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APPLICATION OF COMBAT PLANNING TECHNOLOGY TO RPV COMMAND AND CONTROL

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Data Systems Division
Litton Systems Inc.

FOREWORD

This interim report was prepared by Litton Systems, Inc., Data Systems Division, 8000 Woodley Avenue, Van Nuys, CA under Contract F30602-71-C-0015, Job Order No. 691F0101. Contractor's report number is MS27221. Robert A. Ragazzo (IRAP) was the RADC project engineer.

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APPLICATION OF COMBAT PLANNING TECHNOLOGY TO RPV COMMAND AND CONTROL

ABSTRACT

The material presented herein contains the Final Report for a study of the requirements to command and control RPV missions. Factors considered include the RPV System Concepts as they have evolved over the past several years, technology factors as they impact system capability and system costs, and the employment concepts which encompass the use of RPV Weapon Systems in both a mixed force and a pure RPV deployment.

The study was planned as a confined effort. It was not the intent to analyze in depth all factors impacting RPV Command and Control, but rather to assimilate the conclusions of the many studies of RPV systems that have been conducted, and to integrate these results with Litton's analysis of Air Force mission planning, monitoring, and control, and thus; to derive a viable concept for an RPV Command and Control system.

This report addresses the requirements for planning RPV missions and for controlling and monitoring the missions so the planned mission objectives will be realized. Functional requirements have been identified as physical control and force control. Physical control is defined as that control introduced into the RPV vehicle system that causes the vehicle to fly a preplanned flight profile and to realize a preplanned schedule. It is comparable to that control exercised by the pilot in a manned aircraft system. Force control is defined as encompassing all functions required to assign resources to a mission and to plan the mission profile and schedule so the mission objective is achieved. This planning encompasses requirements to coordinate missions in time and space, to plan supporting (communications relay) operations, and to plan for various contingencies. Included in the force control function is the replanning required to adjust operations in response to unforeseen events or to changed environmental factors (i. e. , intelligence, weather, requirements).

Analysis of these basic functions reveal two primary interfaces that significantly impact the control functions. One is the physical control/RPV vehicle interface. The other primary interface is that between the planning function and the physical control function. Each of these interfaces dictate system requirements unique to unmanned airborne vehicles.

An assumption which is especially significant in the selection of requirements for command and control of RPVs is that the system shall provide the capability for a single controller to control multiple RPVs. The only exception is that over-the-target control of each strike mission requires full time operator attention for a short period. To provide this capability, analysis indicated that:

- There must be an automatic flight control system (AFSC) in the RPV.

- For RPV control, continuous communications with the RPV under control is not required except in the over-the-target phase and for bomb damage assessment.

- Over-the-target control of strike missions and BDA require two way, broadband communications on demand.

The command and control procedures and the associated data processing and display requirements discussed in this report were developed in consonance with these assumptions and constraints.

The conclusion of the analysis of the requirements is that the system providing RPV command and control elements may be airborne or ground-based. The command and control elements consist of a DCF multiple RPV control that can be augmented by adding modules as the number of simultaneous missions increase. These basic elements include:

(1) The Multiple RPV Mission Control Element which provides capability to launch an RPV, fly the RPV on a preplanned flight profile, and recover the vehicle.

(2) The Weapon Delivery Control Element for strike missions which provides the capability to receive, process, and display in real time the video imagery obtained from the BO sensors on board the strike RPV.

(3) The RPV Mission Planning and Force Control Element which provides the system with capability to plan a mission, to monitor the execution of missions, and to replan and adjust operations as required.

The RPV Force Planning and Monitoring Element for the mixed force of RPV and manned aircraft is the 485L TACC which is considered to be external to the RPV command and control system. The report provides data processing, communications, and operator consoles and display requirements for each system element.

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SECTION 1

STUDY OBJECTIVES

1.1 INTRODUCTION

The information in this report presents the findings of a four man-month effort on Remotely Piloted Vehicles (RPV) Command and Control requirements. The study was conducted as an add-on to Litton's existing, "Mission Planner Program" (USAF Contract No. F30602-71-C-0015). It was postulated that the Command and Control functions for manned aircraft in tactical situations as developed in the Mission Planner Program were, in many cases, directly relevant to RPV. The purpose of this study was to validate and define the extent of commonality between the command, control, and communications functions identified in the Mission Planner Program and those required for RPV utilization.

1.2 STUDY BASIS

The Advanced Development Mission Planner System (ADMPS) is presently being conducted as a part of the ground data processing element (691F) of the Advanced Development 691 "Force Protection Program". The ADMPS is sponsored by USAF Rome Air Development Center, but because it places emphasis in Force management and vehicle utilization planning, the present RPV addendum is being monitored by USAF Electronic Systems Division of Air Force Systems Command. The ADMPS is being designed to provide automated support for the detailed planning (and/or simulation) of tactical air missions using manned aircraft. A cursory examination reveals that the ADMPS functions are equally applicable to unmanned as well as manned vehicles.

Although the ADMPS itself is not complete, an intermediate milestone of that development required a demonstration of concept feasibility. For this demonstration a set of software programs which implemented the total spectrum of planning functions to support strike and ECM mission planning were generated. This implementation, successfully demonstrated in December of 1971, is called the Mission Planner Breadboard System (MPBS). MPBS operates on commercial equipment and has been demonstrated to interested audiences from its inception to the present time at Eglin Air Force Base and at Litton's Canoga Park Facility. It was the demonstration of this breadboard that lead to the present study. The functions and operation of the breadboard are detailed in Section 4 of this report, along with the description of the RPV demonstration and an analysis of how MPBS might be modified for RPV purposes.

1.3 STUDY TASKS

<u>Task 1. RPV Mission Planning</u>: Determine the applicability and demonstrate the use of current Mission Planning programs to RPV mission planning requirements.

Task II. Real Time Command and Control Requirements: Identify and describe those functions which should be implemented to satisfy the RPV requirements for real time Command and Control and their hardware and software impact.

1.4 SCOPE

The effort expended on this study was limited by funding to approximately four man-months of effort plus the computer time required for demonstrating the present applicability of the MPBS to RPV. To determine how applicable the MPBS functions might be to RPV command and control, however, (and to plan the demonstration), analysis of the Command and Control requirements imposed by the nature of the RPV itself was necessary. To perform such analysis within the prescribed limits, results had to be based on the data of existing studies and analyses rather than upon a totally new analysis. In some areas, such as assumptions concerning the avionics and performance capabilities of the RPV, it was necessary to use existing data as a "given." Similarily, development of the data processing estimates are primarily based upon Litton's substantial experience in the development of tactical Command and Control Systems. The particular studies and analyses used, together with a specific analysis of the RPV communication problem, are presented in Section 2.

The major portion of the study is contained in Section 3. This section presents the results of the functional analysis and describes, where appropriate, how Mission Planner functions fit, or could be modified for RPV. The definition of functional requirements has been taken to a level of indenture sufficient to provide functional allocation to data processing, display, communications, or operator subsystems. Once the functional analyses are made it is possible to evaluate the data base and processing requirements. These requirements are presented in Section 5.

Section 6 of this report presents the System Concepts for Command and Control of RPVs, including conceptual system design. Section 7 identifies areas for additional study.

1.5 RPV FORCE DEPLOYMENT FACTORS

The force deployment assumptions are based upon guidance provided for this study and, as they relate to RPV strike units, on guidance provided for the man-machine interface studies. The factors which are documented in this section are applied in Section 3, RPV Command and Control, and Section 4, Mission Planning Systems Applications to RPV Command and Control, to establish quantitative factors for operator requirements and data processing and display. In many areas, these factors are relatively independent of mission type. Consequently, the results are relatively independent of the mission mix. The factors that most significantly affect system capacity are:

a. Total number of missions per day and planning response times required

b. Total number of missions simultaneously airborne

c. Total number of strike missions simultaneously in the weapon delivery phase.

The standard RPV force assumed is an RPV Composite Group with three units: a Strike unit, and EW unit, and a Reconnaissance unit. Each unit is capable of launching 80 sorties per day. There will be up to 20 missions simultaneous airborne. Four strike missions may be in the terminal phase simultaneously. Table I. 5-1 RPV Force Factors, tabulates all factors assumed.

Table I. 5-1 RPV Force Factors

No. Units	3
Sorties per Unit/Day	80
Sorties per Mission	1
Total Missions/Day	240
Targets/Mission, Strike	3
Targets/Recce Mission	3
Mission Objectives per EW Mission	2
Total Simultaneous Missions/Unit	20
Total Simultaneous Missions/RPV Force	60
Total Simultaneous Strike Missions Over-the-Target	4
Launch Sites per Unit	2
Total Launch Sites	6
Recovery Sites per Unit	1
No. Emergency Recovery Sites	1
Total Recovery Sites/Force	4

1.6 SUMMARY AND CONCLUSIONS

The material presented in this report is based upon a study of the requirements to command and control RPV missions. Factors considered have included the RPV System Concepts as they have evolved over the past several years, technology factors as they impact system capability and system costs, and the employment concepts which encompass the use of RPV Weapon Systems in a mixed force as well as in a pure RPV deployment.

The study was planned as a confined effort. It was not the intent to analyze in depth all factors impacting RPV Command and Control, but rather assimilate the conclusions of the many studies of RPV systems that have been conducted, to integrate these results with Litton's analysis of Air Force mission planning, monitoring, and control and to derive a viable concept for an RPV Command and Control system.

In consonance with this study plan the report summarizes briefly:

- Operational concepts for the employment of RPVs.
- Air Force funded studies that have been used as a basis for the RPV system performance capabilities.
- Litton's studies of mission planning and control systems applicable to RPV Command and Control.

Because communications for enroute and over-the-target control introduces significant technological problems, a detailed discussion of communications technology as it applies to RPV control is included.

The report addresses the requirements for planning RPV missions and for controlling and monitoring the missions so the planned mission objectives will be realized. Functional requirements have been identified as physical control and force control.

Physical control is defined as that control introduced into the RPV vehicle system that causes the vehicle to fly a preplanned flight profile and to realize a preplanned schedule. Over-the-target control for weapon delivery, on-station control for EW and reconnaissance missions, and control required to respond to system failures are subsumed. It is comparable to that control exercised by the pilot in a manned aircraft system.

Force control is defined as encompassing all functions required to assign resources to a mission and to plan the mission profile and schedule so the mission objective is achieved.

This planning encompasses requirements to coordinate missions in time and space, to plan supporting (communications relay) operations, and to plan for various contingencies. Subsumed in the Force control function is the replanning required to adjust operations in response to unforeseen events or to changed environmental factors (i.e., intelligence, weather, requirements).

There are two primary interfaces that significantly impact the control functions. One is the physical control/RPV vehicle interface. Principal assumptions used in this study on the RPV system are derived from the Air Force Multi-Mission Studies. Physical control requirements are developed by mission phase: i.e., launch, enroute, over-the-target strike or on-station EW and Recce, return to base, and recovery. Other assumptions on the RPV vehicle/physical control interface are documented throughout the section in the particular mission phase where they apply.

The other primary interface is that between the planning function and the physical control function. In considering this interface, it was concluded that the RPV mission is relatively unique since there is little opportunity to obtain knowledge of the flight environment in the execution phase that was not available before launch. Specifically, visual reference to the environment is very limited vis-a-vis that possible in a manned system. Consequently, the conclusion was that planning could and should be very detailed and comprehensive. The principal requirement for physical control is to insure missions are executed as planned. The procedures for physical control are based on this premise. Force Control Functions show how such detailed plans are generated.

The assumption which is especially significant in the selection of requirements for command and control of RPVs is that the system shall provide the capability for a single controller to control multiple RPVs. The only exception is that over-the-target control of each strike mission requires full time operator attention for a short period. To provide this capability, analysis indicated that:

a. There must be an automatic flight control system (AFCS) in the RPV. The AFCS will, at a minimum, provide the capability to maintain (hold) attitude and heading. Additionally, it was concluded that the requirement to provide control of multiple RPVs in a hostile environment dictated that the AFCS also have the capability to initiate and execute maneuvers such as turn, climb, and descend.

b. For RPV control, continuous communications with the RPV under control is not required except in the over-the-target phase and for bomb damage assessment. Contact intervals in the order of 10 seconds are judged to be acceptable; longer periods between contacts are, however, tolerable under certain conditions. In addition, the physical control procedures developed do not require communications to execute a preplanned RPV maneuver at an exact time. The consequence of these conclusions is that requirements for the communications relay subsystem are considerably reduced with respect to physical control. Thus, lower cost implementation of the command/response links are available as viable options. The communications factors documented in Subsection 2.4 derive from these premises.

c. Over-the-target control of strike missions and BDA require two way communication on demand. A broad band data link to transmit imagery from the RPV to the Drone Control Facility (DCF) Controller (ground-based or airborne) is required. The command link, Controller to RPV, must also be available on demand.

The command and control procedures and the associated data processing and display requirements were developed in consonance with these assumptions and constraints. Additionally, the desirability of minimizing on-board processing in the RPV and minimizing communications requirements was subsumed. The conclusion of the analysis of the requirements for command and control is that the system providing RPV command and control elements may be airborne or ground-based. The command and control elements, in turn, consist of a DCF multiple RPV control element that can be augmented by adding modules as the number of simultaneous missions increase. Figure 1.6-1 shows in specification tree format the mission essential elements of

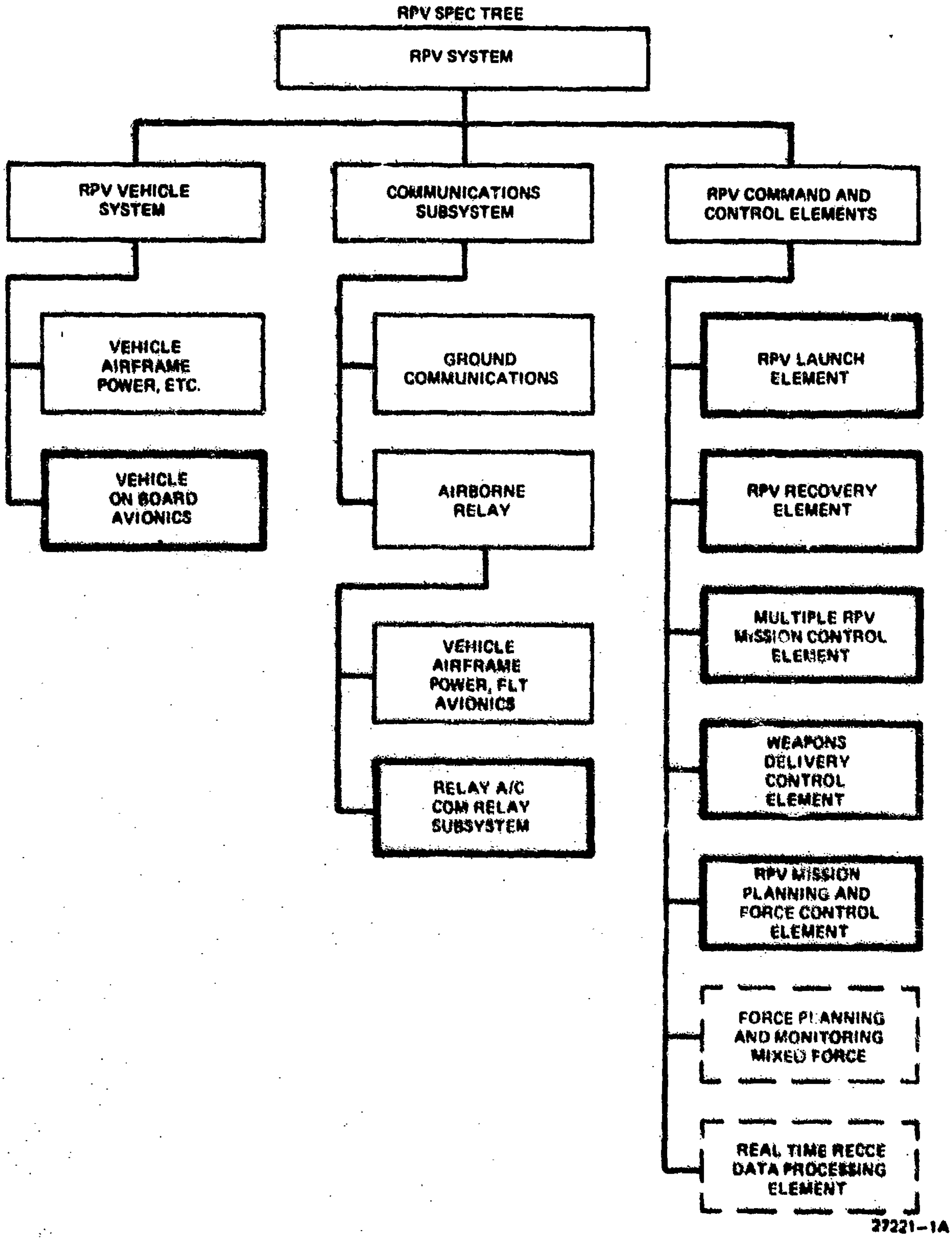

Figure 1.6-1. RPV System Specification Tree

the RPV system. Those elements which are either a part of, or are principal interfaces, with the RPV control system are shown in bold outline. The significant conclusions of this study relate to the features of the RPV command and control element modules.

The Multiple RPV Mission Control Element provides the capability to launch an RPV, fly the RPV on a preplanned flight profile, and recover the vehicle. The capability to provide inflight control and to react to exceptions reported is included. This element consists of personnel, data processing and operator consoles and is common to all RPV units; Strike, EW, and Reconnaissance. It is the essential element required in every deployment situation.

The Weapon Delivery Control Element for strike missions provides the capability to receive, process, and display in real time the video imagery obtained from the EO sensors on board the strike RPV. The element also provides the capability to position the strike RPV exactly on a delivery trajectory and to control weapon release and bomb damage assessment. This element augments the basic element. Consequently, the DCF for an RPV strike unit consists of the basic element plus the Weapons Delivery Control Element. The element contains operator personnel, strike control consoles, and additional data processing capability.

The RPV Mission Planning and Force Control Element is the system element that provides the capability to plan a mission, to monitor the execution of missions, and to replan and adjust operations as required. It also establishes requirements for mission support, e.g., EW support to a strike or reconnaissance mission. It automatically generates a code as a part of the plan which can be inserted into the RPV prior to launch, or transmitted to the RPV inflight. The coding is such that the RPV will maneuver according to the preplanned flight profile within dead reckoning accuracy limits. (It is operationally desirable that this capability also be available in the Multiple RPV Mission Control Element for cases when the two modules are not colocated. The element consists of operator personnel, data processing, and operator consoles. Since this element requires relatively complete data on the enemy order of battle, (especially targets and enemy defense capability) and other data applicable to all RPV units, it is sized to plan and monitor the operations of the total RPV force. The level of capability provided is essential to an effective and rapid response planning capability and is typically required in all deployments. However, if mission requirements are simple and the RPV force is small, the option of manual planning does exist. RPV flight profiles can be manually generated. Conversion to code can be accomplished by the Multiple RPV Control Element. For a pure RPV force, the planning element supports the force planning function.

The RPV Force Planning and Monitoring Element, for the mixed force of RPV and manned aircraft, is the 485L TACC. This element is considered to be external to the RPV system. The additional capability desirable or required within the TACC to effectively plan a mixed force operation is addressed in Subsection 3.3, Force Planning Function. This is reflected as a dotted line box in Figure 1.6-1.

The Real Time Reconnaissance Data Processing Element provides the capability to receive and process in near real time reconnaissance imagery data and other reconnaissance information. It augments the basic module for reconnaissance RPV units if this capability is required. Since the capability to process reconnaissance data in near real time is common to manned aircraft and RPVs alike, the element may be an element of the intelligence processing system, not the RPV system. Thus it is shown as a broken line box and is not addressed in this study. There is, however, a significant interface that will affect the Recce RPV.

Figure 1.6-2 depicts the RPV command and control system in a typical deployment situation with three RPV units. Interfaces between each RPV unit and the planning element is depicted. A digital data link interface is assumed. Each unit interfaces directly with launch and recovery sites; again digital data link is assumed. Interface with the TACS system, the TACC, CRC, and manned aircraft unit TUOCs is through the RPV composite group planning and Monitoring modular element. Not shown on the figure is the interface with the airborne RPVs which is from the unit control module to the RPV, either direct or through the relay aircraft.

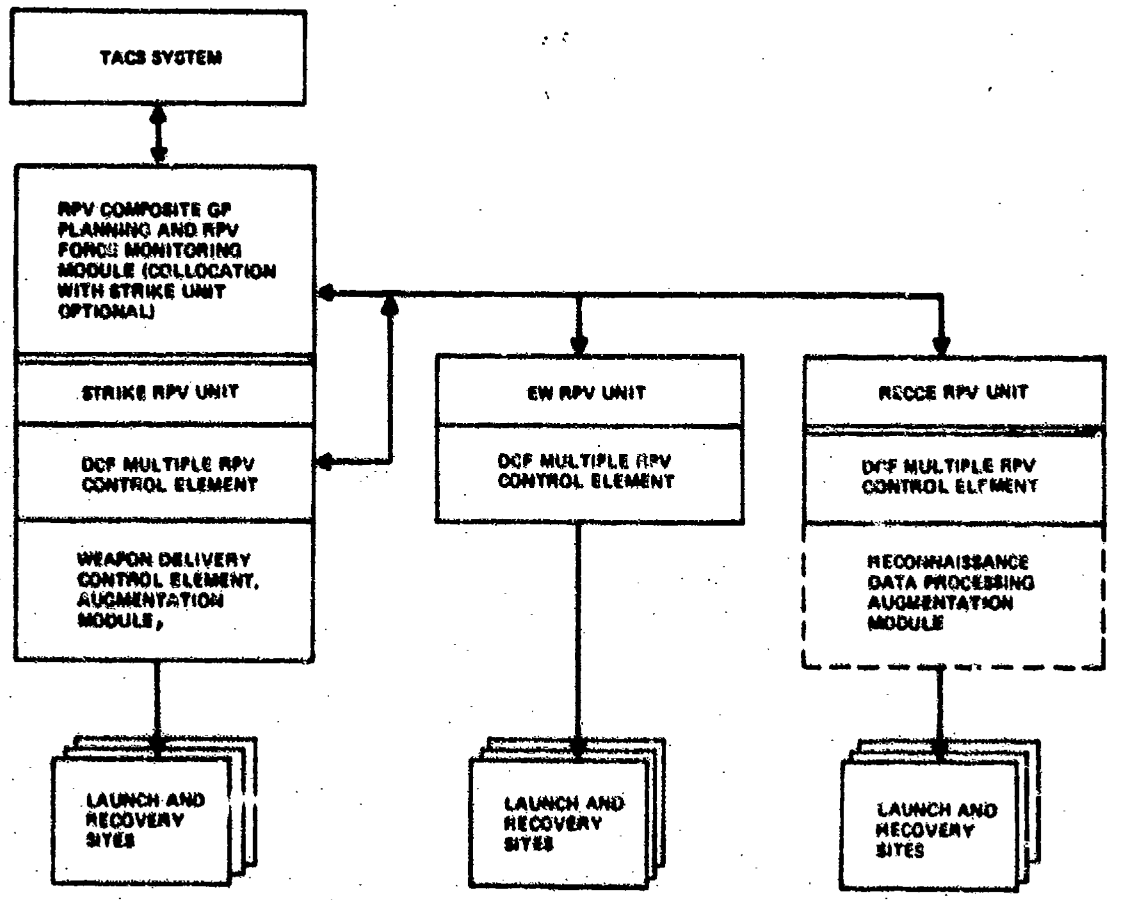

Figure 1.6-2. RPV C&C System Typical Configuration

SECTION 2

RELATED STUDIES AND TOPICS

2.1 INTRODUCTION

A principal source of information was the set of reports derived from various Air Force studies including the Multimission Remotely Piloted Vehicle Systems (Contract Nos. F33615-72-C-1260 and F33615-72-C-1210), Man Machine Interface (Contract No. F33615-72-C-1848), Command and Control Information Processing (CCIP-85 AF Contract No. 4701-71-C-0366), and SEEK FLEX Preliminary Design (USAF Contract No. F19628-71-C-0016) studies. Additional data were derived from other sources including a document entitled "Navigation and Guidance for Remotely Piloted Vehicles," which was presented by Litton Guidance and Control Systems Division personnel at the RPV Symposium (June 1972). Other documentation includes the TACOP Final Report - CORONET ORGAN V, dated 1-11 November 1971; "An Analysis of Remotely Manned Systems for Attacking SAM Sites," USAF Rand Project Report R-710-PR; plus numerous articles concerned with drone/RPV technology and utilization. Key technology areas that have impact on the command and control system requirements are the vehicle navigation technique and the vehicle-ground communication link. The requirements for these two elements are discussed in Subsections 2.6 and 2.7. Additional areas of special impact are the structure, size, and deployment concepts of Tactical Air Forces. Brief discussions of these are included in Subsection 1.5 and Section 5.

2.2 RPV SYSTEM DESIGN STUDIES

Litton used previously conducted, USAF funded, studies for information pertaining to certain areas of this study. This applicable data included the areas of; vehicle design, operational concepts, Force sizes, communications requirements, facilities required for Drone Control, and analyses of man-machine interfaces. These studies covered a wide range of factors pertinent to the development of this system. Therefore, they contributed directly to this study because it was not intended to further define any of these factors but rather to select representative factors from them as a baseline.

2.2.1 RPV Multi-Mission Studies

Two studies were awarded, one to Teledyne-Ryan assisted by RCA, and the other to Northrup assisted by TRW, to determine the system design requirements for remotely piloted vehicles as a tactical weapons system for multiple mission application. These design requirements included consideration of:

Airframe Technology	ECM Vulnerability
Propulsion Systems	Vehicle Control
Avionics Systems	Ground Handling
Sensors	Logistics

The findings of these studies provided the basis for defining vehicle capability, application, and operational concepts. In addition, they provided a source of navigation accuracies versus CEP requirements for various missions/target types.

As these studies developed their baseline system, the keynote was operational flexibility, simplicity, and growth capability rather than a single sophisticated configuration

2.2.2 RPV Man-Machine Interface Studies

Two studies were conducted for the Air Force, one by North American Rockwell and the other by Sperry, which investigated the man-machine interface requirements for employing remotely piloted vehicles as a tactical weapons system for multi-mission application. Six tasks were addressed in these studies and included the following:

- Mission Definition Study
- Functional Analysis
- Determination of Selection Criteria
- Trade-off and Sensitivity Analysis
- Remote Control Station Design
- Program Definition

A large portion of the effort was directed to the definition of an RPV operational unit organization. The organization proposed was a self-sufficient unit consisting of vehicles, launch and recovery facilities, a control element, and support units.

The functional analysis was keyed to eight mission phases which included System Readiness, Pre-Launch Activities, Launch, Navigation, Target Acquisition, Attack, Bomb Damage Assessment, and Recovery. The analysis resulted in a determination of the level of automation (from 0 to 100 percent) for all functions identified. All functions were listed with an indication of whether the function was manual, semi-automatic, or automatic. The results indicate that 44 percent of the functions are manual, 28 percent semi-automatic, and 18 percent automatic.

Subsystem design parameters were defined for each of the major subsystem elements, such as displays, controls, and operator interface mechanisms. Values for these parameters were determined via a series of selection trade-offs. The basis of the trade-offs were a set of selection criteria which included performance, compatibility, flexibility, and cost.

As a result of the functional analysis and trade-off studies, several viable Remote Control Station designs were developed for both near term and prototype application. The designs varied in level of sophistication and automation. The recommended designs were one-operator on one-RPV, with heavy operator interaction for the near term and one man on multiple RPVs for the prototype.

2.3 CCIP 85 STUDY

2.3.1 Future Data Processing Requirements of Tactical Air Forces in the 1980s

In the summer of 1971, Litton conducted a three-month study to identify the automatic data processing required to support tactical Command, Control and Communications for the employment of tactical Air Forces in the 1985 time frame. The study was prepared for the Development Planning Study Group that was organized to examine all facets of ADP support for Command, Control, and Communications in the 1980 to 1990 time frame.

Under the study conducted by Litton, the requirements to plan, monitor, and control tactical air operations were analyzed. Specifically the following functional areas were addressed.

- Tactical Air Control Center (TACC) function.
- Airlift Control Center (ALCC) function.
- Tactical Airborne Element (TABE) Combat and Combat Support functions.
- Airlift Control Element (ALCE) and Airlift TABE function.
- Direct Air Support Center (DASC) function.
- Control and Reporting Center/Control and Reporting Post (CRC/CRP) functions.
- Sensor Reporting Post (SRP) functions.

Under this study, new system capabilities were addressed. One of the new system capabilities analyzed was remotely piloted vehicles. A conclusion of the study was that, "the introduction of remotely piloted vehicles (RPVs) into the inventory does not in itself introduce new command and control functions. There are, however, a number of factors that dictate requirements for more detailed planning within the TACC. One of these factors is the introduction of RPVs into the inventory."

The present study of RPV command and control has been able to use data and experience developed under the study conducted in 1971. The present study has developed the requirement to plan, monitor, and control RPV missions at the TACC in significantly greater detail than is required for manned aircraft. Further, under the present study, the requirements analysis was extended into the area of physical control of the airborne RPV, (the control exercised by the remoted controller) which was not addressed in the previous study.

2.4 SEEK FLEX STUDY AND INITIAL TACC AUTOMATION PROPOSAL

In August 1970 Litton DSD was awarded a study contract oriented toward obtaining the preliminary design and performance requirements for the Data Processing and Display subsystems for an automated post-1975 Tactical Air Control Center (TACC). The principal objectives of the study were to:

a. Define the functions of the post-1975 TACC/ALCC.

b. Define the data processing and display requirements which derive from the functional and operational requirements of the TACC/ALCC.

c. Determine the optimum technical approach for the Automated TACC/ALCC.

d. Describe and define the recommended design approach.

e. Develop an implementation plan for the development of such a system.

The SEEK FLEX preliminary design study was accomplished through a multi-tasked study effort organized around the principal objectives outlined above. Coordination and guidance during the study were provided by representatives of the Electronic Systems Division, the Tactical Air Command and the Mitre Corporation.

The study approach contained two significant innovations. The first and most significant was the extensive use of computer modeling to determine both system requirements and system performance. The second relates to the documentation used in the derivation of the data processing requirements and the computer interface with the computer modeling activities.

This study was submitted to the Air Force in the early summer of 1971. In February 1972, the Air Force issued a Request for Proposal (RFP) for Initial TACC Automation as defined in USAF System Specification 001485. Litton DSD responded to this RFP with a proposal which at present is in the source selection phase with a contract award expected in January 1973.

During the study effort and the response to the RFP, Litton DSD gained a detailed understanding of the functions of the Tactical Air Control System along with its capabilities and limitations. Also gained was a keen appreciation for the external and internal interfaces required of this control system, and how a change of function effects these interfaces. This experience has been applied to this study.

2.5 MISSION PLANNING ADVANCED DEVELOPMENT SYSTEM

As a part of the USAF 691 Force Protection Program, Litton is in the process of developing a computer based system for planning ECM and tactical air missions. This Advanced Development, when completed, will provide automated support to the planning organization for the total spectrum of tactical air mission types (e.g., interdiction, reconnaissance, Close Air Support, Air Defense, etc.) which occur in a tactical environment.

For each mission type the following functions will be performed as appropriate:

- Target Selection and Review
- Ordnance Selection
- Airbase and Call Sign Selection
- Route/Profile Planning (Semi-Automatic and Automatic)
- Fuel Calculations and Tanker Requirements
- Tactical Air Control System Requirements
- Standoff ECM Support
- Enroute ECM Support
- Total Plan Review

Subsection 4.2 of this report describes the Mission Planner Breadboard in detail. This breadboard was developed as a milestone in the design and fabrication of the Advanced Development. It differs from the Advanced Development in the following ways:

a. The breadboard is limited to the interdiction and ECM mission types.

b. The breadboard data base is limited in size.

c. Some of the implementation approaches to functional performance in the breadboard will be changed in the Advanced Development for greater sophistication and reduction in required data base.

d. Functions which are unique to a new mission type, or are presently not included in the breadboard ECM, will be included in the Advanced Development.

In general, however, the referenced breadboard description will provide the reader with a good understanding of the planned functional capabilities of the Mission Planner Advanced Breadboard.

2.6 RPV NAVIGATION SUBSYSTEM

Control and Navigation subsystems are key elements for the effective employment of remotely piloted vehicles. They are closely related and the degree of sophistication of one impacts the other. A review of previously conducted studies indicate a "shopping list" of capabilities available in these areas. All these studies indicate that these capabilities are within the current state-of-the-art, and have potential projected reductions in cost.

These subsystems may vary from a completely self-contained Navigation system, which requires little or no updating from the Drone Control Facility, to one which requires continuous updating from the Control Facility. This cursory evaluation of the desired capabilities falls between these extremes. Based on previous work with the Tactical Air Command, (the assumed user) the dynamic nature of tactical air warfare demands close control of the vehicle by a human operator to enhance the effective employment of the system. It appears therefore, that the minimum navigation capability required is one that provides enroute control of the vehicle during ingress and egress from the target area, reports vehicle status, and accepts corrections during flight.

The following features should be considered in determining the navigational capabilities of the Remotely Piloted Vehicle:

a. Partially self-contained to afford recovery if communications are interrupted.

b. Fully secure to prevent enemy.

c. World-wide employment capability.

d. Reportable status such as position, speed, heading, and altitude; on command.

e. No altitude, weather, or terrain limitations.

f. Navigation system selected has minimum impact on vehicle structure.

g. Minimum size, weight, and power requirement.

h. Possess high availability, reliability, and maintainability.

i. Low cost.

2.7 RPV COMMUNICATION SUBSYSTEM

2.7.1 Introduction and Summary

The system operational concept envisions the use of airborne relays as an element in the communications system for RPVs.

The three dimensional geometry of RPV(s) and Relay(s), together with their antenna gain/directivity characteristics, establish the basis for path loss and jamming vulnerability analyses. These are discussed in Subsection 3.3.4, "Communication Relay Planning" and in Subsection 3.3.5, "Integrated Communications Relay Flight Profile Planning."

Two categories of communication links are required, 1) RPV Control, i.e., command and response links, and 2) the RPV sensor data link. The latter normally requires 10-100 times the bandwidth of the first, although it is likely that control iteration rates will increase considerable over the target area.

Specific system requirements tend to force the use of UHF or microwave frequencies and line of sight (LOS) transmission. The system operational concept requires: 1) small highly directive antennas, 2) relatively high information capacity, at least of the RPV to relay link for sensor data, and 3) frequency spectrum availability. One non LOS possibility does exist, however, and that is the use of an HF command link for the enroute and return portions of the mission. The use of HF for this function is discussed later principally as an item for further study.

The most severe communication problems are: 1) providing adequate antijamming margin for the RPV sensor to relay aircraft link, especially if wide band analog information is transmitted directly, 2) controlling highly directive antennas, and 3) minimizing size, weight, and cost of RPV communication equipment.

In summary, it appears that the most desirable system has the following characteristics:

a. The control link is also used for range measurement.*

b. The relay uses a steerable, highly directive antenna to receive sensor data. Both this antenna and the RPVs antenna are also used for control purposes when over the target area.

c. The RPV antenna may be similar to that of the relay's, but lower directivity would be acceptable during the enroute phase.

d. For economy, RPV communication and radar terrain following (TF) equipment are designed for maximum commonality, e.g., they use the same type of antenna, and perhaps R-T and power supply assemblies for both functions.

e. The relay should employ Interference Cancellation System (ICS) techniques for ECCM as discussed in Subsection 2.7.8.

Various alternative approaches can be considered, however most are associated with antenna selection, frequency of operation, and ECCM.

Following paragraphs describe these links (initially assuming no ECM) and consider first those aspects which are common to both link categories, then ECM vulnerability is considered, potential ECCM approaches are discussed, and finally, areas for further investigation are suggested.

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*This is an alternative means of navigation, or actually RPV position determination. Other approaches to this functional requirement are mentioned in Subsection 2.6, "RPV Navigation System."

2.7.2 Optimum Geometry of Relay(s) Relative to RPV(s)

It is assumed that line of sight (LOS) transmission is required and that it exists continuously during the mission execution phase. Possible brief signal interruptions due to non LOS geometry are assumed enroute to the target area and on return to base.

As is the case with satellite relays, it is the up-link which is vulnerable to jamming because of the jammers difficulty in physically locating himself to intercept the down-link receiving beam (see Figure 2.7-1). Two up-link transmission paths exist; 1) the link from control station to the relay, and 2) RPV response and sensor data up-links to the relay. The first is relatively invulnerable because the jammer must compete with the ground station's high Effective Isotropic Radiated Power (EIRP), a term which includes both transmitter output power and antenna gain. Also, it is unlikely that a jammer will be physically located on the friendly side of the FEBA, hence the relay antenna's directivity also works against him. Finally, the relatively low information rate of the command links greatly ease the A/J signal design problem (compared to RPV sensor up-links).

Since the RPV's up-link power and antenna gain (EIRP) are more likely to be limited than that of the relay, it is obvious that the up-link receiving antenna for RPV sensor data should have the highest practical gain. This means that unless the jammer's physical location is such that he can intercept the beam he will suffer a commensurate power disadvantage. Tactically then, jammers should be located near potential targets within the half-beam width of the relay's sensor receiving antenna. Figure 2.7-1 illustrates this since only the "best" jammer location allows him to jam the main beam while RPV 1 is over target No. 1. The jammer will know which direction to aim his antenna (important unless the jammer can be successful with a horizontal beam approaching 90 degrees) only if commands also emanate from the same point. This can be avoided by using two relay aircraft, one for enroute commands and another for sensor data, when RPVs are attacking targets. Two identical relay aircraft can exchange control responsibility periodically, of course. Minimum (3 dB), ≈30 dB gain, beam widths ("θ" in Figure 2.7-1) approximate five degrees assuming typical steerable parabolic dishes of about one foot in diameter operating in the 15 GHz region of K band. This is probably an upper frequency limit for communication links due to weather effects. Design assumptions were based on the eight-inch dish of the APQ-110 TF radar.

Table II.7-1 lists the kinds of antennas which probably should be considered at the various locations. Where directive antennas are used for enroute functions some means of pointing them correctly is required. At the relay they must be re-directed from one RPV to another at a reasonable update rate. For the five degree beam width case half the distance subtended is approximately four miles at 100 mile range. Hence, two aircraft, flying in opposite directions at right angles to the beam will approach the beam's edge in approximately 12 seconds. Since up-date rates are assumed shorter, antenna repointing will not be required at the RPV as long as it uses an automatic tracking antenna. The same antenna, if used at the relay, must be repointed for each RPV interrogated but pointing angles would not need to be recomputed each time. Only the "last used" settings would need to be stored in memory for each RPV, again assuming auto track operation.

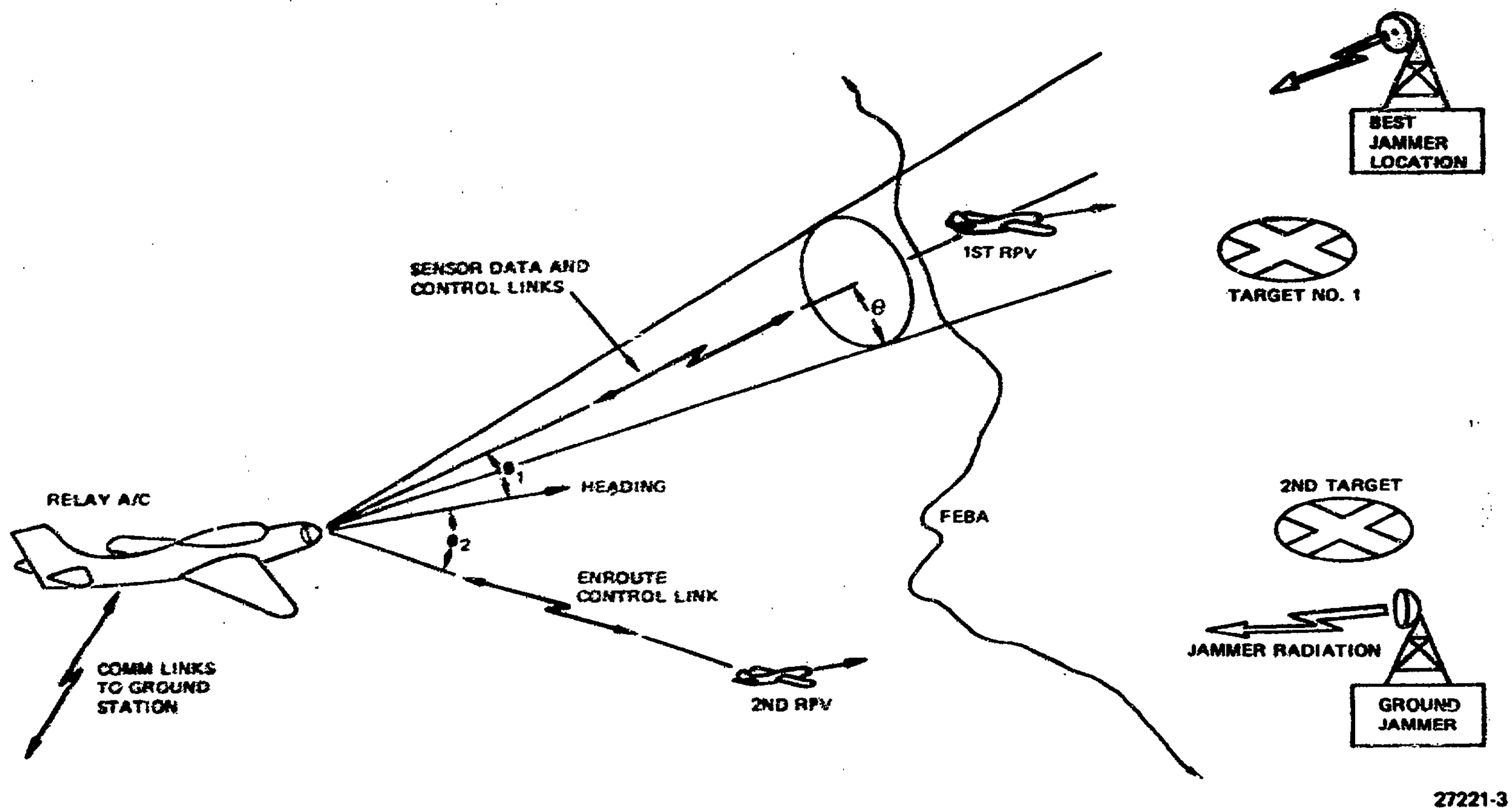

Figure 2.7-1. Geometry of Relay Aircraft and RPVs

Table II.7-1. Antenna Types Considered

Location and Purpose of Antenna	Control Link: Command	Control Link: Response	Sensor Data Up-Link	Potential Use for Navigation
On RPVs				
Enroute Phase				
Transmit on F2	DNA	Omni, sector, or steerable dish	Not in use	Yes
Receive on F1	Omni, sector or steerable dish	DNA	DNA	Yes
HF Receive on F3	Horizontally polarized loop	DNA	DNA	?
Over Target Phase				
Transmit on F2 and F4	DNA	Steerable dish	Steerable dish (required)	No
Receive on F1	Steerable dish	DNA	DNA	No
HF Receive on F3	Loop (if HF is used here)	DNA	DNA	No
ON RELAY A/C				
Enroute Phase				
Transmit on F1	Omni,sector, phased array, or azimuth scanner	DNA	DNA	Yes
Receive on F2	DNA	Omni, sector, phased array or azimuth scanner	Not in use	Yes
Over Target Phase Transmit on F1 and receive on F2 and F4	One steerable dish per RPV or a phased array with one phase shifter assembly per RPV			No
AT GROUND STATION				
Transmit	Steerable dish per relay A/C	DNA	DNA	Yes
Receive	DNA	Steerable dish per relay A/C	Steerable dish per relay A/C	Yes
HF Transmit on F3	Horizontal dipole	DNA	DNA	Yes

Table II. 7-1 indicates that a steerable dish, or equivalent array, is required on the RPV because of the critical sensor wide-band data up-link. To save weight and space it should also be used for all other functions. It can be steered or pointed to the relay A/C by automatic tracking equipment, and thus be independent of navigation functions.

Relay station antenna choices are not so clear cut. Control during the enroute phase would be most desirable via an omnidirectional antenna since this would avoid the repositioning associated with a directive antenna and multiple RPVs. Sector antennas substitute switching for pointing, and are therefore also a reasonable choice. The azimuth scanner operates like an IFF system in that it controls each RPV while the beam impinges on it. If this antenna's scans are accurately controlled and stabilized relative to true North the time delay from a reference pulse indicates the RPV's angular relative bearing in a manner equivalent to the omnirange.

If none of the above approaches are practical and substantial directivity is required for control it appears that a phased array must be used because of the scan rate limitations of mechanically positioned antennas.

Over the target one steerable dish per RPV is adequate since rates of change of angle are limited. A phased receiving array might be advantageous in that a single array could operate with several RPVs as long as an independent phase shift assembly was provided for each.

Ground station antennas do not seem to be a problem, their choice probably being based on minimizing relay A/C cost.

2.7.3 Operational Considerations Relative to Communication

If we assume that the enemy will make a concerted attempt to jam the RPV communications, both operational and technical factors must be considered if this threat is to be counteracted most effectively. The latter aspect, discussed in the following sections, involves such things as transmitter power, antenna gain, modulation techniques, etc.

Operationally the utilization of any relationships with other tactical systems, as well as own system tactics can be of value. Further, several aspects need to be considered prior to the establishment of the total systems technical approach. Some necessary assumptions must be made in response to the following questions:

a. What does the jammer know?

Assumptions:

1. From a priori knowledge he knows:
All details of our equipment such as frequency range, antenna characteristics, power, method and details of multiplexing, ECCM provisions, etc. (Effectively, he buys one complete set from the US factory complete with all documentation.)

2. From field operations he learns:
   - Transmitter frequencies of relays with some delay required for signal acquisition; the delay increasing with relay antenna directivity.
   - RPV transmitter frequencies with a greater delay.
   - Transmitter frequencies at ground control stations; if he needs to know.
   - Identity of relays because of their flight profile and behind FEBA location, EM signature, etc.

b. What doesn't the jammer know?

Assumptions:

1. He doesn't know which targets will be attacked until very late in mission time as attack break-off and deliberate feints are very likely.

2. Which portion of a command data stream is intended for a particular RPV.

3. Which relay is controlling a particular RPV if more than one is present.

4. The effectivity of his jamming except in a gross sense.

c. What tactics are available to enemy other than EW?

Assumptions:

1. He may send missile(s) or manned interceptor(s) to destroy relays.

2. Use missiles which home on RPVs if their transmitted signal characteristics permit.

3. Attempt to destroy the ground control station or launching facilities.

d. What tactics are available to the Relays?

Assumptions:

1. Change location in real time.

2. If there are at least two relay A/C, reallocate communications responsibility periodically.

3. Trade information transfer rate for A/J protection:

- Enroute - reduce interrogation rate.
- Over the target - reduce video up-link data rate.

Other tactical considerations relate to the possibility of cooperation between relays of different groups of the total force; e.g., reallocation of responsibility for control of specific RPVs to deny the enemy consistent means of relating an attacking RPV to its control source. Planning activities can also be directed towards minimization of the ECM threat as discussed in Subsection 3.3.6, "Communications Relay Planning."

2.7.4 RPV Sensor Data Link

Most generally, a TV picture or some other scanned image is being transmitted from the target area to the relay. This information can be either in analog or digital form. This link is the most critical one of all RPV communications links since it must transmit wide-band information and, due to the geometric arrangement discussed in Subsection 2.7.2, is the most easily jammed. Since its output is essential to the most critical phase of the mission it would appear to be the most logical place to expect ECM.

Jamming resistance can be improved most readily for low rate digital transmissions, although the Interference Cancellation System (ICS) is applicable to analog signal transmission in some instances, as is discussed in Subsection 2.7.7. Wide-band information links, however, are more difficult to protect from jamming since spread spectrum approaches inevitably increase the occupied bandwidth by several orders of magnitude; e.g., 5 Mhz becomes 50 MHz for only 10 dB A/J margin thus further complicating synchronization, etc.

One aspect of the data's nature that does help is that it is generally redundant, hence loss of some percentage of the transmitted "frames" can be tolerated. Thus one might perform integration of successive frames/scans to improve SNR or perhaps shift to another frequency slot whenever jamming is detected. If done in a pseudo random manner this can be fairly effective approach without introducing excessive complication; as long as a command link is available to initiate the frequency shifts.

The most elegant approach of course is to reduce the transmitted data rate through redundancy elimination processes. However, such approaches are outside the scope of this study.

At the target, RPVs will have no range advantage over the jammer; hence they should use a steerable highly directive antenna to increase their signal level relative to a ground based jammer which has no size and weight limitations. Also the same antennas, and perhaps the same R-T equipment, via multiplexing, should be used for "over-the-target" control. Since control data rates are lower than sensor output rates they can be easily provided with additional A/J margin to insure reliability of control functions.

Some of these aspects were discussed previously in connection with antenna selection in Subsection 2.7.2.

2.7.5 RPV Command and Response Links

Initially the operational aspects of this function are considered. The assumption is that a given control station will be responsible for multiple (up to 25) RPVs for both the enroute and on-target phases respectively of each RPV's mission. It is also assumed that control transmissions are digital and may be discontinuous; i.e., enroute and RTB the RPVs can fly and navigate themselves automatically with only occasional corrections.

The jammer must be prevented from either controlling the RPV himself or from precluding our control. The former is easy since spoofing can be absolutely prevented by cryptographic techniques which for the latter can be simply extended to provide an appropriate A/J margin. It might be desirable if the A/J margin was made sufficient to allow the use as an omnidirectional antenna, at least for the command down-link.

Since multiple RPVs are assumed, three means of establishing a command link to each can be considered. These are: 1) assign a separate link to each, 2) use a multiplexed single link (FDM or TDM), or 3) use a single link with a separate address for each RPV. Combinations of these can, of course, also be surmised.

Response links could be handled similarly except that self interference between RPV responses must either be prevented absolutely or be of adequately low probability.

The simplest approach appears obvious, i.e., associate a given RPV's response with the command causing it to respond. Since we have assumed that cryptographic security is required, each RPV either has his time clock synchronized with the other RPVs, or is brought into crypto sync periodically by means of a preamble. To maximize efficiency the frequency of command transmissions must be considered since the preamble is either equivalent to an address or must be followed by an address. The first implies a separate crypto key setting for each RPV while the latter assumes the same setting for all.

The simplest approach appears to be the use of a common key with RPVs assigned unique time slots (equivalent to addresses) in a repetitious frame structure. The relay aircraft then transmits continuously, or at least periodically, which maintains sync at the RPVs, and each RPV responds in another unique time slot either periodically or only in response to command receipt. These RPV responses can thus use; 1) the same frequency (time slots reserved for responses), 2) a different frequency in the same band, or 3) perhaps use his sensor up-link frequency. The latter would seem practical only during the execution phase hence either 1) or 2) must be provided in addition.

The encrypted, time slotted TDM approach appears to provide the least information to the jammer since all that he can distinguish may be the existence of a given RPV's responses through radiated energy measurement. Time slot assignments could also be varied in a pseudo random manner to prevent him from burst jamming either commands or a RPV's response time slot from a priori knowledge of frame length, etc. Randomly occurring responses from several RPVs would seem to make DF or homing quite difficult unless the angular differential between RPVs and the jammer's intercept receiver are quite large.

If desirable, the command message structure could also be varied such that an RPV would respond only when directed to do so.

One aspect of continuous, periodic, or even of relatively long duration command transmissions is that a radiation seeking missile could be used to destroy the source of command transmissions just as an anti-radar missile can easily destroy any radar not taking appropriate counter-action. This aspect requires further study but appears to indicate the use of different frequency bands for the enroute and over the target phases. Also multiple relay A/C, with periodic transfer of function would provide more security against this form of attack. Directional antennas on relay A/C appear of value also, for this, as well as ECCM reasons.

2.7.6 Selection of RPV Communication Equipment

Since cost of RPVs must be minimized the possibility of combining the functions of navigation, flight control and communication in one set of equipment should be considered. If one assumes that an RPV's equipment must, as a minimum, include; 1) an autopilot for course and attitude stabilization, and 2) control (command and response) and sensor data links, what approaches to RPV navigation will minimize the cost?

Five possible methods of measuring an RPV's position are:

a. Inertial (rejected as being too expensive).

b. LORAN

c. Radio ranging from relay (requires two relay positions to determine RPV position).

d. NAVSAT (rejected because it takes too long between fixes).

e. TACAN, etc.

Of the above only c. is potentially combinable with the relay to RPV communication function. All others will require extra RPV equipment. Ranging from the relay itself also does not require any other navigation equipment or aids in the area of operations. However, the command and response links will need to be appropriately modulated in order to sense range unambiguously. There are several means of doing this from using psuedo-noise sequences to simply counting doppler cycles. Since the latter requires continuous reception, the former appears more practical and also more consistent with providing security and ECCM.

It might also be possible to combine the terrain following radar function with the command and response links since time multiplexed operation is assumed. R-T equipment would thereby be reduced, however separate antenna(s) would be essential for the radar terrain follower - altimeter portion. This is an area requiring further study and may not be feasible due to differences in optimum operating frequencies.

Figure 2.7-2 is a block diagram of RPV equipment assuming the use of shared equipment as discussed above. As discussed in Section 2.7.2, a steerable dish appears to be a requirement, considering the ECM threat. This antenna must be continuously pointed at the relay A/C and this can be easily accomplished by automatic tracking of control transmissions without requiring coupling to the RPV's autopilot. Ideally, two identical antenna assemblies might be used; one forward for terrain following, and one aft for communication.

2.7.7 Description of Relay Station Equipment

It is not the purpose of this study to describe in detail the various items of communication equipment on either the relay or RPV. Rather, several variations in approach have been suggested in the interest of minimum RPV production cost, minimum ground navigation aids, etc. However, these variations may imply expense in terms of relay complexity.

Figure 1.6-2 of Section 1 indicated the major functions required at the relay. Antenna(s) size depends on transmitter power output and data rate as is usual, however at the relay, greater directivity (and power gain) might be used for improved ECCM. Antenna considerations were discussed in Subsection 2.7.2, together with various means for controlling or pointing each type.

On board communication data processing may involve antenna pointing computations or navigation algorithms; e.g., for a LORAN-Inertial system. Processing tasks on board the relay may be increased to minimize either the amount of data exchanged, or the frequency of command transmissions, or perhaps reduced in favor of similar operations at the ground control station, etc.

Naturally, there will be many items of electronic equipment on board the relay aircraft which are not directly associated with the RPV mission. Included are such things as radar altimeters, navigation aids, radio R-T units, etc. Some of these might be useful or ancilliary to RPV operations but are not subject to discussion here.

2.7.8 ECM Vulnerability Considerations

Often data links are initially designed to provide adequate performance considering only natural phenomena. Inevitably EW considerations will impact both hardware and operational aspects.

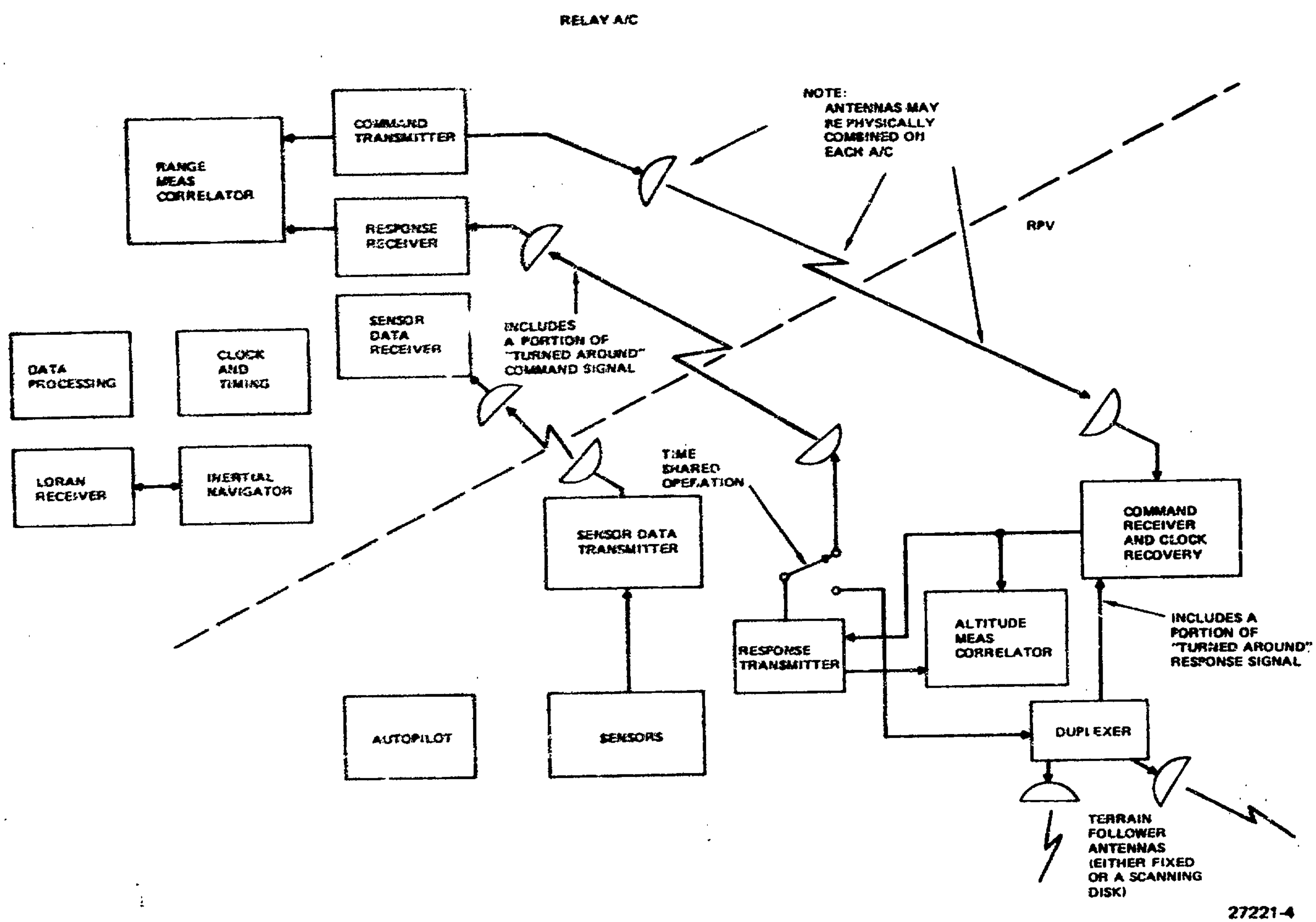

Figure 2.7-2. Functional Block Diagram, Relay/RPV COMM/Ranging Equipment

Assuming that some form of spread spectrum approach is used to provide A/J margin the following changes are likely:

a. For digital systems, internal clock rates and RF bandwidth will increase by the gross A/J margin; e.g., by 10^3 for 30 dB etc. Where crypto security is already included, the impact is primarily one of increasing synchronization accuracy requirements. For frequency hop schemes, frequency synthesizer complexity will increase.

b. For analog systems perhaps the only measures available are increased power, or antenna directivity, or changes in the mode of operation. One other possibility, applicable to either analog or digital transmission, is the Interference Cancellation System (ICS) which is discussed in the final paragraph of this section.

c. Signal acquisition times will probably increase due either to requirements for tighter sync, or sharper antenna directivity, or both.

d. Reliability and Maintainability can be expected to decrease with the increased number of parts, etc.

e. Possibly on board data processing requirements will increase to support c. above.

Anti-jamming tactics which might be employed are; 1) the use of additional relays as discussed in Subsection 2.7.2, or perhaps also additional RPVs, 2) direct physical attack on the jammers themselves by radiation seeking missiles (a special RPV), 3) periodic coordinated shifts in operating frequency, whose effectivity will depend on the enemy's reaction time, and 4) combinations of 1) and 3) such that the jammer cannot concentrate on a single relay/RPV combination.

Other effects such as planning impacts are discussed in Subsection 3.3.5.

2.7.8.1 Automatic Interference Cancellation (AIC)

The block diagram in Figure 2.7-3 illustrates the essentials of interfering signal cancellation for the two cases; 1) a colocated "friendly" (Connection A) transmitter, and 2) an example of one approach to the cancellation of a jamming signal (Connection B). More than one signal can be cancelled if a servomechanism and reference signal is specifically provided for each. The FAA uses a system which protects a receiver from up to four fixed-tuned local transmitters; all sharing the same antenna. Automatic systems with servos can track varying frequency interference, having aribtrary modulation characteristics and wide bandwidth.

The principle is exceedingly simple; merely adjust the level and time delay (RF phase) of the interference reference to equality with the interference

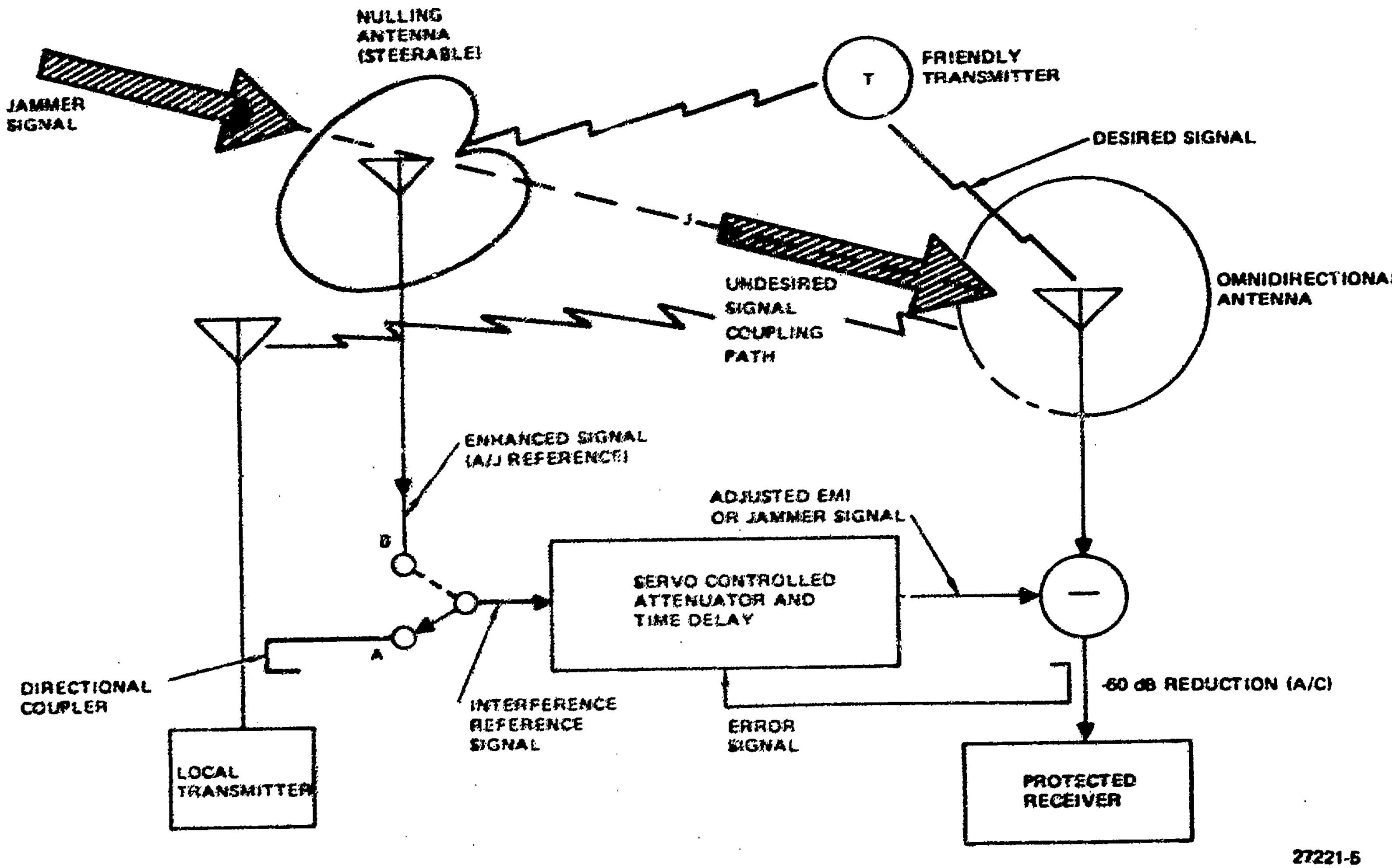

Figure 2.7-3. Interfering Signal Cancellation Block Diagram

actually received so that it can be subtracted from the receiver's composite input. The servo does this automatically for any signal type through auto-correlation. Note that a signal "path" is being simulated, and not the interfering signal itself. A range of 60-80 dB of cancellation is possible in a practical case, as long as the interference does not vary its spatial position more rapidly than the servo can follow. This is unlikely in most instances.

Extension to EW requires that the jammer signal exceed the noise level and be stronger than the desired signal in order for the autocorrelator to control the servo. Hence, at "Connection B" the jammer is "enhanced", relative to signal, by steering the antenna"s null toward the desired signal's direction. Note that the conventional antenna nulling techniques attempt to achieve null against an uncooperative "target" (the jammer) and also that multiple "nullers" are required for multiple jammers. Other approaches are possible, for example, a low order of spectrum spreading (< 10 dB) should suffice without requiring the use of separate receiver and jammer reference antennas.

The advantages of Automatic Interference Cancellation (AIC) for EW include the following:

a. Provides >60 dB A/J which exceeds that possible with spread-spectrum schemes.

a. Operable with analog signals such as TV or other "scanning" devices.

c. Introduces no additional sync problems.

d. Can be added "in front" of existing radios, analog or digital.

The AIC approach described above as an example is not directly applicable to the RPV-to-relay link where jammers are colocated with targets. The basic requirement is to obtain a reference jammer signal which either does not include the desired signal at all or only at a level negligible compared to the jammer's level. Negligible in this case might be only -2 dB.

One cannot assume that the jammer will cooperate by using excessive power, however, this relative level is not easily determined remotely. An RPV's signal level will presumably decrease as it approaches the target (due to an increase in range). It could also be controlled via the command link if this were an appropriate tactic. Also, the RPV signal can be made intermittent on command, hence it appears easy to obtain the jamming signal alone.

To summarize – ICS appears to be worthy of serious consideration for the RPV-to-relay sensor up-link. Should this be a digital link it appears that about 10 dB A/J margin would be sufficient with ICS and the resultant complexity is small.

2.7.9 Areas for Further Investigation

Several areas appear worthy of further study, some being related to technology and others to cost minimization. Previous subsections have suggested alternate approaches, as in Subsection 2.7.6 where a single frequency band and set of RF hardware was proposed for command reception, response transmission, for both functions of a terrain following radar, and for a range measuring link. Separate antennas would, of course, be required for the terrain follower. This particular suggestion is a complex one to analyze, involving both systems performance and hardware cost trade-offs.

The new use of the command and response links for RPV range measurement definitely appears worthwhile and might be considered a minimum objective because the measurement of RPV range directly from the relay provides substantial advantages. One range does not determine position of course, hence two measurements from two known relay positions, either for two separate A/C, or two different positions of the same A/C, are needed. Depending on the relay antenna used, it may also be possible to measure angles to establish RPV position.

The use of HF for a one-way command link directly from a ground station(s) to all RPVs has also been suggested. The low data rate makes this non-line-of-sight transmission mode practical, provided that horizontally polarized antennas are used, since these emphasize the ionospheric path for all distances under consideration. However, only one-way operation can be seriously considered because the only practical horizontally polarized HF antenna for RPVs is a loop which, because of low efficiency, is only suitable for reception. Such a link could also be employed to measure time, hence approximately range, for transmission from the ground station to a particular RPV and back to the relay A/C via the LOS command response up-link. The relay A/C would know the time of arrival of the direct HF signal and the sum of the transmission time to the RPV and the time delay on the RPV to relay up-link. Since he already knows the latter, he knows three sides of a triangle and can solve for the RPV's position unambiguously.

The time delay on the HF link is not directly proportional to range because of ionospheric reflection, however corrections can be entered through data processing either on the ground or perhaps at the relay.

Resulting errors appear to approximate a small fraction of a millisecond, hence, the usefulness of this function may be partially dependent on geometry as errors along a chosen course may be less significant than equal cross-range uncertainty. Obviously, further study of the accuracy attainable is necessary.

The use of highly directive antenna on the relay will require correspondingly high pointing accuracy. If rapid switching between RPVs becomes necessary, a phased array might become an absolute requirement. Study of the data processing impact for a given pointing requirement seems essential. Also, pointing computations would appear much easier if the antenna is placed in an automatic tracking mode when close to the correct angle.

SECTION 3

DRONE/RPV COMMAND AND CONTROL

3.1 DEFINITION OF COMMAND CONTROL FUNCTIONS

There are two different aspects of RPV command and control. One, physical control, insures that the vehicle executes the specific planned mission. The second aspect, force control, insures that RPV as a weapon system is used, alone or in coordination with manned missions, to achieve force objectives. Table III. 1-1, tabulates the Command and Control Functions under these two broad titles. These functions are derived from the comparable functions for manual systems.

Table III. 1-1. Drone/RPV 1st Level Command and Control Functions

Mission Planning Preplanned Missions	Mission Monitoring, Immediate Mission Planning, Replanning and Adjustment	Physical Control
Mission Requirements Analysis		
Resource Analysis	Resource Status Monitoring	Launch
Apportionment	Mission Execution Monitoring	Enroute Control
Unit Assignment	Mission Adjustment	Over the Target Control (Strike)
Detailed Mission Planning	Direction	• Target Penetration
• Over-the Target Operations (Strike)	Mission Replanning	• Target Acquisition
• On Station Operations (EW, RECCE)	• Msn Reqmts Anal.	• Delivery Maneuver
Route Planning	• Detailed Msn Planning	• Weapon Release
Launch/Recovery		• BDA
Communications Relay Planning		• Egress Maneuver
		• RTB Control
		• Recovery Control
		On Station Control (RECCE & EW)

Subsection 3.2 documents the requirements for physical control of the RPV. Where options exist, the effects of viable alternatives are established or, alternatively, the assumptions necessary to select an option are documented. Subsection 3.3, documents the impact of RPV on the Force Control functions. Where applicable, the differences between pure RPV force only and a mixed force (including manned aircraft) are assessed.

The interrelationship between the Force Control functions, the physical control capability, and the RPV baseline system capability is, in some areas, a very complex trade-off chain. This study adapts the system capability developed under the Air Force funded multimission studies for the RPV baseline. Where appropriate, the impact of viable alternatives are assessed. From this departure point the vehicle physical control requirements and implementation concepts are developed. The impact of these requirements on detailed mission planning and other Force Control functions are then assessed, and implementation concepts at the function level are developed. System performance requirements are developed, assembled, and allocated to TACS elements and/or the RPV functional unit, and the system configuration and performance requirements are established. Again, viable alternatives are identified. Figure 3.1-1, Analysis Process, Command and Control for RPV's, diagrams the process.

3.2 PHYSICAL CONTROL OF RPV'S

3.2.1 Introduction

It should be stressed at the outset that complex trade-off analyses would be necessary to justify a final allocation of functions to air vehicle and ground-based system elements, and to select a specific method of implementing each function.

Many of the functions necessary to physical control of RPV's could be performed at a ground control center, on-board the RPV, or on a communications relay aircraft. Examples of these functions would include; RPV position determination, comparison of actual with planned flight profile, computation of corrections to aircraft flight control settings, determination of weapon release point, etc. Many functions could be performed with various degrees of automation; for example, target recognition could be performed by a human operator using remoted RPV sensor imagery. Alternatively, various techniques of automatic pattern recognition could be employed, either as an adjunct to, or instead of, the human operator. Further, the possibility of a completely blind weapon delivery system, relying upon precise navigation and target location, could be considered.

For most system functions, several alternative implementation methods are available. For example, a variety of navigation systems, such as LORAN, OMEGA, TERCOM, CLASS, etc. are potential candidates for RPV use.

An optimum, integrated system design would therefore require a comprehensive cost-effectiveness analysis, considering such factors as air vehicle vulnerability to enemy ground-to-air weapons, communications vulnerability

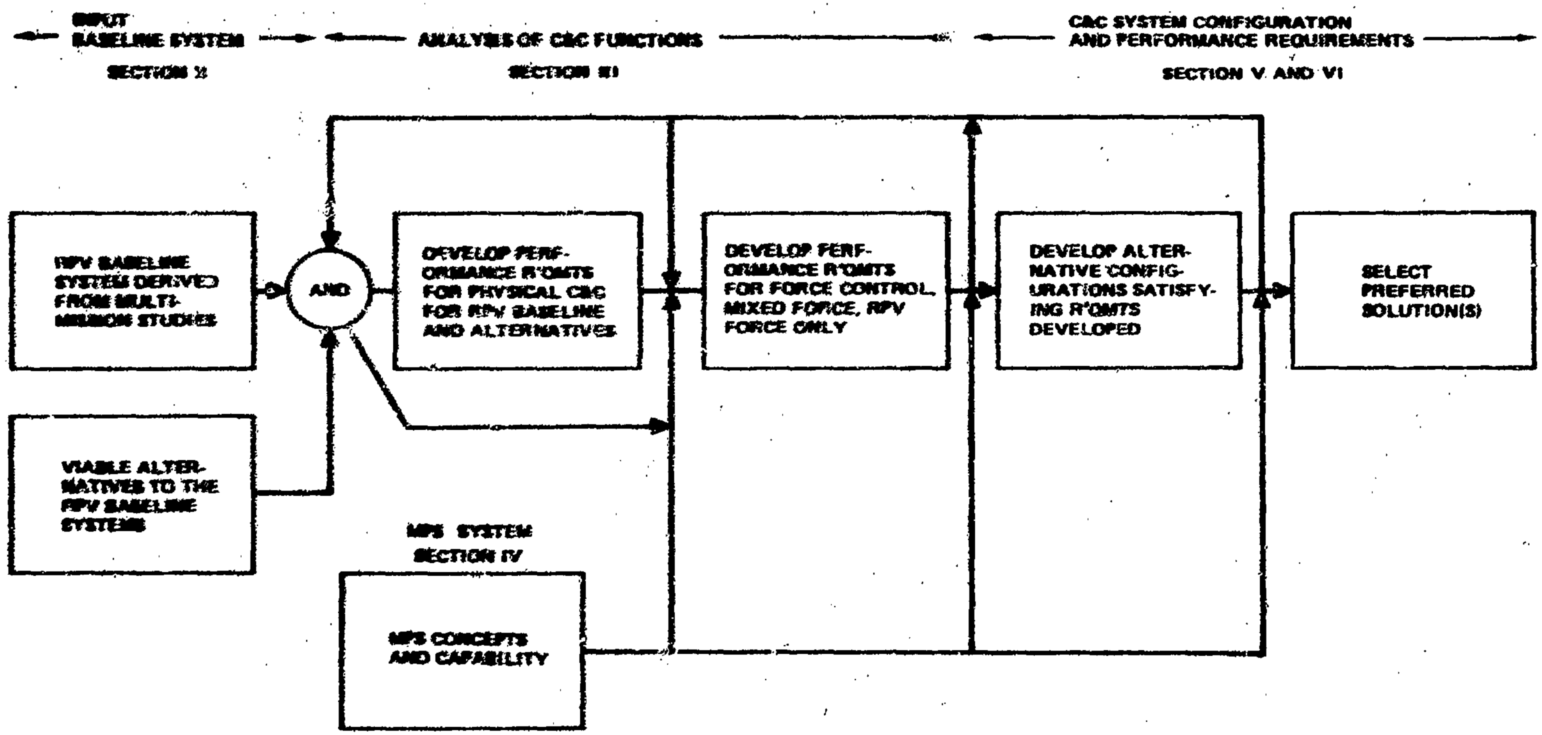

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Figure 3.1-1. Analysis Process, Command Control (C&C) for RVP's to jamming, weapon delivery accuracy, target acquisition probability, etc., for various alternative allocations of functions, implementation methods, mission types, tactics, and flight profiles.

The more modest aims of the present study, in considering the subject of physical control, are to suggest techniques and methods of implementation that appear reasonable or fruitful for further study. The conclusions reached herein are based upon several assumptions, which are documented in the discussions of the various problem areas. The value of the conclusions, of course, is a function of the validity of these assumptions. A number are highly judgemental and, although they appear reasonable, would require detailed analysis or experimentation to fully validate them.

In the development of this analysis, a baseline system is postulated, to provide context for the consideration of various problems and to make quantitative estimates of various load factors. In this baseline system, various functions are allocated to Drone Control Facility, Relay Aircraft, and RPV, and specific implementation methods are assumed (e.g., LORAN is postulated as the navigation system, with position-determining calculations remoted to the DCF). It should be remembered, however, that this baseline system is tentative, and was used primarily as an analytical tool.

Subsection 3.2 identifies the functional capabilities that must be provided to maintain control of the vehicle from launch to recovery. Assumptions concerning the principal RPV capabilities that significantly affect the exercise of physical control are:

a. It is assumed that there is an automatic flight control system (AFCS) in the RPV. The AFCS will, at a minimum, provide the capability to maintain a flight attitude (direction of flight plus level flight or rate of climb or descend) established for the vehicle. Additionally, the AFCS will activate the control surfaces necessary to execute maneuvers, a turn angle, or a rate of climb or descent directed by an input command. Additionally, it is assumed that the AFCS will be coupled with the terrain following radar to maintain a preset terrain clearance.

b. There will be a coupling between the steerable electro-optical (EO) system and the AFCS which will enable the AFCS to initiate turns and climb or descend maneuvers which will maneuver the vehicle into a line of flight at which the zero setting on the electro-optical system (the setting that aligns the electro-optical sensor with the weapon boresight) is on the electro-optical aiming point.

c. Positioning and maintaining the electro-optical sensor on an aiming point will be initiated by an operator at the weapon control console. Signals controlling the EO sensor will be automatically generated and transmitted to the RPV over a command link. Coupling between the electro-optical sensor and the AFCS will be enabled and/or disabled by the operator.

Given these capabilities on the RPV, the functions that must be provided to exercise physical control can be listed (Table III. 2-1). Column 1 identifies the functional area, Column 2 the associated operational requirement, and Column 3 the application of the capability. The first two functions listed, Navigation and Communications, are required by the operation concept. The performance requirements for navigation are constrained by cost factors, and other complex trade-offs, such as navigation accuracy versus requirements for target acquisition. Subsection 3.2.3 reviews the results of previous studies of navigation systems for RPV and, based on selected implementation methods, develops requirements on the DCF related to obtaining and maintaining RPV position data.

Table III. 2-1. Physical Control Functions

Function	Requirement	Application
Navigation	Establish position of RPV in near real time	Necessary so corrective controls can be applied
Communications	Provide communications between RPV and the RPV control site	Position and status data reporting, transmit control data
Status & Position	Monitor RPV Flight, detect exceptions	Establish requirement for corrective controls
Flight Control, Enroute, Return to base	Maintain preplanned Flight profile	Necessary to achieve mission objectives
Flight Control, Enroute, Return to base	Override preplanned Flight profile	Necessary to deal with exceptions
Control, over-the-target Strike mission	Precise positioning of RPV for bomb release	Necessary to acquire target and achieve CEP accuracy required and provide real time BDA.
Control On Station Electronic Warfare (EW)	Activate and control EW Sensor Package, dispense EW packages	Necessary to achieve mission objective
Control over-the-target Recce Mission	Activate and control sensors, control transmission of Recce data	Necessary to achieve mission objective

The performance requirements for the communications system are derived specifically from operational requirements, such as secure jam-resistant communications with multiple RPV's and visual acquisition of a target to achieve required CEP's. Communications requirements are also derived from the method of exercising flight control and the amount of status data required for various mission phases. Subsection 3.2.2, Communications Subsystem Baseline, describes the communications system assumed for the RPV, based on the requirements and concepts developed under the multimission studies and compatible with the requirements to exercise physical control defined in the present study. The concepts for physical control and the associated communications, data processing and operator requirements are developed in Subsections 3.2.4 through 3.2.6.

3.2.2 Communications Subsystem Baseline

This subsection describes the communications system which has been assumed for study purposes. The goal was to select a reasonable baseline system so as to develop physical control procedures which are compatible with the communications system, and to establish the impact of the communications subsystem on the DCF ADP system. The approach selected is judged cost effective, considering operational requirements and communications technology. Data developed under the Air Force funded studies are specifically included.

Two basic communications links are postulated. One is a sensor link transmitting data for target acquisition and lock on. The other is a command response link used to receive data from the RPV and to transmit control data. The sensor link for the Strike RPV is a special requirement. The assumption is that it is provided. The principal alternatives that exist relate to bit rates required to provide the necessary resolution, but these do not significantly impact the physical control function. The command response link introduces more operational factors impacting system design. Excluding the special requirements of over-the-target operations for strike missions, the command response link is characterized by the requirement to periodically or aperiodically contact many RPV's (up to 20 per RPV unit) distributed over enemy territory, and possibly hundreds of miles apart. Operational requirements considered, normal contact intervals with each RPV should not exceed something like one minute, while contact intervals around 10 seconds are satisfactory minimum for design purposes. Contact intervals of less than one second do not appear operationally useful. On each contact the information exchange required is low; frequently no information need be exchanged except that needed to maintain navigation position.

Over-the-target considerations are quite different. The sensor link must be maintained. Additionally, the command response link must be available to a given RPV on demand within fractions of seconds. For certain applications no unpredictable delay is tolerable. Compared to the enroute phases, information exchange on the command response link is relatively high.

Based on such considerations, the following concept is assumed. Two command response links will be available. One is designed for enroute control, the other for over-the-target control. The concept is such that the one can provide backup for the other, although there would be some degradation in the total system capability.

The enroute command response link is a steerable beam with a beam width of less than 5°. RPV's are contacted on a round robin basis. The contact interval per RPV mission is in the order of ten seconds. This implementation requires a determination of pointing angles for each contact. The concept assumes that this is accomplished as follows:

> Normal method: With 10 second contacts, an RPV approximately centered on a communication beam footprint will not have moved out of the footprint before the next contact. The relay aircraft on each contact nulls on the signal which provides the best pointing angle, azimuth, and elevation for the relay aircraft. The RPV pointing angle is the reciprocal of this, which is transmitted to the RPV as a command. This function is presumed to be performed on the relay aircraft.
>
> Initial acquisition, and reacquisition if contact is lost: For the initial contact and during handover between multiple relays, the pointing angle is calculated using the position of the relay aircraft and the expected position of the RPV when the first contact is to be made. To reacquire an RPV that has been "lost," or one that has been predicted to be out of contact because of terrain masking (see Subsection 3.3.3) the pointing angle is calculated using the position of the relay aircraft and the predicted position of the RPV. This function is allocated to the DCF. Assuming an initial calculation of pointing angle and a calculation to reacquire once each five minutes, 12 calculations per mission are required (average mission time: 60 minutes).

Over the target, the second command response link is established on the broad band link used for the sensor data. Although the primary sensor link is one-way (from RPV to relay) the antennas can be used to establish a command link in the opposite direction (see Subsection 2.7.4). A pointing angle is calculated for each pop-up point, or for some point prior to pop-up if desired. Once established, the relay aircraft tracks the RPV continuously and transmits commands as necessary. The RPV response is multiplexed on the video link providing near instantaneous status data. (see Subsection 3.2.6.4). Commands are transmitted from the relay aircraft sensor receiving antenna, providing a command link on demand. Since this antenna may be pointed in any direction, it can be pointed at any RPV enroute and be used to back up enroute command response communications. The sensor link under these circumstances can be used for visual reference or navigation fixes. Program requirements to calculate the pointing angles are identical to the enroute phase. Assuming two targets per strike mission (two actual strikes, or an over-the-target abort and divert to secondary target) and one visual fix enroute there are on the average three calculations per strike mission.

3.2.3 Navigation Subsystem Baseline

This subsection describes the navigation subsystem which has been assumed. The purpose is to select reasonable baseline alternatives so physical control procedures can be developed which are compatible with the navigation system capability and so the impact on the DCF ADP system can be established. Data developed under the Air Force funded studies are specifically considered.

It was assumed that the navigational accuracy provided by the system ranges from 300 feet to 1500 feet at maximum range (over-the-target pop-up point). Trade-offs within these limits significantly affect the electro-optical sensor design requirements but do not significantly affect the physical control function. The primary candidate systems, as developed under the Air Force funded studies, are LORAN and the Omega System.

Considering LORAN, it has been suggested (Reference USAF Rand Project Report) that the use of a fully self-contained system on the RPV would be expensive and unnecessary. For RPV application, an implementation in which the RPV retransmits the LORAN signal received by the RPV over the response link with the actual navigation computation being made in the DCF (or possibly the relay aircraft) would be more cost effective. Applying this concept and drawing on data available for other applications, it has been estimated that the data transmitted by the RPV needed to make the navigation fix calculation is 40 bits (Time differences of LORAN Signals Master Slave #1 and Master Slave #2). The estimated data base required in the DCF to calculate navigation fixes is 280 data words (36 bits) each. An additional 15 words data base and 100 instructions are estimated for tracking, position smoothing, and velocity computations. Program requirements are estimated to be 675 instructions.

The LORAN algorithm on which this computer requirement is based consists of; 1) a control module, 2) a range and bearing computation module, 3) a time difference computation module, and 4) a LORAN position error estimator. This algorithm has been implemented and does perform satisfactorily.

The position smoothing and velocity computation algorithm used here for estimation purposes is a DSD-developed modified Kalman filter. It has been incorporated in several operational systems (CEDPS, TSQ-73), where it operates in a track-while-scan mode. In the RPV context, performance can be improved by making explicit use of the priori knowledge of the time of occurrence and the extent of vehicle maneuvers.

Assuming a 10 second update rate per RPV (see Subsection 3.2.2), the dead reckoning navigation errors that can develop (horizontal wind is the principal variable) and the inherent accuracy of LORAN, navigation updates more frequently than 10 seconds are not required. Less frequent update rates are tolerable, though conditions can occur in which update rates that significantly exceed 10 seconds are undesirable. Considering that the processing required to provide a navigation fix is approximately 775 instructions with a 10 second update rate and 20 RPV's to be updated, the processing rate is 1350 instructions/second which is not excessive. It is concluded that 10 second navigation updates per RPV allows success in attaining mission objectives.

Considerations of the Omega System are similar to LORAN. Specifically, use of the Omega System instead of LORAN introduces comparable data reporting and processing requirements. This alternative does not significantly impact the physical control function nor the DCF data processing requirements.

A third viable candidate, described in Subsection 2.7.9, uses the Communications Command response links to establish navigation position. Given two relay aircraft, it is relatively simple to provide a time measuring scheme that can be used to measure path lengths to accuracies on the order of 100 feet. The additional system requirement is to provide the capability to automatically solve the geometry problem to yield RPV position. Quantitative estimates on the ADP support requirements have not been developed but they are modest.

The solution is attractive since, with this implementation, the RPV System is self-sufficient. It does not require a separately deployed navigation system in employment areas where LORAN or Omega are not in place. The disadvantage is that two relay aircraft are required to provide the navigation fix. There is, however, some possibility that a satisfactory method can be provided to measure distance from the DCF to the RPV using an HF Link.

3.2.4 Status and Position Reporting

There are basically three positions that might be considered in status and position reporting. One position is to report data providing continuous or frequent assurance that the system is functioning normally; i.e. that there are no malfunctions. To achieve this objective, the status of all critical system elements must be reported, and therefore, reporting requirements are maximized. A second position is to report malfunctions only; i.e., to report by exception. Such an implementation presupposes a capability to identify all failures or deviations from normal (or standard) that can occur and predetermine whether the failure or deviation affects mission success. Status reporting requirements, however, are minimum. The problem is to predetermine what failures and/or deviations are significant. In practice, the third position is most common. Actual reporting requirements are a compromise between the two extremes. Failures or deviations are reported that may or may not significantly affect success. The decision to take corrective action or plan for contingencies, should subsequent reports show a need for corrective action, is allocated to a human operator. In addition, certain status data that provide assurance that operations are proceeding normally are also reported.

This subsection develops data on the reporting of RPV status and position data. The basic position results from the following argument:

a. All malfunctions affecting mission success should, ideally, be reported.

b. However, the cost to predict and detect all malfunctions that can affect mission success is high.

c. Operator assurance that the mission is being executed successfully is also important.

d. The cost to generate, communicate, and process reports is a significant factor in selection of data items to be reported.

e. The Status data that is reported must be the basis for making physical control decisions and generating control commands.

Since operational requirements and cost factors depend on the mission phase, reporting requirements are addressed by mission phase. Table III.2-2 Status and Position Reporting Requirements, summarizes the requirements that have been developed. The considerations used to develop these data are:

PRELAUNCH: A vehicle has been selected for a mission, configured as required by the mission plan, checked and determined to be suitable for the mission, and positioned on the RPV launcher. At this point in the process, a final prelaunch check is made to provide assurance that all preparations for launch have been accomplished and that selected system elements pass prelaunch tests. A ground communications link between the launch facility and the DCF is assumed so the cost of transmitting status data is, within reasonable limits, independent of the amount of data transmitted. The limiting factors are what can meaningfully be tested at the launch site and what can practically be assimilated at the DCF. It is assumed that a check list of about 30 items is reported to the DCF and displayed on a tabular display. Assuming 25 characters per item, one byte per character, this is a 750 byte message, which can be formatted for display on an 80 character per line, 15 line tabular display. It imposes no significant ADP or display system requirements. Assuming that usually the system checks OK, typical operator time to assess the report is judged to be 30 seconds (time to read and determine that all items are OK is approximately 10 seconds).

LAUNCH: The prelaunch checkout has been passed and engine startup is initiated. Following engine startup, another sequence of checks and status reporting is initiated. Types of data reported include engine RPM, fuel flow, engine pressure ratio, oil pressure, hydraulic pressure, etc. Additionally, control responses are checked by initiating preprogrammed control instructions and by receiving status data on the response to such control instructions. As with prelaunch, communications are over the ground link and are not a significant performance parameter. (Message length is assumed to be 100 bytes.) A launch checkout program is required as is a status display for the operator. Operator time is judged to be 30 seconds. The final operator action is to initiate launch.

Table III.2-2. Status and Position Reporting Requirements

Mission Phase	Data Reported	No. Bits RPV Response Link (Info Bits)	Total No. Transmission (10 Sec Update)	Total Bits on Response Link per Mission
Prelaunch	Prelaunch Checkout Data	None	None	None
Launch	Launch Checkout Data	None	None	None
Enroute	Nav. Data	40/report	360	14,400
	Comm Contact, No Contact	2/report	360	720
	RPV Subsystems Normal, Not Normal	2/report	360	720
	RPV Subsystem Not Normal Status	240/report	10	2,400
	RHAW ON/OFF	2/report	360	720
Over-the-Target	Video Image	Not estimated		Not estimated
	Other Status	(see Table III.2-5)	N/A	261 BPS(1)
Recovery	Recovery Status	Est. 40	Est. 10	400
Total BPS per Msn over-the-target (except Video)				261 BPS
Total bits/Mission				18,960

ENROUTE AND RETURN TO BASE: Requirements to report status of the RPV enroute are primarily based on the concept of reporting by exception, with complete status reported only on demand. However, position data, communications status, and overall RPV status are routinely reported. These latter requirements are derived in part from the physical control procedures that are described in subsection 3.2.5 and in part from the need to provide assurance to the human controller that the mission is proceeding as planned. Applying these concepts, the following status reports are assumed:

a. Acquisition of the RPV by the communications system verified. This occurs once per acquisition, and two bytes is assumed as the message size.

b. Position Data is sent each 10 seconds with 40 bits per transmission (see subsection 3.2.3).

c. Communications Contact Status, is also transmitted each 10 seconds, (achieved or not achieved) and is estimated at two bits.

d. RPV Condition Status, is reported each 10 seconds, (normal or not normal) and is two bits.

e. Amplifying data on malfunctioning subsystem status is estimated at 240 bits per report. Ten reports per mission are assumed although these estimates may be on the high side.

f. Radar Homing and Warning (RHAW): Assuming the RPV is instrumented to detect acquisition by radar, three states are reported: OFF, ON (not activated) and ON (activated). Two bits can be used to report any state. The simple solution is to report complete status on each contact.

OVER-THE-TARGET ON STATION: The requirement to report status per se during the over-the-target phase of strike missions is basically the same as enroute. Although additional status data are inherent in the video picture this is not interpreted as being status in the context of status reporting. Special status reports over-the-target include such information as EO sensor flight control coupling enabled, lock on achieved, and bombs released. On the order of 300 bits per strike are assumed. Special on station status reporting for EW and Recce are similar. In response to commands to point and activate sensors the fact that the command has executed is reported. As with Strike missions, 300 bits are assumed.

RECOVERY: The operational assumption is that the RPV is recovered by parachute. Recovery is controlled by a ground crew. Within the DCF, there is a requirement to receive data verifying that the recovery crew is in place and ready to assume recovery control. Certain status data are required from the RPV; e.g., that the engine has been shut down, fuel is being dumped, etc. Data rates are low, possibly 40 bits per message. With 10 messages operator time is likewise low; on the order of 30 seconds.

3.2.5 Flight Control, Enroute, Return to Base

3.2.5.1 Introduction

This section addresses the requirement to maintain a preplanned flight profile and schedule. A fundamental assumption is that a preplanned mission profile and schedule have been generated which are to be realized in the execution of the mission. Alternate and secondary targets are preplanned and the criteria under which a preplanned alternative is selected are established.

Generation of such a preplanned flight profile is addressed in subsection 3.3, Force Control Functions. This section begins with the requirement for the physical control function to fly the mission as planned or, if this is not possible, to make adjustments to the mission profile and/or schedule as necessary. Any conditions that may cause the mission not to be executed as planned are reported to the Force Control function.

The physical control function then provides control instructions to the RPV such that the vehicle will maintain the preplanned flight profile and schedule. To accomplish this, it is necessary to obtain position data on the RPV, compare the actual position with the planned position, and establish what control is to be executed to maintain the planned profile. Communication with the RPV is essential.

Considering these data as inputs, and the basic feature of the RPV, (that the vehicle can be controlled in-flight) there are two basic approaches to flight control.

One approach depends upon the DCF to initiate all control necessary to change the flight parameters. That is, the AFCS on the vehicle maintains the flight attitude and the speed or power mode initiated by the controller. The RPV controller is required to initiate all enroute maneuvers to position the vehicle along a desired and preplanned profile. Frequent contact for control is necessary unless the preplanned profile is limited to a few in-flight maneuvers. If the time of maneuver is critical, control directions must be transmitted at exactly the position or clock time that the turn, for example, is to be initiated. If communications are lost, control is lost.

The second approach is to preprogram the in-flight maneuvers and to store the preprogram flight profile aboard the RPV. The RPV, while enroute, first interprets precoded instructions and then maneuvers to maintain a planned flight profile. Precoding alone, however, is unacceptable because unpredictable variables, such as winds, density altitude values, engine and air frame efficiencies are such that position errors build up to unacceptable levels. This deficiency can be overcome if a navigation system that provides data on the location of the RPV is available. Such a system is inherent in the RPV System Concept and is assumed to be existent for this analysis. Position data, or data necessary to establish position, are transmitted to the physical control element. The actual position of the RPV relative to the planned position can be established. If the difference exceeds a threshold value, the physical control element intervenes and issues corrective maneuvers causing the RPV to re-attain the planned schedule. (These functions could, of course, be allocated to the RPV, but the additional complexity of the RPV on-board processor does not appear to be justified.)

This composite approach is more economical in terms of operator time. If communication with the vehicle cannot be maintained, the vehicle continues to maneuver to maintain the planned flight profile. These are very significant advantages.

For either approach, accurate navigation is a requirement. Further, providing communications on demand to all RPVs at all times is costly, while the cost of providing the capability to pre-program the RPV is not high. Considering these cost factors in relationship to requirements, the composite approach is selected as the preferred approach.

3.2.5.2 Physical Control Implementation Concepts

Physical control of the RPV is based on the premise that there is a pre-programmed flight profile on board the RPV coupled with the AFCS. Without any commands from the physical control element the RPV maneuvers to maintain the flight profile and schedule as programmed. Details of how such a precoded flight profile is generated and the data needed to store a profile is contained in sub-section 3.3.2, RPV Flight Profile Program and Insertion. Additionally, the control concept includes the requirement to be able to change the preplanned flight profile enroute. The consequence is that it is not necessary, under this concept, to preload the total flight profile. Segments can be inserted enroute in periods of communications contact. The only constraint is that a segment must be inserted before it is to be executed; otherwise the mission will abort.

With such a concept, if all systems function perfectly and if the planned ground speed and path are realized within threshold tolerances, there would be no requirement for enroute control external to the RPV. Such conditions cannot be expected. Atmospheric winds, temperatures, and density altitudes will not be exactly as forecast; engine thrust and vehicle drag values will not be exactly as estimated; and, a terrain following flight profile cannot be exactly predicted. The vehicle will drift off course and will fail to maintain the pre-programmed airspeed and groundspeed, even with all system elements functioning normally. To compensate for this, control instructions to adjust power setting (or fuel flow) and direction of flight will be required.

With these factors in mind, the following control procedures are proposed. The RPV position is established using status inputs from the RPV (see sub section 3.2.3). The actual position is compared to the planned position. If the deviation exceeds a threshold value (position deviations in hundreds of feet, schedule and time deviations in seconds), a computation is made to establish the new heading required to make good the preplanned flight path and the power increase or decrease needed to adjust airspeed to make good the schedule times. (It is assumed that the AFCS on the RPV will maintain the preplanned altitude within tolerance.) The control commands are generated and transmitted to the RPV over the command link. The exact time of transmission is not critical. All of these functions are automated and can be executed without operator intervention.

Under this concept, the operator intervenes only when deviations are detected that cannot be corrected simply by altering heading and/or power setting. Such deviations may result from system malfunctions that have not yet affected the flight but that may foreshadow problems. Possible examples are; 1) a loss of communications because of terrain shielding or enemy jamming, or 2) tailpipe temperature exceeding a threshold value but not yet affecting engine thrust. Excessive path deviations may be reported resulting from extreme deviations in atmospheric conditions, RPV malfunctioning, or navigation data error. In addition to operator intervention, all deviations that may affect mission success must be reported to the force control element of the system.

It is not possible nor even necessary to identify all possible causes or types of deviations. Considering, however, those that are likely, it is possible to identify the control functions required for physical control. Table III.2-3, RPV Control, Enroute Control Functions, lists these requirements. The list is based in part on familiarity with similar control systems and in part on the control functions unique to RPV and the control concepts selected. Although some critical functional capability may have been omitted, the list is generally believed to be quite complete. Functions identified with an asterisk are required specifically for over-the-target control of the RPV strike mission. They may also provide capabilities that can in many cases be useful in enroute control, assuming that the use is on a no interference basis with over-the-target control.

3.2.5.3 Physical Control, Exceptional Conditions

Under the present concept, normal flight is highly automated and corrective control is only applied in response to unpredicted variables. However, it must be anticipated that exceptions requiring such control will occur. The RPV flight control system must have the capability of detecting various emergency conditions and adopting preplanned contingency instructions and/or other emergency control. Malfunctions of RPV subsystems necessary to mission completion, including loss of communication with the Drone Control Facility, constitute these emergencies.

As long as communication is maintained, the RPV need not be preprogrammed to change course in the event of equipment malfunction. However, the specific type of malfunction must be communicated to the DCF. The more complex case occurs with loss of communications, particularly on the DCF to RPV command link.

With programmed flight profiles, a temporary loss of communications with the ground can be tolerated for a considerable period of time in the enroute phases of a mission. For illustration, assume that without course corrections from the physical control element system, the RPV heading diverges

Table III.2-3. RPV Control, Enroute Control Functions

1.	Compute RPV position.
2.	Compare computed position with planned position.
3.	Compute speed, heading, altitude commands.
4.	Prepare data link messages.
5.	Determine requirement for altering course (change legs to affect arrival time).
6.	Monitor communications continuity.
7.	Generate alert messages for console operators.
8.	Display planned vs. actual course and position.
9.	Display situation data, including terrain, FEBA, hostile AAA, targets for selected portion of RPV flight profile.
10.	Display RPV status information: e.g., fuel, weapons, primary and alternate targets, recovery base, TOT, etc.
11.	Generate routine reports automatically.
12.*	File recorded video, photo, IR data, on targets and prominent land marks for subsequent retrieval by geographic location.
13.*	Display filed geographic data in conjunction with live video, or IR for easy comparison.
14.	Display current RPV location and heading in conjunction with map-oriented target data to facilitate interpretation of file data or as substitute for it if no previous data on target.
15.*	Maintain current target intelligence data, including damage due to other non-RPV missions; (to the extent that this would be useful in recognizing target and/or landmarks enroute to it).
16.	Monitor RPV status of on-board systems, generating alternative commands (e.g., abort mission and RTB) as required. May include computing new heading instructions.
17.	Display enroute threats in conjunction with RPV current path.
18.	Display special ingress/egress lanes for friendly territory and for launch, recovery operations, in conjunction with launch/recovery bases.
19.*	Activate/deactivate video/IR for check points.
20.	Activate/deactivate EW and RECCE sensors, provide pointing commands.
21.*	Record video/IR and select portions for file.
22.	Maintain log of significant events by location (e.g., malfunctions, loss of RPV).

*Specific over-the-target control functions.

from the planned heading by 1 degree. At 600 knots, the RPV would be off course by 456 feet after 60 seconds, or 4560 feet in ten minutes. For enroute mission phases, a discrepancy of 4560 feet would not normally require aborting the mission. If communications were regained at that point, the RPV's actual position could be computed, new flight profile instructions determined, and the mission could regain its preplanned flight profile and schedule and complete the mission exactly as planned.

For emergencies in which onboard equipment fails, but the RPV-to-DCF link remains operative, the onboard processor can be preprogrammed to report the malfunction in a standard format digital message. (This was assumed to be the case in the discussion of status message.) The DCF processor can alert the operator upon receipt of the message and display the nature of the emergency in alphanumeric form in conjunction with the RPV identification.

For certain kinds of emergencies, the timing can be so critical that it is necessary to preprogram the RPV to take contingency actions automatically, without waiting for control messages from the ground center. For example, if the terrain-following subsystem were to malfunction while the RPV was flying at 600 knots 200 feet above the surface of the ground, an automatic climb should be initiated without waiting for a decision by the DCF. However, it is not always desirable to have a fixed action automatically initiated for a particular type of emergency.

One approach to contingency situations, which provides a great deal of flexibility, is as follows. For each basic type of contingency that can be sensed by the RPV, a planned response is preprogrammed for each leg of the flight. Then, if an emergency occurs, the RPV processor takes the action programmed in terms of the current flight leg. To clarify the idea, consider the problem of aborting a mission before the weapons have been expended. It is desirable to jettison stores before initiating recovery of the RPV. However, the preferred course of action varies depending upon whether the RPV is over friendly (including sanctuary), or hostile territory. Over friendly territory, the preferred contingency action, if feasible, is to fly the RPV over enemy territory (or over a body of water or unpopulated friendly ground) before releasing stores. Over hostile territory, when the emergency occurs, it may be feasible to drop the stores over known targets on the route back to the recovery area.

This same principle of preprogramming contingency actions for each leg of the flight can be applied to the loss of communications from the ground. For each leg of the flight, the RPV would be given a specific set of instructions to follow in the event of loss of communications from the ground; after a specified period of time. For example, for a particular leg of the flight, the instructions might permit the RPV to continue on its programmed mission profile for 10 minutes, after which, if no command message were received, the RPV would switch to previously-prepared new heading, speed, and altitude data that would return it to the recovery area.

There are two methods of implementing this approach to contingency operations. One method is to preplan all actions to be taken for each leg of the flight profile for each kind of contingency and store these in the RPV ADP system. The other method is to use a "one-ahead" approach and only store in the RPV the contingency actions to be taken during the next flight leg, or during the next "N" minutes. If the latter approach is used, contingency actions could be performed on line. The method does, of course, imply update of the RPV prior to the start of each leg.

3.2.5.4 Operator Requirements, Operator Facilities, and ADP Support for Enroute Control

The physical control operator's station requires a tabular display console capable of displaying status data and schedule deviations. Operator controls to select modes, to retrieve data, and to generate commands are obvious requirements. A situation display which shows planned flight path, actual RPV position, target or on-station locations, threat zones, and restricted zones, while not absolutely essential, would add significantly to an operator's capability to assess the situation and deal with exceptions. As a result, a requirement for a situation display is postulated.

The control procedures, along with the associated operator time, ADP requirements, and the number of command messages required, are the basis for quantitative estimates of system performance requirements. These items are most easily presented in the form of a scenario that traces the enroute control activity from launch to recovery. Such a scenario is presented below for a single mission. System loads are generated by multiplying the single mission factors by the number of simultaneous missions as appropriate.

Launch acquisition: The launch procedures and the associated system capabilities required have been described as a sequence of status checks in subsection 3.2.4. Launch acquisition is the activity required to acquire the RPV inflight and establish inflight control. After launch, the RPV, following its programmed flight profile, has reached a point in space and has established a flight attitude. The communications to be established have been preplanned. When communication with the RPV is initiated, a response message containing navigation data and subsystem status indicates acquisition. If this initial communication contact is through the relay aircraft, the relay aircraft will have been notified of launch or time for first contact and the pointing angle to acquire the RPV. If local communications are used for the initial contact and close-in enroute control, these communications will be initiated. Handover to the relay aircraft occurs at some point enroute. When communications are established and a response is received, launch acquisition has been completed and enroute control is established.

Periodic updates: Assuming communications contact is achieved, RPV subsystem status is reported at the appropriate interval. If all parameters are normal, processing within the DCF is as follows. The time the report is received, stored, and replaces the time of the most recent report received from this RPV. The RPV position is calculated based on the navigation message. The expected position is then established from the preplanned mission profile stored in the data base. Differences in magnitude and direction between the positions is computed. If this difference does not exceed a threshold value, this fact is coupled with the time of the report and stored. If the position deviation exceeds threshold, checks are made on the validity of the status data. When the deviation is determined to be valid, corrective controls are initiated. If the checks fail, the fact of reported deviation is saved as an indication of a potential trend. Estimates of the size of the data base required, the size of the program to process such a report, and the number of instructions executed is tabulated on Table III.2-4.

Aperiodic Control Directives: The procedures described above determine whether corrective control actions are to be directed. The threshold values, for course and schedule have been preselected for the specific mission and mission phase. (For example, schedule tolerance may be "high" for a Recce mission relative to the schedule tolerance for a coordinated strike mission and supporting ECM approaching the target). If corrective directives are required, the processor calculates the change in direction of flight and/or fuel flow (or power setting) necessary to rejoin the programmed profile at the profile segment end point. The application program used to develop the precoded flight segment, described in subsection 3.3.8, is used to code a new segment and transmit it to the RPV. The update rate for control directives is obviously a function of the magnitude of the threshold values and the magnitude of the variables (e.g. wind, thrust, drag) that affect the RPV course and ground speed. For purposes of estimating system loads, it is assumed that corrective controls are calculated and transmitted, on the average, each 5 minutes to each RPV. (This process also assumes that the RPV position error did not exceed a second threshold value requiring operator alert. Further, the magnitude of the control changes directed are within pre-established tolerance levels.)

Aperiodic Confidence Checks: It is unrealistic, to postulate that an enroute controller will not desire to or need to monitor status, even when no deviations are detected, thus, the enroute controller will periodically or aperiodically check status. Reasonable implementation procedures are many, ranging from a continuously updated large screen group status display, to periodic printouts on a line printer. For estimating purposes, the following is assumed: Two display formats are available; a tabular display and a situation display. The tabular format is selectable by mission number for a single mission or by mission type and/or mission phase for groups of missions. The data may be displayed on the operator console or on a printer. The situation display is a display of mission geometry, planned flight profile, and target or orbit station. The current position of the mission RPV symbols is displayed. Other data, e.g. restricted zones, EOB data, are highly useful. As with the tabular display, the display content is selectable by mission number or type mission and/or mission phase. Other data, e.g. restricted zones, may also be selection criteria. There is no reasonable way to

Table III.2-4. Operator Time, Mission Exceptions

Operator Action	Rate/MSN	Operator Time per Action	Operator Time/MSN (seconds)
ABORT MSN	10%	120 sec	12
ADJUST MSN, SUCCESS NOT AFFECTED	3/MSN	30 sec	90
ADJUST MSN, SUCCESS MAY BE AFFECTED	25%	90 sec	22.5
DIVERT MISSIONS AS DIRECTED	10%	60 sec	6
OPER TIME/MISSION			130.5

establish how frequently such "confidence data" are required. One may postulate that if there are no exceptions requiring operator attention, the operator may continuously or semi-continuously monitor status. To the extent that exceptions requiring operator attention develop, "confidence checking" will be more infrequent. Specific estimates of processing required and operator time for confidence checking is deferred to the next paragraph, Controller Response to Exceptions Reported.

Controller Response to Exceptions: This is the primary function of the enroute controller. While it is not possible to identify all exceptions that can occur, the nature of the procedure and the ADP support requirements can be described and generally quantified.

Three system elements directly impact RPV control functions; the relay aircraft, the RPV vehicle system, and the launch/recovery facility. It is assumed that each of these systems is capable of detecting and reporting its own failures and abnormal performance data. It is assumed that the input message to the DCF from the RPV or the relay is a formatted digital message. ADP must process the message, identify it as an exception report to be displayed, route it to the proper control station, and activate an alarm. The controller requests display of the message in tabular form. In terms of the control action that can be taken by the enroute controller, there are three possibilities:

a. The mission must be aborted. Here, two subsets exist. If the exception reported is that the mission has aborted the controller has no choice. If the reported malfunction convinces the controller that the mission must be aborted, implementation of the operator decision is involved. If amplifying data on the mission, the mission requirements, and the status of other system elements are required, the capability to request data, process the request, and display data must be provided. Coordination with other controllers or a supervisor may be necessary, requiring inter-console transfer of data. Finally, the capability to generate, address, and transmit an abort message is required.

b. Mission success and successful recovery is not affected. Two possibilities exist. One is that the failure or deviation reported may relate to a system element not necessary to the success of the mission. Alternately, the reported exception is one which is tolerable or can be corrected. Schedule deviations, for example, of a magnitude that by Standing Operating Procedures are allocated to the controller to decide what corrective control action is to be applied to enable the RPV to make good its preplanned schedule and flight profile within acceptable limits. No specific console requirements exist other than the display of the exception message and any other data the controller might need to insure that message success and recovery are not affected.

c. The probability of mission success is degraded or coordinated missions are affected. In this case, the controller must assess the impact of the deviation reported and take authorized corrective action to minimize the effect of the deviation on the success of the mission and/or maximize the probability of successful recovery. An exception report must be generated and transmitted to the RPV force control element and to any other elements affected. Again no special console requirements are derived.

There is one final situation that can be considered under the general heading of dealing with exceptions. This is the situation where the force control element directs a change to a mission flight profile and/or schedule. The assumption here is that if a deviation is planned by the force control element, the new flight profile will be planned and coded so it can be transmitted to the RPV. The RPV is capable of receiving an updated profile and, in response to coded segments, fly the new path. In this situation, the divert message is displayed to the controller. The controller requests and receives a display of the RPV mission being adjusted, its previous flight profile, and the new flight profile. He verifies that the point at which the new profile is chained to the old profile is forward of the current position of the RPV. (If this condition does not exist, an exception exists of one of the types previously described.) He then transmits the new profile to the RPV and verifies that the message is received.

Factors derived under the SEEK FLEX and TACC studies and the Mission Planner experience permits reasonable estimates of operator time required. Table III.2-4 tabulates the factors. The relevant factors are as follows:

Aborts: An abort rate twice that for manned aircraft, as specified for TACC, SS001485A, is assumed. Operator time may be high since aborts can be automatic, e.g., if communications is lost, and thus do not require operator action. However, 2 minutes per abort appears reasonable based upon the criticality of the decision, the factors to be considered, and the tasks to be performed.

Mission Adjustments, Mission Success Not Affected: The activity level, (3 per mission), as well as the operator time, obviously depends upon degree of automatic adjustment which is permitted in the system, and the complexity of the adjustment process. The assumption is that major automatic adjustments are not allowed. However, criteria for making "major adjustments" are preplanned or pre-established and the processor displays viable options. Some adjustments may well take several minutes, and many adjustments require very short periods of time, e.g., 10 or 20 seconds. The 30 second average time is based in part on the SEEK FLEX simulation of the mission adjustment process.

Adjust Missions, Mission Success May Be Affected: The rate, 25%, is deliberately selected as high because of the lack of data. As with other adjustments, operator time can vary from 20 seconds to several minutes. The average time, 90 seconds, is based in part on SEEK FLEX simulations.

Mission Diverts: A low divert rate is assumed. Since the operator requirement is principally to verify that the divert directed is possible, operator time is low.

The operator time (130.5 seconds) is the average time required per mission. In the maximum activity period (20 simultaneous missions), total operator time required for handling mission exceptions for 20 RPV's on simultaneous missions is 43.5 minutes, or 0.7 man-minutes per minute. A consideration that enters into tolerable operator loading, during peak activity periods, is that many adjustment actions can be deferred several minutes without affecting the success of operations.

Data processing required to support these functions are more difficult to assess. The type of processing required is highly operating-system oriented, consisting of input and output message processing, message checking, tabular displays, operator requests for data, and data retrieval with fixed format tabular and situation displays.

3.2.6 Control, Over-The Target Strike

3.2.6.1 Introduction

This subsection discusses functional requirements for physical control of RPV's during the over-the-target phase of air-to-ground strike missions. This phase begins with the arrival of the RPV within target acquisition range of the electro-optical sensor, proceeds through weapon delivery and damage assessment (including any additional strike or BDA runs on the same target that are required) and terminates with final escape maneuvers and departure from the target area.

Physical control of the RPV by a human operator is required in the over-the-target strike phase for several reasons. The human operator, using visual imagery from an EO sensor, can identify the target, examine its condition (e.g. state of occupancy, damage, etc.), accurately position the RPV and/or weapon for attacking the target, and assess bomb damage after weapon release.

This study assumes a low-altitude (200-500 feet above ground level) terrain-following approach to the target area. The RPV is controlled automatically to pop-up at a preselected location and climb to a preselected altitude, e.g. 1500 to 2500 feet above ground level. The EO sensor is enabled, at which time the Strike Controller begins visual search for the target. The RPV location at start of climb is selected such that, upon reaching altitude, the slant-range from RPV to target allows adequate time for target recognition, go-no-go decision, RPV position correction, weapon lock-on if appropriate, weapon release, and escape maneuver. Previous multi-mission studies indicate that this slant-range may be 15,000 to 40,000 feet. The planned pop-up range to target may vary from mission to mission, depending upon such factors as: sensor type selected for mission, weather (particularly visibility (TV) and humidity (IR)), target characteristics (size, contrast, sky-ground ratio, masking angle), and ground-to-air threat.

Previous studies have indicated the desirability of having both TV and FLIR options available as the preferred sources of visual imagery for various conditions. Either type of sensor may be preferable for a particular mission, but there does not appear to be a requirement to have the capability of using both types of sensors on the same mission (at least not simultaneously).

3.2.6.2 Pop-Up

Upon reaching pop-up altitude, the RPV EO sensor is activated and transmission of video data initiated. The RPV may be maintained in level flight at the pop-up altitude until target/aiming point recognition by the pilot, or dive may be initiated immediately. RPV airspeed is expected to be on the order of 300 to 600 knots. For this study, it is assumed that the preprogrammed dive angle is 10 degrees, however, the dive angle can be changed during flight by the strike controller.

Upon completion of pop-up, the RPV is positioned at a planned location and heading such that, normally, the target will be within the field of view of the EO sensor. The sensor is turned on and TV or IR transmission initiated automatically when the RPV has reached pop-up altitude. Digital data messages from RPV to DCF will be automatically generated to indicate completion of final approach climb and activation of EO sensor.

From the time of pop-up and start of EO sensor data transmission until weapon release, the RPV pilot may have as little as 12 seconds in which to find the target, make adjustments to RPV heading and dive angle, aim and fire the weapon. Therefore, it is mandatory that familiarization with the target area and the planned mission profile be accomplished prior to initiation of the final approach. Moreover, the Strike Controller should be seated at his console station with certain selector switch settings (e.g. video channel to be displayed) already made. When the RPV approaches the scheduled pop-up location, an automatic alert indicator should be activated at the designated console and an alphanumeric display of current mission status should be activated and updated automatically by the DCF computer, based on comparisons of planned flight profile with actual RPV position, velocity, heading, altitude, and other status data. The alphanumeric display contents should include: mission number, sensor type, weapon type, planned pop-up altitude and slant range to target, time-to-go before completion of pop-up, sensor state (on/off, offset angle), and details of subsequence phases of the planned flight profile (e.g. dive angle, escape maneuver, secondary target).

The EO sensor display should permit superposition of special symbols e.g., symbols uniquely representing sensor boresight, longitudinal axis of the RPV, aiming point, and weapon boresight. A separate display surface should be available for the replay of recorded visual imagery. This display should be positioned to facilitate comparison of the recorded EO imagery with the "live" visual presentation.

3.2.6.3 Target Recognition

When the EO sensor is activated, the widest field of view (FOV) setting will normally be in effect. An RPV sensor with FOV characteristics similar to that of the television system employed on the CONDOR missile is postulated. This TV system has a 21 X 28 degree search mode FOV, and a 4.2 X 5.6 degree track mode FOV. At three nautical miles the width of terrain viewed in the larger FOV is approximately 9,000 feet. This particular system has only the two FOV choices; for the RPV application, a multiple-position or zoom capability may be preferable.

The Strike Controller normally first uses the wide FOV to search for the target. When he recognizes the target, or what appears to be the target, he switches to the narrower FOV to examine a magnified image of the target in order to confirm target identification and examine target detail.

In the initial search for target, control of the RPV normally remains in the automatic mode with AFCS inputs governed by preplanned flight profile data. The Strike Controller may slew the EO sensor to search for the target. Changes in sensor pointing angle are not linked with aircraft flight control instructions during this search period. Ground-to-air command signals are required to slew the EO sensor and to change the field of view. Slew instructions are generated by using a joystick type control to position a marker symbol on the EO display in the direction of the desired new sensor aiming point away from the present display center. Operation of the slew control results in the automatic generation of sensor slewing command signals to the RPV.

Before switching to a narrower FOV, the operator must first ensure that the magnified image is centered on the desired location. If that location is not already at the center of the wide FOV image, the operator positions a sensor-pointing marker symbol at the desired location and slews the EO sensor accordingly.

During the target recognition phase, and throughout subsequent phases of over-the-target control, the visual display presentation must be maintained such that the sensor remains pointed at and focused upon the desired location with a minimum of jitter or unintentional motion. Therefore, capability for automatic slewing of the EO sensor to continue pointing at a selected ground position is required. This function should include; 1) the capability during the mission planning of predetermining EO sensor azimuth and elevation such that the sensor FOV is centered on a specified point upon pop-up, and 2) the capability of automatically maintaining the sensor FOV centered upon an operator-designated point on the current image. The accuracy of preplanned sensor pointing depends upon a number of factors, particularly navigation accuracy.

Sensor slewing to keep a fixed point in view can be initiated and maintained by command messages from the DCF or by self-contained data processing in the RPV. The degree of picture motion away from lock-on is a function of the update rate of sensor azimuth and elevation changes. An update rate of 5 times per second is postulated for sizing the DCF-to-RPV communications requirements and DCF processing loads.

During over-the-target strike operations, the RPV pilot needs continuous access to the visual imagery capability. The timing of his tasks is such that any detectable interruption of the visual display (for example; due to time-sharing wideband video communications) would be unacceptable. This is not to say that a continuous video transmission is required. A succession of rapidly updated discrete video frames, presented in snapshot-like form, is probably acceptable from the human factors standpoint. A priori, continuous presentation appears preferable for imagery interpretation; the use of multiple snapshots is advantageous mainly from the standpoint of reducing communications requirements or increasing AJ protection.

The data processing requirements associated with the use of television and IR sensors depend upon several factors including; the sensor characteristics, the choice between digital and analog transmission techniques, antijam methods used in transmission, and image enhancement techniques to be employed.

The requirement for controlling up to four RPVs simultaneously over targets demands the ability to communicate and process sensor outputs from as many as four RPVs simultaneously. The capability to operate with a mix of sensors is also required; e.g., weather conditions in one target area might dictate the use of TV, whereas in another target area IR might be necessary.

At the DCF, the communications processing subsystem should be capable of routing processed EO data from any RPV to any operator station used for strike control. The specific sensor channel to be displayed at a particular console can be determined by a selector switch at that console. When sensor data are routed to a particular console, the operator display data derived from processed digital data link messages from the same RPV should be routed to that same console. Incoming sensor data, after processing, should be recorded routinely for subsequent use in operator familiarization for future missions. Editing and purging of sensor tapes can be performed off-line during periods of low mission activity.

The Strike Controller can use recorded sensor data to familiarize himself with the appearance of the target and the target environment. Prior to the launch of planned missions, he may spend considerable time comparing stored sensor data with photographs, maps, and descriptive material. Immediately before controlling an RPV over the target, the pilot should review key graphic data.

If the Strike Controller does not see the target on the EO display presentation, he may either switch to a narrower field of view, in order to see greater detail, or he may scan adjacent areas in case the target was not originally in the sensor FOV upon pop-up. To switch to the narrower field of view (or use a zoom capability if that is provided), the Strike Controller could turn a control knob to a setting corresponding to the desired new field of view. This in turn would cause the automatic generation of a digital command message to the RPV that would be interpreted by the on-board processor and converted into electro-mechanical signals actuating the EO lens system. To scan with the sensor, the Strike Controller must first inhibit automatic sensor slewing, if that is in effect, by switch action generating the appropriate control message. Scanning is accomplished by using a manual slewing control on the Strike Operator's console, previously described. (It is recognized that the RPV system will be designed so that with the EO sensor FOV provided, and the Navigation Accuracy and target position error expected, the probability is high that the target will be in the FOV. Still, the possibility exists that the target will be outside the FOV and the system should be designed to cope with that contingency.)

Upon recognizing the target, the Strike Controller will reactivate automatic sensor slewing and use the narrowest FOV to examine target details. He must quickly determine if the target is suitable for attack (e.g., a SAM site may be unoccupied; or a structure may already have been destroyed or heavily damaged by other forces).

It must be anticipated that in some missions the Strike Controller will have difficulty in recognizing the target. The RPV at pop-up may not be positioned at the exact location and heading expected by the controller. The target image may be at an unexpected location in the sensor FOV, or it may not even be within the FOV. Also, if the target is on the periphery of the sensor FOV, it may disappear from the FOV before the controller identifies it, or too late for weapon aiming and delivery. In any event, if the target is not engaged, the options are to abort the target or try to engage the target on a second pass. The option selected will depend on the mission requirements and other tactical factors such as target defenses.

If a second run on the target is selected, the flight control instructions required to turn the RPV and reposition it for a second run at the target can be preprogrammed and activated by operator switch actions at the console. The flight profile segments for this operation are similar to those required for a second weapon-delivery pass at the same target, discussed below.

If the Strike Controller determines that the target is sufficiently damaged or unoccupied to abort the primary mission, he would normally activate the preplanned flight profile instructions for an alternate target.

The selection of alternate courses of action is implemented by presenting the Strike Controller with a visual display of his alternative choices, including any priorities established for these choices, and a means of indicating to the DCF processor which choice is to be activated. This function can be implemented in several ways: e.g., the choices can be listed on an alphanumeric CRT display, with the selection being made by using a light pen or movable cursor; or the choices could be selected by pressing switchkeys bearing the appropriate labels (e.g., "proceed to secondary target", "start second pass", etc.).

The automatic processing requirements for implementing alternative courses of action include keeping track of where the RPV is in its planned schedule of events, and of switching to the planned flight profile corresponding to the alternative branch. The RPV may not be at the pre-planned location at the time the alternative branch is selected if the Strike Controller has been manually generating flight control instructions for the AFCS. However, the DCF automatic processor can determine a heading (and altitude) from the RPV position at the time that the Strike Controller selects the new branch that will bring the RPV onto the desired flight profile. This can be accomplished by comparing actual RPV position, heading, and altitude from the navigation and tracking system with the next segment of the new flight profile, and computing new flight control instructions to get from the former to the latter.

3.2.6.4 Weapon Delivery

Assuming that the target has been acquired and the decision is to proceed with the mission as planned, the next major task is to aim and release the weapon. The process of aiming the weapon may also entail changing the RPV's speed, heading, or dive angle.

Specific requirements for the aiming and control of RPV weapons depend upon weapon type. The control system must be capable of handling a variety of weapon types including; "smart" bombs, rockets, guns, and "dumb" bombs.

Smart bombs have a self-contained means of locking onto the target and generating their own steering directions. Lock-on could be based on discerning contrasting light patterns in the target image, homing on jamming, or on detecting radar, laser, or other energy aimed at and reflected from the target surface. For this study, if the weapon requires an illuminating source, it is assumed that function is performed by a different RPV or aircraft and is considered as a separate mission. Requirements for target-illuminator RPV missions were not analyzed. A priori, the illuminator aiming accuracy and platform stability requirements, which clearly are considerably more demanding than those for the RPV visual sensor, would appear to be critical factors in the use of drones for delivering this class of weapons.

The dumb bomb contains no means of target sensing or changing its trajectory and must, therefore, be released on a free-fall trajectory course that coincides with the target. Because the dumb bomb is a free-fall weapon, precise computation of the release point is required.

Studies to date indicate that the weapon-release computations could be performed either at the DCF or onboard the RPV. The basic advantages and disadvantages of each alternative are clear. Remoting the weapon release computations to the DCF would centralize the function in a single processor and minimize the on-board ADP requirements for the RPV. However, this would increase the amount of data to be transmitted both ways between DCF and RPV, and these communications would have stringent response times and high repetition rates. Performing the computations on the RPV reduces the communications requirements at the cost of requiring increased data processing onboard onboard the RPV.

Smart bombs require less data processing, less DCF-to-RPV two-way communication of digital messages, and less stringent requirements for accurate positioning of the RPV at the relèase point. The primary requirement is that of positioning the RPV within the flight envelope of the weapon.

It is envisioned that the basic method of maintaining the RPV flight profile within the weapon release envelope would be as follows. The Strike Controller would compare the actual RPV position and heading with a pre-established weapon-release envelope computed for the given target location. The weapon envelope could be shown graphically on the Strike Controller's EO display, in the form of dashed lines superimposed on the sensor imagery. The symbol representing the boresight of the RPV would be compared with the outlined weapon-release envelope to determine if changes to RPV heading or dive angle were required. The Strike Controller would use the joystick type control to maintain the RPV boresight within the envelope outline. Movements of the control to repositon the boresight symbol would be automatically translated into commands to the RPV flight control system to alter the RPV heading and dive angle. Response actions by the RPV will result in movement of the boresight symbol position towards the desired location within the weapon-release envelope. (The RPV boresight symbol location is a function of the magnitudes of the EO sensor azimuth and elevation relative to the longitudinal axis of the aircraft.)

For smart bombs having EO sensors with the capability of maintaining lockon automatically when a target is designated, the capability of switching from the RPV EO sensor to the weapon EO sensor is required. The weapon sensor data would be transmitted to the RPV, amplified, and re-transmitted to the DCF via the relay aircraft.

Before switching from the RPV sensor to the weapon sensor, it is necessary to ensure that the target will be within the field of view of the weapon sensor. There are two possible ways of implementing this. One way is to require that the RPV be on a level line-of-sight course with the target at time of attempted lock-on. Then the weapon sensor can be prepositioned with its boresight identical with that of the RPV. The other method consists of using the remote slewing capability to generate command signals to the weapon sensor to point with an azimuth and elevation coincident with that of the RPV sensor. These signals could be initiated by Strike Controller switchkey action, but, considering the limited time available during the final strike maneuver, it is probably better to automate this step, and have the weapon sensor begin tracking along with the RPV sensor as soon as the pop-up altitude is reached and the RPV sensor is turned on. The Strike Controller can have a manual override capability that allows him to aim either sensor independently.

The Strike Controller should switch from the RPV sensor to the weapon sensor prior to weapon release to confirm that this sensor is operative and that the target is seen. When he has the target in view on the weapon sensor, the Strike Controller makes adjustments to the weapon sensor azimuth and elevation to position the boresight of the sensor on the target. When he has done so, he transmits a lock-on command to the weapon sensor by depressing a switchkey.

When lock-on is achieved by the weapon sensor, a digital data message indicating automatic lock-on should be transmitted, via the RPV and relay aircraft, to the DCF, where it would be routed to the console of the Strike Controller controlling the mission. Depending upon weapon type, the lock-on message may be required prior to weapon release. In addition, it must be established prior to release that the RPV is within the weapon release envelope. These two conditions could be determined by an automatic processor; the actual release command could be generated automatically, to take advantage of the computer's more rapid response capability relative to the human operator. After weapon release, the weapon will continue aiming itself, using its own sensor data to update steering instructions.

3.2.6.5 Expendable RPV

The discussion thus far has concentrated upon weapon delivery by RPV's that are recoverable. Another option is the use of expendable RPV's for delivering explosives by flying them right into the targets. In this case, the requirements for physical control are similar to those of smart bombs. The same types of sensors and guidance techniques employed on smart bombs are applicable to expendable RPV's. If an automatic lock-on capability is employed, control requirements are similar to those described above, except that only one EO sensor is involved. If an automatic lock-on capability is not used, the essential requirement is that the Strike Controller maintain the aiming point on the target.

Inasmuch as the expendable RPV is basically a "single-shot" weapon, it is clearly desirable to minimize the cost of on-board equipment, which means that all functions that can be performed at the DCF or relay aircraft should not be allocated to the expendable RPV. If the expendable RPV is to be included in the types of vehicles to be controlled by the DCF, certain alternative functional allocations become much more attractive from a life-cycle cost standpoint, e.g., the use of an external navigation system, such as the range-measuring system described in subsection 2.7.9.

Another candidate weapon system for delivery by RPV is a steerable glide bomb with an EO sensor that can be pointed by control signals from a remote station. By pointing the sensor boresight at the target, a remote operator can steer the weapon into the target. The requirements for control of this type of weapon delivery are essentially identical with those of the expendable drone. The main additional system requirement entailed by this weapon type is that there be the capability of switching to the EO sensor on the weapon, with the associated requirements for capabilities of receiving, amplifying, and relaying the weapon EO imagery via the RPV and relay aircraft.

The Strike Controller's functions in the use of rockets and guns are primarily those of maintaining the RPV boresight symbol on the target or aiming point and firing the weapons when within proper range. The basic tasks performed are similar to those for other weapons. The RPV EO sensor imagery provides the basic data needed to control the mission. The weapons are aimed by flying the RPV towards the target or aiming point and fired when RPV-to-target slant range is within weapon range.

3.2.6.6 Damage Assessment

After weapon release, the RPV could be programmed to take either of two basic courses of action: 1) an immediate escape maneuver to avoid enemy ground-to-air fire, or 2) a maneuver to permit damage assessment while avoiding flying the RPV through the weapon blast. If the latter alternative is selected, it would normally be followed by an escape maneuver, initiated by a control message generated by the Strike Controller. The following discussion assumes that a bomb damage assessment maneuver is to be made prior to escape from the target area.

After weapon release, the Strike Controller attempts to maintain or reacquire visual contact with the target, to assess damage. The maneuver initiated upon weapon release to avoid flying the RPV through the weapon blast should be planned such that the RPV resumes a heading that is compatible with maintaining the target within the EO sensor FOV long enough to determine the extent of damage or accuracy of weapon impact. If possible, rates of turn or climb should be such that the EO sensor can continue pointing at the target without exceeding the EO sensor gimbal limits.

(It was suggested earlier in this report that all incoming EO imagery data be recorded automatically for subsequent familiarization. A capability for rapid playback of the sensor data at the Strike Controller console would have the further advantage of giving the controller a "second look" at the target after the RPV had flown beyond the point where the target was within the sensor gimbal limits. In some cases, this could enable him to determine the extent of damage without requiring a second pass at the target.)

The aircraft maneuver after weapon release can be either preprogrammed or manual. If preprogrammed, manual override is possible. The sensor azimuth and elevation at completion of the escape maneuver should be preprogrammed to maintain the target within the FOV while the aircraft maneuvers. The target whould be relatively easy to acquire visually at this time since there will be visible evidence of an explosion in the immediate vicinity of the target.

If damage assessment cannot be performed during the initial strike run, a second run at the target can be made. (A second pass is always necessary for dumb bombs.)

Damage assessment may indicate that a second strike should be made at the same target. If the RPV is carrying a second weapon suitable for attacking that target and if RPV status (fuel primarily) indicates that a second strike is feasible, the Strike Controller initiates the preplanned flight profile that brings the RPV back around for another pass at the target. The data processing and communications requirements here are similar to en-route flight profile command generation. The main requirement is that of identifying the appropriate branch in the flight plans, keeping track of the RPV's current position, and computing heading, speed, and altitude commands necessary to bring the RPV onto the planned profile for that branch.

It is desirable to provide the Strike Controller with the capability of monitoring the RPV's track and status during the preparatory maneuvers for a second pass on the target, particularly in cases where that second pass is unscheduled. A simple geographic tracking display is suggested, which could use the same CRT as that used to display the EO sensor imagery. This display, in essence, would be a stylized map. containing only essential reference features of the target area, and the scale would be expanded such that the display encompassed the planned RPV flight profile for the return pass, with perhaps a 2000 ft border to allow for discrepancies between planned and actual RPV location. The display should plot the RPV's actual track (within 300 ft, CEP), as determined in the navigation and tracking routine, as well as the planned track for the second run. This display would give the Strike Controller a visual indication of the time remaining before the next pop-up, as well as an indication of the probable location and heading of the RPV at pop-up. The use of the EO sensor for visual checkpoints during the second-pass preparatory turns and climb may also be advantageous here.

3.2.6.7 Summary of Command/Reply Link Data Loads

This subsection summarizes communications load factors derived in preceding subsections of 3.2.6 for the command/reply link in over-the-target strike control. Table III. 2-5 presents the estimated message length and average rate of transmission for each type of message content transmitted from DCF to RPV and from RPV to DCF, respectively.

In the DCF-to-RPV portion of the table, items 10 through 14 represent DCF-computer-generated flight control instructions. These instructions would be generated in over-the-target strike control when the RPV is disengaged from stored flight profile data. An alternative implementation would be to allocate to the RPV on-board processor the interpretation of EO sensor slewing commands and their translation into autopilot setting changes. For purposes of this study, it is postulated that this function is performed by the DCF computer.

From Table III. 2-5, the peak DCF-to-RPV message rate for data bits, as opposed to overhead bits for synchronization, etc., is approximately

Table III. 2-5. Digital Data Messages OTT Strike Control

DCF-to-RPV Message Content	Length	Estimated Average Rate
1. Activate/Deactivate RPV sensor	1 bit	4 per mission
2. Engage/Disengage RPV sensor with autopilot	1 bit	6 per mission
3. Change RPV sensor FOV (Zoom)	6 bits	20 per mission
4. Activate/Deactivate weapon sensor	1 bit	1 per mission
5. Slew RPV sensor and/or weapon sensor	30 bits	5 per second
6. Activate/Deactivate Terrain Following	1 bit	2 per mission
7. Change RPV sensor mode*	1 bit	6 per mission
8. Lock-on weapon sensor	1 bit	1 per mission
9. Release weapon	1 bit	1 per mission
10. Heading	12 bits	5 per second
11. Speed	10 bits	5 per second
12. Altitude	16 bits	5 per second
13. Altitude rate	5 bits	5 per second
14. Turn rate	5 bits	5 per second
15. Engage/Disengage stored profile	1 bit	2 per mission

*Automatic slewing or manual control - not required if all slewing instructions are generated at the DCF.

RPV-to-DCF Message Content	Length	Estimated Average Rate
1. RPV at final approach altitude	1 bit	1 per mission
2. RPV sensor on/off	1 bit	2 per mission
3. Flight control status	2 bits	10 per mission
4. Weapon sensor activated	1 bit	1 per mission
5. RPV sensor azimuth and elevation	30 bits	5 per second
6. RPV sensor mode	1 bit	7 per mission
7. Weapon sensor locked-on	1 bit	1 per mission
8. Weapon released	1 bit	1 per mission
9. Altitude	16 bits	1 per second

Table III. 2-5. Digital Data Messages OTT Strike Control (cont)

RPV-to-DCF Message Content	Length	Estimated Average Rate
10. Airspeed	10 bits	1 per second
11. Dive Angle	11 bits	1 per second
12. Heading	12 bits	1 per second
13. Roll attitude	11 bits	1 per second
14. LORAN TDF	40 bits	1 per second
15. Fuel Status	11 bits	1 per second

400 bps. If one allows again as many bits for addressing, synchronization, etc., the total peak data rate from the DCF to one RPV over-the-target would be approximately 800 bps.

In the RPV-to-DCF portion of Table III.2-5, items 9 through 13 are postulated to be used by the DCF computer:

a. As inputs for generating flight control instructions to accurately position the RPV during pop-up and final dive at the target (when not under manual control by the Strike Controller).

b. To make necessary computations for display generation (e.g., to locate RPV boresight relative to center of the EO sensor field of view, to determine RPV relation to weapon-release envelope, etc.).

As discussed in subsection 3.2.3, use of LORAN, with the RPV position-fix computations remoted to the DCF, is postulated as a baseline navigation system. Item 14 of the table represents LORAN time-difference-fix data used in the RPV position fixing computations. The higher update rate (once per second for the over-the-target portion of the mission, including the leg just prior to pop-up, vs. once per 10 seconds enroute), in conjunction with track smoothing and flight profile correction computations, will reduce navigation error at the start of target acquisition.

On the basis of this table, the peak RPV-to-DCF message rate for data bits is approximately 250 bps. If one also allows 250 bps for overhead, total peak rate for one RPV to DCF would be 500 bps.

As mentioned earlier in this report, additional digital data required for remoting gravity-drop weapon release computations at the DCF were not estimated. The above estimates also do not include communications requirements for video or IR data, which were not estimated in this study.

3.2.6.8 Operator Requirements, Operator Facilities, and ADP Support for Over-the-Target Control

The nature of the over-the-target RPV control function, with its demand for full operator attention and quick response, requires that a Strike Controller concentrate on one mission at a time. Therefore, to meet the operational requirement for simultaneous control of four over-the-target phases simultaneously, four separate Strike Controller stations are required.

At a minimum, each station must include:

a. A dynamic display capability for presenting the EO sensor imagery (TV and IR are prime candidates, but both are not used simultaneously on the same RPV).

b. A means of superimposing and separately controlling the movement of special symbols on the EO image.

c. A dynamic display of alpha-numeric data on RPV flight profile and status and computer-generated operator prompts and alerts.

d. Operator controls that enable the generation of command messages to the RPV governing flight profile, EO sensor, weapon sensor, and weapon release.

A situation display of the type defined in subsection 3.2.5.4 for enroute control is also required at the Strike Controller Station. In addition, the capability of recording and playback of EO sensor imagery appears highly desirable. Use of a separate display surface for playback of recorded data, positioned to facilitate comparison with live imagery, would aid in recognition of targets and visual checkpoints.

A number of ADP support requirements for over-the-target control have been defined, and a tentative allocation of ADP functions to DCF and RFP'v has been suggested. These are summarized in Table III.2-6.

The DCF ADP functions for over-the-target strike control must be accomplished for up to four RPV's simultaneously, while also performing the in-route processing functions for as many as 16 additional RPV's. However, Table III.2-6 does not include additional functions required for weapon release computations, which would be required for other than "smart bombs."

Table III.2-6 ADP Functional Requirements for OTT Strike Control

DCF ADP Functions 1. Display generation and control/switchkey interpretation, 4 Strike Controller Consoles. 2. RPV position-fixing and tracking. 3. Integrating RPV tracking data with flight control data to project RPV future positions. 4. Comparing actual track with planned flight profile and generating corrective flight control messages or operator alerts. 5. Determining if RPV flight path intersects weapon-release envelope. 6. Determining projection of aircraft longitudinal axis on EO sensor image and positioning symbol on visual display accordingly. 7. Selecting operator-designated branch of flight profile and up-dating RPV on-board flight profile. 8. Command message generation, addressing, formatting. 9. Reply message processing, routing.
RPV ADP Functions 1. Perform time-difference measurements on raw LORAN signals. 2. Store flight profile data transmitted from DCF before launch and while airborne. 3. Translate stored flight profile into flight control settings for autopilot at scheduled time. 4. Process incoming command-messages and generate appropriate electro-mechanical signals. 5. Generate and format reply messages on RPV, sensor, and weapon status, exceptional conditions, flight parameters. 6. Translate incoming flight control messages into flight control settings for autopilot. 7. Translating operator changes to EO sensor azimuth and elevation and other control settings into aircraft weapon steering commands.

3.3 RPV FORCE COMMAND AND CONTROL FUNCTIONS

3.3.1 Introduction

3.3.1.1 RPV System Factors Impacting Force Command and Control

The general requirements for command and control of the RPV force are the same as for manned systems. The force objectives must be developed for a mixed force or for a pure RPV force. Mission requirements must be established, resources assigned, and missions planned. In the execution phase, the operation must be monitored and adjustments made to most effectively achieve the force objectives in a dynamic environment. There are, however, a number of RPV features that significantly impact Command and Control functions. Table III.3-1 summarizes these RPV system features and indicates the general impact of these features on Command and Control. The specific considerations and assumptions are:

a. Attrition Factors: A fundamental premise is that the RPV system is designed to be cost effective at sustained attrition rates that are unacceptable for manned systems. The consequence of this premise is that for a mixed force, assuming mission objectives can be achieved using either RPV's or manned aircraft, threat assessment (probably loss) becomes a more important criteria in the weapon selection function. When a weapon system has been selected, planning develops penetration and attack tactics that provide acceptable assurance that the mission objective will be achieved, while concurrently maximizing the survivability. This consideration is applicable to manned systems and RPV systems alike.

b. Low Altitude Penetration: The RPV is designed for low altitude penetration and more frequent high G measures are acceptable than is true for manned aircraft. However, without a pilot the RPV has no capability to sense real time flight hazards and to avoid them (except for its terrain following capability). The consequence is that route safety must be analyzed and made a part of the preprogrammed flight profile.

c. Precision Flight: While the requirement to preprogram the RPV flight profile introduces exacting requirements for route planning, the capability of the RPV to follow a preprogrammed flight profile and schedule introduces potential sophistication in the coordination of primary and support missions. Therefore, requirements which exploit coordinated mission planning are introduced.

d. Communications Requirements: The requirement for semi-continuous communications with the RPV's enroute and continuous communications during the attack phase is affected by the low altitude flight profile of the RPV. This can, in many

Table III. 3-1. RPV System Features Impacting Force C&C

RPV System Design Features Impacting Force C & C	General Effect on Force Command & Control
Attrition - System is designed to be cost effective at higher attrition rates (vis-a-vis manned system).	Mixed Force - Threat assessment, a more important criterion in weapon selection. Pure RPV Force - Weapon selection similar to that for manned systems.
Low Altitude Penetration following preprogrammed flight profile.	All details affecting route safety evaluated in detail and every detail of the flight profile preprogrammed.
Precision Flight - The RPV will follow exactly a pre-programmed flight profile and schedule.	Exacting requirements to plan coordinated missions.
Communications - Requirements to maintain communications through an airborne relay to maintain physical control.	Exacting requirements for planning relay station location(s) compatible with RPV routes and targets.
Flight Profile Preprogramming Requirements.	Requirement to generate a flight profile for insertion into the RPV System.

situations, introduce terrain masking of the line of sight communications links; further, enemy jamming can be expected. These factors combine to introduce new and relatively complex requirements for communications planning.

e. Flight Profile Programming Requirements: An operational assumption is that the response capability of the RPV system must be comparable to that of the manned systems. The consequence is that manual procedures alone cannot provide the required response times. Automated aids to route profile planning and a capability to automatically convert a preplanned flight profile into preprogrammed flight control instructions is required.

Table III. 3-1 summarizes these RPV system features and indicates their general impact on Command and Control.

3.?.1.2 Force Command and Control Functions

At the highest command level, force Command and Control relates to the planning and management of force resources to achieve the overall force objective. At lower levels, it relates to planning and managing a part of the force to achieve some specific objectives which have been assigned. Within the framework of the tactical control systems which have evolved, the Tactical Air Control Center (TACC) of the Tactical Air Control System plans the operations for the total force. Assignments are made in the daily frag order. The tasked units, wings and independent squadrons, develop the detailed plans required to assign specific resources, and to execute the mission.

Table III. 3-2, Force Command and Control Functions, lists the command and control functions related to mission planning, monitoring, and control as they are normally identified. The functions under "total force planning" are those allocated to the TACC Current Plans division. Those under "unit planning", are the planning functions normally assigned to the tactical units. As tabulated, there is a functional overlap between "total force planning" and "unit planning".

TACC planning for assignment cannot be accomplished without considering viable over-the-target tactics, enroute threats and mission support requirements. These same factors are significant considerations in detailed mission planning for execution. When one considers ADP support to mission planning, certain trade-offs are obvious. More detailed planning could be done at the TACC with reduced requirements to plan at the unit level. Alternatively, it is desirable, for several reasons, to allocate detailed planning to the unit assigned responsibility to execute the plan. These reasons involve operational considerations that are not addressed in this study. The analysis that follows presumes that the force has been apportioned and individual mission objectives have been established. The requirements to develop detailed plans are addressed in this study. However, no distinction is made between planning for assignment (TACC) and planning for execution (tactical unit).

The sequence in which the planning functions are listed on Table III. 3-2 is the sequence in which the functions are typically executed in the planning cycle. The text that follows addresses the planning functions in reverse order, starting with the requirement to convert a planned mission profile into the format required for physical control. Route planning and the interrelated requirement to plan the communications relay missions are then addressed. Finally, that planning required to plan over-the-target, or

Table III.3-2. Force Command and Control Functions

<u>TOTAL FORCE PLANNING:</u> Requirements analysis Resource analysis Force apportionment Detailed planning for assignment Frag order generation and distribution
<u>UNIT PLANNING:</u> Detailed mission planning for execution: o Select or validate weapon selection, configure carrier (A/C, RPV) o Select or validate sensor selection, configure carrier (A/C, RPV) o Develop over-the-target or on-station tactics (A/C, RPV) o Plan mission route profile and schedule (A/C, RPV) o Plan communications relay operations (RPV's only) o Convert RPV mission profile into that format required for physical control (RPV's only)
<u>MONITORING AND CONTROL (ALL ECHELONS):</u> Monitor situation data, status and mission progress Replan and adjust missions as required Report data as required

on-station, operations is described. This reverse order of presentation is selected because the unique features of the RPV affect most directly the route profile, communications relay planning, and precoding functions. As one proceeds "up the table" of functions, away from very detailed planning, the impact of RPV on planning functions is generally smaller.

3.3.2 Flight Profile Coding

3.3.2.1 Introduction

It is a requirement of the RPV system that the preplanned flight profile be converted into a set of coded instructions that can be inserted into the RPV. The instructions coded must be such that the power setting or fuel flow for engine control, and the settings for the flight control surfaces, can be implemented by the on-board AFCS and such that execution of the instruction will result in the desired route profile. The AFCS combines the instructions with sensed information concerning deviation from the desired flight attitude (due to atmospheric turbulence, for example) to produce continuous aircraft control. Planned variation of the flight path parameters are accomplished by implementing the next instruction at an appropriate time.

This subsection describes the process that converts a planned flight profile into code that can be inserted into the RPV system. Subsection 3.3.3, Route Planning, describes in detail the procedure for generating the profile itself. Generally, route planning for RPV's is similar to route planning for manned aircraft. The route profile is specified in terms of position, flight altitude, direction of flight, and power setting. Segments such as launch, climb, and descend can be specified. A controlling schedule time is input and from this controlling time all schedule times are derived.

The specific instructions to be coded and the processing required to convert a flight profile into a set of coded instructions depend upon a number of system factors.

To facilitate the following discussion, several definitions are presented.

ROUTE/PROFILE -- The flight path which is to be traversed by the RPV, the flight altitude, and the power mode.

LEG -- A portion of the route/profile which connects two adjacent check points.

FLIGHT MODE -- A description of the manner in which the aircraft is changing its position and/or velocity. Examples are; climb, cruise, and accelerate.

With reference to the above definitions, a leg is composed of a sequence of flight modes, and a route profile is a sequence of legs. At each level, the elements are linked together by using the terminal point of one element as the initial point of the next.

An implementation concept that very significantly affects the processing required to convert the planned profile into a set of coded instructions is the concept of preprogrammed flight segments. In its simplest sense, the concept is that any flight profile can be conceived of as consisting of a number of standardized legs appropriately chained together.

The effect of the execution of a preplanned leg is always to alter the state of the aircraft in a fixed manner relative to its initial point. For example, launch might move the RPV from its pad to a point down range at an altitude of 15,000 feet. The specific position would be determined by the position of the launch site, a specified heading, and RPV parameters.

The following subsections describe the elements at each level of route/profile description. The presentation is from the bottom up. That is, the flight modes are described first, then the legs, and finally a route/profile.

3.3.2.2 Flight Modes

The set of flight modes consist of:

- ACCELERATE
- CLIMB
- CRUISE
- DESCEND
- LAUNCH
- RECOVER
- REMOTE
- TERRAIN
- TRIGGER
- TURN

The effect of executing a portion of the route/profile in any of the above modes is to change the state vector of the RPV. The state vector consists of at least the following:

- RPV Type
- Position (latitude/longitude)
- Altitude
- Heading

- Mach Number
- Gross Weight
- Fuel State
- Drag Index
- Elapsed Time

The state vector of the RPV then is a detailed description of its performance and characteristics at any instant of time. This state vector is used as a basis for describing changes to be implemented in the next flight mode.

The motion of the RPV in any flight mode will result in a change in the state vector. The following variables will always change: position, gross weight, fuel state, and elapsed time. The other variables will change while the RPV is executing specific flight modes. Table III. 3-3 presents the flight modes, any supplementary input parameters required, and state variables (other than those that always change) which are affected. Each flight mode is also described in the following paragraphs.

Accelerate: The accelerate flight mode is used to increase or decrease the mach number of the RPV while the heading and altitude remain constant. At the point of initiation of the mode the mach number to be achieved and a throttle setting (max or mil) must be specified.

Climb: The climb flight mode is used to increase the altitude of the RPV while the heading remains constant. At the point of initiation of the mode it is necessary to specify the desired altitude and a throttle setting (mil or max). The throttle setting determines the appropriate climb schedule which, in turn affects the distance, fuel, and time required to climb and determines the mach number when altitude is achieved.

Cruise: The cruise flight mode is used when the RPV is to maintain a constant heading, altitude, and mach to traverse a specified area. It is used for straight legs, and the distance to be traversed must be specified.

Descend: The descend flight mode is used to decrease RPV altitude while maintaining a constant heading. At the point of mode initiation it is necessary to specify the dive angle or rate of descent and altitude to achieve these maneuvers. The appropriate descend schedule is then determined. This includes mach number at the terminal point of the flight mode.

Launch: The launch mode is used to initiate the flight of the RPV. It changes the state of the vehicle from its initial condition to an independent airborne vehicle. Whether the RPV is initially on a pad or carried by another aircraft significantly affects the launch mode; however, in either case, the primary change which occurs is that the RPV becomes an independent airborne entity.

Table III. 3-3. Flight Mode Required Inputs and Variables

Flight Mode	Supplementary Input Variables	Distinguishing Variable Change	Termination Condition
Accelerate	Throttle Setting	Mach Number	Mach Achieved
Climb	Throttle Setting New Altitude	Altitude Mach Number	Altitude Achieved
Cruise	None	None	Distance Achieved
Descend	Throttle Setting New Altitude	Altitude Mach Number	Altitude Achieved
Launch	Heading	Altitude Heading	Initial Burn Complete
Recover	None	Close Down	Close Down
Remote	Sensor Activate	Direct Operator Control	Operator Command
Terrain	None	Heading Altitude	Distance Achieved
Turn	Heading Radial Acceleration	Heading	Heading Achieved

The result of a launch mode is to place the RPV at its first position and establish its first state vector values. (It is necessary to state the desired heading.)

Recover: The recovery mode is used to terminate the flight of the RPV. Recovery can be by parachute which is the baseline system. Alternatively, runway recovery or other recovery means are possible. In any event, recovery is a process initiated at the end point of the return-to-base flight segments. Recovery is initiated by a handover to recovery control. Recovery maneuvers are not precoded, except for 'triggered' responses such as deploy parachute.

Remote: The remote flight mode is used when it is necessary for the RPV to be under the direct control of an operator. The mode may be initiated only by a real time command since it requires that the operator be in communication with the RPV. However, as a safeguard against countermeasures, such commands will only be recognized during designated periods and when accompanied by appropriate lock keys. This mode allows an update or modification of the stored command stack as well as the ability to maneuver the aircraft in very near real time. It can be used to adjust route/profiles for deviations from planned schedules, and for control of the RPV during critical mission times.

This mode is unique in that it makes reference to other commands in the stored route/profile. Three command numbers are specified as parameters. The first is the command to execute in case the operator does not acquire the RPV, second is the command to execute when the operator returns command to the RPV, and the third is the command to execute in the event of a communications interruption during a period of operator control.

Terrain: The terrain (following) flight mode is used when the aircraft is to maintain a specified altitude relative to the terrain which it is traversing. The heading is to be maintained. It is necessary to specify the relative altitude to maintain, and the total length in distance of the flight mode.

Trigger: The trigger mode is used to change the flight mode in response to conditions which are sensed on the RPV. Examples are:

- On weapon release, the next flight segment is initiated; which could be escape or bomb damage assessment.
- If failure of the terrain following radar is sensed, a climb maneuver is initiated.
- An available option, if radar homing and warning is detected, is that jinking can be initiated.

Turn: The turn mode is used to change the heading of the RPV. At the initial point of the mode, it is necessary to specify the new heading and the radial acceleration of the turn.

3.3.2.3 Route/Profile Legs

The set of leg types consists of:

- CLIMB
- CRUISE
- DESCEND
- LAUNCH
- LOITER
- TERRAIN
- DELIVERY

Each leg type combines a sequence of flight modes into a pattern which, when executed, results in the RPV traveling from the initial check point of the leg to the terminal check point of the leg, according to the characteristics of the leg type. In essence, a leg type is a precoded set of flight modes with certain parameter values not specified. When the parameters are specified, the leg type becomes a specific sequence of flight modes. Leg types are only used as a convenience to the planner and are translated during the coding process into their corresponding set of flight mode sequences before insertion into the RPV.

For each leg type, the initial conditions are the terminal conditions of the preceding leg. Parameter values specified are values to be attained and maintained during the leg. The following paragraphs describe each of the leg types.

CLIMB: Whenever the planner wishes to increase the altitude of the RPV between two check points he defines a CLIMB leg. The general characteristics of a CLIMB leg are; 1) a geographical separation of the initial and terminal check points, and 2) an increase in altitude between the initial and terminal check point. In order to define a specific CLIMB leg the following parameters must be specified:

- Position of the terminal check point of the leg.
- Mach number at the final check point (if not present, a default is made to an appropriate value in the climb schedule).
- Throttle setting to use for the climb.

A CLIMB leg type, for which the throttle setting for climb yields a speed at the end of climb different from the Mach number of the final check point, requires a flight mode of accelerate or decelerate to resolve the difference. An error condition arises if the final check point is not compatible with the heading specified at the initial check point of the leg.

CRUISE: The distinguishing characteristics of a CRUISE leg are: 1) a geographical separation of the initial and terminal check points, and 2) no altitude change between check points.

In order to define a specific CRUISE leg it is necessary to specify the following parameters.

- Position of the final check point.
- Mach number for CRUISE.

If the heading of the RPV at its initial check point is not consistent with the location of its terminal check point the CRUISE leg includes a turn mode to a cruise mode. Similarly, if the Mach number is different at the initial and terminal check points an accelerate/decelerate mode is added to the cruise mode. Any mode other than cruise is implemented at the start of the leg.

An error condition arises if the altitude of the initial and terminal check point are different.

DESCEND: The distinguishing characteristics of a DESCEND leg are: 1) a geographical separation of the initial and terminal check points, and 2) a decrease in altitude from the initial to the terminal leg.

In order to define a specific DESCEND leg it is necessary to specify the following parameters:

- Position of the terminal check point.
- Constant air speed value for descent (if not present, a default is made to an appropriate value).

A DESCEND leg type, for which the constant air speed specified for the descent is different than the value associated with the mach number at the initial check point, requires a flight mode of accelerate or decelerate to resolve the difference.

An error condition arises if the position of the terminal check point is not compatible with the heading specified at the initial check point.

LAUNCH: The distinguishing characteristics of a LAUNCH leg are: 1) it is always the first leg, 2) the air base or carrier aircraft is always the initial check point, 3) the terminal check point is automatically defined by the climb requirement for the leg, and 4) the fuel and time expended include all modes from startup until the terminal check point is reached.

In order to define a specific LAUNCH leg it is necessary to specify the following parameters:

- The direction of LAUNCH. This may be specified either as the direction from the air base to a point, or as a heading.
- An altitude to be reached.

All LAUNCH legs automatically compute the distance, time, and fuel necessary to move the aircraft from startup to the point at which the specified altitude is achieved.

LOITER: The distinguishing characteristics of LOITER legs are: 1) an initial and terminal check point which are geographically coincident, and 2) the requirement to remain in the vicinity of the check point for a specified period of time.

In order to define a specific LOITER leg it is necessary to specify the following parameters:

- Amount of time in LOITER.
- Mach number to maintain.
- Altitude to maintain.

A LOITER leg is made up of a sequence of climb, accelerate/decelerate, turn, and cruise flight modes. If the mach number and altitude do not require adjustment with respect to the parameters at the terminal point of the previous leg, then the leg is a series of cruise modes alternating with 180° turn modes. The length of the cruise legs will be calculated to maintain the aircraft within a specified distance of the check point and to keep the loiter time as an integral multiple of the time around the "race track". The minimum loiter time will be the time required to execute a 360 degree turn.

TERRAIN: The distinguishing characteristics of TERRAIN legs are: 1) a geographical separation of initial and terminal check point, 2) maintenance of RPV heading, and 3) the requirement to maintain a specified altitude relative to the terrain.

In order to resolve a generic leg type TERRAIN into a specific leg, it is necessary to specify:

- The relative altitude to maintain.
- The terminal check point.

The heading and Mach number at the initial check point will be used for the terrain leg. The leg terminates when the specified distance has been traversed.

DELIVERY and BOMB DAMAGE ASSESSMENT: Although defined as legs, one distinguishing characteristic of DELIVERY and BOMB DAMAGE ASSESSMENT is that they are each in fact a standardized sequence of legs. The sequence of legs cannot be discretely designated; they are predesignated to the system. A second characteristic is that the operator is semi-continuously exercising remote control. Finally, the termination of the sequence is triggered, either by conditions sensed by the RPV, (e.g., weapon release or by an operator action, or, a command initiated when bomb damage has been observed) or an abort command if the target is not attacked.

ESCAPE: This leg type, like the delivery and bomb damage assessment, is in reality a standardized sequence of legs that contains predesignated changes in flight mode. It is different from the delivery and bomb damage assessment mode in that remote control is inhibited and termination of the activity is automatically achieved after a given length of time.

3.3.2.4 Command Stacks Organization

The form of a stored route/profile is a table of commands ordered by time of execution relative to mission initiation. It is called a Command Stack. Each entry includes the execution time, the command type (i.e., flight mode), up to four parameters to define the specific command, an enable code to indicate whether or not the particular sequence may be interrupted and remote control accepted, and (whenever remote control is enabled) a lock code (different for each leg) which must be used if the RPV is to accept remote control.

Figure 3.3-1 presents a portion of a hypothetical command stack. Line 1 is the launch command. The parameter value in the table is the heading in degrees. Line 2 is a climb command to be initiated 30 seconds after launch. The RPV is to climb to 10,000 feet (100, 100 foot increments). The RPV will not accept remote control during the climb. Line 3 is a turn command. Since it occurs at 300 seconds, one can infer that the climb mode was computed to be of duration 270 seconds. The turn is to be executed at 1.0 g's and the RPV is to come to heading 305. Notice that the LAUNCH leg has been converted into a launch mode (line 2) followed by a climb mode (line 2). The next leg (CRUISE) is made up of a turn mode followed by a cruise mode. This occurs because the final terminus of the cruise leg required a change in the direction of flight (see previous CRUISE leg description).

Lines 7 through 9 present an interesting sequence of commands. Line 7 is intended to represent a "pop up" to 5,000 feet. Line 8 is a command to accept remote control; if remote control is accepted, when control is returned to the RPV itself, the route will continue at line 10 (parameter 2). In the event that control is not accepted, the command of line 9 is executed, and remote control is not accepted. If communication is interrupted during the remote control, the RPV will take its next command from line 16 of the stack.

Figure 3.3-1 has been presented in English for ease of understanding. In the RPV system, the data would be in numeric coded form. Assuming command times can be expressed in seconds, a maximum of 4 parameters of 2 bytes each, and a 4 byte enable-keyword field, each command in the stack will require 15 bytes.

ID NUMBER	TIME	COMMAND	VARIABLE PARAMETERS				ENABLE	KEY*
			P1	P2	P3	P4		
1	0	LAUNCH	320	--			YES	KEY 1
2	30	CLIMB	MIL	100			NO	
3	300	TURN	305	1.0			NO	
4	480	CRUISE	100	--			NO	
5	1680	DESCEND	220	2			NO	
6	1860	TERRAIN	400				NO	
7	5480	CLIMB	MAX	50			YES	KEY 2
8	5530	REMOTE	9	10	10		YES	KEY 3
9	5600	CRUISE	100	16			NO	
	.							
	.							
	.							

*KEY 1 – INITIATES REMOTE CONTROL MODE.
KEY 2 – "LEVEL OFF" COMMAND IS INITIATED BY RPV ALTIMETER.
KEY 3 – REMOTE CONTROL BY OPERATOR IS ENABLED.

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Figure 3.3-1. A Command Stack Example

3.3.2.5 Command Stack Generation, Program and Data Base

The command stack is generated by application programs as the planner generates a route/profile. Each leg specified by an operator adds commands to the stack. Commonly occurring sequences of legs will be precoded and available to the planner. The route/profile generation program is to be built in a manner integrating operator specified and preplanned legs automatically.

Stack occurrence times for each command are relative to mission initiation time* and computed by processing downward in the stack and adjusting the variables as if the RPV was traversing the route/profile.

The actual process of command stack generation can proceed only after the route/profile has been specified. The command stack is generated by processing each leg of the route/profile and updating an RPV state vector as if the RPV was actually traversing the course. Each leg is converted to a sequence of flight modes. The flight mode parameters are computed taking into account such factors as gross weight (which is a function of fuel consumption), drag index, and requested leg characteristics.

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*Mission initiation time may itself be calculated backward from time over target (TOT) when one is specified in the requirement. If no TOT is provided an initiation time or TOT must be specified by the planner.

The application program to perform the command stack generation can be implemented as a control program supported by an algorithm processor and a data base retrieval module. The actual calculations to perform can be stored in the data base and expressed in terms of a set of standard functions of one and two variables. This approach has been investigated on the Mission Planner program and its feasibility has been demonstrated. The main advantages of the approach are:

- Logic dependent on RPV type is in the data base.
- One program performs all computations.
- Changes to logic and/or introduction of new leg types requires only data base update, not program modification.
- Fuel calculation and performance envelope calculations can be included in command stack generation.

The logic to perform computations for a flight mode determines the space required in the data base. Estimates for some of the modes are presented in Table III.3-4. These have been arrived at by assuming that the computation for RPV's will not differ greatly from those for F4D/C aircraft. It should be emphasized that these estimates contain storage for function parameters as well as boundary value checks and return codes for error indications and/or performance envelope violation checks.

No estimates have been made for the controller or the data retrieval module; however, the algorithm processor requires approximately 5280 bytes.* This estimate is based on an existing processor which has been used for experimentation with data for the F4D/C.

The storage requirements for a route/profile are a function of the number of legs and the data required by the route/profile generator. A reasonable estimate is between 12 and 16 bytes per leg. To this, about 240 bytes will have to be added for a name and any restricted usage or interface constraints.

The data that have been presented make it possible to estimate the total data base required to convert a preplanned flight profile into the command stack code and to estimate the command stack storage required for single route profile from launch to recovery. The operational assumptions which must be made are the number of mode changes per leg, the number of legs per route profile, and the number of standardized preplanned chains of legs. Table III.3-5, Quantitative Factors, RPV Route Segments and Legs, tabulates the

*This represents 120 PL/I statements at 44 bytes per statement, or 11 machine instructions per PL/1 statement which is equal to 1.3 KI.

assumptions. Assuming that contingency (e.g., emergency RTB, climb if terrain following radar fails) are common to many and that there are a total of 60 contingency segments in the system, total system ADP requirements can be summarized as follows:

Program Logic, DCF	1.3 KI's
Mode Logic Storage, DCF	6,972 Bytes
Storage, Single Route Profile, RPV	1,230 Bytes
Storage, 20 mission total, Unit DCF	16,500 Bytes
Storage, 80 mission total, Unit DCF	61,300 Bytes
Storage, 240 mission total, Force Planning DCF	188,100 Bytes

Table III.3-4. Storage Requirements for Mode Logic

Flight Mode	Bytes for Logic
Accelerate	1052 (two throttle settings, MIL and MAX)
Climb	1052 (two throttle settings, MIL and MAX)
Cruise	1920 (5 mach numbers, interpolation between)
Descend	576 (3 descent modes)
Launch	250
Recover	32
Terrain	1920 (5 mach numbers, interpolation between)
Trigger	32
Turn	60 (assumes use of cruise mode as a subfunction)
Total Mode Logic Storage — 6974 Bytes	

Table III.3-5. Quantative Factors, RPV Route Segments and Legs

Leg	Legs/Route	Command Stack Storage Bytes/Route Coded(1)
Launch	1	30
Enroute to TGT	15	225
Delivery	3(2)	135
BDA	3(2)	135
Escape	2(2)	90
RTB	10	150
Recovery	1	15
Contingency Segments	30(3)	450
Total Storage/Route Profile Coded		1230 Bytes

(1) 15 Bytes per leg

(2) e.g., Primary, Secondary, Alternate Target

(3) Judgment Factor

3.3.3 Route Planning

3.3.3.1 Constraints and Assumptions

The output of the route planning function is the input to the flight profile coding function described in the preceding subsection. The requirement for route planning is to establish the route legs. Standardized legs such as LAUNCH are specified by designating the launch site, launch corridor, and the altitude to be achieved. Other legs must be specified in terms of end points, altitude(s) and mode(s) of flight. This is not unlike route planning for manned aircraft systems. However, as has been pointed out, there are some operational considerations that are relatively RPV unique (e.g. low altitude penetration).

Currently, route planning is a two step process. One step relates to flight over friendly territory. The other covers flight over hostile areas. Routes over friendly territory from launch to an ingress point, and from an egress point to the recovery base tend to be constrained by factors under one's control. Constraints include the selection of ingress and egress points that are compatible with routing requirements over enemy territory, refueling requirements if applicable, and TACS control requirements. Restricted airspace must not be traversed. A significant consideration is effective use of air space, all airspace requirements considered. These constraints make the concept of using a few preplanned routes over and over very desirable in one's own environment.

Over enemy territory the primary consideration is the enemy order of battle; i.e., the location and capability of enemy defenses that can interfere with successful flight to and from the target area and target defense penetration. Other considerations include range factors, visual checkpoint requirements, weather factors, etc. Frequent movement of enemy weapons and variability of target locations means that routes to and from the target must be mission specific.

The general considerations for RPV route planning are the same as those for manned systems. There are, however, a number of factors that significantly impact route planning for RPV's.

These factors are:

a. Navigation position accuracy: The degree of precision required depends principally on the target acquisition requirements. Studies of these requirements, conducted for the Air Force, have concluded that navigational accuracies in the order of 300 to 1500 feet are required. Given these limits, accuracy has little impact on route planning.

b. Low altitude penetration: The RPV is designed for low altitude penetration to enhance survivability. Two viable options are open. The one option includes terrain following at 200 to 500 feet. The other option is pressure altitude. If terrain clearance is maintained by flying a preplanned pressure altitude acceptable flight safety altitude will probably range from 1000 to 2000 feet above the terrain or even higher. At these altitudes vulnerability to AAA, especially radar controlled AAA, is significantly increased. For this reason, a terrain following capability is assumed for the baseline system. The effect of having a pressure altitude capability only will then not be assessed.

c. Line of sight requirements: Within the UHF and C Band frequences that may be used to communicate with the RPV terrain masking between the RPV and the relay aircraft can significantly degrade or prevent communications. Consequently, possible enroute and over-the-target terrain masking of the communications links must be considered in route planning.

3.3.3.2 Operational Assumptions Affecting Route Planning, Low Altitude Penetration

Previous studies conducted by Rand, Litton, and other organizations indicate that almost any area will have at least many known and probable AAA sites. While AAA and any SAMs that are present pose a threat to RPV, effective route planning can be applied to noticeably reduce the threat.

Assuming a terrain following capability, the planning requirement for a low altitude penetration to the target is to select the path that maximizes survivability within any other constraints that may be imposed or selected. (For example, one may wish to select a path which conceals the objective of the mission or is not likely to alert target defenses). Since defensive sites however tend to have small lethality areas, and tend to be grouped around targets, it is quite possible to circumnavigate known AAA and SAM sites and other enroute flight hazards. It follows that the effectiveness of AAA and SAM, and the amount of intelligence available on site locations, significantly affects the required capability to plan a defense avoidance flight path. It is assumed that intelligence data are available. For SAM sites, it is assumed that SAM sites are not numerous and at low altitudes can be circumnavigated (target penetration excepted). For AAA, the following is assumed:

a. There are 1600 AAA sites within an area 200 nm square. Assuming an average lethality range of 2.5 Km, there is a 28% probability that the RPV enroute is in a lethality zone if a defense avoidance route is not planned.

b. These 1600 sites are at the more than 2000 locations identified as AAA sites or probable sites.

The question of how much of a threat AAA is for a low-flying RPV is difficult to answer. Previous studies by Litton and other organizations however, do indicate the following:

a. For visual detection and at target speeds of 0.85 Mach in clear weather, there is approximately a 50% probability of visual detection at 1700 meters slant range. At low altitudes, this appears to be relatively independent of the specific altitude. The threat while low is not insignificant. Statistically, given 1600 AAA sites scattered throughout a 40,000 square mile area, approximately 30 lethality zones will be penetrated enroute to a target 180 nm from the FEBA if no defense avoidance is planned.

b. For radar detection, the probable low altitude detection range exceeds the weapon range, so any penetrations of lethality zones present a probability of loss which is significant. None-the less, very low flight, 200 to 500 feet, introduces terrain masking, multipath effects, and background clutter that significantly degrades radar controlled AAA, and hence increases probability of survival.

If the RPV does not have the radar terrain following capability, the pressure altitude level for the flight must also be preplanned. For this option, the minimum safe altitudes are in the range of 1000 to 2000 feet AGL clearance; i.e., excluding very favorable earth surface features and meteorological conditions. This higher penetration altitude enhances the capability of enemy defenses to detect track and acquire the RPV. The consequences are that, enroute, it is even more important to select a path that avoids defense lethality zones.

To plan a defense avoidance path wherein coordinate accuracies are in hundreds of feet and, on the average, in excess of 70 points (from a population exceeding 2000) and which must be avoided by pre-designated distances, it does not appear possible, using manual procedures, to still meet required response times for planning. The next subsection addresses the subject of automated support to route planning for defense avoidance. Before turning to this process, however, the requirement for and desirability of incorporating terrain masking in route selection is addressed.

The importance of terrain masking to avoid long range early warning radars is obvious. Any low altitude penetration that avoids early warning radars by 10 or 20 miles will be masked. The more specific consideration is terrain masking of radar controlled AAA. Assuming a radar detection range of 10 to 20 miles, a zero degree masking angle, the effective AAA lethality range (under 3 Km), and AAA response time (6 to 8 seconds), it is necessary for vehicles flying at 200-500 feet above terrain to be masked to within a few miles of the site in order for them to obtain a significant operational advantage.

There are however, many uncertainties that affect the value of such masking consideration. Exact site locations are not known. Detailed data would also be required on terrain features close in to the radar site. Although favorable siting can be assumed, nevertheless close-in features do generate masking angles. Clutter and multipath effects are possibly as significant as masking.

Quantitative data to substantiate a conclusion are not available. Subjective considerations, however, have lead to the conclusion that uncertainty of the validity of the results of calculated terrain masks, plus the cost, are such that terrain masking of AAA should not be considered. Therefore, the proposed implementation procedures for defense avoidance planning do not incorporate terrain masking for AAA.

3.3.3.3 Route Planning for Defense Avoidance

There are two general approaches to ADP support for planning a defense avoidance route that can be considered; automatic route selection (ARS) and automatic scoring of an operator selected route. For automatic route selection an algorithm that can select the lowest cost route (minimum threat in this case) must be provided. Generally, to find a best route many iterations are needed to find a solution and the associated processing costs (and response times) are high. Many manageable solutions incorporating some set of simplifying assumptions have been suggested; some have been implemented. The second approach, automatic scoring of an operator selected route, requires a program to evaluate the threat intersecting a given flight profile.

Since route scoring is subsumed in any automatic route selection process, route scoring is, by definition, relatively simple as against automatic route selection. Provided the operator can select a number of good routes for trial, the route scoring approach alone is quite satisfactory.

Automated support for route planning has been studied under the USAF Mission Planner program. The analysis of the operational requirements and the cost and effectiveness of alternative implementation methods led to the conclusion that both approaches should be provided. Automatic route selection is applied only in the target area. By limiting the size of the area (50 mile radius) and hence the number of possible routes to be scored, satisfactory response times are realized. Automatic scoring of an operator selected route is applied to the enroute and return to base segments of the route profile where the operator uses his light pen to select a route that avoids heavy enemy defenses. (He uses his keyboard to enter altitude and velocity.) An automatically generated situation display supports this selection process. The route safety score is generated for each selected route as an accumulation of the exposure time to each threat weighted by a measure of threat effectiveness. By trying several routes a near best, or satisfactory, route can be selected.

The capability provided by the MPS, as described later in Section 4, is applicable to the RPV route profile planning function. It provides much of the capability which is required. There are however, two limiting factors. The automatic route selection algorithm severely restricts the maneuvers permitted within the high threat area to one turn no tighter than 120°. The least threat route selected does not exploit fully the capability of the RPV to perform high G maneuvers and to take several of them in close proximity to each other. Increasing the tightness of turn and/or the number of turns permitted increases the number of paths to be evaluated and thus rapidly increases response time.

The second limiting factor relates to operator time. When the operator designates the position, altitude, and flight mode for each leg of the flight profile, the operator time obviously increases as the number of legs increase. With many small enroute threats to be avoided, it is desirable if not necessary to plan a profile with many maneuvers. Under these circumstances operator time may become undesirably high.

3.3.3.4 Automatic Route Adjustment

This section addresses a proposed approach for automatically adjusting a preselected route to minimize the threat. Applied to the MPS ARS, it is an extension to the ARS capability. Applied to operator selected routes, it significantly reduces the operator time required to select and define the route profile.

Given that there are data in the data base on the enemy threats, there are a number of procedures that can be automated to adjust a route to avoid threat zones. Logic that adjusts a straight line segment intersecting a threat zone can create a sequence of shorter length segments chained by turns such that threats are avoided or exposure is minimized. Figure 3.3-2 illustrates the situation. The route segment intersects a single AAA lethality zone. Obviously, by moving the point on the segment that is closest to the AAA site away from the site to a position that is outside the threat envelope, the threat is avoided. For single threats, the logic necessary to do this is quite simple. For multiple threats, the logic is more complex, but conceptually similar. However, if discrete logic only is applied, the route path circumnavigating an AAA site or a defense complex would always reduce to a predictable pattern which the enemy would soon recognize. Hence, it is desirable to introduce a random factor in any automatic route adjustment process.

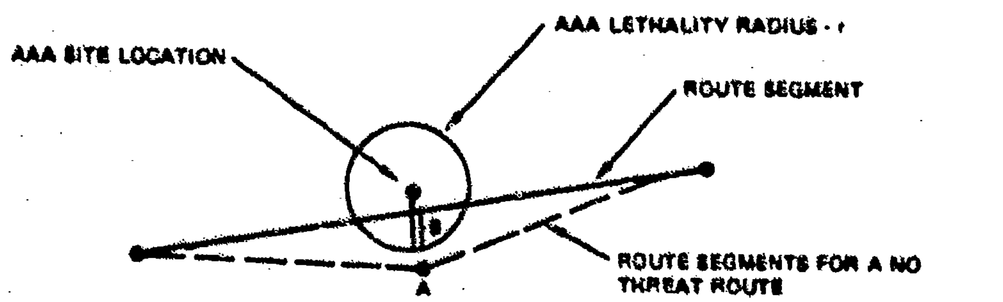

Figure 3.3-2. Route Segment Threat

Assuming an automatic route adjustment procedure based on combining discrete logic and a random factor, the following is required:

a. EOB DATA on enemy threats. These data must include coding which defines the direction to move away from the threat site and may include data on how far to move to avoid the threat. The data can be defined for the individual site, for individual defense complexes, or can be precoded into grids covering the total enemy area.

b. Program logic that establishes the threats to a route segment, selects a point on the segment within a threat area, and relocates that point using a combination of discrete logic and random selection. The route defined by the new point is then evaluated. Such logic may be iterated until a no threat point is found or until trials are terminated and a minimum threat point is selected.

c. A Program logic that can score relative threats to a given route and select the least threat solution. The Route Safety Scoring process as implemented in the Mission Planner System provides the basic capability required.

The data processing requirements for automatic route adjustment are addressed in Section 4.

The process is initiated by the operator who selects a route which is grossly favorable for threat avoidance and satisfies other operational requirements and constraints. The route segments can be relatively long and he need not be concerned if portions of the path penetrate threat zones. He does attempt to locate leg end points, however, in no-threat areas. The operator then selects "automatic route adjustment" and designates the width of the corridor within which adjustments are allowable. This is a variable. The processor then locates the threats which interact with the segment, and selects a point within the segment that is in a threat area. The program logic retrieves the direction to move and calculates the minimum distance (or probable minimum distance) to move to avoid the threat. This is based on the nominal lethality range for the particular threat "B" in Figure 3.3-2. A point is selected for trial that; 1) exceeds the minimum distance, and 2) is less than the corridor width. The path is modified to go through this point and the new path is scored. The random logic determines the distance to move the point and whether movement is from the site to avoid the threat, or through the site to the other side of the threat area. The process is iterated for each threat area. An original straight line segment fifty miles long, for example, may be converted to five segments chained by turns. The no threat route or the minimum threat route found will be displayed for operator approval.

The process described is suitable for a high defense environment to select a low altitude flight path which circumnavigates most enroute threats. The operational advantage of automatic route adjustment as described is two-fold. First, it provides a capability to examine many route variations automatically and select a no-threat or least threat route. The second advantage is perhaps more important. For an RPV flight profile with a primary, an alternate and a secondary target, plus the tactical desirability of avoiding long straight-line segments, it is estimated that about fifty legs are required. Considering that end points should be designated with an accuracy of several hundreds of feet, operator time to define each leg would be excessive. The automatic route adjustment capability makes it possible to plan a profile with many legs with relatively little operator time, since he must only identify the underlying, long, straight-line legs. The data generated by the processor are in a form that can be automatically converted into a command stack which is the form required for physical control.

3.3.4 Communications Relay Planning

3.3.4.1 Introduction

The route planning function discussed in the preceding section did not address the requirement to maintain line of sight (LOS) communications enroute and over-the-target or on-station. The planning requirements are complex because the RPV route and position must be considered concurrently with the position of the relay aircraft at each point in time. The relay aircraft in turn at any time may have to communicate with as many as 20 RPV at 20 different locations. The low altitude profile of the RPV and the altitude limitations of a relay aircraft can lead to significant terrain masking of LOS at long distances. The subsection introduces the operational assumptions that impact RPV route planning and communication relay mission planning. The assumptions are:

a. Loss of communications enroute is operationally acceptable providing the "blackout period" is short, i.e. on the order of a few minutes. Even longer periods may be acceptable if the blackout has been predicted and accepted by the planner.

b. The points on any route at which shielding will materialize depend upon the terrain features relative to the location of the RPV and the relay aircraft.

c. One communications relay aircraft will control multiple RPV vehicles at multiple locations.

These assumptions introduce complex planning problems. The flight path of the relay aircraft is a variable and the altitude of the relay is controllable within limits. The path and altitude of the RPV are also controllable within limits. The best solution cannot be found until all RPV mission profiles have been developed and the requirements for communications established.

The earth's terrain is the only constant factor. Automation involving terrain, however, is dependent upon digitized terrain data. The use of digitized terrain data introduces problems. First, digitized terrain data is presently not available for many potential operational areas. Nonetheless, it is assumed that in the time period that RPV will be operational, digitized terrain data will become more universal. Where digitized terrain data are available, the storage requirement for digitized terrain data is great. The amount of processing required to calculate terrain masking data useful for RPV route planning is also significant. To attempt to make these calculations on-line, while concurrently generating data needed for communications relay flight profile planning, appears to be unacceptable. All factors considered, an off-line solution to establish whether communications links are shielded appears necessary with the results being stored for on-line planning.

3.3.4.2 Shadow Effects on LOS Enroute Communications

The general nature of the terrain masking problem can be appreciated by visualizing the earth shadows that can be seen a few minutes before sundown since at a relay aircraft RPV range of 180 nm and with the relay aircraft at 60,000 feet, the shadow angle is about 2°. Figure 3.3-3, Schematic Diagram of LOS Shadow Geometry, illustrates the nature of the problem.

The upper portion illustrates the vertical profile of a line of sight shadow. The scale is exaggerated. With the geometry assumed, a ridge 3000 feet above the surrounding terrain, the relay aircraft at 45,000 feet at a range of 160 nm from the ridge, the length of the shadow is 22 nm. Increasing the altitude of the relay to 55,000 feet decreases the shadow length to 15 nm, a decrease of approximately 0.7 nm per 1000 feet.

The lower portion illustrates the plane geometry of the shadow area. The radial of the shadow edge depends on the position of the relay relative to the ridge (the length of the shadow area depends on relay altitude as described above). Assuming the 160 nm offset range, as above, and two positions, P_1 and P_2, 50 nm apart as illustrated, the maximum distance between the edges of the shadows from those two locations is 7 nm. A shadow area calculated for a position midpoint between P_1 and P_2, could apply to any point between P_1 and P_2 with a maximum shadow edge error of 35 nm, which is approximately 20 seconds of flight time.

With this introduction the approach to incorporating communications shadow effects in RPV route planning is presented. The approach presented is based on the following assumptions:

a. For RVP's in the enroute and RTB legs, loss of communication for short periods is operationally acceptable.

b. Over-the-target (after pop-up) continuous communications are required.

c. Shadow effects are operationally important for low altitude penetration only. Penetrations above 1,000 feet will be at an altitude where shadow effects need not be considered. If they must be considered because of some exceptional terrain features, standardized solutions can be made available.

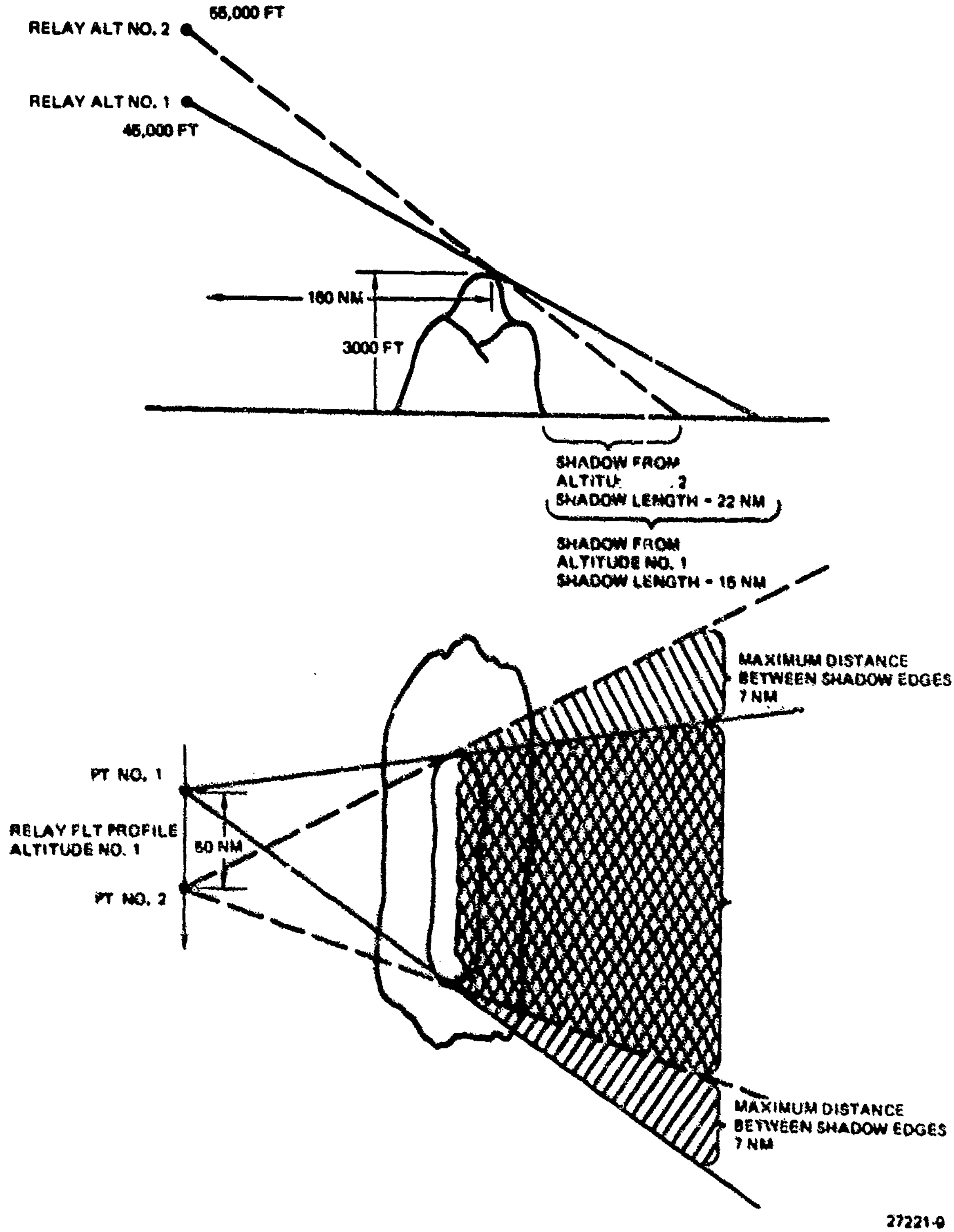

Figure 3.3-3. Schematic Diagram of LOS Shadow Geometry

d. Altitude errors up to 100 to 200 feet can normally be expected in the digitized terrain data used to calculate shadows.

e. Accuracy factors are such that terrain shadows calculated for a relay aircraft at an altitude and a plane coordinate position can be applied to any relay aircraft location within approximately 25 nm of that point, and within 5,000 feet of the altitude.

f. Any shadow depth (vertical distance terrain to the top of the shadow plane) less than flight altitude above the terrain is considered to be no shadow. The RPV altitudes above terrain considered are 200 feet, 500 feet, with 1,000 feet optional.

g. A shadow area smaller than about 10 nm, longest diagonal, about 10 seconds maximum shadow time is ignored. Within such areas, intermittent shadowing less than 0.5 is considered no shadowing, shadowing equal to or greater than 0.5 is considered shadowing.

Considering the shadow area geometry and the operational assumptions, shadow areas for a given operational theatre can be precalculated and be entered into the data base. The approach assumes that the most likely flight path for the relay is basically a perimeter around the enemy area which is the innermost limit of the "safe" area. This perimeter then is the set of positions which is minimizing the distance between the RPV and the relay consistent with relay safety. The perimeter or potential flight path is then divided up into arbitrary segments approximately 50 nautical miles long. Segment length is based on assumption (e) above. The midpoint of each segment is then used to calculate (off line) all the shadow areas which result from the specific terrain features inside the perimeter for each of three potential relay altitudes, e.g., 40,000; 50,000; and 60,000 feet. The location and configuration for each shadow zone is then stored to be used in on-line relay planning.

The calculations required to generate the shadow area data using digitized terrain data are not complete. Since the calculations will be made off line, the processing required to generate these data are not included in the RPV System ADP requirements. Should digitized terrain data not be available for an operational area, shadow areas can be manually generated, with some loss in accuracy and detail, and entered into the data base.

3.3.4.3 Application of LOS Shadow Area Data to RPV Route Planning, Enroute and Return to Base.

The inputs to this function are the "shadow areas" generated as described in the preceding subsection, the perimeter flight path, and a RPV trial route profile. Figure 3.3-4 illustrates the geometry of the situation and depicts, schematically, shadow areas as they might exist. The situation depicts one RPV route profile. Two ridge lines that will shield an RPV 200 feet above the terrain are depicted. For each ridge, shadow areas are depicted for selected segments of the relay flight and illustrated for a 50,000 foot relay

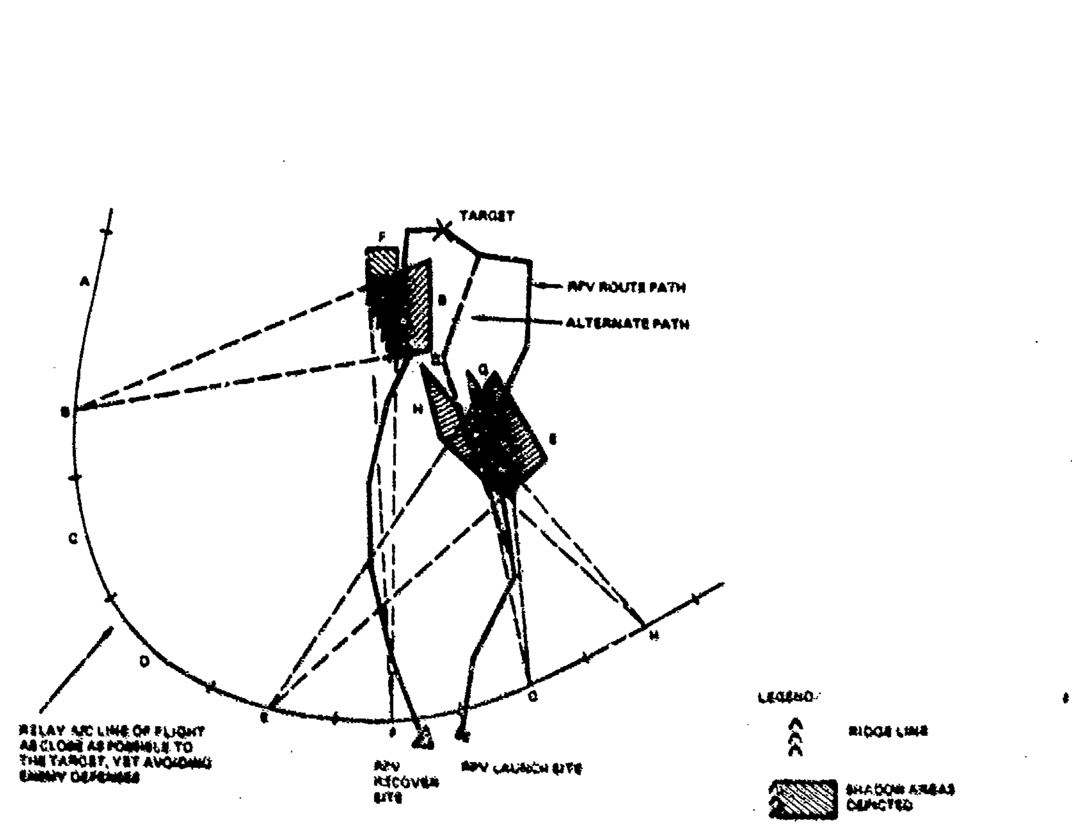

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Figure 3.3-4 Schematic Depiction of Shadow Areas

altitude. The reader can visualize how other shadow areas for other zones and for other relay aircraft altitudes can be superimposed. Many more ridge lines producing other shadows can be envisioned. As illustrated, there is a segment of the flight enroute to the target where the relay aircraft must be in zone "H" to maintain continuous line of sight communications. An alternate route that makes the RPV visible to other relay zones is depicted. Over most of the route, LOS Communications exists to all relay aircraft zones. For many operational areas, this is a likely situation.

In subsection 3.3.3, RPV Route Planning, the concept of route safety scoring and automatic route adjustment to minimize threat was described. The concept for incorporating LOS shadow area data in the bata base is the same as for incorporating threat data. Assume 50 ridge lines that generate operationally significant shadow areas, (a judgement factor to develop estimated data base requirements). If each ridge line causes shadows in four of the relay flight path segments and two RPV altitudes and two relay aircraft are considered, then 1,200 shadow areas must be coded. At 32 bytes per area data storage required is 38.4 K bytes. The data base requirements are not unreasonable.

The concept for use of these data when planning an RPV route profile is as follows. The RPV route is examined automatically to determine whether the route intersects a shadow area for the RPV flight altitude planned. Those segments of the relay flight that produce a shadow are identified and the time period that the RPV is shadowed is maintained.

If there is no segment that will provide LOS Communications, the operator is alerted. He may accept the condition or select to modify the route. The capability to automatically adjust a route profile to provide LOS communications is incorporated in the automatic route adjustment algorithm. ALlowable relay aircraft locations which provide LOS communications, (or alternatively, locations inhibited) are saved and are used in the planning of the communications relay mission planning. This process will be described in subsection 3.3.4.5.

3.3.4.4 Application of Terrain Masking to RPV on Station Planning

The approximate solution to the LOS communications problem developed in the preceding sections is suitable for the enroute phase. Over-the-target, where continuous broad band communications must be maintained, a more precise method for evaluating the effects of terrain mask is needed. The nature of the problem is essentially the same as in terrain masking of ground radar. The problem to be resolved is whether the RPV, at its altitude over the target, is masked from any of the predesignated relay zones. Conversely one must determine where the relay aircraft can be positioned to provide LOS communications. The problem is solved in the same way that the radar terrain masking problem is solved. That solution is to calculate the masking angles for targets. Figure 3.3-5, Masking Angle Geometry, illustrates the geometry of the problem.

Given the masking angle, the range to the masking terrain from the target, the range to the relay aircraft, and the altitude of the RPV over the target, the mimimum relay altitude that provides LOS communications can be calculated. Conversely, given a maximum relay altitude(s), the minimum RPV altitude above the target that provides LOS communications can be calculated. Additional programming is required to apply ground radar terrain masking calculation to the communications relay problem.

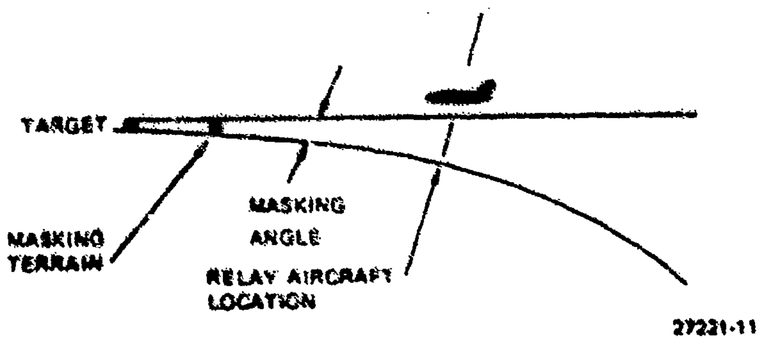


Figure 3.3-5 Masking Angle Geometry

The data base required includes masking angles for each target at 20 azimuths and the range from the target to the masking terrain over the azimuth range subtended by the relay aircraft line of flight. A single record is about four bytes. If one provides in the the processing algorithm a logic that interprets the absence of data as no masking, data need be coded only for targets that are actually masked, and only for those 20 azimuths which are operationally significant. For 200 targets, located such that a 46° sector is masked for each target, the data storage requirements are 16.8K bytes.

These data are used to establish what position(s) along the relay aircraft flight line provide LOS communications over-the-target. The Planned Weapon release altitude is used for the RPV. If LOS communications cannot be realized for any relay position, or if the target is at an extended range and a closer in relay position is desired, the calculation can generate the RPV pop-up altitude and release altitude required to achieve LOS communications for the optimum relay position. Alternatively, it can calculate a position to which the relay aircraft must move, e.g. 50 miles closer at 60,000 feet, to obtain LOS communications. The process conceptualized provides considerable flexibility. The program requirements that provide this capability are presented in subsection 3.3.5.

3.3.5 Integrated Communications Relay Flight Profile Planning

3.3.5.1 Introduction

The data generated in previous subsections defined the operational requirements that must be satisfied by the relay aircraft mission planner.

a. Over the target: Relay areas and associated minimum altitudes that provide LOS communications to each target. If the relay aircraft must be positioned off the predesignated relay aircraft line of flight the position and altitude for the relay aircraft are developed.

b. Enroute: For each RPV route profile the zones within which the relay aircraft can be positioned to provide LOS communications.

The communications relay planning requirement is to plan a relay aircraft mission profile such that all operational requirements will be satisfied. The possibility of enemy jamming is also a consideration. (This factor is introduced in subsection 3.3.5.3.) First, RPV relay mission planning requirements for communications alone are considered. Methods for incorporating jamming considerations are then addressed.

Operational assumptions that impact the planning procedure are:

a. There is more than one type of relay vehicle in the inventory of resources. Each vehicle type has a maximum altitude which is a function of its gross weight. (Fuel load is the primary variable.) The mission duration is a function of the vehicle type and the flight profile selected.

b. To satisfy the operational requirements and/or to provide additional anti-jam protection, two or more simultaneous communications relay missions may be planned. The implementation procedure that will be described provides for simultaneous planning of two simultaneous relay missions. If more missions are required, additional missions can be planned in turn.

The planning procedure is a two-step process. The first step is to plan a relay mission, or a set of missions, that satisfy the operational requirements developed by the route planning function. The second step in the planning process is to incorporate factors that will minimize the effect of possible enemy jamming.

3.3.5.2 Communications Relay Mission Flight Profile Planning

The requirement to plan the relay aircraft mission is to locate the relay aircraft along its line of flight such that at any point in time its location satisfies the enroute and OTT communication requirements. An obvious constraint is that it takes time to reposition the relay aircraft. Considering that the communications requirement for each RPV changes with time (position and phase) and that up to 20 requirements must be satisfied simultaneously, the problem is one of continuous matching of capability to requirements. To make the problem more manageable, a process that yields successive solutions for discrete time intervals is proposed. For purposes of analysis of the processing requirements, a 5 minute time interval is assumed. This time interval is small enough so that mission geometry is not significantly changed, and large enough so the number of processing iterations required are not excessive. (It should be noted that the use of 5 minute time intervals does not prevent a discrete assessment of requirements for LOS communications over-the-target that exist for shorter periods, e.g., one minute.)

The process proposed is as follows. For each 5 minute interval, starting at a time selected by the operator, data are obtained on all locations that can satisfy the communications requirements for RPVs airborne during that interval. Those locations that satisfy all requirements are "saved." The next time period is then examined and the same data are extracted. If relay aircraft locations are different the aircraft is repositioned with the constraint that the aircraft cannot be moved a distance that is not compatible with its air speed and climb rate. The process is interated over the period of the relay aircraft mission. In this manner, a relay aircraft flight profile and schedule can be generated.

An algorithm yielding a good solution requires many checks, enable rules, and operator overrides. Without flow charts and very detailed text, the process envisioned cannot be completely described. The principal features of the program however, are:

a. The operator can designate a preferred or a desired location for the relay aircraft for any time interval.

b. The process for planning a relay mission need not start with take off and first time at an operating location. It may be initiated at a point and time where requirements are demanding; e.g., where maximum altitude is required and very little flexibility in terms of path location is possible. From such a start point, planning can proceed back in time and forward from take off to landing.

c. Rules are provided to automatically select preferred locations for any time interval.

d. Rules are provided that through the iteration process allowable locations are reduced to a set of preferred locations which finally are reduced to selected locations which define a flight profile.

e. Orbiting is allowed but is not selected as a preferred tactic (unless so designated by the operator).

f. Two relay missions may be planned simultaneously. Additional missions that may be required to provide additional capacity or capability and/or backup communications may be planned in turn. (While algorithms can be conceived that would plan more than two missions simultaneously, subjective consideration is that processing requirements increase very rapidly with but little operational advantage vis-a-vis in turn planning).

g. If two simultaneous relay missions are planned, there is an assignment capability which assigns an RPV mission to a relay aircraft. Handover time from one relay to the other are provided. Unassigned RPVs are accounted for.

h. Over-the-target communications take precedence over enroute control.

i. If no complete solution is found, the best solution is generated and displayed together with data on requirements not satisfied (E.G. RPV mission # ______ masked over a segment of the route profile).

j. The process incorporates anti-jam considerations.

The program required to provide the capability described has been considered at a level of detail below what has been documented. The program and processing required to implement the program, documented in subsection 3.3.5.3, is based on these concepts.

3.3.5.3 Communications Relay Planning, Anti-jam Protection

3.3.5.3.1 Operational Factors. There are unknown data that significantly affect the requirements to plan for anti-jam protection. Questions that might be raised are:

- o What is the enemy capability to jam critical RPV communications links?

- o What is the capability within the communications subsystem to counter jamming?

- o How many jamming sites can the enemy activate?

To provide a basis for planning a relay mission flight profile that incorporates anti-jam protection considerations, the following are postulated:

a. Given that the U.S. has a significant number of RPV with a strike capability and that the system can be degraded significantly by enemy jammers, the enemy would seek to jam the RPVs. It is reasonable to postulate that jammers might be deployed in numbers comparable to the number of radar controlled AAA, e.g., around 800 sites in a sophisticated environment.

b. The enemy's extensive jamming capability would be used judiciously. Jamming widely used might degrade his own electronic systems; also, it costs to jam.

c. For an active jamming station, the closer the jammer approaches in-line geometry; (relay aircraft, jammer, and RPV in line in that order,) the more effective the jammer

d. If the jammer is not in line (within a few beamwidths), the closer the relay aircraft is to the RPV the less effective the jammer will be. This results from the narrow beam communication techniques envisioned.

e. During mission execution near real time data on active enemy jammers can be made available. These data can be used to predict the short period effectiveness of jamming.

f In some employment environments where the enemy capability to jam is limited, data will be available to predict with reasonable assurance the probable location of enemy jammers and their performance parameters.

3.3.5.3.2 Planning Relay Missions for an Intense Jamming Environment. Given an intense jamming environment, it is reasonable to assume that the cost to implement an algorithm that discretely selects a "best" relay position(s) is too high for the possible benefits. This is due to the number of potential jammers that must be considered. The alternative is to select relay positions that, within operational constraints, minimize communications distances and maximize the probability that active or known jamming sites are not in line with the relay aircraft/RPV communications path.

Minimizing distance is easily implemented. Subsection 3.3.5.2 described the procedure for selecting route profiles and route schedules that could satisfy the communications requirements without jamming. To minimize distance, one selects that position that minimizes the length of the longest critical communication path.

Providing a communications path that minimizes the probability of the relay/jammer/RPV being in line can be provided by providing simultaneous relay positions for two aircraft. This is certainly a viable solution in an employment environment where intense jamming can be encountered. Having selected a location for the relay aircraft that minimized the length of the longest critical communications path, a second location is selected that, within a cone (e.g. 30° to 60°), is at right angles to the primary communication path and minimizes range. Figure 3.3-6 illustrates the geometry of an employment environment and relay assignments that such an algorithm might have generated. As illustrated, over-the-target control of the strike RPV's is assigned to the closer relay aircraft. The alternate control link is roughly normal to the primary line. Enroute, the control is by the closer relay with the exception illustrated. Terrain masking generates such exceptions.

3.3.5.3.3 Planning/Replanning Relay Mission in a Predictable Jamming Environment. There will also be employment situations where the jamming environment can be predicted; environments that introduce relatively few jamming sites. In the execution phase it can be predicted that jamming being encountered will persist. Thus, predictions of probable jamming can be made, and planning can be initiated to minimize the effect of the jamming. Technically the problem is identical in the planning and in the execution phase. The only real difference between preplanning and replanning, or adjustment, is that for replanning time factors are more constraining.

Given the requirement to communicate with an RPV in a specific time period (assume an RPV over the target) and the location of probable jamming sites, the problem is to select a relay location that provides LOS communications and maximizes the signal to noise ratio. Signal strength is a function of range only. The strength of the noise signal can be calculated provided the signal characteristics of the jammer are known. With these data it is possible to calculate the S/N ratio for several relay aircraft locations and find which location provides an acceptable or a most acceptable S/N ratio. Note that an acceptable solution may necessitate penetration of enemy territory and expose the relay to an enemy threat. From a data processing point of view the problem is analogous to the ECM burn-through calculation which is presently implemented on the Mission Planning System breadboard

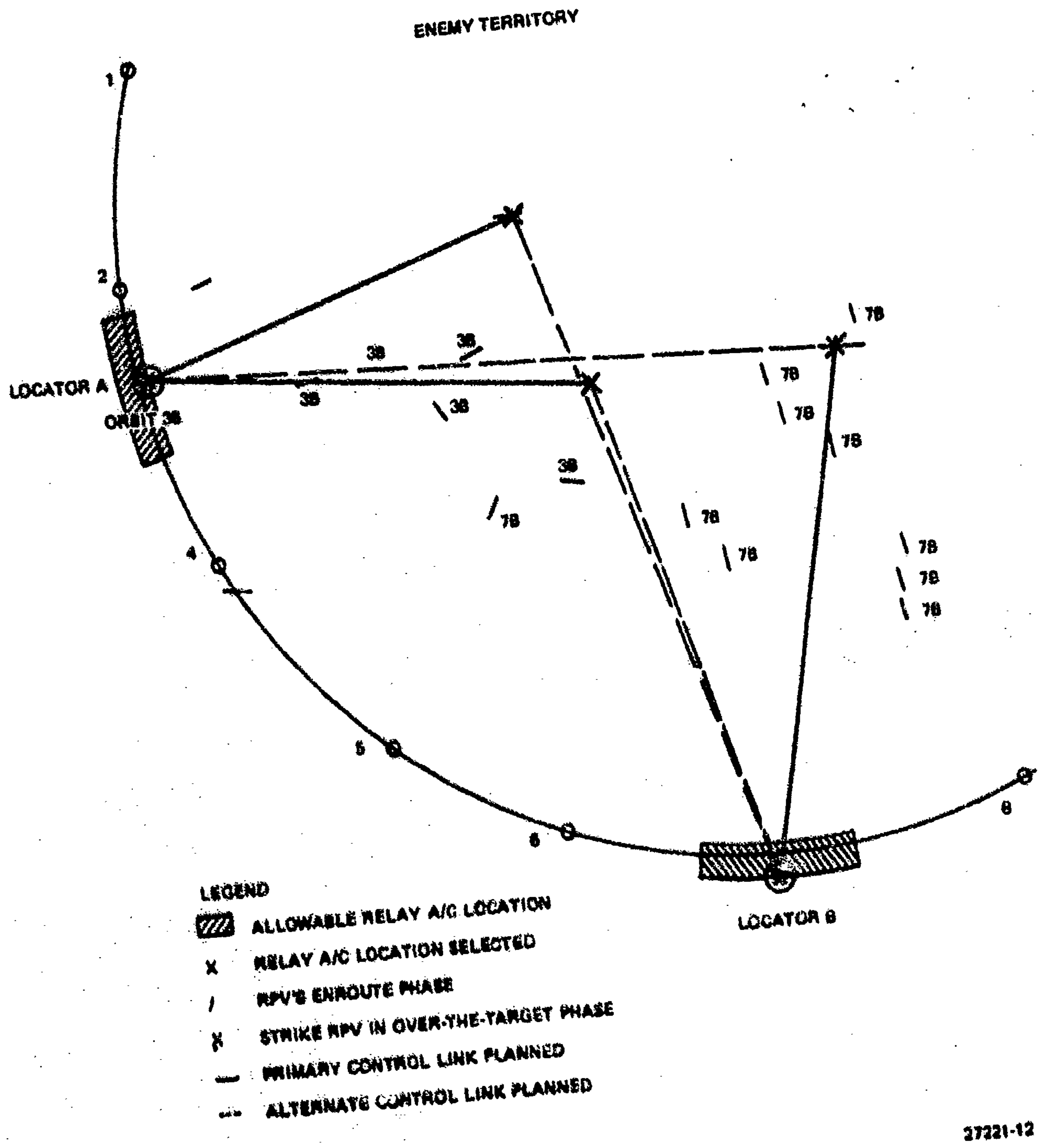


Figure 3.3-6 Geometry of an Employment Environment and Relay Assignments

3.3.6 Over the Target Planning, Strike Missions

3.3.6.1 Weapon Selection Functions

The objective of the weapon system assignment function is to select that combination of ordnance, delivery vehicles, and attack tactics that is most effective in achieving the mission objective with the most acceptable risk. These three selections (ordnance, delivery vehicle, delivery tactics) are interrelated and mutually constraining. The best selection cannot be made unless available options on all three are considered; either concurrently or iteratively.

In planning, the initial consideration is ordnance selection. Available ordnance suitable for the target must be selected. How much ordnance of a given type is needed is a function of the target type (physical features and dimensions) and the delivery accuracy. Delivery accuracy, in turn, is dominated by the delivery tactic which is largely established or constrained by the particular delivery vehicle and ordnance selected. The final determination of how many aircraft or RPV's are needed to deliver the necessary quantity of ordnance is determined by the delivery vehicle and its specific configuration for that ordnance.

The threat factor is a principal constraint. Target defenses may be such that certain combinations of delivery vehicles and delivery tactics are unsuitable or undesirable and may be excluded by the Commander's guidance. Where options are available, the threat must be assessed before the most suitable weapon assignment can be made. Other factors such as weather; the need to assign multiple strike missions on the target, suitability of ordnance mixes, and the constraints of resource availability simply add to the complexity.

Introduction of the RPV into the inventory does not change the nature of the weapon selection problem. For manned aircraft systems the planning load is such that automated support to the weapon selection problem is necessitated by the requirement to rapidly assess the effectiveness and relative risks of available alternatives. The same decisions apply to a pure RPV force though initially RPV's may provide fewer options, vis-a-vis manned systems, making the problem somewhat simpler.

In a mixed force of manned aircraft and RPV's, the total number of available options that must be assessed is increased over pure RPV or Manned A/C forces. More important, perhaps, the RPV system and the manned system differ in respect to capability to achieve a mission objective and acceptable risk. The consequence is that it is necessary to analyze in considerable detail the relative effectiveness and survivability factors for RPV's, vis-a-vis manned systems for each mission prior to assignment. Thus, the load is heavier for a mixed force than for a pure force of either type. The conclusion is that automated support for weapon selection is a firm requirement.

3.3.6.2 Procedures and ADP Support for Weapon Selection

Weapon selection, as used in this report, is the selection of ordnance, the delivery vehicle, and delivery tactic suitable to the strike mission objective. It is assumed that ordnance effects data have been generated by intelligence. Ordnance effects are expressed in terms of delivery accuracy CEP's. Delivery accuracy in turn is a function of specific carriers and delivery tactics.

Under the Mission Planner System program, ADP approaches to support of the weapon selection function have been studied.

The process implemented in the MPSBB for automated support in Weapons Selection is based upon the Joint Munitions Effects Manuals (JMEMs). These tables are organized by aircraft type, target type, and ordnance type. For each aircraft type/target type pair the relevant ordnances are listed along with delivery tactics and fusing data. In addition, an effectiveness measure called the "single pass probability of destruction (SSPD)" is provided. This value is based upon empirical studies and is used by the MPSBB.

The MPSBB data base stores the three ordnances with the highest SSPD for each aircraft/target type pair. When a target type and an aircraft type have been selected, the three ordnances are displayed and the planner selects the ordnance which he prefers. Provision is made for selection of other ordnances besides those displayed. If a displayed ordnance is selected, the system will calculate either the probability of success for a given number of vehicles, or the required number of vehicles for a given (desired) probability of success.

The best ordnance, weapon carrier, and tactic may, however, be undesirable (or unacceptable) because of the target defenses. Consequently, it is important to assess the threat to a mission penetrating target defenses and delivering the ordnance particularly as it affects the delivery tactic. The route safety scoring capability described in subsection 3.3.3, Route Planning, is applicable. The options include Automatic Route Selection or Route Safety Scoring of a designated penetration profile. Use of such threat analysis in the weapon selection process is allocated to the operator. It is especially applicable to choices between RPV and manned systems in a mixed force. Commanders guidance may be the dominant factor in the choice.

ADP Support required to implement the weapon selection function as described is as estimated in Section 5.

3.3.7 On-Station Planning, ECM

3.3.7.1 Introduction

The objective of ECM on-station planning is to evaluate the effectiveness of available ECM techniques in suppressing the enemy defense capability, to select the most effective ECM against the threat to be encountered by planned missions, and to plan the tactics that will maximize the effectiveness of the ECM support selected.

ECM is a support mission. The requirements for ECM are derived from an analysis of the threat to planned missions. The effectiveness of ECM missions can be assessed only in terms of the degree to which ECM degrades the capability of the enemy defenses to engage friendly missions. There are basically two ways of reducing the effectiveness of the enemy defense capability through the application of ECM techniques. One is directed at preventing effective engagement by suppressing the capability of the enemy defense system to detect and track friendly flights and/or prevent effective control of weapon intercept. The ECM techniques available for this application include:

- o Noise jamming of early warning, detection and tracking radars and essential communications links.
- o Various types of decoy jamming and "smart jamming" techniques to induce track break after weapon launch

The specific mission types addressed are Noise Jamming and Chaff Precursor Mission.

Another way of using ECM to degrade enemy defenses is to induce the enemy to expand their defensive capability against false targets and non-existent tracks and threats. To accomplish this, various diversionary and decoy tactics and techniques can be applied, e.g. expendable drones that generate tracks appearing to be manned aircraft flights. The effectiveness of such tactics and technique are highly dependent upon the campaign strategy and tactics employed. The capability to plan such a mission, once the mission objective is established, is not substantially different from the direct support missions that are addressed.

3.3.7.2 ECM Noise Jamming, Mission Planning

Standoff Jamming, Escort, and On-Board Jamming are similar in that these missions suppress the enemy electronics systems by introducing noise into the victim receiver. To be effective, the noise in the victim receiver must exceed the signal being protected by a predetermined threshold

The variables in calculating jamming effectiveness as defined above can be quantified and the relationships among the variables are known. To calculate the strength of the signal to be protected, the following variables are input:

- o Geographic location, power output, and the signal characteristics of the victim radar.

- o Range to the mission aircraft that are to be protected, a function of flight profile.

- o Radar cross section of the mission aircraft which is a function of the type aircraft and their configuration, aircraft formation and the aspect angle.

Given these inputs, the strength of the signal to be protected can be calculated along a given flight profile.

To calculate the signal strength of the jamming signal, the following variable are inputs:

- o Jamming signal strength and jamming signal characteristics which must be matched to the victim radar receiver characteristics.

- o Distance from jamming signal source to victim radar.

Given these inputs, the strength of the noise signal in the victim radar receiver can be calculated.

While the problem can be quantified, the application in a dynamic environment is not simple. The mission aircraft are continuously moving relative to the enemy defenses. The noise source will be moving in an orbit or in some other mission flight profile (in these applications, it is assumed that the noise source is not on the penetrating aircraft or RPV so that triangulation and/or home-on jam techniques are nullified). The noise to signal (J/S) ratio must be calculated along the flight path of the mission aircraft being protected. If the required J/S ratio along the flight path of the mission being protected is not achieved, complete defense suppression is not achieved. Investigation of the J/S ratio along the route will determine when, where, and for how long, the mission being protected is exposed to the defensive radar nets. Options available to achieve more effective defense suppression include modifying the noise source, modifying the flight profile of the jamming mission, and/or modifying the flight profile of the mission being protected. Assuming, however, that the flight profile of the mission being supported was initially planned to minimize exposure, the primary options are to modify the flight profile of the jammer or to add more noise sources.

Manually, this is a time-consuming process. As part of the MPS algorithms have been developed that automatically calculate burn through; that is, a J/S ratio that exceeds a pre-established threshold value. The data can be presented so the effectiveness of alternative plans can be quantitatively compared. The process of calculating effectiveness and presenting data to the operator on the effectiveness of alternative ECM plans is described in Section 4. The process is applicable to the planning of RPV ECM missions. ADP support requirements to implement such ADP support to RPV mission planning is addressed in Section 5.

3.3.7.3 On-Station Planning, Chaff Precursor Missions

There are a number of applications of chaff to defense suppression The chaff precursor mission is commonly used to screen multiple flights of friendly aircraft penetrating on a route. In other applications, chaff may be used to break track or to add clutter to the victim radar when aircraft penetrating target defenses are within the defense lethality zones. These latter applications are typically on-board techniques used reactively when a flight penetrating target defenses is being tracked.

Since the chaff precursor mission is a primary defense suppression support mission, on-station planning for the chaff precursor mission is addressed. However, the principles described can also be extended to other types of chaff missions.

In planning a chaff precursor mission, three decisions must be made:

- What kind of chaff bundles to drop.
- Where and when to drop them.
- How much to drop (drop interval).

The initial requirements data are the outputs of the route safety scoring function which yields data on the exposures to be screened (see subsection 3.3.3). Other data required includes:

- Location and dimensions of the screening corridor, and length, width, dept, and time period over which effective screening must be provided.
- Radar cross sections of the flights to be screened.
- Technical data on the enemy radars to be countered.

The kind of chaff to drop is established from the technical data on the victim's radar(s), specifically the radar frequency bands to be covered. It is expected that this will be accomplished by table lookup. The second decision, where to drop the chaff bundles, is a problem of determining the movement of the chaff reflectors as a function of time, drop rate, dispersion rate and horizontal displacement. The constant factors are the physical characteristics of the chaff reflectors and the dispensing techniques; the variable factors are atmospheric conditions, horizontal winds, vertical component of winds, turbulence, and atmospheric density. At any given pressure altitude, the principal variable is horizontal wind. Given the dimensions of the chaff corridor required and the movement factors, the drop point can be calculated quite simply. There are two constraints, the maximum drop altitude feasible and the optimum time between drop and the time an effective corridor is formed.

The final decision, how much to drop to provide continuous screening, is determined from the dispersion factors described above and the technical data on the chaff reflectors.

Consideration of the type of decisions required, the type of input and output data required, and the nature of the processing, leads to the conclusion that automated support to planning a corridor chaff mission can, and should, be provided. This is currently under study in ADMPS. The data base and data processing requirements presented are based on an implementation concept that applies planning factors for pod selection, still air drop and dispersion rates, and chaff effectiveness versus time after drop (chaff density in still air). Two variables are introduced by the operator; horizontal wind components and an atmospheric dispersion factor related to the air mass stability. With these inputs, the location and density of the chaff cloud versus time is automatically calculated and drop intervals are established along the flight path. Requirements, if any, for parallel drops can also be calculated.

The algorithms required to automatically generate a chaff precursor mission flight profile and to establish the location and time on the flight profile where the chaff is to be dispensed have been conceptualized. Subsumed is a capability to select the chaff pod and the dispensing technique most suitable for the mission. The ADP support required to implement the process is addressed in Section 5.

3.3.8 Reconnaissance Mission Planning Control Considerations

Analysis of the requirements to plan and control RPV reconnaissance missions was not required for this study. However, need for an RPV Command and Control System that can accomplish reconnaissance mission planning and control has been considered in the development of the RPV Command and Control system concept.

Relative to planning, the route profile planning and route profile coding procedures which have been described are applicable to reconnaissance missions.

Reconnaissance target grouping and on station planning for RPV reconnaissance is similar in every respect to manned systems. The ADP support for reconnaissance mission planning, currently being developed under the advanced development MPS study, is applicable to RPV with only minor modification.

The physical control of reconnaissance can be provided by the launch, enroute, return to base, and recovery control system described in subsection 3.2, Physical Control of RPV. The special requirement that the reconnaissance RPV vehicle introduces in the need for the ground station to receive and process intelligence data obtained in real time or near real time. This requirement is not, however, RPV unique since it also applies to manned systems. The RPV does however introduce one unique factor. Since the RPVs may be used to obtain intelligence data in high threat environments where the probability of loss is relatively high, the requirement to provide an inflight intelligence reporting capability is more imperative.

Implementation of real time and near real time transmission and processing of intelligence data impacts all elements of the RPV system. The RPV vehicle must be instrumented to store and forward intelligence data collected. The communication links through the relay aircraft must be designed to provide the communication links and link capacities required. The ground based element must be capable of receiving, processing, and distributing the data. The ground based element can be made a part of the DCF or, alternatively, may be an element of the intelligence processing system colocated and interfaced with the DCF control element.

3.3.9 Launch and Recovery Control

The assumption that dominates the requirements to plan launch and recovery operations is that the launch and recovery operation will be standardized. For each launch and recovery site there will be preplanned launch and recovery corridors. Standard emergency procedures will be preplanned. When one accepts these assumptions (Air Force operations personnel who have been briefed on the concept have accepted them as valid) the requirement to plan launch and recovery is quite simple. The following requirements are inherent:

a. For an operational day (or other operational period) select those preplanned launch and recovery corridors at each launch and recover site that may be used (or identify those not permitted). Operational factors such as zones restricted for Army use, changes in friendly order of battle, and RPV launch and recovery corridors reserved for training may cause temporary restrictions.

b. Within an operational day, the factors that affect the selection of acceptable launch and recovery corridors are resource availability, weather, and the schedule requirements. The considerations are simple. Resource availability refers to the availability of launch and recovery facilities (RPV availability was verified in the assignment function). The principal weather factor is wind and the preferred launch corridor will be up wind. Threshold factors for maximum wind, maximum cross wind, and maximum trail wind components can be established as well as minimum for ceiling and visibility The latter apply particularly to recovery. Schedule factors relate to the maximum launch and recovery rate at any launch and recovery site

The simplicity of these factors leads to the conclusion that there is no requirement to provide a specific algorithm to support corridor selection.

Status data on launch/recovery facilities, and weather are required as are data on RPV operations already scheduled. With an automated system, these data are in the data base and can be automatically displayed on request. It is well within the capability of the operator to manually assess status and select the launch and recovery site and corridor.

An algorithm providing automatic schedule checks and data on the available launch and recovery "time slots" that are equal to, less than, or greater than the desired launch and recovery time slot would be a useful aid. As will be addressed later, such a capability is required for monitoring the operation. A schedule checking algorithm is required to examine the total schedule for possible conflicts. These same ADP capabilities are provided for other applications and should be applied to support the selection of launch and recovery site and time.

3.3.10 Plan Review

The preceding sections have addressed discrete planning functions with little consideration given to the requirement to insure schedule consistency between individual missions and for the force. It might be asserted that appropriate coordinated schedules must have been generated since individual schedules are controlled by the time-over-target or time on station. Also, there is an on-going schedule check since launch, enroute, and recovery schedules were generated to be consistent with the controlling time and, at the same time, not to overload communications relay missions, launch and recovery sites, or other mission-essential facilities. However, because of the number of missions planned (up to 240), and concurrent planning by multiple operators, undesirable (or unacceptable) schedule adjustments may have been introduced in individual missions or schedule conflicts may have been introduced inadvertently. As a result, there is a firm requirement to review the total operation as planned to establish whether coordination of schedules has been achieved. Further, Current Operations would always want to know whether adding a new mission to the schedule or adjusting a mission schedule introduces conflicts.

Accepting that there is a requirement to review a total schedule (Plan) for internal consistency, the next consideration is how it should be implemented. On the MPSBE, there is a capability entitled Time Sequence Review (TSR). The capability, as implemented, provides a graphic display of the location of all airborne missions time-sequenced through a specified time period. Simply stated, the flight plan for each mission is used to generate synthetic track data, which is displayed with update rates greater than real time. The operator can then view the planned movement of "missions" over extended time periods in a few minutes and assess the time and space relationships.

In addition, the TSR capability automatically detects airspace conflicts, both lateral and vertical. The constraint is that an airspace volume surrounding a mission is not permitted to intersect an airspace volume around another mission. This capability can be applied to RPV mission planning to insure that the flight profiles and schedules do not introduce airspace conflicts. The capability can be applied to RPV missions only or to all missions planned in a mixed force.

The requirement to provide a plan review capability was also studied under the SEEK FLEX Study and for the Automated TACC. The implementation concept developed for those studies was a relatively simple check in real time of the individual mission schedules at critical points along the route. Constraints were introduced; e.g., maximum arrival rates allowable, maximum sustained arrival rates allowable over a given time period, or no Bomb Damage Assessment missions on a target within a time period less than Δt minutes after strike or greater than Δt minutes after the strike. This limited concept can provide much of the capability required to automatically review a force plan for consistency and conflict.

ADP support requirements to provide a plan review capability are addressed in Section 5.

3.3.11 Mission Monitoring Functions

3.3.11.1 Operational Requirements and Assumptions

There are two aspects to the mission monitoring function. One aspect is the monitoring of the air vehicle's subsystem performance and the relationship between state planned and state achieved (e.g., time of arrival at a checkpoint). The outputs of such monitoring are control directives necessary to achieve the desired state. In manned systems, such monitoring is accomplished by the pilot. In RPV systems, the controller exercises physical control (subsection 3.2). The other aspect of monitoring, to be addressed in this subsection, is the monitoring of the progress of all force missions. The operational requirements are to assess the state of mission essential resources and the progress of mission execution in accordance with the plan. Additionally, the effect of any new factors (updated intelligence and current weather) on the force employment plan are assessed, as well as any deviations from the plan.

The introduction of RPV into the inventory does not significantly impact the force monitoring function. The operational requirements are basically identical, irrespective of whether the force is a pure manned force, a mixed force, or a pure RPV force. The only differences that can be envisioned are these:

a. Because RPV is capable of maintaining an exact preplanned profile and schedule, there are increased opportunities to plan close coordination between RPV missions, or between RPV missions and manned missions. More exacting coordination may, however, impose requirements for more exacting monitoring to establish what adjustments are required, if any, to achieve the desired coordination.

b. The fact that near-real-time communication between the physical controller and the force control element is operationally feasible introduces additional capabilities to exercise near-real-time control. This may require the maintenance of current status in more detail than is presently required (e.g., more frequent position reporting). This same capability also means that schedule deviation can be detected and reported automatically (human error and prejudice eliminated). Therefore, reporting by exception may be more acceptable for RPV's vis-á-vis manned aircraft.

These differences are not differences in kind; they are differences in degree only. All factors considered, the requirements for monitoring RPV vis-á-vis manned aircraft are basically identical.

3.3.11.2 Implementation Concepts for ADP Support to Mission Monitoring

The basic premise is that the 485L system can provide the monitoring capability required by the Air Force for resource status monitoring.

ADP support is, however, required to exercise physical control of the RPV's. Once ADP is established independent of the requirement to monitor mission progress, it provides a capability to automatically report mission status from the RPV to the control station. In turn, the capability to generate status reports, either actual status or exception reports, can be implemented with little additional cost in terms of data base required and program and processing requirements. Were this desirable, then the following capability is considered as required:

a. Automatic generation and transmission of progress reports, including launch, strike, on-station, off-station, recovery and enroute checkpoints.

b. Automatic generation and transmission of exception reports whenever a condition exists that may, or will, result in an operationally significant deviation of the flight profile and schedule from that planned.

If the 485L data source terminal (DST) is collocated with the DCF, or is an integral part of the DCF, no additional ADP support is required to provide this capability beyond a program interfacing the physical control processor with the message composition processing.

In addition to the above, the plan review capability described in subsection 3.3.10, Plan Review, provides an automated capability to review planned operations and automatically detect facility overloads and airspace conflicts introduced by the plan. To apply this capability to mission monitoring requires only that actual times be substituted for planned times and the review program be executed. The concept is as follows. Schedule exception reports are automatically initiated whenever a deviation exceeding a preset threshold is detected. Such reports are input into the plan review function which automatically establishes whether the deviation generates any schedule conflicts or overloads. If it does, an appropriate alert message is formulated and transmitted as follows:

a. The message is displayed to the operator exercising physical control of the RPV. This message also includes other addresses for this message as dictated by S.O.P.'s.

b. The physical controller takes that action necessary and authorized to resolve the conflict. For example, if an RPV is returning to the recovery point and the recovery facility is overloaded, an orbit turn or hold may be directed by the physical controller to resolve the conflict.

c. Transmission of the exception report to other addresses is authorized by the operator.

d. If the schedule deviation is transmitted to the agency exercising force control, the report will be automatically processed and displayed to the responsible operator. Within the TACC, this will be a function of the 485L system. No additional capability is required.

e. If the schedule deviation is transmitted to the CRC, the unit exercising airspace control, the report will be processed the same as any other schedule deviation report.

In general the ADP capability to support functions involving the supply of data to the TACC for mixed forces is sufficient to support the total mission monitoring function for a pure RPV force deployed without an automated TACC.

ADP support for the monitoring function is addressed in Section 5.

3.3.11.3 Mission Adjustment and Replanning RPV Missions

The mission monitoring function provides data on mission deviations and status data that may require adjusting the operation of the force to minimize the effect of detected deviations. Additionally, within the force there is a capability to receive and assess updated intelligence and status data and immediate requests for missions. The 485L system provides automated processing and display of such reports which may initiate mission replanning. It is assumed that the 485L capability is available at the TACC, and that there is a DST co-located with the DCF (or that the capability of a DST is an integral part of the DCF).

This subsection addresses the requirement to plan an adjustment to an RPV mission and to cause the RPV to execute the adjustment. Requirement to adjust the communications relay mission(s) to minimize the effect of jamming is addressed in the next subsection.

The functional capability required to replan an RPV mission is basically identical to the preplanning function. The only difference is that for replanning it may not be necessary to consider every segment of the mission.

Implementing a new RPV mission or adjusting one already planned introduces a unique RPV requirement, the necessity to code the changed plan and to insert the plan into the RPV system. If the RPV has not yet been launched, the process is identical to that described for preplanning. Response time requirements are, however, more critical. The concept for current operations makes it imperative that the capability be provided to automatically convert a planned profile into a coded flight control program. (It is assumed that the response requirement for RPV's is comparable to those for manned missions.) If an airborne divert is desired, the revised program must be inserted into the RPV system and executed while the RPV is in flight. The concept for physical control described in subsection 3.2 provides this capability.

The conclusion is that the requirement to replan RPV missions and to adjust preplanned missions and to execute the controls to implement the new or modified plan can be satisfied by applying the capabilities provided for preplanning and for physical control. As before, the capability is sufficient to perform the necessary replanning or adjustment in the absence of any part of the 485L system.

3.3.11.4 Mission Adjustment and Replanning Communications Relay

There are any number of conditions that can initiate a requirement to replan relay missions. For example, relay mission delays, aborts, etc., can materialize. One critical cause for replanning would be to reduce vulnerability to enemy ECM. When jamming is encountered, the location of the jamming source can, in many situations, be established as a strobe line, or a location which is an intersection of two or more strobe lines. From an analysis of the jamming signal received and the intelligence data on enemy jammers, the technical characteristics of the active jammers can be established. With ADP support, this can be accomplished in near real time. If one simply considers the geometry of the problem, a relay aircraft at a range of 180 nm from a jammer flying at 500 knots normal to the jammer line of sight will change the line of sight "off angle" at a rate of 2.65° per minute; at 100 nm, the change rate is 4.9° per minute. Assuming reasonable directivity of the communications beam, the relay aircraft can be repositioned in five or ten minutes, such that the new location is significantly more effective.

Enemy tracking of the relay as a countermeasure is fully effective only if the jammer and the target are co-located. The enemy problem is further compounded if there are two relay aircraft on-station. The enemy also does not know ahead of time the target objective of an RPV that he may have detected. The jammer(s) he has chosen to activate may not be the most effective against an attack or attacks that will materialize in five or ten minutes.

The capability required is to assess in near real time the effect of a predictable or experienced jamming environment on the relay communications links and to establish how the relay aircraft might be repositioned to minimize the effect of jamming being encountered. The ADP support required to provide such a capability has been described in subsection 3.3.5.3.3. Replanning of relay missions as a result of other causes is well within the capability of the planning system that has been described.

3.3.12 TACS Interfaces

The requirements to interface the RPV Composite Group Command and Control System with the TACS is similar in every respect to the interface between a manned aircraft wing, its Tactical Unit Operations Center and the other TACS elements. The TACC inputs the frag order to the RPV Group plus directives to adjust and redirect missions. The RPV group reports data to the TACC on the status of resources, mission schedules developed by the RPV planning function, and progress reports of missions in the execution phase. There are, however, certain unique features of RPV operations and the RPV command and control system which will, or may, affect the quantity of data reported, as well as the kind of data.

These considerations are largely dominated by operational factors. It is not possible to resolve them from an analysis of the RPV System alone. They must be resolved by the using commands. They probably cannot be resolved until the RPV system concepts and the operational concepts for employment are clearly specified. A general conclusion can, however, be reached. The opportunity exists for greater data exchange between the TACS and the RPV force. No additional functional capability is required; it is a quantitative factor only. The cost to provide additional capacity, if that is operationally desirable, is not high. It is a factor that does not significantly impact the RPV system design or the design of the RPV system TACS interface.

SECTION 4

MISSION PLANNING SYSTEM APPLICATIONS TO RPV COMMAND AND CONTROL

4.1 INTRODUCTION AND BACKGROUND

The growth of aircraft technology and the requirements arising from the many problems of modern tactical air operations have multiplied the amount of information that must be considered in mission planning. Conversely, these same factors have decreased the time available to do so. Automated aids are therefore necessary which provide the planner with the capability of rapidly reviewing essential elements of information and allowing him to decide, at each critical point in the planning process, the direction in which he wishes to proceed. The critical decisions are formulated by the planner through his unique ability to determine patterns and trends when appropriately presented with a large number of factors.

In a tactical air environment, a planner is almost invariably in a situation where the number of targets which must be attacked far exceeds the available resources. Further, operation in the threat environment is hazardous to the resources. This means that the planner must face four major responsibilities:

a. Insuring that each mission is a success.
b. Insuring the safe return of his resources.
c. Insuring that the value of attacked targets is high.
d. Insuring that his resources are allocated in the best manner.

As mentioned before in most tactical environments these responsibilities must be met within a limited time.

Under the ground data processing element (691F) of the Advanced Development Program 691, "Force Protection Program", the USAF Rome Air Development Center has sponsored the development of a Mission Planner System that offers the capability to preplan and/or simulate combat and combat support missions for manned aircraft. The system includes automatic data processing and display equipment as well as necessary computer programs to: 1) rapidly develop and evaluate alternate plans, 2) through an iterative process, to derive an effective plan for a given mission, and 3) evaluate the overall effectiveness of this planning.

The Mission Planner System is not a single path "canned" process, but rather a comprehensive network of multiple choices. In deciding which path to take at any given mode in the network, the planner is assisted by automated data retrieval and presentation techniques, incorporating comprehensive effectiveness/performance criteria. The System enhances the operator's ability to perform detailed planning of associated combat and support missions, to effectively use his available resources to satisfy all mission requirements, and to maximize the probability of mission success.

The Mission Planner program achieved a significant milestone in December, 1971, with the successful development of a comprehensive group of computer programs known as the "breadboard system." These programs have been installed for test and evaluation, on a commercial data processing system at the Armament Development and Test Center, Eglin Air Force Base.

The Mission Planner Breadboard can be applied, almost in its entirety, to RPV planning. Subsection 4.2 discusses in detail the overlap in preplanning functions for manned aircraft and RPVs.

In addition, an Advanced Development Mission Planning System (ADMPS) is being developed for the Air Force. This ADMPS will have expanded capabilities over the breadboard system. The present breadboard system handles only strike and ECM support missions. The ADMPS, however, will handle additional missions, such as reconnaissance and ELINT missions.

The ADMPS will also have expanded ECM capabilities in areas such as chaff and other expendables which have direct applicability to RPV planning.

In considering the use of the mission planning breadboard for manned aircraft and for RPVs, there are many common functions, as well as unique functions, for each. Not only may the functions be different, but the required detail and accuracy of the plans may differ for manned aircraft and RPVs. There are also unique functions required for the different types of missions such as interdiction, reconnaissance, and ECM support. The following subsections are concerned with these factors as applied to the Mission Planner Breadboard System.

The first subsction (4.2) describes the Mission Planner Breadboard System and illustrates it by providing a single thread planning scenario.

Subsection 4.3 describes how certain of the breadboard functions have already been utilized for RPV mission planning through changes in the data base and/or minor program modifications. Breadboard program modifications necessary for extending the breadboard system to accommodate additional RPV functions of Command and Control are found in 4.4. New system capabilities for RPV planning, monitoring, and Command and Control which could be added to the breadboard are contained in Section 3. In Appendix A there is a description of the demonstration on the breadboard of some of the RPV planning functions accomplished for interdiction, Command and Control, and ECM support missions with the results of these demonstrations.

4.2 MISSION PLANNER BREADBOARD SYSTEM

4.2.1 Introduction

The Mission Planning Breadboard System consists of software programs which are implemented upon a commercial computer and dual displays, as shown in Figure 4.2-1. One display is utilized for graphic information and the second for alphanumeric data. The Breadboard System is capable of demonstrating the automation of certain functions requisite to the planning of such missions as interdiction strikes and ECM support. The System provides the planner with a capability to deal with a multiple mission planning environment while preserving inter-mission relationships over the time period in which which the missions will be executed.

The Mission Planning Breadboard System augments the planner's decision-making process from the selection of a mission requirement through the

Figure 4.2-1. Mission Planning Breadboard System

completion of a mission plan. The operator develops a final plan for each mission through an iterative process with the System in which he considers the nature of the target, the availability of resources, an optimum route to and from the target, the characteristics of existing threats, and all available means by which to minimize the threats in executing the mission assignments. After each mission has been planned the System supports the planner in his review of the overall multimission plan in areas of coordination, time space conflict, and mutual support. The planner calls for various planning functions by using a set of function buttons as shown to the left of the graphic display in Figure 4.2-1.

Some of the planning functions which are presently demonstrable on the Mission Planning Breadboard System at Eglin Air Force Base, and at Litton Data Systems Division, Van Nuys, are:

a. Target characteristics review.

b. Review of previous missions against the target.

c. Aircraft and ordnance selection.

d. Resource assignment.

e. Call sign assignment.

f. Enemy Order of Battle review.

g. Semi-automatic route selection.

h. Route safety analysis.

i. Automatic route selection.

j. Automatic selection of on-board jamming equipment.

k. Automatic configuring of aircraft external stores.

l. Fuel calculation and tanker requirements development.

m. TACS assignment.

n. Automatic selection of standoff jamming orbits.

p. ECM effectiveness analysis.

q. Time sequence review (preflying the missions) to verify mission compatibility (no time-space conflicts) and continuity of planning.

The Mission Planning Breadboard System was developed to address manned aircraft missions in the context of preflight mission planning. The current capability has recently been modified to include some unmanned aircraft mission planning. Many of the existing planning functions can be used in conjunction with air situation data in a logical extension of the system to include real time command and control of both manned and unmanned mission execution.

4.2.2 Mission Planner Scenario

The following pages present Mission Planner Breadboard System capabilities and functions. The presentation is in the form of a scenario which describes the way in which Mission Planner Breadboard software is used to plan interdiction missions, as well as the ECM support for those missions. Although the Advanced Development Mission Planner will plan all types of tactical missions, the present Breadboard is limited to interdiction missions and ECM support.

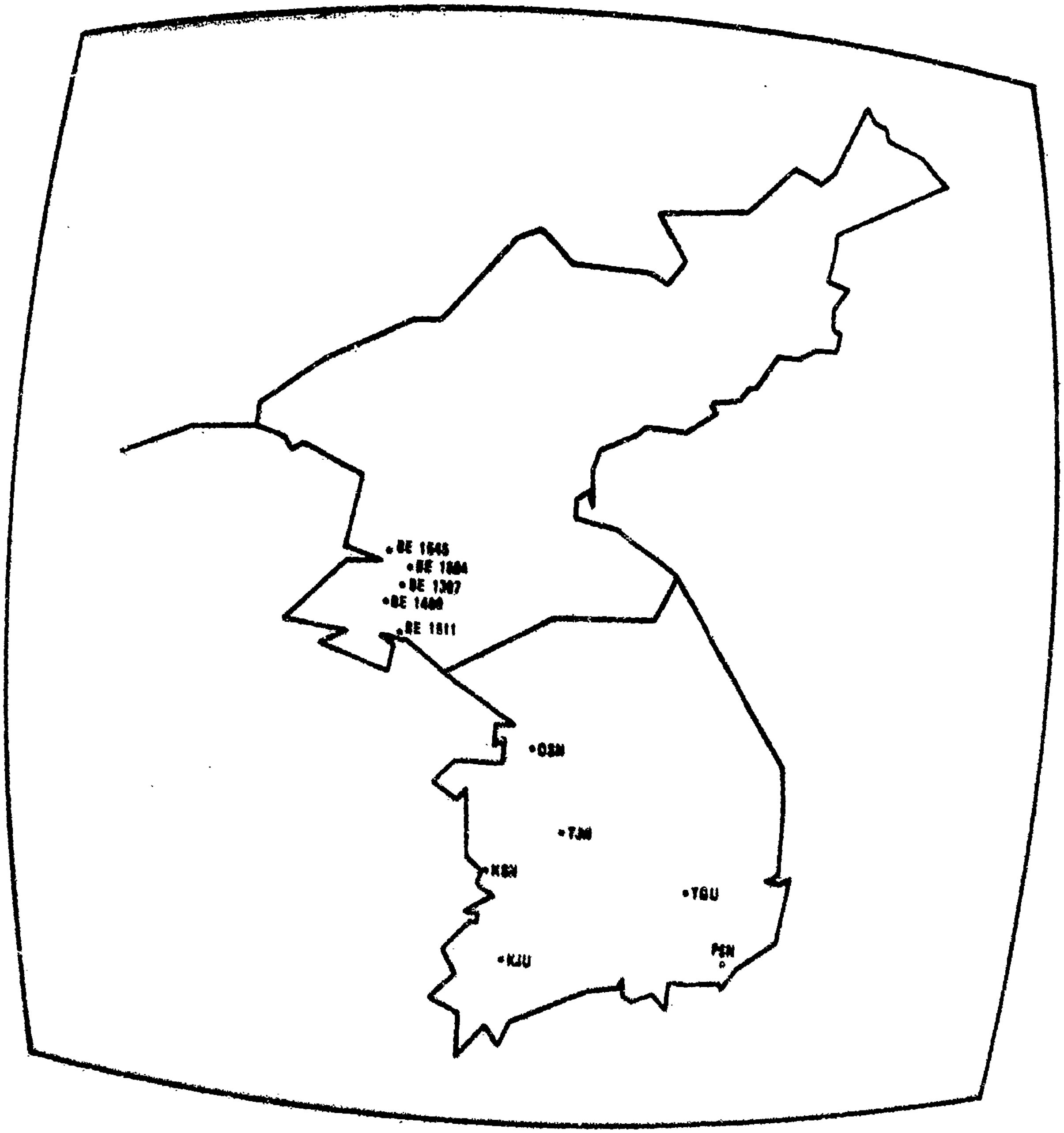
The scenario is set in North Korea and assumes that three things have occurred prior to the start of planning.

a. A set of requirements (targets) has been selected and given to the system for detailed planning.

b. The apportionment of sorties for interdiction and ECM support has been accomplished.

c. The data base has been updated to reflect changes in friendly and enemy status.

With these assumptions, the scenario begins.



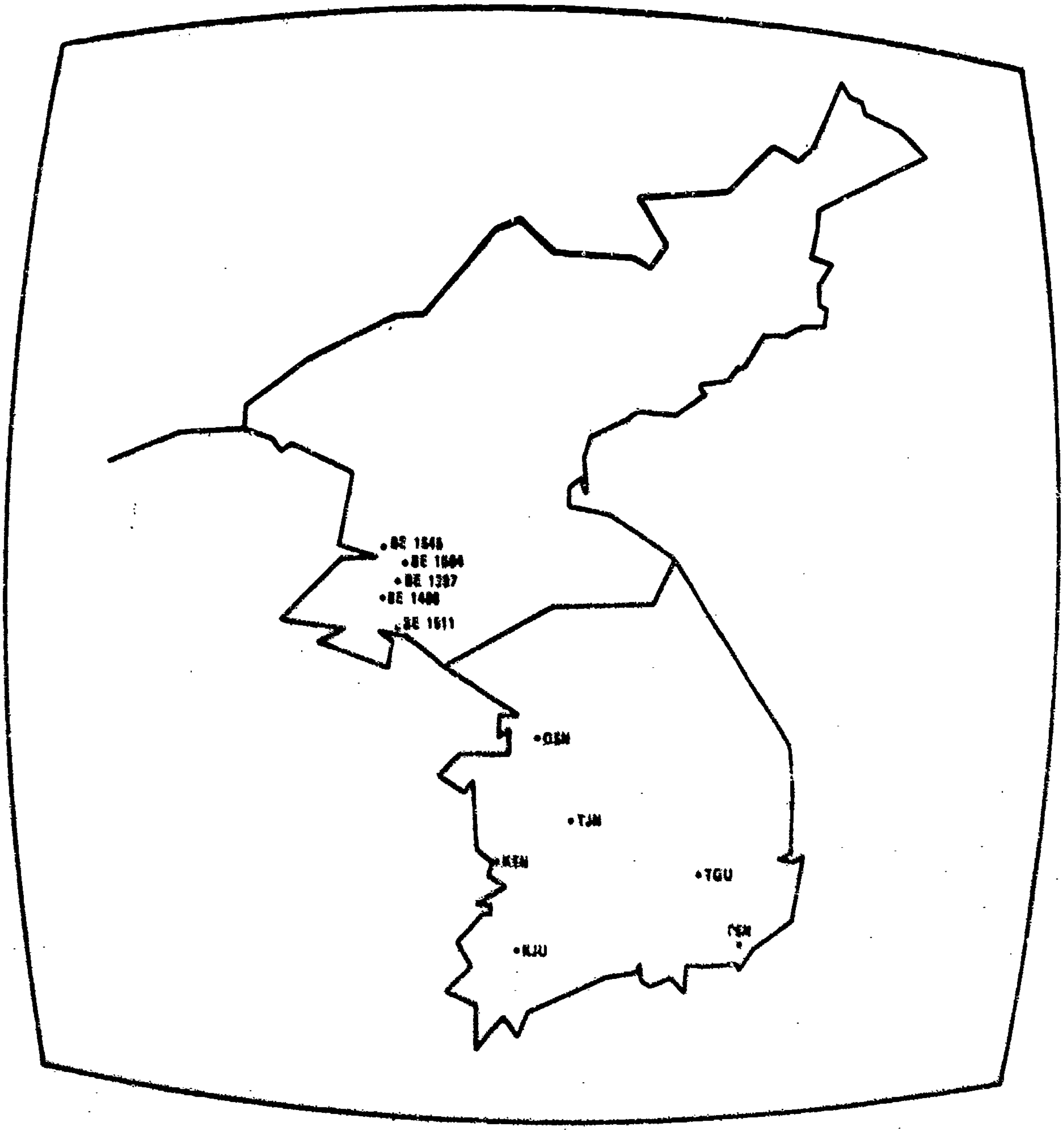
BE 1307
BE 1811
OSN
TJN
KSN
TGU
PSN
KJU

MSN NO.	TARGET	TGT NO.	LOCATION	RESOURCES	REQTS DATE
706	SARIWON MIL. AREA	BE 1307	38.30N-125.45E	4 F-4D PSN	12 DEC 71
707	SONGNIM HIGHWAY BRIDGE	BE 1545	38.48N-125.35E	2 F-111A KSN	STRIKE TIME
708	HAEJU MILITARY DEPOT	BE 1511	38.02N-125.44E	8 A-7D OSN	0800-1000 Z
709	CHAERYONG VEHICLE DEPOT	BE 1406	38.25N-125.36E	4 F-105D KJU	
710	HWANGJU POL AREA	BE 1804	38.38N-125.47E		

_ _ _ _ TO SELECT TARGET ENTER MSN NO. SHIFT/ENTER

Upon activation of the function key INTERDICTION PLANNING the set of requirements for today's planning effort appears. Five requirements were provided in the scenario. The nature of each requirement along with relevant data on each is shown on the alphanumeric (A/N) display. The geographic location of each potential target along with the location of friendly bases is shown on the graphic display.

As of the start of the scenario resources have already been assigned to the first four targets. The scenario describes the manner in which the mission against the Hwangju POL area is planned. The process begins with the planner's entering via the keyboard, the mission number (710) in the indicated space on the display.


BE 1611
OSN
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KSN
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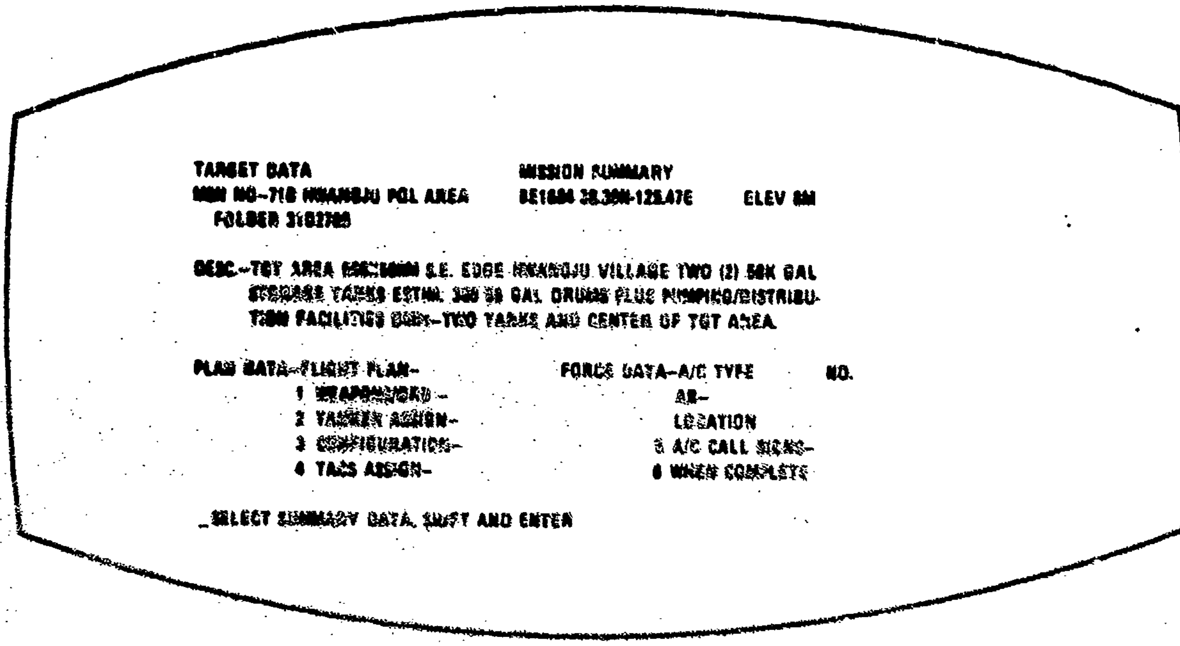
KJU

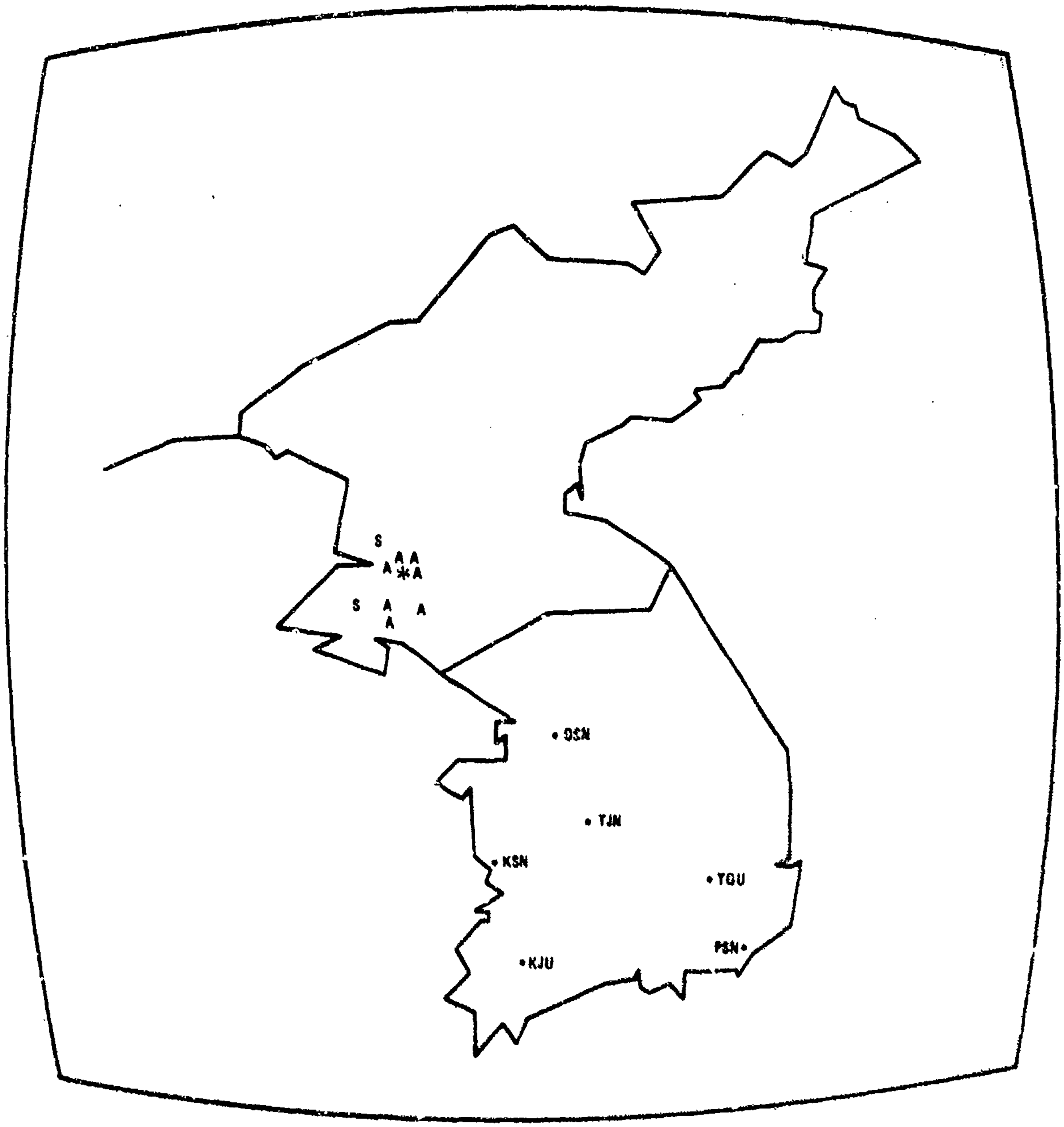


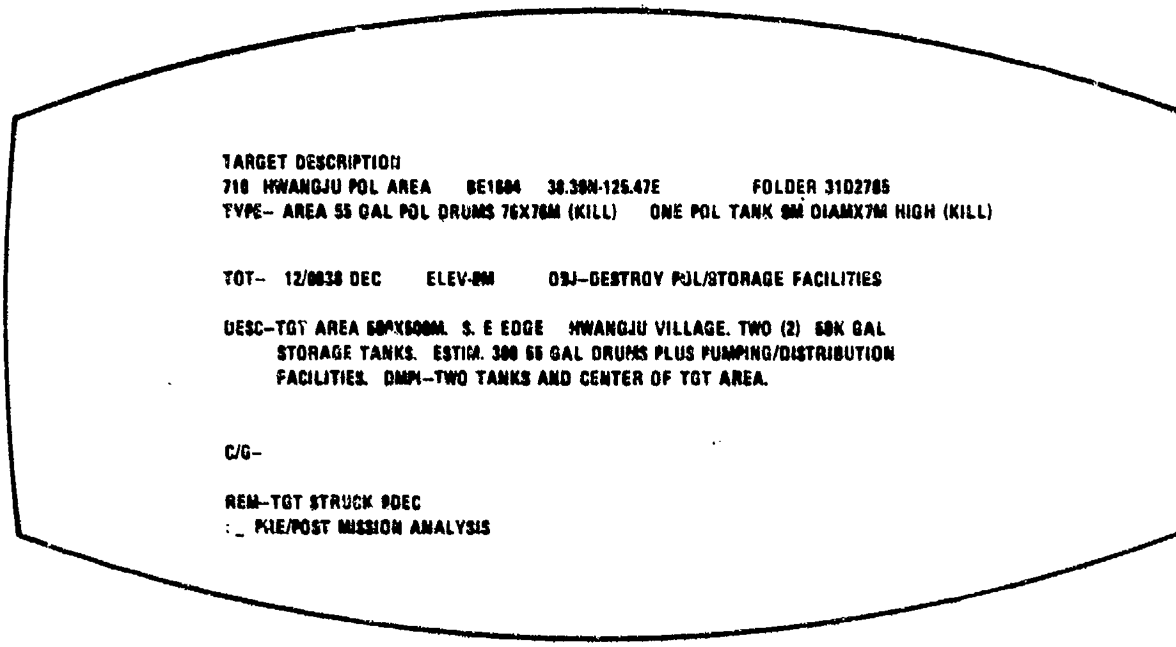
As soon as any target is selected a special table is initiated in which the details of the plan are stored. This table is called the Mission Summary. The display has its own function button and the planner may display this Mission Summary at any time during his planning cycle. The table consists of three sections:

1. Target Data
2. Plan Data
3. Force Data

The target data come directly from the data base. Thus that portion of the table is filled in as soon as the target is selected. The other two sections are filled in as the planner performs the various planning functions.

When the planner completes a function either the relevant data are stored directly in the table or, if the data are voluminous, an asterisk is used to indicate completion. Thus it can serve to remind him of what still needs to be done. If he wishes to review the results of any completed function, he does so by entering the appropriate identifying number in the space at the bottom of the display.

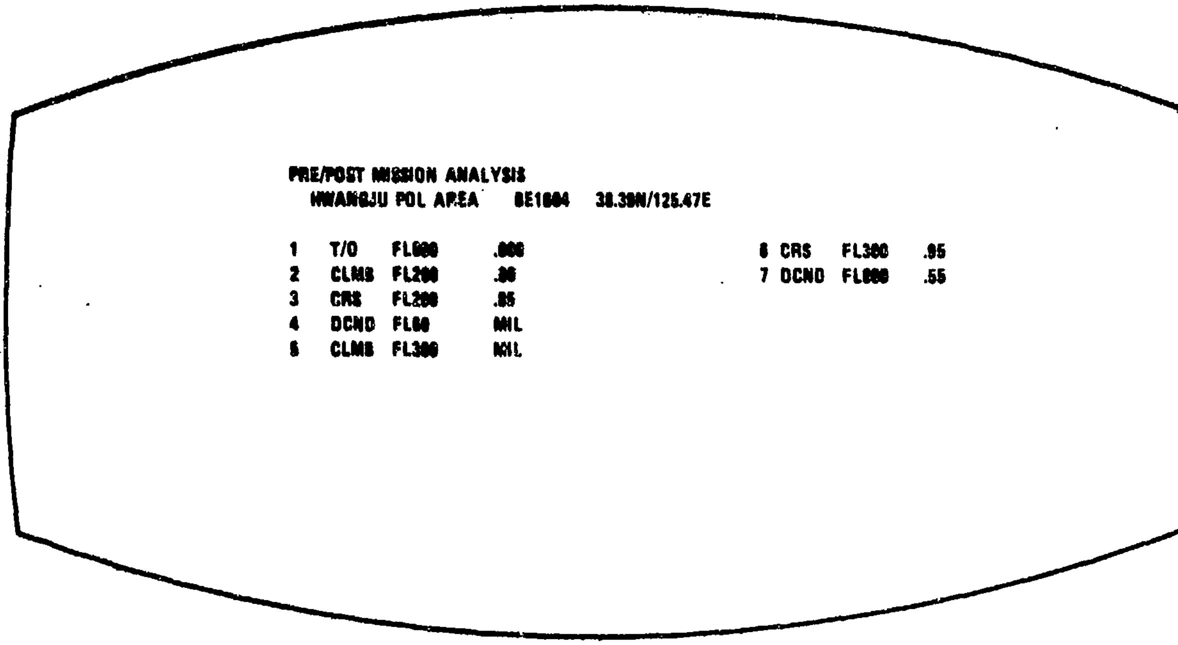

OSN
TJN
KSN
YGU
PSN
KJU



When the planner selects a particular requirement for planning, new graphic and new alphanumeric displays are generated. The A/N display presents detailed target description data from the data base. In addition to the basic descriptive data, the planner gets a reference to a target folder. This folder contains amplifying hard copy data on the target including any reconnaissance photographs. If there is any command guidance with respect to this target, it is included in the display as well as a reference to previous strikes.

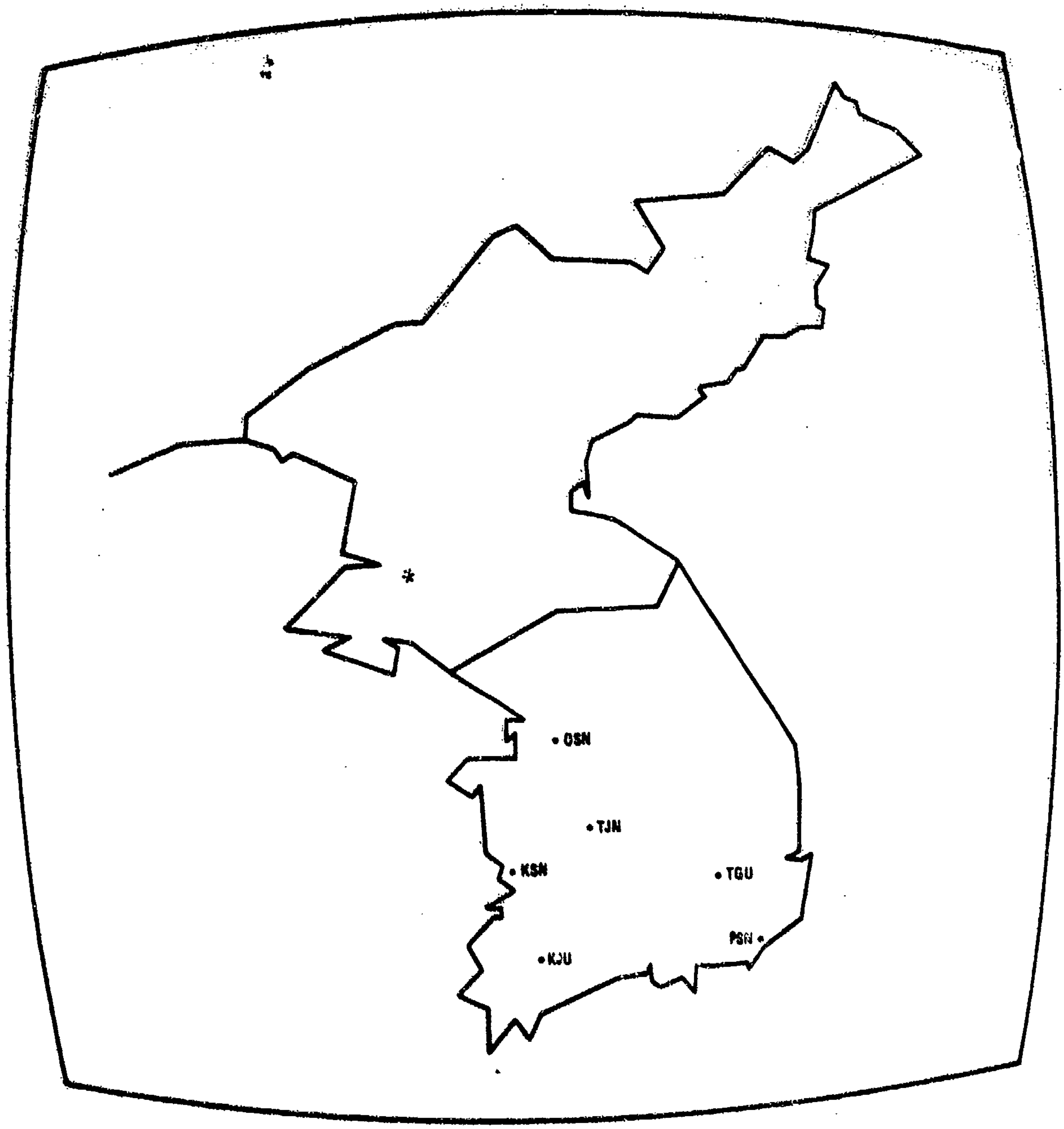
The graphic display continues to display all friendly bases but the upper portion is modified so that only the selected target is shown (as an asterisk). In addition, the enemy missile and AAA defenses within a 25 mile radius of the target are also automatically displayed.

If the planner wishes to review the previous strike against this target he does so by entering a symbol in the space in the bottom line. If not, he activates a different function switch.



If the planner selects "Pre/post Mission Analysis" the displays present basic data on the previous mission against that target. The graphic display presents the route profile as it was planned. In addition, if the data were available and were stored, it would also show the mission as it was flown. Any EOB (Enemy Order of Battle) reports or data associated with the mission may also be displayed. Discrepancies between the "as planned" and the "as flown" routes may be related to events as described in pilot debriefings or in other intelligence sources.

The A/N display presents amplifying route profile data and after reviewing these data the planner can proceed by activating another function switch.

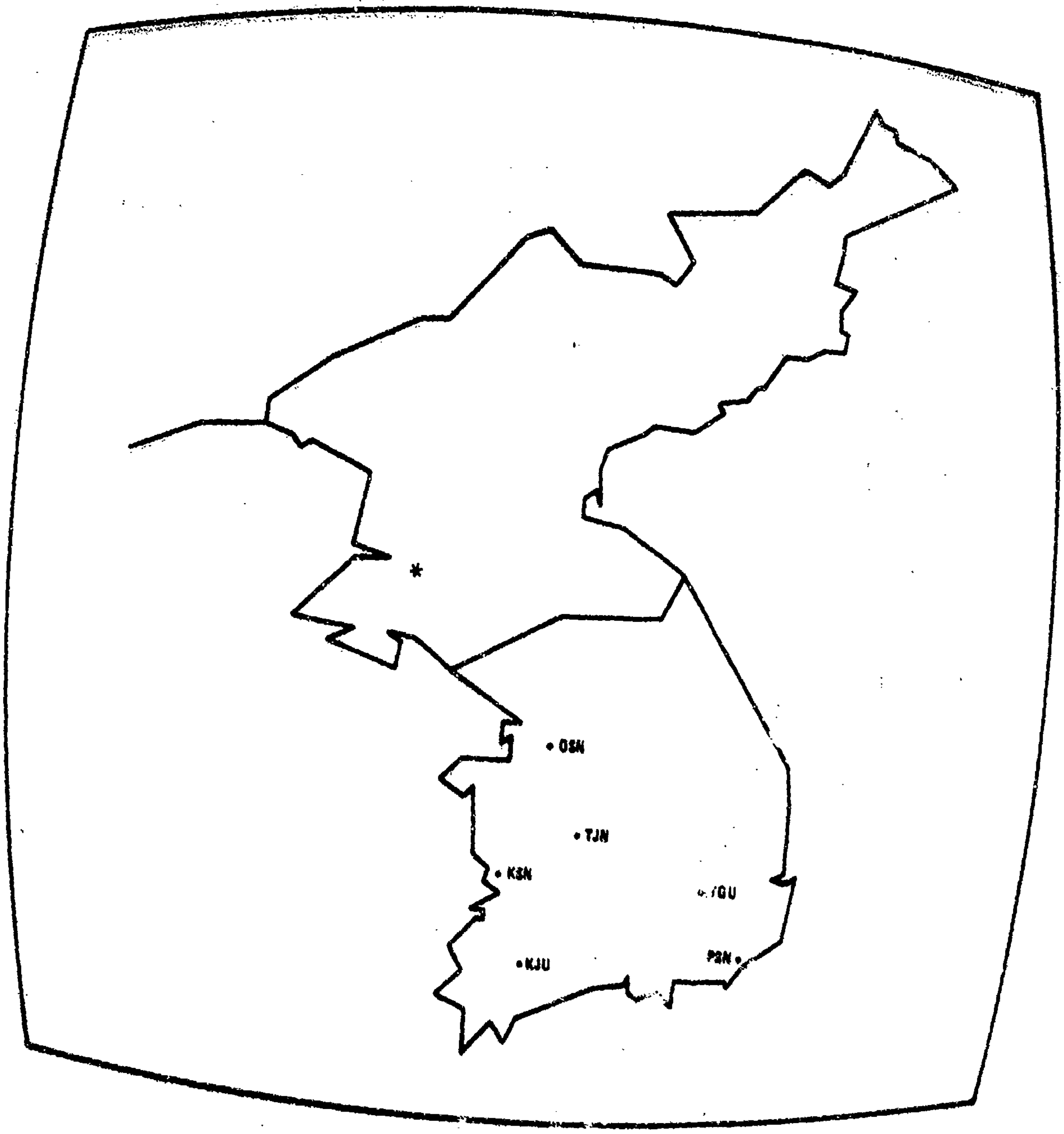


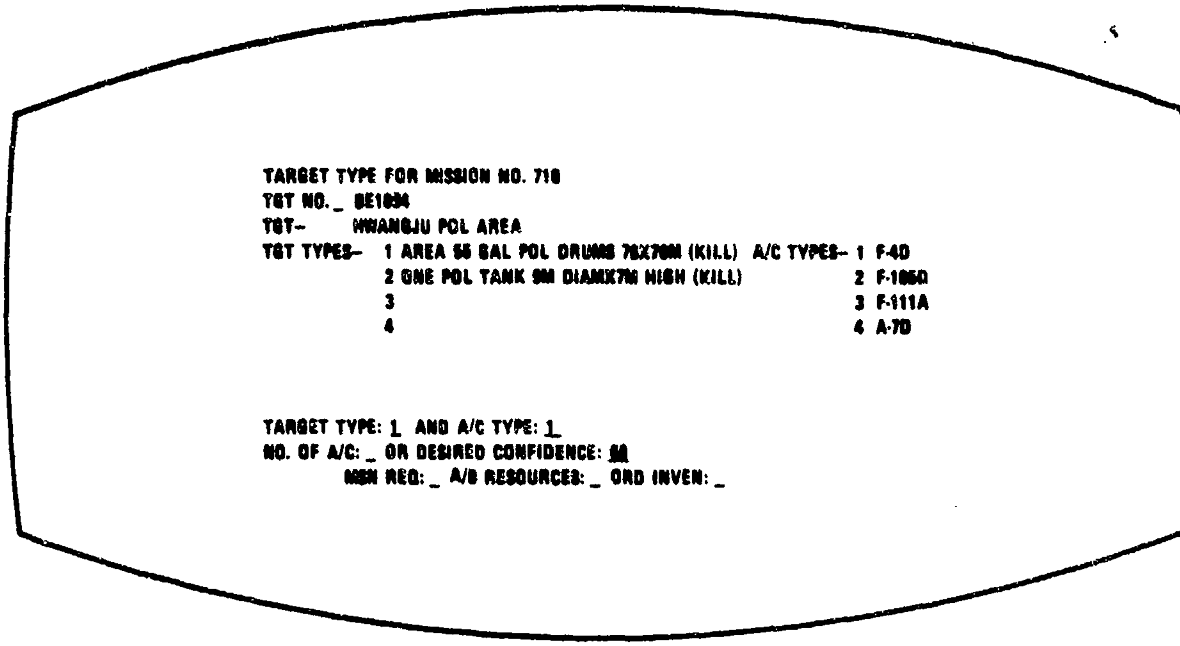
OSN
TJN
KSN
TGU
PSN
KJU

```
COMMAND GUIDANCE      XXXX SHIFT AND ENTER FOR TACS COMMAND GUIDANCE XXXX
TGT AREA-HL:MIN ALT FL 70 AGL. EL: PENETRATION ABOVE FL 50 UNAUTH.
          FL. GM, HM, JM, KN: NO PENETRATION OF YALU RIVER BUFFER ZONE AUTH.
          JL, KL: WX MIN COMBAT OPNS CEILING 50 VIS 5 MILES.
ORD/MDS/TACTIC-
  F106 NO PENETRATION WITHOUT F4E ESCORT.

FUEL-NONE
TGT TYPE-POL TGTS: ORD SHOULD INCLUDE H.E. AND INCENDIARY.
GEN-ALL MSNS WILL ABORT IF WILD WEASEL SUPPORT ABORTS.
    RETAIN TANKS, MERS, MISSILES, PODS.
```

The planner may also wish to review command guidance prior to initiating the actual planning process. A display of summarized command guidance is available when the COMMAND GUIDANCE function switch is activated. Command Guidance may be too voluminous or complex to be shown in toto on the display; therefore the displayed Command Guidance may consist of references to appropriate volumes or documents. To move on from Command Guidance the planner selects a different function switch.

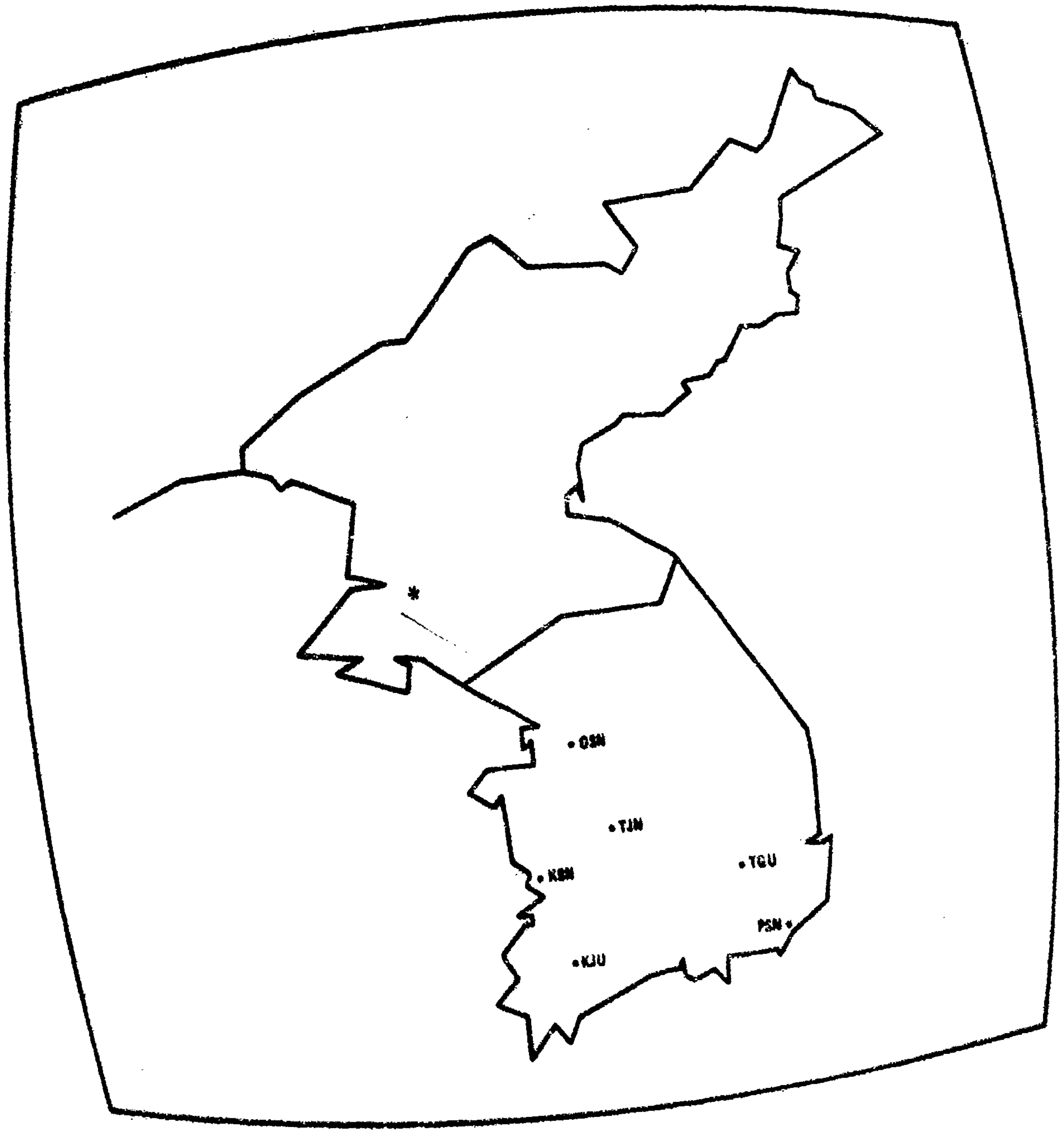

OSN
TJN
KSN
KJU
PSN



The first scenario action for the planner is the selection of ordnance. This function is initiated by the ORDNANCE SELECTION function switch. The initial A/N display requests the planner to select available options for ordnance selection.

Ordnance selection is accomplished through the use of JMEMs or Joint Munitions Effects Manuals. These documents are the result of combined scientific research studies as to the effectiveness of various ordnance/aircraft combinations against different types of targets. Abstracts from these documents have been made for the Mission Planner data base. For each possible target type and aircraft type combination the three best ordnances have been selected. When the planner selects a specific target type and a specific aircraft type then these three best ordnances are displayed.

In the display the planner has chosen target type 1 (Area 55 gal POL drums) and Aircraft type 1 (F-4D's). The planner must also select either the number of aircraft he wishes to use in the attack or the probability of successful attack that he wishes. Whichever value he enters the other is automatically calculated for him. In the present case, he has specified a 60% probability of success.



OSN
TJN
KSN
TGU
PSN
KJU

JMEM TABLE

TGT TYPE– AREA 55 GAL POL DRUMS 76X76M (KILL)

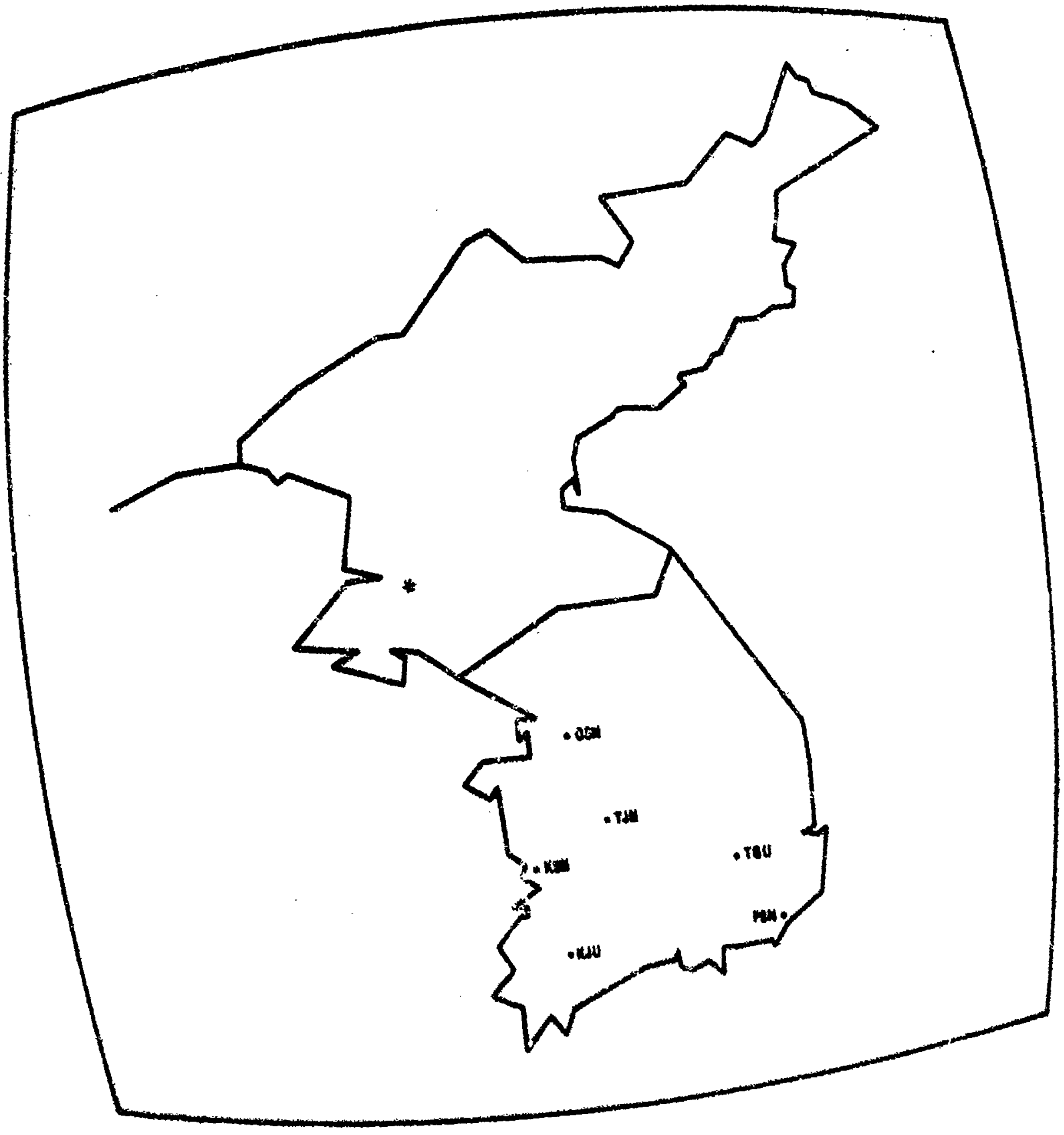
	ORDNANCE	FUZE	A/C	NO.	DIVE	ALT	KTAS	PD	PS
1	9 M224	INST	F-4D	4	[illegible]	150	450	.21	.31
2	9 MK-95	INST	F-4D	5	[illegible]	150	450	.18	.63
3	4 BLU-043	INST	F-4D	5	[illegible]	100	450	.17	.61

ENTER ORDNANCE: 1 OR ORDNANCE MENU: _

TGT TYPE: _ MSN REQ: _ A/S RESOURCES: _ ORD INVEN: _

The A/N display changes to present the abstract from the JMEMs for F-4D aircraft against 55 gal POL drums. Weapon identifiers and other data have been altered to permit this document to be unclassified. The three ordnances which are (1) certified for the F-4D and (2) best for this target type are displayed. In addition, fuze data and optimum tactic are included. The single pass probability of destruction (P_D) is the value upon which the calculations are based and is also displayed. Using this value, the computer programs have determined that four F-4D's are required to achieve a probability of success of 0.60 (or over) using the nine – M-224's. If the planner wishes to use the nine – MK-95's, then five aircraft are required to achieve a probability of success higher than 0.60.

The planner selects the nine M-224's by entering the appropriate digit (i.e. 1) in the space labeled "Enter Ordnance." From here he goes to the next target type.


OSN
TJN
TGU
PSN
KJU

JMEM TABLE

TGT TYPE– ONE POL TANK 9M DIAMX7M HIGH (KILL)

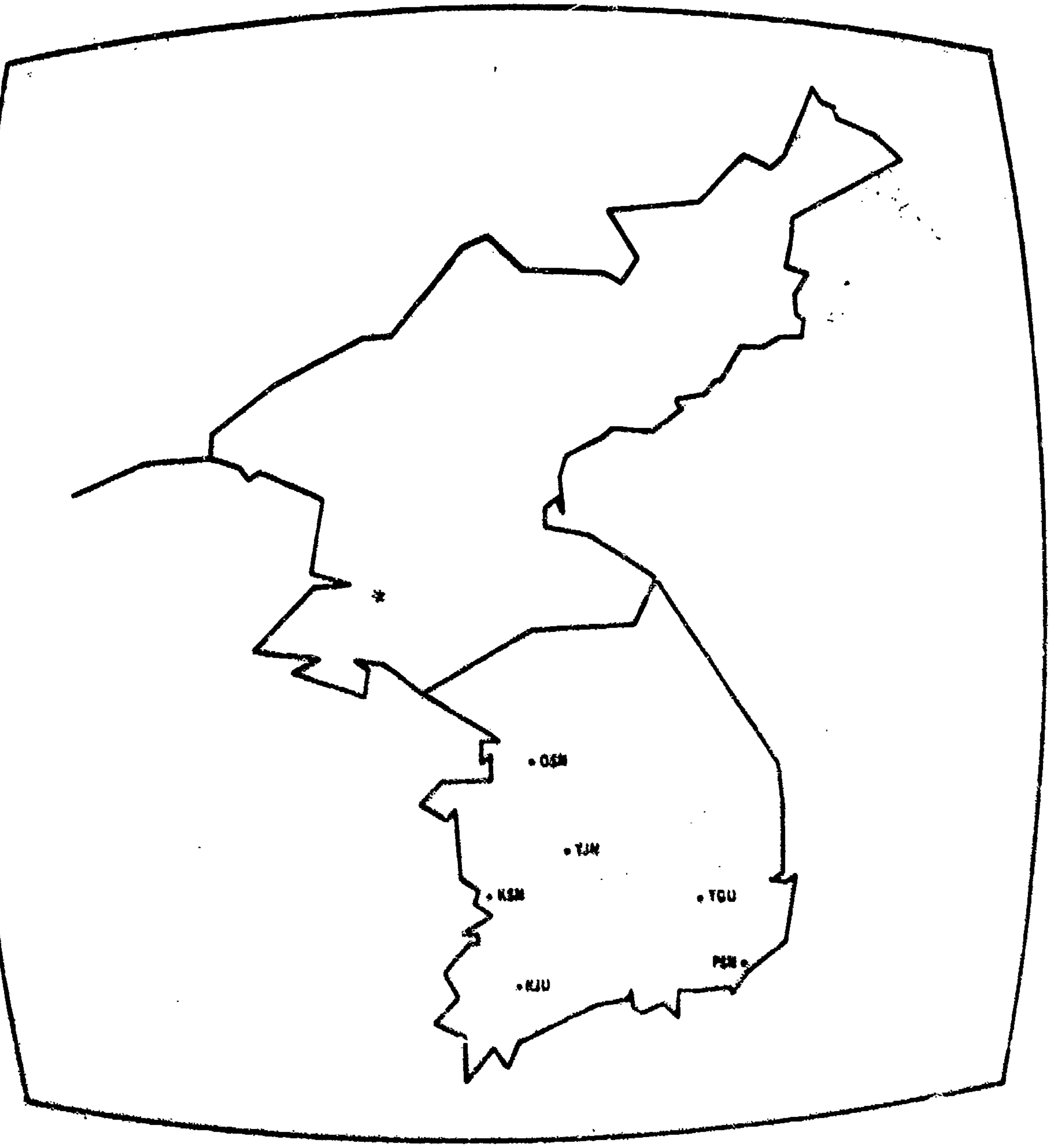
	ORDNANCE		FUZE	A/C	NO.	DIVE	ALT	KTAS	PD	PS
1	6	M224	.010	F-4D	4	0	100	450	.24	.87
2	12	MK-[illegible]	.010	F-4D	5	30	[illegible]	450	.10	[illegible]
3	4	BLU-063	INST	F-4D	5	0	100	450	.10	[illegible]

ENTER ORDNANCE: _ OR ORDNANCE MENU: _

TGT TYPE:_ MSN REQ: _ A/B RESOURCES: X ORD INVEN: _

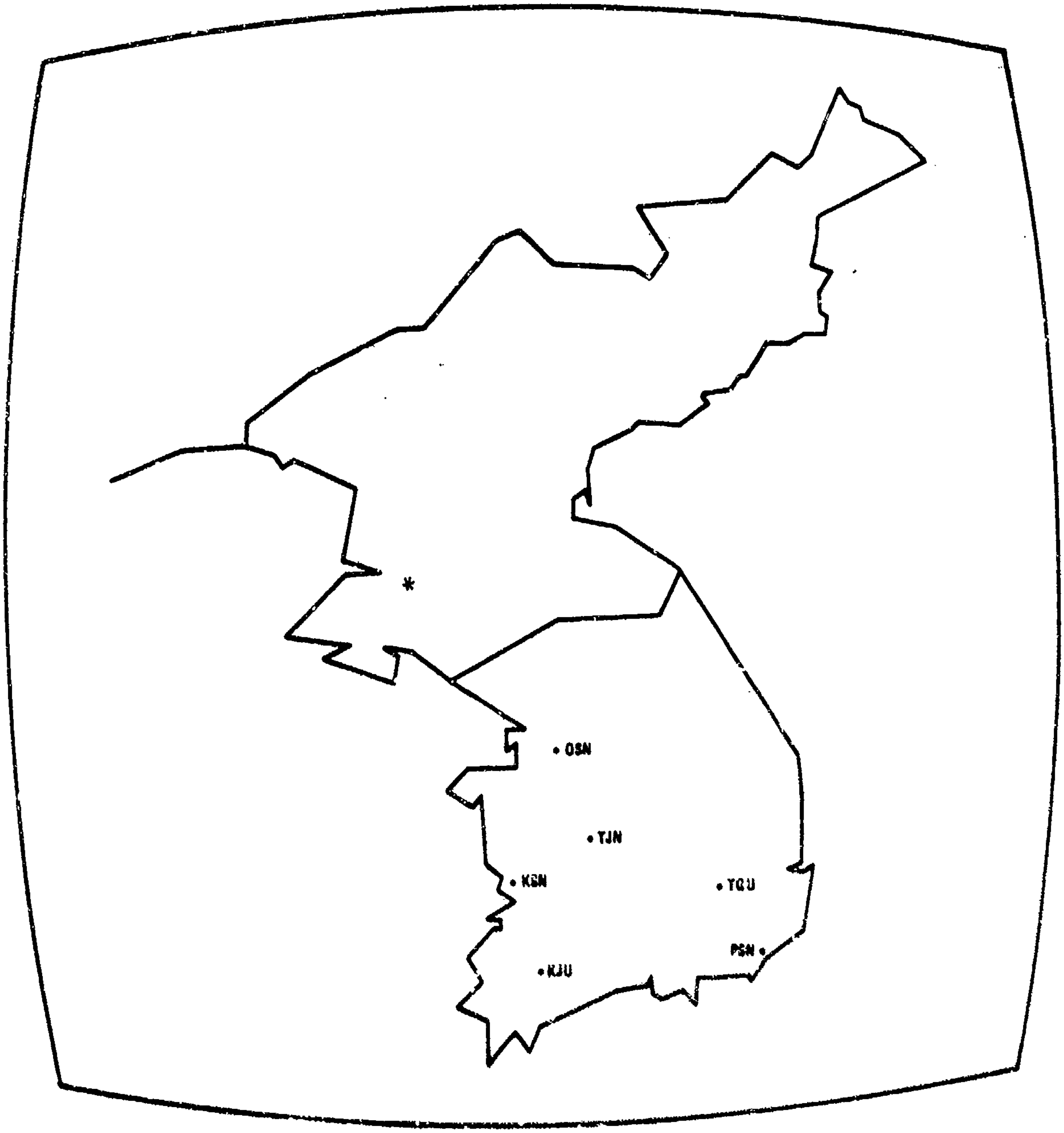
This A/N display presents the JMEM data for the second target type and the F-4D aircraft. For the purpose of the scenario, the planner selects the first ordnance, namely, six M-224's.

After he has selected an ordnance against each target type, he goes to Airbase Resources as indicated in the display. However, prior to the Airbase displays, a short digression is in order to show what happens if the planner wishes to use another ordnance than the ones shown on the JMEM tables. He initiates this capability by selecting "Ordnance Menu."


OSN
TJN
KSN
TGU
PSN
KJU

```
ORDNANCE MENU
  1 AGM-12C  FRAG                 10   CBU-24A/B   AP/AM CLUSTER
  2 AGM-12E  CLUSTER              11   CBU-24B/B   AP/AM CLUSTER
  3 BLU-1C/B FIRE BOMB            12   CBU-29A/B   AP/AM CLUSTER
  4 BLU-27/B (FINNED)             13   CBU-29B/B   AP/AM CLUSTER
  5 BLU-27/B (UNFINNED)           14   CBU-33/A    AVLM CLUSTER
  6 BLU-31/B PENETR. BOMB         15   CBU-38/A    DWM EJ CLUSTER
  7 CBU-1A/A AP CLUSTER           16   CBU-42/A AP   CLUSTER
  8 CBU-2C/A AP CLUSTER           17   CBU-46/A AP   JUNGLE CLSTR
  9 CBU-7/A  AP FRAG CLUSTER      18   CBU-49B/B   FRAG CLUSTER
ENTER ORDNANCE: _ _  AND AMOUNT: _ _  AND NO. A/C: _ _  NEXT PAGE: _
TGT TYPE: _   MSN REQ: _   A/B RESOURCES: _  ORD INVEN: _
```

The planner can override the JMEMs and select any ordnance he wishes if it is available in the theatre. This A/N display presents one page of the Ordnance Menu. Each ordnance type has an identifying number. Using the next-to-last line, the planner selects an ordnance, the amount to be carried by each aircraft, and the number of aircraft he wishes for the mission. Notice that when the Ordnance Menu is used the breadboard does not calculate the probability of success nor does it determine the required number of aircraft. However, the data are stored in the Mission Summary and are used later in Configuration and Fuel Analysis.


OSN
TJN
KSN
TGU
PSN
KJU

A/B RESOURCE AND ASSIGNMENT

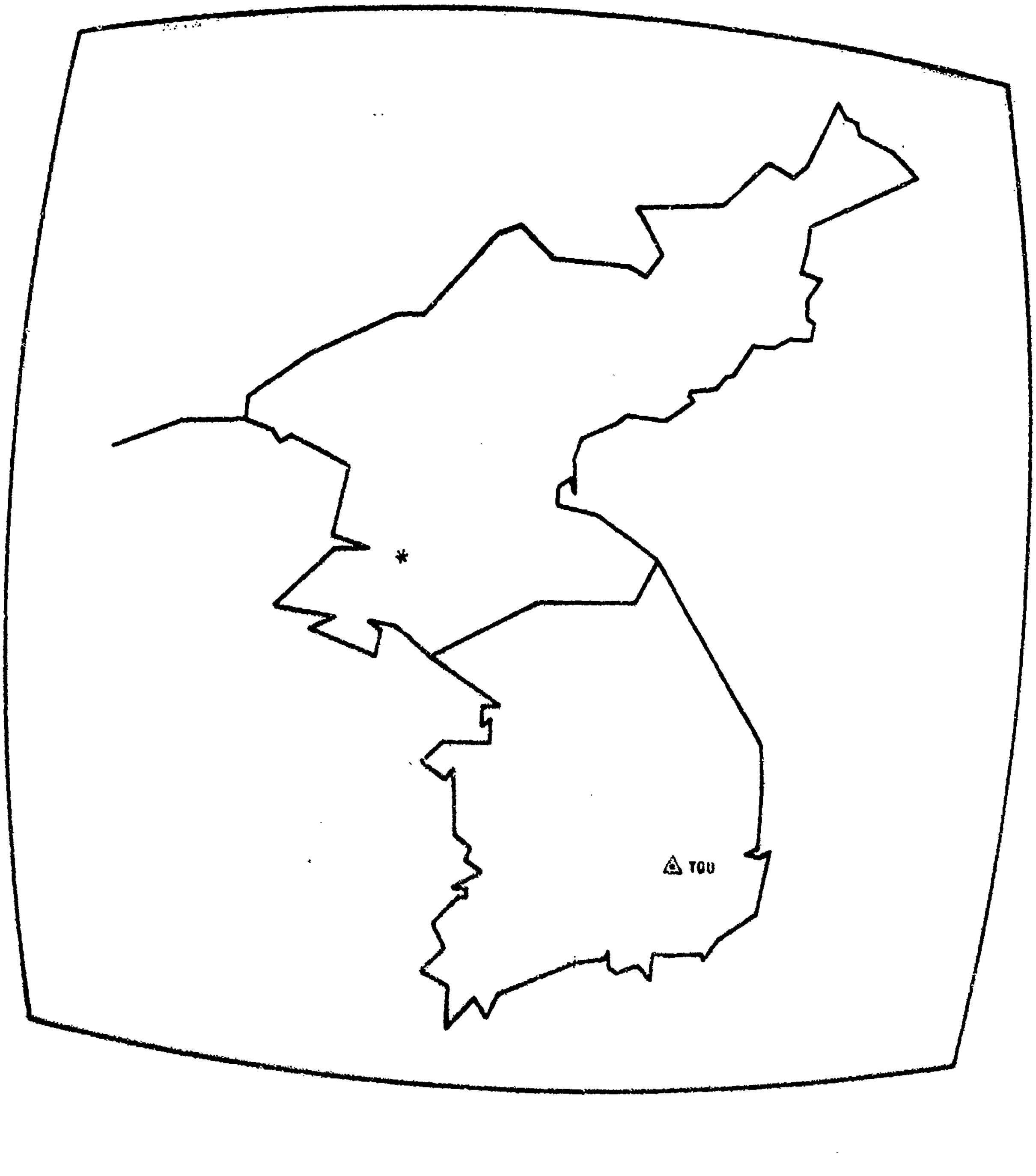
LOCATION	A/C AVAIL	A/C TYPE
PSN	48	F-4D
KJU	44	F-1[illegible]D
KSN	58	F-111A
TJN	44	F-1[illegible]D
OSN	64	A-7D
TGU	56	F-4D

ENTER AIRBASE: TGU

TGT TYPE: _ MSN REQ: _ ORD INVEN: _

When the planner selects Airbase Resources, he receives the data as shown in the A/N display. Since his ordnance selection was predicated on the use of F-4D's, he must select either Pusan or Taegu. He selects Taegu. His ordnance selection also postulated 8 – F-4D's aircraft (four against each target type). Selection of Taegu automatically reduces the "A/C Avail" value at Taegu from 56 to 48.

If it should happen that the ordnance he selected earlier was not available at Taegu, he would be so informed by a message at the bottom of the graphic display. In that case, the planner would presumably select "Ordnance Inventory.".

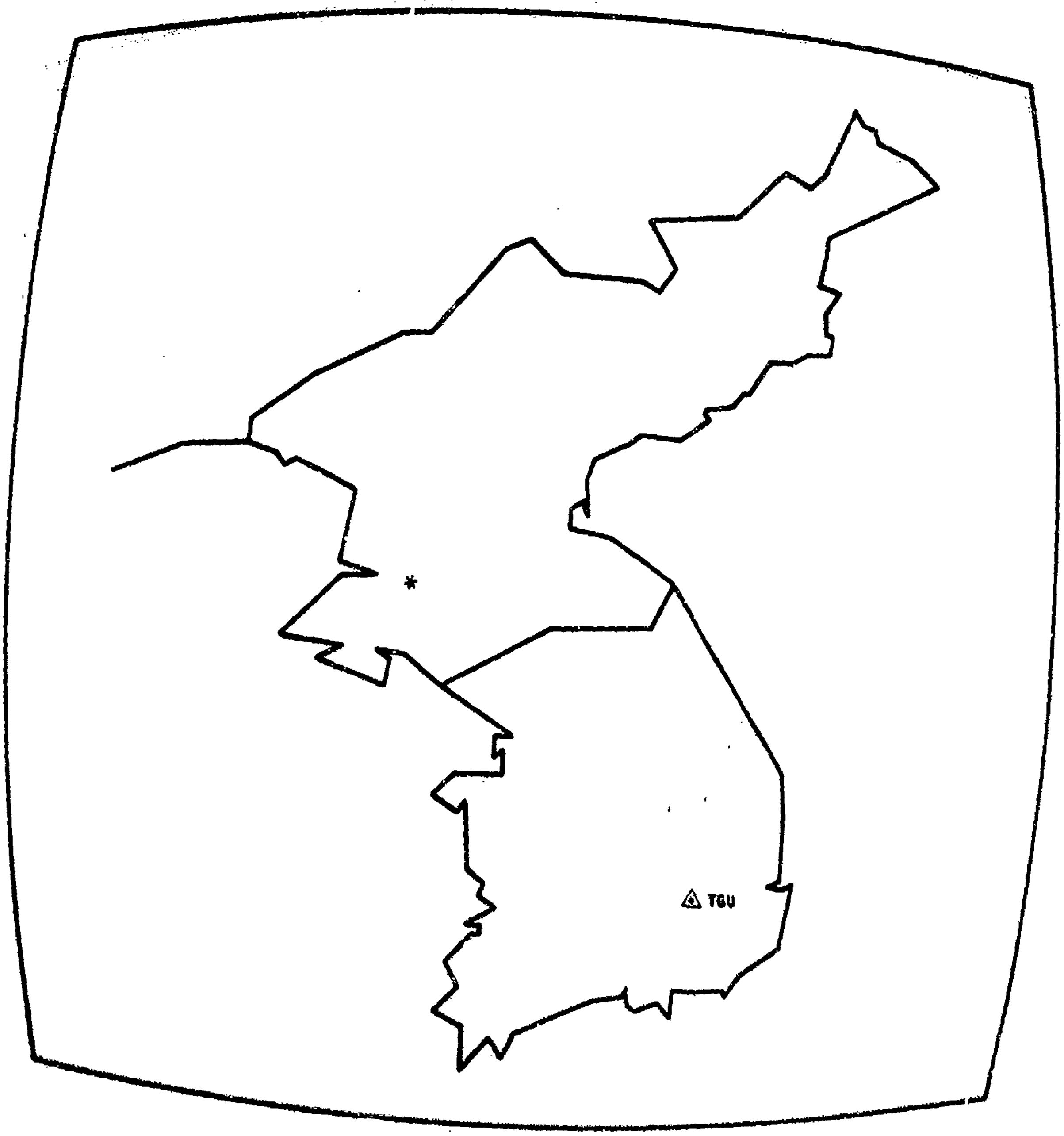

TGU

```
SQUADRON AND CALL SIGN ASSIGNMENT TGU EFFECTIVE 01-31- DEC
1-  53  TFS   F-4D 16          2-  54  TFS F-4D  20        3-  55  TFS F-4D  16
53     TFS     1 NECTAR          2 MOHAWK             3 RED DOG         4 SPEEDY
               5 MUD PIE         6 CORNHUSK           7 SEAFIN          8 DOLLY
               9 IVORY          10 RAISIN            11 OBLIGE         12 MARKOFF
54     TFS    13                14                   15                16
              17                18                   19                20
              21                22                   23                24
55     TFS    25                26                   27                28
              29                30                   31                32
              33                34                   35                36
SQUAD: 1 C/S: _ 2    _4 A/C ALLOCATED FOR AREA 55 GAL POL DRUMS
```

If the ordnance were available at the selected base, the graphic and A/N displays as shown here would appear. On the graphic display only the target and selected airbase are displayed.

The A/N display is modified to show what squadrons are at the selected base and what the authorized call signs are for each squadron. In the actual display, there are 12 call signs provided for each squadron. The planner selects a squadron and as many call signs as he requires for the mission. Call signs are assigned by groups of four with a final call sign being assigned to any left-over aircraft. For example if 5 aircraft had been required in ordnance selection, he would assign a call sign first to four aircraft and then assign a second call sign to the single remaining aircraft. If he wished to send eight aircraft rather than five he could return to the ordnance selection display and specify eight aircraft.

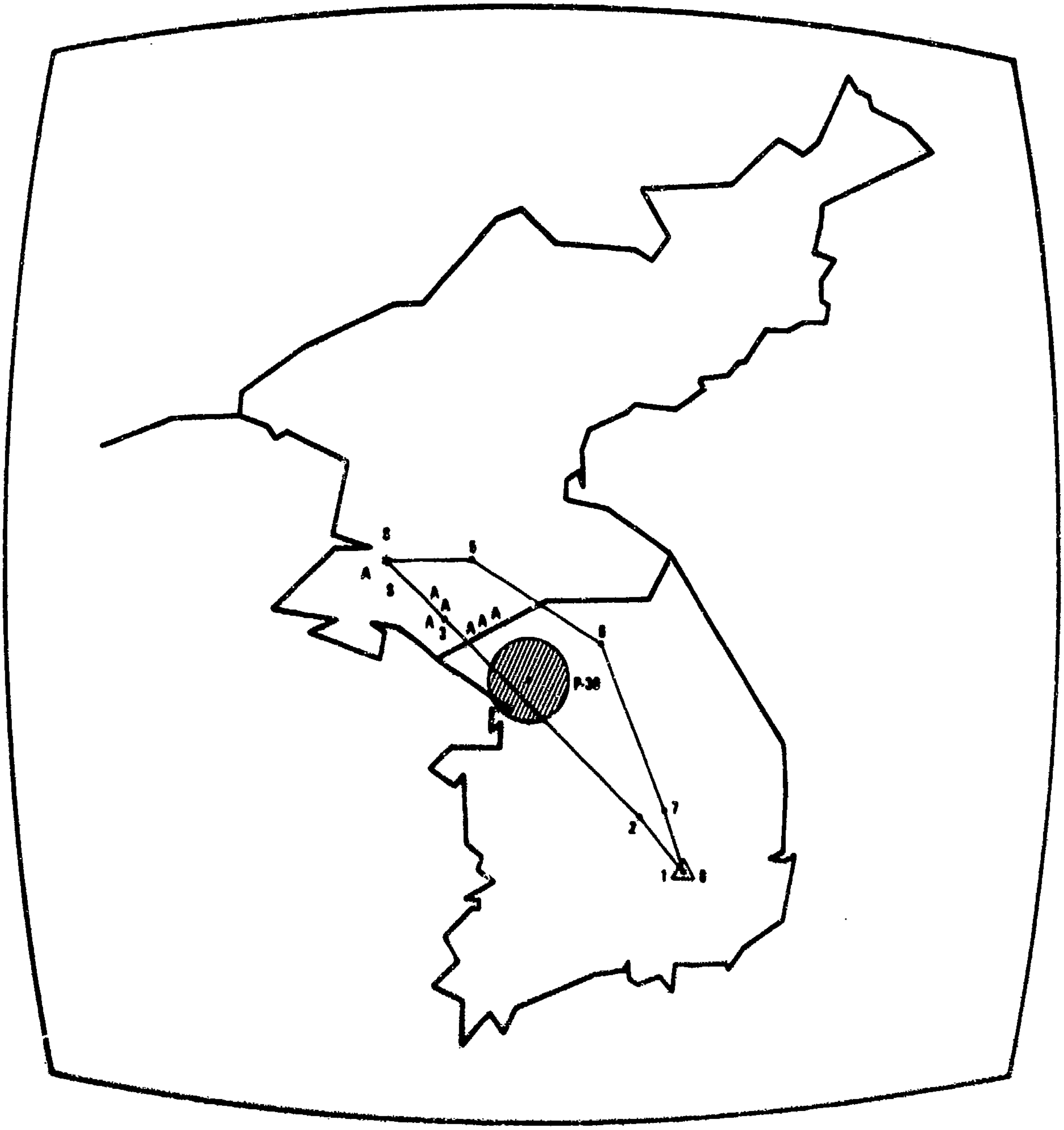
The number of aircraft per squadron are automatically decremented and the bottom line keeps track of how many call signs remain to be allocated as well as how many have already been assigned.


TGU

ORDNANCE INVENTORY	PSN	KJU	KSN	TJN	OSN	*TGU
AGM-12C FRAG	390	560	200	482	300	400
AGM-12C CLUSTER	350	650	250	583	350	400
BLU-1C/B FIREBOMB	800	325	350	394	806	875
BLU-27/B(FINNED)	500	400	275	1233	615	625
BLU-27/B(UNFINNED)	600	525	225	844	895	700
BLU-31/B PENETR BOMB	500	600	300	760	445	440
CBU-1A/A AP CLUSTER	600	900	640	645	555	500
CBU-2C/A AP CLUSTER	450	700	475	685	385	395
CBU-7/A AP FRAG CLUSTER	575	750	450	763	495	375
CBU-24A/B AP/AM CLUSTER	625	500	625	950	515	518

TGT TYPE:_ MSN REQ: _ A/B RESOURCES: _ NEXT PAGE: _

If the planner had selected Ordnance Inventory as mentioned earlier, he would receive this A/N display. It represents one of several pages describing how many units of each ordnance type are available at each base. The planner uses these data either to select a different ordnance or to set up a requirement to fly the ordnance from a base where it is available to the base where it is not.


A
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3
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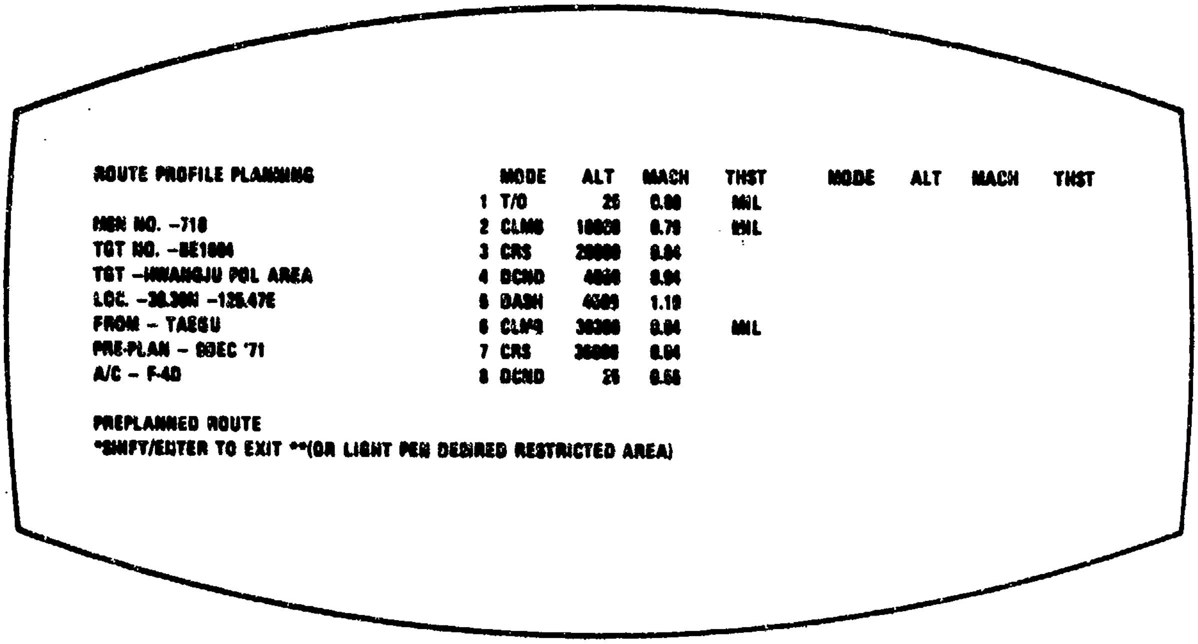
7
1



At this point, the planner is ready to start route planning. This function is initiated through the ROUTE PLANNING function switch. Because the breadboard so facilitates planning it is assumed that there will be times when the system is not being used to plan "tomorrow's missions." Thus it can be used to "pre-plan missions against targets which the planner is sure will become requirements in the future. Such missions can be planned and stored in the data base until that target does become a requirement. At that time, the mission can be retrieved and, if it is still satisfactory, can be used as the actual plan. Even if it is not totally satisfactory, it can be the basis for any planning which must be done.

There are three factors which may make the preplan unsatisfactory. These are:

1. Changes in the Enemy Order of Battle (EOB)
2. New restricted zones
3. Weather

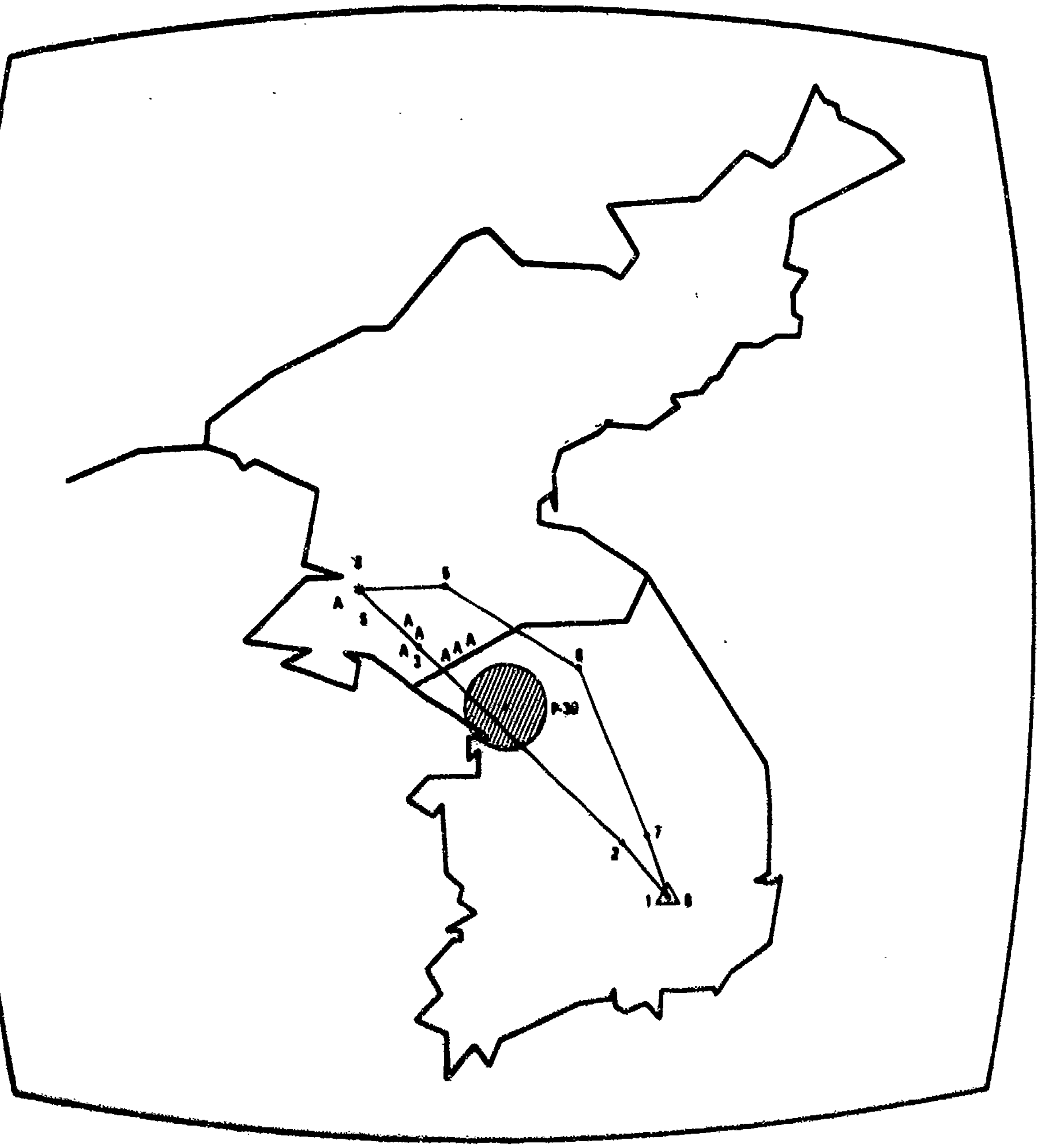
Activation of the Route Planning function automatically displays a preplanned route to the target if one exists. However, in addition to the display of the preplanned route, the graphic display also contains all changes in EOB data which have occurred since the date of the preplan. Any new restricted zones are also displayed. Thus the planner can immediately evaluate his earlier route in terms of these new factors. If they do not appear as cause for route modification, he can accept the route as is.

As will be seen later, a weather display may also be superimposed.

If no preplanned route exists for the target, the last historical route to that target is displayed as the basis for further planning.

In the present scenario, it is clear that the preplanned route now intersects new EOB and a restricted zone (P-30). Further data on the restricted zone are available by lightpenning the area.

Route profile data on a leg by leg basis are presented in the A/N display.



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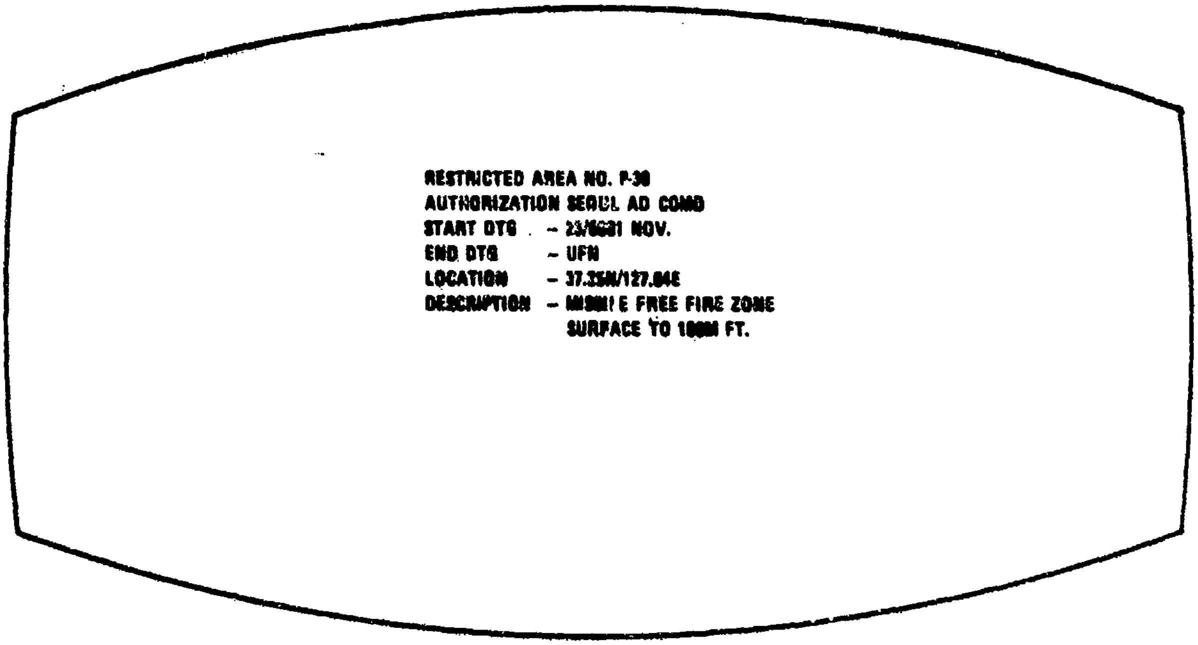
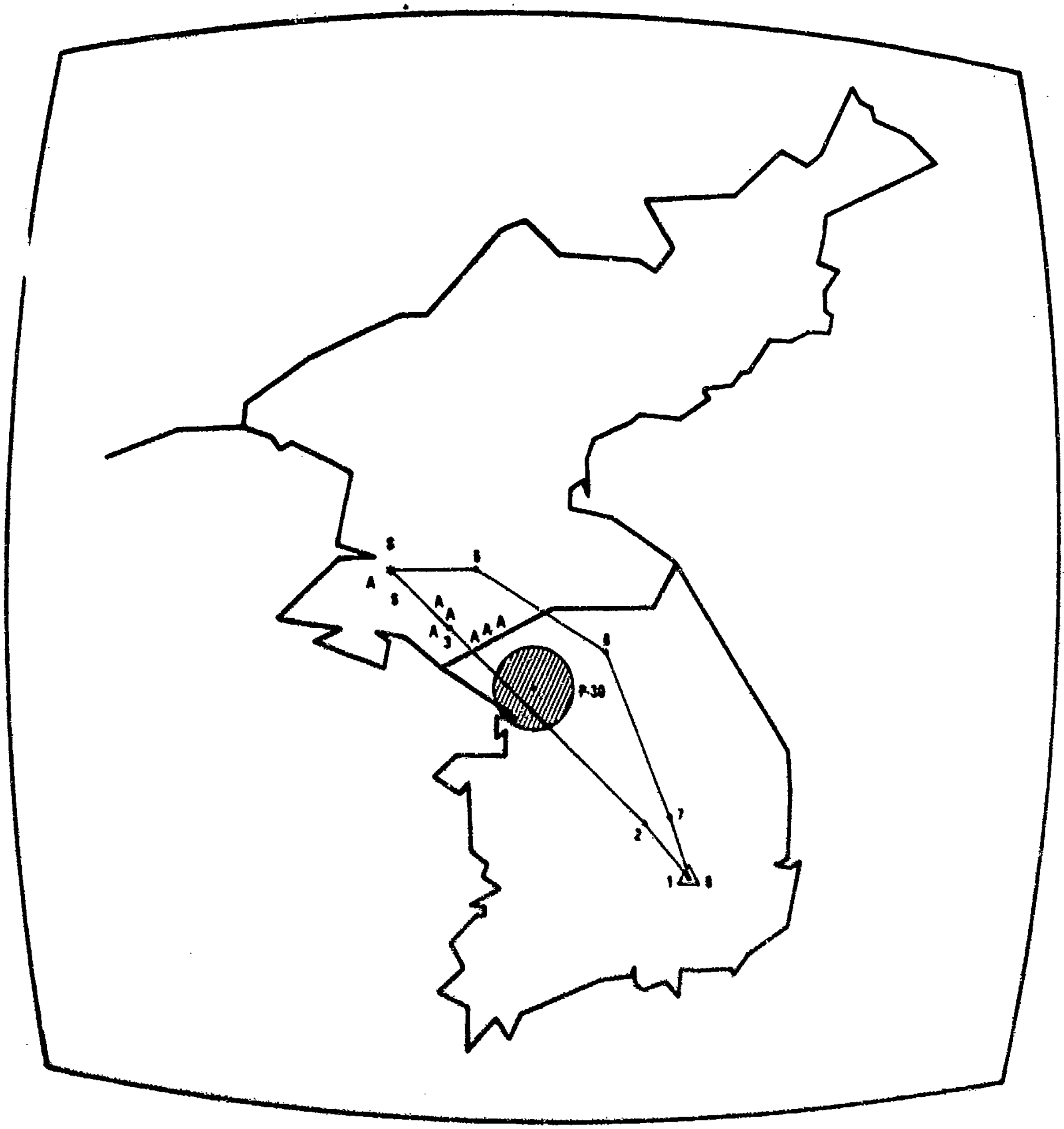


Lightpenning the restricted area provides A/N data describing the zone. In the present case, the altitude to which the zone reaches precludes overflying. Therefore route modification is required.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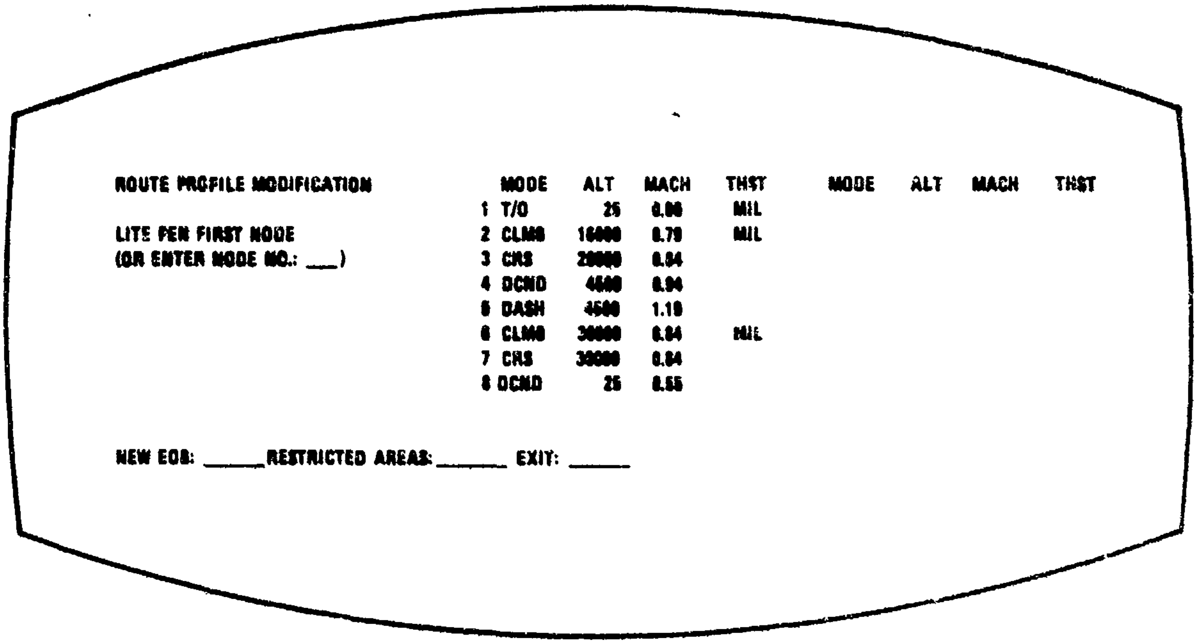
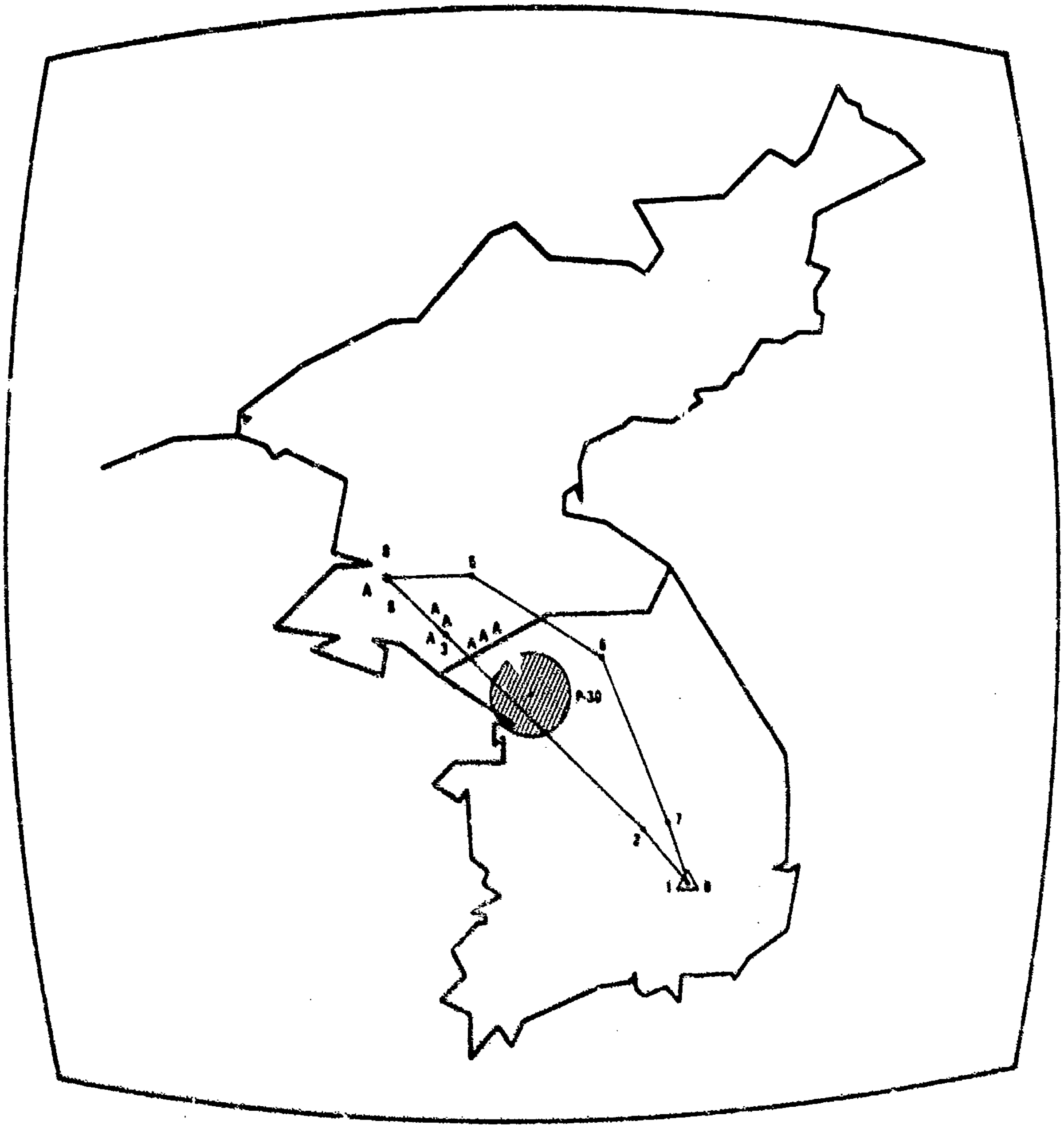
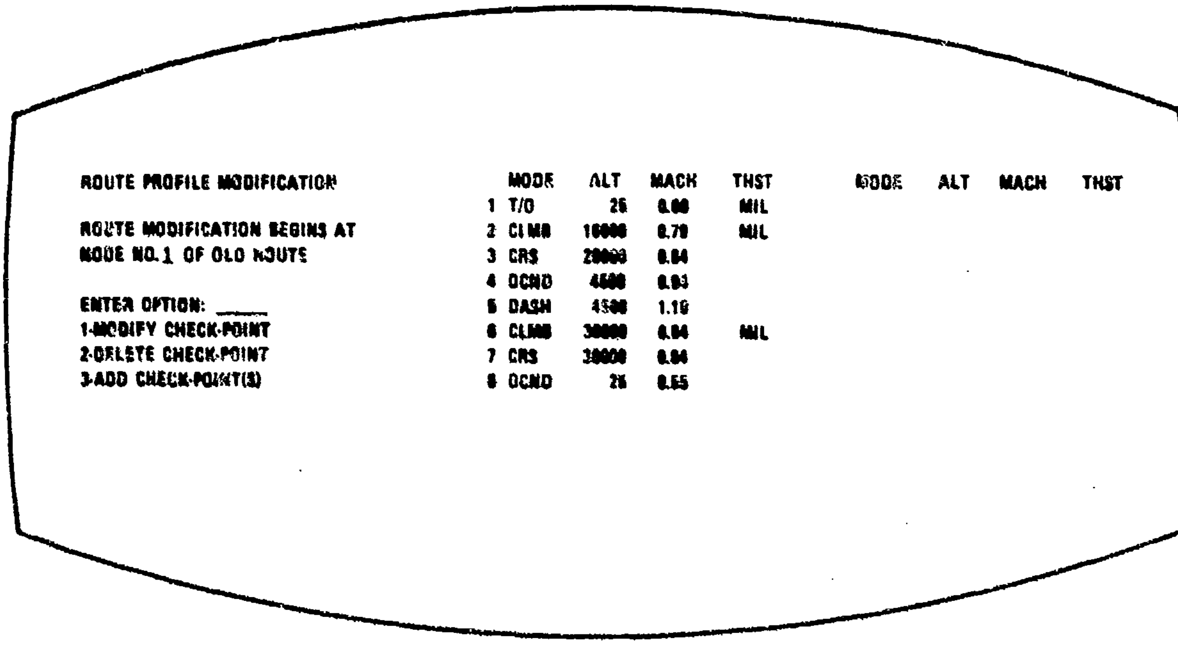


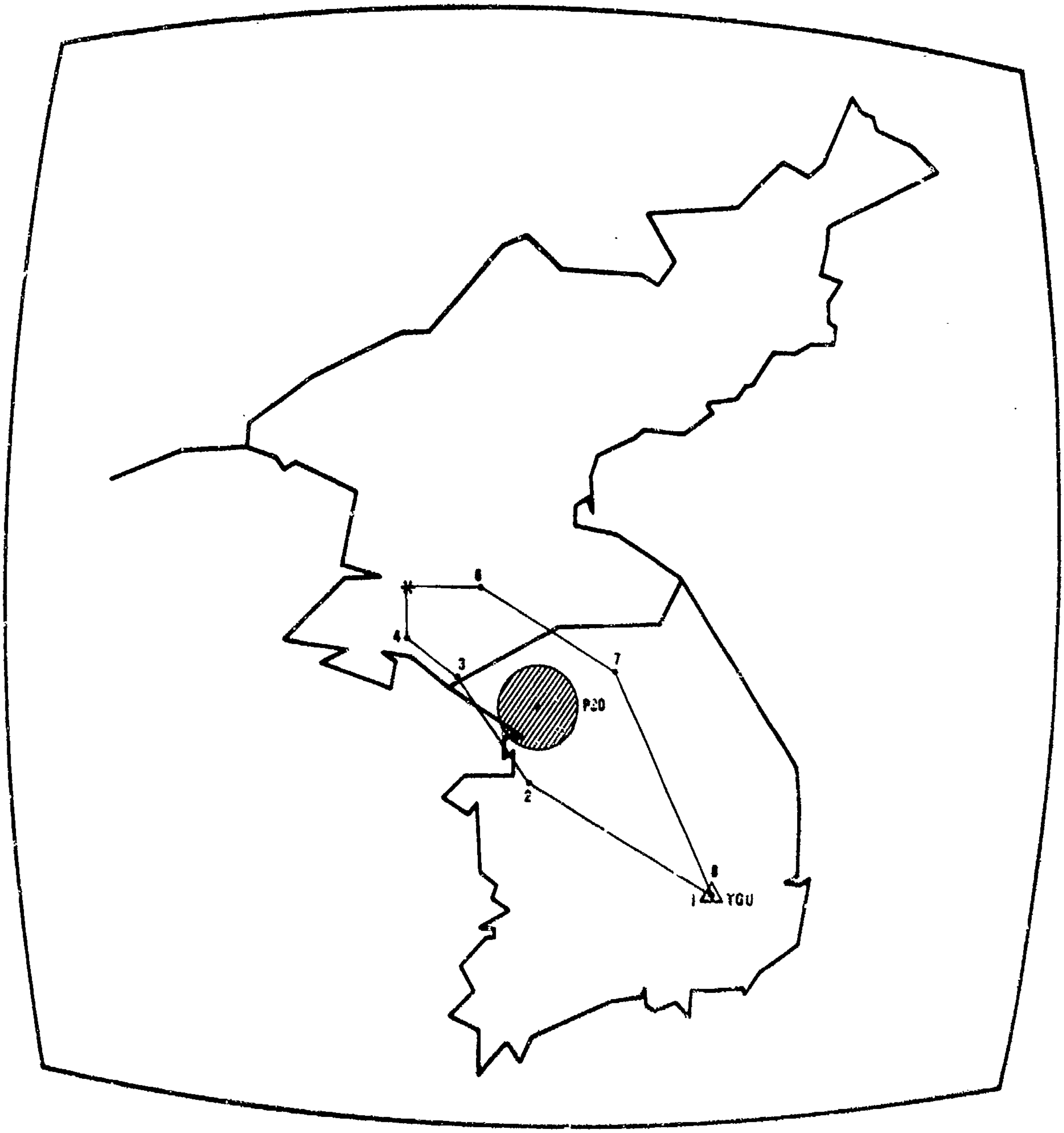
Activation of the "Route Modification" function switch results in the alphanumeric display as shown. The planner may use either the graphic or the A/N display for route modification. This display is used to indicate the node or point at which the planner wishes to start his modification. He may identify a node by number or a point by using the lightpen.


P-30



Selection of a starting point automatically causes the A/N display to change to the format shown here. This format is used to define what the planner wishes to do. Selecting one of the three options results in a new A/N display oriented toward making the desired changes except in the case of "Delete Node." If "Delete Node" is selected, the node which was identified in the previous display is deleted and the route automatically is connected between the node prior to and subsequent to the node(s) deleted.

In the scenario, the planner first selects option 3 – Add Check-point(s).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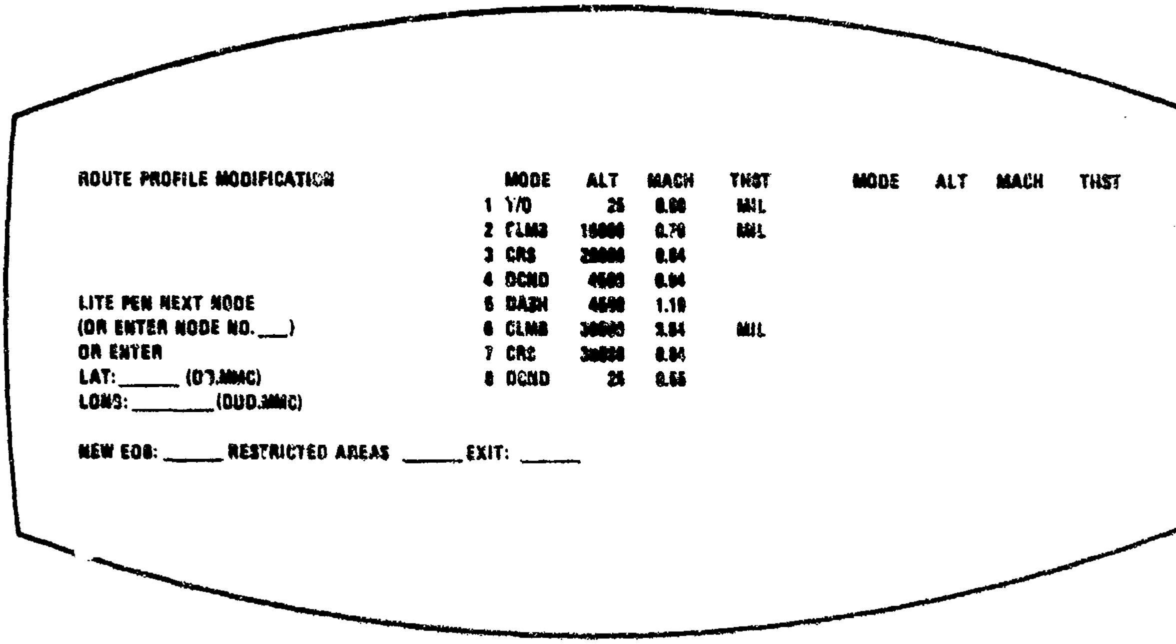
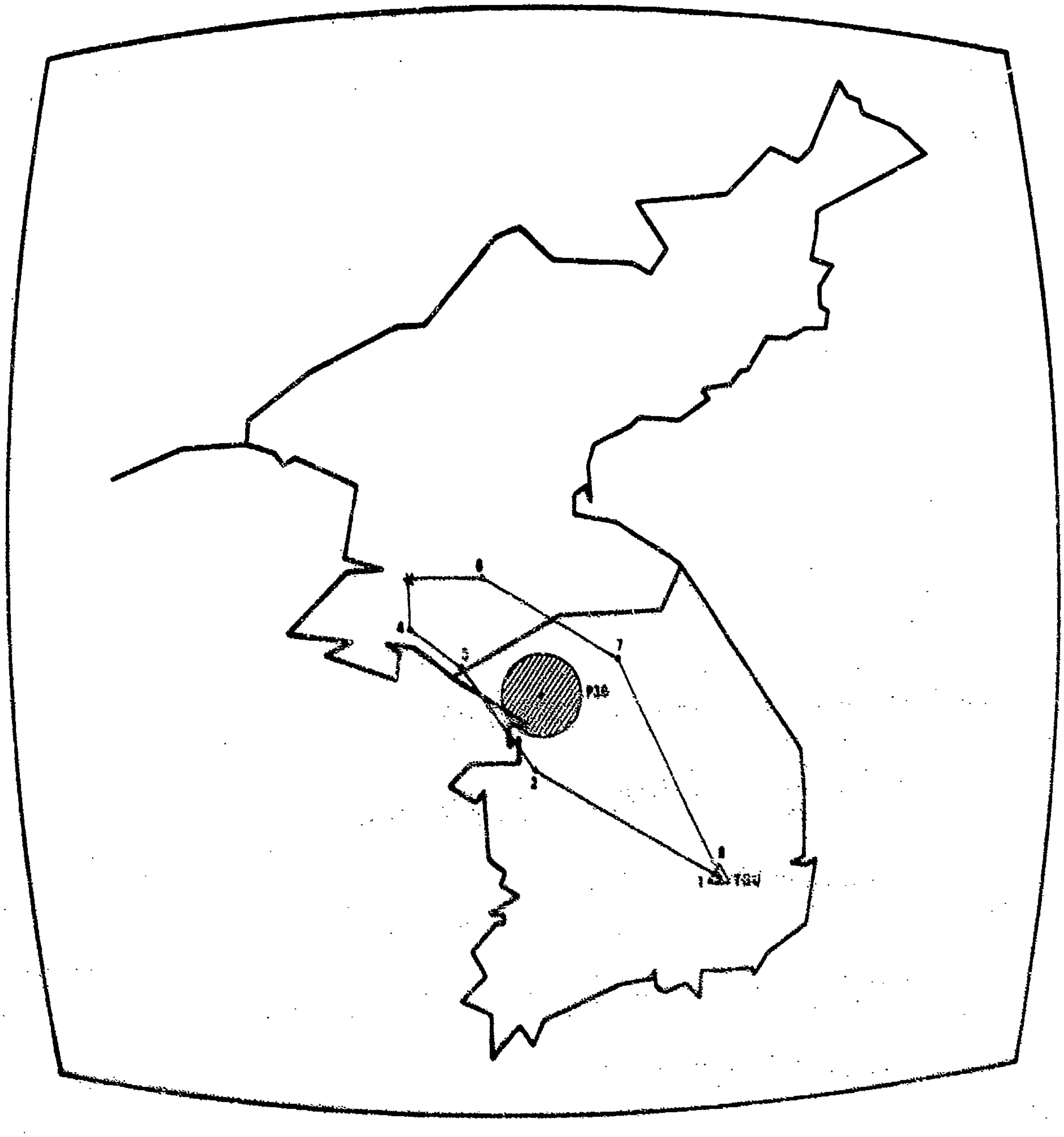


Selection of Option 3 produces this alphanumeric display. The display allows the planner to use either the graphic display (lightpen) or the A/N display (node number or Lat/Long entry) to modify the route.

Using the lightpen the planner indicates where he wants the next node to be. A line is then drawn by the processor from the starting node (in this case node 1) to the indicated point. Subsequent lines can be drawn the same way.

The original route is also maintained until the planner causes the new route to rejoin the old route. At that time, the discarded legs vanish from the scope leaving the new route. Node numbers are automatically changed as required.

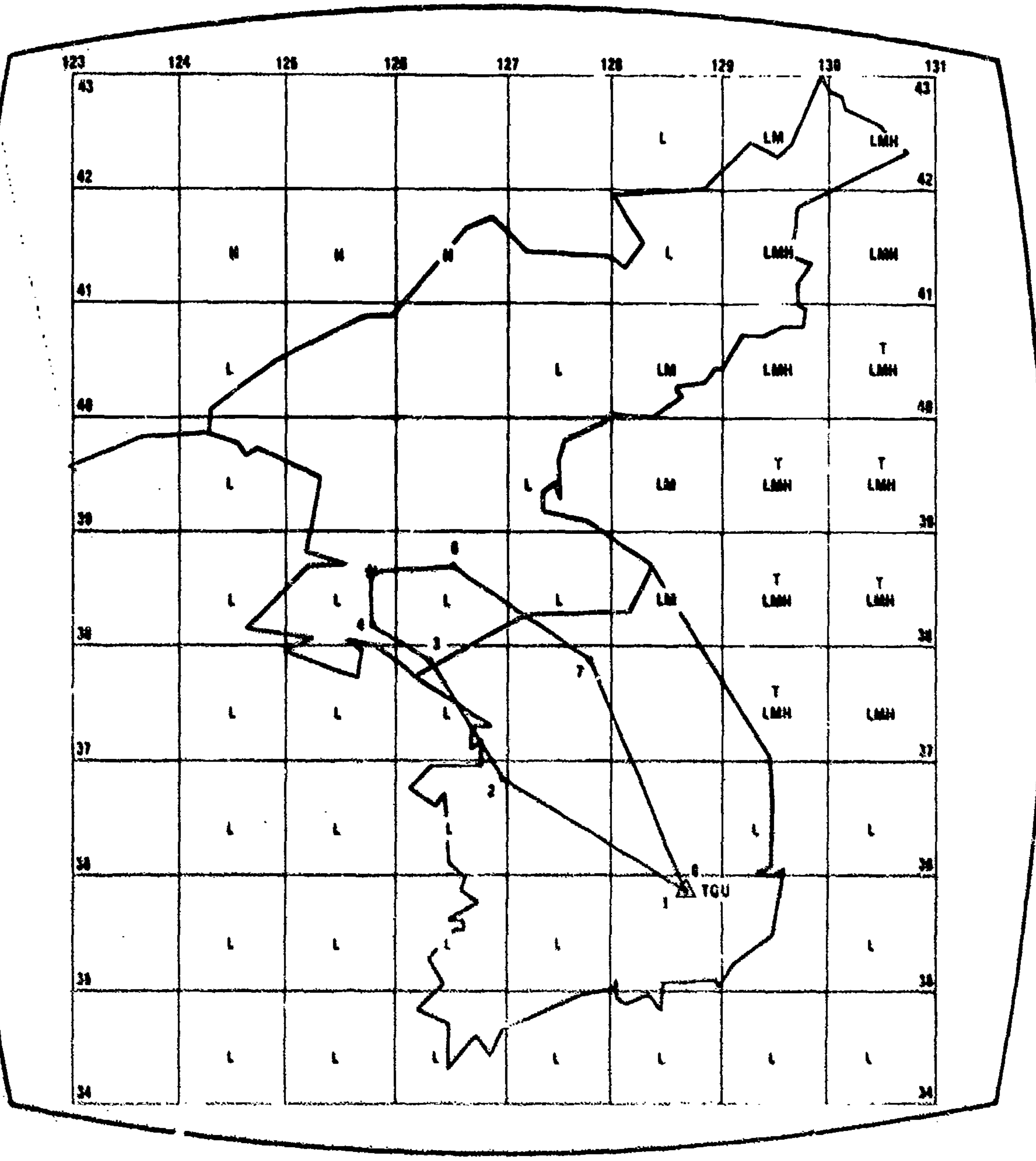
Notice in the graphic display, how a new node 2 was created which by-passes the restricted zone and rejoins the old route at node 3.



```
ROUTE PROFILE MODIFICATION                      MODE    ALT    MACH   THST      MODE   ALT   MACH   THST
                                              1 T/O       25   0.80   MIL
ENTER CHECK POINT DATA                        2 CLMB   10000   0.70   MIL
MODE: C R S _  (CRS, CLMB, DCND,              3 CRS    20000   0.84
                 DASH OR FUEL)                4 DCND    4500   0.64
ALT: 2 0 0  (IN 100'S OF FEET)                5 DASH    4500   1.10
MACH: 0 8 4 (IN FORM 0.00)                    6 CLMB   30000   0.84   MIL
THST _ _ _  (MIL, MAX, XLL, XXL)              7 CRS    30000   0.84
LAT: 37.51N (DD. MMC)                         8 DCND      25   0.55
LONG: 128.12E (DDD. MMC)

NEW EOB: ____ RESTRICTED AREAS: _____  EXIT: _____
```

The planner may also desire to modify other types of data relating to a particular leg. Such items are leg mode, leg altitude, leg Mach number and/or thrust setting. To do so, he would return to display shown on page 33 and select a node. For the example, suppose he chose node 3. The next display would be the one previously shown on page 37. In this case the planner would enter a "1" (Modify Checkpoint). This action produces an alphanumeric display like the present one. The data for leg 3 as they presently exist are included in the format. The planner can change any of these data by overwriting his desired changes in the appropriate location. The route data on the right of the display are automatically updated as are the data in the flight plan summary.



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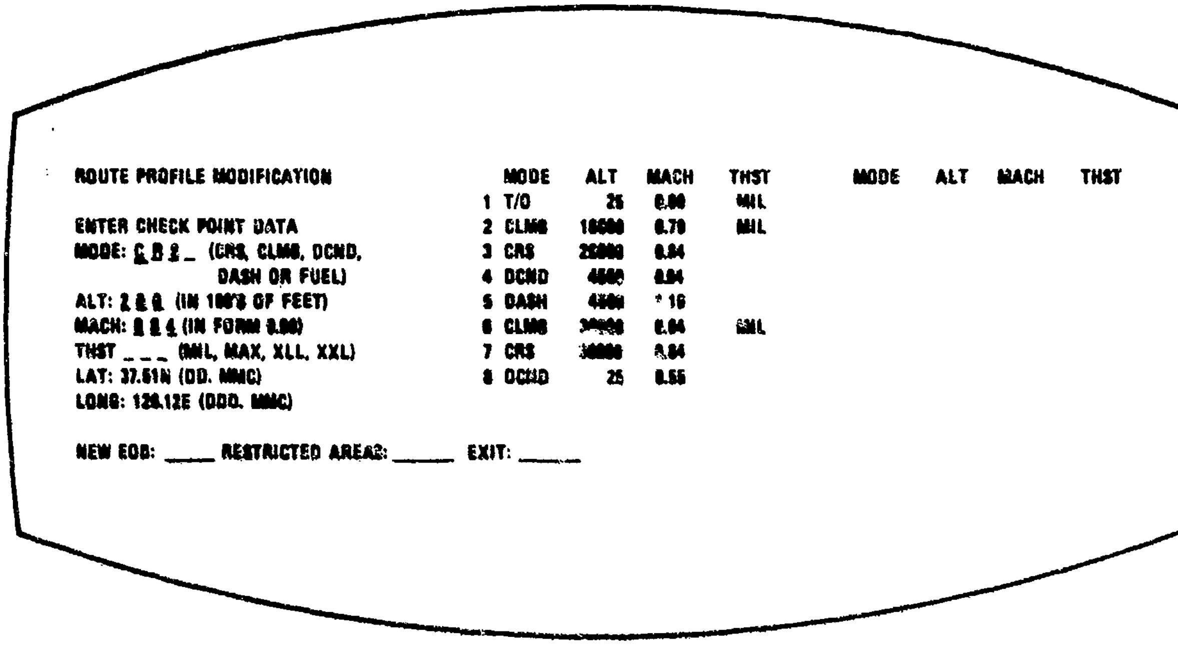


The weather display is generated by activating the WEATHER function switch. This display is used by the planner to determine whether his old route or his new one should be modified because of weather. Two types of weather data are presented on a one degree by one degree grid. First the planner is shown data on cloud cover. Cloud cover is shown where it exists in one, two or three layers. Layers are represented by the letters L, M and/or H.

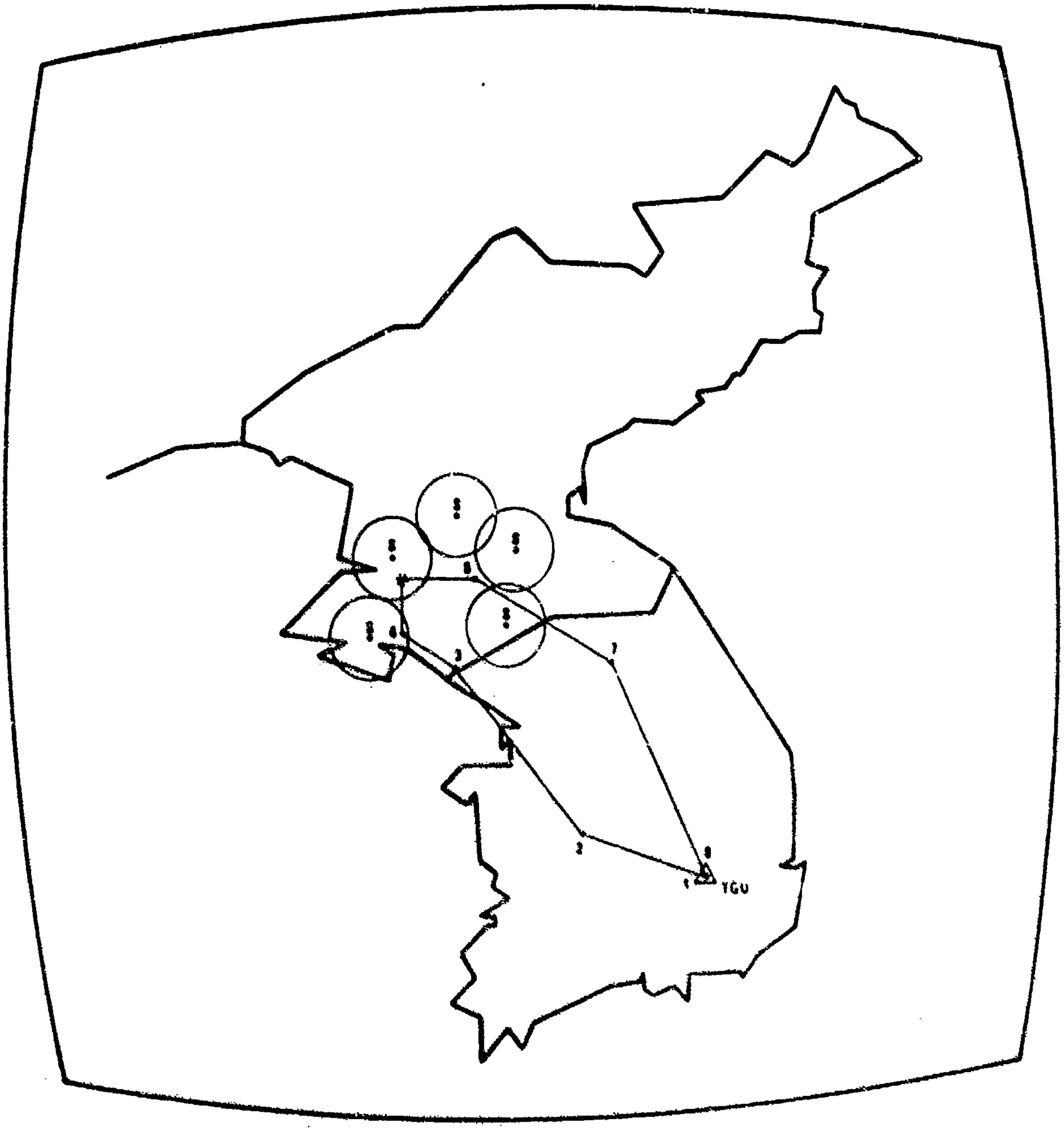
L = low level cloud cover

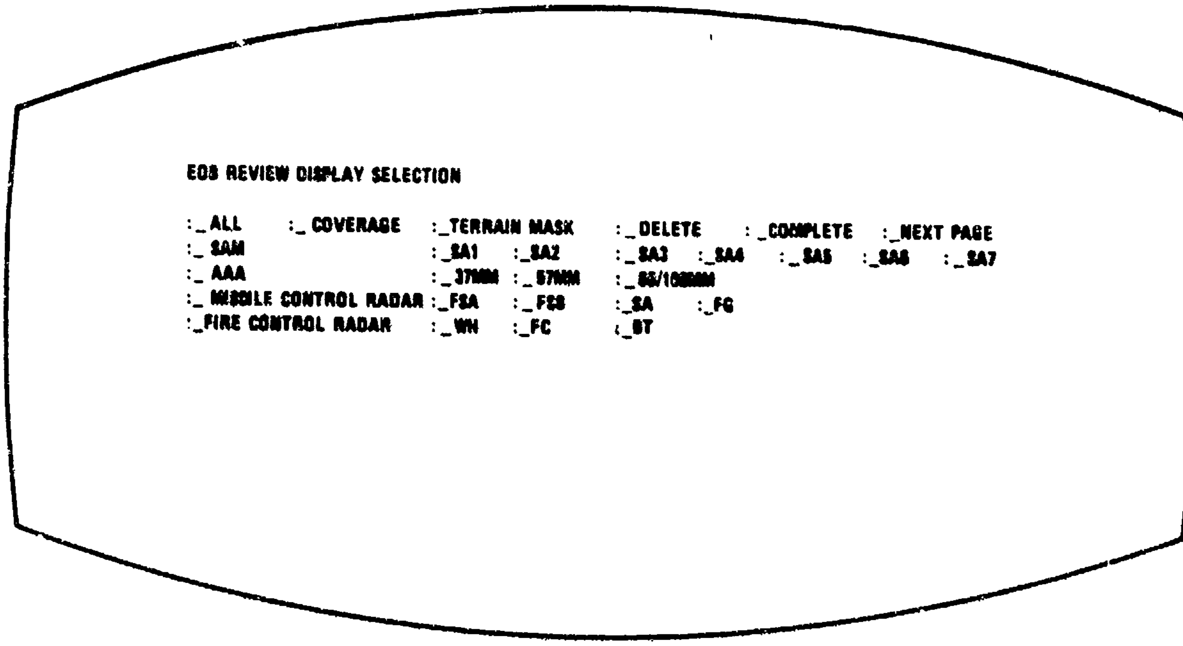
M = medium level cloud cover

H = high level cloud cover

In addition areas with reported turbulence are indicated by a T.

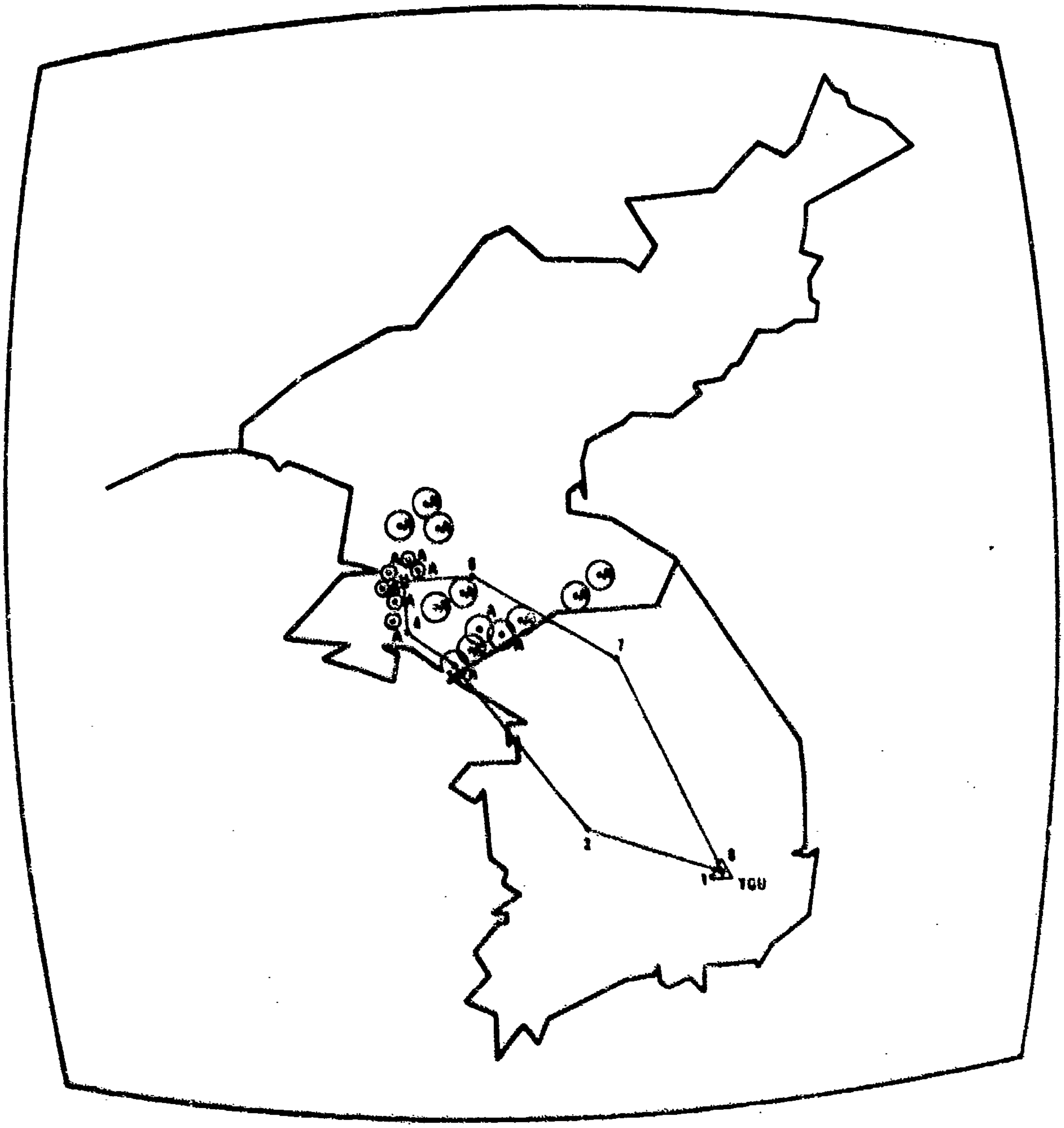
If the weather appears to be a problem, the planner can refer to his hard copy weather data and map for more detail. He may also use the route modification capability to change the route if necessary.


YGU



By selecting the EOB REVIEW function switch, the planner can further evaluate his route on the basis of enemy order of battle (EOB). The planner selects the particular threat types he wishes to see from the menu of the alphanumeric display. He may select one or more classes (e.g. SAM, AAA) or he may select one or more subclasses (e.g. SA2, SA3 and 57 MM AAA). When he finishes his selection, the threat elements he desires are displayed on the graphic display with the restriction that (1) only the location is shown as indicated by a letter and (2) only those threats which actually intersect his track are shown. (The graphic display as shown is slightly different from the description to this point since it is designed to show many capabilities).

Referring again to the A/N display, if the planner selects "ALL" he is shown all the threats of the selected class(es) in the tactical area. Selection of "COVERAGE," when accompanied by light pen action at a site location, produces the circle of range coverage as shown in the graphic display. Selection of "DELETE" when accompanied by light pen action removes the circles. "DELETE" when used with a class selector (e.g. AAA) removes the entire class. During any light pen actions the various function buttons are made inoperative. Selection of "Complete" after light pen action restores the option to choose other functions.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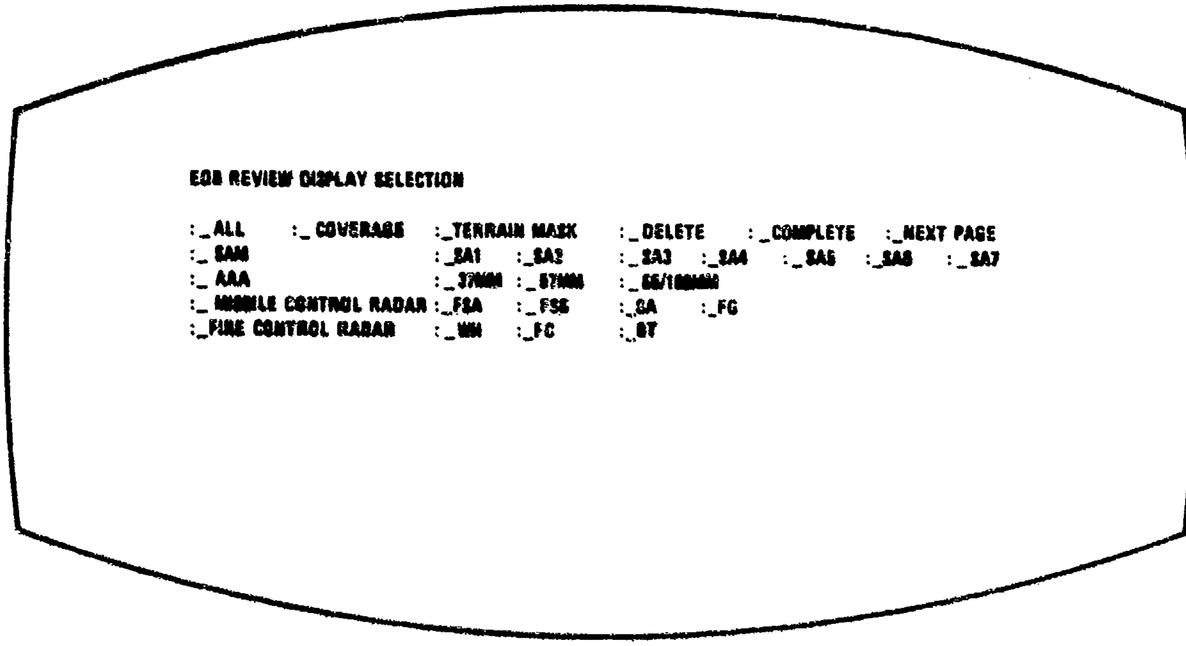
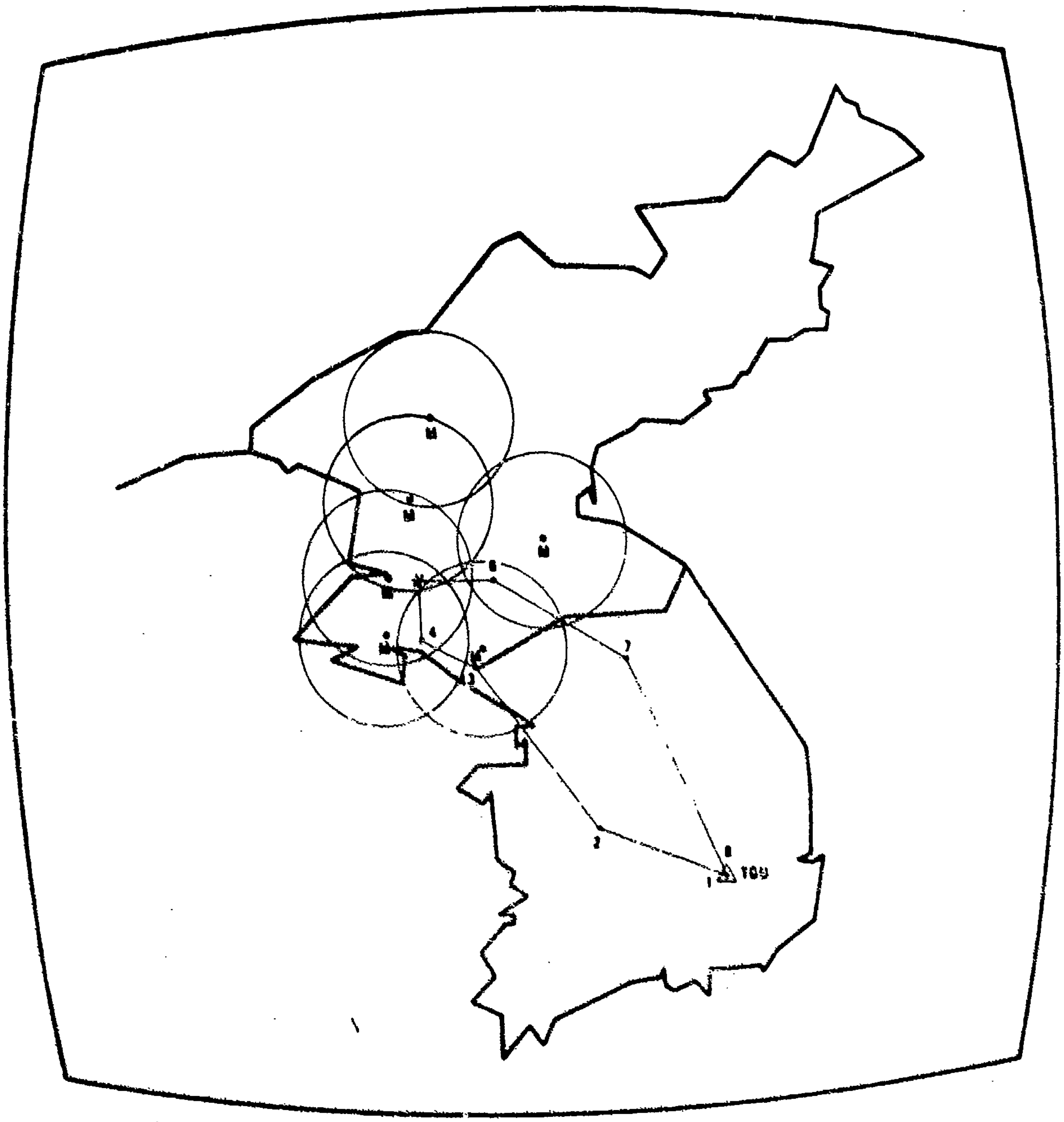
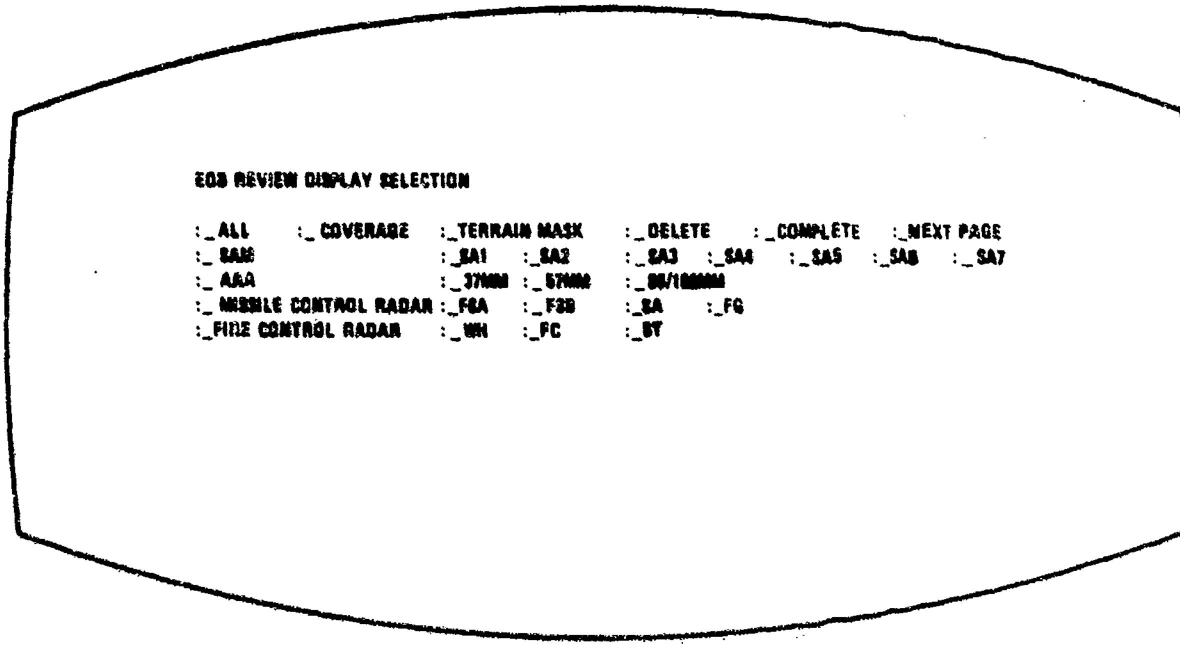
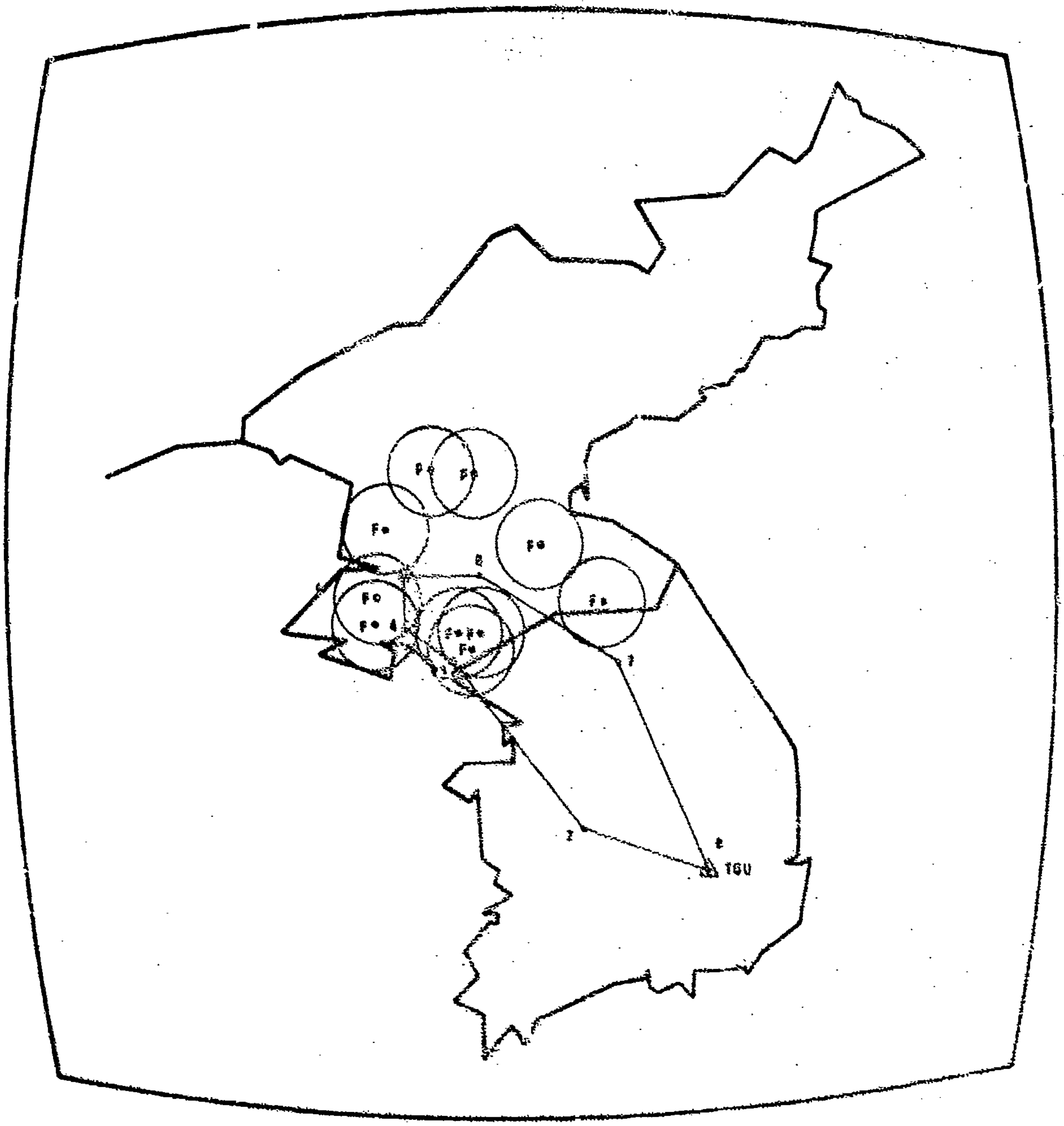


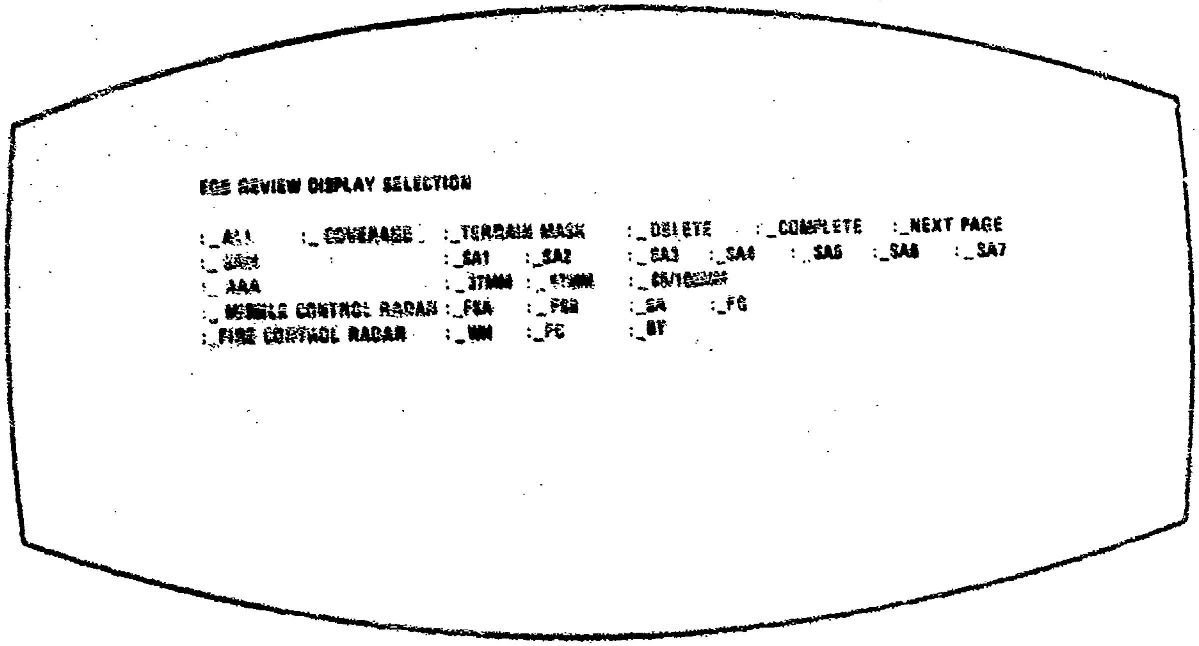
The graphic display shows a typical distribution of AAA sites.



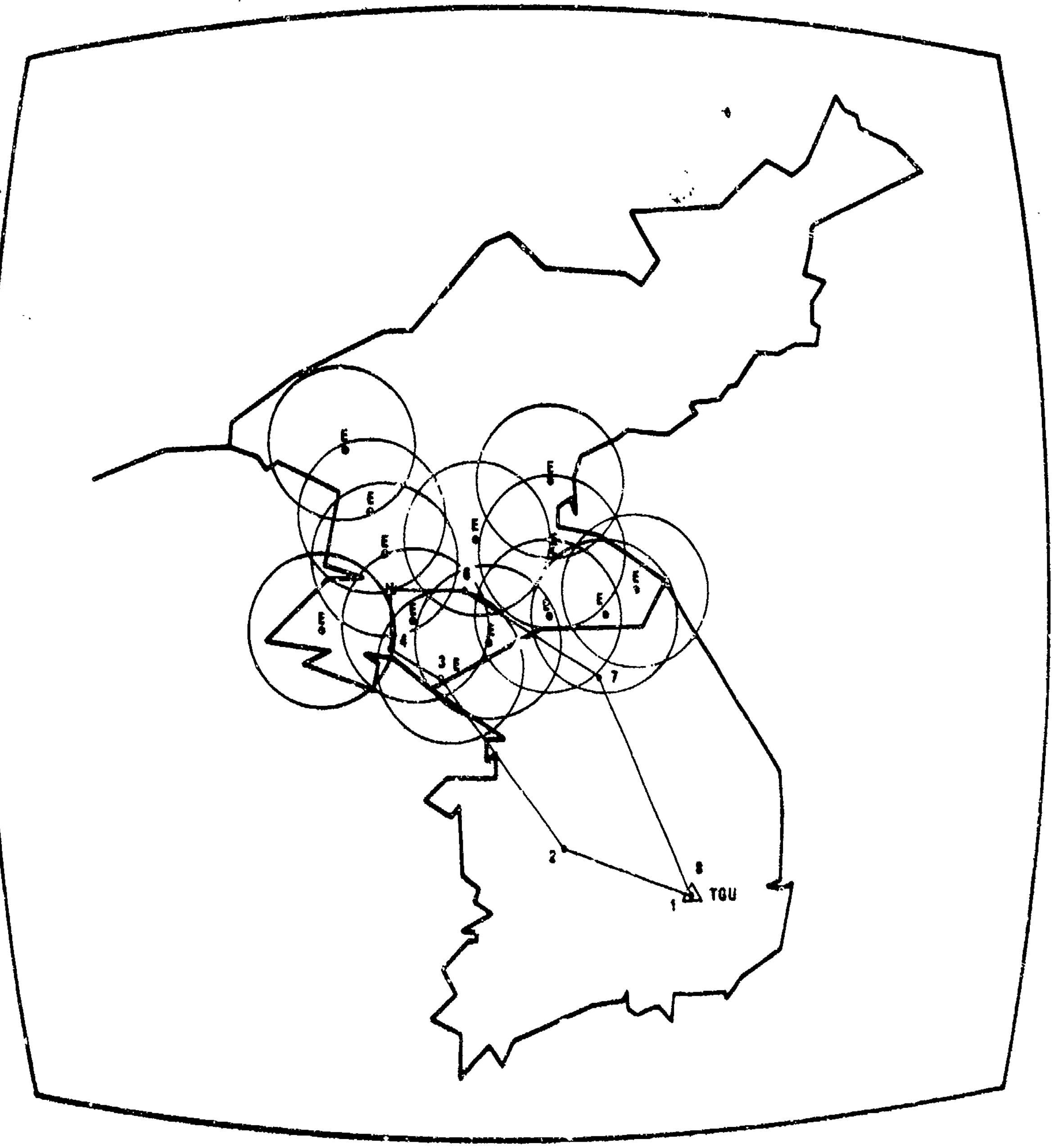


This display shows a possible pattern of Missile Control Radars. This display may be combined with the display indicating the location of SAM sites.

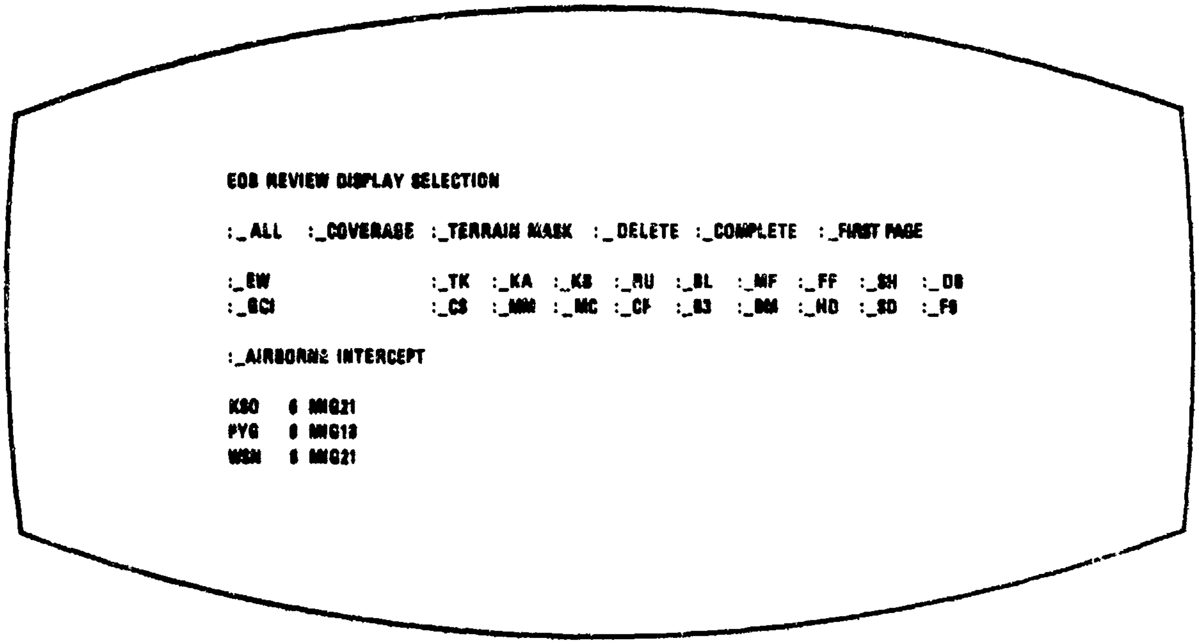

TGU



The graphic display may also be used to display the location and coverage of Fire Control Radars.

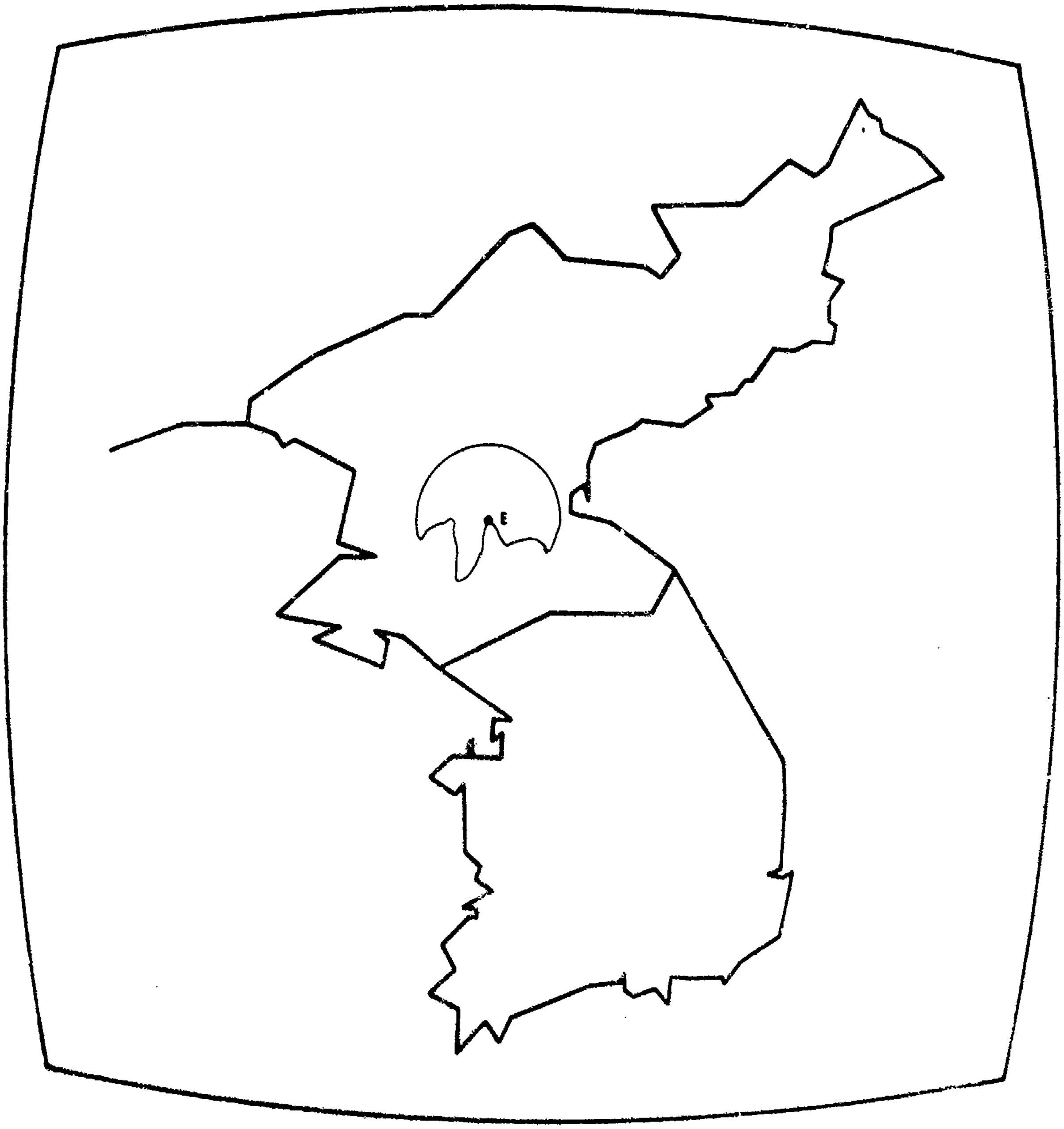


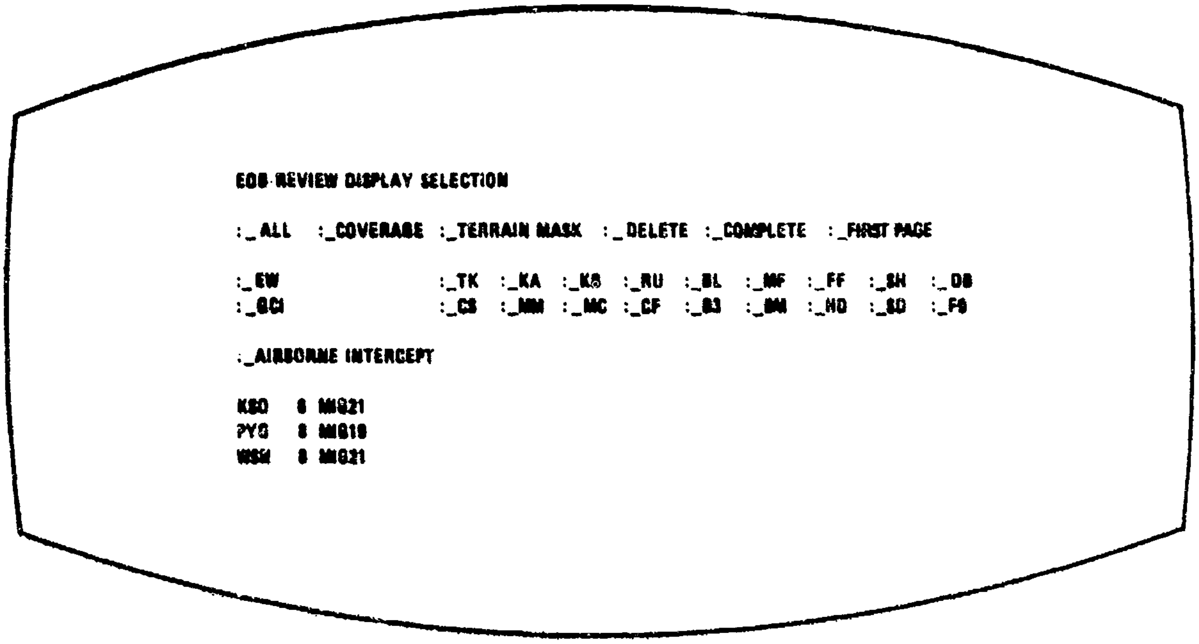
TGU



In order to request a display of enemy Early Warning Radars, GCI sites and Airborne Intercept capabilities, a second menu is required. This format is used in the same way the previous one was used. The planner selects either a class or subclass of threat.

The graphic display shows the location of the EW radars as indicated by an "E."

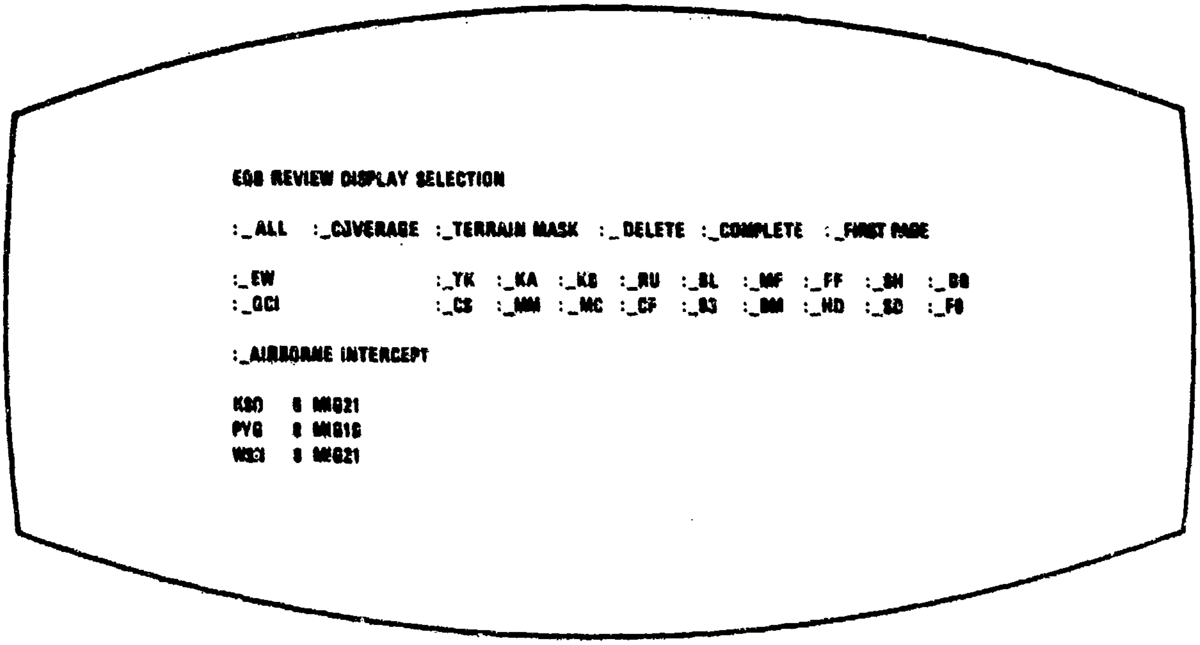

E



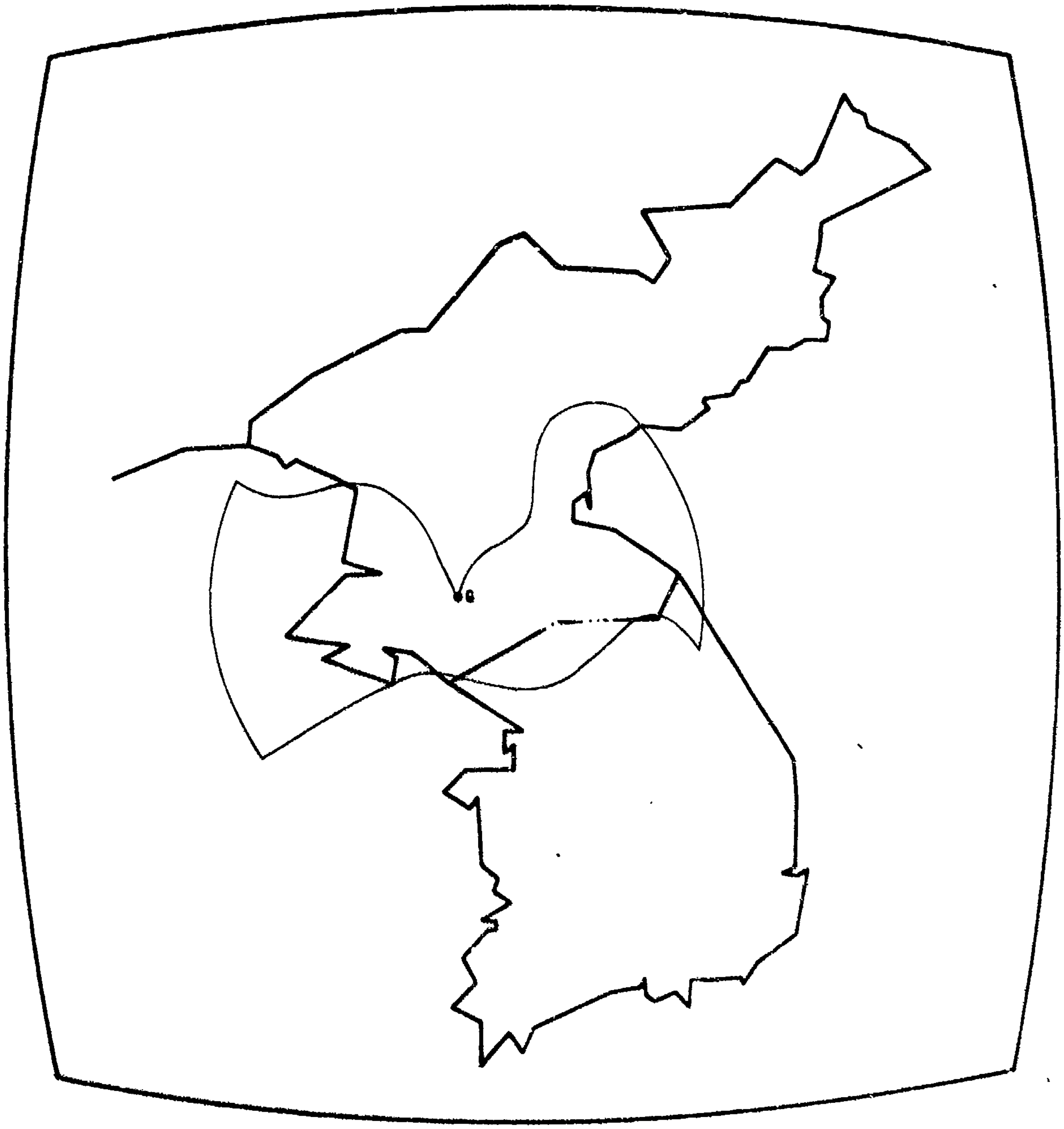
The graphic display now shows the capability to display terrain masked coverage of a radar. This function is initiated by selection of "Terrain Mask." This capability is actually available for Missile Control Radars, Fire Control Radars and GCI sites, as well as Early Warning Radars. The coverage age of an EW radar (selected by light pen action) at the altitude flown by the mission aircraft.

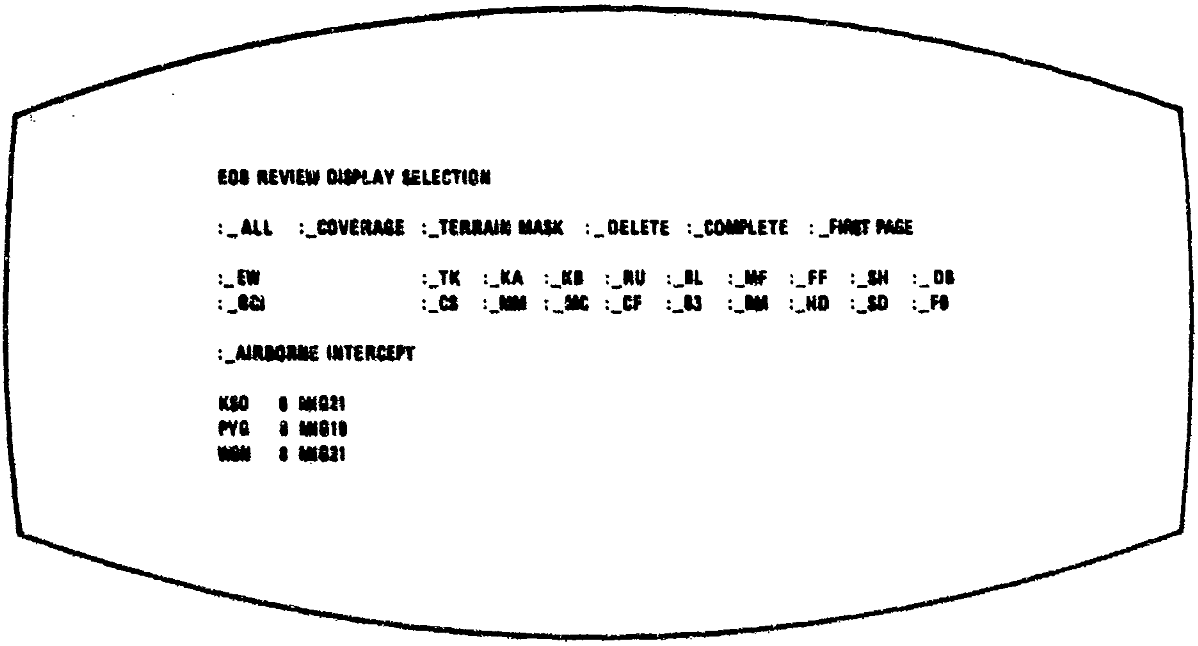
While the programs to provide this coverage are available, the actual implementation of the terrain masking function is severely limited by the relative unavailability of terrain data.


TGU

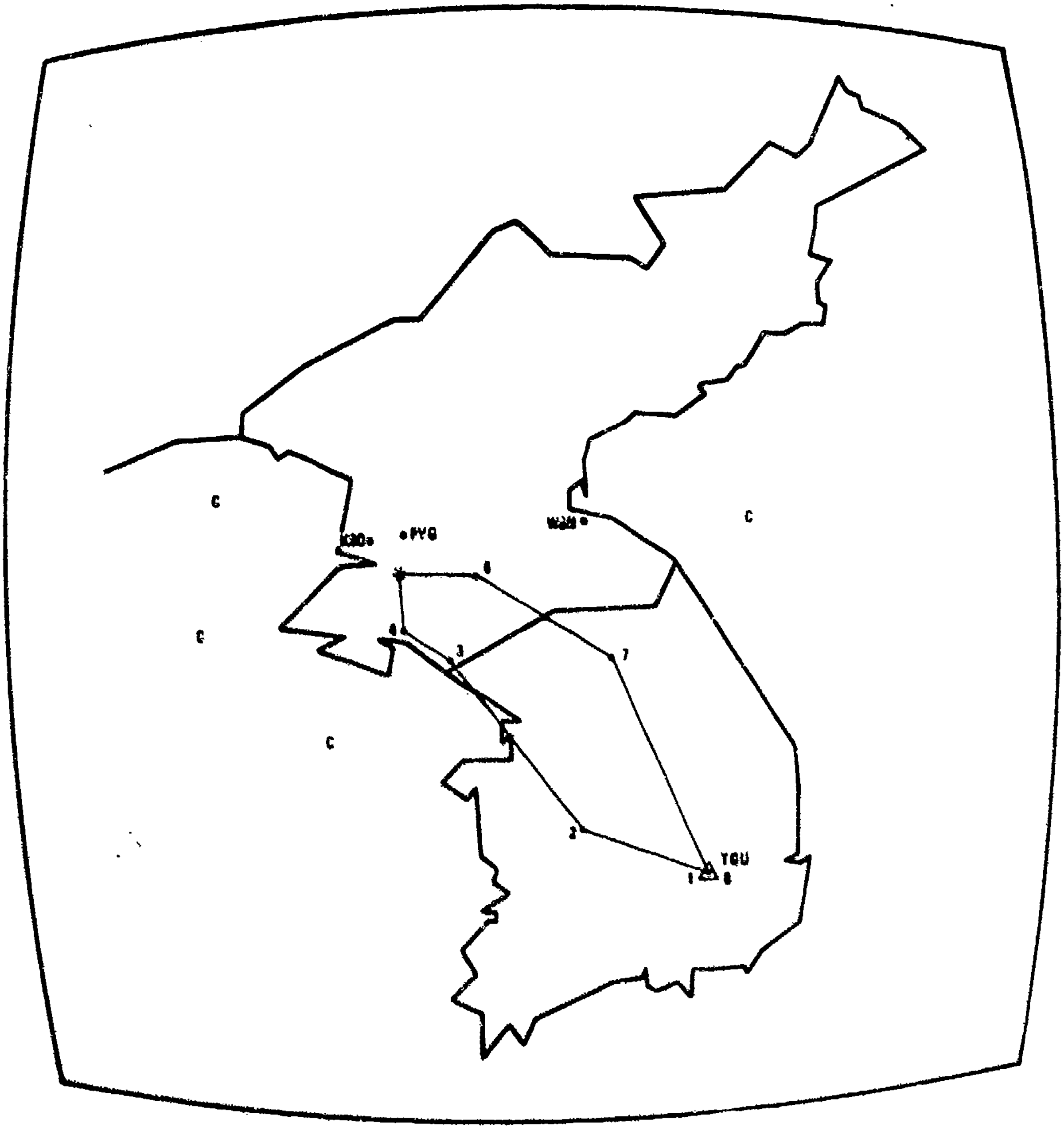


This display is typical of the coverage of enemy GCI sites.





This display represents a typical terrain masked display for a GCI site. The coverage is still altitude dependent, of course.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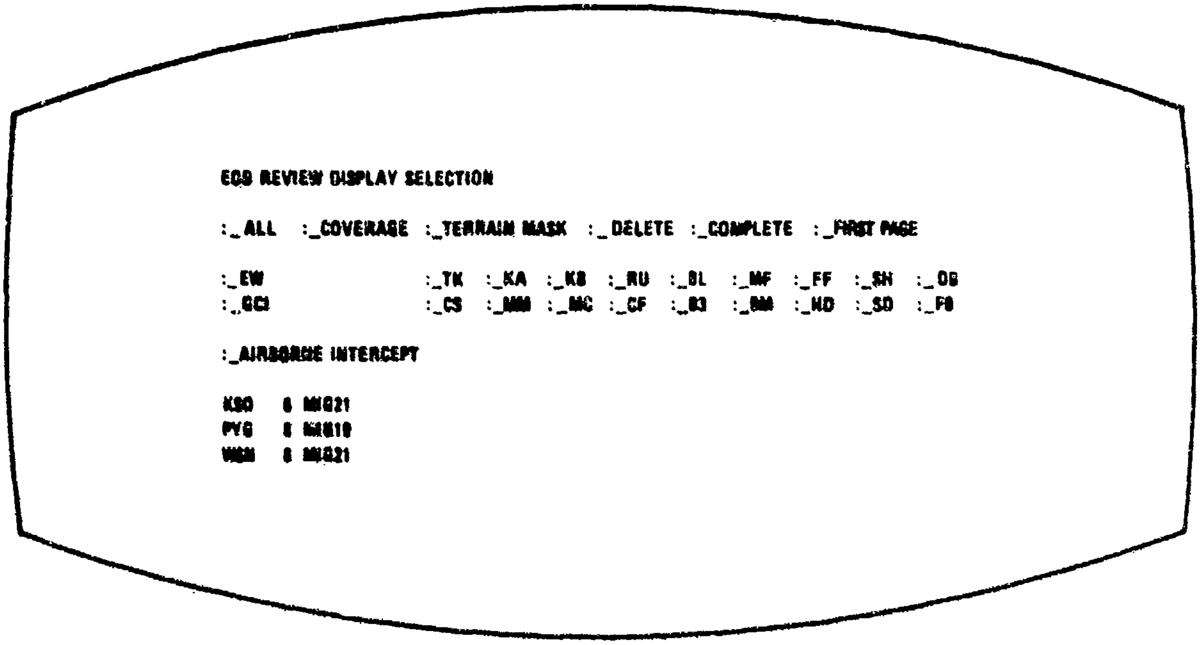
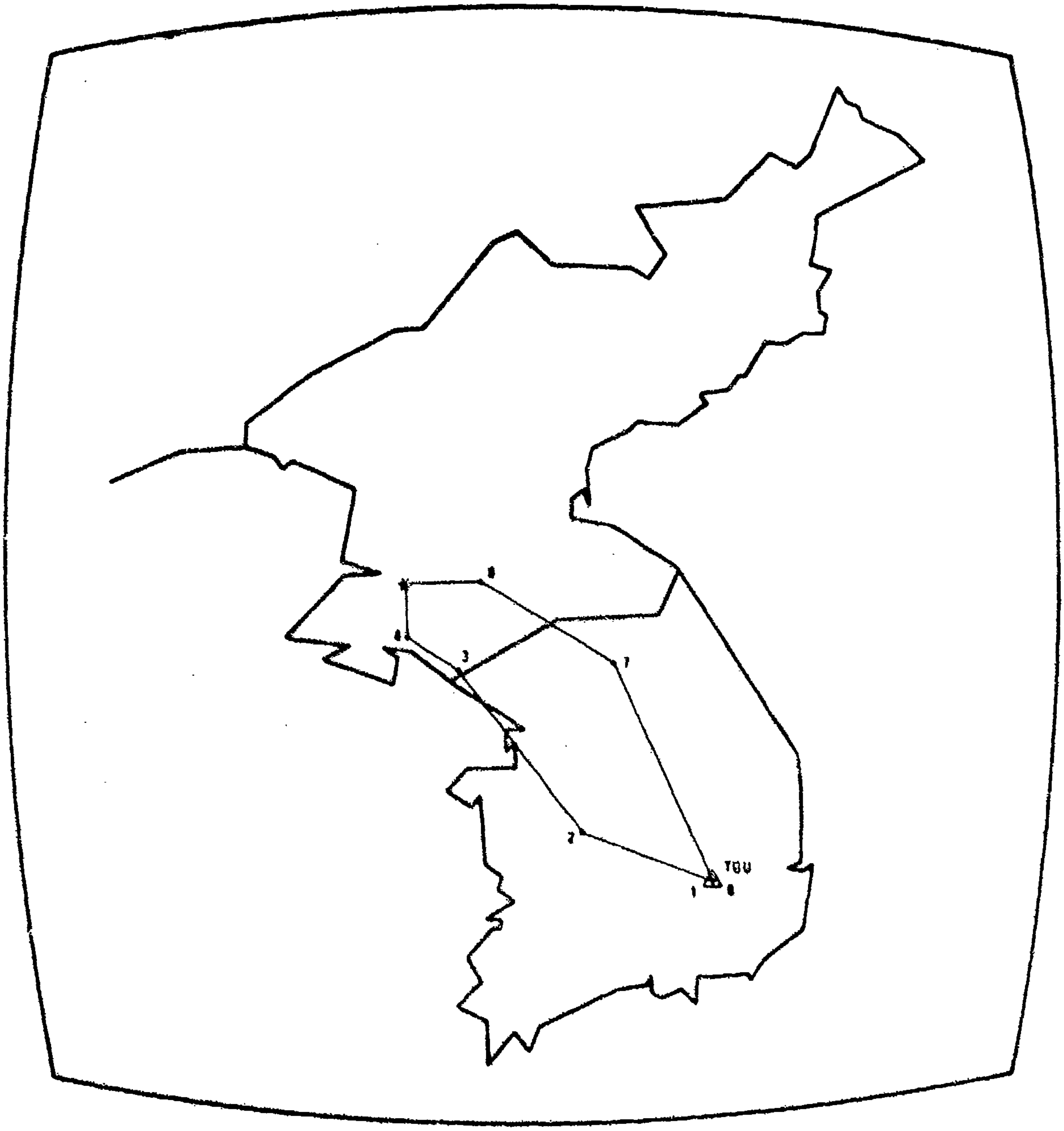


This is the display which the planner sees when he requests "Airborne Intercept" on the threat menu. The A/N display changes to include data on the number and type of enemy aircraft at each base. The graphic display presents the location of enemy airbases with the airbase identifiers. In addition, it uses the letter "C" to indicate the location of known enemy CAP or loiter points.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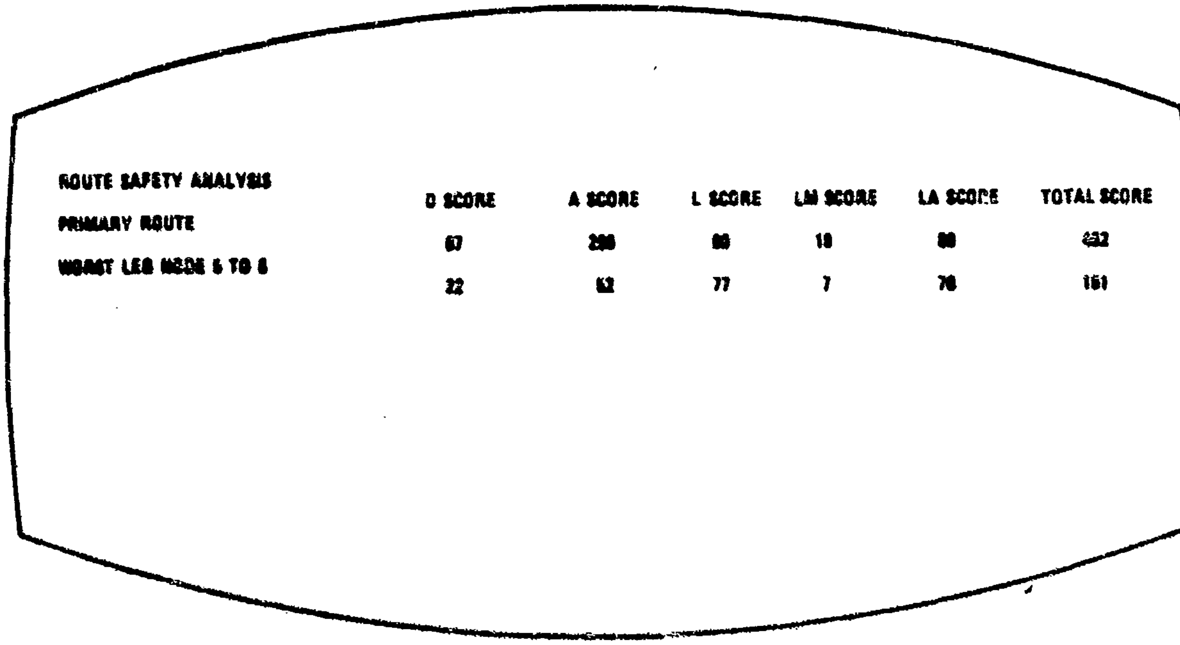


At this point the planner has tentatively selected a route as shown on the graphic display. He may now use a function switch to request that the selected route be scored. The result of the scoring is shown on the A/N display. There is a score for the whole route as well as a score for the worst leg. The total score in each case is composed of three subscores.

1) D score or Detection score which is a measure of the time the mission is within coverage of enemy GCI sites and/or EW radars.

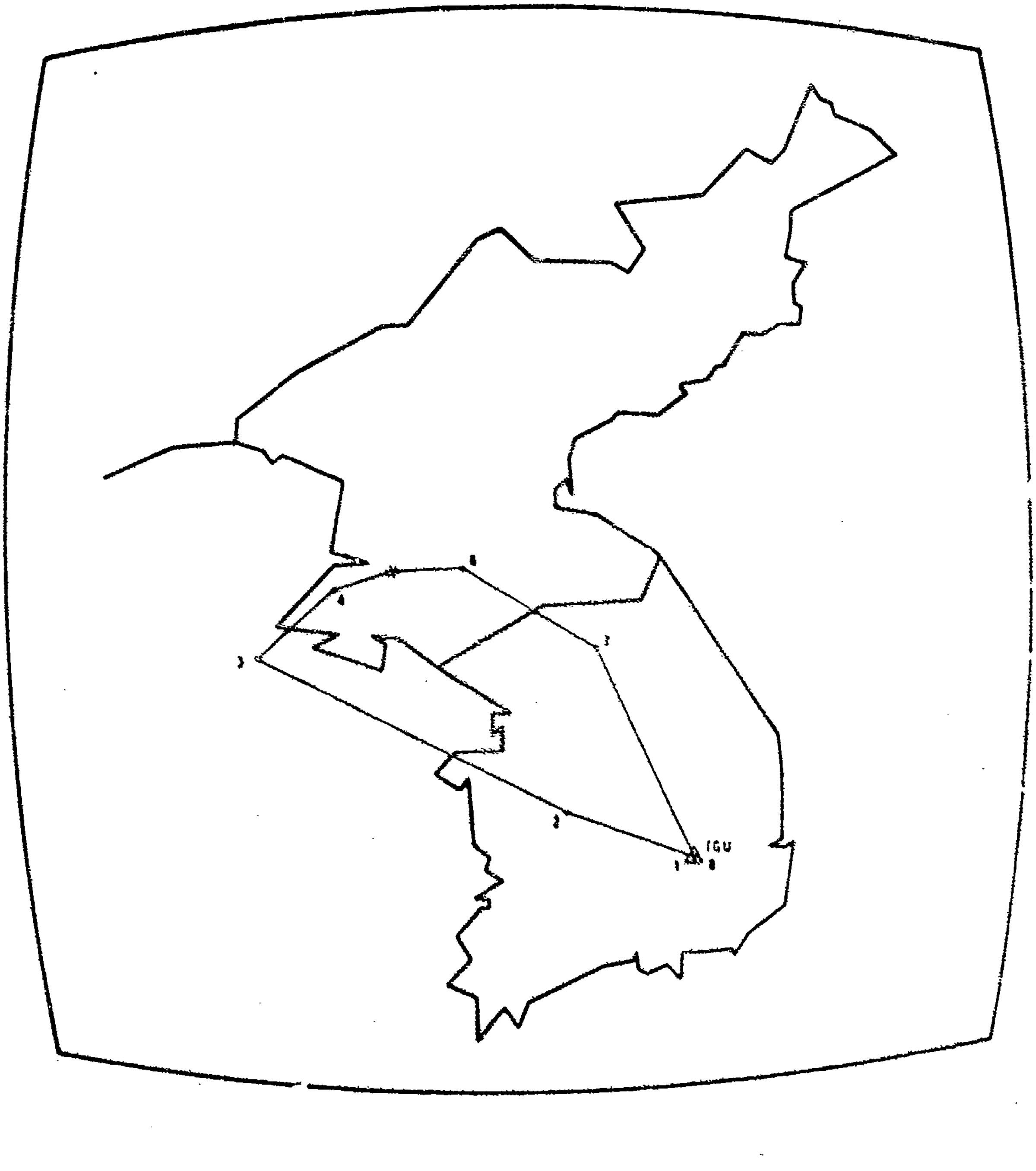
2) A score or Acquisition and Tracking score which is a measure of the time mission aircraft are within coverage of missile control and/or fire control radars.

3) L score or Lethality score which is a measure of the time that mission aircraft are literally within the lethal range of enemy missiles and/or AAA. The L score is further subdivided into L_M and L_A scores which denote respectively the proportion of the L score resulting from missiles (L_M) and AAA (L_A).

Each score is composed of two factors. First there is a time factor representing actual exposure. Secondly, the time factor is multiplied by a factor which represents the effectiveness of the particular threat type. Thus the scores are differentially weighted by type.

Further, the scores are also altitude dependent. That is, even though an aircraft may fly directly over an AAA site, if he is high enough to be out of range his score is zero for that site. In addition, since the coverage range of various radars increases with altitude, higher altitude flight profiles will get larger D and A scores. Other altitude adjustments are also included.

The scores in Route Safety Analysis must be treated as relative rather than absolute scores. They do not imply that a given route is safe. They only imply that one route is safer than another. Thus they can be used to compare alternate routes.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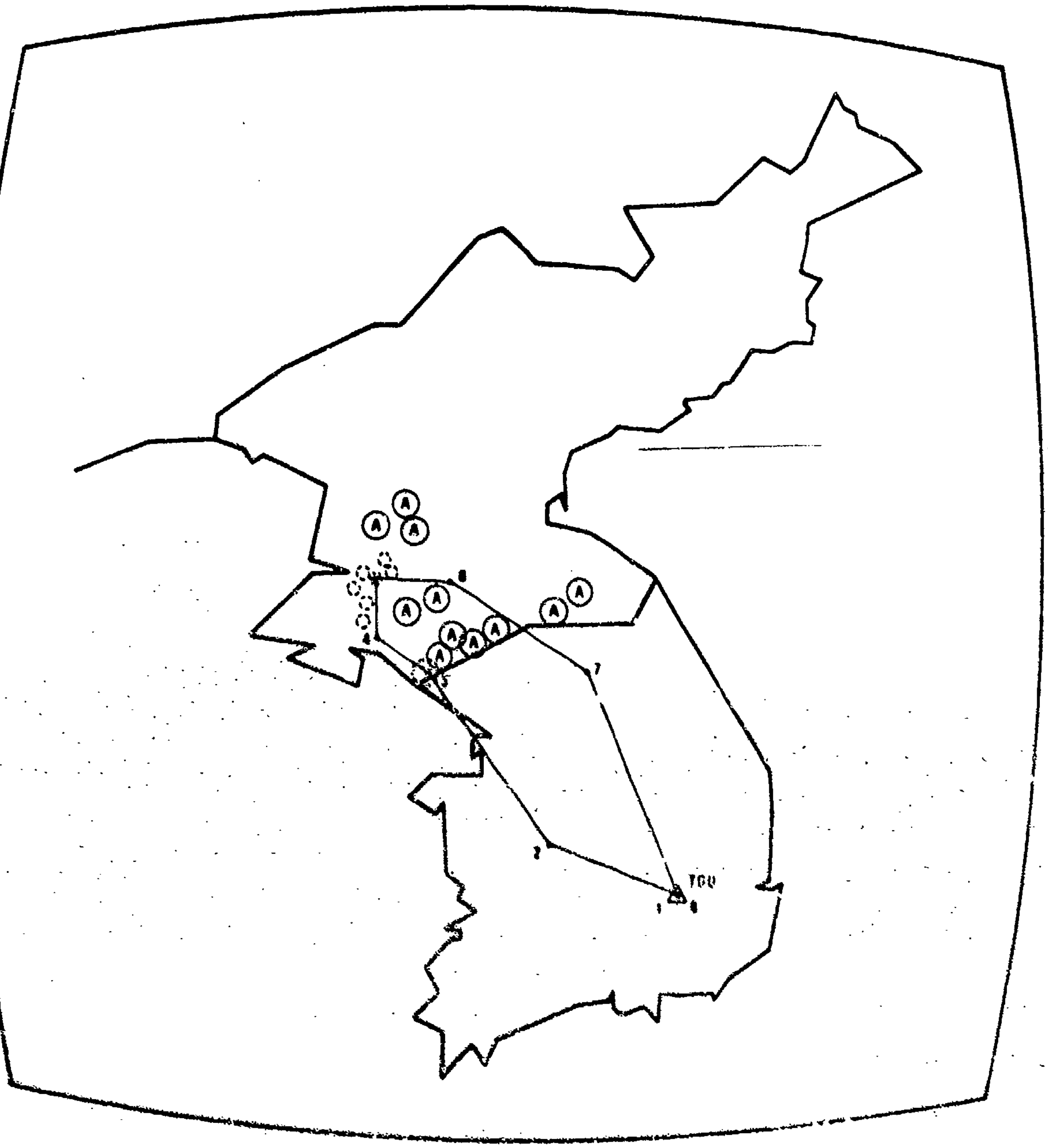
ROUTE SAFETY ANALYSIS

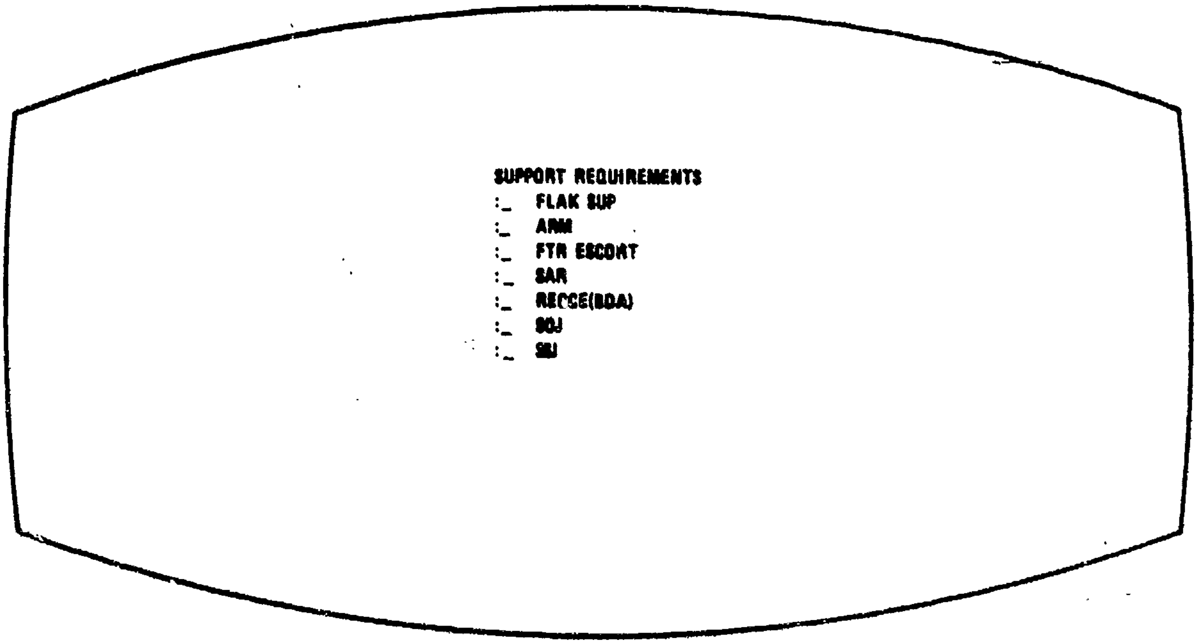
	D SCORE	A SCORE	L SCORE	LM SCORE	LA SCORE	TOTAL SCORE
PRIMARY ROUTE	67	206	90	19	80	462
WORST LEG NODE 5 TO 6	22	52	77	7	70	151
ALTERNATE ROUTE	83	370	126	23	102	578
WORST LEG NODE 4 TO 5	21	63	93	14	79	177

If the planner wishes to compare the scores of two routes, he can do so by first activating a function button which is labeled "SAVE ROUTE." This takes the first route (i.e., the one that is presently on the scope) and stores it in memory with its score pattern.

At this point, the planner uses the "Route Modification" routine in order to develop an alternate route. Presumably, he would also use the EOB Review capability to develop an alternate which had some probability of being as good or better than the old route. Notice that by starting route modification at the airbase, the planner can plan a totally new route to the target as long as he also ends at the airbase. He need not use any of the legs of his earlier or "saved" route.

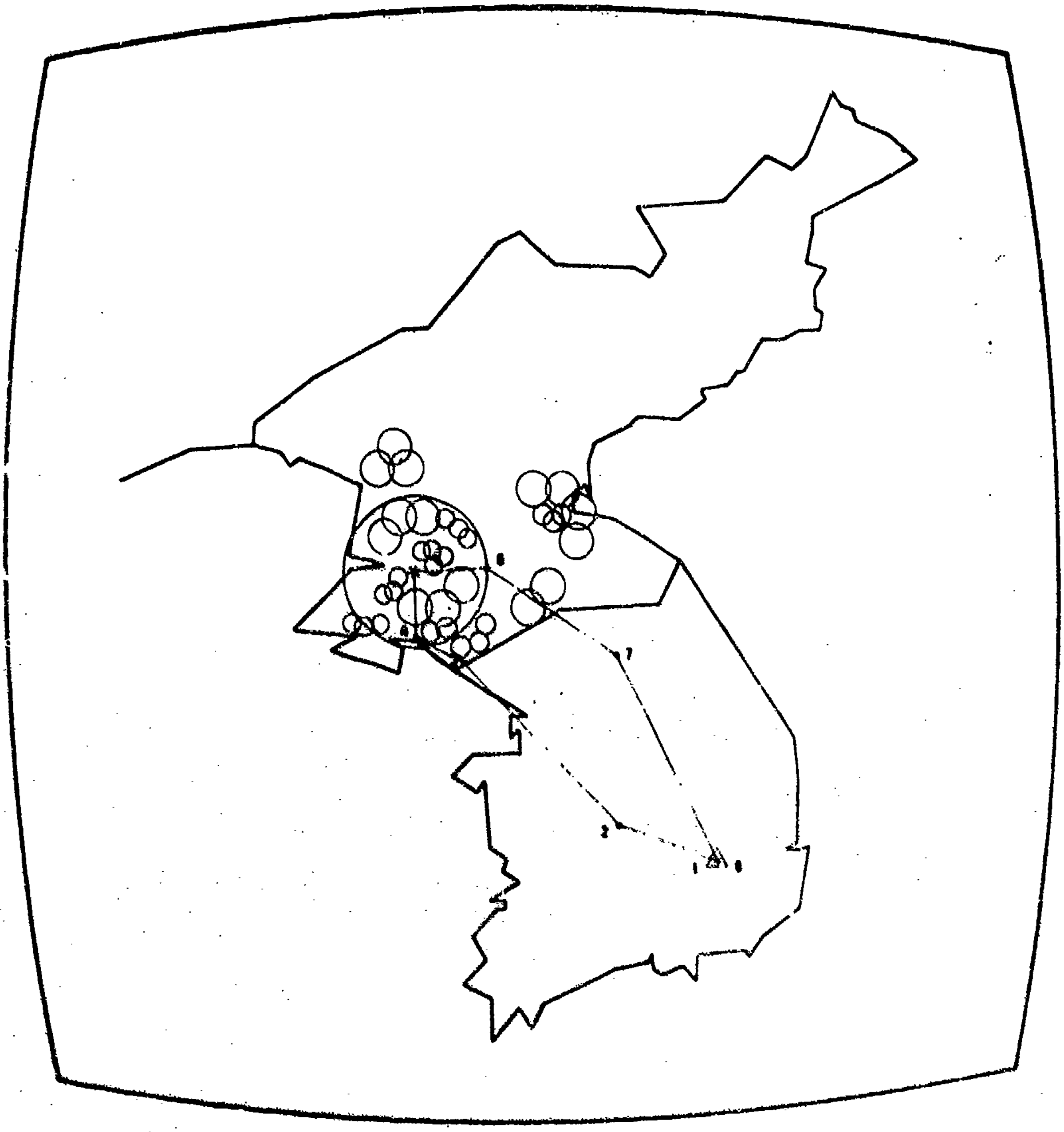
Once the alternate route is defined, the planner then requests that this route be scored. This results in the alphanumeric display as shown. The scores for the primary or saved route are given and a parallel set of scores are given for the alternate route. If the planner wishes to use the primary route, he activates a switch labeled "RESTORE ROUTE" and all data on the alternate route are thrown away. If he wishes to choose the alternate route, he activates the "SAVE ROUTE" switch and the earlier route data are replaced by the alternate route data which now define the primary route.

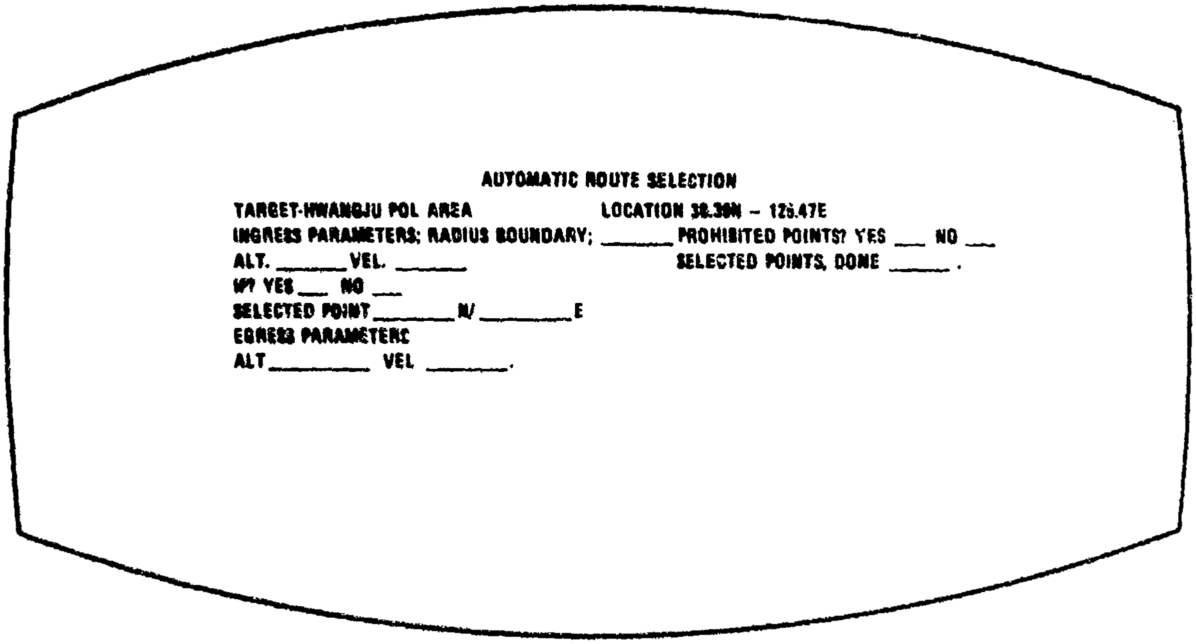




Although the breadboard system does not provide for planning support missions other than ECM, it does allow the planner to specify the kinds of support he feels the mission requires. His selection of support may be a function of the relative values of the scores. If the L_A score is high he may select Flak Suppression. Conversely, if the A score is high, the answer may be ECM support of some kind. (Stand-off Jamming or Special Support Jamming).

He may also recall the relevant EOB on the graphic display to evaluate the actual threat. In the present scenario he decides to select Flak Suppression support against the AAA sites shown as dotted circles.

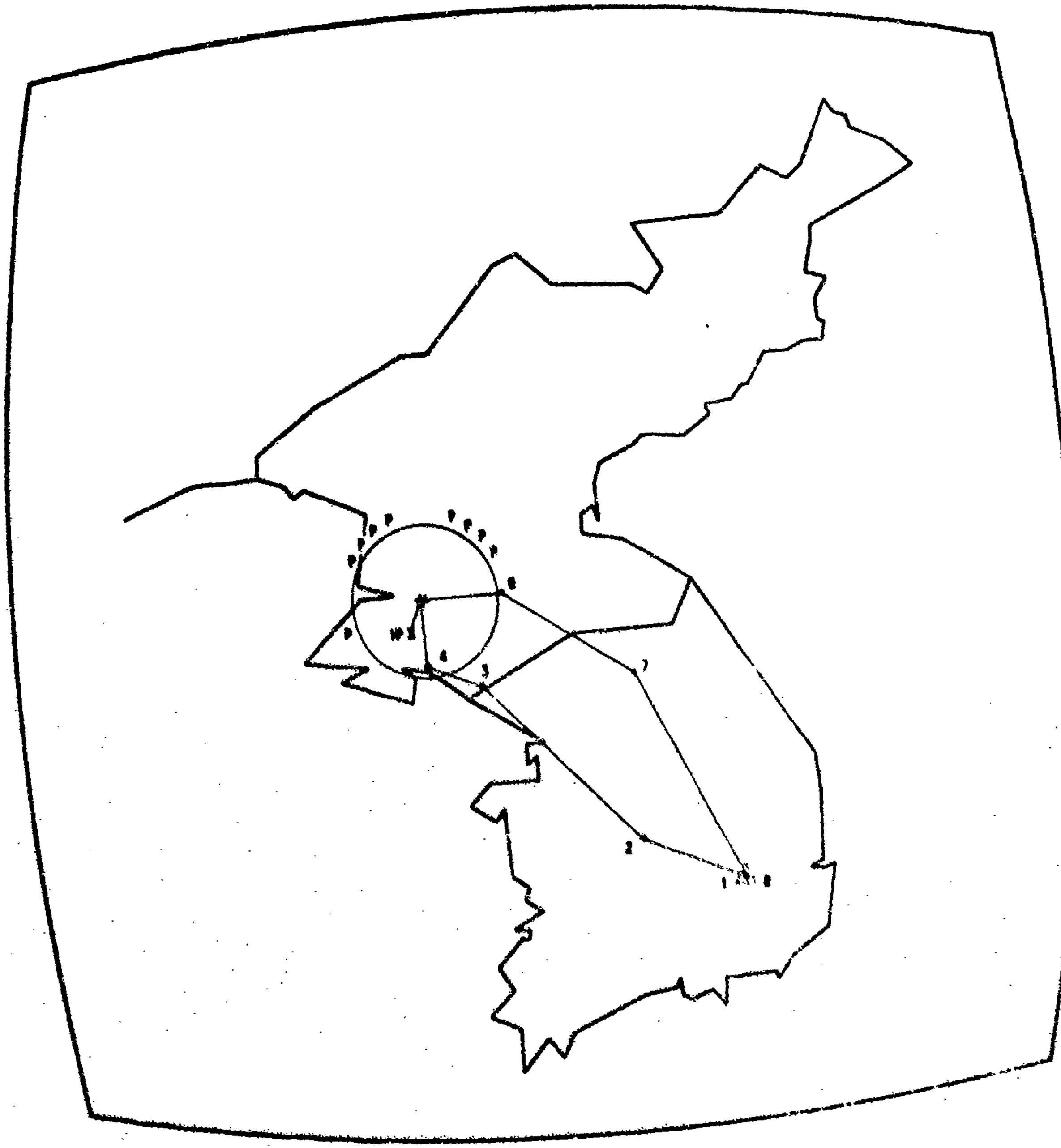


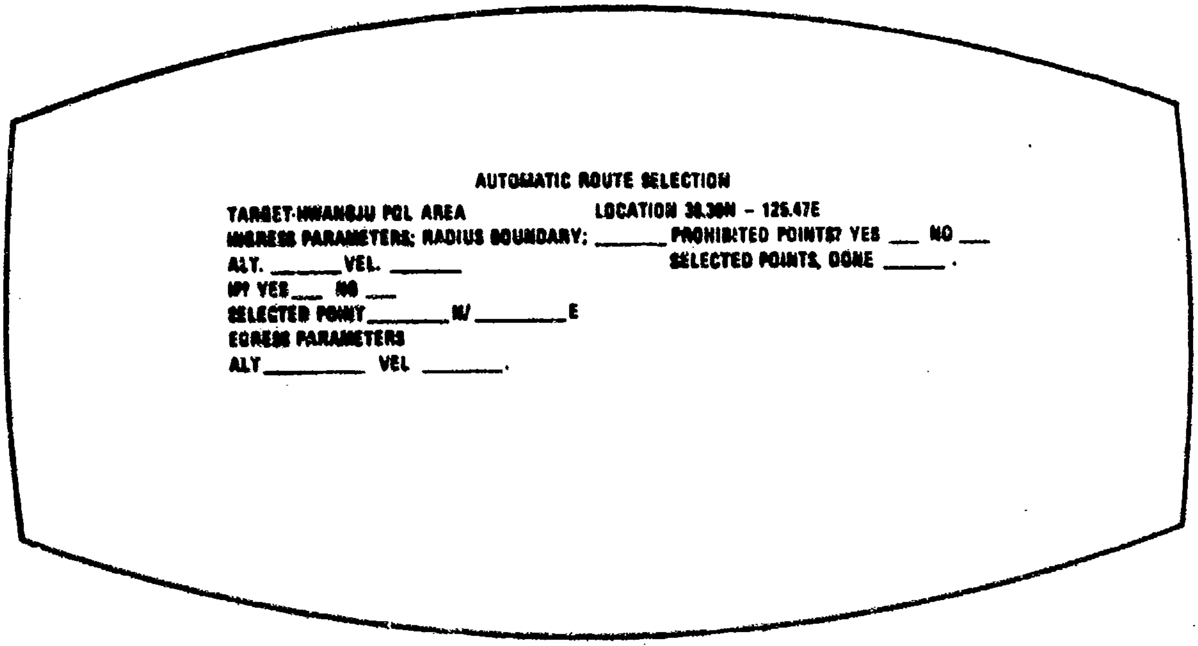


The scoring concept as described earlier is used as the basis for an automatic route selection routine. At the present time automatic route selection is oriented to the area around the target. It is in this area that the planners flexibility to consider alternative routes is most limited because he must penetrate to the target. Outside the target area (i.e., in the en route portions of his profile) he has great latitude in moving the flight path away from areas of high threat density.

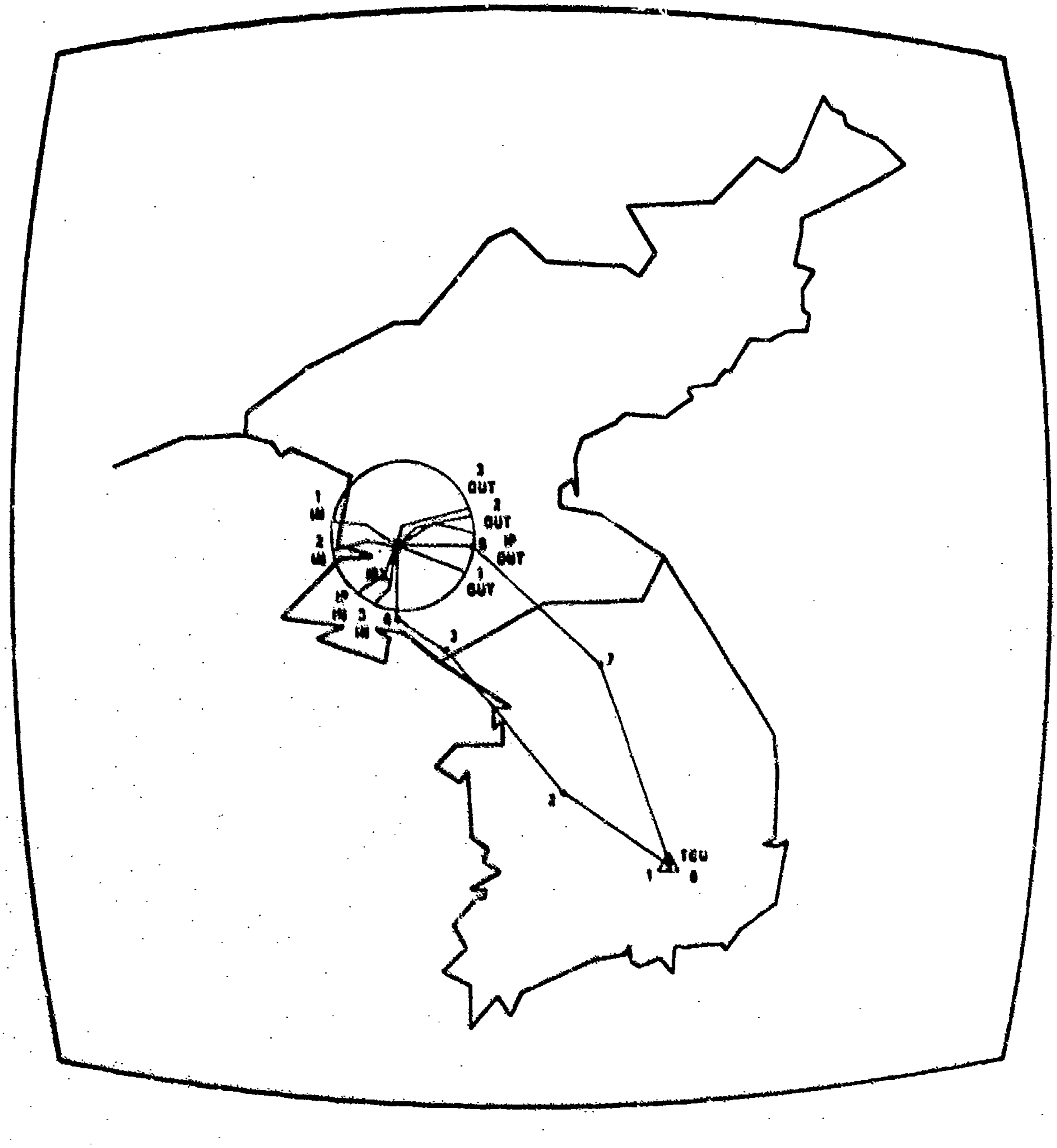
The planner may choose a circular area around the target with any radius up to 50 miles. He may well use the EOB review displays to select the optimum area radius. Since the routine imposes a square grid with a constant number of cells within the circular area for scoring purposes, it is clear that the larger the circle, the coarser the grid and, therefore, the less precise the scoring will be. The planner enters the radius boundary (in miles) in the appropriate spot on the A/N display.

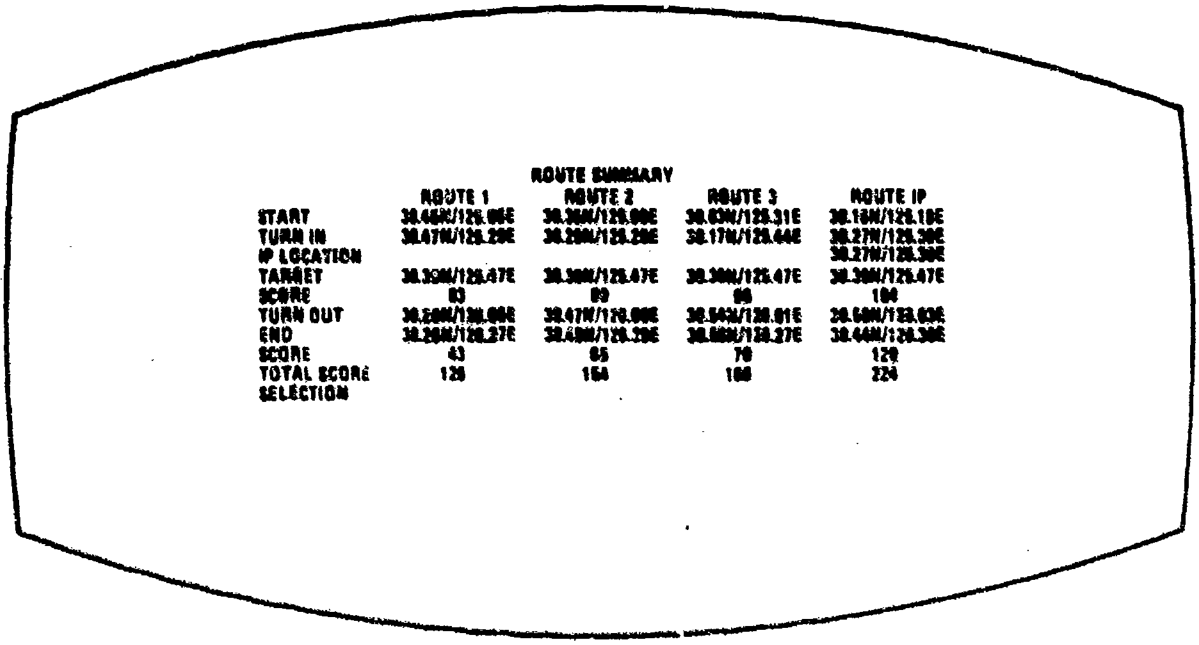
Since scoring is speed and altitude dependent, he must also enter an ingress altitude and velocity as well as an egress altitude and velocity. The planner also has the capability to specify an Initial Point, or I.P. for his attack on the target. He enters his I.P. via light pen (See the next graphic display). Finally, the planner may specify whether he wishes to designate certain points around the circle's perimeter to be excluded as ingress or egress points.





The graphic display indicates the results of the planner's use of his light pen to designate an IP and prohibited points.


3 OUT
2 OUT
IP OUT
1 OUT
1 IN
2 IN
IP IN
3 IN



The processor now uses the grid and the scoring routine to find the best routes into the target from the perimeter and from the target out to the perimeter using the following rules:

1. If no IP is specified, the computer will first find the three best routes into the target.

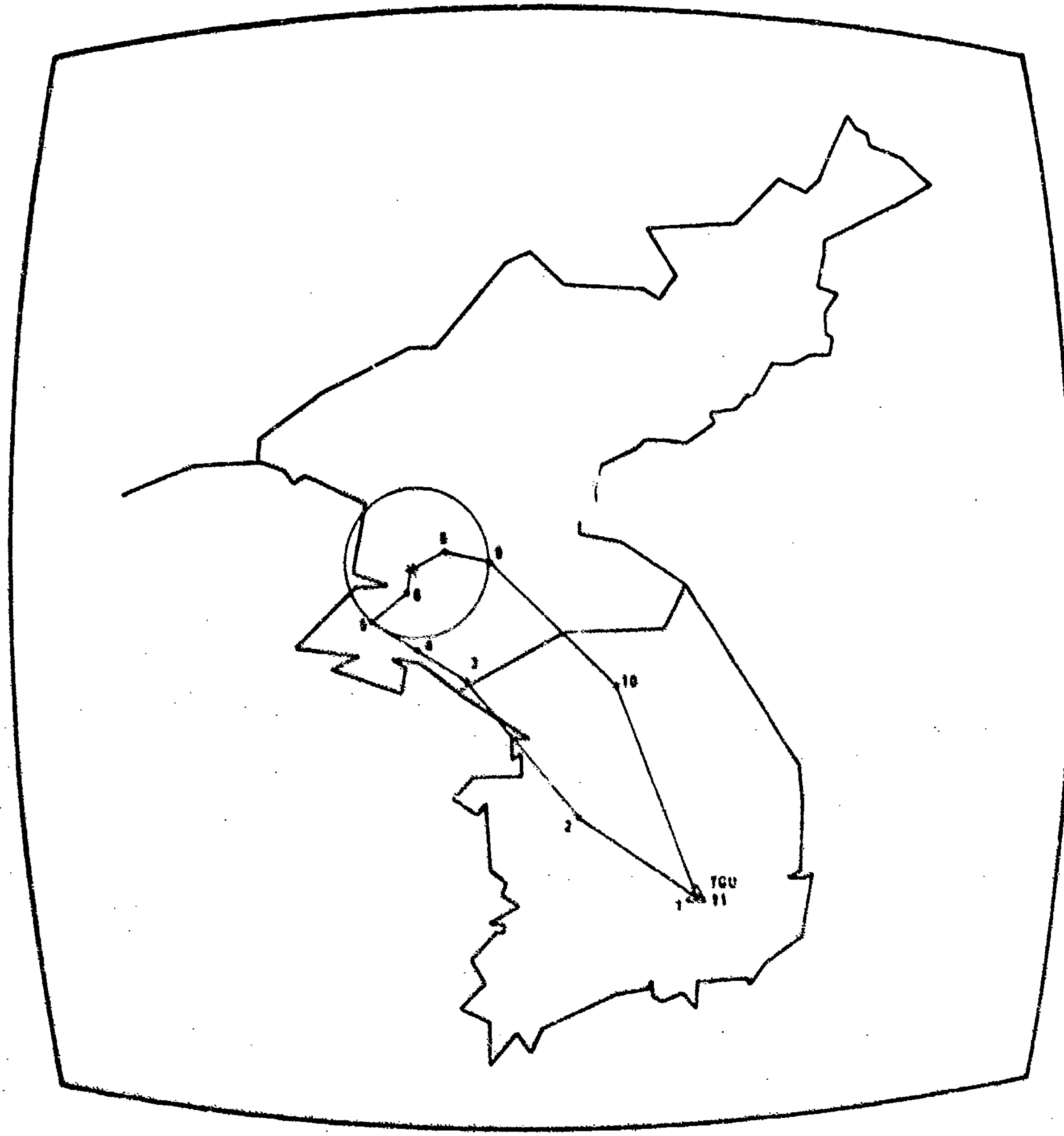
2. It will then find the best route out for each of the three ingress routes with the limitation that no egress route will be considered whose first leg requires a turn tighter than 120° at the target.

3. No route will begin or end at a prohibited point.

4. Each inbound and outbound route will have no more than one turn or bend in it and that turn will be no sharper than 120°.

5. If an IP is chosen, the above rules still apply except that a fourth route using the IP will be generated.

Simultaneously, the alphanumeric display presents the data on each route including the score.

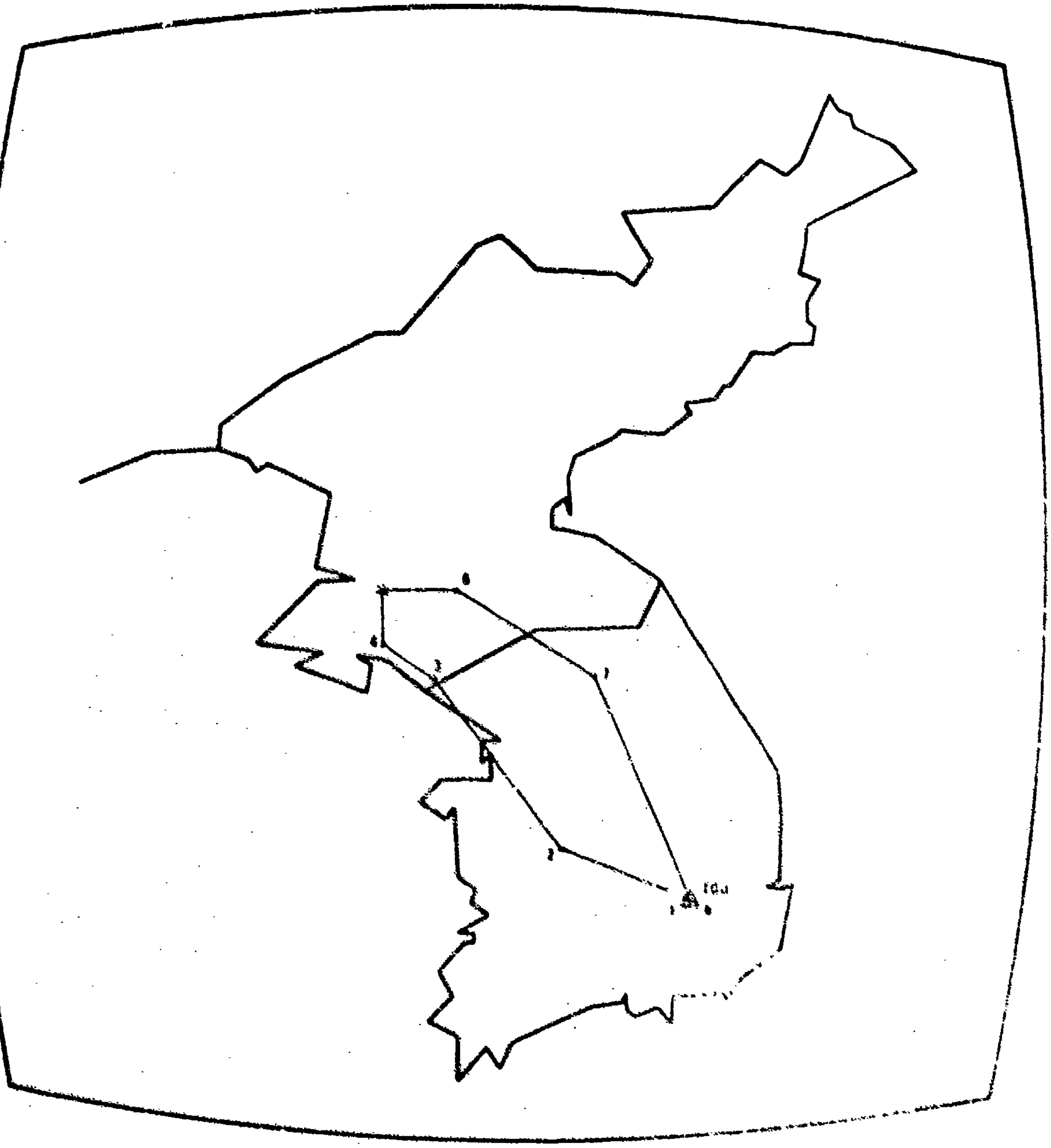


TGU

ROUTE SUMMARY

	ROUTE 1	ROUTE 2	ROUTE 3	ROUTE IP
START	38.45N/125.98E	38.35N/126.08E	38.03N/126.31E	38.16N/126.18E
TURN IN	38.47N/126.20E	38.29N/126.28E	38.17N/126.44E	38.27N/126.39E
IP LOCATION				38.27N/126.39E
TARGET	38.30N/126.47E	38.30N/126.47E	38.30N/126.47E	38.30N/126.47E
SCORE	83	88	86	104
TURN OUT	38.28N/126.08E	38.47N/126.03E	38.64N/126.01E	38.60N/126.03E
END	38.26N/126.27E	38.48N/126.29E	38.56N/126.27E	38.64N/126.30E
SCORE	43	66	70	120
TOTAL SCORE	126	154	168	224
SELECTION				

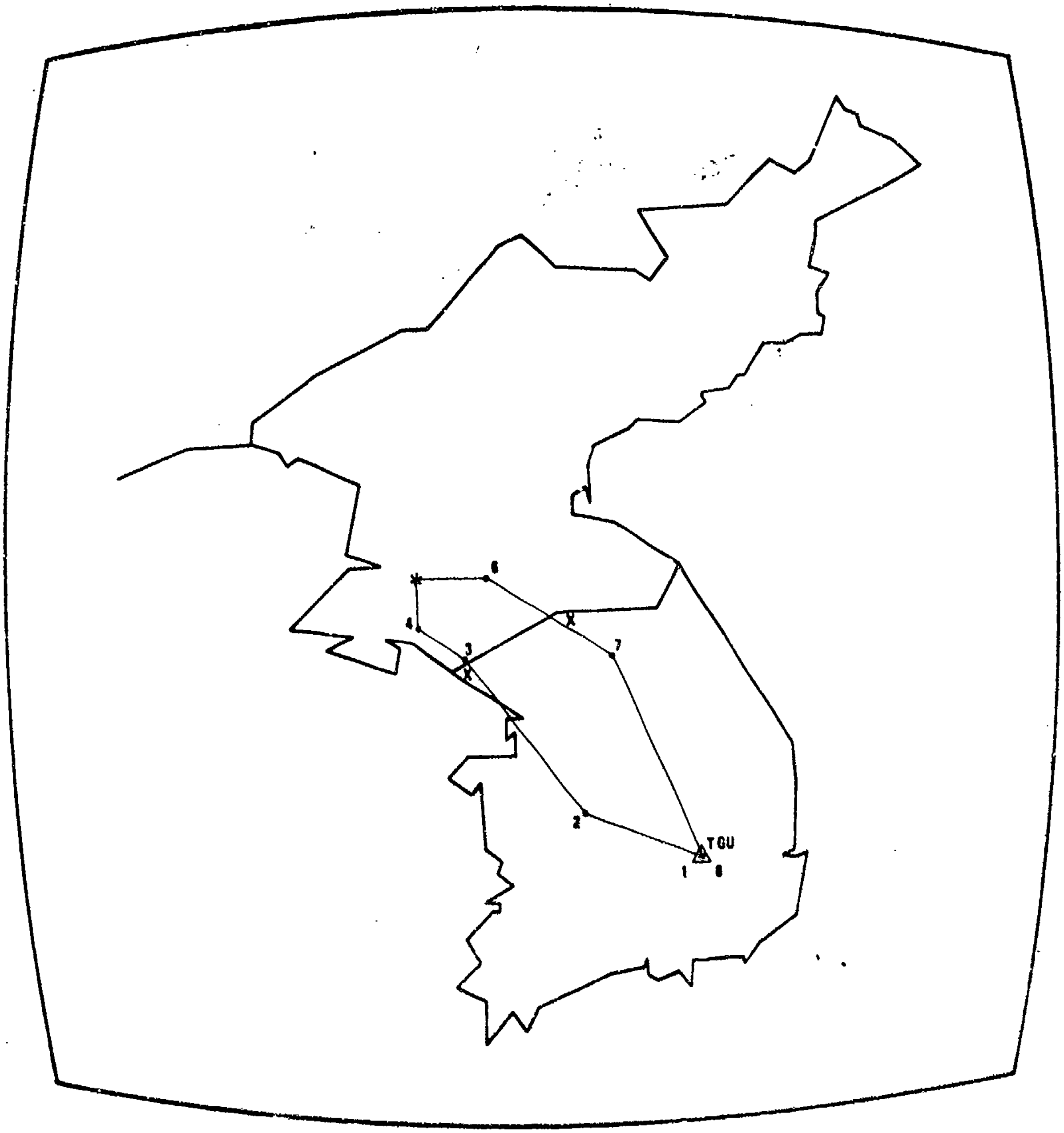
The planner now uses his Route Modification capability to complete the route to and from his selected airbase. The new route may now be scored for comparison with any other route.

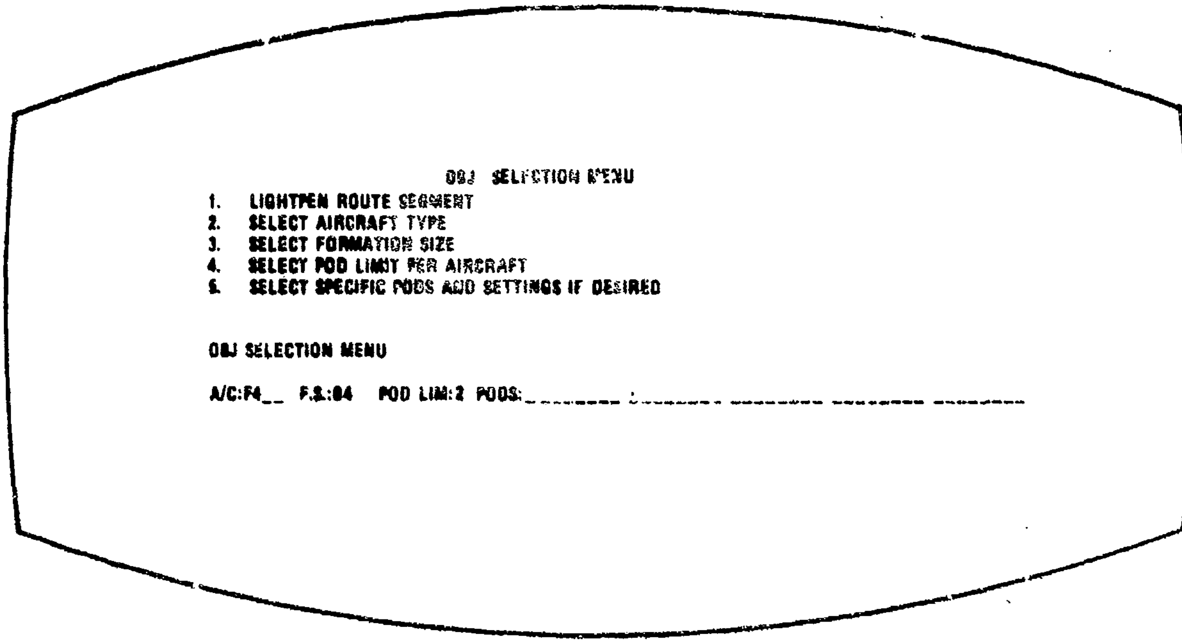


FLT PLAN SUMMARY	***SHIFT AND ENTER FOR NEXT PAGE***						PAGE 1
	LOCATION	MODE	ALT	MACH	THST	HDG	DIST.
1	36.63N-128.30E	T/O	25	0.00	MIL	285	78
2	36.20N-127.27E	CLMB	22000	0.79	MIL	322	120
3	37.61N-126.12E	CRS	20000	0.84		360	35
4	38.00N-125.45E	DCND	4500	0.84		001	38
5	38.30N-126.47E	DASH	4500	1.10		000	42
6	38.30N-126.30E	CLMB	30000	0.84	MIL	119	83
7	37.64N-127.46E	CRS	30000	0.84		166	132
8	36.63N-126.30E	DCND	25	0.55		-	530

For scenario purposes, the planner has chosen the route he planned manually. This route is shown in the graphic display. By activating a function switch labelled FLIGHT PLAN SUMMARY the planner can get an Alphanumeric display as shown. This display was generated within the computer at the time the ROUTE PLANNING function button was activated. It was continuously modified each time the planner made a change in the route. This display not only contains the specifics of each leg in terms of nodes, modes, altitude, Mach and thrust but also contains data reflecting the length and heading of each leg.

At any point in the planning process when the planner is satisfied with the route, he has available a flight plan for that route.

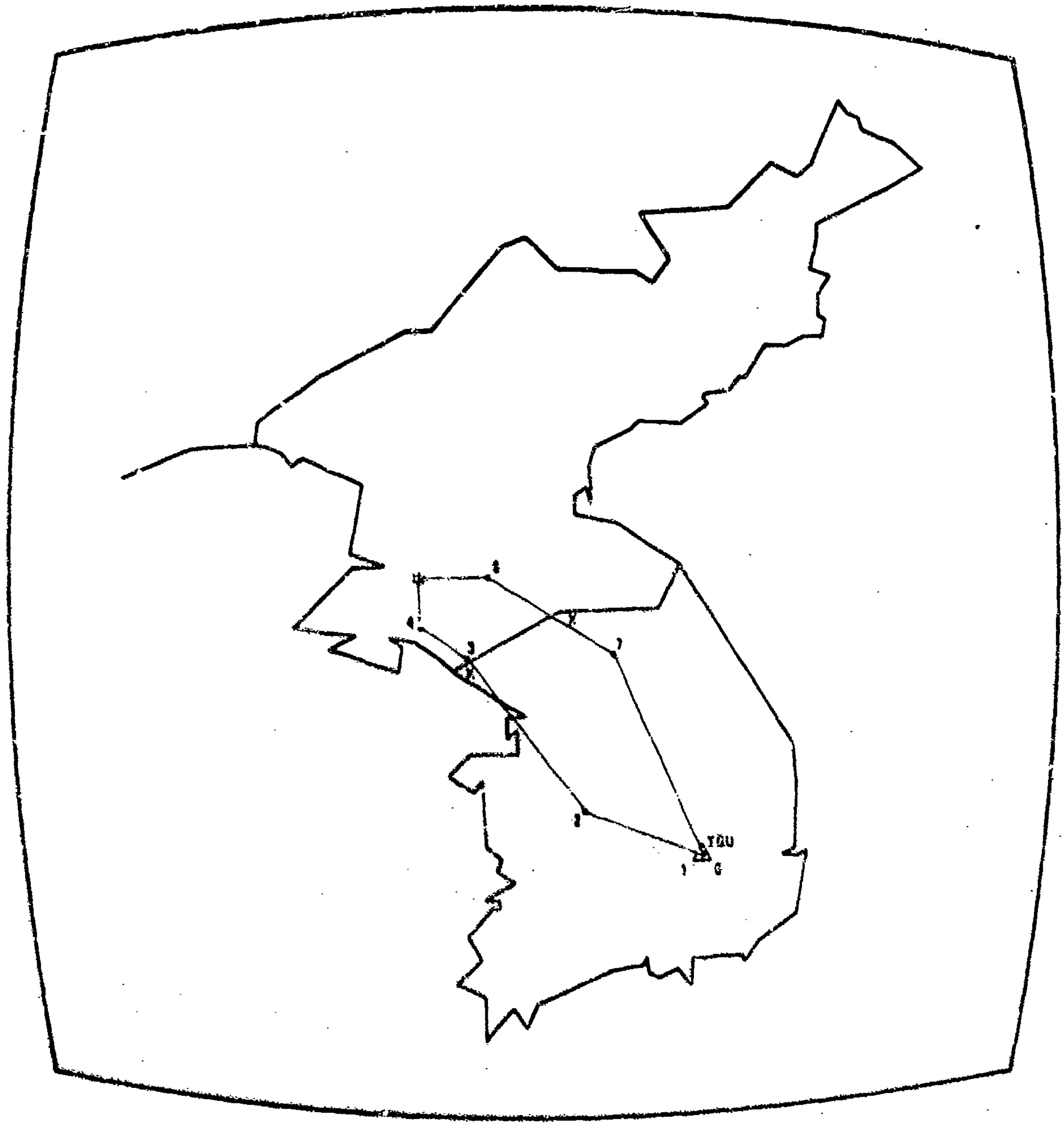

6
4
3
7
2
TGU
1
8



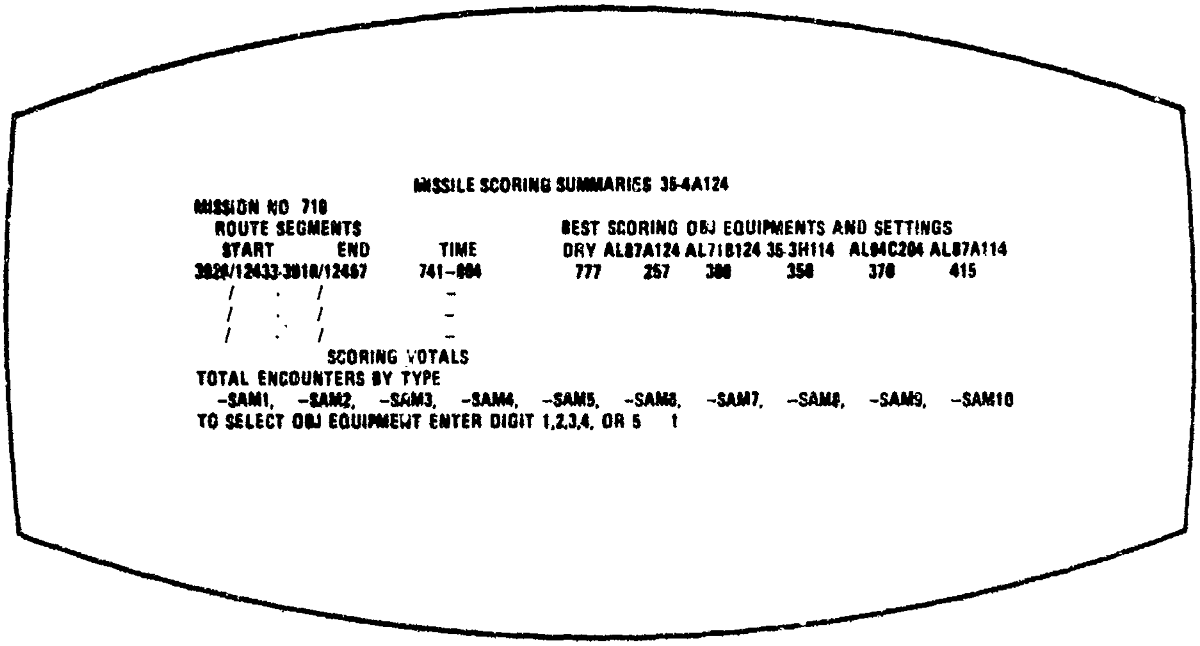
The next major function involves the fuel analysis of the mission as tentatively planned. However, in order to perform fuel analysis, the aircraft must be configured with its external stores. So far the planner has only selected ordnance. Still remaining are such stores as pods, air-to-air weapons and external fuel tanks.

The planner activates a function switch labelled OBJ (On Board Jamming) which results in the A/N display shown here. The planner fills in the bottom line as indicated, entering aircraft type, formation size and whether he wishes to have one or two pods. He also may specify any specific pods and/or pod settings he wishes to have considered.

The planner uses his light pen on the graphic display to indicate the route segment(s) he wishes to have evaluated as shown by the "X" s.



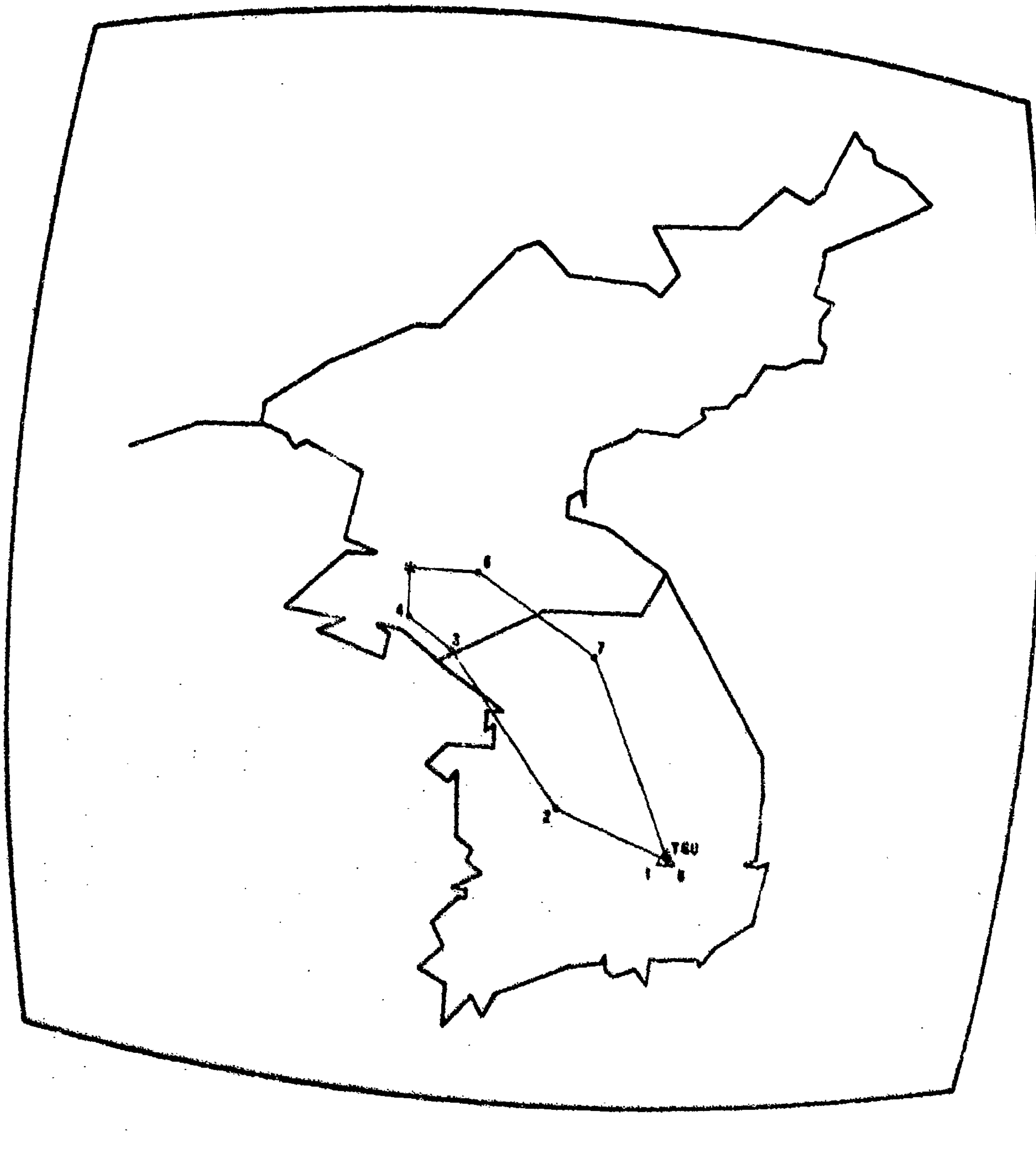
TGU
G



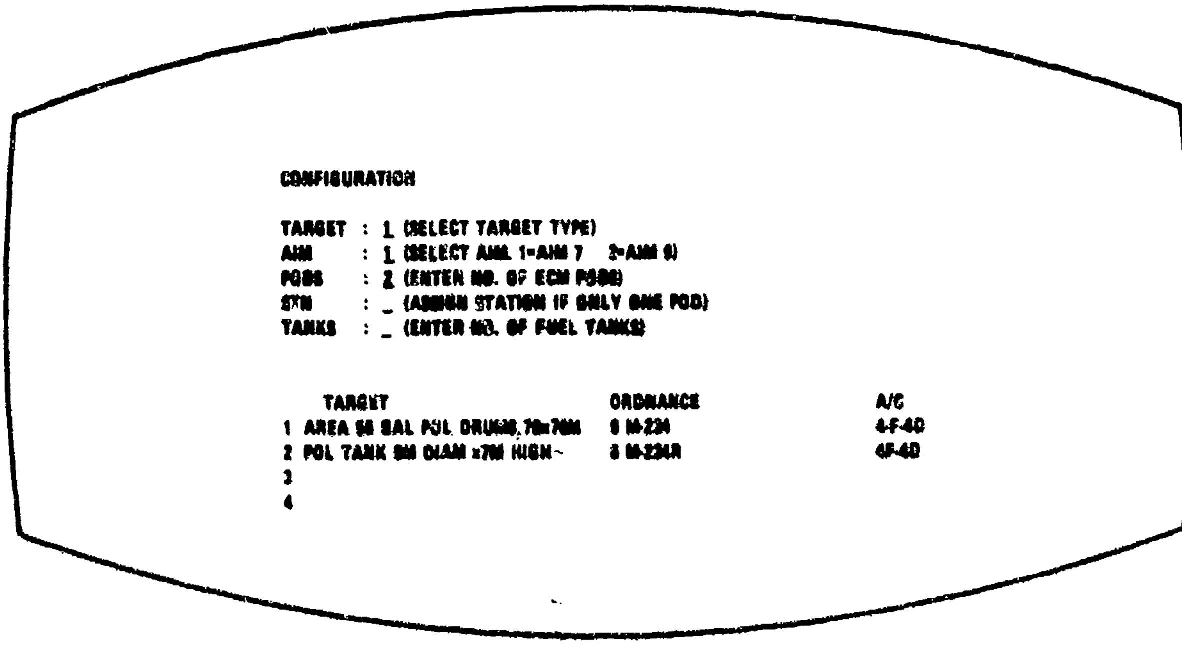
The result of the OBJ analysis is as shown in the present A/N display. The computer has considered the threat along the selected route segment(s). Only those threats which literally do or could interact with the mission aircraft on the basis of threat range are considered. Up to five different pods and/or settings are evaluated against this threat. If no pods/settings were identified on the previous display, then the processor uses the five best pod/settings which are in the inventory and ranks them from left to right against the threat.

If, from one to five pod/settings were identified, they are considered as replacements for the five from the data base. Selected pod/settings replace data base pod/settings beginning with the right hand column (in the case of one selection).

The planner selects a pod/setting combination by entering a digit (1 through 5) in the bottom line. These numbers refer to the five columns reflecting different pods.

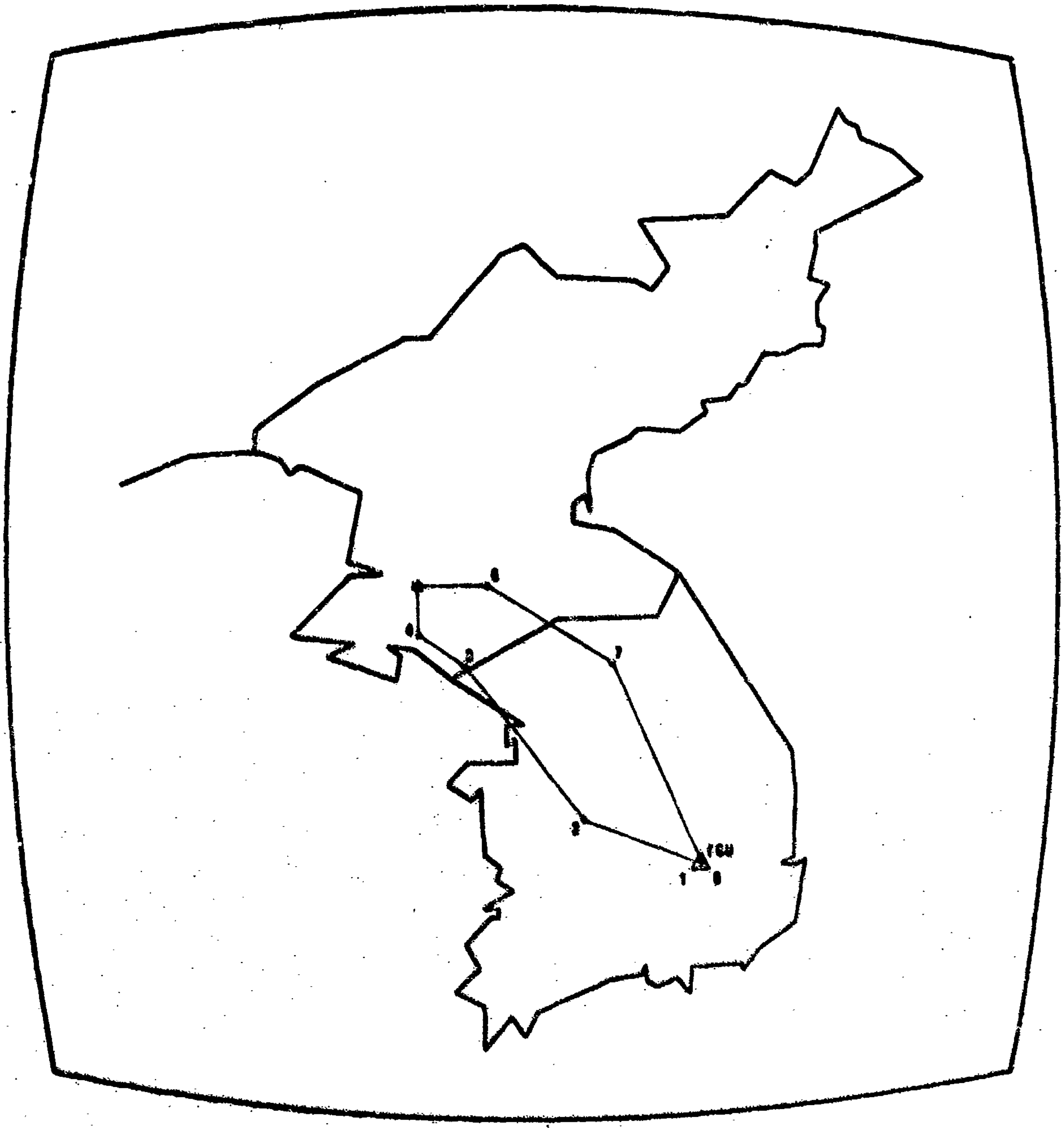


TGU



The next function is produced via a function switch labelled CONFIGURATION. Activation of the switch produces an A/N display as shown. Since different target types require different ordnance each flight must be separately configured. The planner first selects and enters a target type from the list at the bottom of the display. He next selects whether he wishes AIM on the aircraft and which type. (Leaving the entry blank excludes AIM from the configuration).

If OBJ selection was used, the number of pods is shown automatically although the planner can modify this by overwriting. The type and setting are already stored in the mission summary. If only one pod is specified, the planner may if he wishes, specify a station. Finally, the planner enters whether or not he wants external tanks. Leaving the entry blank means no tanks; entry of a 1 means a centerline tank; entry of a 2 means tanks on outboard stations. In the scenario case, no tanks were included.


TCU

CONFIGURATION FOR TARGET - AREA 55 GAL. POL DRUMS 76x76M

STN	ITEM	WT	DF
1	3 M-224	2065	18.1
2	1 ALQ-87	542	4.7
3	1 AIM-7D	482	1.3
4	1 AIM-7D	482	1.3
5	3 M-224	2701	18.0
6	1 AIM-7D	482	1.3
7	1 AIM-7D	482	1.3
8	1 ALQ-87	542	4.7
9	3 M-224	2066	18.1

SHIFT & ENTER FOR NEXT CONFIGURATION

At this point the processor automatically configures the aircraft if the following conditions have been met.

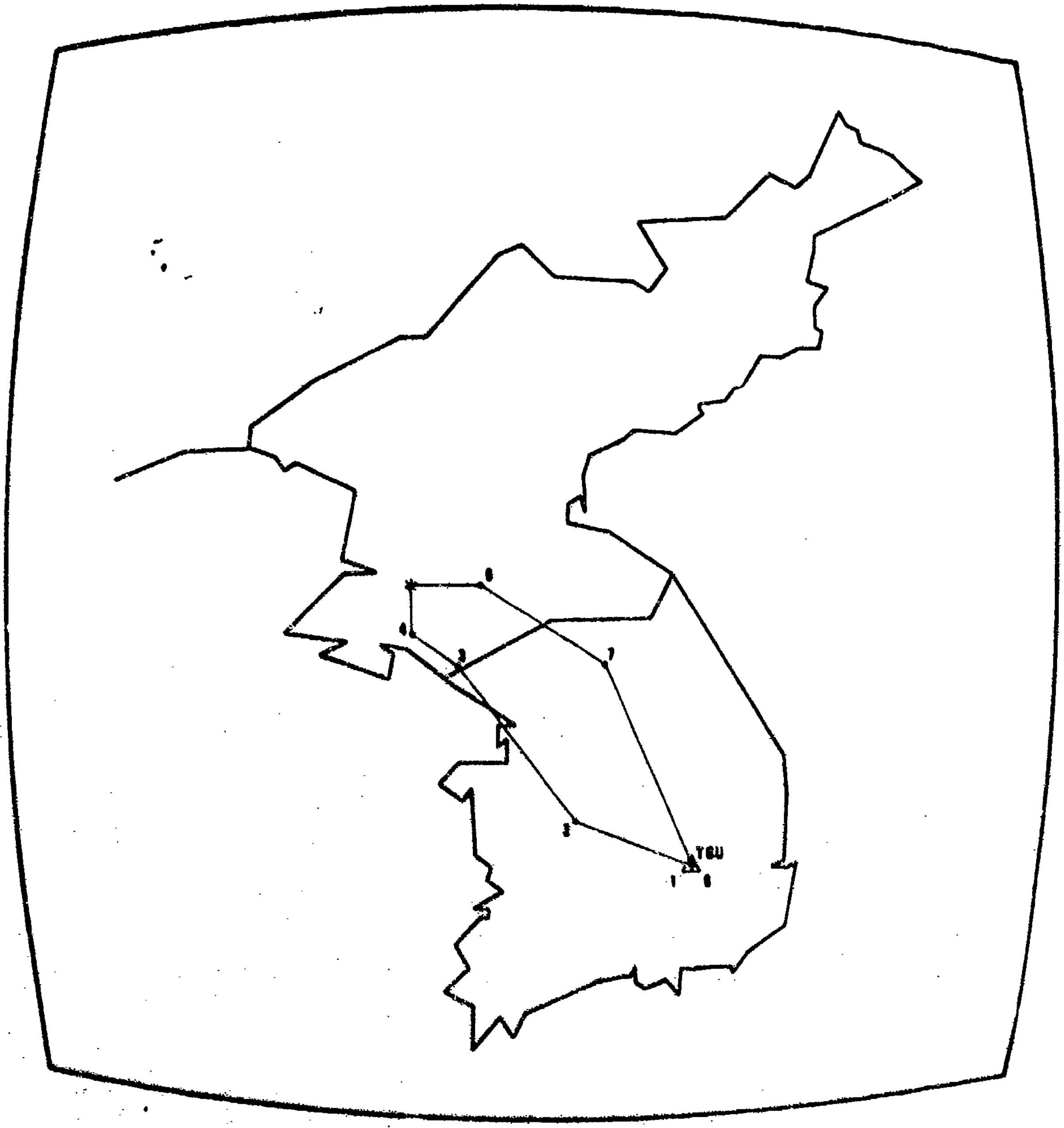
1. The number and type of ordnance are certified for the aircraft.

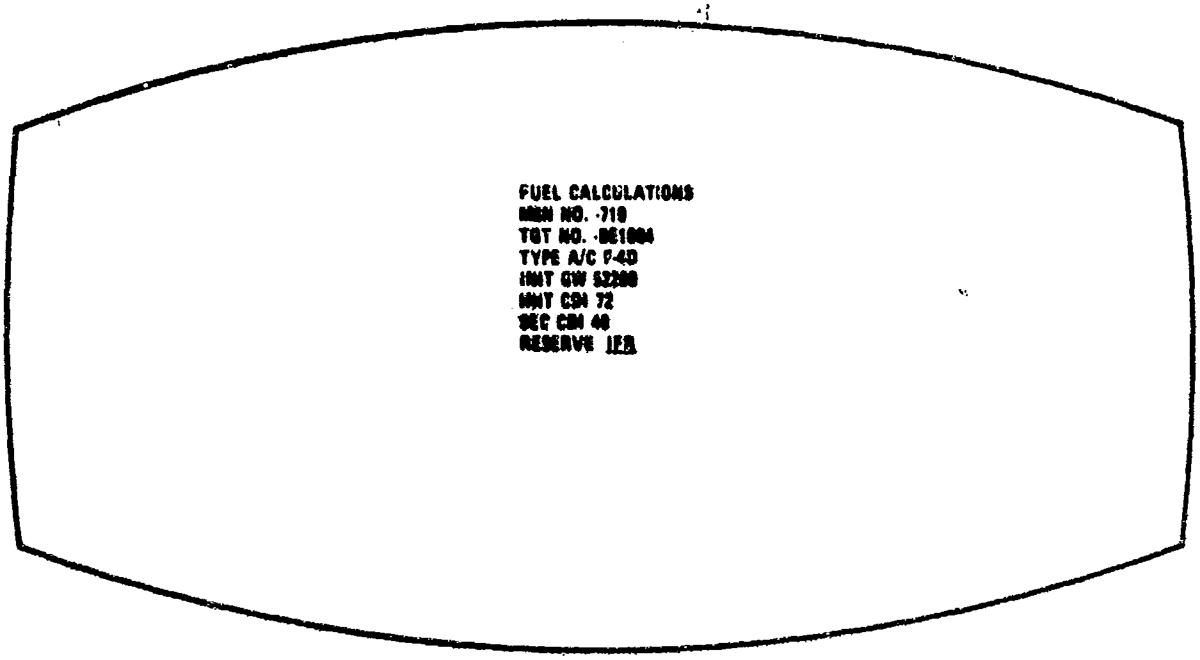
2. There are stations available for all the stores specified.

3. The number of units per station is at or below the maximum allowable for that station.

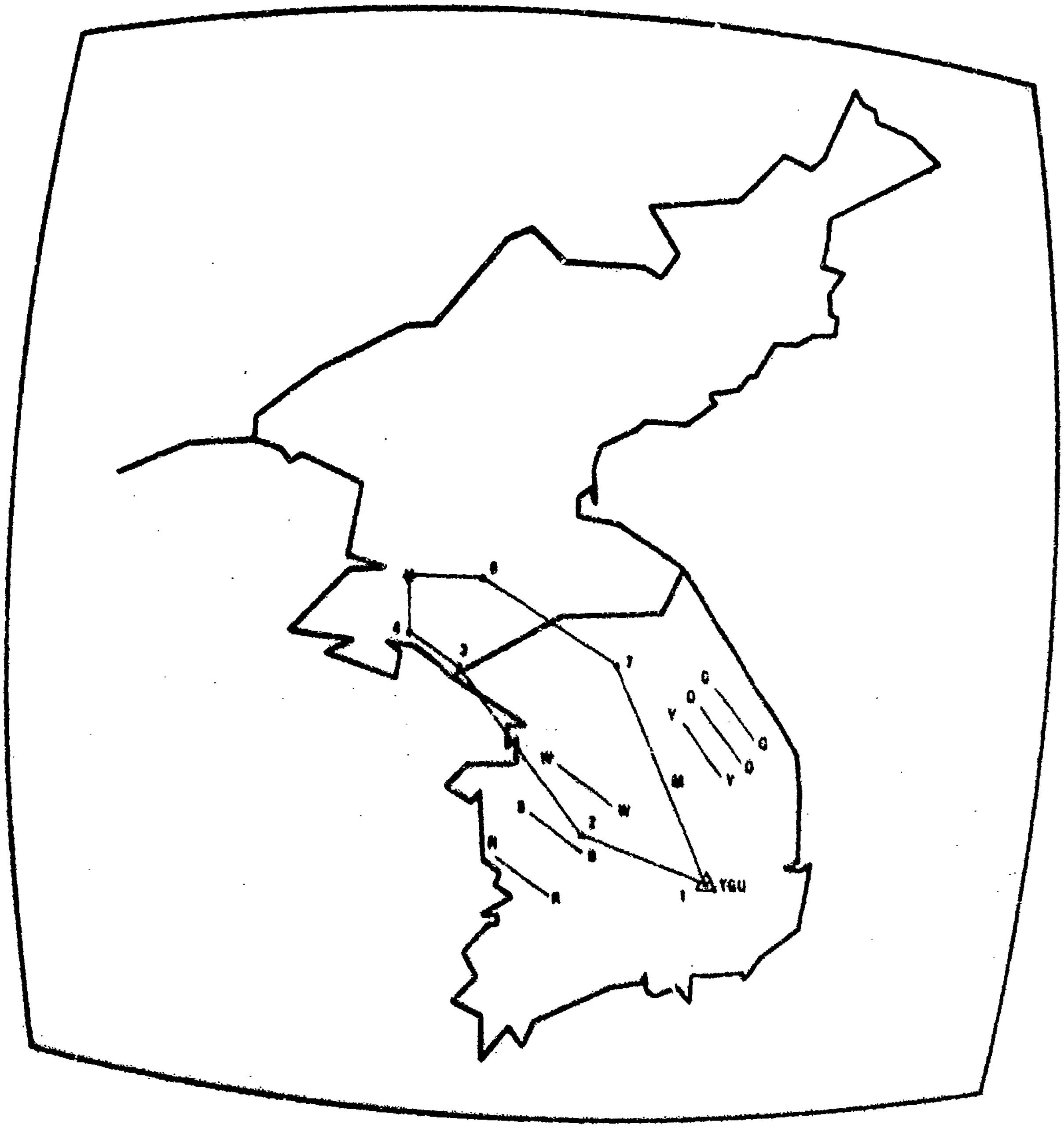
If any or all of these restrictions are not met, the planner is notified to make necessary changes If the stores as defined result in an asymmetric loading, the configuration is accomplished and the planner is notified that the load is asymmetric.

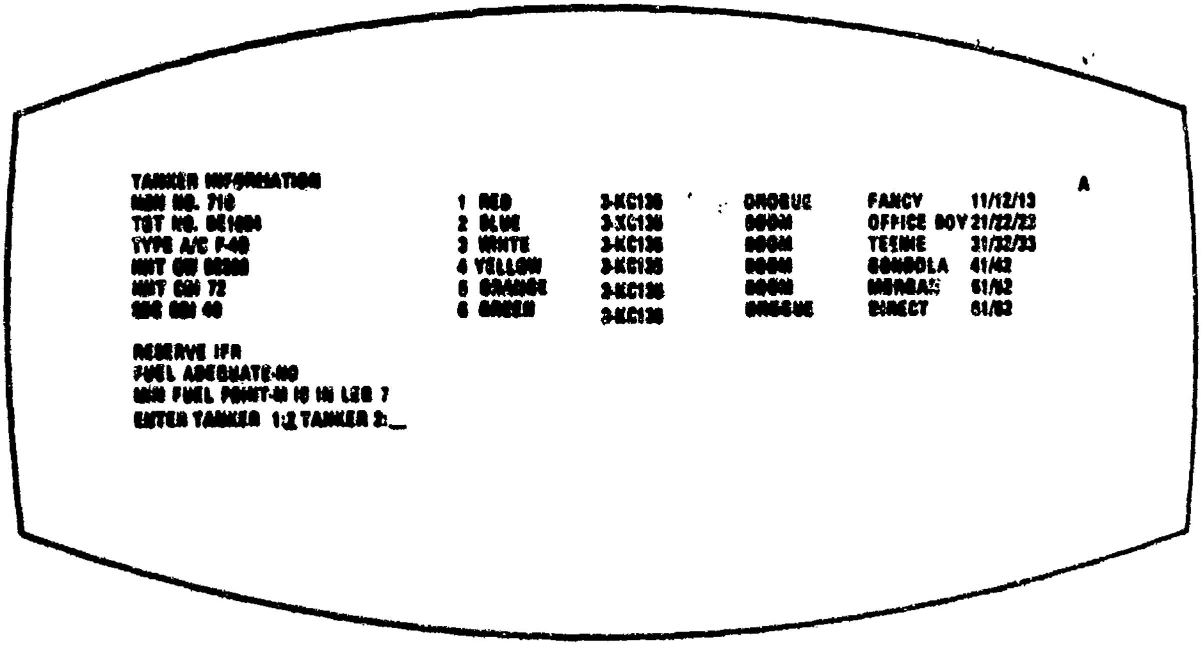
The configuration display also contains the weight and drag factor for each station. If the drag factor is variable by speed and/or wing sweep (e.g., on the F-111) the worst drag on the entire flight is shown. If the total weight of the stores plus the aircraft weight exceeds the permissible take off weight, the planner is informed of the extent of overage.


TGU



Now that configuration is complete, activation of the FUEL CALCULATION function switch produces this alphanumeric display. All the data shown are calculated except for the reserve. The planner specifies whether he wishes the aircraft to arrive home with an IFR or VFR reserve. Actual quantities for these reserves are stored in the processor.


YGU

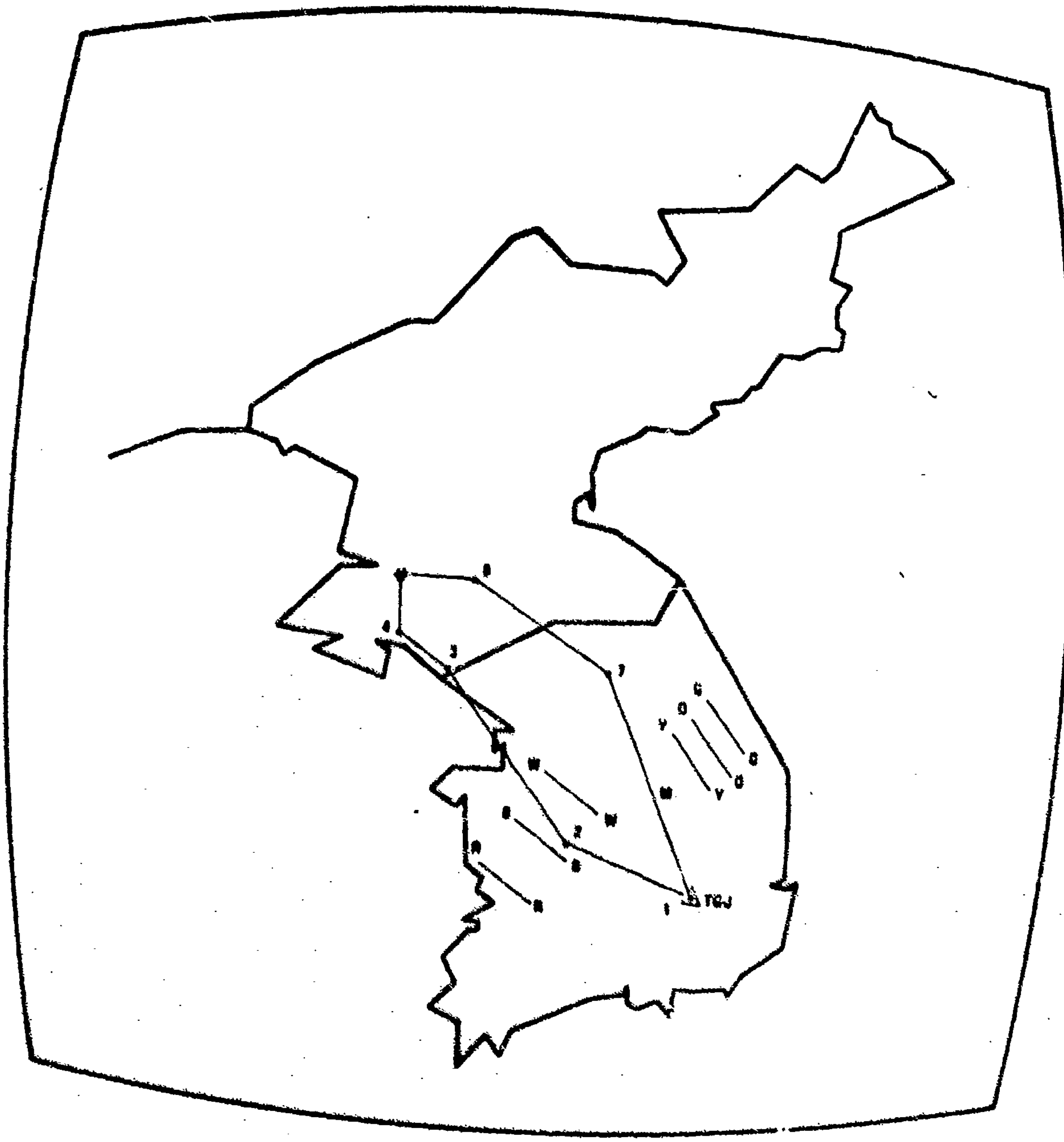


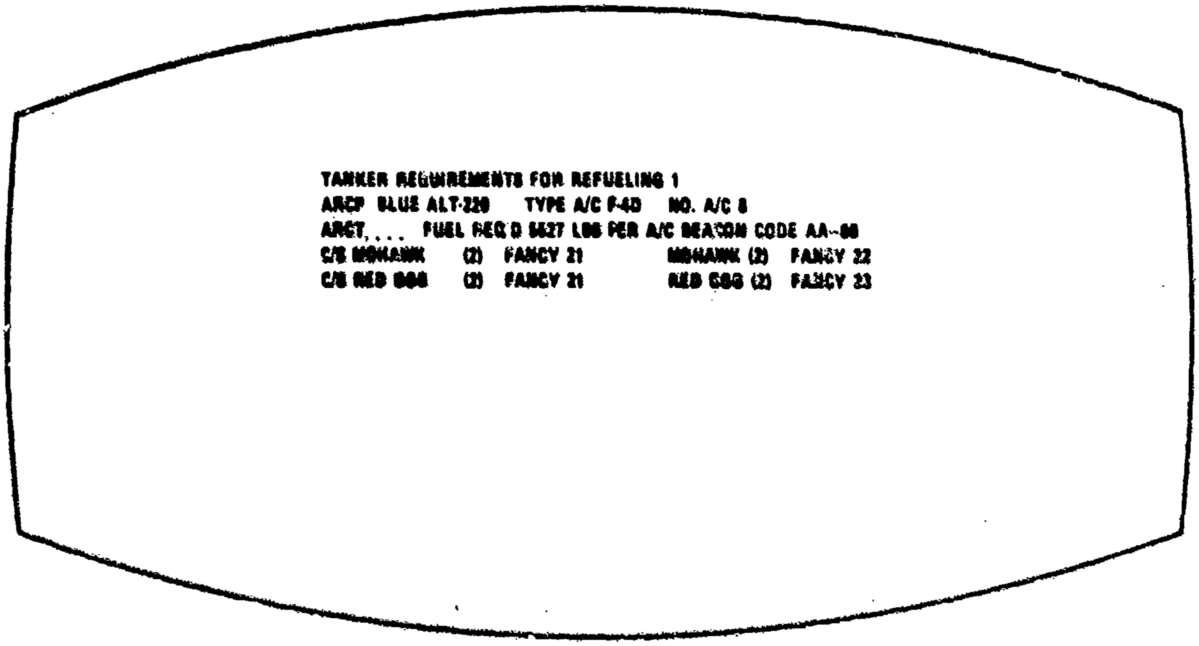
In the scenario, the fuel on the aircraft was not adequate to fly the planned profile. The computer, having determined that there was insufficient fuel, generated the A/N and graphic displays shown here.

The A/N display presents the basic aircraft data plus the information that the fuel was inadequate. It also identifies the leg and point at which the specified reserve is reached. The point is located on the graphic display by the letter "M." In addition, the alphanumeric display provides basic tanker data including numbers of aircraft, equipment type and call signs. The location and identification of the individual tanker orbits are shown on the graphic display.

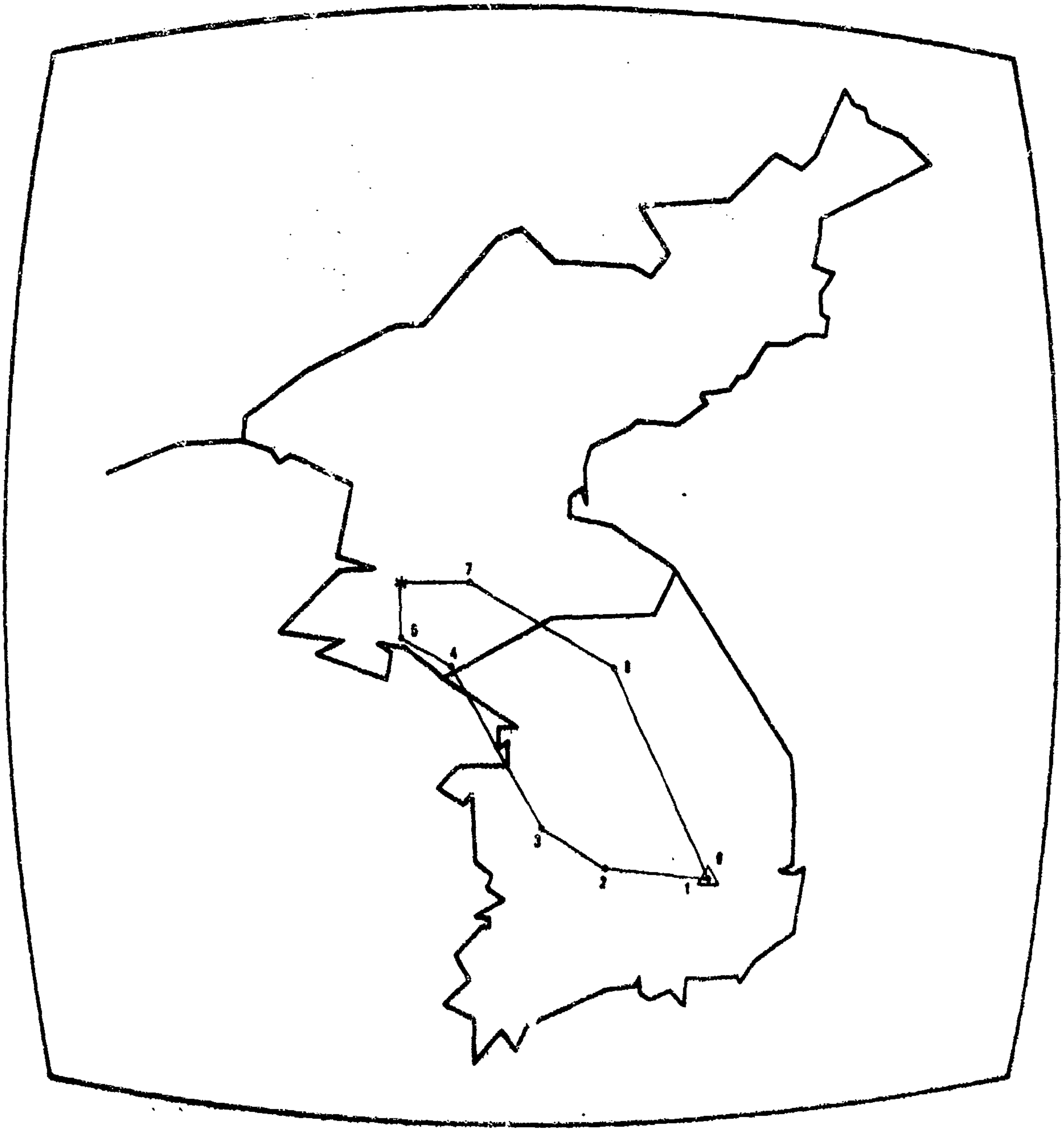
The planner may select either outbound refueling, inbound refueling or both. A refueling track while en route to the target is selected by entering the desired number in the space labelled ENTER TANKER 1. The entry of "2" selects Blue track. If the planner wished further refueling on his way home, he would enter a digit in the space labelled TANKER 2.

If the planner did not want to refuel, he could, of course change his route, change his speed on one or more legs, or reduce his stores. The effects of these options could also be reviewed by recalculating fuel under the changed condition.


4
3
7
2
1
TGJ



Selection of a tanker orbit (or two) results in the generation of the tanker requirement which can be given to the tanker planner or SAC liaison officer as a refueling requirement.

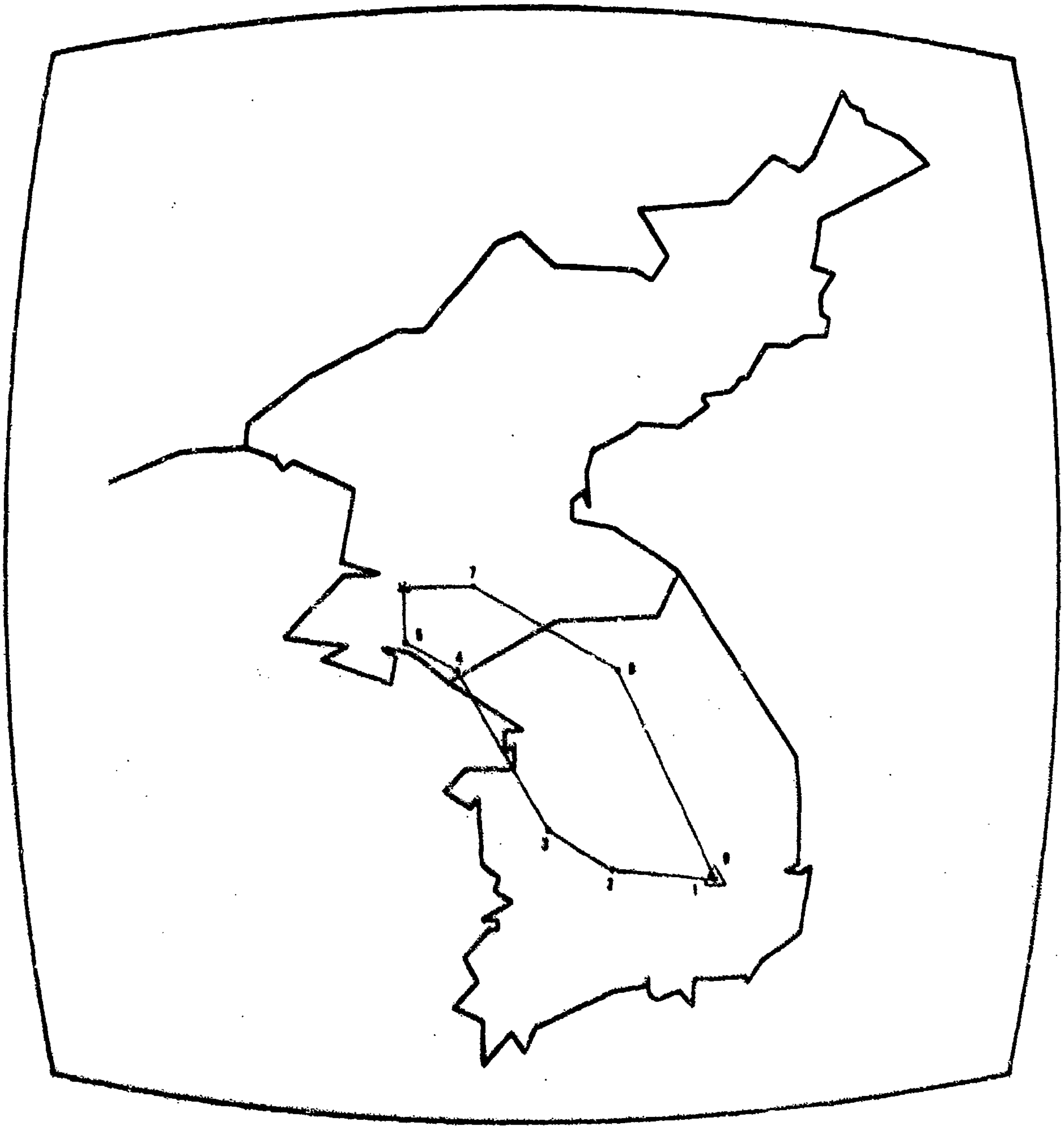

7
6
4
8
3
2
1
8

FLT PLAN SUMMARY *SHIFT & ENTER FOR NEXT PAGE*** PAGE 1

	LOCATION	MODE	ALT	MACH	THST	HDG	DIST.
1	35.93N-128.30E	T/O	26	0.00	MIL	277	60
2	36.24N-127.30E	FUEL	22000	0.79	MIL	304	42
3	36.59N-127.01E	CRS	20000	0.84		339	90
4	37.51N-126.12E	CRS	20000	0.84		306	35
5	38.00N-125.45E	DCND	4500	0.84		001	38
6	38.30N-125.47E	DASH	4500	1.19		090	42
7	38.30N-126.30E	CLMB	30000	0.84	MIL	119	93
8	37.60N-127.65E	CRS	30000	0.84		155	132
9	35.93N-128.30E	DCND	25	0.55		-	633

At this point, the planner uses his route modification capability to add the refueling leg to the route profile. He must not only modify his ground track but he must also be sure to change the mode of the refueling leg to FUEL. The effect of the changes is shown both graphically by the addition of a new leg and alphanumerically by the changes to the flight plan as shown.

If the planner wishes, at this point he may recalculate the fuel expenditure including the refueling leg and the refueling itself.


7
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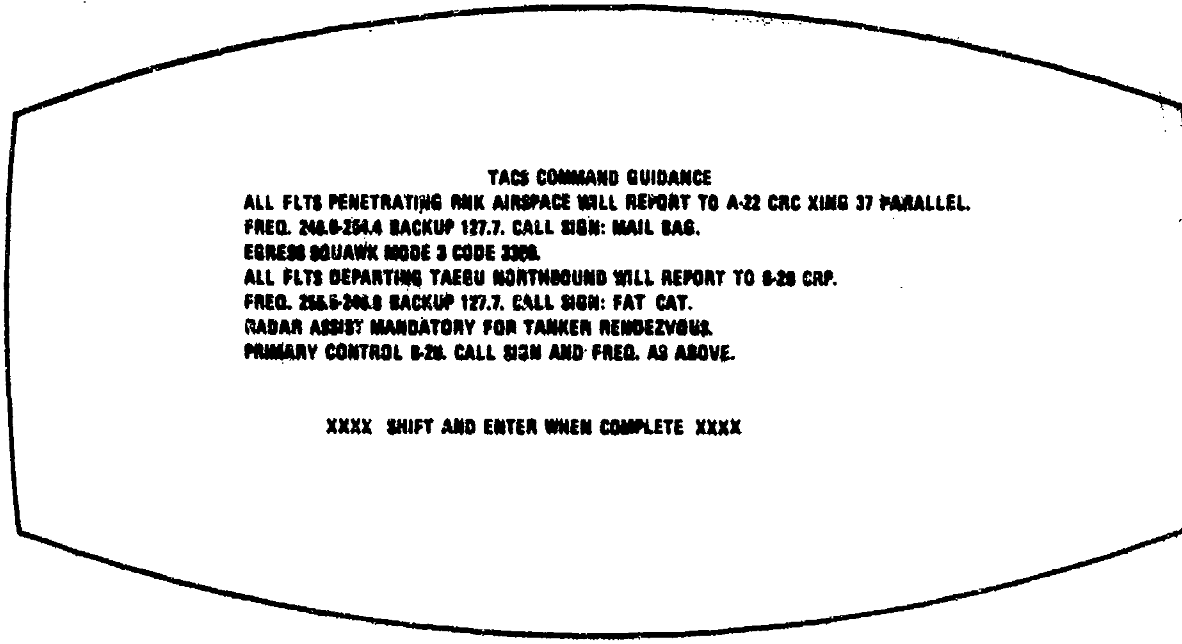
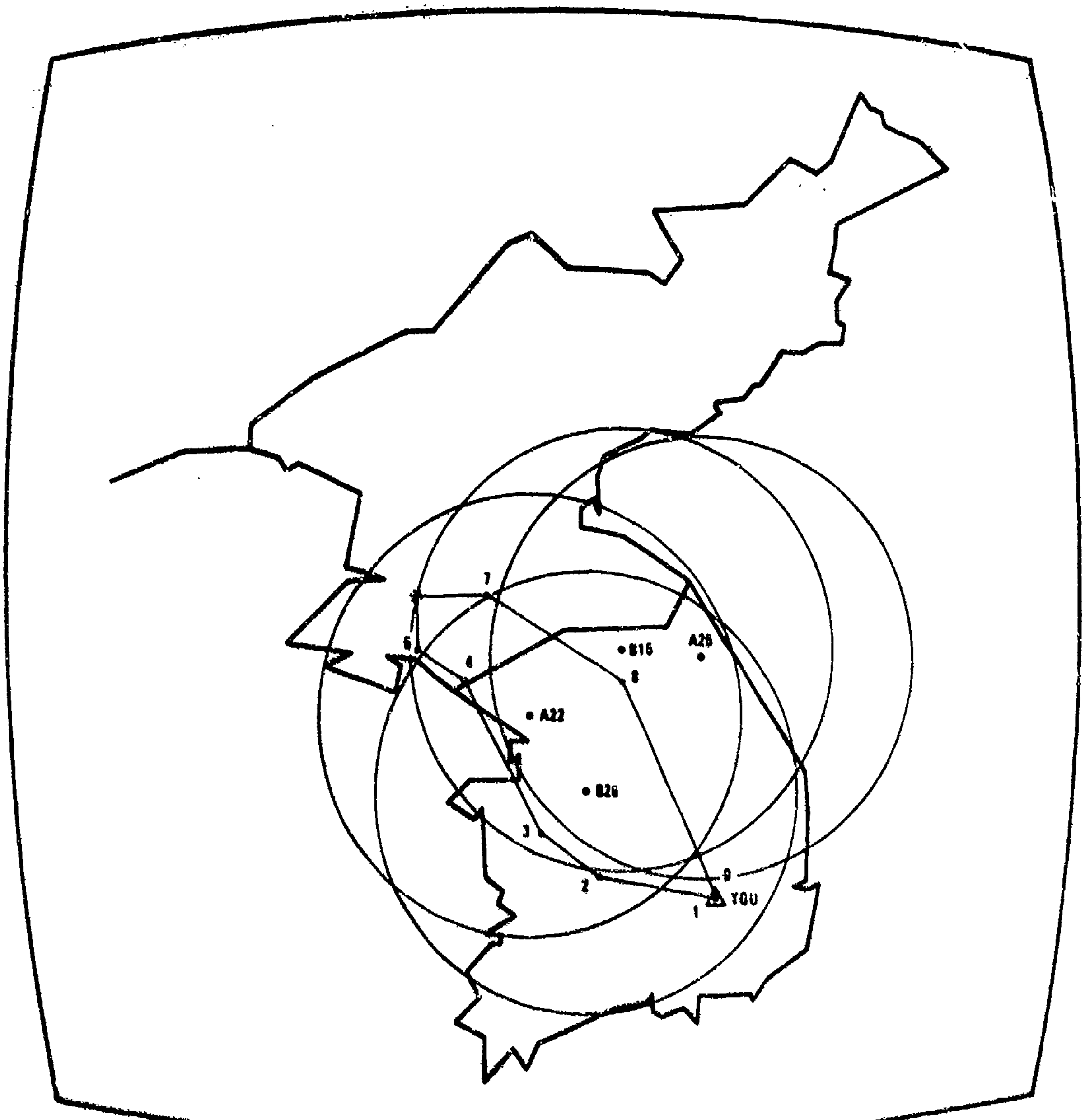
3
2
1



The final activity with respect to this mission involves the assignment of TACS units to the various legs of this mission profile. The planner first may, if he wishes, review the command guidance relating to TACS assignment. The TACS assignment process is initiated by a TACS function switch.


7
6
4
B15
A26
8
A22
B26
3
2
9
1
YOU

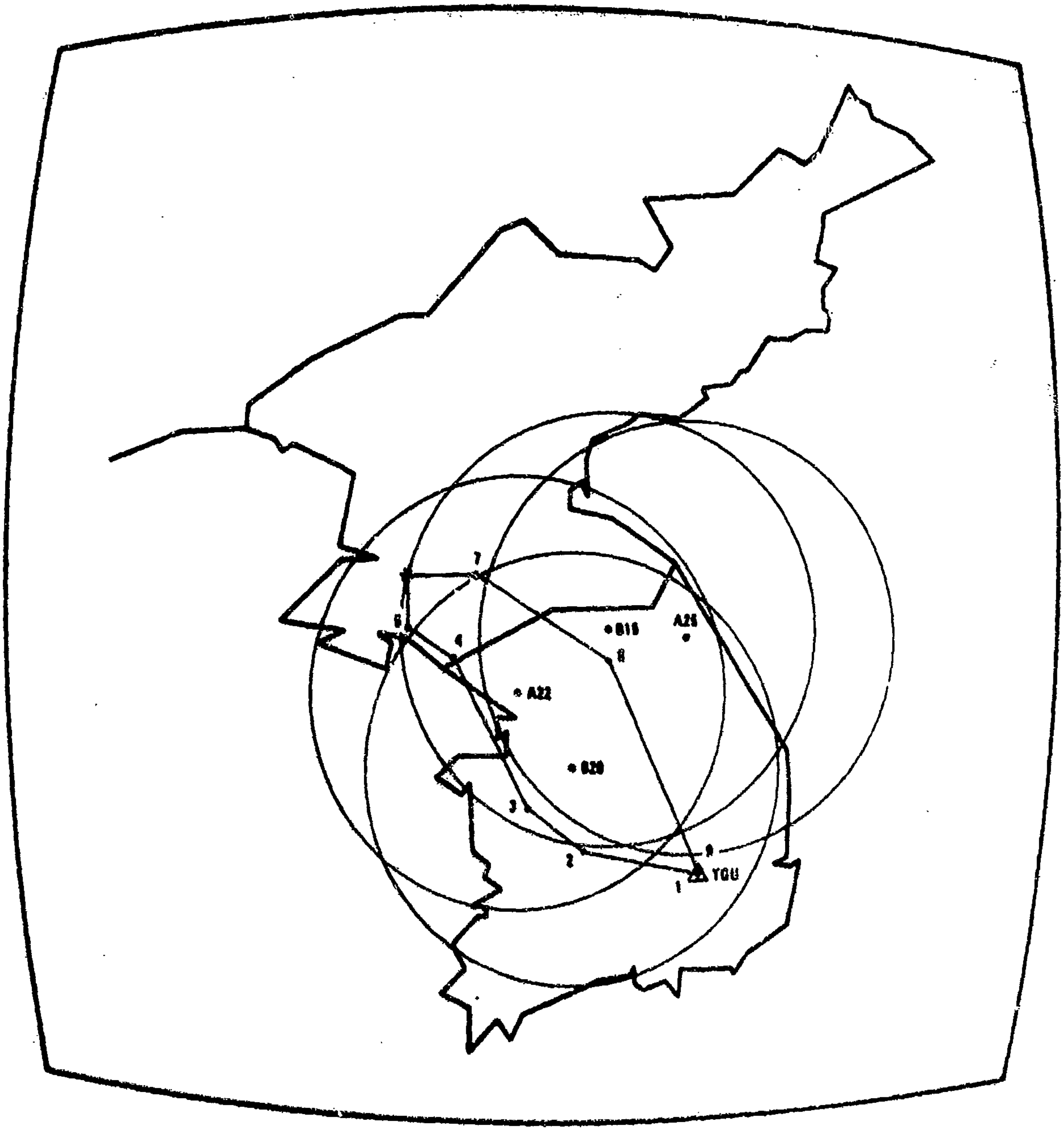
TACS FORSTAT

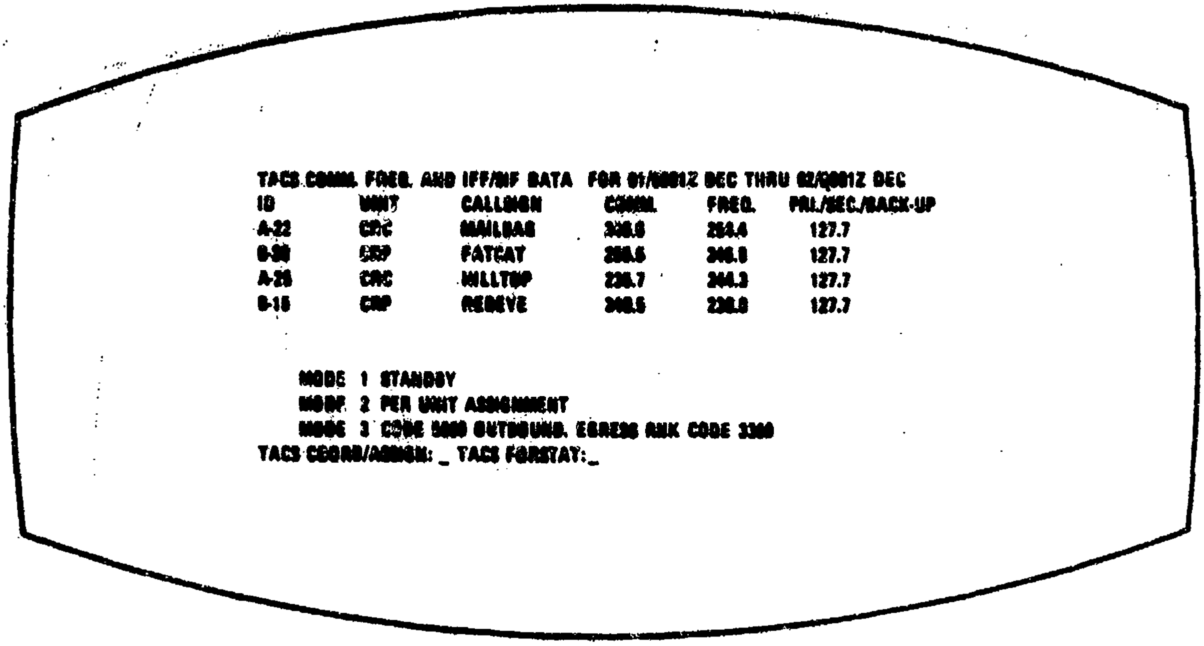
ID	UNIT	LOCATION	CALLSIGN	RADAR	IFF	REMARKS
A-22	CRC	[illegible]	MAILBAG	UP	UP	
B-20	CRP	HG2061	FATCAT	UP	UP	
A-25	CRC	[illegible]	HILLTOP	UP	UP	
B-15	CRP	[illegible]	REDEYE	UP	DN	ETRO OF IFF UNKN

ADD REMARKS— FLTS PENETRATING NNK REPORT TO A-22 AT 37 PARALLEL
RADAR ASSISTANCE MANDATORY FOR TNKER RENDEZVOUS

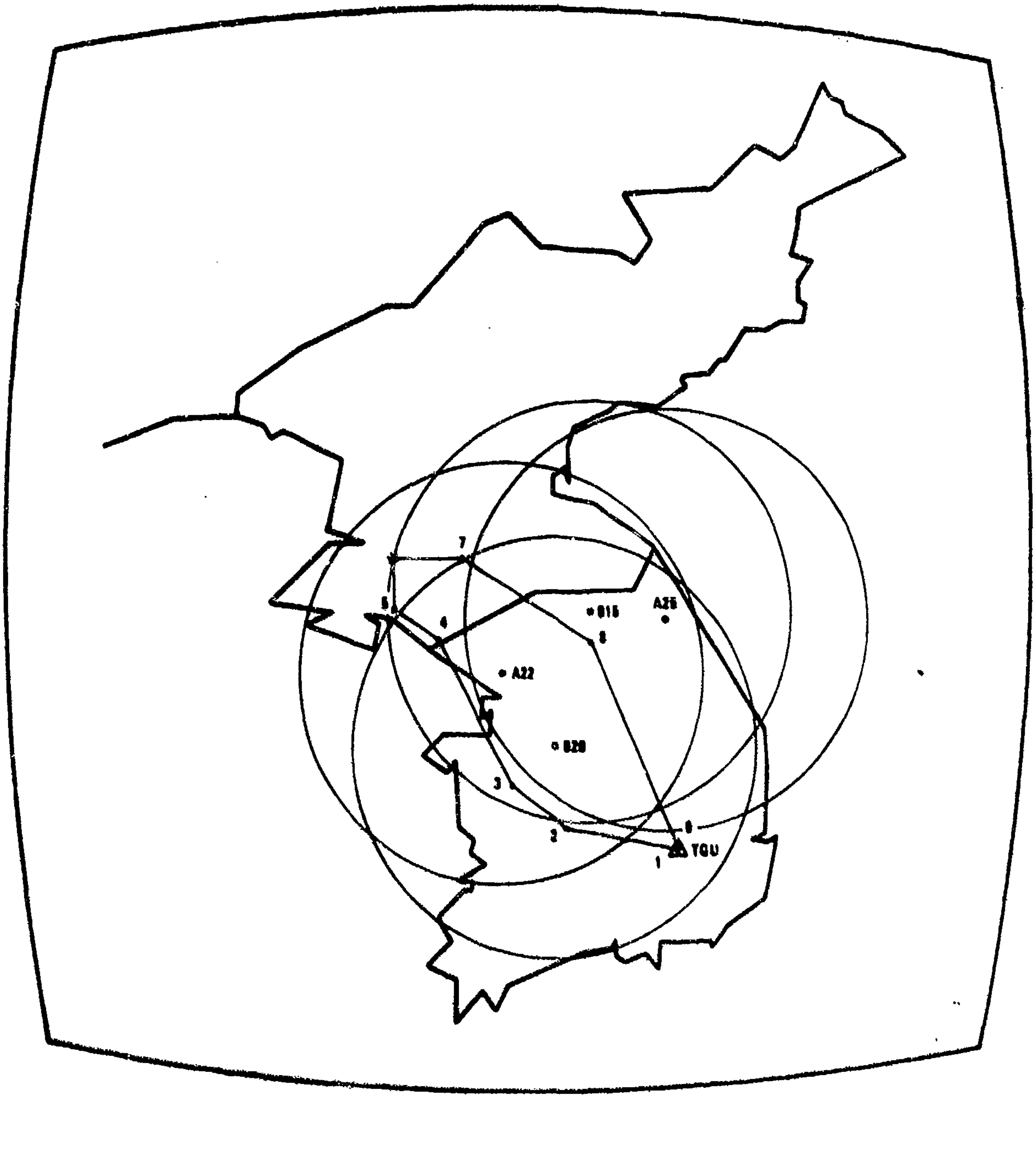
TACS COORD/ASSIGN: _ IFF/SIF: _

The planner next reviews the status of the TACS elements.


7
6
4
B15
A25
8
A22
B20
3
2
9
YOU
1



He may also review the communications frequency and IFF/SIF data for the day.


7
5
4
A22
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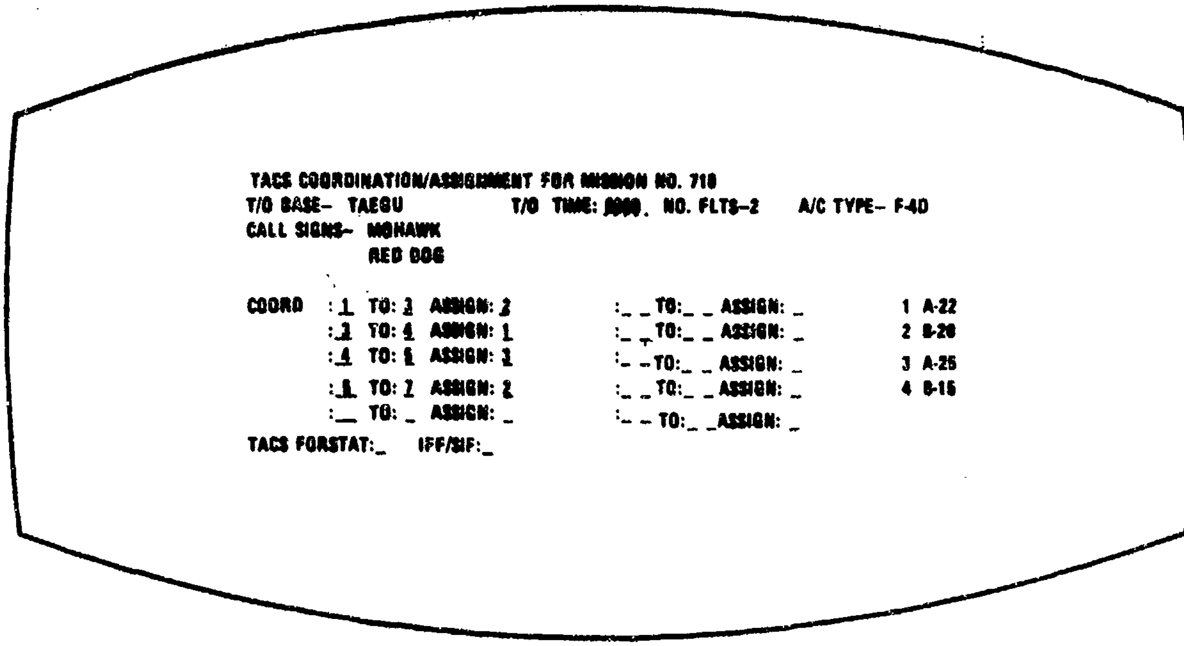
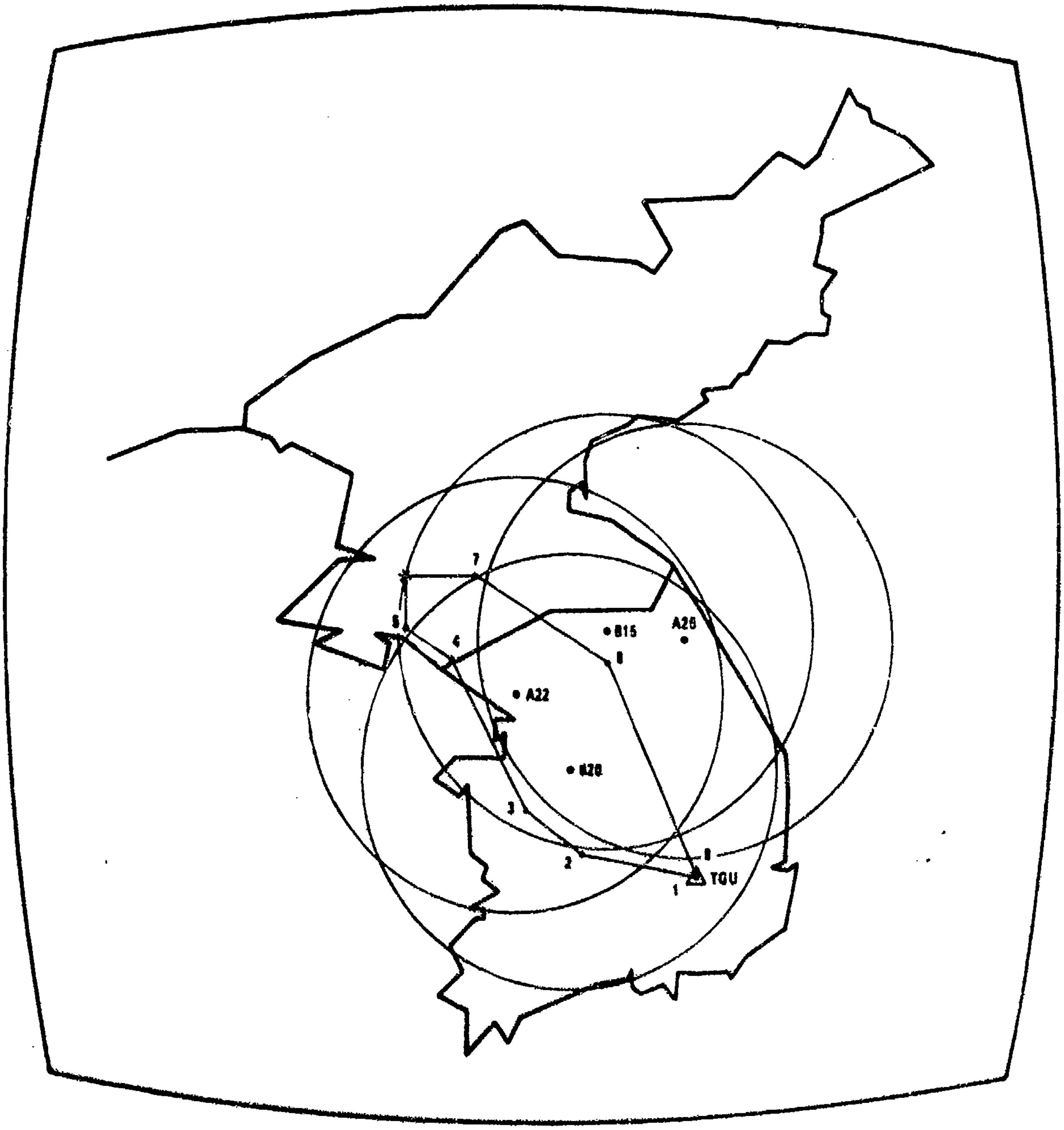
2
TGU
1



The planner uses the A/N display as shown to assign the various legs of the flight to the CRC's and CRP's. Beginning with the first node, he enters the first and last node numbers for the legs which he desires to assign to a particular station. He then enters the code number for that station from the list on the right hand side of the display. Coordination between legs and stations is accomplished through observing the graphic display.


7
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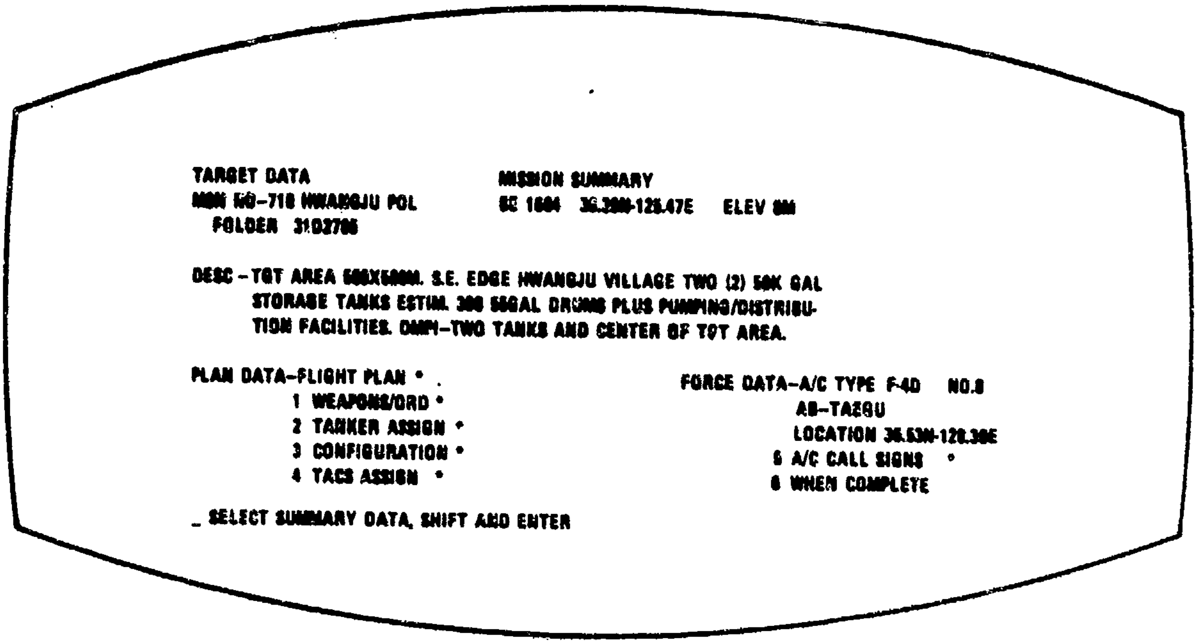
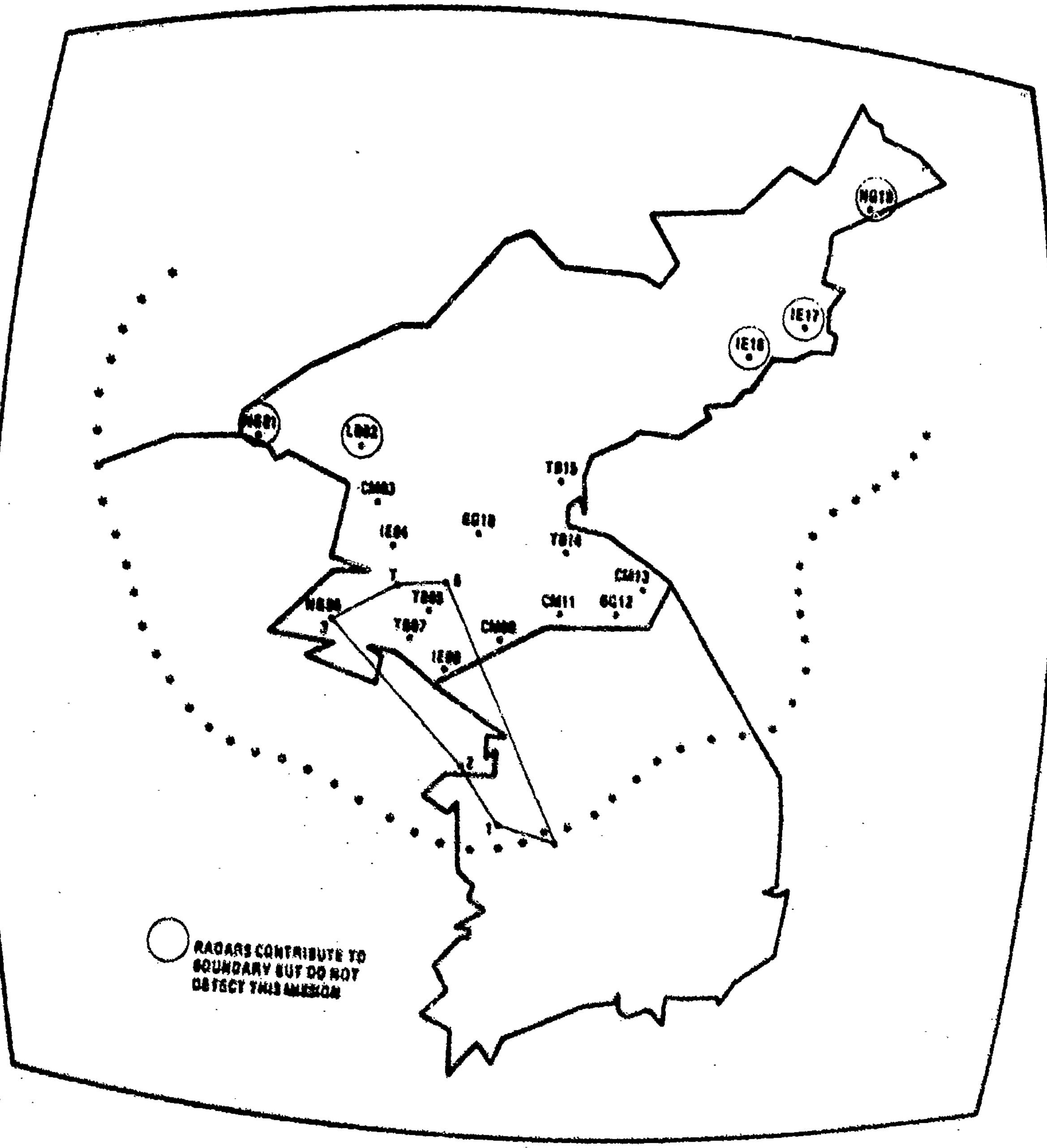
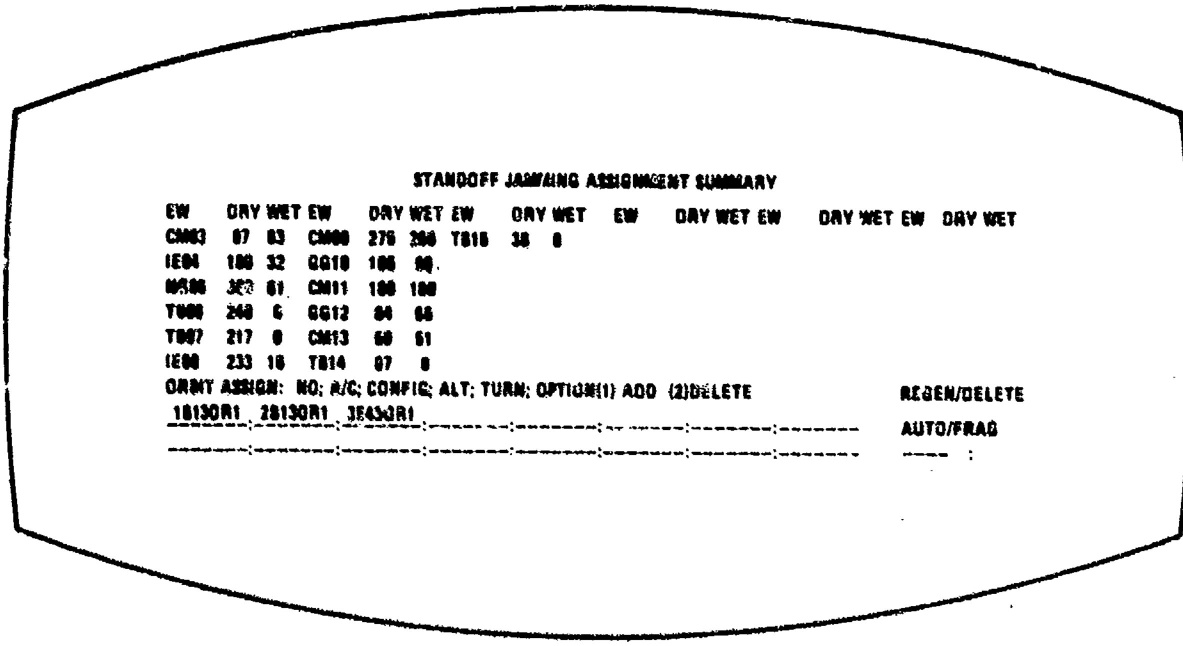
B15
A22
3
2
TGU
1



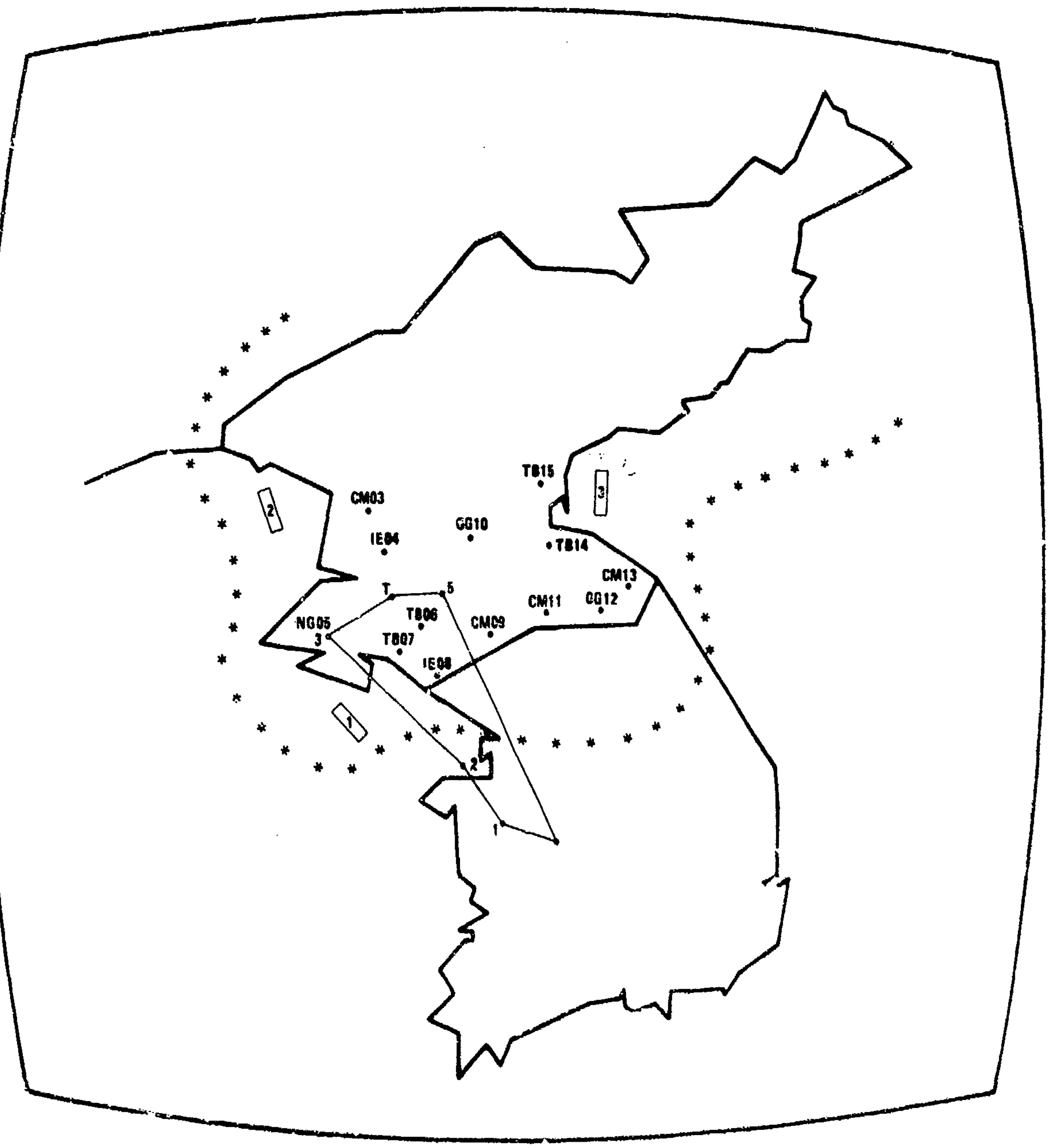
This A/N display presents the completed mission summary table for the mission against the Hwangju POL area. Comparison of this display with the one shown earlier on page 5 will show that the force data has been completed and that the dashes reflecting elements of the plan have been replaced by asterisks. The planner may review any element of his plan by entering the appropriate code number in the bottom line. The flight plan may be reviewed by activating the FLIGHT PLAN SUMMARY function button.

If the planner is satisfied with the plan, it is returned to the data base for future use.


TB15
TB14
IE17
TB08
TB07
CM11
CM13
RADARS CONTRIBUTE TO BOUNDARY BUT DO NOT DETECT THIS MISSION



Evaluation and planning of Stand-off support jamming can be achieved either by manual or by automatic trial and evaluation processes. The planner makes an initial selection of a mission to be supported. The SOJ program then selects and displays those EW/GCI radars which can detect and track the mission aircraft. The program also computes and displays a penetration contour for all EW/GCI radars. This contour shows the points of first detection for penetration into the area of interest.



TB15
CM03
IE04
GG10
TB14
CM13
T
5
CM11
GG12
TB06
CM09
NG05
3
TB07
IE08
2
1

STANDOFF JAMMING ASSIGNMENT SUMMARY

EW	DRY	WET	EW	DRY	WET	EW	DRY	WET	EW	DRY	WET	EW	DRY	WET	EW	DRY	WET
CM03	97	83	CM09	275	266	TB15	38	0									
IE04	100	32	GG10	106	96												
NG05	300	61	CM11	188	188												
TB06	240	0	GG12	84	65												
TB07	217	0	CM13	58	51												
IE08	233	18	TB14	87	0												

ORBIT ASSIGN: NO; A/C; CONFIG; ALT; TURN; OPTION(1) ADD (2)DELETE REGEN/DELETE

1B130R1 ; 2B130R1 ; 3E430R1 ; ——— ; ——— ; ——— ; ——— ; ——— AUTO/FRAG

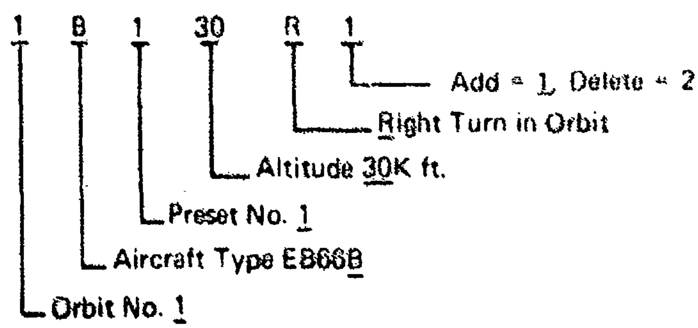
——— ; ——— ; ——— ; ——— ; ——— ; ——— ; ——— ; ——— ——— :

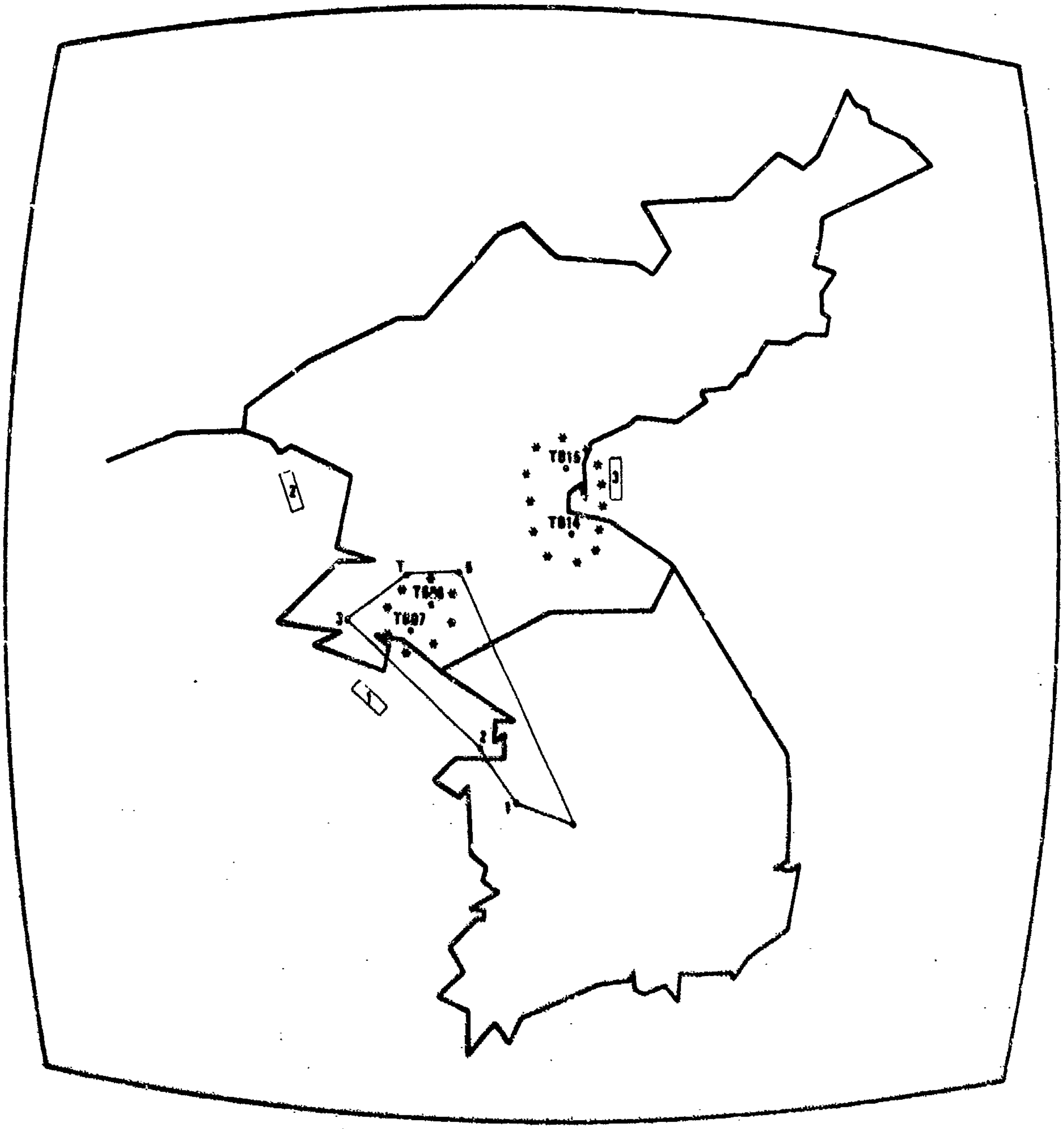
When the planner chooses the manual SOJ mode the alphanumeric display is formatted so as to enable manual placement of orbits and the assignment of aircraft and jammer configuration.

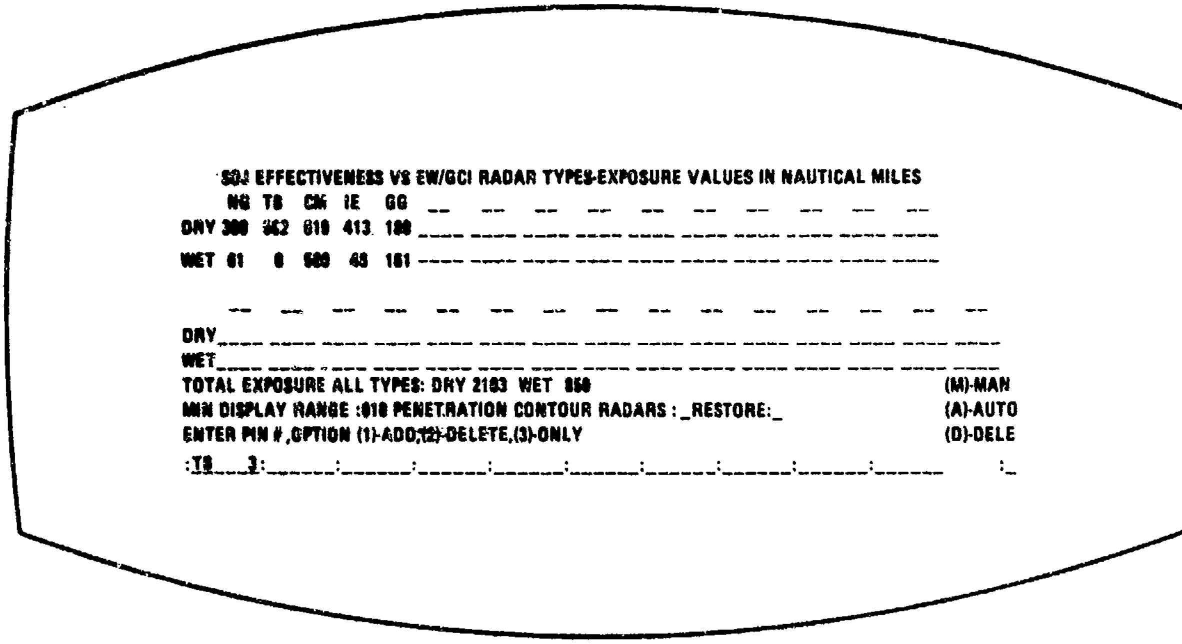
With his light pen the planner creates an orbit of any length and orientation at any position he chooses on the graphic display. On the A/N display he assigns an aircraft type, jammer preset configuration and altitude for each orbit. After each individual orbit assignment the effect of this particular jamming assignment is shown by (1) a change in the shape of the penetration contour and (2) a numerical summary on the A/N display.

The A/N display illustrates that 2 EB66B aircraft are assigned at 30K ft. with presets #1 used and one EB66E aircraft assigned at 30K ft. using presets #4.* A maximum of 16 orbits can be evaluated. The orbits and the resultant penetration contour are illustrated on the graphics. The wet and dry exposure values for each EW/GCI radar are illustrated on the A/N display. Exposure values are reduced by jamming and a value of zero indicates that the radar will never detect and track the mission aircraft.

*Interpretation of the entries in the bottom line are as follows:




T815
T814
T807
3
2
1

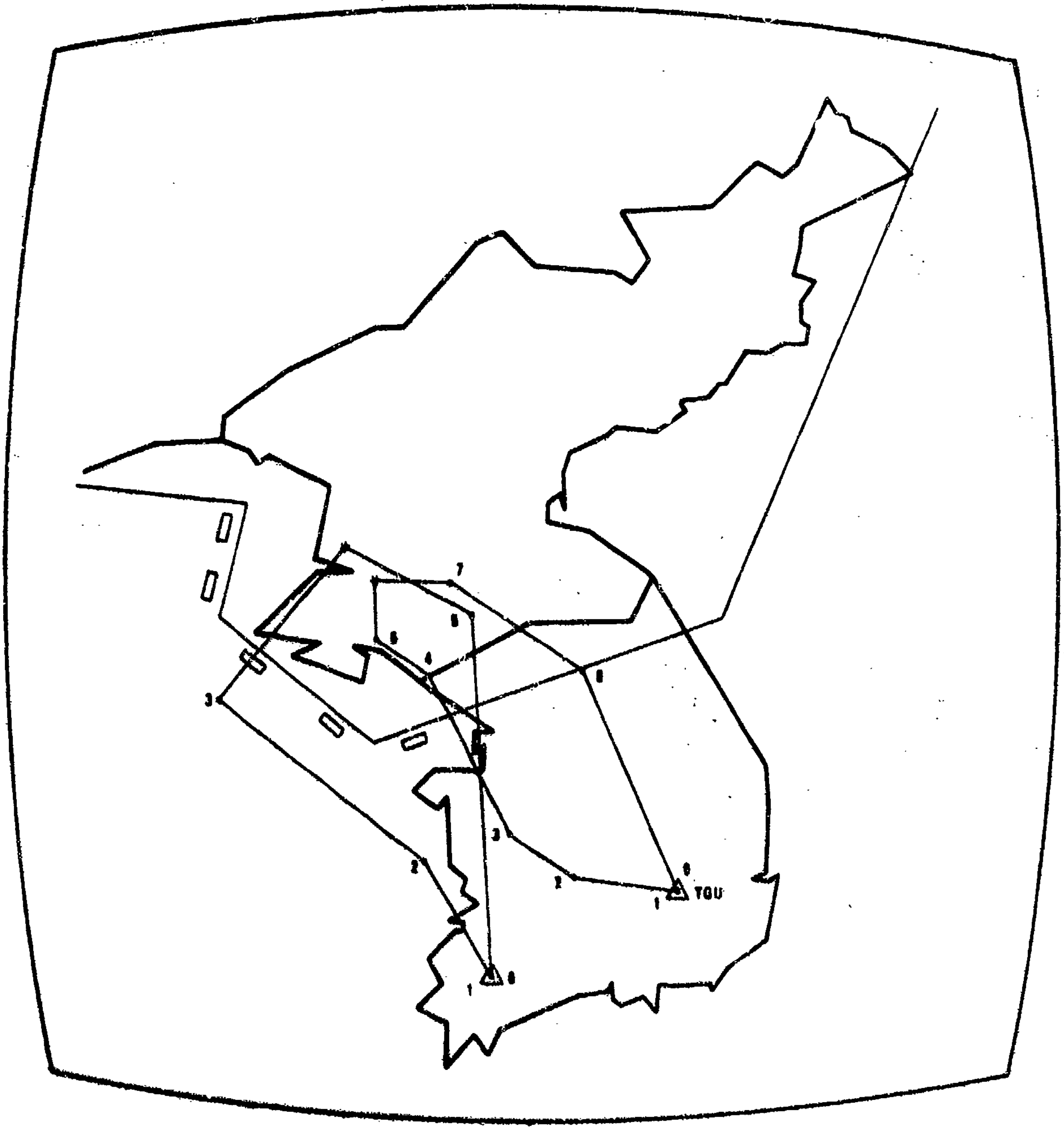


The effectiveness of assigned support jamming is automatically summed and displayed by radar type. These data, as shown on the "SOJ Effectiveness vs EW/GCI Type" A/N display, are available for further analysis. This A/N display may also be used to initiate computation and display options of various types. For example, the planner may specify an arbitrary exposure value. The graphic display then presents only those radars which can equal or exceed this detection and tracking capability in the existing jamming environment. The planner may also wish to see only those radars which are individually responsible for the displayed penetration contour and which must therefore be attacked or further jammed if initial detection is to be further delayed.

Another option is the capability to limit the display to specific radars or to all radars of a given type and the penetration contour associated with the specified choices. The graphic display illustrates the planned selection of all TB radars. Notice that the associated penetration contour has now been reduced to two separate small closed areas.

Similarly the planner might type in the pin numbers of several specific radars comprising a single EW net. He would then be able to visualize and plan jamming activities against that net. Mixtures of specific radars of different types are permissible. The planner uses the "Restore" option to recover the display of all EW/GCI radars.

When the number of displayed radars is limited the wet exposure values still truly reflect the effects of all assigned SOJ support jamming vehicles. The penetration contour, however, demonstrates this cumulative jamming applied against only those specific radars or radar types requested.


TGU

EXPOSURE IMPROVEMENT SUMMARY

TRIAL POSITION	PRESETS							
	E1	E2	E3	E4	B1	B2	B3	B4
1	18	13	14	14	21	23	21	30
2	8	9	10	11	13	12	14	16
3	43	40	40	42	60	65	70	80
4	11	12	7	8	10	9	11	14
5	17	12	11	15	24	26	20	35

DRY EXPOSURE SUM 1864 NM

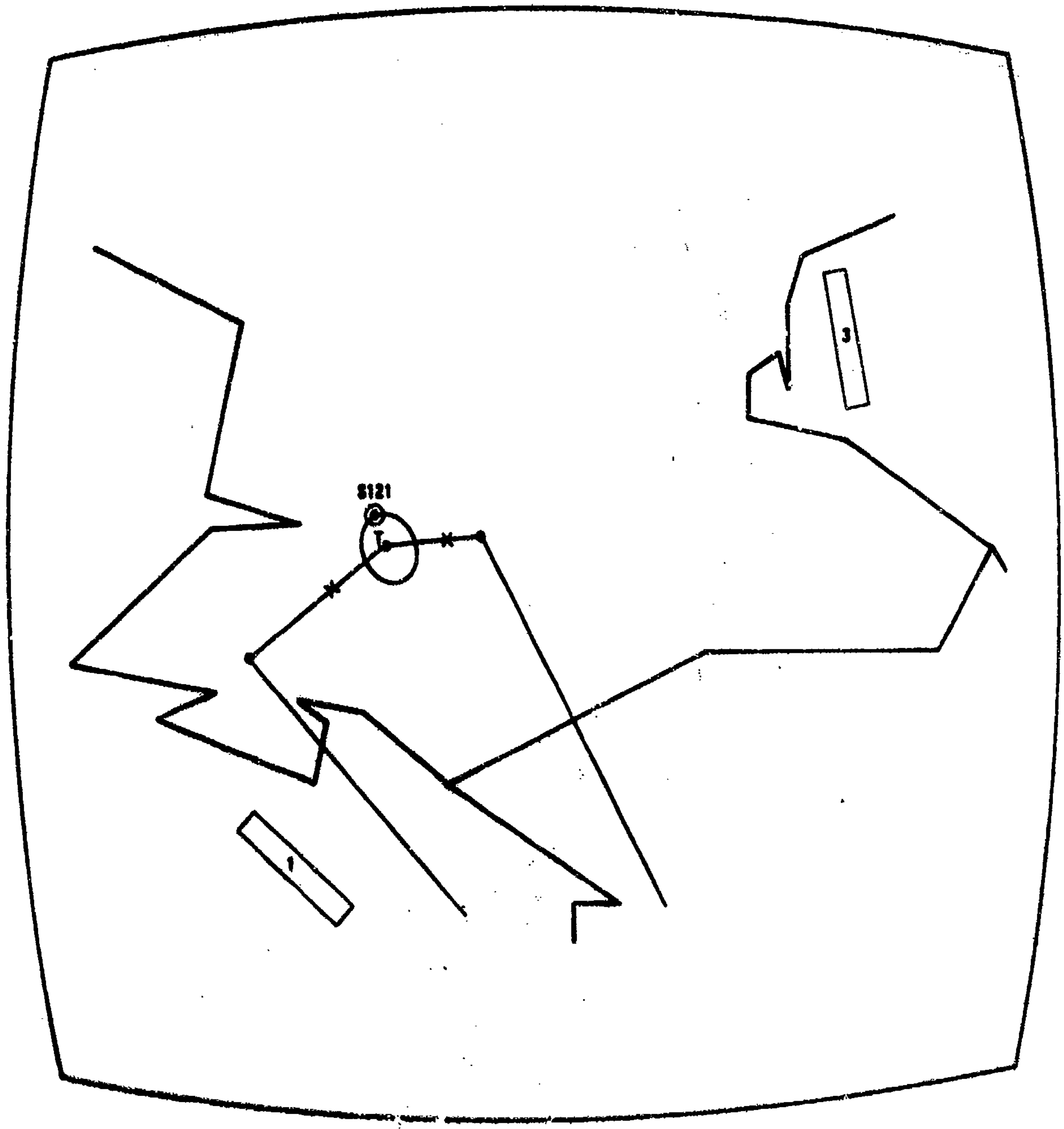
ASSIGNED WET SUM 612 NM

BEST TRIAL IMPROVEMENT: POSITION 3, B4

All the aforementioned capabilities are integrated with the Automatic Orbit Selection (AOS) process. The planner may at any time call the AOS program for assistance to determine the best position and best jamming configuration to achieve desired (specified) results. If the planner wishes to limit results to specific radars or to radars of a given type, he first makes these selections.

In the AOS program the planner can light pen the location for as many as five different orbits for trial evaluation. He can select either a specific combination of aircraft types and jamming configurations or simply ask for analysis of all available aircraft and jamming configurations. The AOS program then analyzes all requested combinations and displays to the planner the relative benefits of each. The planner may then see which orbit position(s) and aircraft/jammer configuration(s) best achieve his intended purpose. The planner can then select one or more of the combinations for assignment and the program automatically updates all computations and displays to reflect these assignments.

The AOS program also operates in a "Delete" mode. Should cancellation or reassignment of vehicles be required the computer uses this mode to test each existing assignment and determines which one makes the smallest contribution.


S121
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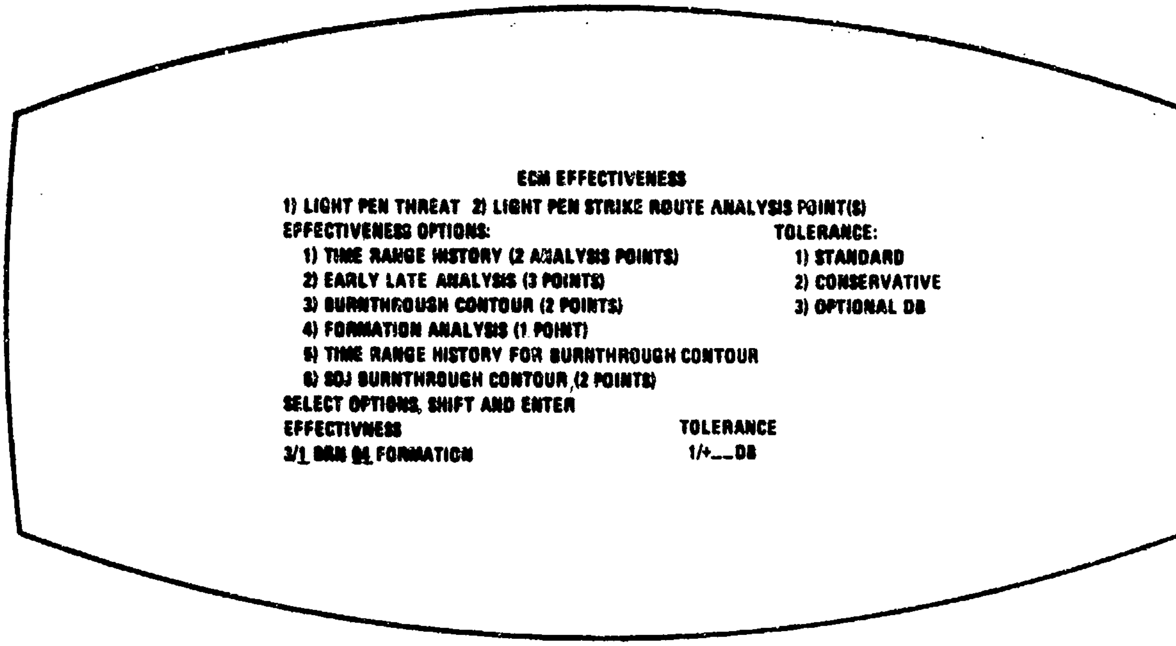
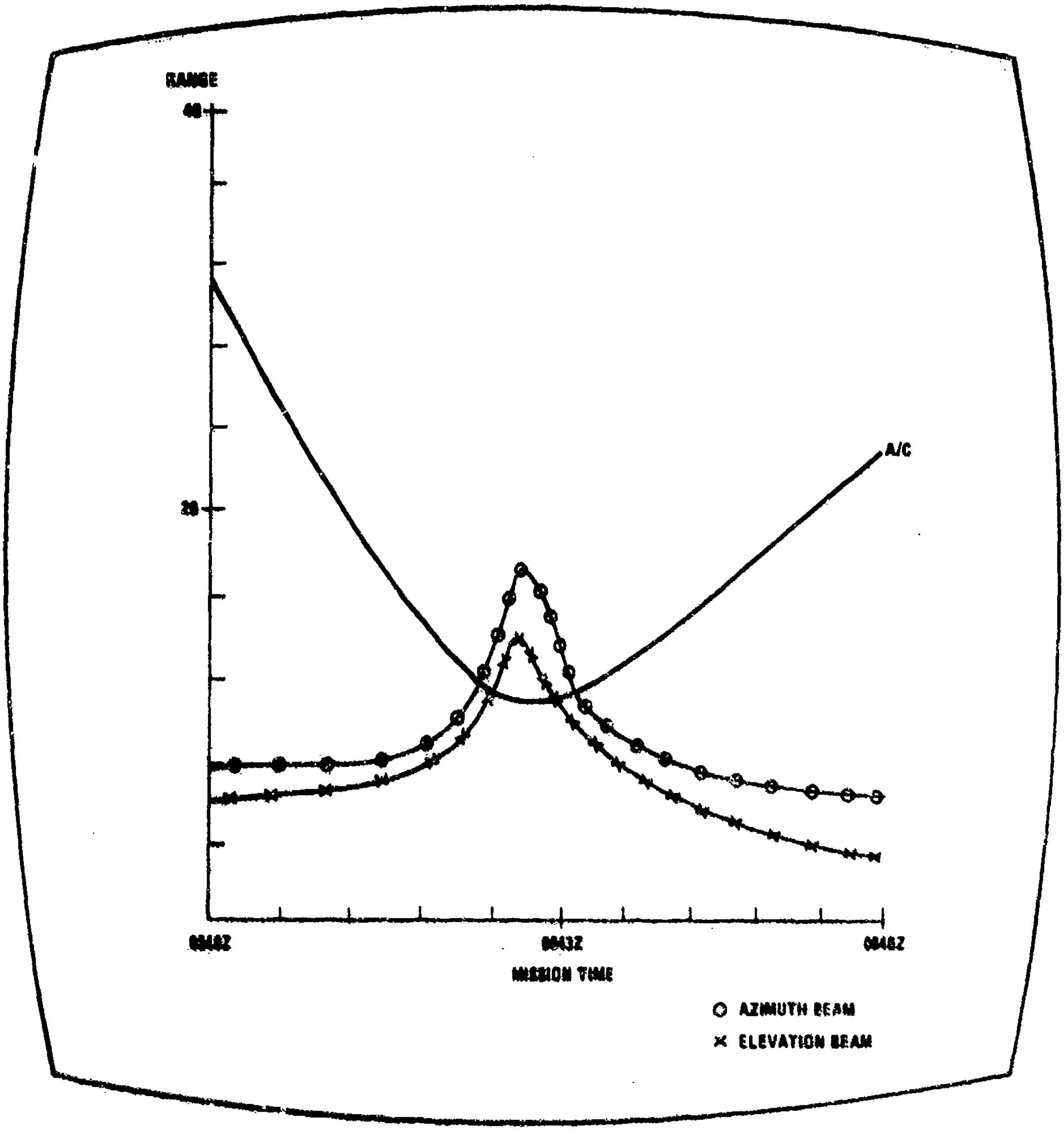
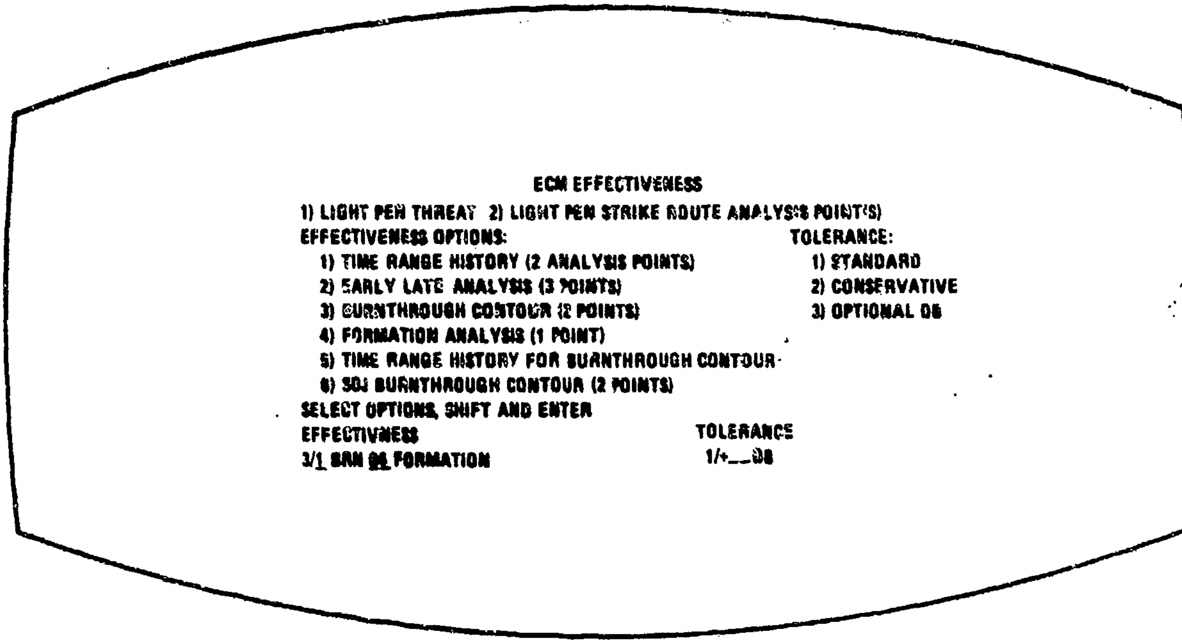
3
1



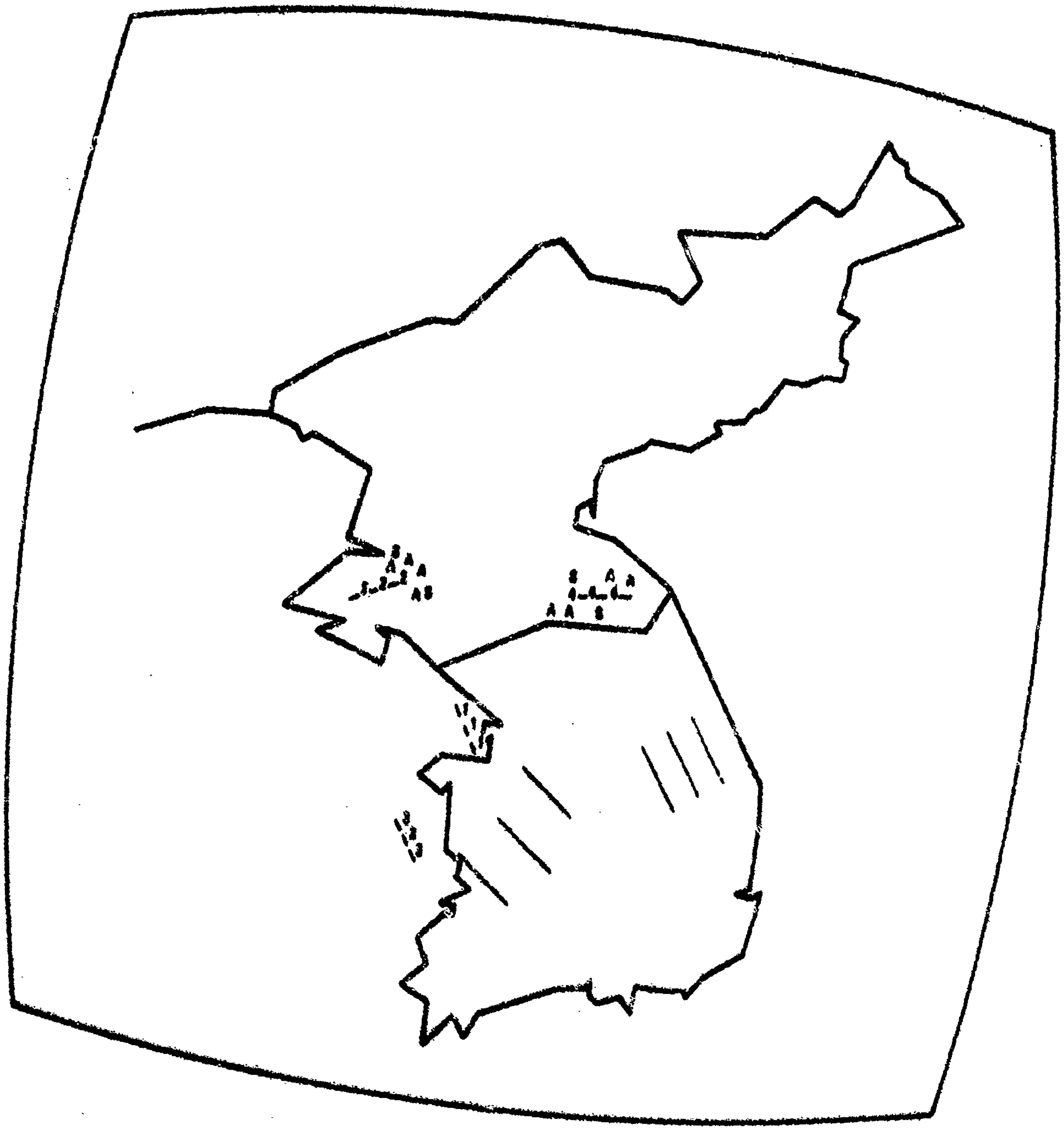
The effects of noise jamming from either support vehicles or on-board jammers can be computed and displayed utilizing the "Burnthrough" concept. The planner may select any radar and request results for any available jammer configuration. The burnthrough range (radar range capability in the presence of jamming) is overlayed on the graphic display when the planner selects (1) the radar of interest, (2) the region over the flight path of interest and (3) the jamming configuration.

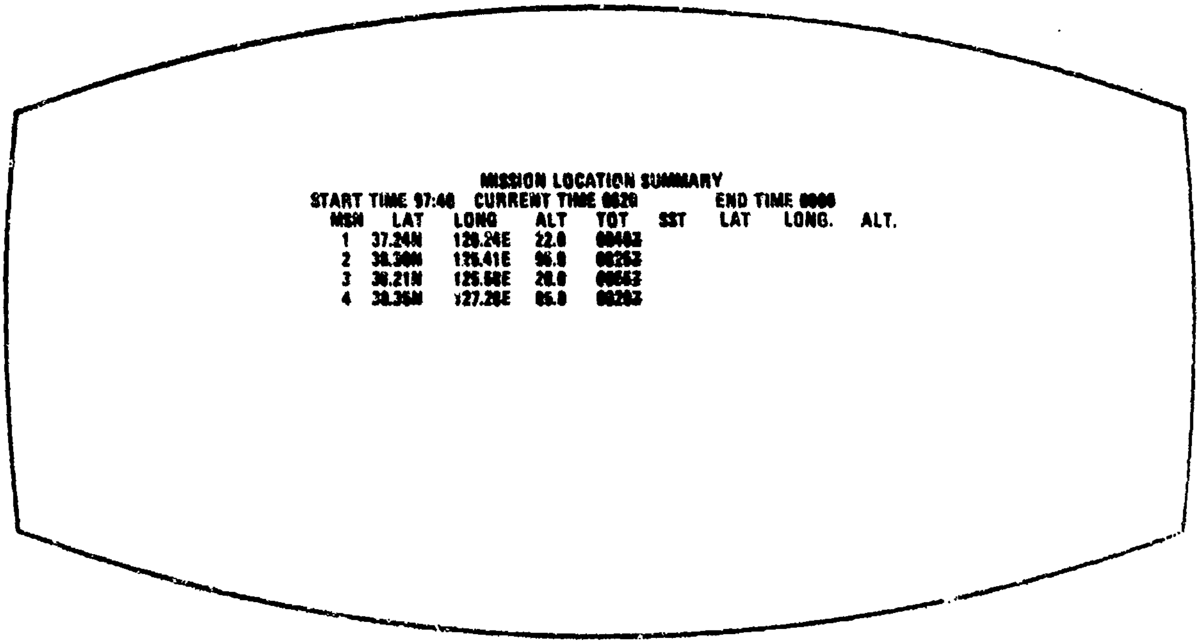
The expanded graphic Display as shown illustrates the polar burnthrough display option. The computations behind this display encompass variable radar cross section; summation of all individual jammer contributions via relative position to the radar boresight axis; three dimensional antenna patterns for the victim radar and the jammers, and variation of parameters to include the effects of aircraft turning.


RANGE
40
20
A/C
MISSION TIME
AZIMUTH BEAM
ELEVATION BEAM



Burnthrough results may also be displayed on expanded scale in the form of a "time range history." This option is illustrated on the graphic display for a TWS radar containing two separate beams. The program can display the range capability for up to 6 individual beams. Mission time is displayed on the horizontal axis. The time and duration of burnthrough are determined by the intersection (if any) of the aircraft range curve with the respective range capability for each of the radar beams.





The final slide represents a plan review and coordination technique referred to as Time Sequence Review or TSR. After missions have been planned against all the requirements, the planner may bring up a graphic display of all the planned missions on a timed basis. The planner specifies a starting time and an ending time, e.g., 0740 to 0900. The computer then retrieves from the data base all missions which will be airborne during that period.

Beginning at 0740 it displays the location of all missions airborne at that time. It then steps through the specified time period in selected time increments. The size of the step may also be varied. It continually displays the location of each airborne mission at each time increment until the Stop Time of 0900 is reached. Whenever threats are encountered they are also displayed. The stepping is either automatic or manual, as instigated by the planner. Choices are handled via function buttons.

In parallel with each change in the graphic display, the A/N display indicates which flights are airborne, the Lat/Long of each position and its altitude data. Any space/time conflicts between two missions result in an automatic alarm to the operator who can stop the process and determine which mission to change and how to change it. This capability may also be used to evaluate the success achieved in coordinating various missions.

Complete design and programming specifications for the Mission Planner Breadboard are available in Data Systems Division's Documents Technical Report, 8003 and Specification 134000 100, respectively.

4.3 Mission Planner Breadboard Applications to RPV Planning

Subparagraph 4.1.1.3.3.1 of Contract F30602-71-C-0015, Change C, 6 July 1972, required that a subset of those existing software programs which satisfy the RPV command and control requirements should be identified as follows:

a. Target Characteristic Review: A mission and targets may be selected for detailed planning. Additional targets can be added to the current data base which are considered to be more typical targets for the currently proposed types of RPVs and their payloads. Details of the assumptions for target types and missions, which were used in the test results of the RPV demonstration, are described in Subsection 4.5. Once the RPV mission and target lists have been input to the data base and a target (mission) has been selected, the planner may analyze the previous mission as it is presently done for manned aircraft. The only critical modification is the addition of the type of vehicle which flew the earlier mission; e.g., manned aircraft or RPV.

b. Aircraft/Ordnance Selection and Assignment: The planner may select the type of ordnance, the type and number of vehicles, and assign a resource location for each target. Both data base changes and minor program modifications are required to accommodate resource selection and assignment for RPVs. Specifically, for ordance selection, new JMEM tables for the various vehicles need to be developed, stores in the data base, and included in the ordnance inventory list. Similarly, data base changes must be incorporated to include launch site location data and data on the availability and numbers of RPVs at the various RPV units and/or launch sites. In the breadboard system, a limit of four different types of manned aircraft are available for resource selection. The use of the breadboard for RPV planning requires minor program modification to replace one of the four manned aircraft by an RPV.

c. Call Sign Assignment: The planner can assign call signs to the RPV (and relay) missions using the technique currently in use. If squadron numbers and/or locations are modified, the call sign data base must be updated.

d. EOB Review: The planner may review the location and effective area of any enemy threat in the data base. As with manned aircraft, this review may be limited to those threats intersecting the RPV profile. No changes are required.

e. Semi-automatic Route Selection: The planner may select an ingress and egress route to the target. He may also specify a speed/altitude profile. The planner may also modify the route semi-automatically and evaluate the results of these modifications. Data base changes must be made to reflect the performance characteristics of an RPV included as one of the vehicles; e.g., Mach number, altitude, and speed limitations.

f. Safety Analysis: The selected route may be evaluated to give a relative safety evaluation based on the threats encountered. A "Relative Safety" score of the route and the least safe segment can then be displayed. The route can be altered and the alternate route "Safety Score" can be computed and compared with the original route's score. Changes in the route safety analysis require an update of the data base to reflect new weighting factors for the various threats to be used in the scoring algorithms. Modifications to reflect extremely low terrain following routes may also be necessary. The relative effectiveness of each threat type must be examined as they affect RPVs.

g. Automatic Route Selection: The program may automatically select the three best ingress and egress routes for the target within a radius of 50 nm using the safety analysis algorithms.

h. TACS Assignment: Tactical Air Control System Station Assignments can be performed on a leg-by-leg basis for the entire route.

i. Effectiveness Analysis: This ECM effect analysis will consist of the following programs:

    1. Burnthrough and Time-Range History: Self-protect ECM may be evaluated by calculating and displaying burnthroughs, contours, and time range histories.

    2. Formation Analysis: The cooperative effect of self-protect ECM may be evaluated for several vehicles flying in formations.

    3. Standoff Jamming (SOJ) Analysis: It will be possible to assign and evaluate SOJ vehicles to support RPV missions, or to assign and evaluate RPV vehicles for standoff jamming missions.

    4. Special Support Jamming (SSJ) Analysis: It will be possible to assign and evaluate RPV vehicles for support jamming roles.

    5. On-Board Jamming (OBJ) Analysis: It will be possible to evaluate the effectiveness of OBJ against a large environment of SAMs. This function requires only an update of the data base. The initial change is to include a radar cross section table for the RPVs as a function of azimuth and

elevation angles. In addition, for formation analysis, different threat dimensional spacing must be added to the formation table. If any new on-board jamming capability is to be considered, the characteristics of the jamming configuration must be added to the available equipment list.

j. Time-Sequence Review (TSR): TSR allows the planner to review his total planning effort. He may view the total planned missions as a series of time frames. In addition, he may see the SOJ and SSJ missions as well as the threats that interact with the missions. No changes are required for Time Sequence Review.

4.4 BREADBOARD SYSTEM EXTENSIONS AND MODIFICATIONS TO ACCOMMODATE ADDITIONAL COMMAND AND CONTROL FOR RPVs

There are three general areas in the Command and Control of RPVs where the present Mission Planner Breadboard could be modified and/or extended to accommodate additional functions. These three areas include additional pre-planning, mission monitoring, and near-real time command and control functions. The following subsections briefly describe some functions in each of the areas, as well as how they might be implemented within the structure of the present breadboard. Thses functions are either new or require extensive modification to existing MPBS implementation.

4.4.1 Additional Preplanning

4.4.1.1 Terrain Following Route Planning

One of the prime tactics presently considered for RPVs is low-level ingress/egress utilizing "terrain hugging' wherever feasible. The basic building blocks for the development of an automatic and/or semiautomatic terrain following route selection based upon route safety already exists in the Mission Planner Breadboard System. These building blocks are terrain masking, route safety analysis, and automatic route selection.

In the present implementation of terrain masking, a set of masking angles and ranges is stored for each threat. These data are available to evaluate the route safety score of the strike force to the threats based upon a given route and altitude. Also, by utilizing the terrain data, one could expand these programs to determine the route safety score for any given route based upon the strike force's flying X number of feet above terrain. Once these algorithms have been developed, a planner could manually select alternate routes until he is satisfied with the route safety, or the technique could be incorporated in automatic route selection.

Automatic terrain following route determination would take considerable computational time and require a large amount of storage. Studies are presently underway to reduce the time and storage requirements. It is important to note, however, that the implementation of the techniques in a straight forward manner on the Breadboard could be an invaluable simulation tool to test the sensitivity of various parameters such as accuracy of navigation data required, required digital terrain data quantitization, accuracy of threat locations, and other variables associated with the problem.

4.4.1.2 Fuel Calculations

Changes and additions to the present fuel calculations which are necessary for RPV planning include design and programming of the following capabilities:

a. Integration of the terrain following mode of operation into the speed/altitude/fuel consumption calculations will be required.

b. Certain missions (ECM in particular) may require on-station orbiting or loiter patterns. For these missions, a special technique is needed wherein the planner can simply input the pattern type, on-station position, and time duration. The computer would then automatically compute the on-station flight path time history and fuel consumption for this segment. In the case of reconnaissance and ECM missions, the on-station flight path dynamics would also be available for evaluation of payload effectiveness and timing requirements.

4.4.1.3 Dynamic Line of Sight Computation and Display

Long range command, control communication links from fixed sites which are subject to LOS limitations may be rapidly evaluated using current Mission Planner terrain masking algorithms together with the capability to update the mission tracks with status reports. A desirable expansion of the present fixed site (CRC/CRP) capability would be to enable terrain interference calculations between airborne C&C plarforms and RPVs (or other vehicles) with arbitrary flight profiles for each element. RPVs on low altitude flightpath segments will be subject to LOS blockage by the terrain and the anticipation of when, and for how long, these interrupts occur can be vital to mission success. The preplanning of an airborne command and control to supervise multiple RPV elements is a complex problem itself and any requirements for rapid real time replanning to include terrain masking calculations would be an almost impossible task to perform manually.

This capability extension will allow the planner to identify any two flight elements and request LOS calculations between the respective vehicles for any time period. The intervals of terrain blockage (if any) can be displayed on the geographics display by interruption (blanking out) of the affected flight path segments. The corresponding times of interrupt can be displayed on the A/N and therefore be available for hard copy print out. All the rerouting options would be available to the planner so that he may replan the route/profile of either vehicle, if necessary, to achieve the desired results.

4.4.1.4 Data Base Update

There are elements of the current MPS data base which are static predictions used for preplanning purposes but which assume a dynamic nature when used for in-flight replanning. Some of the current flight safety and mission success factors which warrant input of new data during mission progress include the following:

a. Weather hazards and cloud layer structure.
b. Changes in SAM and AAA posture.
c. Changes in restricted flight zones.

To facilitate the input and use of these data changes, a temporary file structure can be created. The operator would input from the keyboard directly into these files. Each program using data of this type could be modified to access the temporary files prior to execution of the required function.

4.4.2 In Flight Replanning

4.4.2.1 Schedule Modification

The MPS was not implemented to operate with real time inputs, however, with minor modification, the MPS could be used for execution or simulation of a wide range of C&C operations type problems. In the present system all flight position timing is computed forwards and backwards from the input TOT requirement. Accordingly, when route modifications are introduced during the planning cycle, schedule times are adjusted as necessary. To best achieve the real time replanning capability, it is desirable to add the option of accepting mission progress reports. When such inputs are received the flight path following program (Time Sequence Review or TSR) would then use the input time versus position data up to the last received values. Beyond the last input data point, the remainder of the flight path position versus time sequence would be computed using checkpoints from the plan and the computed ground speed values. With the input of such data the TSR program may then be placed in operation, and the operator will see on the geographics display the actual and preplanned flight progress versus mission time. In response to visual deviations, the planner/controller may wish to redirect the mission to overcome anticipated problems after assessing factors of flight safety and potential mission success. The type of assessments the planner/controller may wish to make and which can be provided by the MPS breadboard, include the following:

a. What is the impact of the current position reports on the TOT?

b. Can the route/profile and speeds be modified to achieve the desired TOT?

c. If route modifications are made will the route safety be severely compromised?

d. If route/speed deviations are made is the fuel adequate? Can the flight reach an alternate base?

4.4.2.2 Techniques of Adjustment and Replanning

Given the ability to accept mission progress reports, various assessments and adjustments can be made with the MPS used in the following manner.

a. Monitoring the impact of flight profile deviation; the TSR program is entered and either manually or automatically stepped to advance to mission time. In the TSR program a small segment of each flight path is shown which indicates present position and path made good over the last few minutes. By inspection of the TSR display the operator/controller can immediately see divergences between planned and actual flight paths. Mission time (or simulated real time) is displayed on the bottom of the CRT. Flight path detours or delays can be assessed as to their impact on the mission by merely noting the time difference required for the respective tracks to reach the same position (assumes that the deviated mission regains a position on the planned track and follows the preplanned check point and speed sequence).

b. Assuming that a significant deviation has occurred, the planner/controller may elect to follow any one of several courses of action depending on the mission priority and nature of deviation. For example:

   1. The planner/controller may accept the schedule variance and choose only to verify that fuel requirements are met. In this case he would activate the FUEL* program and would receive an alphanumeric summary of the refueling plans (if any) and a "go" or "no go" report on fuel adequacy. If insufficient fuel is available, the geographics display will mark on the flight path the position of fuel exhaustion.

   2. The planner/controller may elect to modify the route in order to conserve fuel or to attempt to achieve the desired schedule. In this case he would activate the MODIFY ROUTE program and would now be able to manually modify both the path and/or the speed altitude profile as deemed appropriate. Upon completion of the route modification, he could then return either to the TSR or FUEL programs to verify that his objective has been achieved. Significant changes in the route profile may adversely affect mission success if the number or type of threats encountered changes. To assess this

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*The current fuel programs include F-4, F-105, A-7, and F-111 aircraft. Separate fuel and ordnance loading programs are required for each vehicle type.

possibility the ROUTE SAFETY program will provide an alphanumeric summary and comparison of the preplanned route with the newly created route. The safety analysis provides summation figures of merit (relative safety factors) for the overall mission and for each type of hostile threat. The graphics display will indicate the number of possible lethal encounters for the SAM and AAA sites. If desired, any of the ECM programs may also be invoked to assess the suitability of support and self protect jamming equipments.

3. There may be a requirement to direct an airborne RPV mission to a new target. To enable this capability requires an additional change to the current breadboard system. The reprogramming needed is simply that which will retain the established flight track on the geographics display and enable the recall, display, and selection of an alternate target. Having selected the new target, the planner/controller may now proceed to re-route and evaluate the new mission using any of the techniques available in the breadboard, including the Automatic Route Selection program. He may also look at other aircraft to be diverted to the target, if it is high priority.

4.4.3 New Missions

The MPBS was designed to handle Strike Missions and a subset of the ECM mission. Expanding the breadboard to support RPV requires extensive activity in the areas of planning other ECM missions and the Reconnaissance mission, including ELINT.

4.4.3.1 ECM Missions

The degree of modification required to the MPS will depend on the type of RPV mission. The simplest modifications will be to enable planning of ECM support since many of the ECM effectiveness evaluation techniques already exist in the MPS. Two readily implemented, and effective, ECM mission types are identified below as candidates for early tactical use of existing and forthcoming RPV capabilities.

a. ECM MISSION TYPE I - Orbiting RPVs with Noise Jammers: These vehicles can be flown to critical areas and put into orbit in close proximity to radars to achieve either:

   1. Degradation of the EW/GCI radar net.

   2. Degradation of specific terminal threat SAM and AAA complexes.

b. ECM MISSION TYPE II - Chaff Dispersal: At least two basic chaff missions can be identified:

1. Corridor Chaff dispersal to generate long length screening paths for manned penetrators. These same corridors may also serve as confusion and decoy elements.

2. Pattern Chaff for terminal threats. The patterns may be of various types such as continuous rings around the emitter, or might consist of spot bundles deployed at various altitudes and positions. Whereas corridor chaff will be primarily used for screening, the pattern chaff will also function to create confusion and aid the track breaking of SAM and AAA radars.

4.4.3.2 Reconnaissance Missions

This subsection discusses the data base requirements and planning process for two types of reconnaissance missions. These types are Photo reconnaissance and ELINT. The Advanced Development Mission Planning System will include these mission types while the breadboard does not. Thus, in the present context they are described as major modification of the breadboard.

4.4.3.2.1 Photo Reconnaissance Missions. Two factors of the photo reconnaissance mission are discussed in the following paragraphs. These factors are; the data base requirements, and photo reconnaissance mission planning.

a. Data Base Requirements

The ADMPS data base applicable to the mission-peculiar aspects of photo-reconnaissance includes technical data on vehicles, sensors, and targets, as well as target-associated history files and technical analysis files. The sensor/target technical data must include:

1. Recommended sensor/target combinations.

2. The capabilities of sensor installations to obtain different kinds of information at different resolutions as a function of altitude, speed, lighting, direction of view, visibility, film, and exposure or other setting.

3. The ground coverage of sensor installations as a function of altitude.

4. The requirements of the targets for different sensors, sensor modes (e.g., stereo), resolutions, directions of view, etc., in order to yield various different kinds of reconnaissance information.

The target technical data will also include constraints on vehicle altitude, or vehicle approach or viewing direction, such as may be imposed by terrain or other features in the target vicinity. Other data on targets as well as vehicle status, availability, and performance characteristics are similar if not identical to that for strike aircraft.

b. **Photoreconnaissance Planning**

It is envisioned that the planner will call up, from the ADMPS data base, lists of his assigned targets and target areas, their priorities, TOT requirements (especially important in cases of pre- and post-strike reconnaissance for bomb assessment purposes, and in cases where lighting conditions or special target activity is critical), and required reconnaissance information or required resolution. These will have been generated by command sources external to the ADMPS. He will also call up data on the inventory and readiness status of his reconnaissance vehicles and sensors, and their locations. He may call up recommended target/sensor combinations, sensor/target technical data, references to file data on related past reconnaissance missions, and references to file data on target characteristics (activity times, resolutions required for information yield, local hazards, etc.), as well as weather/visibility/lighting forecast data.

Based on this information, the planner selects a specific target (or target area, or set of targets whose reconnaissance requirements may be met with the same sensor installation on the same mission) against which to plan a mission. He then determines an initial group of candidate vehicle/sensor combinations (with associated estimated over-target altitudes, approach directions, area sweep patterns, etc.).

This initial group of candidates may be chosen directly from past missions, or from a data base recommendation for the particular target type and required recce information.

The initial group of vehicle sensor candidates may be reduced or modified by the planner's estimates of route/profile acceptability, support mission availability, and potential mission effectiveness as in strike mission planning.

The remaining group of vehicle/sensor candidates are subjected to more detailed reconnaissance mission planning. Over-the-target altitudes and flight routes, target area sweep patterns, and inter-target flight paths are displayed on the geographic display. In particular; geographic constraints, reconnaissance targets, and enemy defenses and defense coverages are displayed on which the planner can enter and modify any tentative mission route. He may also request display of the sensor installation's ground coverage swath along it.

Planning continues essentially as it does for strike missions. The only additional mission-peculiar feature of the reconnaissance planning is the need for TOT coordination with strike missions which the reconnaissance mission may support.

For reconnaissance mission planning, as for strike mission planning, the ADMPS prototype provides for the counting down of basic and support mission resources as they are assigned, for the replanning of missions if the time-sequence review turns up conflicts, and for aid in the translation of mission plans into Fragmentary Orders for automatic printing and distribution.

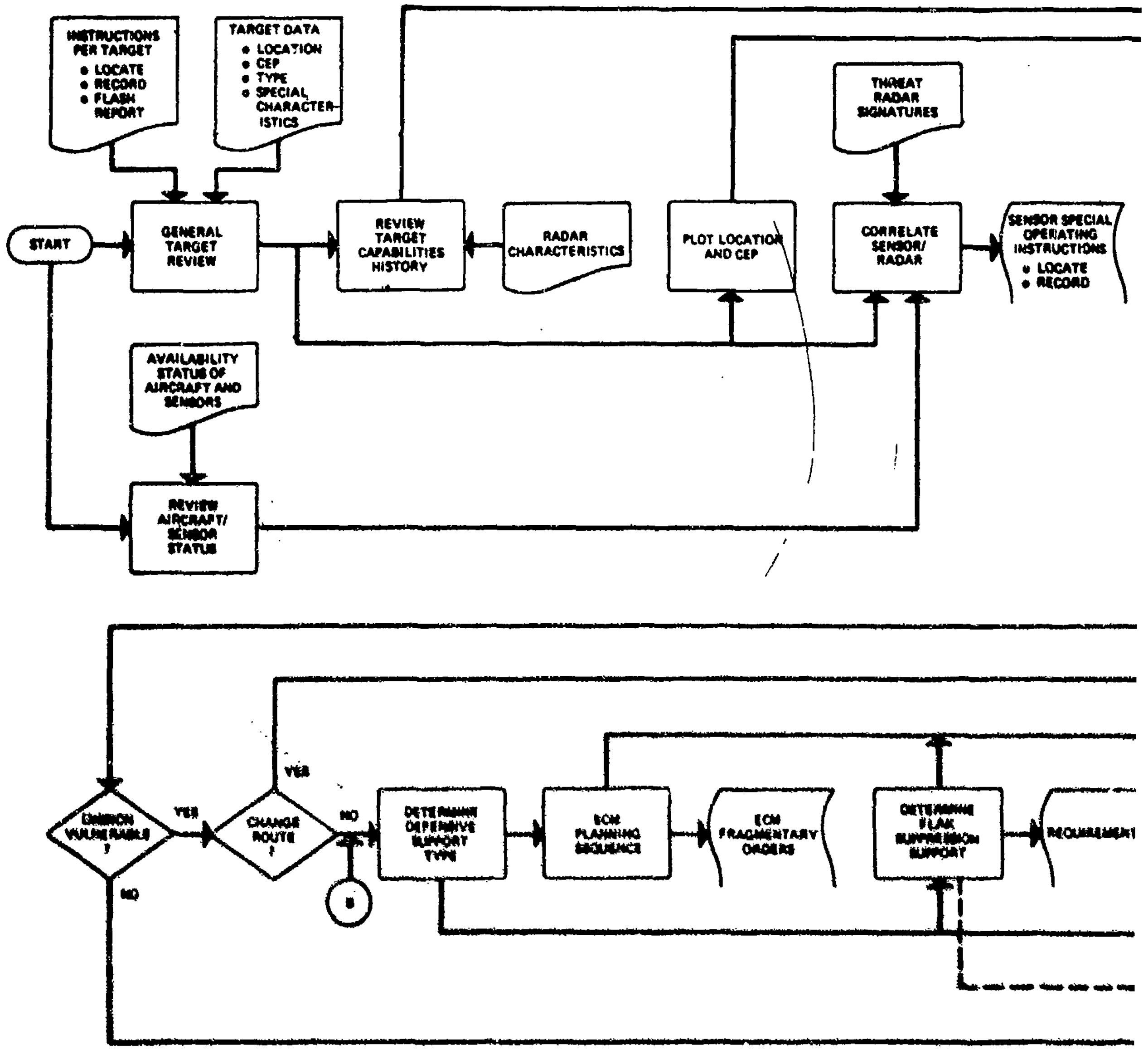
4.4.3.2.2 <u>ELINT Planning</u>. ELINT missions can be identified in two categories: "survey" missions, whose objective is to determine the content of the electromagnetic (E/M) environment over a considerable region, and "specific" missions, whose aim is to collect certain predetermined types of data about specific emitters. Each type of mission may or may not be harmonized; i.e., executed in coordination with other types of missions such as strike, armed reconnaissance, and iron hand missions. Since all recce missions are conducted in response to collection requirements, all missions are correlated to some extent. An ELINT mission may be either an initial or confirming collection effort. Usually (but not always) the initial collection mission is of the survey type while a confirming effort would "usually" be more specifically targeted.

Because the essence of reconnaissance is passive observation, such missions are frequently coordinated with other missions which serve to stimulate the overt actions of the enemy defensive EM environment. Hence, the strike, etc., missions planned with the ADMPS are the foil of the ELINT mission. Therefore, it must be planned to make maximum use of the other missions while not interfering, nor being interferred with, (by ECM elements for instance). This set of circumstances is most reasonable since the thrust of much of the collection effort is to identify threats to strike and other penetration missions.

In order to accomplish coordinated planning of ELINT missions, the planner must employ the functions and data base information which are also used in strike, photo recce, and ECM support mission planning.

ELINT specific functions are addressed after the general situation has been established. A preliminary flight route is developed to optimize probability of detection by correlating range capability of the hostile emitters with the sensitivity of his appropriate sensors. The planner extracts the capability data from the data base for given emitter types, and computes the theoretical range capability using the ADMPS computation capabilities. Using the locations provided in the targeting data or in a data base ROB/EOB, the analyst plots the theoretical coverage of each enemy emitter. Before accepting the theoretical coverage, the planner extracts any pertinent data from the mission history file which necessitates modifications to the coverage such as terrain and individual emitter capabilities. The planner then double checks sensor/target correlation to ensure that the sensor can detect the signal if the ELINT platform is in range. Finally, a mission flight route is drafted which places the ELINT vehicle within detection range of his receivers. Probability of detection is maximized as a function of range, duration of purview and sensitivity. Distance and altitude of sensor, receiver sensitivity, and target radar capabilities all form inputs to determine this first-cut route. A time correlation is then achieved to synchronize the mission with the operating times of the emitter (if these are known). The planner adjusts the flight route to achieve maximum probability of detection based on signal up-time and duration. Further, the ELINT planners also consider techniques to entice an emitter into operation so that the signal can be detected and recorded without jeopardizing mission safety (i.e., "spoofing" the emitter by deploying deception drones which simulate strike vehicles).

Upon completing the ELINT planning cycle, the planner begins a threat analysis process to minimize vulnerability. The threat analysis process, and the analysis of fuel requirements, are almost identical in procedure to Strike mission planning. ELINT missions would be checked against other missions with which they are coordinated through the Time Sequence Review. A flow diagram of the planning process is shown in Figure 4.4-1.


INSTRUCTIONS PER TARGET
• LOCATE
• RECORD
• FLASH REPORT
TARGET DATA
• LOCATION
• CEP
• TYPE
• SPECIAL CHARACTERISTICS
THREAT RADAR SIGNATURES
START
GENERAL TARGET REVIEW
REVIEW TARGET CAPABILITIES HISTORY
RADAR CHARACTERISTICS
PLOT LOCATION AND CEP
CORRELATE SENSOR/ RADAR
SENSOR SPECIAL OPERATING INSTRUCTIONS
• LOCATE
• RECORD
AVAILABILITY STATUS OF AIRCRAFT AND SENSORS
REVIEW AIRCRAFT/ SENSOR STATUS
YES
NO
CHANGE ROUTE ?
YES
NO
ECM FRAGMENTARY ORDERS

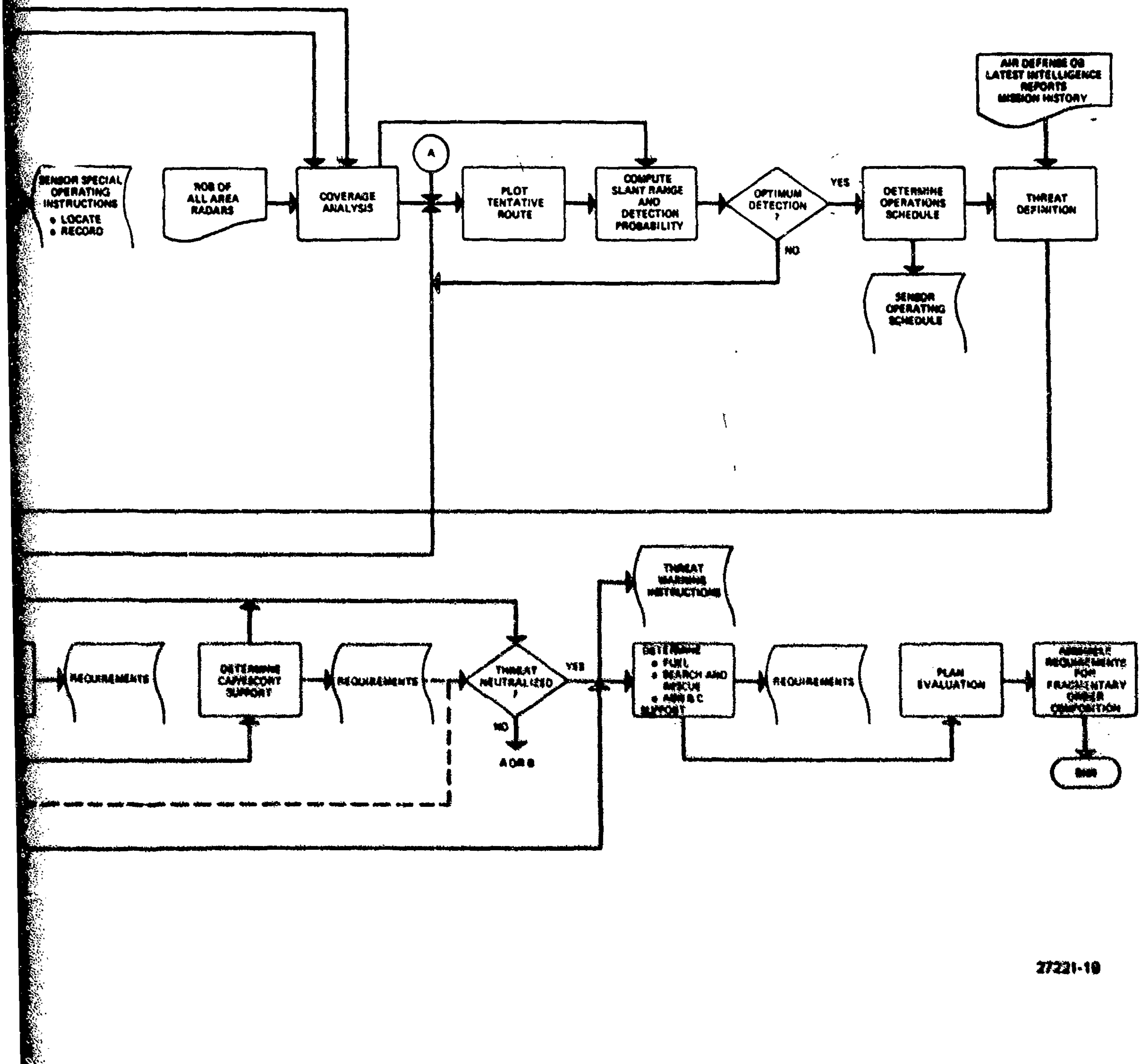


Figure 4.4-1. Major Steps of the ELINT Mission Planner Process

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SECTION 5

ADP SUPPORT TO RPV COMMAND AND CONTROL FUNCTIONS

5.1 INTRODUCTION

The Command and Control functions that must be implemented to plan and execute RPV operations were described in Section 3 and the requirements for ADP support were addressed for each function. Where ADP support was required, specific implementation concepts and procedures were described. Where applicable, ADP Support was based on the Mission Planner Breadboard System implementation. In Section 3 the emphasis was on those functions most affected by the unique characteristics of RPV. Section 4 described the Mission Planner Breadboard System emphasizing its application to RPV Command and Control. Functions not specifically identified in Section 3, which have been implemented in the MPBS and are applicable to any air operation are included, such as, resource management and TACS assignments.

This section integrates the ADP support requirements which have been identified and develops data on the performance parameters for the elements of the ground based RPV Command and Control ADP Support Database and Software.

5.2 APPLICATION PROGRAM REQUIREMENTS

Table V.2-1 and Table V.2-2 tabulate the application programs that support RPV Command and Control in Physical Control and Mission Planning respectively. Column 1 identifies each applications program by a short title with brief description of the program. Column 2 references the section of this report where the program performance is described. Generally the referenced text describes the program in terms of why ADP support is required and how the required support can be implemented.

The programs as listed provide several levels of automated support. Certain programs are required in all employment situations; other programs are optional and may not be required to provide effective planning and rapid response for small force operations. This section considers ADP independent of the frequency or employment situation. The relative importance of various elements of ADP support to RPV Command and Control is addressed in Section 6.

Table V.2-3 tabulates the estimates on the size of the application program the values expressed as thousands of instruction codes (Column 2) conform to the usual conversion for expressing the size of an application program. An entry in Column 3 applies to certain programs where program logic is included in a program data base. Column 4 identifies the operational data files which are accessed when the program is called.

The final column identifies the basis for the estimates. Where the reference is to Section 3 of this report, the referenced section describes the program and its application. When a program description only is provided, the estimated size is based on engineering judgement and analogy to MPBS programs that provide a similar type of processing capability. Where the reference is to MPBS, the program for RPV applications is the same as, or a slight modification of, the MPBS program implementation.

Table V.2-1 Application Programs: Physical Control Of RPVs

Identification and Description	Reference
Navigation Position: This receives LORAN signal data, and extablishes the RPV position	3.2.3
Message Processing: This processes input messages and provides legallty and validity checks, routine logic, and composes and addresses output messages.	3.2.4. RPV Status Reports A capability subsumed in many sections
Flight Control Enroute: This is established from planned Flight Profile Position Location Planned; Compare to Actual. Flight Control Adjustemnt required is calculated, and if any, control directive and Output to RPV, or to Operator, is prepared.	3.2.5.2
Antenna Pointing Angle: This maintains data on communications contacts with each RPV. If contact is not made within a preset time period, it establishes from the Plan the planned location for the RPV, obtains data or Relay A/C location, and calculates the pointing angle.	3.2.5.3
RPV Position for Fixing and Tracking: Target video priority with EO symbol positions is displayed on video. Weapon boresight position is established on the video picture, and weapon boresight is positioned on video. This uses position data, velocity data, and EO sensor angles reported, applying smoothing and prediction to update.	3.2.6.2
Weapon Release Envelope: This determines if the RPV flight path is within the Weapon Release envelope. It inhibits the weapon release envelope, and inhibits weapon release if not in envelope	3.2.6.8

Table V.2-2 Application Programs: RPV Mission Planning

Identification and Description	Reference
Route Profile Coding: This is a route profile specified in terms of flight profile segments identified as standardized flight mode (e.g. launch) and legs specified in terms of end-point positions, altitude, power mode and climb, decend, or cruise. The output is a set of coded flight control instructions.	3.3.2
Semi Automatic Route Planning: This displays the mission geometry and threat data. The capability to use preplanned routes, and/or historical routes is provided. The operator may create or modify any route. Automatic checks are provided.	4.1.2
Automatic Route Selection: Using precoded threat data, the process finds three lowest threat routes through a defended area and a lowest threat route that overflys an operation designated IP.	3.3.2.3 4.1.2
Route Safety Scoring: Using a given route profile the function scores the route expressing route safety in terms of accumulated time within threat zones weighted by the type of threat. The process accumulates scores by route leg and over the total route. Alternate routes may be compared.	3.3.2.3 4.1.2
Automatic Route Adjustment: Using a route profile which is input (grossly defined), the system creates additional route segments, such that the adjusted route avoids or enroute threats or minimizes the threats.	3.3.2.4
RPV Communications Line of Sight Masking: In the route profile planning process, this program obtains prestored data on LOS masking to a predetermined relay aircraft flight profile from the data base.	3.3.4.3

Table V.2-2 Application Programs: RPV Mission Planning (continued)

Identification and Description	Reference
Relav Aircraft Flight Profile Planning: Using data generated by the RPV communications LOS Masking program, the program plans a Relay A/C flight profile and schedule such that over time the relay aircraft is positioned to satisfy operational requirements for LOS communications and to minimize the possibility of jamming in an intense jamming environment.	3.3.4.1 through 3.3.4.5
Relay Aircraft Flight Profile Planning to Avoid Jamming by Specific Jammers: Using data on known jamming sites, the program calculates the communications jam to signal ratio for several relay aircraft positions. The data is displayed and the operator selects the desired position.	3.3.5.3.3 4.1.2
Weapon Selection: Using precoded weapon effects data from the Joint Munitions Effectiveness Manual, the program displays data on the three best weapons (ordnance, carrier, and delivery tactic) against the target type. It calculates a probability of excess Ps if number of A/C or RPV's are input, or number of A/C or RPV's required if desired Ps is input	3.3.7 4.1.2
ECM Mission Planning: This program calculates the jam to signal ratio using mission geometry, radar cross section data, and technical data of emitters and receivers.	3.3.9.2 4.1.2
Chaff Precursor Mission Planning: This program generates a mission profile for a chaff precursor mission using mission geometry data, technical data on chaff packages, and data on variables effecting chaff dispersion such as atmospheric winds.	3.3.9.3
Target Review: This program displays data on the target against which the mission is being planned and other data supporting the planning process.	4.1.2

Table V.2-2 Application Programs: Physical Control Of RPVs (continued)

Identification and Description	Reference
Plan Review: With data based on planned flight profiles, this program generates and displays tracks at rates many times real time, examines plans for airspace conflicts and facility, and operator overloads.	3.3.10 4.2.1 4.3

5.3 DATA BASE AND PROCESSING RATES

The principal operational data which must be in the data base for physical control are the coded mission profiles generated by the planning function. These data are estimated to require 188K bytes of storage for 240 missions (Ref. Subsection 3.3.2.5). Message formats and address and routing tables may require another 100 K bytes of storage. The six application programs required for physical control are relatively small, totaling 3.6 KI's. The first three programs listed above in Table V.2-1 total 3.2 KI's and are executed periodically each half-second. The antenna pointing angle program is executed as required when the relay aircraft has lost communications contact with an RPV mission. The two over-the-target programs are executed each 0.2 second. Based on these programs and these execution rates, it can be estimated that the processing required to execute the application programs for physical control are approximately 7 KIPS for enroute control, and one to two KIPS for over-the-target control. These estimates do not include the processing required to service operator initiated requests for data nor the processing required to generate and maintain displays. Based on TACC and SEEK FLEX simulations of the TACC Current Operations Functions, the processing required to service operator requests and provide operator displays are under 5KIPS on the average. The conclusion is that the processing rates for physical control are not high. An ADP system in the 50 to 100 Kilo instructions per second (KIPS) range is indicated.

For force planning, the operational data base is large. Quantitative estimates can be developed at the function level recognizing the similarity in the data base required for planning RPV missions, to that required to planned manned aircraft missions. Thus it is possible to estimate probable total data base requirements. Under the SEEK FLEX study, it was estimated that to plan and monitor combat and combat support missions (airlift missions excluded) an operational data base of about one million bytes was required. The MPS data base for the Advanced Development Mission Planner System has been estimated at 7.2 million bytes. In ADMPS two files, prescored automatic route selection tables and terrain masks, account for 3.6 million bytes in the 7.2 million total. Another million bytes relate to weapon selection and A/C configuration; 0.5 million bytes are unique to ECM

Table V.2-3 Application Programs, RPV Command & Control

Application Program	Program Sizes No KIs *	Program Logic in the Data Base (K Bytes)	Data And/Or Data Files Used	Basis for Estimates
Navigation Position	0.7	1.3	LORAN Station File	3.2.3
Mission Processing	0.5		Message Formats Addressee Routing	
Flight Control, Enroute	2.0		Codes RPV Mission Flight Profile	3.2.5.2
Antenna Pointing Angle	0.1	0.05	Coded RPV Mission Flt. Profile, Comm. Relay Position	3.2.5.3
RPV Position and Tracking	0.1	0.06	RPV Position and status Data Reported	3.2.3
Weapon Release Envelope	0.2	0.03	Target Position & RPV Position from preceding line	3.2.6.8
Route Profile Coding	1.3	7.0	Route profile segment definition	3.3.2
Semi-Auto Route Planning	26.4		EOB, target, Launch/ Recovery Site Files	3.3.3.3
Automatic Route Selection	11.0		Grid coded prescored threats	MPS
Route Safety Scoring	6.6		EOB File, Route Profile Segment Definition threat Factors	MPS

* KI = 1000 instructions

Table V.2-3 Application Programs, RPV Command & Control (continued)

Application Program	Program Sizes No KIs	Program Logic in the Data Base (K Bytes)	Data And/Or Data Files Used	Basis For Estimates
Automatic Route Adjustment	Route Safety Scoring 6.0		Same as Route Safety Scoring	3.3.2.4
RPV COM. LOS Masking	6.6		Precalculated shadow area	3.3.4.3, 3.3.4.4
Relay A/C Flight Profile Planning	8.0		RPV COM LOS masking from preceding line	3.3.4.5
Relay A/C Flight profile planning to avoid specific jammers	18.0		EOB File on Jammers, tech Data on Jammers and receivers	3.3.5.3.3
Weapon Selector	8.0		JMEMS File Target File	MPS
	9.9		Terrain Masks	MPS
ECM MSN On Station Planning	24.8		EOB Terrain Mask Equipment and radar cross sections Characteristics files	MPS
Chaff Precusor Msn On Station Planning	13.2		Route Profile Segment Definition, EOB File Chaff Char. File	3.3.9.3
Target Review	5.5		Target File Commander's Guidance EOB File Msn Hist. File	MPS
Plan Review	16.5		Coded RPV Mission Flight Profile	MPS

and route safety scoring. Considering these data base totals in the light of specific requirements to plan RPV missions, an operational data base in the order of 4 to 6 million bytes appears required to implement all algorithms for RPV mission planning. Data base usage factors are such that core storage requirements are not excessive.

The application programs supporting mission planning and force monitoring and replanning are estimated to require 162.6 KI's. These programs are operator initiated or are called by operator initiated programs. The processor requirements expressed in KIPS which are needed to execute these programs depends upon many factors. Two dominating factors are; 1) the number of operators simultaneously planning and replanning missions, and 2) the degree to which the operators request amplifying data. This latter factor determines the rate at which application programs are called which in turn influences processor requirements since applications programs use more processor time than the review of amplifying data. Based on the similarity between mission planning and monitoring for RPV and for manned missions, plus experience gained from MPBS, the processing rates required for the RPV force planning and monitoring system are on the order of 100 to 300 KIPS, depending in part on how frequently the operators choose to call programs like terrain masking and automatic route selection.

5.4 OPERATING SYSTEM CONSIDERATIONS

5.4.1 DCF Multiple RPV Control Element

A resident executive function is required to: 1) support the control of 20 drone subscribers, 2) provide operator communications (considering graphical and tabular displays), and 3) provide system scheduling and core allocation for limited real time environment.

An additional requirement exists for: 1) interrupt handlers and the main memory map, and 2) I/O control and handlers.

A non-resident O/S portion including infrequently used operator communication functions such as keyboard processing, report generation, and system functions such as device and resource allocations is allocated to a primary mass storage device. These functions can be swapped in and out of main memory as required. In addition, with a limited main core capacity, applications programs and data could be allocated on the external device and be swapped in the same manner.

5.4.2 DCF Weapon Delivery Control Element

The requirement to provide Video Display control is included in the estimate for the non-resident O/S system function for the DCF Basic Control element. This control function is allocated in this manner considering the co-location of the two elements.

5.4.3 DCF Force Planning Air Monitoring Element

Considering the optimizing of throughput and response requirements in an interactive real time environment, a resident O/S estimated at approximately 75,000 bytes is required. Dynamic core and device allocation, diagnostic error processing, program loading, and interactive operator communication functions are considered.

Table V.4-1 indicates the estimated (in bytes) size of O/S functions allocated for each element.

Table V.4-1 Estimated O/S Functions

System Tasks	DCF Planning Element	DCF Multiple RPV Control Element	
		Total O/S	Resident Exec
Scheduling	400	400	400
Core Allocation	4,000	800	800
Device Allocation	800	400	400*
Resource Allocation	1,200	400	400*
Program Loads	4,000		
Swapping Control	3,600		
Task Dispatching	200		
Interrupt Handler	800	800	800**
Program Terminator	4,000	2,000	1,000
Abnormal End Term.	800	400	400
Generator Commun.	24,000	12,000	1,600
Restart	4,000	4,000	1,600
Diagnostic Error Prc.	4,000	1,200	1,200
Timers	200	200	200**
Program Control Trace	400		
Memory Map	10,000	7,000	7,000
I/O Control Program	10,000	8,000	6,000*
I/O Device Handler	2,400		
TOTAL	74,800	39,200	23,400

* Resident in I/O control region

** Resident in memory map region

SECTION 6

RPV COMMAND AND CONTROL SYSTEM CONCEPTS

6.1 INTRODUCTION

Litton's analysis of the RPV command and control system requirements is documented in Section 3. In the analysis three components of the RPV System; 1) the RPV vehicle, 2) the relay aircraft, and 3) the Command and Control element(s) were addressed. The analysis, however, centered on the command and control elements and the requirements to provide effective Command and Control of RPV operations, e.g., requirements to plan the missions, to execute operations as planned, and to adjust operations as required.

Command and Control procedures and implementation concepts were designed to provide effective Command and Control while concurrently minimizing the RPV vehicle on-board avionics and the communication required to maintain control of the airborne RPVs.

Command and Control requirements group into three functional areas which are separable in terms of operator skill, automated data processing and display support, and communications requirements. These three functional areas are:

a. RPV Mission Planning and Force Control.

b. Control of the RPV inflight from launch to recovery except for close control of the strike RPV vehicle in the weapon delivery phase.

c. Control of the strike RPV during weapon delivery and bomb damage assessment.

Figure 6.1-1, RPV System Elements, depicts in specification tree format the elements of the RPV system which have been addressed in this study (bold outline) and other essential system elements which have been subsumed. The dashed boxes are elements that are or may be external to the RPV system. This section addresses specifically the system performance parameters for the RPV Command and Control Elements of the system. Alternative system configuration for the Command and Control elements are developed, and the advantages and disadvantages of each are addressed. A preferred system configuration is selected, and alternatives to the preferred configuration are then presented.

6.2 SYSTEM CONCEPT

Functional areas for RPV Command and Control are identified as follows:

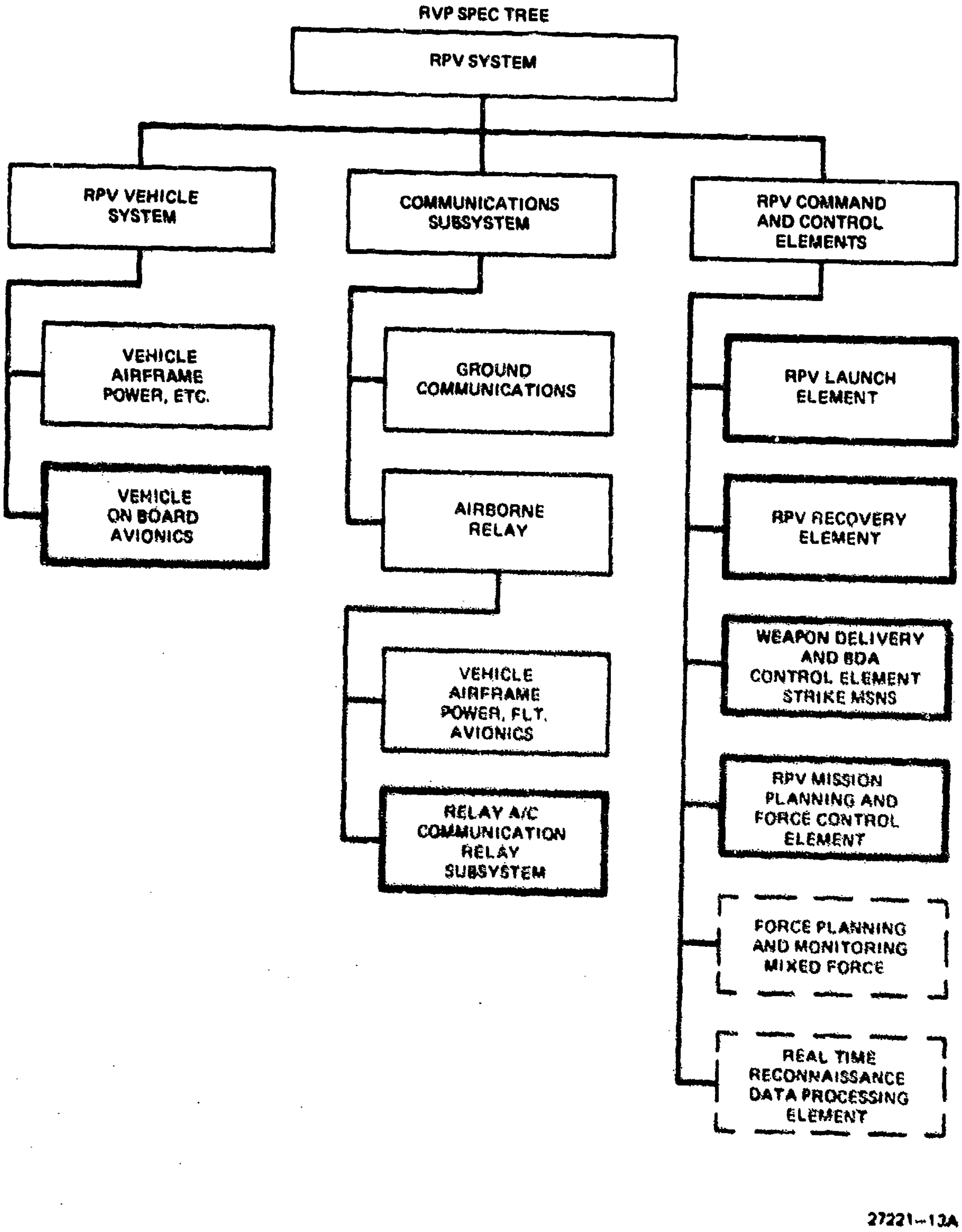


Figure 6.1-1. RPV System Elements

DCF, Multiple RPV Control Element: The functional area included in this element is the physical control of RPV from launch to recovery using status data reported by the RPV and position data provided by the navigation subsystem. This functional area provides the physical control required for RPV operations, excepting over-the-target control of RPV strike missions. For brevity, such control is referred to as the DCF, Multiple RPV Control Element.

DCF, Weapon Delivery Control Element: The functional area included in this element is the physical control of RPV using status data reported and more precise position data which are developed from imagery data obtained from RPV EO Sensor Subsystem. This functional area provides control of the RPV strike mission in the weapon delivery phase and for bomb damage assessment. For brevity, such control is referred to as the DCF, Weapon Delivery Control Element.

DCF Planning and Force Monitoring Element: The functional area included in this element is the RPV planning function, mission replanning, and adjustment. For brevity, such control is referred to in this section as the DCF Planning Element.

The distinctive features of each of these elements are:

DCF, Multiple RPV Control Element Features: The requirements for processing support are characterized by a system that operates principally on data provided by the Communications System. From the RPV, the element obtains data that are used to establish the location of the RPV from launch to recovery. Data on the status of the RPV are obtained. The reported condition is compared to the condition that should exist according to plan. Deviations are detected and appropriate control directives are formulated and transmitted to the RPV. From the planning element, directives may be received to redirect missions. Control directives are formulated and transmitted to the RPV inflight, or to the launch control facility, for missions not yet launched.

The principal operational data required are data on the plans for the RPV missions as generated by the planning function. Activity is generated in near real time by data received from the Communications System. Emergency conditions excepted, response time requirements are not immediate; that is, within fractions of minutes. Communications rates are relatively low.

DCF, Weapon Delivery Control Element Features: In contrast to the DCF Multiple RPV Control Element, the Weapon Delivery Control Element is characterized by near real time requirements for communications, processing support, and operator actions. Imagery data from the RPV must be communicated, processed, and displayed. Near real time reporting and processing of RPV status data are required to provide the capability for manual control. Full time operator action is required. Communications rates are relatively high.

DCF Planning and Force Monitoring Element Features: The distinctive character of the planning element relates to the ADP support required. A relatively large operational data base is required (friendly force status, enemy order of battle, geophysical data, commanders guidance, and planning factors). ADP Support is also characterized by relatively large applications programs required to support the planning functions. For preplanning, rapid response is not an absolute requirement. However, since the ADP System interacts with the operator and the throughput requirements are relatively high, the ADP System must be capable of responding to operator requests for processing in a few seconds. To satisfy response time requirements for mission replanning, a rapid response is required. The ADP System must be capable of simultaneously supporting multiple operators planning different types of missions. The communications requirements are relatively low.

6.3 SYSTEM SYNTHESIS

6.3.1 Introduction

The subsections that follow synthesize the system requirements of the system elements that have been identified and described in the preceding sections. The system requirements are expressed in terms of:

- o Communications interface requirements.
- o ADP support requirements.
- o Operator and operator facility requirements.

Maintenance support requirements are not included.

The quantitative factors presented are based on Sections 3 and 4 as developed and summarized in Section 5, ADP Support Requirements.

6.3.2 DCF, Multiple RPV Control Element

Communications Interfaces: The principal interface is with the airborne RPV. The data presented in this section assumes all communications to the RPV inflight are through the relay aircraft. This maximizes the requirements on the most critical interface links in the RPV system. Any direct communications between the DCF and airborne RPV, within line of sight communications range of the DCF, would merely reduce the link requirements to the relay aircraft without concurrently imposing other critical system requirements.

Other interfaces are with launch and recovery operations and with the DCF planning element. It is an operational assumption that interfaces with the TACS and other external system elements will be through the DCF, RPV Mission Planning and Force Control Element. Table VI.3-1, DCF, Multiple RPV Control Element Communications Interfaces, tabulates quantitative data on these interfaces. Column 1 is the interfacing element, Column 2 the type data exchanged. (I) signifies input to the DCF, Basic Control Element,

Table VI.3-1. DCF Multiple RPV Control Element Communications Interfaces

Interface Element	Type of Data Exchanged	Message Rate	Message Length	Com. Rate BPS/MSN, Info. Bits Only	Com. Rate BPS/Unit, Info. Bits Only	Reference Study Rpt. Sub-section
Launch Control Facility	Prelaunch Checkout Status (I)	1/Msn	6000 Bits	N/A	N/A	3.2.4
	Direct Engine Start (O)	1/Msn	8 Bits	N/A	N/A	3.2.4
	Launch Checkout (I/O)	1/Msn	800 Bytes	N/A	N/A	3.2.4
	Direct Launch (O)	1/Msn	8 Bits	N/A	N/A	3.2.4
RPV Airborne	Nav Position Data or No Com. Contact Report, Normal Status (I)	1/0.5 sec	47 Bits	N/A	94 BPS	3.2.4 & 3.2.5.4
	RPV Status Exceptions (I)	10/Msn	240 Bits	0.67	13	3.2.5.4
	Control Directives (O)	12/Msn	120 Bits	0.4	8	3.2.5.4
	Mission Redirection (O)	2/Hr	240 Bits(1)	N/A	0.1	3.2.5.4
Recovery Facility	Recovery Status Checks (I/O)	1/Msn	400 Bits	N/A	N/A	3.2.4
DCF Planning Monitoring Elem.	Mission Progress Reports (O)	5/Msn	400 Bits	0.6	11	Est.
	Track Data (O)	1/Min/Min	72	1.2(3)	24(3)	485L
	Exception Reports (O)	7/hr	800 Bits	0.1	1.6	EJ
	Control Directives (I)	2/hr	240 Bits		0.1	3.2.5.4
	P/P Mission Profiles	80/day	490×10^3	34(2)		
	Unit Status Reports	6/day	700	0.5		485L
DCF Weapons Del. Element	Handover A Cord Messages	2/Msn	Not Est.	Not Est.	Not Est.	6.3.2

(1) Assume 2 cruise segments recorded for average adjustment.
(2) Averages over 4 hours.
(3) Total Bits on a deducted link

(O) an output. (I/O) signifies a message exchange, e g., inputs generating outputs, and vice versa. The right-hand column is the reference to the subsection in the study report where the quantitative factors on message rate and message length are addressed. The entry 485L means the data were obtained by analogy to the 485L System and are derived from the 485L System Specification. The entry (EJ), signifies an "engineering judgment" factor not specifically addressed in the study. The message length and the bit rates calculated in Columns 4, 5, and 6 are information bits only.

Further discussion of the three basic data links illustrated in Table VI.3-1 are described in paragraphs a., b., and c. below.

a. DCF/Launch Site and DCF/Recovery Site Link: The average bit rates are not calculated. The link must be available on demand. It is assumed that at any launch site there can be only one launch; similarly, at the recovery site, only one recovery. A low data rate link, e.g. 600 BPS, two way simplex, satisfies all requirements.

b. DCF RPV Command Response Link via Relay Aircraft: Total bit rates tabulated, information bits only, are 107 BPS incoming to the DCF, eight BPS outgoing. These rates apply to the DCF to Relay Aircraft Link with 20 RPVs under control. The Relay A/C to individual RPVs rate is one-twentieth of this, 5 BPS RPV-to-Relay A/C, 0.4 BPS to the RPV. These data are meaningful only to highlight that the average information rate that must be sustained is low. There are several factors which now must be considered. There are occasional longer messages to and from individual RPVs. The system must be capable of accommodating such transient peaks. Individual RPV may be serviced in turn. The overhead requirements of addressing and synchronization must be satisfied and error control must be accomplished. Quantitative factors for these functions cannot be established without postulating specific link characteristics, the scanning method, and a signal structure.

However, given that; 1) the average information data exchange rates are low, 2) that exceptions requiring rapid response are RPV-initiated and that simultaneous exceptions are unlikely, and 3) that certain longer messages can be chained over several contacts; there are methods of implementation that can result in relatively low overhead rates. Using a synchronizing signal and time slot addressing, on the order of 200 bits per sector scan are indicated. A factor of two on the information bits returned for redundancy is indicated. Assuming 20 sectors scanned to contact 20 RPVs, such methods yield link capacities like 200 bits per contact on the down link (to the RPV). On the up link, 150 bits provides a capability to transmit larger messages if messages can be chained. With contact intervals like 0.5 seconds (with 20 RPVs, 10 second contact interval for each RPV), a 600 BPS full duplex data link is indicated from the RPV to the relay aircraft. Similar engineering judgment factors yield the conclusion that the DCF to Relay A/C Link should also be in the order of 600 BPS (the information data rate is 107 BPS on the down link.) If the DFC-to-Relay A/C Link has the same characteristics as the Relay A/C-to-RPV Link, direct communications between the DCF and the RPV can be implemented through assignment procedures applying the same method as used to assign an RPV mission to one or another relay aircraft.

c. DCF, Multiple RPV Control Element/DCF Planning and Force Monitoring Element: Considerations on this link are that the sustained data rates are relatively low. Relatively long messages are occasionally transmitted. Communications are required on demand. If these two elements are co-located, this interface is internal to the data processing system. If remoted, a link like 600 BPS appears adequate (on a 600 BPS link, a 65 segment route profile could be transmitted in 16 seconds).

d. DCF, Weapon Delivery Control Element: The fact that Weapon Delivery Control Element has been defined to be separable from the DCF, Multiple RPV Control Element dictates an interface requirement between the two elements. A system assumption is, however, that these two elements are colocated and integrated into a single ADP Support system. The interface is therefore internal to the ADP system. The requirement is to provide a console-to-console interface, a capability usually provided in a multi-operator system of the type being considered.

ADP Support Requirements: The ADP Support requirements for the Multiple RPV Control, developed in section V are:

Data Base Required:	Approximately 161K bytes, one RPV unit of 20 vehicles, 288K bytes, for a 3 unit force.
Application Programs:	4.8 KIs (include 1.3 KIs for Flight Profile coding).
Operating System:	39.2K bytes.

Operator, Operator Facilities: The physical control procedures that have been postulated require an operator console providing simultaneous graphic and tabular displays. This may be a dual display, or a split screen approach may be used. Console control requirements are those typical of Control Consoles such as specified for the 485L System. The number of consoles required depend upon the number of operators required which, in turn, depends upon operator loading. Table VI.3-2, DCF, Multiple RPV Control Element, Operator Loads, tabulates operator load factors. Based on the factors assumed, total operator time per mission is just over three minutes.

Table VI.3-2. DCF, Multiple RPV Control Element, Operator Loads

Operator Function	Activity Rate	Operator Time Per Action (sec)	Operator Time Per Mission (sec)	Operator Time Min/Hr/20 MSNS	Ref.
Prelaunch Checkout	1/Msn	30	30.0	10	3.2.4
Launch	1/Msn	30	30.0	10	3.2.4
Enroute/RTB Control					
Process Msn Aborts	0.1 Msn	120	12.0	4	Table 3.2.5.4-II
Adjust Msns, Sched Maintained	3/Msn	30	90.0	30	Table 3.2.5.4-II
Adjust Msns, Sched Not Maintained	0.25/Msn	90	22.5	7.5	Table 3.2.5.4-II
Divert Msns as directed by DCF, Planning Element	0.10/Msn	60	6.0	3	Table 3.2.5.4-II
Handover to/from Weapon Delivery Controller	2/Msn	10	20	6.7	E.J.

Total operator time for controlling 20 missions simultaneously for a full hour is 71.3 minutes. Considering that this is the load for a peak activity period, and that many of the operator actions can be delayed minutes without any loss in effectiveness, it is judged that two operators can provide the required control. There is, however, a requirement for a third operator to monitor the operation of the unit's force. Additionally, third operator station provides capability to handle transmit peak loads and a backup capability to maintain control, should one operator station fail. Therefore, three operator stations are proposed.

6.3.3 DCF, Weapon Delivery Control Element

Communications Interfaces: The requirement to interface with the DCF, Multiple RPV, Control Element was included in the preceding subsection. The only other interface, and the significant one, is with the RPV through the relay aircraft. Table VI.3-3 tabulates the quantitative data.

The electro optical video data is characterized by a requirement to transmit from each RPV to the DCF high resolution video data in near real time. A high data-rate broad-band link is thus inherent in the requirement to control several RPVs.

Data on the control directives, DCF-to-RPV, are extracted from Table III.2-1. The messages identified as aperiodic are principly once per mission messages which initiate and terminate the weapon delivery phase. The principal exception is the sensor zoom message. The BPS estimate is therefore the bit rate established by the requirement to report at 0.2 second intervals with the sensor zoom message superimposed on every message. The RPV to DCF data rates are dominated by the periodic messages that generate 261 BPS.

Given that there is a broad band link established from the RPV to the DCF through the relay aircraft, the data rates are low relative to the data required to transmit the video. It is assumed that the link is implemented using the same antennae used for the video link with the digital data multiplexed on the video on the up link. The down link, relay aircraft to RPV, will be implemented by routing the message to the Relay Aircraft Video link antenna.

Since the system requirement is to control four RPV over-the-target simultaneously, the link requirements, DCF to relay aircraft, are four times the numbers on the table; that is, approximately 1,000 BPS from the Relay A/C to DCF and 1,600 BPS on the up-link from the DCF to the relay aircraft. Considering that these rates are sustained on dedicated links, link capacities of 2,400 BPS minimum are indicated.

ADP Support Requirements: The ADP Support for Weapon Delivery Control developed in Section 5 presupposed that the Weapon Delivery Control element

Table VI.3-3. DCF Weapon Delivery Control Element

Interface Element	Type of Data Exchanged	Info. Bits Aperiodic Msgs. Bits/0.2 Sec.	Info. Bits Periodic Msgs. Bits/0.2 Sec.	Com. Rate BPS/MSN
RPV	EO Video Data	Not Est	Not Est	Not Est
	Control Directions, DCF to RPV	201	78 Bits per 0.2 Sec	396
	RPV Status Reporting MSG. 1	33	261	261
DCF Multiple RPV Control Element	Handover's and Coord Data	2 Msgs/Msn Not Significant	Not Applicable	Not Significant
DCF Planning & Elem.	Mission Results Report, Over-the-Target Aborts, Etc.	Not Significant	Not Significant	Not Significant

is colocated with a DCF Multiple RPV Control element. Given this, the additional ADP support required is:

Data Base:	Not significant
Applications Programs:	0.3 KIs
Operating System:	Common with the DCF Multiple RPV Control Element. Additional video display control requirements are estimated 2 to 4K bytes.

These estimates do not include:

a. The Data base required to store historical video on the target nor the processing required to display historical video concurrently with the real time video picture.

b. Processing required to calculate, at the DCF, a weapon release point for "dumb bombs" and to transmit a release directive to the strike RPV.

Operator Facilities and Operator Requirements: The console display requirement for weapon delivery is to display the EO Sensor video picture with queing symbols superimposed. An additional capability to concurrently display queing video, is desirable. Some type of cursor control for steering the EO sensor is required. Other controls to couple EO sensor steering to the RPV, to enable or direct weapon release and/or to initiate the escape maneuver, reattack, divert, or return to base are required. Since implementation is based on continual operator control in the weapon delivery phase, an operator and an operator console is required for each target simultaneously engaged. With four simultaneous attacks required, four operators, and four operator consoles, are required.

6.3.4 DCF Force Planning Element

Communications Interface: The interface between the DCF RPV Planning and Force Monitoring Element, and other DCF elements, have been described in preceding subsections. The system concept provides a ground-to-ground data link between elements that may be remoted. The interface requirement is easily satisfied by a low data rate link. If elements are colocated the interface is internal to the ADP Support system and is implemented through a console data transfer function. The TACS interface is similar, from a system's view, to the 485L System interface between the TACC and a Data Source terminal. Another interface required is for track tell. A data link, TADIL B, is required to tell the RPV track data to the TACC or the CRC (it is assumed that distribution within the TACS is provided). A final interface is to the relay aircraft which this element must control. This interface can be through the DCF, Multiple RPV Control Element. None of these interfaces impose any system requirements that cannot be easily satisfied.

<u>ADP Support Requirements:</u> If all applications programs described in Sections 3 and 4 are implemented to support RPV mission planning the ADP Support Requirements for the RPV Planning element are:

Data Base Required:	4 to 6 million bytes
Applications Programs:	162.6 KIs
Operating System:	74.8K bytes

If the requirement for automated support for weapon selection, automatic route selection, and terrain masking were eliminated the ADP Support Requirements would be reduced to:

Data Base Requirement:	Approximately 2 to 3 million bytes
Applications Programs:	132.8KIs
Operating System:	74.8K bytes

The principal saving is in the data base which can be maintained in bulk storage.

If the requirement for automatic support is reduced to a minimum support level, that is selected to include:

- o Route Profile Coding.
- o Semi Automatic Route Planning.
- o Route Safety Scoring.
- o Relay Communication LOS Masking & Flight Profile Planning.

The ADP Support Requirement would reduce to:

Data Base Required:	Approximately 1 million bytes
Applications Programs:	55.9 KIs
Operating System:	50 to 60K bytes

<u>Operator, Operator Facilities:</u> Assuming a 3 unit RPV force with each unit capable of executing 80 missions per day with 20 RPVs simultaneously airborne, the system must provide the capability to plan 240 missions and control 60 RPV missions simultaneously. The operator loading associated with this activity depends upon many factors such as:

a. The planning time allowed: The assumption is that the planning response time is comparable to that specified in the 485L system. That is RPV Mission Planning, which includes detailed mission planning, should be completed in four to six hours.

b. Abort rates, divert rates, and the requirements to plan immediate missions: The assumption is that these factors are comparable to those specified for the 485L system.

With these assumptions, and based on the time required to plan a single mission as developed from SEEK FLEX and TACC simulations and MPS experience, it is estimated that 4 or 5 planners can plan all missions in six hours or less. A minimum requirement is four planning consoles, one each for Strike, EW, and RECCE missions, with the fourth console allocated to a fourth planner for any mission type as required. For mission monitoring one operator for each mission type is minimum with one supervisory console. Based on these assumptions and for a three unit force the minimum operator requirements are eight operators and eight operator consoles. It is probable that this minimum also satisfies the operational requirements.

6.4 SYSTEM CONFIGURATION

6.4.1 Introduction

A given RPV Force consists of a RPV composite group with three RPV units.

1) An RPV Strike Unit
2) An RPV EW Unit
3) An RPV REECE Unit or
   Three Composite Units

Each unit is capable of launching 80 missions (sorties) per day with 20 missions simultaneously airborne. The RPV Command and Control System must be capable of simultaneously controlling 60 missions with four of these missions in the weapon delivery phase. The planning element(s) must be capable of planning 240 missions per day. To provide the required Command and Control there are several ways in which the system elements can be combined. This subsection presents four configurations which are possible and addresses the advantages and disadvantages of each.

6.4.2 Centralized Configuration

In this configuration (Figure 6.4-1) all system elements are colocated. Such a centralized Command and Control facility would most probably be located at the RPV Composite Group level. It applies to any unit deployment but may be most applicable if the deployed units are Composite units. The system components required are three DCF, Multiple RPV Control Elements, one DCF, Weapon Delivery Control Element, and a DCF RPV Planning and Force Monitoring Element with redundant components reduced as follows.

Operator Positions and Operator Consoles: The individual elements as defined include a supervisory position in each DCF Multiple RPV Control Element which was sized for unit control. In addition there were three mission monitoring positions, and one supervisory position in the DCF, RPV Planning and Force Monitoring Element. This is a total of seven monitoring and supervisory positions. In the Centralized Configuration, 3 monitoring positions

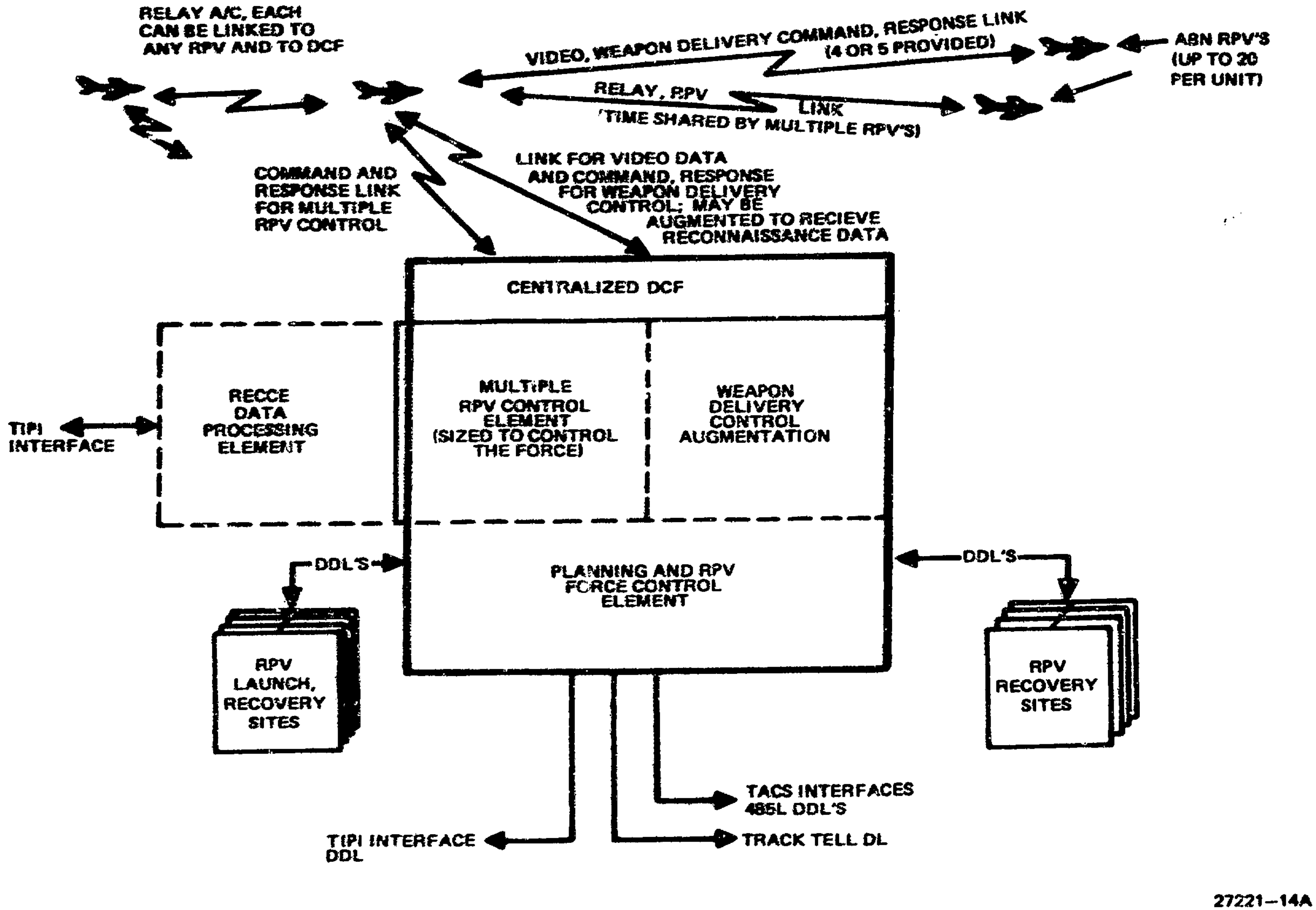


Figure 6.4-1. Centralized RPV Command and Control System

and one supervisory position would probably satisfy the requirements, thus saving three operator positions and three operator consoles.

Communication Requirements: The communication requirements for the Centralized Configuration are the sum of the communications of the individual elements. The implementation of several interfaces are affected however. Inter-element interfaces can be implemented internal to the ADP Support System with a corresponding elimination of the need to interface remoted DCF elements by ground data links. Offsetting this is an increased requirement to interconnect the centralized facility with all launch and recovery sites. The interface to the Relay Aircraft introduces factors on relay aircraft sizing and relay aircraft control that have not been previously addressed. Assuming however that; 1) a relay aircraft is sized to communicate with 20 RPVs simultaneously, and 2) the use of multiple relay aircraft when operational requirements dictate is independent of the RPV Command and Control system configuration and 3) control of the relay aircraft will be allocated to the DCF, RPV Planning and Force Control Element; then communications relay interface requirements are independent of the RPV Command and Control System Configuration. The third primary interface, interface and the TACS, is assumed to be through the DCF, RPV Planning and Force Control Element in all configurations and is therefore also configuration independent.

ADP Support Requirements: The centralized facility can be supported by an integrated ADP Support System with the usual cost saving that results from eliminating the need to duplicate data bases, operating systems, and applicable program requirements. The amount of ADP System capacity that can be saved depends upon the amount of duplication in a distributed system. For this particular system there is no significant duplication in the data base requirements of the DCF, Multiple RPV Control Element. The total data base required in the centralized system is approximately the sum of the total data base' requirements of the individual elements. The application programs for the DCF basic control element need not be duplicated saving storage for 3.6 KIs. The principal saving in the Centralized ADP Support System as against a distributed system is in the system operational support software. One operational support system is required, not three, which indicates an apparent saving of 78.4K bytes storage. Offsetting this however, is the consideration that the centralized ADP System will require a more capable, hence somewhat larger, OS system which reduces the apparent savings in storage and increases somewhat the cost of providing the OS system. The conclusion from these general considerations is that in this system the cost savings of a Centralized System as against a distributed system that will be described is relatively small.

Maintenance Support: The Centralized System concept contains, within itself, centralized maintenance support. It is normally evident that a centralized facility can be maintained at a cost significantly less than a decentralized system. The quantitative savings are dependent on the system maintenance concepts, failure rates and the degree to which one dispersed element can back up another.

Considering all factors that impact cost, it is concluded that the Centralized Configuration for the RPV Command and Control System can be provided at a cost saving, as against a decentralized system. The cost savings are, however, relatively small when compared to total system costs.

Operational Concepts: The other factors to consider are the operational factors. There is no obvious operational advantage in a centralized configuration. The element interfaces are not more effective. There are no significant person to person interface requirements that are enhanced. There are a number of operational disadvantages in the centralized configuration. First, any centralized system is inherently more vulnerable to enemy attack. Secondly, being larger it is less mobile, and set-up time is longer. Finally, the savings in the centralized system were in part realized by reducing system redundancy which makes the system more vulnerable when system components fail. The operational advantages of a decentralized system which is designed to provide element back-up include increased survivability, increased capability to function in degraded modes, and increased mobility which includes the capability to relocate in a leapfrog mode. These features are all disadvantages of a centralized system.

Considering the fact that the RPV system must be designed to operate in a mobile tactical environment, disadvantages of the centralized system seem to far outweigh the advantages.

6.4.3 Decentralized Configuration A:

This configuration is:

a. A DCF, Multiple RPV Control Element at each RPV unit. (Figure 6.4-2 depicts RPV units as mission unique, but Composite units may be deployed).

b. The DCF, Multiple RPV Control Element at the Strike RPV unit augmented with the DCF, Weapon Delivery Control Element.

c. A DCF, RPV Planning and Force Control Element colocated with the Strike RPV Unit DCF.

In this configuration, (Figure 6.4-2) the system elements that provide physical control of the RPVs and monitoring at the unit level are decentralized, and the RPV Planning and Force Monitoring functions are centralized as in the centralized configuration described. The cost factors are the converse of those described for the centralized facility. Three more operator positions and three more operator consoles are required. These operators and operator consoles provide, however, increased system redundancy with the attendant capability to handle transient overloads, or to function with no loss of operational effectiveness in the event of system failures. The fact that the DCF Multiple RPV Control Elements do not significantly require duplicated data bases and that the application program requirements are small, means that it is the operating system (39.2K Bytes) that is the only significant duplicated component. As indicated in the previous subsection, maintenance costs will be increased.

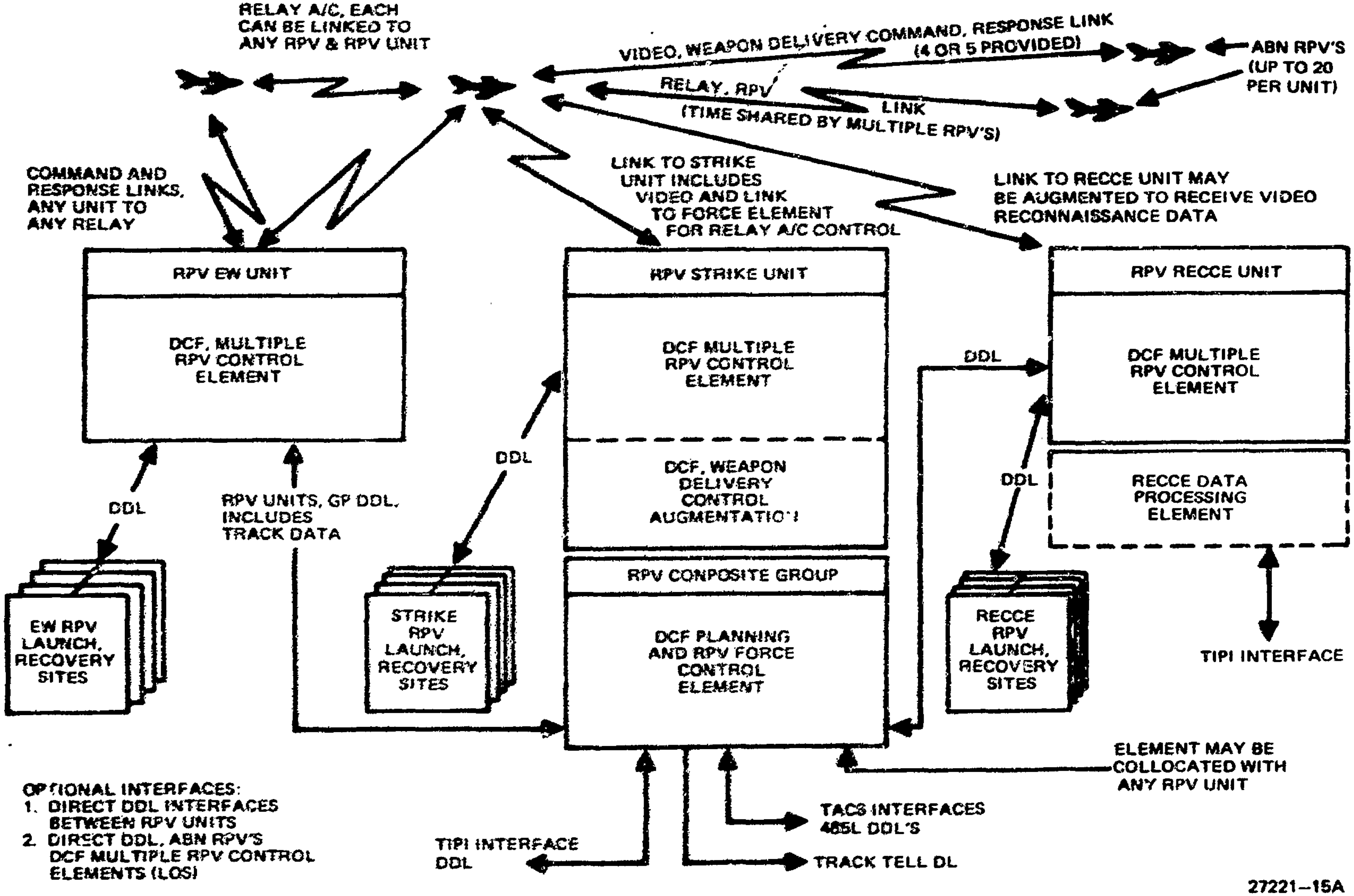


Figure 6.4-2 Decentralized Configuration, RPV Command And Control System, Centralized Planning And Force Monitoring, Decentralized Control

All factors considered, it is a subjective conclusion that the advantages of the Decentralized Configuration A, when compared to increased costs, are such that configuration A is preferred over the centralized configuration. This is especially true if the units are mission unique as depicted in the figure.

6.4.4 Decentralized Configuration B

This configuration (Figure 6.4-3) is identical to Decentralized Configuration A except that the force planning element is collocated with the TACC rather than at the Strike RPV Unit DCF. It applies to mixed force deployments only since for a pure RPV Force the DCF Force Planning element functions as the TACC. The cost factors of Configuration B, as against Configuration A, relate almost exclusively to how the automated TACC of the 485L system is designed, the specific capability provided in the RPV Force Planning Element, and/or the degree to which the Air Force desires to apply the capability of the RPV Force Planning Element to the planning of manned systems. The factor that enters into selecting this configuration, as against Configuration A, are primarily of a Command nature.

6.4.5 Decentralized Configuration C

This configuration (Figure 6.4-4) is similar to Decentralized Configuration A, except that force planning is decentralized to the RPV unit level. The cost factor is relatively high since the data base and program requirements of the individual planning elements are almost the same as for the centralized planning element. Not only are the cost factors high, but there are operational disadvantages in decentralizing planning, including communications relay planning delegated to the unit level. It is concluded that this configuration is not compatible with the operational requirements, and that the cost is high. Table VI.4-1 is a summary chart of the four configurations It presents data on the comparative manning levels and ADP requirements for each configuration. The advantages and disadvantages are also summarized.

6.4.6 Airborne Options

There are several viable airborne options. One is to provide the DCF Multiple RPV Control Element in an airborne command post. Considering the system size, this is quite feasible. The considerations are primarily dependent upon a Command selection of an operational mode and outside the scope of this study. Another possibility is to provide, over the target control, the DCF Weapon Delivery Control Element, on an airborne platform. If the Weapon Delivery Control Element is stripped to its essential elements, a fighter aircraft could be configured to provide Weapon Delivery Control. By overflying enemy territory communications requirements could be considerably reduced. While the latter option has many attractive features there is one significant operational disadvantage, overflight of enemy territory is required. As with other options mentioned, the primary considerations in rejecting or pursuing this option are operational.

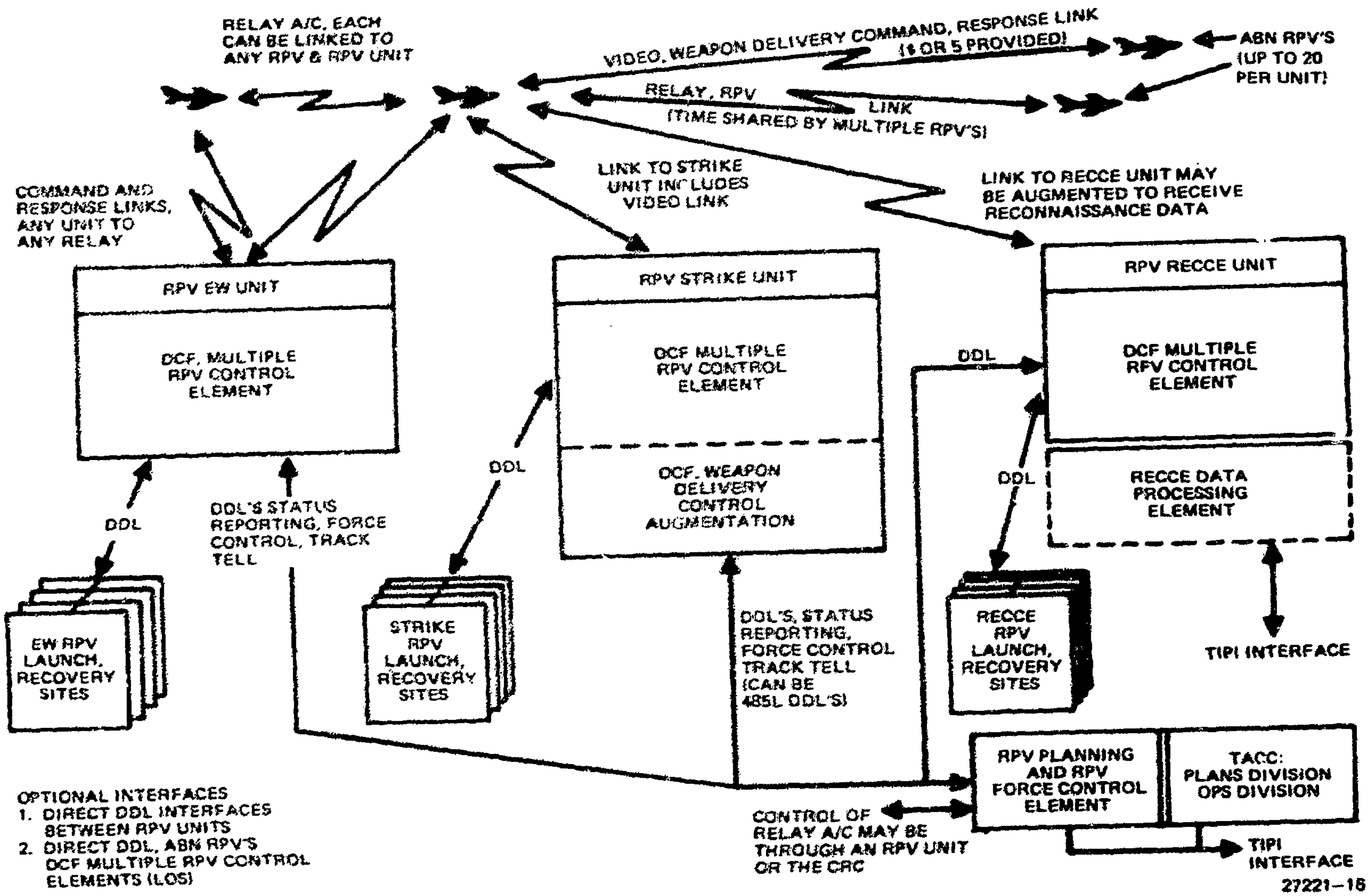


Figure 6.4-3 Decentralized Configuration B, RPV Command And Control, Centralized Planning And Force Monitoring Collocated With TACC

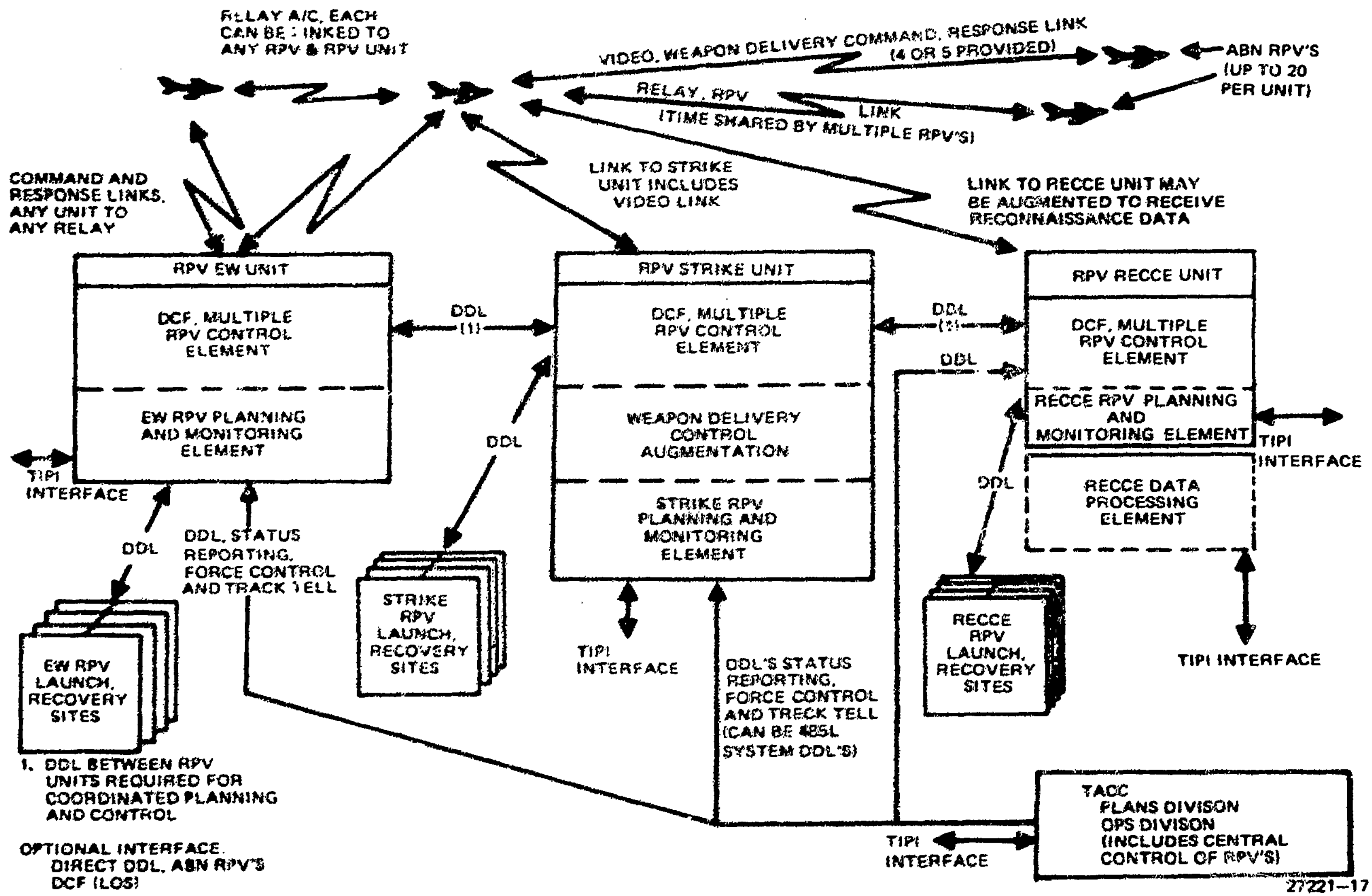


Figure 6.4-4 Decentralized Configuration C, RPV Planning/Replanning Decentralized to RPV Unit

Table VI.4-1. Summarized Features of Four Configuration Concepts

Configuration	Operator Positions, Operator Consoles Reqd.	ADP Software, Data Base Requirements	Remarks
Centralized Configuration	18	DB: 4-6 M Bytes AP's: 167.1 KI's O/S: 20.7 to 22.7 K Bytes	o Communications requirements not significantly effected. o Maintenance costs may be reduced. o Survivability & mobility reduced.
Decentralized Configurations "A" and "B"			o 3 identical units multiple control units are required. o Weapon delivery control element is collocated with a unit multiple control element. o Communications requirements not significantly affected. o Maintenance costs may be reduced. o Increased survivability and mobility. o Increased system backup.
DCF Multiple RPV Control Element	3 per unit	DB: 161.3 K Bytes AP's: 4.5 KI's O/S: 9.8 K Bytes	
DCF Weapon Delivery Control Element	4 for Strikeunit	DB: Not significant AP's: 0.3 KI's O/S: 2 to 4 K Bytes	
Force Planning and Monitoring "A" collocated, RPV Unit "B" collocated, TACC	8	DB: 4-6 M Bytes AP's: 162.6 KI's O/S: 18.7 K Bytes	
Decentralized Configuration "A" or "B" Total	21	DB: 4.5 to 6.5 K Bytes AP's: 176.4 KI's O/S: 50.1 to 52.1 K Bytes	

Table VI.4-1. Summarized Features of Four Configuration Concepts, Continued

Configuration	Operator Positions, Operator Consoles Reqd.	ADP Software, Data Base Requirements	Remarks
Decentralized Configuration "A" or "B" Total			o (Totals for decentralized Configuration B could be reduced if TACC can provide detailed planning for RPV missions).
Decentralized Configuration "C"	5 Unit Plus 4 Weapon Delivery Controllers	DB: ~4-6 M Bytes AP's: ~160 KI's O/S: ~21 K Bytes	o 2 controllers, 2 planners, 1 supervisor per unit; 4 strike RPV over the target. o A TACC providing force planning and control is required.
Decentralized Configuration "C"	19	DB: ~12-18 M Bytes AP's: ~480 KI's O/S: ~62 K Bytes	

SECTION 7

SUMMARY OF FACTORS AFFECTING RPV C&C AND RECOMMENDATIONS

7.1 SUMMARY OF FACTORS AFFECTING RPV COMMAND AND CONTROL

Since the RPV System, the RPV Command and Control System, and the operational concepts for the use of RPV are evolving concurrently, there are many areas that can be identified as requiring further study and analysis. At the highest level there are trade-offs between the total system capability and total system costs. At lower levels there are trade-offs between the RPV vehicle system element and its onboard avionics, the communications and navigation system elements, and the command and control elements. Within each element many trade-offs exist. Within the total pyramid of trade-off options, the objective is to achieve an optimum balance between RPV system capability and RPV system costs within a concept of use that optimally balances the RPV weapon system capability and the capability of manned weapon systems.

In the analysis of the RPV Command and Control System which Litton conducted, many areas were identified where viable options exist which affect Command and Control System requirements or where further analyses are required to develop the Command and Control system requirements. Table VII. 1-1, Summary, RPV System Factors Affecting RPV C&C, lists the principle factors that impact the RPV Command and Control System performance parameters. These factors, identified as "trade-off," relate to alternative communication approaches that affect Command and Control communications. Those factors identified as, "Baseline Assumptions," relate to the capability of elements of the RPV system which impact the Command and Control options. Variations to such a baseline need to be assessed in terms of the effects on the ground based Command and Control. The notation, "further analysis required," indicates that a more detailed analysis is required to establish the system requirements for APP Support, Operator facilities, operator time required, and the associated communications requirements. The Section reference is to the Section of this report where that System Factor is discussed. The consideration in each of these areas are discussed, briefly, in the following paragraphs.

7.1.1 <u>Communication Subsystem Characteristics</u> (Ref. Section 2.7.1)

This section lists some of the characteristics of the communication subsystem which appear to be desirable, as well as: communications technology, RPV system requirements, and cost effectiveness parameters considered. Many alternatives that exist are identified in Litton's study and previous Air Force funded studies. The principle factors affecting the trade-offs which are external to the Communication Subsystem relate to the capability of the RPV on-board avionics, and to the operational requirements for communication on demand versus periodic Communications for the Command and Response Link(s).

Table VII.1-1. Recommended Study Areas

Recommended Study Areas	Section Reference
1. Communication Subsystem Characteristics (Baseline Assumptions).	2.7.1
2. Use of Command Response link for RPV range measurements and location (trade-off).	2.7.6 and 2.7.9
3. Use command response link frequency band and RF hardware to measure terrain clearance (trade-off).	2.7.6 and 2.7.9
4. Use HF for a one way command link from DCF to Abn RPVs, RPV response through a relay (trade-off).	2.7.9
5. RPV Avionics subsystem characteristics (Baseline assumptions).	3.2.1a, b, and c
6. Command Response Links, Weapon Delivery and Enroute Control (Baseline Assumptions).	3.2.2
7. Navigation Subsystem Characteristics (Baseline Assumptions).	3.2.3
8. RPV Position and Status Reporting (Baseline assumptions).	3.2.4
9. Multiple Vehicle Control Procedures (Baseline assumptions).	3.2.5.1
10. Operator time required for control of multiple RPVs (further analysis required).	3.2.5.4
11. Requirements for target acquisition and control of weapon delivery and bomb damage assessment (further analysis required).	3.2.6.8
12. Automatic Route Adjustment implementation (further analysis required).	3.3.2.4
13. Procedure for Relay A/C route profile planning and immediate replanning (further analysis required).	3.3.4, 3.3.5 and 3.3.9.4

Table VII.1-1. Recommended Study Areas (cont)

Recommended Study Areas	Section Reference
14. Develop quantitative parameters for ADP support for RPV Command and Control (software, data base, processor) (further analysis required).	Section 5

7.1.2 Use Command Response Link For RPV Range Measurement (Ref. 2.7.6 and 2.7.9)

Given that an airborne relay is required and that communications security and AJ protection must be provided, it is not technically difficult, nor costly, to add a range measuring capability. With two airborne relays, location data are easily achieved, providing a completely self contained and accurate navigation system for RPVs. The necessity to provide two relay aircraft may increase operating costs during the low activity periods. There is, however, the possibility of using a low cost relay, designed specifically for enroute control only, which may reduce relay aircraft costs, thus making two airborne relays cost effective. Additionally, several possibilities of providing adequate position data using one relay aircraft are available. However, multiple trade-offs are involved.

7.1.3 Use Command Response Link Frequency Band and RF Hardware to Measure Terrain Clearance (Ref. 2.7.6 and 2.7.9)

This is an extension of item 7.1.2 above. The possibility of low cost terrain clearance capability, using the command response link RF hardware, is available.

7.1.4 Use HF for One-Way Command Link From DCF To Airborne RPVs (Ref. 2.7.9)

This option has the promise of reducing significantly the link capacity required of the communications relay aircraft links, thus easing the AJ problem and providing a possible means of acceptable location data, using communications ranging techniques and only one relay aircraft.

7.1.5 RPV Avionics Subsystem Characteristics (Ref. 3.2.1, Sub Paragraphs a., b., and c.)

This section lists some of the capabilities of the RPV avionics subsystems which appear to be necessary or desirable in order to provide a multiple RPV Control Capability. Any change in these assumptions could significantly impact the communications required for RPV Command and the Control.

7.1.6 Command, Response Links, Weapon Delivery Control And Enroute Control (Ref. 3.2.2)

This section assumes two command response links are provided; one provides periodic contacts, the other communication on demand. The assessment is that this provides the required operational capability at the lowest cost. Any change in this assumption could significantly affect the relay link capacity requirements.

7.1.7 Navigation Subsystem Characteristics (Ref. 3.2.3)

To minimize the cost of RPV Avionics, it is assumed that calculations needed to interpret the navigation system signals and calculate RPV position is allocated to the ground based processor. Any change in the assumption affects the RPV on-board avionics subsystem and the communication and control requirements.

7.1.8 RPV Status And Position Reporting (Ref. Section 3.2.4)

Assumptions are documented on status and position data reported and on the update rates. Communications and control requirements are dominated by these assumptions. Any change in assumptions can very significantly affect communication and DCF processing requirements.

7.1.9 Multiple Vehicle Control Procedures (Ref. 3.2.5.1)

The principal options addressed relating to enroute control, are; 1) preprogrammed and preloaded vehicle control instructions with corrective controls issued as required and, 2) all control instructions initiated by the DCF as required to fly the preplanned profile. The option selected to assess the DCF performance parameters was 1) above, preprogrammed Control with Corrective Commands issued as required. Any change in this assumption may significantly affect communications required and, quite possibly, operator requirements.

7.1.10 Operator Time Required For Multiple RPV Control (Ref. 3.2.5.4)

Operator time required for multiple RPV control is dependent on many assumptions regarding operator activities. These assumptions include operational factors such as mission rates, abort, and adjustment rates. Further analysis, and some type of simulation, is required to establish how these variables, coupled with alternatives in control procedures, affect grade of service.

7.1.11 Requirements For Target Acquisition And Weapon Delivery And Bomb Damage Assessment (Ref. 3.2.6)

The principle trade-offs in this area relate to the transmission of video data and the operator target recognition problem. These trade-off factors are internal to the video data transmission processing and display element and do not significantly affect the requirements for the command response data link nor the number of operators required (operator requirements, one on one, are assumed). These factors were not analyzed under Litton's study. The other alternatives that affect the command response data link requirements and the rate at which a single operator can accept control of weapon delivery depend on variables such as requirements for weapon release calculations and operator control required for bomb damage assessments, escape, and reattack. Further analysis and some type of simulation is required to establish how these variables affect communications requirements and operator time required per attack.

7.1.12 Automatic Route Adjustment Implementation (Ref. 3.3.2.4)

The size of the data base and the application program required to implement automatic route adjustment can vary depending upon the specific method selected for coding threat data. The ADP support requirements presented in Table V.2-3 (Section 5) assumed a specific approach. Further analysis is needed to establish that the specific approach selected is the most economical.

7.1.13 Procedure For Relay A/C Route Profile Planning And Immediate Replanning (Ref. 3.3.4, 3.3.5 and 3.3.9.4)

The planning for the relay aircraft route profile introduces many new variable factors in mission planning. To adequately assess all factors requires a quite detailed assessment of the operating environments, operational procedures, and the diurnal distribution of RPV missions to be controlled. Also, some type of simulation is indicated.

7.1.14 Develop Quantitative Parameters for ADP Support (Ref. Section 5)

The factors identified as software, data base, and processor are interrelated. The requirement is to develop in more detail the ADP software requirements to support the ground based command and control, the associated data base requirements, and to establish the processing capability required of the computer to provide timely response under load.

7.2 RECOMMENDATIONS

The factors summarized in the preceding subsection are of two types. One relates to the RPV subsystem performance parameters, the communications and navigation subsystems, and RPV on-board avionics which affect the RPV Command and Control procedures and the Command and Control subsystem performance parameters (trade-off factors and baseline assumptions). The other factors relate to the requirement for further analysis to develop quantitative parameters on the Command and Control system loads, communications system loading, processing and display requirements, and operator loading. The variables affecting the command control system load are of three types: 1) the RPV subsystem performance parameters which affect Command and Control, 2) Alternative RPV Command and Control subsystem and, 3) Operational employment concepts and force level factors which impose performance requirements on the RPV Command Control system. At the system level it is important to be able to assess the effect of these variables, singly and in combination.

Over the past several years, Litton has used a relatively simple, but powerful simulation model to examine Command and Control system parameters with emphasis on communications, computer, and operator load factors. Under the SEEK FLEX study the model was developed to specifically analyze ADP support parameters. The "Load Model" was used to develop computer loads that were then used to drive a simulation model of the SEEK FLEX computer. Under the TACC study, the model was developed further to; 1) make it easier to use, 2) provide more flexibility in its operation, and 3) provide more useful outputs.

A document, "A User-Oriented Aid For System Load Analysis," prepared for Litton's internal use, describes the simulation model in operational terms. It is attached to this report as Appendix B. Since that document was written, the model has been further developed to incorporate task priorities and queueing. The model can be used without modification to simulate the activity of an RPV Command and Control system.

Specifically, the model can be used to establish the parametric relationship between the RPV Command and Control subsystem and factors external to the Command and Control subsystem. The Command and Control subsystem parameters that can be developed include:

a. Communications link requirements, bits per second by link.

b. Operator and operator facility requirements, number required to achieve a specified grade of service.

c. Data processing requirements, data base (number of bytes), software program size (numbered instructions), and processing rates (kilo instructions executed per second).

The factors which can be easily varied to assess the quantitative effects of viable options include:

a. RPV system capability factors such as RPV on board avionics, communications, and navigation subsystem performance parameters.

b. Command Control Subsystem:

- Functional allocations; man and machine.
- Implementation of functional processes.
- Command and Control procedures.

c. Force Size Factors:

- Number of sories per day.
- Number of missions per day.
- Mission Mix.
- Number of simultaneous missions by type and phase.

d. Operational Factors:

- Ratio of preplanned to immediate missions.
- Abort rate and adjustment rate.
- Number of targets per mission planned, and executed.
- Response time requirements.

The feature of the model which makes it a particularly useful tool to assess system trade-offs, and the effect of system trade-offs on the Command Control and Communication subsystems, is that once the system model has been structured the variable parameters are easily changed. Many alternatives can be assessed, singly or in combination, at relatively low cost. Typically, to assess the effect of a system variable, a model parameter is changed and the model is rerun. To exploit the capability of Litton's command and control system load simulator, it is recommended that the Air Force consider a study to simulate the RPV C&C system using Litton's Load Model. The benefits that will be derived will provide insight into the affects of System Load trade-offs on RPV Command Control and Communications and the affects of alternative command and control procedures on RPV System performance.

APPENDIX A

RPV PLANNING DEMONSTRATIONS AND RESULTS

APPENDIX A
RPV PLANNING DEMONSTRATIONS AND RESULTS

INTRODUCTION

On 23 August 1972, a Mission Planning System Breadboard demonstration was given at the Litton Computer Facility in Canoga Park, California, to demonstrate RPV planning. This demonstration satisfied subparagraphs 4.1.3.3.3 and 4.1.3.3.4 of Contract F30602-71-C-0015, Change "C", 6 July 1972. It also satisfied in part all of paragraph 4.1.1.3.3.

The scope of the present RPV study did not allow for extensive changes to the MPS breadboard. It was desired to make very few, if any, coding changes and to minimize changes to the data base.

To this purpose an existing, non-classified North Korea data base was used. This meant that the map and the EOB did not have to be changed. The following paragraphs discuss the changes that were made to the data base and programs.

DATA BASE UPDATE AND PROGRAM MODIFICATIONS

The purpose of this section is to describe the changes made to the data base of the Mission Planning System Breadboard to satisfy subparagraph 4.1.1.3.3.2 of the contract. It was also necessary to make minor modification to the programs in order to run the system for RPV planning. These minor modifications are also described in this section.

The following references were used.

1. Study of Multi-Mission RPV Systems
   Final Technical Report, Northrop Corp., SS-1494
2. An Analysis of Remote Manned Systems for Attacking SAM Site
   Rand Corp. SS-1638

The following assumptions were made:

1. The RPV aircraft has a maximum operating range of approximately 200 miles and weapon load limits of approximately 2000 lbs.
2. There are only three stations on which weapons can be carried.
3. AGM-65A (Maverick) type missile is carried in the place of AMG 12-C (Bullpup B).
4. No fire bomb or incendiary bomb will be carried.
5. The weapon delivery tactics is as follows:
   a. For AGM-65A:
      Dive angle = 30°
      Release Altitude = 7000'
      True air speed = 600 knots
   b. Otherwise:
      Dive angle = 45°
      Release Altitude = 3000'
      True air speed = 600 knots

A. Data base modules changes are listed as follows:

1. Select 10 new targets for the RPV type mission (TGTFILE), Figures 1 to 10 show detailed information for these new targets. The major considerations for the RPV type target list were: (1) the operating range of RPV aircraft is approximately 200 miles, (2) the operating weapon load limit is approximately 2000 lbs., (3) RPV weapon delivery tactics (dive angle, air speed, release altitude) yield higher effectiveness against point targets such as bridges, bunkers, buildings, SAM or AAA sites.

   These new targets were added to the existing target file (TGTFILE) in the data base.
2. Create a new mission requirement file (MSNREQF) such that

the new missions associated with 10 new targets can be selected and planned by RPVMPS.

Figure 11 shows the tabular display of mission number and target information.

Figure 12 shows the graphical display of target locations and airbase locations.

3. Modifications were made to the airbase (AIRBASE) File to reassign aircraft types to airbases, particularly, the F-105D was replaced by the RPV001 vehicle, and the RPV001 vehicle was assigned to the airbase closest to FEBA to satisfy RPV aircraft operating range.

4. The Ordnance Menu (ORDMENU) File was modified to include a new weapon, AGM65-A (Maverick) air to ground missile for RPV vehicle.

5. Figure 13 shows the various target types included in the current JMEM table. Figure 14 shows the various ordnance (weapon) types included in the current JMEM table. The ordnance type code is used in the description of the JMEM table.

TARGET DESCRIPTION

601A HUEY JON RR BRIDGE   RP 0606 40.13N 127.40E   FOLDER - G42163

TYPE - TRUSS BRIDGE (DROP ONE SPAN)

TOT - 01/0800 AUG ELEV - 20M OBJ- DROP ONE SPAN

DESC - RR BRIDGE OVER TRIMEN RIVER TRIB

C/G -

REM -

1- POST/PRE-MSN

FIGURE 1

TARGET DESCRIPTION

602B HUEY CHIN RR BRIDGE RP 0654 39.52N 126.04E FOLDER - K61100

TYPE - SIMPLE GIRDER BRIDGE (DROP 1 SP)

TOT - 01/0800 AUG ELEV -150M OBJ- DROP ONE SPAN

DESC - RR BRIDGE SOUTH OVER CHIN GANG RIVER

C/G -

REM -

:- POST/PRE-MSN

FIGURE 2

TARGET DESCRIPTION

603C PAENG PET PROD STR RP 1167 38.36N 125.46E FOLDER - F30040

TYPE - ONE POL TANK ONE BUNKER
HYDROELECTRIC PLAN

TOT - 01/0800 AUG ELEV-15M OBJ- DESTROY POL FACS

DESC - UNDGND POL STRG AND SPT FACS

C/G -

REM -

:- POST/PRE-MSN

FIGURE 5

TARGET DESCRIPTION

604D CHATO N1 NAV/SUB BAS   RP 2080   40.10N   128.32E   FOLDER - R11121

TYPE - NAVAL FACILITIES   VEHICLE MAINTENANCE FACILITY

RADAR VAN AND ANTENNA

TOT - 01/0800 AUG ELEV- SL   OBJ- DESTROY FACILITIES

DESC - BASE IS ALSO A MISSILE SUPPORT FACILITY

C/O -

REM -

:- POST/PRE-MSN

FIGURE 4

TARGET DESCRIPTION

695E CHASUNAN SITE　　　　RP 2378　39.16N　125.52E　　　　FOLDER -

TYPE -　152MM FLD GUN HOW　　　　CONCRETE TUNNEL

57MM AAA GUN

TOT - 01/0000 AUG ELEV -10M　OBJ- DESTROY DEFENSE COMPLEX

DESC -　SITE CONTAINS 6 UNOCC BLDG WITH ADJ CAVES, 4AAA ON HILL TOP

C/G -

REM -

:- POST,PRE-MSN

FIGURE 5

TARGET DESCRIPTION

606F CHONSAN RR BRIDGE RP 0181 39.12N 126.50E FOLDER - D66301

TYPE - RR GIRDER BRIDGE

TOT - 01/0800 AUG ELEV -1000M OBJ- DESTROY RR BRIDGE

DESC - RR BRIDGE OVER KWANGAN RIVER

C/G -

REM -

:- POST/PRE-MSN

FIGURE 6

TARGET DESCRIPTION

607G CHINNAM AD SECT HQ RP 0691 39.00N 125.52E FOLDER - L63150

TYPE - CONCRETE TUNNEL/BUNKER RADAR EQPT ANTENNA

TOT - 01/0800 AUG ELEV - 18M OBJ- DESTROY HQ COMPLEX

DESC - HQ OF RNK AD SYS

C/G -

REM -

:- POST/PRE-MSN

FIGURE 7

TARGET DESCRIPTION

608H SINGTON MSL SPT FAC RP 2238 39.18N 127.24E FOLDER - KA1772

TYPE - SA2 MISSILES CONCRETE TUNNEL
VEH MAINT DEP

TOT - 01/0800 AUG ELEV - 13M OBJ- DESTROY MSL SPT FAC

DESC - LARGE MSL SPT FAC WITH STRG/NAV FACS

C/G -

REM -

:- POST/PRE-MSN

FIGURE 8

TARGET DESCRIPTION

609I YANGTOK POL STRG   RP 2831 39.54N 127.21E   FOLDER - L79001

TYPE - POL TANK   55 GAL POL DRUMS

MASONRY BLDG

TOT - 01/0800 AUG ELEV -27M OBJ- DESTROY POL FACS

DESC - LARGE POL STRG FAC SE OF YONGTOK

C/G -

REM -

1- POST/PRE-MSN

FIGURE 9

TARGET DESCRIPTION

610J TENYONG N1 SSM SPT   RP 3614 39.00N 125.33E   FOLDER - A67310

TYPE - MSL SPT BUNKERS   SS-3 SHYSTER MSL
STRG/MAINT BLDG

TOT - 01/0800 AUG ELEV -17M   OBJ- DESTROY MSL SPT FAC

DESC - TAC SSM SPT FAC WITH 5 BUNKERS

C/G -

REM -

:- POST/PRE-MSN

FIGURE 10

MSN NO	TARGET	TGT NO	LOCATION	RESOURCES	REQUIREMENTS
601A	HUEY JON RR BRIDGE	RP0606	40.13N 127.40E		DATE
602B	HUEY CHIN RR BRIDGE	RP0654	39.52N 126.04E		17 JUN 72
603C	PAENG PET PROD STR	RP1167	38.36N 125.46E		STRIKE TIME
604D	CHATO NI NAV/SUB BAS	RP2080	40.10N 128.32E		0800-1000Z
605E	CHASUNAN SITE	RP2378	39.16N 125.52E		
606F	CHONSAN RR BRIDGE	RP0181	39.12N 126.50E		
607G	CHINNAM AD SECT HQ	RP0691	39.00N 125.52E		
608H	SINGTON MSL SPT FAC	RP2238	39.18N 127.24E		
609I	YANGTUK POL STRG	RP2831	39.54N 127.21E		
610J	TFNYONG NI SSM SPT	RP3614	39.00N 125.33E		

:____ TO SELECT TGT ENTER MSN NO. SHIFT/ENTER.

Figure11

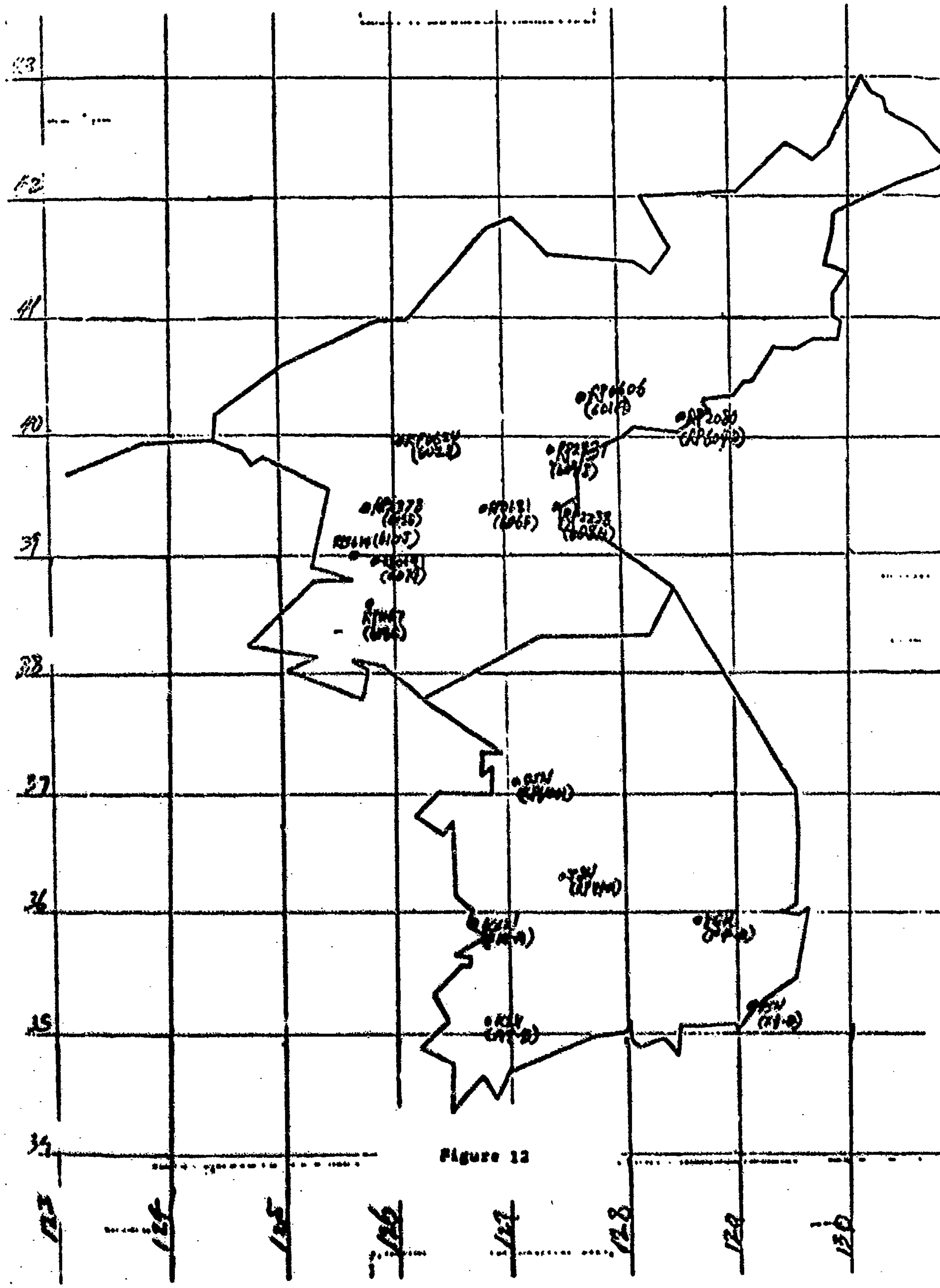


Figure 12

MISSION PLANNING SYSTEM

TARGET LIST

TARGET CODE	TARGET TYPE
1	AREA BARRACKS 280X170M (FIRE OR 50%)
2	AREA MIG-19 11X366M OPEN (KILL)
3	AREA MIG-19 91X1220M REVETTED (PTO)
4	AREA PERS 300X300M STAND (12HR SUP)
5	AREA STACKED AMMO 72X106M (KILL)
6	FORWARD AIRSTRIP (KILL)
7	AREA 55 GAL POL DRUMS 76X76M (KILL)
8	CONCRETE DAM 3M THICK (KILL)
9	CONCRETE RUNWAY 10 THICK (PTO)
10	CONVOY 2.5TN TRKS 6X500M (8HR TRP)
11	TUNNEL STEEL OR CONCRETE
12	CONVOY 7TN TRKS 6X500M (1.5HR TRP)
13	EARTHEN DAM 6X30M (KILL)
14	MASONRY ARCH BRIDGE (DROP ONE SPAN)
15	MASONRY BLDG 12X12M (FIRE OR 50%)
16	ONE LARGE HANGER (KILL)
17	ONE POL TANK 9M DIAM X 7M HIGH (KILL)
18	ONE SMALL HANGER (KILL)
19	RAIL, SINGLE TRACK (CUT ONE RAIL)
20	SIMPLE GIRDER BRIDGE (DROP 1 SPAN)
21	TRUSS BRIDGE (DROP ONE SPAN)
22	AREA PERS 30X300M FOXHOLE (30S DEF)
23	AREA PERS 30X300M PRONE (5 MIN ASLT)
24	LOCOMOTIVE STEAM/DIESEL (KILL)
25	MARSHALING YARD
26	ONE BUNKER (BREACH WALL OR CEILING)
27	ONE MIG-19 OPEN (KILL)
28	ONE PILLBOX (BREACH WALL OR CEIL)
29	HYDOELECTRIC PLANT.
30	ONE RADAR VAN AND ANTENNA (FIREPWR)
31	ONE T-54 MEDIUM TANK (KILL)
32	TRANSFORMER STATION
33	ONE ZSU 57MM AAA GUN (KILL)
34	VEHICLE MAIN. DEPOT
35	ONE 140MM RKT AND LCHR (FIREPOWER)
36	ONE 152MM FLD GUN HOW (FIREPOWER)
37	RIVER LOCKS/GATES
38	PATROL BOAT KOMAR (SINK)
39	SA-2 MISSILE SITE (FIREPOWER)
40	SS-3 SHYSTER MSL VERT (FIREPOWER)

Figure 13

ORDNANCE TYPE CODE	ORDNANCE NAME
1	AGM-12C Frag Missile (Bullpup B)
2	AGM-12E Cluster Missile (Bullpup B)
3	BLU-1C/B Fire Bomb
4	BLU-27/B Fire Bomb (Finned)
5	BLU-27/B Fire Bomb (Unfinned)
6	BLU-31/B Penetration Bomb
7	CBU-1A/A AP Cluster
8	CBU-2C/A AP Cluster
9	CBU-7/A AP Frag Cluster
10	CUB-24A/B AP/AM Cluster
11	CBU-24B/B AP/AM Cluster
12	CBU-29A/B AP/AM Cluster
13	CBU-29B/B AP/AM Cluster
14	CBU-33/A AVLM Cluster
15	CBU-38/A Frag Cluster
16	CBU-42/A APLM Cluster
17	CBU-46/A AP Frag Cluster
18	CBU-49B/B Frag Cluster
19	LAU-3/A FFAR Pod Launcher
20	LAU-59/A FFAR Pod Launcher
21	M36E2 Incendiary Cluster
22	AGM-65A AM Missile (Maverick)
23	M117A1 (M131A1) GP Bomb
24	M117R (MAU-91A/B) GP Bomb Retarded
25	M118 Demolition Bomb
26	MK20 Mod 2 Rockeye II Bomb
27	MK81 Mod 1 LDGP Bomb
28	MK82 Mod 1 LDGP Bomb
29	MK82 SE1 (MK15MOD0) Snake Eye LDGP Retarded
30	MK83 Mod 4 LDGP Bomb

FIGURE 14

ORDNANCE TYPE CODE	ORDNANCE NAME
31	MK84 Mod 2 LDGP Bomb
32	SUU-16/A 20 MM Gun Pod
33	SUU-23/A 20 MM Gun Pod
34	MK82SE (MK15 MOD3) RET GP Bomb
35	M117A1 (MAU-103A/B) LDGP Bomb

FIGURE 14 (Continued)

Figures 15-1, 15-2, 15-3 show the current JMEM tables. Columns 1 and 2 indicate target types. Columns 3, 4, 5, and 6 represent the four major aircraft types currently incorporated in the Mission Planner System (F-4D, F-105D, F-111A, A-7D). There are three subcolumns per aircraft indicating 3 choices of the combination of ordnance type (TYP), weapon amount (AMT), one pass probability of desired effect (PD), and the dive angle for weapon delivery (DIVE).

For the RPV Mission Planner Systems (RPVMPS), the F-105D was replaced by the RPV001. Column 4 of Figures 15-1, 15-2, 15-3 were replaced with the corresponding columns of Figures 15-4, 15-5 and 15-6.

It should be noted that JMEM tables are usually constructed after extensive flight testing. This JMEM table for RPV001 has been approximated from the F-105D JMEM table.

The following considerations were made for the RPV001 JMEM table.

1. Maximum weapon load would be approximately 2000 lbs.
2. Maximum of three stations where weapons can be carried.
3. AGM65A (Maverick) missile would be used where appropriate.
4. Fire bomb, incendiary bomb would be replaced with the high explosive or fragmentary bomb.
5. Weapon delivery tactic would be changed to reflect RPV vehicle advantages.
6. One pass probability of desired effect (PD) would be changed to reflect the advantage or disadvantage of RPV aircraft.

b. The Formation Analysis Table (FAT) File was modified to replace the F-105D entry with the RPV1 entry. Updated formations are listed below:

TARGET CODE	TARGET TYPE	TYP / PD	AMT / DIVE																					TYP / PD	AMT / DIVE
1	Area Barracks 280 x 170M (Fire or 50%)	3	4	24	9	29	12	3	4	24	5	29	12	35	16	29	16	–	–	3	4	23	14	34	12
		.16	0	.14	0	.13	0	.16	0	.14	0	.13	0	.14	0	.13	0	–	–	.17	0	.14	10	.13	0
2	Area MIG-19 11 x 366M Oper (Kill)	26	6	29	12	24	9	11	7	29	12	26	6	29	16	35	16	–	–	11	6	34	12	23	14
		.57	0	.37	0	.32	0	.48	10	.37	0	.57	0	.56	0	.54	0	–	–	.48	10	.37	0	.32	10
3	Area MIG-19 91 x 1220M Revetted (PTO)	29	12	24	9	30	10	23	8	28	8	30	9	25	20	35	16	–	–	34	12	23	10	28	12
		.24	0	.15	0	.07	30	.08	45	.08	45	.07	30	.31	0	.16	15	–	–	.24	0	.17	10	.16	20
4	Area Pers 300 x 300M Stand (12 hr Sup)	11	8	30	11	29	12	11	8	30	11	29	12	–	–	–	–	–	–	11	6	31	4	34	12
		.64	30	.17	30	.15	20	.41	30	.17	30	.15	20	–	–	–	–	–	–	.30	30	.17	30	.15	20
5	Area Stacked Ammo 72 x 106M (Kill)	21	9	23	8	30	2	23	8	28	8	30	2	29	16	35	16	–	–	11	6	23	8	34	12
		.31	0	.22	0	.06	0	.12	0	.11	0	.06	0	.05	0	.05	0	–	–	.33	0	.24	0	.19	20
6	Forward Airstrip (Kill)	24	6	29	6	30	6	24	6	29	6	30	6	29	20	35	16	–	–	23	6	34	6	31	4
		.60	30	.50	10	.46	20	.60	30	.50	10	.46	20	.42	0	.37	15	–	–	.60	30	.50	0	.46	20
7	Area 55 Gal POL Drums 76 x 76M (Kill)	23	9	28	9	3	4	23	8	28	8	3	4	29	20	35	16	–	–	23	9	28	9	3	4
		.21	0	.18	0	.17	0	.19	0	.17	0	.17	0	.30	0	.18	15	–	–	.21	0	.18	0	.17	0
8	Concrete Dam 3M Thick (Kill)	1	2	30	8	31	2	1	2	23	8	28	8	–	–	–	–	–	–	31	4	34	12	28	12
		.24	20	.12	45	.08	30	.24	20	.07	10	.06	10	–	–	–	–	–	–	.31	30	.29	30	.18	20
9	Concrete Runway 10 inches thick (PTO)	28	18	27	18	30	11	6	7	23	8	28	8	–	–	–	–	–	–	31	4	23	8	28	8
		.46	45	.42	45	.28	45	.39	0	.36	15	.35	15	–	–	–	–	–	–	.39	10	.36	10	.35	20
10	Convoy 2.5 Tons Trucks 6 x 500M (8 hr. trip)	8	4	29	9	24	9	11	7	11	5	23	8	–	–	–	–	–	–	11	6	34	20	23	9
		.40	10	.12	45	.08	10	.33	15	.29	15	.19	30	–	–	–	–	–	–	.40	10	.12	0	.08	0
11	Tunnel Steel or Concrete	23	10	28	10	30	6	23	10	28	10	30	6	35	16	29	16	–	–	23	10	28	10	31	4
		.06	45	.05	45	.04	15	.06	45	.05	45	.04	15	.08	15	.06	0	–	–	.06	45	.05	45	.04	30
12	Convoy 7 Tons Trucks 6 x 500M (1.5 Hr. Trp)	11	8	8	4	29	9	11	7	11	5	28	8	–	–	–	–	–	–	11	6	34	10	28	8
		.77	30	.71	10	.38	10	.53	15	.40	15	.33	45	–	–	–	–	–	–	.77	30	.38	10	.33	30
13	Earthen Dam 6 x 30M (Kill)	31	2	30	6	25	1	25	2	31	2	30	6	25	4	31	4	35	16	31	4	23	6	34	12
		.40	30	.39	30	.26	45	.45	30	.39	30	.37	30	.36	15	.28	15	.24	15	.42	30	.36	10	.28	20
14	Masonry Arch Bridge (Drop One Span)	24	6	29	12	1	2	23	8	28	8	1	2	31	4	35	16	–	–	23	6	34	12	28	8
		.06	0	.06	20	.02	20	.02	30	.02	30	.02	20	.09	15	.09	15	–	–	.06	0	.06	20	.02	30

Figure 15-1

TARGET CODE	TARGET TYPE	TYP / PD	AMT / DIVE										RPV001											TYP / PD	AMT / DIVE
15	Masonry Bldg 12 x 12M (Fire or 50%)	1	2	24	6	31	2	1	2	31	2	30	6	31	4	35	16	–	–	23	10	31	4	34	12
		.72	20	.48	20	.30	30	.72	20	.30	30	.11	30	.42	15	.26	15	–	–	.48	10	30	30	.24	0
16	One Large Hangar (Kill)	24	6	29	12	1	1	24	5	29	12	1	1	35	12	31	4	–	–	23	6	34	12	31	4
		.22	0	.14	20	.18	20	.20	0	.14	20	.18	20	26	0	.08	15	–	–	.22	0	.14	20	.16	20
17	One POL Tank 9M Diam x 7M High (Kill)	24	6	29	12	3	4	24	5	29	12	3	4	35	16	29	20	–	–	23	6	29	12	3	4
		.24	0	.19	30	.18	0	.22	0	.19	30	.18	0	.29	0	.26	0	–	–	.24	0	.19	30	.18	0
18	One Small Hangar (Kill)	3	4	24	6	1	1	3	4	24	5	1	1	35	16	31	4	–	–	3	4	23	6	11	4
		.84	0	.31	0	.29	20	.84	0	.30	0	.29	20	.36	0	.22	15	–	–	.84	0	.30	0	.37	20
19	Rail, Single Track (Cut One Rail)	24	9	29	12	1	1	24	5	29	12	1	1	35	16	29	16	–	–	23	8	34	0	28	12
		.74	0	.72	0	.55	20	.65	0	.72	0	.55	20	.81	0	.74	0	–	–	.72	0	12	.70	.64	10
20	Simple Girder Bridge (Drop One Span)	24	9	1	2	29	12	24	5	1	2	29	12	35	16	29	16	–	–	23	8	34	12	31	4
		.04	0	.04	20	.04	0	.04	0	.04	20	.04	0	.05	0	.04	0	–	–	.04	0	.04	20	.03	20
21	Truss Bridge (Drop One Span)	24	9	29	6	1	1	24	5	29	6	1	1	35	16	29	16	–	–	23	8	34	6	31	4
		.17	0	.13	0	.13	20	.14	0	.13	0	.13	20	.19	0	.16	0	–	–	.17	0	.13	0	.14	20
22	Area Pers 30 x 300M Foxhole (30S Def)	7	2	3	4	29	6	7	2	3	4	29	6	–	–	–	–	–	–	11	2	3	4	34	6
		.30	0	.23	0	.01	20	.30	0	.23	0	.01	20	–	–	–	–	–	–	.30	0	.29	0	.02	20
23	Area Pers 30 x 300M Prone (5 Min Aslt)	9	2	29	12	3	4	9	2	29	12	3	4	–	–	–	–	–	–	11	4	34	12	3	4
		.71	0	.24	0	.21	10	.71	0	.24	0	.21	0	–	–	–	–	–	–	.65	0	.24	0	.21	10
24	Locomotive Steam/Diesel (Kill	1	1	24	9	29	12	1	1	24	9	29	12	29	16	35	16	–	–	23	9	34	12	28	12
		.79	20	.47	0	.28	20	.79	20	.47	0	.28	20	.63	0	.59	15	–	–	.47	0	.28	20	.24	20
25	Marshalling Yard	24	9	29	12	30	8	24	9	29	12	30	8	35	16	29	20	–	–	23	14	34	12	31	4
		.06	0	.04	20	.02	30	.06	0	.04	20	.02	30	.33	15	.16	0	–	–	.06	0	.04	20	.04	0
26	One Bunker (Breach Wall or Ceiling)	24	6	29	12	30	8	24	5	29	12	30	8	31	4	35	12	–	–	23	6	34	12	31	4
		.12	0	.09	20	.04	45	.11	0	.09	20	.04	45	.03	15	.02	15	–	–	.12	0	.09	20	.09	10
27	One MIG-19 Open (Kill)	26	6	24	9	30	10	26	2	24	5	30	9	–	–	–	–	–	–	11	6	23	8	34	12
		.69	0	.57	20	.31	30	.76	0	.48	20	.31	30	–	–	–	–	–	–	.74	10	.57	0	.58	10
28	One Pillbox (Breach Wall or Ceil)	24	6	29	12	30	6	24	5	29	12	30	6	31	4	35	16	–	–	23	6	34	12	31	4
		.11	0	.08	20	.03	30	.11	0	.08	20	.03	30	.03	15	.03	15	–	–	.11	0	.08	20	.04	30

Figure 15-2

TARGET CODE	TARGET TYPE	TYP / PD	AMT / DIVE										RPV001											TYP / PD	AMT / DIVE
29	Hydroelectric Plant	1	1	24	9	29	12	1	1	24	5	29	12	25	4	31	4	–	–	23	9	34	12	28	12
		.12	20	.09	0	.07	20	.12	20	.08	0	.06	20	.15	15	.09	15	–	–	.10	0	.09	20	.11	20
30	One Radar Van and Antenna	24	6	29	12	28	12	24	5	29	12	28	12	–	–	–	–	–	–	23	6	34	12	28	12
	(Firepwr)	.81	0	.78	20	.48	45	.80	0	.78	20	.48	45	–	–	–	–	–	–	.81	0	.78	20	.48	30
31	One T-54 Medium Tank	26	6	24	6	29	12	26	6	24	5	29	12	–	–	–	–	–	–	23	8	34	12	31	4
	(Kill)	.43	0	.03	20	.03	0	.43	0	.03	20	.03	0	–	–	–	–	–	–	.04	0	.03	20	.02	20
32	Transformer Station	1	1	24	6	29	12	1	1	24	5	29	12	29	20	35	16	–	–	23	10	28	24	34	12
		.33	20	.27	0	.25	20	.30	20	.28	0	.24	20	.25	0	.24	15	–	–	.30	0	.27	10	.25	20
33	One ZSU 57MM AAA Gun	26	6	24	6	29	12	26	6	24	6	29	12	–	–	–	–	–	–	23	6	34	12	31	4
	(Kill)	.54	0	.09	0	.06	20	.54	0	.09	0	.06	20	–	–	–	–	–	–	.12	0	.06	20	.05	10
34	Vehicle Maintenance Depot	1	1	24	6	29	12	1	1	24	5	29	12	35	16	29	20	–	–	23	6	34	12	31	4
		.18	20	.17	0	.14	20	.18	20	.17	0	.14	20	.32	15	.15	0	–	–	.18	0	.14	20	.12	10
35	One 140MM Rkt and Lchr	26	6	24	6	29	12	26	6	24	6	29	12	–	–	–	–	–	–	23	9	34	12	23	10
	(Firepower)	.45	0	.18	0	.12	20	.45	0	.18	0	.12	20	–	–	–	–	–	–	.21	0	.18	20	.14	20
36	One 152MM Fld Gun How	26	6	24	5	30	10	26	6	24	5	30	10	–	–	–	–	–	–	23	6	34	12	31	4
	(Firepower)	.54	0	.23	0	.19	45	.54	0	.23	0	.19	45	–	–	–	–	–	–	.27	0	.23	20	.20	20
37	River Lock/Gates	24	9	1	1	29	12	24	5	1	1	29	12	25	4	31	4	–	–	23	9	31	4	34	12
		.25	0	.19	20	.13	10	.23	0	.19	20	.13	10	.44	15	.36	15	–	–	.25	0	.23	10	13	10
38	Patrol Boat Komar (Sink)	24	9	1	2	26	6	24	5	1	2	26	6	–	–	–	–	–	–	23	8	31	4	34	12
		.70	0	.60	20	60	0	.65	0	.60	20	.60	0	–	–	–	–	–	–	.68	0	.57	10	.45	10
39	SA-2 Missile Site	29	10	24	6	30	10	29	10	24	6	30	10	–	–	–	–	–	–	34	10	23	6	28	10
	(Firepower)	.65	20	.63	20	.34	30	.65	20	.63	20	.34	30	–	–	–	–	–	–	.65	20	.63	10	.45	20
40	SS-3 Shyster Missile	24	9	29	12	19	4	24	5	29	12	19	4	–	–	–	–	–	–	23	8	34	12	19	4
	Vert (Firepower)	.99	0	.99	0	.87	30	.99	0	.99	0	.87	30	–	–	–	–	–	–	.99	0	.96	10	.87	30

Figure 15-3

TARGET CODE	TARGET TYPE	RPV001 TYP	PD	AMT	DIVE	TYP	PD	AMT	DIVE	TYP	PD	AMT	DIVE
1	Area Barracks 280 x 170M (Fire or 50T)	30	.16	2	45	24	14	2	45	29	.10	4	45
2	Area MIG-19 11 x 366M Open (Kill)	11	.15	2	45	29	.30	4	45	26	.63	4	45
3	Area MIG-19 91 x 1220M Revetted (PTO)	23	.05	2	45	28	.08	4	45	30	.03	2	45
4	Area Pers 300 x 300M Stand (12 hr Sup)	11	.35	2	45	30	.04	2	45	29	.12	4	45
5	Area Stacked Ammo 72 x 106M (Kill)	23	.08	2	45	28	.11	4	45	30	.12	2	45
6	Forward Airstrip (Kill)	24	.45	2	45	29	.58	4	45	30	.40	2	45
7	Area 55 Gal POL Drums 76 x 76M (Kill)	23	.10	2	45	28	.17	4	45	30	.12	2	45
8	Concrete Dam 3M Thick (Kill)	22	.24	4	30	23	.05	2	45	28	.06	4	45
9	Concrete Runway 10 inches thick (PTO)	6	.25	2	45	23	.15	2	45	28	.35	4	45
10	Convoy 2.5 Tons Trucks 6 x 500 M ([illegible] hr trp)	11	.32	2	45	12	.29	2	45	23	.12	2	45
11	Tunnel Steel or Concrete	23	.04	2	45	28	.05	4	45	30	.04	2	45
12	Convoy 7 Tons Trucks 6 x 500M (1.5 hr trp)	11	.44	2	45	12	.40	2	45	28	.33	4	45
13	Earthen Dam 6 x 30M (Kill)	24	.45	2	45	31	.39	1	45	30	.35	2	45
14	Masonry Arch Bridge (Drop One Span)	23	.02	2	45	28	.02	4	45	22	.06	4	30

Figure 15-4

TARGET CODE	TARGET TYPE	RPV001 TYP PD	RPV001 AMT DIVE	RPV001 TYP PD	RPV001 AMT DIVE	RPV001 TYP PD	RPV001 AMT DIVE
15	Masonry Bldg 12 x 12M (Fire or 50%)	22 / .72	4 / 30	31 / .30	1 / 45	30 / .11	2 / 45
16	One Large Hangar (Kill)	24 / .20	2 / 45	29 / .12	4 / 45	22 / .40	2 / 30
17	One POL Tank 9M Diam x 7M High (Kill)	24 / .22	2 / 45	29 / .15	4 / 45	30 / .10	2 / 45
18	One Small Hangar (Kill)	30 / .84	2 / 45	24 / .30	2 / 45	22 / .75	2 / 30
19	Rail. Single Track (Cut One Rail)	24 / .65	2 / 45	29 / .68	4 / 45	22 / .85	2 / 30
20	Simple Girder Bridge (Drop One Span)	24 / .04	2 / 45	22 / .04	4 / 30	29 / .03	4 / 45
21	Truss Bridge (Drop One Span)	24 / .14	2 / 45	29 / .13	4 / 45	22 / .13	4 / 30
22	Area Pers 30 x 300M Foxhole (30S Def)	7 / .52	2 / 45	30 / .23	2 / 45	29 / .12	4 / 45
23	Area Pers 30 x 300M Prone (5 Min Aslt)	9 / .85	4 / 45	29 / .28	4 / 45	30 / .21	2 / 45
24	Locomotive Steam/Diesel (Kill)	22 / .85	2 / 30	24 / .22	2 / 45	29 / 20	4 / 45
25	Marshalling Yard	24 / .05	2 / 45	29 / .03	4 / 45	30 / .02	2 / 45
26	One Bunker (Breach Wall or Ceiling)	24 / .11	2 / 45	29 / .07	4 / 45	30 / .03	2 / 45
27	One MIG-19 Open (Kill)	26 / .85	2 / 45	24 / .48	2 / 45	30 / .18	2 / 45
28	One Pillbox (Breach Wall or Ceil)	24 / .11	2 / 45	29 / .07	4 / 45	30 / .03	2 / 45

Figure 15-5

TARGET CODE	TARGET TYPE	RPV001					
		TYP / PD	AMT / DIVE	TYP / PD	AMT / DIVE	TYP / PD	AMT / DIVE
29	Hydroelectric Plant	22 / .12	4 / 30	24 / .08	2 / .05	29 / .04	4 / 45
30	One Radar Van and Antenna (Firepwr)	24 / .80	2 / 45	29 / .70	4 / 45	28 / .40	4 / 45
31	One T-54 Medium Tank (Kill)	26 / .53	4 / 45	24 / .05	2 / 45	29 / .03	4 / 45
32	Transformer Station	22 / .75	2 / 30	24 / .28	2 / 45	29 / .15	4 / 45
33	One ZSU 57MM AAA Gun (Kill)	26 / .54	4 / 45	24 / .09	2 / 45	29 / .05	4 / 45
34	Vehicle Maintenance Depot	22 / .18	4 / 30	24 / .17	2 / 45	29 / .10	4 / 45
35	One 140 MM Rkt and Lchr (Firepower)	26 / .55	4 / 45	24 / .15	2 / 45	29 / .10	4 / 45
36	One 152 MM Fld Gun How (Firepower)	26 / .54	4 / 45	24 / .23	2 / 45	30 / .14	2 / 45
37	River Lock/Gates	24 / .23	2 / 45	22 / .19	4 / 30	29 / .11	4 / 45
38	Patrol Boat Komer (Sink)	24 / .65	2 / 45	22 / .85	2 / 30	26 / .75	4 / 45
39	SA-2 Missile Site (Firepower)	29 / .65	4 / 45	24 / .63	2 / 45	30 / .27	2 / 45
40	SS-3 Shyster Missile Vert (Firepower)	24 / .85	2 / 45	29 / .82	4 / 45	19 / .87	4 / 45

Figure 15-6

FORMATION CODE	AIRCRAFT TYPE	ASSIGNMENT	# OF ECM PODS
01	F-4D	STRK	1
02	RPV001	STRK	1
03	F-4D	STRK	2
04	RPV001	STRK	2
05	F-4D	RECE	1
06	RPV001, A-4D	RECE	2
07	EB66B	SSJ	1
08	EB66C	SSJ	1
09	F-4D	STRK	1
10	F-111A	STRK	2
11	A-7A	STRK	2

7. The Aircraft Radar Cross Section Table (CST) File was modified to replace the F-105D entry with the RPV1 entry, also the effective cross sections associated with all azimuth, elevation, were reduced to one half of that of F-105D.

8. The Aircraft Characteristics Table (ACT) File was modified to replace the F-105D entry with the RPV1.

B. Computer Program changes are listed as follows:

1. In the Force allocation subroutine (SRORD) changes were made to replace the F-105D entry with the RPV001.

   The changes were made to SRORD to by-pass configuration check, when this new ordnance AGM-65A (Maverick) was selected by the mission planner.

2. In the Route Safety Analysis Subroutine (SSRTST) changes were made to calculate threat score within the envelop of the maximum altitude and minimum altitude of the threat to reflect the RPV advantages of terrain following.

C. A pre-planning run on was made on the RPV Mission Planner System (RPVMPS) to select the candidate Target Mission (607G), Command/Control Relay Orbit Mission (602B), and ECM Support Orbit Mission (606F). These missions were preplanned to establish a general route profile for the subsequence RPV mission planner system run. These routes can be modified to satisfy the mission objectives. Figure 16-1 lists the preplanned route profile for the F-4D command/control orbit mission (602B) from TGU. Figure 16-2 lists the preplanned route profile for RPV ECM support orbit mission (606F) from OSN. Figure 16-3 lists the preplanned route profile for RPV target mission (607G) form OSN.

Figure 17 shows the graphical summary of all preplanned missions.

6028 COMMAND/CONTROL ORBI RP0654 39.52N 126.04E

	LOCATION	MODE	ALT	MACH	THST	HDG	DIST
1.	35.53N/128.40E		116	0.80		328	47.4
2.	36.33N/128.09E		20000	0.80		285	180.2
	37.19N/124.31E		20000	0.80		343	53.1
4.	38.10N/124.12E		20000	0.80		270	29.0
5.	38.10N/123.35E		20000	0.81		164	55.1
6.	37.17N/123.54E		20000	0.81		89	29.4
7.	37.17N/124.31E		20000	0.81		344	55.1
8.	38.10N/124.12E		20000	0.81		270	29.0
9.	38.10N/123.35E		20000	0.81		164	55.1
10.	37.17N/123.54E		20000	0.81		89	29.4
11.	37.17N/124.31E		20000	0.81		111	217.1
12.	35.53N/128.40E		116	0.00			

Figure 16-1

606F ECM SUPPORT ORBIT RP0181 39.12N 126.50E

	LOCATION	MODE	ALT	MACH	THST	HDG	DIST
1.	37.05N/127.02E		35	0.00		301	43.3
2.	37.27N/126.15E		20000	0.81		15	56.0
	38.21N/126.34E		20000	0.80		324	29.5
4.	38.45N/126.12E		20000	0.81		341	29.5
5.	39.13N/125.60E		20000	0.81		75	16.0
6.	39.17N/126.20E		20000	0.81		167	28.6
7.	38.49N/126.28E		20000	0.81		252	13.1
8.	38.45N/126.12E		20000	0.81		341	29.5
9.	39.13N/125.60E		20000	0.81		75	16.0
10.	39.17N/126.20E		20000	0.81		167	28.6
11.	38.49N/126.28E		20000	0.81		252	13.1
12.	38.45N/126.12E		20000	0.81		184	67.1
13.	38.21N/126.34E		20000	0.83		195	56.0
14.	37.27N/126.15E		20000	0.83		120	43.3
15.	37.05N/127.02E		35	0.00			

07G CHINNAM AD SECT HQ RP0691 39.00N 125.52E

	LOCATION	MODE	ALT	MACH	THST	HDG	DIST
1.	37.05N/127.02E	CLMB	35	0.02	MIL	282	32.5
2.	37.12N/126.22E	CLMB	8000	0.82		357	33.0
	37.45N/126.20E	CRS	20000	0.80		10	31.4
4.	38.16N/126.27E	DCND	20000	0.81		14	18.6
5.	38.34N/126.33E	DCND	2000	0.81		300	10.0
6.	38.40N/126.25E	CRS	1000	0.80		280	5.5
7.	38.41N/126.18E	CLMB	1000	0.81		273	15.6
8.	38.42N/125.58E	DCND	2000	0.81		340	9.5
9.	38.51N/125.54E	CLMB	1000	0.81		350	9.1
10.	39.00N/125.52E	CLMB	3000	0.80		266	63.9
11.	38.56N/124.30E	CRS	20000	0.81		180	86.0
12.	37.30N/124.30E	DCND	20000	0.81		106	100.1
13.	37.00N/126.30E	DCND	10000	0.81		79	25.8
14.	37.05N/127.02E	DCND	35	0.00		0	0.0

figure 16-3

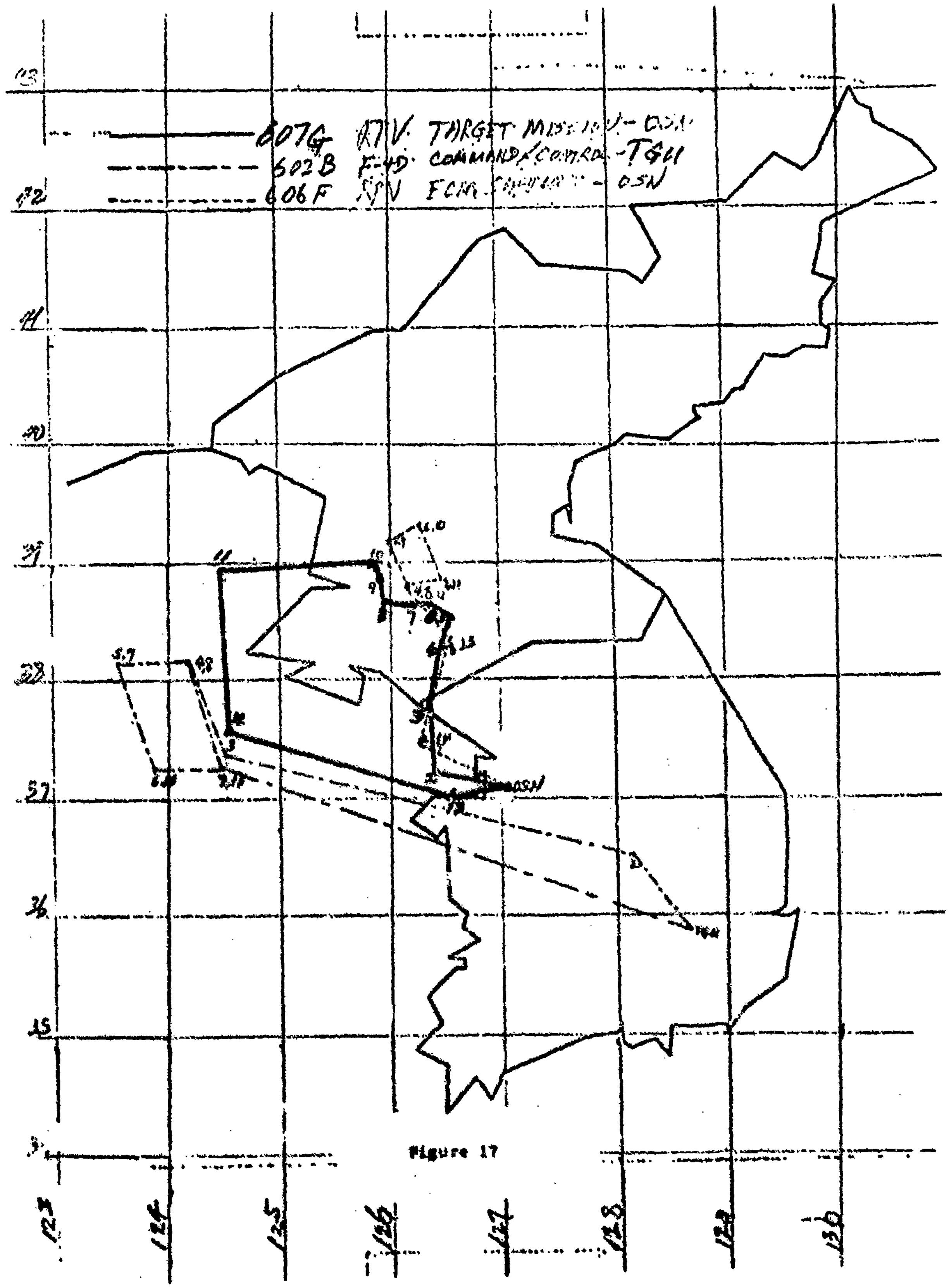


Figure 17

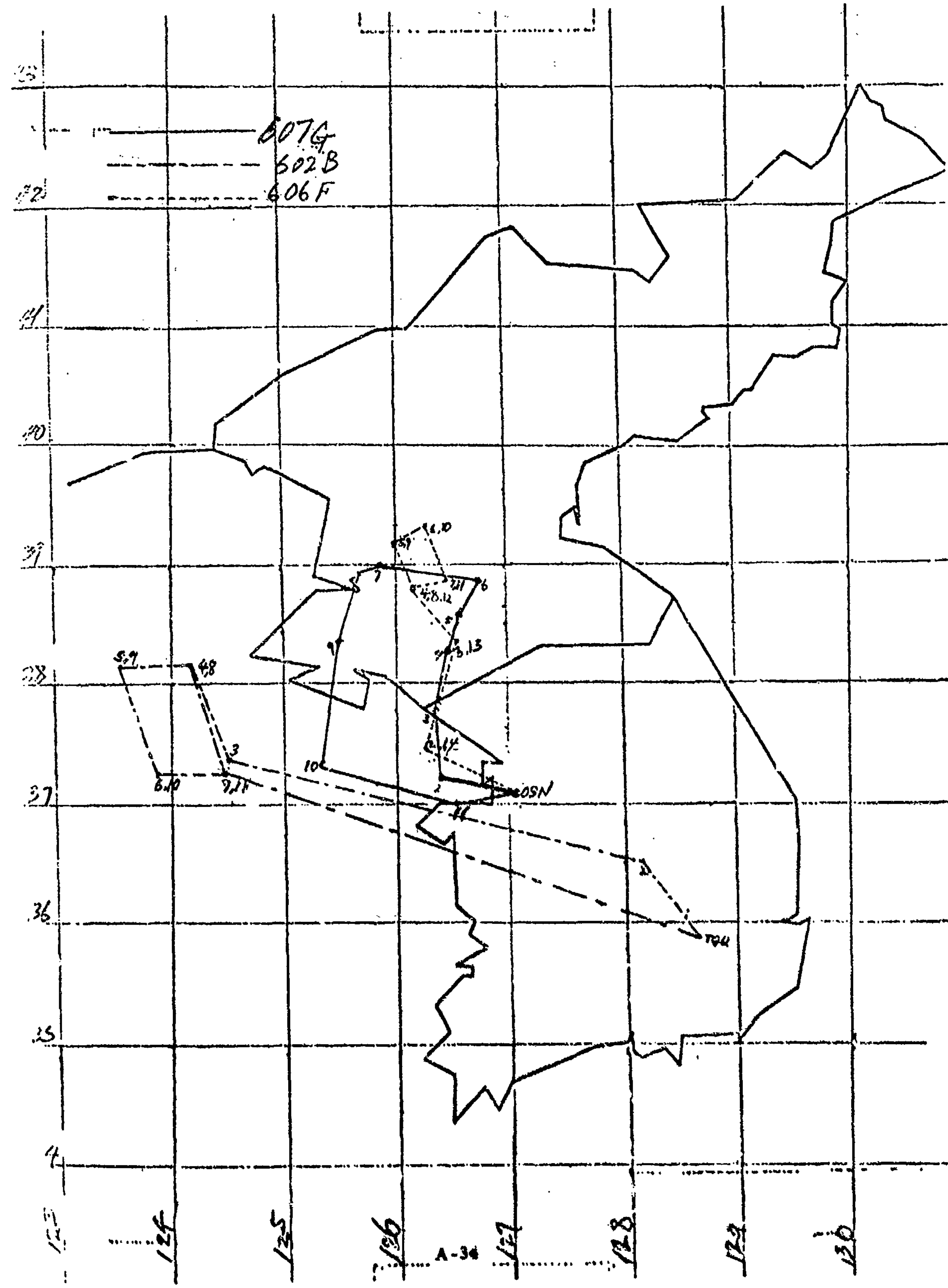
THE RPV PLANNING DEMONSTRATION SCENARIO

The MPS Breadboard system has the capability for printing out any alphanumeric display on the 2260. What follows is a number of the pertinent alphanumeric displays seen during the RPV planning demonstration. Unfortunately, the graphic displays on the 2250 cannot be easily reproduced. Therefore, only certain graphic displays are represented in what follows. These graphic displays are indicative of what was seen during the demonstration

In order to demonstrate the MPS breadboard capability for planning RPV missions, the following scenario was developed and demonstrated to the Air Force. Three missions are shown on the map of Korea. These represent typical missions that need to be planned in conjunction with an RPV operation.

Mission 607G represents a strike interdiction mission to be performed by the RPV. Mission 606P represents an ECM support mission using an RPV in the stand-off jamming role. Mission 602B represents an F-4D utilized as a communication relay aircraft.

The Mission Planning System Breadboard was described in detail in Section 4.1 using the scenario technique. What follows will show the various displays described in 4.1 applied to RPV missions.



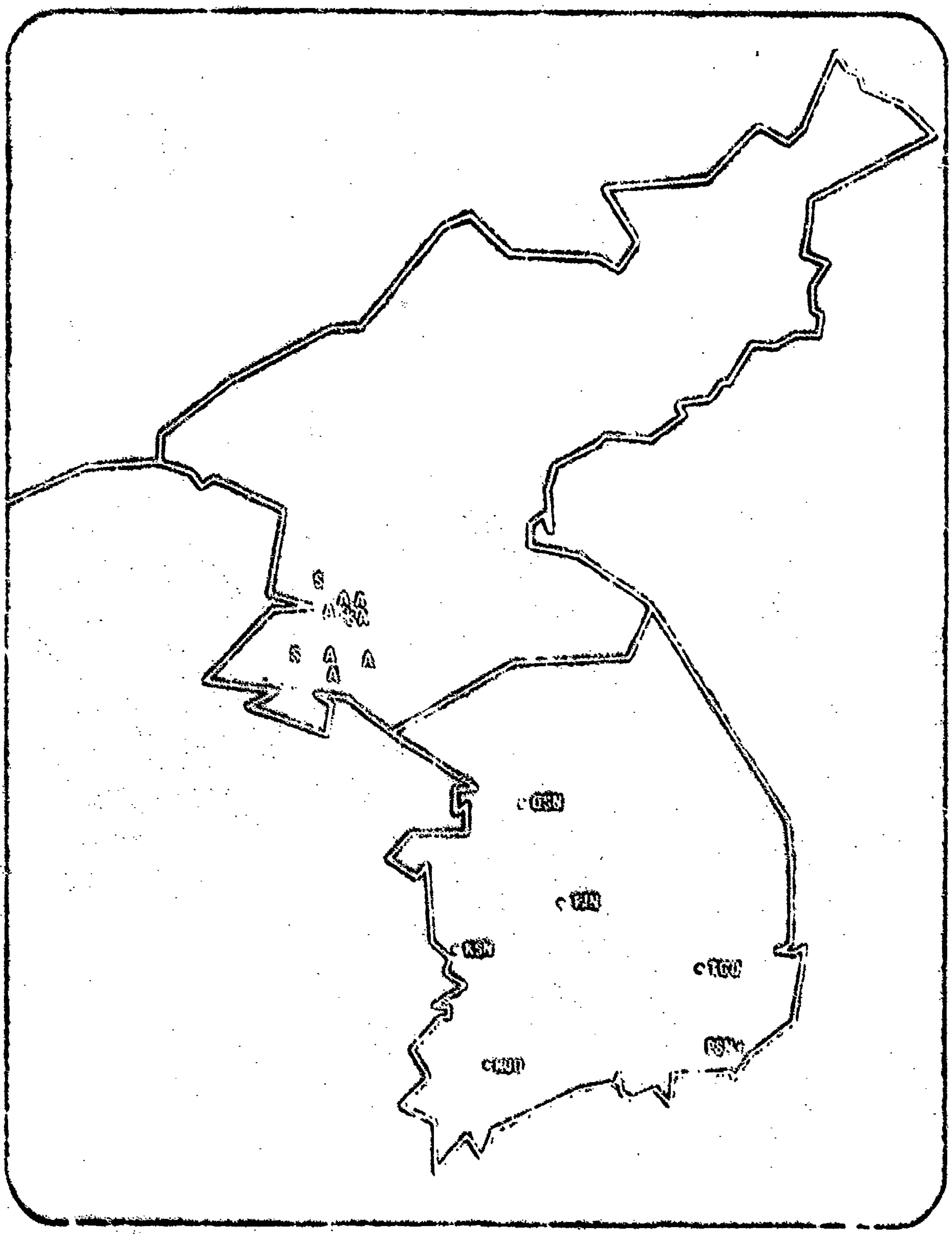
607G
602B
606F
40
38
37
36
35
OSN
TGU
124
125
126
127
128
129
130
A-34

```
MSN NO TARGET              TGT NO LOCATION         RESOURCES     REQUIREMENTS
601A   ORANGE HWY BRIDGE   XZ1008 39.24N-125.37E                 DATE
602B   COMMAND/CONTROL ORBI RP0654 39.52N 126.04E                12 DEC 71
603C   PAT AIRFIELD        WX041C 38.54N-125.14E                 STRIKE TIME
  4D   CHATO NI NAV/SUB BAS RP2080 40.10N 128.32E                08002-10002
605E   BROWN MARSHALLING YD TA0149 41.14N-128.49E
606F   ECM SUPPORT ORBIT   RP0181 39.12N 126.50E
607G   CHINNAM AD SECT HQ  RP0691 39.00N 125.52E
608H   SINGTON MSL SPT FAC RP2238 39.18N 127.24E
609I   KAROON DAM          TZ1024 39.17N-125.42E
610J   RAFFLES POL STORAGE BE1604 38.39N-125.47E
:6076 TO SELECT TGT ENTER MSN NO. SHIFT/ENTER.
```

The first thing that the planner investigates is the target list. This shows the planner which missions need to be planned for the following day. In the breadboard system this target list is limited to 10 targets. However, new targets may be inserted into the data base using off-line data base update programs. In the target list shown the three RPV missions are included.

At this point, the planner can exercise various options. He might select each target one at a time. He will get a target description and a reference to a target folder. He can study each target in as much detail as possible. He may review pre-planned and historical route data and any pertinent command guidance.

In our scenario, we will select mission 607G for planning. This is the RPV strike mission.


S
A
KSN

```
TARGET TYPE FOR MISSION NO. 6076
TGT NO.-   RPG691
TGT-       CHINNAM AD SECT HQ
TGT TYPES- 1 CONCRETE TUNNEL/BUNKER             A/C TYPES- 1 F-4D
           2 RADAR EQPT ANTENNA                            2 RPV001
                                                           3 F-111A
                                                           4 A-7D

TARGET TYPE:1 AND A/C TYPE:2
NO. OF A/C:4_ OR DESIRED CONFIDENCE:__
           MSN REQ:_ A/B RESOURCES:_ ORD INVEN:_
```

-2-

After the planner has reviewed the target description, the target folder, and any pertinent command guidance, the following display is presented to the planner. At this time, the planner will assign aircraft and ordnance to each target type associated with the mission.

This mission has two target types - a concrete tunnel/bunker and a radar antenna. The planner selects the target type and the type of aircraft desired and either the number of aircraft or a desired confidence level.

In this case, the planner has selected the first target, RPV's, and four vehicles.

At this point, the computer retrieves the JMEM table for this type of target. In the MPS breadboard, we limit the data base to the three best entries. This data is extracted from the JMEM tables and loaded into the data base by means of an offline program.

JMEM TABLE

TGT TYPE- TUNNEL STEEL OR CONCRETE

ORDNANCE	FUZE	A/C	NO.	DIVE	ALT	KTAS	PD	PS
1 [illegible] M117A/1	.025	RPV001	4	45	3000	600	.04	.15
2 [illegible] MK-82 LDGP	.025	RPV001	4	45	3000	600	.05	.19
3 [illegible] 2 MK-83 LDGP	.025	RPV001	4	45	3000	600	.04	.15

ENTER ORDNANCE:1 OR ORDNANCE MENU:_
TGT TYPE:_ MSN REQ:_ A/C RESOURCES:_ ORD INVEN:_

This display shows the planner the three best types of ordnance for the selected carrier and target. In our scenario, we selected four RPV's. The computer has taken the single pass probability of destruction and computed the total probability of success for each type of ordnance. If we had specified a desired confidence, the computer would have taken the single pass probability of destruction and computed the number of RPV's required.

Since actual JMEM data was not available for this study, the numbers here represent best estimates based upon various assumptions. One assumption was that the RPV could not carry more than 2000 lbs. of ordnance. The lack of JMEM data does not represent a limitation on the mission planning system. In a tactical planning situation, JMEM data will be available or estimates will be made.

In the present scenario, the planner selects the first type of ordnance for the first target. He will then go back, select his second target for the mission, and assign aircraft and ordnance for the second target.

The planner has the option of disregarding the recommended ordnance and selecting any ordnance in his inventory that is certified for the aircraft. Displays are provided to show all ordnance available.

```
A/E RESOURCE AND ASSIGNMENT
LOCATION  A/C AVAIL  A/C TYPE
PSN         40         F-4D
KJC         44         A-7D
KSN         58         F-111A
TJN         44         RPV001
OSN         54         RPV001
TGJ         56         F-4D

ENTER AIRBASE:OSN
TGT TYPE:_ MSN REQ:_                ORD INVEN:_
```

Once the planner has selected the number and type of vehicles and the type of ordnance, he may wish to select the airbase to support the mission. The next display shows the various airbases and the type and number of vehicles available. This status represents the situation at the start of the planning cycle. The "goodness" of the data is a function of the reporting mechanism available and will represent the best estimates available to the planner.

In our present scenario the planner reviews the airbase resources and selects OSN since it has the desired RPV's based there. At this time there are 54 RPV's available. Once he has made his assignment, that number will be decremented by the amount previously assigned in target selection. In this manner the system will perform the bookkeeping task and will not allow the planner to over-commit his forces.

At this point the planner has various options available. He might elect to assign call-signs to the vehicles that he has designated. The system will present the various call-signs allocated to the selected airbase. From these, the planner can make his selection. The system will keep track of the assigned call-signs and prevent duplicate assignment.

```
ROUTE PROFILE PLANNING             MODE  ALT   MACH THST      MODE  ALT   MACH THST
                                1. CLMB     35 0.02 MIL   11. CRS  20000 0.81
MSN NO.-607G                    2. CLMB  8000  0.82        12. DCND 20000 0.81
T** NO.-RP0691                  3. CRS  20000  0.60        13. DCND 10000 0.81
1       -CHINNAM AD SECT HQ     4. DCND 20000  0.81        14. DCND    35 0.00
LOC     -39.00N 125.52E         5. DCND  2000  0.81
FROM    -OSAN                   6. CRS   1000  0.80
PREPLAN-21AUG72                 7. CLMB  1000  0.61
A/C     -RPV001                 8. DCND  2000  0.81
                                9. CLMB  1000  0.81
PRE-PLANNED ROUTE              10. CLMB  3000  0.80
** SHIFT/ENTER TO EXIT ** (OR LITE PEN DESIRED RESTRICTED AREA)
```

In our present scenario, the planner calls up a pre-planned route for his present mission. It is not necessary to have a pre-planned mission. In fact this route was planned from scratch prior to the breadboard demonstration. It is thought that in an operational system, the slack hours could be used for in-depth planning.

In this case, if the planner were happy with the route, he could accept it as is and proceed to the next mission. For the purpose of our scenario, we will investigate the route further to demonstrate all the capabilities of the MPS breadboard.

Again the planner has various options. He might investigate the MOB to see how it interacts with the mission. The planner has the capability to look at the various threats by individual type and sub-class. If he so desires, he might wish to modify his route based on his assessment of the MOB.

ROUTE SAFETY ANALYSIS

	D_SCORE	A SCORE	L SCORE	LM SCORE	LA SCORE	TOTAL SCORE
PRIMARY ROUTE						
	585	63	952	271	681	1601
WORST LEG NODE 9 TO 10						
	2	5	630	0	630	637

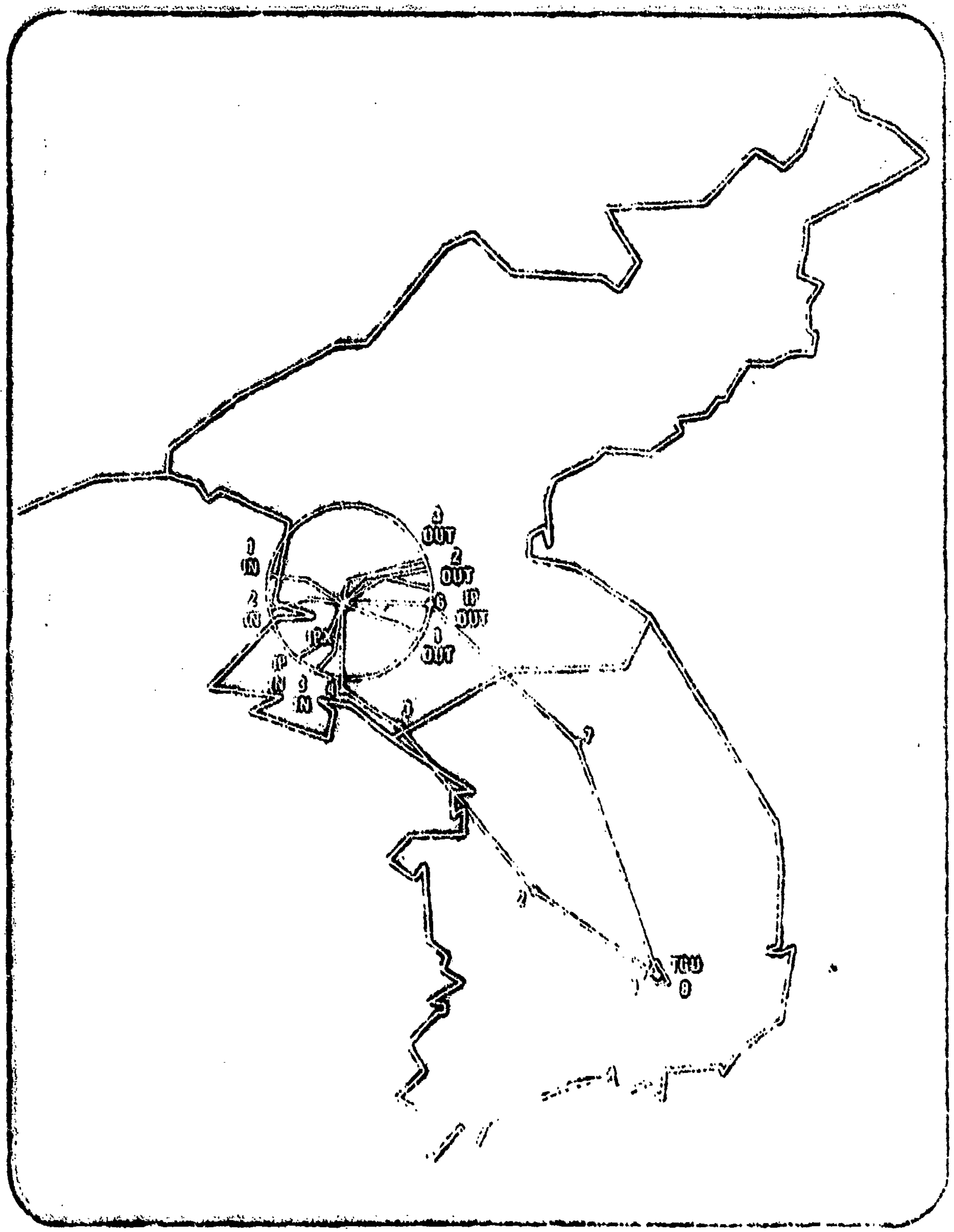
SUPPORT REQUIREMENTS:_ TERRAIN MASKING:_

For the purpose of assessing his route, the planner may invoke Route Safety Analysis. This analysis is based on a weighted exposure time to various threats in the BOB.

The score is composed of a detection score, an acquisition score, and lethality score. The detection score represents a weighting of the amount of time the mission is within the detection range of the EW and GCI radar. The acquisition score represents a weighting of the time the mission is within range of the missile and fire control radars. The lethality score represents a weighting of the time the mission is within range of

the missiles and AAA.

In our present scenario the score for the preplanned route is 1601. This score is neither good nor bad. The score is only relative. It only has meaning when compared against scores for other routes.



3 OUT
2 OUT
IP OUT
1 OUT
1 IN
2 IN
IP
IP IN
3 IN
TGU

AUTOMATIC ROUTE SELECTION

TARGET: CHINNAM AD SECT HQ LOCATION: 39.00N 125.52E

INGRESS PARAMETERS; RADIUS BOUNDRY:40 PROHIBITED POINTS? YES:X
ALT:01000 VEL:0.80 SELECTED POINTS, DONE:_
IPT YES:_
SELECTED __.__N/___.__E
EGRESS PARAMETERS:
ALT:01000 VEL:0.80

In the next step of our scenario the planner will use automatic Route Selection to obtain "best" ingress and egress routes to the target. In the display the planner has indicated an ingress and egress altitude of 1000 ft. and a mach of 0.80. He has asked for the analysis to be performed in a circle of radius 40 N.M. and has asked for prohibited points on the circle.

After entering the prohibited regions on the circle, the computer determines the three safest ingress and egress routes to the target within the 40 N.M. circle.

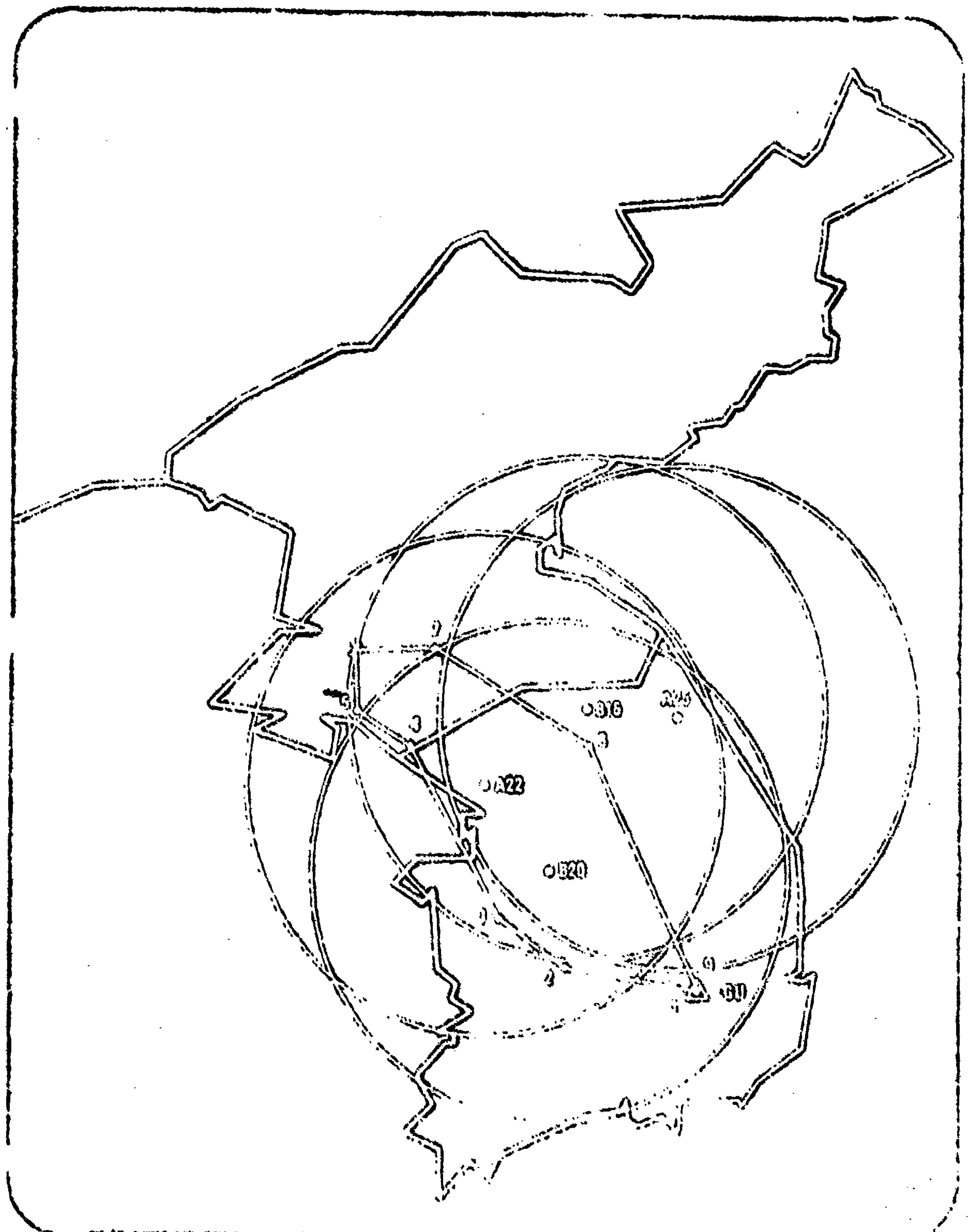
ROUTE SAFETY ANALYSIS

	D_SCORE	A SCORE	L SCORE	LH SCORE	LA SCORE	TOTAL SCORE
PRIMARY ROUTE	565	63	952	271	681	1601
WORST LEG NODE 9 TO 10	2	5	630	0	630	637
ALTERNATE ROUTE	576	63	38	36	0	679
WORST LEG NODE 4 TO 5	5	5	34	34	0	43

SUPPORT REQUIREMENTS:_ TERRAIN MASKING:_

After ARS is completed, the planner may modify his route to utilize the results of ARS. Once the route has been modified, the planner may return to Route Safety Analysis to score the new route.

In the present scenario the score has been reduced from 1601 to 679. This indicates that the new route has less exposure to threats than the previous route. Unless the planner knows of other tactical considerations he will accept the new route. The planner might try some alternate routes planning them manually. He will ultimately accept that route that seems best to him, based on the analysis tools in the mission planning system.


A22
B20

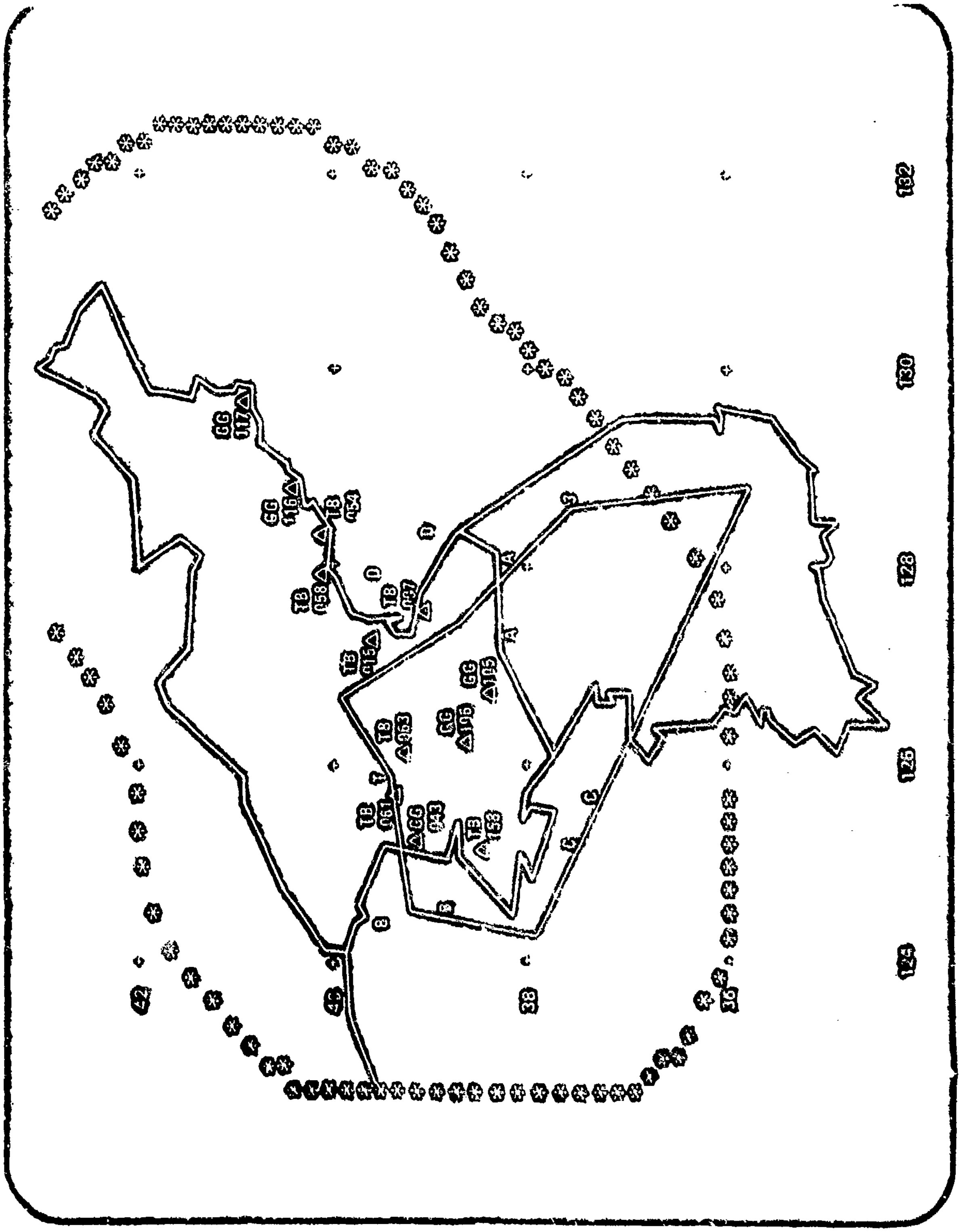
```
TACS COORDINATION/ASSIGNMENT FOR MISSION NO. 6070
T/O BASE= OSAN            T/O TIME :________ NO.FLTS= 2  A/C TYPE= RPV001
CALL SIGNS= CHIEF          COMANCHE

COORD  :1_ TO:6_ ASSIGN:1      :6_ TO:12 ASSIGN:2          1 A-22
       :12 TO:14 ASSIGN:1      :__ TO:__ ASSIGN:_          2 B-20
       :__ TO:__ ASSIGN:_      :__ TO:__ ASSIGN:_          3 A-25
       :__ TO:__ ASSIGN:_      :__ TO:__ ASSIGN:_          4 B-15
       :__ TO:__ ASSIGN:_      :__ TO:__ ASSIGN:_
TACS COORDINATION/ASSIGNMENT IS COMPLETED
```

As the final step in the interdiction planning of the present mission, the planner makes the TACS assignments. The locations of the various TACS units are displayed on the graphics. The planner can assign the total route to one TACS unit or assign various route segments to various TACS units.

```
MSN NO TARGET                TGT    LOCATION          RESOURCES        REQUIREMENTS
601A   ORANGE HWY BRIDGE     XZ1000 39.24N-125.37E                      DATE
602B   COMMAND/CONTROL ORBI  RPC654 39.52N 124.64E                      12 DEC 71
603C   PAT AIRFIELD          WAC418 38.54N-125.14E                      STRIKE TIME
604D   CHATO NI NAV/SUB BAS  RP2060 40.10N 128.32E                      0600Z-1000Z
 5E    BROAN MARSHALLING YD  TA0149 41.14N-128.49E
606F   ECM SUPPORT ORBIT     RP0131 39.12N 126.50E
607G   CHINNAM AD SECT HQ    RP0691 39.00N 125.52E   5 RPV001 OSN
608H   SINGTON MSL SPT FAC   RP2238 39.18N 127.24E
609I   MAROON DAM            TE1024 39.17N-125.42E
610J   RAFFLES POL STORAGE   BE1604 38.39N-125.47E
:602B TO SELECT TGT ENTER MSN NO. SHIFT/ENTER.
```

At this point in the scenario, we go back to the target list and plan a new mission. At this time, the planner selects mission 602B. This mission will be for a relay aircraft. The method of planning the mission is similar to that shown for the first mission.

At the conclusion of planning 602B, the next step in the scenario is to go to ECM planning. At this time, the planner will perform SOJ (stand-off jamming) analysis. This is in preparation for planning an RPV SOJ mission.


132
130
128
126
124
42
46
38
36
TB
GG

SOJ EFFECTIVENESS VS EW/GCI RADAR TYPES-EXPOSURE VALUES IN NAUTICAL MILES

	NG	DT	CB	CH	DL	CN	TP	ND	IE	TI	GG	TB			
DRY	2573	260	427	1853	296	299	294	299	290	293	868	3595			
WET	2573	260	427	1853	296	299	294	299	290	293	868	3595			
DRY															
WET															

TOTAL EXPOSURE ALL TYPES: DRY 11375 WET 11375

MIN DISPLAY RANGE TOCO PENETRATION CONTOUR RADARS :_ RESTORE:_ (D)DELE,(T)TERM

ENTER PIN#,OPTION (1)-ADD,(2)-DELETE,(3)-ONLY REGEN(MSN#),(M)MAN,(A)AUTO

:GG___:TB___1:______:______:______:______:______:______:______:______ :_

The first display shown in SOJ analysis is the SOJ summary. This shows all of the EW by class. The scores represent the total exposure of the flight path to each type of radar. It is possible to limit the analysis to specific types of radars or specific nets. In our scenario, we will limit the analysis to the EW net associated with the missile radars. By jamming these radars, the effectiveness of the missiles will be greatly decreased.

At this point, the planner has several options. He may assign orbits manually anywhere that he wishes, and the system will evaluate their effect. It is quite possible that tactics will dictate specific orbit locations and jamming configurations.

*** AOS SUMMARY ***

	B1	B2	B3	B4	C1	C2	C3	C4	E1	E2	E3	E4
A	315	335	335	___	0	0	0	399	335	335	335	___
B	269	299	299	___	0	0	0	373	299	299	299	___
C	263	295	295	___	0	0	0	374	295	295	295	___
D	___	___	___	___	___	___	___	___	___	___	___	___
E	___	___	___	___	___	___	___	___	___	___	___	___

DRY EXPOSURE SUM: 448NM *** BEST TRIAL IMPROVEMENT POSITION: A,C4
ASSIGNED WET SUM: 446NM *** LEAST USEFUL TRIAL POSITION: C,C3

ALT:__ B:____ C:____ E:____ ALL:_ SUMMARY:_
:AC4 :AC4 :___ :___ :___ :___ :___ :___ :___ :___ :___ :___ :___ :___ :___

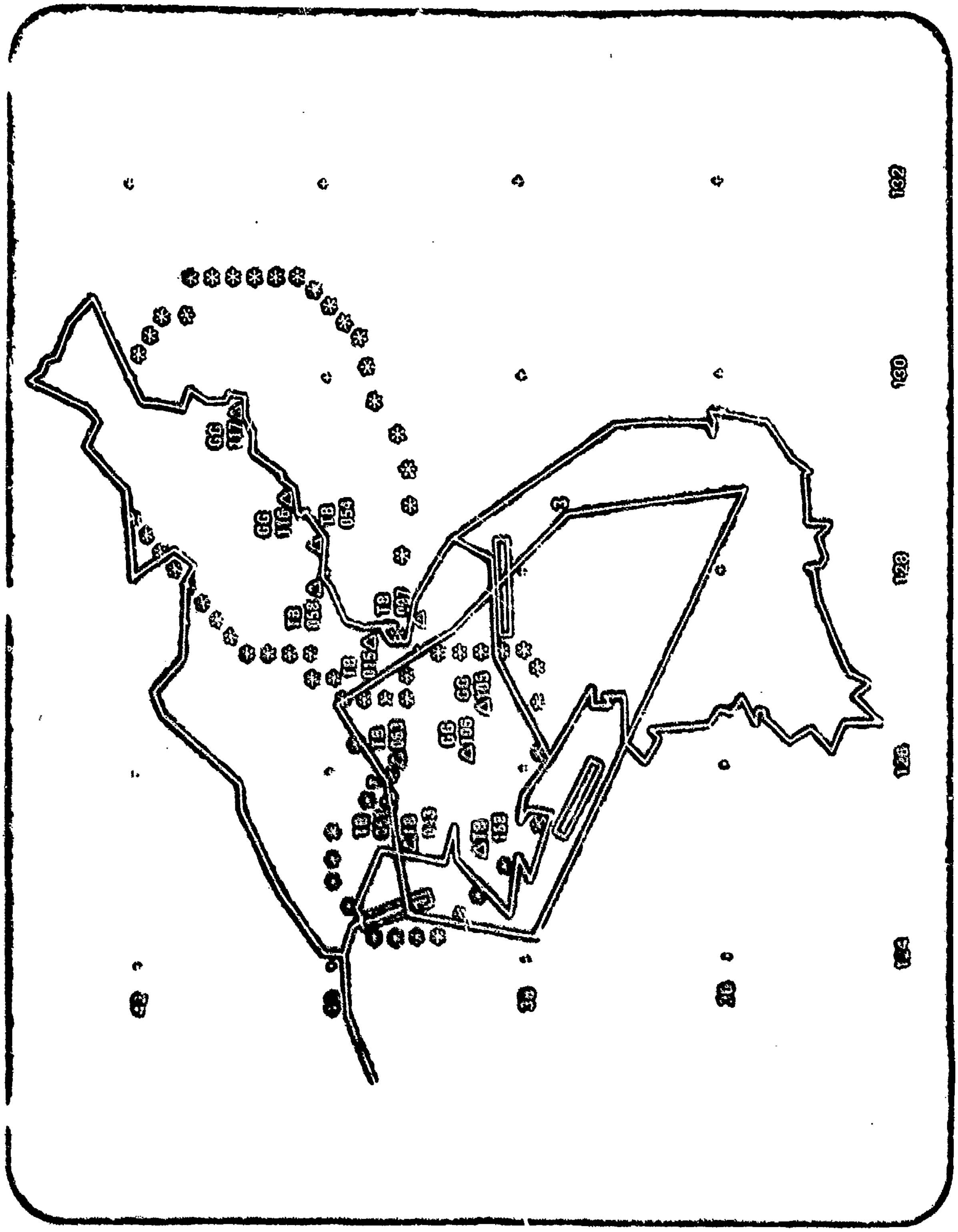
In our scenario, the planner will use the Automatic Orbit Selection (AOS) option. This allows the planner to select five trial orbits and to evaluate any or all of his jamming pre-sets in each orbit position.

In the breadboard system, there are provisions for twelve different jamming pre-sets. By using the data base input program, any jamming configuration may be put into the data base. These jamming configurations will reflect the jamming equipment available.

The results of the AOS analysis is a table showing the score for each jamming pre-set in each trial orbit. The score represents an improvement factor. So the larger the score the better.

In our scenario orbit A with a C4 jamming configuration, represents the best improvement. By using an RPV, it is possible to place the jamming vehicle close to the target. Tactics would make this impossible for a manned aircraft.

At this point the planner may assign permanent orbits and jamming configuration from the AOS table.


132
130
128

```
  SOJ EFFECTIVENESS VS EW/GCI RADAR TYPES-EXPOSURE VALUES IN NAUTICAL MILES
        GG   TE    __   __   __   __   __   __   __   __   __   __   __   __   __
 DRY   860 3595 ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
 WET   270  226 ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

           __   __   __   __   __   __   __   __   __   __   __   __   __   __   __
 DRY    ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
 WET    ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
 TOTAL EXPOSURE ALL TYPES: DRY  4464 WET   497
 MIN DISPLAY RANGE 5000 PENETRATION CONTOUR RADARS :_ RESTORE:_ (D)DELE,(T)TERM
ENTER PIN#,OPTION (1)-ADD,(2)-DELETE,(3)-ONLY       REGEN(MSN#),(M)MAN,(A)AUTO
:______:______:______:______:______:______:______:______:______:______       :T
```

After the planner makes an orbit assignment, he again has the SOJ summary displayed. This display shows the wet and dry scores for each radar type under consideration. On the graphics, the planner will see the penetration contour.

The planner uses an iterative process to obtain the best tactical SOJ assignment. It is possible to add and delete orbits until the planner is satisfied with the plan.

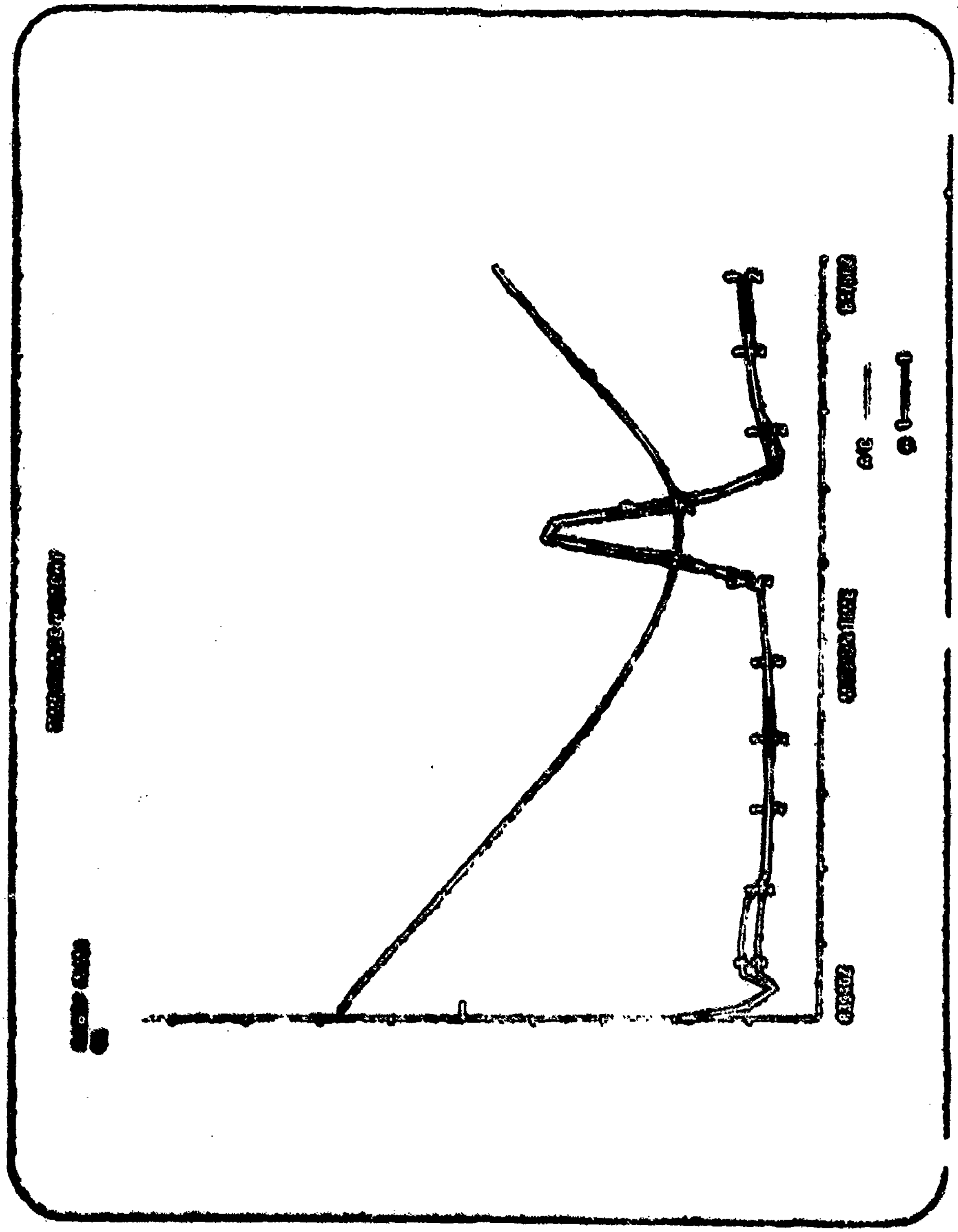
It is now possible for the planner to do more detailed ECM analysis. By using his ECM effectiveness option, he can obtain detailed burnthrough contours and time-range histories for specific radars. In particular he might wish to look at the effects of the standoff jamming against specific radars.

```
                    ECM EFFECTIVENESS
   1) LIGHT PEN THREAT   2) LIGHT PEN STRIKE ROUTE ANALYSIS POINT(S)
EFFECTIVENESS OPTIONS:
   1) TIME RANGE HISTORY  (2 POINTS)
   2) EARLY LATE ANALYSIS (3 POINTS)
   3) BURNTHROUGH CONTOUR (2 POINTS)
   4) FORMATION ANALYSIS  (1 POINT )
   5) TIME RANGE HISTORY FOR BURNTHROUGH CONTOUR
   6) SOJ BURNTHROUGH CONTOUR (2 POINTS)
   7) TERRAIN MASKING CONTOUR (2 POINTS)
   8) MASKING_BURNTHROUGH COMPOSITE (2 POINTS)
EFFECTIVENESS:6    BRN:2    FORMATION:02
```

In our scenario, we show two superimposed burnthrough contours. These contours show the effect of the reduced cross-section of the RPV. Because of its smaller cross-section, the burnthrough contour is smaller. This means that the RPV has less chance of being detected especially when jamming is present.

The same information as shown in the burnthrough contour can be displayed as a time-range history. The time-range history shows the range of the vehicle to the threat as a function of time. It also shows the burnthrough range as a function of time. When the burnthrough range is greater than the aircraft range, the radar can detect the vehicle in spite of the jamming.

The planner can use his ECM tools to come up with the best ECM plan. When he is satisfied with the plan, he may return to interdiction planning to assign vehicles for the ECM support mission.



MSN NO	TARGET	TGT NO	LOCATION	RESOURCES	REQUIREMENTS
601A	ORANGE HWY BRIDGE	XZ1008	39.24N-125.37E		DATE
602B	COMMAND/CONTROL ORBI	RP0654	39.52N 126.04E		12 DEC 71
603C	PAT AIRFIELD	WX0418	38.54N-125.14E		STRIKE TIME
[illegible]D	CHATO AI NAV/SUB BAS	RP2060	40.10N 128.32E		0800Z-1000Z
605E	BROWN MARSHALLING YD	TA0149	41.14N-128.49E		
606F	ECM SUPPORT ORBIT	RP0181	39.12N 126.50E		
607G	CHINIAM AD SECT HQ	RP0691	39.00N 125.52E	5 RPV001 DSN	
608H	SINGTON MSL SPT FAC	RP2238	39.16N 127.24E		
609I	HAROON DAM	TE1024	39.17N-125.42E		
610J	RAFFLES POL STORAGE	BE1604	38.39N-125.47E		

1606F TO SELECT TGT ENTER MSN NO. SHIFT/ENTER.

The next step in our scenario is to plan the ECM orbit mission 606F. The details of this planning are the same as outlined before. In this case, we will use RPV's carrying ECM equipment to orbit in the target area.

MISSION LOCATION SUMMARY

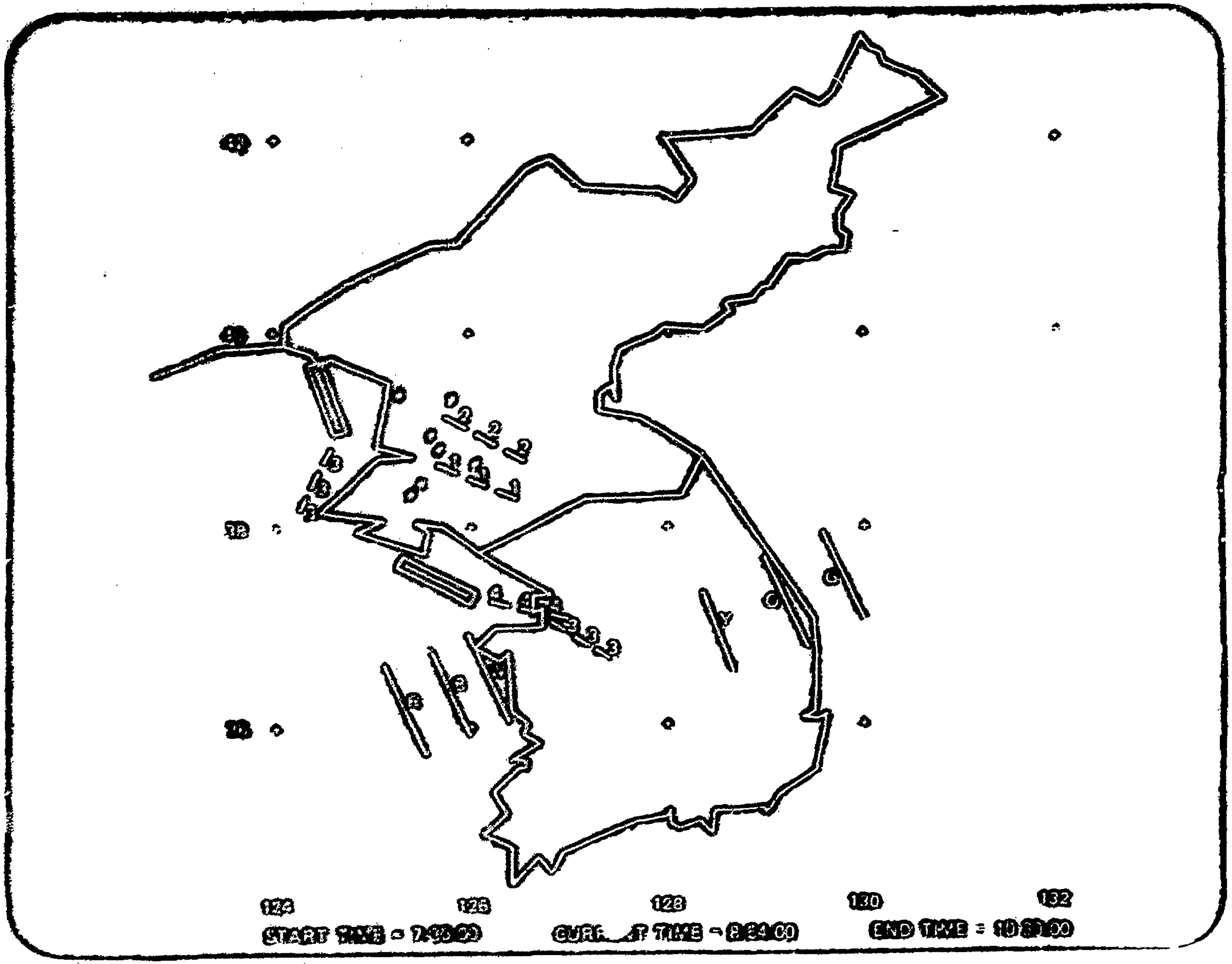
START TIME= 7:15: 0 CURRENT TIME= 7:55: 0 END TIME= 10: 0: 0

MSN	LAT	LONG	ALT	TOT	SSJ	LAT	LONG	ALT
1	39 01N	126 37E	1.0	0800Z	1			
2	37 39N	124 23E	20.0	0800Z	2			
3	36 18N	126 33E	20.0	0815Z	3			

SHIFT/ENTER FOR ROUTES

As a final planning step, the planner may use time-sequence review (TSR) to look at what he has planned. In TSR the planner selects a time period for consideration. The system looks for all missions planned for the particular time period. Then a series of time slices are presented to the planner showing the time relationship of the various missions.

By using TSR, the planner can look for conflicts and omissions in his plan. If there are airspace conflicts, the system will automatically alarm the planner, and he can take appropriate action.



3M

APPENDIX B

A USER-ORIENTED AID FOR SYSTEM LOAD ANALYSIS

Data Systems Division
Litton Systems, Inc.
8000 Woodley Avenue
Van Nuys, California 91409

THE PROBLEM

In the course of executing its business, Data Systems Division of Litton Systems, Inc. is often required to propose data processing systems to function in support of operations within a command and control center. The method of operation, the degree of automation, and/or the particular allocation of tasks to man or machine for the reconfigured center are frequently to be developed and presented as supporting documentation for the particular system proposed. A commonly encountered method of indicating the performance the system must meet is to list the center missions, and specify a rate and maximum response time under load, which may not be exceeded, for each major function of each mission. Within this context, the following analysis problem can be isolated.

Given the mission(s) of a command and control center, perform an analysis to identify appropriate work allocations and operating procedures and to develop estimates of expected:

- system response times,
- data processing loads, and
- operator loads.

THE SOLUTION

The analysis of large man-machine systems usually involves people of many disciplines and a large amount of information. Major problems often arise in the integration of information provided by members of different disciplines, the digestion of the extremely large quantity of data, and the documentation of the analysis process itself as it pertains to tracing the flow from a mission requirement to a specific set of system capabilities. The solution is a computer-aided analysis which uses the power of a computer to store and integrate information provided by analysts to produce the desired results.

The analysis procedure presented in this paper centers around the use of such a computer model. The model itself is used as a device for integrating the large amount of data assembled to produce estimates of response times, processor loads, and operator loads. Its presence has a strong impact on the whole analysis process. Data requirements of the model serve as guides to the specific information which must be produced by analysts.

Analysis processes, however, are not "bent" to comply with computer requirements. Quite the contrary; the model was designed with inputs in forms which are familiar to the particular activities of the analysts who are responsible for their production. Consistent with this policy, each step of the analysis process is aimed at producing one or more items of data for model execution. Each execution of the model produces a list of model inputs which serves as a document to describe the particular configuration and its associated performance.

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Figure 1 presents the analysis process in flow chart form. Although there is some horizontal movement of data across the chart, in general there are three vertical flows corresponding to:

1. specifying the environment;

2. describing the nature and order of the processes necessary to accomplish the system mission(s);

3. describing in detail the specific tasks performed in these processes, which form the system's capability.

The Task Occurrence History File has been used for post execution analysis and as an interface to a detailed processor model to specify the processor job stream. The detailed computer model was described by Herman Fischer in his paper titled "Computer Simulation of an On-Line Interactive System". This paper was delivered at the Winter Simulative Conference, held in New York City on December 8 through 10, 1971. The paper and proceedings were published by ACM and are available from them.

THE DETAILS

The starting point of the analysis is the set of mission requirements and any other requirements which have been imposed on the system. From this point, the three primary analyses separate to join again in the model data set.

Functional flow diagrams are developed for each function. Several levels of diagrams are developed, with each successive level specifying the required functions at a more detailed level. The lowest level must be of sufficient detail to identify tasks which can be allocated to system resources.

In parallel with the production of the Function Flow Diagrams, a system concept is developed. The concept indicates at the top level the kinds of capabilities the system will have and the degree of automation to be provided. It will reflect any guidance given by the user with respect to features desired in the system.

Using the system concept as a guide, the Function Flow Diagrams are analyzed and the specific task capabilities which the system must have are identified. This includes any action an operator may take at the consoles, the software necessary to present guidance and/or selection displays to operators, the software to process operator requests, and the software necessary to perform any fully automatic functions. The identified tasks are compiled into a Task Dictionary. The Dictionary consists of one entry for each capability the system will have. Each of these entries has a user-specified name of up to 20 characters and nine parameters for use in further describing the task. For example, if one of the tasks was "TYPE", one of the parameters could be assigned the number of time steps required to type one character. Then a specific occurrence of the TYPE task would contain the number of characters to type specified in a corresponding variable. During execution the parameter and variable would be combined to produce the time required to execute the TYPE task.

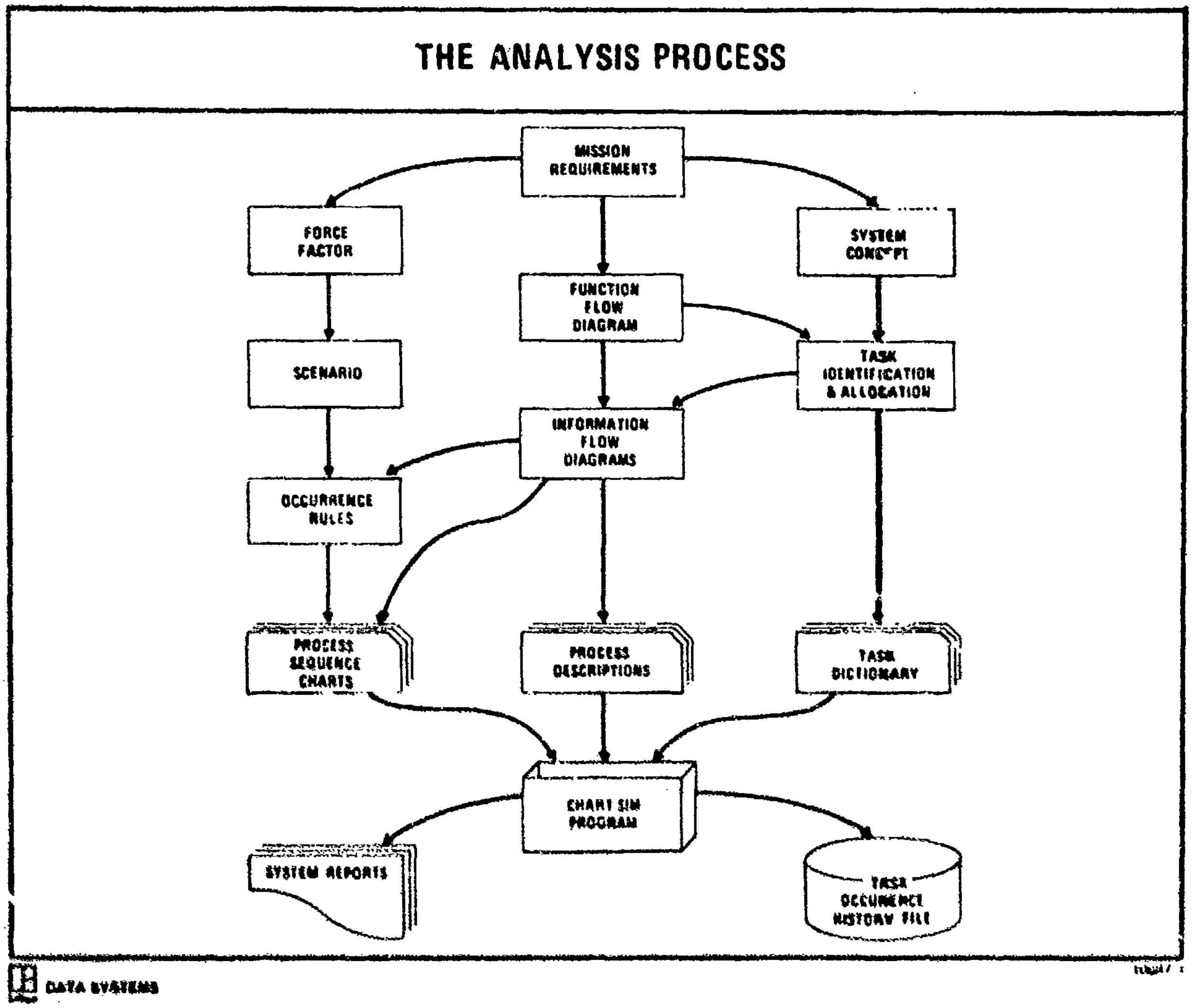

THE ANALYSIS PROCESS
MISSION REQUIREMENTS
FORCE FACTOR
SYSTEM CONCEPT
FUNCTION FLOW DIAGRAM
SCENARIO
TASK IDENTIFICATION & ALLOCATION
INFORMATION FLOW DIAGRAMS
OCCURRENCE RULES
PROCESS SEQUENCE CHARTS
PROCESS DESCRIPTIONS
TASK DICTIONARY
CHART SIM PROGRAM
SYSTEM REPORTS
TASK OCCURENCE HISTORY FILE
DATA SYSTEMS

Figure 1

Information flow diagrams are generated from the lowest level functional flow diagrams, with consideration given to the identified system tasks and their allocation to man or machine. These diagrams are a prime input to the model data set.

The system environment is represented only to the extent that it causes the occurrence of jobs to which the system must respond. For example, if the system must maintain a target list, any part of the environment which could result in information entering the system for update of the target list would be modeled as a message generator with a periodic or stochastic interarrival rate.

Specific rules for message generators are derived from the mission requirements and force factors which vary with the operating force sizes specified. Different system loads can be generated by varying the force size or the message rates.

The three main inputs to the model are:

1. a set of PROCESS SEQUENCE CHARTS,
2. a set of PROCESS DESCRIPTIONS, and
3. a set of TASK DESCRIPTIONS.

A PROCESS SEQUENCE CHART (CHART) specifies the logical relationships of the PROCESSes necessary to perform a function, with the specific details of the PROCESSes omitted. CHARTs are specified in terms of standard box types which are similar to those generally used by operations analysts. Each box of a CHART is described by specifying: a number for reference; a KEY WORD to indicate which of the standard box types it is; two parameters; and the number of the next logical box in the CHART. Table 1 lists the standard box types, their parameters, and their normal use.

The PROCESS box is used to indicate the occurrence of a PROCESS. All other boxes have as their function the specification of the logical and temporal relationships of the PROCESSes within a CHART and/or the relationships between CHARTs.

Using the standard box types, it is possible to express almost any type of operation which can be depicted on a set of information flow diagrams. Any combination of serial operation, parallel operation, substructuring, looping, and or stochastic branching, for example, can be expressed.

The TASK DICTIONARY (DICTIONARY) contains the set of operations which comprise all actions and/or activities which the system can perform. Each TASK is given a name of up to 20 characters and up to nine parameter values which apply to every occurrence of the TASK are specified.

A PROCESS DESCRIPTION is a list of TASKs from the DICTIONARY which, when performed, would result in the completion of the PROCESS being described. A PROCESS DESCRIPTION may contain any number of TASKs. Each DESCRIPTION is given a number and may be referred to from any number of CHARTs.

STANDARD BOX TYPES

KEYWORD	PARAMETER 1	PARAMETER 2	USE
PROCESS	PROCESS NUMBER	–	TO INDICATE THAT A PROCESS IS TO BE PERFORMED
OPERATOR	OPERATOR TYPE	OPERATOR NUMBER	TO SPECIFY THE OPERATOR BY TYPE & NUMBER IN CONTROL OF A CHART
BRANCH	BOX NUMBER	PROBABILITY OF NOT BRANCHING	STOCHASTIC BRANCH/UNCONDITIONAL BRANCH IF PARAMETER 2 IS BLANK OR ZERO
CALL	CHART NUMBER	BOX NUMBER	TO INCLUDE THE SPECIFIED CHART AS A SUBFUNCTION OF THE CHART BEING EXECUTED
CAUSE	CHART NUMBER	BOX NUMBER	TO INITIATE THE SPECIFIED CHART AS A PARALLEL FUNCTION OF THE CHART BEING EXECUTED
SET	REGISTER NUMBER	VALUE	TO SET THE SPECIFIED LOCAL REGISTER TO THE SPECIFIED VALUE
D BRANCH	REGISTER NUMBER	BOX NUMBER	TO FORM A LOOP USING THE SPECIFIED REGISTER TO CONTROL THE NUMBER OF EXECUTIONS
SETC	COUNTER NUMBER	VALUE	TO ASSIGN THE SPECIFIED VALUE TO THE SPECIFIED SYSTEM COUNTER

DATA SYSTEMS

Table 1

STANDARD BOX TYPES (CONTINUED)

KEYWORD	PARAMETER 1	PARAMETER 2	USE
INCREASE	COUNTER NUMBER	INCREMENT	TO INCREASE THE VALUE OF THE SPECIFIED COUNTER BY THE INCREMENT
DECREASE	COUNTER NUMBER	DECREMENT	DECREASE THE COUNTER BY THE SPECIFIED AMOUNT AND IF THE RESULT IS NOT POSITIVE AND A TEST HAS BEEN EXECUTED AGAINST THE COUNTER, RESTART THE WAITING CHART
TEST	COUNTER NUMBER	-	TEST THE VALUE OF THE SPECIFIED COUNTER AND IF THE VALUE IS POSITIVE PLACE THE CONTAINING CHART IN A WAIT MODE
ADVANCE	TIME	-	TO MODEL THE PASSAGE OF TIME WITHOUT ANY REQUIRED ACTIONS IN THE CHART
MARK TIME	CLOCK NUMBER	-	TO STORE THE VALUE OF CURRENT CLOCK TIME IN THE SPECIFIED CLOCK REGISTER
WRITE TIME	CLOCK NUMBER	-	TO PRINT ELAPSED TIME AND TABULATE STATISTICS
NULL	-	-	PROGRAMMING CONVENIENCE
TERMINATE	-	-	TO INDICATE A LOGICAL END OF A CHART
END	-	-	TO INDICATE THE PHYSICAL END OF CHART

DATA SYSTEMS

Table-I

Note that there are both TASK parameters and TASK variables; TASK parameters appear in the DICTIONARY and TASK variables appear in PROCESS DESCRIPTIONs. Variables specified in a PROCESS DESCRIPTION apply to the specific occurrence of the task, while parameters specified in the DICTIONARY apply to every occurrence of the task.

The expected content of a given parameter or variable is determined by the user. He establishes and is responsible for the maintenance of a convention which specifies the significance of each parameter and variable of each TASK. Generally, DICTIONARY parameters are system oriented and are used for the specification of items like I/O rates, typing rates, or the average number of instructions executed for each occurrence of a program. PROCESS DESCRIPTION variables are usually operationally oriented. They are used to specify items like the actual number of a file to access, how many records to retrieve, or the number of lines in a report. Consider the "TYPE" example given above. A reasonable convention would be to specify the number of characters to type in variable 1 of the TYPE tasks in PROCESS DESCRIPTION. Then, specifying the number of time steps required to type 1 character in parameter 1 of the TYPE task in the DICTIONARY would result in the correct time durations for TYPE tasks and they would have the form:

TYPE n, where n is the number of characters to type.

During model execution, when a function is "performed", the program

1. refers to the appropriate PROCESS SEQUENCE CHART,
2. retrieves the required PROCESS DESCRIPTIONs,
3. combines the TASK parameters and variables to compute the time necessary to perform each TASK and
4. causes each TASK to occur at the proper time.

The occurrence time of any task within a CHART is determined by the occurrence time of the CHART, the logic of the CHART, and the execution times of all TASKs which logically precede it in the CHART. When stochastic branches are included in the CHART, the occurrence time of a TASK relative to the occurrence time of the CHART can vary. Indeed, some PROCESSes may not occur at all on any given occurrence of the CHART. When TEST boxes are used, the occurrence time of a TASK can also be affected by the performance of other CHARTs which are being executed in parallel.

AN EXAMPLE

The most efficient way to demonstrate the growth of detail and information present in each step of the analysis is to present a simple example. The example presented is didactic in purpose and is not intended to be complete or exhaustive. With this in mind, Figure 2 presents a functional flow diagram depicting the updating of a target list from combat mission reports. No indication is given as to how the steps are to be accomplished, how much work is to be done, or what system resource is to perform the work.

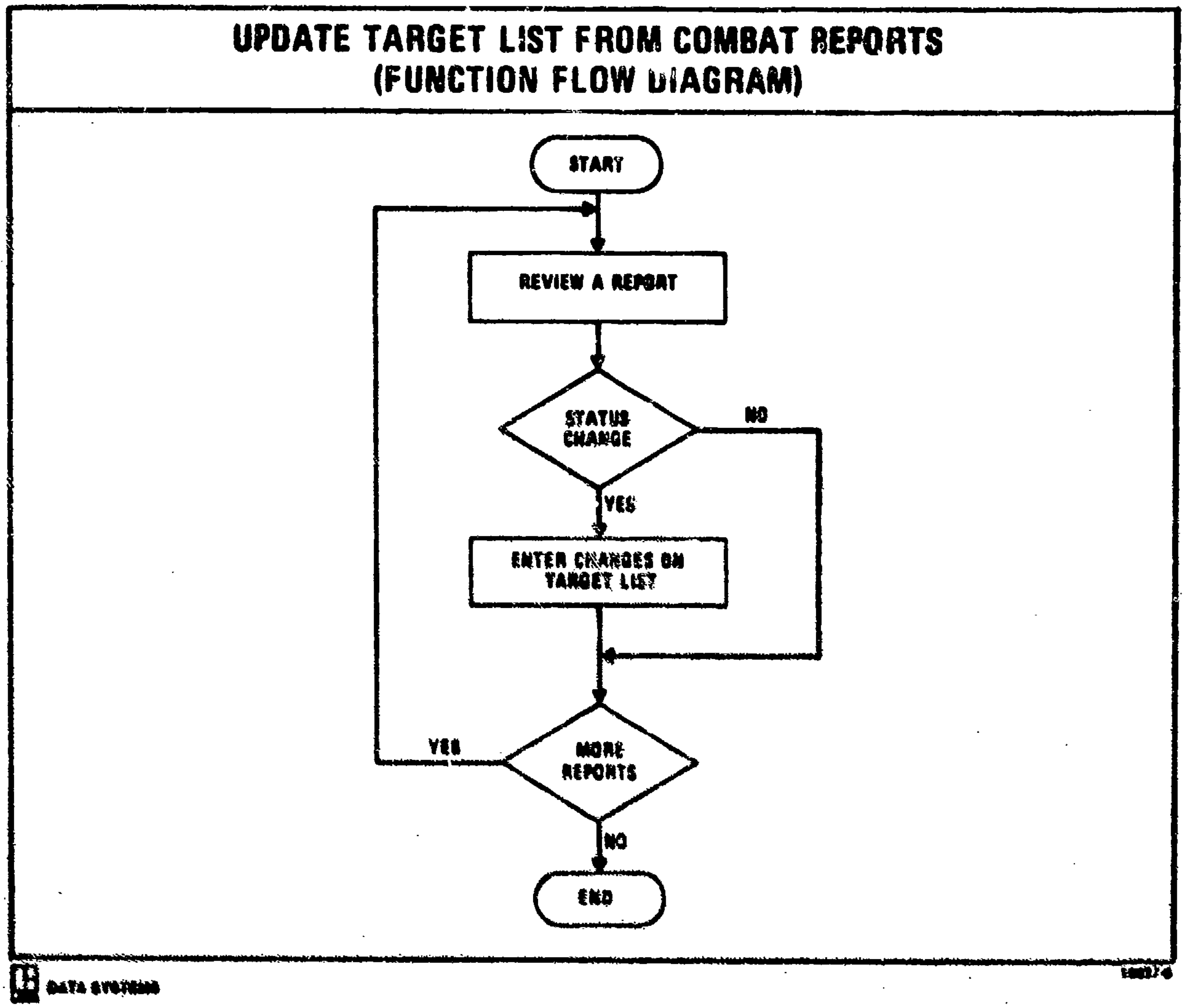

UPDATE TARGET LIST FROM COMBAT REPORTS
(FUNCTION FLOW DIAGRAM)
START
REVIEW A REPORT
STATUS CHANGE
NO
YES
ENTER CHANGES ON TARGET LIST
MORE REPORTS
YES
NO
END

Figure 2

Figure 3 presents the same function expanded to include system concept and task allocation. Several design and allocation decisions are apparent from the expanded diagram. First, a data processor is part of the system. Second, storage of the target list and the combat reports have been allocated to the data processing subsystem. Third, an operator will be responsible for the review of combat reports and the decision to update the target file. And fourth, the operator interacts with the data processing system in real time.

Figure 4 is the function in abstract form. The logical relationship of the PROCESSes is preserved but all details of the PROCESSes have been omitted. It is this form that a PROCESS SEQUENCE CHART represents. Figures 5 and 6 present representations of the functions in Chart Language. Figure 5 is a simple version in which it was assumed that 12 messages were to be examined and there is a probability of 0.95 of a message resulting in a data base change. Figure 6 is more general. It assumes that the number of messages will be passed to the CHART in register 3* and that the probability of a message resulting in a data base change will be passed via register 4*. Both CHARTs are to be invoked by some other CHART and will use register 1 to control looping.

Figure 7 presents hypothetical expansions of the PROCESSes required for the example function. Note each PROCESS has been given a number. The title is optional; however, each PROCESS must have END as its last TASK. For our example, it was assumed that the DICTIONARY contained the following entries:

TYPE	with variable 1 specifying how many characters to type.
THINK	with variable 1 specifying the time duration of the period.
RETRIEVE KEY	with variable 1 specifying the file number and variable 2 specifying how many records.
UPDATE KEY	with variable 1 specifying the file number and variable 2 specifying how many records.

As an example of the detail level attained using this approach, PROCESS 3 of the example has been expanded in flow chart form. It is presented in Figure 8.

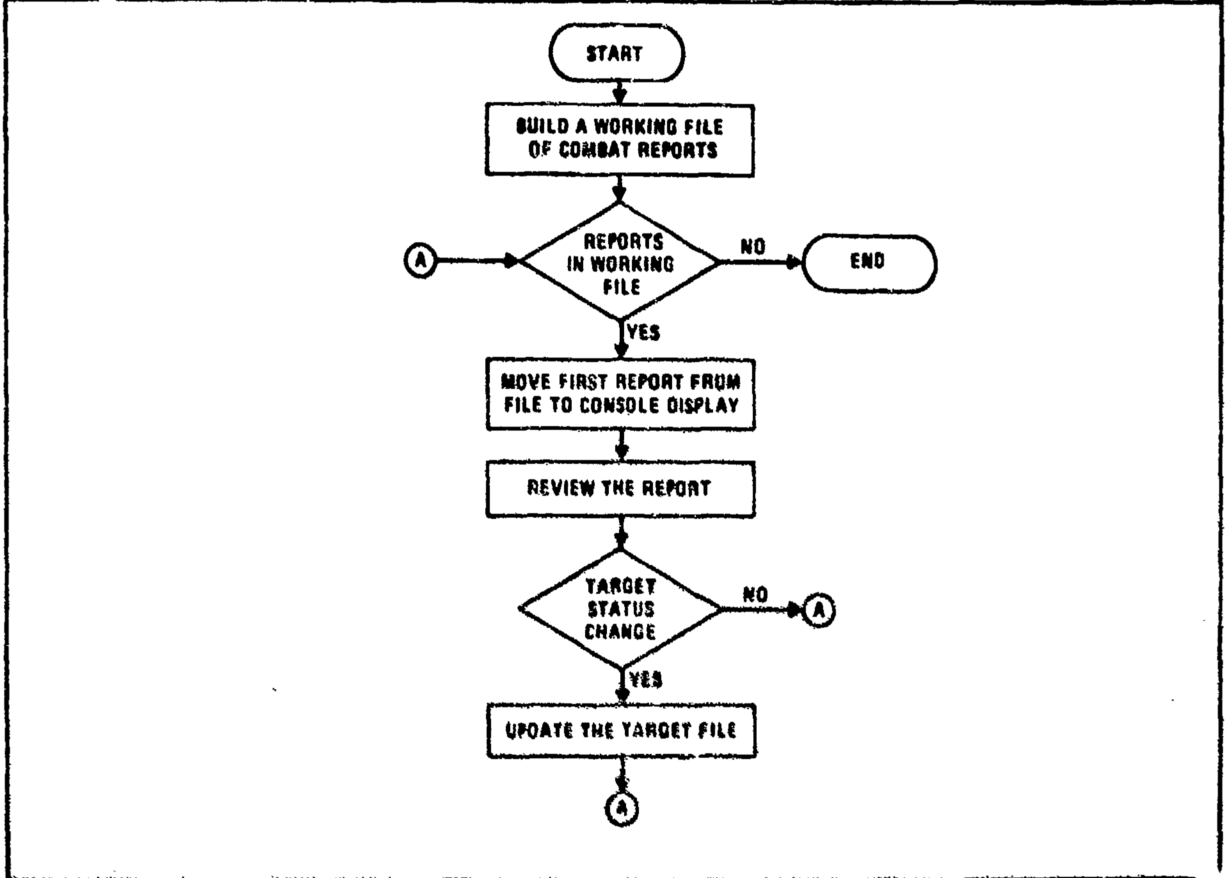
EXPERIENCE

To date, the analysis process has been used twice; once in embryonic form during 1970 and in its current form in 1972.

Several conventions are currently in use for data preparation, and a special version of the statistics subroutine was built to take advantage of these conventions. Before explaining these conventions, a work about TASK time computation is in order.

*Negative parameter values indicate that values are to be obtained from the register specified by the absolute value of the parameter.

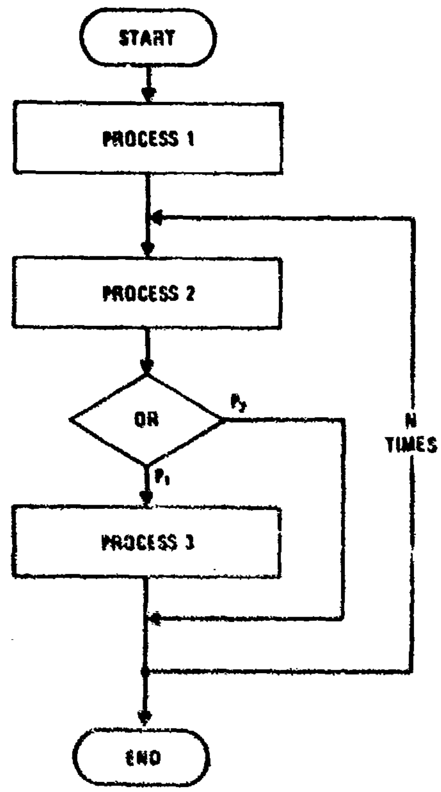
UPDATE TARGET LIST FROM COMBAT REPORTS
(INFORMATION FLOW DIAGRAM)



DATA SYSTEMS

Figure 3

THE LOGICAL RELATIONSHIPS OF THE PROCESSES IDENTIFIED FOR THE FUNCTION.



DATA SYSTEMS

Figure 4

UPDATE TARGET LIST FROM COMBAT REPORTER
(CHART LANGUAGE – SPECIFIC)

10 CHART UPDATE TARGET FILE FROM MISSION REPORTS

OCURRENCE		INVOKE			
1	PROCESS	1		2	* BUILD WORK FILE
2	SET	1	12	3	SET UP LOOP
3	PROCESS	2		4	* GET & REVIEW REPORT
4	BRANCH	6	950	5	STOCHASTIC BRANCH
5	PROCESS	3		6	* UPDATE TARGET FILE
6	D BRANCH	1	3	7	LOOP
7	TERMINATE				END CHART
8	END				

DATA SYSTEMS

Figure 5

UPDATE TARGET FILE FROM COMBAT REPORTS
(CHART LANGUAGE – GENERAL)

10 CHART UPDATE TARGET FILE FROM MISSION REPORTS

OCCURRENCE	INVOKE			
1 PROCESS	1		2	BUILD WORK FILE
2 SET	1	-3	3	
3 PROCESS	2		4	GET & REVIEW REPORT
4 BRANCH	6	-4	5	
5 PROCESS	3		6	UPDATE TARGET FILE
6 D BRANCH	1	3	7	
7 TERMINATE				
8 END				

DATA SYSTEMS

Figure 6

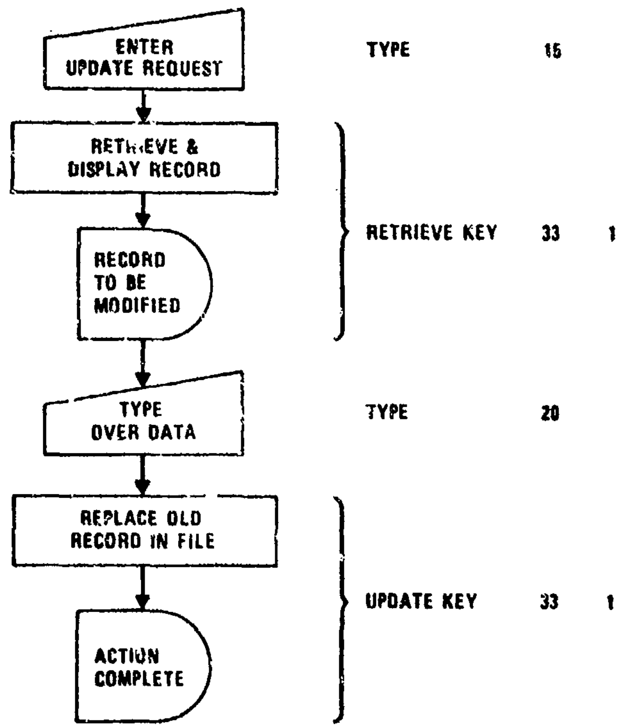
PROCESS DESCRIPTIONS ASSOCIATED WITH THE UPDATE FUNCTION

1	PROCESS	BUILD WORK FILE		
	TYPE		20	
	MOVE SUB		33	10
	END			
2	PROCESS	GET & REVIEW REPORT		
	TYPE		20	
	RETRIEVE KEY		10	
	THINK		30	
	END			
3	PROCESS	UPDATE ONE RECORD OF TARGET FILE		
	TYPE		15	
	RETRIEVE KEY		33	1
	TYPE		20	
	UPDATE KEY		33	1
	END			

DATA SYSTEMS

Figure 7

EXAMPLE PROCESS 3 EXPENDED



DATA SYSTEMS 10687 12

Figure 8

The time required to perform a TASK is computed using both DICTIONARY parameters and PROCESS DESCRIPTION variables. The time is computed using

$$t = A_0 + \sum_{i=1}^{8} A_i P_i$$

where: A_i are DICTIONARY parameters, and

P_i are PROCESS DESCRIPTION variables.

Note that if for a given TASK one of the TASK variables is zero, the corresponding DICTIONARY parameter will not contribute to the time required to perform the TASK.

The convention established was to use two of the DICTIONARY parameters of each task to store the number of kiloinstructions that would be executed in support of the TASK and the number of input/output operations required. The corresponding TASK DESCRIPTION variables were always zero; however, the parameters were tabulated by both TASK and CHART and periodically output. The result was an estimate of the processor power and input/output rates required to support the system.

Extensive use has been made of the subchart capability. Figure 9 presents a structure used to represent the planning operations of a large command and control center. Three CHARTs, 31, 61, and 64, are started at approximately the same time. All other CHARTs in the flow occur as the result of CALLs and/or CAUSEs from these CHARTs or their direct descendants. TEST boxes were used to keep the processing synchronized at appropriate points. MARK TIME and WRITE TIME boxes were used to tabulate the time required to perform various portions of the planning cycle.

The basic time increment used for the last exercise was 0.01 second. With this time step, an execution representing 4.5 hours of system time required 180 CPU seconds and 30 I/O seconds on an IBM 370/165 Computer.

The current capacity of the model is presented in Table 2. These capacities should not be taken as a limitation, as the model is in FORTRAN and they can easily be modified by recompiling the model. The current version of the program requires 255K bytes of core storage during the execution phase.

THE FUTURE

Although use of the analysis process has been highly successful, several areas were discovered where some modifications are in order.

The model automatically produces a listing of the input deck and when comments are included, this list becomes a document which provides traceability from function to system capability. The CHART language, however, is not the best medium for presentation. If an automatic "flow charter" were interfaced with the input processor, a much more readable report would be produced.

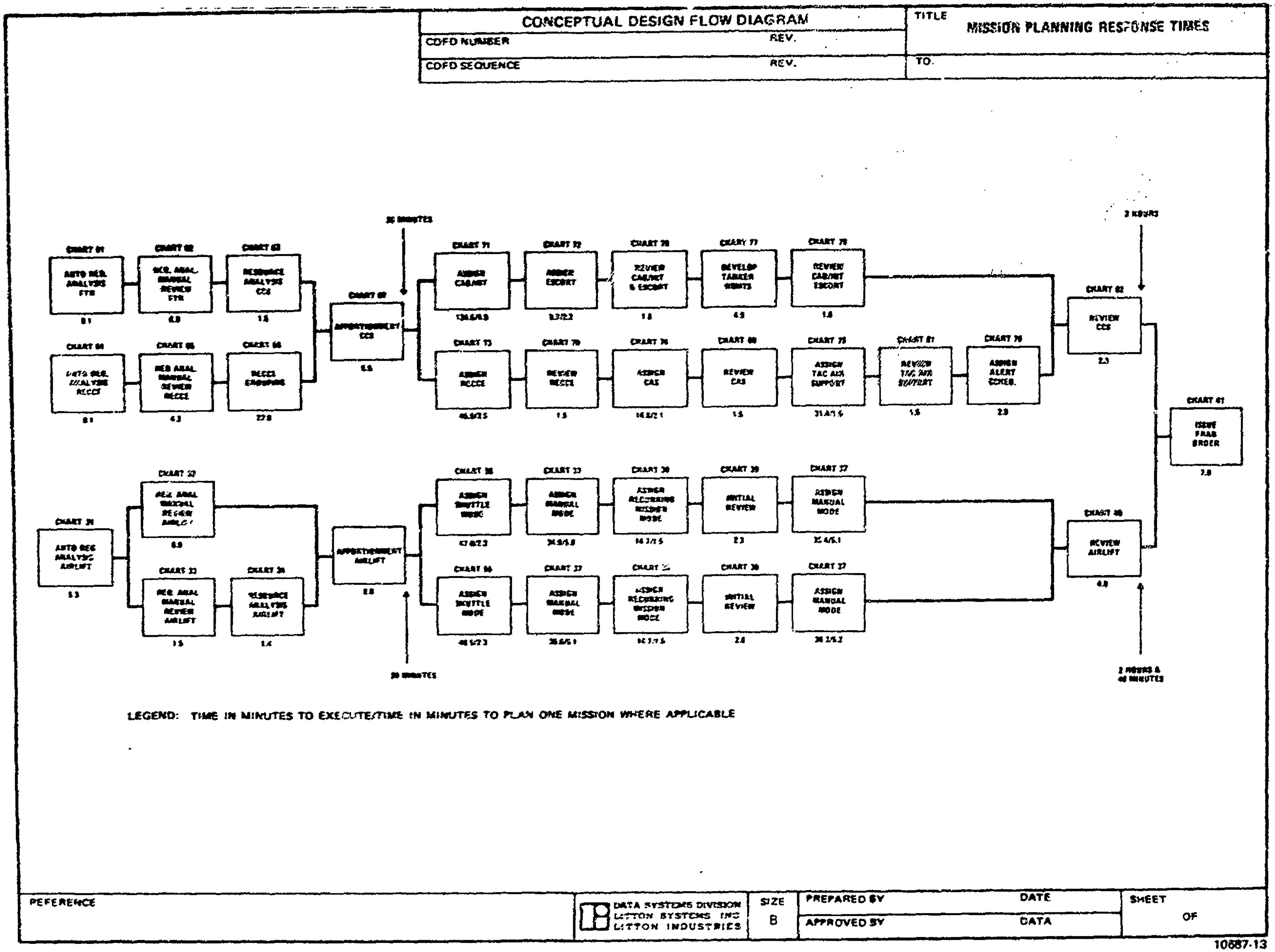

CONCEPTUAL DESIGN FLOW DIAGRAM
CDFD NUMBER
REV.
CDFD SEQUENCE
REV.
TITLE
MISSION PLANNING RESPONSE TIMES
TO.
3 HOURS
30 MINUTES
REVIEW CCS
REVIEW AIRLIFT
ISSUE FRAG ORDER
2 HOURS & 40 MINUTES
LEGEND: TIME IN MINUTES TO EXECUTE/TIME IN MINUTES TO PLAN ONE MISSION WHERE APPLICABLE
REFERENCE
DATA SYSTEMS DIVISION
LITTON SYSTEMS INC
LITTON INDUSTRIES
SIZE
B
PREPARED BY
DATE
APPROVED BY
DATA
SHEET
OF
10687-13

Figure 9

CURRENT MODEL CAPACITIES

CHARTS	250
BOXES	3000
PROCESSES	999
DICTIONARY	
ENTRIES	250
PARAMETERS PER ENTRY	9
TASKS	2000
VARIABLES PER TASK	8
REGISTERS PER CHART	5
COUNTERS	100
CLOCKS	100

DATA SYSTEMS

Table 2

The TEST and associated boxes served the purpose they were intended to; however, they can be expanded to give the model more of a capability in the area of queueing and task stacking.

Finally, with the introduction of very powerful real time systems providing direct access to computers, it appears desirable to change the model to an interactive program. Error checking and diagnostic messages are already included. The modification would give the analyst a chance to correct his errors at the console and enter the execution phase without any obvious errors. During the execution phase, "running diagnostics" could be routed to the console allowing the analyst the options of attempting a recovery, cancelling the function in trouble, or cancelling the execution. An interactive model would most likely reduce system analysis time and expand the number of alternatives to be considered for the center under study.

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13. ABSTRACT

A recent investigation of the applicability of Mission Planner type algorithms toward the planning of RPV Strike missions was conducted under Contract F30602-71-C-0015, the results of which were published in this interim report, "Application of Combat Planning Technology to RPV Command And Control."

A second task was conducted to identify and describe those functions which should be implemented to satisfy the RPV requirements for real time Command and Control with their associated hardware and software implications.

The Mission Planner (Project 691X05) has the responsibility to optimize the ingress and egress of a strike force while simultaneously minimizing the expenditure of resources. Implementation of the Mission Planner System algorithm has been accomplished via a computer aided interactive graphics system which allows the computer to appear transparent to the Planner allowing him easy access to the data base. The system is both simple from an operator's viewpoint while being accurate for survivability and detailed to construct engagements.

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