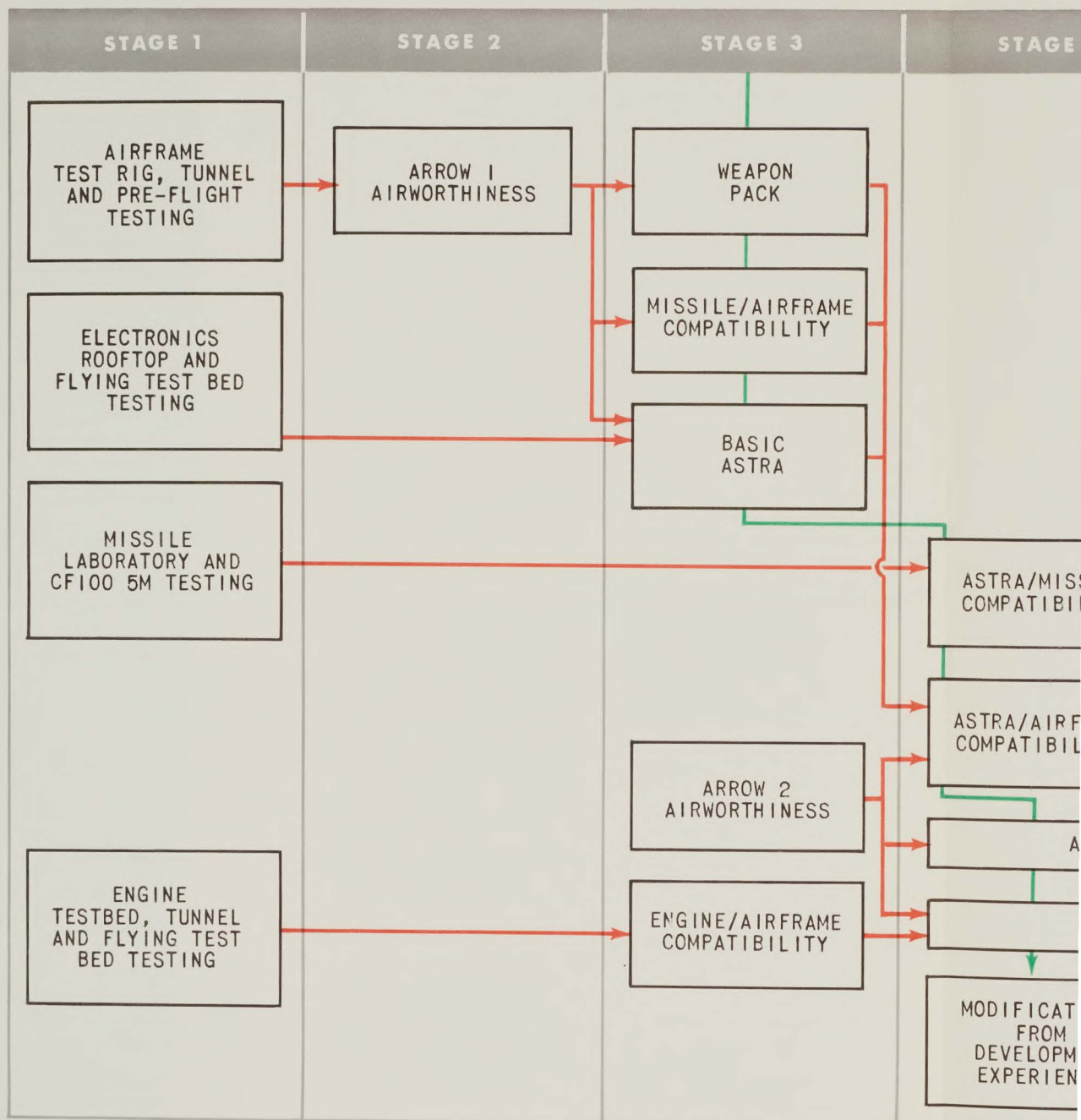
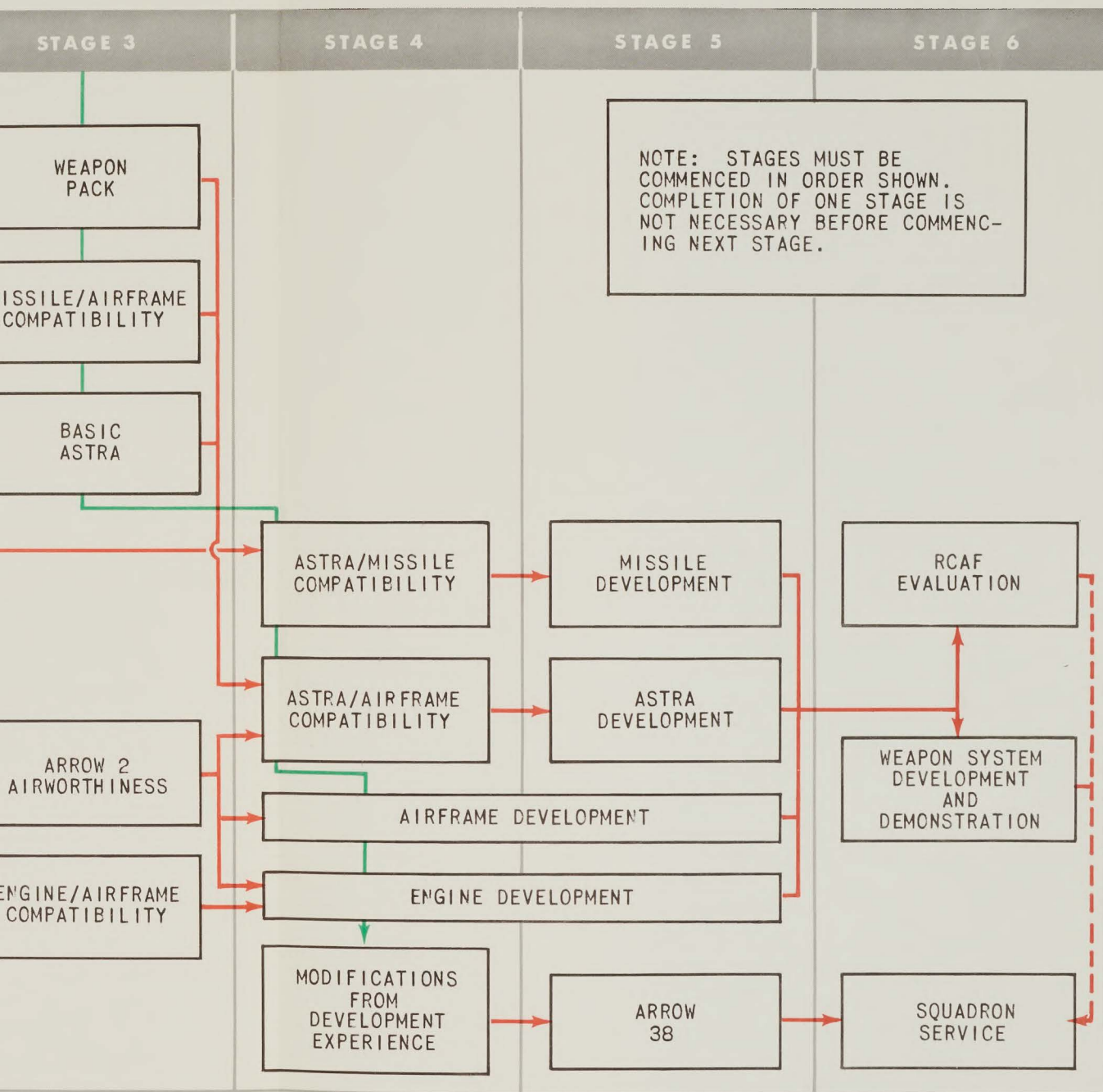


FIG.1 ARROW WEAPON SYSTEM - DEVELOPMENT



ARROW WEAPON SYSTEM - DEVELOPMENT STAGING

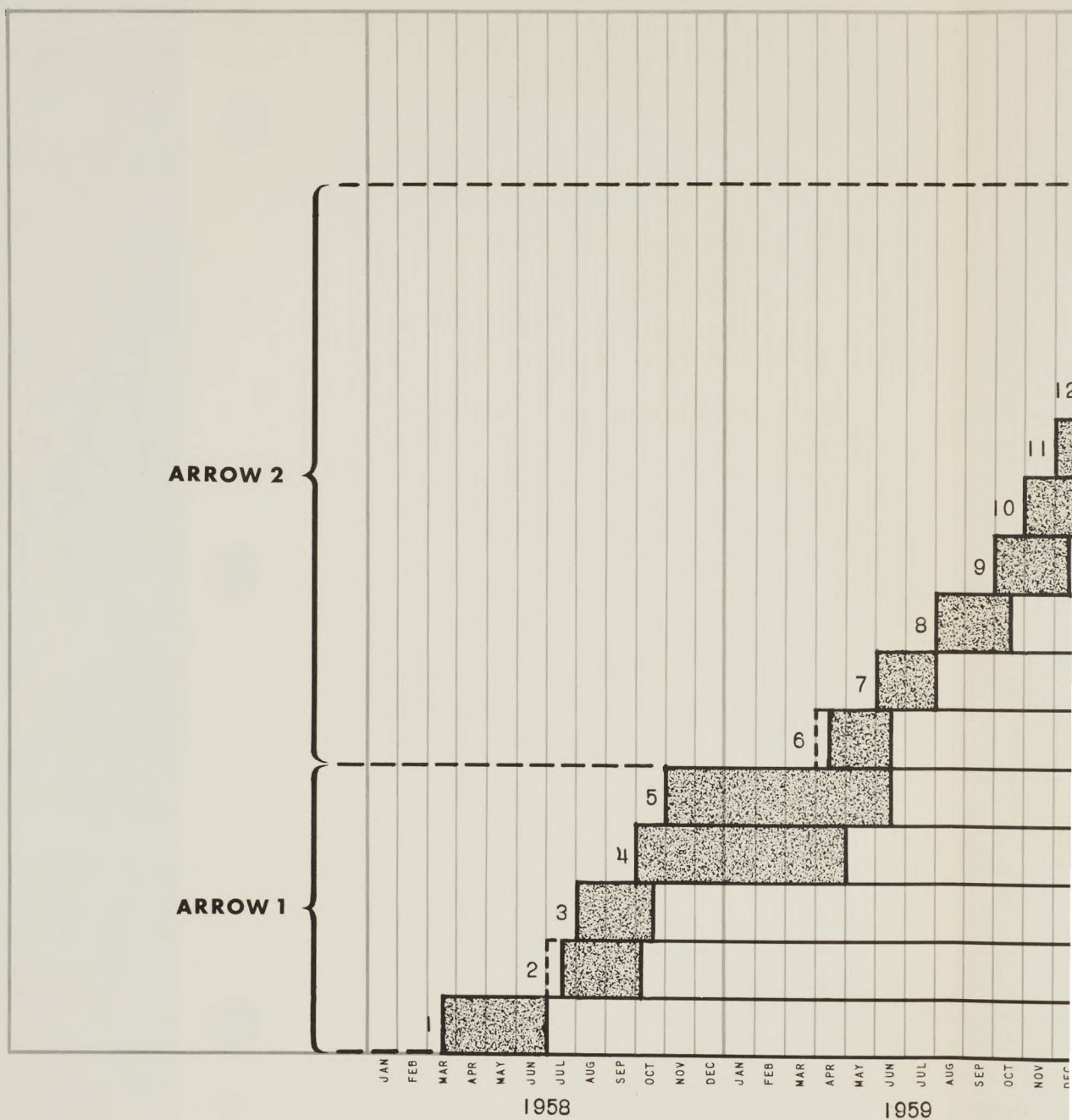
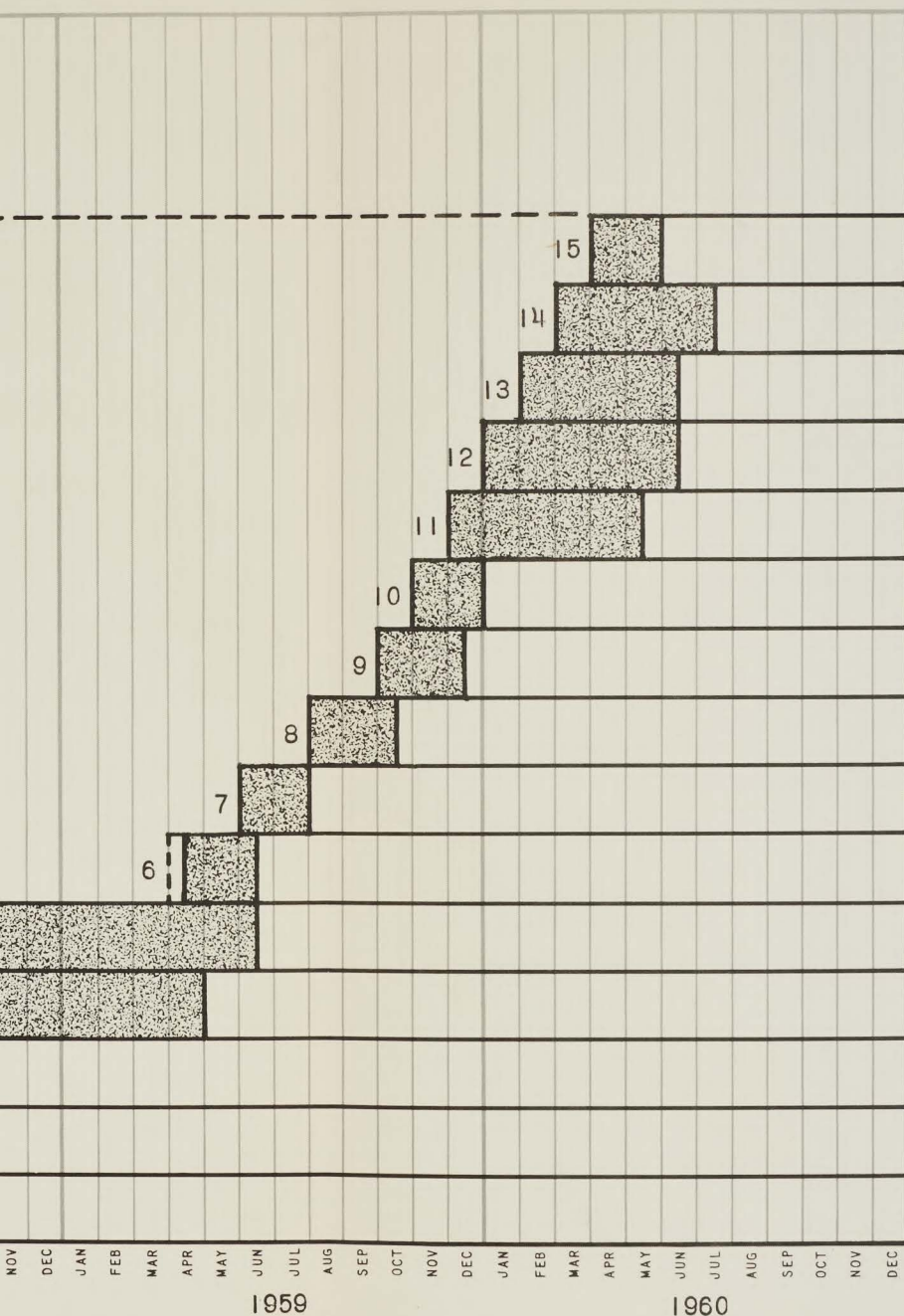


FIG. 2 SCHEDULE OF AIRCRAFT ACCEPTANCE AND COMMENCEMENT OF



NOTE:

DURING SHADED PERIODS
AIRCRAFT ARE BEING
MODIFIED AND BROUGHT
UP TO A STANDARD WHERE
THEY ARE READY TO
COMMENCE THEIR PROGRAMS.

ANCE AND COMMENCEMENT OF USEFUL WORK (CONTRACTOR AIRCRAFT ONLY)

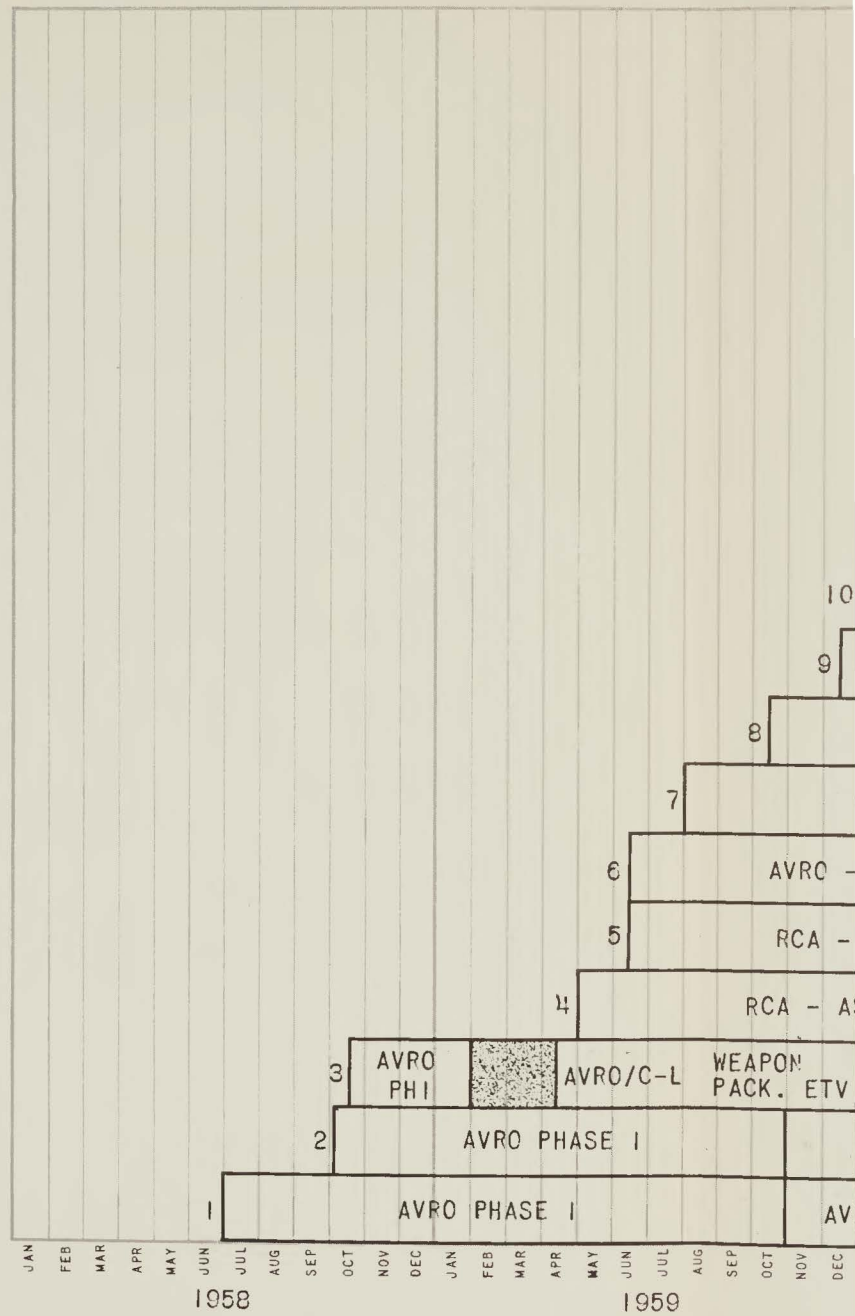
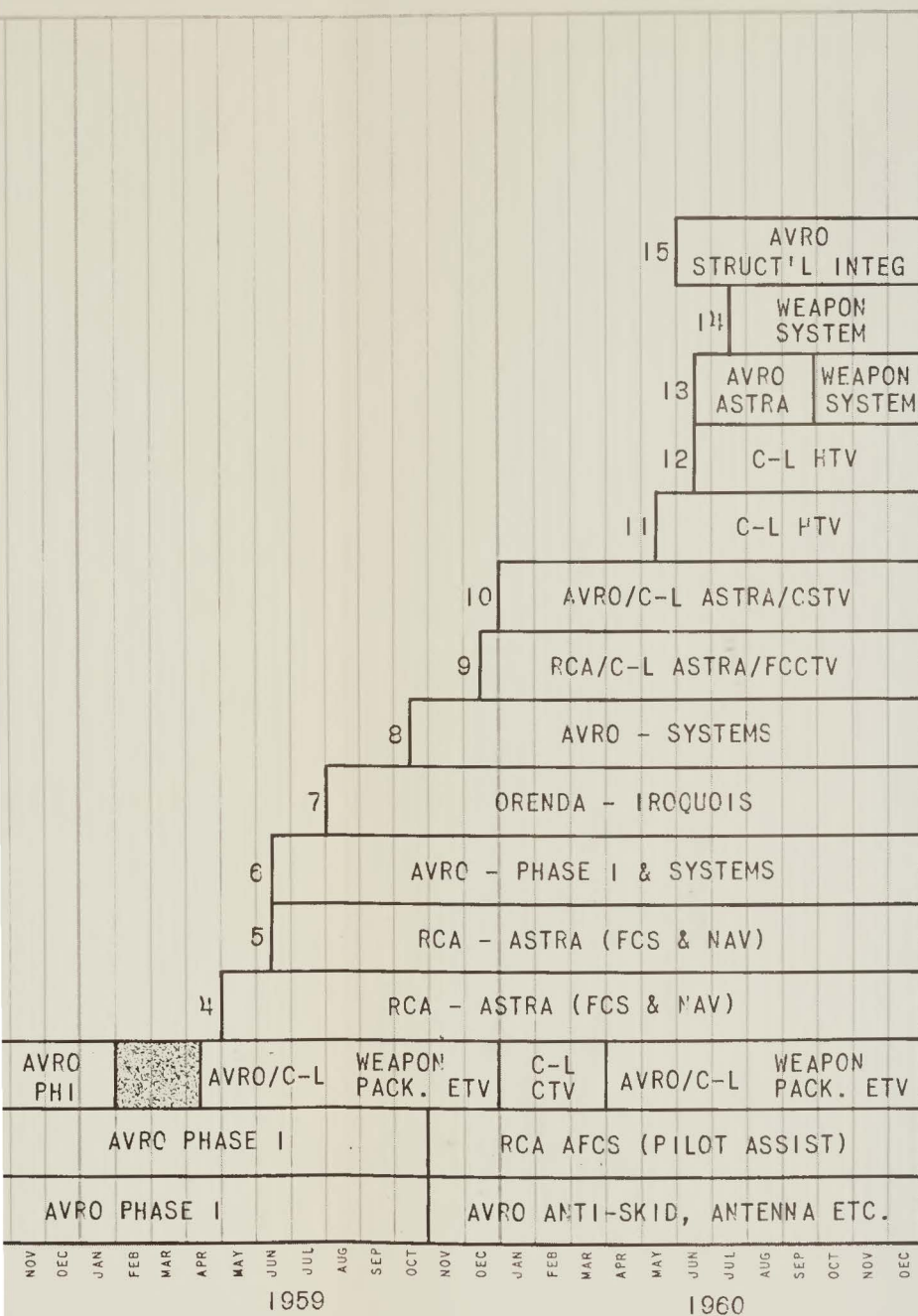


FIG. 3 PROGRAM/AIRCRAFT ALLOCATI



PROGRAM/AIRCRAFT ALLOCATION CHART

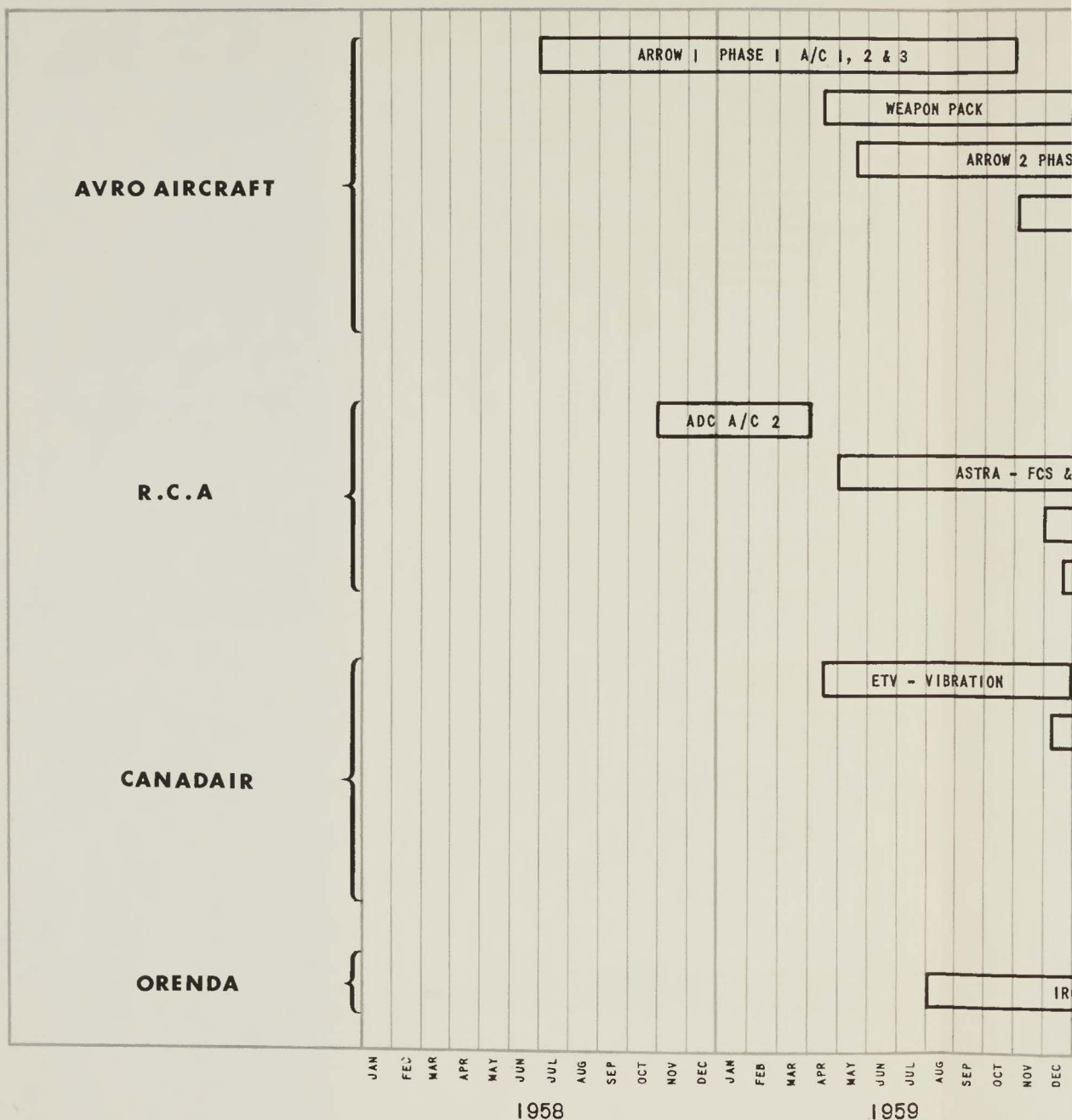
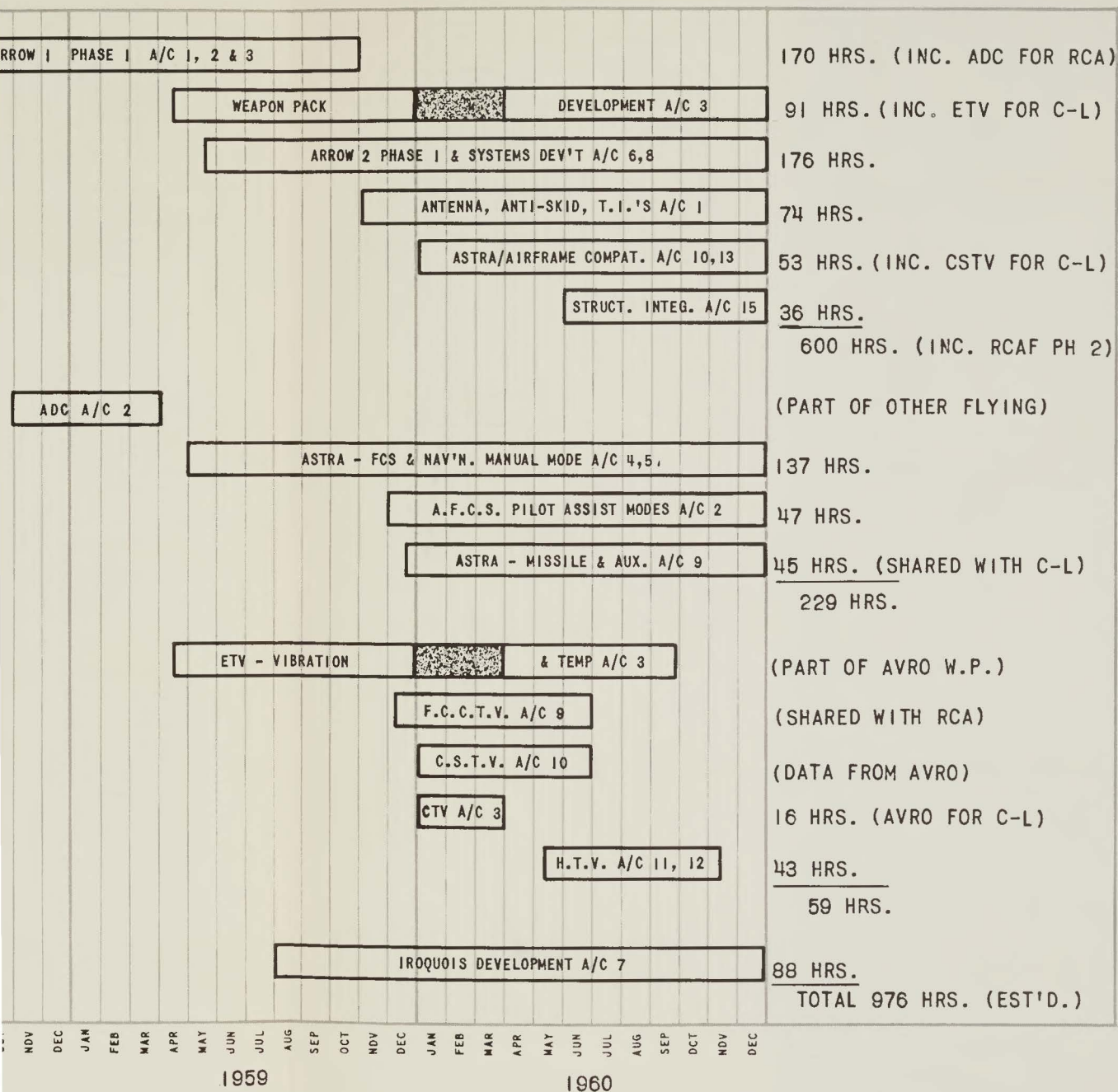


FIG. 4 ARROW WEAPON SYSTEM - DEVELOPMENT PRO



ARROW SYSTEM - DEVELOPMENT PROGRAM PHASING CHART



AIRCRAFT	ACCEPTANCE DATES			1		1	1		1	1	
	AIRCRAFT NUMBER			1		2	3		4	5	
ENGINES	DEL'VY. OF ENGINES TO AVRO								2		2
	SPARE ENGINES										
ELECTRONICS	DEVELOPMENT	PARTIAL SYSTEMS FOR A/C NO.							1		1
		INCOMPLETE SYSTEM FOR A/C NO							6		7
		SUB ASTRA SYSTEM FOR A/C NO							(CNI PORTION OF ASTRA)		
		ASTRA SYSTEMS FOR A/C NO									1
	PRE PROD'N	PARTIAL SYSTEMS FOR A/C NO									4
		INCOMPLETE SYSTEMS FOR A/C NO							THESE SYSTEMS ARE PART OF ASTRA SYSTEMS AND HAV SAME COMPONENT MAKEUP AS PARTIAL SYSTEMS		
		FOR TEST BENCH							THESE SYSTEMS TOGETHER WITH INCOMPLETE SYSTEMS DELIVERED EARLIER MAKE UP ASTRA SYSTEMS		
		SUB ASTRA SYSTEMS FOR A/C NO							ASTRA SYSTEMS ARE SYSTEMS AS DEFINED IN PARA 3.3 OF REPORT		
		FOR TEST BENCH									
		ASTRA SYSTEMS FOR A/C NO									
		FOR TEST BENCH									
	QUALIFICATION PRODUCTION								1	2	2
									2	2	2
MISSILE	SAV TYPE 1 (NON FIREABLE)								28 DELIVERED		
	SAV TYPE 2 (FIREABLE)								74 DELIVERED		

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV

1958

FIG.5 ARROW WEAPON SYSTEM MASTER SCHEDULE CHART OF DELIVERY

[illegible]



National Research Council
Canada

Conseil national de recherches
Canada

Canada Institute for
Scientific and Technical
Information
J.H. Parkin Branch

Institut canadien de
l'information scientifique et
technique
Annexe J.H. Parkin

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