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PROPOSED CF-105 STRUCTURAL INTEGRITY FLIGHT TEST PROGRAM

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A.V. ROE AIRCRAFT LTD.
MALTON - CANADA

PROPOSED CF-105 STRUCTURAL INTEGRITY FLIGHT TEST PROGRAM

1.0 INTRODUCTION

The structural flight test program proposed herein consists of two main parts:

(a) Flutter and Vibration - It is intended to carry out comprehensive flutter and vibration tests both on the ground and during initial flights, prior to commencement of the Flight Load Survey and Demonstration tests. In this way it will be possible to check calculations and predict whether or not critical or detrimental flutters and vibrations will occur during any part of the flight range.

(b) Combined Flight Load Survey and Demonstration

This portion of the flight test program, which is based on § 4.1.1 of MIL-S-5711, constitutes the formal part of the structural flight testing. The main purposes of these tests are to show that the flight loads check with analytical loads, and also to demonstrate that the airplane is structurally satisfactory and is capable of withstanding loads imposed during performance of the manoeuvres of the approved program without failure or without objectionable permanent set in any portion of the structure.

Since proof of structural adequacy of the airplane shall be jointly dependent on the flight test and static test results, a fair amount of co-ordination will be required between the ground and flight tests. This is exemplified in the following excerpts from MIL-S-5710 and MIL-S-5711.

MIL-S-5710 — §3.2.2 "The tests will be initiated as soon as the test set-up is available. The loads used are outlined in paragraph 4.1. If the flight load data are not available, the tests will be based on analytical loads. The complete test to destruction (one condition) will not be conducted until the flight load data from the 100% limit load survey have been incorporated into the test loads".

MIL-S-5711 — §4.1.1.2 "Final Phase - (Tests permitted after completion of ultimate static tests). The tests in this phase shall be conducted to 100% of limit loading condition......".

It is strongly recommended that the above degree of tie-in between ground and flight tests be maintained in the interest of the safety of the airplane.

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2.0 TEST PROGRAM

2.1 Test Vehicle

The second airplane shall be procured and instrumented adequately to carry out the flight test program designated in this proposal. An additional airplane sufficiently late in the production program to insure obtaining the final configuration, should be procured and instrumented to serve either as a standby or back-up aircraft.

2.2 Instrumentation

A consolidated list of instrumentation, required for the "Proposed CF-105 Structural Integrity Flight Test Program", is tabulated in table one. Part (a) in its entirety is required for the "Flutter and Vibration Tests", proposed earlier in this note. Part (a) one, and (b) in its entirety are required during the "Combined Flight Load Survey and Demonstration Tests" proposed herein.

The method of recording shall be such to permit initial scanning of strains and temperatures to ensure that limiting values have not been exceeded, and following this the issuance of required data in the form of graphical trace recordings. The detailed method for absorbing and analysing this data is not available at this time.

In view of the large number of strain gauges required for this program it is strongly recommended that a commutating device be utilized to permit the recording of more than one strain output on one channel, and also, if possible, a switching device to permit the selection of specific groups to strain gauges, prior to and during flight. This would greatly reduce the number of flights necessary to perform the required manoeuvres and record the corresponding data.

2.3 Flutter and Vibration

The instrumentation required for this phase of testing is outlined in table one and constitutes part (a)1 and 2, which total 75 signal outputs.

The flight manoeuvre, loading and configuration of the airplane, required for this portion of testing is not yet available. The method of exciting flutter and vibration during flight has yet to be established.

The recommended pick up location for vibration analysis is shown on figure one. (See Page Five).

TABLE 1 - CF-105 INSTRUMENTATION

PART		DESCRIPTION AND/OR LOCATION	SIGNAL OUTPUTS	REMARKS	USED FOR
(a)	1.	TEST CONDITION INSTRUMENTATION		"Off the Shelf" accuracies are acceptable	ALL TESTS
		Airspeed	1		
		Pressure Altitude	1		
		Normal Acceleration at C.G.	1		
		Aileron, elevator, rudder control forces	3		
		Aileron, elevator, rudder, speed brake position	4		
		Rate of Roll	1		
		Rate of Pitch	1		
		Rate of Yaw	1		
		Angle of Attack	1		
		Angle of sideslip	1		
		Aircraft weight	2		
		Buffeting	1	PART(a)1 Total = 18	
	2.	Accelerometers - Right Wing	20	The required range and accuracy are ± 10g and ± .2g respectively.	FLUTTER & VIBRATION AND SEE NOTE 5 BELOW
		Left Wing	10		
		Fuselage	7		
		Vertical Tail	16	Frequency range 0.60 cps Part (a)2 Total = 57	
(b)	1.	Strains - Center section structure, tank pick up and critical points	50	The recorded data shall be within ± 5% of the actual strain output	COMBINED FLIGHT LOAD SURVEY AND DEMONSTRATION
	2.	Strains - Fin	100		
	3.	Strains - Right Inner Wing, ℄ to side of Fuselage	100		
	4.	Strains - Right Inner Wing, - side of fuselage to transport joint	100		
	5.	Strains - Right Outer Wing	100		

TABLE 1 (continued)

PART	DESCRIPTION AND/OR LOCATING	SIGNAL OUTPUT	REMARKS	USED FOR
6.	Strains - Centre Section Frames & longeron	150		
7.	Strains - Fuselage, normal cases	100		
8.	Strains - Adjoining under-carriage structure (Right)	50	Continuous for U/C tests	
9.	Aerodynamic Heating			
	- Strains	50		
	- Thermocouples	50		
	- plus group 4 above		Part (b) Total = 850	

NOTE

1. All Strain Gauge recordings may be read at .05 second time intervals except as noted otherwise.

2. The Strain Gauges listed in (b) shall be wired in the 9 itemized groups as shown above

3. The thermocouples, shall be wired in a seperate group.

4. The test condition instrumentation shall be recorded on a seperate magnetic tape or trace.

5. The accelerometers shall be wired in a seperate [GROUP WITH PROVISION FOR RECORDING A REDUCED] number ~~of~~ [of] strategically located ~~accelerometers required~~ [ACCELEROMETERS REQUIRED] for inertial load calculations.

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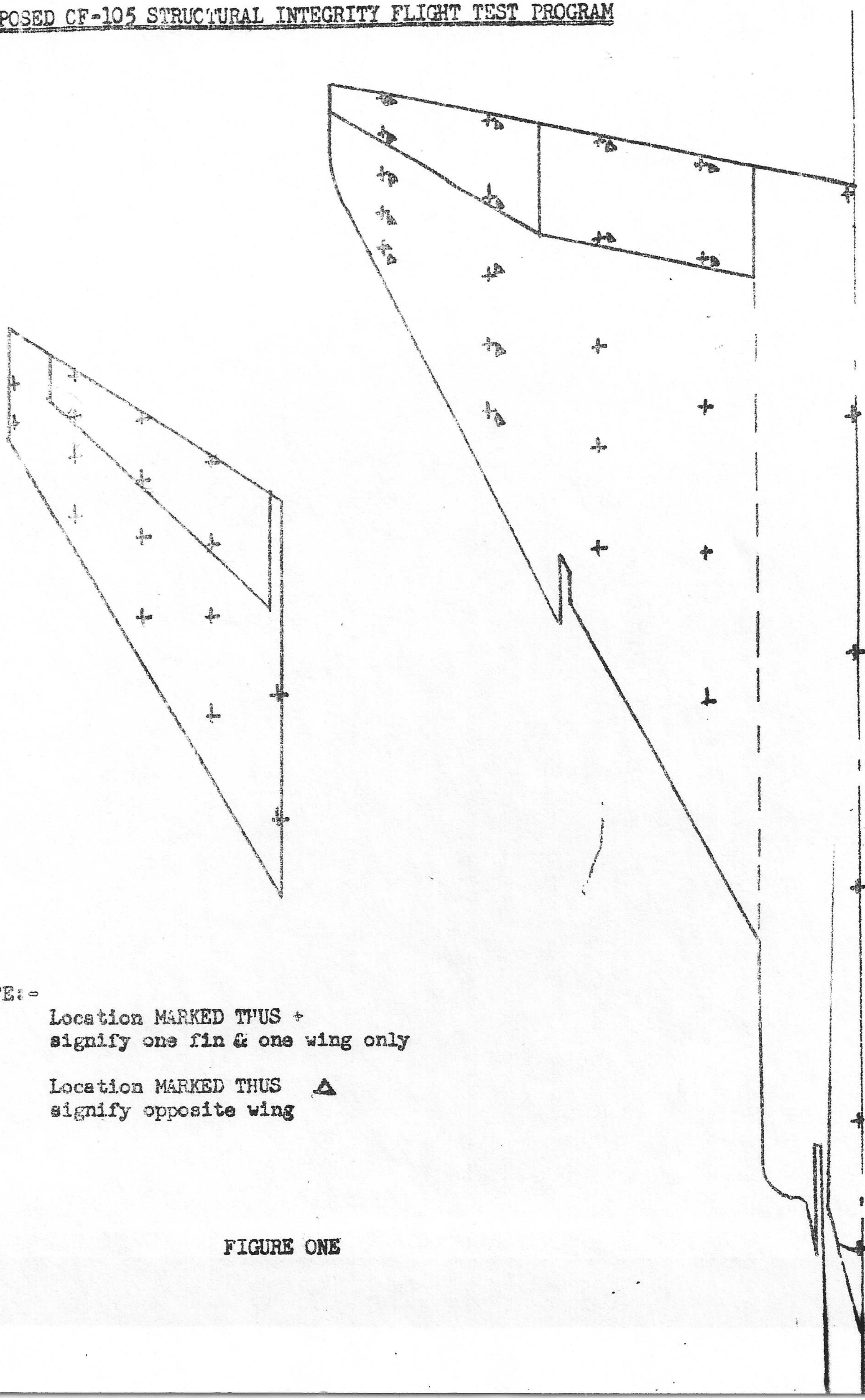

NOTE:-

Location MARKED THUS +
signify one fin & one wing only

Location MARKED THUS △
signify opposite wing

FIGURE ONE

PROPOSED CF-105 STRUCTURAL INTEGRITY FLIGHT TEST PROGRAM

2.4 Combined Flight Load Survey and Demonstration

The combined Flight Load Survey and Demonstration program shall be conducted in two phases as follows:

2.4.1 Initial Phase (Tests permitted prior to completion of ultimate load static tests) - The tests in this phase shall be conducted to 80% of the limit loading condition*. The purpose of this phase shall be to define, by flight measurement over the speed and altitude range, the critical flight conditions for the airplane. This phase shall consist of performing tests outlined in table two, and measuring flight loads during all required manoeuvres. The tests outlined on table two shall be conducted in the order shown:

(a) Manoeuvring Grids at three altitudes as per §4.2.2.1.1 MIL-S-5711

(b) Design Criteria Conditions (not covered in (a) as per § 4.2.2.1.3 MIL-S-5711)

(c) Tests required to define suspected new critical conditions as per 4.2.2.1.3 MIL-S-5711.

* See §2.4.3 of this note.

PROPOSED CF-105 STRUCTURAL INTEGRITY FLIGHT TEST PROGRAM

2.4.2 Final Phase - (Tests permitted after completion of ultimate static tests) - The tests in this phase shall be conducted to 100 percent of limit loading condition.* The purpose of this phase shall be to verify the loads at and demonstrate the airplane for 100 percent of limit loading condition.* This phase shall consist of performing the tests outlined in table three and measuring flight loads during the required tests as specified.

(a) Flight load measurement - demonstration tests at the speed altitude combinations indicated to be critical by the Initial Phase with loadings and configurations tested in that phase.

(1) These tests shall include all applicable types of manoeuvres of § 4.2.2.1.2.2

(b) Flight load measurement demonstration tests at limit Mach number and limit "g" (dynamic pressure), if not covered in (a) with the critical loadings and configuration.

(1) A normal pull-out (4.2.4.1 MIL-S-5711) shall be performed at limit Mach number and at limit "g" (dynamic pressure) with the critical loadings on configurations as per § 4.2.2.1.2.5 of MIL-S-5711.

(c) Demonstration tests to demonstrate the structural adequacy of external Store supports and to establish flight limitations for any configurations not previously tested. The following manoeuvres shall be performed with the loadings and configurations noted. (i.e. external fuel tank configuration)

(1) Normal symmetrical pull-out (4.2.4.1, MIL-S-5711) at minimum and calibrated speeds up to M = .95 with the partially filled external tank loading most critical for the tank supports and supporting structure.

(2) Normal symmetrical pull-out (4.2.4.1 MIL-S-5711) at speeds up to Mach = .95 with external fuel tank configurations not previously tested, as required to demonstrate the maximum load on each set of supports and supporting structure and to establish flight limitations for these configurations.

(3) Normal symmetrical push-down (4.2.4.2 MIL-S-5711) at speeds up to M = .95 with external fuel tank configurations not previously tested, as required to demonstrate the maximum negative load on each set of supports and supporting structure.

* See § 2.4.3 of this note.

2.4.2 (Cont'd)

(4) Abrupt co-ordinated pull-out (4.2.4.11 MIL-S-5711) at speed for maximum rolling velocity with full external tanks and armament load most critical for each set of supports and supporting structure.

NOTE:- The four cases discussed in this section have been modified with respect to speeds to cater for the external fuel tank configuration in accordance with R.C.A.F. AIR-7-4 issue one § 3.7.2

However it would appear that the above cases as outlined in MIL-S-5711 § 4.2.2.2.2 c. should apply to the armament pack with missiles retracted and the more critical, extended positions, and hence be made applicable to the Armament Structural Integrity tests.

In addition it is felt that modifications of manoeuvres 4.2.2.3.2 (d), (i) MIL-S-5711 constituting the following

(i) Normal uncoordinated rolling pull-out with abrupt checking.

(ii) Abrupt uncoordinated rolling pull-out with abrupt checking.

(iii) Normal uncoordinated rolling pull-out followed by abrupt rolling in reversed direction.

(iv) Abrupt uncoordinated rolling pull-out followed by abrupt rolling in reversed direction.

(d) Demonstration test required to demonstrate the structural adequacy of dive brakes.

(1) Deceleration device shall be extended (4.2.4.15 MIL-S-5711) at the maximum design speed for the particular device, with an aft centre of gravity loading.

2.4.3 Special Tests (Not listed in tables two and three)

2.4.3.1 Aerodynamic Heating

It is recommended that an exploratory series of tests be conducted to determine the order of structural temperatures and thermal stresses during flight in the regions of maximum airspeeds. These tests should be conducted prior to completion of the Final Phase of Structural Flight Testing at the maximum Mach numbers and airspeeds.

The instrumentation for this phase of testing consists of 150 strain gauge outputs and 50 thermocouples and 18 test condition outputs (See table one, part (b) 10,4, and part (a) 1.

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2.4.3.2 Undercarriage

It is recommended that strains at the junction of the undercarriage and the inner wing structure be recorded during a series of initial CF-105 landings. The purpose of these tests will be to determine the structural adequacy and limitations of the CF-105 undercarriage prior to the stage of intensive flight testing.

The instrumentation for this portion of testing consists of 50 continuous strain outputs, 100 non-continuous strain outputs and 18 test condition outputs. (See table one (b) 3,9 and (a)1).

2.4.3.3 Critical C/S Structure and Tank Pick-up and Fin

It is recommended that the strains in the region of the fin and the adjoining structure be investigated during the initial critical probing flight. This portion of the airplane is most critical and consequently requires careful observation during flight testing.

The instrumentation for this portion of testing consists of 150 strain outputs and 18 test condition outputs (See table 1 (b) 1,2, and (a) 1).

2.4.4 Weight and Load Factor

The "Gross Weight for Stress Analysis" as defined in AIR-7-4 § 5.2.1.2 is approximately equivalent to the combat weight as defined in MIL-S-5701, § 3.2.2.4 as on alternative mission take-off gross weight class the amount of fuel required to reach the target area. Hence for the purpose of designing the airplane a weight of 47,000 pounds was used in conjunction with limit load factors of +7.33 and -3g.

However the actual corresponding weight, based on the latest available weight data is of the order of 51,500 pounds. Some decision as to which weight will be used with the limit load factors of +7.33 and -3g for the purpose of loading the airplane for the structural integrity tests proposed herein, would be desireable.

3.0 SUMMARY

The Structural Integrity Flight Test program prepared in this note is based on USAF MIL-S-5711 Specification. In some instances the tests were modified to meet the overriding requirements outlined in RCAF AIR-7-4.

The instrumentation required for this program constitutes the following:

DESCRIPTION	SIGNAL OUTPUT
Test Condition	18 (continuous)
Accelerometers	57
Strains	800 (including 50 continuous)
Temperatures	50
TOTAL	925

Unless otherwise specified the strains and temperatures shall be recorded intermittently. A tentative time interval of .05 seconds between points has been suggested.

Provision should be made to initially scan the recorded data to insure that limiting values of strains or temperatures have not been exceeded. Following this, trace recordings in the form of graphs should be presented to the Stress Office for detailed study as soon as possible after the test. The above data shall be recorded against a common time base.

A brief outline statement of the test program is outlined in the following table 4.

ITEM	TEST	SIGNAL OUTPUT	REMARKS
1	Aerodynamic Heating	218	Exploratory in conjunction with probing tests.
2	Undercarriage	168	Initial Flights of CF-105.
3	Critical C/S Struct. Tank Pick-up & Fin	168	Initial Critical Flights of CF-105
4	Flutter & Vibration	73	Initial Flights of CF-105
5	Combined Flight Load Survey & Demonstration - Initial Phase	718	Basically as per MIL-S-5711
6	Combined Flight Load Survey & Demonstration - Final Phase	718	Basically as per MIL-S-5711.

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RESTRICTED UNCLASSIFIED

ARMY AIR FORCES
SPECIFICATION

No. R-1803-11
1 August 1947

STRUCTURAL INTEGRITY FLIGHT DEMONSTRATION REQUIREMENTS FOR AIRPLANES

A. APPLICABLE SPECIFICATIONS.

A-1. The following specifications of the issue in effect on the date of invitation for bids shall form a part of this specification to the extent specified herein:

A-1a. Specifications:

A-1a(1). Army Air Forces:

C-1803	Stress Analysis Criteria
R-1803-9	Structural Tests

B. TYPE.

B-1. This specification covers the structural flight acceptance requirement necessary to demonstrate the structural integrity of aircraft procured by the Procuring Agency.

C. MATERIAL AND WORKMANSHIP.

C-1. Flight Test Article.- The flight test article demonstrated shall embody the same configuration, materials, quality of workmanship, and details of construction as all other flight articles to be delivered on the same contract, or on contracts for similar models, and shall be structurally similar to the design indicated in the stress analysis and drawings (See paragraph C-1b, Specification R-1803-9).

D. GENERAL REQUIREMENTS.

D-1. Aircraft to be Demonstrated.- The first flight article, or the first flight article obtainable for the purpose, of each airplane model procured shall be demonstrated in accordance with this specification unless otherwise specified by the Government.

D-1a. When a static test article is procured on the contract, results of the structural tests, if available at the time of the flight demonstration tests, shall be incorporated in the flight test article prior to the structural integrity flight demonstrations outlined herein.

D-2. Responsibility for Demonstration.- Unless otherwise specified, the airplane manufacturer shall, with his personnel and at his own risk, perform the structural integrity flight demonstrations required by this specification, on such airplanes on each contract as shall be designated by the Procuring Agency.

D. GENERAL REQUIREMENTS (Cont'd)

D-3. Loading Condition.- Airplanes demonstrated shall be loaded with the design useful load at take-off for all demonstration flights, except that on flights wherein full positive limit symmetrical flight manoeuver load factor and limit diving speed are to be obtained, airplanes provided with external fuel tanks shall be loaded with design useful load at time of required test manoeuvers (fuel for climb to altitude to be carried in external tanks, and those tanks dropped before entering manoeuver).

D-3a. The contractor shall furnish to the Procuring Agency an actual weight and balance statement showing compliance with this requirement.

D-4. Instrumentation and Flight Records.- Such indicating and recording instruments as are designated and provided by the Procuring Agency shall be installed by the contractor on each airplane demonstrated. The flight records from the recording instruments shall become the property of the Procuring Agency and shall constitute proof of the aerodynamic loads applied to the airplane during the demonstration. In addition, the contractor shall furnish to the Procuring Agency reports containing the pilots' observations on all demonstration flights conducted.

D-5. Official Witness.- Unless otherwise specified, each flight demonstration shall be witnessed and approved by personnel designated by the Procuring Agency.

D-6. Structural Strength.- Each aircraft demonstrated shall be capable of withstanding the flight manoeuvers required by this specification for its particular type, without failure or permanent deformation in any portion of the structure exceeding that specified in paragraph D-5a(1), Specification No. C-1803.

D-6a. Whether or not permanent set has occurred will be determined by personnel of the Procuring Agency.

D-7. Reinforcements:

D-7a. The demonstration tests shall be discontinued for reinforcement of the airplane, whenever such action is considered advisable by the Procuring Agency's representative, in the interest of safety.

D-7b. Structure failing to sustain the loads encountered during any portion of the demonstration (see D-6., above) shall be reinforced to withstand the required test loads.

D-7c. Reinforcements designed by the contractor shall be subject to review and approval by the Procuring Agency.

D-7d. Those portions of the demonstration tests which resulted in structural failure will be repeated with reinforced structure on the airplane when deemed necessary by the Procuring Agency.

D-7e. If reinforcements are made on the flight demonstration article, structurally equivalent reinforcements shall be made on all corresponding flight articles as directed by the Procuring Agency. Structural equivalence of the reinforcments shall be approved by the Procuring Agency.

E. DETAIL REQUIREMENTS.

E-1. The test manoeuvers to demonstrate the structural integrity of Army Air Forces aircraft are contained in Section F of this specification.

E-2. For structural integrity flight demonstrations the aircraft covered are classified into five groups as follows:

Group I	- Fighter - Penetration, Interceptor
Group II	- Fighter - All Weather
Group III	- Bombers - Heavy, Medium, Light Reconnaissance - Strategic, Tactical, Special Transport - Heavy, Medium, Light
Group IV	- Training - Advanced, Basic, Primary
Group V	- Gliders - All types with and without power

F. METHOD OF INSPECTION AND TESTS.

F-1. Preliminary Demonstration.- The preliminary structural integrity flight demonstration for all types of AAF aircraft shall be performed in accordance with paragraphsF-1a through F-1c(1), below. The requirements of Sections C and D of this specification shall also apply to preliminary demonstrations.

F-1a. Pull-out to obtain a load factor equal to .6(n-1)+1 (where n is the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803) at the minimum airspeed at which it is possible to obtain that load factor (pressure altitude for performing manoeuver optional).

F-1b. Pull-out to obtain a load factor equal to .6(n-1)+1 (where n is the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803) at a calibrated airspeed which is not less than that corresponding to the guaranteed (or estimated) high speed of the airplane. The required acceleration and airspeed shall be obtained at a pressure altitude not lower than that corresponding to the altitude specified for the guaranteed (or estimated) high speed.

F-1c. Abrupt roll from a steady left turn. A steady left turn shall be established with power, bank and dive as necessary to maintain the load factor specified in paragraph F-1c(1), below, and the calibrated airspeed corresponding to the guaranteed (or estimated) high speed of the airplane. With the above-mentioned conditions established and rudder fixed in trim position, the airplane shall be rolled sharply to the right by abruptly applying a force of 30 pounds laterally at the stick grip (80 pounds tangentially at the rim of the wheel) or full aileron deflection, whichever shall occur first. The roll shall be continued to at least the same degree of bank in the opposite direction (altitude for performing manoeuver optional).

F-1c(1). The load factor required for all types, except heavy bombardment and heavy transport, in the above-mentioned manoeuver, is .4(n-1)+1 (where n is the positive limit symmetrical flight manoeuver load factor given in Table I, Specification C-1803). Heavy bombardment and heavy transport types shall maintain 2n/3 in the steady left turn preceding the roll.

F. METHOD OF INSPECTION AND TESTS (Cont'd)

F-2. Final Demonstration.- The final structural integrity flight demonstration for any particular group of aircraft shall be performed in accordance with the applicable subparagraphs below.

F-2a. Group I Aircraft:

F-2a(1). Airplanes of this group with service ceiling above 27,000 feet pressure altitude shall perform the following manoeuvers:

F-2a(1)a. Push-down to obtain a negative load factor of -2.0g at a calibrated airspeed which is not less than the calibrated airspeed corresponding to the design level flight high speed of the airplane at 12,000 feet pressure altitude (the pressure altitude for performing the push-down shall be optional except that it shall not be greater than 12,000 feet).

F-2a(1)b. Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at the minimum airspeed at which it is possible to obtain that load factor (pressure altitude optional)

F-2a(1)c. Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at a calibrated airspeed corresponding to the design level flight high speed of the airplane at 12,000 feet pressure altitude (altitude of performing manoeuver optional).

F-2a(1)d. Dive from service ceiling to a pressure altitude not less than 15,000 feet below service ceiling with the airplane in the minimum drag condition (see paragraph H-1), normal rated power on, and the thrust line of the airplane inclined at least 50 degrees to the horizontal. The dive shall be entered in accordance with paragraph H-3a. The dive shall be terminated in accordance with paragraph H-4 and at a pressure altitude not lower than 17,000 feet below service ceiling.

F-2a(1)e. Dive from a pressure altitude of 27,000 feet to a pressure altitude not greater than 12,000 feet, with the airplane in the minimum drag condition (see paragraph H-1), normal rated power on, and the thrust line of the airplane inclined at least 50 degrees to the horizontal. The dive shall be entered in accordance with paragraph H-3b. The dive shall be terminated in accordance with paragraph H-4, and at a pressure altitude not lower than 10,000 feet.

F-2a(1)f. Abrupt roll from a steady left turn. A steady left turn shall be established with power, bank and dive as necessary to maintain simultaneously two-thirds of the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, and the calibrated airspeed corresponding to the design level flight high speed of the airplane at 12,000 feet pressure altitude. With the above-mentioned conditions established and rudder fixed in trim position, the airplane shall be rolled sharply to the right by abruptly applying a force of 30 pounds laterally at the stick grip (80 pounds tangentially at the rim of the wheel) or full aileron deflection, whichever shall occur first. The roll shall be continued from the initial bank to at least the same degree of bank in the opposite direction (altitude for performing manoeuver optional).

F. METHOD OF INSPECTION AND TESTS (Cont'd)

F-2a(2). Airplanes in this group with service ceiling of 27,000 feet pressure altitude or lower shall perform the manoeuvers outlined in paragraphs F-2a(1)a, F-2a(1)b, F-2a(1)c, F-2a(1)e, and F-2a(1)f, except that the high speed dive shall be entered at service ceiling.

F-2a(3). For airplanes in this group equipped with dive brakes, dive flaps, pull-out flaps, manoeuvering flaps, or other similar devices, it shall be demonstrated by flight test that these devices will operate satisfactorily and will withstand the loads imposed by the limit conditions of the design.

F-2b. Group II Aircraft:

F-2b(1). Airplanes in this group with service ceiling above 27,000 feet pressure altitude shall perform the following manoeuvers:

F-2b(1)a. The manoeuver of paragraph F-2a(1)a.

F-2b(1)b. The manoeuver of paragraph F-2a(1)b.

F-2b(1)c. The manoeuver of paragraph F-2a(1)c.

F-2b(1)d. The manoeuver of paragraph F-2a(1)d except that the thrust line of the airplane shall be inclined at least 40 degrees to the horizontal.

F-2b(1)e. The manoeuver of paragraph F-2a(1)e except that the thrust line of the airplane shall be inclined at least 40 degrees to the horizontal.

F-2b(1)f. The manoeuver of paragraph F-2a(1)f.

F-2b(2). Airplanes in this group with service ceiling of 27,000 feet pressure altitude or lower shall perform the manoeuvers outlined in paragraphs F-2a(1)a, F-2a(1)b, F-2a(1)c, F-2b(1)e, and F-2a(1)f, except that the dive shall be entered at service ceiling.

F-2b(3). The requirements of paragraph F-2a(3) shall apply to this group.

F-2c. Group III Aircraft.- Airplanes in this group shall perform the following manoeuvers:

F-2c(1). Push-down to obtain the negative limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, or -2.0g, whichever is less severe (except transport type aircraft which shall develop -1.0g) at a calibrated airspeed which is not less than that corresponding to the level flight high speed shown on the V-G diagram for the airplane for sea level or 5,000 feet pressure altitude (pressure altitude for performing push-down optional except that it shall not be greater than 10,000 feet).

F-2c(2). Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803 at the minimum airspeed at which it is possible to obtain that load factor (pressure altitude for performing pull-out optional).

F. METHOD OF INSPECTION AND TESTS (Cont'd)

F-2c(3). Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at the calibrated airspeed corresponding to the level flight high speed shown on the V-G diagram for the airplane for sea level or 5,000 feet pressure altitude (pressure altitude for performing pull-out optional but shall not be greater than 10,000 feet).

F-2c(4). Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at the calibrated airspeed corresponding to the level flight high speed shown on the V-G diagram for the airplane for the altitude of highest Mach number in level flight. The required airspeed and acceleration shall be obtained at a pressure altitude within 1,000 feet of the design altitude of highest Mach number in level flight.

F-2c(5). Dive to obtain the calibrated airspeed corresponding to the limit diving speed shown on the V-G diagram for the airplane for altitude of highest Mach number in level flight. This calibrated airspeed shall be obtained at a pressure altitude not lower than the altitude considered on the V-G diagram. The dive shall be terminated in accordance with paragraph H-5.

F-2c(6). Dive to obtain the calibrated airspeed corresponding to the limit diving speed shown on the V-G diagram for the airplane for either sea level or 5,000 feet pressure altitude. This dive shall be terminated with a pull-out to obtain the positive limit symmetrical flight manoeuver load factor for limit diving speed (as shown on the approved V-G diagram for the airplane)at a calibrated airspeed not less than 10 miles per hour below the maximum calibrated airspeed obtained in the dive (pressure altitude for obtaining required airspeed and acceleration optional, except that it shall not be greater than 10,000 feet).

F-2c(7). The requirements of paragraph F-2a(3) shall apply to this group.

F-2c(8). Abrupt roll from a steady left turn. A steady left turn shall be established with power, bank and dive as necessary to maintain simultaneously two-thirds of the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, and the calibrated airspeed corresponding to the level flight high speed shown on the V-G diagram for the airplane for either sea level or 5,000 feet pressure altitude. Then with rudder fixed in trim position, the airplane shall be rolled sharply to the right by abruptly applying a force of 30 pounds laterally at the stick grip (80 pounds tangentially at the rim of the wheel) or full aileron deflection, whichever shall occur first. The roll shall be continued from the initial bank to at least the same degree of bank in the opposite direction (altitude for performing the manoeuver optional).

F-2c(8)a. Heavy bombardment and heavy transport types are to comply with the requirements of paragraph F-2c(8), above, in the preliminary demonstration and need not repeat this manoeuver in the final demonstration.

F-2d. <u>Group IV Aircraft</u>.- Airplanes in this group shall perform the following manoeuvers:

F-2d(1). Push-down to obtain a negative load factor of -2.0g at a calibrated airspeed corresponding to the level flight high speed shown on the V-G diagram for the airplane for either sea level or 5,000 feet pressure altitude (pressure altitude for performing push-down optional except that it shall not be greater than 10,000 feet).

F. METHOD OF INSPECTION AND TESTS (Cont'd)

F-2d(2). Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at the minimum airspeed at which it is possible to obtain that load factor (pressure altitude optional).

F-2d(3). Pull-out to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at a calibrated airspeed approximately midway between the speed determined under paragraph F-2d(2) and the calibrated airspeed corresponding to the limit diving speed shown on the V-G diagram for the airplane for sea level or 5,000 feet pressure altitude (altitude optional).

F-2d(4). Dive to obtain the calibrated airspeed corresponding to the limit diving speed shown on the V-G diagram for the airplane for the altitude of highest Mach number in level flight. This calibrated airspeed shall be obtained at a pressure altitude not lower than the altitude considered on the V-G diagram. The dive shall be terminated in accordance with paragraph H-5.

F-2d(5). Dive to obtain the calibrated airspeed corresponding to the limit diving speed shown on the V-G diagram for the airplane for sea level or 5,000 feet pressure altitude. This dive shall be terminated with a pullout to obtain the positive limit symmetrical flight manoeuver load factor given in Table I, Specification No. C-1803, at a calibrated airspeed which is not less than 10 miles per hour below the maximum calibrated airspeed obtained in the dive (pressure altitude for obtaining required airspeed and acceleration optional, but shall not be greater than 10,000 feet).

F-2d(6). The manoeuver of paragraph F-2c(8).

F-2e. Group V Aircraft.- Gliders shall perform the following manoeuvers in free flight (diving when necessary to obtain required speeds):

F-2e(1). Push-down as specified in paragraph F-2c(1).

F-2e(2). Minimum speed pull-out to positive limit acceleration as specified in paragraph F-2c(2) except that the required acceleration shall be obtained at a calibrated airspeed which is not in excess of 120 percent of the computed stalling speed for limit acceleration.

F-2e(3). Pull-out as specified in paragraph F-2c(3).

F-2e(4). Dive and pull-out as specified in paragraph F-2c(6).

F-2e(5). The manoeuver of paragraph F-2c(8).

F-2f. Special Aircraft.- Any aircraft not covered by paragraphs F-2a, F-2b, F-2c, F-2d, or F-2e of this specification shall be demonstrated in accordance with a test program specified by the Procuring Agency after examination of the aircraft and design data submitted.

G. PACKAGING, PACKING AND MARKING FOR SHIPMENT.

G-1. There are no packaging, packing and marking requirements applicable to this specification.

H. NOTES.

H-1. Minimum Drag Condition.- (See paragraph E-2d(2), AAF Specification No. R-1803-1). Dive recovery flaps or similar devices designed for bringing the airplane out of a dive may be used for the pull-out provided they are not opened until after the specified length of dive at a given angle has been accomplished.

H-2. Failure to Attain Demonstration Requirements:

H-2a. If it is determined by flight test that it is impossible for the airplane to reach the specified limit symmetrical flight manoeuver load factor under extreme compressibility conditions, because of a reduction in maximum lift, a deviation from this particular requirement may be requested by the contractor for the approval of the Procuring Agency provided such request is accompanied by a report containing substantiating flight test data.

H-2b. If the airplane encounters control and stability difficulties during attempts to complete the specified manoeuvers, every effort shall be made to take corrective action. If it is found impossible to eliminate these difficulties in a reasonable length of time, a deviation from the demonstration requirements may be requested by the contractor for the approval of the Procuring Agency provided such request is accompanied by complete reports covering the difficulties encountered and corrective action attempted.

H-3. Dive Entry:

H-3a. Service Ceiling.- The dives shall be entered from level flight high-speed at service ceiling in such a manner that not more than 3,000 feet of pressure altitude are lost before the airplane is in the prescribed diving attitude.

H-3b. At 27,000 Feet Pressure Altitude.- The dives shall be entered at an altitude such that the airplane will be in the prescribed diving attitude and at level flight high speed, or more, at 27,000 feet pressure altitude.

H-4. Dive Pull-Out.- For Group I and Group II aircraft the dives shall be terminated by a pull-out to obtain the positive limit symmetrical flight manoeuver load factors given in Table I, Specification No. C-1803, at a calibrated airspeed not less than 10 miles per hour below the maximum calibrated airspeed obtained in the dive. Termination of a dive shall consist of the attainment of the required positive limit symmetrical flight manoeuver load factor.

H-5. Dive Pull-Out.- For Group III and Group IV aircraft the dives shall be terminated by pull-outs to obtain the positive limit symmetrical flight manoeuver load factor for limit diving speed (as shown on the approved V-G diagrams for the aircraft) at a calibrated airspeed which is not less than 10 miles per hour below the maximum calibrated airspeed obtained in the dive. The required acceleration and airspeed shall be obtained at a pressure altitude not lower than 2,000 feet below the altitude of highest Mach number in level flight as established in the basic flight criteria report which has been approved by the Procuring Agency.

H-6. NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated,

H. NOTES (Cont'd)

H-6. NOTICE (Cont'd)

furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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(Copies of this specification may be obtained from the Commanding General, Air Materiel Command, Wright Field, Dayton, Ohio.)

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HAC/AVRO DEVELOPMENT CONTRACT

for

CF-105 Aircraft Integrated Electronic Control System

Part 1 of Contract

Development of Integrated Electronic System and its installation in CF-105.

Part 2 of Contract*

Development of Falcon missile installation in CF-105.

Part 3 of Contract**

Development of Sparrow II missile installation in CF-105.

*This deals only with HAC contribution to this installation, i.e. - missile launcher, auxiliaries, and tie in to f.c.s., etc. for Falcon and tie in to f.c.s., etc. for Sparrow.

**Douglas to help AVRO on launcher problem, HAC to build what Douglas need for auxiliaries.

NOTE

Aircraft damping system is separate contract.

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PART 1

Integrated Electronic System

What AVRO expect HAC to do

1)	Provide AVRO with preliminary installation data; approximate sizes, attaching points, cooling and power.	February 1955
2)	Provide AVRO with preliminary outline and mounting drawings for the black boxes. Preliminary data on cockpit components. Specification for A.T.M. Requirements for Radome, Telecom antennae and air data sensing. Preliminary list of inter-area cabling.	May 15, 1955
3)	Arrive at agreement with AVRO on responsibility for instrumentation procurement and installation, and have available preliminary instrumentation requirement.	June 30, 1955
4)	Provide to AVRO preliminary inter-connection list.	July 31, 1955
5)	Start training course for AVRO Engineers.	June 1, 1955
6)	Complete training course for AVRO Engineers.	October 31, 1955

7) Provide AVRO with final installation and wiring data for metal mock-up	October 31, 1955
8) From analysis of AVRO drawings, ~~wind tunnel~~ and test data HAC to concurr in AVRO design of missile extension gear.	October 31, 1955
9) Finalise information in Para. 2 for HAC developmental production system with exception of inter area cabling.	November 15, 1955
10) Supply Radar Antenna installation data.	January 15, 1956
11) Supply first issue of system inter-connection list for HAC test aircraft.	January 31, 1956
12) Deliver to AVRO hardware for metal mock-up installation.	February 29, 1956
13) Provide AVRO with fin al instrumentation requirements for HAC test aircraft.	April 30, 1956
14) Complete Analytical Design of AFCS and discuss with AVRO.	May 31, 1956
15) Provide AVRO with design Block Diagram for AFCS.	May 31, 1956
16) Finalise inter connection list for HAC test aircraft and provide list to AVRO.	June 30, 1956
17) Provide AVRO with final inter connection list for pre production systems.	October 31, 1956

18)	Operate first Engineering/Shop training programme.	Oct 1956 - March 1957
19)	Operate second Engineering/Shop training programme.	March - Sept. 1957
20)	Deliver to AVRO hardware for electronic simulation of AFCS.	January 31, 1957
21)	Installation of first Integrated Electronic System and pre-flight on 4th CF-105.	June - Sept. 1957
22)	Installation of second Integrated Electronic System and pre-flight on 5th CF-105.	July - Oct. 1957
23)	Construct Third Integrated Electronic System to be used as a Back up System.	June 30, 1957
24)	Construct Fourth Integrated Electronic System to be used as a Training System.	July 31, 1957
25)	Carry out flight development of AFCS.	Sept. 1957 - Dec. 1958
26)	Carry out flight development of Integrated Electronic System.	October 1957 - Dec. 1958
27)	Confirm data of (8) and (15) (or later data as found necessary by (21) and (22)).	December 31, 1958

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PART 1

Integrated Electronic System

What AVRO expect to do

1)	Transmit to HAC the RCAF system requirement.	February 1955
2)	Provide HAC with final design data for AFCS.	April 30, 1955
3)	Transmit to HAC preliminary data on RCAF Doppler.	May 31, 1955
4)	Provide HAC with missile separation data based on Cornell tunnel tests.	July 31, 1955
5)	Transmit to HAC final data on RCAF Doppler.	November 30, 1955
6)	Provide preliminary input sensor calibration from wind tunnel and theory.	August 31, 1956
7)	Test system wiring intermodulation in metal mock-up, and return test system to HAC.	April - Nov. 1956
8)	First Flight test data available for air data input sensor calibration.	April 30, 1957
9)	Deliver LCF-105 aircraft for test of auto flight control system.	June 1957
10)	Deliver CF-105 aircraft for test of complete integrated electronic system.	July 1957
11)	Provide HAC with first missile separation and trajectory test data for correction of ballistic portion of compution.	January 31, 1958
12)	Provide HAC with complete missile separation trajectory data.	December 31, 1958

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PART II

Development of the Falcon Missile Installation

What AVRO expect HAC to do

✓1)	Review and comment to AVRO on AVRO missile installation design.	February 29, 1955
✓2)	Design Falcon missile launcher and Turnish design data to AV RO.	April 15, 1955
✓ 3)	Construct and deliver 2 prototype Falcon larnchers for use on CF-100 Test.	June 15, 1955
✓4)	Design electronic missile auxiliaries for CF-105 Falcon installation and furnish installation and design data to AVRO.	October 31, 1955
5)	Construct and deliver 10 falcon launchers for use in test of prototype missile package.	December 15, 1955
✓6)	Construct and deliver 30 Falcon launchers for use in test of the missile installation in AVRO aircraft test program.	December 15, 1956

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PART II

Falcon

What AVRO expect to do

1)	Complete the design and install a simple Falcon installation on the CF-100.	June 15, 1955
2)	Complete tests CF-100 with Falcon installation and furnish results of any modification to HAC.	October 31, 1955
3)	Complete the design and construction of a prototype package installation for CF-105 aircraft and submit to HAC for concurrence.	January 31, 1956
4)	Test the prototype package and submit any revisions to HAC for concurrance.	July 31, 1956
5)	Test the Falcon installation in the test CF-105 aircraft co-ordinating with HAC during this period any changes that may occur.	July 1957 - Dec. 31, 195[illegible]

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PART III

Sparrow

What AVRO expect HAC to do

1)	Study the Sparrow missile and submit report to AVRO.	July 31, 1955
2)	Design missile auxiliaries for Sparrow missile and modifications to integrated electronics system and furnish information to AVRO.	September 31, 1956
3)	Construct prototype missile auxiliaries and modify integrated electronic system and deliver to AVRO.	March 31, 1957
4)	Construct second prototype and submit to qualification test.	April 30, 1957
5)	Qualification tests complete.	September 30, 1957

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PART III

Sparrow

What AVRO expect Douglas to do

1)	Study the Hughes integrated electronic system and the AVRO aircraft and determine compatibility of Sparrow with those items.	July 31, 1955
2)	Develop a Sparrow launcher to suit the CF-105 design complete.	June 1955
3)	Provide two Sparrow launchers for initial test.	August 15, 1955
4)	Provide five Sparrow launchers for prototype package test.	February 15, 1956
5)	Provide fifteen Sparrow launchers for AVRO test aircraft.	December 15, 1956
6)	Develop such modification to Sparrow as are required to match the requirements of the electronic system and the aircraft parameters.	December 31, 1957

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PART III

Sparrow

What AVRO expect to do

1)	Complete design of the launcher extension gear and package installation for the Sparrow missile.	June 15, 1955
2)	Design and construct a single unit of the launcher and extension gear.	October 15, 1955
3)	Test on the ground the unit built under Item 2.	January 15, 1955
4)	Design and construct a prototype package of the Sparrow installation.	March 31, 1956
5)	Test on the ground the prototype constructed under Item 4 above.	November 30, 1956
6)	Construct three developmental packages for the Sparrow installation.	January 31, 1957
7)	Test the packages constructed under Item 6 in the CF-105 aircraft both on the ground and in flight.	May 31, 1957 - Dec.31, 1958

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HAC/AVRO DEVELOPMENT CONTRACT

for

CF-105 Aircraft Damping System

This system will be covered by a separate contract to permit the early supply of systems and provide flexibility in negotiation, changes and delivery to suit the aircraft program.

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Damping System

What AVRO expect HAC to do

1)	Analytical phase completion and report furnished to AVRO.	June 30, 1955
2)	Block Diagram completion and furnished to AVRO.	June 30, 1955
3)	Preliminary installation data complete and furnished to AVRO.	June 30, 1955
4)	Final installation and wiring data for metal mock.	October 31, 1955
5)	Electronic simulation hardware delivered to AVRO.	November 30, 1955
6)	Metal mock-up hardware delivered to AVRO.	February 29, 1956
7)	Final Installation data delivered to AVRO.	March 15, 1956
8)	First set flight test hardware delivered to AVRO.	July 31, 1956
9)	Second set flight test hardware delivered to AVRO.	October 31, 1956
10)	Through co-ordinated HAC-AVRO action as result of flight test the development of acceptable damping system is complete.	June 30, 1957
11)	Start delivery of pre-production hardware to AVRO.	August 31, 1957

10	Third	Dec 31/56
11	Fourth	Jan 31/57
12	Fifth	Feb 28/57
13	Sixth	Mar
14	Seventh	Ap
15	Eighth	May
16	Ninth	June

Damping System

What AVRO expect to do

1)	Preliminary aircraft design information delivered to HAC.	November 30, 1954
2)	Final aircraft design information delivered to HAC.	April 30, 1955
3)	Corrected results of aircraft design information from simulator delivered to HAC.	May 31, 1956
4)	Commence delivery of AVRO flight test information to HAC.	November 30, 1956

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C-105 FLIGHT TEST MANUAL

PART	(A)	General Chapt.	1. Introduction 2. Programme (Including overall prior 3. Bar Chart 4. Instrumentation (general) 5. Reporting.......(Flight Reports) (Flight Notes) (Formal Reports)
	(B)	Handling Stability and Control	
	(C)	Engine Installation	
	(D)	Fuel System	
	(E)	Hydraulic	
	(F)	L.P. Pneumatics	
	(G)	Structures	
	(H)	U/C, Brake Parachute	
	(I)	Electrics	
	(J)	Electronics	
	(K)	Armament	
	(L)	Performance	
	(M)	All Weather	
	(N)	Misc. Systems	
	(O)	Misc. Aerodynamics	
	(P)	Logistics	

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C-105 FLIGHT TEST MANUAL

INDEX OF CHAPTERS FOR PARTS B TO F

CHAPTER		REMARKS
1	Purpose of Test	
2	Description (a) Written (b) G.A. Drawing	Note (for performance and handling, description should be of aircraft including wt. and C.G. limits and travel, aircraft G.A, dimensions e
3.	Design data summary	Including design and critical case discussion of known problems.
4.	Engineering programme (manufacturer and/or Avro)	Design Bench and rig tests Mock-ups C-100 tests Pre-flight tests Flight Tests - (Brief general descr (complete the pictu
5.	Flight tests required	Including conditions - Configurations Reasons for test (S
6.	Data required (a) General (b) Instrumentation List	Classify as to monitoring, flight by flight, scanning, reporting and anal Ranges of variables Accuracies required Time delay allowable between flight viewing and/or reporting.
7.	FLIGHT REPORT. 10 FLIGHT NOTE Final Reports	Formal analysis and reporting propo close off test programme. When the are completed and analysed, the prop will be replaced by the report.
8.	References	Including:- (a) Specifications: C-105 Avro Military (b) Avro Reports: Aero Stress D.O. Specialists Test etc. (c) Manufacturers Reports (d) Letters ----- (Central (e) T.I.S.

9. Suggested contacts that may be desirable in preparation of any given part of the manual.

(a) Drawing Office: - Project Engineers, Senior Design Engineers etc.
(b) Technical Office: - Senior Aerodynamicists etc.
(c) Specialists
(d) Structural Test
(e) Flight Test -- (i) Engineering
(ii) Pilots
(f) Purchasing (attached to Technical Office)
(g) Schedule Groups
(h) Manufacturers
(j) Test Organizations (NACA, NAE, RCAF, E&FE, USAF, RAE etc).
(k) (Production)

CF-105 FLIGHT TEST MANUAL
PART E-1
HYDRAULICS - UTILITY

CHAPTER 1 - PURPOSE OF TEST

1.1 Utility hydraulic system flight tests are required primarily to show that the system and its component sub-systems as installed in the aircraft meet the aircraft design specification.

1.2 In addition to the specification testing, certain quantitative data, not normally obtainable by rig test or other means, is required to verify engineering assumptions.

CHAPTER 2 - DESCRIPTION

The Utility Hydraulic System is basically a 4,000 p.s.i. pressurized closed center variable delivery pump control system. In addition, a 1500 p.s.i. compensator pressurizing and emergency circuit is provided.

The over-all utility system is composed of the basic pump 4000 p.si. circuit, 1500 p.s.i. circuit, and the following sub-systems:

- Landing gear
- Speed brakes
- Nosewheel steering
- Wheel brakes
- Armament package
- Afterburner shroud emergency retraction
- Shock strut recuperation
- Compensator pressurizing) (1500 p.s.i. circuit)
- Emergency brakes)

The basic pump circuit and 1500 p.s.i. circuit are shown on drawing 7-0119-4 and described in report 7-0119-6. The principles of pump operation (Vickers Type PV-3915, AA-60659-L) are discussed in Vickers Bulletin A5202.

The Undercarriage Emergency System, a pneumatic system (5000 p.s.i. air bottle supplying a 3400 p.s.i. system), is shown on drawing 7-1900-3 and described in report 7-0119-5.

In addition to the landing gear and wheel brakes hydraulic sub-systems discussed in this part, other tests pertaining to the gear and brakes are given in part H.

The armament hydraulic sub-system is not included in this part but is included in part K.

CHAPTER 3 - DESIGN DATA SUMMARY

Some significant design characteristics and specifications affecting Utility System test program and instrumentation are as follows:

3.1 Temperatures

Temperature is not considered to be as critical a problem for the utility system as for the flying control system because of the larger oil capacity of the utility system and the intermittant nature of its operation. However, in view of the more or less unknown quantities of external heat source and sinks of the installed system, particular ly at high Mach numbers, general temperature measurements per specification MIL-T-5522 are advisable. In addition, Heat Exchanger inlet and outlet temperatures should be measured.

Temperature histories during ground runs and flight, and also after engine shut-down will indicate stabilized temperatures and/or rates of change of temperatures (shock) of the system for comparison with the component specifications, qualification testing and rig testing. In this respect, the following is quoted from MIL-T-5522: "System temperature should be determined during ground tests......... . Instrumentation for flight test temperatures, which are more necessary and realistic, could be used in the ground tests if properly planned." In this regard it is worth noting that this intention has already been expressed by Mr. F. Brame in memo 6582/22/J, as follows:

> "It is essential that flight and static test measurements be made at the same locations in all systems in order that the results of the tests may be correlated. The Design Office will therefore establish, in agreement with the Static and Flight Test Departments, the locations of the measurement pickups for all systems covered by this memo."

Excess temperature is a major factor in seal life. The system specifications are now at their limits in this respect (250°F max. expected with 275°F specified to give a safety factor).

CHAPTER 3 (cont'd)

Simultaneous with undercarriage retraction, braking is automatically applied to the wheels. Following prolonged taxi, and perhaps crosswind take-off, which may raise brake temperatures several hundred degrees, the braking during retraction may contribute to local heating of the hydraulic fluid when the hot wheels are stowed in the confines of the undercarriage bay. While this does not seem to be a real design problem, difficulties in this respect have apparently been experienced (Boeing 707).

3.2 Pressures

Pressures will require careful attention, particularly with regard to surge. Surge in the order of 300,000 to 400,000 p.s.i./sec. and peak pressures of the order of 8000 p.s.i. might be encountered. Surging of this magnitude would result in shock loading of equipment and piping, producing wear and fatigue. In view of difficulties in providing flexibility in the circuits (no hose connections, no direct oil to air accumulator), a tight record of piping and component life for experimental aircraft is desirable. In consideration of the surge problem factors of 4 for the piping, with 5 for bends, and 1/4 hard material, with 1/8 for bends, are proposed in the design as well as a surge damping valve in the speed-brake sub-system.

Pressure measurements in the return system are desirable to assess compensator operation, to ensure that pump inlet pressure is always positive as required, and to determine that relief valves and reducing valves do not chatter.

3.3 Operating Times

The time of operation by half cycles of all services must be determined under a flight condition which duplicates as near as practical the average, expected design conditions.

CHAPTER 3 (cont'd)

3.4 Sub-Systems

(a) Landing Gear Sub-System: - (ref MIL-T-5522B). Gear retraction and extension tests are required in flight. In conjunction with these tests measurements are required of gear temperature, ambient air, hydraulic temperature, operation time and sequence for both extension and retraction of gear. During retraction: "time should start when down locks open, and stop when gear is up and locked and all fairing doors closed. Any lag between selector valve operation and opening of down locks, if appreciable, should be noted separately." During extension at normal approach engine R.P.M., I.A.S. and airplane attitude: "time should start when uplocks or fairing doors start opening and stop when all gears are down and locked for safe touchdown. Any lag of getting pressure from the selector valve to the system, if appreciable, should be noted separately." In gear lowering, unlocking and door opening are hydraulic, but gear extension is by gravity and air load only with the result that damping of the swinging leg may be a difficulty.

In gear raising, the hydraulic system must not only overcome the weight of the leg but also the leg fairing air loads arising from the fact that the undercarriage hinge line is canted with leading edge outboard.

Undercarriage and door jack loads have been requested (ref letter 6382/22/J) by measurement of supply and return line pressures within the jack cylinders. Air loads on the undercarriage are given in letter ref. 6209/09/J, which gives undercarriage placard speed as 250 K E.A.S.

(b) Speed Brakes Sub-system: Continuous indication of speed brake position is required to determine half cycle operating times and to check synchronization. Opening of the speed brakes is not expected to affect longitudinal trim to any great extent.

There is no provision for mechanical interconnection of brakes or hydraulic restriction, since small increments of out-of-synchronization (5° or less) probably will have only small effects on yaw and roll; however increments much beyond this may be

CHAPTER 3 (cont'd)

serious in yaw.

Temperature measurement of the Speed Brake sub-system is desirable.

(c) Afterburner Shroud Emergency Retraction: (To be determined when engine installation finalized)

(d) Shock Strut Recuperation: Current proposal is to delete Hydraulics and use pneumatic bottle

(e) Nose Wheel Steering: (see also Part H - Undercarriage)
Nose wheel steering and shimmy damper assessment measurements will consist primarily of relative motion between leg and wheel. For steering, pilots control position will also be required (pilots control system in design stage). Nose wheel system pressure is desirable witha pressure pick-up capable of sensing shimmy. Hydraulic temperature measurement is desirable since thermal relief at high temperatures of the shimmy damper may result in reduced pressure at low temperatures.

(f) Emergency Systems: During at least one operation of each emergency system at applicable altitudes and speeds, pressure, elapsed operating time and free air temperature are required.

Included in this category are emergency brakes and emergency undercarriage.

The emergency undercarriage system is a 5000 p.s.i. air bottle supplying a 3400 p.s.i. system, which utilizes hose with the contention that this is satisfactory for 'single shot' operation at this pressure. It may be desirable therefore to determine ambient air conditions in the hose region if the hose is sensitive to temperature.

Down selection is accomplished by air pressure releasing uplocks and door unlocking. Nose wheel doors are wiped down by

CHAPTER 3 (cont'd)

nose wheel but main doors must be down before the undercarriage. Gear lowering, as in the main system, is by gravity and air load.

On an Up selection if, for some reason, electrical or hydraulic, the gear is unlocked but fails to retract, there appears to be some doubt, whether the gear will lock down without raising the speed or jarring the aircraft since Down selection, either emergency or normal, puts no pressure in the gear jacks.

Emergency Up selection is an electrical overide of the weight lock pin, followed by hydraulic raising of the gear. Since the leg hinge lines are canted with leading edge outboard, the hydraulic system must overcome not only the air load on the leg fairing and the weight of the undercarriage, but also friction drag loads due to the hinge orientation.

3.5 Miscellaneous

Vibration may prove to be a problem resulting in pipe fractures, valve chattering, etc. Vibration measurements however are not catered for in the instrumentation, and if such measurements are eventually required, they should be considered as ad hoc development.

Other measurements desirable include compensator piston position, and door positions.

Undercarriage door operation and control is by means of three jacks, 5 locks and 1 microswitch (commercial type). The design problem is of course to locate the one microswitch on the critical lock. It has been suggested that for experimental aircraft, test microswitches be installed on all locks and signals. recorded. Door deflections are also a problem and assessment of deflections may be desirable.

CHAPTER 4 - ENGINEERING PROGRAM

CHAPTER 5 - FLIGHT TESTS REQUIRED

5.1 Utility system flight testing will consist of routine, pre-initial-flight ground tests, spot checks during routine flying and finally, a series of systematic flight tests.

5.2 The major portion of this testing is based on the requirements of specification MIL-T-5522, which is summarized as follows:

Peak Pressure Tests

Peak pressure tests shall be performed on the installed hydraulic system of one experimental airplane of each new model in flight, on the ground or in the laboratory depending on which conditions offers the most critical pressures.

Ground Tests

(a) Ground test peak pressure
(b) System temperature
(c) Normal system test (functioning, etc.)
(d) (Low Fluid level tests)
(e) Emergency operations
(f) Time of operation

Flight Tests

(a) Pre-taxi-check
(b) Taxi tests - (i) normal system
(ii) emergency system
(c) Operation in flight:
(i) 2,000 feet
(ii) operational ceiling (at end of a simulated mission, or at least at end of 1/2 hour at altitude)

I flight test peak pressures
II Temperatures
III time of operations
IV drag brakes
V (reservoir levels)
VI possible malfunctions
VII emergency system operation
VIII auxiliary systems

CHAPTER 6 - DATA REQUIRED

6.1 General

1. Complete report covering installation, maintenance, servicing and inspection of all components.

2. Complete log of each component (flight time, snags, etc.).

3. Complete report coverall all engineering aspects of taxi and flight tests of the basic system and sub-systems, including typical records for assessment of:

a) pressures	-	nominal, peak or surge, max. rate of increase
b) temperatures	-	stabilized temperatures, maximum rate of change
c) operation times	-	half cycle times and sequences
d) emergency system operation	-	

6.2 Instrumentation - Utility Hydraulics

Measurement - Pressure	Range	Accuracy	Resolution	Method of Interpretation			
				Visual during flt.	Trace (scan)	Auto. Anal.	Remarks
Pressure hydraulic pump: inlet outlet return seal drain u/c supply	8000 psi						
Undercarriage jacks (3 off): supply return							
Undercarriage doors - main jacks - 6 off-return-supply locks -10 off-return-supply Undercarriage doors - nose jacks - 1 off supply return locks - 2 off supply return							
Dive brakes - supply return							
Brakes - normal supply - emerg. supply - return							

6.2 (cont'd)

Measurement - Pressure	Range	Accuracy	Resolution	Method of Interpretation: Visual during flt.	Trace (scan)	Automat. Analysis	Remarks
Nosewheel steering & Shimmy damper: - supply - return - system pressure							Capable of sensing shimmy
Compensator circuit: pressure							
Armament package							See Park K
Afterburner							Awaiting eng. information
Shock strut recuperation							Hydraulics deleted
Undercarriage emergency system : pneumatic supply							
Brake emergency system; supply							

6.2 (cont'd)

Measurement - Temperature	Range	Accuracy	Resolution	Method of Interpretation: Visual during flt.	Trace (scan)	Autom. Analy.	Remarks
Pump: inlet outlet return body							
Heat exchanger: inlet outlet							
Brakes- normal inlet emerg. inlet return							
Undercarriage-gear body; u/c inlet outlet emerg. hose ambient							
Dive brakes - inlet outlet							
Nosewheel steering and shimmy damper - system							
Compensator circuit: inlet outlet							
Armament package							See Part K
Afterburner							
Shock strut recuperation							Hydraulics deleted

6.2 (cont'd)

Measurement- Operating times and Positions	Range	Accuracy	Resolution	Method of Interpretation			Remarks
				Visual Dur'g Flt	Trace (scan)	Autom. Analy.	
Undercarriage and doors: Selection signal door locks signals leg lock signals sequence measurements							(camera?)
Dive Brakes: Dive brake selection sign. Dive brake position							
Nosewheel steering and Shimmy Damping Relative motion between wheel and leg Pilot control position							
Compensator Piston position							
Doors deflectors lock signals							
Measurement - Emergency Systems							
Undercarriage							
Brakes							
REFERENCE VARIABLES							
RPM gear box ASI Alt. OAT							

CHAPTER 7 - REPORTS

CHAPTER 8 - REFERENCES

Avrocan Specifications

E210	Accumulators - hydraulic pressure air loaded
E232	Coupling, hydraulic pressure
2247	Hydraulic Sight gauge
E254	Liquid spring and recuperator system for nose
E249	Filter hydraulic replaceable micronic element, line type H.P., 40U.S. GPM
E235	Filter hydraulic swivelling Line type, replaceable micronic element
E257	Valve for liquid spring recuperator
E258	Separator and cylinder for liquid spring recuperator

Drawings

7-1900-2	Schematic - hydraulic - utility pump circuit and 1500 p.s.i. circuit
7-1900-3	Landing gear sub-system
7-1900-4	Speed brakes sub-system
7-1900-5	Nosewheel steering sub-system
7-1900-6	Normal and emergency wheel brakes sub-system
7-1900-7	Armament package sub-system
?	Afterburner shroud emergency retracter
?	Shock strut recuperation

Reports

Avro Report Number	
7-0119-6	Description of Basic Utility System (D. Buckingham, Jan. 4/55)
7-1900-1	Description of Nose Wheel Steering System (D. Buckingham, Jan.17/55)
7-1900-2	Wheel Brake Sub System (D. Buckingham, Jan. 18/55)
7-0119-5	Undercarriage System (D. Buckingham)

CHAPTER 8 (cont'd)

Letters

6382/22/J - CF-105 Flight Test Program (To J. Morris from F. Brame)

6209/09/J - Undercarriage Air loads (including load report P/loads/37)
Nov.12/54

Brochures

Vickers Incorp. Bulletin A 5202 - New Vickers EDV Pump (Library reference V-9-3-1)

Specifications

MIL-H-5440 Hydraulic systems - Design installation and tests of Aircraft.

MIL-T-5522 Test Procedure for Aircraft Hydraulic Systems

AVR-ADS-105-1 Design Specification for Fighter Airplane CF105 MK 1

ARDCM-80 Handbook of Instructions for Aircraft Designers.

R.T.'s

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

1. Purpose of Flight Tests

1.1 The primary purpose of flight tests for the undercarriage and brake parachute installations will be to demonstrate that the design is adequate for the operational requirements of the airplane.

1.2 Secondary purposes of the flight tests will be to obtain quantitative data which may be used to verify that design assumptions were reasonable and to estimate the service life of components, and to lay down practical maintenance schedules.

2.0 Description

2.1 General

The undercarriage is a fully retractable tricycle gear with twin nose wheels and two-wheel bogie-type main gear. The nosewheels retract forward into a compartment below the pilot's cockpit and the main gear folds inward and forward into the wing. Provision is made for power steering of the nosewheel and anti-skid operation of the brake on each main wheel.

2.2 Operation and Indication

Details of the undercarriage operation are outlined on drawing 7-0119-3 and in technical department report 7-0119-5, which is attached. A three-position selector (up, down, emergency down) is mounted ahead of the left console in the pilot's cockpit. A light in the handle comes on when

(A) selection has been made but operation has not been completed

(B) throttles are closed and gear is not locked down.

In addition, undercarriage position indicators are provided to show,

(A) gear locked down

(B) doors locked up

(C) gear not locked

and an emergency retraction (ground override) button is installed, although the main gear may not retract if the aircraft is rolling forward.

The gear is retracted hydraulically by fluid at 4,000 p.s.i. pressure from the utility hydraulic system. Reducing valves are fitted to give --- p.s.i. for nosewheel steering and 1500 p.s.i. for braking. Emergency lowering of the gear is accomplished through a 3,000 p.si. pneumatic system which operates the gear and doors simultaneously.

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

2.3 Main Gear

2.4 Nose Gear

2.5 Nose Wheel Steering

2.6 Wheels and Brakes

2.7 Brake Parachute

2.8 Tail Bumper

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

3.0 Design Data Summary

3.1 Weight

Normal landing weight	W_{LN}	47,000 lbs
Maximum " "	$W_{L\ max}$	55,000 "
Minimum " "	$W_{L\ min}$	37,600 "
Operational take-off wt.	W_{TO}	55,000 "
Maximum take-off wt.	$W_{T\ max}$	65,000 "

3.2 Speed

Landing	132 K	at W_{LN}
	142 K	at $W_{L\ max}$
Retraction and Extension	250 K	
Ground Rolling	200 MPH	= 174 K

3.3 Rate of descent at touchdown

9 ft/sec proof at W_{LN}
5 ft/sec " " $W_{L\ max}$

3.4 Retraction and Extension Times

3.5 Temperature Limit

Operating range	-65°F to + 160°F
Max. soaking temperature	260°F for 20 minutes

3.6 Minimum Radius of Turn on Ground

Approximately 30' radius to center line of aircraft, since nosewheel is limited to ± 55° angular travel.

3.7 Tires (Tubeless)

Maximum ground rolling speed: 200 MPH
= 174 K

3.9 Ground Clearance (cont'd)

With main legs fully compressed and main wheel tires flat:

(1) Tail bumper limits and if fully compressed $\beta = 15.2^{\circ}$

(2) Tail bumper limits and if fully extended $\beta = 13.2^{\circ}$

Case (B)

With main legs fully extended and aft main wheel tire just in ground contact:

(1) If exhaust nozzle closed, tail bumper limits and if fully compressed $\beta = 22.7^{\circ}$

(2) If exhaust nozzle fully open and tail bumper not fully extended, nozzle limits and $\beta = 21.2^{\circ}$

(3) Tail bumper limits if fully extended and $\beta = 20.5^{\circ}$.

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

4.0 Engineering Program (time and purpose)

Design

Bench and Rig Tests

Mock-ups

Pre-flight tests

Flight tests

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

5.0 Flight Tests Required

5.1 Pre-flight

(A) Clearance for operation and retraction.

(B) Functioning - retraction and locking
indication
nosewheel steering
brakes
parachute

(C) Servicing - access
removal and installation
adjusting
snags
towing
jacking (flat tires and oleos)

(D) Vibration checks

(E) Emergency Systems
- undercarriage extension
brakes.

5.2 Taxying

Brakes
Parachute
steering
shimmy
flat tires
anti-skid functioning
undercarriage walking

5.3 Flight

Take-off - speeds to lift wheels
directional control
shimmy
weight
retraction times
asymmetric flight - gear down

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

5.3 Flight (cont'd)

Landing - gear lowering times
landing speeds - vertical
- horizontal
speed to lower nosewheel
parachute operation
braking - anti-skid
shimmy
icy runway
temperatures

5.4 In flight

- door deflections under high speed, 'g'
- clearance (main gear to upper wing structure).

6.0

6.1 Data Required - Undercarriage

1. Complete report covering installation, maintenance, servicing and inspection of all components.

2. Complete report covering history of each component -- aircraft, flight, take-off weight, landing weights, severity.

3. Complete report covering engineering and aircraft handling aspects, including typical records for assessment of:

shimmy	-	tendency, damping; effect of load and temperature.
steering	-	static and dynamic; effect of oleo inflation, temperature, etc.
oleos	-	behaviour with static load and temperature
	-	deflections due to engine run-up, landing, braking
brakes	-	torque, energy absorbtion, anti-skid operation
stowage	-	interference or clearance with structure under 'g' deflection of doors (open and closed positions)
parachute	-	opening time, effect on drag and handling.
controls & indications	-	pilot's assessment (operating times)

6.2 CF-105 Flight Test Instrumentation

Temperature measurements for undercarriage components. Record temperatures at the following locations at 30-second intervals (max) throughout flight simulating combat mission (commutate on 1 channel if desired).

Item	No. Required
1. Main gear door jacks - case temp.at inlets	2 (1 side of a/c)
2. Main gear retraction jack " " " "	2 (1 side of a/c)
3. Nose gear door jack " " " "	2
4. Nose gear " " " " " "	2
5. Main gear door & uplock jacks " " "	4 (1 side of a/c)
6. Nose " " " " " " " "	2
7. Nose Oleo " " " "	1
8. Main " " " " "	1
9. U/C selector valve " " " "	1
10 Brake control valve " " " "	1
11 Tail bumper jack " " " "	2
12 Nose wheel bay-air temp	1
13 Main " " " "	1
	22

RECORDED MEASUREMENTS FOR UNDERCARRIAGE TESTS

No.	Measurement	Range	Accuracy	Resolution	Method of Interpretation: Visual (during flt)	Method of Interpretation: Trace scan	Method of Interpretation: Automatic Analysis	Notes
1	Brake pressure #1 wheel	0-1500 psi	±50 psi	±25 psi		✓		To assess anti-skid operation
2	" " #2 "					✓		
3	" " #3 "					✓		
4	" " #4 "					✓		
5	Brake system pressure - P	0-1500 psi	"	"		✓		To assess braking technique
6	" " " - S					✓		
7	Brake control valve inlet pressure	0-1500 psi	"	"		✓		To check pressure available
8	Main wheel rotational speed	0-2800 rpm	±100 rpm	±50 rpm		✓		To correlate angular acceleration with anti-skid operation & to assess a/c accelerat-ion & deceleration.
9	" " "	"				✓		
10	" " "	"				✓		
11	" " "	"				✓		
12	Anti-skid function signals	Not known	Not k'n.			✓		
13	" " "	" "	" "			✓		
14	" " "	" "	" "			✓		
15	" " "	" "	" "			✓		
16	Oleo position - P	15.5"	± 0.5"	± 0.25"		✓		To correlate anti-skid operation with wt. on wheels.
17	" " - S					✓		
18	Bogie angle - P	From Geometry	± 5%	± 2%		✓		
19	" " - S					✓		
20	Longitudinal Acc'n at Bogie pivot	± 75'g'	± 3'g'	± 1.5'g'		✓		To assess undercarriage walking
21	" " " "	"	"	"		✓		
22	Nosewheel Steering System pressure	0-3000 psi	±100 psi	±50 psi		✓		
23	Nosewheel angle	± 55°	± 2°	± 1°		✓		To assess steering and shimmy
24	Front rudder quadrant position	± 20°	± 1°	± 0.5°		✓		To assess steering
25	Brake plate Temperature					✓		To check max. Temp. when a/c stops & rate of cooling
26	" " "					✓		
27	" " "					✓		
28	" " "					✓		
29	Longitudinal accelerat'n	± 0.8'g'	±.008'g'	±.004'g'		✓		To check take-off performance and landing

No.	Measurement	Range	Accuracy	Resolution	Method of Interpretation: Visual (during flt)	Trace scan	Automatic Analysis	Notes
30	Brake parachute release signal	--	----	----		√		To check release time
31	Camera coding signals	--	----	----		√		
32	Temperatures (see list)	-65 to +250°F	± 5°	± 3°		√		To verify design conditions

Miscellaneous Items

1. Clearance between main gear and wing upper skin at up-locks for various 'g' conditions. -- check after structural integrity flights.

2. Camera installations -- to assess undercarriage walking, rates of retraction and extension, vibration and deflection of doors open in normal and yawed flight, door deflection at high speeds and 'g' - parachute operation.

3. Tail bumper clearance.

7.0 Final Reports

- Report by specialist or design engineer
- Maintenance and servicing instructions
- Design certificate
- Pilot's notes.

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

8.0 References

8.1 Specification s

Avrocan	E-245,	Nose landing gear
"	E-252	Nose wheel tires
"	E-211	Main landing gear
"	E-228	Wheel and brake assemblies
"	E-251	Main wheel tires
"	E-254	Liquid springs and recuperator system for nose gear
"	E-255	Valve, nose wheel steering control
"	E-256	Cylinder, nose wheel steering
"	E-257	Valve, liquid spring recuperator
"	E-258	Separator and cylinder, liquid spring recuperator.
"	P-4-1	Castings; classification and inspection of.
AVR-ADS-105/1		Design Specification for Fighter Airplane, CF-105, Mark 1.

MIL-S-8552	Strut, Aircraft shock absorber
MIL-C-5041	Casings; aircraft pneumatic tires
MIL-W-5013B	Wheel and brake assemblies, aircraft
MIL-T-5522B	Test procedure for aircraft hydraulic and pneumatic system.

8.2 Drawings

A.V. Roe Can.:

7-4391-1	Nose landing gear geometry
7-0119-3	Schematic - landing gear hydraulics
7-0111-0024	Schematic - electrics
7-4291-1	G.A. - nose landing gear
7-4291-2	Assembly - liquid springs
7-1991-11	Assembly - retraction jack
7-4427-3	G.A. - towing arrangements
7-0162-12	Geometry - inner wing forward portion
7-0162-84	Geometry of main landing gear - stowed
7-0162-85	Down geometry of landing gear
7-0162-86	Overall geometry of main landing gear
7-0162-87	Structural clearances-landing gear bay
7-0162-91	Installation and removal of main landing gear

8.3 Reports

A.V. Roe Technical Reports:

7-0590-2006 - Preliminary Design Particulars - Main and Nose Undercarriage.

7-0590-2007 - C105 Wheels and Brakes; Specification Particulars

7-0590-2009 - Preliminary Design Particulars for Nose Landing Gear

7-0119-5 - Landing Gear Operation

7-0119-6 - Description of Basic Utility System

07-1900-1 - Description of Nose Wheel Steering System

07-1900-2 - Description of Wheel Brakes - Sub-system

C O P Y

Report Number 07-1900-1
Prepared by D. Buckingham
Date: 17 Jan/55
Subject: Description of Nose Wheel Steering System
Aircraft CF105

Reference: Schematic - Hydraulic Utility Nose Wheel Steering Sub-system 7-0119-5, Issue 3 dated 17 Jan/55 (to be superseded by 7-1900-5 later)

Nose wheel steering is accomplished by a hydraulic jack mounted on the bottom of the nose wheel strut. The jack is controlled by a follow-up valve mechanically linked to the pilot's rudder pedals. To obtain steering it is necessary that the nose gear scissors micro-switch be actuated by weight o n the nose gear, then the pilot must depress the steering selector button on his stick grip to open the solenoid valve which sends high pressure fluid to the valve and thence to the jack in response to rudder pedal movements.

Normally, when steering is not being used, t he jack serves as a shimmy damper during taxying and take-off runs. Presuare is shut off and both sides of the valve are connected to return at the solenoid selector valve to take care of thermal volume changes.

To save plumbing, the pressure for the steering unit is drawn off the "nose gear down" pressure line in the nose wheel bay. This line has pressure on it at all times on the ground (with the starboard engine running). Nose gear steering return cannot be connected to the "nose gear up" pressure line in the nose gear bay as it is pressurized in the "UP" selection. Instead the nose gear steering return line must be carried right back into the duct bay.

C O P Y

CF-105 Aircraft
Report No. 07-1900-2
Prepared by D. Buckingham
Date: 18 January, 1955
Subject: Wheel Brakes Sub System (Utility Hydraulics)
(Dwg 7-1900-6 to be released later)

Braking is provided by the action on the rudder pedals which is carried back to the brake control valves in the duct bay by cable runs. At the valve two master brake cylinders are actuated -- one the normal system and the other the emergency system which is not effective due to cutoff of the emergency braking pressure. Failure of normal system pressure automatically activates the emergency system so that braking is available as soon as the pilot depresses the braking pedal.

During retraction of the gear the brakes are automatically applied by an electric solenoid valve in the electric circuit of the "UP" solenoid on the landing gear selector valve. This applies and maintains braking on the main wheels until all gear and doors are up and locked. In the brake valve block the normal brake sylinder is by-passed and 1500 p.s.i. is applied directly into the brake lines.

The automatic switchover to emergency braking on failure of the normal system is accomplished by a spring loaded piston which is held in normal position by normal pressure of 4000 p.s.i. When this pressure falls off the spring moves the piston to the "emergency braking on" position porting emergency braking fluid at 1500 p.s.i. into the emergency brake cylinder and out again to the brakes themselves.

An anti-skid device will be fitted on each of the main wheels. This will consist of a detector and a relief valve which releases brake pressure until wheel speed builds up again beyond the skidding speed. In some of the systems now being examined, these two parts are combined in one body devoid of any electrical connections. Other versions with electrical type skid detectors usually in the wheel hub, have solenoid operated relief valves located elsewhere in the brake lines. One advantage of the electrical versions is that braking on the same tire on the opposite side of the aircraft can be released at the same time thus avoiding the ground loop hazards of unsymmetrical braking.

The anti-skid return line is used for emergency braking with the anti-skid unit relief valve protected by a check valve. Emergency pressure, in the absence of any normal pressure, shifts the shuttle valve and gives straight proportional braking without anti-skid operation.

The brakes are of the Goodyear disc type. They have to operate with higher system return pressures (50-130 p.s.i.) than is the usual case.

CF-105 - UNDERCARRIAGE AND BRAKE PARACHUTE

Undercarriage Sketches

Sketch of legs and door schematics

Brake system

Emergency system

UNCLASSIFIED

S U M M A R Y

A programme of flight tests is presented for the CF-105 aircraft based on nine active aircraft. Since J-67 engines will not be available in quantity at the start of the programme, the temporary installation of a smaller engine (J-57) has been considered. Because of this and since no allowance has been made for development work, it is expected that the test programme will continue until the middle of 1959.

PRE J-75!

W. Kuzyk

2.0 INDEX

INTRODUCTION

A preliminary flight test programme for the CF-105 all-weather, supersonic fighter has been prepared with the following objectives in mind:

1. To demonstrate that the aircraft meets the requirements of R.C.A.F. Specification AIR-7-4.
2. To obtain flight data which might be required to finalize the design of the aircraft or its components for production purposes.
3. To obtain quantitative data about the aircraft and its systems in order to release it for squadron service.

4 FLIGHT TEST PROGRAMME

4.1. General

The test programme is shown in graphical form in Fig. 1 on page__________. It is noted that nine aircraft are used for testing and development work by A.V. Roe and Hughes Aircraft Co., and that, since J-67 engines probably will not be available in quantity as the aircraft are built, smaller engines will be installed initially in all but two aircraft. It is assumed that Pratt and Whitney J-57 engines will be used and that these aircraft will be limited to subsonic testing until J-67 engines are available.

While considerable testing can be done with these aircraft and engines, the date for completing the overall test programme will probably slip by six to eight months for two reasons:

1. Additional problems due to a second engine installation.
2. Delay in solving development problems due to the lack of supersonic back-up aircraft.

The test programme consists of three phases as below:-

(1) Probing tests in which the speed and height ranges of the aircraft are investigated gradually. During this phase of testing, the auto-stabilization system must be set up and finalized and the behaviour of the basic aircraft structure and systems must be monitored.

(2) Follow-up Tests, in which the detailed investigations of aircraft handling, performance, systems operation, and structural integrity are carried out.

(3) Operational Systems Tests, during which the armament, communications, fire-control, automatic flight control, and all weather phases are completed.

The tests required for each system are discussed below, with allowances for the temporary J-57 engine installation.

4.2 AERODYNAMIC PROBING

Following the initial functioning checks of the first aircraft, the first flight tests will be to determine the stability and control characteristics of the aircraft. A series of flights will be required to measure the damping characteristics about all three axes with automatic stabilization throughout the speed and height range of the aircraft. Some tests will also be required without the automatic stabilization system working.

It is anticipated that the first three months of flying for the first aircraft will be needed to set-up and assess the automatic stabilization system over the flight range from sea level to 40,000 ft. below M = .85. By comparison, sixteen flights were required over a two month period of time to clear the initial yaw damper installation on the CF-100 over the same speed and altitude range. Since this phase of the work is subsonic, smaller, more reliable engines than the J-67's could be fitted to the airframe during this period.

When the second aircraft becomes available, it should continue this phase of testing, gradually probing higher speeds and altitudes until the full flight range of the aircraft has been tested. Since systematic testing of certain aircraft utility systems will have to keep pace with the probing, progress will be slow, and it is anticipated that at least sixty flights and nine months time will be required to complete the programme.

4.2 AERODYNAMIC PROBING

Although these tests are primarily to provide a well-stabilized vehicle for further testing, considerable information will be obtained about the performance and handling characteristics at the same time.

4.3 HANDLING CHARACTERISTICS

Following the aerodynamic probing tests, a series of detailed handling trials will be required to assess the flying qualities of the aircraft and to obtain data for the Pilot's Notes. U.S.A.F. Specification #1815-B "Flying Qualities for Piloted Airplanes" has been reviewed as it would apply to the CF-105 aircraft and a preliminary estimate has been made for the flying time required to carry out this programme. This is summarized below:-

TEST	NUMBER OF FLIGHTS ALLOWED	
	SUBSONIC TESTS	SUPERSONIC TESTS
1. Dynamic Stability Tests	18	32
2. Static Longitudinal Stability	8	6
3. Elevator Power, Elevator Control	6	9
4. Effect of Air Brakes	2	
5. Lateral Control, Rates of Roll	4	4
6. Stalls, CL Max, Buffet Boundary	8	12
7. Asymmetric Power	4	2
8. Diving Tests	6	12
9. External Tank	3	
	59	77

Since some of the subsonic tests are affected by engine characteristics, ninety to 100 flights (13-14 months flying) would be required using J-67 engines, while about 60 flights (8 - 9 months flying) could be done using smaller engines.

4.4 PERFORMANCE TESTS

Performance tests will be required for the CF-105 aircraft to demonstrate its ability to meet the specification and to provide data for Pilot's Notes for the aircraft. While many useful data will be obtained during other tests, at least sixty six flights (ten months flying) will be required with the final air-craft and engine condigurations:

TEST	NUMBER OF FLIGHTS REQUIRED
1. Calibration of pitot, static, temperature, sideslip and angle of attack probes	5
2. Level speed and fuel consumption	
(a) A/C clean	12
(b) External Tank fitted	8
(c) Single Engine operation	7
3. Combat & Ferry Missions	6
4. Climb, Descent, Ceiling	6
5. Take-off, Landing (normal)	0
6. Take-off - engine failure	4
7. Acceleration and deceleration	10
8. Minimum Turning Radius at altitude	8
	66

4.5 AERODYNAMIC DEVELOPMENT

This cannot be programmed at this stage, but a standby aircraft should be available for detailed investigations and modification as required. Such items as intake duct studies, flutter, aeroelastic distortion, stabilization problems, and drag measurements might be included.

4.6 FUEL SYSTEM

Tests required to assess the fuel system include:

(a) ground rig tests

(b) prototype aircraft pre flight tests

(c) Flight tests (i) spot checks

(ii) systematic tests

The fuel system is relatively unorthodox and although much development and test work will have been completed before first flight, certain features will require in-flight checking, particularly since a number of important parameters such as temperatures and reference pressures are difficult to simulate or predict for ground rig tests.

The fuel transfer system, of which the pilot has no indication or control, is of particular interest since the resulting fuel load distribution governs c.g. travel. In conjunction with this, tank pressure regulation, collector tank level regulation and venting checks are advisable since rig tests can give only limited results. Since fuel is being used as coolant for both oil and engine, and fuel temperature limits are relatively severe, fuel temperature measurements are desirable. In addition, auxiliary tank tests and incidental checks of baffling, unusual altitudes, etc are required. Since allowable engine inlet fuel temperatures may be marginal for certain high Mach Number cases of extended time, fuel temperatures checks should be carried out during thermodynamic investigations.

4.6 FUEL SYSTEM (cont'd)

Spot checks of the above points should be made on each flight of the first few aircraft until a series of systematic tests can be completed to clear the system throughout the flight range. Program time required for systematic testing would be in the order of 14 flights. These flights are not necessarily consecutive but rather should they follow closely behind the aerodynamic probing. This scheduling is for test time only, any development work required as a result of the tests should be catered for by provision of a back up air-craft. In order that flight test time be kept to a minimum, it is important that close co-ordination and cross checking of design, rig tests, ground tests and flight tests be made in terms of program content as well as test results.

Flight test requirements as outlined in reference 1* are of very limited use since the fuel system is somewhat unconventional, however where applicable this report should be used as a guide.

It should be noted that if more than one type of engine is fitted to the aircraft, the proto-type pre-flight tests and in-flight spot checks will be required for each prototype.

4.6 FUEL SYSTEM (cont'd)

* Reference:- U.S.A.F. Memo report WCNEI-525-460
Test Procedure for Turbo Prop & Turbo Jet
Aircraft Power Plant Installations.

4.7 ENGINE INSTALLATION

Tests required to assess the engine installation include

(a) Ground rig tests

(b) protptype aircraft pre-flight tests

(c) flight tests - (i) spot checks

(ii) systematic tests

Engine Installation problems requiring test investigations include engine and afterburner cooling, throttle handling and response, lubrication, auxiliary drives, engine performance, afterburning operation, auxiliary long range tank functioning, engine de-icing, velocity distribution at the engine intake etc.

On intake - engine ground rig will provide much pre-flight data and subsequent development work should then be minimized. However in addition to the rig tests, certain of the problems

4.7 ENGINE INSTALLATION (cont'd)

particularly engine cooling, require pre-flight checking on the prototype aircraft.

During the initial flying of prototype aircraft, spot checks of engine and afterburner cooling etc will be required until systematic tests of the installation are carried out. These systematic investigations will require a program time allocation of approximately 20 flights. These flights are not necessarily consecutive but should carried out in phase with aerodynamic probing. In addition to these flights the systematic cooling checks should be continued during thermodynamic testing where high Mach numbers will be experienced for extended periods of time.

Auxiliary long range fuel tank checks will be required by the time the aircraft proposed for delivery to Hughes Aircraft are ready for ferry.

Since aircraft performance is of course dependent on engine performance which in turn depends on intake and cooling system characteristics, checks of these items will be required during aircraft performance testing.

Icing trials will be required before clearance of the aircraft to squadron use. However, since it does not appear feasible to allocate J67 aircraft time to this problem till the winter of 1958, this program will then extend into the spring of 1959.

Close liaison of flight test with design and rig testing is required throughout all phases to minimize flight test time.

4.7 ENGINE INSTALLATION (cont'd)

If more than one type of engine is installed in the aircraft, rig tests, pre-flight checks and in-flight spot checks will be required for each engine installation. Systematic investigations however would be limited to the J-67 installation only. Since the flight imes allocated are for testing only, any development work which may be required should be catered for by means of a back up aircraft.

Recommended test procedures of refere(1)* will be used as a guide but may not be sufficient or applicable in certain cases.

* Reference (1) - Test Procedure for Turbo Prop and Turbo Jet Aircraft Power Plant installations.
U.S.A.F. Memo Report - WCNEi-625-460

4.8 HYDRAULICS

The aircraft hydraulics consist of two basic systems:-

(a) Flyung Control System

(b) Utility System which is used to operate:

(i) Air brakes

(ii) U/C and Door Retraction

(iii) Brakes

(iv) Steering

(v) Armament

In addition to the two basic systems, oil to fuel and oil to air heat exchangers are provided which also provide cooling for gear box and constant speed unit fluids.

Testing of the hydraulics and heat exchangers will consist of:-

(a) ground rig tests

(b) pre-flight checks on prototype aircraft

(c) flight tests.

Control system hydraulic flight tests will be done in conjunction with Auto-stabilization and aircraft handling tests and there for no specific flight time has been allocated.

Utility system flight testing, other than routine checks both pre-flight and in-flight, will consist of a series of systematic tests to determine operating times, peak pressures, pump and fluid temperatures, emergency system functioning etc. in general accordance with reference (1).

4.8 HYDRAULICS (Cont'd)

Programme time allocation to complete these tests is in the order of seven flights not including armament system tests which are considered separately under armament.

Heat exchanger checks are required and initially should be considered as part of hydraulic, fuel and engine test programmes. Final checks, however should be made during thermodynamic tests where high Mach Numbers are experienced for extended periods of time.

If more than one type of engine is fitted to the aircraft, the amount of work required in addition to that detailed above would depend to a great extent on simularity of pumps gear boxes etc. installed.

Ref. (1) Test Procedure for aircraft Hydraulic and Pneumatic Systems - General Military Specification MIL-T-5522.

LOW PRESSURE PNEUMATICS

Low Pressure pneumatics, fed by engine compressor air, supply air for air conditioning, cockpit pressurization, canopy seal, anti-g suits, and fuel transfer system pressurization. Of these, the air conditioning and cockpit pressurization are of most interest in test programming, (other than fuel tank pressurization which is considered under the fuel system).

Air conditioning and pressurization tests will include:-

(a) rig tests

(b) pre-flight tests

(c) flight tests

Flight checks of a preliminary nature to check functioning of equipment will be incidental to initial flying programmes. Systematic testing of the system throughout the flight range will be required concurrent with aerodynamic probing although not necessarily on the same aircraft.

This systematic test programme, including checks of flow and temperatures to all air conditioned compartments and equipment, for typical as well as critical cases, will require about 14 flights.

Aircraft fitted with engines other than J-67 are probably useful for equipment checking or development but systematic tests will require a J-67 aircraft.

Certain electronic system, cooling checks may be carried out on the aircraft by Hughes in conjunction with their test programme, however, finalized systematic testing to include critical cases will probably require testing on the first aircraft at Avro fitted with production type electronic system.

LOW PRESSURE PNEUMATICS

Armament bay air conditioning, beyond the checking of supply, will be carried out in conjunction with armament testing.

4.10 ELECTRICAL SYSTEM

Tests for the electrical system will consist of:-

(1) Mock-up Tests

(2) Pre-flight ground tests

(3) Flight Tests

Flight tests will consist primarily of functioning and cooling checks of electrical equipment in the aircraft. Since some operational equipment will not be available until late in the test programme, dummy loads will have to be substituted in order to assess the power supplies and controls. Electrical system checks will require seven hours of the flying listed under "Mechanical Systems Probing and Development", with J-67 engines.

Additional checks will be required on an aircraft with J-57 engines.

4.11 STRUCTURAL INTEGRITY

The C-105 Structural Integrity Flight Tests will be preceded by extensive structural ground testing, ~~hence~~ and the main purpose of flight tests will ~~be~~ to demonstrate the flight envelope. ~~It is considered~~ ~~check the load distributions obtained in flight with ground test data and subsequently compare the resulting airloads~~ In addition it is considered desireable to compare in flight air loads with the estimated values used for ground testing.

The initial flight testing will be controlled by the progress of Auto-Stabilization tests in the subsonic region. However every effort will be made to clear the CF-105 as a test vehicle throughout the Subsonic portion of the flight envelope during the first five months of flying. Following this spot check will be carried out during aerodynamic probing in order to extend the g limitations in the transonic and supersonic regions at an early date, so that a supersonic test vehicle will be available for preliminary probing flight on the Hughes Falcon and Douglas Sparrow missile packages. In general a limited structural integrity test will be integrated with the general flight test programme prior to extensive Thermodynamic and Structural Integrity testing scheduled during the last nine months of testing on aircraft number 5.

Aircraft numbers 1, 2, 3, and 7 will be strain gauged to record data during the incidental and major structural integrity checks. A brief resumé of the flight test programme is shown in the following table:

ITEM	TEST	AIRCRAFT	FLYING TIME HOURS
(a)	Structural Integrity for subsonic flight envelope(to be integrated with subsonic probing)	#1	14
(b)	Structural Integrity for transonic & supersonic flight envelope up to M = 1.8 (integrated with aerodynamic probing)*	#2	41
(c)	Structural Integrity and thermodynamic (aerodynamic heating) up to M = 2.0 throughout entire flight envelope	#5	63
(c)	Back up for structural integrity and thermodynamic	#3	

4.12 C-105 ARMAMENT PROGRAMME

4.12.1 Hughes Falcon - GAR-1A, GAR-1C Missiles

SUMMARY

The GAR-1A and GAR-1C XXXXXX constitute the supersonic launched semi active micro wave homer, and the supersonic launched infra red passive homer. It is anticipated that the external configurations of both missiles to be the same, and hence while programming for the more critical GAR-1C (IR) missile sufficient data would be obtained for the more flexible GAR-1A (MW) missile.

The C-105 Armament Flight Test Programme is to be preceded by extensive ground and C-100 rig flight tests. Briefly this constitues:

(1) Mock-up of one missile bay

(2) Functional mock-up of one missile bay

(3) Mock-up of armament package

(4) Actuating mechanism Test Rig (CF-100 Mk.4)

(5) CF-105 Armament Installation Tests

(6) Wined Tunnel Trajectory

This will constitute the bulk of development work on the Hughes Falcon Missile Pack.

The proposed CF105 Armament Falcon Flight Test Programme, for which an allotment of two CF-105's will be necessary is shown in the following table:-

4.12 CONTINUED

ITEM	TEST	FLIGHT TIME	EXPENDED LIVE MISSILE LESS GUIDANCE	DUMMY MISSILES
(a)	Subsonic	24	18	Nil
(b)	Transonic	26	18	Nil
(c)	Supersonic	46	18	Nil
(d)	Missile Trajectory & Angle of Attack	18	88	Nil
(e)	Missile Jettison	12	Nil	48
	TOTAL	126	142	48

This Test Programme is designed essentially to determine:-

(1) Handling characteristics of the aeroplane during the firing cycle, and "hang fire" positions.

(ii) The strength stiffness, and functioning of missile package.

(iii) Effect of buffet, flutter on doors.

(iv) Blast and air pressures on doors and surrounding structure.

(v) Armament Bay Temperature History throughout entire flights, i.e. before engine start to after engine stop. Hydraulic temperatures and pressures.

(vi) Missile launchings including trajectories and interference effects.

(vii) Missile Jettison Programme.

which with completion of the Hughes MX 1179 Fire Control System will make available an aircraft weapon combination for a system evaluation at Cold Lake.

DEVELOPMENT OF FALCON MISSILE PACK

The CF-105 Armament Flight Tests are to be preceded by an extensive development programme on the Hughes Falcon Installation. Briefly this development programme would consist of:-

4.12 CONTINUED

(1) Mock-up on one missile bay, on which proposed changes will be tried before being incorporated in any other rig or drawing.

(2) Functional Mock-up of One Missile Bay, which will be of metal construction. Tests will be conducted to measure hydraulic pressures and missile loads during extensions. In general the basic design will be tested.

(3) Mock-up of Armament Package - This mock-up will include a full compliment of dummy missiles. The object of this mock-up would be to check clearances, method of attachment to aircraft, assess the suitability of ground handling, and assist in design of ground handling equipment.

(4) Actuating Mechanism Test Rig - This will consist of a C-100 Mk.4 aircraft fitted with a single Falcon Missile Bay manufactured to CF-105 drawings. Initially ground functioning tests will be carried out preparatory to air functioning tests. On completion of these flight tests several missiles will be ground fired at the tunnel butts to determine blast and corrosive effects. Completing this will be a limited flight firing programme to correlate the ground and flight observations.

(5) CF-105 Armament Installation Tests - This specimen will consist of a package complete with mechanism, programming box and intervalometer, and be capable of ground firing. The tests will cover timing, sequencing, functioning, hoisting, servicing, arming, rigidity and mock-up installation checks. In general this rig will complete the development work prior to releasing drawings for manufacture.

The forgoing programme is expected to yield a fully developed Falcon Missile Package for installation in the CF-105. Assuming that all the flight conditions have been properly simulated and covered in ground and CF-100 rig tests the C-105 Armament Flight Test Programme will

4.12 CONTINUED

essentially be a "Test Programme" and not a development one. It is felt however that some provision should be made to allow for development work. The exact simulation of air loads, and effect of "hang-fire" on stability would be difficult to predict. In short it is recommended that a back up aircraft be allotted for armament tests to handle any development problems that would appear.

In addition some wind tunnel tests, are planned to assist in the aerodynamics of the Missile Pack as utilized in the CF-105. It is expected that the results of such tests will be known and analysed prior to actual flight testing of the Falcon Missile Pack in the CF-105.

(6) C-105 Wind Tunnel Armament Testing

A brief Wind Tunnel Test Programme will be carried out to determine the effect of firing cycle on Handling, Jettison cases, and missile trajectory data.

FLIGHT TESTING THE FALCON MISSILE PACK

The purpose of this programme will be to clear the Falcon Missile Pack throughout the required flight range and also to provide Hughes Aircraft with Missile Trajectory, angle of attack and other data necessary for the successful completion of the MX1179 Fire Control System. Following this will be the evaluation the aircraft/weapon combination probably to take place at Cold Lake Alberta.

TEST PROGRAMME

In order to proceed systematically and with caution the Armament Flight Test Programme will be divided into five stages of testing, i.e.

4.12 <u>CONTINUED</u>

(a) Subsonic $M \ngtr .85$
(b) Transonic $M \ngtr 1.2$
(c) Supersonic $M \ngtr 2.0$
(d) Missile trajectory + angle of attack
(e) Missile Jettison

With the first three stages being further subdivided into

(i) Handling and response

(ii) Structural Integrity and Functioning

(iii) Missile Trajectories

With respect to item (iii) Missile Trajectory, only a limited firing programme is planned during the subsonic and transonic stages of testing. As the flight testing progresses to the supersonic stage and results are favourable, a <u>comprehensive</u> Missile Trajectory programme will be undertaken covering the entire flight range in three stages, subsonic, transonic and supersonic. An all out effort will be made to clear the aeroplane to 720 kts. (Design Diving Speed) before this final phase of testing begins.

From the foregoing it is apparent that a large portion of armament testing can be carried out on a J-57 equipped CF-105, with provision for occassional supersonic "probing" on a J-67 equipped CF-105. This would result in economical utilization of the two J-67, CF-105's allotted for initial flight testing. The final stage of testing, i.e., Missile Trajectories in the Supersonic regions will be carried out on a J-67 equipped CF-105, which at this time may be in abondance.

DETAILED PROGRAM

(a) <u>SUBSONIC TESTS M $\ngtr$ .85, E.A.S. $\ngtr$ 520 KNOTS</u>

The entire subsonic test program is scheduled on a J57 powered CF 105. It will be during this stage of testing that the Falcon Missile Package design will tend to solidify. This initial period of testing will afford to the pilots familiarity with the flying and operating qualities of the aeroplane with respect to the Hughes Falcon Missile Pack.

ITEM	TEST	SPECIFIC DATA AND REMARKS	FLT. TIME HOURS	EXPEND MISSILES
1	Qualitative Handling and Response for firing cycle	Check auto stability "Hang fire" case	6	0
2	Structural Integrity (a) Missiles retracted g = 3, 5, 7.33 ϕ	Check door clearances & deflections; bay pressures; fuselage & pack deflections; stream gauges	2	0
	(b) Missiles Extended g = 3,5, 7.33 ϕ	On add'n link deflections, missile vibrations & drag, buffet. Armament bay temperatures before T.O. & a after engine shut down Hyd. pressures	2	0
3	Structural Integrity and functions g = 2.5, 4.0	During firing cycle & g application measure bay pressures & temperatures*, missile accelerations, and motor temp gas survey, Jack pressures missile position as program box, engine flame out & compressor stage. Blast Pressures missile trajectory, armament bay temp, Hyd. pressures & temp	10	8
4	Missile Trajectory - Limited launchup for initial function & trajectory	During(3) above missiles fired snugly. In add'n ½ & full salvo fired at 35,000ft engine flame-out &	4	10

ITEM	TEST	SPECIFIC DATA AND REMARKS	FLT TIME HOURS	EXPEND MISSILES
4 cont.		effects. Armament Bay Temperature. Hydraulic temp. press.		
		Totals	24	18

Δ actual & simulate
ϕ 7.33 G or max permissable at the time of programme

(b) TRANSONIC TESTS M ≯ 1.2 E.A.S. ≯ 720 KNOTS

The transonic tests will be conducted between M .8 - 1.2 and at speed up to 720 Knots. This region must be thoroughly explored by the pilot so that all characteristics of transonic flight during which the firing cycle may be operated are known. The "Hang Fire" condition especially presents an acute problem for transonic flight.

ITEM	TEST	SPECIFIC DATA AND REMARKS	FLIGHT TIME HOURS	EXPENDED MISSILES
1	Qualitative Handling and response during firing cycle	Check anti stabilization, Hang fire case included	6	0
2	Structural Integrity (a) Missiles Retracted g = 3,5, 7.33 ϕ	Check door clearance, deflection fuselage and pack deflections; strains	2	0
	(b) Missiles Extended g = 3,5, 7.33 ϕ	In addition:- link deflection missile accelerations, missile drag:door flutter, buffeting. Armament Bay Temp. Hydraulic temp & press.	2	0
3	Structural Integrity & Function g = 2.5, 4.0	During firing cycle & g application, measure arm bay pressures, gas concentration temperature; missile	12	8

ITEM	TEST	SPECIFIC DATA AND REMARKS	FLT TIME HOURS	EXPENDED MISSILES
3 cont.		& motor temperature, jack pressure missile position as program box, engine flame-out. Blast pressures, missile trajectory. Armament Bay Temp., Hyd temp & press.		
4	Missle Trajectory Limited Launching for function & trajectory	During (3) above missile fired snugly. In addition ½ and full salvo at 35,000' altitude for engine flame-outs & missile interference checks. Armament Bay temperatures.	4	10
		Total	26	18

A Actual & simulated
Φ 7.33 G or max permissable at time of program.

(c) SUPERSONIC TESTS M 2.0, E.A.S. 720 KNOTS

T This portion of testing will be mainly concerned with the Mach Number effects and the final clearance of the Structural Integrity and function up to the design dive speeds of the aeroplane. Aerodynamic heating will constitute one of the basic problems during this phase of flying. Accurate recordings of Armament Bay Temperatures will be taken throughout the operating cylce of the aeroplane to ~~xxxx~~ ensure that danger limit is never exceeded.

ITEM	TEST	SPECIFIC DATA AND REMARKS	FLT TIME HOURS	EXTENDED MISSILES
1	Qualitative Handling and response during firing cycle	Check auto stabilization Hang fire condition	10	0
2	Structural Integrity (a)Missile Retracted g = 3,5, 7.33 ɸ	Door deflections, fuselage & pack deflections, strains parting	4	0
	(b)Missile Extended g = 3,5,7.33 ɸ	In add'n link deflections missile accelerators, missile drag door flutter buffeting. Armament Bay temp, Hyd. temp & press.	4	0
3	Structural Integrity & function	During firing cycle; armament bay, press. temperature, gas survey; missile acceleration, motor temp jack pressure, dynamic loads engine flame out, missile position or program box, blast pressures, missile trajectory. Armament Bay temp., Hyd Temp and pressure	24	8
4	Missile Trajectory Limited Launching for function area trajectory	During(3) above missiles fired snugly, in add'n ½ and full salvo at 35,000' engine flame out, and missile interference checks. Armament bay temp.	4	10
		Total	46	18

△ Actual & simulated

ɸ 7.33 g or maximum permissable at time of program

(d) MISSILE TRAJECTORY & ANGLE OF ATTACK

M 2.0 E.A.S. 720 KNOTS

The purpose of this portion of the programme will be mainly to provide design data for the H x 1179 development at Hughes aircraft. In general the data required would be:

- Angle of attack
- Missile trajectory for jump factor
- Missile rocket motor temperature
- Aircraft flight parameters

A limited portion of the above data will be obtained during the test programme outlined in sections (a) (b) & (c), i.e. during the structural integrity & functioning tests. It is proposed to commence this missile trajectory programme on completion of the Supersonic portion of the above mentioned tests.

A tentative programme to supply missile trajectory data would be as follows:-

	MACH NUMBER						
ALTITUDE	.8	.85	1.0	1.2	1.5	1.7	2.0
10,000'	X	X		X			
20,000'							
30,000'		X△	X	X△	X	X△	X
40,000'							
50,000'		X		X		X	
60,000'							

Where "X" represents the flight conditions at which missiles would be fired singly 3 times each from the rear row. In addition three salvos of 4 would be fired to determine the missile interference at "△" conditions. A further schedule of firing only half the above combined number, from the front row would follow.

A limited number of missiles would be launched under g loading up up to 4.g.

The estimated missiles for air firing would be

Rear Row	Singly Launched	12 X 3 = 36
Rear Row	Salvo Launched	4 X 3 = 12
Front Row	Snugly launched	6 X 3 = 18
Front Row	Salvo Launched	2 X 3 = 6
Front & Rear	a cores(0.4)	16
	TOTALS	88 Missiles

Estimated flying time: 18 flights @ 1 hour = 18 hours

In addition and simultaneous with the air firing tests the angle of attack missile rocket motor temperature, and aircraft flight parameters will be recorded to provide integrater data for the development of the MX 1179 - Fire Control System .

Note: This missile trajectory program is designed to find the "trend" and check wind tunnel results, and hence only a limited number of firings as planned at this stage.

(e) Missile Jettison

The missile jettison programme is scheduled for this armament development & "airplane". This would permit the jettison & missile firing programmes to progress together which is a desirable feature in so much as a photographic and observation platform will be available.on the missile firing CF105.

It is assumed of course, that this program will be superceded by extrusive Wind Tunnel Testing, the critical cases would then be flight tests along with occassional check points to correlate Wind Tunnel with Flight Test results.

It is estimated that such a program, which is planned in detail on completion of Wind Tunnel Testing, would require approximately:-

12 Flights @ 1 hour/flights = 12 hours

and 48 dummy missiles

4.12.2 DOUGLAS SPARROW MISSILE

The Sparrow Missile Pack is being designed to contain a total of four supersonic launched active, Sparrow Missiles. The operation of this Missile is different from the Falcon in so much as the missile must be first lowered into firing position and then steered on to the target prior to launching. This missile must be directed to within 4° of the target prior to initial guidance which accurs about .2 seconds after launching.

Prior to comprehensive Flight Testing most of the development of the Sparrow Package will be completed in a comprehensive ground test programme which would be similar to that planned for the Hughes Falcon Missile Package. A brief resumé of the proposed Flight Test Programme, which is similar to that of the Hughes Falcon, is outlined in the Table shown below:

ITEM	TEST	FLIGHT TIME	EXPENDED LIVE MISSILES	DUMMY MISSILES
(a)	SUBSONIC	25	~~2~~ 10	Nil
	Handling and Response Structural Integrity & Stiffness Armament Bay Temperatures Air Loads Pressures Functioning Blast effects, buffet, flutter Missile Interference Trajectory Fire Control Data, Firing Cycle			
(b)	TRANSONIC	25	~~2~~ 10	Nil
	Handling & Response Structural Integrity & Stiffness Functioning Air Loads, Pressure Blast effects, buffet flutter Missile Interference, Trajectories Fire Control Data, Firing Cycle Armament Bay Temperature			
(c)	SUPERSONIC	50	~~4~~ ~~24~~ 10	Nil

(Continued on next page)

4.12.2 (Cont'd)

ITEM	TEST	EXPENDED FLIGHT TIME	LIVE MISSILES	DUMMY MISSILES
(c)	Handling & Response Structural Integrity & Stiffness Functioning Air Loads, Pressures Blast effect, buffet, flutter Missile Interference, Trajectories Fire Control Data, Firing Cycle Armament Bay Temperature			
(d)	MISSILE TRAJECTORY	6	50	Nil
(e)	Missile Jettison & Interference	6	Nil	24
	TOTAL	112	80	24

The initial missile trajectory programme is considerably less intensive than the Hughe Falcon, only 16 missiles being programmed. It is anticipated that extensive Wind Tunnel testing will precede the Flight Test programme and also considerable data will be available from the supplier of the Sparrow i.e. Douglas Aircraft. Hence the Missile Trajectory and Interference will be spot checked to determine the trend. The final analysis of this data will then determine the necessity of a further missile trajectory programme.

TELECOMMUNICATION AND NAVIGATION

Telecommunication and Navigation Testing will consist of:-

(a) Mock-up and bench tests.

(b) Development tests on a C-100 vehicle

(c) Ground Tests

(d) Flight Tests.

Much development work will be completed with mock-ups and C-100 testing, however a great deal of Telecommunication and Navigation flight testing will be required before aircraft are released for squadron use. Since the telecommunication and navigational equipment are part of the integrated electronic system it is proposed that the bulk of the test work be carried out by Hughes with certain tests and back up provided by Avro.

Although integrated systems will not be fitted to the initial aircraft, certain tests are required at an early date. These tests are to prove the communication and navigation facilities in these early aircraft and also since the integrated system and test programme are so dependent on antennae, coverage and range checks are required very early in the programme.

The preliminary testing required consists of elementary checks of the basic navigation and communication equipment i.e.: Radio Compass, Gyrosyn Compass, U.H.F. transmitter-receiver, and interphone. Test time, not necessarily all on one aircraft, will be in the order of 15 flights. Radar Altimeter and Antenna checks of U.H.F. Homer, Tacan, Ground to Air IFF, Air to Air IFF and Doppler all require early preliminary checking much of which can be done in conjunction with the primary navigation tests and during normal flying. Scheduling of these tests must be considered in conjunction with the overall test schedule for the integrated electronic system which is now being established with Hughes Aircraft.

TELECOMMUNICATION AND NAVIGATION

As a follow-up to the preliminary testing of Antennae and Navigation Equipment, final systematic testing of these items is required concurrent with the MX-1179 testing. Test time required is in the order of 6 to 8 months. No development time has been allocated. Development, if required, would probably be carried out on the Aerodynamic-Mechanical back-up aircraft.

Aircraft with engines of lower power than the J-67 would be quite suitable for the Navigation and Antenna checks.

4.14
4.15 Automatic Flight Control & Fire Control Systems

It is assumed that two aircraft will be sent to Hughes Aircraft Company for development of the fire control system and the automatic flight control systems. Flight investigations of the cooling conditions should be done by Hughes Aircraft Company during their development flying.

In addition a pre-production system is proposed for installation in an aircraft at A.V. Roe in mid 1958.

ALL WEATHER

Flight assessment of the 'ice worthiness' of the aircraft includes assessment of the aircraft's sensitivity to ice as well as the operation of its ice protection systems.

Although one winter of testing could be sufficient, depending primarily on weather encountered, two seasons are preferable. Testing in the winter of 1957 - 58 may have to be done with a J-57 aircraft depending of course on the priority of work on the J-67 aircraft at that time. In any event since engine ice worthiness is of prime importance final testing must be carried out on a J-67 aircraft.

In this region useful icing test seasons are approximately from November to April. Any clear air checks required before icing is encountered should be scheduled before the icing season.

5. COMMENTS

(1) This flight test programme has been drawn up to indicate the amount of test flying required by the company to clear the aircraft for squadron service. Minimum allowances have been made for development work and no time has been allocated to evaluation by the R.C.A.F. or U.S.A.F.

(2) This programme is based upon current estimates of aircraft and engine availability. Since some aircraft will be ready before J-67 engines are available for them, the effect of a temporary installation of a smaller engine (J-57) has been considered for subsonic test work.

While much useful flying can be done with the J-57 engines, it is felt that the main usefulness of these aircraft would be for modification and development tests as J-67 engines become available or were substituted from aircraft number two and three

(3) While six J-67 engines are allocated for the test programmes on aircraft #2 and 3, their service life is not known at the moment and production engines might be required during the programme. This would affect the engine change-over dates on two other aircraft.

6. RECOMMENDATION

(1) It is recommended that aircraft number 1, 2, 3, 5 be allocated to aerodynamic and mechanical systems testing and be instrumented in a similar manner so that their test programmes could be interchanged.

6. <u>RECOMMENDATIONS (Cont'd)</u>

(2) It is recommended that aircraft number 4, 8 be allocated to armament testing exclusively. Instrumentation for armament ~~testing~~ tests should be contained within the armament package so that tests could be carried out on other aircraft, if required.

(3) It is recommended that close attention be paid to instrumentation and data analysis requirements in order to keep the overall cost in terms of programme time, equipment, and analysis time to a minimum.
In this connection, this test programme should be reviewed in detail in order to specify (1) data required for computation and analysis work.
(2) data required to pinpoint deficiencies and permit quick, positive corrective action to be taken.