TL-113-58/10

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Issued to ..RCAF.....

Date .....October 2nd 1958.....

APPENDIX B

CAPABILITIES OF THE MARK 1A SYSTEM

ASTRA

September 17, 1958

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ASTRA System Integration

CAPABILITIES OF THE MARK 1A SYSTEM

The MK 1A System was described in the Arrow Weapon System Coordinating Contractor Reports 1 and 3, and was termed the "Minimum Astra System."

The basic subsystems of the Mk 1A System are:

1. Aircraft Instruments (Attitude Indicator and Mach Meter)
2. Navigation [Dead-Reckoning Computer, Low and Medium Frequency Automatic Direction Finder (ARN-6) UHF Automatic Direction Finder (ARA25)] .
3. AI Radar (Antenna, Transmitter, Receiver, Synchronizer, Power Supplies, Search Computer and Programmer, AMTI Signal Processor, Range and Angle Track).
4. Fire Control Computer and Sparrow II Missile Auxiliaries.
5. Automatic Flight Control (Hold Modes).
6. Air Data Computer
7. Vertical and Heading Reference [Vertical Gyro (GG48), Directional Gyro (LDG-1), Flux Valve, and 3-axis Repeater]
8. Identification [Ground-to-Air Transponder (APX 25A)]
9. Communications [UHF Command Set (ARC 552), Intercomm (AIC 10 A)]
10. Ground Support Equipment

The MK 1B System, or "Full System" differs from the MK 1A by the addition of the following:

1. Doppler Navigational Radar
2. Data Link Receiver and Coupler
3. Infra Red Seeker
4. Air-to-Air IFF Interrogator
5. Air-to-Air IFF Transponder
6. AFCS Integrated Coupler
7. Increased Power Magnetron

The following modes are not available in the MK 1A due to the lack of a portion of the equipment required for the mode.

1. Beacon Reception (Since the a-a IFF interrogator receiver is used in this function)
2. Quasi-Passive Ranging (Since this mode depends on IR for angle tracking)

The capability of the MK 1A System is different from MK 1B in the following basic areas due to lack of equipment, data, or flight evaluation time:

1. Manual insertion of GCI data, rather than automatic.
2. Manual control of the aircraft, rather than automatic.
3. Decreased detection range by 10 per cent.
4. Manual insertion of meteorological wind data, rather than automatic doppler radar inputs.
5. IR and QPR ECM capabilities.

6. Air-to-Air Identification.

7. Genie capability.

The following presentation is intended to show the overall capability and accuracy of the MK 1A System by function and mode.

1.0 Aircraft Instruments (ASTRA Only)

1.1 Aircraft attitude is presented on a moving horizon type display of aircraft elevation and roll angles from 0 to 360° to an accuracy of 1.7°. Elevation trim is adjustable from 20 degrees dive to 10 degrees climb.

1.2 The mach indicator displays aircraft mach and limit mach. Aircraft mach is displayed from M 0.65 to 2.2 accurate to M 0.028.

2.0 Navigation to Intercept and Return-to-Base

2.1 Broadcast Control

2.1.1 The navigation subsystem provides the following displays and manual entry equipment.

a. Pilot and Observer Destination Indicators:

PDI

Mode of Operation	Interceptor Heading Card	Bearing Pointer	Command Bug	Distance Counter
Broadcast Control	Magnetic Heading	Relative Target Bearing	Heading Error when read against Lubber Line	Distance to Target
Close Control	Magnetic Heading	Relative Target Bearing	Heading Error	Distance to Target
Return to Base	Magnetic Heading	Relative Error	Heading Error	Distance to Base

2. 1. 1 (a) Cont'd. PDI (Cont'd)

Function Selector Switch in ADF Position				
Mode of Operation	Interceptor Heading Card	Bearing Pointer	Command Bug	Distance Counter
ADF	Magnetic Heading	Relative Bearing of Radio Station	Heading Error	Flag Covers Distance Counter

ODI

All of the signal inputs to the ODI are the same as those listed in the previous table except that grid heading is shown rather than magnetic, and for the Set Indicator position which follows:

Mode of Operation	Aircraft Heading Card	Bearing Pointer	Command Bug	Distance Counter
All Modes	Aircraft Grid	Relative Bearing of Fix Point	Same as PDI	Distance to Fix Point

b. Target Data Display -- Target data is presented in rho-theta coordinates on two dial and counter type displays. The following information may be manually inserted:

Function	Range	Increments	Type of Display	Relative to:
Target Range	0 - 999 N. miles	1 mile	Counter	Interceptor or GCI
Target Bearing	0 - 360 degrees	2 degrees	Dial	Interceptor or GCI
Target Speed	0 - 1,500 knots	1 knot	Counter	Interceptor or Grid

c. Wind Data Display -- Meteorological wind speed (0 - 200 knots) and direction (0 - 360°) is inserted manually.

2.1.1 Cont'd

d. Time-to-go to destination continuously presented.

e. Five Ground Control Interceptor Reference Stations are selectable including "grid zero" for target data entry and display.

f. Five bases are selectable for return-to-base.

g. Command heading to the pilot is held while data is being inserted until "Heading Hold - Off" is selected.

h. Check points received from the LF/MF ADF, UHF ADF, GCI, or ground map are manually inserted.

2.1.2 Check Point Facilities

ARN-6	--	LF/MF ADF
ARA-25	--	UHF ADF
ARC-552	--	Communications Set (GCI fix)
Ground Map	--	AI Radar

2.2 Close Control

The same dead-reckoning facilities are available with the pilot receiving steering instructions directly by voice from GCI.

2.3 Performance

For the standard high speed mission profile the expected error in computed position and heading is 2 miles (1σ) and 0.75 degrees (1σ) at AI radar acquisition and 5 miles (1σ) after return-to-base exclusive of wind errors, with no check point insertion.

3.0 Fire Control

3.1 Detection

3.1.1 Clear Environment

The probability of detection for a 5 m^2 target closing at M 4 is 80% at a range of 29 nm. The basic parameters of the MK 1A System pertinent to the detection range are:

Pulse Width	2.35 μ s
Pulse Repetition Frequency	330 cps ±0.8% FM
Transmitter Power	750 KW ±0.4 db
Transmit Insertion Loss	0.8 db
IFF Injection Loss	0 db
Antenna Gain (9,400 mc)	34 db
Beamwidth (9,400 mc)	2.9°
Side Lobes	-22 db
Polarization	Horizontal, Vertical, Left and Right Circular
Overall Receiver Noise Figure	9.5 db
IF Bandwidth	1.5 mc
Minimum Discernible Signal	-103 dbm
Assumed Field Degradation	7 db
Range Scales	200 nm, (ground map and beacon, 80, 40, 16 nm AI search, 8,000 yd. VIP
Indicator Resolution	300 lines

The 16 nm and 8,000 yard ranges are operated with the radar in the short pulse mode (0.5 μ sec., 1 KC PRF).

3.1.1 Cont'd.

The operating point of the transmitter is magnetically regulated for optimum performance.

Scan Pattern:

Central axis controlled by navigation computer output with manual trimming or full manual control.	Narrow -- 40° x 13.5° 3 Bar Palmer with center bar retraced. Wide -- 140° x 13.5° 3 Bar Palmer with center bar retraced. Searchlight - 5° conical scan

Scan Pattern Stabilization:

±2° for all aircraft attitude within antenna gimbal limits.

Antenna Gimbal Limits:

+75°, -50° elevation, ±75° azimuth

Look Angle Limits:

(Excluding Beamwidth)

With respect to A/C Datum Line.

+70°, -45° elevation, ±70° azimuth

GCI Target Designator:

Circle presented on B scan at predicted azimuth and range.

3.1.2 AMTI Performance

The parameters of the radar are the same as 3.1.1 with the exception of the following:

Pulse Width	0.5 μ sec.
Pulse Repetition Frequency	4,000 cps

3. 1. 2 Cont'd

Transmitter Frequency	9, 200 mc/sec.
Transmitter Power	375 KW ±0. 4 db
IF Bandwidth	4. 0 mc
Range Scale	16 nm

Double delay line cancellation is used. Cancellation of ground clutter is 30 db along the ground track.

3. 1. 3 Detection of Barrage Jammer

A 2 watt per megacycle barrage jammer may be detected at a range of 200 nm. The criterion for detection is a 6db jamming signal to noise ratio.

3. 1. 4 Display

The B scan display provides 4. 5" x 4. 2" effective area with the GCI target designator, elevation marker, and local target designator superimposed.

3. 1. 5 Counter-countermeasures Capability for Search

a. Magnetron tuning at 70 mc/sec.^{2} for avoidance of "friendly" jamming or interference.

b. Random magnetron tuning at rates up to 200 mc/sec.^{2} to avoid spot jamming.

3. 2 Local Target Designation and Acquisition

The target designation in range and azimuth is by two dots on the B scope used to bracket the target. The designators are 1 mile apart in range, positioned by the radar hand control, and are heading stabilized.

3.2 Cont'd.

On depressing the acquisition trigger, acquisition is automatic with the antenna slewing to the designated azimuth and the range gate sweeping over the one mile interval designated.

Target reject-in range only overrides the automatic lock-on circuitry to reinitiate range sweeping at the designated range and azimuth.

The radar parameters are the same as during track with a minimum acquisition sensitivity of -92 dbm for a 2,400 knot closing rate.

3.3 Track

3.3.1 Clear Environment

The tracking parameters of the AI Radar are as follows:

Pulse Width	0.5μ sec.
Pulse Repetition Frequency	1,000 cps ±1.5% FM
Transmitter Power	750 KW ±0.4 db
Transmit Insertion Loss	0.8 db
IFF Injection Loss	0 db
Antenna Gain (9,400 mc)	34 db
Beamwidth (9,400 mc)	2.9°
Conical Scan Offset	1.05°
Conical Scan Frequency	66 2/3 cps
Beam Crossover (one way)	-1.5 db
Side Lobes	-22 db
Polarization	Horizontal, Vertical, Right and Left circular

3.3.1 Cont'd.

Overall Receiver Noise Figure	9.5 db
IF Bandwidth	4.0 db
AGC Threshold	-82 dbm
AGC Dynamic Range	110 db
Range Track Limits:	
Range	25 nm max., 150 yds. min.
Range Track Error	$\frac{\ddot{R}}{3/\text{sec}^2} + \frac{\dot{R}}{1,000 \text{ sec}}$ $\pm \frac{R}{100} \pm 20$ yds.
Angle Track Limits:	
Angle	$+70^\circ$, -45° Elevation $\pm 70^\circ$ Azimuth
Target Angular Rate	0.5 rad./sec.
Angle Track Error	$\frac{\ddot{\theta}}{28/\text{sec.}^2} + \frac{\dot{\theta}}{85/\text{sec.}}$ ± 1.0 mr +6 mr (Radome & Boresight)
Base Motion Attenuation	$\frac{\ddot{\theta}}{340/\text{sec.}^2} + \frac{\dot{\theta}}{340/\text{sec.}}$

Pre-gated video and nose tail tracking are both approaches to the chaff and ground clutter problem. Analysis shows that these modes will be effective to within $\pm 15^\circ$ of the beam aspect angle for continuously dispensed chaff and less than 5° for bundles.

Continuous random magnetron tuning is available with a maximum rate of 200 mc/sec.^{2}.

3. 3. 1 Cont'd.

Antenna polarization selection of right circular, left circular, horizontal and vertical provides 3 to 20 db rejection of jamming power depending on jammer sophistication.

ECM homing is provided as a range-denied tracking mode for barrage or spot jamming.

In the event of completely effective countermeasures, the optical mode provides capability under clear weather conditions in tail attacks.

In the design of the radar many of the parameters chosen increase the effectiveness of the Astra System against jamming. Servo dynamics have been selected to provide both range rate and angular rate memory. The microwave AGC extends the dynamic range of allowable signal levels to +28 dbm.

An aural presentation of the angle track error signal is used to alert the operator to ECM and, with the B scope, provide identification of the type being used.

3. 4 Attack

The fire control computer and missile auxiliaries provide steering signals and preparation for the following armament and courses.

3.4 Cont'd

Armament	Environment	Courses
Four Sparrow II, fired in the order of lock-on; in pairs, or all.	Clear	Lead Collision Lead Collision Snap-up Lead Pursuit Optical
	ECM (Range denied)	Home on Jam Fixed-Range Lead Pursuit Collision
	ECM (Completely effective)	Optical

The pilot's attack display is composed of the following elements:

Element	Mode	Range
Steering Dot	All Except Optical	20°/in. to 25° of steering error
Ref. Circle	Lead Collision, Lead Collision, Snap-up,	5° of steering error
	Collision Lead Pursuit, Fixed Range Lead Pursuit	Variable diameter to indicate allowable steering error as a function of altitude. Scale 20°/inch.
Artificial Horizon	All Attacks Except Optical	Roll: 1°/1° Vertical Translation: Corresponds to sine of pitch angle, one inch translation corresponds to 25°.
Range or Time Arc		Range to Rmin. and Rmax. minus Rmin. 222 yds./deg.

3.4 Cont'd

The system provides data readout for a non-firing visual identification pass.

Azimuth and elevation angles are read from the observer's scope; range and range rate are read from a meter located beside the scope.

4.0 Communication and Identification

Air-to-air and air-to-ground communications are provided by the ARC-552 command set. Intercomm facilities are provided by the AIC 10 A.

The ground-to-air IFF transponder is the APX 25A.

5.0 Automatic Flight Control

The AFCS provides the following pilot assist modes:

Mode	Range	Accuracy
Mach Hold	0.2 to 0.98 and 1.06 to 2.2 M	±.0015 M
Altitude Hold	-1,000 ft. to 65,000 ft. (pressure alt.)	±25 ft.
Pitch Attitude	±60°	±0.5°
Heading Hold	0 - 360°	±0.5°
Bank Hold	±60°	±0.5°

6.0 Installation Requirements

6.1 Electric Power Requirements

The power requirements shown are for the MK 1B Astra System and

6.1 Cont'd.

four Sparrow II Missiles. For MB-1 the power consumption is lower. Flight Instrumentation is not included.

6.1.1 Power Consumption

	115V/200V - 400 cps-3ø	27.5 VDC
Normal with all missiles	KVA	Watts
Normal with all missiles at steady state.	28.0	1,250
Max. generator load at a-c peak (last missile starting).	40.0	1,250
Max. generator load at d-c peak (first missile starting).	26.5	1,950
Emergency	1.0	200
Emergency during UHF channel change (3 sec.)	1.0	325
Maximum transient (Missile start)	12.0	700
Power Factor	0.75 to 1.0	
6.1.2 Tolerance		
Steady State voltage	±1.5%	±1.0 volt
Voltage Transient	±8%	±5.0 volts
Voltage Transient Recovery Time Constant	0.2 sec.	0.2 sec.
Harmonic Content	2%	
Steady State Frequency	±1%	
Frequency Transient	±1.5%	
Frequency transient recovery time constant	0.5 sec.	
Min. Frequency for load connected	380 cps	
Ripple		1.0 V p - p
Min. voltage (emergency)		20.0 V

6.2 Air-Conditioning Requirements

87#/min. at 70°F. -- This does not include the cooling air requirements of the missiles.

6.3 Hydraulic Power Requirements

3.5 gallons per minutes at 4,000 psi.

6.4 Pressurization Requirements

126 cubic inches/min. (STP) supplied at 14 to 74 psia.

6.5 Total Weight

The following figures are for a MK 1B System, the MK 1A is somewhat lighter.

Electronic System	--	2,220 pounds
Racks and Cabling	--	440 pounds
TOTAL	--	2,640 pounds

6.6 Reliability

90% probability of remaining operational standard missions of 80 to 130 minute duration.

6.7 Availability

18 missions during a 30 day period. Six 30 minute periods of "Standby", with three operational missions per 24 hour period.

6.8 Standards

RCA ASTRA I Standards Handbook.

6.9 Environmental Conditions

RCA ASTRA I Environmental Specification.

6.10 Sensor Requirements

6.10.1 Indicated Temperature

6.10.2 Pitot - Static Pressures

6.10.3 Angle of Attack

6.11 Radome Requirements

RCA Drawing #8940240-A Type B

7.0 Ground Support

The maintenance concept is based on semi-automatic flight line test sets to minimize aircraft down time and in-aircraft repairs, complemented by second-line test, alignment, and repair consoles in the maintenance shops.

The semi-automatic fire control test set generates a target return which is detected and tracked utilizing 85% of the fire control system, checking the system for miss resulting from alignment errors or failures.

The navigation system is also checked by the insertion of a typical problem which in this case is done by the manual data entry controls.

The communication system is checked by means of a test set which operates through the ARC 552, AIC 10A, and ARA 25.

The AFCS, Air Data Computer, Attitude Indicator, and Mach Indicator are checked by the flight control semi-automatic test set.