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REPORT OF A VISIT TO WADC
AND HAC, 4 TO 16 DEC 58
TO ASSESS THE ARROW PROJECT

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REPORT ON A VISIT TO WADC AND HAC

4 DEC 58 TO 16 DEC 58

Ottawa, Ontario.
19 December, 1958.

INTRODUCTION

1 A team of technical officers visited WADC, Wright Patterson AFB and Hughes Aircraft Company (HAC) from 4 Dec 58 to 16 Dec 58. The purpose of the visit was to examine and report upon the status of the AVRO/HAC project on the Arrow Weapon System. The team consisted of:

W/C DA Maclulich	DIE Eng
S/L ACW Barrett	DATel
S/L JK Young	AAWS
S/L JJ Collins	DArmEng
S/L EW Ryan	AAWS
F/O WS Smith	DArmEng

2 Problem areas are discussed in the main paper. Detail under these problem areas and description of the weapons system are contained in the appendices listed under para 49.

FLIGHT TEST

3 Detail on the discussions at WADC, Hughes Aircraft Company and (unofficially) at Douglas Aircraft Company is contained in Appendix "A". The following problem areas are evident from consideration of this detail:

(a) Management Control Charts for F106 A and B Program. A current copy is held in the AMTS Technical Library. These charts are revised quarterly, and arrangements should be made to have the revisions sent automatically to the AMTS Technical Library.

(b) AVRO/Convair Liaison Arrangements. The Arrow flight test program must take maximum advantage of F106/MA-1 flight test data. The F106 WSPO at WADC advises that authority is needed from Headquarters USAF to release Convair data to the Canadian Government and its contractors. Therefore, action is required by AFHQ and/or DDP to request this authority. (See Appendix "A", para 6.)

(c) Targets. No arrangements have been made for targets for the Arrow flight test program. Decisions, funding and supply arrangements are required when the flight test program is approved. (See Appendix "A", para 10 and Appendix "U".)

(d) Instrumented MB-1. Telemetry packs produced by Sandia Corporation (the warhead contractor) are required to measure warhead accelerations. In addition, ASCOP-PDM/FM telemetry installations used by Douglas should be considered for use in this program. (See Appendix "A", paras 11(a)(iii), 31 and 32.)

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by authority of ....(date)..........
Signature .... Rank ....

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(e) Pit Drops. Discussions at Hughes indicated that Convair had completed an extensive pit drop program prior to flight test, and then between each flight a drop to check the ejection gear was required. On the other hand, Macdonnell Aircraft Company did not eject into a pit between each firing flight. These requirements should be examined at Holloman AFB to determine the best approach for the Arrow program. (See Appendix "A", para 11(a)(vi).)

(f) Objectives of Flight Test Program. Based on results of F106 flight test, the following objectives appear desirable:

(i) Standard deviation of errors from fire control system (including pilot steering errors and radome) - 15 milliradians in azimuth and 15 milliradians in elevation.

(ii) Standard deviation of separation and launch errors - 20 milliradians.

(g) Limited Flight Test Envelope. The results of discussions with WADC, Hughes and Douglas indicate that the initial objectives for a firing program should be those which can be achieved by 1960. Thus, as a first approach, the following limitations appear practical:

(i) Altitude - 30 to 50,000 feet.

(ii) Speed - M1.2 to M1.5.

(iii) Load Factors - 0.8 to 2.0.

(h) USAF Special Weapons Systems Safety Group. This group is composed of high-ranking representatives from all USAF Commands and the Inspector-General Branch. It is examining all present nuclear carriers and is requesting changes in present and future designs. Liaison should be established by the RCAF with this group. (See also para 12 of Appendix "E".)

(j) Douglas/AVRO Liaison. A visit clearance exists for AVRO engineers to visit Douglas on the MB-1, but not vice versa. An unimpeded two-way channel for personnel and data needs to be arranged.

(k) Instrumentation. Details on this problem are contained in paras 29 to 33 of Appendix "A".

(j) Ranges. Adequate ranges to enable accomplishment of an Arrow flight test program must be made available.

SCHEDULES

4 The following schedules are contained in Appendix "B":

(a) MA-1/CF105 Schedule (HAC Plan).

(b) F106A Program Summary.

(c) F106B Program Summary.

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(d) F106A Flight Test Program (4 Charts).

(e) F106B Flight Test Program.

(f) F106A and B Aircraft and Weapon Control System (AWCS) Program (2 charts).

(g) F106A Offensive Armament Program.

(h) AWCS and Armament Development (AAD) Program.

(j) Support Program for MA-1/CF105 Program.

(k) Support Program for GAR 3A/4A/CF105 Program.

(l) Accession List of MA-1/GAR3A/4A Documents in AMTS Technical Library.

MA-1 INSTALLATION IN ARROW

5 Two major problem areas exist in the MA-1 Installation in Arrow airframe No. 25202:

(a) The provision of 400 cycle power (see paras 17-21 and Appendix "H").

(b) The configuration of the two cockpits (see Appendix "P").

6 Other problem areas examined in Appendix "C" are:

(a) Stable platform. (Also see Appendix "F".)

(b) Intercommunications (Also see Appendix "G", para 26.)

(c) Pressurization.

(d) Waveguide switching.

(e) Radio Compass inputs.

(f) Antenna multiplexing.

7 Discussion of other installation problems are contained in other parts of this report. References to these discussions are:

(a) Safety interlock requirements (para 12, Appendix "E").

(b) Preflight and acceptance data for F106 (para 16, Appendix "E".)

(c) Computer Programming (paras 22-29, Appendix "E").

(d) Installation of the Horizontal Situation Indicator in the Rear Cockpit (para 11 and Appendix "F").

(e) Radome (para 24 and 26(b)).

(f) Optical Sight (Appendix "K"). This sight is large and would obstruct pilot vision in the Arrow.

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CURRENT MA-1 STATUS AND IMPROVEMENTS

8 A summary of the current MA-1 status and planned improvements is contained in Appendix "D". In addition, Appendix "J" contains details on MA-1 status and improvements.

FIRE CONTROL SYSTEM, ARMAMENT AUXILIARIES AND COMPUTER

9 Detail on the MA-1 Fire Control System, the armament auxiliaries and the computer will be found in Appendix "E". With regard to the status of the F106 program, the consensus of the people contacted at WADC was that the present F106 A and B program (184 aircraft to end of FY 1959) is on firm ground. A decision on the FY 1960 buy will not be made until June 1959 and will have an impact on MA-1 development and production. (For more information on this subject, see Appendix "J" in addition to para 2 of Appendix "E".)

10 In Appendix "E" will be found a description of the remote scope recorder, some safety interlock requirements, and cockpit controls references in addition to some F106 pre-flight and acceptance data.

INSTRUMENTS

11 The subject, "Instruments", includes the Air Data Computer, the Gyro Reference System, Flight Instruments and the Automatic Flight Control System. The following problems are discussed in Appendix "F":

(a) Adoption of ARDC (vertical scale) Flight Instruments.

(b) Installation of the Horizontal Situation Indicator.

(c) Canadian facility for map film strips.

(d) Automatic navigation.

(e) Automatic response to data link control.

(f) Automatic attack.

COMMUNICATIONS, NAVIGATION AND LANDING (CN&L)

12 Appendix "G" contains detail on the CN&L system which includes UHF Communications, UHF Direction Finding, Instrument Landing System, Tacan, Air-to-Ground IFF, Air-to-Air IFF, and Intercommunications.

13 The basic circuitry of the CN and L equipment incorporated in the MA-1 System resembles that of certain specific stock items already in general use in the RCAF and other services. However, the unique method employed by Hughes Aircraft Company and their subcontractors in packaging the equipment to meet a systems concept, with built in test, fail-safe, and space/weight saving features would make it expensive in time and money to make substitutions.. The form factors and electrical characteristics of plant, repair depot, and squadron test equipment caters for systems checking on the basis of the HAC configured equipment.

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14 The major changes to the CN and L equipment contemplated by the USAF are the replacement of Frequency Division type data link by Time Division type data link during the period 1962-63 and changes to the IFF equipment to make it compatible with the Mod 12 crypto system which may be brought into use at that time.

15 The proposed CN and L package of the MA-1 System will be compatible with the Canadian environment when Tacan and Data Link ground facilities are available. However, there has been no action yet to make provision on the computer for an automatic correction input from doppler.

16 The present system does not include a medium frequency direction finding equipment. However, provision could be made for the manual insertion to the computer of MF/DF information obtained from a conventional radio compass receiver which is already incorporated in the CF105 Aircraft.

ELECTRIC POWER SUB-SYSTEM

17 This sub-system presents one of the major problems in the MA-1/ Arrow installation and, therefore, Appendix "H" is summarized below.

18 At present the F106 aircraft has a Sundstrand constant speed drive carrying four generators, two for aircraft power and two for the MA-1 system. The latter two are triple output generators producing two kinds of AC power (400 cps and 1600 cps) and four voltages of DC power. The system is fully loaded. Scheduled improvements to the MA-1 require over 4 KW more power; therefore, a new power system has been designed using 400 cps. Nearly all the MA-1 units have been redesigned to operate on 400 cps. It is advantageous to use the 400 cps MA-1 for the CF105 and thus retain the main power supply already engineered into the Mark 2 aircraft.

19 Many parts of the prototype 400 cycle MA-1 have been borrowed for the CF105 and already shipped to AVRO. The Hughes production plant at El Segundo is supplying a production MA-1 on the AVRO contract to be modified, and from this the borrowings will be returned. The new system distributes 400 cycle power to the MA-1 system by an AVRO junction box. Certain amounts of other sorts of power are produced internally in the new MA-1C system.

20 The MA-1 system can operate past transients of 102-124 volts but requires 108-120 volts in steady state. Frequency must be controlled to ± 1 percent which agrees with the Avrocan Specification E-500, but an effort will be made to improve this. Variation in frequency causes the same percentage variation in computer time base and hence in system output.

21 In the MA-1 the 1600 cycle power source allows operation of the four missiles only in a staggered sequence, thus increasing preparation time and cutting into the placement diagrams. However, in the MA-1C for the Arrow aircraft, parallel, simultaneous preparation of four missiles will be permitted.

MA-1 IMPROVEMENTS AND ECCM

22 Detail on the MA-1 improvement, including counter countermeasures (CCM), program is contained at Appendix "J". The current CCM capability provides a home-on-jam feature, it permits operation in a modified close control mode if SAGE becomes saturated; the magnetron is tunable and edge tracking is provided, as in the MG-2; range is extrapolated if jamming does not commence until after lock-on has been achieved; and the GAR-3A is provided with home-on-jam and edge tracking.

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23 By January 1960, a sniffer circuit, random prf, antenna angular memoray, and silent lobing will have been added. It is claimed that random prf and leading edge tracking will counter range gate stealers. The silent lobing technique will counter (HAC hope) inverse gain repeating jammers. A range gate stealer, to be effective, will be forced to short delay (somewhat less than 0.2 micro seconds) repeating or high-power, wide-pulse operation, to achieve AGC capture. A conical scan jammer will be forced to swept or gated frequency operation.

24 Further features will be introduced to production in January 1961, provided such production is authorized by USAF by next summer. Master oscillator power amplifier (MOPA) may provide protection against spot jamming, but not against wide-band (cascaded) barrage jamming equipment. It may be noted that the MOPA frequency range design objective will pose a severe radome problem and this could be the program pacing item. Antenna angular memory is expected to provide immunity against chaff on a beam attack. A passive ranging technique has not yet been accepted by WADC. The accuracy of such a technique will not be sufficient for firing of MB-1 weapons, may be accurate enough for GAR weapons, but may only be sufficiently accurate for a nuclear-warhead GAR.

25 Further CCM features can only be added subsequently to Jan 61 on a backfit basis.

26 Thus the major problems posed by the USAF/HAC CCM program are two-fold:

(a) Careful scheduling of the Arrow program to ensure as far as possible that improvements to the MA-1 AWCS are picked up from production rather than expensive retrofit.

(b) Ensuring that the radome produced for the 1961 Arrow makes the best compromise between:

(i) Aerodynamic performance.

(ii) Optimum power transmission over the required MOPA bandwidth.

IR SUB-SUSTEM ANDOPTICAL SIGHT

27 Details on IR sub-systems and the optical sight are contained in Appendix "K".

HUGHES FIELD SERVICE AND SUPPORT DIVISION

28 Details on the Hughes Field Service and Support Division are contained in Appendix "L". The following problems arise:

(a) Close liaison with HAC Field Service and Support staff will be required to ensure that RCAF requirements will be met with a minimum of cost and delay.

(b) Maintenance Depot. The question of what depot facilities the RCAF will require must be considered. HAC are prepared to offer technical or administrative assistance in setting up such a facility.

(c) (i) Technical representatives. During the first six months of operation each F106 squadron will employ 17 Hughes' field engineers to assist in squadron maintenance of the MA-1. After two years of operation, this number will be reduced to four engineers attached to the base

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permanently.
(Note: ~~that~~ these figures do not include the three technical representatives who are attached permanently to the base for airmen trade training.)

(ii) With the retention in the RCAF of relatively large numbers of trained technicians with experience on fire control, communications and aircraft control systems, a substantial reduction in the number of technical representatives required by the RCAF can be expected.

MAINTENANCE, TEST EQUIPMENT, GROUND HANDLING EQUIPMENT

29 Because this subject represents a major consideration in the Arrow Weapons System, Appendix "M" is summarized below.

Maintenance

30 The maintenance concept on the MA-1 was defined by consideration of the following factors:

(a) Squadron aircraft operate on a short scramble-time basis, so not more than five minutes is available for the serviceability check-out.

(b) The USAF will continue to lose large numbers of trained technicians, so automatic self-checking circuitry is incorporated into the equipment wherever possible.

31 Maintenance on the flight line is limited to checking the system on a "Go-No-Go" basis, fault finding and box replacement at the electronic box level, and making a minimum number of adjustments and alignments. The test is designed so that the confidence level in a "go" signal is such that there is 75% to 85% probability of successful mission completion .

Test Equipment

32 A major item of test equipment is the Mobile Automatic Radiation Tester (MART). The MART is atrailer fitted with receiving and low-powered transmitting equipment. The trailer is designed for unattended operation. In respons~~ible~~e to a system interrogating signal from an aircraft on the flight line, the MART transmits signals which test the aircraft's UHF equipment, ILS equipment, data link receiver, automatic UHF D/F facility, TACAN receivers, IFF group and a portion of the computer.

33 Electrical power for the MART can be provided by a gasoline driven motor generator, or may be obtained from commercial power outlets. Power specifications are: 12.5 KVA, 120/208 volts, three phase, four wire, 60 cycles.

34 Seven maintenance test stands are required in the shop area. The stands are designed to conform with the rack configuration in the aircraft. Thus a suspect item of equipment can be removed from the aircraft, plugged into the appropriate area on the stand, and tested for serviceability.

35 The MA-1 digital computer plays an important part in the maintenance procedures. The tactical magnetic drum is removed from the computer and a test drum is inserted for shop maintenance. The computer is programmed so that each of the sub-systems (radar, flight control and measurement, communications - navigation, computer, and power) are tested in detail. The complete shop test takes six hours to perform.

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Ground Equipment

36 Cooling Air. The MA-1 requires 45 pounds per minute~~s~~ of cooling air at 70°F at equipment inlets. The cooling air must be provided from a ground source whenever the equipment is operated in the aircraft on the flight line or in the dock/shop maintenance area. AFHQ Tech Library Reference No. 8251 describes an equipment which Hughes Aircraft Co. has found satisfactory.

37 Ground Electrical Power. The MA-1, with all planned improvements, will require 22 KVA of electrical power. Power specifications are contained in Appendix "H".

TRAINING - PERSONNEL

38 Details on training are contained in Appendix "N".

TRAINING AIDS

39 Details on training aids are contained in Appendix "O".

COCKPIT SUB-SYSTEM

(Details are in Appendix "P")

40 The cockpit sub-system consists of those parts of the MA-1C AWCS which are located in the two cockpits. These include an "F" scope in the front cockpit, and a "B" scope and Horizontal Situation Indicator in the rear cockpit.

MA-1 ECP's (ENGINEERING CHANGE PROPOSALS)

41 Details on ECP's are contained in Appendix "Q".

MISSILES

(Details are in Appendix "R")

42 The Falcon GAR-3A (which is a semi-active radar homing missile) and the GAR-4A (which is an infrared homing missile) are improved versions of the GAR-3 and GAR-4, respectively. The GAR-3 and GAR-4 are limited in their operational use by temperature and humidity restrictions. They use an ethylene oxide power supply which requires a long warm-up period prior to missile launch. The GAR-4 has very poor background discrimination characteristics and, as a result, frequently loses its target. The GAR-3 is being produced in limited quantities only and all GAR-4 production was stopped in May 58.

43 To overcome the problems and deficiencies in the GAR-3 and GAR-4, an extensive redesign and development programme was instituted to produce improved models of both missiles. Production of both the GAR-3A and GAR-4A is scheduled to begin in Aug 59. Additional information on the missiles and the production schedules is available in Appendix "R" to this report.

44 Certain problem areas which require staff action, planning or co-ordination exist in the Falcon portion of the Arrow/MA-1 programme. These are:

(a) The availability of and procurement arrangements for test missiles to meet the Arrow flight test programme.

(b) The availability of and procurement arrangements for tactical missiles for combat stocks.

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(c) The availability of and procurement arrangements for missile test equipment.

(d) The availability of and procurement arrangements for suitable targets for the second phase of the Arrow programme.

(e) The study and provision of suitable missile check-out and storage facilities at ADC bases.

(f) The provision of funds for the necessary procurement in items (a) to (e) above.

(g) Provision of additional telemetry decommutation equipment at Cold Lake for the second phase of the Arrow programme, due to incompatibility between the missile telemetry and the ground station.

SECURITY

45 Details on security are contained in Appendix "S".

COMPANY ORGANIZATION

(Details are in Appendix "T")

46 Hughes Aircraft Company have organized an Arrow Task Force at Culver City. Mr. Joe Scanlan is the manager of this task force and should be contacted initially on Arrow problems of concern to Hughes.

TARGETS

47 Details on targets are contained in Appendix "U".

MA-1 AND GAR-3A/4A DOCUMENTS

48 An MA-1 and GAR-3A/4A Accession List of documents in the AMTS Technical Library is in Appendix "V".

APPENDICES

49 The following appendices are attached to this report:

(a) Appendix "A" - Flight Test

(b) Appendix "B" - Schedules

(c) Appendix "C" - Installation CF105

(d) Appendix "D" - Current MA-1 Status and Improvements

(e) Appendix "E" - FCS, Armament Auxiliaries and Computer

(f) Appendix "F" - Instruments

(g) Appendix "G" - Communications, Navigation and Landing

(h) Appendix "H" - Power Supply

(j) Appendix "J" - MA-1 Improvements and ECCM

(k) Appendix "K" - IR Sub-system and Optical Sight.

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(l) Appendix "L" - Field Service and Support

(m) Appendix "M" - Maintenance, Test Equipment and Ground Handling Equipment

(n) Appendix "N" - Training - Personnel

(o) Appendix "O" - Training Aids

(p) Appendix "P" - Cockpit

(q) Appendix "Q" - ECP's

(r) Appendix "R" - Missiles

(s) Appendix "S" - Security

(t) Appendix "T" - Company Organization

(u) Appendix "U" - Targets

(v) Appendix "V" - Accession List

APPENDIX "A"
TO S1038CN-180 (AAWS)
DATED 19 DEC 58

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FLIGHT TEST

F106A and B/MA-1/ASQ-25 Program

1 Complete detail on the flight test program and delivery schedules for the F106A and B/MA-1/ASQ-25 is contained in the F106 A and B Management Control Charts, dated 2 Oct 58. These Management Control Charts are registered in the AFHQ Technical Library. The charts are issued quarterly and it is recommended that 1RU be advised to send them automatically to the AFHQ Technical Library.

2 The following summarizes the status of the F106 A and B program:

(a) First delivery: F106A - Dec 56; F106B - Apr 58.

(b) Commulative delivery to Sep 58: F106A - 27; F106B - 3.

(c) First production aircraft: F106A - Sep 57; F106B - Apr 58.

(d) First operational aircraft: F106A - Jan 59; F106B - Nov 58.

(e) First wing equipped: F106A - Sep 59; F106B - Jun 59.

(f) Deliveries by Sep 59: F106A - 106; F106B - 28.

(g) Delivery rate of 15/month for F106A - Aug 59.

(h) Delivery rate of 3/month for F106B - Sep 59.

(j) Category II Testing: F106A - Aug 58 to Jan 60 (11 aircraft).
F106B - Dec 58 to Apr 59 (3 aircraft).

(k) Category III Testing: F106A - Aug 59 to Jan 60 (21 aircraft)
F106B - Apr 59 to Jan 60.

3 <u>AAD Program on F106A and B</u>. In addition to the category I to III testing undertaken on the F106 A and B program, an AAD (AWCS and Armament Development) program has been arranged. This program does not include ballistic and separation trials, but data is gathered to supplement information obtained on ballistic and separation trials. Col. Kruge is the Test Director for the AAD program at Holloman AFB, while Col. Housley is the Test Director for the Category II and III Tests at Edwards AFB. Detail on the AAD program is attached at Appendix "B" to this report.

4 <u>Ballistic and Separation Trials on F106A and B</u>. Detail on the ballistic and separation trials on the F106A and B aircraft is contained in Appendix "B" to this report and also in the following paragraphs.

Discussion at WADC on Flight Test Problems

5 The USAF WSPO at WADC advised that most of the launch error data required for the F106 program will be available by 1 Jan 59. The final launch error data will be reduced and the computer tapes ready by 30 Jun 59.

6 It became apparent, from discussions at WADC and HAC, that AVRO will require much data and data analysis from Convair. The WADC/F106 WSPO recommended that a joint AVRO/HAC/Convair group be formed, with liaison from RCAF/USAF WSPO. This group should be formed as soon as possible. During the middle phase of this operation, AVRO should have representatives at Convair. The ballistics and separation data will be at Convair.

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7 In order to form such a group, the USAF WSPO requires direction from the Pentagon that F106 test data may be made available to the RCAF and its prime contractor(s). Having this authority, the USAF WSPO would than require a detailed breakdown of the type of data and analysis required. A conference of all interested agencies should consider this problem in order that Convair can produce a report. It is probable that a technical liaison agreement or contract between Convair and AVRO will be necessary.

8 Immediate action is required by the RCAF and DDP to get the appropriate permission from HQ USAF to WADC for Convair to release data to the Canadian government.

9 Holloman AFB. The USAF WSPO at WADC advised that if the USAF experienced major weapon system problems, or if the weapons or fire control system didn't work, then Holloman AFB was regarded as the place to go. There is an air space problem at Holloman, but small priority programs can be accommodated.

General Discussion at HAC on Flight Test Problems

10 Targets - Using MB-1's and GAR's without warheads, HAC are firing against manned targets - both B57's and F100's. With complete missiles, monostatic reflectors cannot be used - bistatic reflectors are required. For high altitude work, unmanned targets are mandatory, and thus HAC fire at parachutes or pogohi. An evaluation target is needed for hit missiles. HAC have made no provision for targets, but have assumed they will be AVRO or HAC supplied. HAC will be recommending a target requirement after a flight test program has been agreed on. The details on targets may be found in Appendix "U".

11 Ballistic and Separation Testing - The following notes were taken during a short presentation by HAC on ballistic and separation testing:

(a) There were several phases in the MB-1/F106 program:

(i) Launch mechanism and safety proof. This program was done by the airframe contractor for the USAF. The ejections were first conducted without live motors. Blast effects were then studied. Ground static tests (ejecting into a pit from a ground stand) were completed with a dummy mass having the right inertias.

(ii) Air Ejections with Inert Missiles. Approximately 12 dummies were used for this phase, but HAC believe AVRO could get along with fewer. It is believed that Douglas had telemetry in these MB-1's to relay pitch rates. Since, cameras on wings have done a better job. For photo purposes, a lanyard was hooked into a flash powder charge.

(iii) Warhead Environment Testing. Some rounds carried Sandia instrumentation - data to determine shock and modes of vibration which might effect warhead accelerations was telemetered. However, telemetry should not be required during missile flight.

(iv) Motor Light-Offs. Safe separation has to be established throughout the flight regime. One or two launches at +3 g and -1 g would give confidence.

(v) Co-altitude Firings. About 8 data points need to be established with 3 rounds per data point. An important parameter is angle of attack which should be explored at

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low speed/high altitude and high speed/low altitude. The objective for angle of attack measurement should be accuracies within plus or minus one quarter degree.

(vi) General

1. Need about 25% spare motors.
2. Need about 10 rounds for snap-up ballistics, plus 25% spares.
3. Want ballistic samples for all cases.
4. About 12 rounds at +3 g and -1 g at various altitudes.
5. Holloman use pit drops between each early firing, with a minimum of three per aircraft (F106).

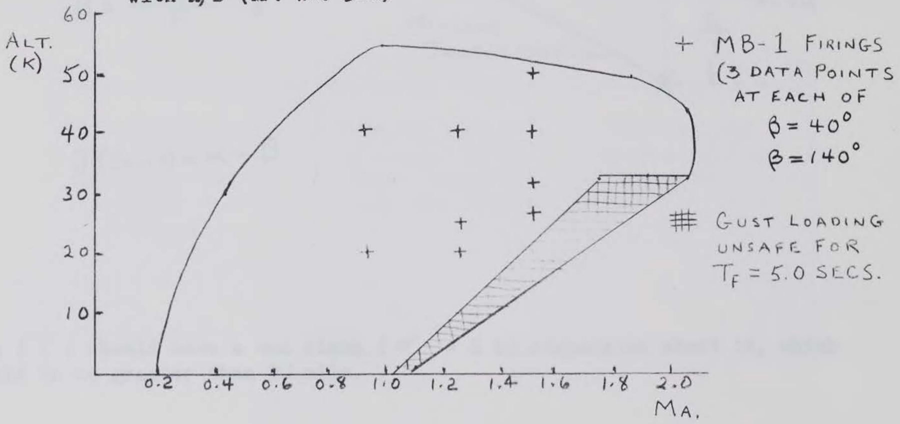
(vii) Limited Envelope. If priority were given to firing within a limited envelope, some additional rounds would be needed at high and low q and other q's and Machs to ensure that no gross errors exist in the basic equations for the ballistic computer.

(viii) Order of Importance of Flight Test Data

1. Safe separation
2. Angle of attack and jump angle.
3. Release time.
4. Ejection mechanism delays.

(b) Speed Envelope for F106/MB-1 Firings

F106A Max. Power
with A/B (Gr. Wt. 30K)



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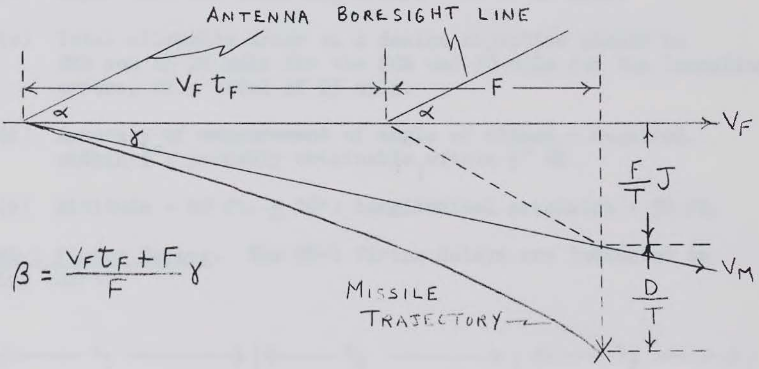
Alt. (K)	VF	Target	VT		No. Rounds
25	1.2)	Manned	-	Ejection test	1
40	1.2)	A/C	-	Ejection test	1
20	1.2	Tow	.7	Manual, co-alt.	2
40	1.5	Tow	.7	Manual, co-alt.	5
50	1.5	Chute	-	Manual, co-alt.	2
30	1.5	Tow	.7	Manual, climbing	3
40	.9	Balloon	-	Optical	1
20	.9	QB 17	-	Optical	1
40	1.5	Tow	.7	Auto, co-alt.	8
35	1.5	Balloon	-	Auto, snap-up	8

12 FCS Plus MB-1 Versus Target. About 40 rounds are scheduled for F106/MA-1/MB-1 versus a target.

MB-1 Ballistics and Separation Requirements

13 HAC Definition of Jump



$$\beta = \frac{V_F t_F + F}{F} \gamma$$

$$J\,(\text{Jump}) = \alpha - \beta$$

Gama (γ) should have a one sigma (σ = S D) dispersion about it, which should be no greater than 20 mils.

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14 To achieve a 95% confidence factor that the dispersion will be no greater than 20 mils, 20 rounds must fall within a S D of 14 mils. The same confidence factor exists for 35 rounds having a S D of 16.5 mils, or 100 rounds with a S D of 18 mils.

15 HAC recommend an allocation of 35 rounds at a wide variety of Mach, q, etc. About 25% additional rounds should be allocated for aborts, attrition, unserviceability, etc. HAC advise that AVRO, in discussions, suggested firings from Mach .95 to 1.8, 10 K to 50 K, with 6 snap-ups, - Total 35 rounds.

16 Other programs have stablished trajectory data for the MB-1, so the Arrow program would be concerned with the first five seconds of flight, since separation (damping of transients) requires about 2.5 to 3.0 seconds.

17 HAC advise that all the necessary data for AVRO can be determined by airborne instrumentation. The most critical (and difficult) measurement is angle of attack, because it is such a dominant factor in the jump equation. It is desirable to measure angle of attack within $\frac{1}{4}^{\circ}$, but present programs are only measuring angle of attack within $\frac{1}{2}^{\circ}$ S.D.

18 Error Tolerances. The following error tolerances are approximate, but represent practical objectives for the Arrow program:

(a) SD of FCS (including pilot steering errors and radome) - 15 mils (az); 15 mils (el).

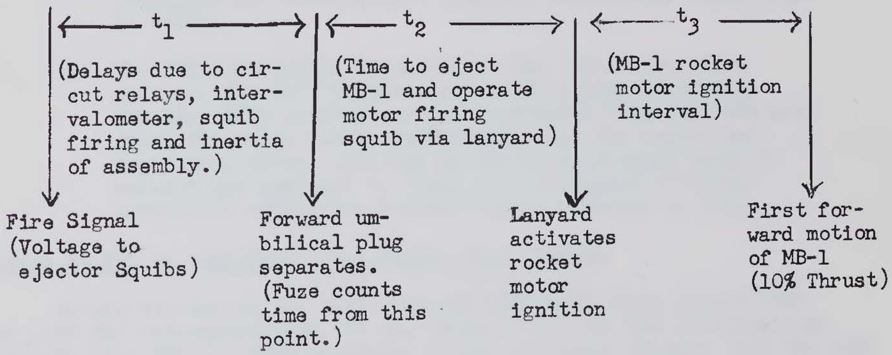
(b) Separation and launching errors - SD of 20 mils.

(c) Total allowable error as a design objective should be RMS sum of 15 mils for the FCS and 20 mils for the launching errors, or a total of 25 mils.

(d) Accuracy of measurement of angle of attack - required, within $\frac{1}{4}^{\circ}$; probably obtainable, within $\frac{1}{2}^{\circ}$ SD.

(e) Altitude - 20 ft. ± 10'; longitudinal precision - 50 ft.

19 MB-1 Firing Delays. The MB-1 firing delays are indicated in the following chart:



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There is a requirement to establish t_1, t_2 and t_3, because zero fuze time occurs at the end of t, whereas the FCS is mechanized for the end of t_3. Typical values for these time delays are (in the F106 installation):

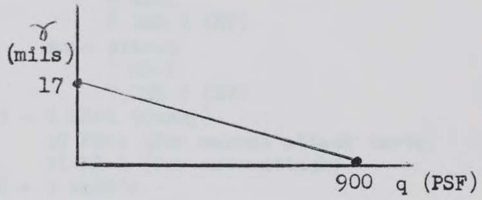
t_1 - 30 milsecs (approx.)

t_2 - 30-100 milsecs (approx.)

t_3 - 95 milsecs (approx.) (this figure depends on temperature, motor aging, etc.)

In practice, the end of t_1 is measured as the time of hook release, which is within five milsecs of umbilical plug separation.

20 F101B subsonic jump variation with q is quite linear as is shown in the following sketch of γ (see para 14) versus q



Discussion at WADC/F106 WSPO on RCAF/AVRO Joint Flight Test Program

21 The proposed RCAF/AVRO Joint Flight Test Program was discussed with the F106 WSPO at WADC. It was agreed that:

(a) This program does not constitute a full weapon system evaluation.

(b) The F106 objectives for weapons launch and separation errors and for FCS (including pilot error and radome error) errors would be suitable for objectives in the Arrow program.

(c) The limited combat flight envelope would be a realistic objective for describing a squadron operational capability by 1960.

(d) The FCS performance described by the F106 flight test program, the MB-1 trajectory data from other programs, the GAR 3A/4A performance data extracted from the F106 program, the Arrow radome performance, and the launch and separation errors achieved by the Arrow program could be related and analyzed to yield good estimates of system capability within the limited flight envelope by 1960.

Discussion at HAC on RCAF/AVRO Joint Flight Test Program

22 Before discussing the RCAF proposed RCAF/AVRO Joint Flight Test Program with HAC representatives, it was evident from various presentations and comments that HAC and AVRO envisaged a more elaborate program than the RCAF had in mind. The two companies apparently had in mind the exploration of the

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UNCLASSIFIED

full Arrow flight envelope for safety, separation and launch error characteristics and the firing of MB-1's to define the ballistic characteristics for the MA-1 AWCS. They pointed out that it has been extremely difficult to define the ballistics of the MB-1 from the F106 and stressed the need for an instrumented range. The following flight test program was suggested:

(a) Missile and MB-1 Requirements

202 - None
205 - 20 MB-1 (36 preferred by HAC)
* 40 GAR 3 (EVs)
9 WSEM's
1 GAR 3 (instrumented for vibration testing)
6 MB-1 (dummies for ejection tests)
1 MB-1 (temp self instrumented to establish need for heater blanket)
211 - Manual Attack Tests
* 6 MB-1
* 6 GAR 3 (EV)
Auto Attack
* 7 MB-1
* 7 GAR 3 (EV)
217 - 2 MB-1 (dummy)
* 19 MB-1 (for manual attack tests)
* 21 MB-1 (for auto-attack)
218 - 3 WSEM's
* 6 GAR 3 (EV)
* 32 GAR 3 (for manual attack tests) (EV)
* 40 GAR 3 (for auto-attack) (EV)

* includes 25% allowance for no data firings

(b) Detailed Aircraft Programs

202 - Aug 59 to Apr 60. MB-1 lead collision manual attack tests; ride along tests; pursuit modes; snap-up; AMTI: optical; extrapolated lead collision. 202 could be used as target after Apr 60.

205 - Shakedown - Jan to mid Feb 59
fit MB-1 - mid Feb to late Apr
fly Malton - Apr to end Jun
inert drops - Jul to Oct
fit pack - Nov
MB-1/GAR firings - Dec 59 to end Jul 60

211 - MB-1/GAR - mostly dry runs with some firings
Shakedown - Feb 60 to mid Apr 60
Manual attack - Apr 60 to mid Jul 60
Auto-attack - Jul 60 to Mar 61 (system back-up after Mar 61)

217 - MB-1 only - dry runs and live firings (MA-1 production system)
Shakedown - Aug 60 to Oct 60
Manual Attack - Oct 60 to end Jan 61
Auto-attack - Feb 61 to Dec 61

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218 - GAR only - dry runs and live firings (MA-1 production system)

Shakedown - Sep 60 to Nov 60
Manual attack - Nov 60 to end Feb 61
Auto-attack - Mar 61 to Dec 61.

(c) Utilization Rates

AVRO advise HAC to expect five good flights per month on the basis of one month for engine changes. HAC state that the objective on the F106 program is seven to eight flights per month or 100 flights per year per aircraft.

23 The RCAF proposed RCAF/AVRO flight test program was then discussed in detail with HAC as follows:

(a) Flight Test Envelope. It was agreed that a realistic approach to defining an operational capability by mid 1960 is to give priority to defining separation and launch error characteristics within 30 K to 50 K and 1.2 M to 1.5 M. However, ballistic equation data must be evolved for the entire flight envelope and programmed in the computer. To ensure that the program will not have to be repeated at a later date, it is essential that some rounds be fired around the flight envelope to ensure no gross errors in calculations.

(b) 1.0 g Limitation. The RCAF proposal to limit g investigations to 1.0 g to 1.3 g was discussed. HAC felt that safe separation should be ensured from -1 g to + 3 g. The 1.0 g end of the limitation was critized by pointing out that even in the co-altitude case some negative g might be pulled. Therefore, HAC strongly recommended and the RCAF representatives at the meeting agreed that the lower limit of the restricted g envelope should be 0.8 g.

(c) 1.3 g Limitation. The 1.3 g end of the limitation was criticized by pointing out that the MA-1 may voluntarily go into a pursuit mode and that 1.3 g limitation may seriously limit the areas in space available to the Arrow for an attack. The RCAF requested HAC to do a brief analysis on the g limitation in pursuit attack. Five cases were examined. These cases are isolated and cannot be correlated. Therefore, more complete analysis should be made before the RCAF defines the upper g limitation.

Case 1: GAR Attack

V_I = M1.5
V_T ~~=~~ M0.8
Alt. = 50K
R_L = 25 K
R_{LO} = 100 K

In pursuit attack, any aspect angle (B) greater than 102° gives greater than 1.3 g.

..../9

Case 2: GAR Attack

V_I - M1.5
V_T - M0.8
Alt. - 30K
R_L - 25K
R_{LO} - 100K

In pursuit attack, aspect angle (B) of 140° gives g of 1.42

Case 3: MB-1 Attack

V_I - M1.5
V_T - M0.8
Alt. - 30K
R_L - 15.2 K
R_{LO} - 100K

In pursuit attack, aspect angle (B) of 140° gives g of 2.54

Case 4: GAR Attack

V_I - 1.39M
V_T - 0.7M
Alt. - 30K
R_L - 15K
R_{LO} - 100K

In pursuit attack, aspect angle (B) greater than 110° gives greater than 1.3 g.

Case 5: MB-1 Attack

V_I - 1.5M
V_T - 0.8 M
Alt. - 30K
R_L - 15K
R_{LO} - 100K

In pursuit attack, any aspect angle (B) greater than 96° gives greater than 1.3 g

It would appear from the above analysis that an upper 1.3 g restriction, in the pursuit case, would limit the allowable aspect angle to within 90° off the tail of the target. However, this conclusion must be reated with great reservation for two reasons:

(i) the five cases were examined in great haste by the analysis group at HAC and are, therefore, subject to error;

(ii) only five isolated, almost unreleated, cases were studied.

Discussions at Douglas Aircraft Company

24 Ejection System. The following notes cover DAC remarks on problems associated with the ejection system for the MB-1:

(a) It is necessary to eject sufficient inert rounds to define the ballistic characteristics prior to motor ignition.

(b) On the F101 program, when carrying two rockets and firing one, the MB-1 nosed down about 45°. This problem was solved by placing a deflection vane between the two rockets.

..../10

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(c) The Arrow installation problems appear to resemble more closely those on the F106 than those on the F101. However, the F106 has one large bay door, whereas the Arrow ~~had~~ has individual doors.

(d) The Bohanan rack is simpler than the Horkey-Moore rack, but the H-M gun has more provision for changes. Ratio of forces changes can be put on the H-M rack by adjustments, whereas these changes require baffles and vanes on the Bohanan rack. the H-M gun gets different thrusts by using different sleeves; the Bohanan uses orifices for varying thrusts - these orifices tend to clog up with gas residues.

(e) There is a Special Weapon Board at Albuquerque which assesses and approves all USAF Special Weapons installations. The RCAF should establish liaison with this Board.

(f) MIL Spec E8591B is the installation specification for internal and external stores.

25 <u>MB-1 Supply</u>. Captain Bill Lyons at ARDC Detachment 1, Wright Patterson AFB (RDZSFF) is responsible for the allocation of MB-1's to Holloman AFB. At Headquarters USAF, the contact personnel for MB-1 requirements are Major Jack Bower and Major Brookes Favorite.

26 <u>Technical Assistance</u>. The following notes cover Douglas recommendations for technical assistance:

(a) DAC would go to Malton to ensure all necessary equipment is available and serviceable.

(b) As with all other MB-1 programs, DAC would insist upon checkout of all rockets by a DAC team consisting of engineers, inspectors and mechanics. DAC would wish to control the MB-1, during the flight test program, right through to loading on the racks.

(c) DAC are very unhappy about the present engineering situation. At present, AVRO have a six month blanket clearance for six men to visit DAC at any time (Chamberlain, Lindow, Lucas, Lindley plus two). Meanwhile, AVRO, DAC or HAC must be authorized to execute an operational analysis study so that the safe escape times can be mechanized into the fire control system computer.

(d) Previous DAC studies have been classified "restricted data" by the USAF, so that the source for this material is AFSWC, Kirtland AFB, Albuquerque. Somehow a channel for RCAF/AVRO into AFSWC needs to be opened. Contact personnel at AFSWC are Major-General Canterbury, Col. John Dishuck and Captain John Walsh (office symbol - SWV). A special weapons study, such as that completed on the Arrow about three years ago, may be required. Major Franklin is in the operational research group that would do such a study.

27 <u>AVRO/DAC Liaison</u>. DAC expressed willingness to support any RCAF project. It was pointed out that DAC and HAC are competitors, and that DAC would prefer to work directly with AVRO rather than through HAC to AVRO. On all other MB-1 programs, DAC works directly with the airframe contractor.

...../11

UNCLASSIFIED

28 **Flight Test Program.** DAC advised that the ballistic trajectory of the current MB-1 contributes about 12 to 13 mils SD error, independently of separation and launch errors, fire control system errors and radome errors. DAC also pointed out the need to establish the directional vector of the aircraft, on each shoot, by measuring characteristics at time before launch. With regard to the proposed RCAF Stage 1 flight test program, little time was available for discussion but DAC expressed general agreement with the assumptions and objectives in the flight test time available. It was emphasized that about five good rounds per data point on a small number of data points would yield better results than the same number of rounds fired over a larger number of data points.

MA-1 Instrumentation

29 Instrumentation for MA-1 flight test in the Arrow is a "standard" Hughes package. The instrumentation is engineered in such a manner that everything (such as amplifiers, oscillographs and power supplies) except for wiring leads and strike cameras is contained in a detachable package. Thus the instrumentation may be maintained and calibrated in parallel with normal aircraft maintenance, greatly reducing flight test "down-time". The instrumentation package fits onto a missile rack and may contain facilities for recording 50 or 28 channels of data. The MA-1 is pre-wired at the Hughes factory to bring out 350 parameters to seven connectors in the MA-1 racks. (These 350 parameters are detailed in AMTS Tech Library No. 4971.) The wiring is led to a junction box, to which is also connected leads to the instrumentation package. Those parameters to be recorded on a particular flight are simply "patched" across in the junction box. The cathode followers, scale amplifiers, and other electronic circuits are all built as standard, potted, plug-in assemblies. The records are standard Consolidated Engineering galvanometer type recorders (as already used by both AVRoe and AAED). During flight test operations at Palmdale, this instrumentation technique has aided materially in reducing "down" time. Further, the extensive use of potted circuits has increased circuit stability and reduced high altitude instrumentation problems.

30 It is understood that AVRoe are presently making arrangements with HAC for training of AVRoe data reduction and analysis personnel at Culver City. It was stated that a period of two months training was under consideration to check out on miss evaluation and missile ~~evaluation~~ evaluation techniques as used by Hughes.

MB-1 Instrumentation

31 Two requirements exists for telemetry during MB-1 flight test work. The warhead contractor (Sandia Corp) requires rate histories (linear accelerations and angular accelerations) experienced by the missile warhead over the profile of launching conditions. To facilitate gathering this data Sandia have built and supplied telemetry packs (to replace the warhead section) on previous weapons installation programs such as those on the F101 and F106. This telemetry equipment is understood to be FM/FM. In addition, Douglas have used ASCOP PDM/FM telemetry installations extensively to assist in obtaining separation and ballistic data for evaluating jump and time to range.

32 The MB-1 rocket motor is rated for operation over the temperature range -20 to +140 degrees Fahrenheit. It is fitted with a 0.25 inch thick insulating blanket. With this blanket the motor normally gets no cooler than zero, even with no heat. Thus, it has been possible to use the heating

..../12

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wires imbedded in the insulating blanket as instrumentation to measure the rocket motor grain temperature during typical flight profiles. The temperature gradient across the rocket motor from outside wall to centre of grain has been found not to exceed 5 to 10 degrees. Hence this technique has not only proved to be extremely simple, but has also measured propellant temperature to within 10 degrees, which is considered by Douglas to be sufficiently accurate.

GAR 3A Instrumentation

33 The Hughes GAR 3A PDM/FM telemetry is a 30 by 30 100 KC gated oscillator type of system. Design requires pulse restorers but PW electronics are not required for the recorders. The GAR 3A package provides the sequentially sampled data matrix (such data as control surface position, power supply voltages and AGC voltages) with a second RF carrier (single channel FM/FM - a 14 KC standard channel) to record error signal. The GAR 4A package is essentially the same except that the second RF carrier data includes gyro speed decay and power supply data. The VHF carrier frequencies used are 227.7, 230.9, 225.7, 242.0, 232.9, 235.5, 237.8 and 245.3 mcs. (The first two frequencies are for SANDIA telemetry, the last four for salvo rounds only.)

APPENDIX "B"
TO S1038CN-180
DATED 19 DEC 58

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SCHEDULES

1 The following schedules are contained in this appendix:

(a) MA-1/CF105 Schedule (HAC Plan)

(b) F106A Program Summary

(c) F106B Program Summary

(d) F106A Flight Test Aircraft

(e) F106A and B Flight Test Program (4 charts)

(f) F106A and B MA-1 AWCS Schedule (2 charts)

(g) F106A Offensive Armament Program

(h) F106 Aircraft and Armament Development (AAD) Program

(j) CF105/MA-1 Support Program (HAC Plan)

(k) CF105/GAR 3A/4A Support Program (HAC Plan)

(l) Falcon GAR 3/3A/4/4A Delivery Schedules.

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Exhibit D

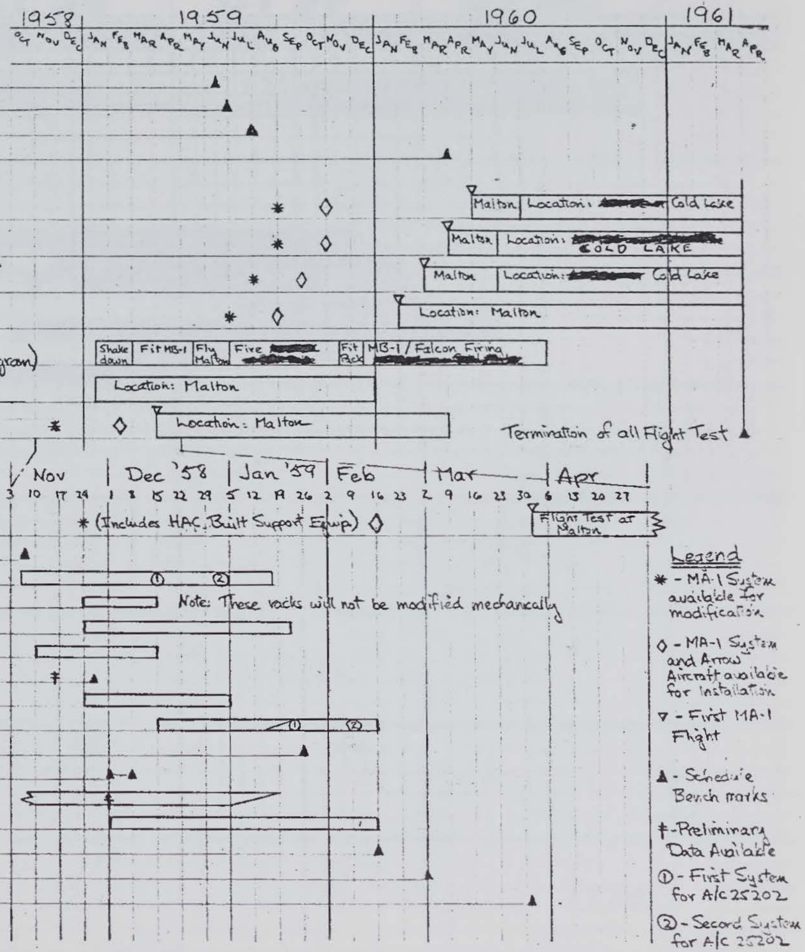
MA-1/CF-105 SCHEDULE (PLAN AT HAC)

Item

Contemplated Production Schedule
1. Letter of Intent or Pre-Contractual Authorization
2. Production Drawing Release
3. Receipt of Production Contract
4. First Production Delivery

Aircraft Flight Test Schedule
1. Aircraft 25213 -- Target and System Test Backup
2. Aircraft 25212 -- MA-1 System Development - Falcon or MB-1 Firing
3. Aircraft 25211 -- MA1 System Development - Falcon or MB-1 Firing
4. Aircraft 25210 -- MA1 System and AFCS (Pilot Assist) Development
5. Aircraft 25205 -- Armament Separation and Ballistic Data (AVRO Program)
6. Aircraft 25203 -- AFCS (Pilot Assist) Developmental Flight Test
7. Aircraft 25202 -- MA-1 System / MB-1 Armament Development

Expanded Schedule for Aircraft 25202
1. Expanded from Line 7 above
2. XMA-1C System and Support Equipment Master Indices
3. Modification and Construction of units, including spares
4. Electrical Modification of First System Racks
5. Electrical, Mechanical, and Instrumentation Modification of Second System Racks
6. Modify System Tie-in Test Position
7. Interconnection List for System Tie-in Test Position
8. Modify Support Equipment
9. Roof house Checkout of Systems, including spares
10. Instrumentation System Available
11. Wooden Mockups or spare units available in Malton
12. Aircraft Installation Engineering
13. Aircraft Modification by AVRO at Malton
14. Transfer entire test activity to Malton
15. Installation complete
16. Checkout complete



Legend
- ✱ - MA-1 System available for modification
- ◇ - MA-1 System and Arrow Aircraft available for Installation
- ▽ - First MA-1 Flight
- ▲ - Schedule Bench marks
- ǂ - Preliminary Data Available
- ① - First System for A/c 25202
- ② - Second System for A/c 25202

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APPENDIX "B" TO S/1038CN-180 (AAWS)
19 DEC 58.

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F-106 A
SUMMARY

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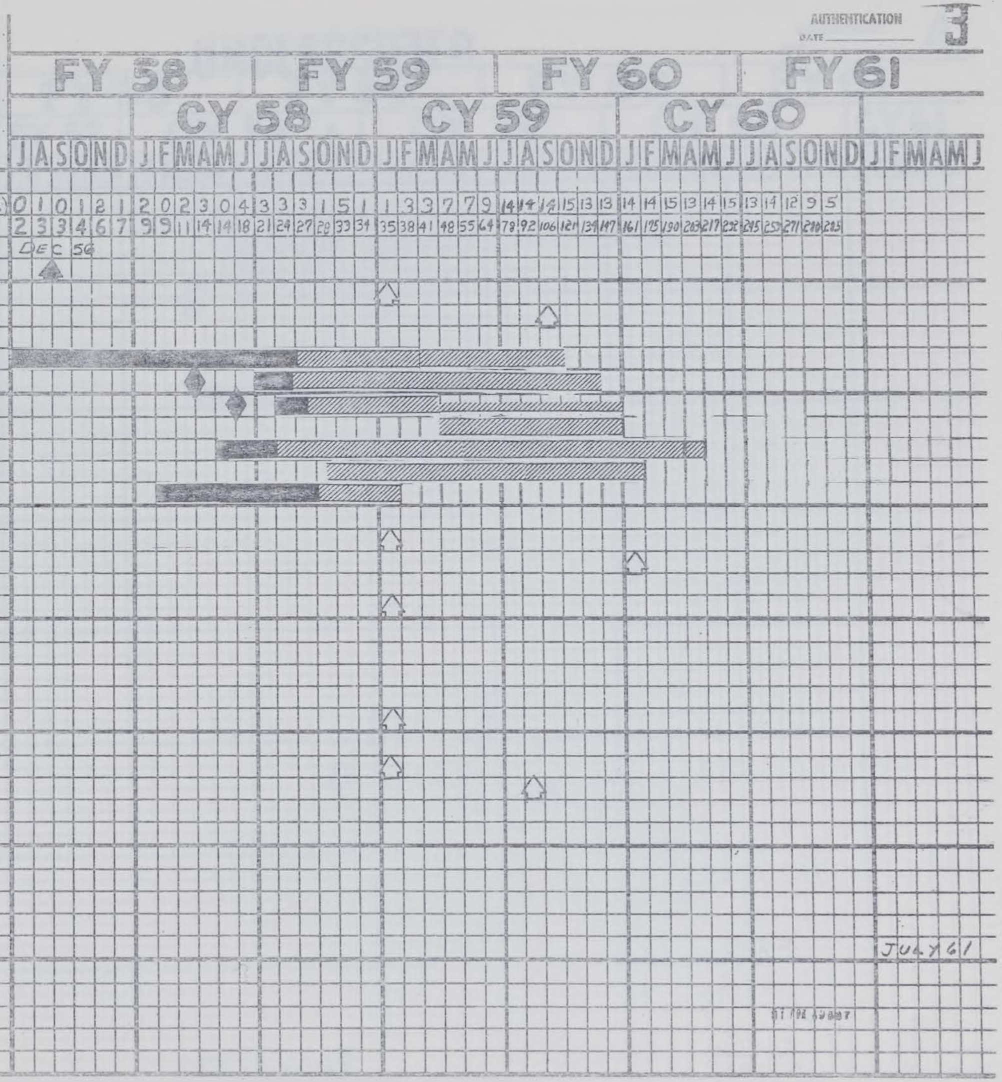

	J	A	S	O	N	D
2 DELIVERY SCHEDULE - PER MONTH (2)	0	1	0	1	2	1
3 - CUMULATIVE	2	3	3	4	6	7

CY 58	J	F	M	A	M	J	J	A	S	O	N	D
2 DELIVERY SCHEDULE - PER MONTH	2	0	2	3	0	4	3	3	3	1	5	1
3 - CUMULATIVE	9	9	11	14	14	18	21	24	27	28	33	34

CY 59	J	F	M	A	M	J	J	A	S	O	N	D
2 DELIVERY SCHEDULE - PER MONTH	1	3	3	7	7	9	14	14	14	15	13	13
3 - CUMULATIVE	35	38	41	48	55	64	78	92	106	121	134	147

CY 60	J	F	M	A	M	J	J	A	S	O	N	D
2 DELIVERY SCHEDULE - PER MONTH	14	14	15	13	14	15	13	14	12	9	5	
3 - CUMULATIVE	161	175	190	203	217	232	245	259	271	280	285	

1
2 DELIVERY SCHEDULE - PER MONTH
3 - CUMULATIVE
4 FIRST FLIGHT PROTOTYPE
5 FIRST PROD'N A/C
6 FIRST OPERATIONAL A/C
7 FIRST WING EQUIPPED
8
9 PHASE I II III IV & V
10 AAD PROGRAM
11 CAT II
12 CAT III
13 HAC
14 NACA
15 P&W
16 SUPERSONIC SEAT
17 A/C PROVISIONS
18 A/C INSTALLATION
19
20 ECP 4132
21 J-75-P17
22 INLET DUCT
23 EJECTOR
24
25 ECP 4144 - INCREASED FUEL
26
27 MA-1 FDS (COLLINS)
28 VERTICAL INSTRUMENTS (USAF)
29
30
31
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JULY 61

F 106 A MASTER SCHEDULE

APPENDIX "B" TO
S1038 CN-180 (AAWS)
14 DEC 58

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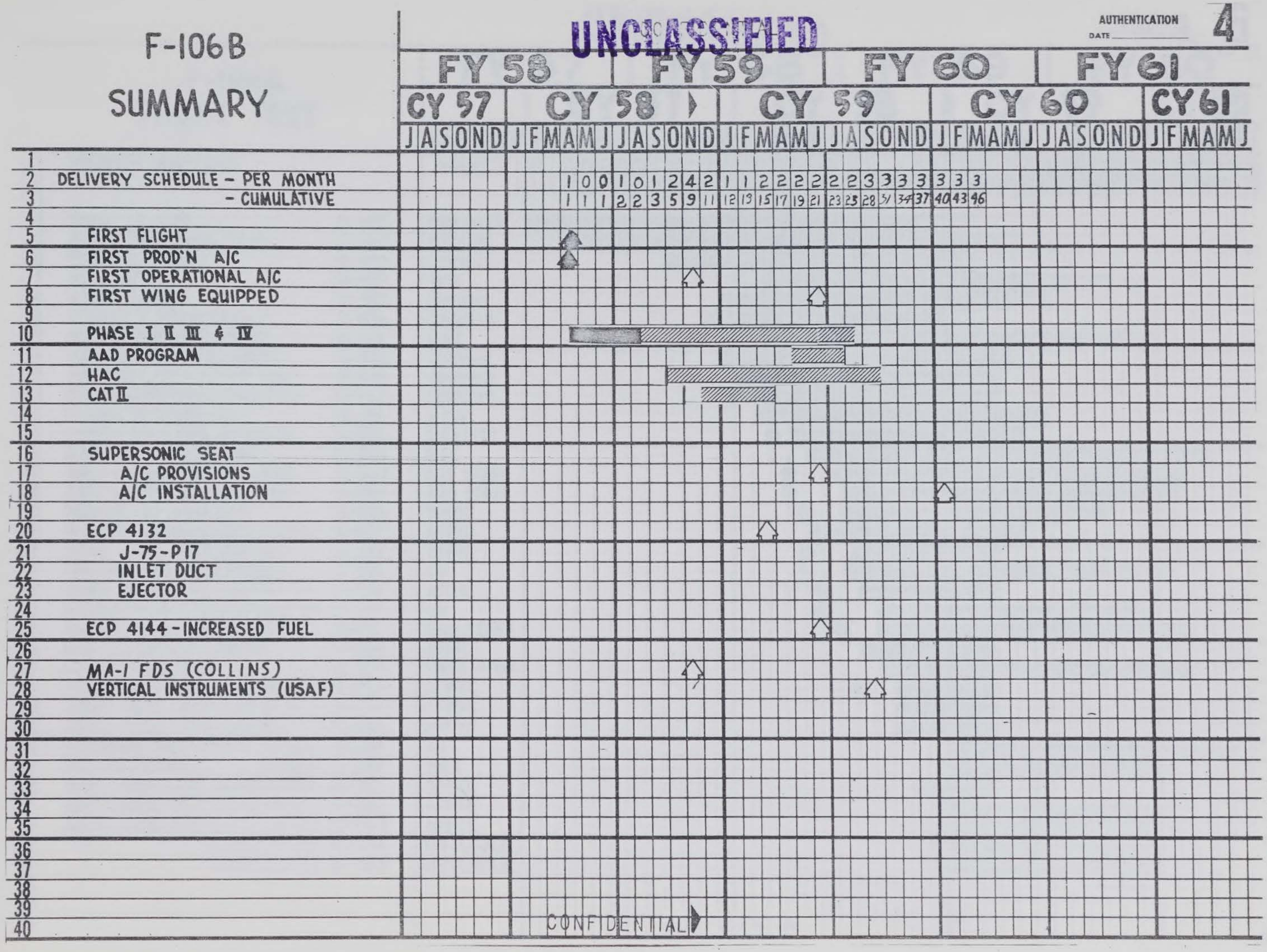
DATE ____________

4

F-106B
SUMMARY



	A 58	M	J	J	A	S	O	N	D	J 59	F	M	A	M	J	J	A	S	O	N	D	J 60	F	M
DELIVERY SCHEDULE - PER MONTH	1	0	0	1	0	1	2	4	2	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3
- CUMULATIVE	1	1	1	2	2	3	5	9	11	12	13	15	17	19	21	23	25	28	31	34	37	40	43	46

F 106 B MASTER SCHEDULE

"APPENDIX "B" TO
5103X CN-180 (AAWS)
19 DEC 58.

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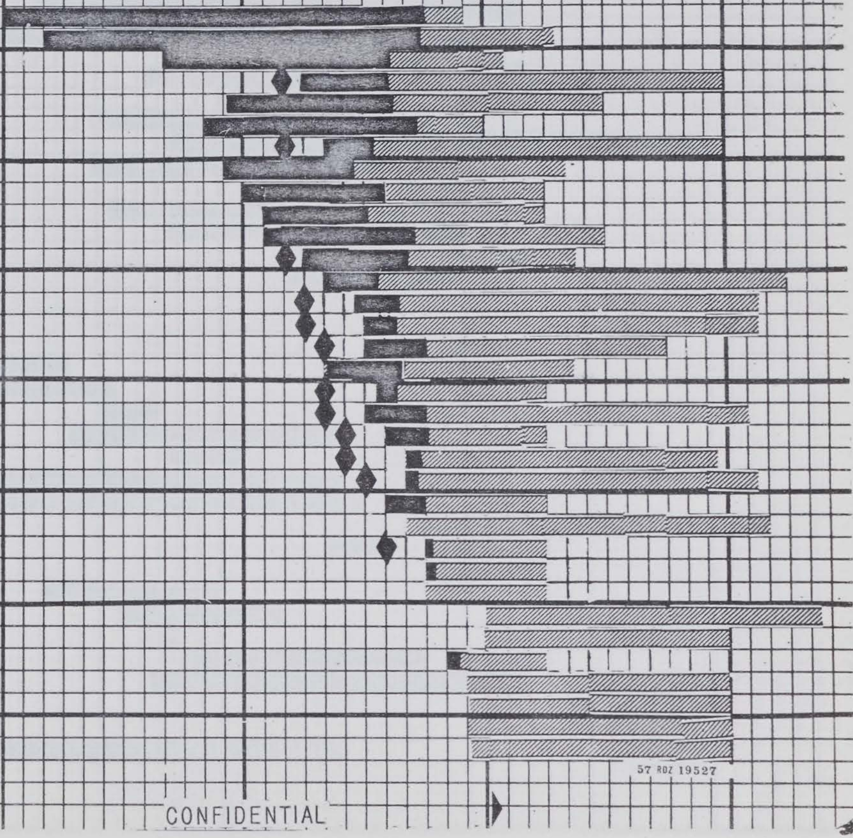
AUTHENTICATION
DATE 1 JULY 58

5

F-106A FLIGHT TEST

	FY 57												FY 58												FY 59												FY 60											
							CY 57												CY 58												CY 59												CY 60					
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1 DELIVERY SCHEDULE						1	0	1	0	0	0	0	0	1	0	1	2	1	2	0	2	3	0	4	3	3	3	1	5	1	1	3	3	7	7	9	14	14	14	15	13	13	14	14	15	13	14	15
2						1	1	2	2	2	2	2	2	3	3	4	6	7	9	9	11	14	14	18	21	24	27	28	33	34	35	38	41	48	55	64	78	92	106	121	134	147	161	175	190	203	217	232

			AGENCY
3			
4	PHASE I, II, & III	56-451	CVAC/AFFTC
5	PHASE I, III, & POWER PLANT	56-452	CONVAIR
6	FLIGHT CONTROLS	56-453	CONVAIR
7	MA-1 AFCS	56-454	HAC
8	FLIGHT LOADS	56-455	CONVAIR
9	STABILITY DERIVATIVES	56-456	CONVAIR
10	MA-1 SYSTEM DEVELOPMENT	56-457	HAC
11	MB-1 SEPARATION & BALLISTICS	56-458	CONVAIR
12	AIR COND. & J75-P17 PROP. SYS.	56-459	CONVAIR
13	FALCON SEPARATION & BALLISTICS	56-460	CONVAIR
14	ENGINE DEVELOPMENT	56-461	P&W
15	CENTER STICK EVAL. & PHASE IV	56-462	CV/AFFTC
16	GAR-3 & 4 DEVELOPMENT	56-463	HAC
17	AWCS & ARMAMENT DEV PROG	56-464	AAD STAFF
18	AWCS & ARMAMENT DEV PROG	56-465	AAD STAFF
19	PHASE V, ANTENNAS, C & N	56-466	WADC
20	PHASE IV PERFORMANCE (P-17)	56-467	AFFTC
21	JOINT ARDC-ADC CAT II	57-229	AFFTC
22	CASE XXIX EVAL. & TEST SUPPORT	57-230	CV
23	JOINT ARDC-ADC CAT II	57-231	AFFTC
24	AIR CONDITIONING & PRODUCTION SUPPPORT	57-232	CV
25	AWCS & ARMAMENT DEV PROG	57-233	AAD STAFF
26	MOD.CL.CONTROL / CAT II	57-234	AFFTC
27	NACA - AFCS DEV.	57-235	NACA-AMES
28	JOINT ARDC-ADC CAT II	57-236	AFFTC
29	JOINT ARDC-ADC CAT II	57-237	AFFTC
30	JOINT ARDC-ADC CAT II	57-238	AFFTC
31	AIRFRAME PROTOTYPE (P-17)	57-239	CV
32	FCS PROTOTYPE (P-17)	57-240	HAC
33	JOINT ARDC-ADC CAT II (P-17)	57-241	AFFTC
34	JOINT ARDC-ADC CAT II (P-17)	57-242	AFFTC
35	JOINT ARDC-ADC CAT II (P-17)	57-243	AFFTC
36	" " (SAGE) (P-17)	57-244	AFFTC/AFCRC
37	" " (SAGE) (P-17)	57-245	AFFTC/AFCRC
38			
39			
40			



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APPENDIX "B" TO
S1038 CN-180 (AAWS)
19 DEC 58.

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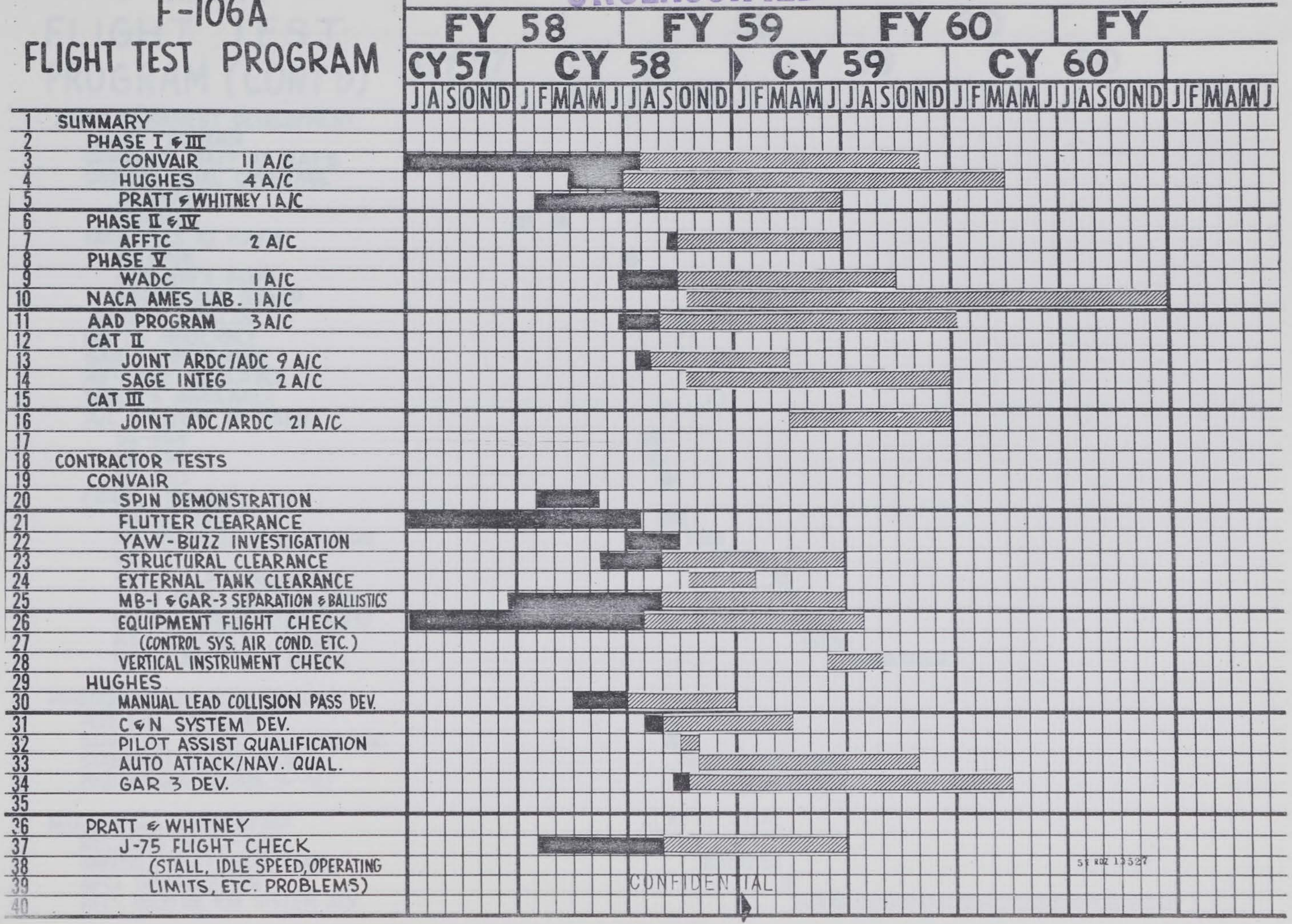
F-106A FLIGHT TEST PROGRAM



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APPENDIX "B" TO
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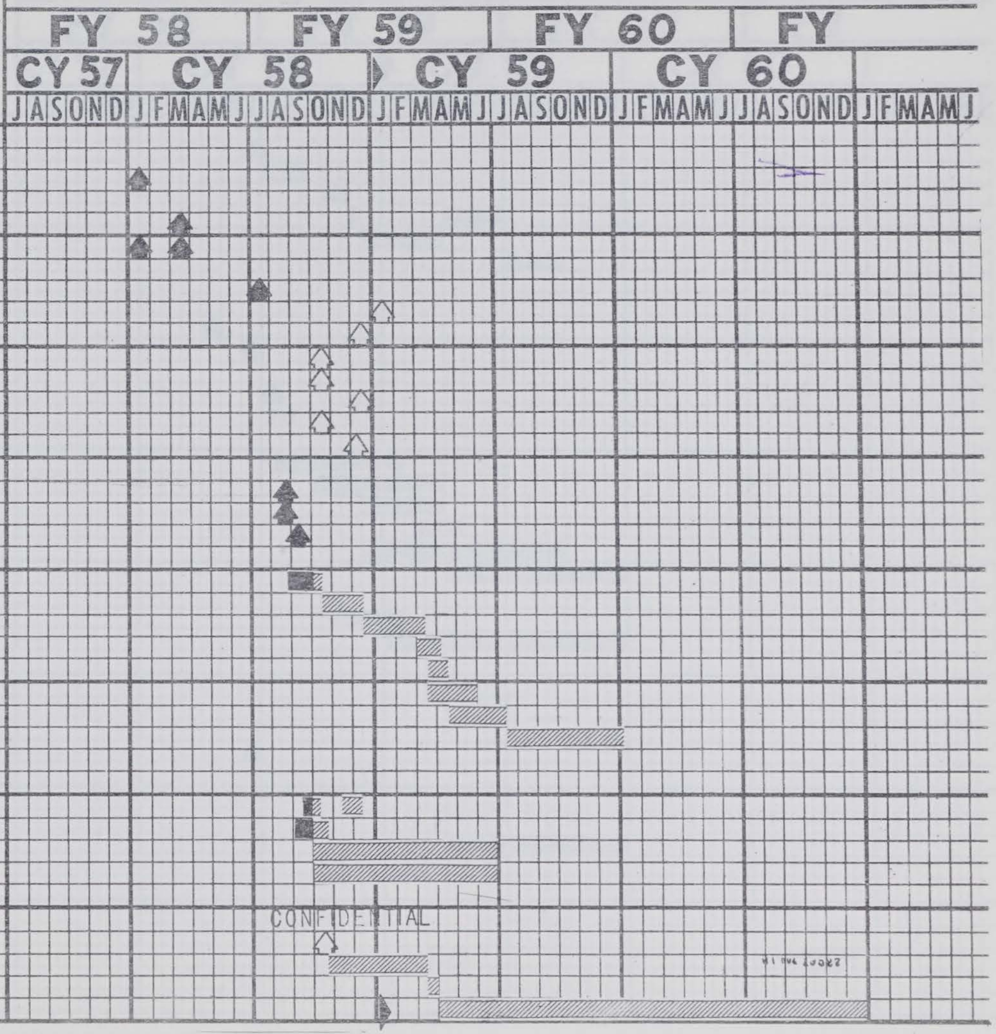
7

F-106A FLIGHT TEST PROGRAM (CONT'D)

1 AWCS ARMAMENT DEVELOPMENT
2 (AAD) PROGRAM
3 COMPLETE STAFF AT HAFB
4 CONTRACTUAL COVERAGE
5 CONVAIR
6 HUGHES
7 FACILITIES AT HAFB
8 INTERIM
9 G/M ASS'Y BLDG
10 ENGINE RUN STAND
11 TARGETS AVAILABLE
12 MB-1'S AVAILABLE
13 GAR-3's AVAILABLE
14 MB-1 RME AVAILABLE
15 WSEM'S AVAILABLE
16 A/C DELIVERY TO HAFB
17 56-464
18 56-465
19 57-233
20 FIRING PROGRAM
21 SHAKE DOWN
22 MB-1 MANUAL (PILOT ASSIST) MODE
23 GAR-3
24 GAR-3 CCM EVALUATION
25 AUTO. MODE INSTALLATION
26 ECP 4132 INCORPORATION S/N 233
27 MB-1 AUTOMATIC MODES
28 GAR-3 AUTOMATIC MODES
29
30 PERFORMANCE STAB & CON (PH II & IV)
31 PERF. EVAL. S/N 56-453
32 STAB & CONT. EVAL. CASE XIV VS XXIX WING
33 STAB & CONT: TESTING 56-462
34 PERFORMANCE TESTING 56-467
35
36 NACA AMES LABORATORY
37 DELIVERY OF 57-235
38 VARIABLE INLET GEOM. EVAL.
39 AFCS INSTALLATION
40 AFCS. INERTIAL NAV. SYSTEM DEV.



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F106A - F.T.

APPENDIX "B" TO
S1038 CN-180 (AAWS)
19 DEC 58.

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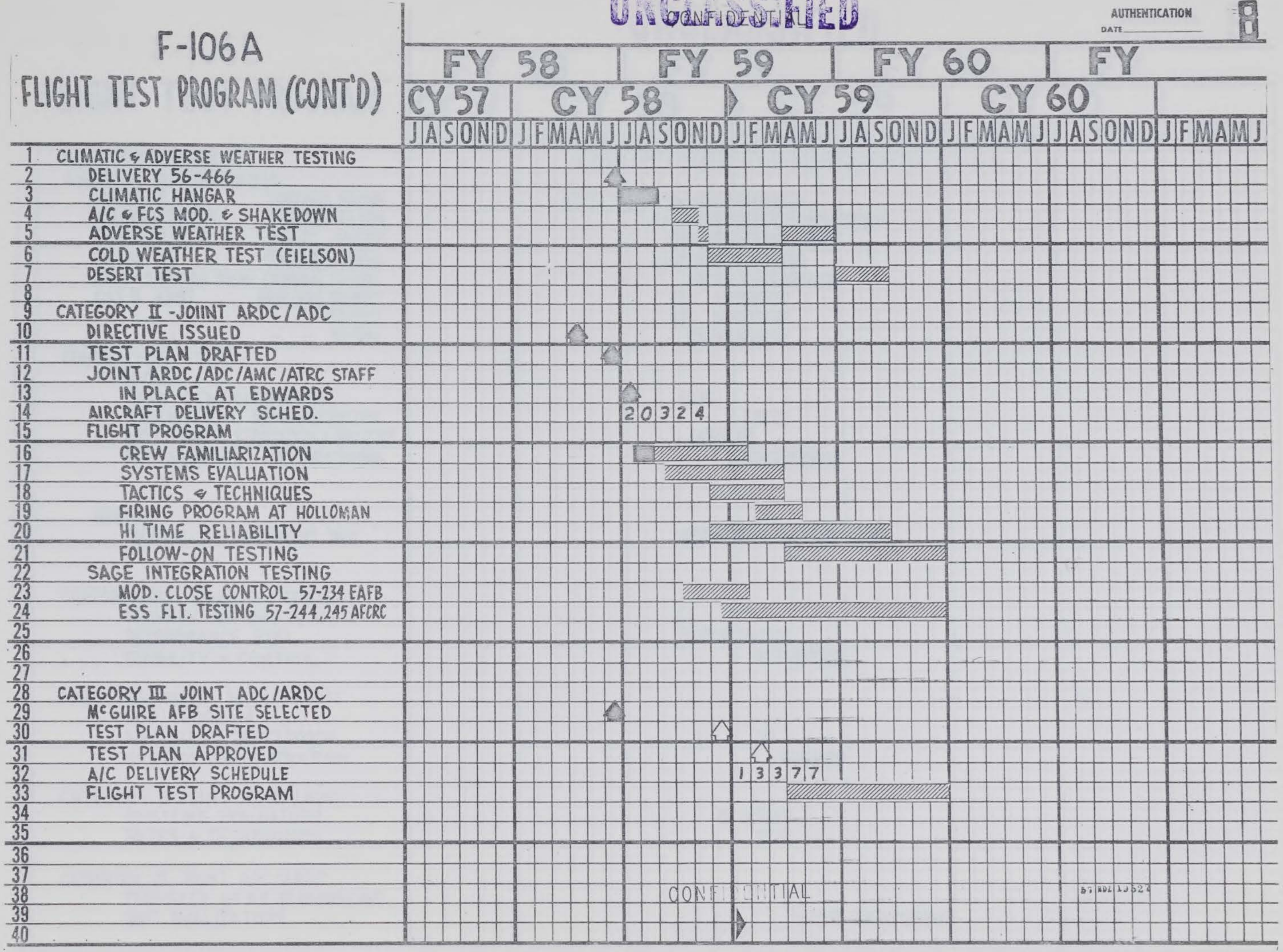
8

F-106A
FLIGHT TEST PROGRAM (CONT'D)



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57 RDL 13524

F106A - F.T.

APPENDIX "B" TO
SIO38 CN-180(AAWS)
19 DEC 58.

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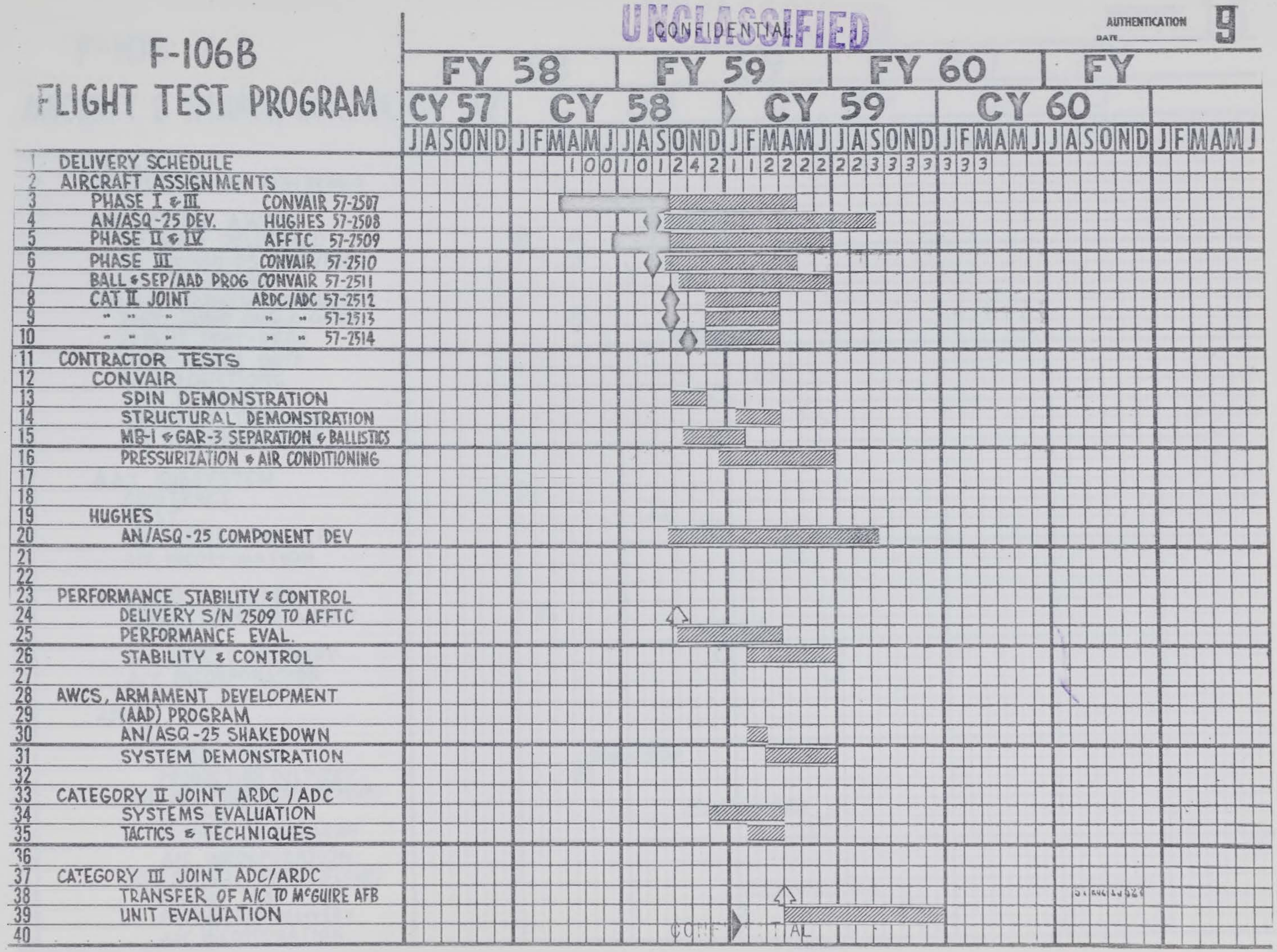
F-106B FLIGHT TEST PROGRAM



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F106 B - F.T.

APPENDIX "B" TO
S1038 CN-180 (AAWS)
19 DEC 58.

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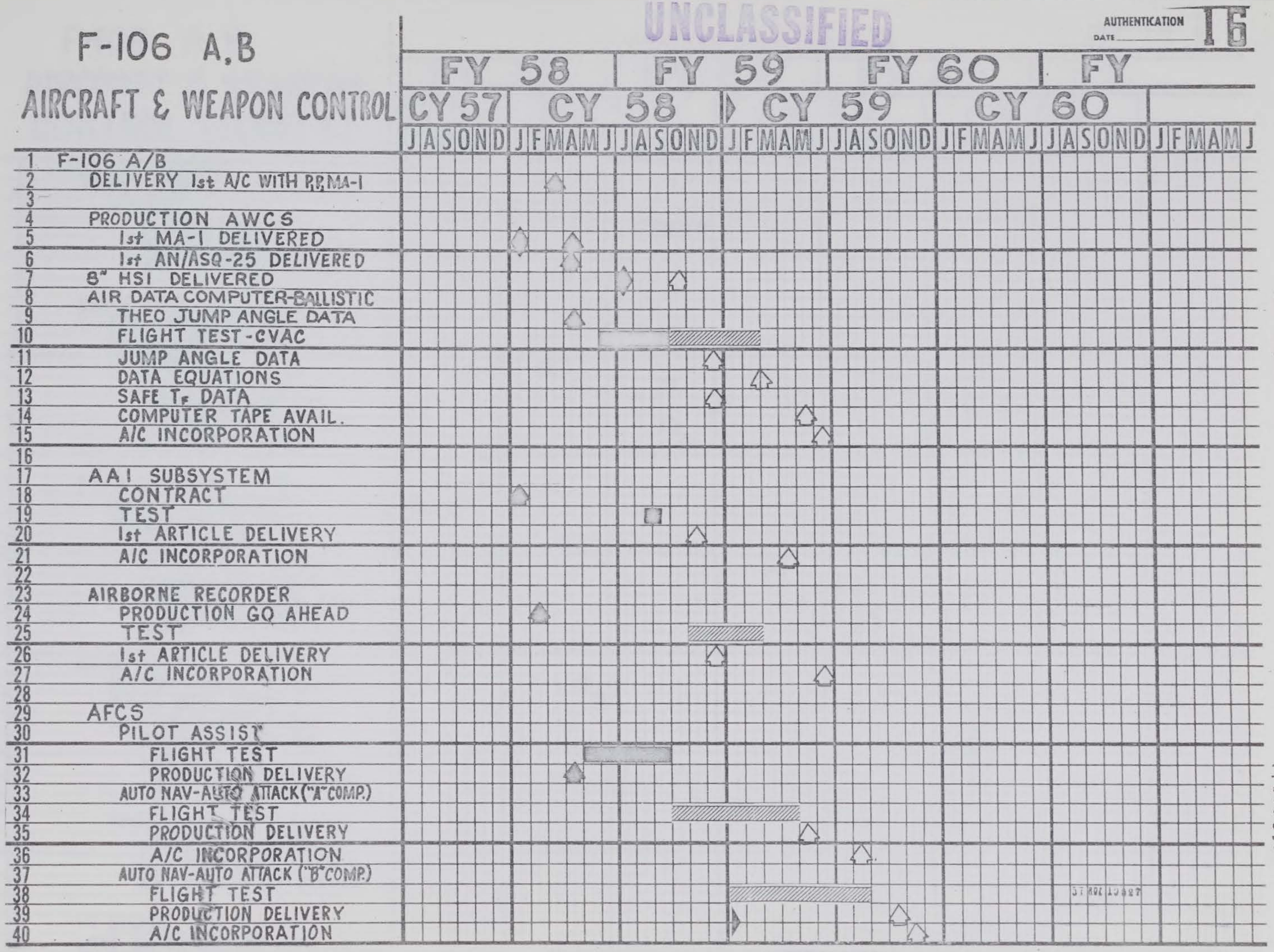
AUTHENTICATION
DATE

16

F-106 A,B

AIRCRAFT & WEAPON CONTROL



FY 58 | FY 59 | FY 60 | FY

CY 57 | CY 58 | CY 59 | CY 60

J A S O N D | J F M A M J J A S O N D | J F M A M J J A S O N D | J F M A M J J A S O N D | J F M A M J

1 F-106 A/B
2 DELIVERY 1st A/C WITH P.P. MA-1
3
4 PRODUCTION AWCS
5 1st MA-1 DELIVERED
6 1st AN/ASQ-25 DELIVERED
7 8" HSI DELIVERED
8 AIR DATA COMPUTER-BALLISTIC
9 THEO JUMP ANGLE DATA
10 FLIGHT TEST-CVAC
11 JUMP ANGLE DATA
12 DATA EQUATIONS
13 SAFE T_F DATA
14 COMPUTER TAPE AVAIL.
15 A/C INCORPORATION
16
17 AAI SUBSYSTEM
18 CONTRACT
19 TEST
20 1st ARTICLE DELIVERY
21 A/C INCORPORATION
22
23 AIRBORNE RECORDER
24 PRODUCTION GO AHEAD
25 TEST
26 1st ARTICLE DELIVERY
27 A/C INCORPORATION
28
29 AFCS
30 PILOT ASSIST
31 FLIGHT TEST
32 PRODUCTION DELIVERY
33 AUTO NAV-AUTO ATTACK ("A" COMP.)
34 FLIGHT TEST
35 PRODUCTION DELIVERY
36 A/C INCORPORATION
37 AUTO NAV-AUTO ATTACK ("B" COMP.)
38 FLIGHT TEST
39 PRODUCTION DELIVERY
40 A/C INCORPORATION

F106 - AWCS

APPENDIX "B" TO
51058 CN-180 (AAWS)
19 DEC 58

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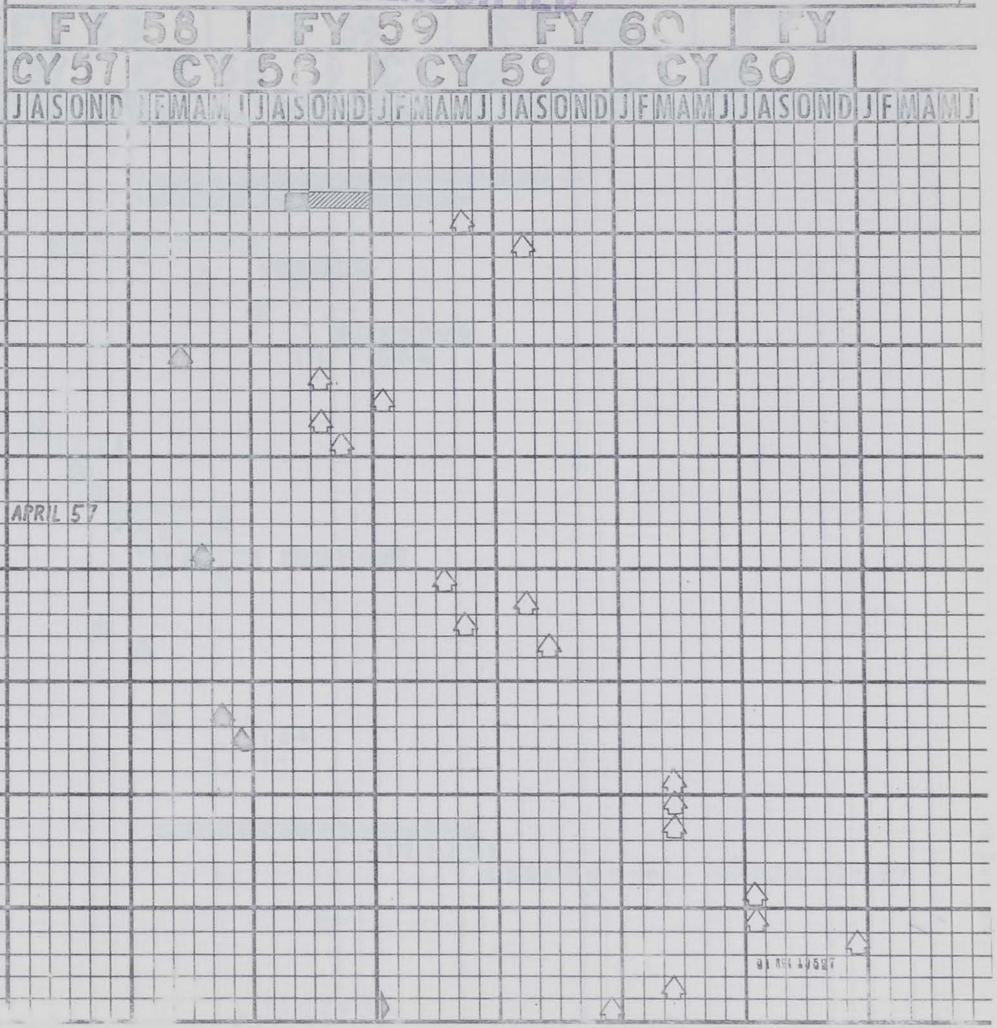
AUTHENTICATION
DATE ____________ I-7

F-106 A, B AIRCRAFT & WEAPON CONTROL (CONT'D)

1 F-106 A/B (CONT)
2 AFCS (CONT)
3 AILAS
4 FLIGHT TEST
5 PRODUCTION DELIVERY
6 A/C INCORPORATION
7
8 MA-1 FDS (COLLINS)
9 REQ. ESTABLISHED
10 MODIFIED AWCS
11 CONTRACT
12 MA-1 PROD. EFF.
13 F-106A DELIVERED
14 AN/ASQ-25 PROD. EFF.
15 F-106B DELIVERED
16
17 USAF VERTICAL INST.
18 REQ. ESTABLISHED
19 MODIFIED AWCS
20 CONTRACT
21 MA-1 PROD. EFF.
22 F-106A DELIVERED
23 AN/ASQ-25 PROD. EFF.
24 F-106B DELIVERED
25
26 CCM MODS
27 RETROFIT INFO. TO USAF
28 57-4 REQ. EST.
29 A/C INCORPORATION
30 AUTO RF TUNING
31 RANDOM PRF
32 ANTI CHAFF (PHASE I)
33
34 TIME DIVISION DATA LINK
35 MODIFIED AWCS
36 RCA AIRBORNE EQUIP. AVAIL.
37 A/C INCORP. (IN SERVICE)
38
39 IR SIGHT
40 LONG RANGE DETECTION



F106 - AWCS

APPENDIX "B" TO 51038 CW. 180 (AAWS) 19 DEC 58.

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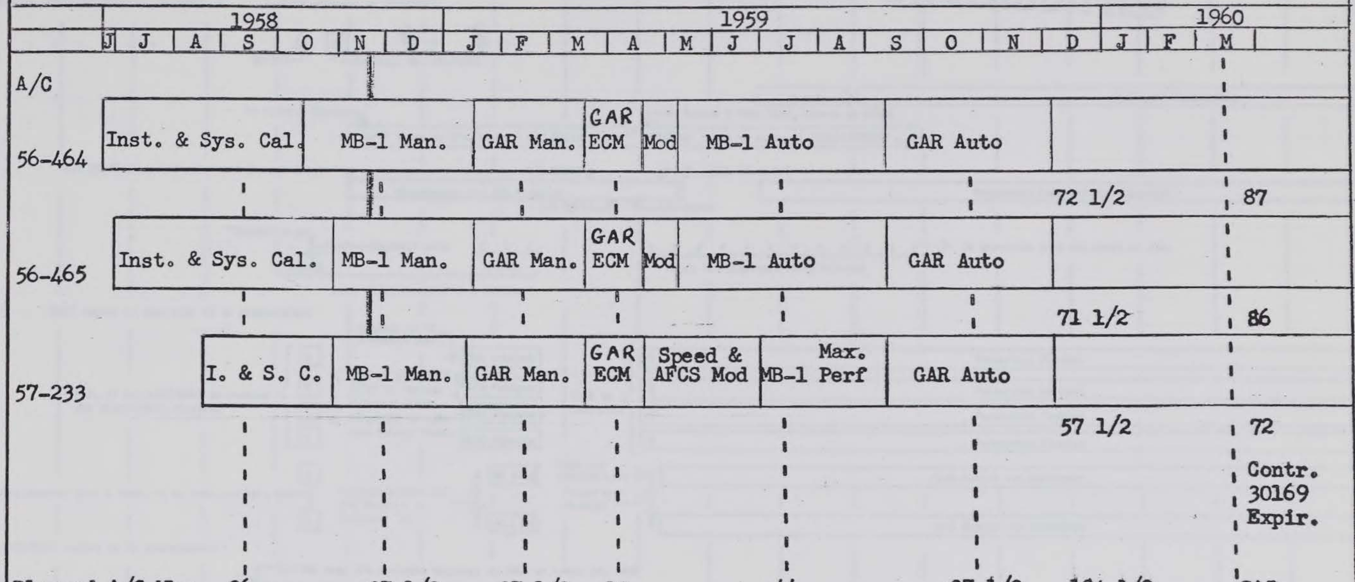
APPENDIX "B"
To
S1038CN-180(AAWS)
19 DEC 58

AAD PROGRAM SCHEDULE

Date: 23 November 1958



Planned A/C Wks	26	37 1/2	27 1/2	12	44	37 1/2	184 1/2	245
Actual A/C Wks	43	12	-	-	-	-	201 1/2	
Firing Missions	-	23	17	4	27	23	94	
Re-flys (25%)	-	6	4	-	7	6		
Dry Runs (2/FM)	-	46	34	20	54	46		
Data Flights		75	55	24	88	75		

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AAD PROGRAM SCHEDULE

APPENDIX "B"
To
S1038CN-180(AAWS)
19 DEC 58.

PPORT PROGRAM

IC AWCS FOR AVRO RCAF/CF-105 SUPPORT
PROGRAM, ISSUE NO. 2
(PLANNING PURPOSE ONLY)
(TITLE UNCLASSIFIED)

HUGHES AIRCRAFT COMPANY

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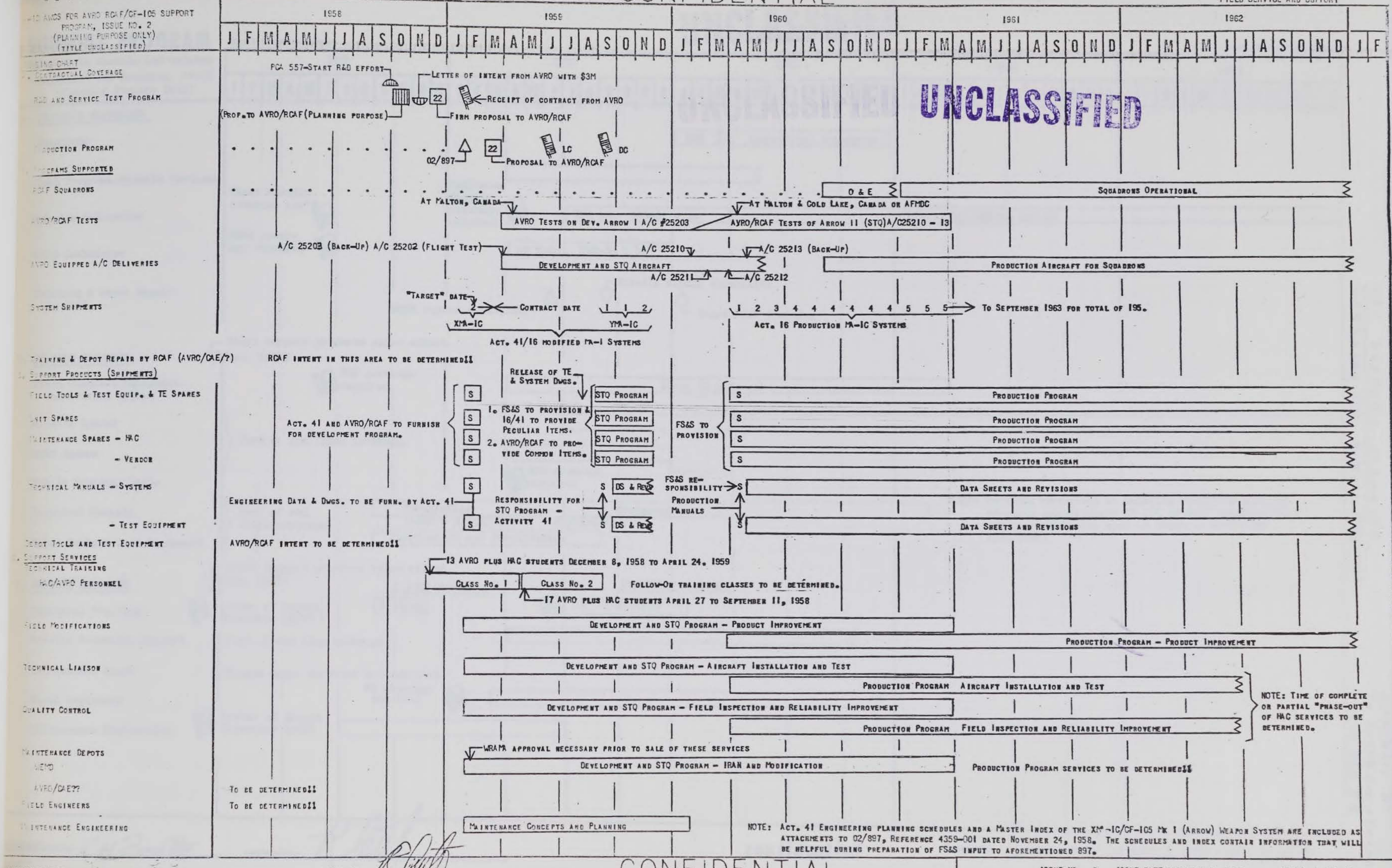
APPENDIX "C"

FIELD SERVICE AND SUPPORT

UNCLASSIFIED



NOTE: TIME OF COMPLETE OR PARTIAL "PHASE-OUT" OF HAC SERVICES TO BE DETERMINED.

NOTE: ACT. 41 ENGINEERING PLANNING SCHEDULES AND A MASTER INDEX OF THE XMA-IC/CF-105 MK I (ARROW) WEAPON SYSTEM ARE INCLUDED AS ATTACHMENTS TO 02/897, REFERENCE 4359-001 DATED NOVEMBER 24, 1958. THE SCHEDULES AND INDEX CONTAIN INFORMATION THAT WILL BE HELPFUL DURING PREPARATION OF FS&S INPUT TO AFOREMENTIONED 897.

ADMINISTRATOR:

APPROVED:

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ISSUE NO. 2 ISSUE DATE DECEMBER 5, 1958 PAGE 1 OF 2

HAC SUPPORT PLANNING
MA-1C ACWS.

APPENDIX "B"
TO
S1038 CN-180 (AAWS)
19 DEC 58.

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APPENDIX B
TO S1038CN-183
DATED 19 DEC 58

FALCON GAR-3/GAR-4 DELIVERY SCHEDULES

CALENDAR YEARS	1957											
MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
YGAR-3 (75 ORDER)										7	5	11
GAR-3 (196 ORDER)												
GAR-3 (284 ORDER)												
XGAR-3A (13)												
GAR-3A (792)												
YGAR-4 (75 ORDER)										7	8	11
GAR-4 (CANCELLED AFTER 60)												
XGAR-4A (16)												
GAR-4A (60)												
GAR-3/GAR-4 CHECK-OUT CONSOLES											2	2
TYPE II (TRAINING) MISSILES (25)										5	5	5
TYPE III (TEST) MISSILES (295)										30	38	45
YGAR-3 TYPE IV (WSEM)												
GAR-3 TYPE IV												
GAR-3A TYPE IV												
YGAR-4 TYPE IV												
LE-6 LAUNCHERS (631)												
GAR-3/GAR-4 MTU (4)												

CALENDAR YEARS	1958											
MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
YGAR-3 (75 ORDER)	12	13	3									
GAR-3 (196 ORDER)			15	20	25	25	25	25	25	25	11	4
GAR-3 (284 ORDER)											14	25
XGAR-3A (13)												
GAR-3A (792)												
YGAR-4 (75 ORDER)	12	13										
GAR-4 (CANCELLED AFTER 60)			15	20	25							
XGAR-4A (16)												
GAR-4A (60)												
GAR-3/GAR-4 CHECK-OUT CONSOLES	2						2	3				
TYPE II (TRAINING) MISSILES (25)	5											
TYPE III (TEST) MISSILES (295)	45	50	50									
YGAR-3 TYPE IV (WSEM)											6	→
GAR-3 TYPE IV												
GAR-3A TYPE IV												
YGAR-4 TYPE IV											4	→
LE-6 LAUNCHERS (631)				55	63	63	66	63	77	92	95	57
GAR-3/GAR-4 MTU (4)												4

CALENDAR YEARS	1959											
MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
YGAR-3 (75 ORDER)												
GAR-3 (196 ORDER)												
GAR-3 (284 ORDER)	35	35	35	35	35	35	35					
XGAR-3A (13)	←			13			→					
GAR-3A (792)								2	5	15	25	45
YGAR-4 (75 ORDER)												
GAR-4 (CANCELLED AFTER 60)												
XGAR-4A (16)		←			16		→					
GAR-4A (60)								2	5	15	35	3
GAR-3/GAR-4 CHECK-OUT CONSOLES	1	1	1	1								←
TYPE II (TRAINING) MISSILES (25)												
TYPE III (TEST) MISSILES (295)												
YGAR-3 TYPE IV (WSEM)				TO BE COMPLETED BY JAN 59								
GAR-3 TYPE IV				←		40		→				
GAR-3A TYPE IV											←	
YGAR-4 TYPE IV				TO BE COMPLETED BY JAN 59.								
LE-6 LAUNCHERS (631)												
GAR-3/GAR-4 MTU (4)												

CALENDAR YEARS	1960											
MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
YGAR-3 (75 ORDER)												
GAR-3 (196 ORDER)												
GAR-3 (284 ORDER)												
XGAR-3A (13)												
GAR-3A (792)	100	100	100	100	100	100	100					
YGAR-4 (75 ORDER)												
GAR-4 (CANCELLED AFTER 60)												
XGAR-4A (16)												
GAR-4A (60)												
GAR-3/GAR-4 CHECK-OUT CONSOLES	(FIRST DELIVERY DEC— THESE WILL BE GAR-3A/4A)	9				→						
TYPE II (TRAINING) MISSILES (25)												
TYPE III (TEST) MISSILES (295)												
YGAR-3 TYPE IV (WSEM)												
GAR-3 TYPE IV												
GAR-3A TYPE IV		45					→					
YGAR-4 TYPE IV												
LE-6 LAUNCHERS (631)												
GAR-3/GAR-4 MTU (4)												

CALENDAR YEARS	1961										
MONTHS	J	F	M	A	M	J	J	A	S	O	N
YGAR-3 (75 ORDER)											
GAR-3 (196 ORDER)											
GAR-3 (284 ORDER)											
XGAR-3A (13)											
GAR-3A (792)											
YGAR-4 (75 ORDER)											
GAR-4 (CANCELLED AFTER 60)											
XGAR-4A (16)											
GAR-4A (60)											
GAR-3/GAR-4 CHECK-OUT CONSOLES											
TYPE II (TRAINING) MISSILES (25)											
TYPE III (TEST) MISSILES (295)											
YGAR-3 TYPE IV (WSEM)											
GAR-3 TYPE IV											
GAR-3A TYPE IV											
YGAR-4 TYPE IV											
LE-6 LAUNCHERS (631)											
GAR-3/GAR-4 MTU (4)											

(NOTE – THIS SHEET SHOWS DELIVERIES AGAINST EXISTING CONTRACTS ONLY AND DOES NOT SHOW PLANNED BUT UNFUNDED FUTURE PROGRAMS)

APPENDIX "C"
TO S1038CN-180
DATED 19 DEC 58

INSTALLATION - CF105

General

1 HAC were extremely well aware of the "ground rules" under which the MA-1C contract for the Arrow had been raised:

(a) For aircraft 25202 a current production MA-1 was to be fitted with as little modification as possible.

(b) On any later orders improvements would be incorporated into MA-1C in some regular manner e.g. via ECP's, to ensure that in any given period the MA-1C would differ as little as possible from the USAF funded MA-1 system.

2 The MA-1C differs from the MA-1 in two major areas at the present time:

(a) The provision of 400 cycle power for the Arrow.

(b) The cockpit configuration, i.e. the pilot and radio navigator cockpits of the Arrow versus the single pilot position of the F106.

3 HAC staff advised that the MA-1C more closely resembles the MA-1 than the two place ASQ25. The latter designation is used to describe the two seated trainer version of the F106. Since it is a trainer aircraft, the second cockpit is an exact duplicate of the front cockpit.

Problem Areas

4 Cockpit Configuration - A recent proposal for a cockpit configuration was shown to the visiting team members. HAC staff stated that they were working closely with AVRO personnel on the problem. They feel that they have been able to explain the importance of incorporating the 5 inch rather than the 3 inch scope into the front cockpit. A collapsible hood, extended when needed, should remove the objection to the fixed hood which obscured certain instruments on the cockpit panel.

5 Stable Platform - Different departments in the HAC organization expressed concern over the intention to mount the stable platform near the center of gravity in the Arrow aircraft. They would prefer a mounting position near the radar and flight control sub-system racks to minimize stray pick-up in cable leads since they feel that the platform's torquing motors are capable of correcting for a non-C of G installation point.

6 Intercommunications - The CF105 with its AIC 10A intercom system will not use the intercom equipment of the MA-1/F106. The AIC 10A will require some integration into the system but HAC staff feel that the installation will be an improvement over the F106 intercom.

7 Pressurization - The UHF communications transmitter is pressurized to 15 psi gauge. In the F106 a check valve is included as an airframe component to hold the system at gauge pressure if the MA-1 pressure supply should fail. To avoid damage to the equipment, it is imperative that AVRO include such a check valve on the Arrow aircraft - including 25202. All other electronic

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equipment receives light pressurization from the cooling air pumped through the system. The air enters the racks at about six inches (water) pressure and escapes through small vents in the boxes to cabin pressure.

8 Waveguide Switching - A problem exists in the F-106 in connection with a waveguide switch which was incorporated to check the air-air IFF system. Switches in each of the antenna lines of the interrogator and responder were connected by an R/F cable to provide a self-test feature for the system. The cable used is RG 143U with an attentuation of 0.6 db per foot. In the F-106 installation the cable provides about 35 db attenuation between the equipments. Since 115 db is required, 40 db attenuators were included at each of the waveguide switches. The switch configuration - 3" x 3" x 6" - gives rise to a space problem. In the CF105 installation, it will be necessary to ensure that the cable and switches provide the necessary degree of attenuation to satisfactorily test the IFF system.

9 Certain other topics, not necessarily of immediate problem interest, were discussed:

(a) UHF Channel Annunciator - The channel indicator in the F106 cockpit is a mechanical instrument. A circular card with channel numbers listed vertically around the circumference is rotated past a cut-out window. The RCAF may wish to incorporate one of the electrical type ennunciators already tested for the Arrow aircraft.

(b) Radio Compass Inputs - The radio compass, ARN 6, which is not part of the MA-1, is being included in the Arrow communications - navigation system. The RCAF's TACAN - ground net will not be fully activated until mid-1961 so the ARN 6 was included to provide an LF/MF DF facility until that time. With the possibility of incorporating manual inputs into the digital computer (refer to Appendix "F"). The ARN 6 equipment takes on added importance in that a fix obtained from two radio beacons could be fed into the computer as Tacan information and so can be used during the navigation-to-attack phase.

(c) Antenna Multiplexing - The F106, like the CF105, uses a fin cap antenna for UHF communications and a belly antenna for Data Link reception. In the MA-1/F106, the airframe provides 30 db isolation between the antennae and a tunable filter in the data link line provides a further 30 db. HAC advised that they had no plans for multiplexing the equipment so that either equipment could use either antenna. They recognize that with certain bank angles the airframe will shield the data link antenna from the ground transmitter but state that a study of the multiplexing problem conducted for them by Stanford University indicated that the solution would be too complex. It is interesting to compare this answer with the two proposals for multiplexing received from RCA on the Astra contract. One of the proposals was approved for further investigation but the study was halted on contract cancellation. Technical and operations staffs may wish to reassess the problem and the proposed solutions for future use.

APPENDIX "D"
TO S1038CN-180
DATED 19 DEC 58

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CURRENT MA-1 STATUS AND IMPROVEMENTS

Summary of Key MA-1 Capabilities

1 Improved Armament

- (a) Nuclear capability
- (b) Improved Falcon Missiles - higher P_k (See Appendix "R")
  - (i) Improved CCM capability
  - (ii) Reduced environmental restrictions
  - (iii) Greater tactical flexibility

2 Extended Attack Capability

- (a) Zero to 70,000 feet - with AMTI and snap-up mode
- (b) Performance to match aircraft speeds up to Mach 2.0
- (c) Command, Computer Control and DR of intercept mission

3 Counter Measure Capability (See Appendix "J")

- (a) If ECM is directed against the interceptor's ground stations:
  - (i) The interceptor will operate in Modified Close Control and,
  - (ii) will use DR on approach to the target
- (b) If ECM is directed against the interceptor, it will use
  - (i) Range and course extrapolation
  - (ii) Wide dynamic range of reception
  - (iii) Anti-chaff circuitry

4 Improved System Maintenance (See Appendix "M")

- (a) Rapid, semi-automatic flight line system check
- (b) Built-in self test for alignment and fault location.
- (c) Completely integrated shop maintenance stands.

MA-1(40) Improvements (See Appendix "J")

5 A number of improvements were planned for the MA-1 for use in the F-106, models C and D.

- (a) Phase 1 Improvements
  - (i) Sniffer circuitry

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(ii) Random Pulse Repetition Frequency (PRF)

(iii) Extended range - 80 mile sweep
- Bones Marshall Grid
- Extended search range

(iv) Improved anti-chaff circuitry

(v) 400 cycle power supply

(vi) 40 inch hydraulic-antenna with silent lobing

(vii) Time Division Data Link (TDDL)

(viii) Provision for Master Oscillator Power Amplifier (MOPA).

(b) <u>Phase 2 Improvements</u>

(i) Production of MOPA

(ii) Complete anti-chaff circuitry

<u>MA-1(28) Improvements</u> (See Appendix "J")

6 The planning and design activity has been transferred from the MA-1(40) to the MA-1(28) system for the F-106 A and B:

(a) <u>Phase 1 Improvements</u> - these items are planned MA-1 ECPs.
- Production is scheduled for Jan 1959.

(i) Sniffer circuitry

(ii) Random PRF

(iii) Extended range - as above.

(b) <u>Phase 2 Improvements</u> - Production planned for Jan 1960.

(i) Improved anti-chaff circuitry

(ii) 400 cycle power supply

(iii) 28 inch hydraulically-driven antenna with silent lobing

(iv) TD Data Link

(v) Provision for MOPA

(c) <u>Phase 3 Improvements</u> - Production planned for Aug 1960.

(i) Production of MOPA

(ii) Complete anti-chaff circuitry

7 In addition to the improvements listed above, provision is being made to extend the lock-on range from 22.5 miles to 36 miles.

8 If the improved programme is approved, HAC expects an "early 1960" availability to the USAF. Production models for the CF-105 would be available 6 - 9 months later.

APPENDIX "E"
TO 1038CN-180
DATED 19 DEC 58

FIRE CONTROL SYSTEM, ARMAMENT AUXILIARIES AND COMPUTER

Introduction

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1 Relevant Hughes Aircraft documents available in AFHQ Technical Library, are:

(a) HAC MA-1-5-S "Operational Characteristics and Capabilities of the F-106 A/MA-1" Apr 58 - (Secret), gives a good description of system characteristics in operational terms.

(b) ES 464-00-1 Issue 6 - Specification for MA-1 System.

(c) HAC MA 1-115 "Production Radar Sub-system Design Specification".

(d) MA-1-C/CF-105 Mk2 (Arrow) Weapon System Master Index, 12 Dec 58.

(e) HAC FPS 3-020-1 Issue 1 "Functional Program Specification of the Model A Navigation and Attack Digital Computor Program" 24 Nov 58.

(f) "Digitair" - Hughes. Unclassified brochure of computer's technical features.

(g) "Digital Arithmetic Primer" 5 Aug 57 by R. J. Hagerty of HAC Field Service and Support (Unclassified). This is an elementary introduction to the type of digital algebra used in the MA-1 digital computor.

2 WADC were asked for an expression of opinion as to firmness of the F-106 program and the design workload existing at Hughes. WADC consider the present F-106 program (184 A/C to end of FY-1959) is on firm ground. A decision as to a FY 60 buy will not be taken until next summer and will have an impact on MA-1 development and production. (Note that some items in MA-1/40 program are also F-108 items and, therefore, not necessarily tied to the F-106). With respect to the HAC design staff workload, the MA-1 design peak was passed approximately six months ago. Since that time MA-1 effort has subsided to a level approximately 30 to 40% of last summer's peak. The F-108 program will not peak for at least 18 months, by which time it is considered all MA-1 development will be complete.

Fire Control System & Armament Auxiliaries

3 The MA-1/40 (vice MA-1/28) program items are covered in detail at Appendix J. Four prototype copies of all Phase 1 MA-1/40 items have been built. Phase 2 prototypes are expected to be available in approximately a year.

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If an MA-1/28 go-ahead is given, the first 28 inch antenna will be available approximately May to July 1959. For the CF-105, the antennas for A/C 202 through early production are the standard 23 inch electric drive models. With availability of the hydraulically driven 28 inch model (1500 psi, 15 boxes) in 1961, the RCAF could fit a non-standard diameter antenna (say 32 to 36 inches) provided Hughes had been given the requisite six months development time.

4 It may be noted that all MA-1 system units (black boxes) are identified by a six-digit Hughes Part Number, which may be followed by a three-digit number (equivalent to designating the "Mark"). The first three digits of this number are used by HAC to identify the contract against which the unit was developed. This information is of value in that the source of any unit may be readily identified. Those units which have a part number whose first three digits are 470 are unique for the MA-1-C (Arrow 2) installation. A list of the pertinent "first - 3 - digit" numbers encountered in the MA-1-C system, and their development source contract is:

1st 3 digits	Parent System
435	E-Series
463	MG-10
464	MA-1
468	MG-13
470	MA-1-C (unique)
471	LRI (F 108)
472	AN/ASQ 25
476	MA-1/40

5 The 468355-110 unit provides range and range rate meters and was developed for the MG-13 to provide additional data for Visual Identification Pass (VIP) attacks. HAC and AVRO considered including this unit in the MA-1-C but dropped the idea as not worth the cost (HAC went so far as to purchase some 468355 units from the USAF). Pertinent factors in this consideration were:

(a) The present unit includes some controls duplicated in the MA-1 and does not have a satisfactory outline configuration for CF-105 installation. The required repackaging would probably result in a unit cost, for a limited production run, of about $1800 to $2000.

(b) The MA-1 display includes a four mile (8000 yard) scale (available even in search); it has simultaneous presentation of the attack display and "B" scope when locked-on (providing azimuth, elevation and range), and a 250 yard warning light comes on at the appropriate time.

(c) The 355 unit provides no information unless the radar is locked-on, and then provides it in a manner causing the operator to divide his attention.

(d) The meters can be (and are) calibrated to

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permit firing, but this calibration is good only for one case; whereas the firing data provided on the scope accounts for such parameters as altitude and closing rate.

6 The Remote Scope Recorder to record the scope displays (464149-150) received production go-ahead Feb 58. First article was manufactured Dec 58 and initial aircraft incorporation is scheduled for June 59. It is not included in the system procured for aircraft 202 but would be included in any later production MA-1.

7 This unit weighs 20 pounds and consists of two one-inch oscilloscopes, a highly modified AN/N9 camera with special magazine, associated electronics and a dust cover. The unit is capable of recording approximately 15 minutes of continuous attack or 200 minutes of search on one 100 foot roll of film. This is sufficient for approximately five attacks. The recorder does not function in operating modes other than search and track (will not record VIP, snake formation, beacon or ground map).

8 The camera is basically an N9. With all the modifications described below it is designated as a Bell & Howell 917F (Hughes Part Number 651553). It has been fitted with a reduced pull down (cut to half of normal), thus effectively doubling the recording capacity. The camera drive motor has been modified to run at eight frames per second. It has also been fitted with a solenoid-operated clutch with over-ride brake to permit pulsed operation with the shutter open. In search the clutch is pulsed once at the end of each horizontal sweep of the antenna (once every 1.4 seconds). The shutter is arranged to stay open between each pulse so that each frame of film, during search, records one complete horizontal sweep of the antenna. To record during track operation the clutch is locked in and the camera operates at eight frames per second. Film used is standard double track unsplit 8 mm film (used for closer sprocket holes). This camera is built by Bell & Howell to HAC specification PS 3-003-2 dated 1 Jul 58.

9 The camera magazine is also modified. It accepts a 100 foot roll of film. It must be hand loaded but is light-tight at the half open position. This permits threading the film in the light after the film has been inserted in the magazine in a darkroom. The magazine includes a film sensing switch to prevent the film from running completely off the reel. A light trap access door and adaptor is also provided. This permits direct feed of the exposed film from the magazine into the automatic film processor. Bell & Howell builds this magazine to HAC Spec PS 3-004-2.

10 The film is processed in a Fairchild MINIRAPID 16 mm Film Processor Model F316, fitted with a small Fairchild adaptor to accept the above magazine. Projection is with the normal Time and Motion Study Projector which has been modified to make the pull down and aperture compatible. Necessary mods have been designed by Bell & Howell.

11 Two of the MA-1 armament auxiliaries units have been modified for installation in the CF 105. These are the 470264-100. Relay Assembly, Armament Control #1 and the

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470464-100, Relay Assembly, Mode Selection units. Two units Convair supplied for the F 106, are HAC supplied for the CF 105 and are the 470805-100, Armament Control Panel and the 470664-100 Armament Control Relay Assembly #2. A third unit new for the CF 105 is the 470726-100 Motor Generator 1600 cps.

UNCLASSIFIED

12 New safety interlock requirements had just been laid down prior to this visit by the Air Force Special Weapons Centre (at Kirtland AFB). These are being incorporated into the MA-1 armament units for the CF 105 and include

(a) an Ejection Release Switch to control a mechanical restraint fitted to prevent inadvertent MB-1 movement

(b) an Ejection Release Annunciator to indicate the position of the above pin (mechanical restraint)

(c) a removable mechanical restraint which prevents selection on the ARM Selector of Special Weapon (MB-1) unless the mechanical restraint has been removed.

13 Other cockpit controls include Master Arming Switch, SPL WPN annunciator, Pursuit Switch, Missfire Lights, Retract Switch, MB-1 Armed Monitor and Missile CCM Switch. Descriptive detail is available in literature referenced above.

14 Discussions were held with HAC Flight Test personnel at Hughes (Palmdale) and with Hughes MA-1 aircraft installation-crew personnel at Convair (Palmdale). Items of discussion have been included elsewhere under targets, instrumentation and maintenance. Several remaining items are presented below.

15 The complexity of the MA-1 is reflected in the size of the aircraft installation crew required. The largest such crew on previous contracts (such as MG-13, MG10, E5 etc) has been 50 personnel. The present crew installing MA-1 into the F106 at Palmdale comprises 150 personnel, and this is to be increased shortly to 170 personnel.

16 Time required to pre-flight the F 106 is currently running approximately three hours, with the major item being the airframe . MA-1 system acceptance flights require about 15 hours to complete. The average number of flights to acceptance is currently running to about 10.5 but it is hoped that this will come down to eight flights or less. Reliability figures on #1 production MA-1 system (in operation at Holloman) were quoted at five to seven hours of system operation between failures. Hughes draft specifications are proposing to require 10 hours between failures. It was estimated that a reasonable figure for early field use of the equipment might be seven hours between failures.

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UNCLASSIFIED

17 The pattern flown at Palmdale for FCS flight test yields a range of 28 miles at turn-in onto target. Using a B57 (Canberra) target with no radar augmentation immediate target pick-up on turning-in (i.e., 28 n.m.) has been consistently achieved. In initial test flights of the automatic attack coupler some transient problems were experienced but these have been ironed out. Good AFCS performance has been demonstrated from 175 knots to M1.8.

Digital Computer

18 The computer memory element is a rotating magnetic drum, which is contained in an individual "black box". Two drum units are supplied with the MA-1 system; a "Tactical drum" for operational use and a "Test drum" for scheduled maintenance operations. Constants, initial conditions, program of arithmetic operations and other intelligence is magnetically impressed upon the drum by playing a punched paper tape through a conversion unit connected to the computor.

19 The test drum provides a facility to exercise and analyse the system for scheduled maintenance operations. The Test drum is loaded for this purpose from two tapes. The Test Program Tape (consisting of three reels) provides the basic program applicable in general to all MA-1 systems. The Test Program Change Tape provides the capability to modify the test program to account for system modifications or changes in procedure.

20 The Tactical drum is loaded from four tapes. The Tactical Tape contains instructions for the arithmetic operations necessary to accomplish attack, navigation, control, TACAN operation and the short system ground check utilizing the tactical test equipment, "MART" (described in Appendix "O" - Maintenance). The Tactical Program Change Tape provides the facility for effecting changes to the basic tactical program. The Auxiliary Data Tape contains required geographical co-ordinate data and is uniquely determined by the particular box of 35 m.m. film (map) strips loaded into the system. The Data Link Timing Tape contains the intelligence required for signal data processing, identification, synchronizing, and the constants necessary for interrogating MART. One of 16 possible Data Link Timing Tapes is loaded at one particular time. The time required to load, rewind and automatically check the complete drum is approximately two hours. However, auxiliary data (TACAN coordinates, having points and sector co-ordinates) may be changed in a 5 minute loading cycle.

21 The present computer tactical program (called the "A" program) is well described in documents available at AFHQ. It provides coplanar lead collision; JAT; normal and AMTI pursuit; visual identification pass; navigation; and tactical test features. If the aerodynamic characteristics of the CF-105 reasonably approximate those of the F-106, and if the other parameters such as weapon/interceptor separation parameters and snap-up range criteria are reasonably similar, no problems will be involved in modifying the computer program for CF-105 operation. However, if significant changes are

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involved it will be necessary to completely reprogram, involving a HAC effort of approximately 3/4 man-year expended over a period of approximately four months but the possibility of this contingency arising will not be assessable until considerable CF-105 flight test data has been obtained.

UNCLASSIFIED

COMPUTŒR ATTACK MODES

"A" Program - lead collision (coplanar only)
- by crew selection
- on Jam Angle Track using extrapolated range

Pursuit
- by crew selection
- on Jam Angle Track
- in low-altitude AMT1 mode

Visual Identification Pass
- automatic flight control
- manual or for snake formation

"B" Program
- clean-up of A program
- snap-up made normal attack mode
- modified close control (SAGE provides target coordinates, altitude and velocity - computer then computes offset point navigation and subsequent attack)
- provision for automatic flight and navigation
- partial altitude hold (to overcome humped or submarine courses).

22 The "A" program provides no snap-up although there is a deceleration correction term. It may be noted that the navigation functions already occupy about 40% of the drum capacity. Addition of a doppler capability is considered impractical since this addition would require drum space equal to that now occupied by both navigation and attack functions.

23 The "B" program will be finalized in January 1959, and is expected to have been flight tested and be available in the third quarter of calendar 1959. This program will feature an improved (de-bugged and shortened) "A" program together with extension of range extrapolation to the snap-up case, lead collision snap-up, provisions for automatic flight control and navigation tie-in and partial altitude hold during attack (to alleviate humped/submarine attack paths).

24 The possibility of a further computer program change as part of the so-called MA-1/40 package has been considered by HAC but is not defined at this time. USAF

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have not yet received a decision regarding a FY 1956 buy of F-106 aircraft and further MA-1 development is partly contingent on this decision.

UNCLASSIFIED

25 Addition/modification to the "B" program considered by HAC as part of an MA-1/40 program include Differential Altitude Ranging (DAR), considered sufficiently accurate for GAR 3Y only; IR sub-system program (including a power rate ranging routine); adoption of Altitude Hold in the Phase 1 steering equations (to obviate humped/submarine attack path problems) and the inclusion of more self-test sub-routines so that it would not be necessary to change drums for minor maintenance operations such as scale factor adjustments.

Possible Computer Development

26 To accommodate more sub-routines (to provide more computational capabilities) HAC have proposed a drum longer by approximately 2.5 inches. WADC have not accepted either HAC's proposal to enlarge the drum nor their proposal to transistorize the computer. Although a computer with a larger capacity would be desirable, the present storage capability is adequate for presently authorized programs, including automaticity and TDDL. This subject cannot be considered closed, however, since either the inclusion of auxiliary ranging (such as DAR, PACOR or PADAR) or a weapon change (such as a GAR 3Y) would necessitate incorporating a greater memory capacity (larger drum).

27 All normal attacks are presently mechanized ("A" program) for co-planar lead-collision geometry. However, the snap-up attach provides a better target (larger radar cross-section for example), is less complicated to mechanize in the computer than programming to altitude for a co-planar attack, and utilizes an area where the interceptor is easier to control. With the advent of the "B" program the normal attack will be snap-up (approximately 8 to 10 secs before fire) with a 20,000 foot differential if the target is below 45,000 feet and with the interceptor at 45,000 feet if the target is above that altitude.

28 Although the MA-1 is specified to cater to a M 2.4 interceptor, it will cater to higher speeds. However, the above M 2.4 temperatures are experienced outside the MA-1 Weapon Control System operating range. The same heating problem exists with the missiles if they are fired at these higher Mach numbers.

29 The "B" program provides more flexible environmental freedom for the GAR missiles together with better control of the missile CCM features (see Appendix J). In contrast to the "A" program which optimizes the altitude variables on six parameters, the "B" program is optimized on virtually infinite parameters. The facility to select edge tracking for the missile, if CCM has been called for, permits the computer to select the tracking mode in accordance with the following logic chart:

	Missile Anti-Chaff		Normal	
	Nose	Tail	Nose	Tail
Altitude greater than Launch Range	LE	TE	Centroid	Centroid
Altitude less than Launch Range	LE	Centroid	LE	LE

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UNCLASSIFIED

30 The possibility exists that the LRI computer (F108) could be used in later production MA-1 for CF 105. This is an advanced transistorized computer (possibly available end - 61 to early 62). It is a four-phase machine with independent operation, for example, of the arithmetic unit and control unit. A large number of manual inputs may be inserted through a keyboard. This manual input is being given priority consideration, motivated by a desire to utilize the capacity of the two-man crew and to operate in a very weak ground environment. The capacity will be approximately 3 to 4 times that of the present MA-1 (Mod 6) computer and about twice as fast. The word length may be increased to 20 or 21 to provide more flexibility in writing instructions. Maintainability and reliability are claimed to be much superior. A prototype has been built. Six months are estimated to check this prototype, with possibly a further year of development (production presently not defined).

31 The drum check mode has been found to work well in both the MA-1 and the LRI (this check essentially adds up all the digits on the drum). However, in incorporating MA-1 functions (such as A, B and C magnetic core arithmetic registers and magnetic flip-flop control register) onto the drum, by virtue of its four-phase operation, the LRI computer can be drum checked in the air, provided its operation may, tactically, be temporarily interrupted.

32 Another possibility for the CF 105 would be a transistorized version of the Mod 6 computer. This version might remain single phase or be modified to a two-phase machine. Modules from the LRI computer would be used to achieve transistorization. If this were done the first problem would be output, which would have a maximum value of 100 volts. This output level would pose a problem with transistors, possibly necessitating vacuum tubes on the outputs.

Programming Theory

33 An MA-1 problem (also common to the MG-2) is the occurrence of "humped" or submarine" attack paths. These are caused by failure or inability to eliminate bias in the antenna rate gyros. It can be shown that for a constant speed tail chase the maximum departure (h_m) from a coplanar attack is

$$h_m = \frac{\frac{1}{4} D(W_E) R_o^2}{\mathring{R}}$$

where R_o is initial lock-on range. This relationship displays the fact that early lock-on yields greatly increased humps, hence suggesting partial altitude hold as a rudimentary solution.

34 As stated elsewhere, Hughes have looked at four methods of possive ranging from the point of view of computer programming. These are differential altitude

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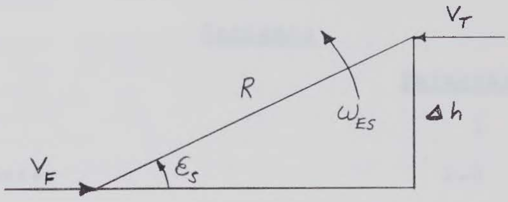
ranging, elevation rate ranging, ranging by change in Line of Sight (LoS) direction and change in LOS rate (the latter two presumably three-dimensional extensions of the first two). Other, more sophisticated, schemes have been looked at but not to the point of investigating required computer programming. These four schemes all solve basically simple geometric relationships with certain assumptions and approximations to within (hopefully) required missile accuracy. With respect to the following diagram



Differential Altitude Ranging is got from

$$R \sin E_s = \Delta h \cong h_T - h_F$$

whence $R = \dfrac{\Delta h}{\sin E_s}$

where subscripts
F refer to interceptor
T refer to target.
E refer to elevation
S refer to inertial space coordinates

and target altitude is received from the ground environment.

35 Elevation rate ranging is derived by integrating the above equation to get (with altitude held constant)

$$\dot{R} \sin E_s + R W_{ES} \cos E_s = 0$$

whence $\dfrac{R}{-\dot{R}} = \dfrac{\sin E_s}{W_{ES} \cos E_s} = -T_c$

where T_c is time-to-go to fighter-target collision.

36 As noted elsewhere, HAC are carrying out system integration design studies for a proposed Infra-Red (IR) subsystem. These studies include mechanization of a passive ranging technique. The equation for IR power rate ranging was stated to be

$$\frac{R}{\dot{R}} = \frac{\tau}{\sqrt{\dfrac{i_2}{i_1} - 1}}$$

from which, again, time to go is readily obtained.

...../10

UNCLASSIFIED

CONFIDENTIAL
APPENDIX "F"
TO S1038CN-180
DATED 19 DEC 58

INSTRUMENTS

Contents

INTRODUCTION

1 The MA-1 Airborne Weapon and Control System includes air data equipment, gyro reference system, horizontal situation display, command Mach and command altitude indications, and automatic flight control equipment. Instruments that have to be provided separately include the engine instruments, airframe instruments and flight instruments other than the horizontal situation indicator (HSI).

AIR DATA COMPUTER

2 People consulted: D. Stockman of WADC, and A Gill of HAC. The type is MG-1, range to Mach 3 and 80,000 feet, manufacturer Bendix, and specification - HAC PS2-699. It is an analogue device doing its computation without reference to the digital computer. Its accuracy is stated in the spec, a copy of which was supplied and is in the Technical Library.

3 The inputs are provided by sensors provided by the airframe manufacturer as follows:

(a) Pitot Static Tube, type MA-1, range to Mach 3, 22 inches long, 22 watt heater, made by Gibbons Manufacturing Co., Los Angeles.
(b) Angle of Attack Sensor, type MA-1, a wedge vane, on side of fuselage of F-106, on nose boom on CF105. The precision of angle of attack measurement is important for the MB-1 missile and constitutes a problem in assessment and study at present. For the MB-1 an accuracy of $\frac{1}{4}$ degree in angle of attack is required.
(c) Free Air Temperature sensor, type MA-1, stagnation temperature.

4 The air Data Computer consists of:-

(a) The Static Pressure Compensator, HAC #464721. This uses a three-dimensional cam for correction. To illustrate the possible magnitude of corrections note that the static error in the F101B reaches 2000 feet.
(b) The basic Air Data Computer, HAC #464646.
(c) The converter characterizes outputs as required for user equipment and is tailored to the aircraft. This is not an off-the-shelf item. The converter contains servos driving output potentiometers, digitizers, etc. The number is HAC #464420,
(d) A converter for altitude rate, HAC #464320 and a normal accelerometer, 464061 are used. Total weight of the five Air Data boxes is 80.5 lbs.

5 There are thirteen outputs such as dynamic pressure, log static pressure, Mach number, maximum safe Mach number,

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corrected temperature, etc. Four additional autosyn outputs will be added on units to be connected to the ARDC instruments.

6 The Production status of the Air Data Computer is that 300 have been built, and over 1,000 contracted for.

7 The Air Data Computer coupled to vertical scale instruments is now starting maneuvering flight tests. Its qualification is to be complete by 15 Mar 59. Mr. Scanlan emphasized that air data flight test points should encompass the whole flight envelope of the aircraft because this would ensure that the work would not have to be done over again with a costly retrofit. The curves of parameters are shaped and established better by the whole range with a limited amount of flying than by concentrating that flying in a limited range because the latter fixes only the average value at the centre of the limited range but not the shape of the curve.

8 Mr. Stockman of WADC recommended buying the MA-1 less the Air Data computer supplied by HAC. Their version of the MG-1 differs from the standard USAF one by deletion of the true air speed computing device this being calculated in the digital computer. He claimed that lack of TAS would prevent flying without the digital computer. This would not hinder local pilot practice but ferry flight would be inadvisable and operational missions impossible without the digital computer.

GYRO REFERENCE SYSTEM

9 People consulted: D. Stockman of WADC, A Gill and W.A.Lebitz of HAC. Description - The Gyro Reference System used in MA-1 and for the new ARDC flight instruments is commonly called a "Stable Platform" and consists of:-

(a) Stable Element, HAC #464289, sometimes called "Two-gyro element ". This unit has to be boresighted when it is installed in the aircraft. It has "bearing diddling" on the outer gimbal which means 20 revolutions one way followed by 20 revolutions the other way. The weight is 55.7 lbs. A directional gyro is included on the stable platform. The number will change to 476288 when the power is changed to 400 cps and the mounting changed to fit our aircraft. It has to be mounted inverted hanging from above and the roll wires have to be reversed internally. Two gyros sense torques that affect the Stable Element in the X and Y axes aligned according to the free directional gyro azimuth. The gimbals on all three axes are servo driven with high gain loops. The ARDC version is made by Lear and Hughes' version by Kearfott.

(b) Integrator, HAC #464009. This unit provides the time constant of integration of the 84-minute Schuler tuning. Weight is

...../3

14.2 lbs.

(c) Amplifier for Roll and Pitch, MAC #464109, weight 8.6 lbs.

(d) Demodulator, HAC #464209, wt 3.6 lbs.

(e) Azimuth Amplifier, HAC #464309, wt 12.2 lbs. This unit drives the azimuth gimbal and adds the correction from the flux valve to produce magnetic heading.

(f) Latitude Counter and Junction Box HAC #464409, weight 8.0 lbs. When it is converted to 400 cps power the number will change to HAC #476409. This is mounted in rear cockpit.

(g) Test Set, Communication and Navigation Sub-system, HAC #464396. This provides self-test facilities for the Gyro Reference Sub-system. The total weight of the above item is 109.2 lbs.

(h) Azimuth Rate Gyro, USAF Type MG-1, no. 60-5938. Erection Signals are cut out during turns by this unit and it provides rate signals to the Flight Director.

(j) Flux valve - provided by Avro.

(k) Gimbal Controller - Optional with ARDC instrument system and apparently not included in HAC sub-system. To make the system good for all attitudes a third gimbal controller is required to lock the roll gimbal.

Weight is 10 lbs extra.

10 Operation of the Gyro Reference Sub-system -

(a) Initial Mode - This occurs during the first two minutes while the gyros are being brought up to speed and erected by a tight closed loop from the accelerometers in the X and Y planes. It also provides the initial point of the Schuler term according to heading and latitude. Heading is set manually in the cockpit in unit HAC #476905, which contains also the power system controls. Latitude is set on HAC unit #464409, Latitude Counter.

(b) Normal Mode - In normal operation the accelerometer gain is reduced greatly and the Schuler tuning term is used. Correction signals are provided for the earth's rate of rotation corrected for latitude and for the

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platform orientation.

11 Accuracy - Accuracy of verticality is plus or minus one third of a degree and the drift rate of the vertical gyros is one third of a degree an hour. The drift rate of the Directional Gyro is one degree an hour.

FLIGHT INSTRUMENTS

12 People consulted: D. Stockman of WADC. The MA-1 system does not now include any flight instruments except the Horizontal Situation Indicator (HSI). The ARDC instruments, with the exception of the HSI, are to be put into the 90th and subsequent F106 system. They are remote operating and driven by outputs of the Air Data and Vertical Reference Sub-systems. Five hundred sets of these instruments are on order. Delivery is in eight months from date of contract. A report, "ARDC Vertical Instrument Test Report" by Major Sviminoff, is going to press in the week starting 15 Dec 58 and a copy will be sent to RCAF HQ.

13 The ARDC Attitude Director, made by Lear, has bank scale at top, moving horizon, turn and slip ball at bottom, and director needles with the lateral deviation pointer remaining vertical. The amplifier is integral but it can be detached. Weight 6.5 lbs.

14 The ARDC Flight Director Computer is procured from both Collins and Sperry, both having contracts for 250 of them to the same specification. Sperry's is transistorized and weighs 5 lbs. but the Collins unit, using tubes, weighs 10 lbs. Collins are transistorizing theirs now.

15 The ARDC Mach/Airspeed Indicator costs $8000, weighs 10 lbs and is panel mounted. The dimensions are 3-½" wide x 8-½" high x 8" deep. There are settable Command Markers, but when in Data Link mode they are set automatically. There is afailure warning flag. The following vertical scales are shown on the face: angle of attack, "g", Mach and IAS. Across the bottom are: - "g" counter, command Mach and IAS. There is a separate amplifier box.

16 The ARDC Altitude/Rate Instrument is in the same size as the Mach/IAS Indicator, weighs 10 lbs, costs $8000, and has a separate amplifier box. The vertical scales are: - rate of climb, to 12000 ft/min then a counter shows the higher rates, the altitude tape with 2200 feet showing in the window at any time, and thirdly a fixed planning scale with settable indices for target altitude, and command altitude and an indicating index for cabin pressure. Across the bottom are barometric setting, command altitude (automatic by Data Link or manually set) and a target altitude counter.

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17 Lighting and Paint Colour. Integral wedge plate lighting is used on all the ARDC new instruments. It wasdemonstrated to the writer and appeared successful. The bulbs are operated on 5 volts and have a life of 10,000 hours. They stand vibration better than the 28 volt bulbs as their filament is ¼ as long and has four times the cross-sectional area. Grey knobs are used on black instruments with a grey panel.

18 Flight Tewting. - The vertical scale instruments are just starting manoeuvring flight testing. These instruments are in a simulator in the Flight Control Laboratory at WADC and an invitation was extended to have RCAF pilots come and try out these instruments. Three days notice is all that was requested. Furthermore RCAF pilots were invited to come for trial flying with these instruments in a TF102 with side by side seats. We would have to ask for it officially through CJS and the Pentagon next March or April, ACTION RCAF HQ.

19 Qualification. - All qualifications are to be completed by 15 Mar 59. Qualification has been waived on the first thirty Gyro Reference System intended for use with ARDC instruments apart from the MA-1 system.

20 Relation to MA-1 System.CF105 Mark 2 aircraft nos. 210, 211, 212, and 213 should be like production aircraft. HAC will propose that they be equipped with the new ARDC instruments. Being remote indicating they are well integrated with the central air data computer and the gyro reference subsystem. Mode selection is done by a single selector switch for the MA-1 and the ARDC instruments. If those instruments are not selected, and the present ruling by the COR staff is that they are not acceptable, certain functions such as Command Mach number will require additional instruments. One needle of the RMI will probably be used for Command Heading. It is recommended that the RCAF should re-consider the question of using the ARDC vertical scale instruments.

ACTION RCAFHQ

DR NAVIGATION EQUIPMENT

21 The ARDC Horizontal Situation Indicator (HSI), made by Collins in size 5" x 5-1/4", has a moving card, director index, command marker (set by Data Link or manually), radio or radar bearing index, distance counter, and mode windows around the periphery. There will be a HSI in size 5" wide x 4" high, like the other but lacking the mode indications. A separate coupler is required and is airframe contractor furnished equipment tailored to the related systems that may be in the aircraft. Sperry makes one of these couplers. The Collins HSI will be finished qualification during the week starting 15 Dec 58. The ARDC Horizontal Situation Indicator is replaced in the MA-1 and MA-1C by a different unit developed by Hughes Aircraft Co.

22 HAC Horizontal Situation Indicator, (HSI). - Data from Mr. Slocum of HAC-Hughes have produced their own Horizontal Situation Indicator (HSI) HAC #470180 using film strips to project maps from behind onto a screen. The HSI shows interceptor and target position

...../6

and track direction. The centre of the map display is a map reference point such as, but not limited to, a TACAN station. The TACAN selector can select the appropriate map strip for any preset location or reference point. The HSI with its inputs from the Digital Computer constitutes the DR Navigation facility. It weighs 82 lbs. It is entirely dependant on TACAN as the digital computer does not start navigation computation without at least one TACAN fix received while airborne.

23 Hughes are funded by Avro to study how manual insertion of fixes could be done. The following procedure requiring two new switches is being considered:-

(a) Move the course control to put bearing line from interceptor across the location of the fix on the map display.

(b) Use a new "range control" to put interceptor over the fix.

(c) Press the new "insert button" putting data into the computer as if it came from TACAN. The computer continues by DR.

(d) If the process is repeated later over a second fix the computer will compute a wind from the two fixes. The wind information can be erased by use of the AILAS switch. New switches are mentioned in (b) and (c). A difficulty and expense would be encountered for lack of spare wires in the connectors and cables.

24 The requisite film strip maps are being produced by the Aeronautical Chart and Information Centre (ACIC) at St. Louis. They also make the data tapes for the digital computer. They do not have the necessary Canadian information in processed form, and they are fully loaded with work. Mr. Boucher recommended setting up a Canadian firm or Government Department to make these strips and tapes, to avoid encountering delay. (Boucher and W. H. Bell of HAC and Stegner of WADC.) ACTION RCAF & DDP

25 Installation of the HSI in the CF105 aircraft presents a problem in that it willnot fit in the proper central position in the rear cockpit. It might require repackaging. This might be done by a Canadian firm like CAE as a modification rather than complicate and delay the production line at Highes. It allows only six inches on either side for the man's legs and comes within an inch of the front edge of the seat.

26 From J. Scanlan of HAC - Future developments

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for Accurate Navigation - Two approaches are worth considering, e.g. inertial navigation and Doppler-aided DR.

(a) Inertial Navigation encounters very severe limitations to its tactical use in the present state of the art. For instance, floated gyros are used but these require one hour's warm-up time.

(b) Doppler-aided Dead Reckoning is a self-contained system which could replace TACAN. Additional computer capacity would be needed which could be provided by going to the transistorized computer, or possibly by deleting part of the time division data link facility.

Automatic Flight Control Sub-system

27 People consulted: - At WADC Mr. M. S. Feldman and Captain J. A. Fraser of Flight Control Laboratory and at HAC Mr. Mansfield, Mr. Nuttall and Mr. J. A. Scanlan.

28 Description - The AFCS provides pilot assist functions and automatic operation in several modes. Pilot Assist mode includes heading hold, altitude hold, Mach hold, and pitch and roll hold. A functional box diagram is attached. The specification is included in the MA-1 equipment Specification and HAC report no. MA-1-9S(V) "Functional description chapter V: Automatic Flight Control Subsystem" refers to the equipment in its MA-1 configuration. The weight is 32.1 lbs for the pilot assist units alone and 73.5 lbs. for the complete AFCS.

29 Pilot Assist Mode - Heading hold was set to engage within 5 degrees of wings level but this has been found unacceptable to pilots because it prevents them from making small corrections. It is being changed to a switch for heading hold. Preselect heading with a button has

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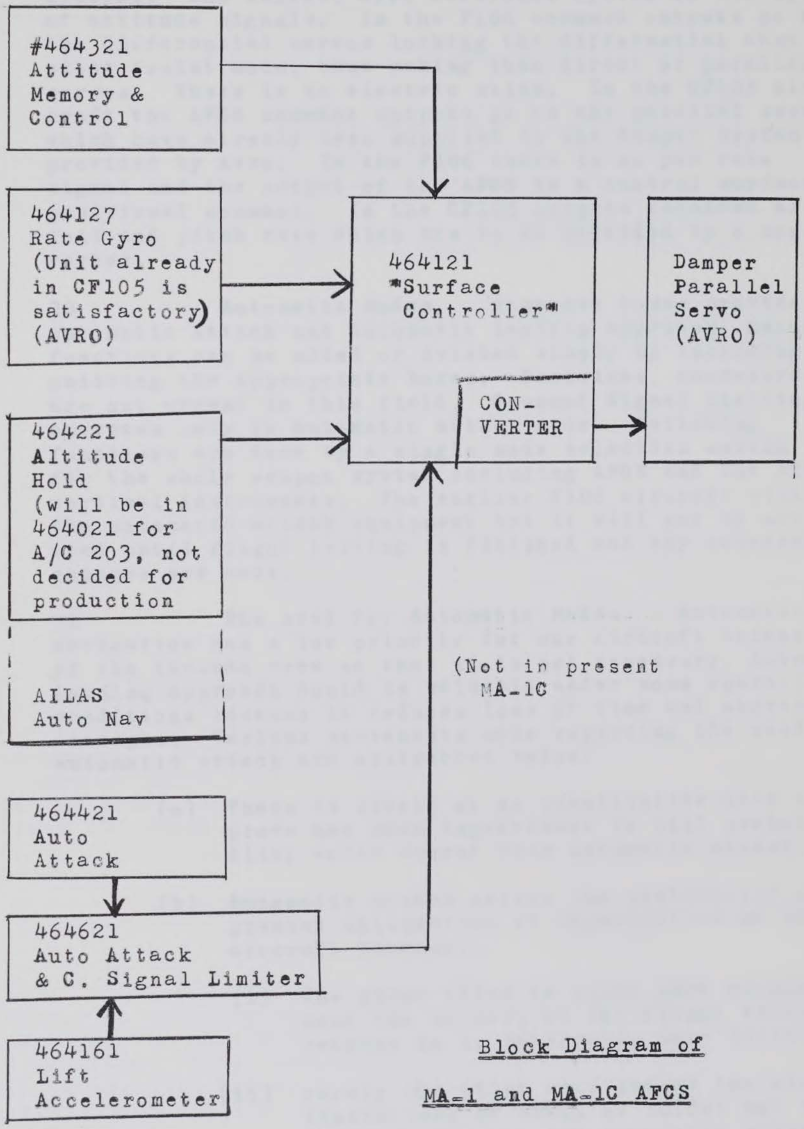

Block Diagram of

MA-1 and MA-1C AFCS

been developed and flight tested but is not in the first systems. The central Gyro Reference System is the source of attitude signals. In the F106 command outputs go to the differential servos locking the differential when in pilot assist mode, thus making them direct or parallel servos. There is no electric stick. In the CF105 aircraft the AFCS command outputs go to the parallel servos which have already been supplied in the damper system provided by Avro. In the F106 there is no yaw rate signal and the output of the AFCS is a control surface positional command. In the CF105 outputs required are roll and pitch rate which are to be provided by a converter.

30 Automatic Modes. - Separate boxes provide for automatic attack and automatic landing approach, hence functions can be added or deleted simply by including or omitting the appropriate boxes. Decisions, therefore, are not urgent in this field. Command Signal Limiting operates only in automatic attack mode. Switching functions are done by a single mode selection switch for the whole weapon system including AFCS and the ARDC vertical instruments. The earlier F106 aircraft will have the automatic attack equipment but it will not be activated until flight testing is finished and any required changes are made.

31 The need for Automatic Modes. - Automatic navigation has a low priority for our aircraft because of the two-man crew so that it is not necessary. Automatic Landing Approach could be valuable under some operational conditions because it reduces loss of time and aborted attempts. Various statements made regarding the need for automatic attack are abstracted below:

(a) There is little or no quantitative data to prove how much improvement in kill probability would accrue from automatic attack.

(b) Automatic attack offers the probability of greater utilization of capabilities of the aircraft because:-

  (i) The pilot tries to allow more margin near the borders of the flight envelope because he is inherently more variable.

  (ii) rarely the pilot will exceed the aircraft limitations of stall or buffet and so abort an attack; the automatic system would not do this at all.

(c) Automatic attack offers more relief for the pilot at the most critical time allowing him to give more attention to survey the tactical situation.

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(d) Automatic attack corrects errors more speedily and earlier than the pilot can; this being particularly valuable in late lock-on.

(e) Automatic attack equalizes pilot capability.

(f) There is no reason to believe the pilot cannot generally steer accurately enough to aim the MB-1 (the significant word being "generally").

(g) Close to the performance limit of the aircraft the AFCS will do better than the pilot.

  (i) Automatic attack permits useful flight at higher altitude than does manual flight.

  (ii) Near the margin of the flight envelope there is generally a gain in maneouvrability.

(h) Automatic attack will be an aid to a form of snap-up attack. Altitude hold would be used until B time when automatic attack would be engaged causing the aircraft to immediately snap-up and stabilize in the climb before firing.

32 There is no plan at present for inclusion of automatic modes in the CF105 but Avro will recommend to the RCAF what degree of automaticity they think should be incorporated. The computer calls for the aircraft to go automatically to a collection point after an attack. If there is no automatic mode an extra display will be necessary in the cockpit to direct the pilot to fly to the collection point.

ACTION IN HAND BY AVRO

RCAF to monitor and decide.

33 Fitment of Hughes AFCS to CF105 - (WADC input)- Fifteen to eighteen months is optimistic for HAC to adapt their AFCS to the CF105. The pilot assist would take 60% of the time. They consider we could get pilot assist from HAC in our 21st aircraft and automatic attack about 9 months later. However, see the next paragraph for Hughes' statement.

34 Fitment of AFCS to CF105 Aircraft Cont'd (Hughes information). There will not be an AFCS, even pilot assist, in aircraft 202. The functional diagram for the CF105 pilot assist installation is made, hardware is being modified and a set was shipped by air express to Avro approximately 15 Dec 58. At Avro it will be connected to the simulator for trials before being put into aircraft 203 in January 59. A spare set will be sent. Design of the coupling to the damper system gave little or no trouble at this stage. Aircraft 203

will have special cabling and modified racks. Later installations will have standard MA-1^{C} racks and cabling provision for automatic function boxes. If we do not want AILAS or automatic navigation, altitude hold could be put in box 464021 saving space but not cost.

35 Status - The AFCS is buried in the basic MA-1 contract and in the MA-1 specification. WADC have not released AFCS items for production but they expect to release the pilot assist items within two months. Preselect heading will be put into the production line in about 9 months by ECP number 1119. Automatic Landing Approach System (2 boxes) will be released about May or June, 1959 and Automatic Attack during the last quarter of 1959.(WADC information)

36 Flight Testing of AFCS - The USAF expects to flight test pilot assist functions in the next two months. If automatic attack is adopted by the RCAF the following program considerations would apply:-

(a) At least the major portion of pilot assist program on CF105 should be done first.

(b) MA-1 automatic attack capability will have been proven on the ground and by flight test in the F106 by that time.

(c) Additional testing in the CF105 to include the automatic attack capability would be relatively small, about 15-20 hours.

37 Verification of Aerodynamic Derivatives - (W.N. Turner of HAC)

The WSPO people at WADC had expressed doubt that F106 No. 464 was serving a worthwhile purpose in confirming aerodynamic derivatives. Mr. Turner was asked - is it necessary to have an aircraft devoted to flight testing for aerodynamic derivatives to accomplish AFCS design?

38 Mr. Turner said these tests would have been more valuable if they had been done two years ago in an F102. They were delayed by miscellaneous flight delays on the F106. Also the Flight Test facility did not run the tests of greatest interest, e.g., in the high speed region and in the transonic region. The data are useful now for confirmation only and no re-design was necessary. The original data were good enough that actual flight conditions were within the adjustment range. The control surface effectiveness data are the parameters most likely to be poorly estimated. Some difficulty was experienced with oscillation in the transonic region but it was cured by further wind tunnel data.

39 Turner has a great deal of confidence in Avro's approach to getting aerodynamic data and in the accuracy of their data. They already have considerable flight data and confirmation of satisfactory operation of the damper system,

hence the aerodynamic and control surface parameters provided by Avro must be good. Therefore, HAC consider that our aircraft needs only confirmation during normal flying after the work on a/c 203.

40 Faults - It will be easy to distingush between coordinated turns commanded by Data Link and faults which will cause either disengage shown by the barber pole signal, or random gentle turns.

Summary

41 The areas of uncertainty or problems in the instrument sections of the MA-1C system are:-

(a) Precision of angle of attack.

(b) ARDC Instruments - should they be adopted?

(c) DR Navigation

  (i) Installation of Horizontal Situation Indicator - modification or replacement is probably required.

  (ii) Source for map film strips

  (iii) Provision of Manual inputs

  (iv) Dependance on TACAN

(d) Automatic Flight Control System

  (i) Decisions on automatic modes

    (1) AILAS

    (2) Automatic Data Link and Automatic Navigation

    (3) Automatic Attack

  (ii) Assurance of adequate design.

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APPENDIX "G"
TO S1038CN-180 (AAWS)
DATED 19 DEC 58

COMMUNICATIONS, NAVIGATION AND LANDING (CN&L)

SUBSYSTEM OF MA-1

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General

1 The functions of the CN&L subsystem of the MA-1 system are: UHF communications, UHF data link, UHF direction finding, instrument landing system, Tacan, air ground IFF, air-to-air IFF, and Intercommunications.

2 Circuitry of the equipment is somewhat similar to that of existing equipment in general use in aircraft but the physical factors bear little resemblance.

3 The packaging has been designed by HAC and their sub-contractors to meet a systems concept with built-in test, fail safe, and space/weight saving features. In general, the equipment is made in small packages with front panel and chassis. These plug into spaces in a shock-mounted rack in the aircraft, or into the requisite spaces of the test consoles.

4 Details of the equipment are contained in the Handbook of Field Maintenance Instructions Aircraft and Weapon Control Interceptor System Type MA-1 TO 11F1-MA-1-12-3. Refer to AFHQ Tech Library.

Voice Commumications

5 The UHF Command Communications function is performed by an equipment of which the specification and circuit resembles that of the AN/ARC-34. However, it has been packaged in three "plug into rack" type units and it has a much higher output power: 50 watts ± 2 db.

6 The equipment is made by Electronics Incorporated (ECI) to meet the HAC requirement of the MA-1 system. It has an associated control unit which provides for selection of 20 preset channels and manual setting of any channel in the 225-400 mcs. range. An associated readout indicator on the instrument panel enunciates the channel selected.

Data Link Receiver

7 The data link receiver resembles the AN/ARR-44 in circuitry and is made by ECI to meet the HAC requirement of the MA-1 system. It is of the frequency division type and covers a range of 225-400 mcs. It incorporates a voice channel. A Tuner/preselector unit is used to reduce the interference from the UHF transmitter. The aerial for the data link receiver is beneath the F-106 aircraft while the UHF communications aerial is in the fin cap. The airframe provides 30 db isolation between the UHF voice and data link equipments and an additional 30 db is provided by the data link preselector. The data link receiver is compatible with the UHF/ADF facility and can be switched to it by the pilot.

8 The USAF have a program to convert from frequency division to time division data link, experimentally by 1960 with complete conversion in the period 1962-63. HAC will make the necessary changes to the MA-1 system working with RCA who will provide the equipment, type AN/ARR-61. The AN/ARR-61 will use the same tuner/preselector unit as that now used with the frequency division type data link receiver.

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9 The AN/ARR-61 data link receiver is described in MIL-R-26573. The following are the principal sub-assemblies:

Receiver data link R884/ARR-61 MIL-R-26573
Computer digital-digital CV703/ARR-61 MIL-R-26575
Control Converter-Receiver C2558/ARR-61 MIL-C-26577
CF.703/ARR-61, Converter digital to digital, also acts as a coupler to the computer.

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UHF/ADF

10 A UHF/ADF equipment similar to the AN/ARA-25 but manufactured by Collins to meet the HAC requirement is provided with the MA-1 system. The equipment can be selected by the pilot to work with the communications or data link UHF receivers by means of a switch in the cockpit. Provision is made for feeding UHF/ADF information to the computer and the Horizontal Situation Indicator (HSI).

Instrument Landing System

11 The instrument landing system comprising a glide slope receiver and marker beacon receiver in one box and a localizer receiver in another box, both of which "plug into rack", is Collins equipment made to form factors suitable for the Hughes MA-1 system. The frequency ranges are conventional. Twenty ILS Channels are provided on localizer and 10 are provided on glideslope.

12 The marker beacon receiver output has a transistor amplifer to flash 14 volt indicator lights. The usual relay system is not used. AVRO may have to install a transformer to activate the 28V. indicator lights in CF-105. Some functions of altitude hold are included in the ILS boxes.

TACAN

13 The Tacan system is referred to as AN/ARN-53. It is made by Federal to meet the HAC/MA-1 requirement and it incorporates integral self test features.

14 The MA-1 Tacan system has 126 crystal controlled channels and comprises four "plug into rack" boxes into which have been built an oscilloscope, a distance counter and a bearing indicator. These instruments are for self test and to check the information getting into the computer and HSI.

15 A reliability indicator in the cockpit indicates when Tacan is not providing the necessary inputs. The antenna in the F-106 is located in the fin cap.

16 The USAF has no known plans for changing the type of Tacan in the MA-1 System.

Air-Air IFF

17 The MA-1 system uses the AN/APX 26B and APX 27B equipments made by HAC. This equipment is not fully compatible with the MOD 12 crypto equipment. However, HAC has a contract to make the necessary modifications. When modified by the addition of a computer box having a volume of 1/3 cubic foot, the equipment will be identified as APX 42 and APX 43. The Computer on which the design will be frozen in July 1959 is being made by Hazeltine. Production quantities are expected in 1961.

18 The APX 26B and APX 27B equipment in the MA-1 system operate from the central power supply and incorporate a self test feature. It is synchronized with the fire control radar and uses the same antenna,

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19 The USAF has a development program for an air-to-air IFF known as APX 40 and APX 41. This equipment is about 7/10 the size and weight of APX 26B and APX 27B. However, they have no future program FOR production quantities of this equipment.

20 Another development program in progress is for APX 38 and APX 39. Development models have been built and prototypes are expected in July 1959. Combined services tests of this equipment is scheduled for the first half of 1961. The equipment is about the same size as APX 42, 43.

21 The USAF do not intend to replace APX 26B and 27B with new equipment but rather they intend to modify it to the APX 42, 43 status.

Ground Air IFF

22 The MA-1 system has a version of the AN/APX-19 incorporated for Ground-Air IFF. The equipment was made by Hazeltine and as it stands, it is not compatible with the MOD 12 crypto system. The addition of a computer box, the development of which is covered by Rome Air Development Center Project 1981, will be required for use with MOD 12. In the MA-1 system, the Air-Air IFF and Ground Air IFF will share the same computer box.

23 The APX-19 has a version of KY-148 for SIF modes.

24 On the F-106 aircraft, the ground-air IFF is associated with an aerial on top and one on the bottom of the aircraft. A switch continuously cycling at 20 RPM ensures optimum coverage.

25 HAC has placed an additional shroud around the APX-19 and connected it to the aircraft air pressure system but otherwise the form factors have not been changed.

Intercommunications

26 The MA-1 system incorporates an audio amplifier and mixing network of HAC design and manufacture. The system mixes and amplifies the audio from UHF communications, data link, Tacan, ILS, and intercomm. A common volume control in front and rear cockpits is used to adjust the combined level to suit the occupant. "Hot mike" is used continuously in both cockpits.

27 The chief disadvantage of the above system is the masking of intercomm by other inputs. There is no facility to give intercomm a preference or higher level.

ECM

28 Apart from the ECM features of the fire control system, on X-band, which are treated elsewhere in this report there are no ECM features in the MA-1 system. Refer to Appendix "J".

29 WADC representatives advised that there has been no consideration toward the use of the radar homer AN/ARD-501 or similar equipments with the MA-1.

Cooling

30 Because of the high concentration of electronic equipment in a limited space there is a need for an adequate volume of refrigerated air for cooling during a ground test. This requirement is treated more fully in Appendix "M".

UNCLASSIFIED
APPENDIX "H"
to S1038CN-180
DATED 19 DEC 58

UNCLASSIFIED

POWER SUPPLY

CONTENTS

Unclassified
~~APPENDIX "H"~~
~~S1-38-N-180~~
UNCLASSIFIED
DATED: 19 DEC 58

POWER SUPPLY

1 Information is from F.J. Rees of WADC and R. J. Boucher of HAC.

MAI-F106 Electric Power

2 At present the F106 aircraft has a Sundstrand Constant speed drive unit #45GB04 (F106) which is about half through its test program and may be finished in 3 months or so. The T.O. is 9H6-3-14-2. Pads are provided for four generators as follows:-

For the a/c system
- Pad A - Generator J&H G-129 or GE-8-06263, 8000 rpm, 100 amp DC at 28V.
- Pad B - Generator J&H G-280 or GE-0264, 12,000 rpm, 200/115V, 3ø, final version to be 25KVA.

For the MA-1
- Pad C - Generator J&H G-51, i.e. HAC #464189, 12,000 rpm, DC, giving:
  - 300V, 3.5 amp (WADC) to 2½ amp. (HAC)
  - 150V, 6.2 amp.
  - -140V, 4.0 amp (WADC) to 5 amp. (HAC)
  - It is oil cooled, brushless, and is starting running tests.
- Pad D - Generator J&H G-52, i.e. HAC #464089, 12,000 rpm, AC/DC, giving:
  - 1600cps, 7.5 KVA, 115V
  - 400cps. 3.0 KVA(WADC) to 4.5 (HAC), 115V, 3ø
  - 28V, DC, 60 amp.
  - It is oil cooled and brushless.

The above MA-1 generators are to specification HAC #ES-1-753. There are further sub-units converting to 600V, 50V, -15V and others. The system for MA-1 is at maximum loading and cannot support more load.

400 cps POWER SYSTEM

3 Scheduled improvements comprising what is called the MA-1/28 and MOPA require over 4 KW more power. To meet this requirement a new power supply with larger capacity is being developed for the F106. A second G-280 would be installed instead of the G-51 and G-52. MA-1/28 requires 18 KW so the G-280 with 25 KW allows ample margin. The MA-1 is being simplified by converting nearly all the units to operate on 400 cps power. All the engineering has been done and a hand built set of electric units and modified MA-1 system is entering the stage of test operating.

4. It is advantageous to use the 400 cps units for the MA-1C and to use the already designed 400 cps aircraft power supply of the CF105 aircraft. Many parts of the prototype set of 400 cps electric power units and modified

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MA-1 system units have been borrowed for the CF105 program and already shipped to AVRO(in week starting 15 Dec 58). The Hughes production plant at El Segundo is supplying a production MA-1 on the AVRO contract to be modified and from this the borrowings will be returned. A second set will be modified as a spare.

5 The 400 cps, three phase, aircraft power is distributed to units of MA-1C by an AVRO junction box. Certain amounts of other sorts of power are still required and are supplied by conversion units as part of the MA-1C system, except for 100 Amps of 28 DC from the aircraft rectified DC power. The DC is used for relay energizing. The internally generated power is as follows:-

(a) +50V, DC, 2 amp, from a mag-amp unit
(b) -50V, DC, 2 amp, from the same unit as (a)
(c) +300V, DC, 2.4 amp, series tube unit
(d) +150V, DC, 6 amp, mag-amp
(e) -140V, DC, 5 amp, mag-amp
(f) -250V, DC 1.2 amp, series tube unit.
(g) +100V, DC, 200 ma, for reference in computer
(h) -140V, DC, 100 ma, for reference
(j) 115/57.5V, 1600 cps, 100VA, for reference
(k) 115V, 1600 cps, 300VA, for AFCS } motor generator
(l) 115V, 1600 cps, 500VA, other load }
(m) 115V, 1600 cps, 2.5 KVA, for missiles, motor generator, weight 25 lbs.

6 The internal power units in the MA-1C system weigh 150 lbs in total. MA-1 units that have been modified to operate on 400 cps are numbered 476...instead of 464... and units peculiar to the MA-1C system alone are numbered 470...

7 Accuracy of Control - The MA-1 system can operate past transients of 102-124 Volts but requires 108-120V in steady state. Frequency must be controlled to ±1 percent which agrees with the Avrocan spec E-500 for the aircraft power system but ±½ percent would be better. Variation in frequency causes the same percentage variation in the time base of integration from the gyros and hence the same percentage error in system output. Being saturable reactor-regulated transients are minimized, and also, transients are on the 40 KVA power source instead of on 7.5 KVA and so have a smaller effect. Reference-Hughes Report No. FRS3-068-1 "Functional Requirement Specification for Power Supply Subs-system", dated 26 Nov 58.

8 Power for Missiles - In MA-1 the 1600 cps power allows operation of the four missiles staggered so only one missile uses power at a time. This increases the preparation time and cuts into the placement diagram.

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However, in the MA-1C and in MA-1 when modified for 400 cps power parallel simultaneous preparation of four missiles is permitted.

9 Ground Power Unit - The motor generator set is MC-1A. The -1A set is an improvement over the - 1, with less ripple. It has been tested and qualified. It is made by Ideal Electric Manufacturing Co, Mansefield, Ohio, to specification MIL-M-0397A. Its size is 8 ft x $3\frac{1}{2}$ ft by 40 inches high and its weight about 5000 lbs. The imput is 220 or 440V, 60 cps and the output 400 cps, 115V, 37.5 KVA, and 28V, 500 amps.

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APPENDIX "I"
TO [illegible]
DATED 19 DEC 58

MA-1 IMPROVEMENT AND COUNTER COUNTERMEASURES PROGRAM

Introduction

1 The MA-1 Counter Countermeasures program will be discussed under the following headings (which actually cover MA-1/40, MA-1/28 and advanced development. These are not all CCM items but are included together here for coherence.)

- (a) Current CCM
  - (i) modified close control
  - (ii) jam angle track (JAT)
  - (iii) range and course extrapolation
  - (iv) edge tracking (Nose-Tail Switch)
  - (v) tunable magnetron
  - (vi) missile CCM
- (b) Phase I of CCM development
  - (i) supersearch
  - (ii) sniffer circuit
  - (iii) random prf
  - (iv) extended range
    - (A) 80 mile sweep
    - (B) Bones-Marshall grid
    - (C) extended lock-on range
  - (v) improved anti-chaff
  - (vi) 40/28 inch antenna
  - (vii) 400 cycle power.
- (c) Phase 2 of CCM Development
  - (i) MOPA
  - (ii) complete anti-chaff
  - (iii) provisions for IR sub-system
  - (iv) differential altitude ranging (DAR)

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(d) Advance Phase of CCM Development UNCLASSIFIED

(i) advanced passive ranging

(ii) CHIRP

(iii) miscellaneous

2 The MA-1 counter countermeasures development program is funded under USAF letter Contract AF 33(600)-36799(MA-1 counter countermeasures). This program is divided into two phases, Phase 1 of which is for progressive introduction into production from September 59 to Jan 60. Phase 2 is for production in Jan 1961. The development contract is funded for Phase 1 and Phase 2, but production is funded for Phase 1 only at this time. (Phase 2 production is partly dependant on a FY 60 F106 buy.)

3 The advanced phase is a part of the continuing Hughes development of possible counter countermeasure items which could be included in later contractual negotiations. It may be noted that Hughes break the program down into three phases. Phases 1 and 2 of the Hughes program correspond to Phase 1 of the USAF program and the USAF Phase 2 corresponds to the Hughes Phase 3. The breakdown shown is the USAF listing. The advanced phase of CCM development at Hughes is classified under the heading of advanced studies, and is not funded by a specific USAF contract. Advanced phase items could only be included in the MA-1 system on a backfit basis.

4 Due to the long lead times involved for some of the component items an early production fund release is required from USAF in order that the dates may be met. Four prototypes of all Phase 1 items have already been built, and are currently under test.

Modified Close Control

5 The Modified Close Control (MCC) capability is classed as a CCM feature in that it is expected to provide a capability in those cases where ECM may have overloaded the SAGE data handling capability. It is expected to greatly increase the SAGE handling capacity. Essentially, it is a subroutine in the computer program which is available on demand.

6 Under close control conditions the direction center gives the All Weather Fighter (AWF) a vector to fly, in order to reach the correct offset point. Under modified close control, the Direction Center gives to the interceptor: target ground velocity, altitude and co-ordinate information. This information is used by the computer together with TACAN derivation of its own position to compute direction and distance to offset point for attack. SAGE can transmit ECM, cut-off attack, or snap-up attack override instructions.

Jam Angle Track

7 Jam Angle Track (JAT) is provision of a facility to enable the FCS antenna to angle track the jamming signals when range information has been denied due to jamming. There is no JAT capability in the face of a conical scan inverter type of deception jammer.

8 If the interceptor is in the search mode when jamming is first experienced, the fighter will complete its attack in a pursuit course approach to the target, after the crew have achieved angle lock-on with the HOM mode selected. If the interceptor fire control radar has already been locked-on

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for at least 1.5 seconds prior to being jammed by the enemy, then the interceptor will complete its lead collision attack utilizing extrapolated range (provided HOM is selected within a few seconds after jamming commences and the navigator obtains angle look-on).

9 Operation in JAT mode (from search or track) is initiated by selecting "HOM" and then locking-on in a normal manner. If transition to JAT is required from track, this operation is facilitated by the long time constants in the antenna tracking servo which maintain the antenna's angular orientation for some seconds after loss of look-on, thus approximately indicating the target's angular orientation. A 30 db (ferrite) attenuator is automatically inserted when the AGC voltage indicates receiver saturation is being approached.

10 If jamming ceases during the course of a jam angle track approach to the target, then the half action switch on the hand control is selected to the half action position to permit the operator to control the range gates without losing angular look-on of the antenna. Range look-on is achieved in the normal manner of running the range gates in/out as required to correctly place the range strobe over the target and releasing the action switch to achieve look-on. The antenna will maintain its orientation angle for approximately 1 to 2 seconds (due to angle memory circuits) which is considered a sufficient length of time to permit the radar operator to obtain range look-on without disturbing the antenna angle position.

11 The effectiveness of jam angle track is presently being evaluated in flight test. (Also see para 38).

Range and Course Extrapolation

12 Approximately 1.5 seconds after normal look-on has been achieved the radar supplies a Delayed Range On Target (DROT) signal to the computer. The occurrence or non-occurrence of this signal is used by the computer to determine whether an attack should be pursuit or lead-collision when the JAT mode is selected. If DROT has been received, the computer first directs the interceptor onto the correct lead collision heading; and adjusts the previously measured range and range rate to account for the new heading obtained after this turn. This adjusted range rate is used to maintain the range data approximately correct via computer bookkeeping operations. The resultant attack will maintain the interceptor in a favourable position in case relock is possible (by virtue of "burning through" the jamming); it may be sufficiently accurate for successful GAR firing if range re-look is not obtained, but will not be accurate enough for MB-1 attacks.

Edge Tracking

13 As in the MG-2.

Tunable Magnetron

14 The present magnetron is capable of a tuning rate of approximately 120 to 140 megacycles/sec/sec. Hughes state this tuning rate is presently limited by back lash problems in the present RCA magnetron. Hughes consider that this tuning rate may be adequate to permit the fire control system radar to remain ahead of a tracking enemy spot jamming equipment of early vintage, and would therefore, force such a jammer into a barrage jamming mode.

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15 Prior to incorporation of the sniffer capability, tuning is continuous during the period that the "ANTI JAM" button is depressed. With the advent of the sniffer capability to automatically operate the magnetron tuning motor, manual control of this tuning motor has been removed from the ANTI JAM button and the manual control feature provided on a side console in the cockpit. (Magnetron tuning is unavailable after 20 seconds to go with microwave GAR as the radar automatically seeks the missile frequency at that time.)

Missile Counter Countermeasures

16 GAR 3A is provided with a capability to automatically complete an attack in a home-on-jam mode in the event that jamming is sensed at any time during the missile's attack.

17 With the GAR 3A the computer is enabled to select either Leading Edge (LE) or Trailing Edge (TE) tracking alternatives to the normal centroid tracking. The computer compares computed launch range with interceptor pressure altitude and then selects the missile's tracking mode according to the following logic chart:

	Missile "CCM" Selected		Normal (CCM not Selected)	
	Nose Attack	Tail Attack	Nose Attack	Tail Attack
Altitude greater than Launch Range	LE	TE	Centroid	Centroid
Altitude less than Launch Range	LE	Centroid	LE	LE

18 Missile "CCM" versus "Normal" is a cockpit selection. The switching in the missile is done by blowing either a LE or TE squib (thermal relay). Firing of the squib by the computer is done approximately one second before launch. The action is irreversible, but the cockpit switch may be operated at any time up to the instant the squib is fired. The missile centroid tracks if neither squib is fired.

Super-Search

19 One of the items in Col. Marhsall's program to improve USAF AWF's range capabilities was the ability to auto-search over a relatively narrow angular field. This was considered desirable because GCI information at least permits the AWF crew to localize the area in which to search for the target. This localization greatly decreases the frame time, giving more "looks" per second and thus improves the chances of obtaining an early detection range. Also, with the advent of the MA-1/40 program, it was realized that the antenna pattern would be much circumscribed, increasing frame time to cover a given area, and, therefore, search problems might be encountered. For these reasons, it was decided to develop the narrow search capability referred to as super-search.

20 In super-search, the antenna will search plus or minus ten degrees in azimuth about the nominal position set for the antenna, and will search a two bar pattern in elevation.

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21 It was noted above that as part of the sniffer circuit modification the old anti-jam button function of tuning the magnetron has been transferred from the hand control switch to a separate switch on side console, freeing the anti-jam button for other use. Operation of this button will cause the antenna elevation search pattern to step upwards one bar width each time the anti-jam button is depressed. The actions necessary for the operator to utilize the super-search are simply to depress the half action switch to the half position and then to orientate the antenna in elevation by means of the anti-jam button.

Sniffer Circuit

22 The sniffer circuit requires an initial operator selection (decision) to sniff or not to sniff. The sniffer circuit consists of the addition of a gate, 150 microseconds wide, at the extreme end of each listening-time period of the radar. Signals appearing within this 150 micro-second gate are integrated and compared with a pre-determined power level. When the signals are greater than this pre-set amount, a plate relay is tripped which automatically causes the magnetron tuning motor to operate and (hopefully) to tune through to a clear band. When the amount of noise or signal within the gate drops below the preselected value then the tuning of the magnetron automatically ceases.

23 It should be noted that the sniffer circuitry is purely an rf function. It will accommodate railing and noise jamming but will be ineffectual against a range gate stealer, or other type of deception jammer.

24 After incorporation of the MOPA modification, the sniffer action will be changed, so that the 150 microsecond gate will sniff at the frequency of the next pulse to be transmitted and will cause the video information to be blanked (removed) on the sweep following the gate if the noise level exceeds the preset threshold. An alternative to video blanking is being considered which would cause the frequency of the radar to be nudged by approximately 5% if the sniffer detected jamming. (It has not yet been demonstrated that the MOPA section will permit this frequency nudge (called "jam drift" by Hughes) once it has selected a frequency for a particular pulse.) The sniffer also controls random prf (para 25) and variable rf coupling (para 38).

Random PRF

25 Random pulse repetition frequency (together with edge tracking) is designed to counter the effects of a range gate stealer type of jammer. This type of jamming equipment is required to receive, demodulate, assess, and then re-broadcast the signal it receives. This involves a time delay. A solution, which can be used by the jammer to obviate this time delay, is to measure the PRF of the incoming signals and use this information to anticipate the arrival of future incoming signals. In this way, he can re-broadcast a large signal in the gate of the victim and thus capture his AGC in preparation for stealing the range gate. Use of edge tracking forces the jamming equipment delay to be less than 1/5 micro second. However, addition of random prf to the edge tracking function will virtually eliminate the possibility of the jammer using this technique successfully.

26 The normal MA-1 radar prf's are 416 pps in search and 1000 pps in track. In random prf operation, this repetition frequency is jittered at random within a band 5% either side of the nominal centre frequency. Random prf operation is automatically switched out at 7 to 5 seconds-to-go when using microwave missiles since a RAD or ALL (MISSILE) selection automatically locks the prf to a crystal-controlled 2000 pps at about 7 to 5 seconds-to-go.

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Extended Range

27 In addition to the extension of the radar range capability through the use of super-search, other proposals are being included such as the 80 mile sweep, extended range and Bones-Marshall grid. These are all part of the FCS improvement program sparked by Col. Marshall of USAF ADC. They are not necessarily CCM except in the sense that radar range improvements provide data earlier in an attack and, thereby, assist the interceptor to build up data for an extrapolated or manual attack.

80 Mile Sweep

28 The 80 mile sweep is not a modification to the radar but is a modification to the scope display. It consists of an additional saw-tooth sweep generating circuit calibrated for 80 miles, a new scope overlay with an 80 mile range scale added, and a new switch detent to permit selection of the appropriate display circuit for this 80 mile range scale.

Bones-Marshall Grid

29 The so called Bones-Marshall grid consists of the addition of grid lines on the present overlay with approximately 1/3 inch spacing between adjacent grid lines. The intent is that the operator (by means of this grid) may get good position co-relation on his display. This will permit him to concentrate his search in a particular area on the scope and thus detect the target at a greater range.

Extended Lock-On Range

30 The present lock-on range of the MA-1 fire control system radar is 22.5 nautical miles. This range capability is being extended to 37.5 miles through a re-design of the range lockon circuits. This facility will not provide an actual increase in range, but merely the ability to lock-on at a greater range should a sufficient signal be available to permit this to be accomplished.

31 The particular range of 37.5 miles was selected because a greater range would require that the system be mechanized to permit lock-on in long pulse at the greater ranges, and the incorporation of an automatic circuit to switch the operation of the radar from long pulse to short pulse at the range where accuracy becomes more important. To avoid this extra complication, the compromise was taken of setting the maximum lock-on range at the limit of 37.5 miles.

Improved Anti-Chaff

32 The action of the circuitry utilized to accomplish leading edge and trailing edge tracking presently exhibits considerable hysteresis effect. The circuitry is being cleaned up to alleviate this effect. The antenna tracking loop circuitry is also being re-designed. The intent here being to optimize the tracking loop gains from an anti-chaff point of view.

33 It is suspected by Hughes engineers that chaff has been depressing the automatic gain control of present radars and for this reason the MA-1 radar's AGC will be selected off the leading edge, rather than the center of the range tracking gate, as an added interim anti-chaff feature.

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40" Antenna

34 In fact, the size of this new antenna has not yet been established. Four prototype 40" antennas have been built, as noted above. As preparation for a possible future economy drive, a study is under way (by HAC for WADC) of re-packaging the Phase 1 features in present boxes and the provision of a 28 inch antenna. Upon completion of this auxiliary study, WADC will make a final decision as to whether the 40 or the 28 inch antenna will go into the F106 (provided there is a FY 1960 F106 buy). It may be noted that the hydraulic drive for the 28" antenna will handle any antenna size up to 54", and would, therefore, be amenable for use with an RCAF requirement for an antenna size between 32 and 36 inches. If a go ahead on the 28" antenna is available by 1 Jan 59, the first item will be built in 5 to 7 months, with a subsequent rate of one a month for subsequent prototypes.

35 Both the 28 and the 40 inch antennas are horizontally polarized, silent-lobing type antennas. Hydraulic drive has been utilized to cope with the extra gear required to accomplish silent lobing. This silent lobing has been obtained through provision of a new feed to the antenna, and adding a sector scanning feature.

36 Feed is accomplished by means of a four barrel cluster of rectangular wave-guides introduced to the antenna axially from the rear (projecting through the center of the dish from the rear). The four front corners of the waveguide cluster present a wedge-chamfered appearance. The returning energy in the four-barrel waveguide is scanned at 75 to 200 cps by means of a rotating quarter-wave plate to obtain the required angular tracking error signals.

37 The silent lobing modification also features variable rf coupling which alters the ratio of the sum and difference signals presented to the antenna tracking loop. In the search mode, only the sum signals are utilized. In the normal track mode of operation, the ratio of sum to difference signals used is unity. In the Jam Angle Track mode of operation, the signal ratio is approximately 10 to 1 (difference to sum). Thus the percent modulation per mil track error is considerably increased and a much more sensitive tracking system is achieved in the JAT mode. This provides better performance against swept frequency type of angle jamming equipment. This variable rf coupling is brought into play by the sniffer circuitry just as is the random PRF.

400 Cycle Power

38 The present 1600 cycle power supply is inadequate, witness the fact it will not bring a full load of missiles up to readiness, and has been a major source of difficultyin the MA-1 fire control system. In order to correct this deficiency, and to make provision for the future addition of the MOPA system (which will require more power) the system is being converted wherever possible from 1600 cycles to 400 cycles operation. Wherever 1600 cycle power is still required a Hughes 1600 from 400 cycle converter will furnish the power.

MOPA (Master Oscillator, Power Amplifier)

39 MOPA features pulse-to-pulse random tuning, with the design objective of achieving this over a frequency band of one third (33.3%) the centre frequency. This is achieved through the use of a Varian backward wave tube oscillator and high-power HAC TWT's. In the MOPA system, the sniffer will sniff the frequency

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prior to transmission and will then either blank the video for the succeeding pulse (video blanking), or nudge the frequency by approximately 5% prior to transmission (jam drift), depending on an evaluation of effectiveness and ease of mechanization of these two proposed alternatives.

40 HAC quote MOPA output as 250 KW peak power out of the antenna (which is equivalent to about 325 KW peak as measured in the standard manner at the directional coupler - thus roughly double the MG-2 peak power). The average power delivered is stated to be 375 to 400 watts. With an increased repetition frequency the duty cycle is .0015. No change in pulse lengths are presently contemplated due, for example, to beacon considerations.

Complete Anti-Chaff

41 The difficulty with present anti-chaff circuitry is that protection is not afforded for those attacks which occur near the beam. For this reason, angular rate memory for the MA-1 radar is being developed. This will probably be made a dual mode whereby the antenna tracking servo time constants and smoothing filters will be optimized both with angular rate memory and without angular rate memory so that the system may be optimum in both the chaff and non-chaff modes. In addition, work is being done with an F102 against a B47 chaffing aircraft. The intent is to get recognition criteria by which anti-chaff circuitry may be evaluated.

Provisions for IR Sub-System

42 These are developments required for an IR/AI interlocked system with (hopefully) an integrated scope display. Detail planning is based on the HAC proposal. Neither a Convair selection from among the three proposals, nor a USAF decision as to further development and production funding, will be available before next summer. Detail on IR sub-system will be found at Appendix "K".

Differential Altitude Ranging

43 Differential altitude ranging may attain an accuracy within 10% of true range and may possibly be sufficient for GAR firing. (The accuracy quoted by WADC is 70% , marginal for GAR 3Y, inadequate for other GAR.) It will definitely not be sufficiently accurate to permit the firing of MB-1.

44 Evaluation is to be carried out in an F101 at Culver City. Prototype equipment is now being constructed, it will then be installed in the aircraft and flight test is scheduled for commencement in Jun 59. Attacks will be conducted against an aircraft carrying an ALT 6 spot jammer. IFF equipment will be used to get exact range to compare with the range measured with the DAR equipment. Testing will be conducted under both quasi-static and lead collision course conditions.

Advanced Passive Ranging

45 Indications received at WADC were that they were prepared to buy a study on passive ranging techniques at this time, but were not presently prepared to go further. Differential altitude ranging, ranging by manoeuver and angular rate ranging are all under study by Hughes. Fixed range lead pursuit or fixed range pursuit have been investigated theoretically but are not considered to be suitable at this time. BARON was studied at one period but is not presently under active consideration. Further, the Hughes BARON studies were directed towards range but did not consider the resolution of range rate through filtering the doppler on the basic signals.

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46 PACOR is a likely contender in the eyes of WADC. Some work on this subject is being done at Hughes, presently company financed.

47 PACOR has been under development by the Fairchild Guided Missile Division with flight test activities being conducted in C123 aircraft. The next test bed will be an all-weather fighter type aircraft. It is expected that production would be possible in approximately two years.

48 The feasibility of this system has been proven. Ranges of up to 50 miles have been obtained with an accuracy of approximately 90%. The accuracies have not been sufficient for use with the MB-1, but have been adequate for GAR type weapons. (The accuracy is dependent upon the altitude and altitude differential, the ground roughness, the type of jammer signal and with range rate (this latter effect has not been evaluated, but theoretically is of small consequence.)

49 The present PACOR system utilizes an auxiliary antenna, pointing down, to pick up the signal reflected from the ground (but does not have to measure the auxiliary antenna angle). A variable delay, achieved by means of a rotating magnetic drum, is used to compare the direct and reflected signals to measure the delay between them but tracking functions to make this process automatic have not yet been built in. Fairchild are to determine the optimum configuration for the auxiliary antenna under terms of a recently negotiated three month contract. There are hopes for development of a slot array antenna, either electronically or mechanically scanned, to eliminate the requirement for the present type of auxiliary antenna.

50 The counter to PACOR is a jamming signal with a delay fixed by the geometry of the attack situation. WADC consider it will be difficult, therefore, for the jammer to counter PACOR.

CHIRP

51 CHIRP is a technique of frequency modulating transmission in finite steps using a frequency stable oscillator. The method is to transmit for, say a quarter micro second at one frequency, shift frequency slightly, transmit a quarter micro second at a new frequency, and so on for, say, 2.5 micro seconds. The frequencies are again stepped on reception and thus on the display the range resolution is effectively that attained with a quarter micro second pulse width, but the range obtained is still good since the power per pulse can be held up. It is possible to get away from AMTI tracking problems and retain good resolution. This item is in an early stage of development and might possibly be available in approximately two years. If adopted, the circuitry for this item will be packaged into one of the present two AMTI boxes.

Miscellaneous Items

52 Some A scope development was done for the MG 13 fire control system, (the production status was not ascertained). It was stated that this might permit cross-over being obtained at approximately double the normal cross-over range by virtue of an increase, effectively, in the signal to noise ratio, of about 5 db (this is discernability, not trackability). The A scope also permits better observation of chaff and range gate stealers.

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53 The ECM threat for the 60--65 period considered by Hughes is an equipment of the ALQ 27 type, radiating 200 watts which would provide approximately .6 watts per megacycle over a 1000 megacycle band assuming an antenna gain of three. In a spot jam mode, it would be possible to get approximately 60 watts per megacycle over a 10 megacycle wide band. If the Soviets concentrated on barrage jamming, they might possibly get a 10 watts per megacycle capability as an upper limit.

54 Travelling wave tubes for pre-amplification have not received any work at Hughes. In contrast Hughes have worked on Mazers to reduce the noise figure itself. They believe it may be able to achieve several db of noise reduction.

55 The idea of multiple gates for achieving a rapid re-lock capability is believed not to have been considered by Hughes. HAC have investigated the possibility of causing the range gates to sweep rapidly over a small increment in range, with the centroid of this area perhaps caused to move by range rate memory. No plans exist for further work on a rapid re-lock capability.

56 The idea of firing alternately into a dummy load in order to set-up a "spoof" type of track operation has not been considered by the Hughes development department.

57 It was stated that any CCM development beyond those features detailed at Phase 2 of the programme would be items to be included on a retrofit basis only.

58 The use of audio data presentation as a CCM feature is being studied to determine if it would be a useful addition to the F108/LR1 system. It is considered that, in conjunction with the LR1 pulse doppler, audio CCM may be a valuable feature. Its use with older style radars (MA-1, MG-2) is not considered to be able to add sufficient capability to justify development.

APPENDIX "K"
TO S1038CN-180
DATED 19 DEC 58

INFRA-RED SUB-SYSTEM AND OPTICAL SIGHT

IR SUB-SYSTEM

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Introduction

1 An active ECCM program exists on the MG-2 FCS in the CF100. An IR sub-system for the CF-105 has been a continuing RCAF requirement. In both contexts, information was required for use in project planning. This was obtained with reference to the proposed MA-1 IR sub-system for the F-106 interceptor, together with brief details on other USAF IR AI systems (current and under development). The information on other USAF IR AI sets is summarized at Table 1.

TABLE 1 - USAF IR AI PROJECTS

NAME	CONTRACTOR	TYPE	STATUS	REMARKS
AN/AAG-2	GE	Search	A modified model understood being worked on.	For daylight application. All transistor IRIS FCS. 10" collector.
AN/AAG-5	ITT	Search	Two models available.	1 sec frame time, 5" collector. Sensitive in 1.8 to 6 micron range. Standard cryostat techniques. Model 1 has 40° elevation coverage. Elevation coverage and frame time cut to 13° and 1/3 sec in Model 2.
AN/AAR 20	AVCO/GE	Search/ track	Very old project. Tests are to be completed by end of Jan 1959. AVCO report by March/April 1959.	This is a 20 inch system. GE are evaluating a monocular ranging technique with GE funds on STRANGER.
AN/AAR 21	ITT	Search/ track and ranging	New since July 1958. Prototype model scheduled for delivery August 1959.	This program is extending the basic AAG-5 set by increasing the collector to 6 inches, adding track and ranging functions, and putting in a 3 micron cut-off to get rid of 1.8 to 3 micron clutter.

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2 In discussing the IR field at WADC, some comments of a general nature were made. USAF considers that the clutter and noise characteristics of state-of-the-art equipment render it necessary for the operator to devote his complete attention to the search scope to acquire a target. The degree of concentration required militates against successful use of this type equipment in a single place interceptor.

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IR Proposals for F-106

3 If an IR sub-system is installed in the F-106, it will be CFE. Convair invited bids from Avion, Aerojet and Hughes for a system compatible with the AI such that the IR and the FCS may be slaved together. The operator is to have the option of IR or AI (hopefully with the IR data on the AI scope in an integrated display). A pursuit mode with manual firing is to be mechanized with design development also to be directed toward an automatic firing capability (at least with the GAR's). These three IR systems are in a feasibility investigation phase. Convair is expected to have assessed the bids and made a selection within six months, with production items appearing about twelve months later (mid 1960).

4 The AVION proposal is for a 4x1 degree cell, using a reticle and a four bar scan to cover a twelve degree field of view through an irdome of approximately 6.5 inches diameter. The Aerojet proposal uses a dual field reticle to achieve search and track. Search covers a hollow core approximately 12 to 42 degrees with tracking in the central field. The conical scan is obtained by rotating the optics. Detail on these systems was not available from USAF since each consists of a proposal from one contractor to another, none are yet a USAF funded program and data is therefore proprietary at this time.

HAC F-106 IR Proposal

5 The HAC proposal is available in AFHQ Tech/Library (Library Reference 4975) titled "Hughes Interim IR Systems - 4115.4/13 dated 11 November, 1958". The design leans heavily on integration with MA-1 FCS electronics wherever possible. For a single IR head system the added weight due to IR is estimated at 38 lbs. A research model is undergoing flight test in a C131 aircraft. The HAC proposed program envisages fabrication of an engineering model with B-57 flight test to start March 1959 and production December 1959/January 1960.

6 Four modes are proposed: IR Track/Radar Slaved, Radar Track/IR Slaved, Simultaneous Radar and IR Search, IR Search/Track with Radar off. Some of the proposed capabilities are: IR ranging (power rate and/or angle), radar angle hold against chaff, quantitative visual display of angle spoof jamming, and passive attacks. These capabilities would require that the computer memory have added capacity.

Note: To obtain the quantitative visual display of angle spoof jamming effects, the IR and radar antenna tracking error signals would be compared for phase and amplitude. The phase and amplitude difference would be available to rotate a line on the scope and to set the length of such line. Thus, in the presence of angle deception jamming, a display would be available showing the direction and magnitude of error introduced into the AI radar by the angle jamming.

7 Liquid nitrogen cooling is employed for the Lead Selenide detectors. An indium arsenide filter rejects radiation below 3 microns. A saphire window aids in attaining the long wave cut-off of 5.5 microns. The irdome is silicon with 7 inch diameter.

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8 The IR head mechanical assembly is readily amenable to repackaging to a variety of shapes and, as such, would be adaptable to a variety of installations such as dual wing root, dual side of fuselage, forehead, chin or fin etc.

NON-COMPUTING FIXED SIGHT

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9 The MA-1 system includes a non-computing (optical) fixed sight calibrated for GAR 4 and MB-1 manual attacks. Documents describing this sight which are available in AMTS Tech/Library are (all unclassified and filed under Library No.):

(a) HAC Product Specification PS 2-690, Issue 1 (November 1957) "Sight, Fixed, Noncomputing (651375) HUG P/N 464169-150."

(b) HAC Drawing, Sight, Fixed, Non-computing, Outline & Mounting dimensions 464169-550.

(c) HAC Drawing, Reticle, Optical Sight 428993.

10 The sight is cylindrical in form, 10.37 inches long, approximately 2.75 inches diameter, and is fitted with a collapsible rudder eyepiece. It is a 4 power telescope with a view of 5.75 degrees, exit pupil of 7.5 m.m., eye relief of 2.25 inches and eight reticle plates. The reticle plates provide an appropriate HVY (Heavy aircraft, nominally a 170 foot wingspan) reticle, and MED (medium aircraft, nominally a 117 foot wing span) reticle at each of four altitude ranges (0.18,000, 18-36,000, 36-47,000, 47,000-up). Each reticle consists of three concentric rings, providing for correct firing range for IR GAR, and MB-1. The reticles are based on the conditions detailed below at Table 2.

TABLE 2

	LAUNCH RANGES (1000's of Feet)			
	GAR 4			
Altitude (1000's feet)	0-18	18-36	36-47	47-up
Maximum launch range (intermediate dashed circle)	4	8	15.5	19.5
Minimum launch range (large dashed circle)	3	4.5	6	8
	MB-1			
Small unbroken circle	10.1	14.3	20.3	24.1

Assumed Conditions:
Launch Mach 1.2
Closing Rate........... 300 ft/sec.
Tail Aspect (Max) MB-1.. 15°
GAR 4. 20°

APPENDIX "L"
TO S1038CN-180
DATED 19 DEC 58

HAC FIELD SERVICE AND SUPPORT

Reference: AFHQ Tech Library 4997

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General

1 One of the major divisions of the Airborne Systems Group of Hughes Aircraft Co. (HAC) is the Field Service and Support (FS&S) Division. An organization chart of FS&S is contained in Reference 1 above. This appendix covers the activities of two of the major sub-sections of the Division: Field Engineering and the Radar Maintenance Depot.

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2 The activities of the FS&S Division are based on the following support considerations:

(a) Training Personnel - Refer to Appendix "N" - The program covers training on the installation, maintenance and operation of the equipment and the training of military instructional staff.

(b) Spares - The provision of maintenance and stock spares.

(c) Tool and Test Equipment - Covers all aspects of standard and special tools and handling devices.

(d) Handbooks - The production of installation handbooks, operating handbooks, parts catalogues, maintenance handbooks and training manuals.

(e) Facilities - Deals with installation, overhaul, maintenance, and training facilities.

(f) Support Services - Field modifications, product improvement, provision of technical representatives and field engineers to user units.

3 "Required Support Studies and Planning" . The support services provided for the user by HAC are developed from a time-phased consideration of the following elements:

(a) maintainability requirements

(b) maintenance concept, e.g. an operational requirement for a fast turn around will require a quick check maintenance facility and a rapid repair/replacement capability

(c) initial Quantitative Personnel Requirements Information (QPRI) - information on job analysis, numbers required, etc.

(d) training concept

(e) handbooks

(f) final QPRI

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(g) maintenance plan - layout of maintenance facilities, tabulation of equipment requirements at the flight line and in the maintenance repair areas, etc.

(h) training plan - technician training, supervisor training, instructor training, staff orientation courses, etc.

(i) spares support detail of the procurement procedures; production of Tables of Allowances (Scales of Issue); outline of special problem areas, etc.

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(j) "System Support Requirements Summary" - an end result of the planning is the production of this summary of factual data which establishes the requirements for all support consideration. The document is used by maintenance personnel at the tactical unit level, and serves as a check list on all of the support items required to carry out a maintenance task: Does the unit have all of the necessary standard and special tools and test equipment? Does it have the proper quantities and types of ground handling equipment? etc.

4 Comment. Close liaison with FS&S will be needed to ensure that RCAF requirements under the various headings listed above will be met with a minimum of cost and delay.

Radar Maintenance Depot

5 An integral part of the FS&S organization is the Radar Maintenance Depot at HAC. The maintenance concept for the MA-1 and the associated radar and special test equipment is to operate it to failure rather than to institute maintenance on a periodic time expiring basis. (J. MacArthur at WADC advised that the Production MA-1 is now running from five to seven hours between failures.)

6 Repairs on any of the MA-1 sub-systems which are beyond the capability of the shop level maintenance staff (refer to Appendix "M") are forwarded to the radar maintenance depot. This depot occupies an area of 139,000 square feet and contains a $5,000,000 inventory of special tools and test equipment (USAF and HAC owned) and a further $100,000 worth of equipment is being added for the Arrow Program.

7 The depot repairs the equipment on a first-in, first-out basis. HAC keeps an estimated 30-day supply of serviceable parts and sub-assemblies on hand in the depot. This stock is drawn from Air Materiel Area, Warner-Robbins Air Force Base, Macon, Georgia. When an unserviceable item is received at the depot, the unserviceability tag is used as a unit demand and a serviceable item is forwarded as replacement. The unserviceable equipment is inspected visually and replacement parts are drawn from repair stock. The unit is repaired, tested and placed in the serviceable stock area for shipment when required.

8 In addition to being repaired, the equipment is up-dated at the time of overhaul. All of the modifications which the equipment lacks are incorporated in to it while it is undergoing repair. A restriction on any such modification is that it must not affect the interchangeability of the equipment among aircraft. The modifications, therefore, are mainly of the product improvement type: improved circuit changes, substitution of better radio tubes, etc. If the costs of making such modifications are reimbursable, HAC must request permission from the user to incorporate the modification. If the modification is a company cost item no such approval is

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necessary. HAC advise that they have requested reimbursement on such items only twice in the past eight years.

9 At present, equipment turn-around time is 2.0 weeks. The depot processes 100,000 major assemblies each year and 60,000 bits and pieces or subassemblies. Repair costs run between 8 percent and 10 percent of replacement costs. For items not available from USAF stock, the depot has LPO authority from Warner-Robbins AFB.

10 Comment. If an Arrow Production Program is approved, a number of items related to depot operation will require consideration:

(a) Location of the Canadian depot facility - at the present time HAC serves as depot for USAF bases west of the Mississippi River including Alaska, the Pacific area and Japan, while Warner-Robbins AFB serves as depot for the European Theatre and for units east of the Mississippi River.

(b) Would Warner-Robbins or HAC be used as a back-up depot for some other prime depot?

(c) What degree of assistance (technical and administrative) would be required from HAC in setting up a separate depot?

Technical Representatives

11 A prime function of the FS&S Division is the training and provision of technical representatives and field engineers to support the maintenance program at tactical units. USAF ADC are planning on a single F106 squadron per base with eighteen aircraft per squadron. Faced with a high turnover rate among technician airmen the USAF will rely heavily on technical representatives assistance. For the F106 missiles one technical representative will be attached permanently to the base. For the F106/MA-1 system the present planning figures are: sixteen technical representatives per base for the first six months of operation; of these sixteen, nine will remain for the second six months; of these nine, six will remain for the second year of operation. After the second year three technical representatives will be attached permanently to the base for the fire control system. It should be noted that the above figures do not include technical representatives attached to the base as part of the Field Training Detachment (FTD). Refer to Appendix "N".

12 Comment. With the retention of relatively large numbers of technicians with experience on previous fire control systems a substantial reduction in the number of technical representatives required by the RCAF can be expected.

Factory Production

13 The team visited the HAC production facilities at El Segundo near metropolitan Los Angeles. The plant is large, well equiped and uses many of the most modern production techniques. Present production value of the output exceeds $3,000,000 per week.

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APPENDIX "M"
TO S1038CN-180
DATED 19 DEC 58

MAINTENANCE, TEST EQUIPMENT, GROUND HANDLING EQUIPMENT

Reference: AFHQ Technical Library: No. 4961 (Maintenance)
No. 4962 (Maintenance)
No. 4945 (MART)
No. 8251 (Cooling Air)
No. 8256 (Maintenance)

Maintenance

1 HAC provided the early recommendations for the maintenance concept. It was recognized that automatic check-out equipment would be required to minimize time and wear on the separate component boxes of the system.

2 The basic rules which defined the concept were:

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(a) Squadron aircraft would operate with a short scramble time therefore, not more than five (5) minutes would be available for serviceability check-out.

(b) If a "GO" signal was received on a short system check, the confidence level in the signal should be such that there would be a 75% - 85% probability of mission completion.

(c) If a "NO GO" signal was received, an indication was wanted of what subsystem was at fault.

3 HAC fell that they are meeting the requirements by the use of the following:

(a) Mobile Automatic Radiation Tester (MART). The MART is a trailer fitted with receiving and low-powered transmitting equipment and is designed to check out the communication-navigation sub-system and certain portions of the computer and flight control sub-systems, on a "GO-NO GO" basis in 56 seconds. The vehicle operates, unattended, from an unobstructed area within a mile of the flight line. The operation of the unit is described in some detail below.

(b) Self check features on the separate sub-systems. If a "NO GO" signal is received from a MART, the fault can usually be assigned to one of the sub-systems. The technician then institutes a self check procedure on that sub-system, and the check is designed to indicate the specific box at fault. The flight line repair which the technician carries out is limited to the substitution of serviceable boxes. A time period for complete fault isolation to one box is approximately 4 minutes.

4 A continuing program exists to minimize the number of maintenance controls. Four hundred have been eliminated so far; two hundred remain of which only sixteen need testing with the complete system operating.

Maintenance Levels

5 There are four maintenance levels:

(a) Flight Line

To carry out flight line maintenance the technician requires ground power, ground cooling, a MART, a Short Ground Test Panel, a check list and the self test features of the sub-systems. His responsibility is limited to carrying out the test checks and replacing unserviceable boxes in the system.

(b) Dock Level

Periodic routine maintenance is carried out at the dock level. A dock shelter is required, electrical power and cooling must be provided and the system test benches for each of the five sub-systems must be available: radar, computer, communication-navigation-landing, flight control and measurement, and the system power supply. The test equipment is mounted on mobile racks so that it may be taken to the aircraft for sub-system checking if necessary.

(c) Shop Level

Repair of bits and pieces within a sub-system box is carried on at the shop level. Modification work and re-programming of the computer are done at this level. The most highly qualified technicians are employed in this area and, as in the dock level area, they require power, cooling air and a complete set of the sub-system test units.

(d) Depot Maintenance

Refer to Appendix "L".

6 Fault Finding in the dock and shop level areas is aided by the use of a separate test drum in the digital computer. The tactical computer drum contains the program for the navigation and attack phases of the interceptor. In addition, a portion of the drum capacity is programmed to process the MART testing signals. For more complete shop testing of the system, the tactical drum is removed and is replaced by a test drum which is programmed to check sub-system operation in detail. If a fault is present in the sub-system under test, the computer stops operating at a particular point in the program and the malfunctioning part can be located by a visual interpretation of the oscillograph display or of the particular combination of signal lights on the computer panel. A complete test of all the circuitry in the subsystems using this equipment requires six hours.

Maintenance Test Stands

7 A total of seven test stands are needed for shop maintenance. The allocation per sub-system is: three stands for the computer sub-system, two for the radar (FCS) sub-system, one stand for the communication-navigation-landing sub-system, one stand for the flight control and measurement sub-system and for the power sub-system.

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8 A large part of the wiring in the sub-system boxes is in the form of printed circuitry on wafer cards approximately four inches square. A wafer with its associated resistors and condensors is easily removable from the box assembly. The test drum in the compuer can isolate a fault down to the wafer level. The wafer can then be located, removed and checked on a separate test stand. The operation of this stand is comparable to that of a commercial tube tester. The wafer is inserted into an appropriate slot, proper voltages are applied by setting dials in accordance with a check list and an indication of the serviceability of each element on the wafer appears on the test dials. A fault is thus isolated to a particular element in the circuit and is corrected by standard shop repair practices.

9 The equipment boxes for each of the sub-systems are designed as plug in units. The inputs and outputs of each box are available on pin connectors that are plugged directly into receptacles on the aircraft rack. The maintenance test stands are designed with the pin receptacles so that the equipment can be plugged directly into the stands. This design makes the substitution of alternative equipment extremely difficult. For example, in accordance with RCAF planning for UHF aircraft communications, it might appear desirable to substitute an ARC 52 equipment for the ARC [illegible] type equipment in the MA-1. However, such a substitution would entail a complete redesign of the equipment to fit it into the space configuration available on the communications rack and on the maintenance test rack. If a complete communications-navigation facility was substituted to avoid such unit redesign, it would be necessary to provide self checking features on the equipment to minimize serviceability check time. The maintenance test stand for the new communications package would then require redesign. Suggestions for substitution of equipment in any of the sub-systems should, therefore, be examined carefully to insure that the impact of such substitution on the total integrated system-operational and maintenance-is understood.

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MART

10 The Mobile Automatic Radiation Tester is utilized in the following manner: A technician in the aircraft selects one of the four MART computer functions - system test: MCC data link, CC data link or unit test-and listens out on the allocated uhf MART frequency. If the MART equipment is testing another aircraft at the time, the technician hears a busy signal. As soon as the frequency is clear, he presses an interrogation button in the aircraft. If the technician has asked for a full system check, the following operations take place:

(a) The MART receives theinterrogating signal on an ARC 27.

(b) A decoder box in the trailer activates the MART units.

(c) Instrument landing signals are radiated from MART and are received by the aircraft.

(d) Simulated TACAN signals are radiated and the information appears on the cockpit horizontal situation indicator. In addition, the computer enunciator indicates "OK" - the standard indication for the reception of TACAN signals in the MA-1.

(e) An IFF signal is transmitted to interrogate the aircraft. The MART equipment compares the reply with the known reply. If the equipment is functioning correctly, a four hundred cycle tone is transmitted to the aircraft later in the test via the data link voice channel.

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(f) A data link signal is transmitted by the MART. If the aircraft equipment is operating correctly, the following indications appear in the cockpit:

(i) "DL" appears on the computer enunciator.

(ii) The time-to-go (to offset) appears on the scope.

(iii) A steering signal is displayed on the HSI.

Ground Equipment

11 Cooling Air - The MA-1 requires refrigerated air when it is operated on the ground. HAC maintenance facilities at Palmdale, California, have tested two ground air conditioning units: A KECO provided for the USAF by Convair and an American Electronics model. (American Electronics, Inc., El Monte, California). The KECO model was assessed as unsatisfactory because of unreliable service and the extremely high noise level of the equipment. Members of the reporting team can confirm the objectionable noise level of the equipment. In the 300-600 cycle per band, noise measurements taken ten feet from the equipment varied in intensity between 96 db and 115 db, while the general noise level of the hangar area was 64 db. HAC advise that they have arranged purchase of four American Electronic Model No. MA 3-MN, an electrical driven (440 volts) air conditioner. The equipment is said to be more reliable and quieter than the KECO models. Specifications for this model (a gasoline driven model is also available) have been passed to AVRO by HAC. Purchase price is approximately \$15,000 - \$17,000 per unit, depending on the quantity ordered.

12 Ground Power - The MA-1 system, including all planned improvements will require 22 KVA of electrical power for ground operation. HAC-Palmdale use an American Electronics 40 KVA ground power unit Model MD-3. A modification kit is necessary with the unit to maintain voltage readings within the tolerance needed in the MA-1. Convair has all the information available on the modification.

13 Ground Handling Equipment - The final configuration of the handling equipment for maintenance is not yet complete. WADC favour "push up" units to hoist equipment into place, while ADC want crane type equipment. One equipment that has been accepted is a dolly-mounted winch used to remove, carry and replace the radar dish and the associated RT package. The equipment was designed to serve the F-106 and it will need a height modification if it is to be used on the Arrow.

APPENDIX "N"
TO S1038CN-180
DATED 19 DEC 58

TRAINING - PERSONNEL

Reference AFHQ Technical Library No: 4970, 4962

1 The MA-1 system is comprised of five interdependent sub-systems each of which bear varrying degrees of resemblance to contemporary conventional equipments insofar as circuit detail is concerned but very little similarity from the aspects of form factors, layout, testing, fail safe, and maintenance concept.

2 Because of the intermarriage of equipments from the armament, communications, radar, instrument, and electrical fields there is a need for a systems technician capable of checking out the entire system to verify that it is serviceable. If it is not serviceable, the systems technician should be capable of determining the location of the fault and exchanging the faulty assembly. It is not necessary for him to be a specialist in all the allied fields nor is such an achievement practically possible. Specialists in each of the trade fields should be capable of all levels of field maintenance on their respective equipments.

3 The USAF plan is to train the bulk of their technicians on the MA-I system, in the field, through the use of Mobile Training Units (MTU) with the assistance of permanent technical representatives from HAC. There will be three HAC tech reps for this purpose for each squadron of 18 aircraft. The Mobile Training Units, which are described in Appendix "O" - Training Aids, normally come to a squadron three months in advance of receiving the MAI fitted aircraft. The first MTU will go to McGuire AFB in New Jersey about the 1st January 1959.

4 Air Training Command USAF now have technicians on courses at the HAC plant. It is their intention, as soon as they have enough competent instructors, to phase out large scale contractor training and to give their technicians initial training for the MAI system at Lowry Air Force Base.

5 Hughes Aircraft Company is currently providing training courses for personnel of the USAF who will be employed initially on maintenance of the MAI system and who will serve as instructors at Lowry AFB and on Mobile Training Units. The following table shows the course specialty, the USAF career field of the personnel on each course, the duration of courses, the number of personnel in each category required for a squadron of 18 aircraft, the maximum number of students per training equipment and the skill levels required by the entrants:

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Course Specialty	USAF Career Field	Duration of Course in Weeks	No Required per Sqdn of 18 Aircraft	Maximum Number per Trainer	Skill Level of Entrant	Notes
SYSTEM	322X0	26	9	10	5-7	1
RADAR	322X0	22	4	6	3-5	1
COMPUTER	322X0	24	4	6	3-5	1
FLIGHT CONTROL & MEASUREMENT	322X0	15	4	6	3-5	1-2
CN and L	301X0	15	3	6	3-5	3
POWER	432X0	9	3	6	3-5	4
TEST EQUIPMENT	324X0	22	2	-	3-5	5
GAR 3 MISSILE	311X0	12	2	-	3-5	

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NOTE 1 - Technicians on these courses are basically radar trained. The systems man will normally have had a longer and greater experience in the field.

NOTE 2 - FC&M technicians also do an additional four week course at Convair on flight integration.

NOTE 3 - Technicians on the CN and L course are basically the equivalent of comm techs.

NOTE 4 - Technicians taking the power course have an additional training in electronic fundamentals before reporting to HAC.

NOTE 5 - USAF has basic Trade Test Equipment Technician.

6 HAC capacity for training is 50 students per course (25 per shift, 2 shifts) on the system and 30 students per course (15 x 2) on sub-systems.

7 Potential instructors for the USAF receive the same training in the plant as maintenance personnel. The USAF take care of their own requirement for the instruction on handling courses, techniques of instruction, etc. Each USAF squadron of 18 aircraft will have three HAC tech reps assigned permanently for training purposes. These are in addition to the field service representatives provided for maintenance on the scale of:

16 - for first 1 to 6 months reduced to,
9 - for 6 - 12 months reduced to,
6 - for 12 - 24 months reduced to,
3 - for 24 and subsequent months.

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8 HAC representatives indicated that training courses could be made available for the RCAF.

9 In addition to the above, HAC are providing the following courses for staff personnel and operators:

(a) <u>Supervisors Planners Course (for Staff Personnel)</u>

This course is of 3 weeks duration and accommodates 12 persons per course. It is designed to give staff officers and other management people a knowledge of the overall MAI system, its capability and support requirements.

(b) <u>Pilots and Operators Orientation Course</u>

This course is of 8 days duration and is designed to familiarize Pilots and Operators with function and manipulation of controls, interpretation of displays and general considerations which help the operator get the best results from the use of the equipment.

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10 The cost of courses to the USAF is approximately $3.25 per student hour. Thus a technician's course of 26 weeks or 1040 hours at $3.25 costs about $3,300. This covers the cost of course preparation and tuition but does not include anything for training equipment cost, or spares support and maintenance. The MAI systems and sub-subsystems now at HAC for training are the property of the USAF and loaned to HAC for training purposes.

11 The cost of the Supervisor's Planners Course approximates $3,500 for 12 people for 3 weeks and for Pilots and Operators $800 to $1,000 for 10 people.

12 Advance notice required for courses runs at 4 to 6 weeks for pilot/operator, 2 months for supervisors and planners and three months for technicians.

13 HAC has unofficially quoted AVRO a price of $800,000 for training a total of 126 RCAF technicians in two courses of 63 weeks comprised of 12 systems techs and 9 sub-system techs in each sub-system. This price is understood to cover course preparation and tuition but does not cover training equipment or its support and test equipment.

14 The USAF course numbers applicable to each of the above courses are as follows:

System - SM32251A-7

Computer - SM32251A-4

Test Equipment - SM32251A-6

FC and M - SM32251A-5

Radar - SM32251A-3

Power - SM42350-72

CN and L - SM30150-7

GAR 3-4 - SM31170E-5

Supervisor Planner - SM3234A-1

Pilot Operator - Number not obtained

UNCLASSIFIED
APPENDIX "O"
TO S1078CN-180
DATED 19 DEC 58

TRAINING AIDS

CONTENTS

UNCLASSIFIED

UNCLASSIFIED
APPENDIX "O"
TO S1038CN-180
DATED: 19 DEC 58

TRAINING AIDS

Mobile Training Unit (MTU) Equipment

1 Information from Sgt. Ramo at WADC,Convair procured a nine panel mock-up of the MA-1 system as part of the MTU. The panels are capable of being connected to stimulate to some degree the operation of the whole system. The panels are connected by 50 foot cables to permit use in separate rooms. The first MTU was accepted by the USAF on 26 Nov 58 and has been loaned to Convair for the F106 school. An instructor training course was finished on 17 Dec 58. The first USAF MTU will be located at McGuire AFB, in New Jersey. The cost of an MTU for the F106 consisting of 26 panels is over $1,000,000 and the price does not include the set of MA-1 equipment which is GFE, at a cost of about $800,000 to $900,000. Power is derived from a 220V 40 H.P. motor driving the aircraft equipment, and in addition an APU is used. There is no GAR equipment, only charts.

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School Equipment

2 Information from G. Goebel of HAC. The equipment used at the HAC school since it started Dec 57 includes literature, classroom equipment, MA-1 Maintenance Benches, GAR Checkout Equipment, "Crazy Noses", Field Test Equipment, and Test Equipment for Maintenance Equipment.

3 Reference Handbooks are, T.O.'s on the MA-1, numbers T.O. 11F1-MA1-12-1 to -5, a set of technical papers for maintenance training on Radar set /AN SPS (XN-1) and other subjects, also the document HAC MA-1-1-S.

4 Classroom training equipment is:-

(i) Schematics
(ii) Block diagrams
(iii) Technical descriptions
(iv) Text workbooks produced by the school
(v) Tests, written, and practical on actual equipment.

5 MA-1 Maintenance Benches unmodified.- These exist for five sub-system specialties. They are not interconnected except for a common power supply. An additional set of the power section of MA-1 is required to provide the power for operating, thus leaving the power bench complete for student training use.

These benches are:-

(1) Radar Maintenance Bench
(2) CN & L Maintenance Bench
(3) Flight Control and Measurement Bench
(4) Power System Maintenance Bench
(5) Computer Maintenance Bench

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6 The Power Requirements of M A-1 System Test Benches at the Technical Training School by actual measurement are as shown below for each set, on the average:-

Type Power	28V	300V	150V	-140V	400cps 3Ø	400cps 1Ø	1600 cps	28V CVAC	400cps CVAC	60 cps
	Amps	Ma.	Ma.	Ma.	VA(0.9PF)	VA(0.9PF)	VA(0.PF)	Amps	VA(0.75P^F	Amps
MA-1 System	52.7	2327	5216	3352	1429	1933	6524	-	-	-
Test Stand	11.6	189	289	263	-	36	348	55.8	4989	105
Total	64.3	2516	5505	3615	1429	1969	6872	55.8	4989	105

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This applies to Squadron Shop or Training on MA-1 and would be different for MA-1C. See MA-1 Test Equipment Master Index Dwg. #464000-507 Rev. R. and Master Index for MA-1C/CF105 Mk. 2 (Arrow) Weapon System.

7 GAR-3/4 Checkout Equipment is as follows:-

Voltage	Item	Current	Power
	CHECKOUT CONSOLE - HAC - 177000		
115-230 V, 60 cps single phase, 3 wire or two 115V phases and neutral of 208V, 3 phase system		60 amps per phase	14KVA
	MAINTENANCE CONSOLE - HAC - 177001		
115-230 V, 60 cps single phase, 3 wire or two 115V phases and neutral of 208V, 3 phase system		30 amps per phase	7KVA
or 115V, 60 cps single phase, 2 wire one 115V phase or and neutral of 208V, 3 phase system		60 amps per phase	
	AIR COMPRESSOR - HAC - 156906		
208V, 60 cps three phase, 4 wire		25 amps perphase	16KVA

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MOTOR GENERATOR (WSEM) - HAC - 187196

208V, 60 cps three phase, 4 wire 9 amps per phase 3.24KVA

NOTE: ONE ADDITIONAL WIRE TO EACH PIECE OF EQUIPMENT MAY BE REQUIRED TO PROVIDE GROUNDING OF EQUIPMENT FRAMEWORK IN ACCORDANCE WITH LOCAL PRACTICE.

8 System "Crazy Noses" or Three-dimensional System Trainers. System training is given on these not sub-system specialist training. Five students can train on one "Crazy Nose" at a time. A "Crazy Nose" consists of a tubular frame supporting the MA-1 racks and a crude cockpit in approximately realistic configuration with an air pump, a radar dummy load and a power supply. The Ground Power Unit used in MA-1 Training (Long Life Type) can also be used at a Squadron. Data is:-

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Input	220/440 Volt, 60 cy., 3φ, 200/100 Amp.
Output	115/200 Volt, 400 cy., 3φ, 20 KVA, 0.75 P.F. 115/200 Volt, 400 cy., 3φ, 5 KVA, 0.9 P.F. 115 Volt, 1600 cy., 1φ, 12 KVA, 0.9 P.F. 28V DC., 75 Amp. 28V DC., 100 Amp. -140 Volt DC., 7.5 Amp. +150 Volt DC., 7.5 Amp. +300 Volt DC., 3.5 Amp
Description	- Generator Set - Portable, Motor Driven Type AF/ECU-10/M AEI Part No. 4-408100001 Model No. EPM 2261 CVAC Part No. 8-96025-803 CVAC Spec No. 8-06453B T.O. #35C2-2-25-44

A changed ground power unit may be required for the MA-1C system. A "Crazy Nose" costs about $25,000. for pump and frame, $15,000. for cabling, $900,000. for the MA-1 and $20,000 for the power supply, for a total of $960,000. The air pump delivers about 6½ inches pressure of air but cooling has been deficient sometimes in hot weather. Utilization has been 85%. Maintenance is required .

9 Field Test Equipment - It is set up in portable stands called "Dock Maintenance Stands". There is one for Radar, one for CN&L, one for Flight Control and Measurement and Power, and four others. They were designed by HAC but are supplied by Warner Robbins AFB at Macon, Georgia.

10 Another item of field test equipment is the Mobile Automatic Radiating Tester, or MART which when interrogated by an MA-1 set by radio then gives a cycle of various radio signals in a period of 52 seconds to test the communications gear of the

...../4

MA-1. Two minute fault finding signals may be commanded in any of the channels. It is normally not manned. It gives a failure warning if it goes out of order. It is effective for one mile distance in a 30 degree cone.

11 There is test equipment for the Maintenance Equipment and a course is given on its use. A trade of Test Equipment Technician exists.

12 CREW TRAINERS Flight Simulator - Since it is procured from Link HAC could not tell us about it except to confirm that it includes MA-1 simulation. Sgt Ramo at WADC stated that it includes MA-1 and ARDC vertical instruments. The delivery date is Jun 59. There is no cockpit procedure trainer.

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COCKPIT SUB-SYSTEM

1 The Cockpit Sub-System consists of those parts of MA-1 which are located in the two cockpits. In addition to this MA-1 sub-system, the cockpits, of course, contain environmental equipment, escape equipment, manual flying controls, engine controls, engine instruments, flight instruments and some miscellany. Of these, the flight instruments must be mentioned here because they may be closely integrated with the MA-1 system if desired. Independent flight instruments may be chosen or instruments may be operated remotely from the MA-1 Flight Sensing Sub-system. The ARDC new instruments are of this latter class and have been described in some detail in Appendix "F".

2 The cockpit controls and displays for the MA-1C are listed in detail in the Master Index, HAC Report No. 470000-100, Preliminary Issue, ref No. 4359. The MA-1C items in the front cockpit include:

(a) Radar scope, No. 476080, on panel

(b) Optical sight, 464169, on panel

(c) Radar indicator control, 435071, on panel

(d) UHF Command Preset Channel Indicator 081, on panel

(e) Control, Frequency Selector, Communications, 464505, on console

(f) Control, Receiver ILAS, 464755, on console

(g) Control Panel, Transfer Relay, 470105, on console

(h) Armament Control Panel, 470805, on console
(j) Control, Flight Mode, AFCS, 464163, on console
(k) Converter Signal Data, Cockpit Display No. 1, 464,520

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3 The MA-1C items in the rear cockpit include:

(a) Control Panel, transfer relay, 470105, on console

(b) Control, Radar set, 464305, on panel

(c) Radar scope, 476080, on panel

(d) Control, Radar Set, Azimuth Scan and Horizon Adjustment, 470855, on panel

(e) Control, Antenna, Hand, 470019, on console

(f) Filter, light, cathode Ray Tube, 464025, purchased from outside vendor

(g) Visor, Cathode Ray Tube, 464125, purchased from outside vendor

(h) Control, Radar Set, Identification, 464555, on console

(j) Control, channel selector, TACAN, 464405, on panel

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(k) Control, Frequency Selctor, Communications, 464505, on panel

(l) Control, Power-System, 476905, on console

(m) Control, Converter-Receiver C2558/ARR (Separate Contract), 464019, on incorporation of Time Division Data Link

(n) Annunciator, Computer Mode, 464034, on panel

(o) Control, Coder, Decoder, 464655, on console

(p) Control Selector - Auto-navigation, 464955, on console

(q) Indicator, Horizontal Situation, 470180, between man's knees

(r) Relay Assembly, Control Transfer, 470764

(s) UHF Command Preset Channel Indicator, 081, on panel

(t) Panel, Self Test, 464796, on console

(u) Rack, Electrical Equipment, 464002

(v) Rack, Electrical Equipment, HSI, 470102

(w) Converter Signal Data, Cockpit Display No.2, 464620

(x) Control Converter, Bearing Select Switch, 464463.

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19 Dec. 58

ECP Procedures on MA-1 Program

Discussions at WADC

1 The following notes outline the discussion held at the Electronic System Branch (ESB) of the Airborne System Laboraties, WADC, on ECP (Engineering Change Proposals) procedures for the MA-1/F106 Program:

(a) There are two types of ECP: (i) Convair ECP (ii) HAC ECP. Certain Convair ECP's crossover on HAC ECP's and vice versa. Thus MA-1 ECP's from HAC go to the ESB and meet the Convair ECP which is sent over from the F106 Weapons System Project Office (WSPU). Conversely, F106 ECP's go to the WSPO and meet the HAC ECP which is sent over from the ESB.

(b) There are two categories of ECP: routine and mandatory emergency:

(i) On routine ECP's, the contractor goes through normal channels to AMC who forward it to ESB for technical review. ESB may call on the laboratories for technical advice. A WADC position is then sent to AMC. If retrofit is involved, an AMC/AMA (Air Material Area) takes over for kits, etc. 45-60 days are usually required to get contractual authority to the AMA. The AMA has people at the contractor who take immediate steps on retrofit. This is called the "failure to fix" group.

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(ii) On mandatory emergency ECP's, the contractor submits the ECP by TWX to ESB and AMC (fighter branch of aeronautical equipment division - LMEGF). LMEGF takes care of the whole AMC problem. ESB handles the technical situation. A five day target deadline is established for technical analysis. AMC require an additional three days if an indication of approval or disapproval is phoned over by ESB. If this ECP effects Convair, F106 WSPO are called in and are given the same five day deadline.

2 The office symbol of ESB is WCLOOE, and of F106 WSPO is RDZSDG.

3 If there should be a substantial RCAF MA-1 program, Mr. Stegner (ESB head) recommends that an RCAF officer be attached to WCLOOE in order that ECP's would not hit the RCAF cold.

Discussions at HAC

4 The following notes outline the discussion held at HAC on ECP procedures for the F106 program:

(a) There is a joint HAC/Convair plan for joint ECP's. If there is an RCAF program, a copy of this plan will be available.

(b) A HAC/Convair Configuration Control Committee meets weekly. HAC supplies membership from all divisions of the company. Discussion is held on changes initiated by USAF, Convair or HAC. If an ECP does not effect HAC, the HAC representative often sits in.

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(c) If a HAC change may effect the airframe, or if Convair financial coverage is required, the whole ECP is discussed with Convair. An EDRA (Engineering Drawing Release Authorization is then raised and co-signed by HAC and Convair.

(d) When a DAG ECP is submitted to USAF, there is always cross-reference made to a Convair ECP or a Convair covering letter.

5 There is a clause in HAC and Convair contracts requiring them to liaise on any changes which might have cross-effect. A statement of concurrence is required from Convair even if a HAC ECP does not effect Convair.

6 A chart showing the latest MA-1 ECP status is attached.

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MA-1/ASQ-25 ECP STATUS

APPENDIX "Q"
TO S103BCN- 180 (AAWS)
19 DEC 58

CURRENT TO: 12 NOV 1958

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CHG NO	ECP NO	TITLE OF CHANGE	PROP EFF MA-1	PROP EFF ASQ	DRAFT SCH	DRAFT ACT	FS&S SCH	FS&S ACT	MFG SCH	MFG ACT	TO AF SCH	TO AF ACT	CCN DUE	CCN DATE	CCN NO CONTRACT • ● ■	RETRO REQ	COMMENTS
0213	1009	MECHANICAL COMMUTATOR 523 BOX	54	17		8-14		8-27		8-27		9-4	10-20	10-28	25 20	YES SUBM	
0344	1011	SLIP RING ALTERNATOR			○												
0291	1016	INCREASE AUDIO OUTPUT			○												
0281	1017	DUAL HEAD DRUM			○												
0702	1032	WAVE-FORM FIX J&H REGULATOR	43	11		5-5		5-16		5-7		6-6		8-25	15 12	YES SUBM	
0639	1034	WIDE MISSILE LOOK ANGLE															
0814	1036	DEHYDRATOR BRACKET	88	37	10-24 ◄		10-31		10-31		11-7 10-31		1-9 1-9			YES	
1089	1041	REVISION OF SWITCHING REQUIREMENT	39	17		8-12		8-13		8-14		8-15		9-19	20 16	YES	TO BE RESCHEDULED
0926	1042	ADJUSTMENT REMOVAL															
1024	1043	REDUCTION OF RADIO INTERFERENCE															
1166	1045P	ALTITUDE & HEADING HOLD SWITCHES															SUSPENDED UNTIL REQUESTED BY CUSTOMER
1060	1046	PREVENT NOISE ON REFERENCE VOLTAGE	67	13								7-16	9-15				
0877	1047	REDESIGN OF BEARINGS				7-7		7-10		7-10		8-13	9-19	10-28	26 21	YES	
1385	1049	REDESIGN OF 464080 UNIT			10-31	11-7	11-7 ◄		11-7		11-14		12-19			YES	
1028	1051	HEADING SELECTOR ASSEMBLY			11-16		12-23		12-23		11-30		4-7				
0580	1052	AUTO NAV 28 POSITION SWITCH			[illegible] ◄		8-13		8-13		8-19		10-17				
1398	1058	CHANGE CAMS IN 464521 UNIT				8-13		8-28		8-14		9-10	11-10				
1683	1060	HI POWER - LO DISTORTION XMTR	34	9		8-12		8-14		8-14		8-19		9-25	21 17	YES	TO BE RETROFIT ONLY
1160	1068	MULTIPLE PASS WSEM CAPABILITY			11-27		11-28		11-20		12-5		2-6				
1856	1071	FALSE ZERO RANGE LOCK-ON	19	4		8-20		8-21		8-21		8-21		8-27	18 14		
1700	1077	RELAY DROP-OUT IMPROVEMENT			11-21		11-28		11-28		12-5		2-6			YES	
1644	1087	COOLING OF AZ. ANT. DRIVE			○												
1778	1088	RESISTOR CHG. RANGE RATE OSC.			11-7 ◄		11-14		11-14		11-21		1-23				
1487	1092	TRANSISTOR POWER SUPPLY REDESIGN			11-21		11-21		11-21		12-5		2-6			YES	
1821	1089	CHANGE 80V SUPPLY TO 341 UNIT			○												
1960	1103	STEERING DOT PHASING	32	8		9-17		9-17		9-17		9-17		9-25	22 18	YES	BY TWX FORMAL ECP DUE
2009	1114	ADF BEARING CORRECTION			10-8	10-30	10-9	11-6	10-9	11-3	10-10	11-11	10-24			YES	
0741	1128	MAGNETIC DRUM LABEL			11-7 ◄		11-28		11-28		12-17						
1799	1119	REDESIGN FL MODE SWITCHING			11-14		11-21		11-21		11-28		1-30				
1984	1120	RELAY LENS			11-14		11-21		11-21		11-28		1-30				
2060	1121	CAM UP-LOCK			12-5		12-12		12-12		12-19		2-20				
2061	1122	GROUND STRAP LEAD CLAMP			11-14		11-21		11-21		11-28		[illegible]				
2062	1123	HOLDBACK RELEASE HANDLE POS. SWITCH			12-12		12-19		12-19		12-29		[illegible]				
1840	1125	HORN DRIVE BEARING			11-7 ◄		11-14		11-14		11-21		1-23			YES	
1766	1127	FAILURE IN VIBRATION			11-21		11-28		11-28		12-5		2-6			YES	
1793	1130	DIGITAL COMPUTER RESET			11-21		11-28		11-28		12-5		2-13			YES	
2038	1134	STABLE PLATFORM ERECTION VOLTAGE			○												
0799	1135	IMPROVE GAR-3 CAPABILITY			○												
2097	1136	TARGET PULSE						11-3				10-22		10-30	27 22		BY TWX FORMAL ECP DUE
1365	1139	RECEIVER CONDUCTED NOISE FIX			○											YES	
2066	1140	IFF TACAN-MULTIPLEXING			○												
2147	1141	READ TRANSFORMER CHANGE			○												
1755	1142	TRIGGER FIRE SIGNAL DISPLAY			○												
2168	1144	MODIFICATION OF AMPLIFIERS HSI			○												
		A.F. REQUESTS															
1094	★1038	FIGURE 8 COLLISION WARNING			11-28		12-5		12-5		12-12		2-13				
1549	★1072	LANDING GEAR WARNING SIGNAL			1-2		1-9		1-9		1-16		3-13			YES	
1552	★1115	LONG RANGE DETECTION			12-12		12-15		12-15		12-19		1-23				
0484	1027P	DATA LINK STUDY				11-3		11-3		N/A	11-5	11-7	1-5				
1547																	
1553																	
1566																	
1546																	
1027	1039	DRIVE CIRCUITRY FOR REMOTE IND	21	19		5-20		5-28		5-28		6-13		8-15	14 10	YES	
0810	1093P	ADD TWO POSITIONS ON AUTO MODES SW.				9-6						9-9					
	1110P	RELIABILITY OF MA-1AWCS				10-9		10-9		10-9		10-10					NO ECS STUDY ONLY
1174	1148	AAI INCORPORATION			○												

ECN'S TO BE SUBMITTED CHG NO	ECN'S TO BE SUBMITTED ECN NO
0646	1033
1576	1060
1596	1065
1435	1066
1684	1070
1636	1075
1796	1078
1842	1079
1810	1080
1391	1081
1496	1085
1812	1086
1901	1090
1623	1091
1714	1094
1607	1095
1645	1096
1891	1098
1897	1099
1892	1100
0784	1101
1594	1102
1964	1104
1957	1105
1774	1106
1947	1107
1948	1108
1956	1109
2006	1111
1962	1112
1229	1113
2016	1116
1996	1117
1854	1118
2077	1124
1967	1126
2065	1129
1920	1131
1686	1132
1859	1133
2090	1137
1451	1138
1921	1143
2133	1146

LEGEND
★ AF REQUEST
○ NO ESTABLISHED SCHEDULE
▨ SCHEDULED DATE
◄ BEHIND SCHEDULE
• 33782 CONTRACT
■ 38011 CONTRACT
● 34133 CONTRACT

APPENDIX "R"
TO S1038CN-180
DATED 19 DEC 58

FALCON GAR-3A AND GAR-4A MISSILES

Introduction

1 This appendix provides information on the GAR-3/3A and GAR-4/4A improvement, test and production programmes. Additional information on other areas is provided in Annexes to Appendix "R" as follows:

(a) Annex 1 - Weapon System Evaluator Missiles (WSEMs)

(b) Annex 2 - GAR-3A/GAR-4A Maintenance

(c) Annex 3 - GAR-3A/GAR-4A Training

(d) Annex 4 - The LE-6 Launcher

(e) Annex 5 - Missile Launch Sequence

(f) Annex 6 - F-106 AWCS and Armament Development Programme.

Security

2 Security information on the Falcon GAR-3 and GAR-4 and the missile check-out equipment is contained in Security Classification Guides which are held in AFHQ Tech Library as reference No. 4987.

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Definitions

3 The various models and types of missiles in the GAR-3/GAR-4 programme are defined as follows:

(a) Models

(i)	XGAR-3/XGAR-4	Experimental models
(ii)	XGAR-3/YGAR-4	Preproduction models
(iii)	GAR-3/GAR-4	Production models
(iv)	XGAR-3A/XGAR-4A	Experimental models of higher performance version
(v)	GAR-3A/GAR-4A	Production models of higher performance version

(b) Types

(i)	Type I	Tactical missile - uses all live components
(ii)	Type II	Training missile - uses inert components
(iii)	Type III	Test missile - uses live motor but warhead and fuze are replaced by telemetry package.
(iv)	Type IV	Weapon System Evaluator Missile - the fuze warhead and motor are replaced by recording equipment.

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Characteristics of GAR-3A/GAR-4A

4 The GAR-3A/GAR-4A versions of the Falcon GAR-3/GAR-4 will have essentially the same operational characteristics (i.e. launch ranges, altitude capabilities, etc) as the original versions but will include many improvements. Certain parts of the GAR-3/GAR-4 limit the temperature range in which the missile may be used to 0°F to +130°. Other problems have been encountered due to humidity. The GAR-3A/GAR-4A versions will extend the temperature range to -65°F to +160°F and remove any limitations due to humidity.

The GAR-3/3A and GAR-4/4A Programmes and Schedules

5 The "X" period in these programmes has usually been of approximately 12 months duration. The "Y" period has varied from 9 to 15 months and overlaps the "X" period to some extent. The production period does not overlap the "Y" period.

6 The "X" models of the missiles are built at Hughes Aircraft Company, Santa Monica, and the "Y" and production models are manufactured at the Hughes plant in Tucson, Arizona. Changes can be fed into any missile during the "Y" programme but once the production programme starts changes are made only at the beginning of a "lot". All missiles manufactured during a two month period (i.e. Feb/Mar) will be of one lot.

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7 The following table lists the missile firings which have taken place to date. The launch aircraft in each case has been an F-102 with the MG-10 FCS suitably modified for GAR-3/GAR-4 launching. The targets for these firings have been foil-lined parachutes, balloons and drones but the parachutes are the most commonly used.

Model	Number Launched	Number Guided	Number Hit
XGAR-3	20	13	9
YGAR-3	28	18	10-12
GAR-3	11	10	5
XGAR-4	13	10	9
YGAR-4	16	13	9

8 The XGAR-3A programme calls for the first launch in late Jan or early Feb 59 and the XGAR-4A first launch in Apr 59. Both these firing programmes are to be completed by 1 Oct 59. It is not proposed to produce any YGAR-3A or YGAR-4A missiles but to start directly on production missiles (GAR-3A/GAR-4A). The GAR-4A development is lagging the GAR-3A development by approximately two months.

9 The GAR-3/GAR-4 programme is summarized below.

Model	Quantity	Period	Remarks
YGAR-3	75	Jan 57/Feb 58	Preproduction missiles - All for test and evaluation purposes.

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Model	Quantity	Period	Remarks
GAR-3	196	Mar 58/15 Nov 58	First production procurement by USAF. These are non-tactical missiles and will be used in test programmes. 70 are being used at Eglin AFB for Ground Handling Tests and for check-out of Ground Servicing Equipment.
	284	15 Nov 58/Jul 59	Second production procurement by USAF. These will be limited tactical missiles and will go to the ADC squadrons.
XGAR-3A	13	Jan 59/Jul 59	Experimental models 3 for Environmental tests 4 for Laboratory tests 6 for Category I (joint Contractor-USAF) firings
GAR-3A	792	Aug 59/Jul 60	Combat stocks for ADC squadrons The production is scheduled for 2 in Aug, 5 in Sep and increasing until a rate of 100 per month is reached.
YGAR-4	75	Jan 57/Feb 58	As for YGAR-3.
GAR-4	60	Feb 58/May 58	This production was cancelled at the end of 60 missiles because of poor results obtained. These missiles are being fired for aircraft compatibility tests and others are being used for lab tests.
XGAR-4A	16		Experimental models. First 6 will be used for qualification, verification and lab tests. The 10 remaining will be used for Category I firings.
GAR-4A	60	Aug 59/Jul 60	Production builds up to a rate of 35 per month. All these will be used in evaluation and test programmes.

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10 The production quantity of 60 GAR-4A missiles is limited by USAF funds. The USAF are endeavouring to obtain funds for additional GAR-4A's. They would like to obtain 130 to 150 more missiles for evaluation and testing. In addition, they will be placing orders for combat stocks and the quantity obtained for this purpose should be approximately the same as for GAR-3A (792) as it is planned to supply squadrons with 71 GAR-3A's and 70 GAR-4A's. (Total - 141 per squadron of 18 aircraft.)

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11 The programmed Category I (Contractor/USAF) firings for the period 1 Oct 58 until 1 Oct 59 are as follows:

GAR-3	35	
GAR-4	2	
XGAR-3A	6	
XGAR-4A	10	
E.V.	4	(Separation trials with missiles with motor, no guidance)
Total	57	

GAR-3 Limitations or Deficiencies

12 The first production run of GAR-3's will be non-tactical missiles. The following deficiencies or limitations in the early GAR-3 have been partially responsible for the introduction of the GAR-3A programme.

(a) Radome-antenna combination has only a two channel capability whereas a six channel capability is required. This refers to the requirement for different operating frequencies being allotted to different aircraft to prevent mutual interference when missiles are fired.

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(b) Servopositioners are not sealed. This results in conditions similar to a vapour lock in the hydraulic system after the missiles have been cycled through various altitudes.

(c) Fuze - difficulty in attaining the temperature and humidity limits required resulted in the fuze being behind the rest of the missile program. A potted design was being used for the fuze.

(d) Rocket motor (XM 18E4) - would not qualify over the required temperature range. It has been given a Pre-Flight Test Rating only, which means that it can be fired only by development and test agencies.

(e) Electronics package - limited to 0°F to +130°F operation.

(f) Mk 5 power supply - This is a liquid propellant (ethylene oxide) power supply which requires a warm-up period prior to missile launch. In addition, a switch has to be mounted in the aircraft and the pilot has to switch heating "on" which is not too satisfactory. Another limitation is a four to six month shelf life for the power supply.

13 Later production lots of the GAR-3 will incorporate improvements which will also be used in the GAR-3A. There will be 13 major changes in this second production run including such items as:

(a) Mk 6 Power Supply - uses a solid propellant to produce the gas to operate the turbine for both hydraulic and electrical power.

(b) Sealed servopositioners.

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(c) Rocket motor (HX-19F) - this is an old rocket motor which has been re-instated and produced for this second production run of GAR-3's. It has been qualified from -40°F to +170°F for operational use.

14 This second production run is just starting. The aim is to produce GAR-3's which will have no hardware deficiencies and will be suitable for limited tactical use. The operational temperature limits will be 0°F to +130°F while the storage temperature limits will be -40°F to +140°F. There still will be limitations due to humidity which will not be eliminated in the GAR-3. If the GAR-3 is subjected to high humidities while on an aircraft, it must be removed, dried and tested before it can be considered as serviceable for flight again.

15 There has been some slippage in this second production run because of some difficulty in meeting certain specifications. The USAF do not want to give waivers on these missiles. The two areas giving trouble are:

(a) Radio noise - In all the previous missilesSpecification MIL-I-006181C (USAF) Interference Control Requirements, Aeronautical Equipment (now MIL-I-26600) has been waived and Specification MIL-I-6051 (Interference Limits and Methods of Measurement, Electrical and Electronic Installation in Airborne Weapons Systems and Associated Equipment) substituted. HAC is having difficult meeting MIL-I-6181 even though the USAF have given a waiver of 10 db for the overall missile system. The GAR-3 still exceeds the Spec plus 10 db waiver by approximately 18 db. This represents a considerable improvement over the first production run missiles which ran 60 to 80 db higher in noise. The noise level generally is quite close to the Spec requirements except for some high peaks at certain frequencies.

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(b) Mk 6 Power Supply - The testing of the solid propellant power supply was going well and was practically completed when trouble was encountered. After aging a power supply at +170°F for 60 days, it was fired at -60°F. The propellant restrictor failed in this firing (restrictor-inhibitor on surface of propellant). A series of penalty runs are being done to quality the power supply for a temperature range of -40°F to +140°F for these GAR-3's. This power supply is to be fully qualified for the GAR-3A and GAR-4A.

GAR-3A

16 The GAR-3A uses the GAR-3 airframe but there is a considerable amount of redesign and relayout of circuits and components within the missile itself, and circuitry has been added. Because of the changes and additions the weight of the missile has increased and the center of gravity has moved. Pieces have been added to the wings to provide greater aerodynamic lift and to change the center of pressure (See Figure 1).

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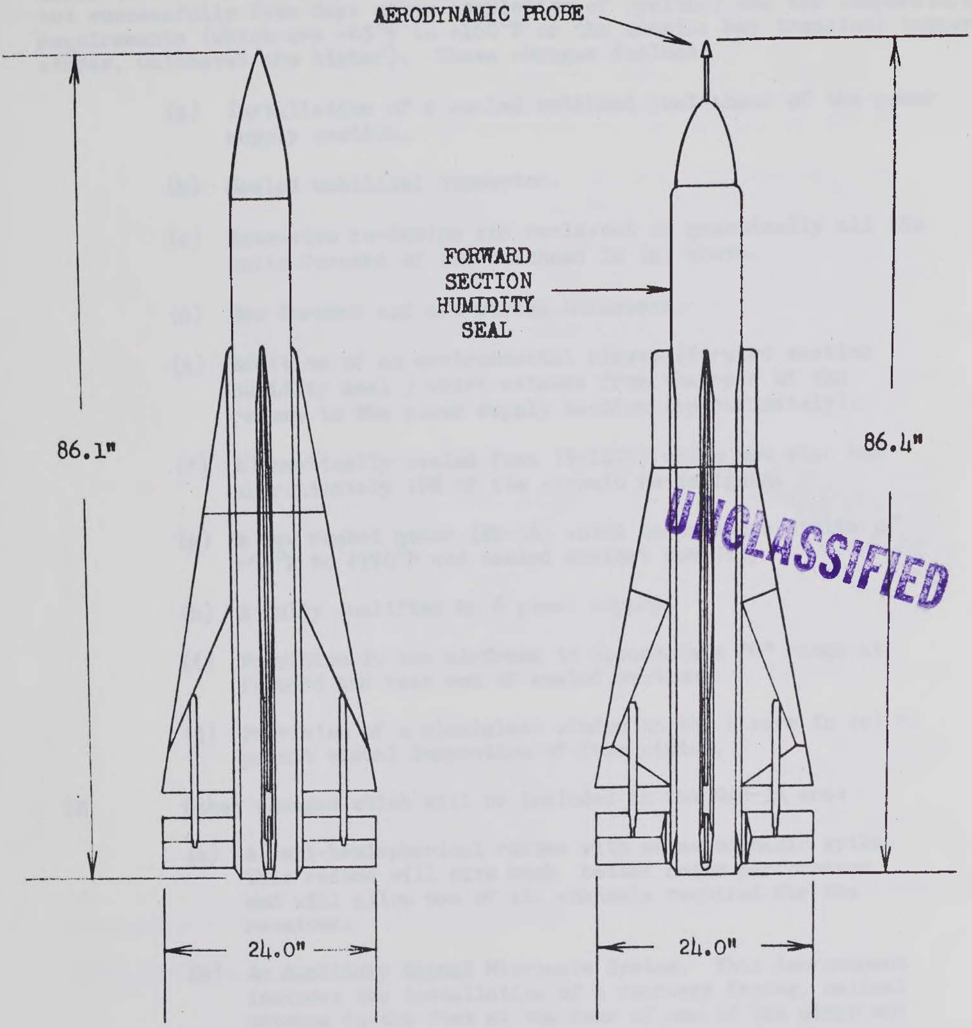

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(ALL DIMENSIONS ARE APPROXIMATE)

FIGURE 1. MISSILE EXTERNAL CONFIGURATION

17 The GAR-3A will incorporate changes to meet the humidity requirements (which are 15 cycles through 100% humidity at 100° ± 5°F, then check-out successfully five days after completion of cycling) and the temperature requirements (which are -65°F to +160°F or the missile bay transient temperatures, whichever are higher). These changes include:

(a) Installation of a sealed bulkhead just ahead of the power supply section.

(b) Sealed umbilical connector.

(c) Extensive re-design and re-layout of practically all the units forward of the bulkhead in (a) above.

(d) New forward and aft wiring harnesses.

(e) Addition of an environmental sleeve (forward section humidity seal) which extends from the rear of the radome to the power supply section (approximately).

(f) A hermetically sealed fuze (T-1407) which has also had approximately 10% of its circuit re-designed.

(g) A new rocket motor (XM-46) which temperature limits of -65°F to +190°F and sealed against humidity.

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(h) A fully qualified Mk 6 power supply.

(i) Provision in the airframe to accommodate "O" rings at forward and rear end of sealed section.

(j) Provision of a plexiglass window in the sleeve in (e) to permit visual inspection of fuze pistol.

18 Other changes which will be included in the GAR-3A are:

(a) A semi-hemispherical radome with an aerodynamic spike. This radome will give much better radar performance and will allow use of all channels required for the receiver.

(b) An Auxiliary Signal Microwave System. This improvement includes the installation of a rearward facing, helical antenna in the foot at the rear of one of the wings and a microwave mixer section along with certain other circuitry. This system samples the main bang from the FCS transmitter when the missile is in flight, then turns off the main receiver section when the cross-over, illusion or blind range in approached. The receiver stays off from this time until intercept or, in other words, the missile continues on the course that it is flying at the time of cross-over with no further guidance changes. Chassis which are changed to accommodate this system are the range tracking and I.F. chassis.

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(c) The firing connections for the Mk 6 power supply and the rocket motor igniter have been removed from the umbilical connection and will be made through separate connections and leads from the Igniter Safety Package on the LE-6 launcher. These changes have been incorporated as safety measures to reduce the possibility of inadvertent firings. The motor igniter is also "sealed" in the rocket motor and requires no testing or checking.

(d) The XM-46 rocket motor will provide approximately 10% greater thrust primarily in the sustain phase. This is required because of the increased weight and drag of the GAR-3A. The motor grain will be produced by Thiokol but as yet, the material for the grain has not been selected. Three different grains are being studied and tested and the new rocket motors should be available shortly after the GAR-3A goes into production (approximately Nov 59). This program is in the development and pre-qualification phase and is scheduled to complete qualification by 1 Aug 59.

(e) The GAR-3A has additional anti-chaff circuitry. The pilot selects "Normal" at all times unless there is chaff because the selection of edge tracking (CCM) does degrade missile performance. When "CCM" is selected by the pilot, then either Leading Edge Tracking (LET) or Training Edge Tracking (TET) is selected by the MA-1 computer and at the time of missile launch the appropriate squibs are blown in the missile to give the desired type of tracking for the attack conditions. Further information is included in Appendix "J" (MA-1 Counter Countermeasures Program), paras 16 to 18.

(f) The GAR-3A has a home-on-jam (HOJ) capability. If jamming occurs while the missile is in flight, the radar receiver will automatically select the home-on-jam mode and the missile continues to home on the target. When HOJ ceases, the missile does not range re-lock.

19 The first experimental GAR-3A has just been completed. Production drawings will be released in January 1959.

GAR-4 Limitations and Deficiencies

20 The GAR-4 initial production run was stopped after delivery of 60 missiles because of the poor results being obtained with the IR guidance unit which was essentially a GAR-2A guidance unit. This seeker had very poor background discrimination characteristics and consequently was losing its target. In addition, the temperature and humidity problems encountered in the GAR-3 programme were the same in the GAR-4.

GAR-4A

21 The decision was made in May 1958 to change from the lead sulphide cell to a longer wavelength cell. The two types being considered are indium antinimide and lead selenide with the indium antinimide being favoured. These cells are effective in the 3 to 5 micron band and will home on the jet plume. A crash program is underway and is proceeding according to schedule. Texas Instrument Co. of Dallas, Texas, are producing the indium antinimide detectors and are having production difficulties. Philco may also become a source of supply. Hughes at Santa Barbara are producing the lead selenide detectors in limited quantities to ensure that an alternate seeker is available in the event that difficulties with the indium antinimide detectors develop.

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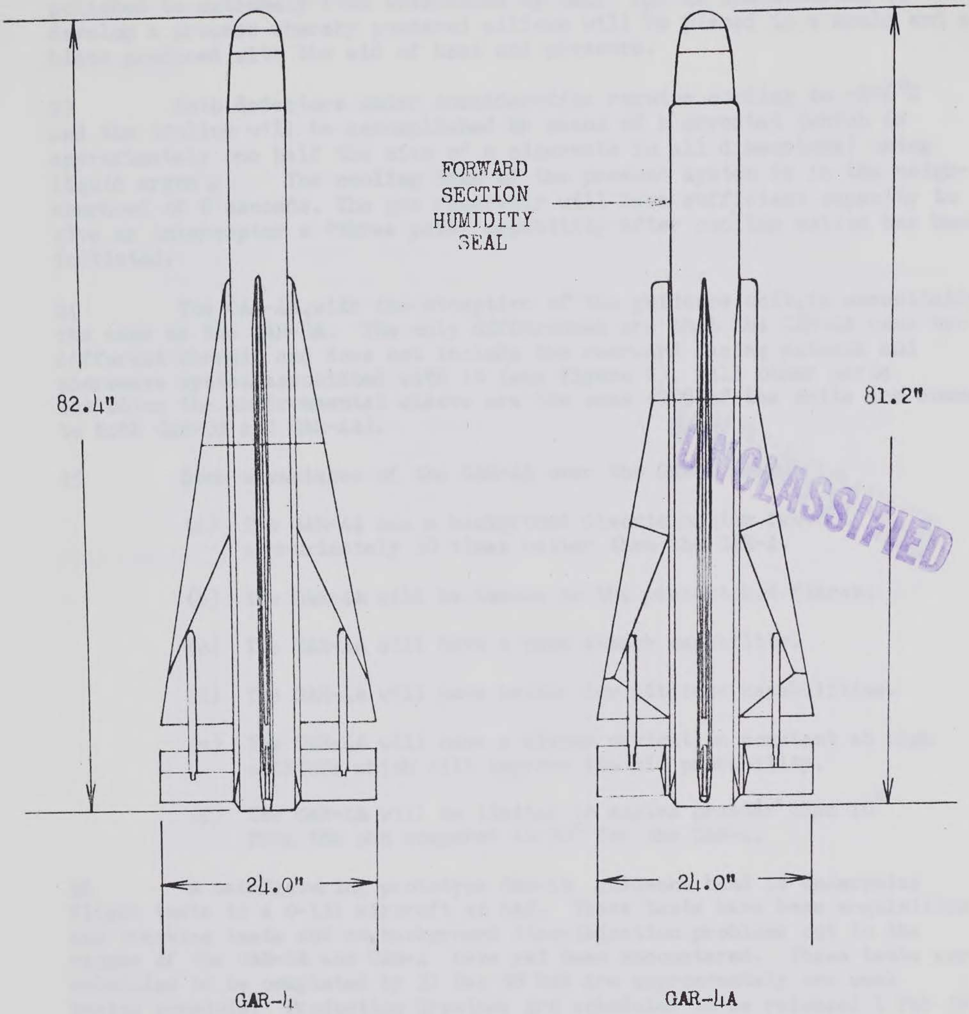

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(ALL DIMENSIONS ARE APPROXIMATE)

FIGURE 2. MISSILE EXTERNAL CONFIGURATION

22 An expensive and perhaps critical item from the supply point of view is the irdome. The irdomes and optical lenses for the GAR-4A are made from silicon crystals which are grown and then cut, machined and polished to extremely fine tolerances by HAC. HAC is endeavouring to develop a process whereby powdered silicon will be placed in a mould and a blank produced with the aid of heat and pressure.

23 Both detectors under consideration require cooling to -196°C and the cooling will be accomplished by means of a cryostat (which is approximately one half the size of a cigarette in all dimensions) using liquid argon. The cooling time of the present system is in the neighbourhood of 8 seconds. The gas reservoir will have sufficient capacity to give an interceptor a "three pass" capability after cooling action has been initiated.

24 The GAR-4A, with the exception of the guidance unit, is essentially the same as the GAR-3A. The only differences are that the GAR-4A uses two different chassis and does not include the rearward facing antenna and microwave system associated with it (see Figure 2). All other parts including the environmental sleeve are the same (90% of the units are common to both GAR-3A and GAR-4A).

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25 Some advantages of the GAR-4A over the GAR-4 are:

(a) The GAR-4A has a background discrimination factor approximately 30 times better than the GAR-4.

(b) The GAR-4A will be immune to the present hot flares.

(c) The GAR-4A will have a beam attack capability.

(d) The GAR-4A will have better low attitude capabilities.

(e) The GAR-4A will have a higher navigation constant at high altitude which will improve its hit probability.

(f) The GAR-4A will be limited to angles greater than 10° from the sun compared to 30° for the GAR-4.

26 A manufacturing prototype GAR-4A guidance head is undergoing flight tests in a C-131 aircraft at HAC. These tests have been acquisition and tracking tests and no background discrimination problems out to the ranges of the GAR-2A and GAR-4 have yet been encountered. These tests were scheduled to be completed by 31 Dec 58 but are approximately one week behind schedule. Production drawings are scheduled to be released 1 Feb 59.

Self Destruct Mechanisms

27 Both the GAR-3A and GAR-4A Type I missiles contain a "Self Destruct Mechanism" which operates to destroy the warhead 31 seconds after the missile "first motion" on the launcher. This mechanism is actually part of the T-1407 fuze and operates when the fuze clock runs down. It fires the fuze and warhead just as if the trigger wires had operated.

28 The Type III (Test) missiles are fitted with a Range-Safety Self-Destructors which are used to prevent test missiles from leaving the safe firing range area. After 20 seconds of missile flight, two fuzes detonate

..../11

a length of primacord that breaks the missile in half. The use of these destructors at Holloman AFB is mandatory. It has also been found that by using the destructors the missile parts are sometimes recovered for study purposes since the missiles do not travel so far.

Publications

29 The following Technical Orders have been issued and those indicated by * are held in the AFHQ Tech Library:

21-GAR3-2	GAR-3 Handbook Assy, Service, and Maint Instructions
21-GAR3-3	
21-GAR3-4	Illustrated Parts Catalogue
21-GAR3-6	GAR-3 Handbook Inspection Requirements
21-GAR3-101	Supply Support of Falcon Missile and Field Checkout Equipment
21-GAR4-2	GAR-4 Handbook Assy, Service, and Maint Instructions
21-GAR4-3	
21-GAR4-4	Illustrated Parts Catalogue
21-GAR4-6	GAR-4 Handbook Inspection Requirements
33D9-30-1-112	GAR-3/GAR-4 Missile Field Checkout Equipment Handbook Service Instructions
33D9-30-1-114	GAR-3/GAR-4 Missile Field Checkout Equipment Illustrated Parts Breakdown.

Estimated Costs

30 The estimated cost of the various missiles is indicated below:

GAR-3		$32,000 ea.
GAR-3A		$32,000 plus ea.
GAR-4		$28,000 ea.
GAR-4A	up to	$45,000 ea.
GAR-3 WSEM		$52,000 ea.
GAR-3A WSEM		$60,000 ea.
GAR-3/GAR-4 Shipping Container		$1200 ea.

(Note: as stated above, these are estimates only.)

ANNEX 1
TO APPENDIX "R"
TO S1038CN-180
DATED 19 DEC 58

WEAPON SYSTEMS EVALUATOR MISSILES (WSEM'S)

Description

1 The WSEM is essentially a Falcon which has had the warhead removed and the rocket motor replaced by instrumentation. WSEM's are designated as YGAR-3 WSEM's etc. and are known as Type IV missiles. These are specially built missiles which are used for MA-1 system maintenance, evaluation and test programmes, and air crew training although they are primarily designed to air check the Fire Control System operation.

2 The WSEM is installed on the launcher in the aircraft in the same manner that the other missiles are loaded. The WSEM operates like the model of the missile that it represents, going through the same sequences and performing in the same manner as the real missile. It simulates the missile even to the point of switching to internal power for a short interval (2 secs.) when it has been fully extended. Range lock-on from the actual target or home-on-jam if there is jamming can be checked during the interval.

3 The instrumentation package is a Hathaway recorder which provides 27 channels for recording information. There are 19 digital channels and 8 analogue channels. The analogue channels are used to monitor the A through F missile preparation functions, AGC, range gate slewing, etc. The digital channels are used to monitor On-Off functions.

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4 The recording is made on quick developing photographic paper which can be developed by any photographic section or by means of a portable rapid processing unit which has been developed and is available. The time required to process the record in this unit is approximately 15 minutes. Special slide rules and templates are required for the interpretation of the record and are supplied with each WSEM. The WSEM has a three pass capability (limited by amount of photographic paper which may be carried).

5 HAC recommended that the USAF should scale these 8 per squadron but the USAF are providing 4 per squadron and one of the portable developing units per squadron.

Development and Production Programme

6 Pre-production models of the GAR-3 and GAR-4 WSEM's (YGAR-3 WSEM's and YGAR-4 WSEM's) are being delivered now. The production has been delayed somewhat due to difficulties encountered with the galvonometers in the recorder. The GAR-3A and GAR-4A WSEM's will have improved galvanometers.

7 The production programme is as follows:

Model	Quantity	Time Period	
YGAR-3 WSEM	6	Delivery completed by end of Jan 59.	Will have the capability of checking either the umbilical or safety package igniter circuit.

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Model	Quantity	Time Period	
GAR-3 WSEM	40	Apr 59/Aug 59	Six of these will go to ADC squadrons and remainder will be used on test and evaluation programmes.
GAR-3A WSEM	45	Nov 59/July 60	The quantity shown is on contract but this may be increased to 63.
YGAR-4 WSEM	4	Delivery by Jan 59	
GAR-4A WSEM			No firm programme.

8 The GAR-3A WSEM which is being developed will be interchangeable with the GAR-3 WSEM but will have the added capability of monitoring the Edge Tracking Channel.

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9 HAC have recommended to the USAF that they (USAF) make a small purchage of GAR-4A WSEM's which would be used to support the test programmes and for pilot training but not for use as a maintenance tool. The GAR-4A WSEM performs or checks only two functions which the GAR-3A WSEM does not check and these are relatively minor hence the small requirement for GAR-4A WSEM's.

10 The WSEM is considered to be an indispensable piece of equipment. It is used to check the overall FCS operation including the circuitry to the missile launchers. A single WSEM can check from 70% to 80% of the FCS and the portion which cannot be checked by a single WSEM is primarily those circuits leading to each of the other three launchers.

11 The USAF, before they accept an aircraft from the manufacturer, now perform a final system flight test using WSEM's to check out the FCS.

Test Equipment

12 The WSEM is checked out on the missile check-out console which is used in the usual manner. An additional piece of equipment, the WSEM Motor Generator, is required however. The GAR-3/GAR-4 check-out consoles when retrofitted for GAR-3A/GAR4A will have the capability for GAR-3A/GAR-4A WSEM check-out.

13 The WSEM signal data converter and signal data recorder units are tested and maintained using the Test Set, Recorder and it's associated maintenance cabinet and test panel and a Recorder Maintenance Kit. These items are mobile in that they may be moved around to the required position in the missile check-out area.

Training

14 WSEM training is included in the GAR-3/GAR-4 training since the WSEM is a type IV missile. No other course or special training is provided on WSEM's.

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Costs

15 The estimated cost of WSEM's is $50,000 to $60,000 each.

Publications

16 A preliminary handbook produced by Hughes Aircraft Co. is available on YGAR-3/YGAR-4 WSEM's. Particulars of the publication are as follows:

Hughes Aircraft Co. Publication No. 67-136
WSEM Model YGAR-3/YGAR-4 (Falcon)
dated 15 Jul 58.

17 The detail specification for each missile includes the specification for the WSEM.

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GAR-3A/GAR-4A MAINTENANCE

Concept

1 The maintenance concept for the GAR-3A/GAR-4A is essentially the same as for GAR-1/GAR-2. Information on this subject is available in AFHQ Tech Library Ref. 4145.

2 At ADC units, all GAR-3A/GAR-4A repairs will be done by replacement of the faulty package, assembly or card. The faulty item is then shipped to the Depot for repair. Middletown (Pa.) Air Material Area (MAMA) has the responsibility for all Falcon missile repairs after the missiles go into service therefore MAMA will be the GAR-3A/GAR-4A Depot.

3 The missiles test equipment, however, will be calibrated, repaired, and maintained by the ADC unit which will have a capability of carrying out 90% of the repairs including component and part replacement (see also GAR-3A/GAR-4A Training).

4 The Hi-Valu Concept is used to provide the quickest and most economical method of maintenance for certain items. Information on this concept is available in AFHQ Tech Library reference No. 4145.

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Facilities

5 The ADC facilities provided for GAR-1/GAR-2 are used for GAR-3/GAR-4 with very little change.

6 There is no requirement for humidity, dust or temperature control in the storage bays for the GAR-3A/GAR-4A although heating would be advisable. The check-out area must have heating and should be capable of being maintained in as clean a condition as possible although air-conditioning with dust control is not required.

7 Adequate storage space for storing and handling missiles in their shipping containers is essential and storage space for spare missile packages and components and test equipment spares must be provided.

8 Since the missile contains live rocket motor, fuze and warhead at all times during its handling, buildings must be constructed or provided with this in mind. The USAF requires that missiles be stored with their forward end against a 12 inch reinforced concrete wall so storage bays are constructed in this manner. In addition, 12 inch walls enclose the missile check-out area. (Report of a Visit to Eglin AFB on Missile Buildings and Ground Handling Equipment dated 17 Apr 57 file C817-100 and C1920-105-1B is available at AFHQ and is generally applicable to GAR-3A/GAR-4A). Missiles in their containers are normally stacked in the storage bays in groups of six - stacks two wide by three high with the successive layers separated by pieces of 4 x 4" lumber to provide space for fork lifting.

Test Equipment

9 The GAR-3/GAR-4 test equipment is considerably different to the GAR-1/GAR-2 test equipment both in appearance and operation, however, the same general type of flow and check-out is performed.

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10 The GAR-3A/GAR-4A missile check-out console will be different to the GAR-3/GAR-4 check-out console to accommodate the various differences in the missiles. The changes necessitate about 10% redesign and hardware changes to the equipment. Approximately one half the changes will be circuitry or electrical changes and the other half mechanical changes. The GAR-3/GAR-4 consoles that the USAF will have in use when the GAR-3A/GAR-4A are introduced to the service will be retrofitted for GAR-3A/GAR-4A over the period Nov 59 to mid 1960. The first GAR-3A/GAR-4A production consoles with GAR-3A/GAR-4A features built-in are scheduled to be delivered starting in Dec 59.

11 Some of the main changes in the field check-out equipment (both the missile check-out console and the electrical test and maintenance console are involved) are:

(a) Changes to check-out console hardware to accommodate missile with environmental sleeve.

(b) Wiring harness changes to meet the missile wiring changes.

(c) Inclusion of a blind range test.

12 Lists of the special missile test equipment (CFE) and the items of standard test equipment (GFE) along with views of the CFE equipment are available in the AFHQ Tech Library (ref AFHQ Tech Library Ref. No. 8273.) . These have not been included in this report because of the limited number of copies available.

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Ground Handling Equipment (GHE)

13 Although the missile shipping and storage container (Type EGSC-3) is not commonly considered an item of GHE it could be since the missile is kept in this container during all phases of storage and handling and is only removed for check-out or for loading on aircraft. The whole handling concept is based on using the container in that manner.

14 The following is a list of items of GHE for the GAR-3/GAR-4 on the F-106 and the companies who provide the items.

(a)	Missile shipping container	Hughes
(b)	Three wheeled dolly (2 per missile)	Hughes
(c)	Hoisting tongs	Hughes
(d)	Manual stacker	Hughes
(e)	Transport trailer (5 GAR-3A/4A)	Convair
(f)	Lift bar, 2 man	Convair
(g)	Missile loading and handling frame	Convair
(h)	Case rolling device	(Being proposed to USAF by Hughes)
(i)	Electric fork lift	
(j)	Tow vehicles	

Note: - CFE items are not listed here but are listed in the reference in para 11.

...../3

Check-Out Facility

15 The check-out facility for an ADC squadron contains one complete set of missile check-out equipment. The Falcon GAR-3A/GAR-4A will be checked with the environmental sleeve in place and the actual check-out time required is approximately 5 minutes if no troubles are encountered. If the missile fails to pass a test it can, in some cases, be repaired by replacement of the faulty package while on the check-out console. In other cases, the missile is removed and placed on a maintenance stand and the necessary work is performed there. The missile is then re-checked.

16 The missile check-out console is capable of checking an intermixed line of CAR-3A and CAR-4A missiles without interruption. The check-out procedure followed by the console operator does, however, vary according to the type being checked.

17 The check-out console has the capability to check several times the number of missiles (171) planned for the USAF ADC squadrons based on the planned frequency of check-out.

Missile Check-Out Frequency

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18 All missiles will be checked on receipt at a unit and then will be loaded on an aircraft or placed in ready use storage.

19 Those missiles in ready use storage will have the humidity indicators on the shipping containers checked while in storage to ensure that the humidity inside the container is not excessive. These missiles will be cycled through check-out every 60 days.

20 It is intended to cycle those missiles which are installed on aircraft through the check-out console on the following basis:

(a) Every time the missiles are removed from the aircraft.

(b) After 15 days on an aircraft or 25 flying hours, whichever comes first.

Shelf Life

21 At the present time the shelf life of the missiles has been set at two years. This figure is governed by the life of the explosive components and probably will be increased as more data becomes available on the storage characteristics of these items.

Test Equipment Costs

22 The present GAR-3/GAR-4 check-out consoles being delivered to the USAF are costing approximately $725,000 each. A follow-on order for nine GAR-3A/GAR-4A consoles is being negotiated and the cost of these may approach $1,250,000. (Note: - as this contract has not yet been negotiated, this figure must be quoted with discretion.)

ANNEX 3
TO APPENDIX "R"
TO S1038CN-180
DATED 19 DEC 58

GAR-3/4 TRAINING

1 GAR-3/GAR-4 training is being carried out at Hughes Aircraft Company by HAC and at Lowry AFB, Denver by Training Command of the USAF.

2 HAC set up training courses to train:

(a) HAC personnel

(b) Personnel from other contractors associated with the weapon system programme i.e., Convair, AVRO.

(c) USAF personnel:

  (i) for employment on test and evaluation programme

  (ii) for employment as instructors at Lowry AFB

  (iii) selected few for early ADC employment.

3 As the programme advances, the burden of training gradually shifts from HAC to the USAF Training Command although HAC generally retain a training facility and capability for some time after training has shifted to the USAF.

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Courses

4 HAC trains only one level of technician for GAR-3/GAR-4 whether the students are to be employed as instructors or maintenance personnel. The course entrants from the USAF are NCO, 7 level technicians (311X0 - Guided Missile Field) who generally have had GAR-1/GAR-2 training or fire control system backgrounds. Hughes can plan and adjust the course offered to suit the qualifications of the entrants. The level of training, proficiency required of the students, etc. must all be negotiated with the Company prior to the start of a course.

5 The 7 level course produces technicians who are essentially missile test equipment maintenance technicians. These techs are given a thorough training in the operation, calibration, repair and maintenance of the missile checkout Console and sufficient training on the missiles so that they can perform checkouts, establish whether the missile or the test equipment is faulty, and understand the various functions and relationships between missile and test equipment. A technician of the highest skill level is required for the test equipment maintenance because the test equipment is repaired, parts replaced and calibrated at unit level whereas in the missile only units or cards are replaced and there is no repair work done at unit level. The ADC unit has the capability of performing 90% of the maintenance and repair which should be required for the checkout console.

6 The training course provided at Hughes and that provided at Lowry AFB are very similar. The course length is 12 weeks.. At Hughes, three consoles are available and a maximum of three students per console is the rule. This gives the training department a capability of training nine students per shift, two shifts per day for a total course loading of 18 students. The course is divided into approximately 50% classroom instruction and 50% practical work on the console.

7 WSEM (Type IV Missile) training is included in the GAR-3/GAR-4 course.

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8 Missile checkout on the checkout console at ADC units is performed by 30 and 50 level personnel. These personnel are less highly trained and skilled than the 7 level technicians and are essentially apprentices and mechanics. HAC does not train personnel of these levels. This training is provided at Lowry AFB or at the ADC unit by the Mobile Training Unit. The 50 level course at Lowry AFB is of 12 weeks duration.

Mobile Training Unit (MTU)

9 The USAF employ the Falcon MTU to train technicians at the ADC units.

10 The Falcon MTU is comprised of an instructional staff from Training Command and a set of Training Aids. The training aids include:

(a) Technical Orders

(b) Training slides and charts

(c) Cutaway or sectionalized missile

(d) Plexiglass missile

(e) Components

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11 The MTU does not include any actual missiles, test equipment or spares. This had led to the main disadvantage of the Falcon MTU which is that the operational checkout console, operational missiles and spares are used for training. This increases console down time and subsequently maintenance, repair and calibration which in turn may interfere with the missile checkout capability of the unit.

12 This training is provided as a type of conversion training for mechanics who previously had been trained on the GAR-1/GAR-2 and On-the-Job Training (OJT) and trade advancement training for personnel who have received the basic electronics training at Lowry AFB.

13 Additional information on training may be found in Appendix "N" - Training.

ANNEX 4
TO APPENDIX "R"
TO S1038CN-180
DATED 19 DEC 58

THE LE-6 LAUNCHER

Description

1 The LE-6 Launcher (Launcher - Rocket Airborne - Model LE-6) is a launcher which has been designed and built by Hughes Aircraft Co. for use with GAR-3/GAR-4 missiles. At the present time the F-106 is the only aircraft which uses this launcher and it is used in conjunction with the MA-1 FCS.

2 The launcher is designed to perform the following duties:

(a) Support the missile in readiness in the aircraft.

(b) Provide electrical connections between the missile and the FCS.

(c) Provide hold-back restraint with a specific force and work output required to free the missile.

(d) Provide a track along which the missile slides for initial trajectory control.

3 The missile is loaded by sliding it into place on the launcher tracks and in so doing the electrical and mechanical connections (with two exceptions) are made automatically. The GAR-3A and GAR-4A missiles have separate leads for the motor igniter and the power supply igniter circuits brought out to the tail of the missile. These two connections have to be completed manually by plugging leads from the safety package at the rear or aft end of the launcher into the proper connections at the tail of the missile. Upon missile firing the launcher electrical contact block is retracted into the launcher and protected from the rocket motor blast to avoid damage.

Design Considerations

4 The following points received close consideration in the design and development of the LE-6 launcher.

(a) Maintenance - The design is such that only a minimum of maintenance is required to keep the launcher in satisfactory operating condition.

(b) Interchangeability of Parts - The whole launcher has been made to close tolerances and, therefore, spare parts are readily interchangeable and the complete launcher is also interchangeable.

(c) Safety of Operation - The whole launcher design has been aimed at producing a launcher which gives a high degree of safety.

(d) Ease of Loading - Loading is easily and quickly accomplished as indicated in para 3. The loading operation requires a simple piece of handling equipment and three men to load a missile on a launcher in the F-106.

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Igniter Safety Package

5 The igniter safety package is a small unit which is being added to the rear or aft end of the launcher. This package will contain necessary circuitry to provide a motor igniter safety circuit and a power supply safety circuit. All the circuits are kept inactivated until the power supply igniter signal is received approximately two seconds prior to missile launch. The leads to the missile connections are dead before launcher retraction. The drawing for the igniter safety package will be available in the AFHQ Tech Library probably by the end of Jan 59.

Mounting

6 The launcher is easily installed or removed from the aircraft. It is held in position by the extension gear mounting bracket (6 bolts) at the rear and a forward attach fitting (1 bolt) at the front. The forward attach fitting permits one to two degrees of movement and is provided so that any installation misalignment is taken up by it rather than causing twisting of the launcher frame.

Maintenance

7 As stated in para 4(a), the launcher is easily maintained. Between flights, it is visually inspected for signs of wear or damage. The material used in its construction (7075 T6 al) is treated and painted with a special paint which is very resistant to damage by friction and missile exhaust gases. A detergent and water are used to clean the launcher.

8 The launcher is quite similar to a 50 cal. machine gun in many respects - the parts are made to close tolerances so are fully interchangeable; the mechanism is primarily mechanical with an electrical switch interlock system and umbilical wiring harness; it is easily stripped and assembled.

9 The only part of the launcher which is subject to a fairly high amount of wear or breakage and, therefore, replacement is the "hold-back pin". When the missile is loaded on the launcher the holdback pin in the launcher is caused to lower and engage in the missile bushing. This pin is the only mechanical connection between the launcher and missile and serves to hold the missile in place prior to launch. In other words, the holdback pin prevents any fore and aft movement of the missile on the launcher prior to launch. The holdback pin is designed to shear at approximately 8 g's and is the weak link in the system provided to prevent damage to other parts of the launcher. This pin becomes worn or chipped due to loading, unloading or firing of missiles and consequently must be replaced when it shows these signs of wear. This can be quickly and easily done on the launcher mounted on the aircraft without removing other parts. The holdback pin should be checked after every missile firing.

Temperature Limits

10 The launcher temperature limits are established by the capabilities of the electrical wiring harness and the switches in the launcher and are from -65°F to +250°F.

Production, Supply and Costs

11 The launchers are built by Hughes at Tucson and sent to HAC El Segundo factory. They are normally shipped with the FCS and are considered a part of it.

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12 Over 600 of the LE-6 Launchers have been manufactured. The production rate approached 100 per month.

13 No exact cost figure was obtained but an estimate of approximately $1000 each was given.

Additional Information

14 Additional information on general launcher description and disassembly procedure and photographs are available in the AFHQ Tech Library under Reference No. 4949.

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ANNEX 5
TO APPENDIX "R"
TO S1038CN-180
DATED 19 DEC 58

MISSILE LAUNCH SEQUENCE

1 The sequence of events leading up to and following missile launch is detailed for GAR-3A and GAR-4A in "GAR-3 and GAR-4 Falcon Missiles Co-ordination Specification No. 185508" which is held in AFHQ Tech Library as Reference No. 4951.

2 An abridged launch sequence chart for GAR-3 fired in the automatic mode on a lead collision attack is attached for general information.

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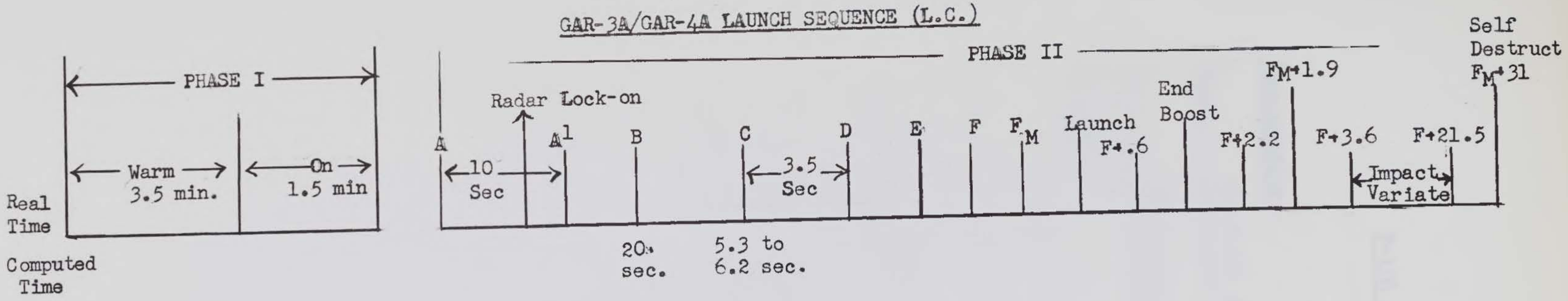
GAR-3A/GAR-4A LAUNCH SEQUENCE (L.C.)



PHASE I - **Warm** - From 3.5 to 4.5 mins. - must be completed prior to take-off.

On - 1.5 mins. for other radar components to heat.

PHASE II - Attack Phase - starts with A signal and continues to missile impact

A - start Armament Preparation - hand action switch
B - radar starts tuning to missile frequency (GAR-3A) - auto
C - doors open, launcher extended, missile internal power, radar PRF tuned to GAR-3A, GAR-3A range gate slaved
D - parameters and CCM computed and squibs blown
E - waveguide shutter open, "G" weight released
F - firing signal
F_M - first motion (missile)
Launch - Range and angle track target - no steering
End Boost - steering starts
F+2.2 - Launcher up and doors closed
F_M+1.9 - missile armed
F+3.6 to F+21.5 - time to impact
FM+31 - self destruct

Notes: Missile committed at C signal.
Pilot can prevent launch prior to E signal,

ANNEX 6
TO APPENDIX "R"
TO S1038CN-180
DATED 19 DEC 58

F-106 AWCS AND ARMAMENT DEVELOPMENT PROGRAM (AAD)

Introduction

1 The F-106 AAD Program is a combined development test involving the USAF and contractors being carried out at Holloman AFB.

2 The purpose of the program is to develop the tactical capability of the F-106A Weapon System beyond the capabilities shown by the R and D program.

Schedule

3 Three F-106 aircraft are assigned to the program.

4 The AAD Program began in Jun 58 and is scheduled to be completed by Nov 59.

5 There are 50 Genie (MB-1) and 44 Falcon (GAR-3) firing missions planned. The Falcon mission will use 6 Type I (tactical) missiles and 85 Type III (telemetered) missiles.

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Jun 58	Program started
Oct - Jan 59	MB-1 Manual Firings (23)
Jan 59 - Mar 59	GAR-3 Manual Firings (17)
Mar - Apr 59	GAR-3 ECM Firings (4)
Apr - May 59	Aircraft Modifications
May - Sep 59	MB-1 Automatic Firings (27)
Sep - Dec 59	GAR-3 Automatic Firings (23)

Note: The numbers in brackets indicate the quantities to be used for each phase.

7 Additional information may be found in Appendix "B" - Schedules.

APPENDIX "S"
TO S1038CN-180
DATED 19 DEC 58

SECURITY

1 Hughes people consulted:

John L. Murphy - Security Inspector
Ralph E. Ringwald - Security Inspector
Charles Beach - Clearance Manager

Classification of Equipment

2 The Security Requirements Check Lists, SRCL's, are made up and issued by AMC on Form DD254. The RCAF will have to issue SRCL's for the MA-1C equipment. To assist us in doing this a complete set of MA-1 and GAR 3 and 4 SRCL's has been provided. Security Classification Guides are provided to expand on and interpret the SRCL in detail regarding every piece of equipment.

3 Training aids are classified according to the information they reveal. Technical reports are classified according to their content, with secret being the highest classification except as affected by paragraph 4 below. The only secret information is on countermeasures.

4 GAR 3A will be no higher than confidential. GAR 4A will be secret as regards guidance and frequency band until it gets into production delivery to tactical units when it will go down to confidential and the SRCL's will then have to be revised. Regarding Note 7 on page 5 of GAR 3 Security Classification Guide, dated 17 Jun 1958 - "Proven countermeasures data will be classified Top Secret"; the RCAF will have to act accordingly when the time comes. - Action RCAFHQ.

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5 An SRCL for the other weapon will have to be produced for our program; HAC cannot help on this. - Action RCAFHQ.

Visits

6 A letter from USAFHQ to AFPR at Hughes, file ref. AFCIN-X1C, dated 3 Dec 1958, cc: to USAF Central Co-ordinating Staff, Ottawa, has set up the channel for visit requests as follows:

(a) HAC visitors to Canada - Request by HAC to USAF Plant Representative who forwards it to RCAF representative attached to their staff, F/O Kendall by name. RCAF (F/O Kendall) will forward the request to the CF-105 Project Office in Ottawa (actually to the Department of Defence Production). HAC are submitting a list at once.

(b) Canadian visitors to HAC - The above noted letter designates F/O Kendall as the official channel for sponsoring requests for Canadian representatives of AVRO to visit HAC.

(c) The Security Check List of Visitors on MA-1C Program formed according to paragraphs (a) and (b) above is to be reviewed on 31 April 1959. Those on the list may visit on short notice without further security arrangements.

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7 HAC representatives suggested RCAF rperesentatives be handled in the same way. The RCAF nominations should be added to the Security Check List of Visitors on MA-1C Program. Undoubtedly, this will have to be done by PMov and CJS concurrence. - Action RCAFHQ.

8 When and if CAE or other Canadian firms are required to visit HAC on this program, the appropriate names should be added to the list. HAC representatives though CAE should have representation at once as they have a sub-contract from HAC.

9 The authority conferred on F/O Kendall by the USAF should be confirmed by letter to him from RCAFHQ. - Action RCAFHQ.

Documents

10 F/O Kendall is fully accredited to HAC to receive classified documents or secret aural and visual information pertaining to MA-1 AWCS and its Canadian version plus the GAR 1, 2, 3 and 4. We should have "GAR 3A and GAR 4A and those portions of ASQ 25 and of MG-13 that will be applicable to the MA-1 installation (MA-1C) in the RCAF CF-105 aircraft" added to F/O Kendall's accreditation.

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Hardware

11 As stated in the referenced letter F/O Kendall's accreditation is being amended by separate action permitting him to receive for Canada HAC hardware involved in the CF-105 installation. He accepts custody of the hardware at Culver City, costs of shipment being borne by the RCAF; the HAC representatives said the contract will read FOB Culver City.

Publicity Releases

12 The channel for a draft publicity release is to USAFPR, to AMC for USAF concurrence, to RCAFHQ for RCAF concurrence, and return.

HAC Visit Reports

13 The Military Sales people are required to submit reports on visits by foreign nationals. Actually the USAF Plant Representative is charged with producing this report. He asks HAC to give him the report as a favour instead of sending a USAF officer around with the visitors. This is a problem between HAC and USAF.

APPENDIX "T"
TO S1038CN-180
DATED 19 DEC 58

HUGHES AIRCRAFT COMPANY ORGANIZATION

1 The Hughes Aircraft Company (HAC) is wholly owned by the Howard Hughes Medical Institute, a non-profit institution organized for the purpose of furthering research in the medical sciences. All of the profits of the company not used for expansion are used by the Medical Institute for research. HAC is an outgrowth of the Hughes Tool Company and came into being in 1953. Annual sales now exceed $300,000,000 and the company's plants in Culver City, El Segundo, Inglewood, Palmdale, Tuscan and Santa Barbara employ 31,000 people. Ninety five percent of the output from HAC is in support of the military services.

2 The Centre of the HAC is at Culver City, California, where the executive offices and research and development activities are located. It is here that abstract concepts and initial designs evolve into practical designs and proven systems, missiles and products. Many of the supporting functions as well as commercial products facilities are located in Inglewood, which is nearby. Electronics manufacturing operations are done in an ultra modern plant covering 40 acres and employing 7,000 persons at El Segundo, near Culver City. The airborne armament control system is manufactured in El Segundo and the Falcon guided missile is produced in their plant at Tuscon, Arizona.

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3 The HAC maintains a special Products Research Centre at Santa Barbara, California, and a flight test activity at Palmdale, California, where they co-operate with the airframe manufacturer, Convair, in getting the systems into aircraft and flight testing to achieve the optimum results.

4 A repair depot which is now doing contractor repair and overhaul at a rate of 100,000 black boxes per year, covers 139,000 sq.ft. of plant space, occupies 1,000 personnel, and is located in rented space adjacent to the commerical airport.

5 The Ground Systems Division employing 3,000 persons on ground radar, data processing and Traffic Control radar is located at Fullerton, California.

6 The Hughes program of electronic research, development, and manufacturing for the military and for industry embraces seven fields of activity as follows:

(a) <u>RESEARCH</u> - Fundamental and Applied Research develops new ideas, and solves specific problems, and improves existing designs.

(b) <u>AIRBORNE SYSTEM AND MISSILE DEVELOPMENT</u> - This activity creates and continually improves the airborne armament control systems and guided missiles needed for defence against supersonic high-altitude aircraft.

(c) <u>FLIGHT TESTING</u> - New and improved electronic systems and weapons are evaluated under actual conditions of use.

(d) <u>SYSTEM AND MISSILE MANUFACTURING</u> - Weapons and Systems which have proved satisfactory in the exhaustive flight test and evaluation stages are produced in quantity in this field.

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(e) FIELD SERVICE AND SUPPORT - The HAC Field Service and Support activity aids the user in maintaining systems in the field and feeds back performance information to the company for constant improvement of design and reliability.

(f) COMMERCIAL PRODUCTS DEVELOPMENT - As the name implies, this activity is devoted to the production of electronic components, instruments, and systems for industry.

(g) GROUND SYSTEM DEVELOPMENT AND MANUFACTURING - This facility develops and produces surveillance radar and data-processing equipment for ground tracking, recording and control of aircraft.

7 The HAC began work in the weapon system field in 1948 with the development of the radar fire-control system for the US Air Forces first all-weather jet interceptor. Since then, it has developed weapons and control systems for every interceptor of the USAF plus systems for the USN and the RCAF. An outstanding feature of these projects has been the close partnership with the airframe manufacturer from initial concept to the full operational status of the complete weapons system. Co-ordination between HAC and Convair, for example, has produced the F102A and the F106A and B with their completely integrated weapon system and control features.

8 The organization of the company as it relates to the MAI system is shown in chart form at Annex 1 to this Appendix.

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9 It is noted that while the MAI project officer (Mr. B. Turner) is responsible, through the Officer-in-Charge of the Airborne Systems Lab, to the officer in charge of the Airborne Systems Group for the MAI project he has another function under the F106/MAI/GAR3-4 project where he reports directly to the Officer-in-Charge of the Airborne Systems Group. Also of interest is the fact that the F106/MAI/GAR3-4 project officer has a representative on his staff from each of the allied divisions. These representatives give their full time to the project and return to their own division upon completion of project.

10 The CF105/MAI project is being processed by a team headed by Mr. Joe Scanlan.

11 Sub-Contractors and companies associated with HAC in the production of the MAI/GAR 3-4 combination are listed in Annex 2.

12 Not listed in Annex 2 is AVRO of Canada Ltd., with whom HAC is currently collaborating in getting an MAI system installed in a CF105 Mk 1, and Canadian Aviation Electronics (CAE), with whom HAC has contracted for some field support and who now have three of their people at Culver City learning something about the MAI C system.

13 Current USAF contracts with which the Hughes Aircraft Company are connected are listed for information at Annex 3.

14 Annex 4 lists the name, function and telephone number of persons contacted at HAC during the visit.

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ANNEX 2 TO
APPENDIX "T"
TO S1038CN-180
DATED 19 DEC 58

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SUB-CONTRACTORS AND ASSOCIATED COMPANIES

COMPANY	ADDRESS	PRODUCT
Convair	Los Angeles	Airframe
Electronics Incorporated	St. Petersburg, Fla.	UHF Comm. Data Link Receiver
Federal Telephone and Radio Corporation	Peterboro, N.J.	TACAN
Edison Pioneer Bendix Aviation	Peterboro, N.J.	Air Data Computer
Collins Radio Corporation	Cedar Rapids, Iowa	UHF/D F, ILS
Kearfott		Stable Platform
RCA	Camden, N.J.	Time Division Data Link
Jack and Heintz	Cleveland	Power Supply Units
Hazeltine		Ground-Air IFF IFF Computer

ANNEX 3
TO APPENDIX "T"
TO S1038CN-180
DATED 19 DEC 58

CURRENT USAF CONTRACTS WITH HAC

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AF-33(600)-36453

A.W.C.S. and Armament Development Program (AAD). An Air Force sponsored test program currently being performed at Holloman Air Force Base with support from Convair, Douglas and Hughes. Aircraft presently involved are F-106A S/N 464 and S/N 465 with "STQ" (pre-production) MA-1 AWCS. F-106A S/N 233 is the third aircraft assigned to the program and contains a production MA-1 AWCS. It is anticipated that an F-106B with ASQ-25 AWCS will enter the program during mid-1959. The Hughes contract covers the following fire control system engineering services to support Holloman test operations through 1959:

1. Flight test engineering co-ordination
2. Maintenance and modification of MA-1 systems and instrumentation
3. Data processing
4. Pilot services
5. Introduction of corrective changes to MA-1 design
6. Informal letter type reports.

AF-33(600)-36626

This contract covers the missile engineering services provided by Hughes in support of the above noted AAD Program. Briefly the GAR 3/4 engineering services cover the following:

1. GAR Telemetering
2. GAR Missile checkout
3. Targets
4. Technical Director Assistance
5. Flight Test Engineering
6. Launcher
7. Operations and Control

AF-33(600)-36401

A Contractor Flight Test Development Program during calendar year 1959 embracing the following major tasks:

1. Evaluation of AFCS for F-106A aircraft S/N 454
2. Evaluation of MA-1 system in F-106A aircraft S/N 457
3. Evaluation of AN/ASQ-25 AWCS in F-106B aircraft S/N2508
4. Operation and maintenance of Target Aircraft
5. Laboratory evaluation of ASQ-25 AWCS and auxiliary equipment in support of flight test program
6. Engineering liaison with Convair for system/aircraft compability problems
7. Informal monthly progress reports.

AF-33(600)-32038

MA-1 R&D, Production of Services Test Quantity systems, Production Implementation.
Remaining work concerns ARDC Integrated Instrument System (R&D Program for integration of "Phase II" cockpit panel) and procurement of spares for STQ systems.

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AF-33(600)-36799

R&D, including flight test of advanced MA-1 system improvements including hydraulic, silent lobing antenna; CCM; MOPA; provisions for TDDL and IR sight and low altitude capability; static (400 cycle) power supply.

AF-33(600)-37591

Management of MA-1 Time Division Data Link Integration. Including liaison with RCA and Convair. Biggest effort is scheduling and program planning.

AF-33(600)-33782

Original MA-1 Production Contract.
110 MA-1 Installation Systems, Training Systems, MTU Systems.
Spare components and parts in support.
Maintenance Tools and Test Equipment.
Materials and services for incorporation of AF approved engineering changes.
Verification Tests.
Maintenance Data.
Engineering Data.
Training parts, tools and test equipment.
Deliveries - March 1958 through May 1959.

Additional Work:
AAI
Phase II Panel
Airborne Recorder
AFCS Modes

AF-33(600)-34133

Original AN/ASQ-25 Production Contract

41 - ASQ-25 Installation Systems

Spare components and parts in support
Maintenance Tools and Test Equipment
Material and services for incorporation of AF approved changes.
Verification Tests
Maintenance Data
Engineering Data
Royalty Payments

Deliveries - May 1958 through November 1959.

Added Work:
AAI
Airborne Recorder
AFCS Modes
Phase II Panel

....../3

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AF-33(600)-38011

Follow-on MA-1 Production Contract

34 - MA-1 Installation Systems
Spare components and parts in support
Maintenance Tools and Test Equipment
Revisions to Maintenance Data
Revisions to Engineering Data

Deliveries - April 1959 through September 1959.

AF-33(600)-38280

FY-59 Follow-on MA-1 Production Contract

112 - MA-1 Installation Systems
Spare components and parts in support
Maintenance Tools and Test Equipment
Maintenance Data
Engineering Data

Deliveries - June 1959 through April 1960.

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ANNEX 4
TO APPENDIX "T"
TO S1038CN-180
DATED 19 DEC 58

HUGHES AIRCRAFT COMPANY

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PERSON CONTACTED		TELEPHONE NO.
02-10 - Contracts		
JC (Jack) Bratton	Visit Co-ordinator	3432
HB Fuller	ECP Organization	2934
DJ Knapp	Sub-Contractors	3987
George McBride	ECP Procedure	
Mr. Adams	ECP Procedure	
08-10 - Field Service and Support		
EM Boykin	Vice President and Director	3618
08-30 - Service Contracts and Requirements		
RW Flather	Supervisor Service Contracts	5605
08-40 - Radar Maintenance Depot		
RA (Bob) Johnson	Manager	5561
W Schoneman	Assistant Manager	5546
08-50 - Field Engineering		
TG Macklin	Manager	5347
GW Goebel	Head of Technical Training	OS 5-0371 Ext 41
CA Noel	Programming Training	OS 5-0371 Ext 45
AJ Courtney	Technical Liaison Section Engineer	4956
RL Erickson	Field Service and Support Engineering	4067
EW Cullen	Field Service and Support Engineering	6172
AH McCulloch	Field Service and Support Engineering	4166
08-60 - Quality Control		
GL (Glen) Coates	Manager	5541
08-80 - Support Co-ordination and Programming		
JV Ferrero	Programming MA-1	2128
EM Walrabstein	Programming GAR-3, 4 and 3Y	4192
KM Boulter	Programming GAR 3/4 and 3Y	5829
20-10 - Staff		
H Bouck	Programming Manager	2402
DJ Comstock	Programming MA-1/MA-1/40	2881
KJ O'Donnell	Programming GAR-3/4/3Y	6174
40-00 - Technical Laboratories		
RM Mitchell	Weapon Systems Testing	3917

..../2

TELEPHONE NO.

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41-03 - Project Management - MA-1, ASQ-25

BE (Barry) Turner	- Project Manager	3066

41-11 - Computing and Controls Department

KM Stevenson	- Manager	3383
TH Mansfield	- Assistant Manager - Analog Equipment Development	2891
WS Shockency	- Assistant Manager - Digital System Development	2954
TJ Burns	- Head of Analysis and Program Design Sec.	3418
WE (Wayne) McNutt	- Section Engineer - Analysis and Program Design Section	4914
JA (Jake) Kelly	- Navigation and Test Programming	4930
WR Krafft	- Head of Communications Equipment Section	4309
HV Nuttall	- Head of Dynamics and Analysis Section	2526
WN Turner	- Aircraft Dynamics and Control	
AE (Abner) Gill	- MA-1 Equipment I	4922
EG (Eldon) Rowberg	- MA-1 Equipment II	2745
WA Lobitz	- Stable Platform	2354

41-15 - Radar Department

RM Tryon	- Acting Assistant Manager - Seeker Head and Controls	2554
AG Wedin	- Head of AAI Section (IFF)	4992
RL (Bob) Brackney	- ECCM	2153
RW Stafford	- ECCM System Analysis	6201

41-43 - MG Series Systems Department

WH Bell		4303

41-44 - MA-1 System Department

V Welge	- Manager	4913
JA (Joe) Scanlan	- Assistant Manager (CF-105 Project)	4195
EW (Everett) Durfee	- Acting Head System Evaluation Section	4211
PE Norsell	- Planning and Analysis (Flight Tests)	4744
WG (Winston) Walker	- MA-1 Reliability (CF-105 Project)	4744 (4256?)
NW Hall	- Head of MA-1 Operations Section (Palmdale)	
LO (Leo) Langlois	- MA-1 Airborne System Engineer	3288
RA (Bob) Boucher	- MA-1/40 Development	4020
John Buskirk	- Flight Test	

41-48 - Equipment Engineering Department

J Aristei	- Section Engineer Armament Engineering Section	4733
JB (John) Lyon	- Section Engineer Armament Engineering Section	4733
WR (Bill) Gockel	- Project Engineer Armament Engineering Section	2401
JB (Bruce) Roberts	- Armament Launching Problems	2020
Alex Mathieson	- Armament Auxiliaries	
DM (Don) Piehler	- MB-1 (Ballistics and Separation)	4452

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41-03 - Project Management - MA-1, ASQ-25

BE (Barry) Turner	Project Manager	3066

41-11 - Computing and Controls Department

KM Stevenson	Manager	3383
TH Mansfield	Assistant Manager - Analog Equipment Development	2891
WS Shockency	Assistant Manager - Digital System Development	2954
TJ Burns	Head of Analysis and Program Design Sec.	3418
WE (Wayne) McNutt	Section Engineer - Analysis and Program Design Section	4914
JA (Jake) Kelly	Navigation and Test Programming	4930
WR Krafft	Head of Communications Equipment Section	4309
HV Nuttall	Head of Dynamics and Analysis Section	2526
WN Turner	Aircraft Dynamics and Control	
AE (Abner) Gill	MA-1 Equipment I	4922
EG (Eldon) Rowberg	MA-1 Equipment II	2745
WA Lobitz	Stable Platform	2354

41-15 - Radar Department

RM Tryon	Acting Assistant Manager - Seeker Head and Controls	2554
AG Wedin	Head of AAI Section (IFF)	4992
RL (Bob) Brackney	ECCM	2153
RW Stafford	ECCM System Analysis	6201

41-43 - MG Series Systems Department

WH Bell		4303

41-44 - MA-1 System Department

V Welge	Manager	4913
JA (Joe) Scanlan	Assistant Manager (CF-105 Project)	4195
EW (Everett) Durfee	Acting Head System Evaluation Section	4211
PE Norsell	Planning and Analysis (Flight Tests)	4744
WG (Winston) Walker	MA-1 Reliability (CF-105 Project)	4744 (4256?)
NW Hall	Head of MA-1 Operations Section (Palmdale)	
LO (Leo) Langlois	MA-1 Airborne System Engineer	3288
RA (Bob) Boucher	MA-1/40 Development	4020
John Buskirk	Flight Test	

41-48 - Equipment Engineering Department

J Aristei	Section Engineer Armament Engineering Section	4733
JB (John) Lyon	Section Engineer Armament Engineering Section	4733
WR (Bill) Gockel	Project Engineer Armament Engineering Section	2401
JB (Bruce) Roberts	Armament Launching Problems	2020
Alex Mathieson	Armament Auxiliaries	
DM (Don) Piehler	MB-1 (Ballistics and Separation)	4452

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TELEPHONE NO.

42-00 - Guided Missiles Laboratories

FV (Frank) Flynt	- GAR Project Office	3455
QC McKenna	- MA-1/GAR 3-4	6169

42-03 - Project Management, GAR-3/4

CC LeGrand	- Project Manager	2725

42-12 - Field Operations Department

BW Beers	- Assistant Manager	3861

42-14 - Launchers and Power Plants Department

(Mechanical Engineering Section)

DN Paxton	- Head	2445
JF Skinner	- Launchers	4382

(Propulsion Section)

DA Mahaffy	- Gas Generators (Mk 6 Power Supply)	4372
EP Gebhard	- Rocket Engines	4372

60-66 - Information Security - General Office

JL (John) Murphy	- Security Classification	4758
RE (Ralph) Ringwald	- Security Inspections	4622
CJ Beach	- Personnel Security - Clearance	2775

San Diego

Herb Campbell	- Manager - Hughes Installation, Convair	

Palmdale

John Seymour	- Manager - Palmdale Facility	WIndsor 7-3191
Jack Hall	- Palmdale Electronics	
Mr. Dugan	- Palmdale Test Pilot	
Dave Perkins	- Palmdale MTU's	

El Segundo Plant

JR Breen	- El Segundo Tour	

APPENDIX "U"
TO S1038CN-180
DATED 19 DEC 58

TARGETS

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Reference AFHQ Technical Library No: 4944 Summary of Operational Targets
4958 Falcon Fourth Quarter 1957 Progress Report
4956 Falcon Second Quarter 1958 Progress Report

1 Various targets have been and are being used in the Falcon programs. The targets can be divided into two broad categories which are:

(a) dynamic targets and,

(b) static targets

Dynamic Targets

2 The dynamic targets are drones of the following types:

(a) Q-2A Ryan Firebee

(b) QF-80 Droned F-80

(c) QB-17 Droned B-17

3 All the drones for the Falcon firings are supplied as Government Furnished Equipment. HAC have been developing or directing the development of Q-2A drone radar and infrared augmentation.

Static Targets

4 Numerous static targets used in the Falcon programmes include:

(a) Parabag - Mk 3 - radar-target, parachute (air dropped)

(b) Parabomb Mk 2 - IR-target, parachute (air dropped)

(c) Radar Balloon - radar target, balloon (ground released)

(d) Beacon Balloon - nonscintillating radar target, balloon (ground released)

(e) Hasti (High Altitude Strike Indicator) - Infrared target, balloon (ground released)

(f) Pogo-Hi II - radar and IR target, parachute (ground launched by rocket)

5 The air dropped parachute targets have been most extensively used because of the relative ease with which they may be accurately positioned over the range. A disadvantage of these is the altitude capability of the releasing aircraft.

6 Pogo-Hi is one of the most satisfactory target systems available because:

(a) The target may be positioned in space quite accurately (range, azimuth and altitude)

(b) It has an altitude capability of over 75,000 ft.

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Radar Augmentation

7 To provide adequate radar targets for both ground tracking radar and the AI radar and missile receiver, the radar type targets in most cases require special provisions to produce the necessary radar reflective area. The following chart indicates the method used to obtain the radar reflective area:

(a) Parabag Mk 3 - Parachute is made of silver impregnated nylon fabric.

(b) Radar Balloon - Balloon is covered with thin metal foil.

(c) Hasti - Hasti cage containing corner reflectors.

(d) Q-2A Firebee - Monostatic tail cone reflector is added to drone. In addition, a seven foot radar reflective pod containing bistatic and monostatic corner reflectors has been developed by Ryan for the Q-2A.

(e) Pogo-Hi - Radar reflective parachute.

IR Augmentation

8 The targets used for the IR missiles require an IR source to be fitted. This has been accomplished as follows:

(a) Parabomb Mk 2 - T-3 Mod BB9 flares are used in sufficient quantities to produce 200 watts/steradian.

(b) Hasti - Uses same flares as above.

(c) Q-2A - Four BB-9 flares mounted on each wing tip.

(d) Pogo-Hi - Pyrotechnic flares or thermic charge.

Genie Targets

9 Manned B-57 and F-100 aircraft are being used as targets for the Genie firings in which no warheads are used. The aircraft go into a standard escape manoeuvre when the rockets are fired. High performance aircraft are used because of the necessity to perform the escape manoeuvre quickly.

Targets for Miss Evaluation

10 The targets which are used for both Miss Evaluation work and aircraft acceptance flight test are B-57's and F-100's. Normally, the B-57 does not use any radar augmentation, however, if augmentation is required, it has been provided by installing a corner reflector under the canopy behind the pilot. Occasionally passive reflectors have been used on the F-100's. These have been corner reflectors in tanks mounted on the aircraft. Active radar augmentation has not been used.

11 It has been found that at least 200 square feet of effective radar cross-section is desirable with 100 square feet being the absolute minimum for these tests.

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Target Usage

12 The following table provides an indication of the types of targets used and the number of times they have been used for HAC/Falcon firings during the period 1 Oct 57 to 30 Sep 58.

(a)	Parabag radar parachute	- 22
(b)	Q-2A drones	- 13
(c)	Parabomb IR parachute	- 11
(d)	Beacon balloon	- 9
(e)	Hasti	- 6
(f)	Pogo-Hi	- 6
(g)	Radar Balloon	- 6
(h)	QF-80 drones	- 5
	TOTAL	78

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Note: Pogo-hi is a newly developed target system which has just come into operational use.

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APPENDIX "V"
DATED 19 DEC 58

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December 58

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HUGHES AIRCRAFT COMPANY GAR (FALCON) AND

MA-1

DOCUMENTS HELD AS OF 22 DEC 58

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ACC NO.	SOURCE	TITLE	CLASSIFICATION
934	Hughes A/C Co.	"Falcon Missile Packaging and Handling "	
938	Hughes A/ C Co.	"Falcon Missile Summary Report on Guidance & Control "	
949	Hughes A/C Co. TM 221	"Launching Radar & Seeker Ranges for MX-904 Missile (Falcon)"	
978	Hughes A/C Co.	"Preliminary Handbook Operating Instructions for Guided Aircraft Rocket YGAR-1"	
979	Hughes A/C Co.	"Preliminary Handbook, erection and Maintenance instructions for Guided Aircraft Rocket Ygar-1"	
980	Hughes A/C Co.	"Preliminary Handbook Service Instructions for Field Assembly and Checkout Equipment Xgar-1".	
988	Hughes A/C Co. TM 341	"X-Band Radar Cross-Section Measurements (Falcon)".	
1197	APG 57S-134001-3	"Personnel requirements for use of Falcon Missile by Fighter Units - and Appendixes 1-3, 1950	
2052	Hughes A/C Co.	"Weapons Systems Developments Labs. Aerodynamic Data, Gar-1 A Missile "	
2397	Hughes A/C Co. SRSM7-30	"The Gar-1 Falcon Ground Support System"	
2456	Hughes A/C Co. TM 370	"A Turbine-Driven Electrical-Hydraulic Power Supply for the Gar-1A Falcon"	
2641	Hughes A/C Co. TM 357	"Analytical and Simulation Techniques used in Predicting Falcon Probability of hit".	
3956	Hughes A/C Co.	"Second Quarter 1957 - Progress Report No. IV-2VF-Falcon GAR 2"	C
3971	Hughes A/C Co.	"Second Quarter 1957 - Progress Report No. IV-2EG Falcon GAR-3 GAR-4"	S
3976	Hughes A/C Co.	"Special Research No. SRSM 7-46. Effect of T47 and T58 Rocket Motor Exhaust on Structural Materials. 15 Nov 54.	
3977	Hughes A/C Co. TM 393	"Aerodynamic Data Report, GAR-1D and GAR-2 Falcon Missiles" 15 Sep 56	C

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ACC NO.	SOURCE	TITLE	CLASSIFICATION
3985	Hughes A/C Co	"Falcon GAR-1 - GAR 1B Progress Report No. 11-2DF Second Quarter 1955. 15 Aug 55	
4033	APGC-TN-58-9	*Evaluation of the F-89J Armament System - GAR-2A Mode. Feb 58	
4145	APG/ADA/38-A	*Final Report on Project APG/ADA/38-A & ST of GAR-1 (Falcon) Missile 12 Feb 57"	
4147	Hughes A/C Co. SRSM9-79	*Detail Specification GAR 1/GAR 2/GAR 1D Field Checkout Equipment*. 30 Jun 55 Amended 15 Oct 56	
4317	Hughes A/C Co. 4113.7/54	*Comments on Missile Jump and Weathercock" 15 Jan 57	C
4318	Hughes A/C Co. Res. Study 187	*Addendum 1 to M-111. Evaluations for Balloon Targets*. 8 Mar 57	C
4319	Hughes A/C Co. M-111	*General Techniques for Determination of Missile and Rocket Launching Error for use in Evaluation of Dry Run and Live Firings*. 1 Aug 56	C
4344	Hughes A/C Co.	"Analysis of the E-9 (XY-2) and MG-3 Fire Control Systems and the Falcon Missile*. 4 Dec 53	
4851	Hughes A/C Co. Cpy 43 Rev *A*	*Specification No. SRSM9-147A Detail Specification GAR 3 Missile *. 15 Mar 58	
4852	Hughes Systems Dev. Lab.	*Installation Requirements. Drawings - MA-1-F-106A. 9-15-58	
4853	Hughes A/C Co. Doc. Cod4 947	*Post Provisioning Review List". 15 June 57	
4854	Hughes A/C Co. TM-561 Ref 1DC 41145/88 -	*Cockpit Subsystem MA-1 Aircraft and Weapon Control System*. 1 Apr 57	
4855	Hughes A/C Co.	*Convair-Hughes Technical Coordination Index for Weapons System F-106A/MA-1. Issue A". 1 Jul 58	
4856	USAF TO IM2-GAR 4-2	"Handbook Assembly, Service, and Maintenance Instructions Missile Model GAR-4" 15 Feb 58 Revised 1 May 58.	
4857	USAF TO-IM2 GAR3-2	*Handbook, Assembly, Service and Maintenance Instructions Missile Model GAR-3 (Falcon). 15 Feb 58 Ref 15 May 58	
4858	USAF TO-11F1-MA1-12-4	"Aircraft and Weapon Control Interceptor System Type MA-1 15 May 58	
4859	USAF TO 11F1-MA1-12-1	Aircraft and Weapon Control Interceptor System Type M A-1 (Power Subsystem). 15 May 58	

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ACC NO.	SOURCE	TITLE	CLASSIFICATION
4860	USAF TO-11F1-MA1-12-5	"Aircraft and Weapon Control Interceptor System Type MA-1" 15 May 58	
4861	USAF TO 11F1-MA1-12-2	"Aircraft and Weapon Control Interceptor System Type MA-1". 15 May 58	
4862	USAF TO-11F1 MA-1-12-3	"Aircraft and Weapon Control Interceptor System Type MA-1" 15 May 58	
4863	Hughes A/C Co. X173775	"Preliminary Outline -GAR.4A Sealed Missile" (Nominal Dimensions ". 8 Oct 58	
4864	Hughes A/C Co. ES-464-00-01 MA/1F-106A	"Production Issued 29 Oct 56. Revision F 1 - 1 Aug 58. Equipment Specification ES 464-00-1 (Issue 5A) 29 Oct 56	
4931	Hughes A/C Co. Rpt PS-2-723	"Integrated Air Data Computing System for the 1 AWCS Type MA-1 AND AN/ASQ-25 and the ARDC Cockpit. (Product Spec.) 28 Mar 58	C
4932	Hughes A/C Co. Rpt. TS2-661	"Armament Control Group of 1 AWCS Issue 6-Electrical Tests (Test Spec)" 28 May 58	U
4933	Hughes A/C Co. Rpt. TS-2-657	"Electronic Control Amplifier Group. Missile Antenna, Electrical Tests". (Test Spec) 13 Oct 58	C
4934	Hughes A/ C Co. Rpt TS2-484	"MA-1 AFCS/F-106A, HUG P/N 464000, Group Electrical Tests. Issue 11 (Test Spec" 26 May 58	U
4935	Hughes A/C Co. Rpt. PS-2-442	"Generator Set Stabilization Data, Issue 5 (Product Specification" 15 Jul 58	C
4936	Hughes A/C Co. Rpt. ES464-00-1 (Amend1)	Equipment Specification Issue 4A"6 Apr 56	C
4937-V	Hughes A/C Co. Rpt. MA-1-9S	"Air Data Computer - Functional Description - Automatic Flight Control System - MA1 (Chapter V) Sep 58	C
4937-VII	Hughes A/C Co. Rpt MA-1-9S	"Automatic Flight Control Subsystem-Functional Description - MA1 (Chapter VII) Sep 58	C
4938	Hughes A/C Co. Rpt. MA-1-11S	"Production Radar Subsystem Design Specification for the MA-1" 20 Jul 58	C

...../4

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ACC NO.	SOURCE	TITLE	CLASS-IFICATION
4939	Hughes A/C Co. Rpt. MA-1-5-S	"Operational Characteristics and Capabilities of F-106A/MA-1 (SDN8-36522/40) Apr 58	S
4940	Hughes A/C Co. Rpt. ES 464-00-1	"Specification to the 1AWCS Type MA - 1 System Issue 6 (Equipment Spec) 1 Nov 58	C
4941	Hughes A/C Co. Rpt. PS1-971	"Antenna, ADF HUG (651252) P/N 464117-150 Issue 2 (Product Specification)" 17 May 58	O
4942	Hughes A/C Co. Rpt PS1-251	" Tactical Air Navigiation (TACAN) Set, Issue 1 (Product Specification) 19 Dec 58	O
4943	Hughes A/C Co.	"Missiles - Manufacturing Delivery Schedules" 28 May 58	C
4944	Hughes A/C Co. Ref 4212 2/1784 1C	"Summary of operational targets" 6-11-57	C
4945	Hughes A/C Co. M-143	"Mobile Automatic Radiating Tester HUG Part No. 486116-110" 13 Mar 57	C
4946	Hughes A/C Co. SDN 8-523423/40	"List of CCM Features Present and Proposed for MG-13 systems" (Cp No. 1)	S
4947	Hughes A/C Co. PR No. 11	"F106 AAD Program & F106 AWCS Armament Development Program Progress Report - Log No. 313 - AAD - 3053-47 for Period 10-11 thru 23-11-1958" 26 Nov 58	C
4948	Hughes A/C Co. M111	"General Technizues for Determination of Missile and Rocket Launching Error for use in Evaluation of Dry Run & Live Firings" 1 Aug 56	C
4949	Hughes A/C Co. MA-1-8-S	"MA-1 Aircraft & Weapon Control System- A Technique for the Flight Test Evaluation of a FCS in dry rum MB-1 Attacks (Cp 30) 30 May 58	C
4950	Hughes A/C Co. FPS3-020-1 Issue 1	"MA-1/AN/ASQ-25 Aircraft & Weapon Control Interception System Functional Program Specifications of the Model A Naviation & Attach Digital Computer Program" 24 Nov 58	C
4951	Hughes A/C Co. Spec 185508	"MA-1 Aircraft and Weapon Control System GAR-3 and GAR-4 Falcon Missiles Coordination Specification" 2 Feb 58	C

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ACC No.	SOURCE	TITLE	CLASS-IFICATION
4952	Hughes A/C Co. MA-1-5-s	"Operational Characteristics & Capabilities of the F106A/MA-1 (SDN8-36522/40) Apr 58	S
4953-1 -2 -3	Hughes A/C Co. Dwgs. 169421, 169450, 464054-550	"Drawings - Launcher LE-6" 21 & 25 Oct 57 19 Feb 58	C
4954	Hughes A/C Co.	"Drawing - Development Plan (Program Plan) for MA-1C/CF105 Weapon Control System" 24 Nov 58	C
4955	Hughes A/C Co. V-1PR	"GAR-1D/2A/3/4 Falcon Missile - First Quarter 1958 Progress Report (SDN8-36089) 40F-338) 15 May 58	S
4956	Hughes A/C Co. V-2PR	"GAR-1D/2A/3/4 Falcon Missiles-Second Quarter 1958 Progress Report (SDN8-3610/40-346) 15 Aug 58	S
4957	Hughes A/C Co. V-3PR	"GAR-1D/2A/3/4 Falcon Missiles, Third, Quarter, 1958 Progress Report (SDN8-36128/40F-332) 15 Nov 58	S
4958	Hughes A/C Co. 1V-4PR	"GAR-1/1D/2:4 Falcon Missiles-Fourth Quarter 1957 Progress Report (SDN8-36039/40F-356) 15 Feb 58	S
4959	Hughes A/C Co. PR.1V-3DF	"GAR-2 Falcon Progress Report, Third Quarter". 15 Nov 57	C
4960	Hughes A/C Co 1V-3EG	GAR 3/4 Falcon Missile Progress Report for Third Quarter 1957 (SDN7-36091/40F-445) 15 Nov 57	C
4961	Hughes A/C Co. PB-7	"AN/ASQ-25 Self-Test Features for CD1/CTC1 Inspections (8 Sep through 12 Sep 58) - AN/ASQ-25 Aircraft & Weapon Control System" 2 Sep 58	O
4962	Hughes A/C Co. M-148	"Maintenance of the MA-1 Aircraft and Weapon Control System" 9 Apr 57	O
4963	Hughes A/ C Co. Spec. SRSM9-150A (REV)	"Detail Specification for GAR4 Missile (Rev A) 15 Mar 58	C
4964 See also 4851	Hughes A/C Co. Spec. SRSM9-147A (REV)	"Detail Specification for the GAR-3 Falcon Missile (Cp 41) 15 Mar 58	C

...../6

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ACC No.	SOURCE	TITLE	CLASSIFICATION
4965	Hughes A/C Co. Spec. SRSM-9-149A (REV)	"Verification Test Specification on the GAR-3 Falcon Missile (Rev. A) (CP 3) 15 Mar 58	C
4966	Hughes A/C Co. Spec. SRSM-9-121C (Rev)	"Detail Specification on GAR 3-GAR 4A Field Checkout Equipment (Rev. C) Cp. 81) 15 Sep 58	C
4967	Hughes A/C Co. 470000-100 Prelim.	"MA-1-C/CF105 Mk 2 (Arrow) Weapon System (HAC-Ref 4359) Master Index" 12 Dec 58	U
4968	Hughes A/C Co. Dwg SP-69546	"General Arrangement on GAR-4A Falcon Missile (Drawing) 5 Dec 58	C
4969	Hughes A/C Co. TM. 554	"A technique for Measurement of Fire Control Launching Error on Falcon Snapup or Coaltitude Attacks" 1 Jan 57	U
4970	Hughes A/C Co. 58H-6437/4177	"Proposal to Provide a Training Program for Air Force Personnel on the MA-1 AWCS during Fiscal Year 1959" 8 Aug 58	U
4971	Hughes A/C Co. X470073	"Instrumentation List - First Cut for CF105 (Does not include AFCS)	U
4972	Hughes A/C Co. Dwg 470000-207	"Test Equipment Master Index - YWA-lo systems"	U
4973-1 to 4973-8	Hughes A/ C Co.	"Hughes Drawings for the GAR 3/3A/4 Falcon Missile " 1958-1958	C
4974	Hughes A/C Co. Rpt 1 C	"MA-1c AWCS and GAR-3A/4A for AVRO RCAF/CF105 Support Program, Issue 2 (Planning Purposes) (Interdepartmental Correspondence) 8 Dec 58	C
4975	Hughes A/C Co. Rpt. No. 4115. 4/13	"Hughes Interim 1 R System". 1 Nov 58	C
4976	Hughes A/C Co.	"F 106A and F106B Management Control Charts. w/Quarterly Program Review". 2 Oct 58	C
4977	Hughes A/C Co. Rpt PS2-786	"Accelerometer, Aircraft Normal 464161-150 Issue 1 (Product Specification). 26 Jun 58	U
4978	Hughes A/C Co. RPT DWG 464200-206	"Functional Schematic Armament Control, MA-1 Production (7 Sheets) - (Drawings). 16 Sep 58	U

...../7

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ACC NO.	SOURCE	TITLE	CLASSIFICATION
4979	Hughes A/C Co. Rpt. PS2-699	"Integrated Air Data Computing Cyctem for Interceptor Aircraft and Weapon Control Types MA-1 and AN/ASQ-25 (Product Spec) 22 May 58	C
4980	Hughes A/C Co. Rpt. PS-1-730	"Radio Receiving Set ILAS Issue 6 (Product Specification) 23 Jun 58	U
4981	Hughes A/C Co. Rpt. PS-1-747	" Communications Subsystem, Radio Set, AN/ARC-67, Receiving set, Data Link AN/ARR-50 Issue 3 (W/Als to No. 23)(Product Spec) 30 Apr 57	C
4982	Hughes A/C Co. Rpt. PS2-103	"Switch Radio Frequency Transmission Line, 651244 HUG-P/N 464263-150 Issue 2 (Product Specification). 26 Apr 57	U
4983	Hughes A/C Co. Rpt. FPS-3-020-1	"MA-1/AN/ASQ 25 Aircraft and Weapon Control Interceptor System. - Functional Program Specification of the Model a Navigation and Attack Digital Computer Program". 24 Nov 58	C
4985	Hughes A/C Co. Ltr. 158H-11594/4359	"Letter Reference-Transmittal of Documents to the RCAF" 12 Dec 58	C
4986	Dept of Defense (US) Dwgs	"Power Distribution - 1 AWCS (set of Thirteen Diagrams) Dec 58	U
4987	Industrial Security	"Security Classification Guides" 1958	U
4988	Dept of Defense (US) DD Form 254	"Security Classifications Check List (Prime & Subcontract) 1 Jul 56	U
4989 Pt1&2	Hughes A/C Co. Pts 1 & 2	"Pt. 1-"General Launcher Description" Pt. 2:-"Launcher-Rocket Airborne-Model LE-6 Disassembly Procedure"	U
4990	Hughes A/C Co.	"R65398, R65399, R65396, R65397, R65400, R65401, R65406, R65405, R65407, R65402. R65404, R65403, R65408, R65409, R65411, R65410, R65412, R65413, R65414, R65415 (MA-1 & CF105) Dec 58	U
4991	Hughes A/C Co. Dwg. MA-1 CF105	"Instrument Panel, Front & Rear Arrow 11" 11 Dec 57	U
4992	Hughes A/C Co. FRS3-068-1	"MA-1 C/CF105-Functional Requirement Specification for Power Supply Subsystem (Brief No. 1, PCA 537) 26 Nov 58	U

...../8

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ACC NO	SOURCE	TITLE	CLASS-IFICATION
3993	Hughes A/C Co. PS2-690	*Sight Fixed,Non Computing (651375) HUG P/N 464169-150 (Product Specification) see also Acc #4994 & 4995) 27 Nov 57	U
4994	Hughes A/C Co. Dwg 464169-550	*Sight, Fixed,Noncomputing Outline and Mounting Dimensions (Drawing) (See also Acc Nos. 4993 & 4995) Feb 57	U
4995	Hughes A/C Co. Dwg 428993	*Reticle - Optical Sight (Drawing) See also acc Nos. 4993 & 4994) Apr 57	U
4996	Hughes A/C Co. FSS-Act. 08	*A digital Arithmetic Primer (Field Service and Support Activity 08) 5 Aug 57	U
4997	Hughes A/C Co.	*The Story of Field Service Support: Hughes Airborne Systems (Brochure)	U
4998	Hughes A/C Co. 10-58/LP/2M	*DIGITAIR - A Digital Computer Produced by Hughes (Brochure)	U
8160	Hughes A/C Co.	(Issue 5A) ES-464-00-1 W AL No.1 & Erratas-Specification for the Interceptor System Aircraft and Weapon Control Type MA-1 & GAR-$\frac{3}{4}$ 30 Nov 56 to 21 May 57	
8161	Hughes A/C Co. M-96	*The MA-1 Aircraft and Weapon Control System* 15 Nov 55 to Apr 56	
8225	Hughes A/C Co.	*X470000-100 Issue A - MA-1-C1/CF-105 Mk. 1 (Arrow) Weapon System (Contract Brief No. 1 PCA No. 537) Preliminary Master Index. 27 Oct 58	
8226	Hughes A/C Co. Spec. PS2-699	*Integrated Air Data Computing System for the Interceptor Systems, Aircraft and Weapon Control Types MA-1 and AN/ASQ-25. Issue 6) 22 May 58	
8227	Hughes A/C Co. Spec. PS2-723	"Integrated Air Data Computing System for the Interceptor System Aircraft & Weapon Control Types MA-1 & AN/ASQ-25 and the ARDC Cockpit. 28 Mar 58	