RYAN

AEROSPACE

RYAN AERONAUTICAL CO., LINDBERGH FIELD
SAN DIEGO, CALIFORNIA

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J. R. HAWKINS CO. SAN DIEGO

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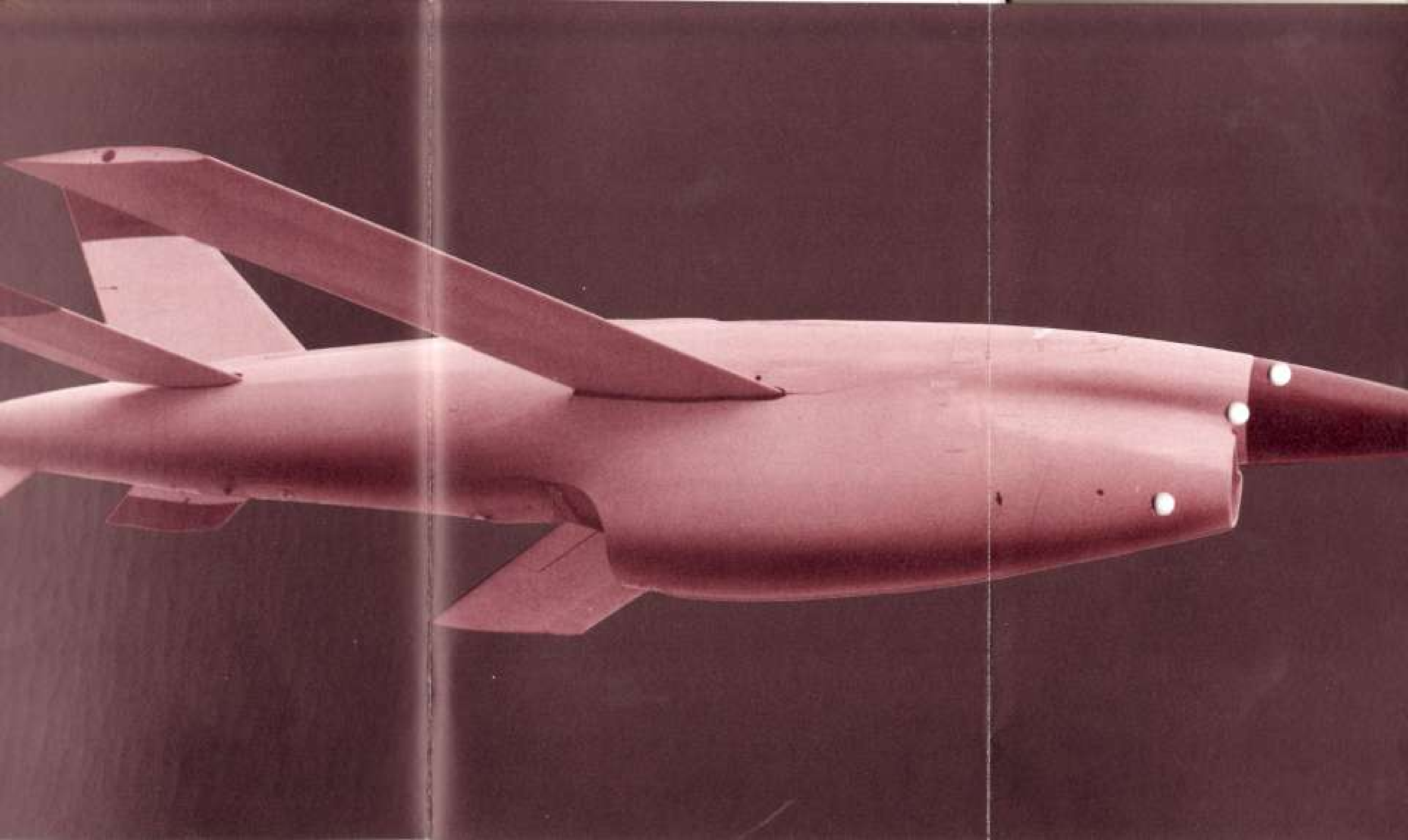
SYSTEMS DESCRIPTION

RYAN Q-2C FIREBEE TARGET



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INTRODUCTION

The Q-2C Firebee target drone, manufactured by the Ryan Aeronautical Company, is the newest, most versatile member of the well known Firebee family. It is currently in operational service as a realistic aerial target testing the most modern weapon systems and developing intercept skills for the United States Air Force and Navy.

The Q-2C was developed as an outgrowth of its Firebee predecessors to extend flight capabilities and improve the target systems to keep pace with the rapid advancements of weapon systems. Extensive flight testing at Holloman Air Force Base, New Mexico, demonstrated the functional capability, effectiveness and reliability of the Q-2C. Additional operational testing at Tyndall Air Force Base and NMC Pt. Mugu substantiated the results of the Holloman tests. As a result of this evaluation, the Q-2C was selected as the high-speed, high-altitude target for Project William Tell 1961. The target performance and reliability during this USAF World-Wide Weapons Meet contributed immeasureably to the outstanding records achieved.

In recognition of the axiom of combat — know your adversary — this technical bulletin has been prepared to give descriptive information about the operational systems, capabilities, and general characteristics of the Q-2C Target Drone.

DESCRIPTION

A

A-1 General The model Q-2C Firebee is a remotely-controlled target drone manufactured by the Ryan Aeronautical Company, San Diego, California. The basic mission of this drone is to provide a realistic aerial target for air defense training and weapon systems evaluation. The Q-2C is a high-speed near-sonic drone designed to be launched either from a zero-length ground launcher or from a suitably equipped launch aircraft. It is of mid-wing construction and is propelled by a Continental J69-T-29 turbojet engine.

The Q-2C is designed for a sustained flight capability of one hour or longer and to operate at altitudes ranging from 300 feet above terrain to in excess of 50,000 feet MSL at over 500 knots TAS. During flight, the drone is remotely controlled by radio through all normal flight maneuvers. A radar beacon is employed for tracking, and telemetry supplies in-flight data to aid the remote control operator. Radar, infrared and visual augmentation devices are utilized to meet mission requirements, and scoring systems provide for weapon systems and interceptor evaluation.

Recovery is accomplished by a two-stage parachute system. Operation of the system is initiated either remotely by command or automatically by loss of power or loss of radio control carrier. Automatic glide enables the operator to maneuver the drone to a suitable recovery point upon fuel depletion.

The Q-2C is designed for operations over land or water. Styrofoam flotation blocks, compartment sealing, and a fuel expulsion system to reduce weight insure flotation while the drone awaits retrieval from water.

A-2 Structure The basic structure of the Q-2C, composed of five major sub-assemblies (Fig. 1), promotes ease of maintenance and repair. These readily installed structural components are the fuselage, nacelle, wing, empennage and tailcone.

FOLD OUT FOR FIGURE 1

Wing	Area 36.0 sq. ft. Aspect Ratio 4.632
Horizontal Stabilizer	Area 16.69 sq. ft. Aspect Ratio 3.30
Vertical Stabilizer	Area 11.28 sq. ft. Aspect Ratio 1.5
Ventral Stabilizer	Area 1.43 sq. ft. Aspect Ratio 1.6

Gross Weight (Basic)	2060 pounds
Power Plant	J-69-T-29, Continental
Rated Thrust	1700 lbs. S.L.S.
Width	12.9 ft.
Length	22.9 ft.
Height	6.7 ft.

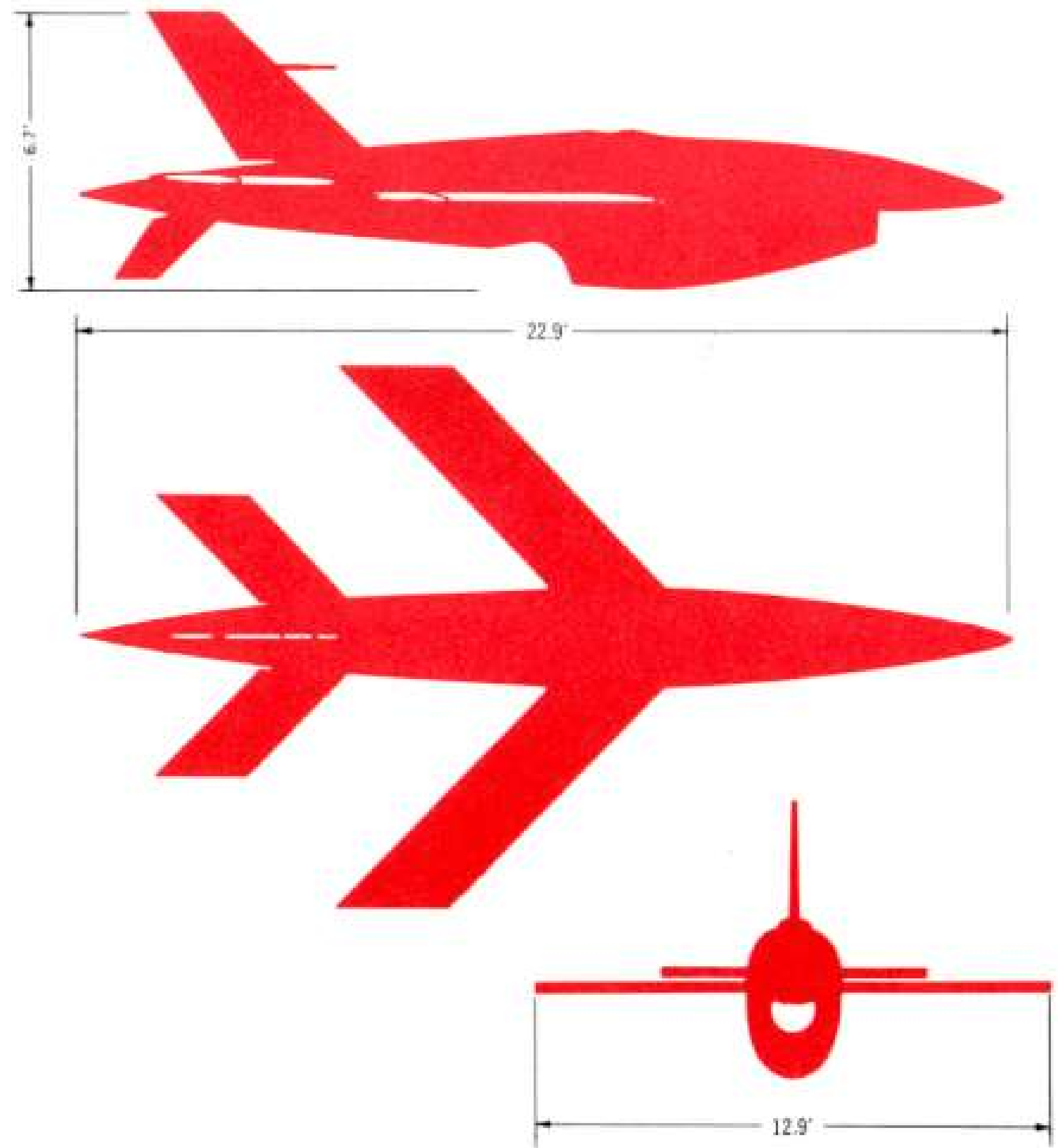
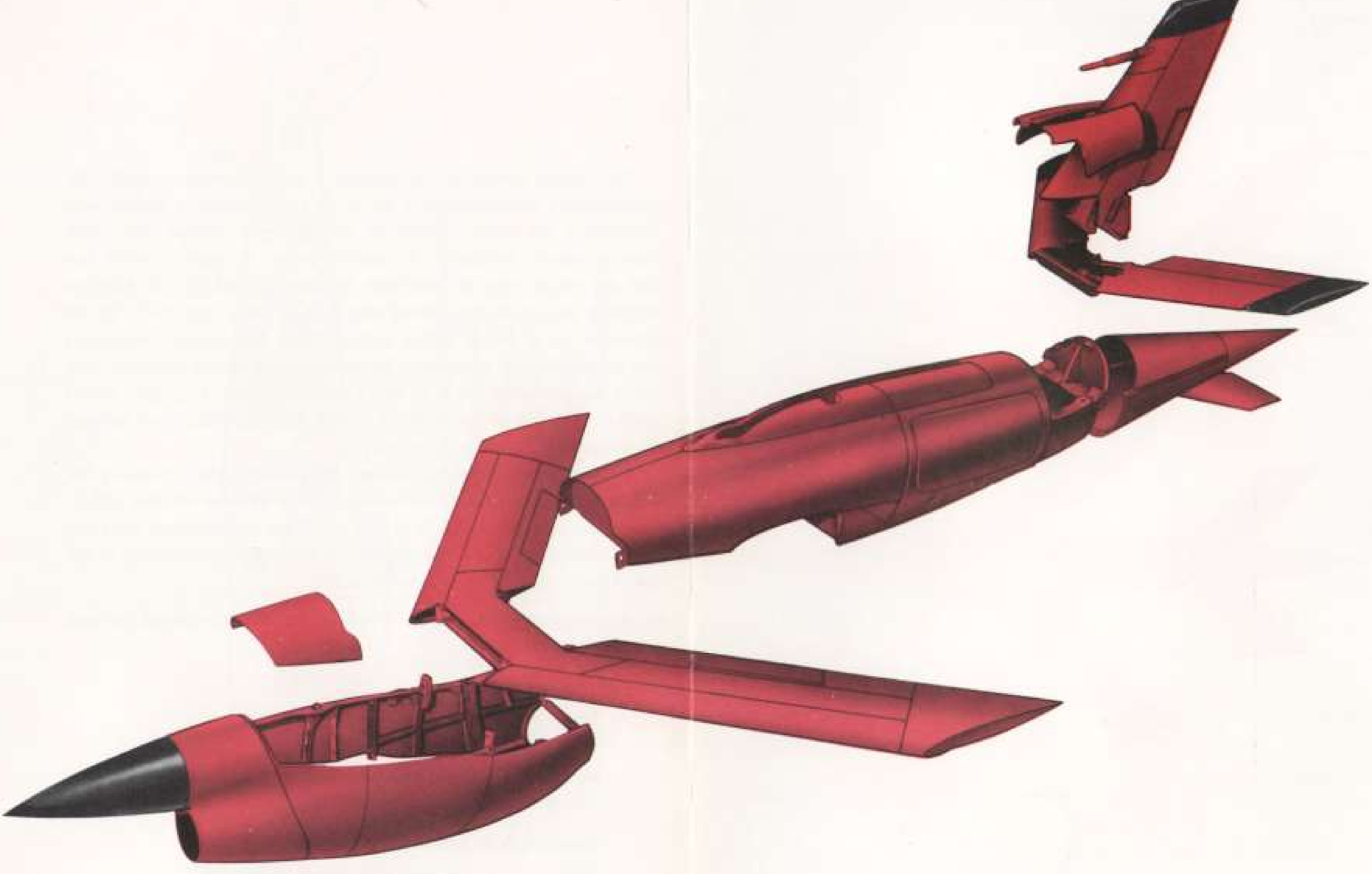


FIGURE 2 GENERAL ARRANGEMENT

FIGURE I   BASIC STRUCTURE



The fuselage consists of two sections, a forward section containing four interconnecting fuel compartments, and an aft section containing the equipment compartment. The nacelle contains the J69-T-29 engine complete with engine-driven accessories, tailpipe and air induction system. The plastic laminate nose cowl and radome nose are detachable for repair and service. The 45-degree sweptback wing incorporates leading edge droop to reduce drag, due to lift, and detachable tips to reduce landing damage. Torque tube actuated ailerons are located approximately at mid-span. The horizontal and vertical stabilizers, comprising the empennage, are of 45-degree sweptback design. A fiberglas antenna housing is mounted on the tip of the vertical stabilizer. Conventional elevators and a directional trim rudder are provided.

The tailcone consists of two sections. The forward section, containing the main parachute, is attached to the fuselage by three implosive bolt type fittings. A 45-degree sweptback ventral fin is attached to this main parachute container. The aft section, the drag chute container, is a fiberglas cone attached to the main chute container by two explosive fittings.

A-3 General Arrangement Principal dimensions and inboard profile are indicated in Figures 2 and 3.

A-4 Performance

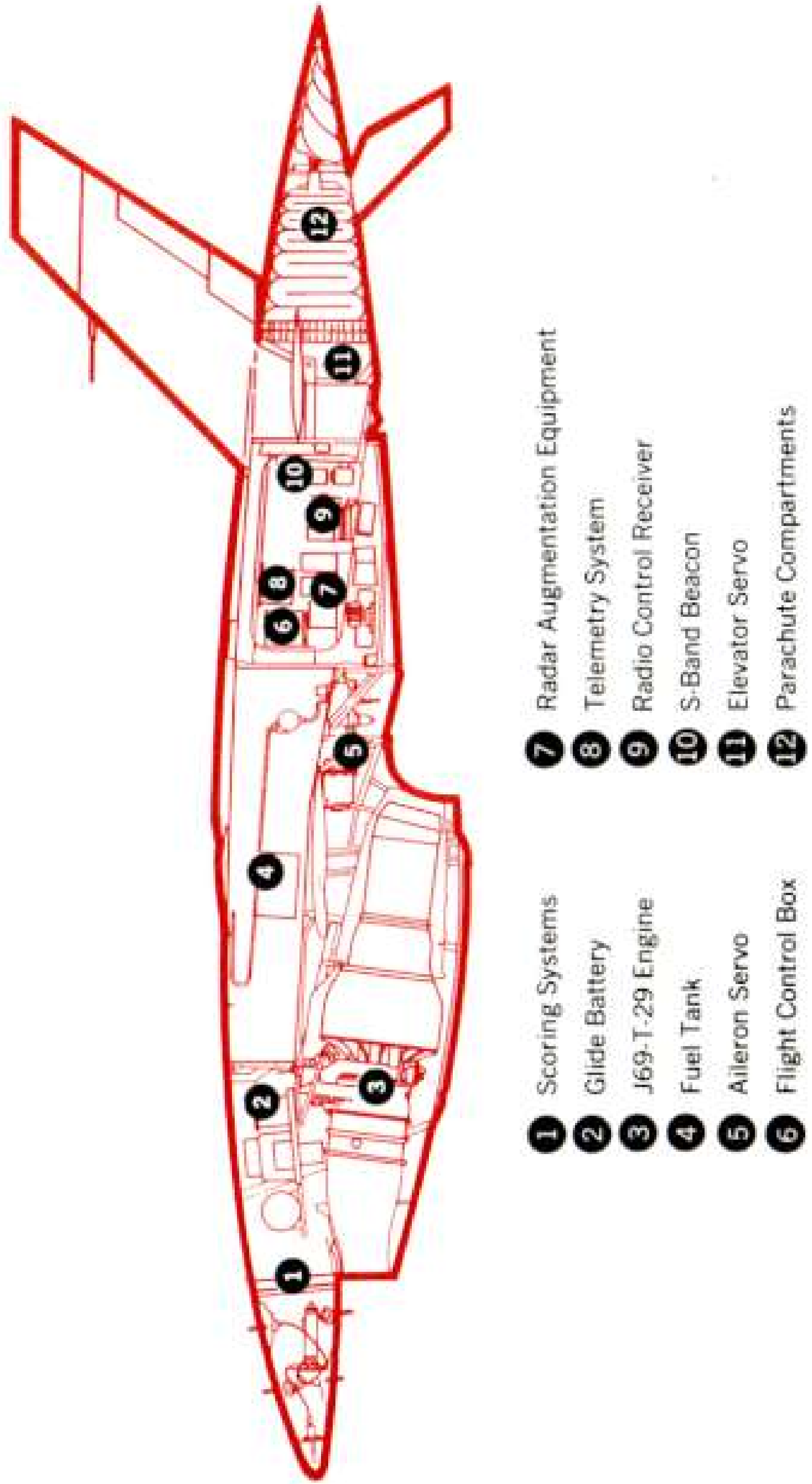
Design Objectives:

Speed	500 knots TAS at 50,000 feet
Altitude	From 300 feet to in excess of 50,000 feet above MSL
Endurance	One hour above 50,000 feet

Demonstrated Performance:

Speed	.96 Mach (550 knots at 50,000 feet)
Altitude	59,800 feet maximum
Endurance	96.8 minutes — Powered
	77.5 minutes — Above 50,000 feet

FIGURE 3 INBOARD PROFILE



Typical Operational Performance The following operational performance data are from seven typical Q-2C ground-launched missions made during 1961:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Date	7/6	7/7	7/12	7/13	7/18	7/20	7/24
Weapon	MB-1T GAR-1D	MB-1T GAR-1D	MB-1T	MB-1T	MB-1T GAR-1D	MB-1T GAR-1D	GAR-3A GAR-4A
Mission Alt. (x 1,000 Ft.)	40	40	40	40	40	40	45
Time to Climb (Min.)	9	8	7	8	8	8	14
Time on Station (Min.)	19	78*	66	67	52	56	34
No. of 70 Mile "Hot" Legs	1.5**	4	4	4	3	3	2
No. of Intercepts	8	17	10	13	14	18	4
No. of Firings	6	14	6	7	10	8	3

* Target held on station after mission completion to fuel out.
** Second hot leg terminated by kill.

DRONE SYSTEMS

B

B-1 Power Plant A Continental J69-T-29 turbojet engine, rated at 1700 pounds S. L. S. thrust, provides the power for the Q-2C. This engine has a dry weight of 335 pounds, a maximum diameter of 25.17 inches, and is 44.81 inches long. It employs two stages of compression (one radial, the other axial), straight-through flow annular combustion chamber, and a one-stage axial turbine.

The engine burns standard JP-4 fuel and uses 10/10 oil in the lubrication system. The fuel system, including tank, booster pump and solenoid shut-off valve, are a part of the basic fuselage tank assembly. Lubrication is supplied by engine driven oil and scavenge pumps, with a 1.5 gallon oil tank as an integral part of the Q-2C air inlet assembly. Control of the electrically operated throttle actuator is accomplished by impulse signals from the remote control guidance system. A tachometer generator and tailpipe thermocouples are the only instruments employed on the engine. These provide information necessary for engine operation.

Primary electrical power is furnished by an engine-driven 28-vdc generator of 200 ampere capacity. The generator also serves as a starter motor for ground engine starts. Engine starts for air launch are accomplished by shaft windmilling. A 400-cycle, 115-volt inverter, located in the equipment compartment, furnishes AC power required by the various drone systems. Power for electrical devices of the recovery system and for drone control during the glide phase is provided by a 28-volt, 12.5 ampere-hour lead acid storage battery.

B-2 Flight Control and Stabilization The flight control system of the Q-2C is designed to automatically stabilize the drone in flight and to respond smoothly and accurately to maneuvering commands from remote control radio. The control surfaces consist of a small trim rudder and conventional ailerons and elevators.

Positioning movement of the trim rudder is controlled directly through the radio command link by a relay operated actuator. Movement of the rudder, to

correct for out-of-trim conditions, is limited to 12 degrees either side of center by electrical limits set in the actuator.

The ailerons and elevators are controlled through linkages by a flight control subsystem. This subsystem consists principally of a flight control box in the equipment compartment and the associated elevator and aileron servo actuators. The flight control subsystem is a two-axis maneuvering autopilot. It provides automatic stabilization in roll and pitch axis by sensing deviations from a reference and smooth and structurally safe response to remote radio command signals.

Significant operational features of the flight control subsystem include automatic scheduling of bank angles during turns as a function of altitude; programming of pitch maneuvers as a function of airspeed; a glide system to aid in maneuvering to a planned recovery area upon termination of powered flight; and a power-off climb feature to assure safe-recovery operation at low altitudes.

Turns Climbing, diving, and constant-altitude turns are provided. Bank angle schedules for climbing or constant-altitude turns are:

Below 15,000 feet	30 degrees
15,000 to 32,000 feet	45 degrees
32,000 to 60,000 feet	decreases linearly from 45 to 15 degrees.

Diving turns are scheduled for 45 degrees at all altitudes. A bank angle override command is included and may be used to increase any turn to 45 degrees.

Climbs and Dives Pitch maneuvers are accomplished on pre-determined airspeed schedules to automatically maintain a rate of climb or dive that will prevent stalling or overstressing the airframe. Climb and dive modes are locked in by single beep commands; and elevator positioning is automatically varied, as necessary, to establish and maintain the air-speed schedule.

Glide The glide feature is automatically activated upon loss of primary power above 15,000 feet. During this phase the flight control subsystem is battery powered and automatically positions the elevators to maintain 205 knots IAS. Turns during the glide phase are accomplished on the same bank angle schedules as shown above for climbing and constant-altitude turns.

Power-Off Climb The power-off climb feature is initiated automatically below 15,000 feet by loss of engine power, generator failure, or a normal recovery command. Its purpose is to gain altitude and reduce speed for safe low-altitude recovery. Upon activation of power-off climb, the elevators are driven up for a steep climb. Airspeed is programmed into this maneuver, and when speed is reduced to 180 knots by the power-off climb, both drag and main parachutes deploy simultaneously.

B-3 Command Guidance System Remote control of the Q-2C for maneuvering, operation of augmentation equipment, and activation of the recovery system is by a frequency modulated, UHF radio guidance system. The system utilizes an AN/ARW 59 radio receiving set as an airborne package in the Q-2C and a compatible transmitting set at the remote control station. The radio receiver is installed in the fuselage equipment compartment. The antenna is located in the plastic tip section of the vertical stabilizer.

The function of the AN/ARW 59 equipment is to receive and decode radio signals transmitted to control the drone and to energize a relay for the function desired. Commands issued at the Remote Control Panel activate audio oscillators which modulate the transmitted RF carrier. The receiver discriminator detects this audio frequency modulation and feeds it into a filter circuit designed to pass only that particular frequency. The output of this filter actuates a relay which controls the servo mechanism or end instrument that provides the function commanded. By use of multiplexing, a total of 25 control functions are possible.

A flight safety feature incorporated in the system activates automatic recovery system if the UHF command carrier signal is lost or interrupted for a period in excess of a pre-selected 10/20/30 second period.

Power for the AN/ARW 59 equipment is supplied by the 28 VDC drone electrical system. The carrier frequency range is 406 to 420 megacycles.

B-4 Tracking System The radar energy reflected by the drone skin alone is normally insufficient for dependable radar tracking. Therefore, an S-Band Beacon is employed to extend the tracking range. This beacon is basically an interlocked receiver-transmitter combination which receives a pulse-coded signal from the tracking station and responds with a coded reply at a fixed power output.

Q-2C target drones used by the United States Air Force are equipped with the AN/APN-91 S-Band Beacon. The United States Navy utilizes the AN/DPN-17. Both are pulse-type tracking beacons operating within the S-Band frequency range. The beacon is installed in the fuselage equipment compartment and operates from the drone 28 VDC power supply. The receiving antenna is located underneath the aft section of the fuselage, and the transmitting antenna is in the antenna housing on the vertical stabilizer.

B-5 Telemetry System A telemetry instrumentation system is incorporated in the Q-2C to relay performance data to the drone remote Controller. The telemetering system consists of data collection, conversion and transmitting equipment in the drone, and receiving and data display units at the remote control station.

The FM/FM transmitting system transmits an RF carrier with the performance information impressed upon it as frequency modulation. Flight data are measured by transducers and changed into varying voltages which are used to modulate the frequency output of audio oscillators. The output of these voltage-controlled oscillators, in turn, modulates the frequency of the RF carrier. The remote control station receiver detects, amplifies and demodulates the transmitted signal. The demodulated signal, composed of the composite sub-carrier frequencies, is delivered to band-pass filters which select the individual subcarrier frequencies and present them to discriminators. The discriminators demodulate the audio frequencies reproducing DC voltages proportional to the VCO input voltages. These voltages are used to drive data presentation indicators at the remote control site.

Performance data most essential to the drone remote controller are airspeed, altitude and engine RPM. These items of information plus an indication of radio control carrier loss are available in the standard Q-2C telemetry configuration. Additional information, such as TWT augmentation antenna position and flares remaining, may be telemetered as desired.

The Q-2C telemetry transmitter, manufactured by Dorsett Laboratories, Inc., operates in the 225-260 megacycle frequency band. It is installed in the drone fuselage equipment compartment. A multipurpose antenna located in the antenna housing on the vertical stabilizer, is connected to the transmitter unit by coaxial cable.

B-6 Recovery System In order to obtain full economic use of the Q-2C, a recovery system is incorporated to enable operating organizations to recover and retrieve the drone for additional missions. The basic requirement of the system is to decelerate the drone from all expected operating conditions to a terminal speed which is limited by the amount of energy the target can safely dissipate at landing impact.

The recovery system of the Q-2C employs a two-stage parachute sequence to assure a safe landing impact. The two parachutes used for this purpose include a 6-foot diameter drag and an 81.6-foot main chute. The drag chute is deployed immediately on system activation to decelerate the drone. The main chute lowers the drone in a horizontal attitude to the ground or water at approximately 16 feet per second (see figure 4).

During flight the drag parachute is housed in the tailcone of the drone and the main parachute is housed in a container immediately forward of the drag parachute. Both containers, prior to recovery, form a part of the fuselage. The parachute compartments are detached from the drone by means of electrically ignited explosive devices to permit parachute deployment. Activation of the recovery sequence may be initiated either by command of the remote controller, or automatically upon loss of engine or electrical power, or loss of command radio carrier signal.

The operational speed-altitude envelope of the Q-2C, encompassing near sonic speeds and altitudes ranging from 300 feet above terrain to approximately 60,000 feet MSL, requires various types of recovery system operation. Each type of recovery involves a different mode of operation. These are divided into high altitude (above 15,000 feet MSL) and low altitude (below 15,000 feet MSL).

In the high altitude mode, the recovery system may be activated by command or by loss of control radio carrier signal. (In this mode, loss of engine or electrical power will initiate a glide from which normal recovery may be commanded.) Immediately upon high altitude recovery system activation, the engine is shut down and the drag parachute is deployed. After a ten second delay the main parachute ejectors are armed, and upon descent of the drone through 15,000 feet this chute deploys.

Low altitude recovery may be initiated by command, lost radio carrier or loss of engine or electrical power. In this mode the drone enters a power-off climb phase, and when speed is reduced to 180 knots, both chutes are deployed simultaneously.

An emergency recovery system is incorporated which is entirely separate from the normal activation channels. This system has its own path for drag and main primer voltage, provides its own time delay (five seconds rather than the normal ten) between drag and main parachute arming, and has its own 15,000 foot altitude switch. The emergency system is available in both high and low altitude operation and may be activated at any time prior to main parachute deployment. Parachute response to this command is similar to the normal command except for the reduced time delay.

A low battery voltage automatic recovery feature is provided in the glide mode. During the glide phase, electrical power for all drone systems is provided by a storage battery. Since long periods of glide may drain the battery to a point where insufficient voltage is available for commanding recovery system operation, a battery under-voltage sensor is provided. This senses a drop in battery voltage below 23 volts and automatically initiates a recovery sequence.

A reefing line and timed cutters are employed to delay main parachute canopy opening, thus reducing initial deployment shock. The line encircles the parachute skirt and restricts its opening diameter to approximately seven feet. The two reefing line cutters are four-second delay pyrotechnic devices. They are armed upon main parachute deployment, and four seconds later sever the line in two places, permitting the canopy to open to its full diameter.

A main parachute release assembly releases the parachute from the drone upon land or water impact. This separation prevents the parachute from dragging the drone. Provision for dumping fuel at recovery is included. This reduces impact loads and retrieval weight. An electrically operated valve is opened upon release of the main parachute container and closed when the drone impacts on land or water.

SUPPORTING SYSTEMS

C

C-1 Launching Systems The Q-2C is designed to be launched either from a ground launcher or from wing racks of an aircraft.

Ground Launch This method utilizes a short rail type launcher inclined 15 degrees from horizontal and permanently mounted on a concrete pad (see figure 5). Normally, there are two of these launchers installed, both controlled from a block house centrally located between them. This dual installation provides a back up for each launch. Launch thrust is produced by a solid propellant Jato bottle installed in an adapter attached beneath the aft end of the drone. A pre-launch check of all the drone systems is conducted after the drone, with Jato, has been positioned on the rails. Upon completion of the pre-launch check, the Jato igniter is installed, the engine is started, umbilical connections are retracted and the Jato is fired. The Jato burns for 2.2 seconds, furnishing a nominal thrust of 11,300 pounds. At burnout the bottle along with the adapter falls free of the drone. The remote controller assumes command of the drone immediately.

Air Launch Specially equipped GC-130 and P2V type aircraft are currently in use as Q-2C air launch platforms. Drones are suspended from the launch racks and are controlled through umbilical connections for pre-launch checks, engine starting, and launching. The GC-130 is equipped to carry four drones, two on each wing; the P2V has a capacity of two. The drone may be air launched from altitudes of 10,000 to 20,000 feet at approximately 200 knots IAS. The Remote Controller assumes control about five seconds after drone drop-away, and commands functions as necessary to meet mission requirements. (see figure 5)

C-2 Remote Control Facility The remote control facility consists of all equipment necessary for in-flight data and target control. This includes an S-Band radar tracking unit with associated plotting facilities, a telemetering receiving set with a remote indicator panel, an FRW-2 radio control transmitter, and a remote control box with which flight and auxiliary commands are given to the drone.

AIR LAUNCH

FIGURE 5

GROUND LAUNCH

FIGURE 6 DRONE RETRIEVAL

In addition to the radar plot, the following information is normally available to the Remote Controller at the indicator panel:

- Airspeed
- Altitude
- Engine RPM
- Lost carrier indication
- Last command indication

Drone flight commands which may be issued with the Remote Control Box are:

- Turns, Climb and Dive (Control Stick)
- Straight and Level Command
- Bank Angle Override Switch
- Rudder Trim Control
- Throttle Control
- Command Chute Switch
- Emergency Command Chute Switch
- Carrier On Control (Radio Transmitter Control)

Supplemental data and controls which may be made available to the Remote Controller include:

- TWT Antenna Control (right or left antenna selection)
- Indication of TWT antenna position
- Flares Ignite Control
- Indication of flare ignition and flares remaining
- Scoring Equipment On-Off Control
- Smoke Command

C-3 Drone Retrieval Drones are normally retrieved by helicopters (see figure 6). Specially equipped boats and trucks may be utilized as retrieval vehicles.

To aid in helicopter retrieval, a metal blade erector is attached to the parachute riser in a manner to elevate the riser, creating a loop that facilitates insertion of the lifting hook.

TARGET AUGMENTATION

D

D-1 Introduction Because of its relatively small size as compared with conventional aircraft, the Q-2C utilizes special augmentation equipment to successfully evaluate weapons systems and aid in interceptor training. Provisions are made for positive target identification, GCI tracking, and controllable radar and infrared reflectivity. All Q-2C drones are painted Day-Glo for ready visual identification. Smoke or flashing light systems are available to aid visual acquisition. An AB-53, L-Band, radar beacon may be installed for electronic identification and GCI tracking. An active radar traveling wave tube augmentation system is used for controllable radar reflectivity. Flares, mounted on pylons on each wing tip, provide IR reflectivity and reduce drone destruction by heat-seeking missiles.

D-2 Visual Augmentation—Daylight Smoke systems may be employed to aid in visual acquisition and positive identification of the Q-2C during daylight operations. Two different systems are available. The first, for low altitude missions (below 20,000 feet), uses a smoke generator. This system consists of an oil/nitrogen charged cylinder and associated valves, tubes, wiring and nozzle. For high altitude operation (above 20,000 feet), JP-4 fuel is used from the drone's fuel tank. In both systems, the oil or fuel is released into the engine exhaust stream to produce smoke. Smoke, when commanded by the Remote Controller, is issued in a series of automatically programmed one-second puffs which occur every other second for an elapsed time period of 20 seconds.

Night Time An ACR-281 Flashing Light assembly may be installed for visual location and identification of the drone during night operations. The light is located on top of the drone in the forward section of the parachute riser fairing at station 140. It is designed to flash for three hours, approximately 50 times per minute, with a peak intensity of 1,000,000 lumens.

The installation is a self-contained, battery-powered unit consisting of a lamp and globe built into a case containing four batteries, a heating circuit, and wiring connection to the drone arming switch. The batteries supply power for the light and heaters. The heaters are included to insure operations at temperatures as low as minus 65 degrees F. (—54 degrees C.) The unit is armed and commences operation when the safety pin is automatically extracted from the target arming lanyard switch at drone launch.

D-3 Infrared Augmentation Drones scheduled for heat-seeker missile operations are normally equipped with pyrotechnic flares for infrared augmentation. Provisions are made for installing the flares in pylon mountings attached to the drone wing tips as shown in Figure 7. This wing tip mounting reduces target losses resulting from missile hits. Flares are ignited in sequence by command of the Remote Controller. Flare design prevents parasitic ignition caused by heat from adjacent flares. The Controller may be provided with a flare-ignition and flares-remaining indication at the remote indicator panel by telemetry feedback signals from the drone.

Various flare types in the 2-6 micron region are available to present the desired output characteristics. The W-211E flare, which has been used extensively, is approximately 13" long and 2" in diameter. It contains two pounds of IR composition which is ignited electrically and is designed to burn a minimum of 80 seconds. W-211E specifications require a minimum output in excess of 1,000 watts per steradian in the 2.0 to 3.0 micron wave band at sea level. Recent tests indicate the average flare has an output of approximately 2200 watts/steradian and a burning time of about 92 seconds. At 30,000 feet MSL, the average burning time is 2.7 to 3.2 minutes.

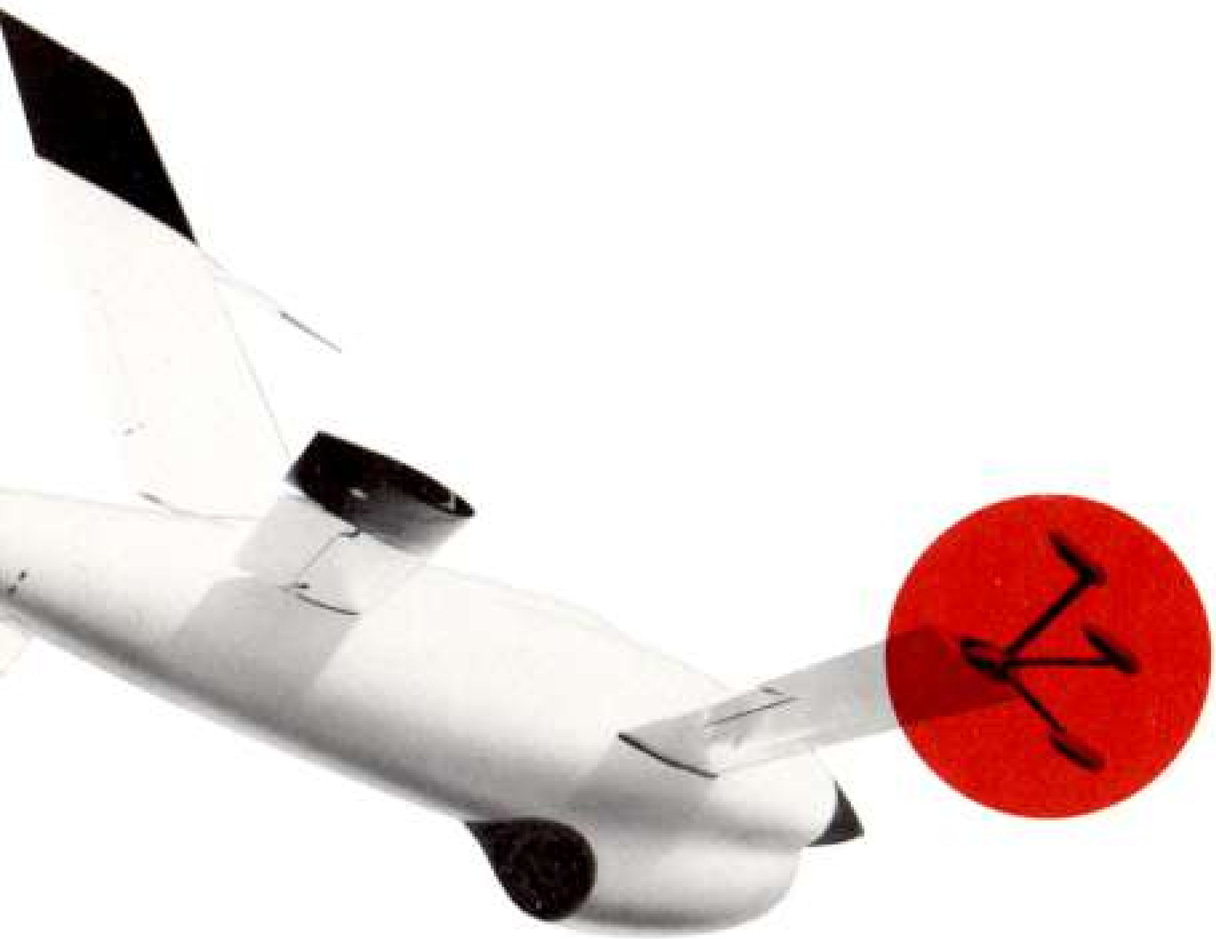


FIGURE 7 INFRARED AUGMENTATION

D-4 L-Band Radar Beacon To present a positive means of electronic identification and to offer a realistic target for interceptor ground control, an AB-53, L-Band radar beacon is used. This system provides tracking response at the radar receiver which is independent of the small physical size of the target, thereby providing much greater tracking ranges than would be possible with skin tracking.

The AB-53 radar beacon consists of a power supply, receiver, decoder, transmitter and associated coaxial cabling and antenna. The basic components are installed in the fuselage equipment compartment and connected to the multipurpose antenna in the fin cap.

The unit operates on conventional radar beacon principles. It is a pulse type receiver-transmitter utilizing a common antenna. The receiver and transmitter operate at different frequencies, thereby eliminating complex antenna switching. The antenna receives a signal from interrogating equipment on the ground, consisting of two pulses of the same duration, separated by a fixed time interval. The receiver detects and amplifies the signal, and delivers it to the decoder unit.

If the pulse width and spacing are correct, it is accepted and decoded. The decoder output initiates trigger pulses to key the transmitter and provides the coded reply.

The drone generator furnishes the 28 vdc, 50-watt power required for operation of the L-Band beacon. The peak pulse minimum transmitter power output is 184 watts, sufficient to ensure adequate tracking at all anticipated operating ranges.

D-5 Active Radar Augmentation Due to the relatively small physical size of the Q-2C, its radar reflectivity must be augmented to simulate the level of actual threat aircraft. The wide range of simulated radar areas required varies from the tail aspect of a fighter to the beam aspect of a bomber. To increase the reflectivity area to the desired level and present a realistic target for the various radar guidance weapon systems, an extremely versatile augmentation system is provided. The system utilizes traveling wave tube (TWT) amplifiers and a series of antenna configurations.

The TWT radar augmenter is a one-tube microwave amplifier consisting of a single traveling wave tube and associated transistorized power supply. The traveling wave tube can amplify numerous microwave signals simultaneously over a very wide range of frequencies. As installed in the Q-2C, the unit provides radar echo augmentation in various patterns by the use of specially designed antenna systems. Any incident radar signal falling within the frequency range of the TWT and the antennas will be accepted, amplified and retransmitted as a true "skin" echo with all the reflection characteristics of the specific radar type. The size of the echo can be conveniently varied by adjusting the system gain to simulate various target sizes.

To satisfy operational requirements, TWT radar augmentation is available in the L, S, C, and X-Band frequencies. The C and X-Bands are covered by one TWT, while L and S-Band coverage is accomplished by separate amplifiers. Antenna systems have been designed for individual frequency bands and for dual-band operation. Augmentation is omnidirectional for L and S-Bands. For C and X-Bands, remotely selected right or left side coverage can be provided if maximum power output is required for a given sector, or paralleled antennas can be employed to achieve omnidirectional azimuth coverage. In addition, nose antennas present frontal coverage above and/or below.

Various polarization requirements may be met with currently available antennas. Additional requirements can be accommodated with antenna modifications. Since radar augmentation is active, the "reflected" radar energy is dispersed in a broad pattern to satisfy the bistatic angle requirements of semi-active seekers.

Figures 8 and 9 are relative target area plots of a typically augmented Q-2C drone. The TWT augmentation level at 90° from the drone tail is used as the "0" db reference. Relative target area about the Q-2C drone (Figure 8) at a co-altitude level is represented in "db" above or below the reference level with every 3 db change in level representing a 2:1 target area change.

Example: 1

Assume the "0" db reference level = 5 square meters
then + 3db (increase) target area level = 10 square meters
and —3db (decrease) target area level = 2½ square meters
also —6db (decrease) target area level = 1¼ square meters

The actual "0" db reference level is that prescribed for the mission. By substituting the actual target area at the 90° aspect in place of the 5 square meters (reference Example 1), target area in square meters may be determined for any aspect about the Q-2C drone by referring to Figure 8. Target area versus elevation angle through the beam aspect can be determined in a similar manner by referring to Figure 9.

The dashed curve, Figure 8, represents Q-2C target area from skin return only relative to the augmentation radar return (solid curve) for the illustrated configuration.

Augmentation antenna switching from side to side may be provided through the remote control radio link.

D-6 TWT Operating Principles Since the traveling wave tube is comparatively new and is being used increasingly for augmentation, a brief explanation of operating principles may be of value. The system has a number of advantages over beacons and other radar augmentation systems. The most important of these features are:

1. High power amplification (over 1,000,000)
2. Wide band width (over 2:1)
3. Adjustable gain (to simulate various target sizes)
4. Nearly zero time delay (radar ranging not distorted)

The TWT is a long vacuum tube about two inches in diameter and from 12 to 18 inches in length as shown in Figure 10. An electron gun at one end of the tube emits a beam of electrons. A high DC voltage on a collector at the other end draws the electrons through the tube. The tube is enclosed by a magnetic field which keeps the electrons focused into a narrow beam as they travel from the gun to the collector. Between the electron gun and the collector, a wire helix is mounted within the tube. The two ends of the helix are coupled to two antennas. The end nearest the electron gun is connected to the receiving antenna, and the other to a transmitting antenna. The diameter and spacing of the helix turns are such that the transverse velocity vector of the wave motion of the received RF energy is slightly less than the speed of the electron stream. Thus, the signal wave and the electrons traverse the tube at approximately the same speeds.

RELATIVE RADAR AREA PLOT OF AUGMENTED Q-2C FOR TYPICAL MISSION

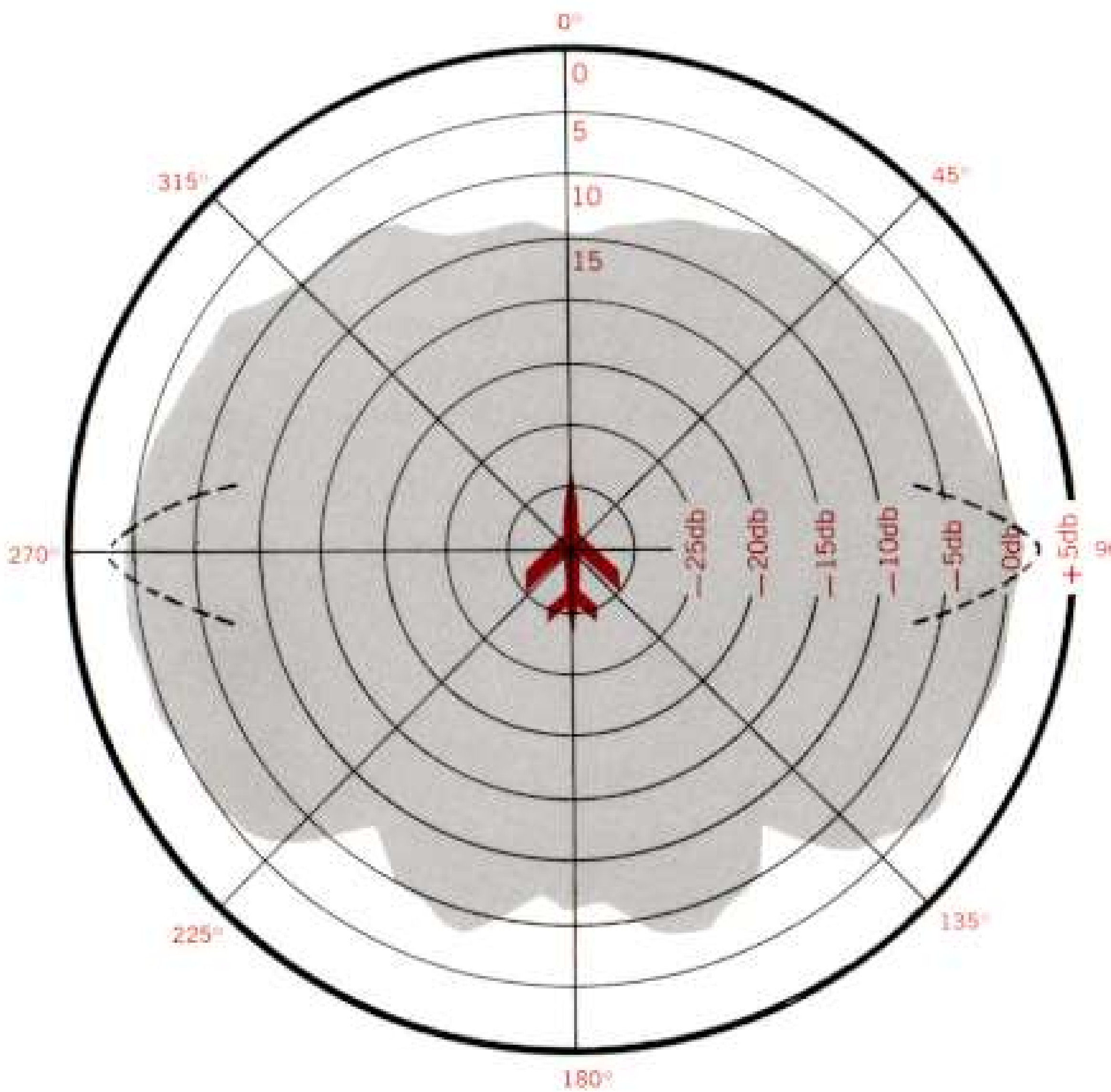


FIGURE 8 AZIMUTH CUT AT CO-ALTITUDE

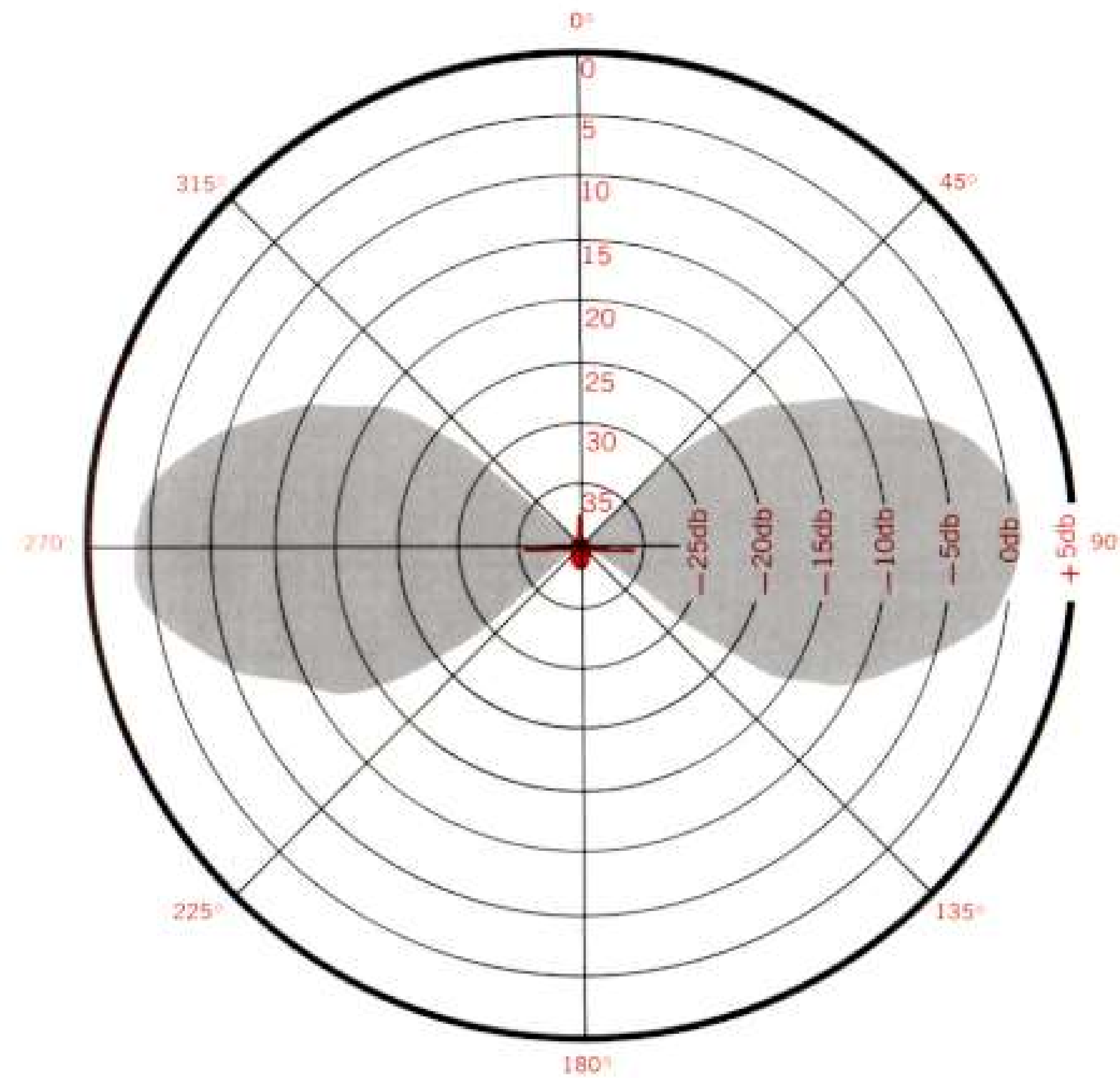


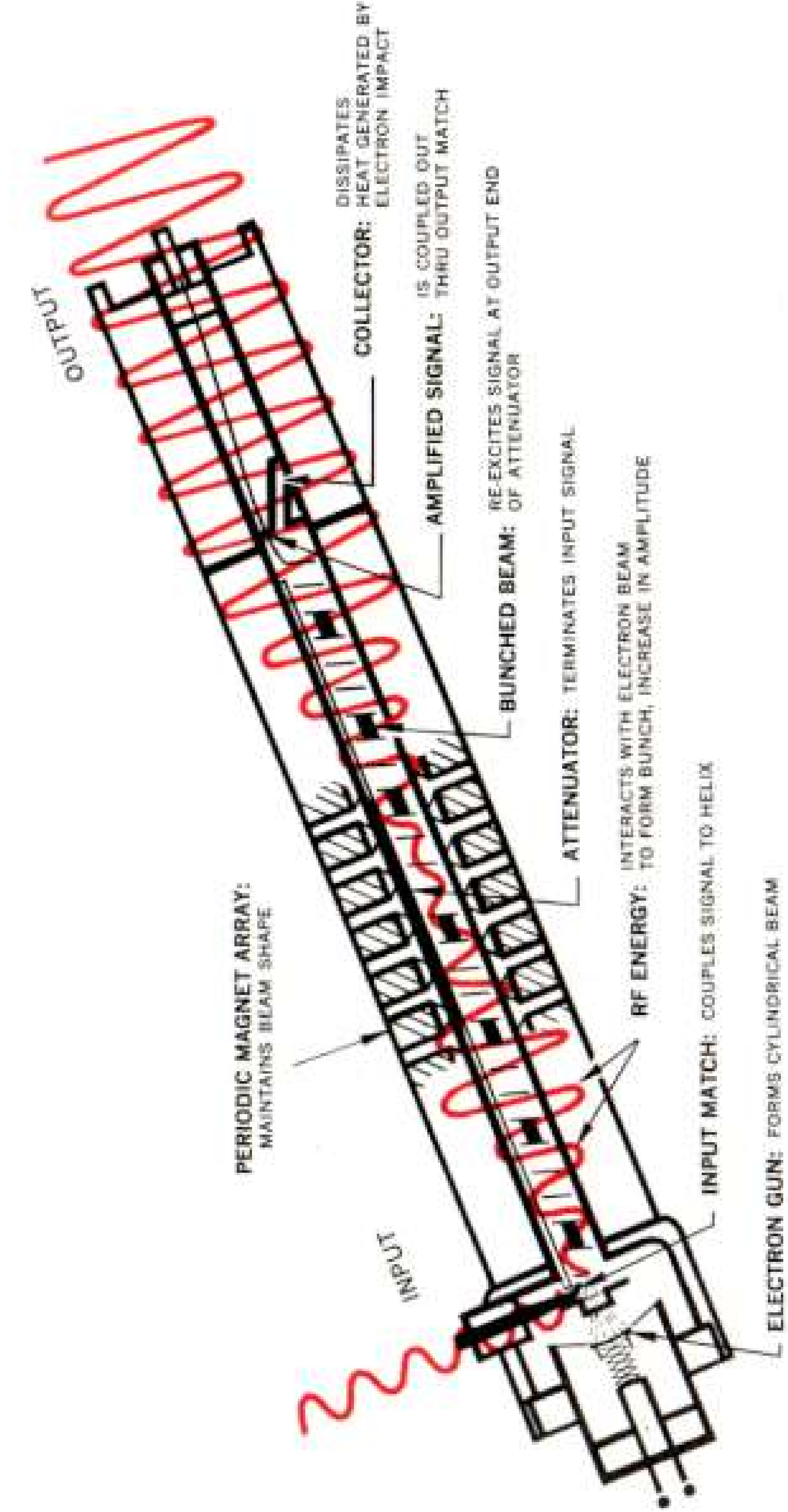
FIGURE 9 ELEVATION CUT THROUGH "BEAM" ASPECT

Amplification starts at the beginning of the helix when the electrons in the beam re-arrange themselves in bunches in accordance with the electro-magnetic energy or polarity of the RF wave. As the bunched electron stream passes the turns of the helix, it appears as an alternating current which induces a voltage into the helix. This induced voltage is in phase with the RF signal and strengthens it. This stronger RF wave causes greater electron bunching, and the process repeats itself continually down the tube, increasing the amplitude exponentially. The transfer of energy to the helix causes the electrons to slow down. Amplification continues until the electrons are slowed down to where they can no longer keep up with the wave. Just prior to this point, the electrons are caught by the collector electrode and the amplified wave is transferred from the helix to the transmitting antenna.

The TWT gain is dependent on the collector electrode DC voltage and the tube length. This gain can be increased by increasing either the DC voltage on the collector (which increases the transverse speed of the electrons), or by lengthening the tube. Because of the exponential amplification, considerable gain can be obtained with a relatively small increase in physical length. The speed of a wave down the helix is independent of frequency; thus the TWT will amplify over a wide frequency range.

To eliminate internal oscillation in the tube, the TWT is constructed to prevent signal waves from being reflected backwards through the helix due to possible mismatch of the transmitting antenna. This is achieved by placing an attenuator about half way down the length of the tube. The attenuator removes all signals traversing the helix in either direction, but does not affect the electron stream which has already been bunched prior to the attenuator by the incoming RF signal. The bunched electron stream passes the attenuator unaffected, and immediately regenerates an RF signal in the helix which duplicates the original received signal. Amplification of this induced signal continues in the normal manner but with the cumulatively increased amplification factor. The transmitted signal is actually a new signal whose energy has been entirely extracted from the electron beam; however, except for the amplification, it exactly duplicates the original signal.

FIGURE 10 TRAVELING WAVE TUBE AMPLIFIER



SCORING SYSTEMS

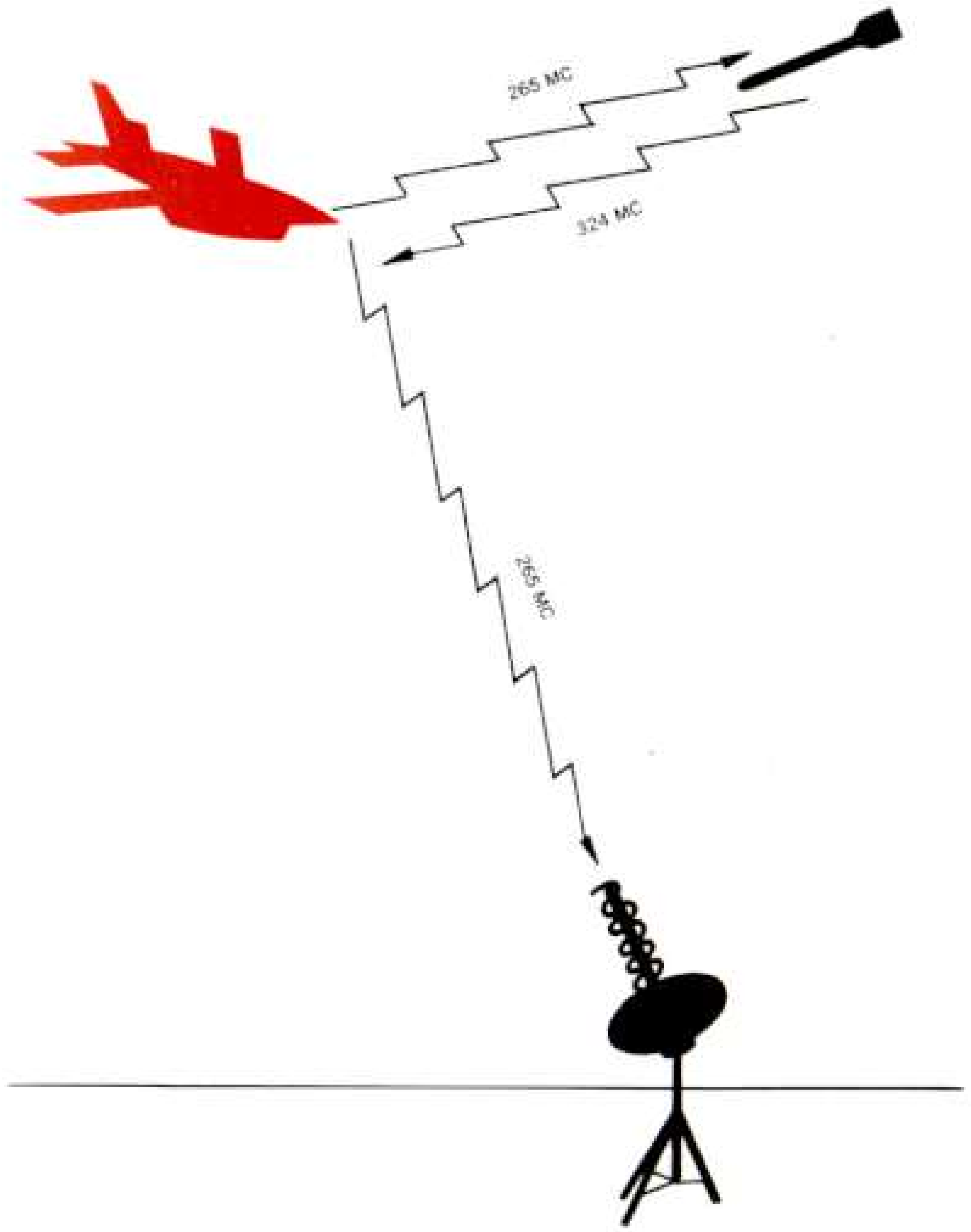
E

E-1 Introduction Three different scoring systems are currently in use for evaluation of the effectiveness of weapon systems and interceptor teams. The Parsons Active Ring Around Miss Indicator (PARAMI) and the Multiple Airborne Target Trajectory System (MATTS) are used by the Air Force, and the Miss Distance Measuring System (MDMS) is employed by the Navy.

E-2 PARAMI The Parsons Active Ring-Around Miss Indicator (PARAMI) is a system for electronically measuring the separation between the Q-2C target drone and the missile. A permanent time-history record of distance is produced at the remote ground station, from which the closest approach of intercept can be determined in less than ten seconds. The basic principle of PARAMI operation is a measurement of the time required for an electronic pulse to travel between the drone and missile. To accomplish this, PARAMI employs two airborne transponders and a ground computer station.

The airborne system is a space-coupled oscillating loop with a receiver and transmitter installed in the target and another transponder combination in the missile. Random pulses are transmitted by the transponders as a result of normal receiver noise. When one of these random pulses is received at the other location, the received signal triggers the transponder which transmits a new signal on a different frequency. This new signal, in turn, triggers the opposite transponder, and the ring-around oscillation continues. Sufficient gain overcomes system attenuation, and the signal passes around the loop in a regenerative fashion. The frequency of oscillation in the loop depends upon three factors: the internal delays in the equipment, transmission distance between transponders, and the speed of light. Since the internal delays are fixed, the ring-around or oscillating frequency will vary with the varying distance between transponders. The target

FIGURE 11 PARAMI



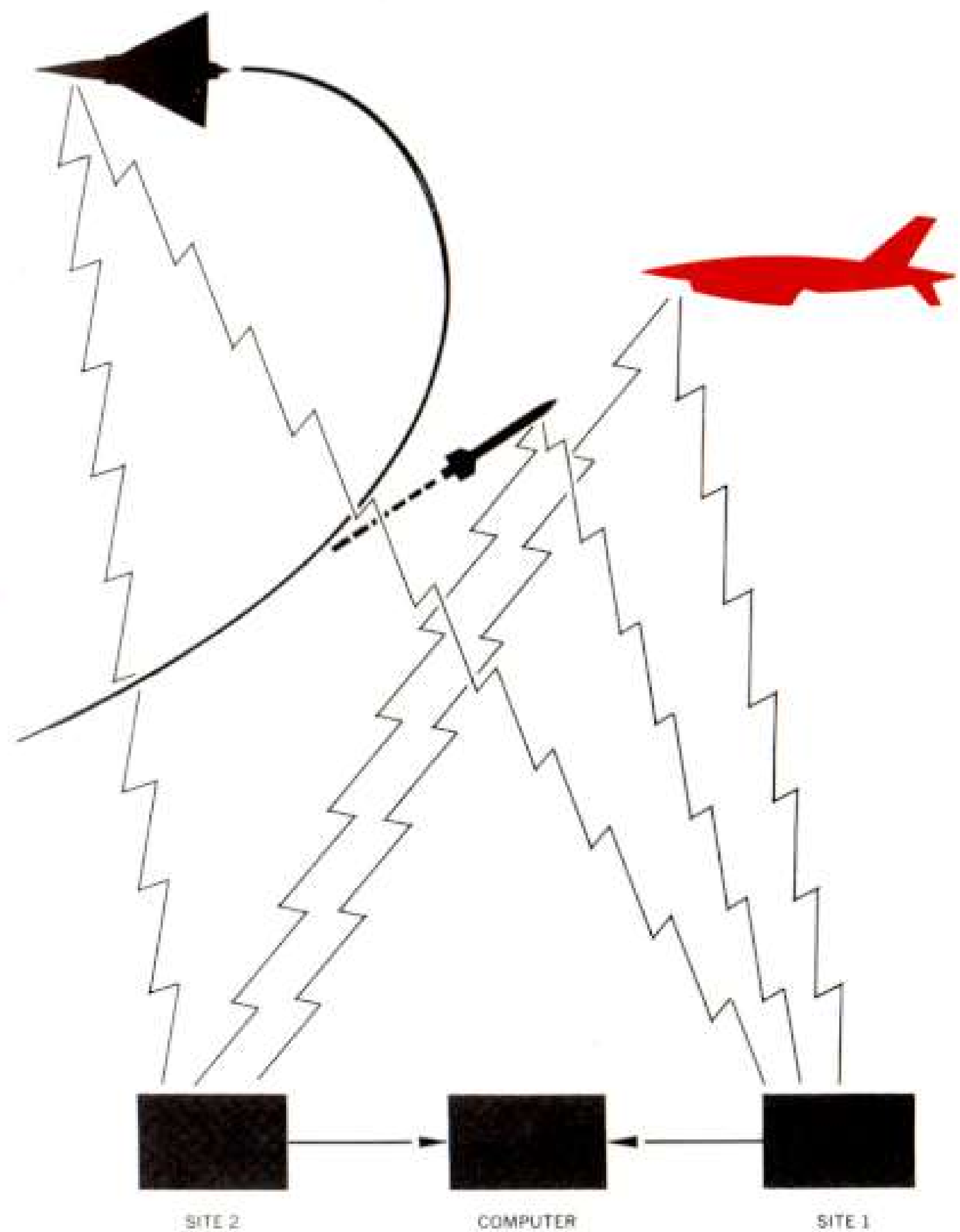
transponder signal serves as the data transmitting link to the ground station receiver. The signal received at the ground station operates a computer which extracts the distance factor from the frequency of oscillation and converts to range in tens of feet. A ground station recorder provides a permanent real time history record of scoring data.

E-3 MATTS The Multiple Airborne Target Trajectory System (MATTS), officially designated as the AN/GSQ-29, provides complete trajectory information on multiple targets by the combination of range and angular data. CW transmitters are installed in the Q-2C drone, the interceptor, and the missile. Signals from these transmitters provide for continuous electronic tracking at two separated ground stations. Since each transmitter operates at a different frequency, identification is automatic. Direction data from the two stations is combined by triangulation to give continuous and precise position information of each vehicle.

A computer van receives direction-cosine data from the tracking sites via microwave links. For back up purposes, the same data is also recorded at the tracking sites. The computer outputs include the Cartesian coordinates of the drone and the interceptor before launch or the missile after launch. These outputs are converted to analog form for trajectory presentation on standard plotting boards. Burst and escape distances are displayed in real time for immediate scoring evaluation.

E-4 MDMS The AN/USQ-11A Miss Distance Measuring System accurately measures the minimum slant range (miss distance) between the missile and target, their intercept velocity and their instant of closest approach. The MDMS is composed of three basic components: a simple transmitter in the missile, a receiver-recorder at the monitoring station, and a transponder in the target. The target

FIGURE 12 MATTS



transponder acts as a relay station. It receives a signal from the missile transmitter on one frequency and retransmits it to the monitoring receiver on a different frequency.

Operation of the MDMS is based on the Doppler principle. The missile transmitter radiates a signal at a given frequency. This signal, as received at the target, consists of the missile frequency and the Doppler frequency component which is added due to the relative velocity between the missile and target. The signal received at the target is mixed with the target oscillator frequency and transmitted as a composite containing all three component frequencies. The monitor station receives both the target and the missile transmissions with their related Doppler shift components. Through a system of mixers, discriminators and filters, the Doppler frequency shift (as the missile approaches and passes the target) is selected and recorded at the monitor station. This record provides precise data on the miss distance, relative intercept velocity, and the time of closest proximity of missile and target.

FIGURE 13 MDMS