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Notes on the Operation and Installation of the Sparrow II Missile

Sep 54

A. V. ROE CANADA LIMITED

MALTON · ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

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INTRODUCTION

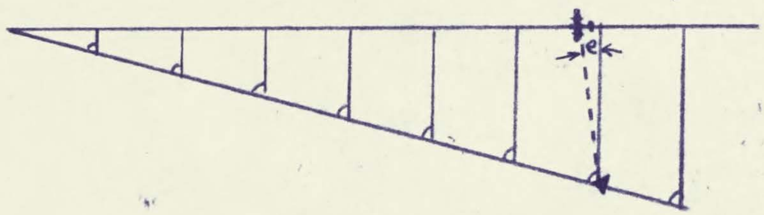
These notes are compiled from information received during two visits to Douglas Aircraft Ltd during July and August, 1954.

The Sparrow missiles are developed by Sperry (I), Douglas (II) and Raytheon (III) for the U.S. Navy. All use the same motor; manufacturing by Aerojet-General. The Sparrow I is a beam rider, the II is a fully active K-band guidance and the III is a semi-active using proportional navigation C.W. in X-band. All missiles are in the 320 to 380 # class and are generally 8" diameter body, 156.8" in length with cruci-form wings and tail about 40" and 32" diameter respectively.

THEORETICAL DESIGN CONSIDERATIONS

1. Principles of Guidance

1.1 Constant true-bearing principle is used, the antenna is not servoed but maintains a constant 'look' angle while the missile is servoed round to correct bearing errors. (This is similar to the proportional navigation system.)



1.2 Steering is thus effected by checking the error angle e on the constant bearing, and steering the missile in such a manner as to eliminate this loop error.

1.3 Gain is maintained with range to give better steering servo characteristics. The factor used is:-
$(e + \dot{e})(1 + 1/R + 1/\dot{R})$

1.4 As detailed above, the antenna is not tracked, the missile itself doing the tracking required.

1.5 As above, no automatic track means less servo sensitivity is required.

1. Principles of Guidance (Cont'd)

1.6 Manoeuvre is smaller as the missile approaches the target.

(NOTE:- Douglas say that all missiles are subject to instability near to the target as the 1/r terms are increasing rapidly. This is also true of Sparrows.)

2. Principles of Detection

2.1 The aircraft A.I. radar will detect and lock-on to the target. The missile auxiliary units will then slave the missile antennae onto the targets, and run their range gates up to the target range. The missile magnetrons will by then be energized and the missile radar systems should achieve 'lock-on'. It should be noted here that the missiles must be locked on prior to launch as the target discrimination depends, in the case of fully active missiles, on the narrowness of the missile antenna beam. Thus it is very unlikely that the missile could acquire the target if not locked on prior to launch by the broader-beamed A.I. radar system.

2.2 Immediately after the missile systems achieve lock-on the missiles are fired. This is provided the aircraft steering is correct.

2.3 Control of the missile after launch is only withheld for $\frac{1}{4}$ second, as any increase in this "controls locked" period would lead to a considerable decrease in the allowable launching error.

2.4 As sudden manoeuvre may result as soon as the missile steering is enabled, it is unwise to launch missiles simultaneously. Two missiles are recommended to a salvo, which should be ripple-fired providing the missiles are widely separated, such as on wing mid span.

2.5 If internal stowage of the missiles is necessary, it is recommended that a resolver be incorporated in the antenna slaving system to avoid a build up of sighting errors during lowering. This resolver would be located on the lowering linkage.

DETAILED DESIGN CONSIDERATIONS

Missile Radar System

The radar (AN/DPN-21) system is a 'K' band pulsed transmission of 50 KW peak power using 1/8 µS pulse width. Conical scanning systems are used. The beam is 4 degrees wide between half-power points, and the scanning cone has 1.8 degree diameter. A rotating dish type scanning system is used, and the dish forms the fly-wheel of the antenna stabilizing gyro. The antenna has a ±60° look angle. Discrimination of targets down to 200' apart at maximum range is claimed. A magnetron life of 15 hours is claimed and 100 hours has been achieved.

A range rate memory is incorporated with the idea of overcoming ECM's in the form of 'chaff'.

The receiver incorporates an 'X' band klystron with a frequency multiplier. It is hoped to incorporate a 'K' band klystron when a suitable tube becomes available.

The complete radar transmitter-receiver including all waveform generators and scanning circuitry, is housed in the 8" diameter body just aft of the radome, and is generally called the 'seeker' unit.

The radome is, at present, a $2\frac{1}{2}$:1 axis ratio semi-ellipsoid, but it is hoped to have an ogive form of radome in the production models. The radome construction of the first 9 units was of Fiberglas using Styrol #16B resin. The tenth missile (M-137) was designed for a higher altitude test fire and used an Orlon fabric, impregnated with resin. The radome is sealed at sea-level atmosphere and must maintain this pressure at all altitudes. In the test vehicles (only one was at considerable altitude) no appreciable leakage was experienced. The operational environment, as laid down in specs Navy Bureau of Aero SD-3000 and SD-3004, and the Bureau of Aeronautics Electronics Division XEL 233 and 224, give the following:- Operational environment -67°F to 131°F. ; Non-operational environment -85°F to 185°F. These include the case of 100% humidity up to 112°F maximum, at all altitudes from sea-level to 50,000' with a rate of change of pressure of up to $\frac{1}{2}$" Hg/Sec.

Vibration of; up to 9G peaks in the 10-60 c.p.s. range,
up to 5G peaks in the 60-500 c.p.s. range,
up to 3G peaks in the 500-1, 200 cps range.

Missile Warhead

This unit is immediately behind the 'seeker' unit, and occupies the full body diameter for an undisclosed length. The warhead consists of a 45 lb. fragmentation charge detonated on the proximity principle. The range of the proximity fuze is restricted to 100'; at greater miss distances than this, the missile is not detonated. As this is a Navy weapon designed for carrier-borne operations no self-destruction facility is provided. This would, of course, have to be provided for ground-based operations. The effective area of the fragmentation charge is in a sector about the warhead centered 65 degrees off the centre line looking forward. Thus a time delay must be incorporated to bring the charge to the most vulnerable area of the target. This time delay must differ for nose and tail approach, therefore r and $\dot{r}$ information is fed to the fuze to introduce variable time-delay into the detonating circuits. This delay is very critical in some approaches and is critical to ±5 degrees in a beam attack.

The warhead charge is made by the Naval Ordnance Labs., and the fuze is made by the Diamond Ordnance Fuze Labs., (Old National Bureau of Standards).

Automatic Pilot

The auto-pilot used in this missile is similar to that used in the NIKE missile which has proved satisfactory in a large number of tests. The auto-pilot is, in principle, a command acceleration type system. That is, when a certain acceleration is commanded, the servo system calls for a certain wing deflection, this deflection produces an acceleration moment. This moment is sensed by the missile accelerometer and compared with the acceleration called for by the system, and the 'error' signal resulting gives the new acceleration called for. Rate and fin displacement feed-back is used for damping.

The command signals are smoothed and limited to ±14G - ±16G. A shaping network is included in the servo loop and the actuator is a hydraulic valve. This valve will provide a hinge moment on the wing of 240 lbs at 3,500 psi and will operate with a hydraulic pressure varying between 3,500 and 1800 psi.

Roll position stabilization is not used, therefore, a roll resolver is incorporated in the missile. Roll rate stabilization is used. Steady roll rates of 5°/sec. and transient up to 200°/sec are allowed for. This unit is situated immediately aft of the warhead unit.

Hydraulic and Electric Power Supplies

These units are situated aft of the auto-pilot unit, and forward of the motor.

The motive power of the hydraulic system is a nitrogen pressurized direct loss system operating from an accumulator, but a very sensitive valve is at present used that is subject to fouling with dirt. A better valve as used on the NIKE missile is being introduced. The system operates the four cruciform wings within the limits of 3,500 to 1,800 psi as mentioned above. The electric power supply is from a silver/zinc battery in the present models. These batteries supply the required 1,200 W., but are not very convenient. They have a short shelf life, require some time to activate and have a one day life after activation. It is proposed to introduce a liquid (ethelyne-oxide) propellant-driven turbo-generator some time in the future (1956), this will supply 1,000 W at 4,000 CPS.

Turbo-Products, a sub-division of American Machine and Foundry, are to supply the unit.

Propellant Motor (Prime Mover)

The motor is an Aerojet, solid propellant type, which burns for 1.85 seconds. Considerable effort has been made to develop a smokeless charge, as smoke is undesirable both from an ECM standpoint, and because of obscuring the target for succeeding missiles.

The specification requires that the motor should operate satisfactorily between -70 degrees and +150 degrees. However, up to now, -40 degrees has proved to be the practical limit.

Layout and Structure

The missile has a body diameter of 8", and a length of 13' 0.8" with ogive nose. It has one set of fins, or wings, (4 fins in cruciform layout), and a similar set of stabilizers at the tail. The wings have a span of 40.1", with their leading edge swept at an angle of 57°, while the tail has a span of 32", and a 30° leading edge. The weight of the fully operational missile is 380 lbs. The missile will be supported on the new launcher by three 'buttons' which protrude from the skin of the missile for loading and retract after launch. These buttons will each withstand an axial (tensile) load of just over 13,000 lbs. As previously stated, from structural and other considerations, manoeuvre after launch is restricted to 14G in any one plane, or a total of 20G, thus, taking a safety factor into account, the missile structure must withstand up to 30G loads.

LAUNCHER DETAILS

The launcher, whose rails pick up on the retracting 'buttons' on the missile as previously described, provides three feet of guidance to the missile. This launcher has not yet been tried out in flight, as all the test launches carried out to date have been from zero-length launchers.

The launcher here described is the proposed prototype launcher, described by BuAer as: Missile, Launcher, Aero 1A and is for Sparrow I only. A new launcher is in design for production equipment which will be designated as the Aero 2A Universal Launcher. (i.e. capable of carrying Sparrow I - II - III)

The Aero 1A launcher is 80½" long, and weighs 36 lbs. The controlled 'run' of 3 feet is the minimum length required to provide the missile with sufficient stability to allow the wings to be locked for ¼ second after launch without collision during that period. This time is necessary to allow the missile to clear the aircraft before introducing a possibly violent manoeuvre , but should be as short as possible, as guidance is most effective early in flight. Thus too long a "controls locked" period would mean a reduction in the maximum steering error allowable at any given range. It should be noted that the missile antenna is gyro stabilized, and this gyro is uncaged at 5.0 mS prior to launch, therefore the antenna will maintain its orientation despite missile manoeuvre due to local flow, after launch.

The missile, when launched, is only marginally stable but becomes more stable due to forward shift of C.of G during the motor burning period.

MISSILE AUXILIARIES

There are two proposed methods of deriving the launching information, one from AI radar, and the other from an optical sighting arrangement. None of these system auxiliary units have yet been designed and are still in the philosophizing stage. However, thinking, and some bread-board work, has produced some box parameters as follows:-

Taking AI radar tie-in units first:-

No. Off (for 2 missiles)	Unit for AI Radar Tie-in	Wt.	Cubic '
1	Co-ordinate transformation unit	12 lb.	0.15
2	Antenna positioning units	25 lb. (for 2)	0.3
1	Range search unit	5 lb.	0.06
2	Range lock detectors	5 lb. (for 2)	0.06
1	Firing angle indicator (#)	15 lb.	0.06
1	Firing range indicator	10 lb.	0.3
1	Presentation and control unit	5 lb.	0.1

(#) This unit is a lead angle computer, it compares the existing lead with the allowable lead to give suitable firing signals.

Optical tie-in units:-

No. Off (for 2 missiles)	Unit for Optical Sight Tie-in	Wt.	Cubic '
1	Range search unit (range gate sweep)	5 lb.	0.06
1	Range lock detector (stop sweep)	5 lb.	0.06
1	Firing range indicator (#)	5 lb.	0.01
1	Presentation and control unit	5 lb.	0.01

(#) This unit uses information of range, velocity, G, etc., to compute the maximum and minimum firing ranges.

All the auxiliary units would be designed by Douglas to operate with any standard radar giving range and bearing information. The units would be required to operate in the ambient conditions called for the missiles.

The function of the auxiliaries is detailed below:-

(1) Co-ordinate Transformation Unit

Requires AI antenna azimuth and elevation angle information. Its output is the polar angles of rotation and deflection to control the seeker antenna. Initiated by lock-on.

(2) Antenna Positioning Unit

Receives the output of (1) above, and amplifies the signal to position the seeker antenna.

(3) Range Search Unit

This sweeps the seeker range gate through the AI range gate and an error margin. Its output is a sawtooth of a certain voltage. Initiated by -3 sec. signal from the computer.

(4) Range Lock Detector

This detects the presence of a target signal in the seeker range gate, and stops the range search. Indicates lock-on acquired, and closes the interlock.

(5) Firing Angle Indicator

Requires inputs of: AI range, existing AI lock angle, altitude and, if available, the slewing rate of the AI antenna.

The unit computes the desired lead angle plus allowable errors, in two planes in interceptor co-ordinates.

(6) Firing Range Indicator

Requires inputs of: AI range, aspect angle (approx.) computed from antenna slewing rate, range rate and interceptor velocity, and altitude.

The unit computes maximum and minimum firing range.

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COCKPIT LAYOUT AND MISSILE AUXILIARY TIE-IN

The cockpit presentation envisaged will be similar to the AI radar steering signals. The pilot will have a presentation showing a circle representing the maximum steering error that the missile can compensate for under the conditions of range, speed, altitude and approach angle obtaining at the moment. The steering dot will show the pilot the direction to fly to reduce the steering error to a minimum, and will show him when the error is sufficiently small to permit missile firing. When the steering dot lies within the minimum error circle, the launch is enabled, but launch will not take place until the missiles are locked on to the target. To inform the pilot of the missile set-up situation, he has some indicator lights. These lights may be above the steering indicator and there will be a switch and a 'power on' indicating light for each missile, on the pilot's console. The installation is planned for compatibility with the E-10 system, but AN/APQ-50 is a second possibility.

With an optical steering system using a 'straight' optical sight with no lead angle, the missile antennae would be pre-aligned to the boresight requirements, and in pursuit, an automatic missile range gate sweep (6,000'/sec) would be energized when the transmitter is switched on by a switch on the pilot's console. Firing could be automatic as soon as each missile achieves lock-on, or firing could be manual when lock-on is indicated.

If an optical system was used with a launcher configuration that required the missiles to 'toe-out' then a separate set of auxiliaries would be required for each missile.

The cockpit control functions would be in some similar form to that tabulated below:-

(1) Power on STANDBY - Everything is switched on with exception of the modulator, carried out at any time after take-off. There might be a switch for each missile or one switch for all, with indicator lights to show which missiles are on.

(2) HYDRAULIC WARM-UP - Heaters are normally turned on with STANDBY, but this is an override switch to turn them on earlier, if required, in cold conditions.

(3) MISSILE SELECT - Selecting the number of missiles to be fired. (Douglas would prefer to fire any missile rather than a particular one.)

(4) AUTO-MANUAL - There is really little difference between these positions except that the firing button is cut out in the AUTO position.

(5) If an optical mode is provided two further switches are needed:

AI-OPTICAL switch and TRANSMITTER ON switch to turn on the transmitters in the optical mode. (In the AI mode the transmitters are turned on automatically at lock-on.)

(6) JETTISON

EXTERNAL POWER REQUIREMENTS

The external missile power requirements will depend on whether batteries or a turbine power supply is used, because, to increase running time, and to reduce the contamination in the missile bay, the turbine is run up to speed by driving the alternator from the aircraft power supply. Therefore a heavy drain is imposed on the aircraft 115/208 V Y. 3 phase AC supply. The AC drain is 1,420 VA on standby and 2,360 VA on full power for each missile. Half this latter drain being used to supply turbine losses. Full power drain must be started early (several minutes) for the turbine requires at least 1 minute to come up to speed.

It is not definite that a turbine will be used, and if it is not used the external power requirements will be 2,000 - 2,500 watts at 28 volts DC.

The missile auxiliary units, including the computer, are 750 VA of AC + 4 amps at 28 V DC for the basic units, with an additional 250 VA of AC for additional units for each missile carried.

MISSILE LAUNCHING PHILOSOPHY

Missile launch is enabled, all other things being equal, when the target lies within range of the seeker (depending on the effective area of the target) and within the aerodynamic range of the missile (depending on the closing rate). Also, the launch must be so aligned, that aiming error correction can be carried out during the missile flight, without calling for unacceptably excessive manoeuvre. This latter parameter will vary with altitude, as will the aerodynamic range of the missile. Thus, the aerodynamic range at 30,000' will vary between 10 nautical miles for a nose approach and 2 nautical miles for a tail approach for a particular set of speed parameters. While the seeker range, based on some BofA figures for effective area of a F3D-1 aircraft, give a calculated seeker range of 32,000' for a nose approach, 25,000' for a tail approach, rising to a figure in excess of 10 nautical miles for a beam approach. It might be stated here that experiments carried out by the guidance unit contractor show that the water-absorbtion properties of K band transmissions is of the order of 1/10 dB/mile.

The following page contains the curves illustrating the nature of the above mentioned parameters, and showing the nature of the minimum range curves. These curves form the basis of the minimum range information, and maximum allowable lead-angle, to the computer.

The various time delays will, of course, be taken into account in the computations of firing range. These delays will include; ½ second required for the missile to clear the launcher, but, as the calculations assume missile lock-on is achieved, they do not include the 1½ seconds between AI lock and missile lock, and the 50 mS required to energize the magnetron.

PERFORMANCE

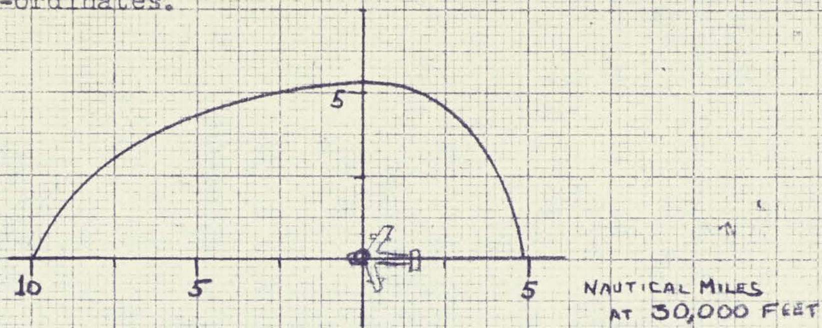
As a result of considerable amount of statistical and simulator work, Douglas estimate that the probability of kill of a two missile salvo will be of the order of 80%. That is, assuming a figure of 60% reliability (which is realistic from NIKE experience), the total probability of kill is 50%. Using three dimensional simulation, the predicted miss of an average missile is 12' to 16' RMS.

Ten test vehicles have been made and fired, and five of these would have successfully completed their required role. The first 2 failed to steer immediately after launching, and it was found to be due to loss of lock-on caused by the change of impedances within the missile after launch, due to the removal of the mass of metal of the launcher from the vicinity of sensitive tuned circuits. This was an oversight, and should have been foreseen. In two other missiles power supply failure was responsible for loss of control, one due to an excessive G load, the other burnt out due to some unspecified

MISSILE LAUNCHING PHILOSOPHY (CONT'D)

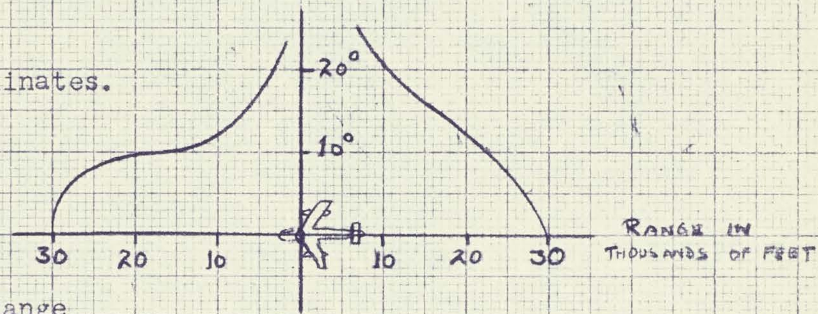
(1) Aerodynamic Range

In bomber co-ordinates.



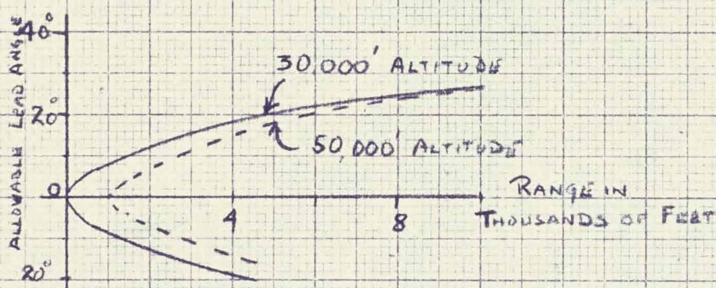
(2) Seeker Range

In bomber co-ordinates.

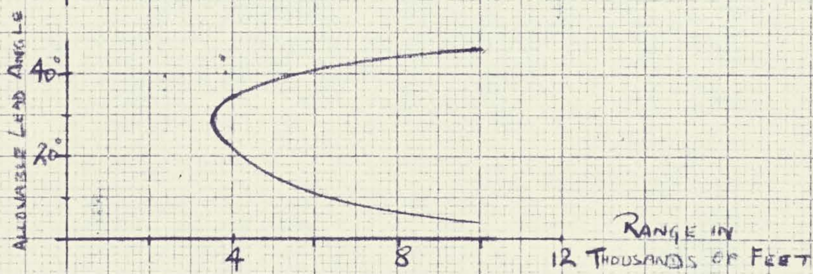


(3) Minimum Firing Range

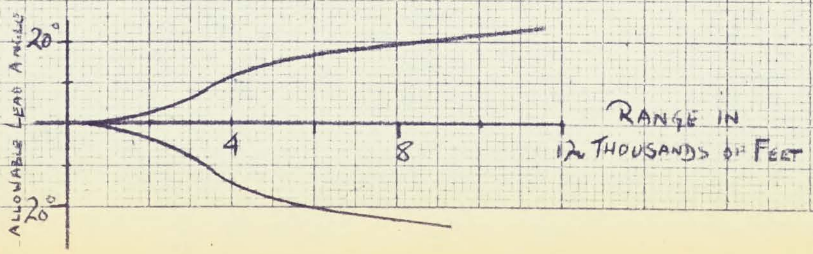
Tail approach.



Beam approach.



Nose approach.



shock. The fifth failure lost lock due to some unknown cause. The miss distance of the five successful missiles were: 8', 2', 12', 16' and 45' respectively.

The maximum altitude considered was 50,000', but Douglas are confident that there is no immediate altitude limitation, but capabilities do start falling off with altitude. Minimum altitude of operation is very satisfactory; of the trials carried out, one was at 1,100', and another at 700', and both were successful. It is predicted that satisfactory operation can be carried out as low as 400', however, as 700' in the minimum height for CGI operation, lower altitudes than this need not be considered.

MISSILE LAUNCHER LOCATION

It has been already stated that only external stowage has been considered by Douglas up to the present, and internal stowage presents a number of problems, as does the location of missiles in proximity to one another.

The necessity of the missile to achieve lock-on prior to launch is the main problem, and the difficulties will be discussed. In the present Douglas configuration one missile is carried under each wing, with its nose extending ahead of the wing. This installation may not be ideal aerodynamically, and tests have shown that two missiles carried externally will reduce maximum speed by 40 knots at M.0.8 and by more than 60 knots at M.1.4. There is a temperature limitation due to aerodynamic heating with supersonic carry. In all other respects this is an ideal installation, missile manoeuvre after launch is unrestricted; antenna look angles are unrestricted; and launching is as simple as possible. However, if the missiles are internally stowed close to one another they must be extended after AI lock-on, their antennae servoed onto the target, or, if previously servoed, they must be servoed to compensate for their change of line of sight. An extreme error of 2 degrees can just be tolerated but it is highly desirable that the line of sight error should not exceed ½ degree, and this would call for accurate launching mechanism. But, by far the greatest problems are those of avoiding the missiles fouling the mother ship after launch when control must be introduced, with its consequent sudden manoeuvre, within ¼ second of launch. The missile look angle, when obscured by the fuselage ahead of it, presents a problem in manoeuvre, although Douglas have done successful tests on antennae, with the incident angle ahead of the missile as low as 4^o, without aberration effects. The difficulty of launching two missiles (or three) mounted side-by-side when they must be extended at least 2 secs. to achieve lock-on, and $\frac{1}{2}$ sec. for launching, say $2\frac{1}{2}$ secs. prior to firing, is another problem. Also, the second missile's radome will receive the full blast of the first missile's motor. (Douglas say simultaneous launching of two missiles is impossible due to their very rapid manoeuvre.) Douglas also have made some tests on the buffet loads experienced when a missile bay is opened at high Mach numbers and they are worried about these.

The missile will travel at speeds of Mach 1.5 + the launcher velocity but the missile is very susceptible to excessive heating, particularly the flight control units, so the effect of aerodynamic heating during missile extension must be considered.

TEST EQUIPMENT

As this missile was designed for carrier based operations the tests are short, concise, and foolproof wherever possible. In principle the tests are automatic wherever possible, and they consist of calibrating the missile against a standard, and the auxiliaries against a standard, with no spot check after arming the aircraft.

Checking the missile is carried out on a specially designed bench. This has two main checks; power supply and auto-pilot tests, and guidance tests. Hydraulic power at 3,000 lbs pressure is required for this test bench. A roll stand is supplied to hold the missile for these tests. Radar checks are also carried out, and as removing the sealed radome is discouraged in the field, a special absorbing chamber is supplied in place of the usual dummy load for transmitter tests. This absorber is just a box lined throughout with 2" thick absorbing material, the size of this box is of 15' side at the moment, but a box of $2\frac{1}{2}$' side is hoped to be made. Ground operation of the radar should be restricted to a total of 5 minutes, due to the undesirable heating effects. Airborne operations should also be restricted to 20 minutes with B+ turned on, indefinite operation in the air with filaments lit is permitted.

The missile auxiliaries in the aircraft are checked out using a dummy missile box.

Spot checks are carried out immediately prior to arming-up. One of these checks is to check the output of the local oscillator, and if this gives the correct readings, the transmitter and receiver have been checked. A check on the output of the IF stage checks the sensitivity of the receiver. Checking the video signals to simulate guidance, range track, etc. is easier than checking K band signals.

A power meter, a frequency meter and an oscilloscope are all the test equipment required to check if the missile is in satisfactory condition.

The test history of a missile is as below:-

STAGE	COMPONENTS	SECTIONS	MISSILE ASSEMBLY
Factory	Complete test	Tested as section	Tested as assy.
Depot	Selection	Tested	Tested
Carrier	-----	Faulty sections replaced	Tested (1 month without retesting)

<u>Note</u>: Douglas consider that 'turn-on' causes more failures than a protracted shelf-life.

A. V. ROE CANADA LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT (Aircraft)

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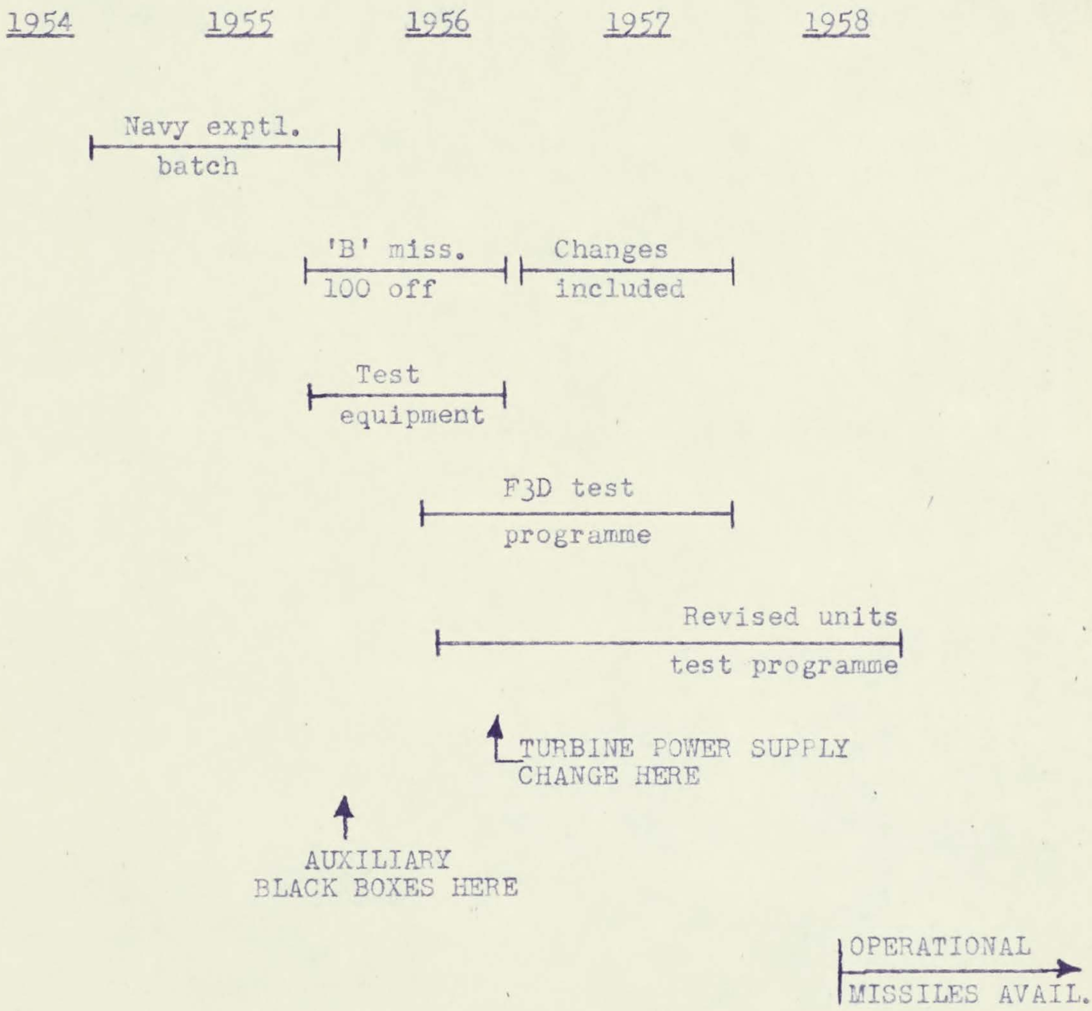
		CHECKED BY	DATE

AVAILABILITY

The supply situation, and development planning, is tabulated below:-



There is a possible private development that Douglas are a little reticent about, and is very unofficial at the moment. (The impression conveyed was that they regretted mentioning it.) This suggestion is of a controlled airframe missile with interchangeable guidance and power supply. This would be designed for supersonic launch, either externally or internally carried. The timing of this might be; commencing at the end of 1954, with production at the middle of 1957.

The availability of launchers is:-

Launcher AERO 1A - Available immediately if in small quantities, and Navy agree to inclusion in their programme which commences in 2 months time.

Launcher AERO 2A - Authority to be obtained soon, engineering release 6 months later, factory production time 5 months after that, in 13-14 months.

A dummy missile, if required, could be constructed in 7 months, if expedited, as none are available from stock, but full set of drawings exists for their construction.

CONCLUSIONS

1. The missile is designed for external stowage under the wing leading edges, with two missiles to an installation. This introduces the problems:-

   (a) Of internal stowage, which should not be insuperable, though missile alignment and buffeting problems may cause some difficulties.

   (b) Avoiding sudden missile manoeuvre before it is clear of the aircraft belly.

   (c) Avoiding damage to the second missile by the exhaust of the first one launched.

   (d) Achieving lock-on without excessive A/C manoeuvre or limitations to A/C manoeuvre.

   These three latter problems need some thought and experimental results before they can be resolved.

2. The missile radar set-up time is of the order of 2-2½ seconds. This time includes the 1½ seconds required to slave the antenna and range gate, and ½ second required for the missile to achieve the force of 2G required to shear the launcher missile retaining pin, and to clear the launcher. The maximum missile radar acquisition range is now being determined.

3. The missile receives information of target heading and range from either a standard type AI radar system, or from a fixed type of optical sight. The missile auxiliary units either for AI radar tie-in or for optical tie-in have not yet been designed in detail. However, their sizes have been estimated, and they will be designed to work in the environment required by the missiles. If they are mounted in the missile bay, baffles may have to be used to protect them from buffeting during the time when the bay doors are open.

4. For most efficient operation Douglas recommend the use of a two missile installation, a three missile installation should be more effective, but whether it would be economically advantageous to expend another missile for a small increase in kill effectivity would, they think, be questionable. They do not recommend the use of a one missile installation.

5. The cockpit presentation will be in the form of a maximum error angle circle and a steering dot on a conventional pilot's CRT display. This circle will shrink down to a dot when insufficient time is available for missile set-up.

6. If the optical system is used, the missile antenna will be pre-boresighted for a direct pursuit course, and, when the aircraft is flying on a correct pursuit course the range gate of the missile radar system will be swept until lock-on is achieved, when the missile will be fired.

7. The missile will operate successfully at altitudes down to 400 feet.

8. A proximity fuze is used which will operate at ranges up to 100 feet. A variable time delay is incorporated which will adjust the delay to suit the rate-of-closing.

9. The warhead is a 49 lb. fragmentation charge.

10. The missile, including a 60% reliability factor, will give a probability of kill of 50%.

APPENDIX 1

Details of the Sparrow Programme

1. Sparrow 1

This is an X-band, semi-active beam riding missile with a 7 degree cone of search. Orientation is carried out using a coded beam signal giving a different signal in each quadrant. No guidance during motor burning, so launching error angle is more limited. It is designed for 3 seconds burn time, 3½ seconds guidance. A three gyro and accelerometer autopilot is used, to give a straight-line course. A computer is used to steer the aircraft on the correct lead course for missile release. This missile is in full production.

2. Sparrow 2

This is the K-band, fully active missile, with facilities for radar or optical launching, that we have been considering.

3. Sparrow 3

This is an X-band, CW, semi-active missile. This missile operates by discriminating between the frequencies of the transmitted and reflected signals to deduce the target velocity. To this end it carries two antennae, in nose and tail. Steering is by the proportional navigation method, with antenna tracking. A doppler fuze is used. Raytheon are making this equipment. It was hoped that CW would give better low-altitude results, but it has been found that this theory has not obtained in practice.

AIRCRAFT		PREPARED BY	DATE
CF-105	UNCLASSIFIED SECRET	A. N. Parsons	Sept 27/54
		CHECKED BY	DATE

APPENDIX II

Miscellaneous Notes

1. 'Sidewinder' is an IR seeking 5" HPAG missile with a 26 lb. warhead and an 'influence' fuze. This weapon is designed to operate from an optical launch system.

2. The telemetry system used by Douglas is a PWM 28 channel + 2 sequencers using a rate of 30 samples/sec. This unit is made by the Applied Science Corporation of Princeton.

3. The engineering staff of Douglas's guided missile wing who co-operated in providing the above information, included:-

   E. P. Wheaton ...... Guided Missile Projects Engineer.

   J.C. Solvasen ..... Project Engineer Sparrow Missiles.

   W.H. Hess .... Asst. Project Engineer, Sparrow.

   S. L. Colby .... Aerodynamicist, Sparrow Missiles.

   Dr. A.F. Johnson .. Electronic Specialist, Sparrow.

   Frank Lemmon ...... Electronic Design Engr., Sparrow.

4. The Drone always used by Douglas is the F6F.

APPENDIX III

Miscellaneous Notes on the Sparrow Missile

1. The Motor

This is an 'Aerojet' solid propellant type motor, developing 14,400 lb/secs thrust for approximately 2 seconds. It has a shock-proof ignitor. Black powder type was abandoned as introducing high shock. A new type is used (Alclo) which sprays molten magnesium and aluminum.

2. Radome and Antenna

The radome is a solid dielectric type of construction. The antenna has a very sharp 2 degree beam to half power points with side lobes 30 db down. Cross-talk is less than spec.

3. Missiles and Supplies

The external supplies required by the missile prior to launch are 2,500 W per missile max., all 28 V DC. The umbilical plug carries 20 wires (size and type unspecified). Heater blankets are required by the missiles under certain conditions. These are for the electrical and hydraulic power supplies, and require 250 W for 30 minutes to heat the missile from -65 to +60 degree F. In hot ambient conditions, no cooling is provided for the missiles. Missile units are tested to operate under acceleration conditions of 20 - 30 G in manoeuvre, and 80 G in shock.

4. Power Supply Turbine System

The 400 c.p.s. AC frequency output of the alternator must be closely held, as it establishes the p.r.f. of the transmitters and runs synchronus motors. It is therefore necessary to hold the aircraft 3 phase supply to this accuracy when running the turbine prior to motor ignition.

Ignition is by means of a glow plug that heats the Ethylene dioxide mixture to its flash point 1,050°F. The lower and upper explosive limits are 3% - 100% by volume at 1,050°F. The mixture is not readily ignited

4. Power Supply Turbine System (Cont'd)

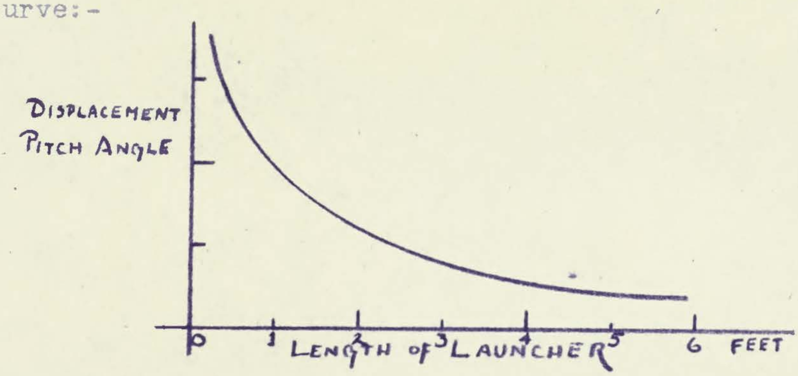
by a hot surface because of the cooling effect on the surface of the high latent heat of vapourization of the gas. Neither is it ignited by a rifle bullet.

The products of combustion are methane and carbon monoxide, which, though toxic in a confined space, are quite safe in a ventilated area.

5. Launching and the Launcher

To give conditions of radio silence, all the transmitter supplies are energized and allowed to warm up, but the magnetron field supply is held off. Full power transmission is obtained 50 ms after field energization. Experiments have shown that in a transonic aircraft the opening of the missile bay can produce buffets of up to -1G.

All Douglas launches to date have been from zero length launchers. The decision to take the optimum length of launcher to be for 3 feet of controlled run, was based on some test results illustrated in the accompanying curve:-



The AERO 1A launcher is $80\frac{1}{2}$' long and weighs 36 lbs. The pick-up buttons are, 61.35" from the nose, and 22.31" apart. A launching shear-pin is provided with a shearing strength of 2 G. The launcher has a retain detent with breaking strength of 10 G as part of the jettison facilities. These are provided in the Sparrow 2 philosophy, because it is designed for carrier operation

5. Launching and the Launcher (Cont'd)

where a jettisonable load may be necessary for survival, and are carried out by blowing the missile backwards to the end of the rails.

6. Sequence of Operations in an Attack

Pilot Functions	Operations Resulting
(1) Pilot turns on HYDRAULIC WARM-UP switch.	Hydraulic and battery power supply heating systems turned on.
(2) Pilot selects MANUAL or AUTO-FIRE, No. of MISSILES required, switches power to STANDBY.	General missile auxiliaries and auxiliaries associated with selected missiles turned on. The following items energized in the missiles selected: Filaments, Gyro motors, Modulators, Inverters, also, through time delays, the control signal and B+ voltages are supplied to the selected missiles. (The hydraulic and battery heating systems are turned on if function #1 is not selected.)
(3) Pilot finds and locks AI onto the target.	Pilot's scope steering presentation appears. In the selected missiles: The transmitters are turned on, the seeker antennas are slaved to the AI antenna, the range sweeps are started. When each seeker locks on: Missile lock-on signal appears on the pilot's console, automatic range track is initiated, automatic slaving ceases, automatic antenna tracking of target commences, the "missile ready" tone becomes available.
(4) The pilot flies the steering dot on his scope display.	The selected missiles fire in ripple when the range is correct if AUTO has been selected. If MANUAL has been selected, then two further functions, (a) and (b) as below, are required.

6. Sequence of Operations in an Attack (Cont'd)

Pilot Functions	Operations Resulting
(4) Cont'd	
(a) Pilot holds down his firing button.	The following sequence of operations occurs: Ignitor selects the missile to fire, internal power is switched on, (external power off), roll gyro is uncaged, antenna is uncaged, ignitor fires. (This sequence then repeats for the next missile, if ripple firing has been selected. If single firing has been selected then sequence (b) occurs.
(b) Pilot releases button and presses it again.	Sequence (a) is repeated for another missile.
(5) Pilot pulls out.	AI looses lock, search presentation returns.
(6) If missiles have not been fired by the time minimum range is shown on the scope, the pilot pulls out.	As (5) above, but also: missile transmitters are turned off, auto-track discontinues, range sweep discontinues and slaving of the antennas discontinues.

Note: The following conditions must be satisfied before the firing signal is enabled:-

Landing gear up.

Seeker locked on.

Within range allowabe.

Within heading angle allowable.

Missile on internal power.

Instrument gyros uncaged.

Firing circuit energized.