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PRELIMINARY DEVELOPMENT PHASE

OF CF-105 FALCON ARMAMENT

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PRELIMINARY DEVELOPMENT PHASE
OF CF-105 FALCON ARMAMENT

Introduction

The object of the present intensive effort on CF-105 Weapons Systems, is to achieve development such that CF-105 aircraft can be delivered to the RCAF in keeping with the proposed program for operational evaluation.

Armament has been given a high priority in the flight test program, and aircraft will be available for use as soon as the damping system has been developed to a stage where it will be safe to commence armament work.

A schedule of flight development for the weapons systems has been worked out, and from the amount of work to do and the time available, it is obvious that if we are to meet our objective, only a minimum amount of trouble can be accommodated.

It is therefore, essential that, prior to flight, we have developed the installation to as high a pitch as possible, using all reasonable means within our power. It is this preliminary development phase that is the subject of this note.

The Falcon Installation

The installation consists of 8 Falcon GAR-~~1A~~3 or GAR-~~1C~~4 missiles stowed in a removable package. These missiles are arranged in two rows of four, one row behind the other.

A pair of doors underneath each stowed missile form the skin line. These doors open to permit extension of the missile to the launching position, and are closed when the missile is fully extended to prevent the ingress of corrosive gases and to minimize buffet and aircraft pitch. Each missile has its own lowering mechanism separate from that of other missiles. Door actuation is mechanically linked to missile actuation. Hydraulic power is used for missile lowering and retraction.

In order to optimise kill probability and minimize aircraft disturbance, it is proposed to adopt an attack sequence which involves lowering the missiles to the firing position in approximately one half second.

Some Outstanding Design Problems

Consideration of the strength of the missile airframe and its attachments to the launcher shows that it is possible to extend it to the launching position in the desired time, without exceeding its strength limitations, provided the form of motion is independent of external conditions, e.g. air speed and aircraft manoeuvre.

Due to the limited space available within the fuselage, the missile fins are exceedingly close to the doors. When the doors are opened during missile lowering, air pressure, due to the air flow past them, will cause them to deflect. It is anticipated that this pressure will fluctuate erratically, due to breakdown of the flow. In order for the lowering mechanism to function, the mass of the doors must be kept low. In order to prevent the doors deflecting sufficiently to interfere with the missile fins, they must be very stiff. To prevent failure of the doors, due to vibration, they should work at low stress. These conditions can only coincide over a very small range.

The actuating mechanism we have adopted was chosen as the only practical one to accomplish lowering in the desired time, and because we believe that when it is fully developed it will give reliable service. The jack load will however, vary very considerably throughout the motion, due to variation in its mechanical advantage on the doors. A very accurate knowledge of door loading at various angles of opening, and under all conditions of flight, is necessary to correctly size the jack and the components of the mechanism.

The use of a simple storage type hydraulic system would be extremely heavy in this mechanism as the loads are at their highest when the available pressure is at its lowest. We are proposing a part storage part pump hydraulic system, which should be about 200 lbs. lighter than the simple storage system, but which will require considerable development. To optimise this system, it is obvious that correct jack sizing is extremely important.

Proposed Solutions to some of our outstanding Design Problems

1. Lowering Mechanism Control

The required form of motion is shown in Fig.I. Regardless of external conditions, this motion must be adhered to within very narrow limits. When a particular form of motion is required, it is a fairly common engineering solution to put this motion into a pilot shaft and slave the main mechanism to it. This is the solution we have adopted. In our case, a "Programming Box" rotates a pilot shaft through the same motion as we wish the rear shaft of the linkage to go through.

The principle of the "Programming Box" is outlined in Fig. II. It consists of an electric motor driving through a clutch on to a cam. The clutch is energized, when we wish motion to begin, causing the cam to rotate. The cam is profiled in such a manner as to cause the output shaft, which works on a cam follower, to perform the desired motion.

The main mechanism actuation is slaved to the pilot shaft, as shown in Fig. III. It will be seen that none of the mechanism loads feed back on to the pilot shaft, and that the rotation of this shaft can be independent of external conditions. The shaft is connected to the spool of a servo valve, which is mounted on the cylinder of the main actuating jack. Rotation of the input shaft causes the spool to move from the neutral position opening up pressure and return ports in such a manner as to cause the valve housing to move in a direction tending to close these ports. When the input shaft is moving slowly, the main mechanism shaft will lag it by only a small amount. In this condition, the port openings are just sufficient to permit the jack to follow the motion of the input shaft. When the input shaft is moving rapidly, the main mechanism will lag by a larger amount, so that the ports approach full opening, giving a less restricted path for a larger flow of oil. Again, the jack will follow the motion of the input shaft. The maximum lag amounts to the stroke of the servo valve, and is small compared with the total motion.

This mechanism control will ensure that the mechanism adheres to the desired motion within the limits of the valve lag necessary to give the desired oil flow.

Although the principle underlying this solution has been well tried out, it has not, to our knowledge, ever been used in a similar manner to the way in which we propose to use it. Our oil flows are extremely high, and our experience with similar flows on the CF-100 Rocket Pack indicates that performance is not predictable by conventional methods.

Servo valves, such as we are proposing to use, have a time constant which is a measure of the speed with which they cancel out an error signal. The proposed system is,of course, controlled by a magnitude of the error signal at the servo valve. Valves of the type we are proposing to use have a time constant which is of the same order as the total time we propose to take for the complete lowering cycle. This indicates that the control will be much more loose than we would like to see it, and hence, that motion will not be truly independent of external conditions. In order to make the system perform within the essential limits, a very considerable development program will be required, with much stringent testing under variable external conditions.

Because of the high flow rates, it is impractical to use hydraulic pumps to supply oil as required, and it is necessary to use a storage system. This means that the available pressure will vary throughout the lowering cycle. This, in turn, will show up as an additional complicating factor in the error signal at the valve.

The bugbear of all servo systems such as this, is achieving an acceptable balance between stability and response. In this application it is essential that we achieve a standard of response not normally required of such a system. This, in turn, means accepting a stability level which is just sufficient for our needs. The fact that our proposed solution is not truly irreversible will mean that the required stability level will have to be determined by extensive test under varying external conditions.

Above all, for the proposed system to work at all, it must be a master of the situation under all conditions, and must never lack power under any conditions, or the result will be disastrous.

2. Small Clearances

The solution to this problem is to build doors which are adequately strong and stiff and yet are of small mass. To do this we need a knowledge of the variation of hinge moment with angle of opening and of the severity of flow breakdown.

Work is proceeding on the optimum construction for these doors, but the actual article can only be the result of test under representative conditions.

3. Correct Jack Sizing

The jack has been sized on predicted loads. The size can be considerably out, because of the difficulty of predicting these loads, and because of the large magnifying effect of the linkage.

Once again, the optimum size can only be determined as a result of these under representative conditions.

4. Hydraulic Actuation

Considerable weight can be saved by using low pressure storage accumulators as a source of energy during those portions of the motion when jack loads are low, and switching to pumps for those portions of the motion when jack loads are high. It is essential that the change over be smooth and precise, or extremely high loads on the missile could result.

The successful development of this part of the installation will be the result of gradual development, starting with static operation and progressing to test under representative maximum conditions.

Development Media Available

The following development means can be made available:-

(1) Mock ups.

(2) Ground Test Rigs.

(3) Wind Tunnel Tests.

(4) Airborne Test Rigs.

(5) Rocket Propelled Sleds.

a) Mock-Ups

Wooden or metal mock-ups can be of great value in proving our basic operating principles, pointing out areas where workmanship is critical and in generally getting a "feel" for the problem.

Such a mock-up for a single Falcon missile has been built and has amply proved its worth. A single Sparrow mock-up is in an advanced stage of construction.

Because of its limited strength and equipment, it is of little use however, in sorting out problems where rapid motion is involved.

b) Ground Test Rig

A ground test rig is essential in finding the answers to many of the problems involved in successful mechanism design. It can be very fully instrumented with no space limitations for recording equipment, and it is the only opportunity the designer gets to see it functioning at close quarters. Ideas can be tried out without particular regard for safety. Relatively unlimited time is available and so, within the rig limitations, every aspect of operation can be investigated.

The limitations of a ground test rig are however, that external conditions (g, airspeed etc.) cannot be varied and cannot be successfully simulated.

Such a test rig for the Falcon installation will shortly be in operation at Malton.

c) Wind Tunnel

Wind tunnel tests can be used to obtain an indication of air loads and missile path after launch. Because of scale limitations, the results of these tests can be of a general nature only.

Wind tunnel tests of the CF-105 installation will shortly take place. It is anticipated that we shall obtain good values of the peak pressures within the bay, overall moments on the aircraft and missile path immediately after launch.

We shall not obtain any information on the severity of flow breakdown, or much information on detail loads which will be of use in mechanism development.

d) Airborne Test Rig

The airborne test rig is capable of carrying development to a stage which it is not possible to achieve with a ground test rig. The ideal airborne test rig would be one which has the same performance as the ultimate aircraft. In our case, this is not possible, but much can be done with one having lesser performance (say a CF-100).

With this rig, external conditions can be varied to a certain extent. (Air speed can be varied and g's pulled). Although maximum air loading cannot be achieved, the desirable progression from low to higher loading can be carried out, giving a basis for extrapolation. Due to the size of the test vehicle, quite comprehensive instrumentation can be incorporated. Considerable time is available for tests to be repeated several times under identical conditions, to ensure correlation. A good

Test Pilot, during such a program, can tell a lot which is of invaluable assistance, by the seat of his pants.

The limitations of such a test vehicle are however, that the all important maximum air flows cannot be achieved.

Such a test rig is planned for Falcon development.

e) Rocket Propelled Sled

The rocket propelled sled is capable of simulating the actual air loading which will be encountered in flight, and will therefore, be a very essential final stage to the preliminary development test program. It is not possible to simulate normal accelerations in conjunction with representative air loading.

Apart from the fact that normal accelerations cannot be applied to the specimen under test, there are some drawbacks to using the sled as a normal development device. It is considered that data gathering will have to be by telemetry, and that hence, the number of channels will have to be kept to a minimum. Additionally, because of the short length of track, only one function can be carried out on a run, causing development to be a necessarily slow process.

These considerations indicate that as much of the development program as possible should be carried out elsewhere under more suitable conditions, and that the sled should be used to cover those portions of the development which cannot be carried out elsewhere.

Sled tests are planned for Falcon development. It is worth noting that the lower the ambient temperature, in which the tests are conducted, the higher the Mach number which can be achieved without over stressing the specimen, and the more representative the test.

Outline of Proposed Test Program

a) Basic Data Gathering

This part of the program will be confined to wind tunnel tests. Here we shall get overall air loads, information on stability, and preliminary launch trajectory data. While this data is not complete, it will be of very considerable value in indicating the order of magnitude of the problem we face.

b) Mechanism Development

As we have indicated on earlier pages, the development of the mechanism is a very considerable task. To ensure peak development prior to flight in the CF-105, we propose that every possible means at our disposal shall be used. Initially, development will commence in a ground test rig, where the basic principles can be thoroughly investigated and modifications resulting from experience tried out. When the majority of the lessons to be learned from this rig have been digested, it is proposed to incorporate them in a mechanism for flight test in a CF-100. The proposed installation is outlined in Fig. IV. It is considered that the very extensive testing required with external loading variations can best be accomplished in this manner, with adequate space for instrumentation and time for testing. When this stage of the development is complete, we propose to continue testing on a rocket propelled sled. Here, operation under representative air loading can be carried out, and the effects of flow breakdown on door behaviour measured.

c) Missile Launching

Until CF-105s are available for flight test, it is considered that the wind tunnel will be the only source of trajectory data. However, data on the actual launch and the effects on the mechanism due to blast, to movement of centre of pressure, and to corrosion, must be obtained as early as possible. To this end, it is proposed to fire dummy missiles from the CF-100 test vehicles, which is the earliest occasion on which a suitable mechanism will be available. Further firings are proposed from the rocket propelled sled. If jettisoning should be confirmed as a requirement, preliminary jettison tests will be made to prove the mechanism as the opportunity arises.

d) Servicing, Arming and General Handling

In order to develop the installation as a whole, to a state where it is fit to be used by line personnel during flight test development work, we propose to construct two test armament packages which will be used for general handling development. The first of these packages will be fabricated as rapidly as possible, using wooden or welded construction, where necessary, to speed completion. The second package will be built to aircraft drawings.

With these packages, we will develop suitable ground handling equipment and generally modify the design to assist servicing and re-arming.

Time Schedule

It is estimated that we shall require three Falcon armament packages in May 1957 to undertake the flight development program. There is considerable work involved in constructing these first packages, as production dies for forgings etc. will not be available at this time. This will mean completing the major portion of our preliminary development program by May 1956, in order to complete the drawings by August.

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Our proposed program is based on a logical step-by-step method, in which Stage 1 is completed and the results incorporated in the Stage 2 specimen before Stage 2 is commenced, and so on. On this basis, our proposed program is:-

1. Single Missile Mock-Up. Working model of actuating linkage for 1 missile in wood. To be kept up to date throughout development program, incorporating changes as they are made.
   Mock-up constructed and up-to-date at present.

2. Single Missile Ground Test Rig. Working model of actuating linkage for 1 missile in metal. Capable of actuation at representative lowering speed.
   Constructed. Will be in full operation prior to the end of February 1955.

3. Wind Tunnel Tests. Model of aircraft with missiles attached and at various positions ahead of launchers.
   Tests commence in March 1955.

4. Full Package Mock-up. Package mock-up in metal and wood containing actuation gear for 8 missiles. Capable of going through attack sequence at slow speed.
   In manufacture - completion expected at end of April 1955.

5. Airborne Test Rig (CF-100) Single missile actuating linkage installed in fuselage of CF-100.
   Installation work to commence in March 1955.
   Completion expected ready for flight by May 1955.

6. Rocket Sled Test. Single missile actuating linkage installed on rocket propelled sled.

Proposed that tests commence in September 1955.

7. Full 8 Missile Package. Full package to preliminary aircraft drawings. Proposed completion date of specimen December 1955. Static firing tests January 1956. If practical, specimen to be fired on sled in March/April 1956.

It will be noted that the schedule is a tight one, and that hold ups, through any cause, will result in considerable disturbance to the progress of development.

Conclusions

It is considered that for us to meet our objective of the CF-105 aircraft being ready for operational evaluation at the time the first aircraft are handed over to the RCAF, we must start the flight development program with an installation which has had as much development as possible in a preliminary development program.

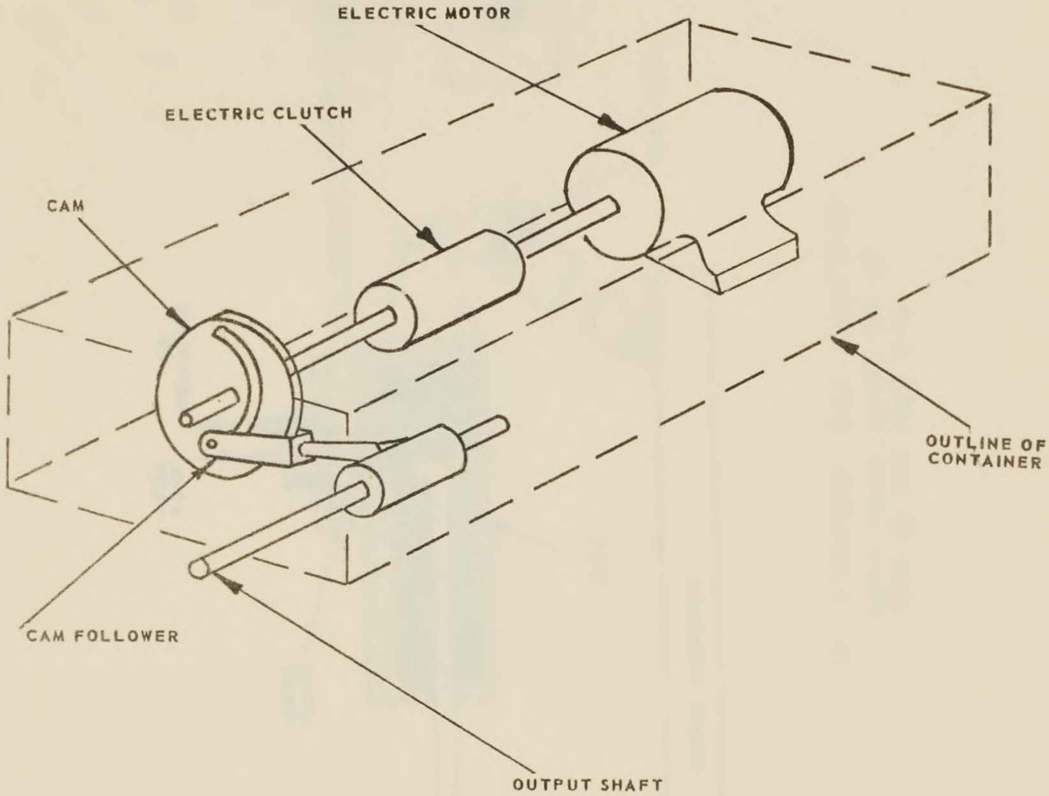
The outline of the proposed preliminary development program has been presented. It is proposed to use the wind tunnel, mock-ups, ground test rigs, an airborne test rig, and a test specimen mounted on a rocket propelled sled.

It is postulated that each of these stages is essential to attain the desired end, and that elimination of any one of these stages will interfere in the achievement of this aim.

Ian R. Craig.

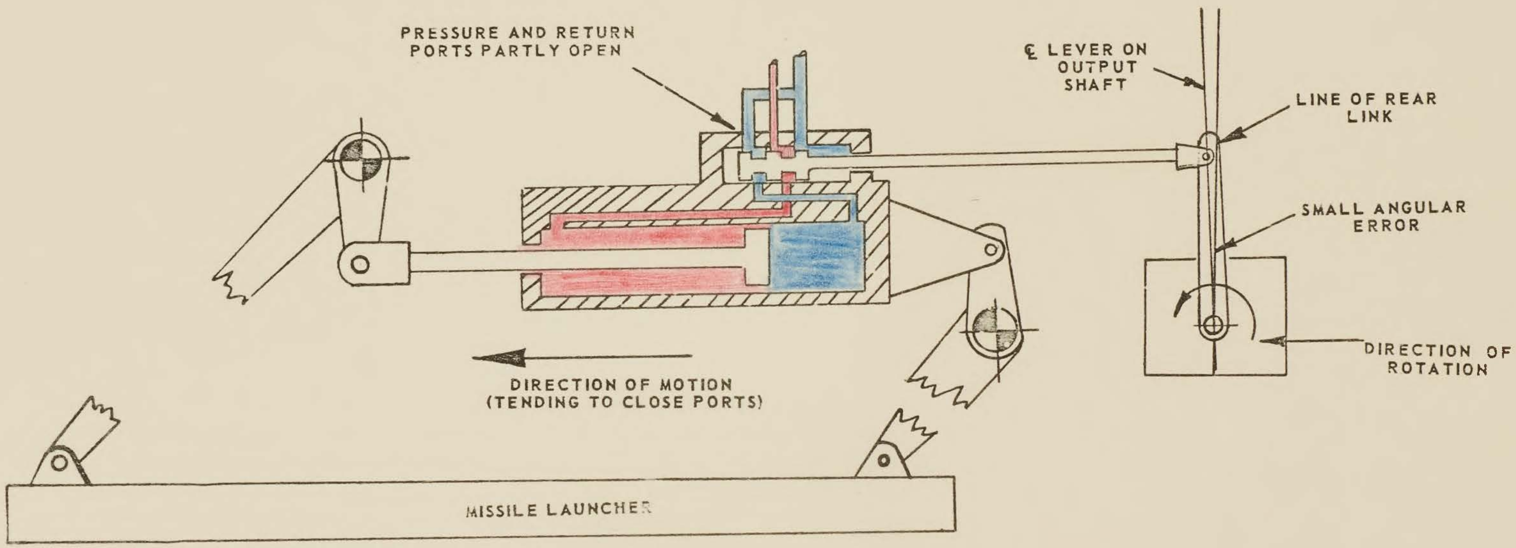
SCHEMATIC OF PROGRAMMING BOX
(CAM ACTUATOR)

NOTE: THIS SCHEMATIC IS NOT COMPLETE AND IS INTENDED ONLY TO ILLUSTRATE THE OPERATING PRINCIPLES.



MOTOR RUNS CONTINUOUSLY AFTER ARM/SAFE SWITCH IS PUT TO 'ARM'. CLUTCH IS ENERGISED WHEN MISSILE IS SELECTED 'EXTEND' CAUSING CAM TO ROTATE. CAM FOLLOWER RUNS IN SLOT IN CAM CAUSING OUTPUT SHAFT TO ROTATE. TIME FOR FOLLOWER TO RUN FROM ONE END OF SLOT TO OTHER IS 0.45 SECONDS. SLOT IS CUT TO THE SHAPE WHICH CAUSES OUTPUT SHAFT TO ROTATE AS SHOWN IN FIG. 1.

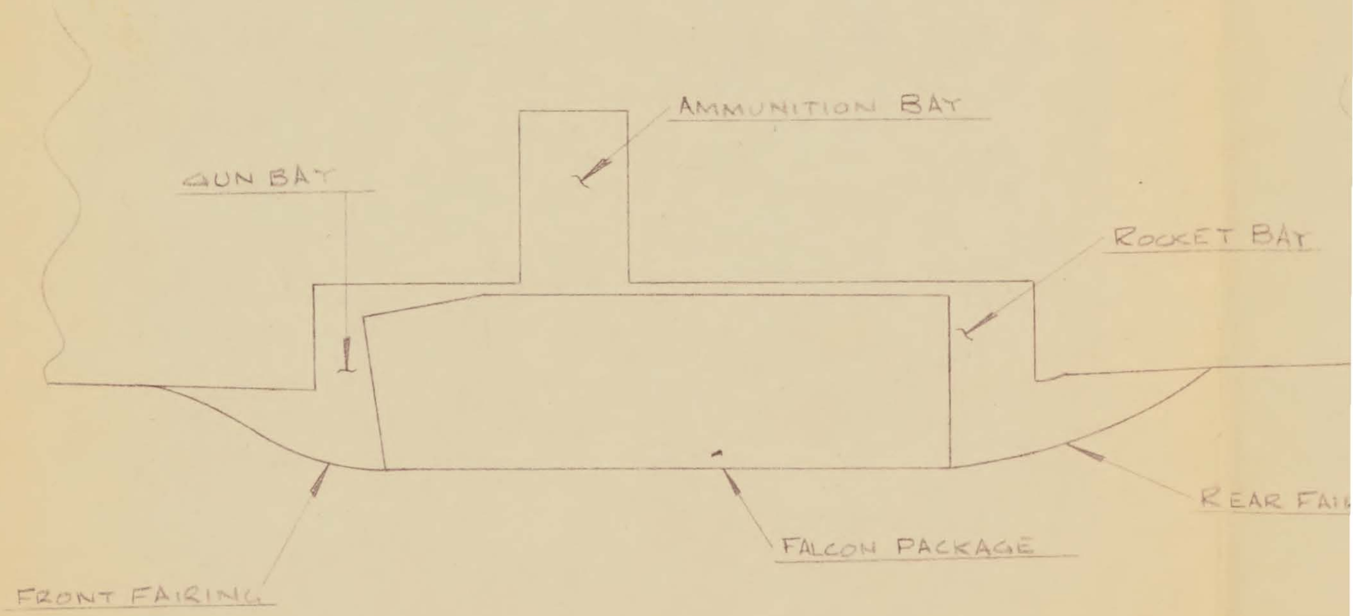
FIG. II



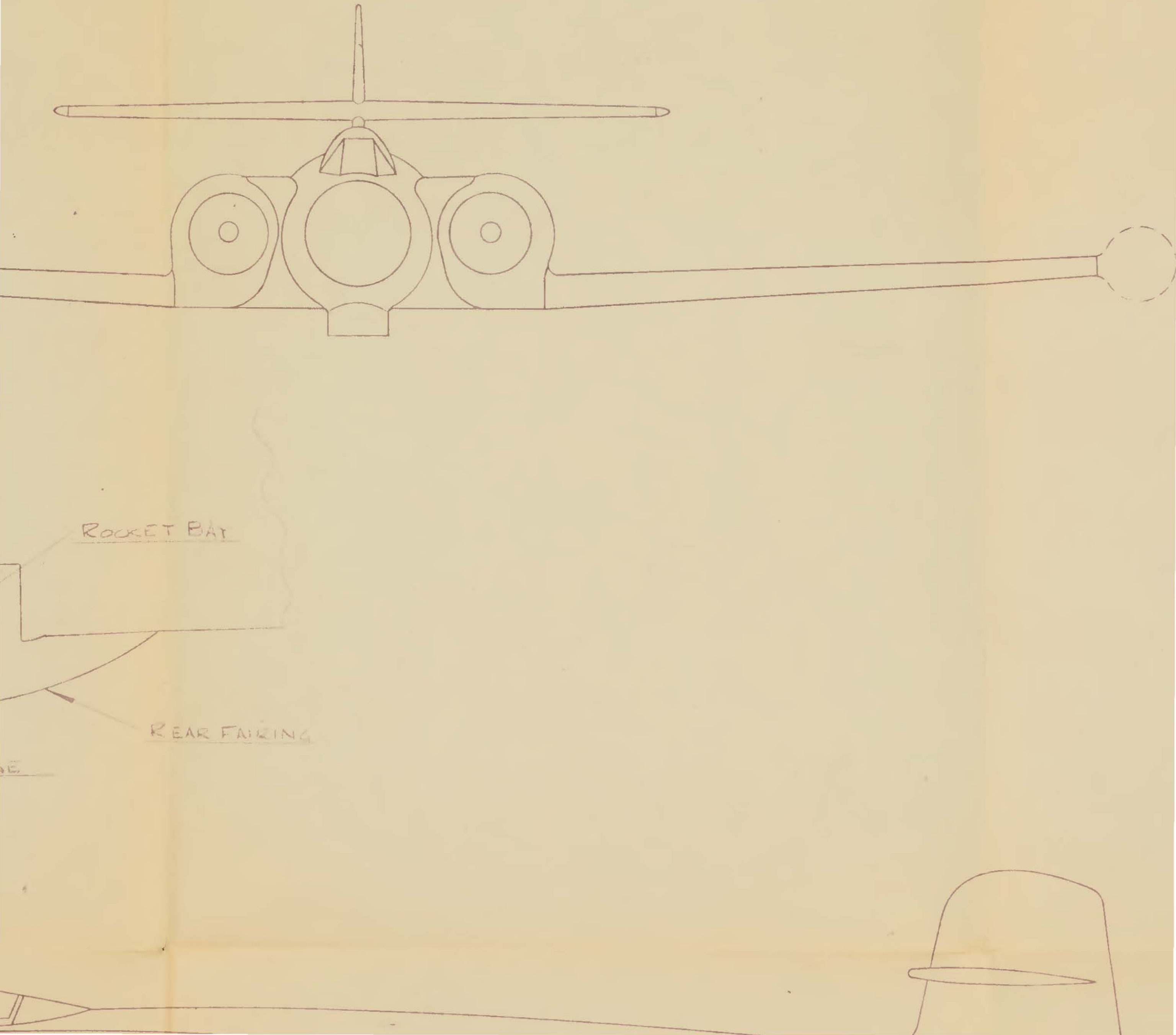
(2) PROGRAM BOX OUTPUT SHAFT ROTATING SLOWLY

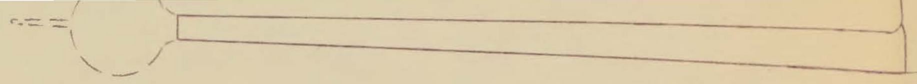
REAR LINK LAGS OUTPUT SHAFT BY SMALL AMOUNT. PORTS PARTLY OPEN GIVING THROTTLED FLOW OF OIL TO MOVE REAR LINK IN SAME SENSE AS PROGRAM BOX OUTPUT SHAFT.

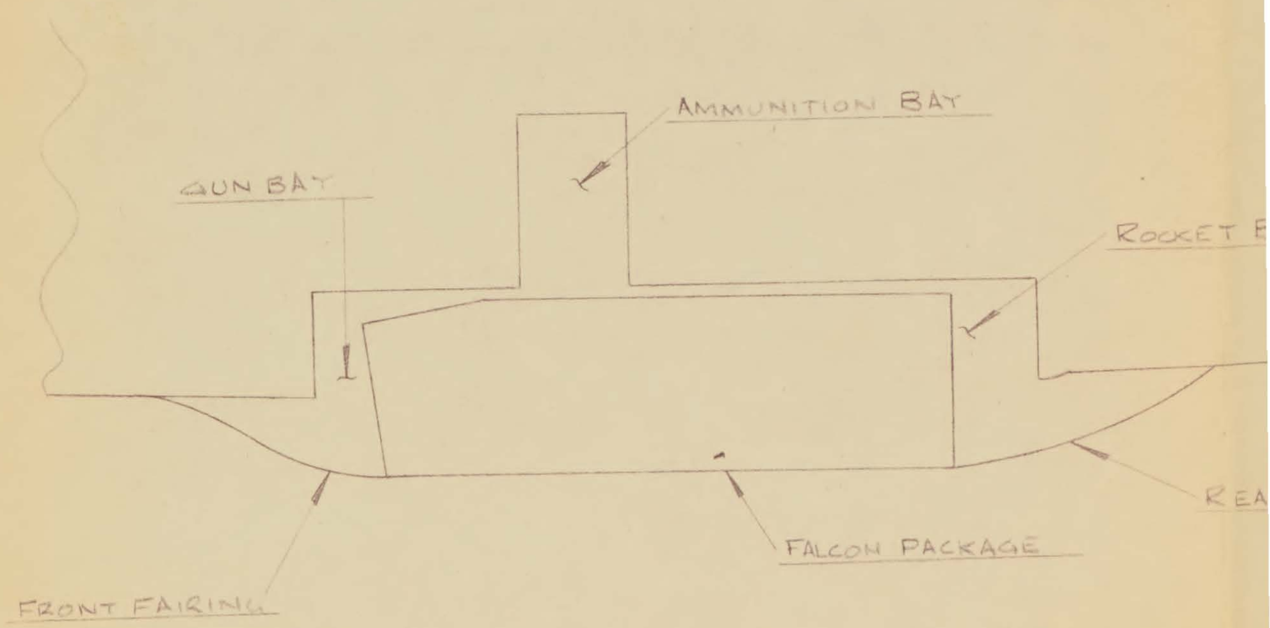
FIG III (2)



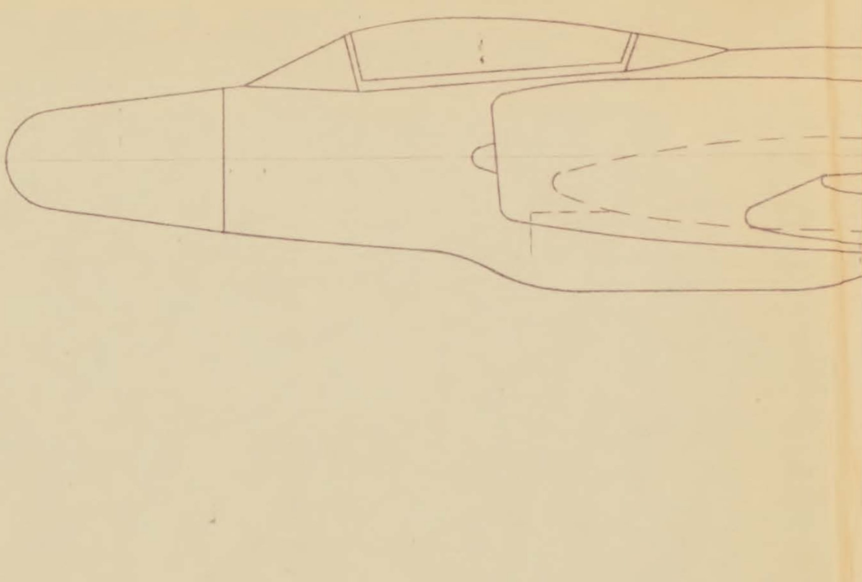
SCRAP VIEW of FALCON
PACKAGE IN BAY


ROCKET BAY
REAR FAIRING





SCRAP VIEW of FALCON PACKAGE IN BAY



CF100 EQUIPPE

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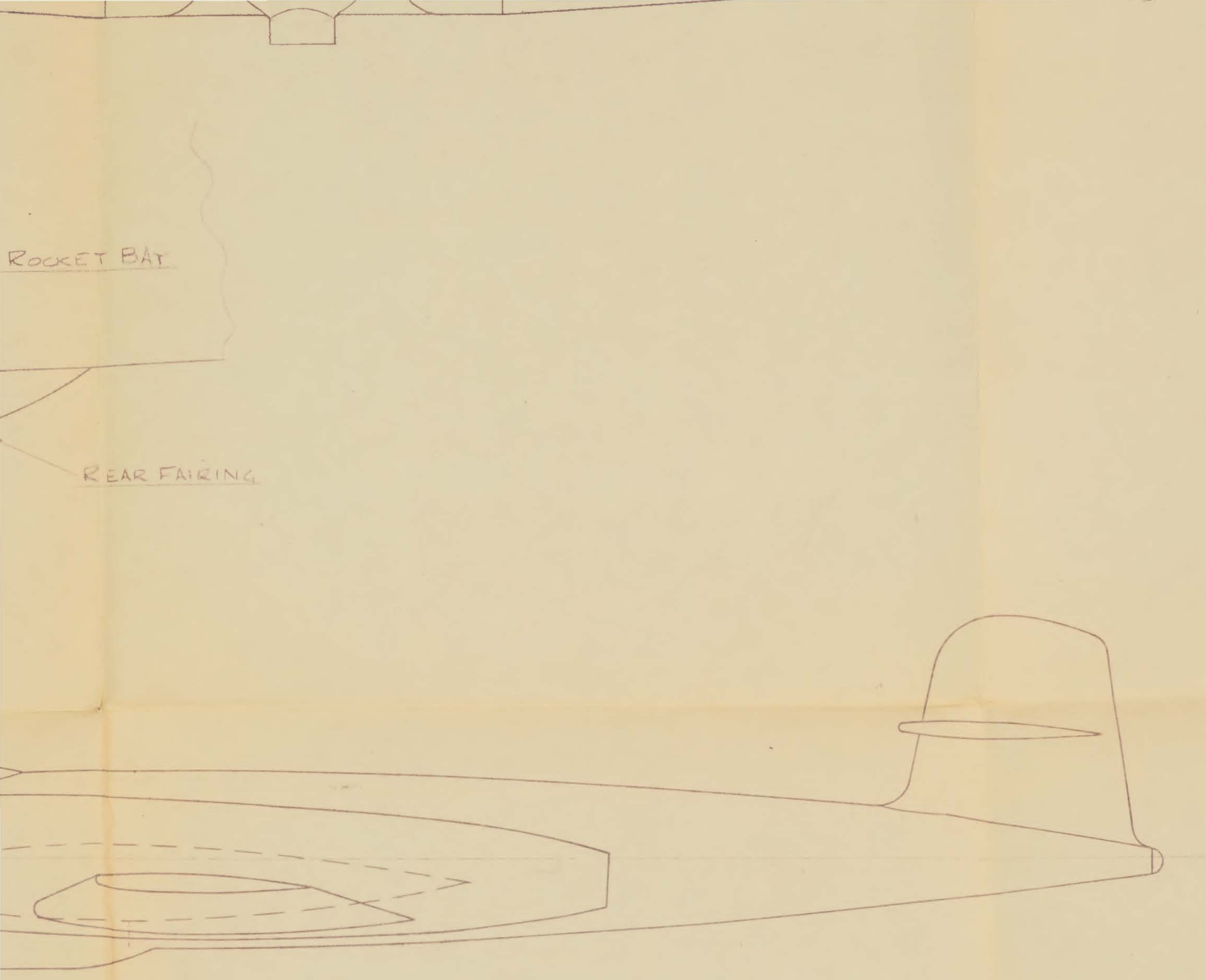

QUIPPED WITH ONE FALCON MISSILE

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