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A.B. Markov, T.E. Ollevier, S.G. Penzes, A.E. Turner,
D.M. Bergeron, T.V. Meidinger and W.A. Jones

PCN No. 21V10

August 1984



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ABSTRACT

SD // In support of Canadian Forces remotely piloted vehicle and drone research requirements, the Defence Research Establishment Suffield (DRES) has acquired an in-house expertise in aerial targets, drones and remotely piloted vehicle design, development and testing. Overviews of current range capabilities and proposed range improvement programs are given with emphasis on telemetry, on video tracking capabilities, and on laboratory structural and engine testing facilities. Past and ongoing research programs are also reviewed. //

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PREFACE

This report is based on the paper "DRES RPV and Drone Development Programs and Flight Testing Facilities" presented by A. B. Markov and T. E. Ollevier at the Tenth Annual Association for Unmanned Vehicle Systems Symposium at Salt Lake City, Utah on June 28 – 30, 1983 and by C. G. Coffey at the DREP Composite Workshop held in Victoria, B. C. on July 1 – 3, 1983.

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1. INTRODUCTION

The Defence Research Establishment Suffield (DRES) is located approximately 240 kilometers (150 miles) to the southeast of Calgary, Alberta and is one of two lodger units (the British Army Training Unit Suffield (BATUS) is the second) at the Canadian Forces Base Suffield (CFB Suffield). Figure 1 shows the location of DRES relative to Calgary and also presents an enlarged view of the range area itself.

The total surface area of the Suffield Military Reserve is slightly over 2600 square kilometers (1000 square miles), a size that makes it attractive for military and defence science activities. The majority of the terrain is rolling, prairie grasslands. Substantially more relief is present on the east side of the range where the South Saskatchewan River has formed a winding river valley. Access to all parts of the range is facilitated by a series of graded roads that are normally open throughout the year.

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The range area is divided into two sections as indicated in Figure 1. The northern three-quarters of the range is used by BATUS to conduct live firing tank battle group training exercises. These training exercises are normally conducted in the months of April to November. The southern quarter is under the control of DRES and is referred to as the Experimental Proving Ground (EPG). If required the entire range can be made available for use in DRES tests provided that appropriate steps are taken to coordinate these tests with British training activities.

The entire range has been a game preserve since August, 1958. Residents of the range include pronghorn antelope, mule deer, wild horses, numerous smaller animals and rattlesnakes. Since 1975 the range has also been extensively explored by the Alberta Energy Company for natural gas deposits. By the end of 1982 approximately 2,200 wells had been drilled of which 1,400 are in full operation. Some oil exploration has also recently commenced in the northwest corner of the base. As the natural gas well heads are located in silos, they do not interfere with normal range operations.

Historically DRES traces its roots to the Suffield Experimental Station (SES). The SES commenced operations on June 11, 1941 as a joint United Kingdom-Canadian experimental station under the administrative control of the Canadian Army. In 1946 the SES became an all Canadian establishment when British support terminated. In 1947, the SES and associated range ceased to be administered by the Army and was turned over to the Defence Research Board (DRB). In July, 1967 the name was changed to the Defence Research Establishment Suffield. With the 1971 ratification of an agreement permitting UK Forces to use the range for armoured vehicle training, a Canadian Forces Base Suffield under the control of Force Mobile Command was created. The role of CFB Suffield was and continues to be to provide administrative and logistic support to BATUS and DRES.

DRES has approximately 200 personnel of whom some fifty are engineers and scientists representing a wide range of disciplines. It is one of six research establishments which provide scientific and technical support to the Department of National Defence. As well as performing research and development for DND, DRES occasionally provides assistance to other government agencies and to industry when the establishment has applicable expertise or facilities which do not exist elsewhere in Canada.

There are two technical divisions, the Defence Sciences Division (DSD) and the Defence Technologies Division (DTD). DSD is currently involved in R & D in the areas of defence against chemical and biological warfare and in the control of infectious diseases. DTD is currently involved in R & D in the areas of mines and range clearance, effects of shock and blast, military use of explosives, vehicle mobility, weapon system performance monitoring and aerial targets, drones and RPV's.

The remainder of this report will focus on the latter two areas of R & D. Section 2 reviews aerial target programs. Section 3 reviews RPV and drone programs in nontarget applications of unmanned vehicles. Section 4 describes a number of field test areas. Section 5 describes ground test facilities. Section 6 describes a number of specialized instrumentation systems available for RPV and drone development. Section 7 describes available design and data processing facilities. Finally, Section 8 describes the flight testing methodology adopted in the DRES RPV and drone programs.

Research and development work in aerial targets, drones and RPV's is currently being conducted at DRES within the Systems Integration Group (SIG) of the Systems Section (SS) under the mandate of Technical Program 21V (TP21V). This program was officially started in 1980. Prior to that time some aerial target work had been carried out at DRES under the auspices of a weapon system monitoring technical program (TP21S) and a number of Canadian Forces (CF) task agreements.

The air defence weapon systems and aerial targets, drones and RPV's technical programs have recently been amalgamated under TP21V with the title Aerial Targets, Drones and RPV's. The aim of this program is now as follows:

- i) To develop and maintain a capability for advising and assisting the Canadian Forces in the selection, development and deployment of remotely piloted vehicle (RPV) systems and airborne vehicles for use as targets, surveillance platforms, or any other roles proposed by the CF.
- ii) To retain a capability for advising the CF in the selection and deployment of air defence systems.

This amalgamation has served to accentuate the systems nature of the work carried out within this technical program. In general, emphasis has been placed on developing complete target systems including not only suitable airframes, but also associated avionics, scoring systems, ground stations, launchers, active and passive radar, IR and visual augmentation subsystems, and flight test facilities.

In RPV research, emphasis is being placed on the support of Canadian contractor flight test requirements such as utilization of the EPG by Canadair in the flight testing of the CL-227 surveillance RPV and in-house research directed towards the evaluation of other roles in which RPV systems could be used in support of long-term (through the decade of the nineties) Canadian Forces operational requirements. These in-house studies include vehicle conceptual configuration and structural design, low-cost autopilot design, navigational/homing aids, target acquisition avionics, use of ordnance devices and use of artificial intelligence (AI) in flight control.

Research and development work within this program has been initiated both in direct response to specific Canadian Forces requirements and in anticipation of future needs for which basic research should be initiated immediately. The former is generally carried out with additional task funding support from the sponsoring agency of the CF. The latter is generally carried out with the Establishment's own R & D funds.

The majority of the research and development work initiated under this technical program has been conducted in conjunction with contractor support from private industry. This is essential in order to facilitate transfer of technology to the private sector and in order to abide by staffing ceilings while maintaining the scope of the program.

A number of programs are currently being conducted in which DRES (SIG) has taken on the role of the design authority. Using this philosophy, DRES has direct control of aerial platform configuration design, aerodynamics, stability and control, and flight testing while subcontracting elements such as detailed airframe and avionics design and construction to private industry. It should be emphasized that this philosophy is applied only to proof-of-concept development. Once a system's feasibility is demonstrated, and accepted by the Canadian Forces as an inventory item, the technology is transferred to a private sector contractor for advanced development and production. The identification of a production prime contractor and subcontractors is normally facilitated by experience accumulated with subcontractors utilized during proof-of-concept development. At this final stage of a system's development, DRES provides support to the Canadian Forces for advanced development and assists in trouble shooting production system problems.

2. AERIAL TARGET PROGRAMS

2.1 Aircraft Towed Targets

In support of tasking from the Director of Maritime Combat Systems (DMCS), the low-cost, low-drag, acoustic miss distance indicator (MDI) equipped MILKCAN towed target shown in Figure 2 was developed to meet surface-to-air gunnery training requirements. Further information on this target is given in Reference 1.

To meet CF(Air) requirements, studies are currently being undertaken to establish an air-to-air gunnery target complete with a scoring system. This system is required for CF-5 and CF-18 training.

As high performance test aircraft are not available at DRES, towed target preliminary design and laboratory tests are completed in-house and then final flight testing is carried out at CFB Cold Lake with support from the Aerospace Engineering Test Establishment (AETE).

2.2 Rocket Boosted Targets

In 1979, under the auspices of The Technical Cooperation Program (TTCP), it was agreed that a joint US/Canadian feasibility study be undertaken on improving the US Army Ballistic Aerial Target System (BATS) by using the higher specific impulse, Canadian developed CRV-7 70 mm (2.75 in) rocket motor. As part of this program, the US Army contributed 100 BATS airframes and Canada contributed CRV-7 rocket motors. The required development work, including prototype trials, was carried out at DRES.

The TTCP program culminated in a vehicle that was originally designated CRV7/BATS and is now known as ROBOT-5 (Figure 3), the acronym ROBOT standing for "**RO**cket **BO**osted Target". This vehicle has not only incorporated the CRV-7 rocket motors, but also has been redesigned to permit multistaging. The latter significantly improves range performance while limiting maximum airspeed, for structural and operational reasons, to Mach 1.5.

The improvement in overall performance of ROBOT-5 over the original BATS vehicle was significant enough to strongly suggest the possibility of further improvement by using more CRV-7 rocket motor stages. This prompted a DRES initiated

development program of a multistaged CRV-7 powered vehicle. Consideration was given to both 7 and 9 motor configurations, and ultimately a nine motor, four stage configuration was chosen and designated ROBOT-9 (Figure 3).

Both ROBOT-5 and ROBOT-9 have been trialed in operational conditions as point defence weapon system targets. Both systems have proven to be well-suited for use by the Canadian Navy. The ROBOT-9 vehicle has been accepted by the Navy as an interim high-speed target while a more sophisticated, over-the-radar-horizon, low altitude target simulating an antiship missile or low flying invader aircraft is developed. ROBOT-5 was also trialed at DRES as a BLOWPIPE missile target.

While ROBOT-5 and ROBOT-9 have proven to be effective and extremely low-cost high speed targets, their relatively short ranges preclude their use as targets in 'surprise' tactical naval scenarios, i.e. they do not have the range to come up over the radar horizon of the ship at which a simulated attack is being directed. As well, being ballistic targets, they have very limited low altitude simulated attack profile capabilities.

In order to remedy these limitations while still retaining many of the attractive low-cost features of the rocket-boosted target technology, DRES has undertaken the proof-of-concept development of a winged, rocket-boosted, multistaged target that has been named ROBOT-X. This target will have high subsonic speed, low altitude hold, preprogrammed maneuvering, and greater than 37 km (20 nm) range.

After considering a number of candidate configurations and after wind tunnel testing in 1982, the configuration of ROBOT-X was frozen to the canard configuration and characteristics shown in Figure 4.

More information on DRES rocket boosted targets is given in References 2, 3, 4, 5, 6 and 7.

Due to the current research interest in the use of rocket propulsion in target systems, existing laboratory and field testing facilities are being expanded to meet this requirement.

2.3 Remotely Piloted Vehicle Targets

In response to CF(Land) requirements for a low-cost target system suitable for Low Level Air Defence (LLAD) exercises, DRES monitored the development of a

64 m/s (125 knot) propellor driven, low-cost target system designated TATS-102 (the acronym TATS stems from Tactical Aerial Target System). The target configuration and operational characteristics are shown in Figure 5.

To allow this type of target to be flown visually in race track profiles ranging between 2000 and 6000 meters from the pilot, in-house investigations were undertaken to develop techniques and handling aids to allow the pilot to visually determine the vehicle's attitude at extreme ranges.

To improve this type of target's visual signature to weapon firing personnel both smoke and light augmentation systems have been developed and will continue to be developed.

In response to long-term interest in this type of low-cost target technology serious consideration will be given to expanding existing facilities to allow development of higher performance targets of this type.

2.4 Gun Launched Targets

In order to establish a suitable inexpensive target that could be used in the training of shipboard Fire Control System (FCS) operators, DRES is currently investigating the use of 5 inch gun launched radar augmented projectiles (see Figure 6). The existing test facilities will be maintained and expanded as required.

2.5 Target Accessory Items

While the operational performance envelope of any target system is an important factor, serious consideration also has to be given to the development and testing of a number of accessory items including radar augmentation systems and miss distance indicators (MDI's).

In support of passive radar augmentation design, DRES has developed a software capability for the design of various types of corner reflectors and Luneburg lenses.

In support of research directed towards the development of active radar reflector systems, DRES has initiated investigations through the use of R & D contracting.

A requirement currently exists to evaluate commercially available acoustic and doppler RF type miss distance equipment suitable for use in CF target systems. In support of this requirement, testing facilities will be expanded as required to meet future performance evaluation studies.

3. RESEARCH REMOTELY PILOTED AIRCRAFT AND DRONE PROGRAMS

The emphasis on target systems given in the previous section is a natural one in that the majority of the research and development effort at DRES within TP21V has been directed towards aerial target applications of RPV's and drones. This is partly a consequence of the existence of pressing CF requirements for target systems, but is also a consequence of the more clearly defined requirements and simpler nature of aerial platforms that are to be used in this role.

Involvement in the target areas has conveniently given the TP21V program, and more importantly the personnel within the program, time to mature. This has allowed accumulation of both expertise and various types of test equipment in the areas of flight dynamics, aerodynamics, composite materials, configuration design, flight testing, structural design and testing, command and control, digital and analog autopilots, visual, IR and RF passive and active augmentation systems, ground support equipment, mainframe and minicomputers, telemetry systems, radar systems, video systems and so forth. These elements are now gradually being absorbed into the synergistic technology base that is required of more complex research and development programs, including a number of remotely piloted aircraft and drone developments that are not geared to target applications.

The main long-term, nontarget interest within TP21V is to provide technical support to the CF in fulfilling their RPV and drone requirements. Such interest includes not only roles that have already been identified (e.g. CF(Land) battlefield surveillance and targeting), but also the anticipation of future roles that are not currently firm requirements. The areas in which in-house expertise is desirable and is gradually being acquired include aerial surveillance, targeting, remote mine field detection and over-the-horizon communications, among others.

Efforts have been underway to gather background information from a number of sources that are conveniently available, including NATO and TTCP. As well, ongoing programs in RPV's and drones are monitored. These have included the U.S.

Army/Lockheed Aquila program and the Industry, Trade and Commerce/Canadair CL-227 program. For the CL-227 program, testing and building space was provided to Canadair at DRES in the fall of 1981.

With the potential roles of remotely piloted aircraft and drone systems being so diverse, DRES has identified the need for aerial platforms that are reliable, provide great flexibility in weight and configuration of payload, and are relatively cheap to produce and operate. These platforms may then be used to flight test various types of airborne equipment (e.g. autopilots, data transmission equipment, surveillance sensors and so forth) and roles (e.g. over-the-horizon communications).

In the past, DRES aerial test platforms have included modified TATS-102 and HULK research remotely piloted vehicles, but these have been found to be of limited payload flexibility. Thus, in the fall of 1982, DRES initiated the preliminary configuration design of a large payload capacity (23 kg (50 lb) expandable to 45 kg (100 lb)) Research Remotely Piloted airPlane (R²P²). A configuration under consideration for this vehicle is shown in Figure 7. The configuration characteristics for these test airframes are shown in Tables 2, 3 and 4.

4. FIELD TEST AREAS

To meet both aerial target and RPV research requirements, various specialized laboratory and field test areas are being developed within the DRES Experimental Proving Ground. These areas are described in the following sections.

4.1 Building 15 Test Complex

The Building 15 test complex shown in Figure 8a includes the following facilities: a central Building 15 laboratory building, an asphalt runway site (Baker Field), a field office complex, and a heated storage building. The central test laboratory is 24.4 m (80 ft) × 36.6 m (120 ft) and contains an open floor area for airframe and instrumentation assembly and separate electro-optical, telemetry and control, avionics, and flight instrumentation laboratories, an engine test cell, and a structural test rig.

The site is used for target/RPV assembly, vehicle subcomponent testing and flight testing of RPV aircraft.

The same area also contains laboratory buildings for mines and range clearance and vehicle mobility research.

4.2 Range and Accuracy (R & A) Test Site

The R & A test site shown in Figure 8b has been developed for the launching of rocket boosted targets and gun launched projectiles, and for the testing of MDI systems. The firing line provides a nominal 60 km range. The site contains a hardened instrumentation bunker, an instrumentation laboratory, a rocket assembly building, a target and instrumentation storage building, and gun shelters and firing pads for two 5-inch naval guns and other smaller weapons. Consideration is also being given to the installation of a 36.6 m (120 ft) CRV-7 rocket launching tube.

4.3 Low Level Air Defence (LLAD) Test Site

To allow the evaluation of current and future (LLAD) weapon systems, a dedicated test site is being developed. At present no permanent buildings are situated at the site as instrumentation trailers and portable bunkers are used to support trials.

5. GROUND TESTING FACILITIES

Ground testing facilities are being established at DRES for the purpose of providing a design, testing and analysis capability in the RPV and drone program. A number of these facilities are located in the Building 15 test complex (see Section 4.1) where the majority of SIG's RPV and drone work takes place. These activities include the following:

- a) Engine and composite airframe construction, modification and repair.
- b) Component construction and interfacing (e.g. autopilots with servomotors).
- c) Tracking and monitoring equipment maintenance and calibration (e.g. video and radar equipment).
- d) Instrumentation installation (e.g. strain gauges and autopilot sensors).
- e) Engine and airframe testing.
- f) Flight testing of RPV's.

The specialized ground testing facilities available are a static structural test rig, an engine test cell, and a static rocket firing site.

5.1 Structural Test Facility

Since the strength to weight ratio is a major consideration when designing airframes, the current trend is to incorporate increasing amounts of composite materials. In aid of developing an in-house capability in the use of composite materials, a structural testing facility is being commissioned. Initially the facility will be used in the evaluation of the redesigned TATS-102 wing and ROBOT-X airframe components.

The facility is composed of a rigid test structure (a 2.4 m \times 2.4 m \times 3.7 m steel frame), a whipple tree type loading apparatus, strain gauge and other miscellaneous signal conditioners and an HP 9845/2240 data acquisition system.

5.2 Engine Test Facility

To further enhance the RPV design process, an engine test cell has been constructed. The cell itself is composed of a sound proof chamber which is vented to the outdoors. System measurements are taken with a dynamometer, and a stand instrumented to measure thrust and torque. The control panel is adjacent to the viewing window and also to the signal conditioning and analysis system, all of which are enclosed in a regulated environment. The data acquisition task is performed by the HP 2240 which is currently configured to accept 32 analogue inputs at a rate of 2000 channels per second. The HP 2240 is interfaced to an HP 9845 desktop computer which will perform the data analysis and presentation functions. This acquisition/analysis system is shared with the structural testing rig discussed in Section 5.1.

This facility will be used for tests such as verification of performance specifications of RPV and drone engines, and evaluation of propeller performance.

5.3 Static Rocket Firing Test Site

To monitor structural effects on rocket-boosted target airframes, an existing tower is currently used to secure the target when conducting static rocket motor firings. Portable instrumentation is used when required.

6. SPECIALIZED INSTRUMENTATION

Background remarks concerning the size of the test range and its users have already been given in Section 1, and so in this section the discussion will be restricted to flight test instrumentation.

To date, the RPV and drone development work carried on at DRES has not required extensive flight test instrumentation support, e.g. in the form of multichannel telemetry, tracking radars and so forth. This has been possible largely because of the low-cost of the vehicles involved. As an example, for ROBOT-5 and ROBOT-9 development testing, it was more convenient and cost-effective to use trial and error methods rather than elaborate airborne and ground based instrumentation. For tests in which more elaborate instrumentation was required, trials were conducted at other establishments where such instrumentation was already available (e.g. AETE).

This unsophisticated flight test philosophy is rapidly giving way to more elaborate and instrumentation intensive techniques as testing requirements become more demanding (e.g. the ROBOT-X program) and as more sophisticated flight test instrumentation and expertise are acquired. It is worth noting that in parallel with this range instrumentation improvement, there has been a corresponding emphasis on improving static test facilities (e.g. the engine test cell and the static structural test rig as described in Sections 5.1 and 5.2).

The capabilities of three major flight test instrumentation systems, acquired in the past three years, are outlined in the following sections. These systems are a VEGA portable control system, a telemetry system and a tracking radar. In addition to these major systems, DRES has acquired a number of video systems for use in airborne vehicle tracking and data acquisition, and is currently in the process of integrating these systems with the other flight test instrumentation.

6.1 VEGA Portable Control System

The VEGA portable control system is a self-contained tracking, command and telemetry system that is ideally suited to the flying of remotely piloted aircraft. It employs a radar-transponder tracking link for accurate range and angle measurement. All command and telemetry data are sent via pulse-position coding (PPC).

The system has the capability of transmitting eight channels of data both to and from the airborne vehicle. The airborne encoder/decoder packages were designed by VEGA for DRES. Uplink data is presented in a digital, eight bit parallel format along with eight channel strobes. The downlink data encoder accepts analog voltages in the range of 0 – 5 volts.

The basic specifications of the system are presented in Table 5. The system is shown in Figure 9.

DRES is currently flight testing a microprocessor based autopilot unit that can interface directly with the VEGA encoder/decoder and with the test RPV's control system.

Future plans include installation of the ground based portion of the system into a command and control trailer. The operator's control and display panel will be optimized for the type of vehicle being flown. The pen plotter will be augmented by a larger digital plotter and/or by a computer generated video display of the vehicle's position.

6.2 Telemetry System

DRES has recently completed installation of a capable telemetry receiving system in a mobile trailer unit (Figure 10). The system was designed and constructed by SED Systems of Saskatoon, Canada, under contract to DRES. It consists of a single axis tracking antenna, L and S band telemetry receivers, and a L band video receiver. The front end telemetry processor is capable of handling Pulse Code Modulated (PCM) and Pulse Amplitude Modulated (PAM) signals. The system includes an analog tape recorder and visicorder for data storage and playback. A bank of FM discriminators is also available for the reception of FM multiplexed data.

A summary of the system's components is given in Table 6.

The telemetry front end processor unit is an EMR EXPRT unit that provides the operator with real-time flight test data. It can be programmed to alert the operator if the data channels of interest exceed predefined limits. The unit is microprocessor controlled and is capable of being preprogrammed to decode signals from the airborne encoder. This program is stored on a magnetic tape cartridge so that the system may readily be reconfigured to the identical state if and when required.

In addition to the above units, a video receiver has been incorporated in the telemetry ground station. This receiver is used in conjunction with an airborne sensor and video transmitter to provide data to evaluate various types of surveillance cameras and to provide feedback to the pilot of the remotely piloted aircraft.

It is anticipated that extensive use will be made of the telemetry system for flight testing both the R²P² airframe (and its payloads) and ROBOT-X. The airborne package of the telemetry system will be directly interfaced to the autopilots of both these vehicles during flight testing.

The airborne portion of the system will consist of a two watt FM telemetry transmitter and of either a module of subcarrier oscillators for FM multiplex telemetry or a PCM telemetry encoder. The PCM encoders currently used at DRES are configured for 64 channels of analog data to be telemetered at a rate of 25,000 channels of 10 bit data per second. This data rate provides 64 channels of data with a useable data bandwidth of approximately 80 Hz. The encoders are modular and may be reconfigured depending on the required number of channels and data rate.

Over the next year DRES hopes to extend the performance of the existing telemetry system through the addition of an Advanced Data Presentation and Data Formatting Facility (ADPDFF). The existing telemetry ground system is capable of presenting real-time data in a format suitable for flight test control but is limited in its ability to perform detailed post trial analysis. At present the only method of obtaining continuous time history data records is to use the Digital to Analog (D/A) output board of the EXPRT system and record the data using either a visicorder or an analog tape drive. Data in these formats has to be read either by hand in the case of the visicorder chart outputs or digitized using the Analog to Digital (A/D) computer facility in the case of analog tapes. Both of these methods are time consuming and introduce inaccuracies in the data analysis process.

In an effort to remedy these deficiencies, DRES has initiated a R & D contract to design and construct the ADPDFF. The system, as shown in Figure 11, will consist of a minicomputer, a digital tape recorder, an interface to the EXPRT telemetry system front end and the required control software. The software required to enable the VAX 11/780 computer to read the tapes generated by the ADPDFF will also be supplied as part of the system.

As an added benefit the minicomputer may complement the present EXPRT real time display of telemetry data by being able to display additional data channels in real time. This would provide the flight test director with more information on which to base decisions on how well the test flight is proceeding.

6.3 Tracking Radar

As the result of a 1982 TTCP long-term loan agreement between Canada and the United Kingdom, DRES was provided with a portable X-band tracking radar. The radar (Figure 12) is a product of APT Electronic Industries, England and was designed and built in the early 1960's for use by the British Army in tracking reconnaissance drones. The unit has since been used to track various targets ranging in size from mortars to large aircraft.

The radar was fully refurbished before being delivered to DRES and was deployed at DRES with the aid of engineers from APT. The system was recently upgraded with the installation of components required for higher slew/tracking rates and with the addition of circuitry to provide quantitative measurements of radar cross-section.

The basic specifications of the radar are presented in Table 7. Although the system is old, its tracking performance and reliability have been excellent.

The radar will be used as a back-up tracking system when aircraft utilizing the VEGA command and control system are flown at long ranges, for tracking ROBOT system vehicles, and for tracking radar augmented rounds.

6.4 Video Capabilities

The Systems Integration Group (SIG) has extensively made use of video systems in order to perform in-flight monitoring and miss distance scoring and to provide general trial documentation.

An example of a monitoring/scoring system utilizing video techniques is the Army BLOWPIPE missile range instrumentation subset. The system is comprised of two separate video camera locations equipped with satellite time code receivers, video monitors, and video recorders. Camera 1, located directly behind the BLOWPIPE launch point, tracks the missile throughout its flight from launch to its intended intercept of the target (a TATS 102 RPV aircraft). Camera 2 is located at some acute angle

relative to the firing line and missile safety envelope. This camera tracks the target from the side using a wide field of view lens to monitor the missile position at its closest point of approach (CPA) to the target. The camera 2 station operator reviews the recorded video track, and relays the CPA with reference to a specific satellite time. The camera 1 personnel then rewind to that time point on their video recorder and, knowing the dimensions of the field of view, can calculate the distance between the missile and target in the head-on target presentation. The video recorders at the camera stations are equipped with slow-motion and stop-action playback functions to facilitate the calculation of precise CPA and, in turn, an accurate miss distance score.

An optional vector graphics display can be superimposed on the bottom corner of the recorded video from camera 1. This display is created by monitoring the joystick command inputs of the BLOWPIPE operator and converting the data to a circular screen display representing joystick position and magnitude of input. This enables an operator to simultaneously view the flight of the missile and his own flight corrections within minutes after the firing. This feature is anticipated to be a very valuable training aid and should assist in determining if a missile malfunction occurred or an operator error caused an inaccurate firing. The overall system is shown in Figure 13.

Other video capabilities within SIG are as follows:

- a) A video camera mount slaved to the binocular sights of the RPV pilot's CHAIR (Control and Handling Aid for Increased Range), providing a video record of the target performance at all times during a flight.
- b) A high-speed, phase controlled shuttered color camera system with up to 1/10000 second exposure capability for image-motion analysis.
- c) A special effects generator.
- d) Two video disks (black/white and color) with up to 20 seconds of storage for stop-action playback.
- e) Video data encoder/reader equipment to permit insertion of serial digital code onto any composite video signal for continuous updating of time, azimuth, and elevation information.
- f) A complete Beta I editing system, allowing for editing of independent video and audio tracks from either Beta I or II footage.

7. DESIGN AND DATA PROCESSING FACILITIES

In the design and development of RPV and drone systems, significant computing power and data processing are required. As well as numerous micro-computers that are available (see the discussion in the previous sections), DRES has two mainframe systems that are used to support major analysis and design software and design data bases. These are the Honeywell DPS8/70C and the VAX 11/780 computer systems (see Figure 14).

A number of related facilities and software capabilities are now presented in more detail.

7.1 Data Analysis Systems

The Systems Integration Group (SIG) has access to three computer facilities to perform data analysis, computer modeling, simulations, analog to digital conversions and Computer Aided Design and Drafting (CAD/D).

The central computer facility for DRES is a Honeywell DPS8/70C. This system has 10 Mbytes of RAM plus 2.5 Gbytes of on-line storage. The computer's operating system is CP6. The system has FORTRAN, PASCAL and COBOL compilers, several mathematical and statistical utility libraries, the Tektronix graphics libraries IGL, Easy Graphics, TCS-IGL Bridge and Preview, plus a Calcomp graphics library.

Another computer facility that SIG has access to is a DEC VAX 11/780. This computer is part of a high speed data acquisition system. The memory on this system is 4 Mbytes of RAM plus 250 Mbytes of on-line storage. VMS is the computer's operating system and the system has a FORTRAN compiler. The graphics libraries on the system are Tektronix TCS, AGII and TLD.

The third computer is a Honeywell DPS 6 minicomputer. This is a 15 bit, 16 channel analog to digital conversion system. It has 256 Kbytes of memory with 10 Mbytes of on-line storage. GCOS 6 MOD 400 is the Operating System for the computer. It has a FORTRAN compiler and a Tektronix TCS graphics library.

7.2 CAD/D Capabilities

In an effort to streamline the design process, a computer aided design/drafting (CAD/D) system was recently acquired. The main requirements for a CAD/D system

at DRES are in the areas of drafting, and electrical and mechanical design. After a thorough feasibility study and a six month trial period, an up-to-date version of the Honeywell Canada Ltd. ANVIL CAD/D system was purchased and installed on the DPS8/70C computer.

7.3 Other Software Packages

DRES has developed and/or purchased numerous specialized software packages that are used in the design and development of RPV's and drones. These include the following (brackets denote source):

- 1) Six degree-of-freedom simulation — BALSIM (DRES, Reference 8), NLSRBX (DRES), NONLIN (DRES), AUTOPILOT (UTIAS).
- 2) Control law synthesis — NATMOD (DRES), LINEAR (UTIAS), FRQRES (UTIAS).
- 3) Aerodynamic Analysis — PREAER1 (DRES), HNGEMMTS (DRES), AEROX (COSMIC-NASA).
- 4) Flight Testing — MMLE5 (NASA, References 9 and 10).
- 5) Plotting Software — PLOT10 (TEKTRONIX), RBTPLT (DRES), RBTXPLT (DRES), PLTNLSRBX (DRES), PLOTBALSM (DRES).
- 6) General purpose mathematical subroutines — IMSL Package.

7.4 Design Data Bases

DRES has acquired the following design data bases:

- 1) USAF Stability and Control DATCOM.
- 2) ESDU Aerodynamic and Structural Data Sheets.

8. FLIGHT TESTING

Flight testing at DRES is primarily concerned with performance and operational evaluation of unmanned vehicles and secondarily with the evaluation of their dynamic characteristics. A number of facilities have been developed, or are currently under

development, for this purpose. These include the acquisition and development of flight test instrumentation tailored to RPV and drone flight testing, a Flight Instrumentation Laboratory (FIL), and data analysis software.

8.1 Structural Flight Testing

In conjunction with the ground testing facility discussed in Section 5.1, a capability for flight testing of structure is also being developed.

The airborne components will consist of various transducers and associated signal conditioning, and the telemetry downlink.

The data acquisition and analysis facilities have been discussed in Sections 6 and 7.

The data reduction and analysis portion of the testing will be performed on either the VAX 11/780 or the Honeywell DPS8/70C as dictated by speed, capacity, and available software requirements.

A block diagram of the general system configuration is shown in Figure 15.

8.2 Instrumentation for Performance, Stability and Control Flight Testing

Available flight test instrumentation consists of inertial, barometric, displacement and force transducers selected for their small size and light weight. Inertial transducers sense the acceleration, the gyration rates and the attitude of the aircraft, while the barometric transducers measure total and static pressure from which airspeed and altitude information can be computed. Displacement and force transducers are used to record, respectively, the positions of the control surfaces and the forces required to move them.

Flight test booms, small and light enough to be installed on most of SIG's drones and RPV's, have been designed for a wide range of flight regimes extending from low subsonic to transonic speeds. The variables measured by the booms include total and static pressure, angle of attack, angle of sideslip and outside air temperature.

8.3 Flight Instrumentation Laboratory (FIL)

The Flight Instrumentation Laboratory (FIL) facility is currently being established at DRES in the Building 15 complex near the flight vehicle assembly area.

This location was selected to allow for convenient testing and calibration of flight instrumentation as it is installed aboard the vehicle to be flown.

The FIL primarily assists in inertial and barometric flight test data calibration, but it can also accommodate temperature, position, displacement, motion, force and structural measurements. It is equipped with sufficient instrumentation to conduct static calibration on autopilot and flight test transducers. Variables such as acceleration, gyration rate, absolute and differential pressures, angular and linear displacements (or position), forces, moments and temperature can be handled by this facility. The transducers are calibrated, usually at room temperature, over a range sufficient for flight test work and only to the accuracy that will ensure successful data acquisition. It should be emphasized that the FIL supports only static calibrations at the present time, but its capabilities will be extended to include some dynamic and environmental calibration.

The calibration procedures for the FIL are semi-automated so that the turnaround time and the manpower required to obtain calibration results are minimized. The acquisition of calibration data points will be done by a microcomputer at the operator's request, once the proper conditions are obtained. When all of the calibration points are acquired, the microcomputer will fit the best straight line through the data, compute the scatter and plot the results.

8.4 Flight Test Data Analysis

Software is to be developed and/or implemented on the VAX 11/780 for flight test data analysis. It is the objective to minimize turnaround time required to obtain the reduced results for a given flight test. Four software packages will be available. These are for data conditioning and manipulation, flight performance evaluation, aerodynamic loads estimation and stability and control parameters estimation.

The data conditioning and manipulation software package will be used to sort the data obtained through telemetry (see Section 6.2). The package will be capable of smoothing and digital filtering. Furthermore, the software will have the ability to select and extract data from the raw data using parameters such as channel number and IRIG time (to be recorded with the flight data). In order to reduce computational loads, the software will be capable of data compression, i.e. to reduce the number of data points without losing the useful information. Finally, the software will present the data in a variety of graphical formats (variable vs variable, variable vs time, and so forth).

The flight performance software package will be developed to allow a flight path reconstruction using selected portions of the flight test data. Attitude and angle of attack histories will be extracted from which the lift and drag histories will be computed. Lift and drag can then be combined to produce a portion of the drag polar. Other flight test information will be used to compute performance characteristics such as take-off distance, rate of climb, range, endurance, glide and rate of turn.

The aerodynamic loads estimation software will use flight test data from the lifting surfaces and fuselage. These will be instrumented with strain gauges and calibrated, using the structural test rig (Section 5.1). The structural deformations will be correlated with aerodynamic resultants as determined by the performance software, allowing good approximation of wing and canard loadings and of control surface hinge moments.

Stability and control parameters will be estimated using a NASA developed modified maximum likelihood estimation software package, the MMLE5 (MMLE5 is a FORTRAN 77 version of MMLE3, see References 9 and 10). The program has been implemented on the VAX 11/780 computer and will be interfaced with the Tektronix PLOT-10 graphics package.

9. SUMMARY

In response to short-term and anticipated long-term CF RPV and drone requirements, DRES has acquired in-house research and development facilities and expertise to support the related R & D programs. The availability of a large land area of relatively hospitable terrain has made Suffield a desirable location for the development and testing of such vehicles, and thus considerable effort and funds have been expended towards improving in-house static and flight test capabilities. The latter have included the acquisition of a VEGA portable command system, a capable multichannel telemetry system and a tracking radar. The improvement in range facilities will also provide more opportunity for international cooperative programs with flight testing based at DRES.

To date flight vehicle research and development has focused on towed, rocket-boosted and propeller driven aerial targets, but upcoming programs will gradually distribute emphasis more evenly between aerial target and nontarget applications. Emphasis will continue to be on the system aspects in these development programs. Whenever possible these programs have been coordinated with private sector involvement in order to facilitate the technology transfer and eventual production of the systems being developed.

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Table 1

ROBOT-9, ROBOT-5 AND BATS PERFORMANCE COMPARISON

CONFIGURATION	MOTOR TYPE	LAUNCH ELEVATION	RANGE		APOGEE		FLIGHT TIME (secs)	MAXIMUM MACH NO.
			km	nm	m	ft		
ROBOT-9 Standard Shot	9 × CRV7	70	14.1	7.6	5200	17100	83	1.4
ROBOT-5 Standard Shot	5 × CRV7 Sustainer	65	10.5	5.7	4415	14500	71	1.1
US Army BATS All Motors Fired at t = 0	5 × Mk4 Sustainer	48	6.4	3.5	1900	6200	43	0.8

Table 2

TATS-102 SPECIFICATIONS

WING SPAN	● 3.4 m (11 ft)
LENGTH	● 2.4 m (8 ft)
GROSS WEIGHT	● 36 Kg (80 lbs)
MAXIMUM SPEED IN LEVEL FLIGHT	● 64.3 m/s (125 knots)
VISUAL AUGMENTATION	● Smoke and/or Light
ENGINE	● 15 HP modified Yamaha KT-100S with 0.46 m (18 in) diameter, constant pitch propeller
FUEL CAPACITY	● 8 Litres (1.8 Imperial Gallons)
ENDURANCE (Full Fuel, Sea Level, Max. Throttle)	● 1.25 hours

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Table 3

TWIN HULK SPECIFICATIONS

WING SPAN	● 3.7 m (12 ft)
GROSS WEIGHT	● 41.3 Kg (91 lbs)
PAYLOAD	● 18.1 Kg (40 lbs)
MAXIMUM SPEED IN LEVEL FLIGHT	● 36 m/s (70 knots)
ENGINE	● Twin 60 cc Single Cylinder, Two Cycle
FUEL CAPACITY	● 4.5 Litres (1 Imperial Gallon)
ENDURANCE (Full Fuel, Sea Level, Max. Throttle)	● One hour

Table 4

R²P² PRELIMINARY SPECIFICATIONS

WING SPAN	● 4.0 m (13 ft)
FUSELAGE LENGTH	● 3.0 m (9.8 ft)
FUSELAGE DIAMETER	● 0.3 m (1 ft)
WING PLANFORM AREA	● 2.05 m ² (22.1 ft ²)
PAYLOAD	● 45 Kg (100 lbs)
GROSS WEIGHT	● 114 Kg (250 lbs)
MAXIMUM AIRSPEED (23 HP engine)	● 57 m/s (110 knots)

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Table 5

VEGA MODEL 657-10 GROUND STATION

● Uplink (Command) Channels	8
● Downlink (Data) Channels	8
● Update Rate (per channel)	62.5 Hz
● Airborne Package Weight	1.9 Kg (4.25 lbs)
● Tracking Antenna Operating Envelope:	
Azimuth	360°
Elevation	0 – 85°
● Operating Range	≈ 37 km (20 nm)

Table 6

TELEMETRY SYSTEM COMPONENTS

RECEIVING STATION:

- EMP STS-12C Tracking Antenna
- Microdyne 1100AR Telemetry Receiver (L and S band)
- Microdyne 1100LS Video Receiver
- EMR EXPRT Telemetry Front End (PCM and PAM)
- Metraplex Model 120 FM Discriminators (5 channels)
- Honeywell 1868 Visicorder (9 channels)
- Honeywell 101 Tape Recorder (14 channels)
- Datum Model 9300 Time Code Generator

AIRBORNE PACKAGE:

- Aydin Vector MMP-600 PCM Encoder (64 channels)
 - Omnitek SCO's (5 channels)
 - Emhiser Research 10 w Video Transmitter
 - Emhiser Research 2 w Telemetry Transmitter
 - Tecom Blade Antenna
 - Haigh-Farr Omni-Slot Antenna
-

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Table 7

TRACKING RADAR SPECIFICATIONS

MANUFACTURER	● APT Electronic Industries Ltd.
MODEL	● FA, No. 13, Mk 2
FREQUENCY	● X-band
PEAK POWER	● 135 kW
RANGE	● 183 km (600,000 ft)
ANGLE TRACKING	● Nutating Aerial
ACCURACY	● Range: 14 m (45 ft) (RMS) ± 9 m (30 ft) bias Angular: 3' (RMS) ± 1' bias
TARGET DISCRIMINATION	● Range: 90 m (300 ft) Angular: 2°

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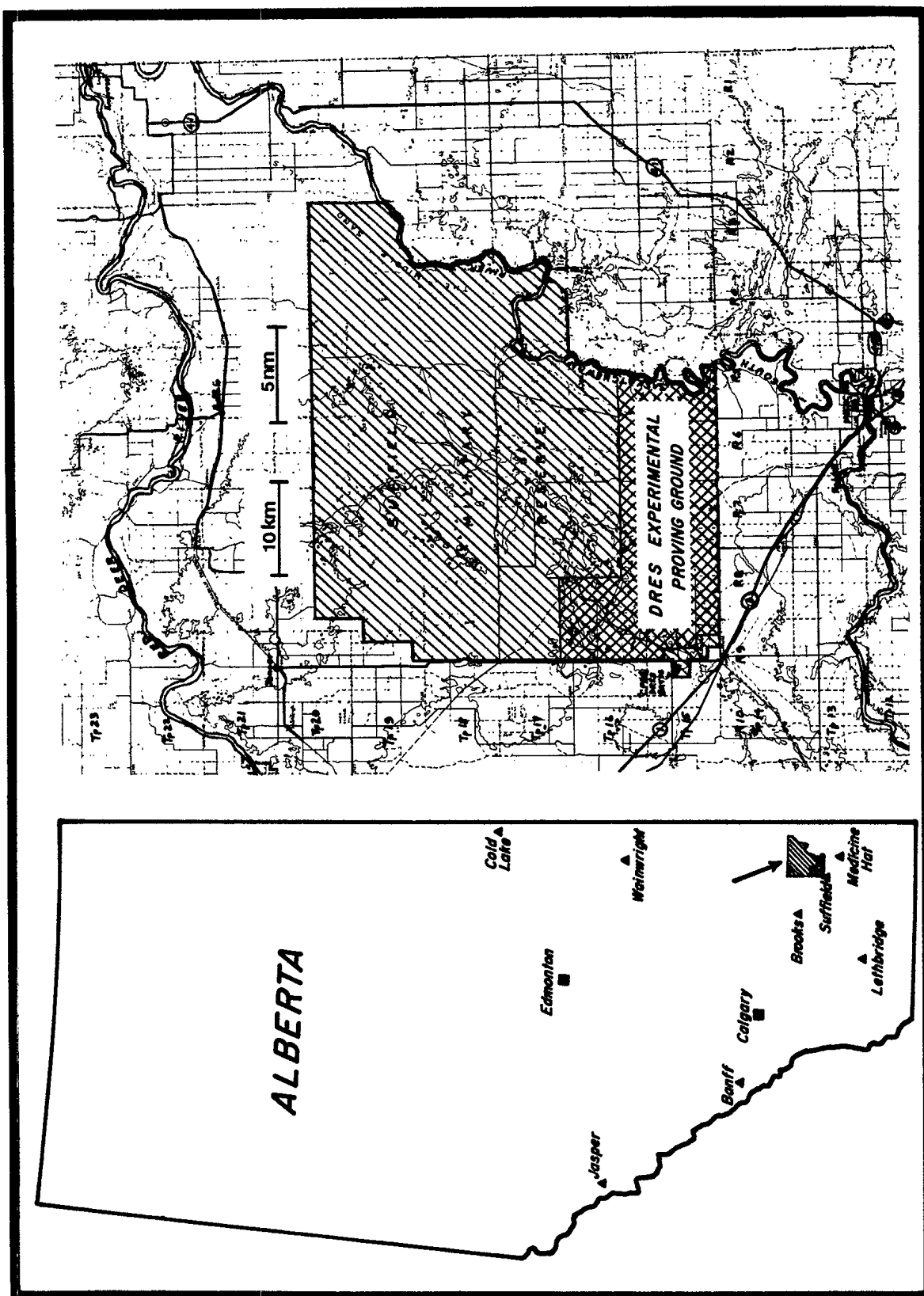
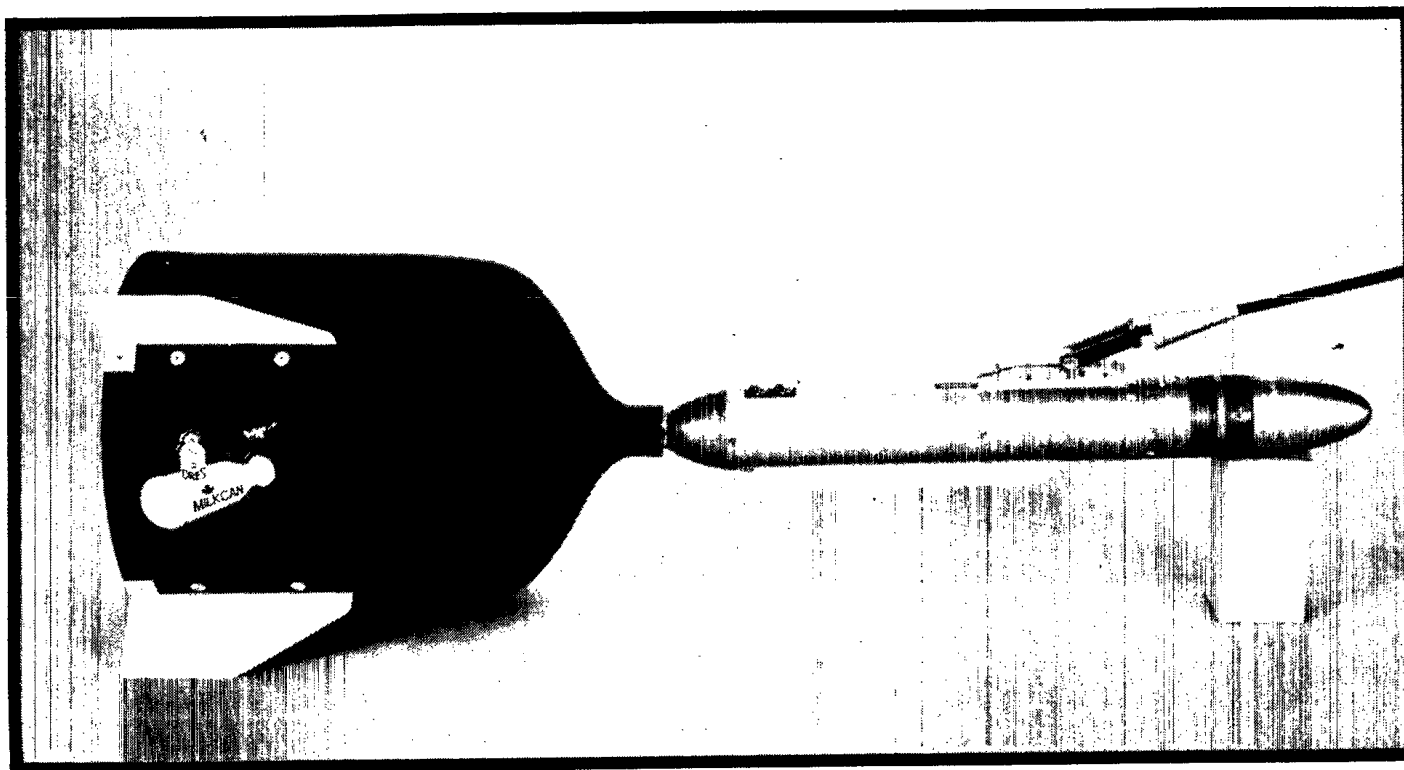


FIGURE 1. THE SUFFIELD RANGE

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SPECIFICATIONS

LENGTH: 1.1 m (3.5 ft)
BASE DIAMETER: 0.3 m (1.0 ft)
WEIGHT INCLUDING MDI: 5.9 kg (13.0 lbs)
TOW LINE: 0.1 cm (0.04 in) DIAMETER, 3050 m (10,000 ft) SINGLE STRAND CABLE
TOTAL DRAG: AT 180 m/s (350 kts) 1090 N (245 lbs)
MAXIMUM SPEED: 180 m/s (350 kts) AT SL WITH 3050 m (10,000 ft) CABLE

FIGURE 2. MILKCAN TARGET WITH ACOUSTIC MDI

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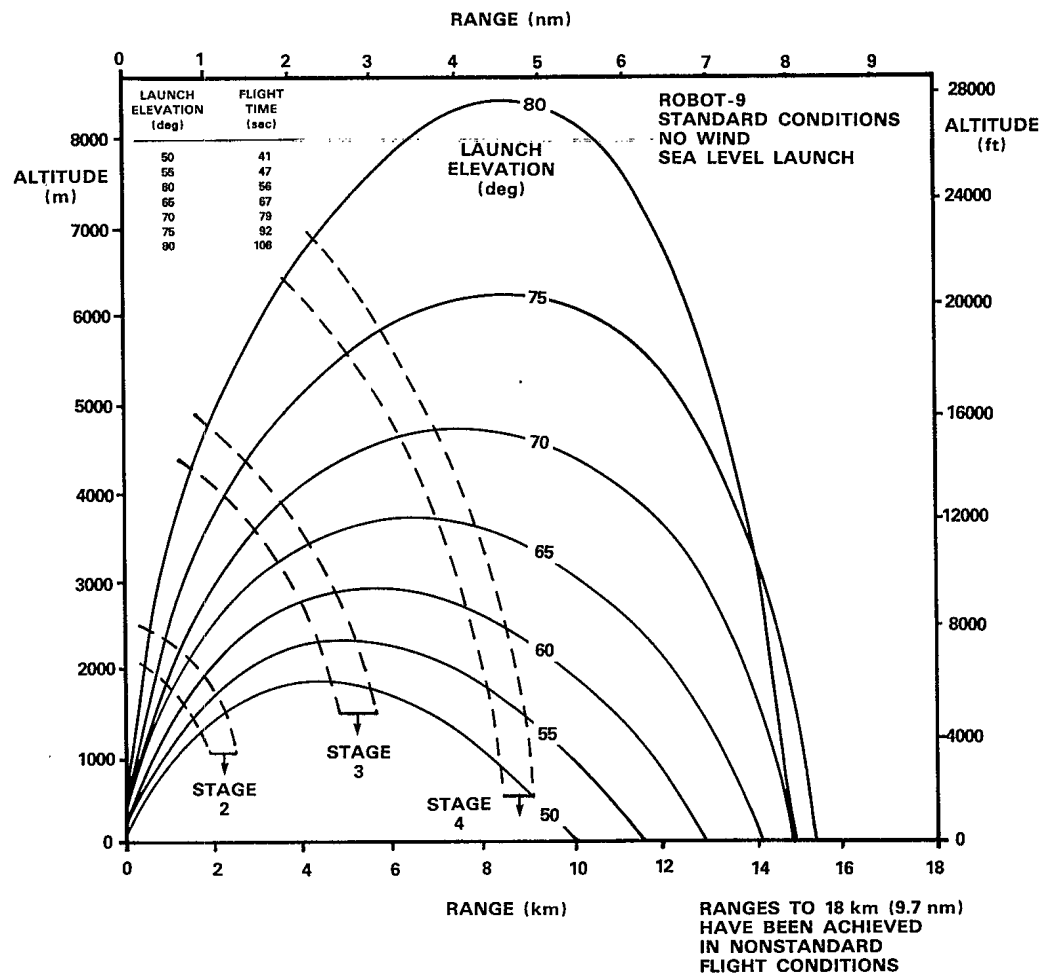
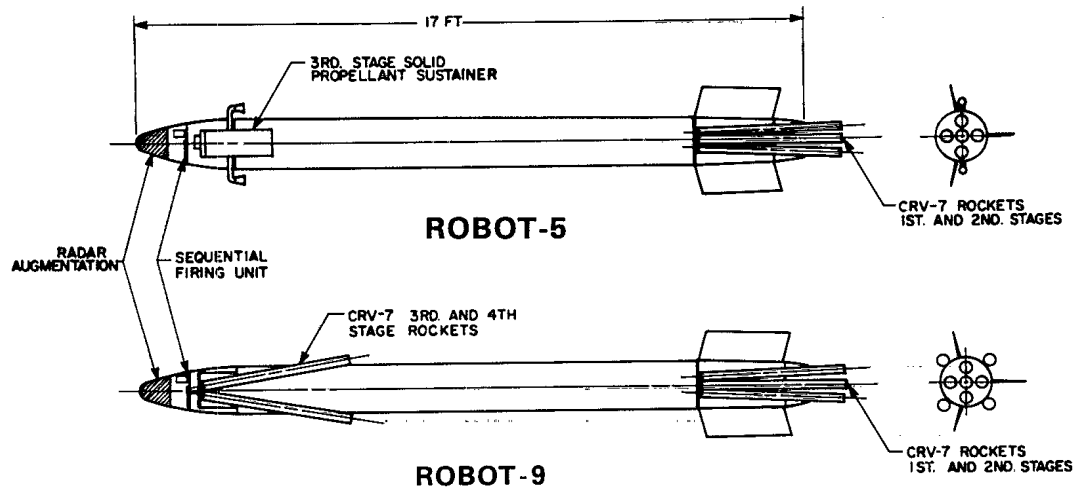
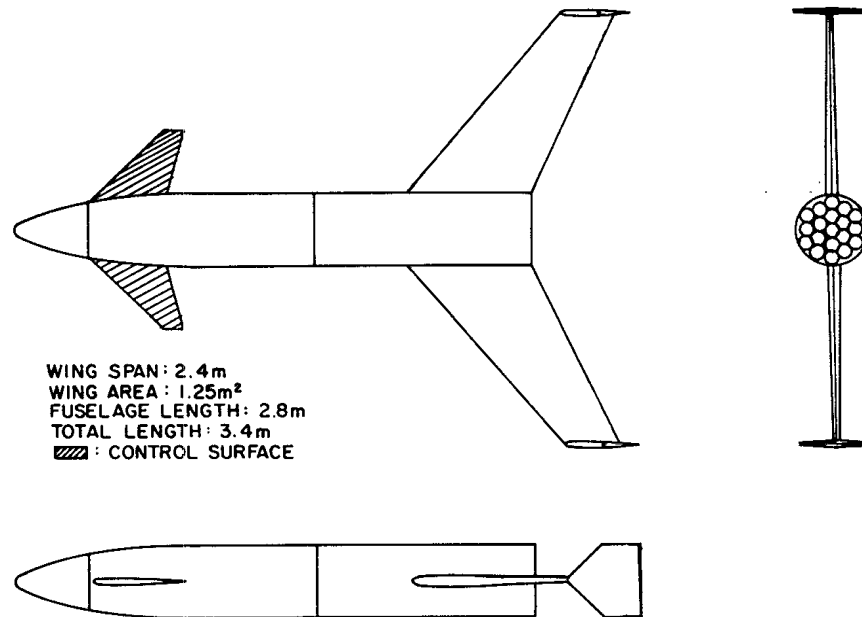


FIGURE 3. ROBOT-5 AND ROBOT-9 ROCKET-BOOSTED TARGETS



ROBOT-X CONFIGURATION

WING SPAN	● 2.4 m (7.9 ft)
FUSELAGE LENGTH	● 2.8 m (9.2 ft)
FUSELAGE DIAMETER	● 0.4 m (1.3 ft)
WING PLANFORM AREA	● 1.25 m ² (13.5 ft ²)
LAUNCH WEIGHT	● 250 kg (550 lb)

ROBOT-X CONFIGURATION CHARACTERISTICS

FIGURE 4. ROBOT-X CANARD CONFIGURATION

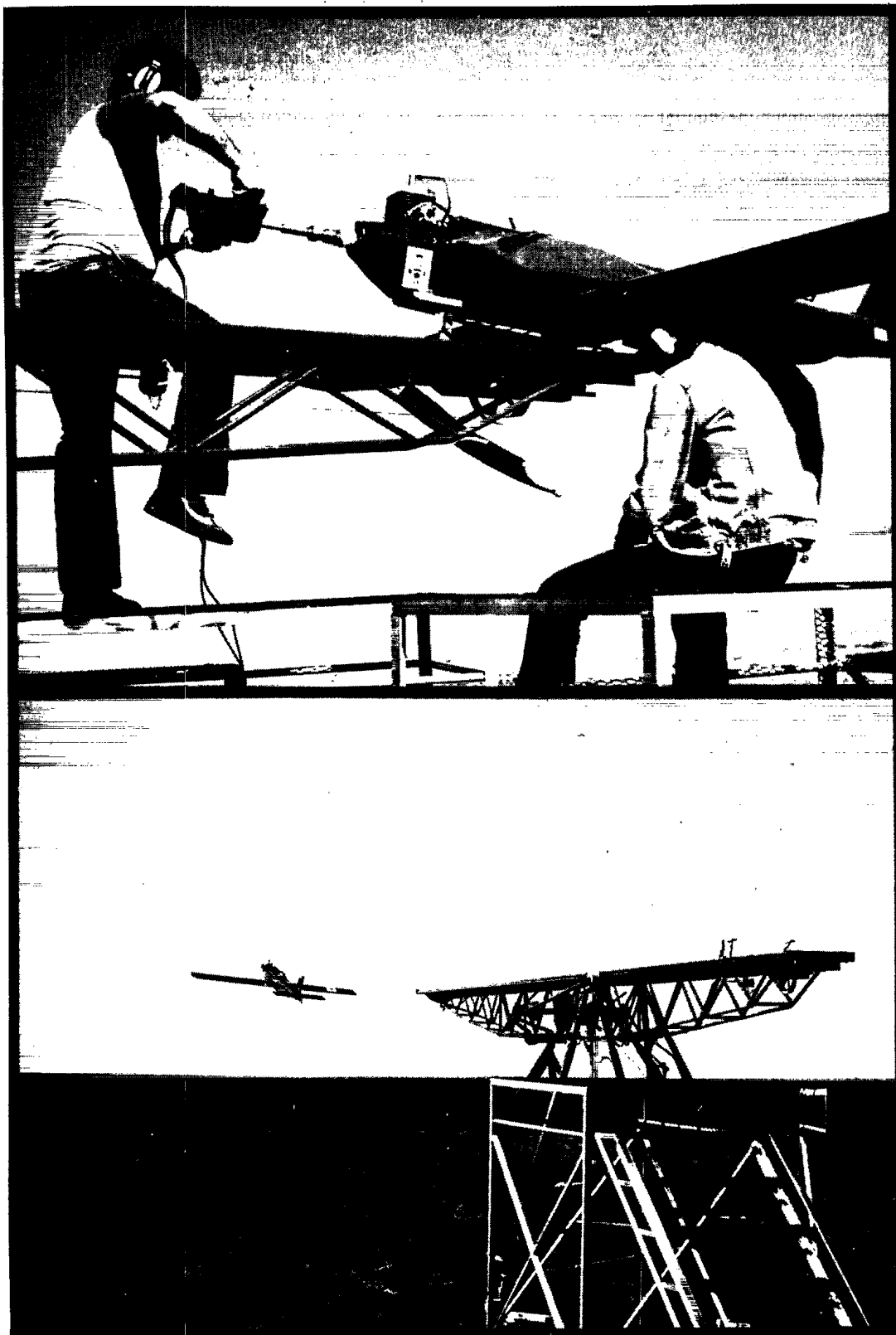
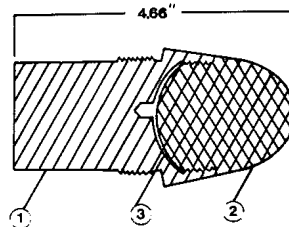


FIGURE 5. TATS-102 TARGET SYSTEM

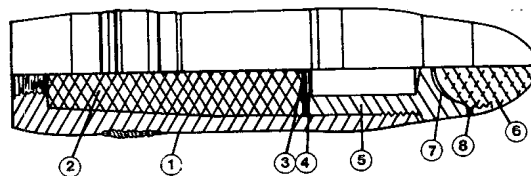
PASSIVE RADAR AUGMENTATION TRAINING DEVICES

FUSE PLUG REPLACEMENT AUGMENTOR



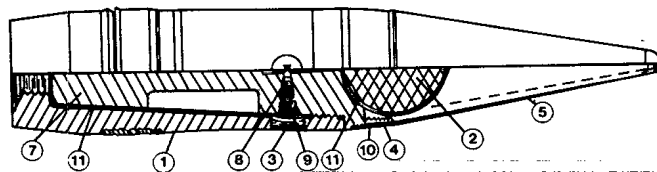
- ① BASE
- ② LENS
- ③ EPOXY

SUB CALIBER AUGMENTOR



- ① BODY
- ② INERT FILLER
- ③ FELT PAD
- ④ ALUMINUM DISC
- ⑤ LENS BASE
- ⑥ LENS
- ⑦ EPOXY
- ⑧ SET SCREW

FULL CALIBER AUGMENTOR



- ① PROJECTILE
- ② LENS
- ③ PLUG
- ④ COLLAR
- ⑤ RADOME
- ⑥ CAP
- ⑦ INSERT
- ⑧ VALVE
- ⑨ PIPE PLUG
- ⑩ "O" RING
- ⑪ EPOXY

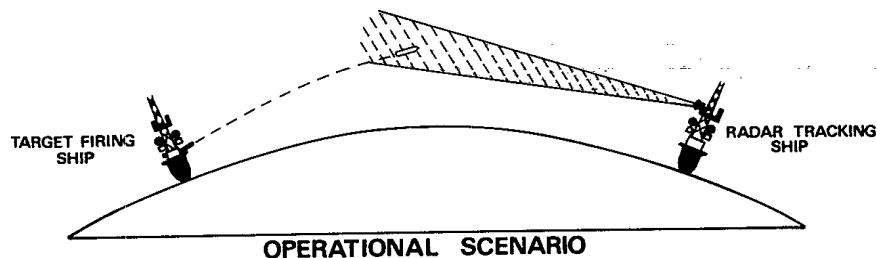


FIGURE 6. 5" / 54 RADAR AUGMENTED PROJECTILES

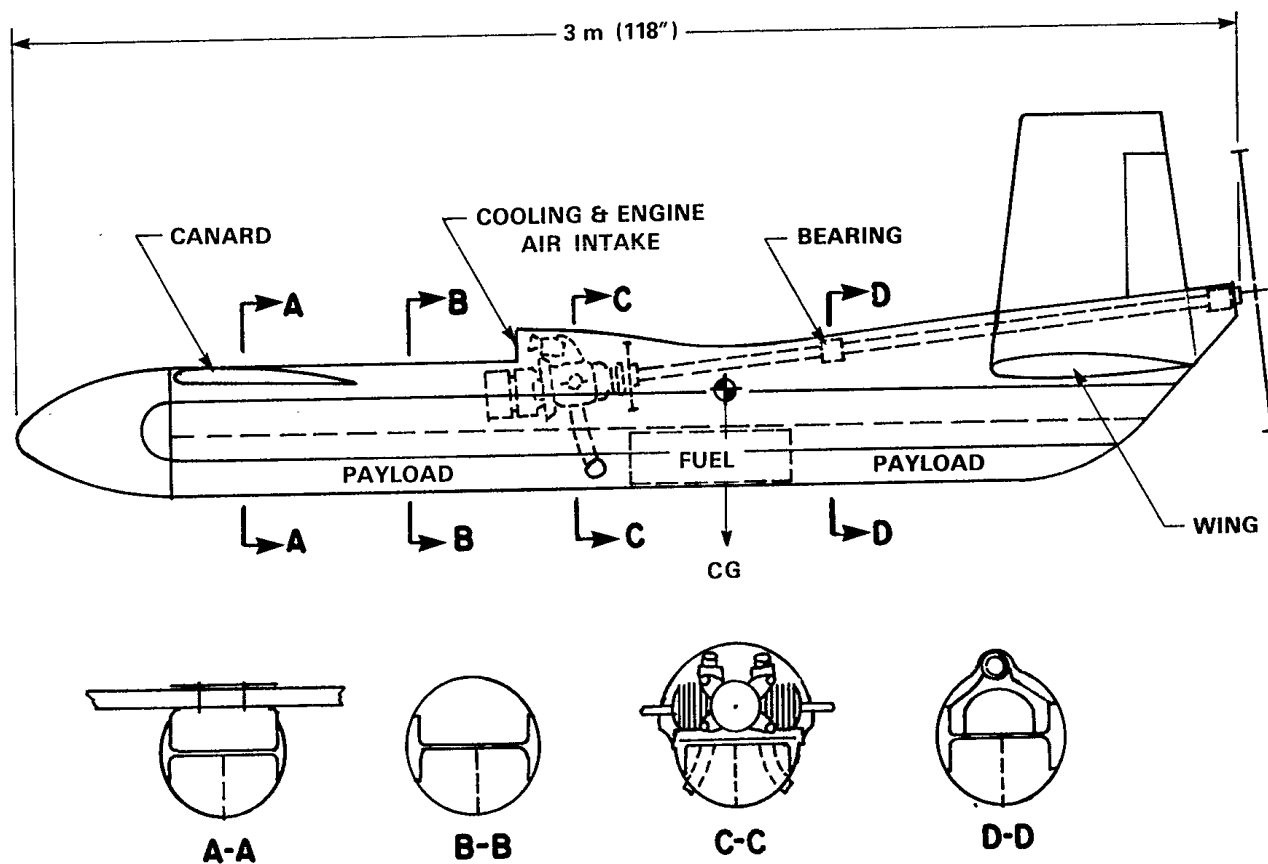
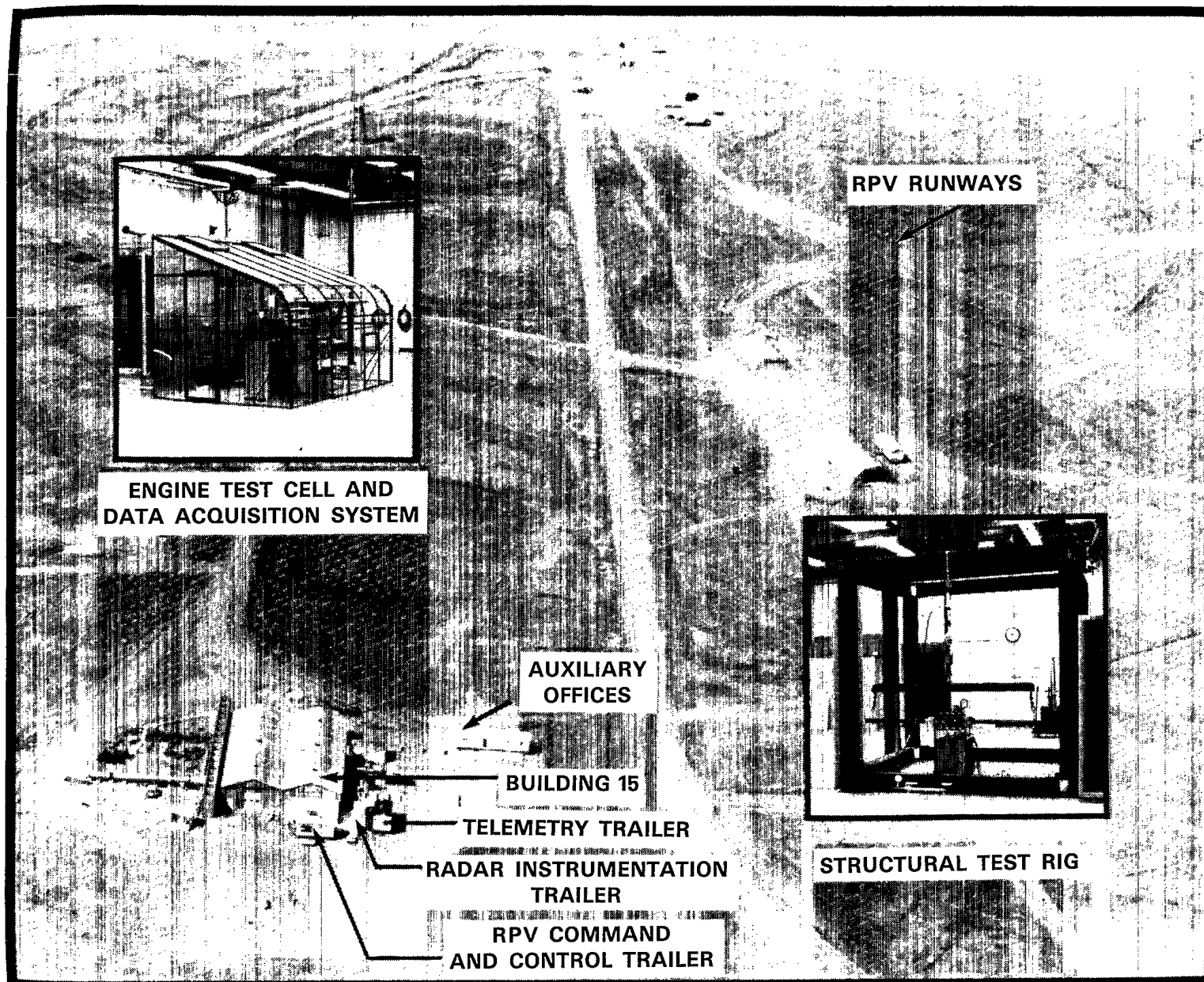


FIGURE 7. R²P² CONFIGURATION
 REAR MOUNTED ENGINE CONFIGURATION IS CURRENTLY BEING CONSIDERED

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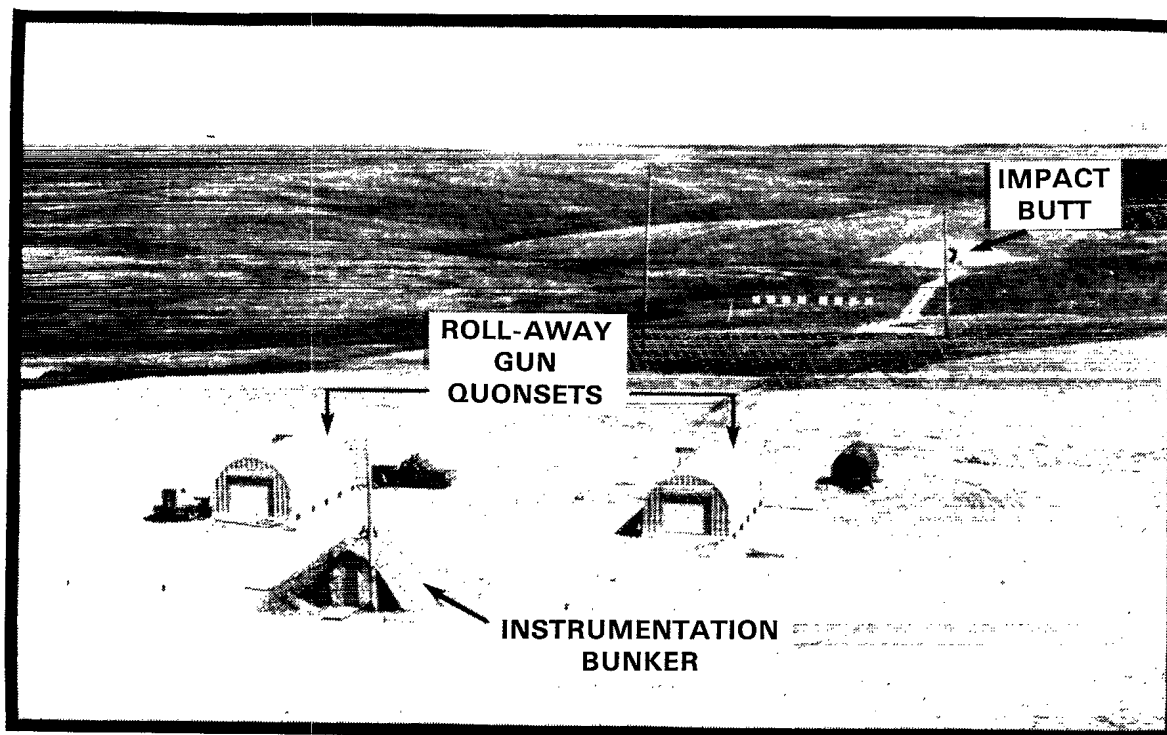
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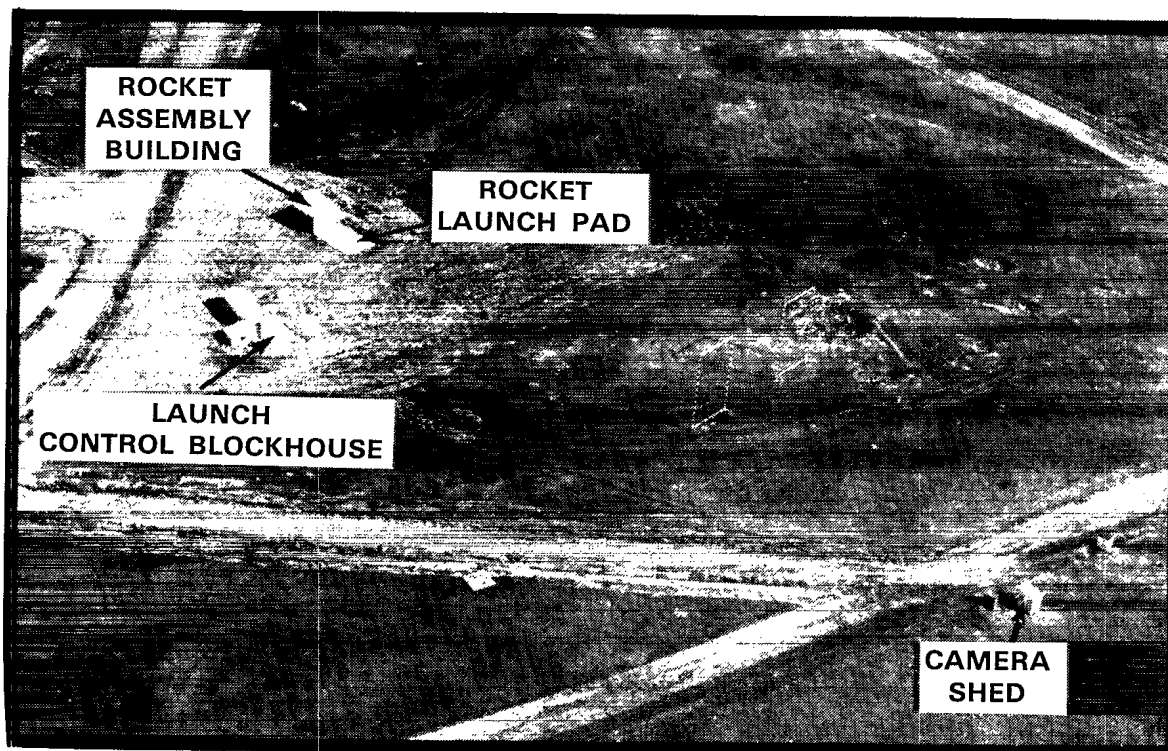
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Figure 8a. BUILDING 15 TEST COMPLEX

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FIVE INCH GUN SITE



ROBOT FAMILY LAUNCH SITE

Figure 8b. R & A TEST SITE

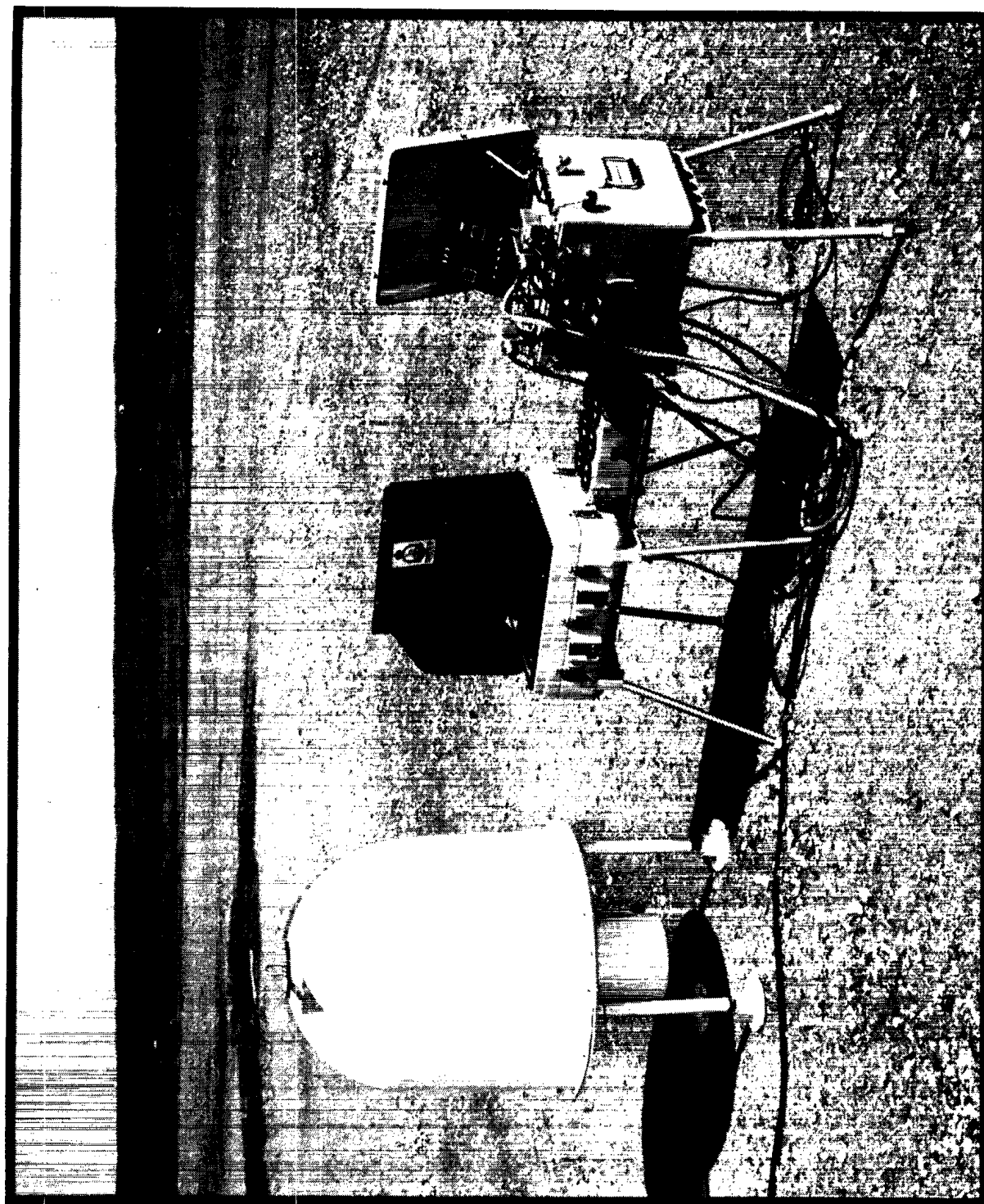


FIGURE 9. VEGA PORTABLE CONTROL SYSTEM

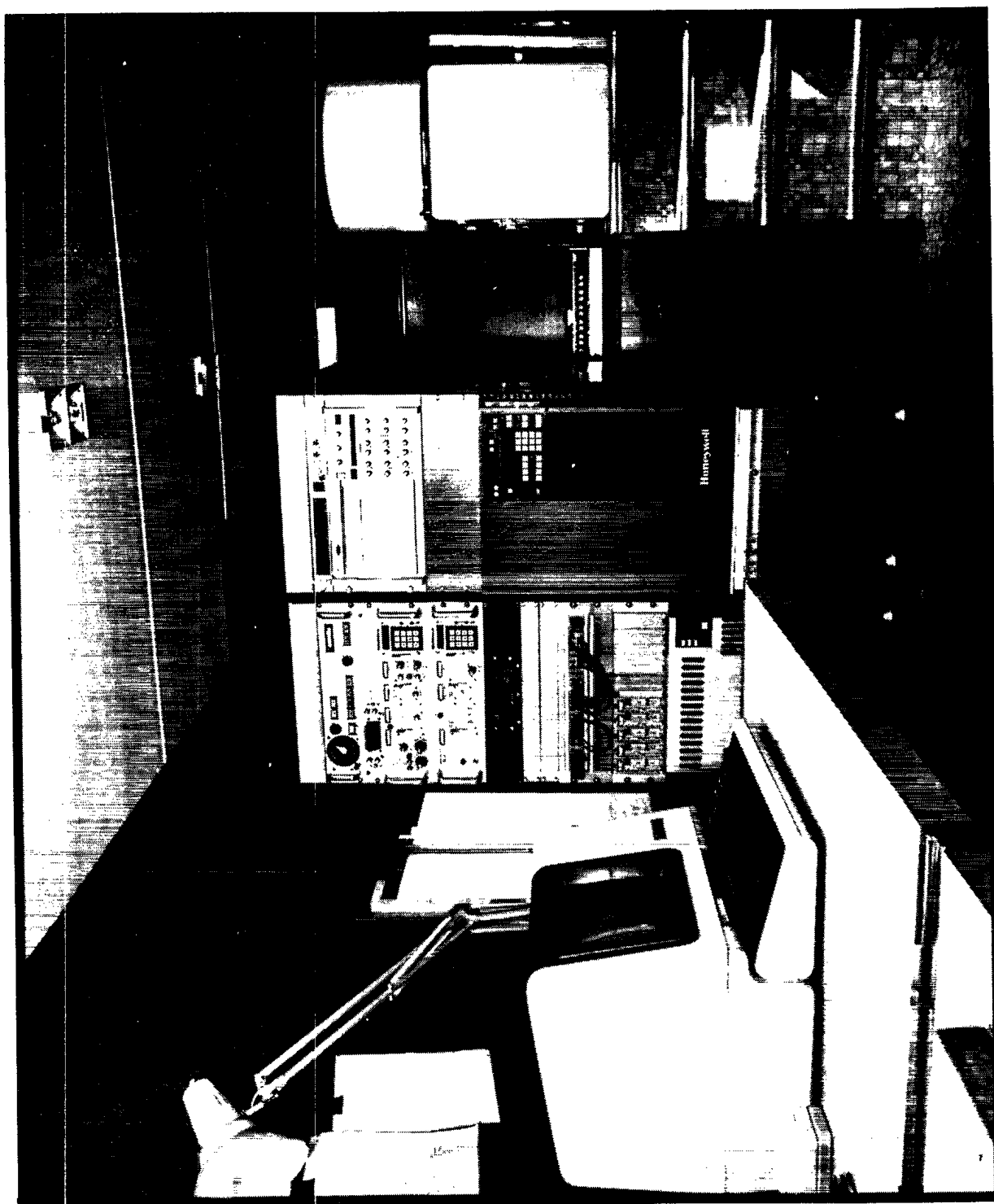


FIGURE 10. DRES TELEMETRY SYSTEM IN COMMAND TRAILER

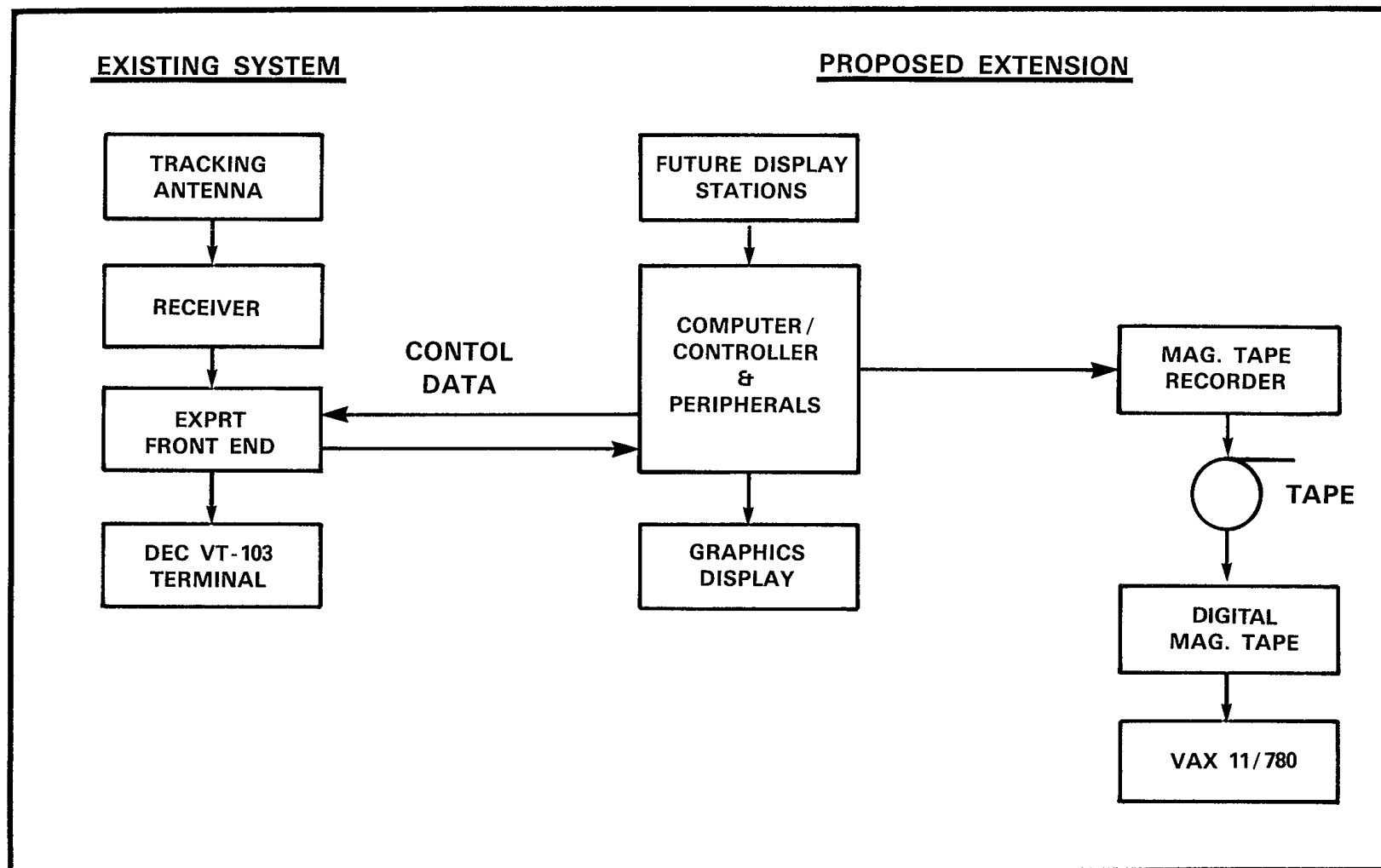


FIGURE 11. BLOCK DIAGRAM OF ADPDFF SYSTEM

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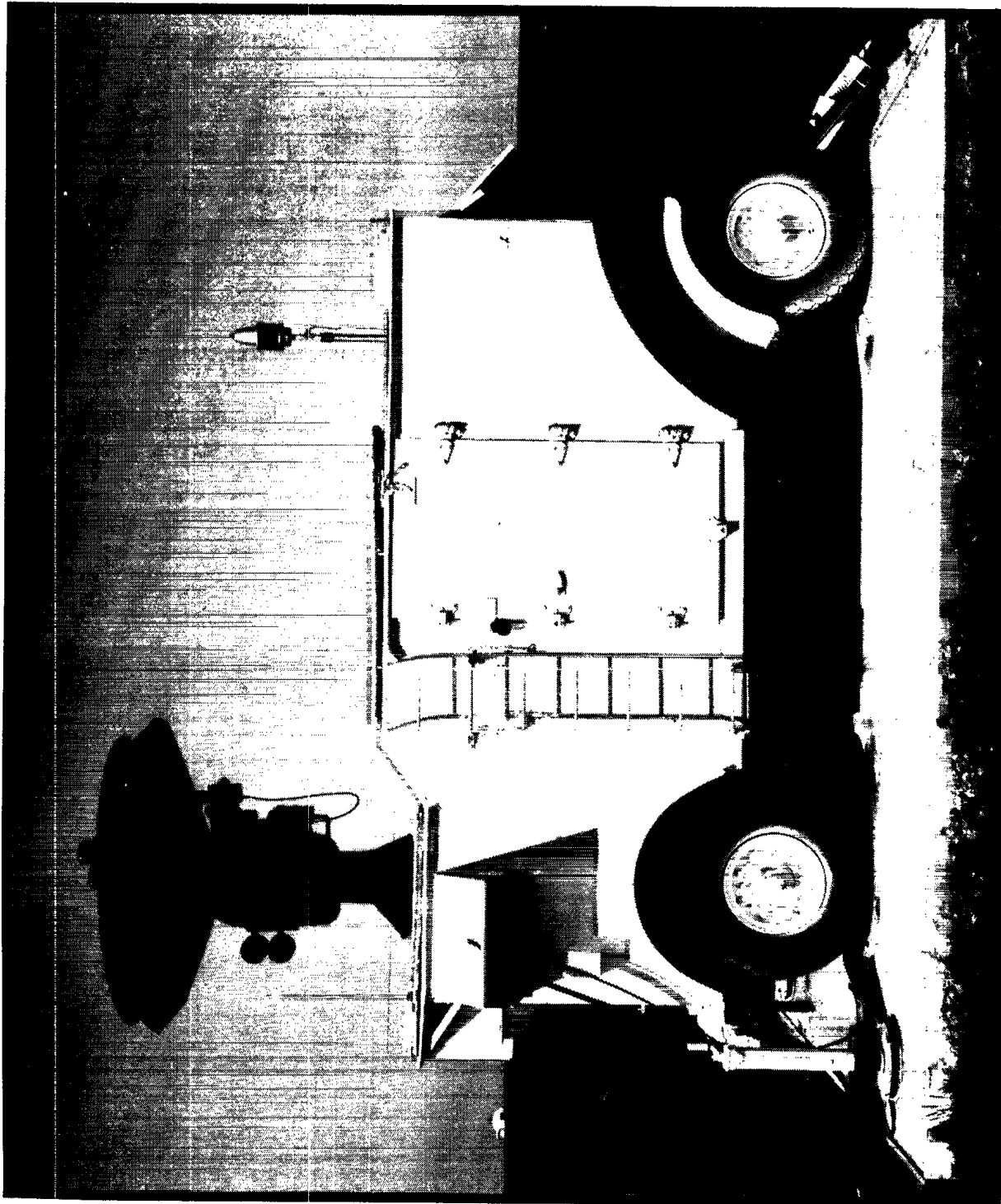


FIGURE 12. DRES RANGE TRACKING RADAR

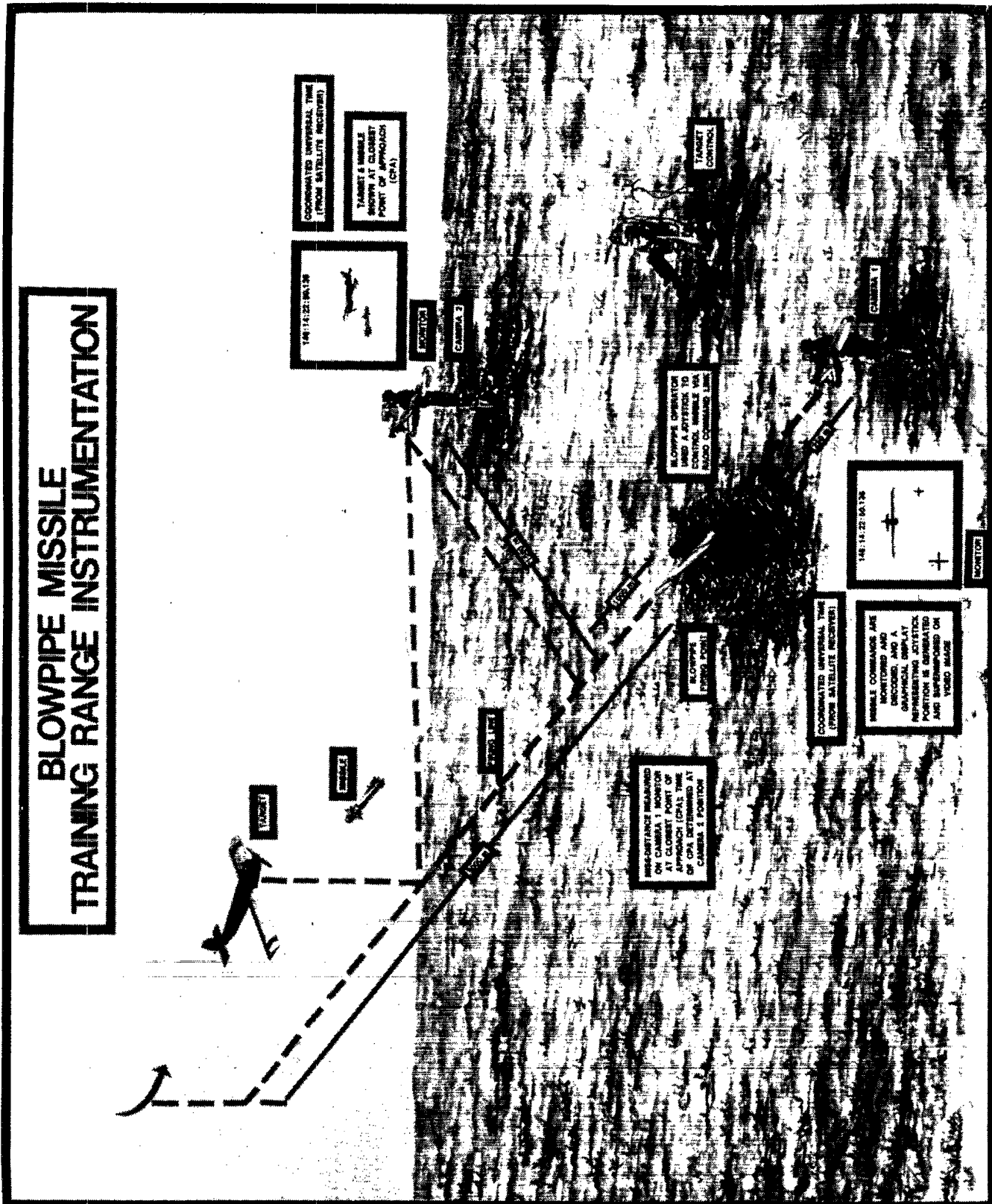
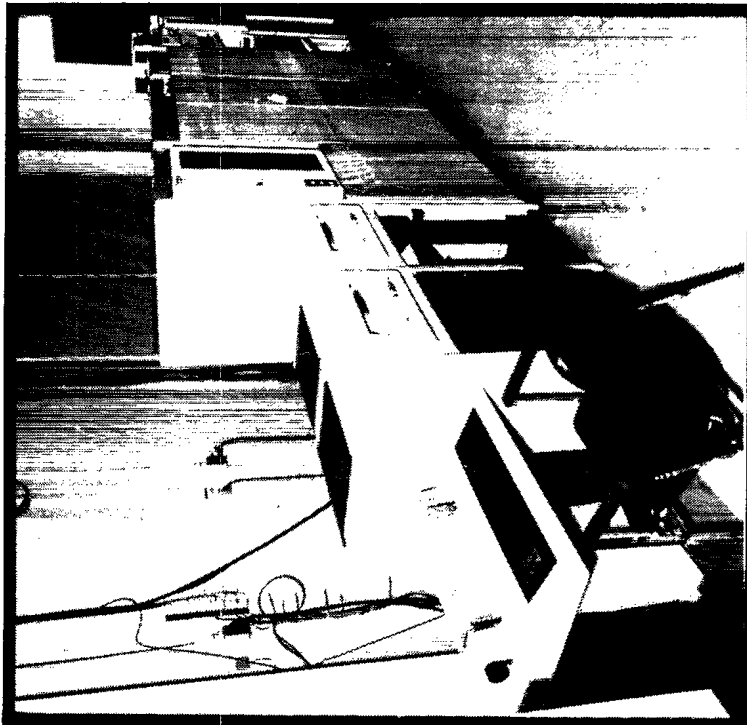


FIGURE 13. BLOWPIPE MISSILE TRAINING RANGE INSTRUMENTATION



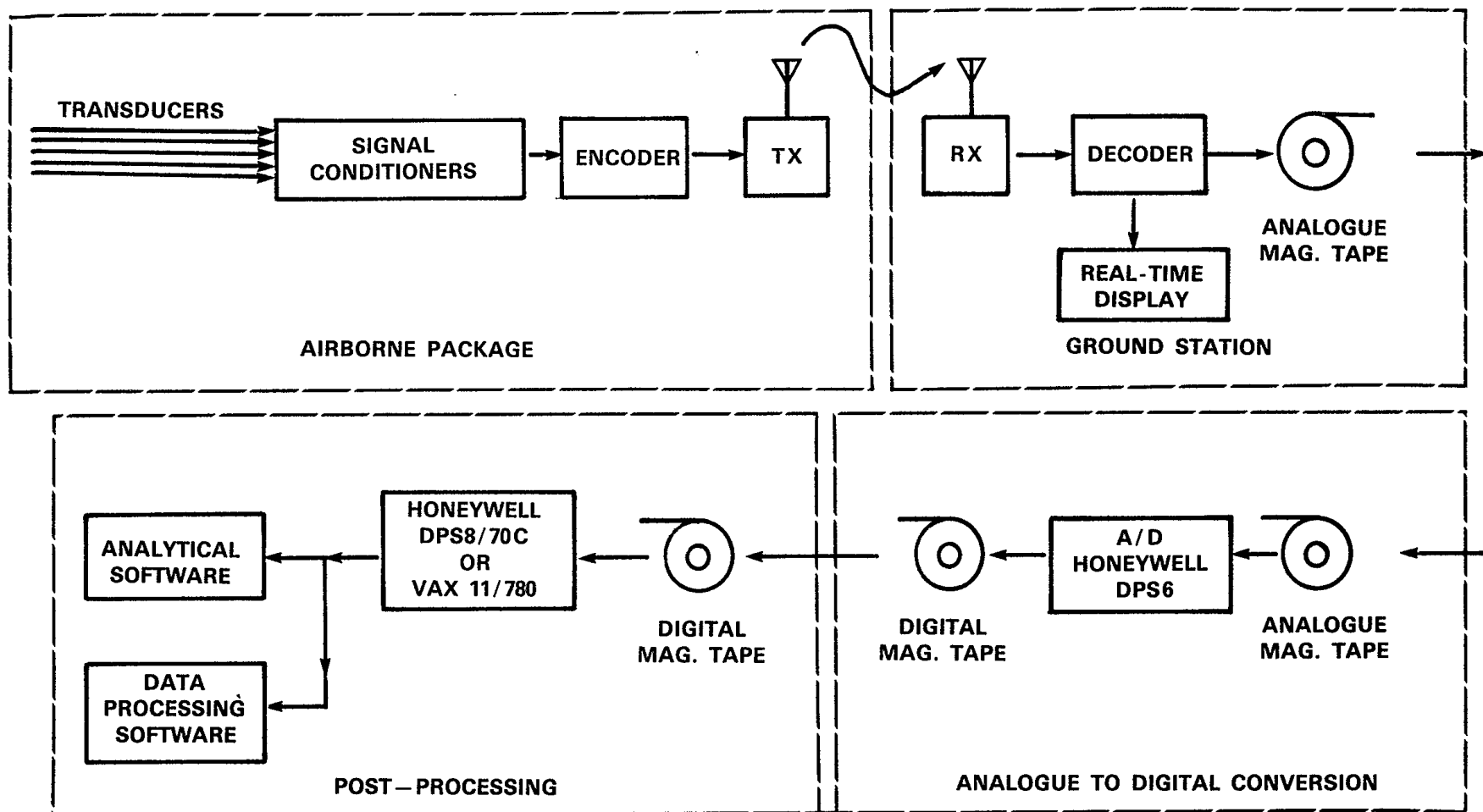
HONEYWELL DPS-8/70C



VAX 11/780

FIGURE 14. DRES MAINFRAME COMPUTERS

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FIGURE 15. EXISTING FLIGHT TEST DATA ANALYSIS FACILITIES

DOCUMENT CONTROL DATA - R & D

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13. ABSTRACT In support of Canadian Forces remotely piloted vehicle and drone research requirements, the Defence Research Establishment Suffield (DRES) has acquired an in-house expertise in aerial targets, drones and remotely piloted vehicle design, development and testing. Overviews of current range capabilities and proposed range improvement programs are given with emphasis on telemetry and video tracking capabilities, and on laboratory structural and engine testing facilities. Past and ongoing research programs are also reviewed. (U)			

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KEY WORDS

Aerial Targets	Radar Augmentation
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Towed Targets	Flight Test Facilities
MILKCAN	Range Instrumentation
TATS-102	Remotely Piloted Vehicles
ROBOT-5	Flight Test Instrumentation
ROBOT-9	Radar Augmented Rounds
ROBOT-X	Rocket Boosted Targets
CRV-7	
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