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14020RPT001

PARAMETRIC ANALYSIS OF MAP DATA

Henry B. Hoyle
DCS Corporation
1330 Braddock Place
Alexandria, VA 22314-1698

31 May 1988

Final Report
Contract Number DAAB07-87-C-F069

Distribution: Unclassified / Unlimited

Prepared for
CENTER FOR NIGHT VISION AND ELECTRO-OPTICS
Fort Belvoir, VA 22060-5677

U.S. ARMY CECOMM
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An approach to using digital map data is needed for future weapons systems. Automatic target recognizers (ATR) need information from digital maps to aid in image interpretation. Digital maps can provide information to help ATRs interpret signatures, to exclude portions of the images from detailed processing, and to put the images in context with the background. Pilots need digital maps to fill in where Forward Looking Infrared (FLIR) sensors are obscured by atmospheric conditions, and to give them the ability to know what to expect over the next hill. This research studied the feasibility of correlating digital maps with FLIR images by doing a parametric error analysis. The concept of an Integrated FLIR/Map System was defined and an approach to further validation of the concept is recommended.

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INTRODUCTION

An approach to using digital map data is needed for future weapons systems. Automatic target recognizers (ATRs) need information from digital maps to aid in image interpretation. Digital maps can provide information to help ATRs interpret signatures, to exclude portions of the images from detailed processing, and to put the images in context with the background. Pilots need digital maps to fill in where Forward Looking Infrared (FLIR) sensors are obscured by atmospheric conditions, and to give them the ability to know what to expect over the next hill.

In the Phase I Small Business Innovative Research (SBIR) number A87-305 effort "Parametric Analysis of Map Data" for the Center for Night Vision and Electro-Optics (CNV&EO), DCS developed a system concept for integrating digital map data with FLIR imagery to benefit both ATR systems and pilotage. DCS first investigated helicopter mission characteristics and developed a system concept for night pilotage applications. To prove the feasibility of this system concept, DCS then determined representative navigation, FLIR, and display subsystems, and investigated the characteristics of available digital map data. DCS derived the error equations for each source of error in the subsystems and data, and developed simulated pictures that showed the errors as they would effect the night pilotage on a display. The results of this study are provided in Appendix A, the interim report. Incorporating feedback from CNV&EO, DCS revised the system concept to emphasize ATR applications, and revised the error calculations for ATR assumptions. This presentation is provided as Appendix B. To conclude the Phase I effort, DCS developed an approach to demonstrate and prove the ATR and pilotage system concept. The proof of concept presentation is provided in Appendix C.

INTEGRATED FLIR/MAP SYSTEM

Figure 1 shows the block diagram for the Integrated FLIR/Map System. The inputs come from the navigation subsystem, the piloting and ATR FLIRs, and the digital map subsystem. The processing is divided into scene correlator map manager and map analyzer modules. The outputs are pixel maps that provide specialized information for each pixel in the ATR FLIR's field of view, and displays for the pilot.

The navigation subsystem provides the latitude, longitude, altitude, heading, and attitude of the aircraft. These parameters are used with the bearing and elevation values from the piloting FLIR's to determine the field of view of the piloting FLIR within the digital map data base. This digital map data and the piloting FLIR image will provide information to the scene correlator. The navigation parameters are used with the bearing and elevation values from the target acquisition FLIR to determine the field of view of the target acquisition FLIR within the digital map data base.

This digital map data will be used by the map analyzer to provide detailed pixel information to the ATR. There are several sources for digital map data from the Defense Mapping Agency. The Digital Terrain Elevation Data (DTED) level II provides elevations at approximately 30 meter intervals. It can be used to construct a three dimensional model of the terrain. Other sources of elevation data include Digitized Elevation Data for FIREFINDER and TERCOM - Terrain Contour Matching Data Base. The Digital Feature Analysis Data (DFAD 1, 1C, 2, 2J) provides map features, such as rivers, lakes, forested areas, road, railroads, and structures. The Vertical Obstruction Data (VOD) provides information on vertical obstructions above a predetermined altitude.

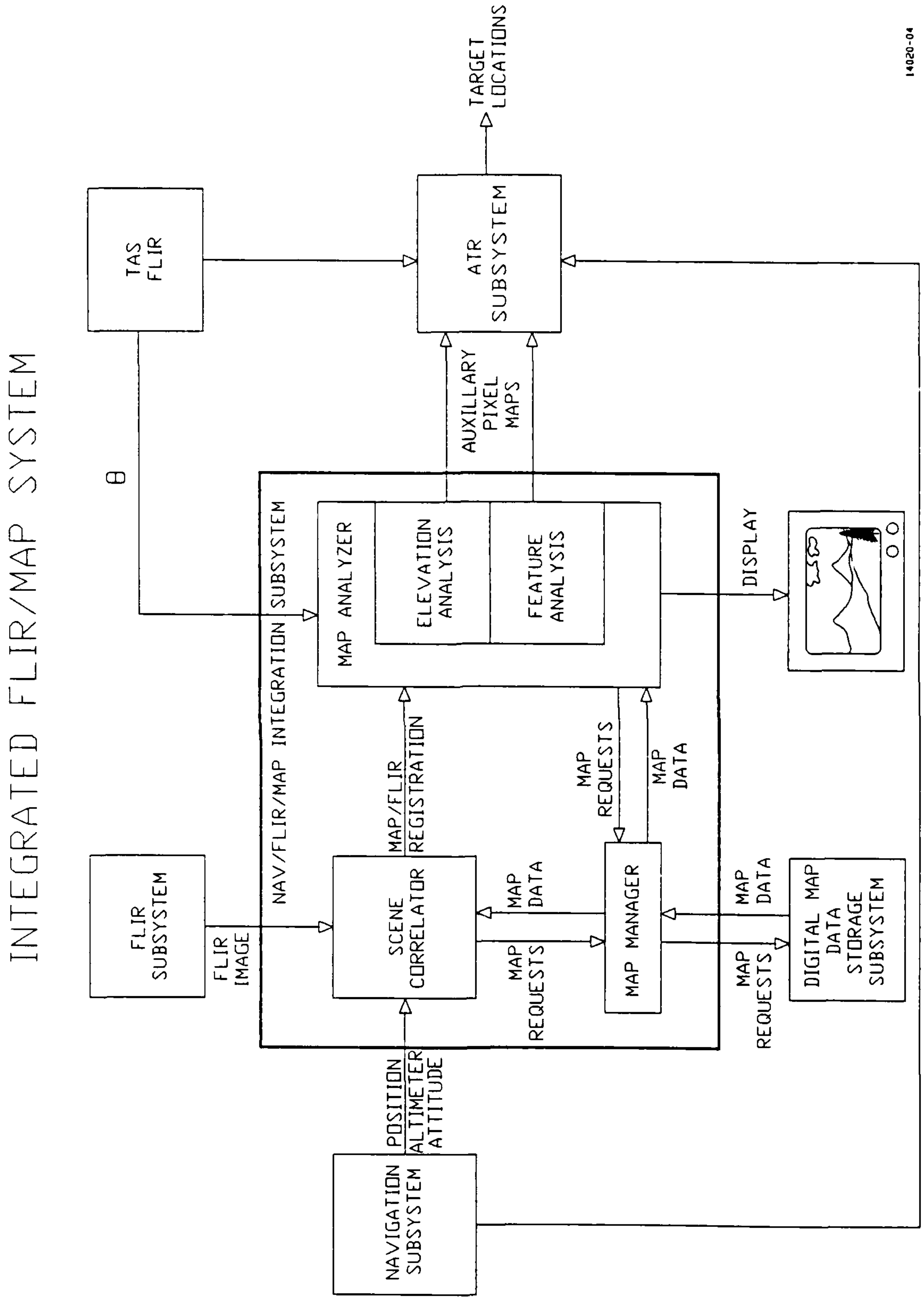

Figure 1. <u>Integrated FLIR/Map System Block Diagram</u>

The scene correlator, map manager, and map analyzer modules process the inputs and produce outputs for the ATR and for the pilot's display. The scene correlator determines what part of the digital map elevation and feature data matches the navigation FLIR image. It determines from which viewpoint the FLIR would be looking into the digital maps, so that it can make the best alignment of FLIR and map data. This correlation eliminates the navigation errors from effecting the accuracy of the system. It will maintain the FLIR/map correlation from the start of the mission to minimize the magnitude of each correction. The map manager is the interface to the digital map data storage subsystem. It maintains the local map data base for the other modules. The map analyzer performs elevation data analysis and feature data analysis. It provides detailed pixel map outputs to the ATR, and it generates FLIR/map displays.

The outputs are pixel maps to the ATR that correspond to the pixels in its target acquisition FLIR, and displays for the pilot. There are a number of different pixel maps. The range map provides the range for each pixel to the FLIR. It can be used by the ATR to determine the pixel sizes, which will indicate the sizes of potential targets. The slope map provides the ground slope for each pixel. It can be used to determine aspect ratios for potential targets, and can exclude targets from impossible slopes. The feature map has a feature code for each pixel that indicates the presence of a feature, such as a lake or a building. It also has a confidence code for each pixel that represents the confidence that the feature is in that pixel. This allows the ATR to compensate for positional uncertainties. The suitability map assigns a rating (e.g. 1-9) to each FLIR pixel. The rating represents the likelihood of a particular target type to be at the pixel. For example, it might assign 1 for a tank in a lake, which is not generally expected, and 9 for a tank along a road which is more probable. The signature map shows the expected signal intensity for each pixel, given known features, and assuming no targets are present. The signatures would be adjusted for the temperature, time of day, and atmospheric conditions. The system will also generate FLIR/map displays for the pilot. Digital maps can overlay FLIR images, and feature symbology can be displayed. The pilot could also ask for a display from a different position and altitude to anticipate what is over the horizon.

ERROR ANALYSIS

DCS performed an error analysis for the inputs to the scene correlator to determine the feasibility of overlaying FLIR imagery with digital map data. A typical helicopter mission is depicted in Figure 2. The helicopter starts in an assembly area and then flies at an altitude of 100 to 200 feet to a holding area. From there it would fly at about 30 feet (called nap of the earth flight) to its battle position. At the battle position it would hover at about 10 feet, popping up to 30 feet to find a target and fire. From the battle position it can either go to a rearming and refueling area or return to the holding area on its way home to the assembly area. From the rearming and refueling area it can either return to the battle or return to the holding area. A mission would last about one hour, and the velocities can reach up to 180 knots. For this error analysis, DCS assumed the aircraft was in the battle position at 30 feet altitude in a hover-hold mode.

Errors are introduced in the system from the navigation, digital map, FLIR, and display subsystems. The navigation errors are in latitude, longitude, altitude, yaw, pitch, and roll. The digital map errors are in latitude, longitude, and elevation. The FLIR and display errors are in their linearities. DCS derived formulas for the angular error for each error source as a function of range, and produced the corresponding graphs. Pictures showing each expected error on a display were produced for a 300 foot hill at a range of 0.75 km and a 3,000 foot peak at a range of 4 km for night pilotage applications. These pictures showed how much the expected errors would effect a pilot's display. A combined error was also computed using the root mean square of the errors, and its corresponding display picture was produced. Next, DCS computed the errors at 1.5 and 3.0 km for use by an ATR system. The biggest error contributor is the digital map, followed closely by the navigation subsystem.

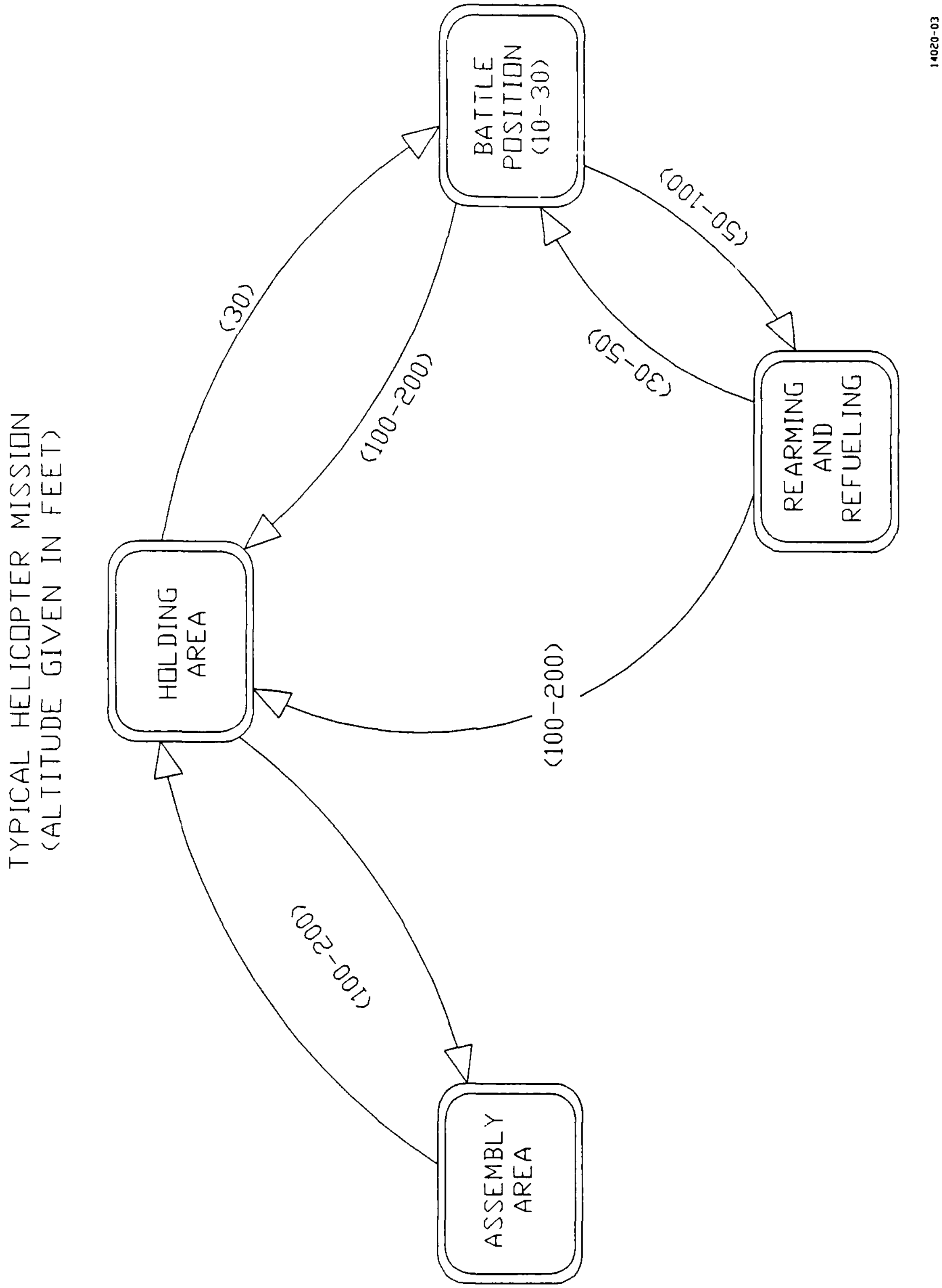

Figure 2. <u>Typical Helicopter Mission</u>

The error computations so far assumed an open loop system, where there is no attempt to compensate for the errors. DCS then computed the errors for a closed loop system with a scene correlator to register the digital map with the FLIR image. This effectively removes the navigation errors from consideration. See Figures 3, 4, 5, and 6 for a summary of the combined errors for open loop and closed loop systems. The Phase I interim report for contract DAAB07-87-C-F069, "Parametric Analysis of Map Data", contains the error analysis details. The report has been provided as Appendix A.

The errors for a closed loop system are within a reasonable margin to be able to provide useful information to a pilot and an ATR.

OPEN LOOP
COMBINED AZIMUTH DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
NAVIGATION POSITION	0.6146°	16.00	0.3066°	16.00
DTED	0.6992°	18.24	0.3489°	18.24
NAVIGATION HEADING	0.1000°	2.62	0.1000°	5.24
DISPLAY LINEARITY @ 50%	N/A	N/A	N/A	N/A
FLIR LINEARITY @ 50% (USING SAIRS)	0.1000°	2.62	0.1000°	5.24
STATISTICAL SUM	0.9416°	24.54	0.4855°	25.37

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Figure 3. Open Loop Combined Azimuth Errors

OPEN LOOP
COMBINED ELEVATION DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
NAVIGATION POSITION	0.0353°	0.9194	0.0175°	0.9194
DTED	0.3862°	12.1615	0.2324°	12.1615
NAVIGATION ATTITUDE	0.1000°	2.6180	0.1000°	5.2360
DISPLAY LINEARITY @ 50%	N/A	N/A	N/A	N/A
FLIR LINEARITY @ 50% (USING SAIRS)	0.0750°	1.9635	0.0750°	3.9270
STATISTICAL SUM	0.4075°	12.6276	0.2645°	13.8414

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Figure 4. Open Loop Combined Elevation Errors

CLOSED LOOP
COMBINED AZIMUTH DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
DTED	0.6992°	18.24	0.3489°	18.24
FLIR LINEARITY @ 50% (USING SAIRS)	0.1000°	2.62	0.1000°	5.24
STATISTICAL SUM	0.7063°	18.43	0.3629°	18.98

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Figure 5. Closed Loop Combined Azimuth Errors

CLOSED LOOP
COMBINED ELEVATION DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
DTED	0.3862°	12.16	0.2324°	12.16
FLIR LINEARITY @ 50% (USING SAIRS)	0.0750°	1.96	0.0750°	3.93
STATISTICAL SUM	0.3934°	12.32	0.2442°	12.78

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Figure 6. <u>Closed Loop Combined Elevation Errors</u>

BENEFITS

An integrated FLIR/map system will benefit ATRs by providing them signature aids, exclusion aids, and context aids. It will benefit pilots by providing map displays.

The system will provide signature aids to help an ATR in its analysis of a FLIR image. A range pixel map will give the range to each pixel in the target acquisition FLIR's image. This will allow the ATR to better estimate the sizes of candidate targets. A slope pixel map will allow the ATR to estimate the aspect ratio of candidate targets in the image, and reduce their possible number of orientations. Expected signature characteristics for the background in the current environment can be computed from the digital feature data. The ATR can use variations in the image from the expected background as an indication that detailed analysis of a region is justified.

The system will provide exclusion aids to help an ATR exclude false targets. The indication of a lake or a dense forest from the digital feature analysis would allow many potential targets to be ruled out. A target might be unlikely to be on terrain that is at a given slope. A candidate target might match a digital feature of a similar size.

The system will provide context aids to help an ATR determine whether a candidate is a target. Digital feature analysis data can indicate the candidate is on or near a road, railroad, air strip, or body of water. Digital terrain elevation data could indicate the target is in the air.

The system will provide map displays to help the pilot. Digital maps will overlay FLIR images to fill in areas that are obscured by conditions in the atmosphere. Feature symbology will be displayed to help the pilot recognize geographic and man-made landmarks. The pilot can also ask for a display from different position and altitude to anticipate what is over the horizon.

RECOMMENDED PHASE II TECHNICAL OBJECTIVES AND APPROACH

TECHNICAL OBJECTIVES

The technical objectives that are recommended for the Phase II effort are to:

1. Validate the concept of the Integrated FLIR/Map System.

2. Demonstrate that the system would provide the stated benefits for ATR and pilotage uses.

The first objective is to validate the system concept by developing the algorithms to accurately register the FLIR and map data. To validate the system concept, the scene correlation capability must be developed. Without an accurate registration of image and map data, the ATR and piloting aids are inaccurate and could be dangerously misleading. When the digital map accurately overlays the FLIR image, then the pixel maps to assist ATRs can be computed and displays can be generated. The second objective is to demonstrate the scene correlation, pixel maps and pilot displays with real FLIR imagery and map data on a computer workstation.

APPROACH

DCS's approach to meeting the technical objectives is:

1. Obtain digital maps of the Shenandoah region of Virginia.

2. Collect FLIR imagery of Shenandoah region from a helicopter.

3. Develop an integrated FLIR/map workbench, which allows

graphic display of imagery and map data, and allows easy choice and modification of algorithms.

4. Use the workbench and the Shenandoah data to test correlation and pixel map algorithms, and display techniques.

5. Demonstrate FLIR/map correlation with the Shenandoah data.

This approach of using real FLIR and digital map data will validate the system concept by demonstrating graphically the registration of FLIR imagery and digital maps. The demonstration will follow the helicopter on its mission, continually updating the FLIR/map registration as it goes. The ATR system aids may be displayed by operator command at any time.

RECOMMENDED PHASE II WORK PLAN

INTRODUCTION

DCS recommends implementing its approach by breaking down the work into three work packages: data collection, workstation design, and algorithm development and demonstration. The data collection task will develop and execute a plan to collect FLIR imagery and record navigation data from a helicopter flight. Digital elevation and feature data will be obtained for the flight path. The workstation design task will develop a computer based workstation that is capable of digitizing the FLIR video, performing various image processing functions, and displaying the images. It will also be able to read digital maps from magnetic tape, crate graphics to overlay the FLIR imagery, and generate pixel maps for use by an ATR. The algorithm development and demonstration task will develop the scene correlation and pixel map algorithms. A demonstration will be developed using the algorithms on the workstation to dynamically show the scene correlation in action for the data collection task flight. Graphic representations of the pixel maps will be displayed.

DATA COLLECTION TASK

The DCS recommendation is to rent a helicopter, assemble a data collection system on it, and collect imagery on a route from Northern Virginia to the Shenandoah region of Virginia and back. DTED and DFAD digital map data will be obtained for the route. Figure 7 is a block diagram of the helicopter data collection system. A DCS owned FLIR can collect the FLIR imagery, which will be recorded on a portable U-Matic format VCR. The latitude/longitude position will be maintained by a global positioning system (GPS) navigation system that uses satellite signals to determine the position. The altitude will be determined by a radar altimeter. The bearing and attitude will

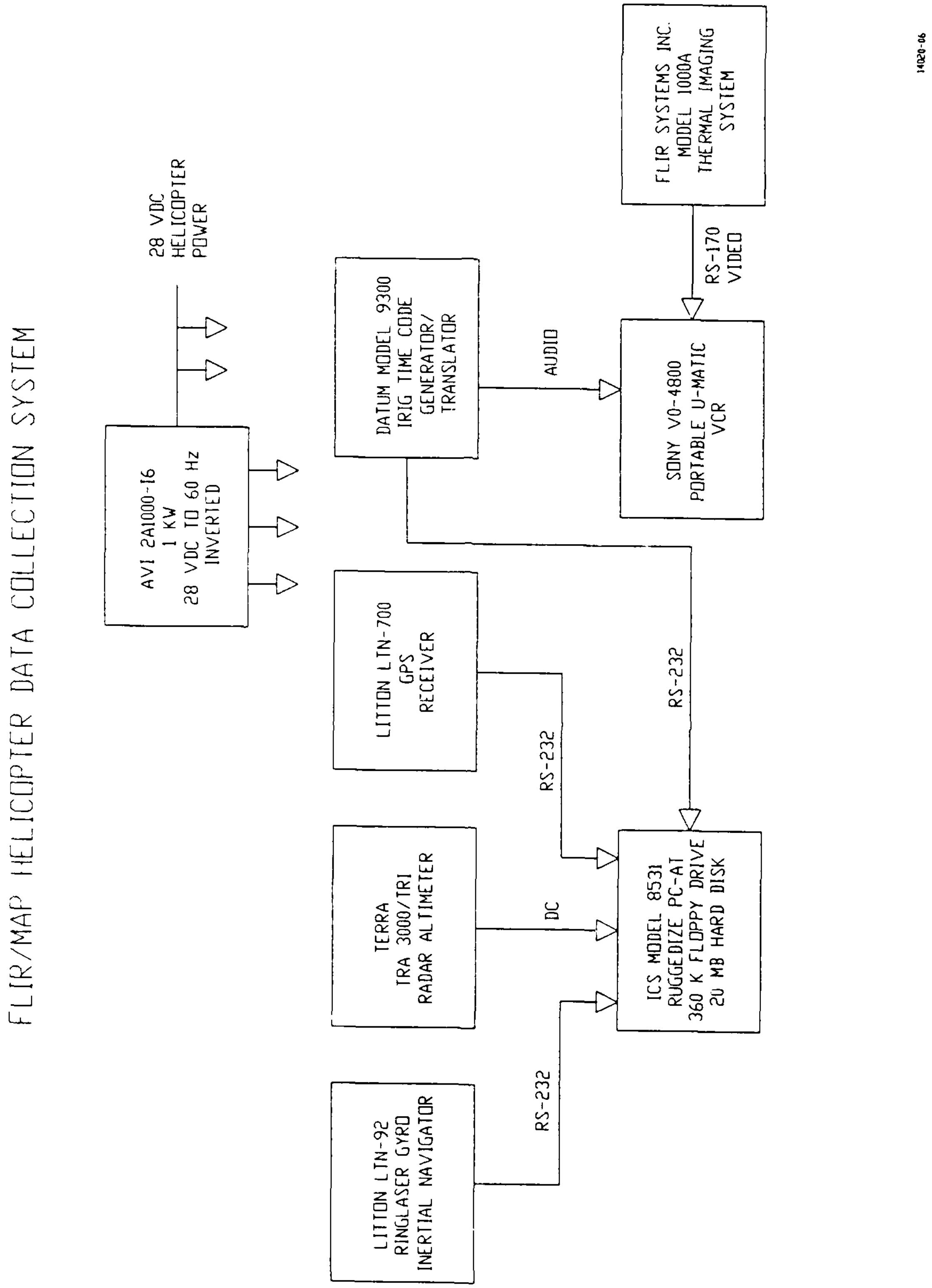


Figure 7. <u>Helicopter Data Collection System Block Diagram</u>

be determined by an inertial navigator. These navigational systems will be connected to a ruggedized personal computer, which will store the data on a hard disk during the flight. An IRIG time code generator will provide time of day data to the personal computer and to the audio track of the VCR for accurate time coordination of the imagery and navigation data. A power invertor will convert the 28 VDC current available on the helicopter to 60 Hz AC power for use by the instruments.

A route for the helicopter will be planned to go from Northern Virginia to the Shenandoah region of Virginia. It will provide a view of major peaks, and will go through a valley as a helicopter mission might be expected to do. It will also go through the Piedmont region, which will require scene correlation without being able to key off of major peaks. The route should also follow and cross major roads as a secondary means of verifying the position, and may need to pass an airport for refueling. The Government will approve the general flight plan. Details will be worked out with the pilot.

DCS considered two alternatives for the data collection: using the system described above, or using a Government owned aircraft without the precise navigation equipment. While the latter alternative would save money on the rental of equipment, more manual effort would be expended in generating the aircraft location and orientation after the flight. This would be expensive. The results would be less precise and would not provide realistic flight data. This would make the algorithms for scene correlation more difficult, and if they failed to correlate satisfactorily, the results of this proof of concept would be inconclusive. The safest course of action is to use the sophisticated data collection scheme described above.

The data collection task will produce the following deliverables:

1. Data collection plan
2. Data collection software and user guide
3. FLIR imagery on U-Matic tape
4. Navigation data in digital format
5. Data collection hardware that was purchased
6. Data collection mission report

WORKSTATION DESIGN AND FABRICATION TASK

DCS recommends the design of a computer workstation that is capable of processing the FLIR imagery, navigational data, and digital map data. It will be able to display the imagery with graphics overlays of map data and ATR aids derived from map data. Figure 8 is a block diagram of the workstation. The main computer is a Sun Microsystems 3/260 CXP workstation with 654 MBytes of disk space and both half and quarter inch magnetic tapes. It has a floating point accelerator and graphics accelerator to maximize the performance. A 19 inch color monitor with a resolution of 1152 x 900 pixels will provide its display capability. Attached to the workstation is an image processing subsystem, consisting of an analog/digital interface, frame buffer, a pipeline processor and a real-time convolver. The analog/digital interface will digitize an analog video signal and put the digital representation in the frame buffer. It can also convert the frame buffer to a video signal to display on an analog video display. The pipeline processor is programmed to perform various filters on the data, as specified by the controlling program. The real-time convolver allows very fast applications of convolution algorithms to the data. A U-Matic format VCR is connected to the image processor to read in the video signal. An IRIG time code generator/translator reads the time signal from the audio track of the VCR to provide time coordination between the video signal and the navigation data. The workstation design and fabrication deliverables are:

1. Workstation Plan
2. Workstation Hardware and Vendor Software
3. User Manuals

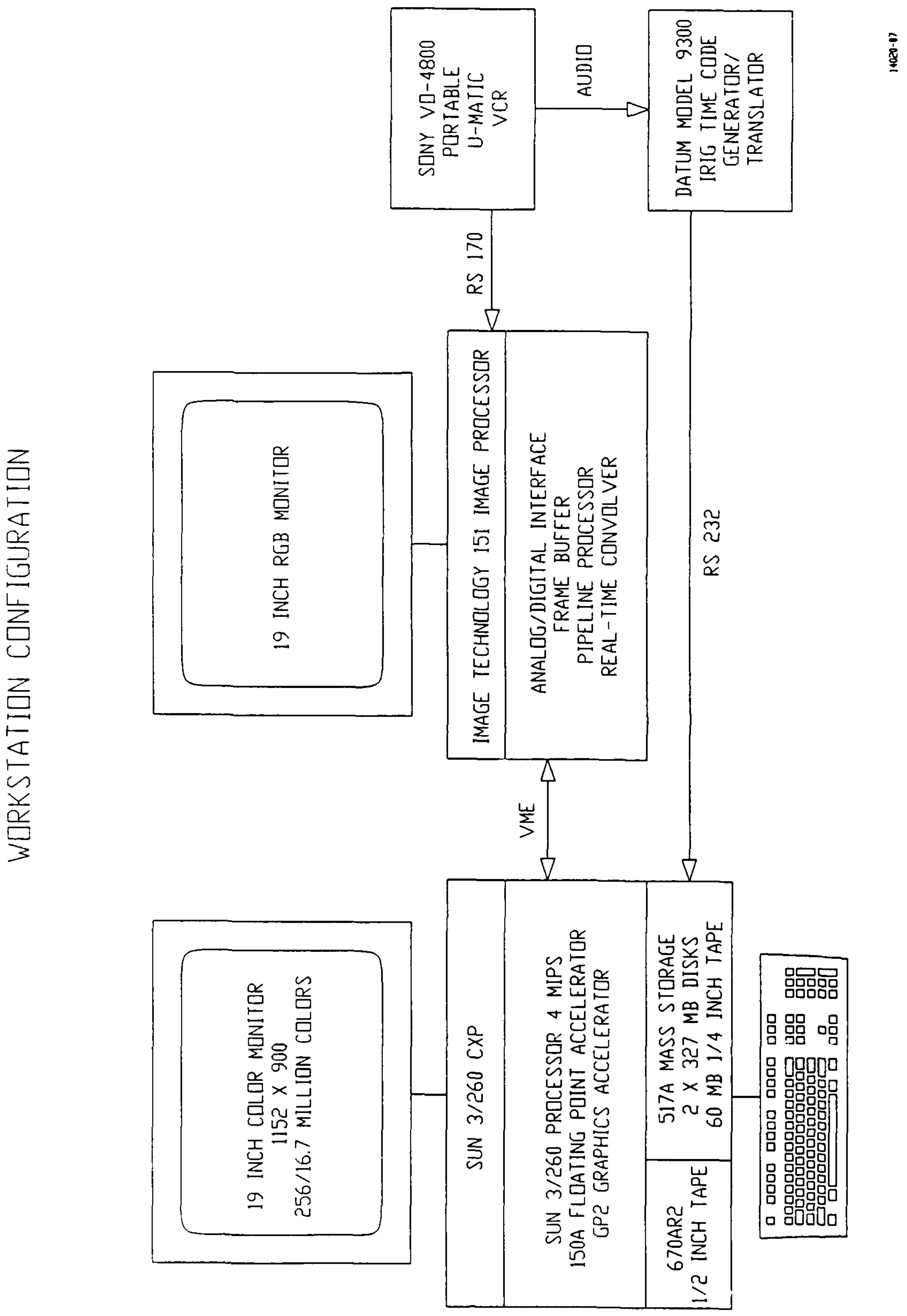


Figure 8. <u>Workstation Block Diagram</u>

ALGORITHM DEVELOPMENT AND DEMONSTRATION TASK

Figure 9 shows the software functional organization for the workstation. Functionally, the software has four major sections: the user/data interface, the FLIR/map correlation, elevation data analysis, and feature data analysis.

The <u>user/data interface</u> gets commands from the user and presents menus, data, and graphics for the user. It also provides the interface to the physical devices connected to the workstation: the image processor, the IRIG time code translator, and the data management devices (disks and tapes). It simulates the interface to a navigation subsystem, by reading the navigation data collected on the mission and coordinating it with the IRIG time.

The <u>FLIR/map correlation</u> provides the scene correlation capabilities. DCS would initially approach the correlation by approximating the map position from the navigation data, and estimating the maximum error from a dynamic error analysis. DCS will seek to develop metrics for map projections that will allow rapid discrimination between the ridge lines extracted from the image and the candidate map projections. The final candidate map projection will be aligned with the image.

The <u>elevation data analysis</u> will produce the range and slope maps derived from the elevation data. These maps will provide the range and the slope corresponding to each pixel of the target acquisition FLIR. They can be used by an ATR to determine pixel sizes and aspect ratios.

The <u>feature data analysis</u> will produce the feature, suitability, and signature maps derived from the feature data. A feature map will consist of a feature code for each pixel in the target acquisition FLIR. Since there is some uncertainty associated with the exact location of the features, a confidence code will

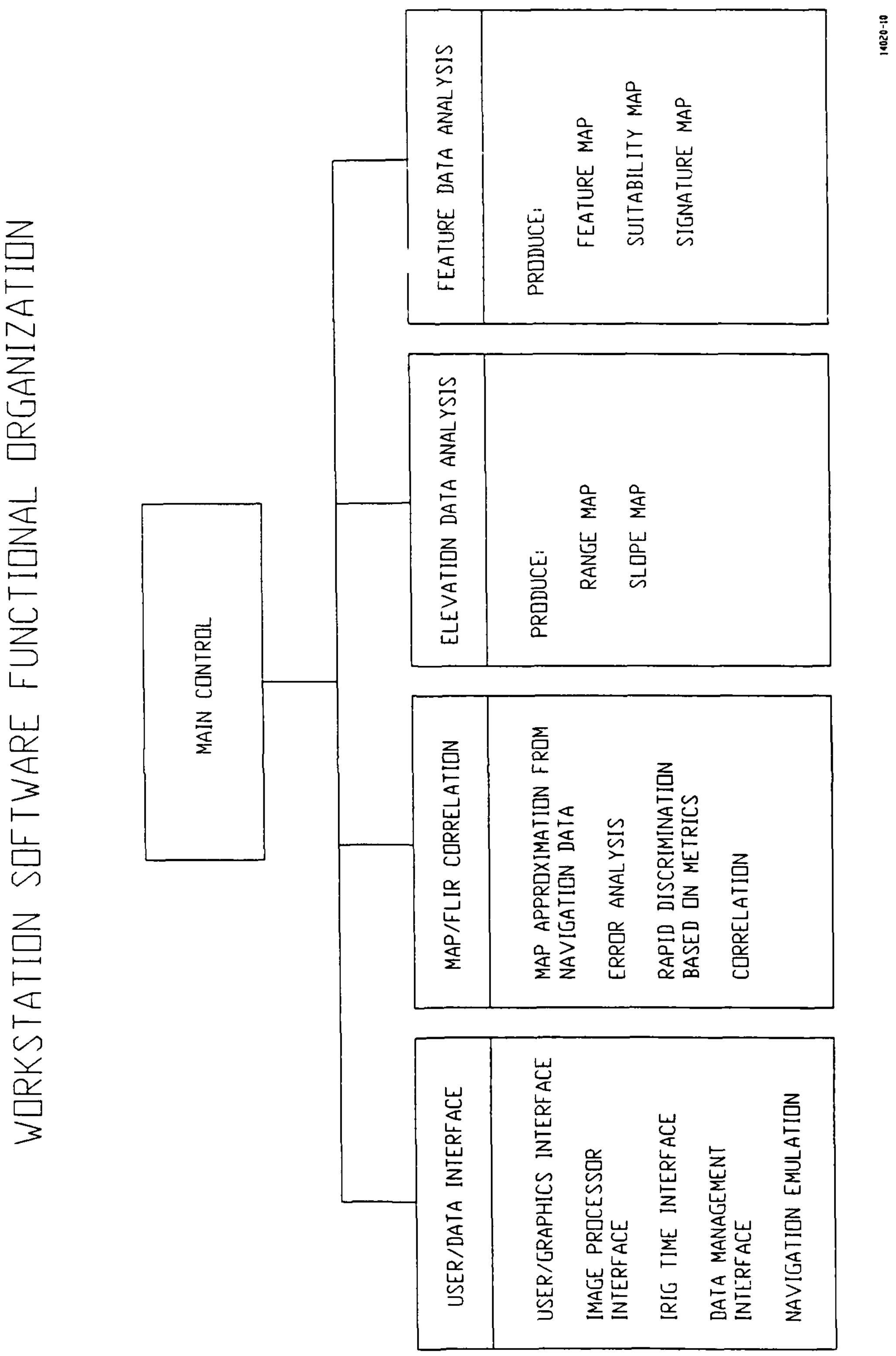


Figure 9. <u>Software Functional Organization</u>

also be provided for each feature for each pixel. The feature map can be used to prevent features from being classified as targets. A suitability map will provide a rating for each pixel which represents an estimate of the suitability for a particular type of target to be located at that pixel. The workstation will compute a signature map that represents the expected intensity for each pixel based on the type of terrain and features, adjusted for the temperature, time of day, and atmosphere.

The algorithm development and demonstration task will culminate in a demonstration. Figure 10 shows the possible organization of displays for the demonstration. The image processor can display the raw FLIR image, or processed images. The high resolution of the Sun monitor can show the FLIR image overlaid with the correlated digital map projection using approximately one-fourth of its screen. The demonstration would show the correlation taking place dynamically. The rest of the screen can be divided into windows to show various pixel maps, commands, statistics, and graphs.

SCHEDULE

The Phase II effort will be performed over a 24 month period. Figure 11 shows the Phase II schedule.

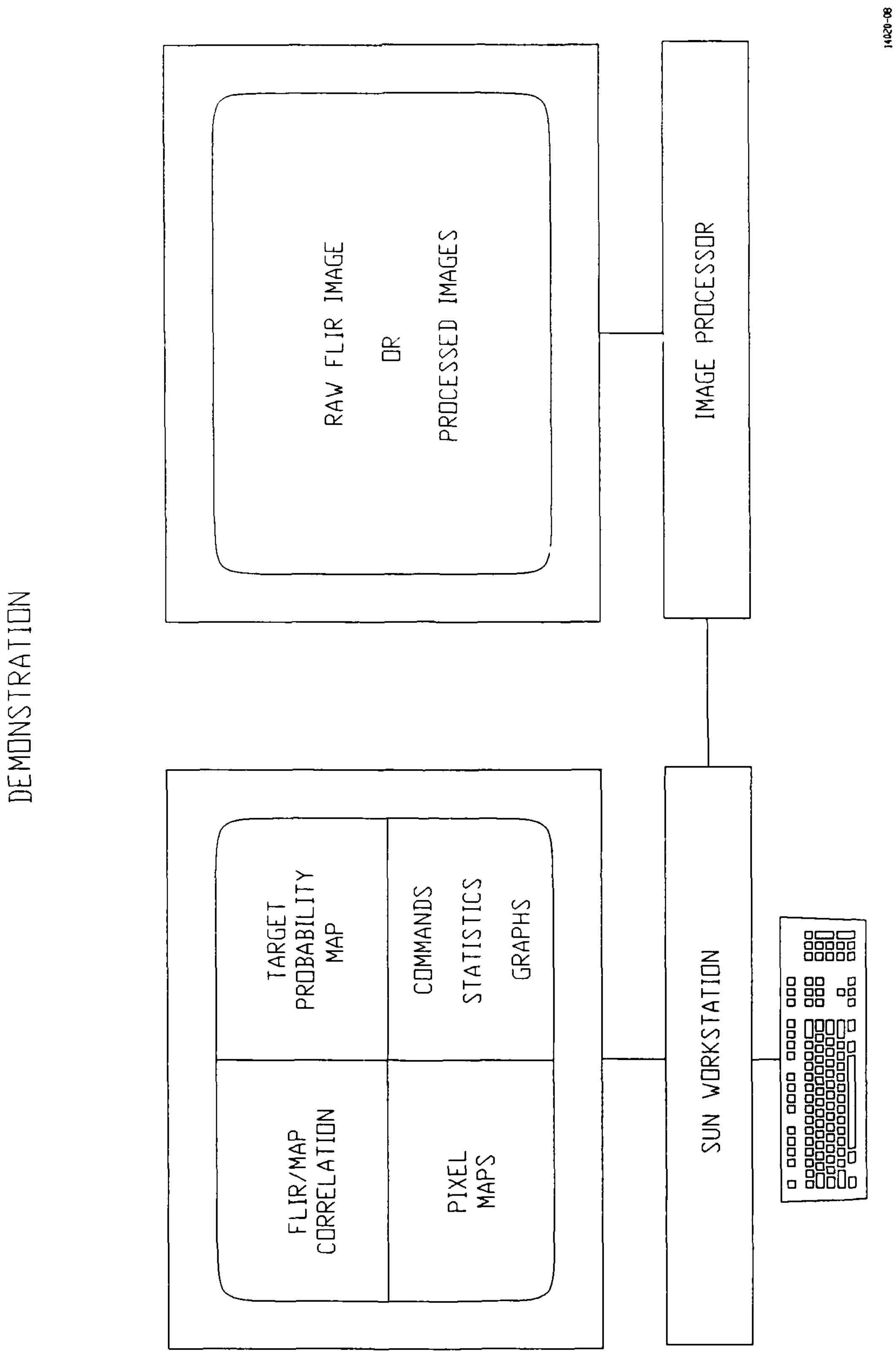


Figure 10. <u>Demonstration</u>

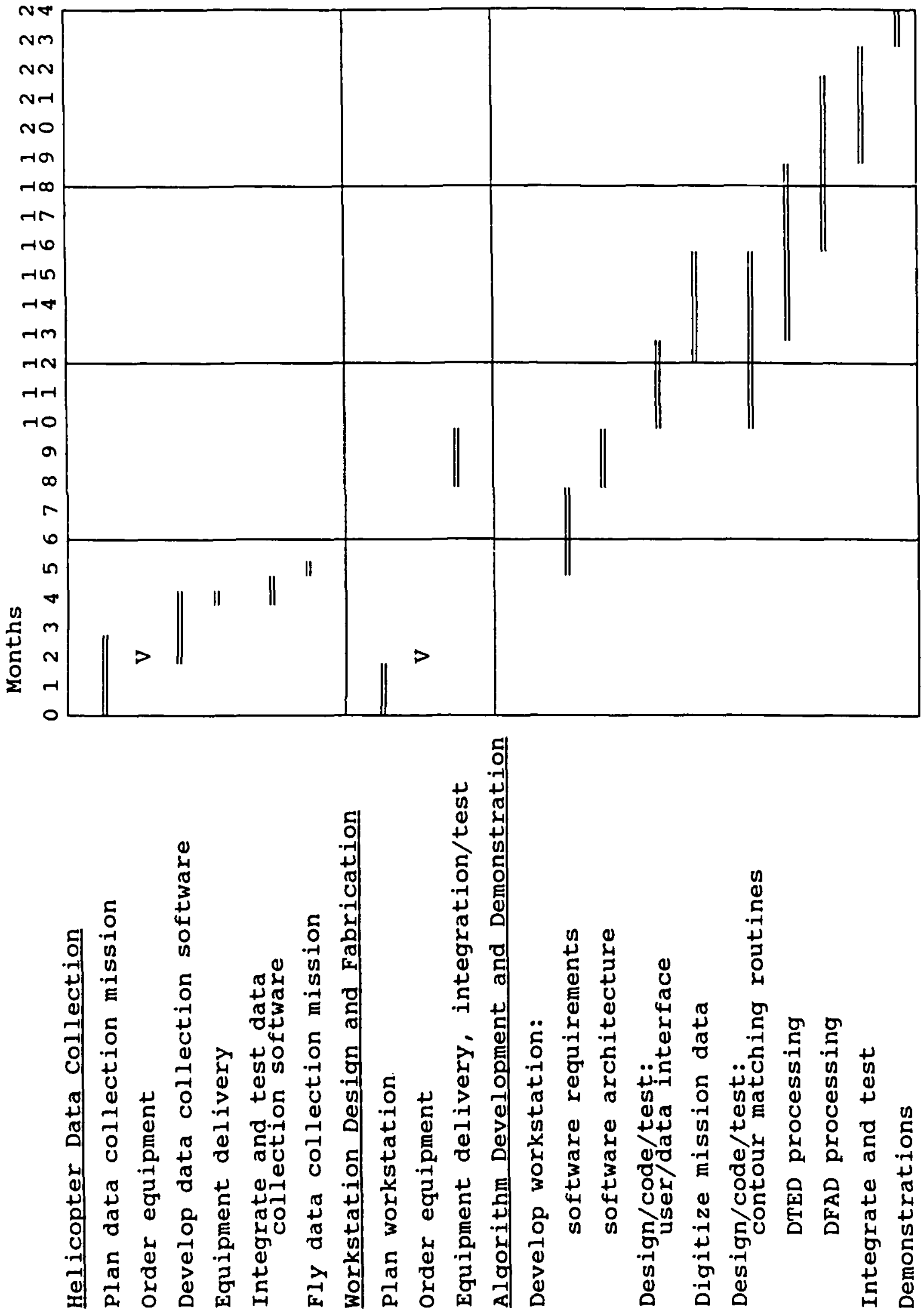


Figure 11. Phase II Schedule

PURCHASES FOR PHASE II

The following items need to be purchased for the data collection task:

TERRA	TRA 3000/TRI 30 Altimeter
DATUM	Model 9300 IRIG Generator/Translator
AUI	Model 2A1000-16 Inverter
ICS	Model 8531 Ruggedized PC-AT
SONY	Model V0-4800 Portable U-Matic VCR

The following items need to be purchased for the workstation design and fabrication task:

3/260 CXP-8 SUN Workstation With 8MB
- 19" Color monitor 1152 X 900
- 256/16.7 Million Colors
- Graphic Acceleration H/W
- Double Buffering
- 16 Bit Z Buffer For Fast 3-D

150A Floating Point Accelerator

517A 654 (2 X 327)MB Disk With 60 MB 1/4 Inch Tape Cartridge

670AR2 1600 bpi 1/2 Inch Tape Subsystem

950A Meter High Cabinet For Tape

SYS3-01 System Software

Imaging Technology 151 Image Processor

- ADI-151 Analog/Digital Interface
- FB-151 Frame Buffer
- ALU-151 Pipeline Processor

RTC-151 Real-Time Convolver

ITEX 151 Software Library

DATUM Model 9300 IRIG Generator/Translator

SONY Model VO-4800 Portable U-Matic VCR

The U-Matic VCR and IRIG time code generator/translator are shared with the data collection task.

RENTALS FOR PHASE II

The following items need to be leased for one month for the data collection task:

LITTON LTN-92 Inertial Navigation System

LITTON LTN-700 GPS Receiver

16 hours of helicopter rental (10 hours to equip, 6 hours of flight time)

APPENDIX A

DCS CORPORATION 1055 N Fairfax Street * Alexandria, Virginia 22314 * (703) 683-8430

February 24, 1988

Center for Night Vision and Electro-Optics
Fort Belvoir, Virginia 22060-5677
ATTN: AMSEL-NV-ACD (G. D. Singer)

Subject: Parametric Analysis of Map Data

Reference: Contract DAAB07-87-C-F069

Enclosure: (1) *Contractor's Progress, Status, and Management Report - Interim*

Dear Mr. Singer:

This interim report is submitted in accordance with CDRL Sequence A002 for the referenced contract and covers the period from the start of contract to 15 February 1988.

Please contact me at (703) 683-8779 if you have any questions or comments concerning this report.

Sincerely,

DCS CORPORATION

Henry B. Hoyle

Henry B. Hoyle
Project Engineer

Contract DAAB07-87-C-F069

Parametric Analysis of Map Data

Contractor's Progress, Status, and Management Report - Interim

24 February 1988

CDRL Sequence A002

For

Code W26P72
Center for Night Vision and Electro-Optics
Fort Belvoir, Virginia 22060-5677
ATTN: AMSEL-NV-ACD (G. D. Singer)

By

DCS Corporation
Henry B. Hoyle
1055 N. Fairfax Street
Alexandria, Virginia 22314
(703) 683-8779

UNCLASSIFIED

Contract DAAB07-87-C-F069
Parametric Analysis of Map Data

Contractor's Progress, Status, and Management Report - Interim
24 February 1988

a. Summary of work performed:

1. Defined the Integrated FLIR/Map Display System concept.

2. Investigated navigational systems.

3. Investigated FLIRs and FLIR displays.

4. Investigated digital map data.

5. Performed error analyses.

See Attachment (1), Viewgraph Presentation - Interim Program Review for details of the work performed.

b. Work to be performed for the remainder of the contract:

1. Determine the system requirements to bound the error to acceptable limits.

2. Develop a computer model to demonstrate the concepts.

c. Status of contract funds:

Costs accumulated through January 1988: $17,631

Funds remaining: 31,755

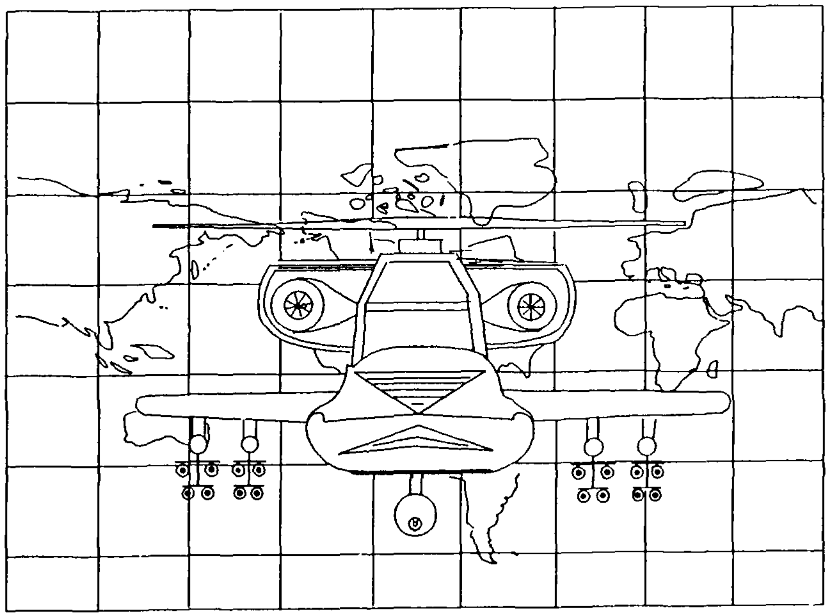
ATTACHMENT (1)

INTERIM PROGRAM REVIEW

PARAMETRIC ANALYSIS OF MAP DATA

INTERIM PROGRAM REVIEW

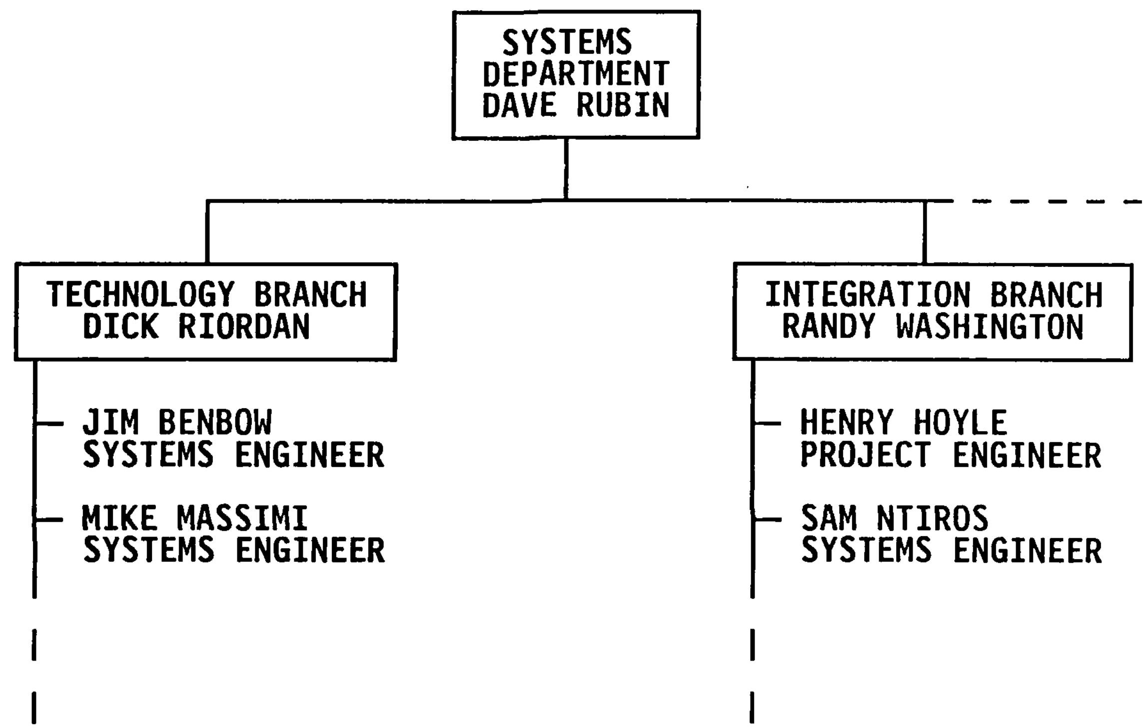
PARAMETRIC ANALYSIS OF MAP DATA



JCP 02/24/88
14020-29

AGENDA

OVERVIEW	HOYLE
SYSTEM CONCEPT	HOYLE
ERROR ANALYSIS	NTIROS
CONCLUSION	HOYLE
PROGRAM STATUS	HOYLE


SYSTEMS
DEPARTMENT
DAVE RUBIN
TECHNOLOGY BRANCH
DICK RIORDAN
JIM BENBOW
SYSTEMS ENGINEER
MIKE MASSIMI
SYSTEMS ENGINEER
INTEGRATION BRANCH
RANDY WASHINGTON
HENRY HOYLE
PROJECT ENGINEER
SAM NTIROS
SYSTEMS ENGINEER

OBJECTIVE

TO ASSESS THE DEGREE OF CORRELATION THAT COULD BE ACHIEVED BETWEEN FLIR VIDEO AND SOME FLIR VIDEO ENHANCEMENT DERIVED FROM DMA DIGITAL MAP DATA.

THE INTENT IS TO EVALUATE THE POTENTIAL APPLICATION OF THIS SENSORY INTEGRATION AND TO PREDICT ITS SUCCESS IN NIGHT-TIME AUTONOMOUS NAVIGATION AND SCENE FEATURE RECOGNITION.

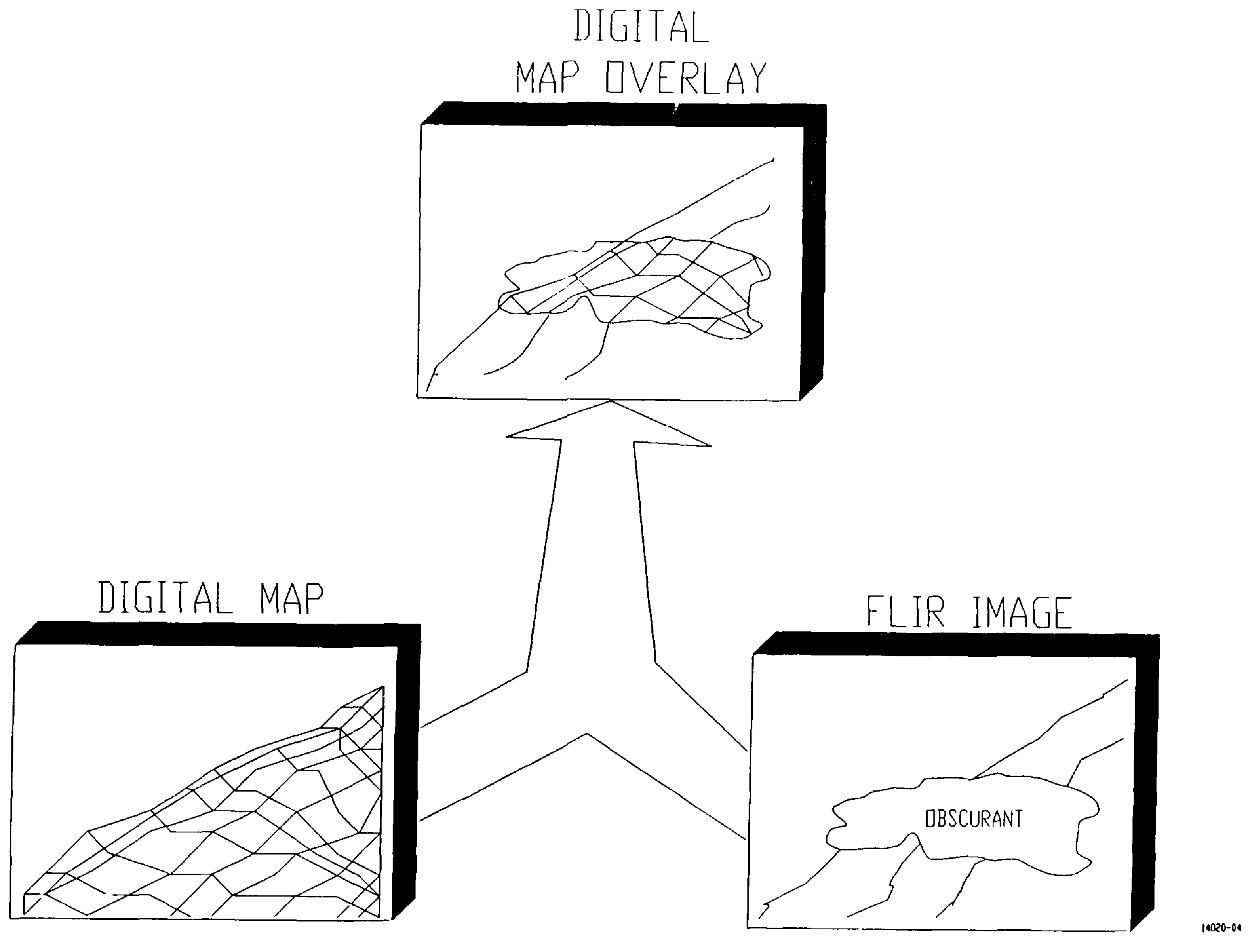
ACCOMPLISHMENTS TO DATE

* DEFINED SYSTEM CONCEPT
* INVESTIGATED NAVIGATIONAL SYSTEMS
* INVESTIGATED FLIRS AND FLIR DISPLAYS
* INVESTIGATED DIGITAL MAP DATA
* PERFORMED ERROR ANALYSIS

INTEGRATED FLIR/MAP DISPLAY SYSTEM CONCEPT

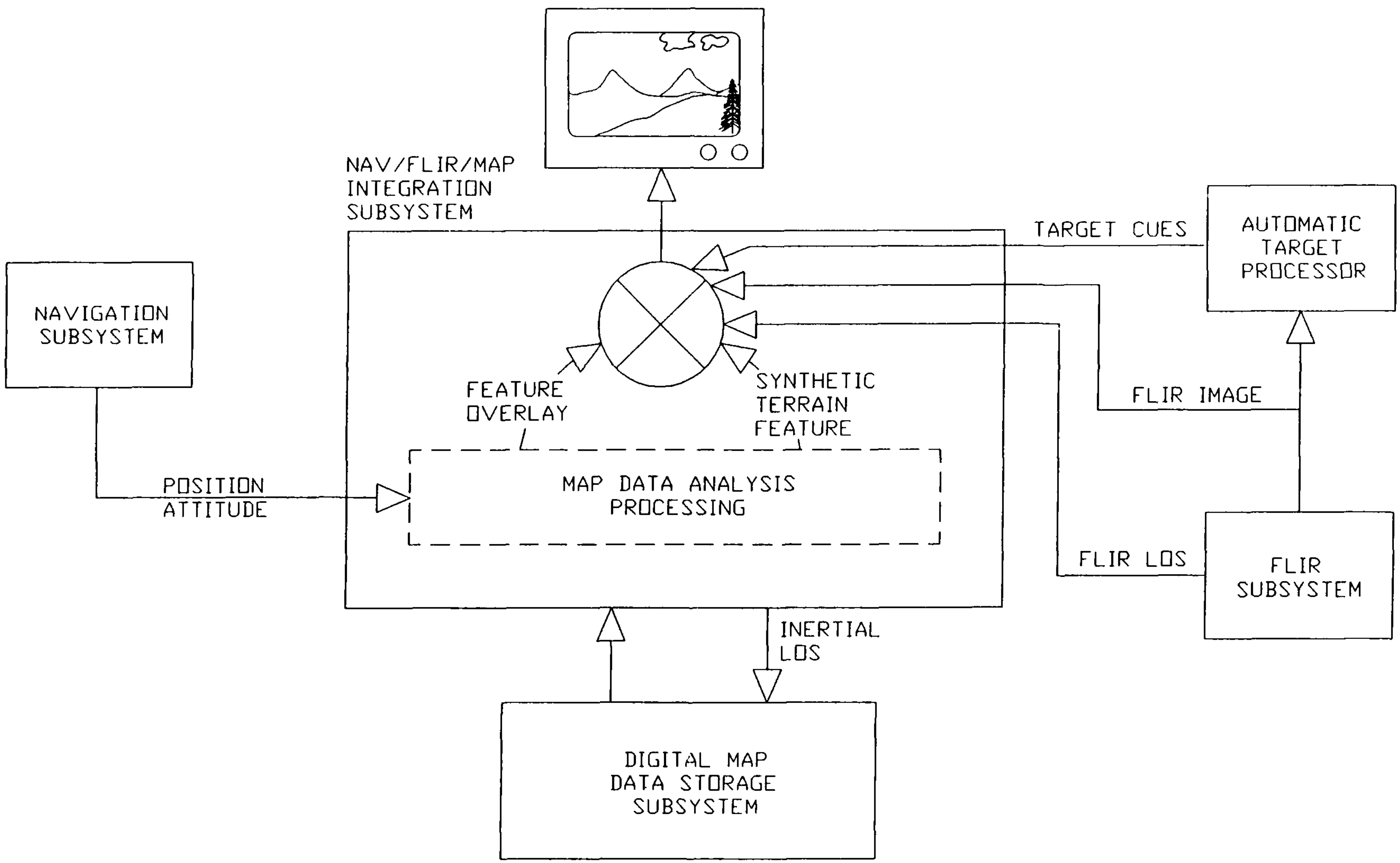
* DISPLAY CONCEPT
* DISPLAY SYSTEM BLOCK DIAGRAM
* PROCESSING CONCEPT
* TYPES OF MAP DISPLAYS

INTEGRATED FLIR/MAP DISPLAY SYSTEM - DISPLAY CONCEPT



INTEGRATED FLIR/MAP DISPLAY SYSTEM

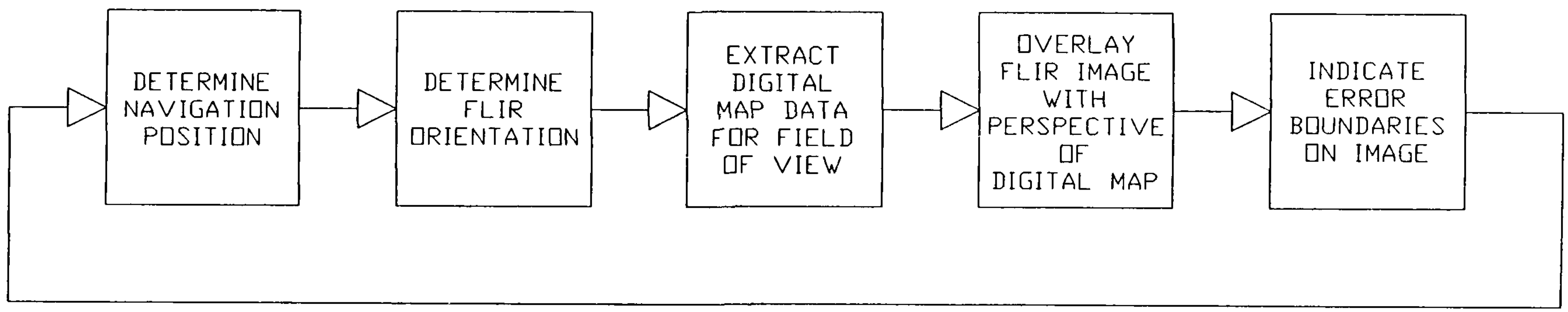
BLOCK DIAGRAM



14020-02

INTEGRATED FLIR/MAP DISPLAY SYSTEM

PROCESSING CONCEPT



14020-01

Wire Frame Perspective Map

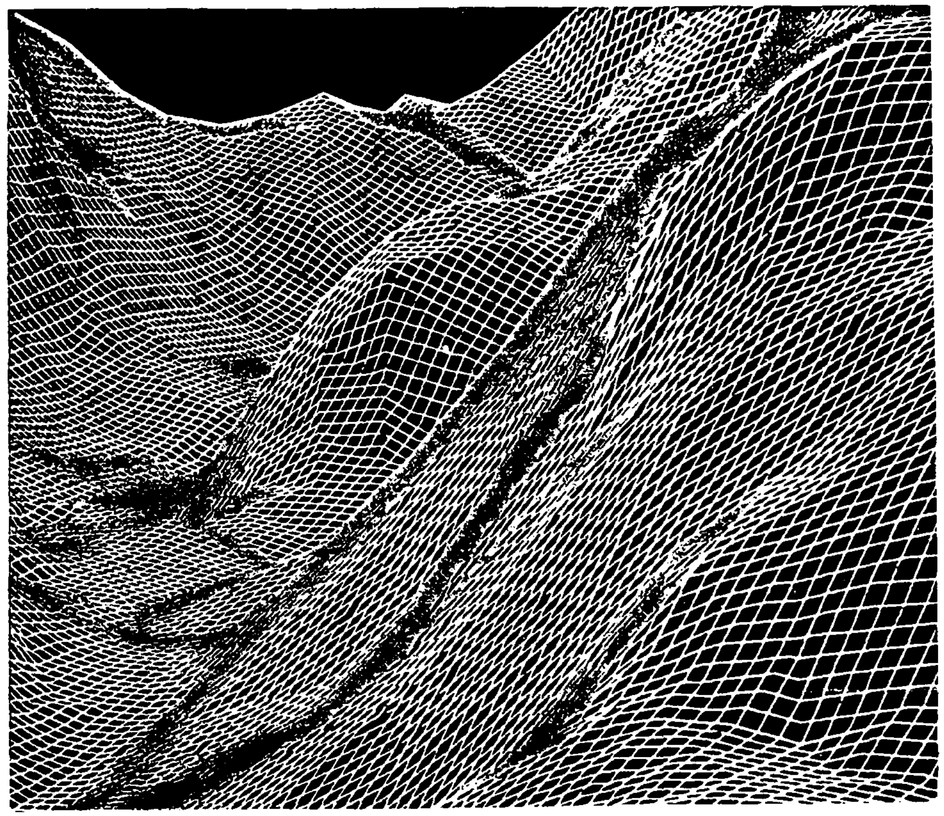
Advantages

Fast to compute

Easy to overlay on another image

Disadvantages

Does not have a natural appearance



Shaded Perspective Map

<u>Advantages</u>

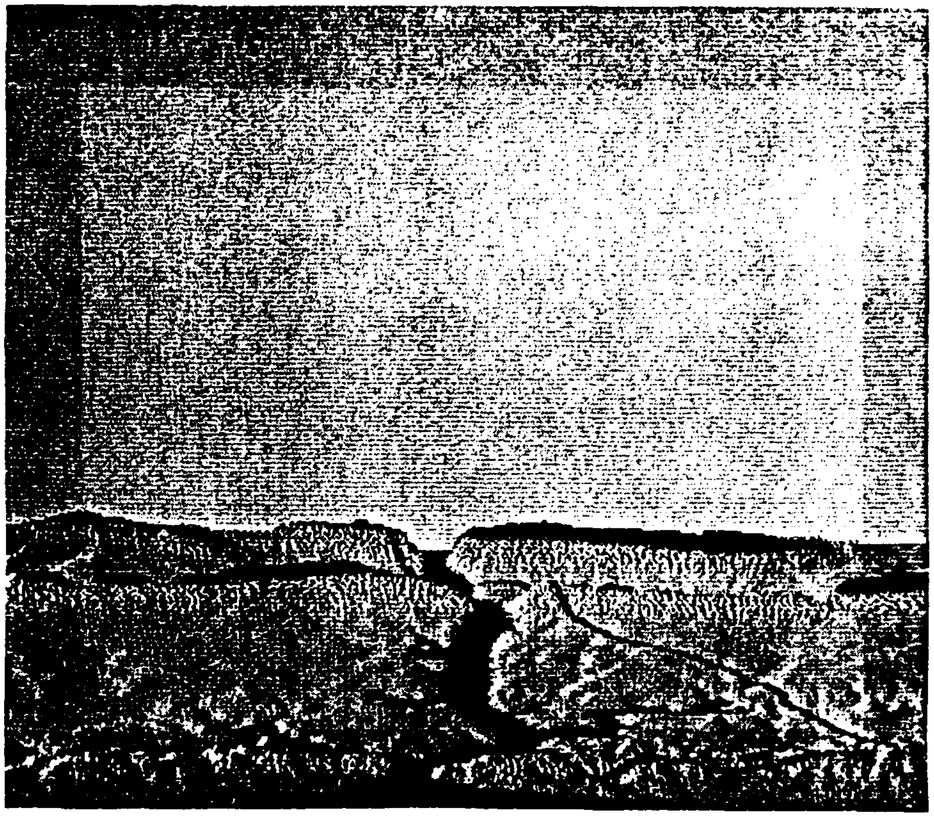
Has a natural appearance

<u>Disadvantages</u>

Must define an artificial light source

Slower to compute

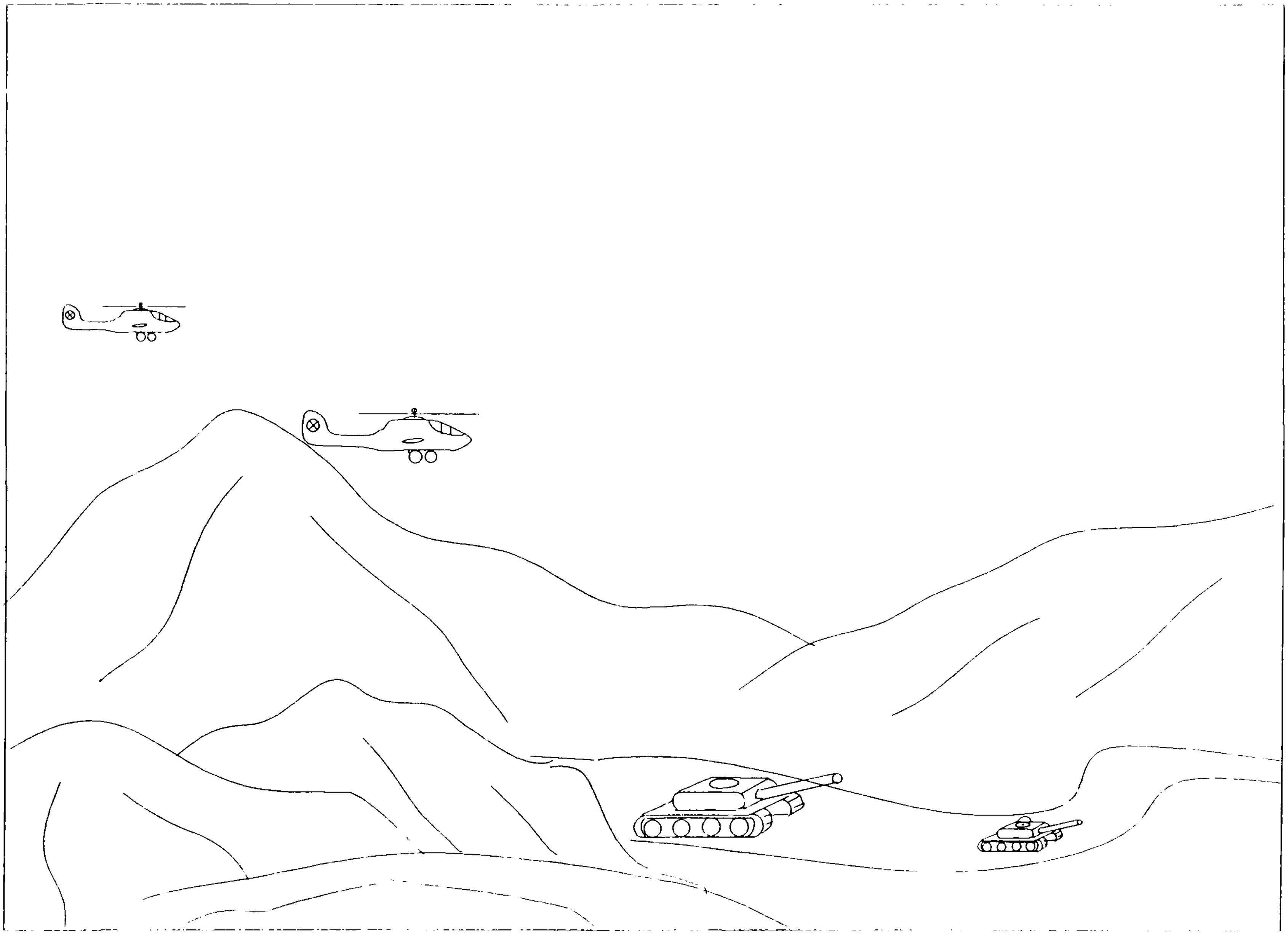
Complicated to overlay on another image



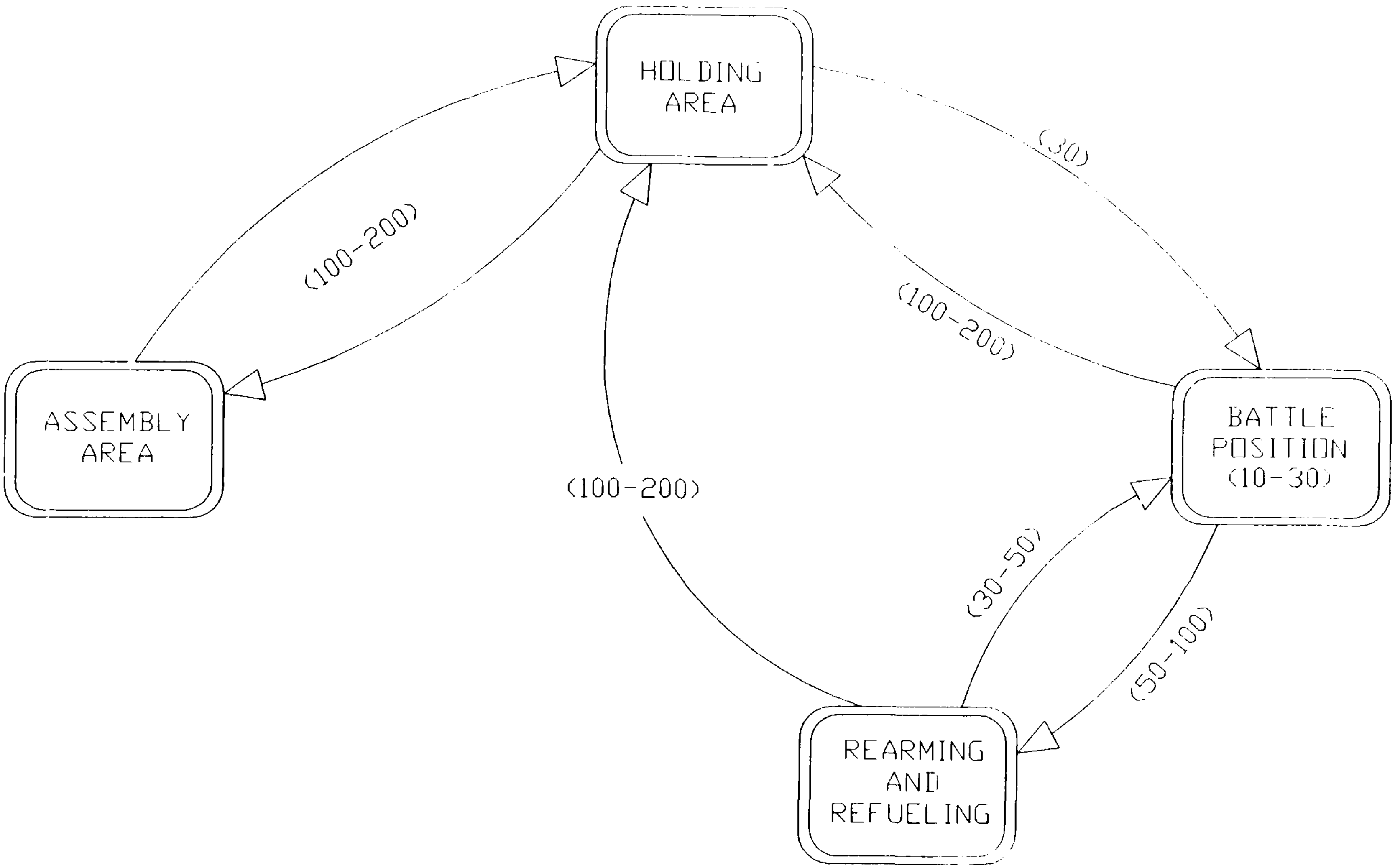
ERROR ANALYSIS

* HELICOPTER MISSION CONCEPT
* SOURCES OF ERRORS
* IMPACT OF ERRORS ON FLIR/MAP IMAGE CORRELATION

TYPICAL MISSION



TYPICAL HELICOPTER MISSION
(ALTITUDE GIVEN IN FEET)



14020-03

MISSION CHARACTERISTICS

MODES OF FLIGHT

* GLOBAL NAVIGATION
* HOVER-HOLD
* TARGET HANDOFF

FLIGHT POSTURES

* LOW LEVEL FLIGHT (100-200 FEET)
* CONTOUR FLIGHT (50-100 FEET)
* NOE FLIGHT (10-30 FEET)

FLIGHT PARAMETERS

* VELOCITY RANGE .... 0-180 KNOTS
* AVERAGE MISSION TIME ..... 1 HOUR
* ALTITUDE .... 0-200 FEET

SOURCES OF ERROR

* NAVIGATION ERRORS
* DTED ERRORS
* FLIR ERRORS
* DISPLAY ERRORS

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14020-25

NAVIGATION ERRORS

1) TRANSLATIONAL NAVIGATION ERROR
   - A) HORIZONTAL (X AND Y)
   - B) VERTICAL (ALTITUDE)

2) ROTATIONAL POSITION ERROR
   - A) YAW
   - B) PITCH
   - C) ROLL

NAVIGATION SYSTEM COMPONENTS

REQUIRED COMPONENTS FOR INTEGRATED NAVIGATION SYSTEM ON LHX

* INERTIAL REFERENCING UNITS (2)
* DOPPLER RADAR
* GLOBAL POSITIONING SYSTEM
* RADAR ALTIMETERS (2)

NAVIGATION SYSTEM ACCURACIES

TYPICAL INERTIAL COMPONENTS

NAVIGATION SYSTEM	POSITION (NM/HR CEP)	VELOCITY (FPS-RMS)	ATTITUDE°	HEADING°
HONEYWELL H-423 (LRG)	.6	---	---	---
LITTON LN-39	.8	2.5	.1	.1
LITTON LN-93	.63	---	---	---
SNU 84-3	.2	1.5	.1	.1
LITTON LR-80 (AHRS)	1%	---	.25	.50
NORTHROP (SAHRS)	1%	.2 M/S	.25	.50
ARMY (HI-OREL) IRU	---	---	.11	.17

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14020-11

NAVIGATION SYSTEM ACCURACIES

TYPICAL DOPPLER COMPONENTS

NAVIGATION SYSTEM	VELOCITY ACCURACY
TELEDYN-RYAN MODEL 2000	.25% $V_T \pm 1$ KNT.
	.10% $V_T \pm .05$ KNT.
SINGER/KEARFOTT SKD-2110/2111	.30% $V_T + 1$ KNT. (2 SIGMA)
	.20% $V_Z + 1$ KNT. (2 SIGMA)
SINGER/KEARFOTT AN/ASN-128/137	.25% $V_T + .1$ KNT.
	.10% $V_Z + .05$ KNT.

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14020-12

NAVIGATION SYSTEM ACCURACIES

DOPPLER

NAVIGATION SYSTEM	VELOCITY ACCURACY
TELEDYN-RYAN MODEL 2000	.25% $V_T \pm 1$ KNT.
	.10% $V_T \pm .05$ KNT.
SINGER/KEARFOTT SKD-2110/2111	.30% $V_T + 1$ KNT. (2 SIGMA)
	.20% $V_Z + 1$ KNT. (2 SIGMA)
SINGER/KEARFOTT AN/ASN-128/137	.25% $V_T + .1$ KNT.
	.10% $V_Z + .05$ KNT.

JCP 02/10/88
14020-12

NAVIGATION SYSTEM ACCURACIES

GPS

MODEL	POSITION ACCURACY
NORTHROP (GPS/SAHRS)	16M.
COLLINS 3A	16M.
CANADIAN MARCONI CMA-774	16M.
STANFORD-TELEDYNE AN/APN-217 (DOPPLER/GPS)	16M.

NAVIGATION SYSTEM ACCURACIES

RADAR ALTIMETERS

MODEL	ACCURACY	TRACKING RATE	RANGE
TELEDYN-RYAN MODEL 1044	±3 FEET OR ±2%	3000 FPS.	1-8192 FEET
AN/APN-194	±2 FEET OR ±4%	2000 FPS.	0-5000 FEET
AN/APN-232	±2 FEET OR (0-100)	2000 FPS.	0-50,000 FEET
	±2% (100-5000)		
	±100 FEET (5000-10,000)		
	±1% (10,000-50,000)		

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14020-13

SELECTED NAVIGATION COMPONENTS FOR ERROR ANALYSIS

* INS
  - SNU 84-3 (F^3 PRECISION)
* DOPPLER
  - SINGER/KEARFOTT AN/ASN - 137
* GPS
  - NORTHROP (GPS/SAHRS)
* RADAR ALTIMETERS
  - TELEDYN-RYAN MODEL 1044

INTEGRATED NAVIGATION SYSTEM ACCURACIES

(1 SIGMA)

	SELECTED SYSTEM
POSITION ACCURACY	
HORIZONTAL	16 M.
VERTICAL	± 3 FEET OR $\pm 2\%$
ALTITUDE ACCURACY	0.1°
HEADING ACCURACY	0.1°
VELOCITY ACCURACY	$0.25\%\ V_T \pm 1.00$ KNT $0.05\%\ V_Z \pm 0.05$ KNT

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14020-08

DIGITAL TERRAIN ELEVATION DATA
DTED

* UNIFORM MATRIX OF TERRAIN ELEVATION VALUES
* DATA RESOLUTION

  DTED LEVEL I:

  - APPROXIMATELY EQUAL TO INFORMATION ON 1:250,000 CONTROL CHART
  - DATA POINTS AT APPROXIMATELY 100M INTERVALS (ZONED ARC MEASURE SPACINGS)

  DTED LEVEL II:

  - APPROXIMATELY EQUAL TO INFORMATION ON 1:50,000 CONTOUR CHART
  - DATA POINTS AT APPROXIMATELY 30M INTERVALS

* DATA ACCURACY
  - ACCURACY STATEMENTS INDIVIDUALLY CALCULATED AND PROVIDED IN ACCURACY HEADER RECORD
  - TYPICAL PRODUCT VALUES

TYPICAL PRODUCT VALUES	90% C.E./L.E.	1 SIGMA
POINT TO POINT HORIZONTAL	25 TO 30M	18.24M
POINT TO POINT VERTICAL	±25 TO 30M	12.16M

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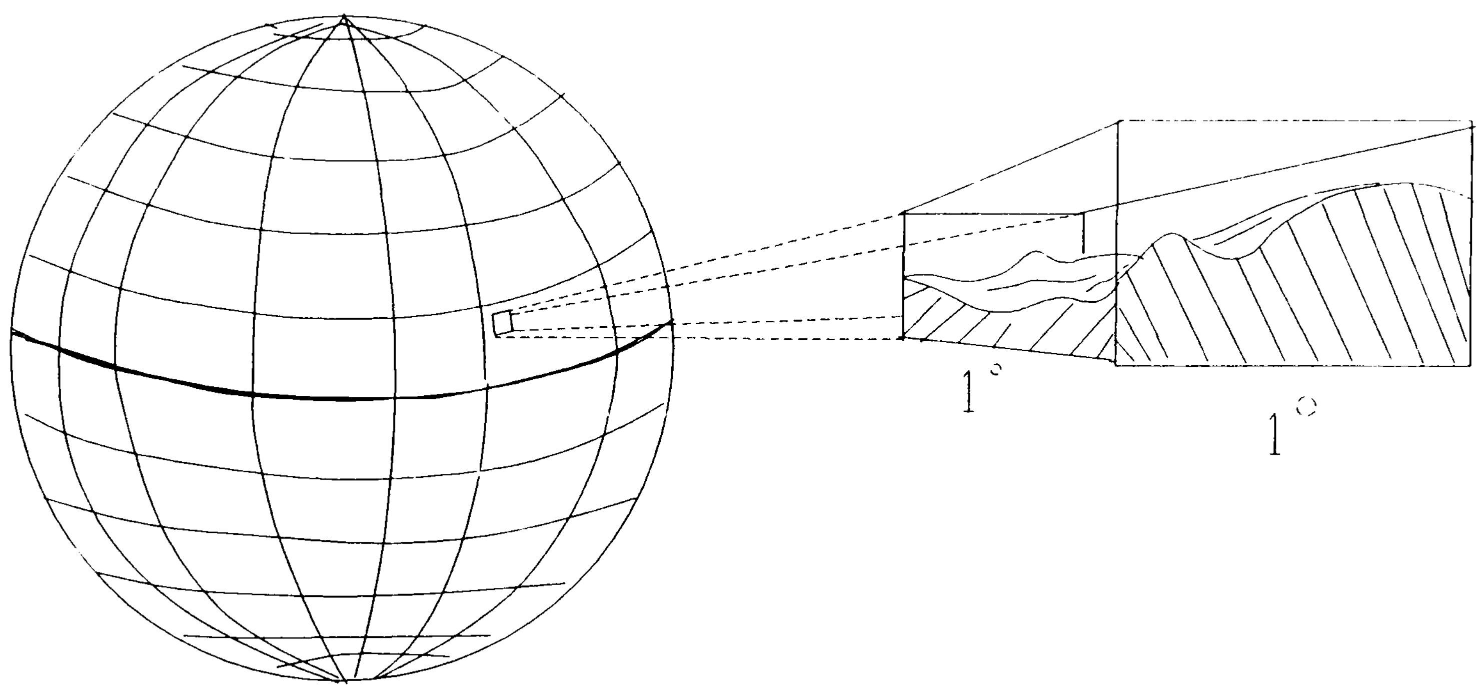
14020-18


1°
1°

FLIR SYSTEM ACCURACIES

TYPICAL FLIR CHARACTERISTICS (AH-64 PNVS)

FIELD OF VIEW	$30^{o} \times 40^{o}$
FOV DISTORTION	$\pm$ 5%
SCAN STABILITY	.2%
BORESIGHT ACCURACY	$.3^{o}$
ALIGNMENT ACCURACY	$.06^{o}$

DISPLAY SYSTEM ACCURACIES

TYPICAL DISPLAY CHARACTERISTICS
KAISER-MRDI AVIONICS DISPLAY
(F18, A-6, AV8-B)

USABLE SCREEN AREA	5" X 5"
VIDEO INPUT	525/875 LINE
RESOLUTION	120 LINE PAIRS/IN.
REFRESH RATE	60 HZ
PHOSPHER PERSISTENCE	2 MILLISECONDS TO 10%
LINEARITY	$\pm$ 2% DISPLAY FROM CENTER

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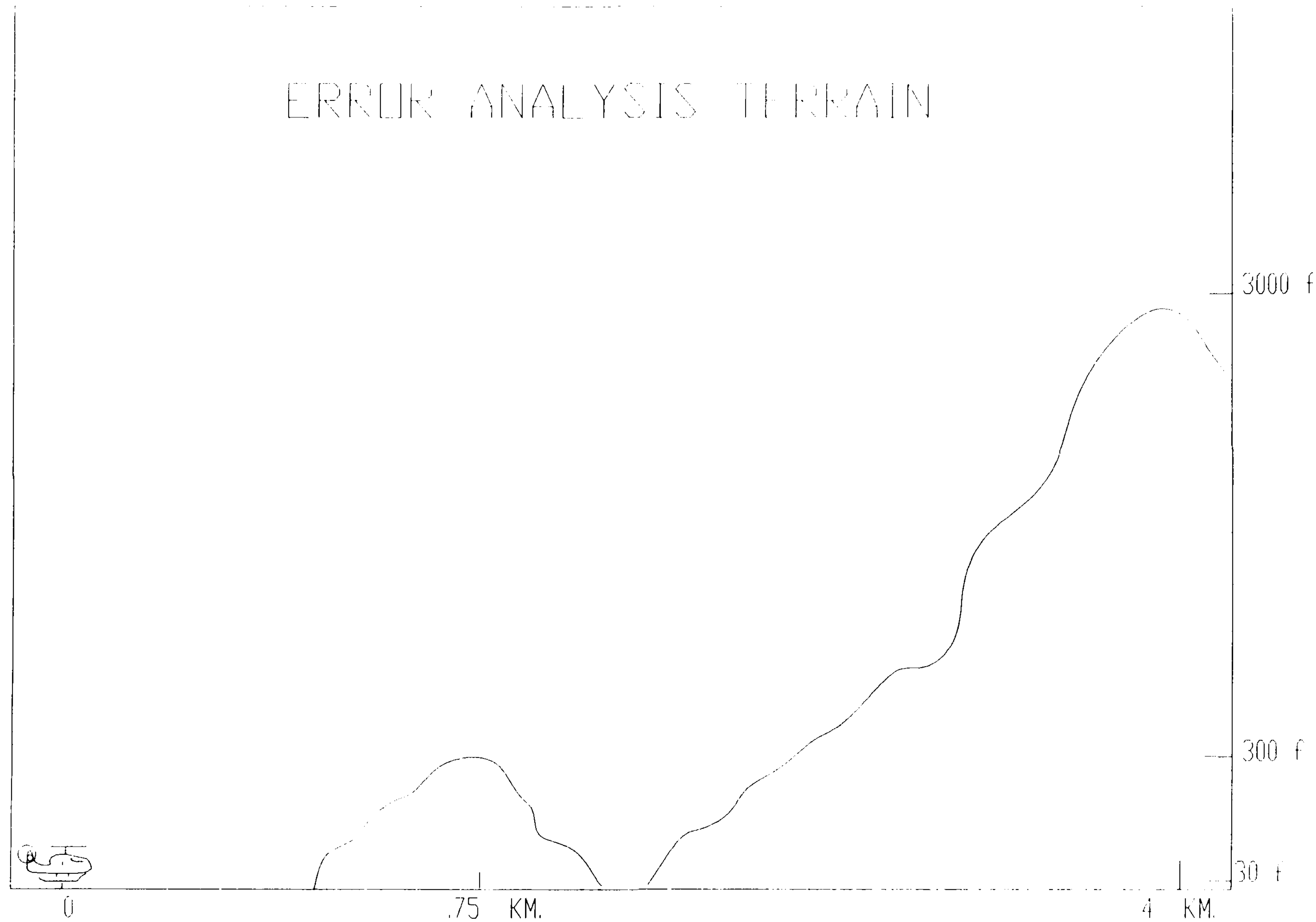
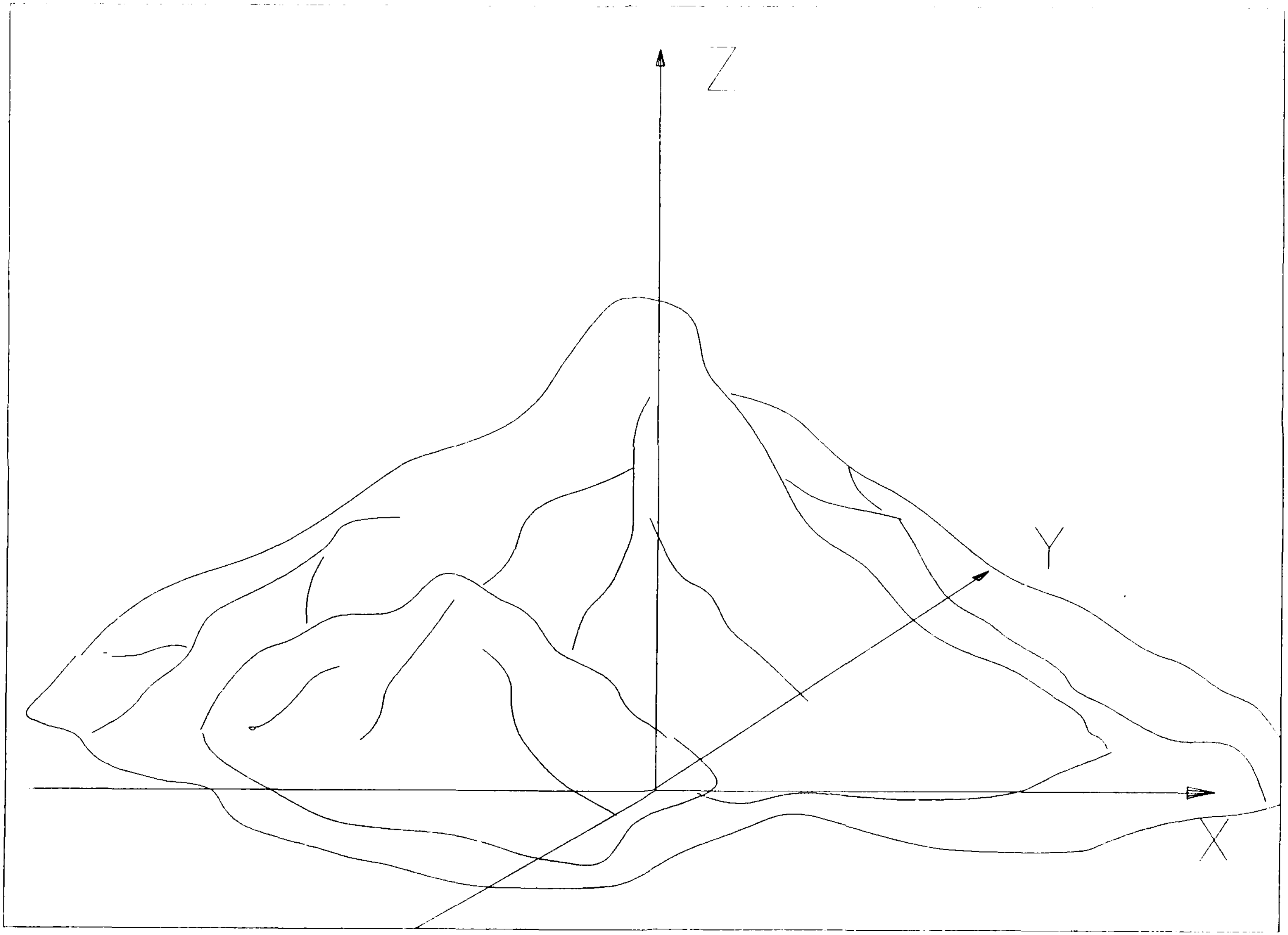
14020-40

IMPACT OF ERRORS ON FLIR/MAP CORRELATION

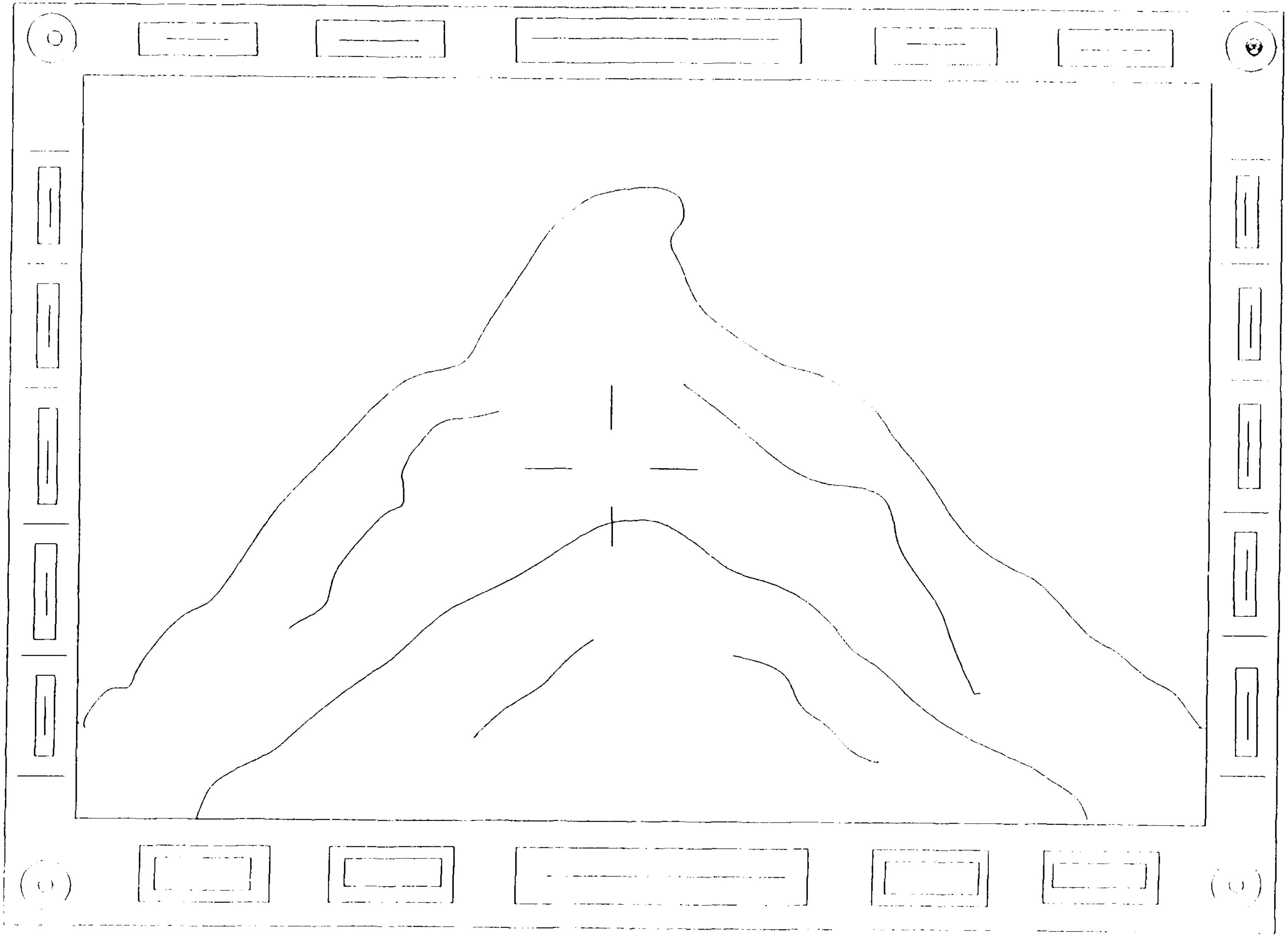
JCP 02/24/88
14020-31


ERROR ANALYSIS TERRAIN
3000 f
300 f
30 f
0
.75 KM.
4 KM.

COORDINATE SYSTEM ORIENTATION

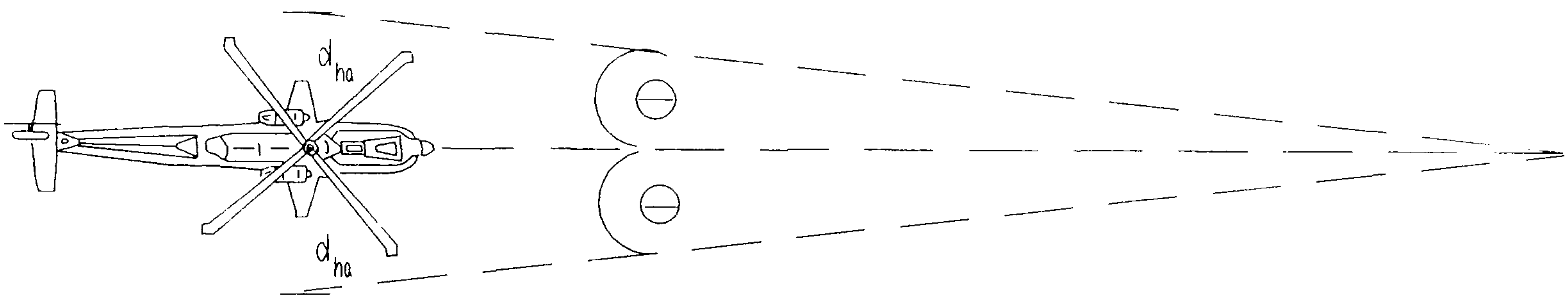


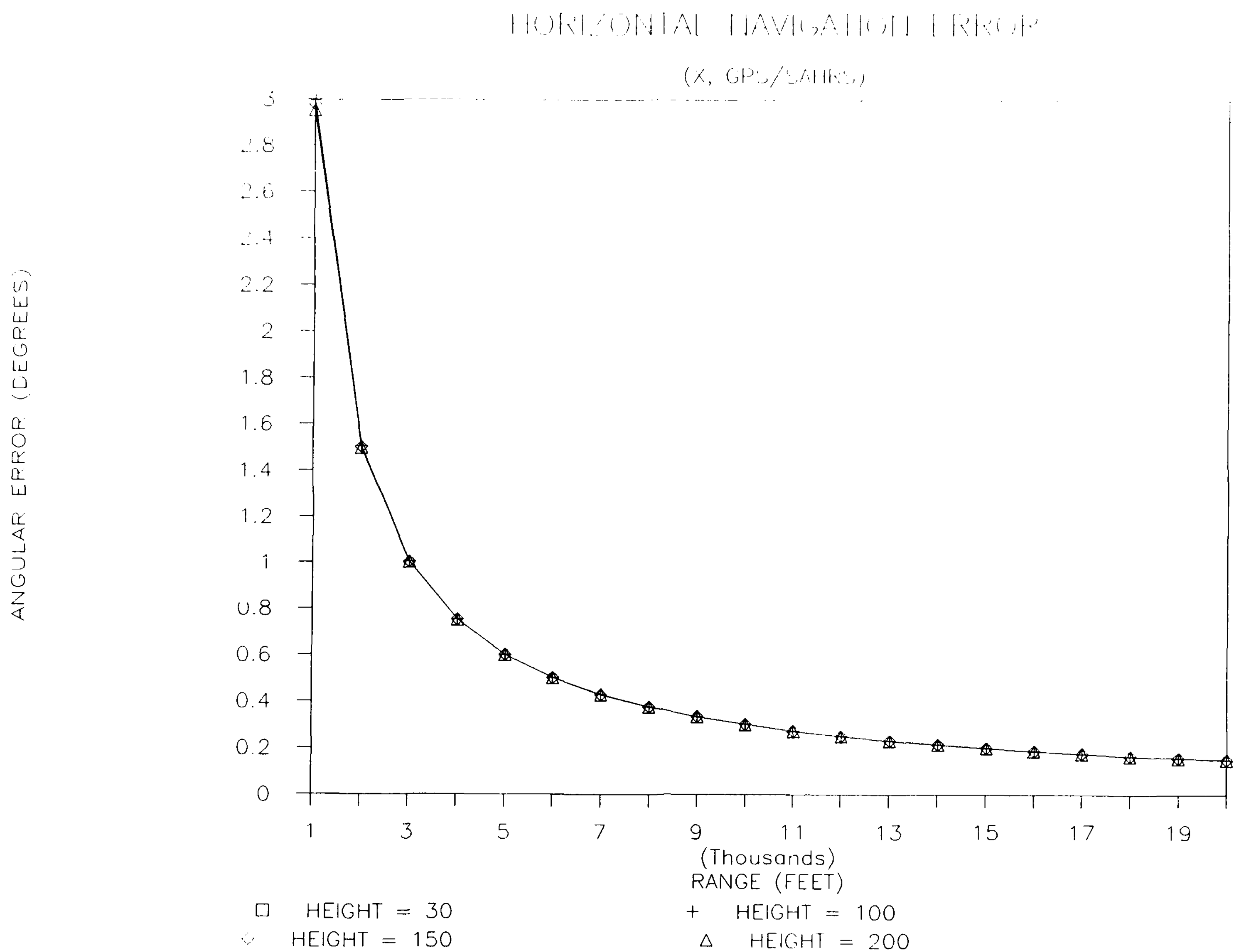
FLIR IMAGE



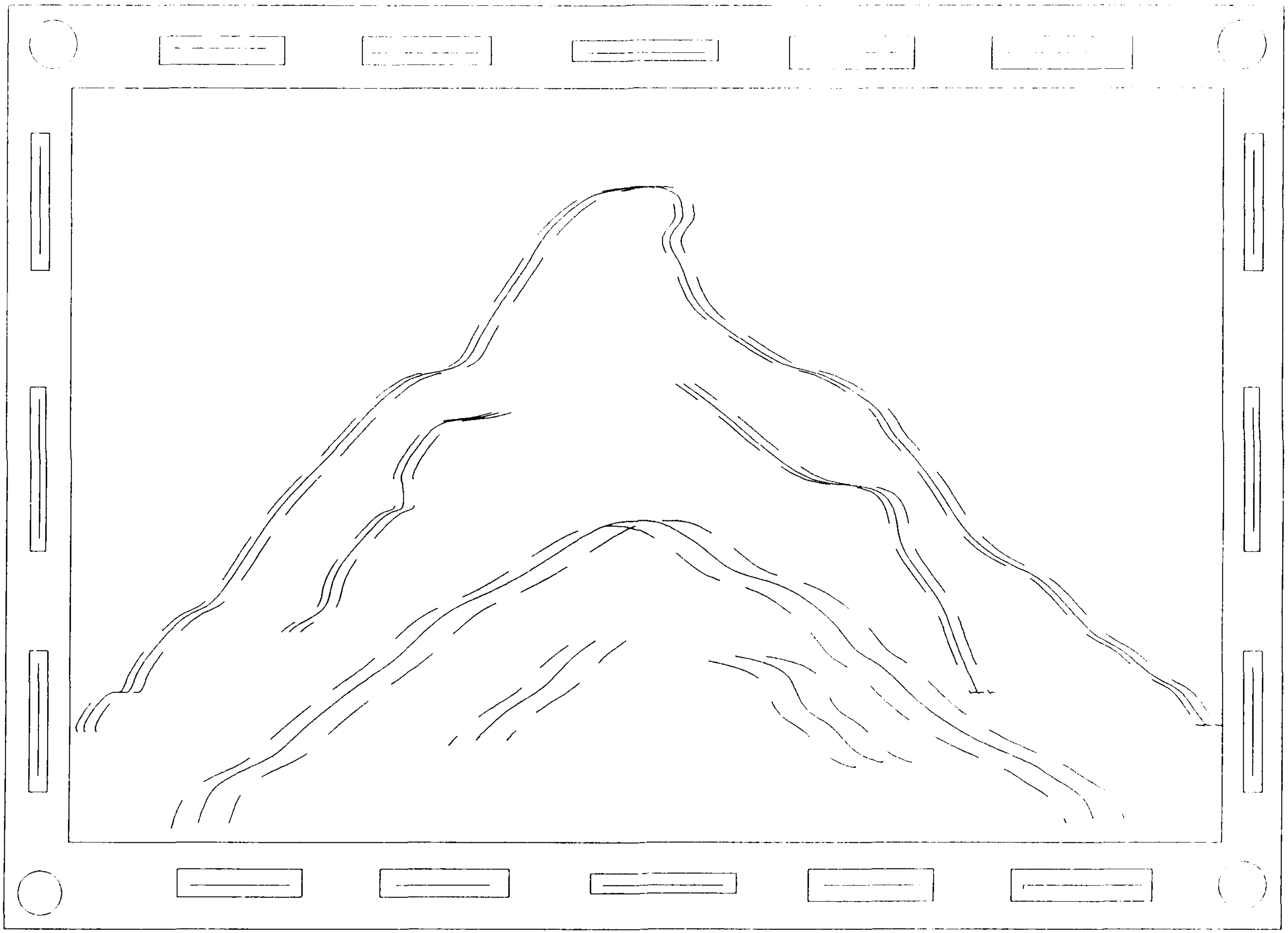
HORIZONTAL NAVIGATION ERROR - X

$$\theta = \arctan\left(\frac{d_{ha}}{\sqrt{r^2 + h^2}}\right)$$



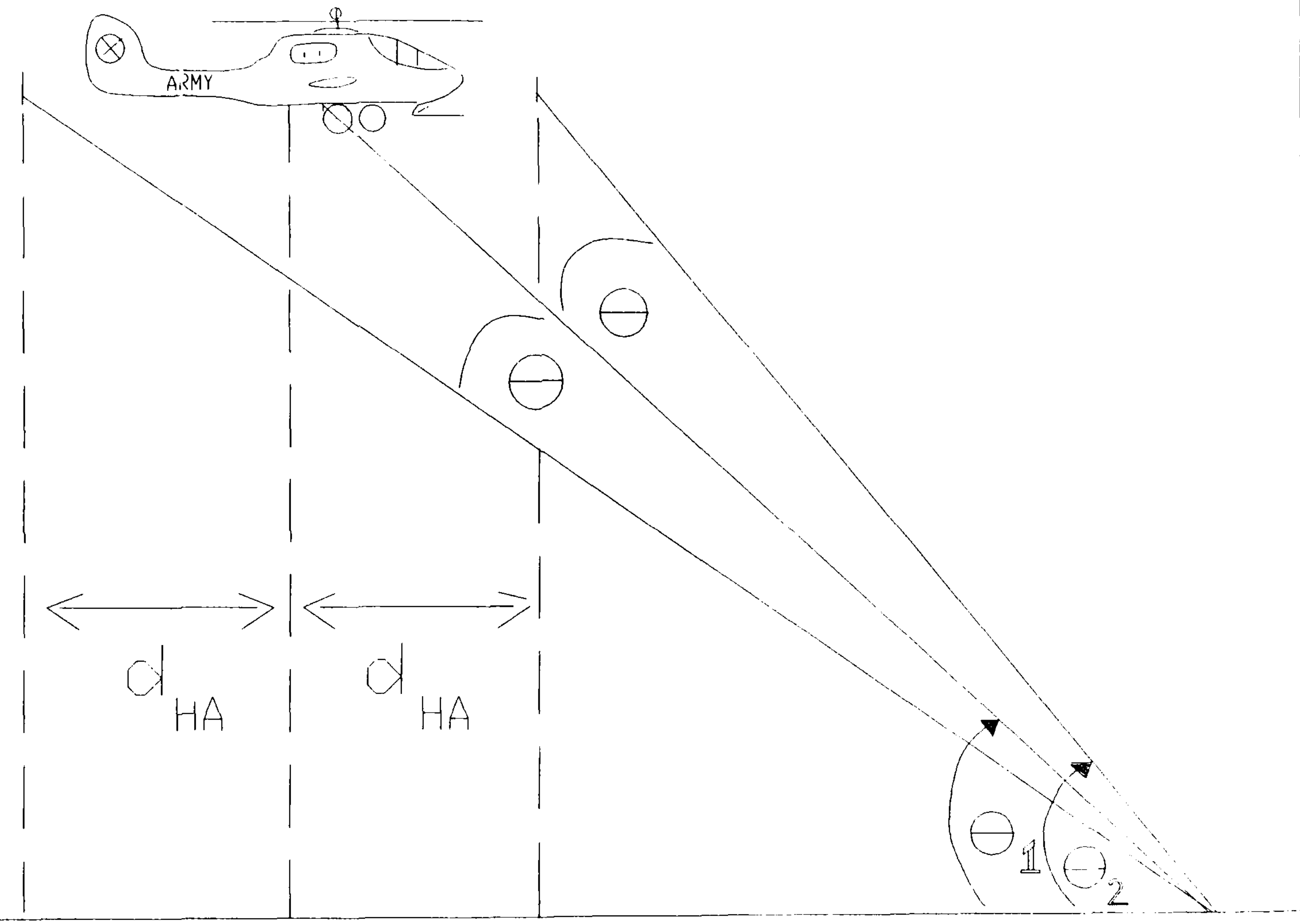

HORIZONTAL NAVIGATION ERROR
(X, GPS/SAHRS)
ANGULAR ERROR (DEGREES)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
(Thousands)
RANGE (FEET)
□ HEIGHT = 30
+ HEIGHT = 100
◇ HEIGHT = 150
Δ HEIGHT = 200

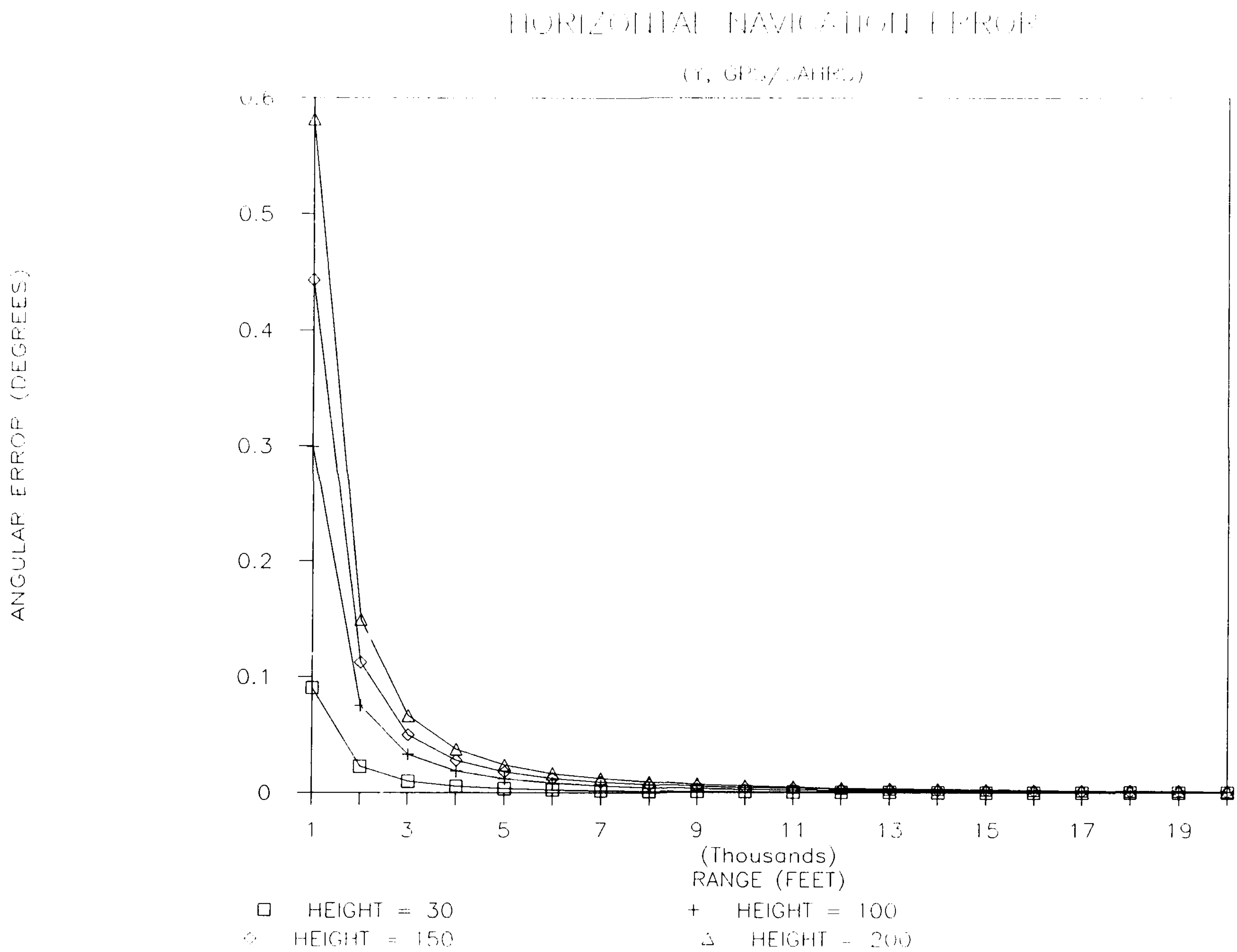
HORIZONTAL NAVIGATION ERROR X



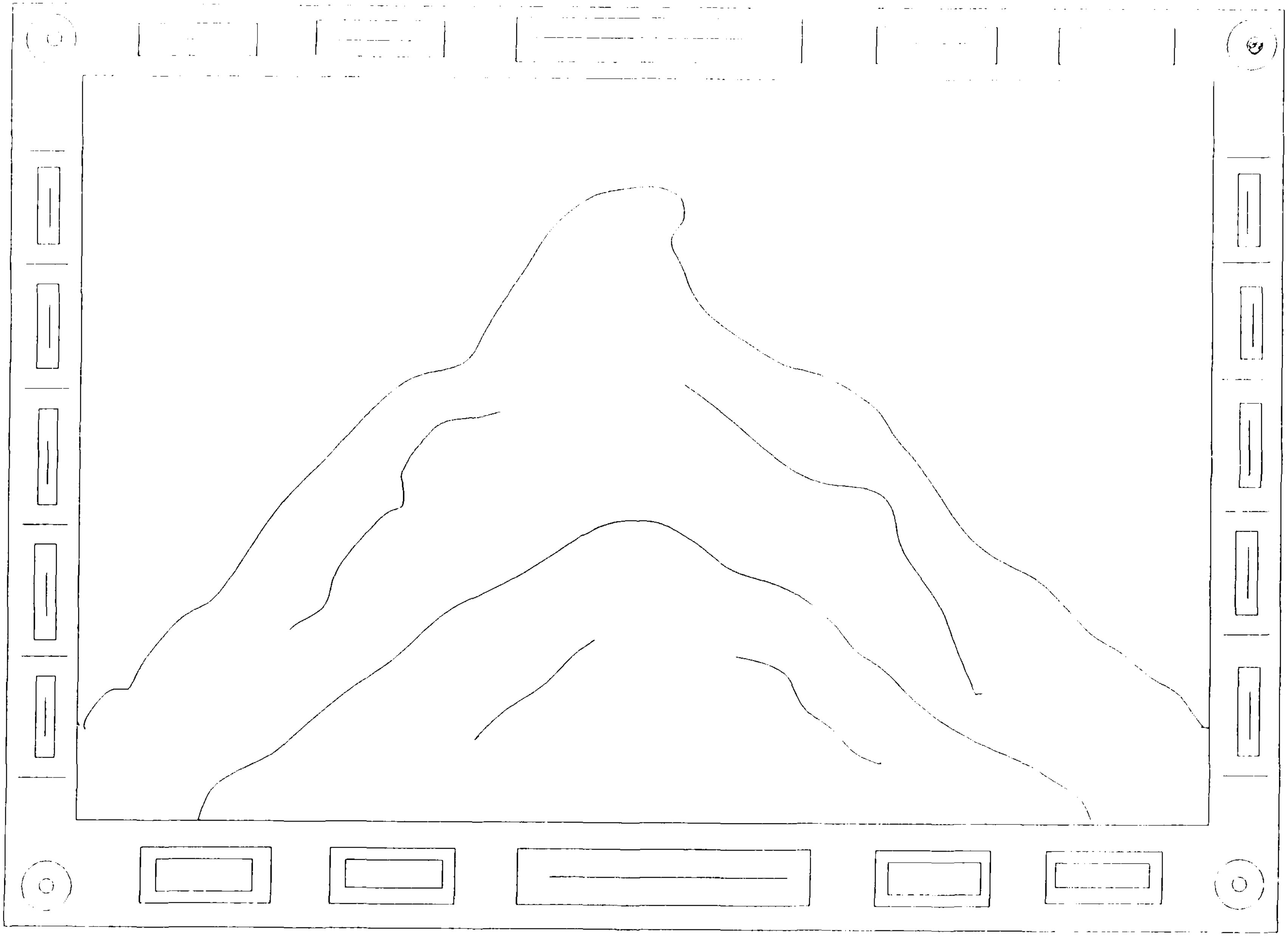
HORIZONTAL NAVIGATION ERROR (Y

$$\theta = 1/2 \left(\arctan\left(\frac{h}{|r - d_{ha}|}\right) - \arctan\left(\frac{h}{|r - d_{ha}|}\right) \right)$$

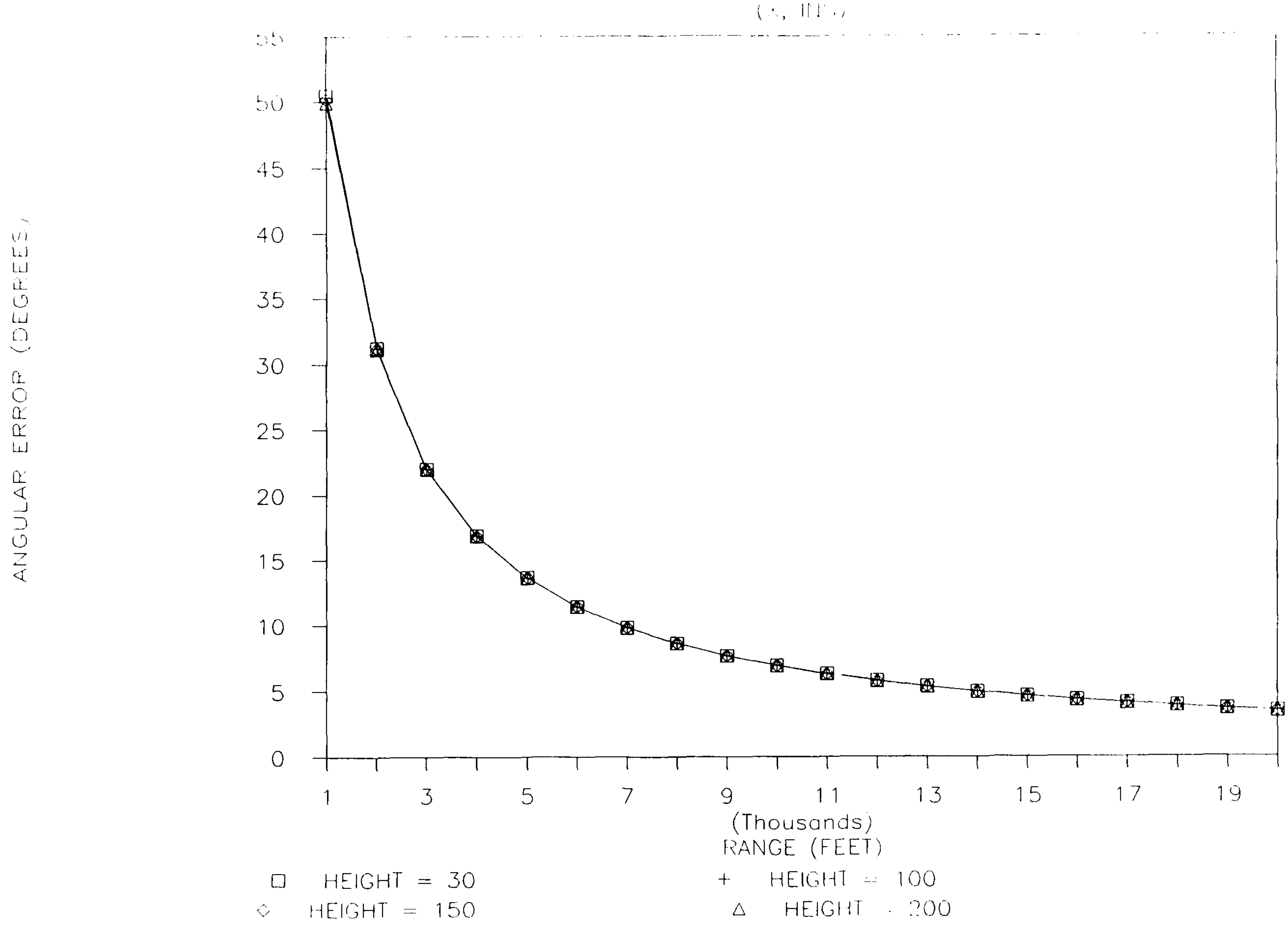



HORIZONTAL NAVIGATION ERROR
0.6
0.5
0.4
0.3
0.2
0.1
0
ANGULAR ERROR (DEGREES)
1
3
5
7
9
11
13
15
17
19
(Thousands)
RANGE (FEET)
□ HEIGHT = 30
+ HEIGHT = 100
◇ HEIGHT = 150
△ HEIGHT = 200

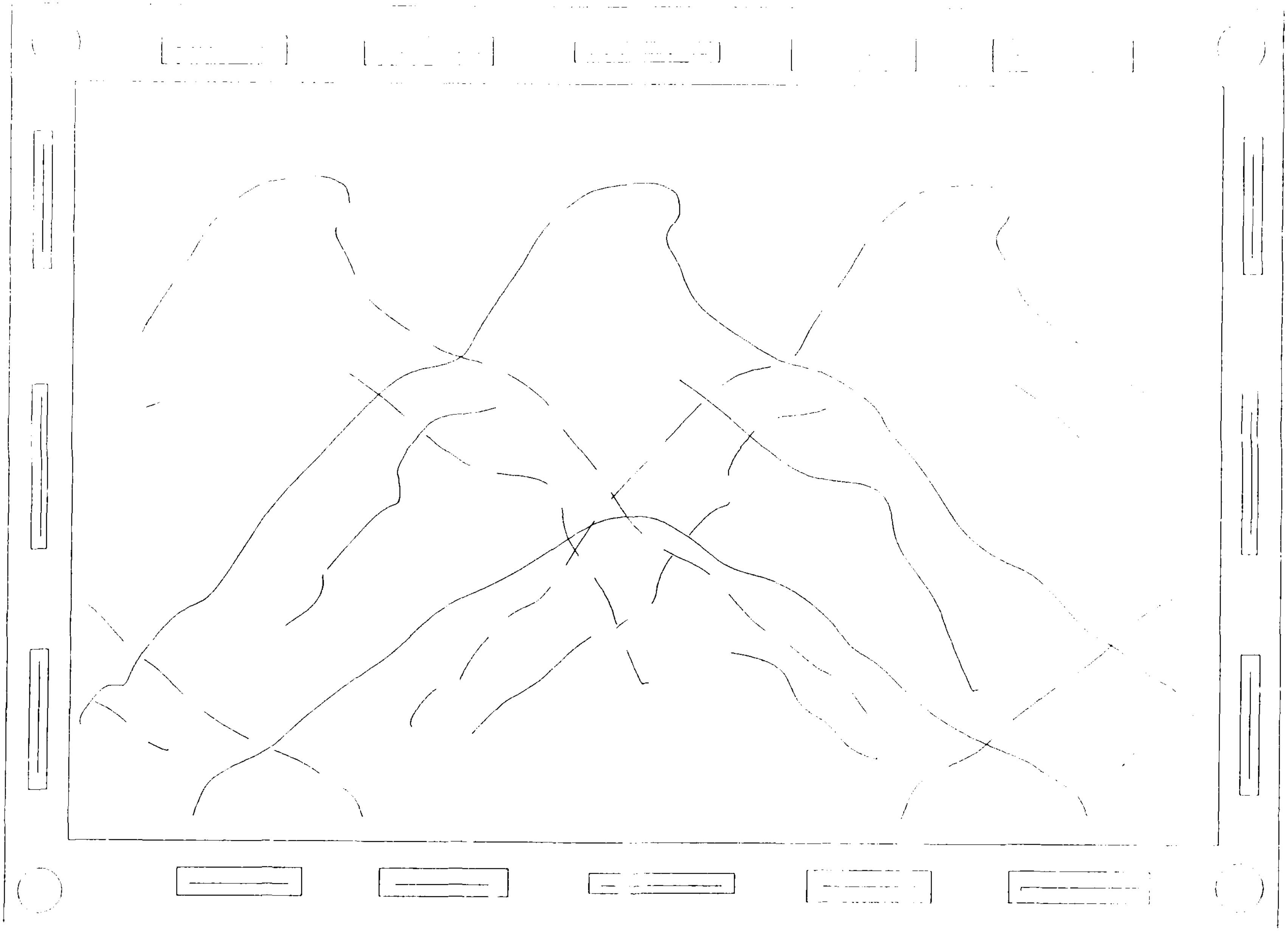
HORIZONTAL NAVIGATION ERROR Y

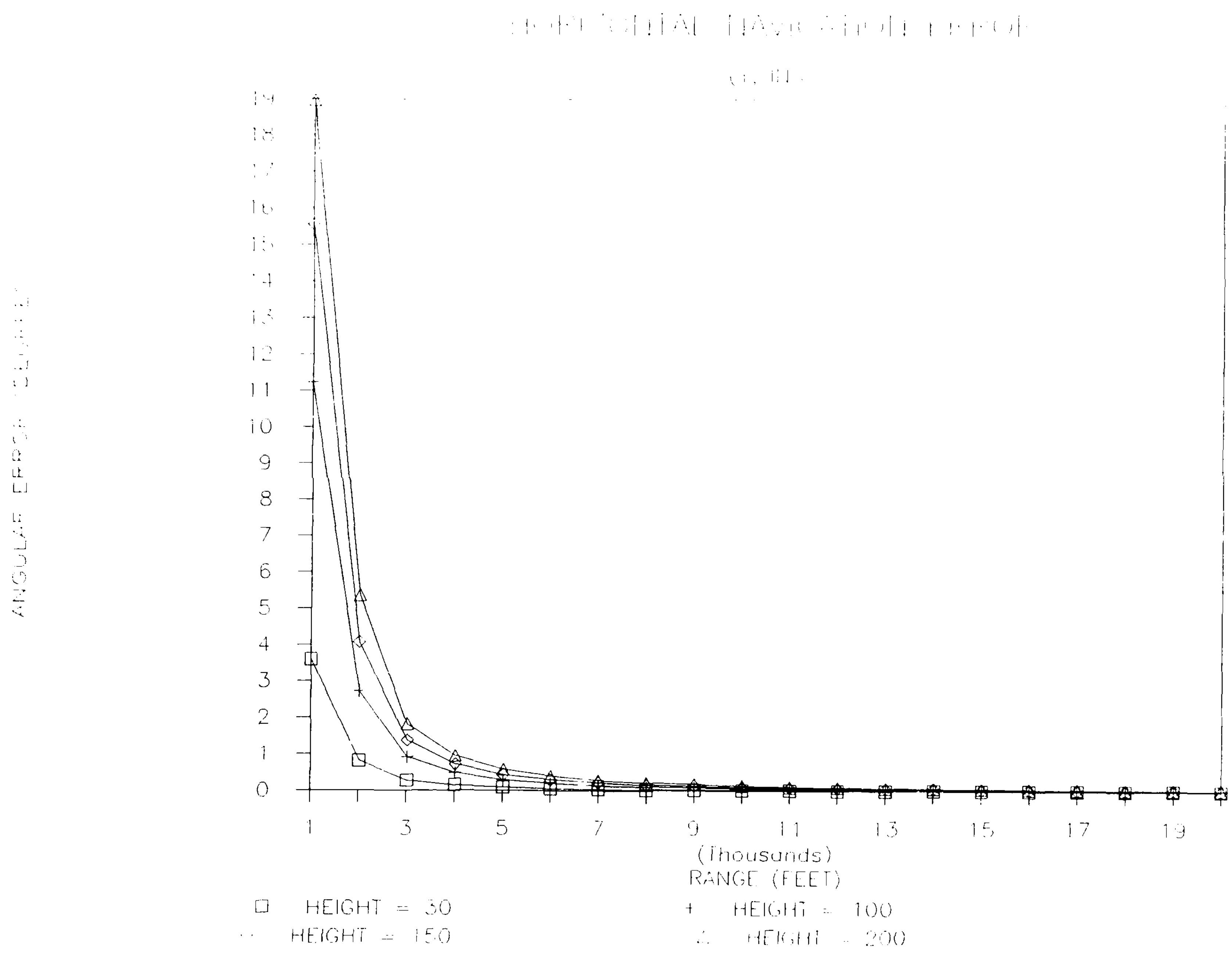


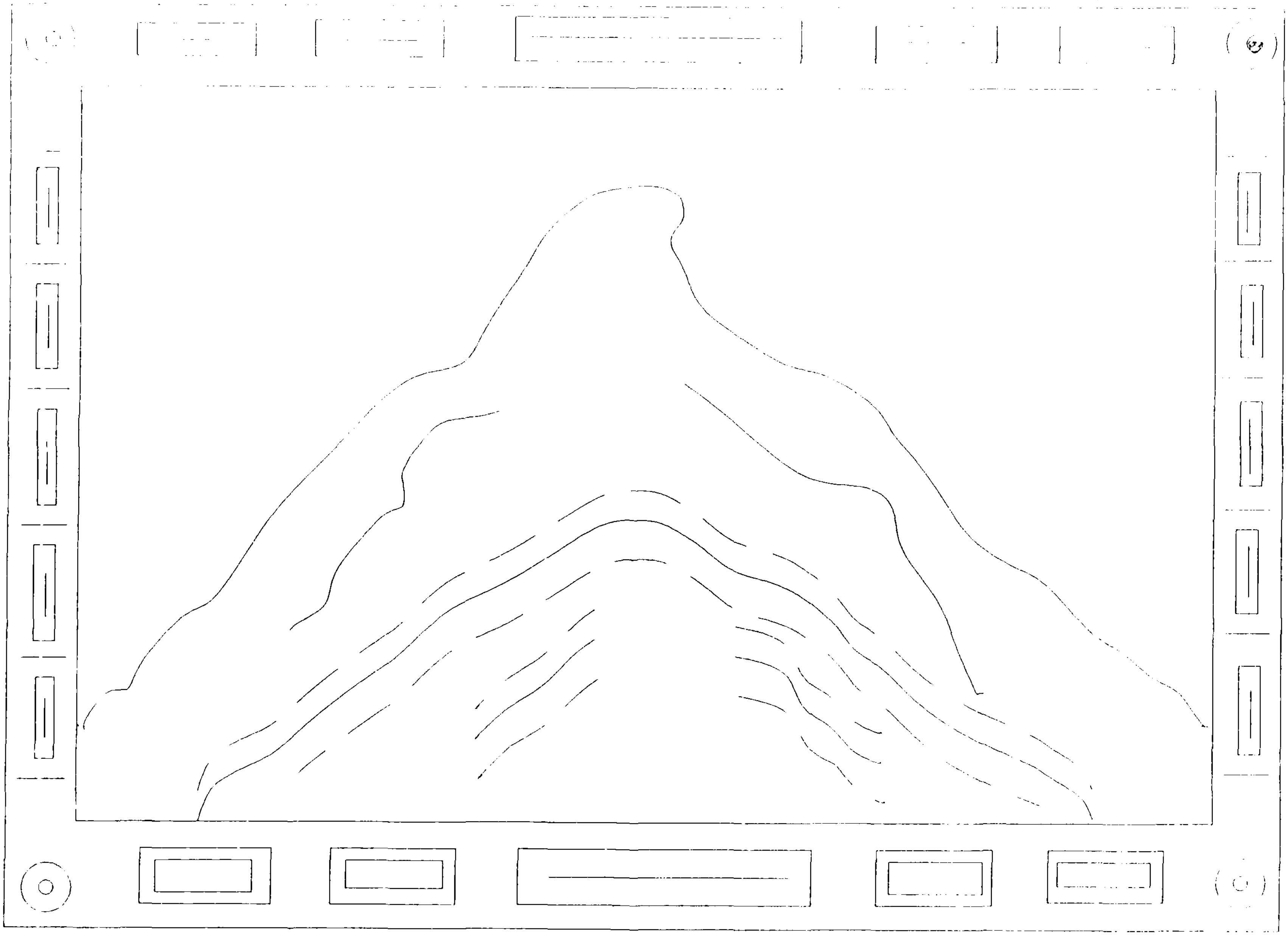
HORIZONTAL NAVIGATION ERROR



NAVIGATION ERROR

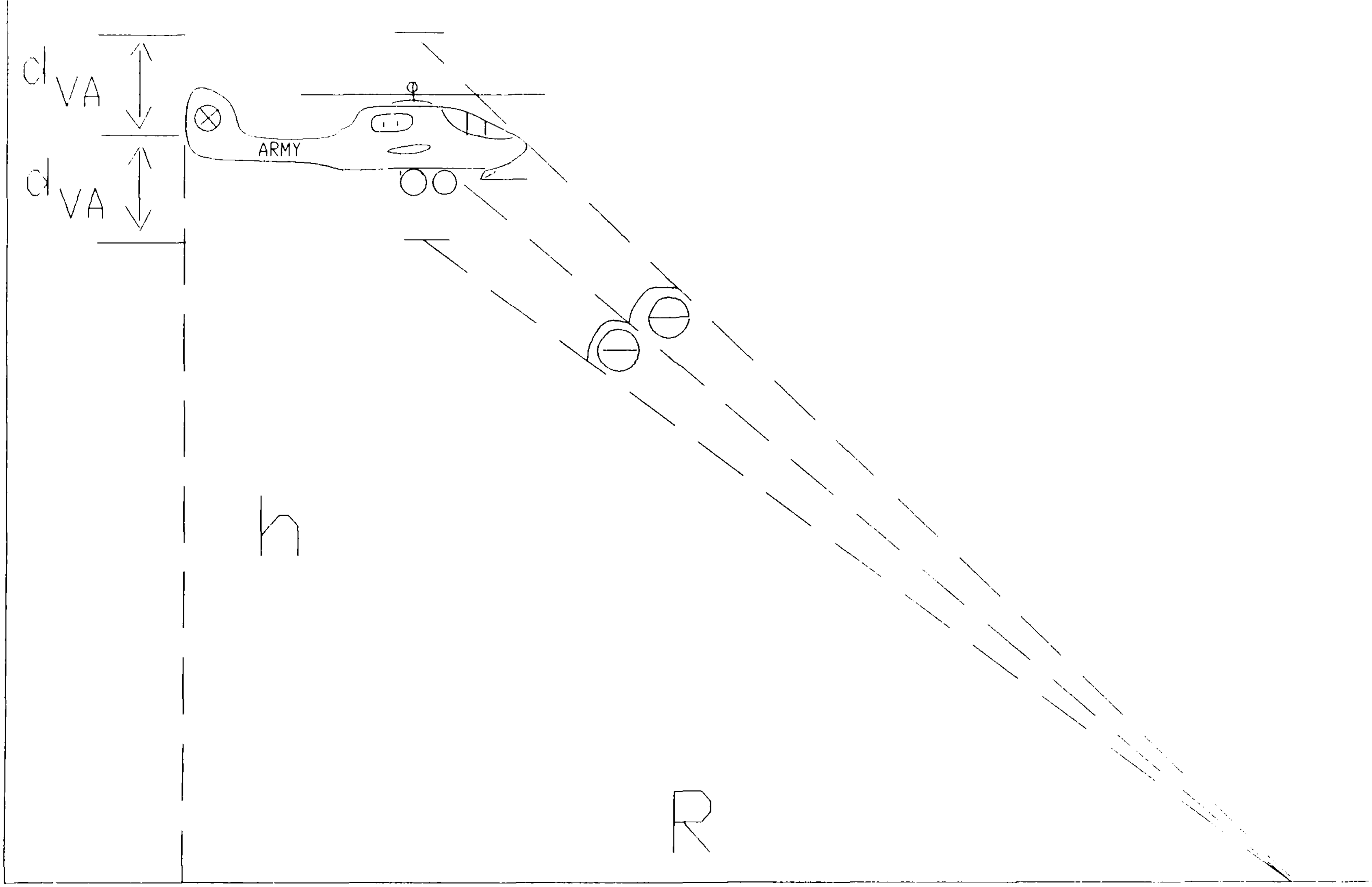



ANGULAR ERROR
0
1
2
3
4
5
6
7
8
9
10
11
12
1
3
5
7
9
11
13
15
17
19
(Thousands)
RANGE (FEET)
HEIGHT = 30
HEIGHT = 150
HEIGHT = 100
HEIGHT = 200



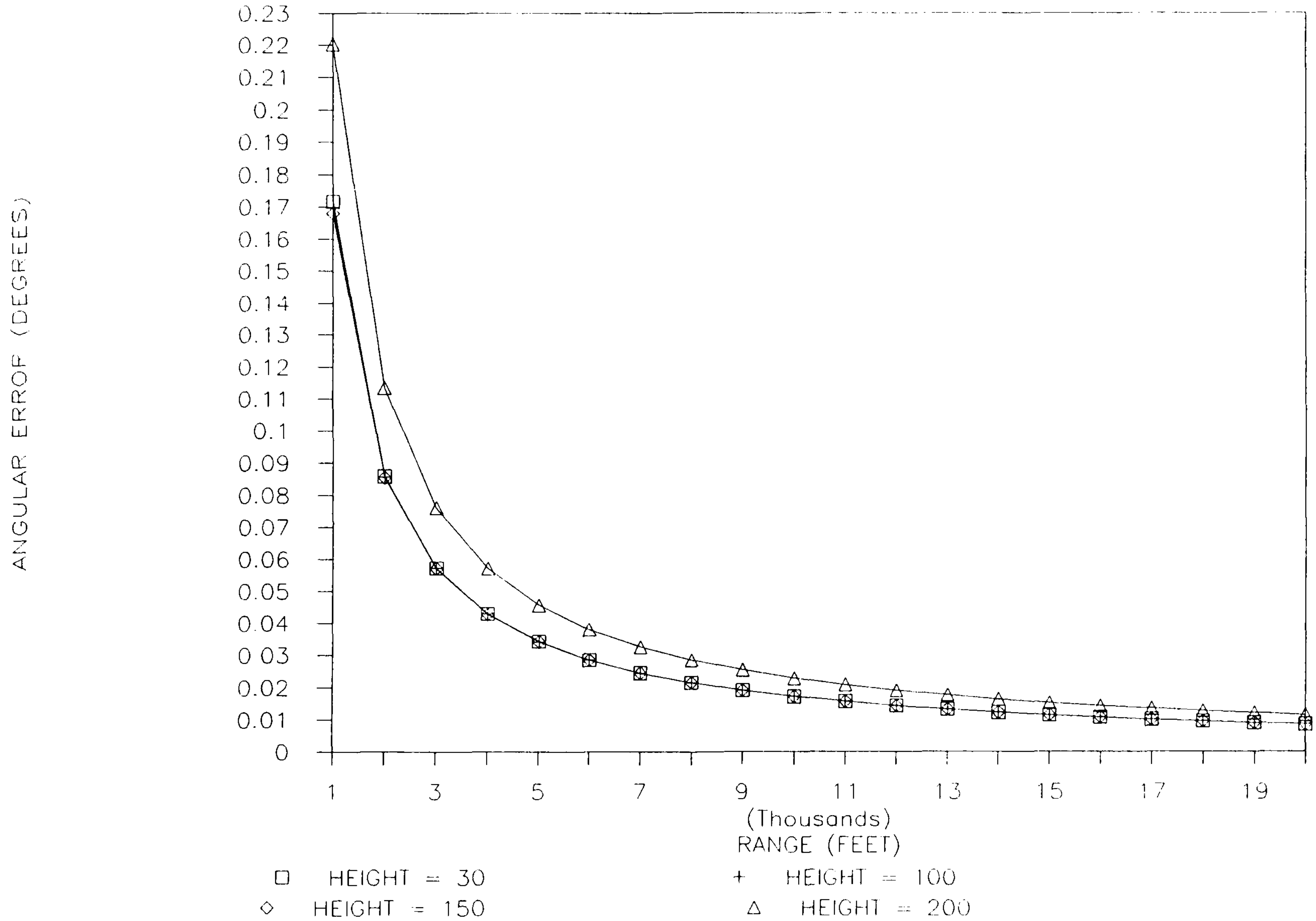
VERTICAL NAVIGATION ERROR

$$\theta = 1\backslash 2 \left(\arctan\left(\frac{h + dva}{r}\right) - \arctan\left(\frac{h - dva}{r}\right) \right)$$

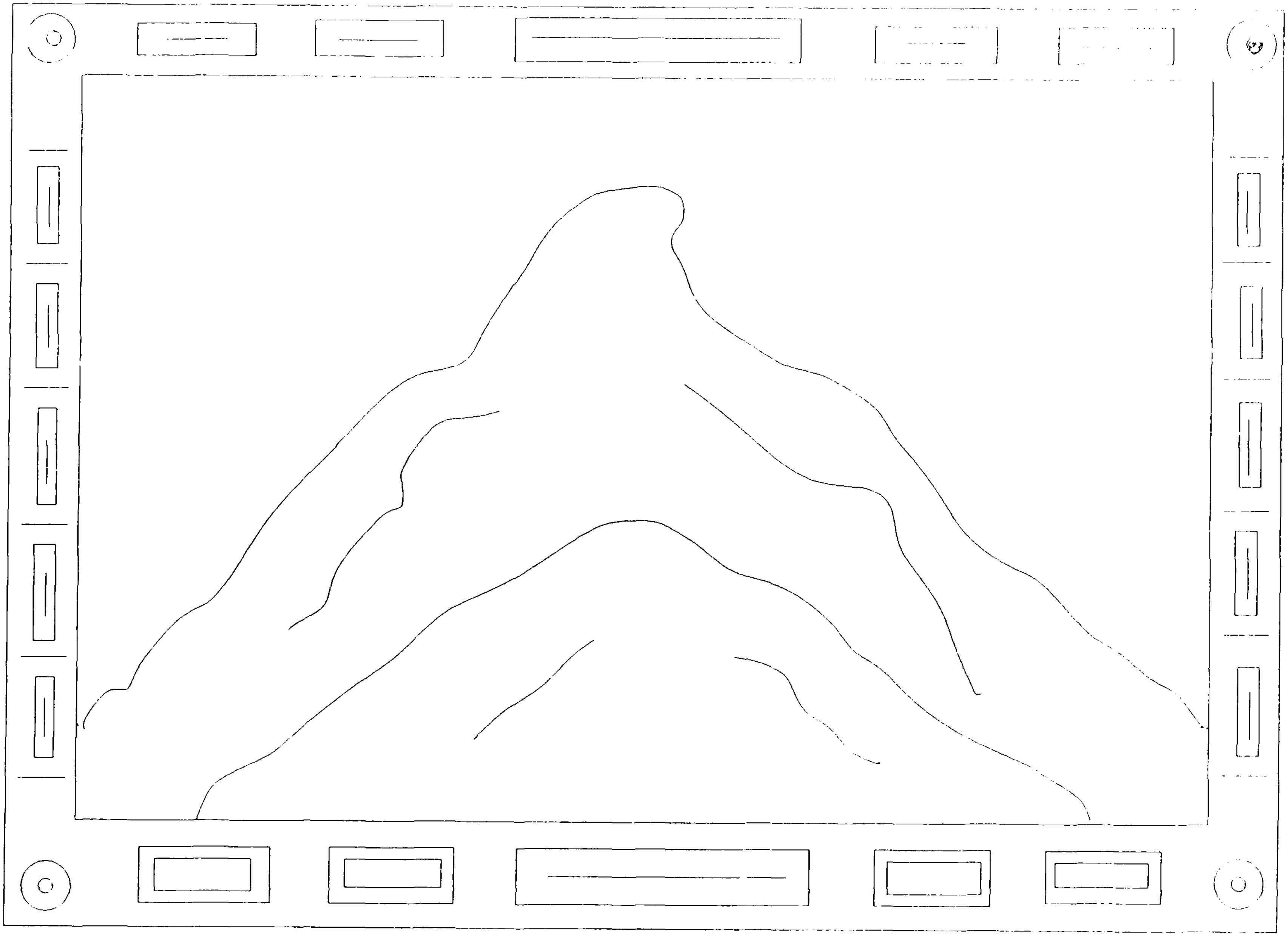


VERTICAL NAVIGATION ERROR

(TRANSIT)



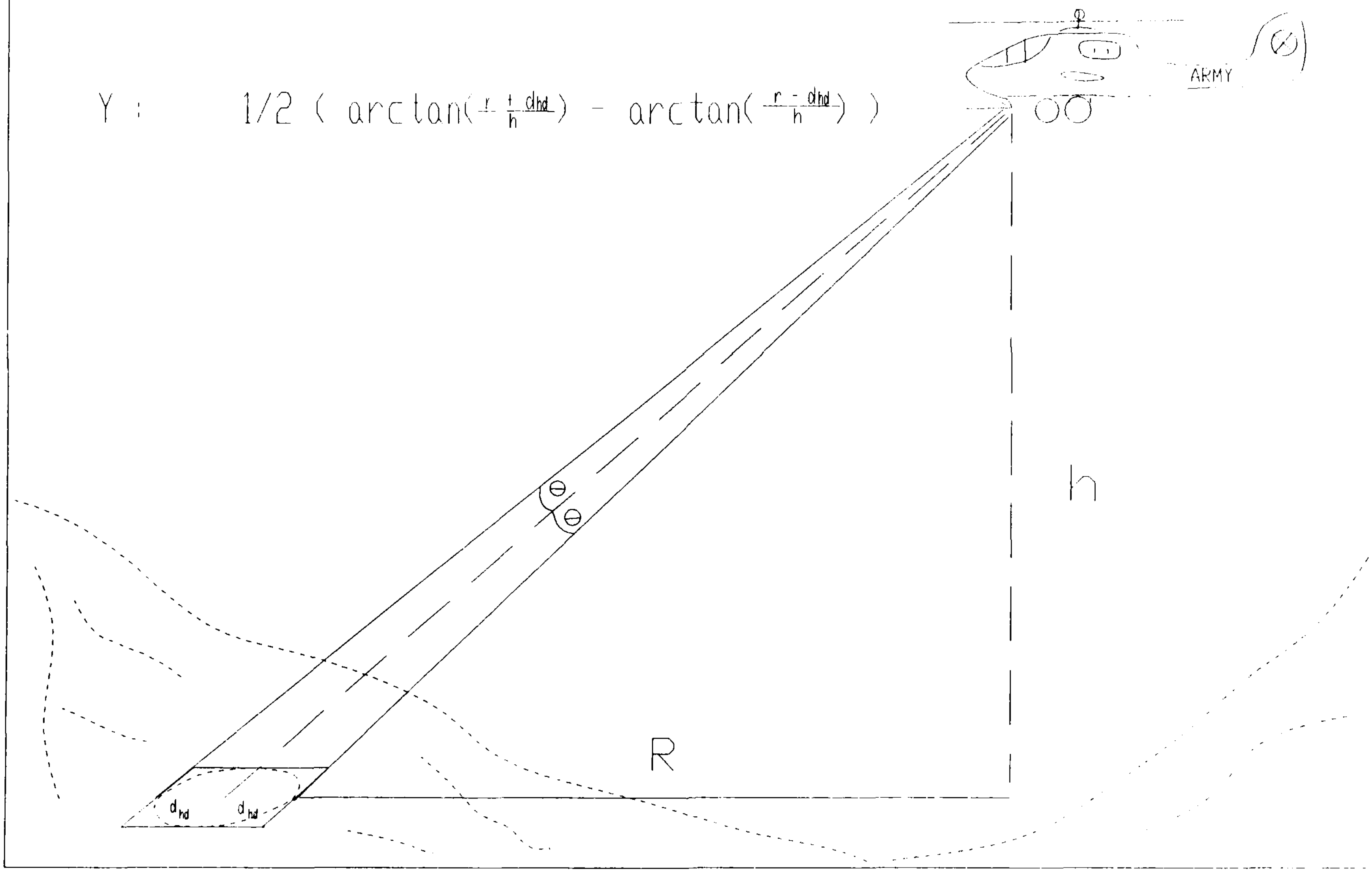
VERTICAL NAVIGATION ERROR

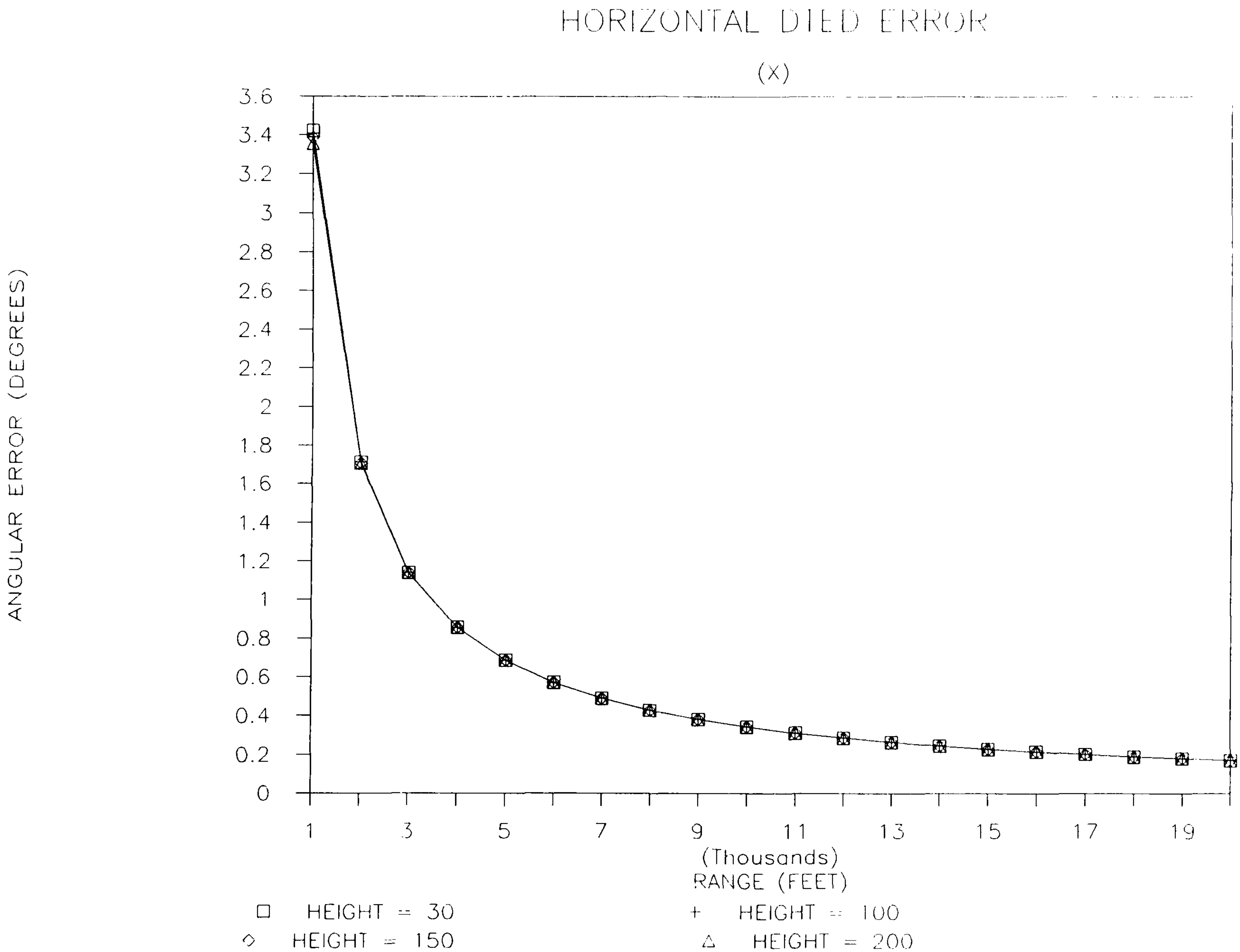


HORIZONTAL DTED ERROR

X : $\arctan\left(\frac{d_{hd}}{\sqrt{r^2 + h^2}}\right)$

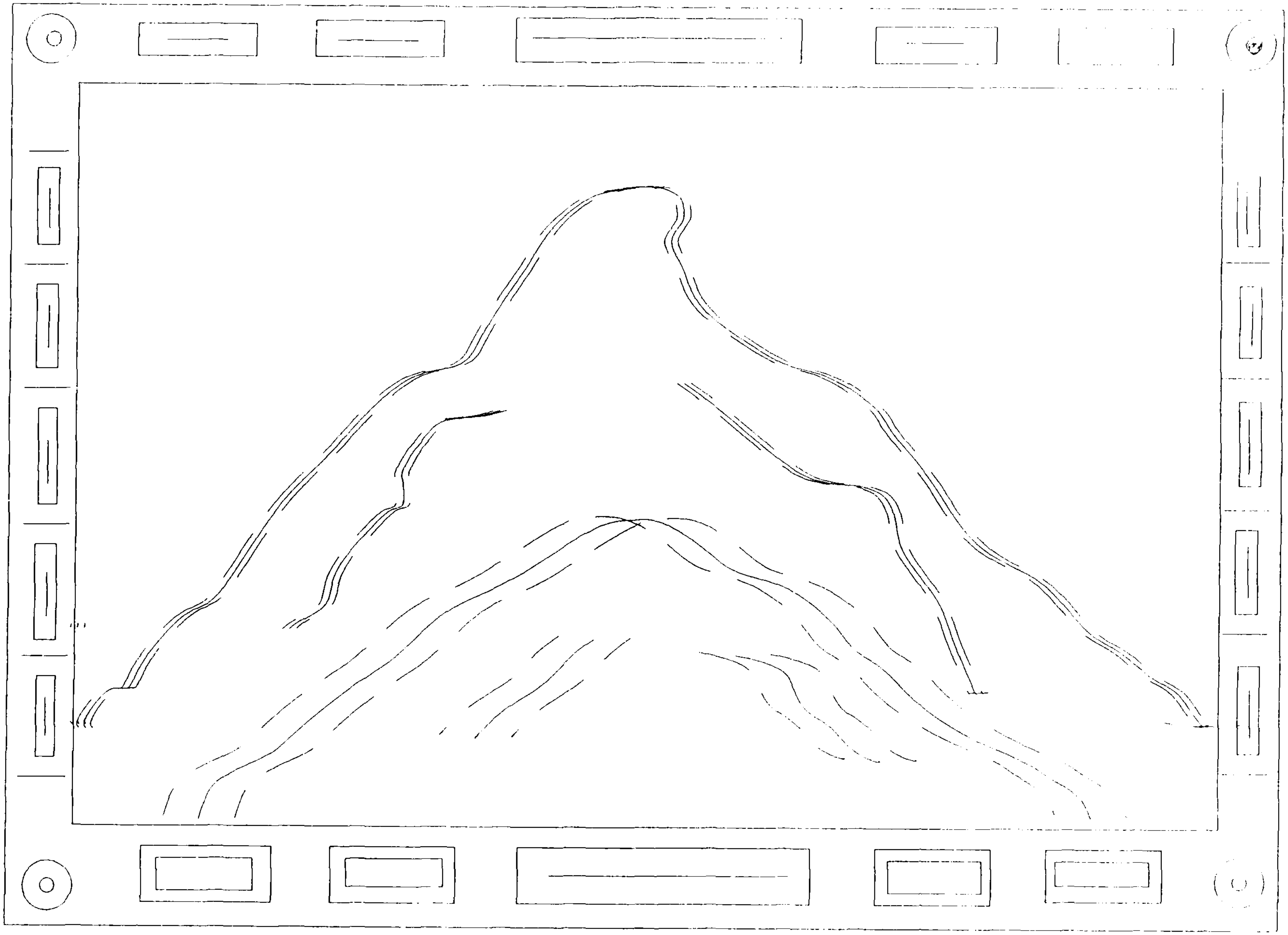
Y : $1/2\left(\arctan\left(\frac{r + d_{hd}}{h}\right) - \arctan\left(\frac{r - d_{hd}}{h}\right)\right)$





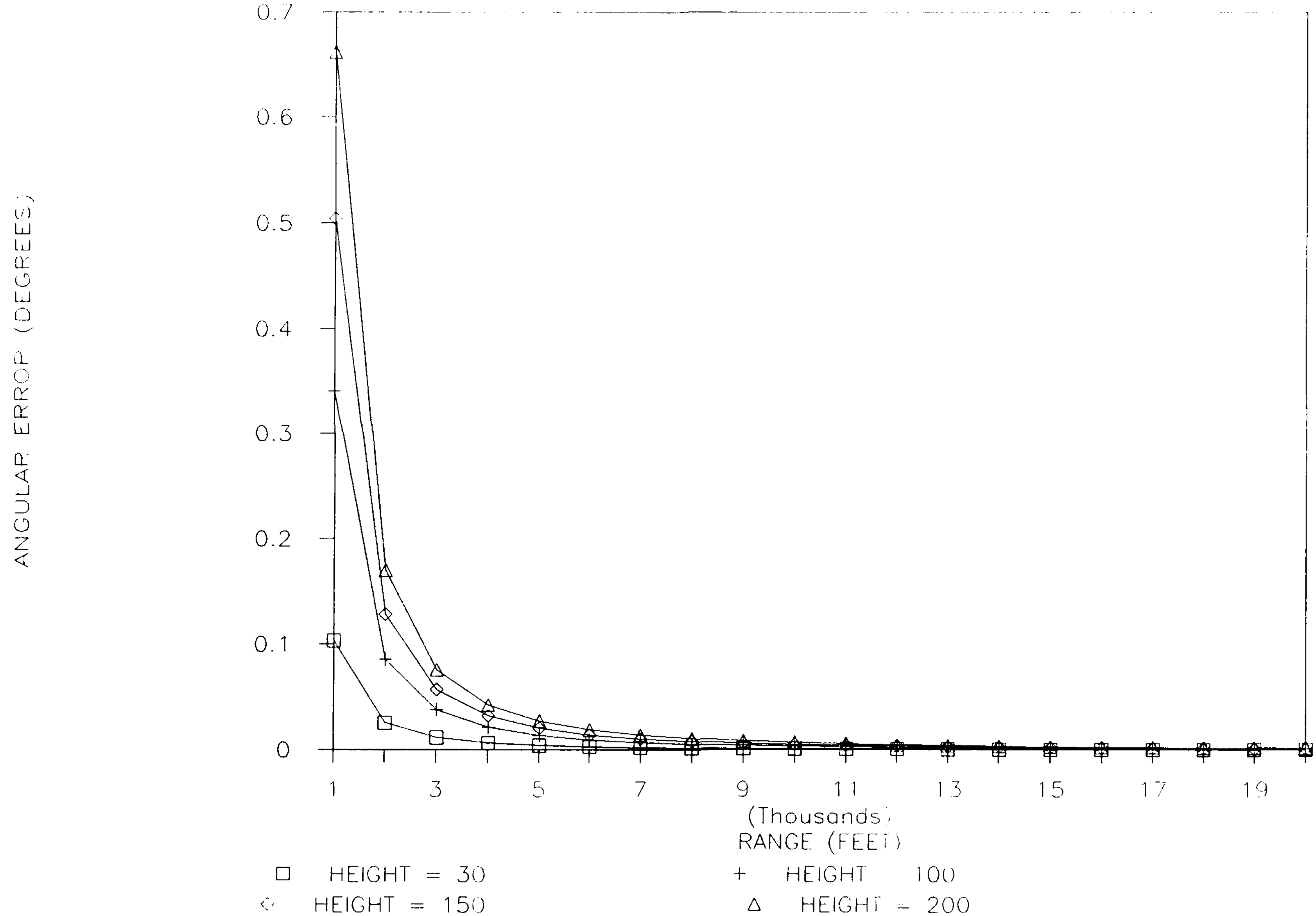
HORIZONTAL DIED ERROR
(X)
ANGULAR ERROR (DEGREES)
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
(Thousands)
RANGE (FEET)
HEIGHT = 30
HEIGHT = 100
HEIGHT = 150
HEIGHT = 200

HORIZONTAL DTED ERROR X

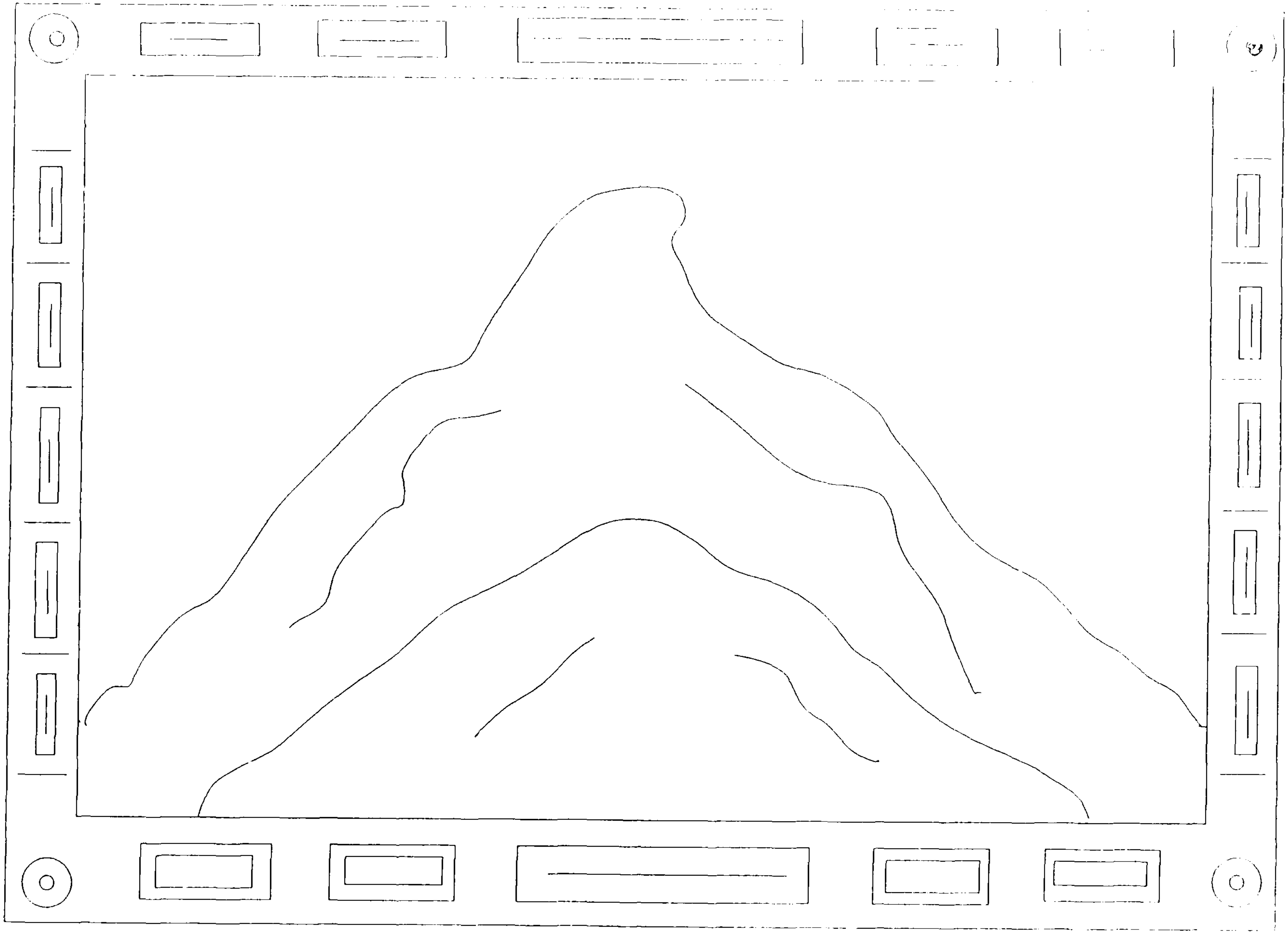


HORIZONTAL DIFD ERROR

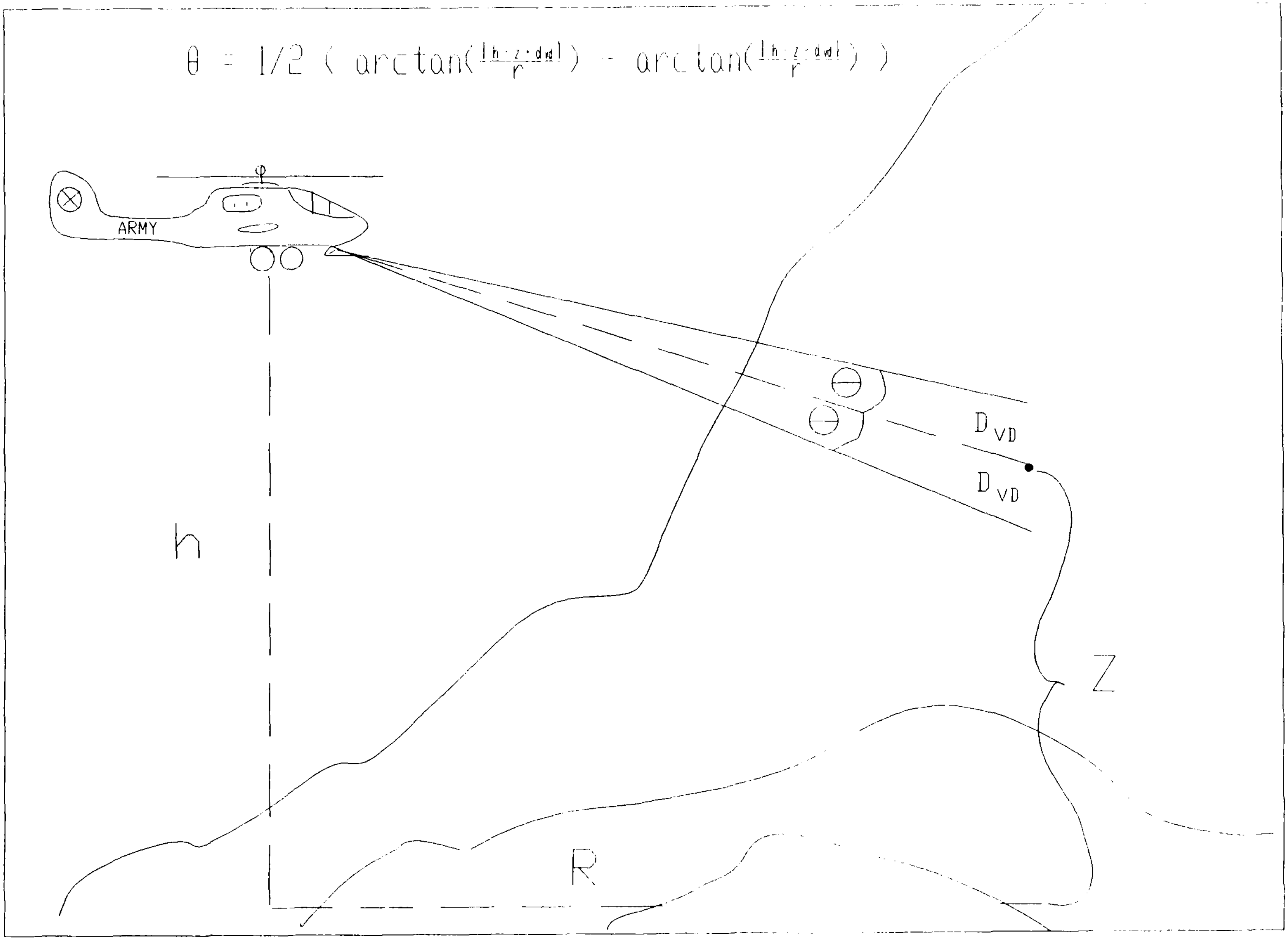
(Y)



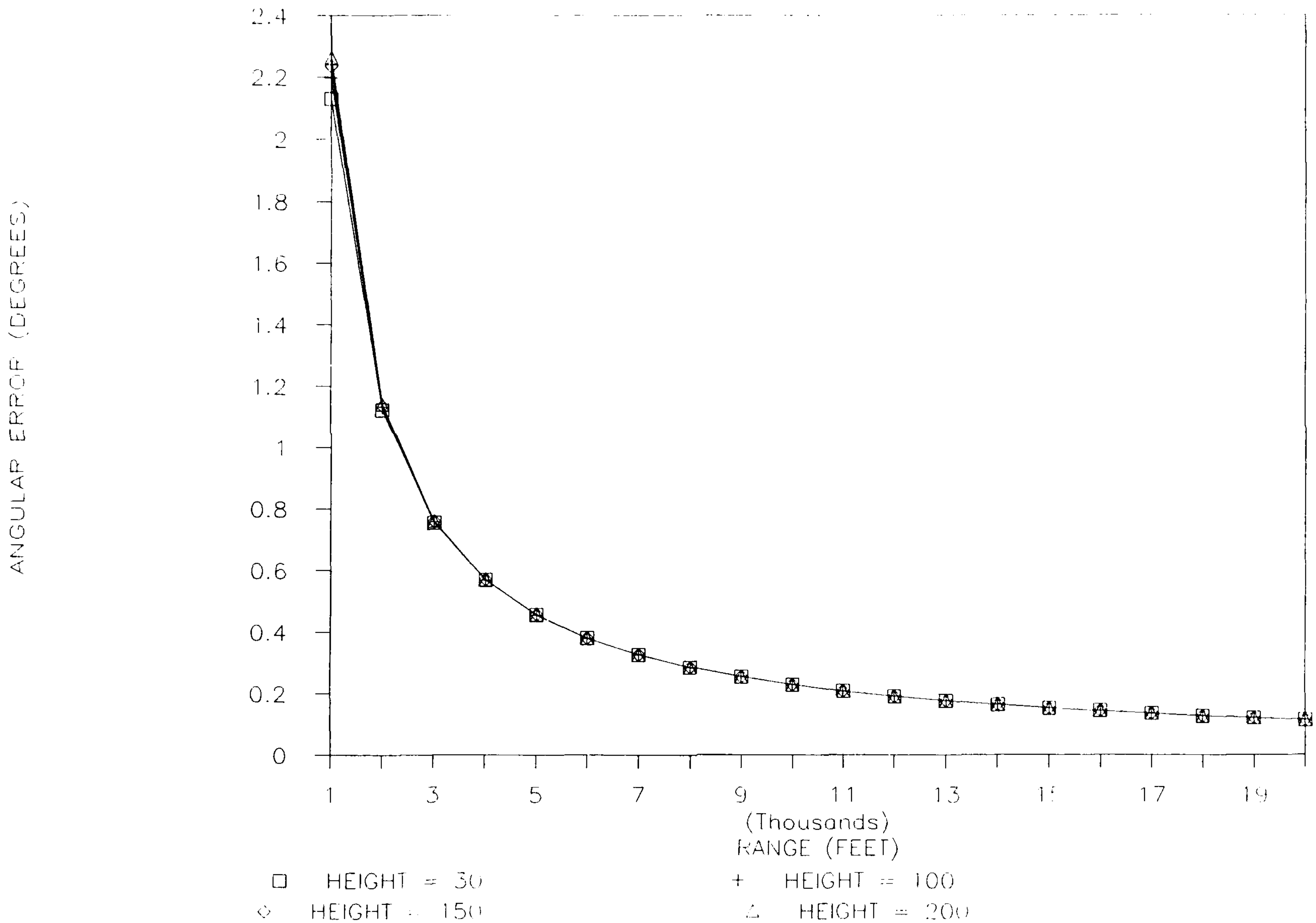
HORIZONTAL DIED ERROR Y



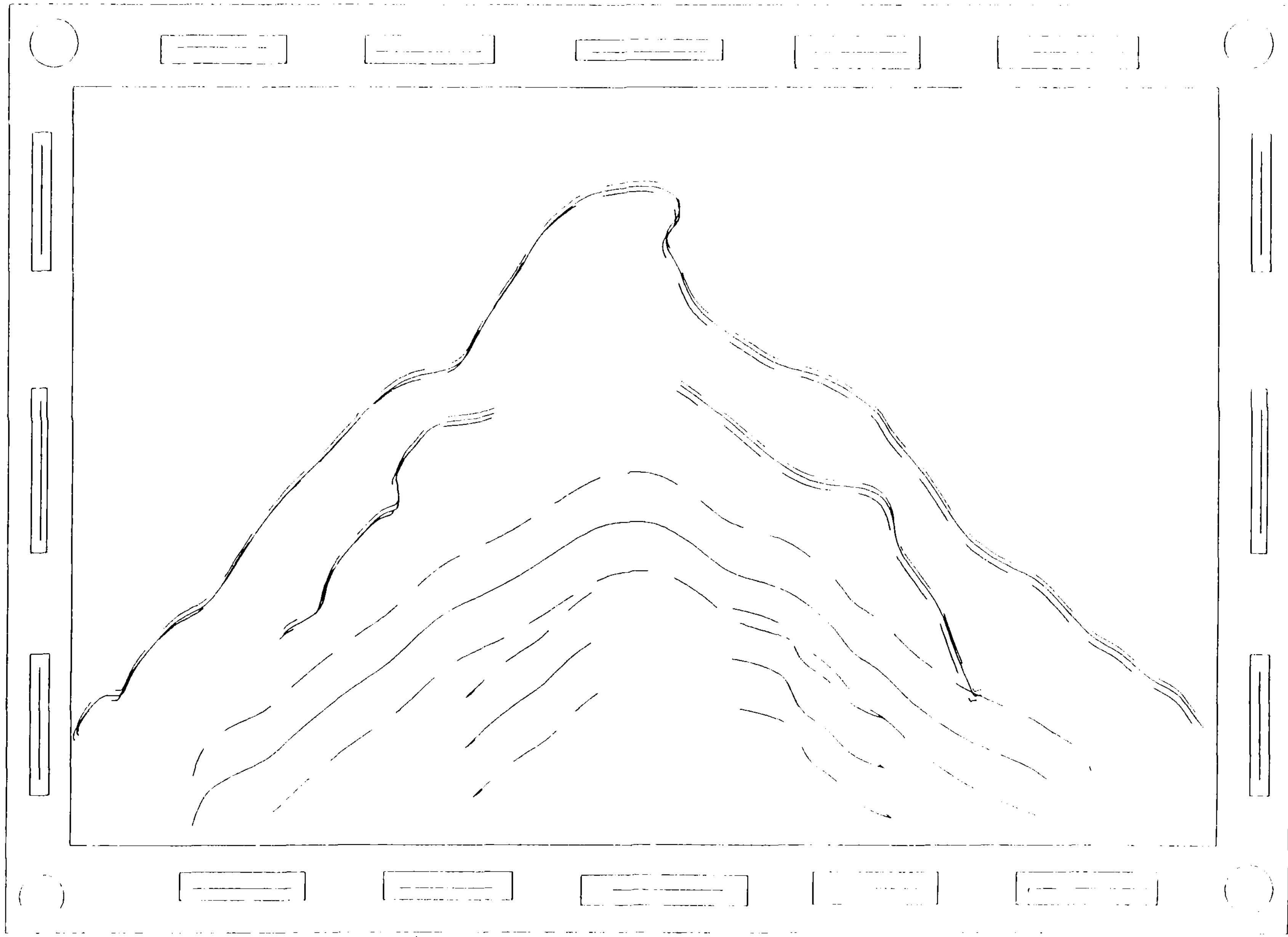
VERTICAL DTED ERROR



VERTICAL DTED ERROR

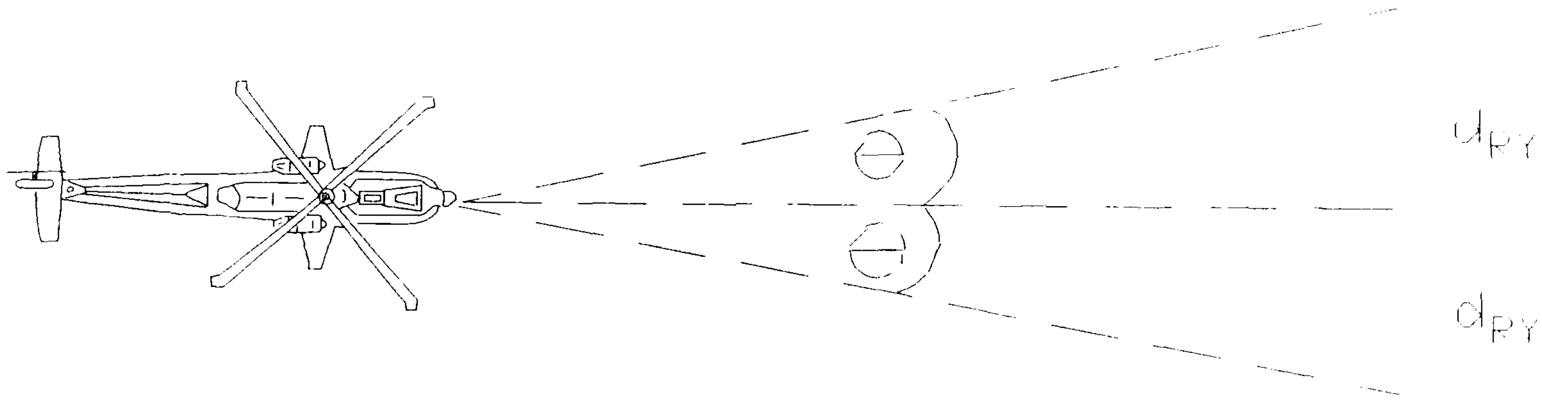


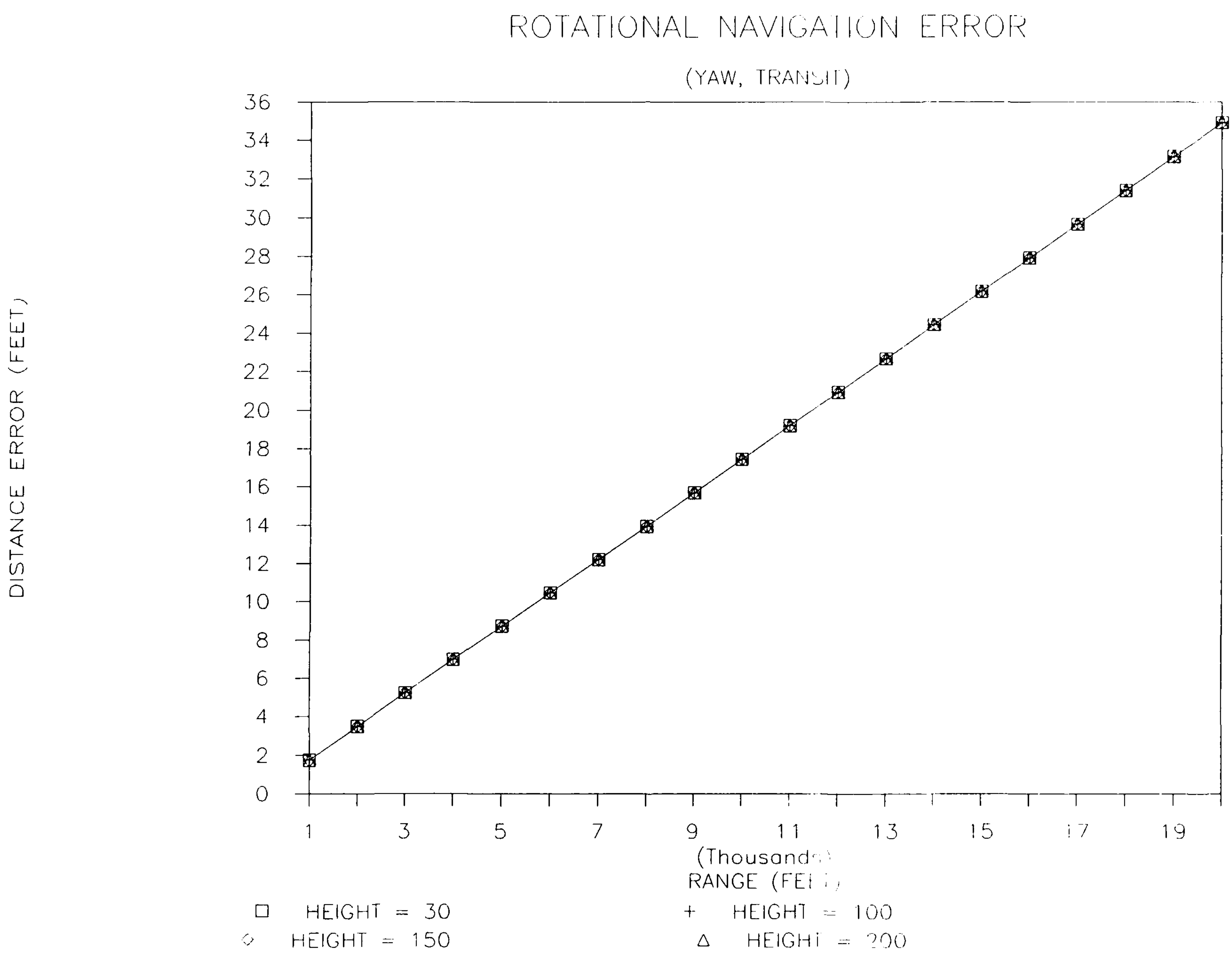
VERTICAL DIELECTRIC



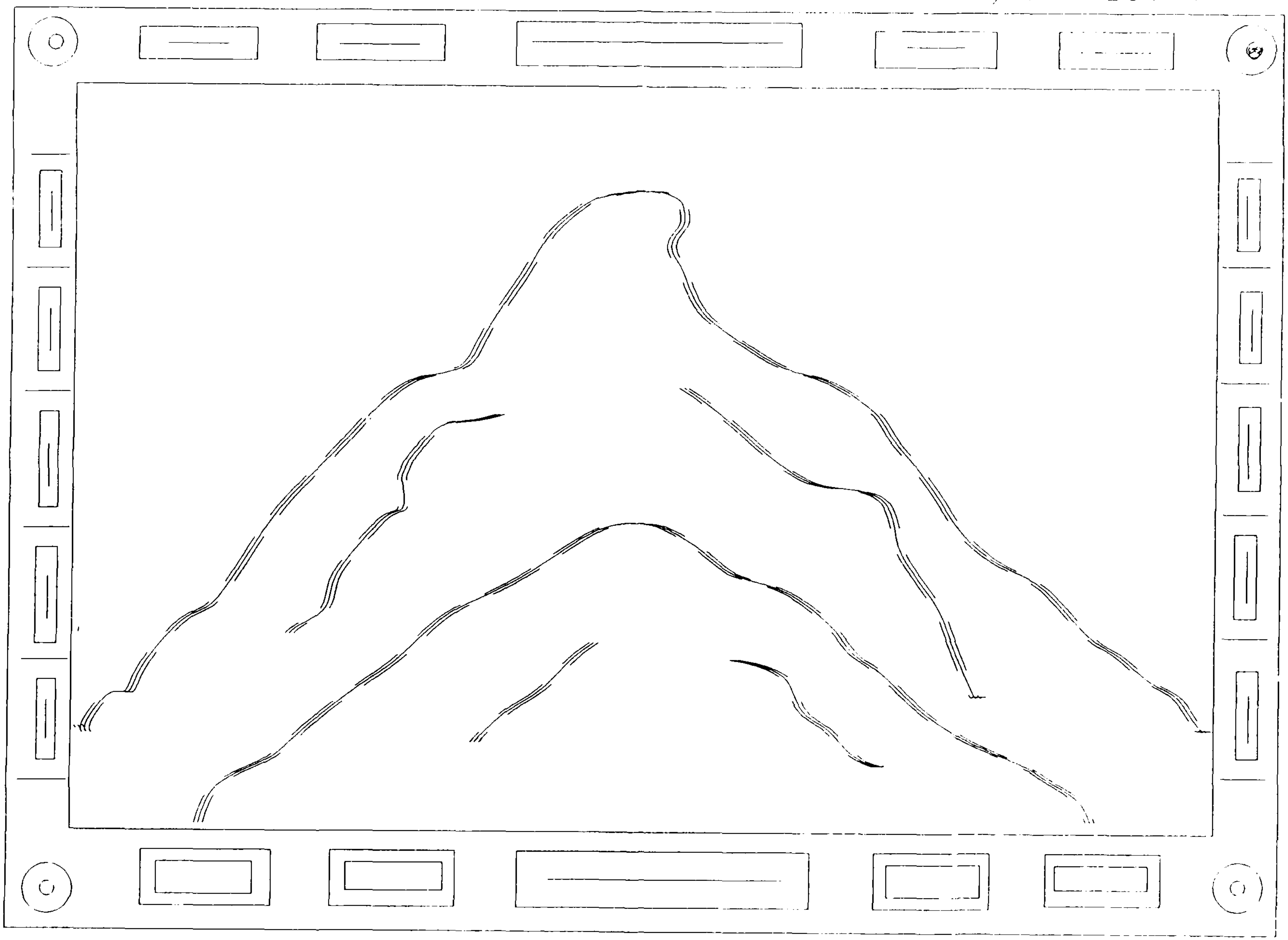
ROTATIONAL NAVIGATION ERROR   YAW

$$d_{ry} = r \tan \theta$$



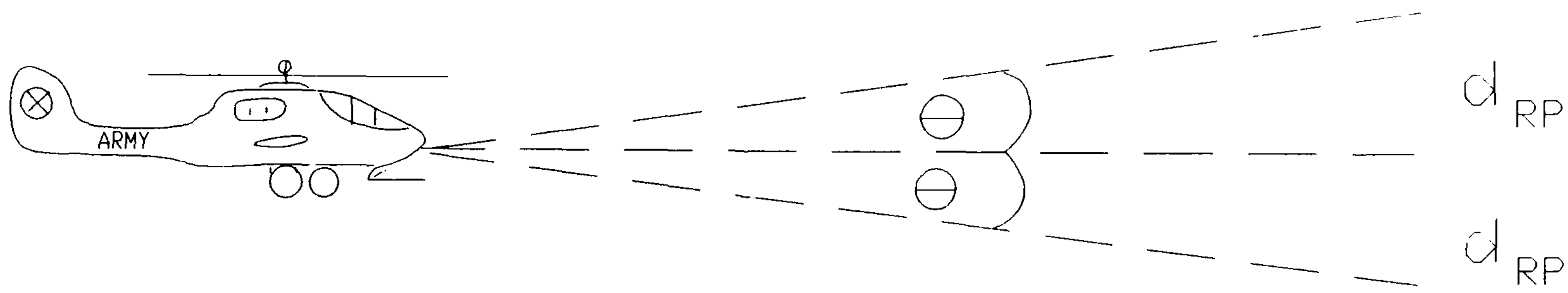

ROTATIONAL NAVIGATION ERROR
(YAW, TRANSIT)
DISTANCE ERROR (FEET)
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
3
5
7
9
11
13
15
17
19
(Thousands)
RANGE (FEET)
HEIGHT = 30
HEIGHT = 100
HEIGHT = 150
HEIGHT = 200

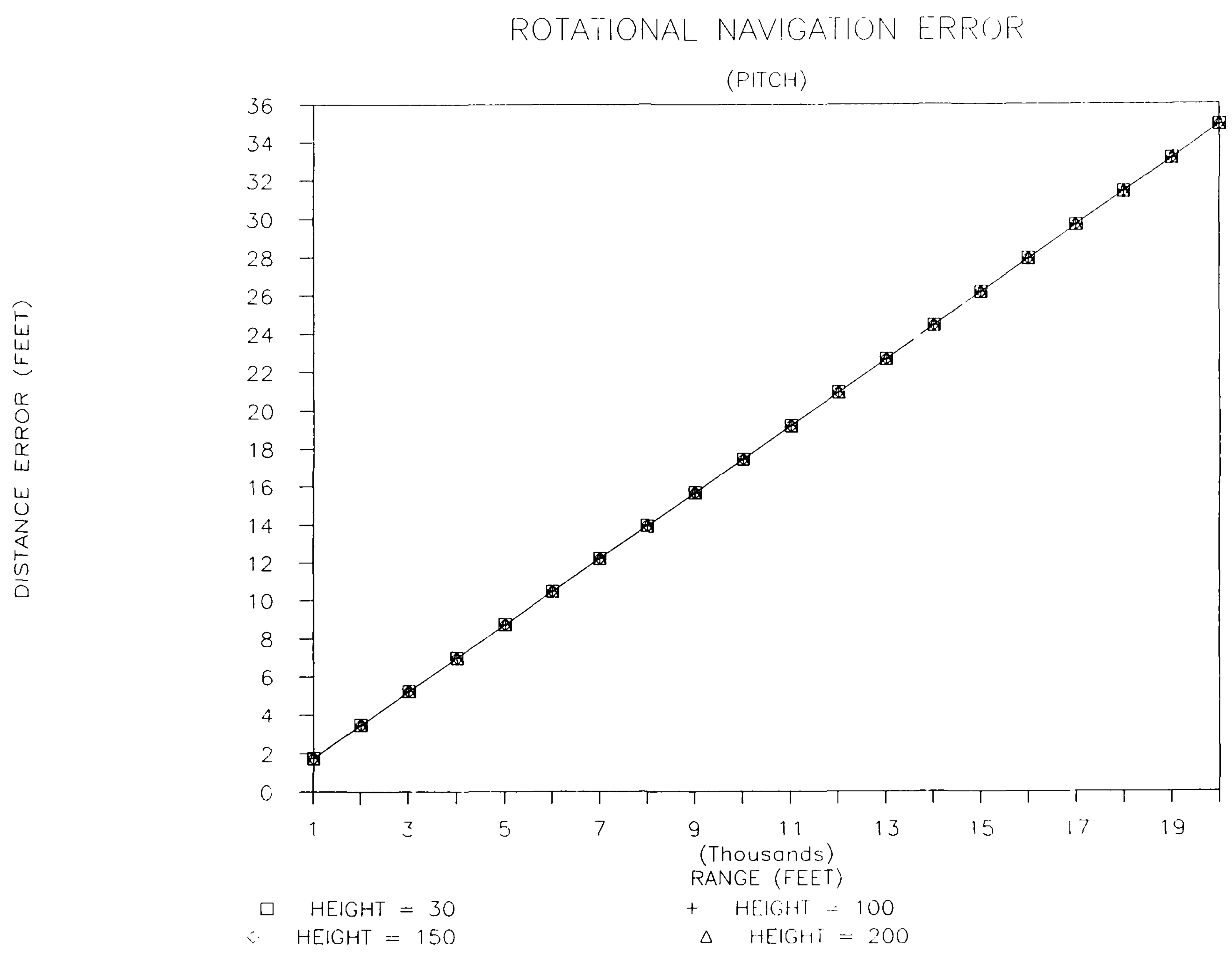
ROTATIONAL NAVIGATION ERROR - (YAW,TRANSIT)



ROTATIONAL NAVIGATION ERROR - PITCH

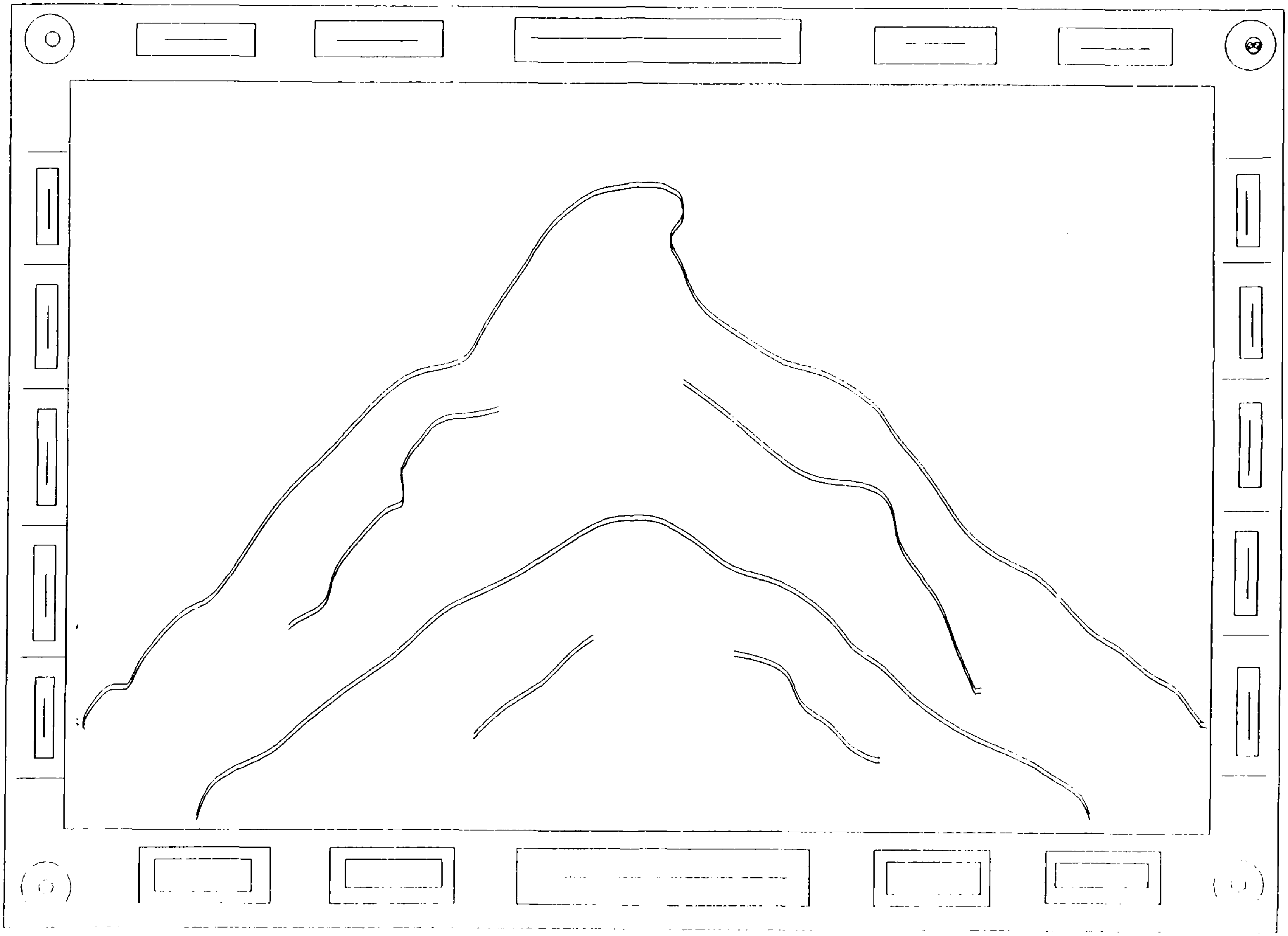
$$d_{rp} = r \tan \theta$$



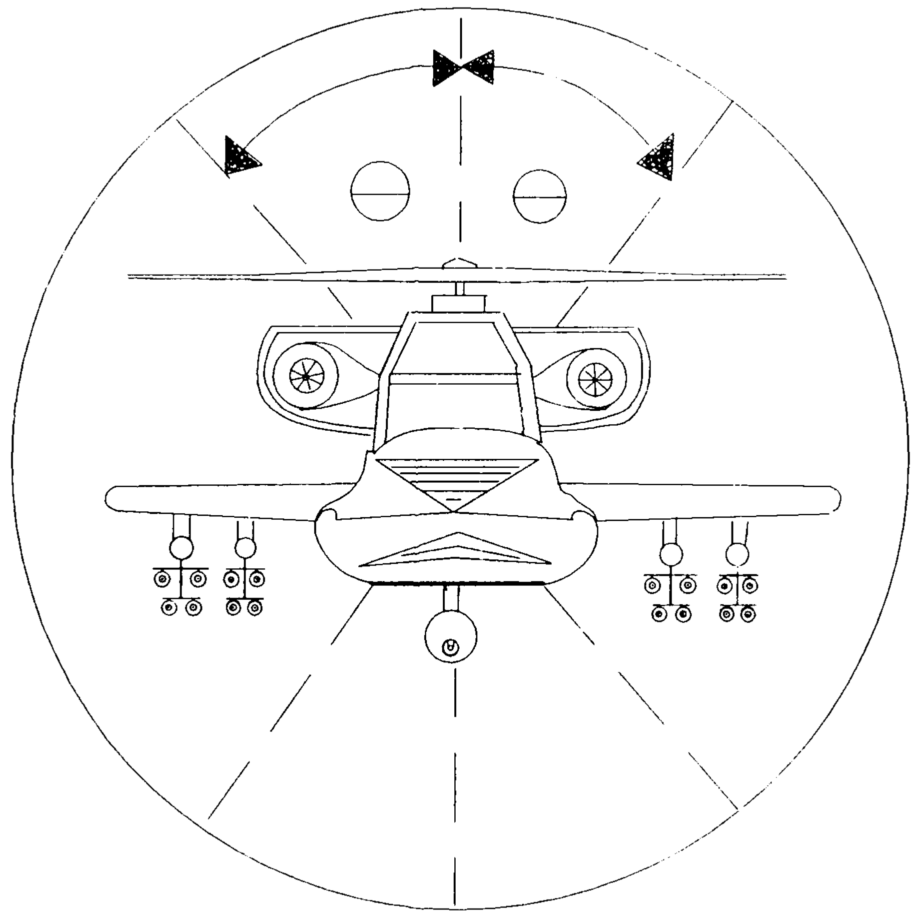


ROTATIONAL NAVIGATION ERROR
(PITCH)
DISTANCE ERROR (FEET)
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
3
5
7
9
11
13
15
17
19
(Thousands)
RANGE (FEET)
HEIGHT = 30
HEIGHT = 100
HEIGHT = 150
HEIGHT = 200

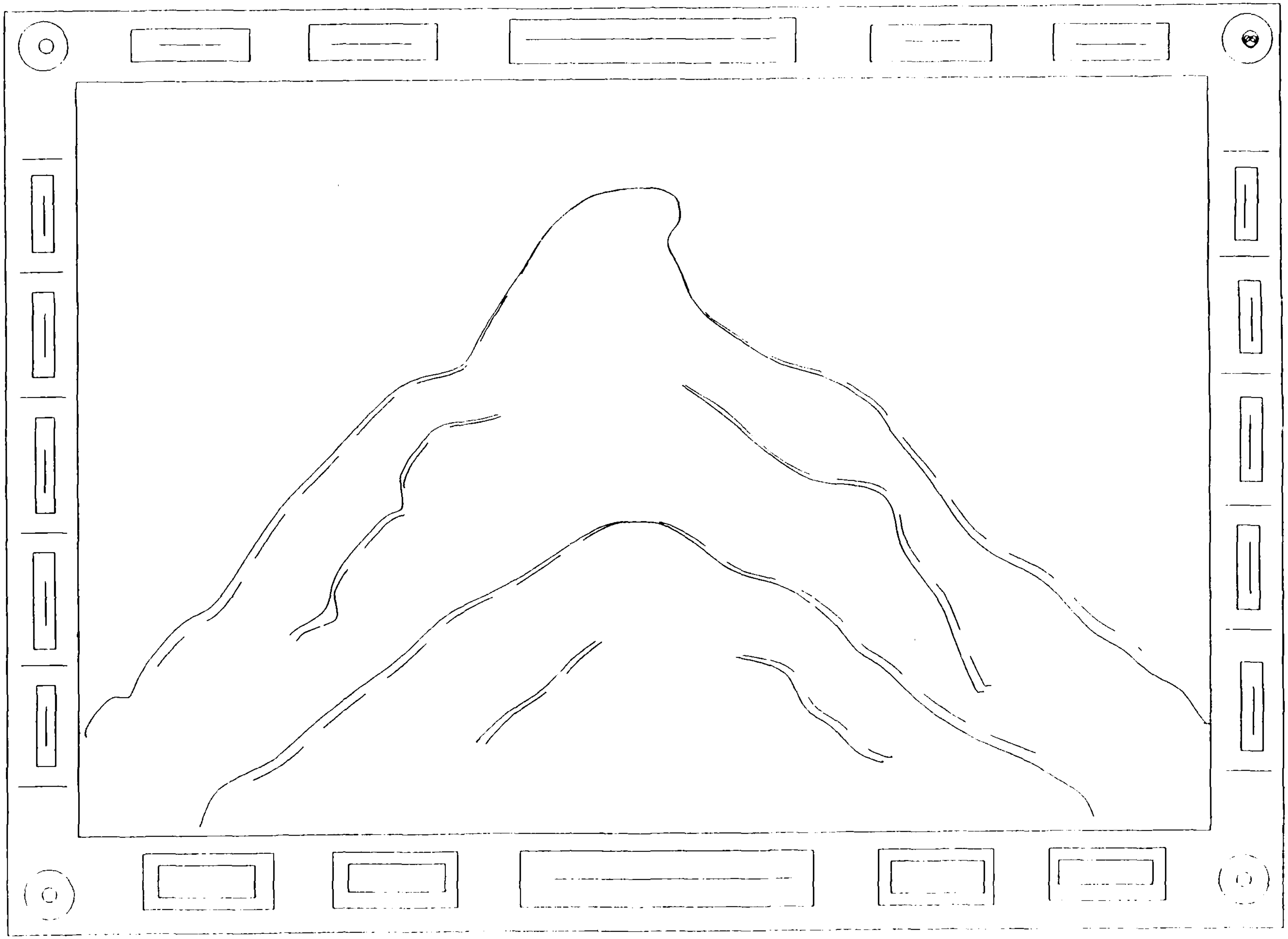
ROTATIONAL ERROR - (PITCH)



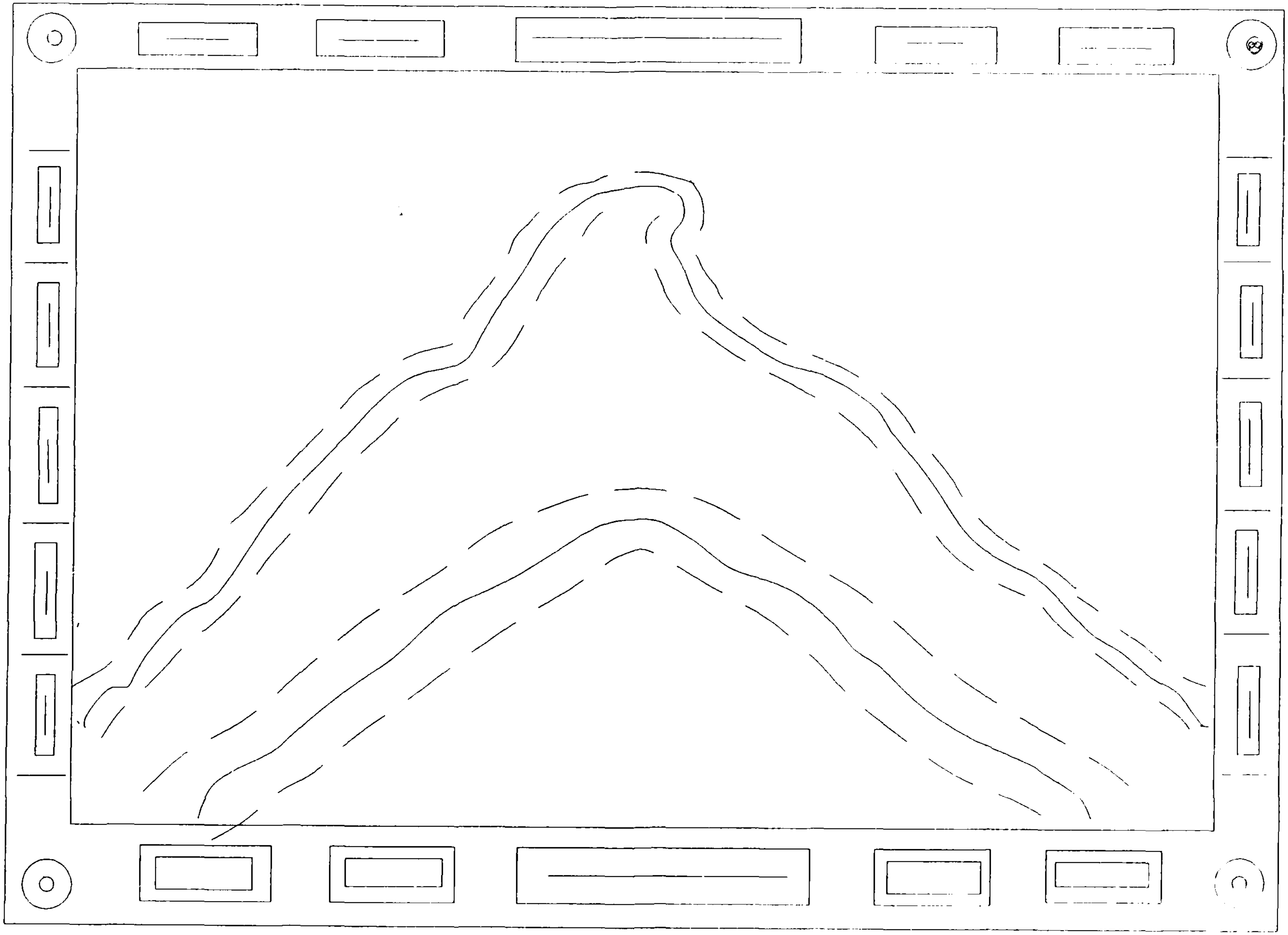
ROTATIONAL ERROR - ROLL



ROTATIONAL ERROR - (ROLL)



COMBINED ERROR



COMBINED AZIMUTH DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT .75 KM	% SCREEN AT .75 KM	0 ERROR AT 4 KM	% SCREEN AT 4 KM
NAVIGATION POSITION	1.1414	2.85	0.2283	0.57
DTED	1.2984	3.25	0.2597	0.65
NAVIGATION HEADING	0.10	0.25	0.10	0.25
DISPLAY LINEARITY @ 50%	0.20	0.50	0.20	0.50
FLIR LINEARITY @ 50%	0.25	1.25	0.25	1.25
STATISTICAL SUM	1.7623	4.41	0.6408	1.60

JCP 02/24/88
14020-37

COMBINED ELEVATION DISPLAY ERRORS

TYPE OF ERROR	O ERROR AT .75 KM	% SCREEN AT .75 KM	O ERROR AT 4 KM	% SCREEN AT 4 KM
NAVIGATION POSITION	0.0651	0.22	0.0130	0.04
DTED	0.8569	2.86	0.1731	0.58
NAVIGATION ALTITUDE	0.100	0.33	0.100	0.33
DISPLAY LINEARITY @ 50%	0.150	0.50	0.150	0.50
FLIR LINEARITY @ 50%	0.188	0.60	0.188	0.60
STATISTICAL SUM	0.900	3.00	0.320	1.07

JCP 02/24/88
14020-38

PRELIMINARY CONCLUSIONS

THE SYSTEM AS DEFINED IS MARGINALLY USEFUL
DUE TO THE MAGNITUDE OF THE COMBINED ERRORS

TO DO

* DETERMINE THE SYSTEM REQUIREMENTS TO BOUND THE ERROR TO ACCEPTABLE LIMITS
* DEVELOP A COMPUTER MODEL TO DEMONSTRATE THE CONCEPTS

PROGRAM SCHEDULE

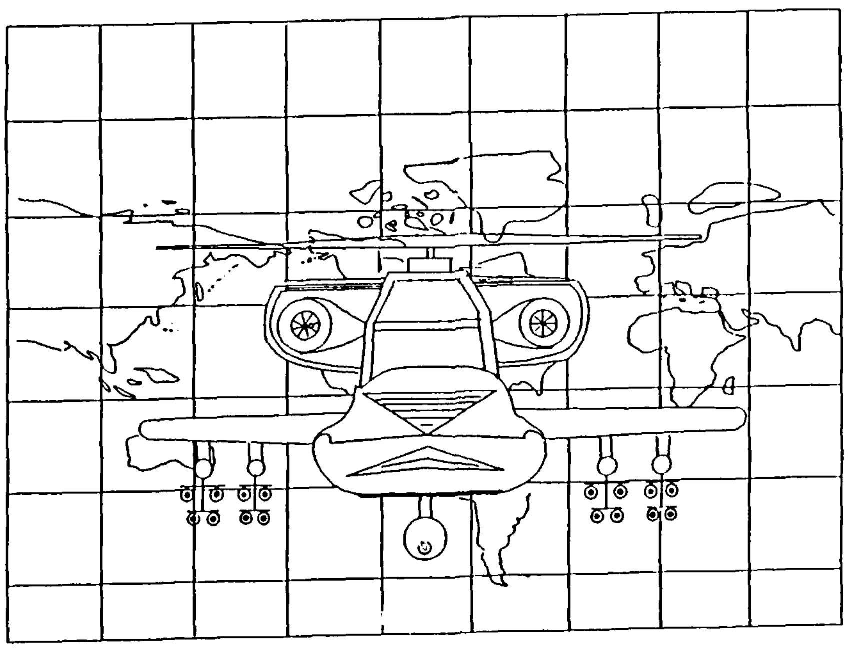
Task	Schedule (FEB 1988 – JUN 1990)
PHASE I	
INTERIM PRESENTATION	V TODAY
DETERMINE SYSTEM REQTS	——V 3/31
DEVELOP COMPUTER MODEL DEMONSTRATION	———V 4/30
DEVELOP FINAL REPORT	——V 5/31
(NO COST CONTRACT EXTENSION)	- - - - - V 5/31
PHASE II	
INVESTIGATE METHODS OF DISPLAYING ERROR BOUNDS	———V 7/31
DEFINE REQUIREMENTS FOR PROTOTYPE	————V 10/31
DEVELOP SYSTEM H/W AND S/W DESIGN FOR PROTOTYPE	—————V 2/28
DEVELOP PROTOTYPE	——V 5/31/90

Timeline: 1988: FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC; 1989: JAN, FEB; 1990: JUN

APPENDIX B

PROGRAM UPDATE
8 MARCH 1988

PARAMETRIC ANALYSIS OF MAP DATA



JCP 02/24/88
14020-29

AGENDA

8 MARCH 1988

* ERROR REVISIONS FOR ATR USE
* HOW CAN MAP DATA HELP AN ATR?
* SYSTEM CONCEPT
* NEXT STEP - PROOF OF CONCEPT

OPEN LOOP
COMBINED AZIMUTH DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT .75 KM	DISTANCE ERROR (M) AT .75 KM	0 ERROR AT 4 KM	DISTANCE ERROR (M) AT 4 KM
NAVIGATION POSITION	1.1414°	16.00	0.2283°	16.00
DTED	1.2984°	18.24	0.2597°	18.24
NAVIGATION HEADING	0.1000°	1.31	0.1000°	6.98
DISPLAY LINEARITY @ 50%	N/A	N/A	N/A	N/A
FLIR LINEARITY @ 50% (USING SAIRS)	0.1000°	1.31	0.1000°	6.98
STATISTICAL SUM	1.7630°	24.33	0.3736°	26.19

JCP 03/03/88
14020-42

OPEN LOOP
COMBINED ELEVATION DISPLAY ERROR

TYPE OF ERROR	O ERROR AT .75 KM	DISTANCE ERROR (M) AT .75 KM	O ERROR AT 4 KM	DISTANCE ERROR (M) AT 4 KM
NAVIGATION POSITION	0.0651°	0.9194	0.0130°	0.9194
DTED	0.8569°	12.1615	0.1731°	12.1615
NAVIGATION ATTITUDE	0.1000°	1.3090	0.1000°	6.9813
DISPLAY LINEARITY @ 50%	N/A	N/A	N/A	N/A
FLIR LINEARITY @ 50% (USING SAIRS)	0.0750°	0.9817	0.0750°	5.2360
STATISTICAL SUM	0.8679°	12.3055	0.2139°	14.9967

JCP 03/03/88
14020-43

OPEN LOOP
COMBINED AZIMUTH DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
NAVIGATION POSITION	0.6146°	16.00	0.3066°	16.00
DTED	0.6992°	18.24	0.3489°	18.24
NAVIGATION HEADING	0.1000°	2.62	0.1000°	5.24
DISPLAY LINEARITY @ 50%	N/A	N/A	N/A	N/A
FLIR LINEARITY @ 50% (USING SAIRS)	0.1000°	2.62	0.1000°	5.24
STATISTICAL SUM	0.9416°	24.54	0.4855°	25.37

JCP 03/03/88
14020-44

OPEN LOOP
COMBINED ELEVATION DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
NAVIGATION POSITION	0.0353°	0.9194	0.0175°	0.9194
DTED	0.3862°	12.1615	0.2324°	12.1615
NAVIGATION ATTITUDE	0.1000°	2.6180	0.1000°	5.2360
DISPLAY LINEARITY @ 50%	N/A	N/A	N/A	N/A
FLIR LINEARITY @ 50% (USING SAIRS)	0.0750°	1.9635	0.0750°	3.9270
STATISTICAL SUM	0.4075°	12.6276	0.2645°	13.8414

JCP 03/03/88
14020-45

CLOSED LOOP
COMBINED AZIMUTH DISPLAY ERROR

TYPE OF ERROR	Θ ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	Θ ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
DTED	0.6992°	18.24	0.3489°	18.24
FLIR LINEARITY @ 50% (USING SAIRS)	0.1000°	2.62	0.1000°	5.24
STATISTICAL SUM	0.7063°	18.43	0.3629°	18.98

JCP 03/03/88
14020-47

CLOSED LOOP
COMBINED ELEVATION DISPLAY ERROR

TYPE OF ERROR	0 ERROR AT 1.5 KM	DISTANCE ERROR (M) AT 1.5 KM	0 ERROR AT 3 KM	DISTANCE ERROR (M) AT 3 KM
DTED	0.3862°	12.16	0.2324°	12.16
FLIR LINEARITY @ 50% (USING SAIRS)	0.0750°	1.96	0.0750°	3.93
STATISTICAL SUM	0.3934°	12.32	0.2442°	12.78

JCP 03/03/88
14020-46

HOW CAN MAP DATA HELP AN ATR?

SIGNATURE AIDS

* RANGE TO THE PIXEL CAN HELP ESTIMATE THE PIXEL SIZE
* SLOPE AT THE PIXEL CAN DETERMINE THE ASPECT RATIO
* SIGNATURE CHARACTERISTICS OF DIGITAL FEATURES CAN HELP DISTINGUISH FEATURES FROM TARGETS

EXCLUSION AIDS

* LAKE FROM DIGITAL FEATURE ANALYSIS
* DENSE FOREST FROM DIGITAL FEATURE ANALYSIS
* TARGET UNLIKELY AT GIVEN SLOPE
* DIGITAL FEATURE MATCHES CANDIDATE TARGET

CONTEXT AIDS

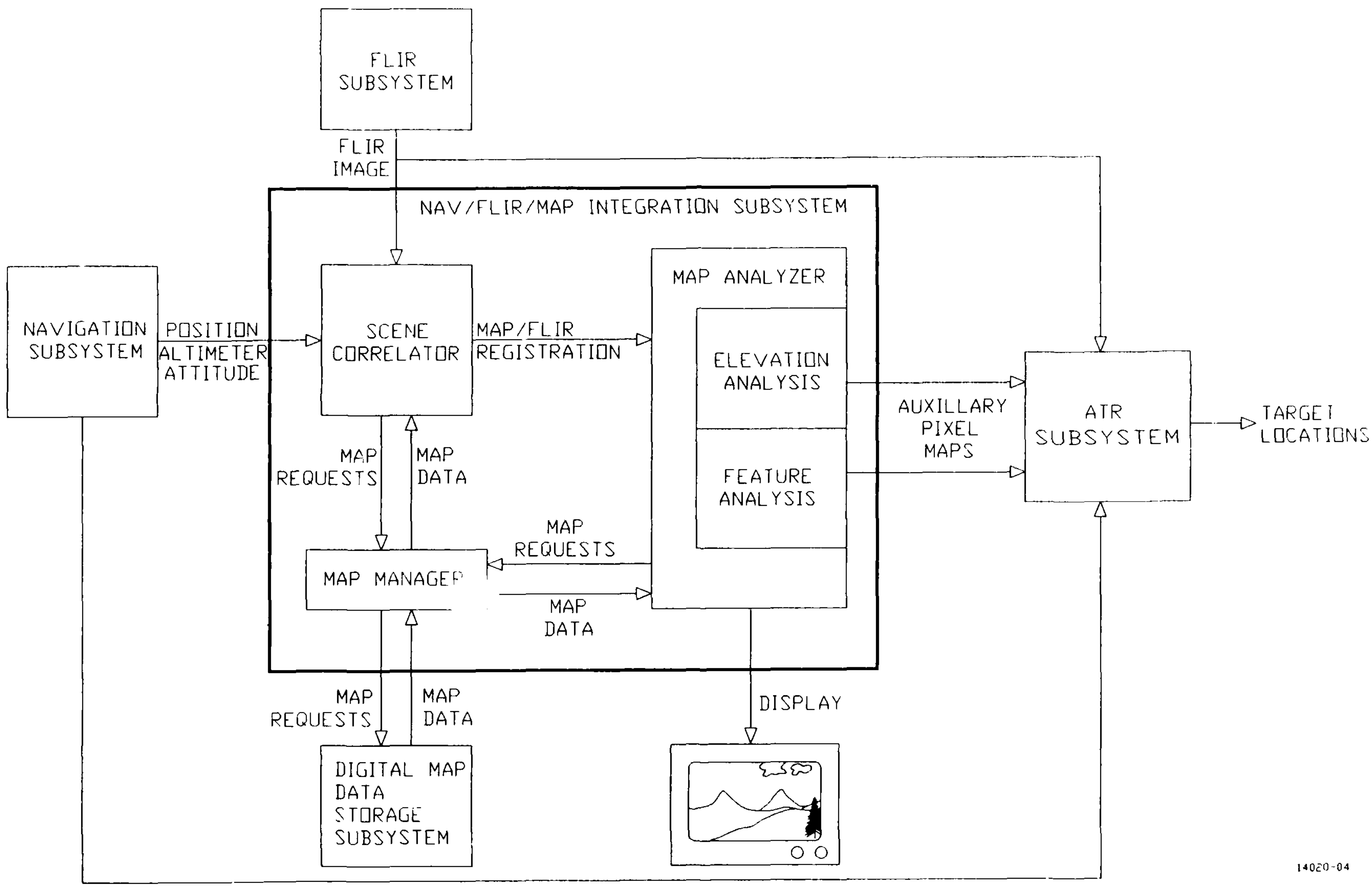
* DIGITAL FEATURE ANALYSIS DATA INDICATES THE TARGET IS ON OR NEAR:

  - ROAD
  - RAILROAD
  - AIR STRIP
  - BODY OF WATER

* DIGITAL TERRAIN ELEVATION DATA INDICATES THE TARGET IS IN THE AIR

JCP 03/04/88
14020-52

INTEGRATED FLIR/MAP ATR SYSTEM



SCENE CORRELATOR

* REGISTERS FLIR WITH MAP ELEVATION AND FEATURE DATA
* REMOVES NAVIGATION ERRORS FROM CONSIDERATION
* TRACK FROM START OF MISSION, SO NEVER FAR OFF

MAP MANAGER

* INTERFACE TO DIGITAL MAP DATA STORAGE SUBSYSTEM
* KEEPS LOCAL MAP DATA BASE FOR OTHER MODULES

MAP ANALYZER

* ELEVATION DATA ANALYSIS
* FEATURE DATA ANALYSIS
* MAP/FLIR DISPLAY

JCP 03/04/88
14020-55

ELEVATION DATA ANALYSIS

<u>SOURCES</u>

* DTED - DIGITAL TERRAIN ELEVATION DATA
* DIGITIZED ELEVATION DATA FOR FIREFINDER
* TERCOM - TERRAIN CONTOUR MATCHING DATA BASE

ELEVATION DATA ANALYSIS

PRODUCTS

* RANGE MAP
  - RANGE FOR EACH FLIR PIXEL
  - CAN BE USED BY ATR TO DETERMINE PIXEL SIZE
* SLOPE MAP
  - SLOPE FOR EACH FLIR PIXEL
  - CAN BE USED BY ATR TO DETERMINE ASPECT RATIOS

FEATURE DATA ANALYSIS

SOURCES

* DFAD (1, 1C, 2, 2J) - DIGITAL FEATURE ANALYSIS DATA
* VOD - VERTICAL OBSTRUCTION DATA

JCP 03/04/88
14020-58

FEATURE DATA ANALYSIS

PRODUCTS

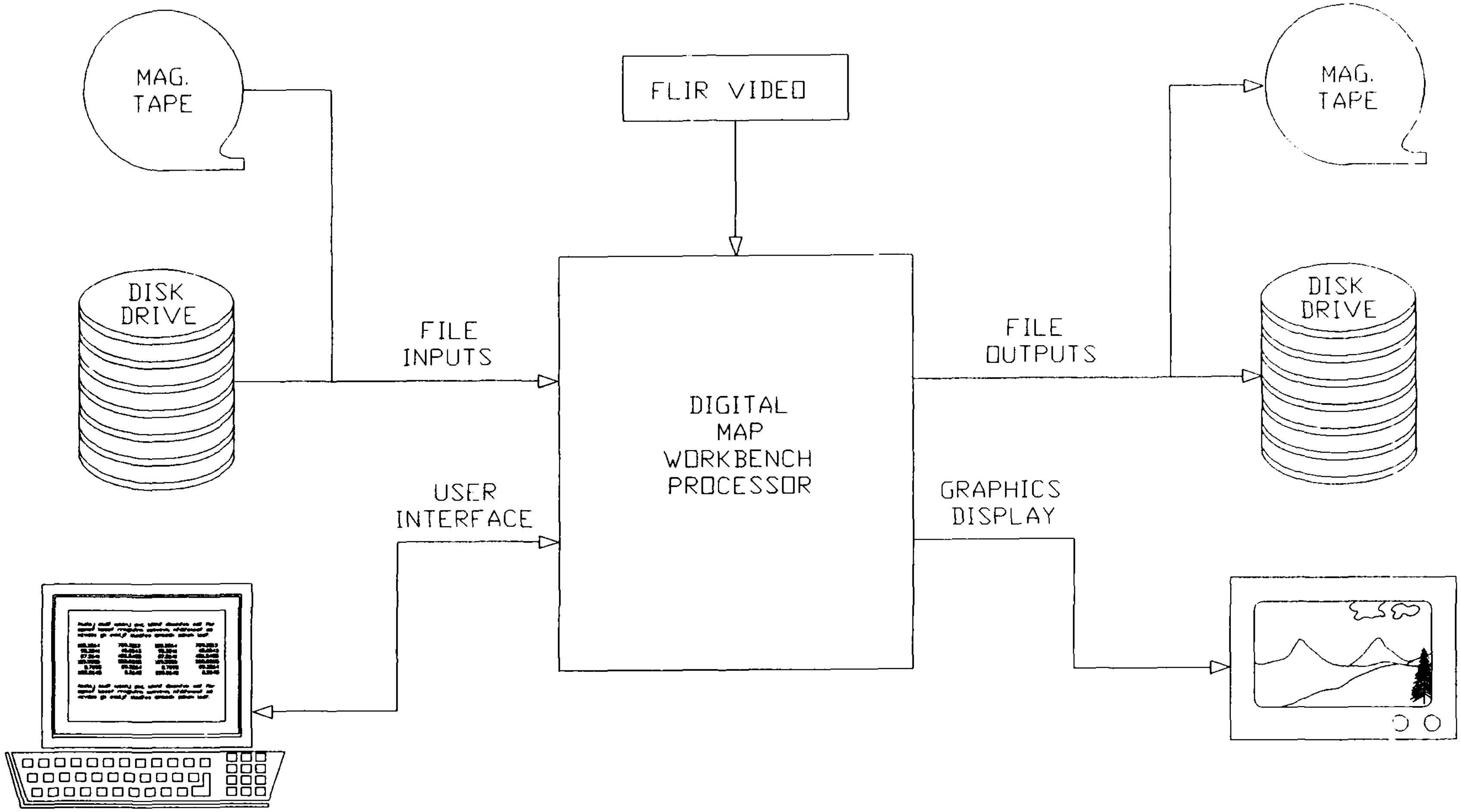
* FEATURE MAP
  - FEATURE CODES FOR EACH FLIR PIXEL
  - CONFIDENCE CODE FOR EACH FLIR PIXEL
  - CAN BE USED TO ELIMINATE FEATURES AS TARGETS
* SUITABILITY MAP
  - SUITABILITY RATING (E.G. 1-9) FOR EACH FLIR PIXEL
  - HOW LIKELY IS A TARGET TO BE AT THAT PIXEL?
  - FOR EXAMPLE, 1 FOR A TANK IN A LAKE, 9 FOR A TANK ON A ROAD
* SIGNATURE MAP
  - EXPECTED SIGNAL INTENSITY FOR EACH PIXEL
  - ADJUSTED FOR: TEMPERATURE, TIME OF DAY, AND ATMOSPHERE

NEXT STEP

PROOF OF CONCEPT

* OBTAIN DIGITAL MAP DATA FOR SHENANDOAH
* COLLECT FLIR IMAGERY OF SHENANDOAH
* DEVELOP DIGITAL MAP - ATR WORKBENCH

DIGITAL MAP - ATR WORKBENCH



14020-05

DIGITAL MAP - ATR WORKBENCH

FILE INPUTS

* ELEVATION DATA
* FEATURE DATA
* FLIR IMAGERY
* TARGET OBJECT DATA BASE

DIGITAL MAP - ATR WORKBENCH

USER INPUTS

* DATA BASE SPECIFICATION
* ALGORITHM CHOICES (TRY DIFFERENT ELEVATION SMOOTHING AND INTERPOLATION METHODS)
* VIEWING PARAMETERS (LOCATION, ORIENTATION)
* FLIR PARAMETERS (FIELD OF VIEW, PIXEL RESOLUTION)
* TARGET OBJECT SPECIFICATION (TANK, TRUCK, ETC.)
* WHICH FUNCTIONS TO PERFORM

DIGITAL MAP - ATR WORKBENCH

PROCESSING

* COMPUTE PIXEL RANGE MAP
* COMPUTE PIXEL SLOPE MAP
* DETERMINE RIDGE LINES
* REGISTER RIDGE LINES WITH FLIR
* COMPUTE REGISTRATION CORRELATION STATISTICS
* COMPUTE DIMENSIONS OF CLOSED OBJECTS IN FLIR BIT MAP
* PROJECT TARGET OBJECTS ONTO FLIR BIT MAP
* COMPUTE FEATURE PIXEL MAP
* DETERMINE CONFIDENCE OF FEATURE AT EACH PIXEL
* DETERMINE SUITABILITY PIXEL MAP FOR A TARGET OBJECT

JCP 03/04/88
14020-63

DIGITAL MAP - ATR WORKBENCH

<u>FILE OUTPUTS</u>

* RANGE PIXEL MAP
* SLOPE PIXEL MAP
* FEATURE PIXEL MAP
* FEATURE PIXEL CONFIDENCE MAP
* TARGET SUITABILITY PIXEL MAP
* EXPECTED SIGNATURE MAP

DIGITAL MAP - ATR WORKBENCH

DISPLAYS

* USER SPECIF'ED OVERLAYS OF:
  - FLIR IMAGERY
  - RIDGELINES WITH ERROR BOUNDS
  - RANGE MAP
  - SLOPE MAP
  - TARGET PROJECTIONS
  - FEATURE MAP
  - TARGET SUITABILITY
  - EXPECTED SIGNATURE MAP
* STATISTICS ON:
  - RIDGELINE CORRELATIONS
  - TARGET-FLIR CORRELATIONS
  - TARGET DIMENSIONS

DIGITAL MAP - ATR WORKBENCH

HARDWARE CONFIGURATION

* COMPAC 386/20 COMPUTER
* NUMERIC PROCESSOR
* LARGE CAPACITY DISK
* MAGNETIC TAPE INTERFACE AND DRIVE
* VIDEO FRAME GRABBER
* HIGH RESOLUTION GRAPHICS PROCESSOR BOARD AND MONITOR

JCP 03/04/88
14020-67

PHASE II

* OBTAIN DIGITAL IMAGERY OF SHENANDOAH
* COLLECT FLIR IMAGERY OF SHENANDOAH
* DEVELOP DIGITAL MAP - ATR WORKBENCH
* USE WORKBENCH AND SHENANDOAH DATA TO TEST ALGORITHMS
* DEMONSTRATE MAP-FLIR CORRELATION WITH SHENANDOAH DATA

APPENDIX C

INTEGRATED FLIR/MAP ATR SYSTEM

PROOF OF CONCEPT

31 MARCH 1988

JCP 03/30/88
14020-70

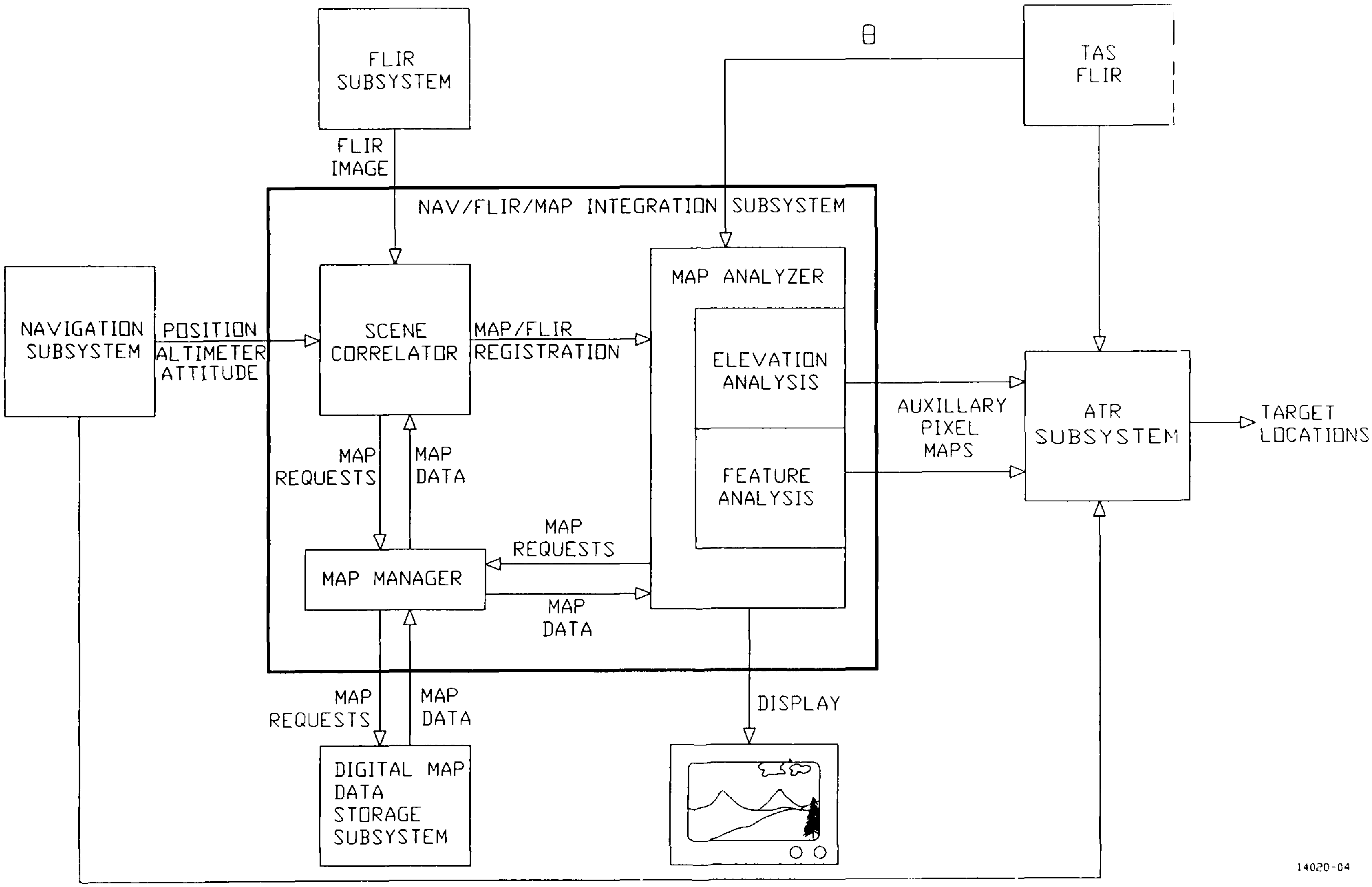
AGENDA

* QUICK REVIEW

* MAJOR STEPS
  - DATA COLLECTION
  - WORKSTATION DEVELOPMENT
  - ALGORITHM DEVELOPMENT

* TENTATIVE SCHEDULE AND COST

INTEGRATED FLIR/MAP ATR SYSTEM



PHASE II

* OBTAIN DIGITAL IMAGERY OF SHENANDOAH
* COLLECT FLIR IMAGERY OF SHENANDOAH
* DEVELOP DIGITAL MAP - ATR WORKBENCH
* USE WORKBENCH AND SHENANDOAH DATA TO TEST ALGORITHMS
* DEMONSTRATE MAP-FLIR CORRELATION WITH SHENANDOAH DATA

MAJOR STEPS

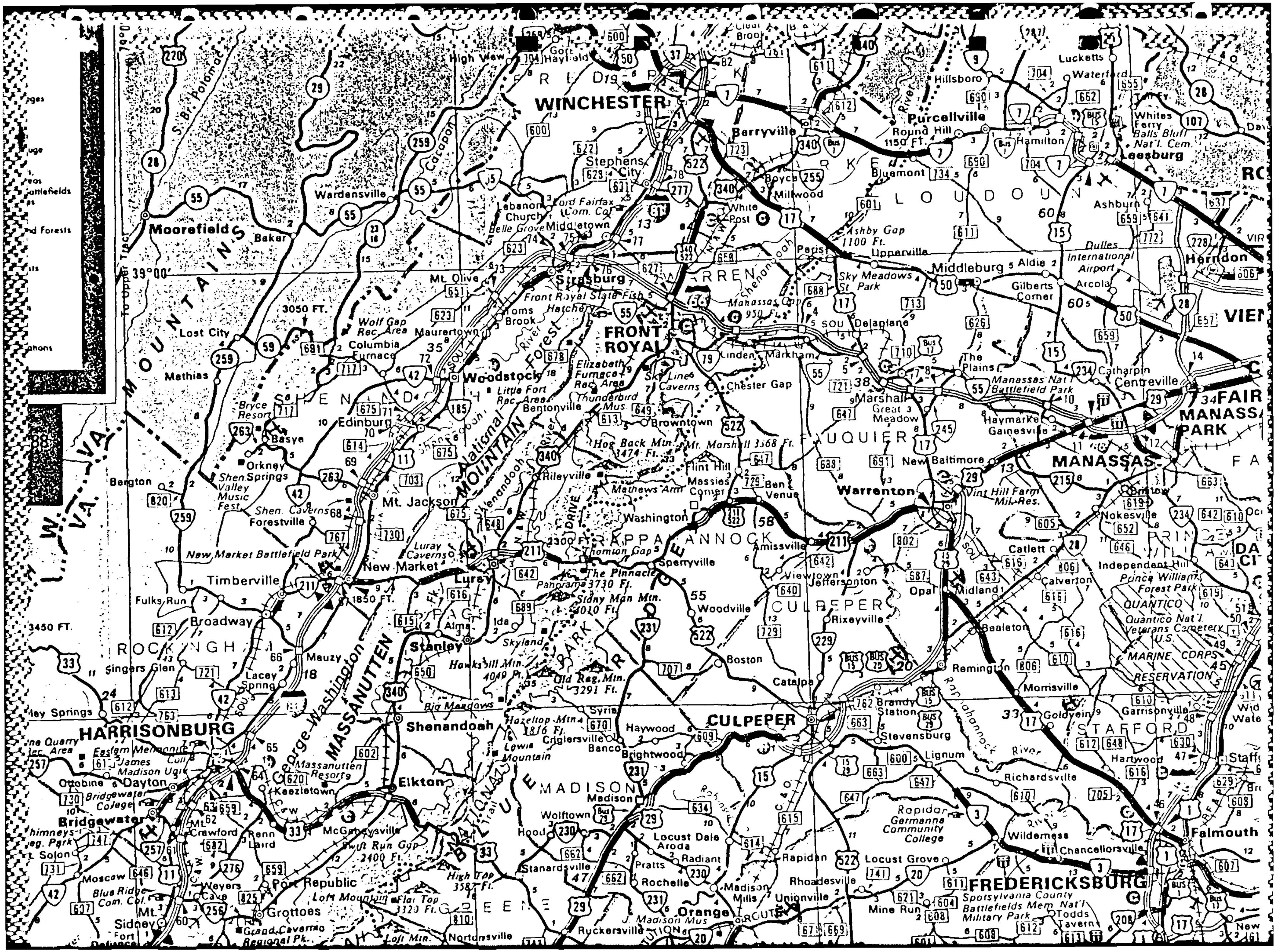
* DATA COLLECTION
* WORKSTATION DESIGN AND FABRICATION
* ALGORITHM DEVELOPMENT AND DEMONSTRATION

DATA COLLECTION

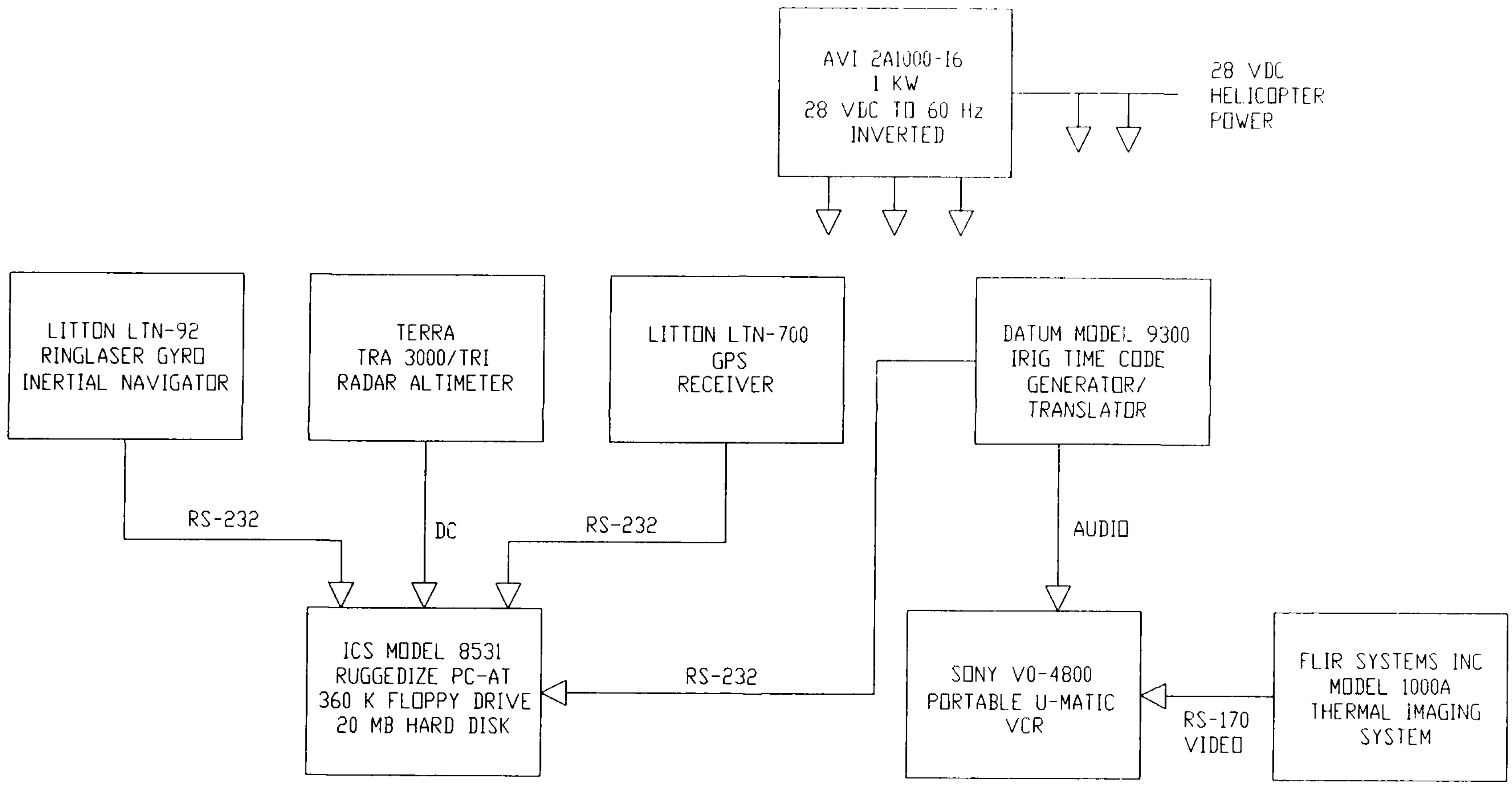
DATA COLLECTION ROUTE ATTRIBUTES

* FOLLOW MAJOR ROADS } VERIFY POSITION
* CROSS MAJOR ROADS } VERIFY POSITION
* MAJOR PEAKS IN VIEW
* GO THROUGH VALLEY
* PASS AIRPORTS FOR REFUELING

JCP 03/30/88
14020-74


WINCHESTER
Berryville
Purcellville
Leesburg
Hillsboro
Round Hill
Bluemont
Middleburg
Upperville
Stephens City
Middletown
Strasburg
FRONT ROYAL
Woodstock
Edinburg
Mt. Jackson
New Market
Timberville
Broadway
HARRISONBURG
Bridgewater
Dayton
Elkton
Grottoes
Shenandoah
Stanley
Luray
Washington
Sperryville
Warrenton
The Plains
Marshall
Haymarket
Gainesville
MANASSAS
MANASSAS PARK
Centreville
Catlett
Bealeton
Remington
CULPEPER
Madison
Orange
FREDERICKSBURG
Falmouth
Moorefield
Wardensville
Lost City
Mathias
Basye
Orkney Springs
Forestville
Boston
Woodville
Amissville
Rixeyville
Brandy Station
Stevensburg
Locust Grove
Wilderness
Chancellorsville
Dulles International Airport
MARINE CORPS RESERVATION
MASSANUTTEN
W. VA.
VA.
39°00'

FLIR/MAP HELICOPTER DATA COLLECTION SYSTEM



14020 06

FLIR/MAP HELICOPTER COLLECTION SYSTEM

PERFORMANCE CHARACTERISTICS

FLIR VIDEO

- SERIAL SCAN	RS-170 OUTPUT
- FOV	17° X 28°
- IFOV	1.87 MRAD
- MRTD	0.2° C @ 0.27 CYCLES/MRAD

NAVIGATION ACCURACIES

- POSITION	40 M
- ALTITUDE	5%
- HEADING	0.4°
- PITCH & ROLL	0.2°
- VELOCITY	0.1 M/S

FLIR/MAP DATA COLLECTION TASK

MATERIAL

FSI	FSI-100A	CFE
LITTON	LTN-92 INS (1 MONTH LEASE)	$9,000
LITTON	LTN-700 GPS RECEIVER (1 MONTH LEASE)	2,770
TERRA	TRA 3000/TRI 30 ALTIMETER	2,995
DATUM	MODEL 9300 IRIG GENERATOR/TRANSLATOR	2,700
AUI	MODEL 2A1000-16 INVERTER	3,950
ICS	MODEL 8531 RUGGEDIZED PC-AT	7,449
SONY	MODEL VO-4800 PORTABLE U-MATIC VCR	3,250
		$32,114

JCP 03/28/88
14020-69

HELICOPTER RENTAL

WHIRLYBIRD, INC

(800) 458-5870

WAIT TIME	10 HOURS X $100/HOUR	1000
FLIGHT TIME	6 HOURS X $550/HOUR	<u>3,300</u>
		<u>$4,300</u>

JCP 03/30/88
14020-75

DATA COLLECTION DELIVERABLES

* DATA COLLECTION PLAN
* DATA COLLECTION SOFTWARE AND USER GUIDE
* FLIR IMAGERY ON U-MATIC TAPE
* NAVIGATION DATA IN DIGITAL FORMAT
* DATA COLLECTION HARDWARE (NON-LEASED)
* DATA COLLECTION MISSION REPORT

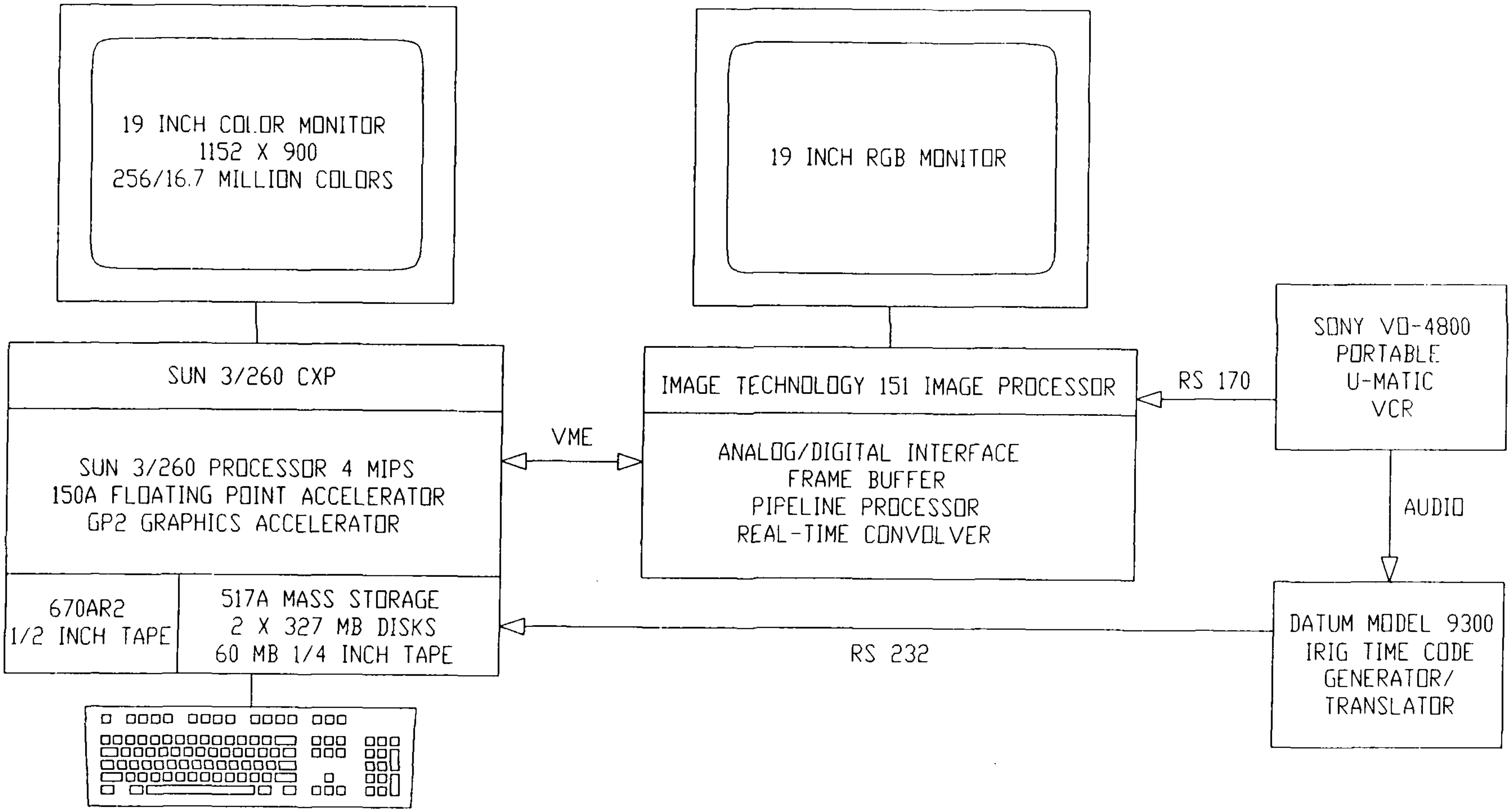
WORKSTATION DESIGN AND FABRICATION

JCP 03/30/88
14020-77

DISK SPACE REQUIREMENTS

SYSTEM RELATED	180 MB
SOFTWARE DEVELOPMENT	20
DIGITAL MAPS	40
IMAGES - 200	50
BIT MAPS: RANGE, SLOPE, FEATURES, PROBABILITIES	200
	490 MB

WORKSTATION CONFIGURATION



14020-07

SUN WORKSTATION

3/260CXP-8 DISKLESS WITH 8MB 19" COLOR MONITOR 1152 X 900 256/16.7 MILLION COLORS GRAPHIC ACCELERATION H/W DOUBLE BUFFERING 16 BIT Z BUFFER FOR FAST 3-D	$36,582
150A FLOATING POINT ACCELERATOR	3,882
517A 654 (2 X 327)MB DISK WITH60 MB 1/4 INCH TAPE CARTRIDGE	14,110
670AR2 1600 BPI 1/2 INCH TAPE SUBSYSTEM	7,885
950A METER HIGH CABINET FOR TAPE	1,868
SYS3-01 SYSTEM SOFTWARE	351
SUBTOTAL	$64,618
1ST YEAR MAINTENANCE .13 X 64,618	8,400
2ND YEAR MAINTENANCE .13 X 64,618	8,400
TOTAL 2 YEAR COST	$81,418

JCP 03/30/88
14020-79

IMAGE PROCESSOR

IMAGING TECHNOLOGY 151 ADI-151 ANALOG/DIGITAL INTERFACE FB-151 FRAME BUFFER ALU-151 PIPELINE PROCESSOR	$11,495
RTC-151 REAL-TIME CONVOLVER	3,995
ITEX 151 SOFTWARE LIBRARY	1,495
FIELD INSTALLATION	1,335
WARRANTY PLUS AGREEMENT (1ST YEAR)	1,335
SUBSYSTEM SUPPORT AGREEMENT (2ND YEAR)	2,005
SUBTOTAL	$21,660
SONY PVM-1910 19" RGB MONITOR	943
TOTAL	$22,603

JCP 03/30/88
14020-80

WORKSTATION DESIGN AND FABRICATION DELIVERABLES

* WORKSTATION PLAN
* WORKSTATION HARDWARE AND VENDOR SOFTWARE
* USER MANUALS

ALGORITHM DEVELOPMENT AND DEMONSTRATION

ALGORITHM DEVELOPMENT AND DEMONSTRATION

* USER/DATA INTERFACE
* MAP/FLIR CORRELATION
* ELEVATION DATA ANALYSIS
* FEATURE DATA ANALYSIS

JCP 03/30/88
14020-83

USER/DATA INTERFACE

* FLEXIBLE, EASY TO USE OPERATION
* EMULATION OF NAVIGATION SUBSYSTEM
* CONTROL OF FLIR IMAGE PROCESSING
* CONTROL OF DIGITAL MAP DATA ANALYSIS

MAP/FLIR CORRELATION

* USE NAVIGATION DATA FOR MAP APPROXIMATION
* COMPUTE MAXIMUM ERROR
* DEVELOP METRICS FOR FAST SCREENING
* CORRELATE MAP WITH FLIR

ELEVATION DATA ANALYSIS

PRODUCTS

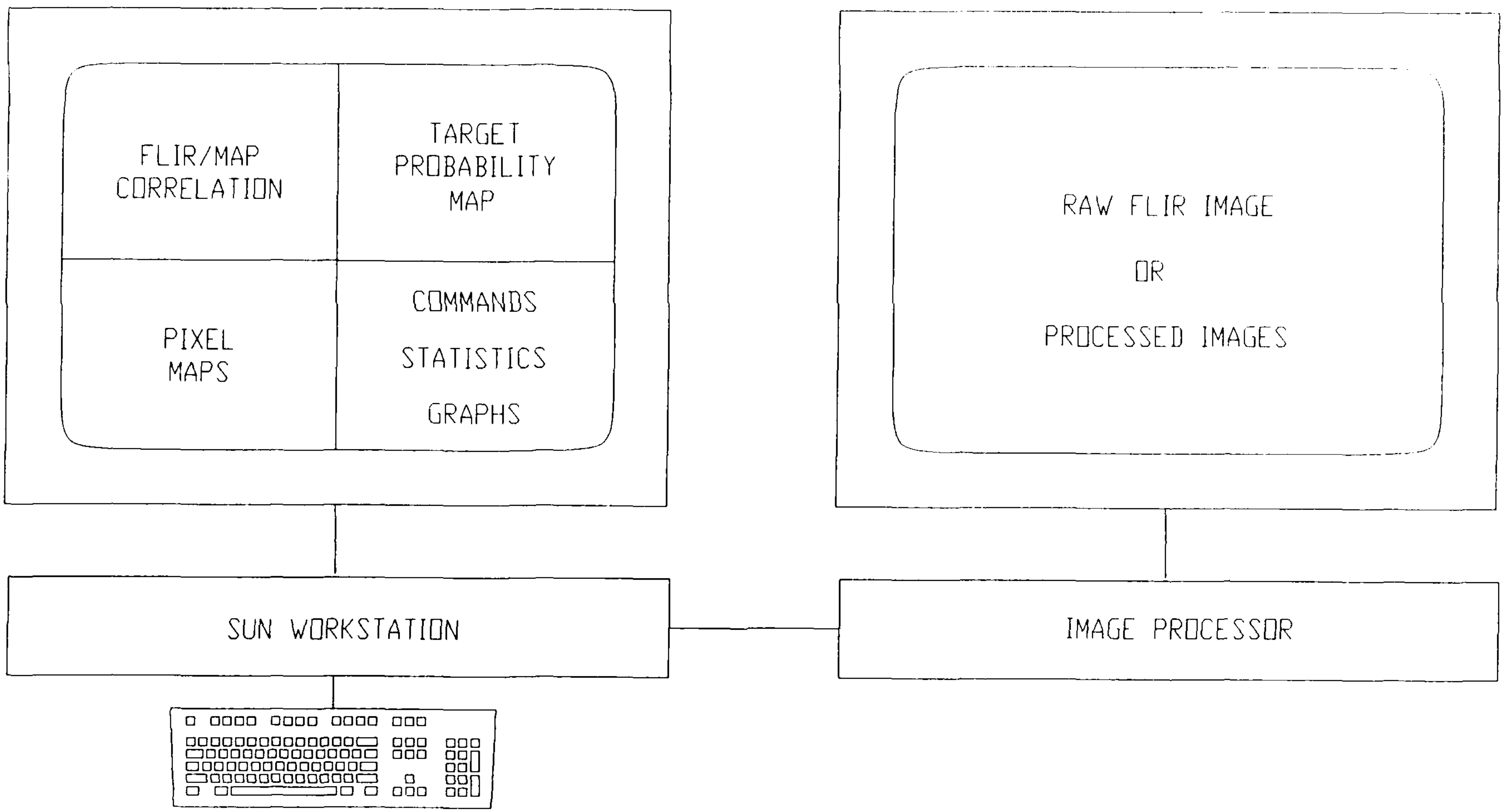
* RANGE MAP
  - RANGE FOR EACH FLIR PIXEL
  - CAN BE USED BY ATR TO DETERMINE PIXEL SIZE
* SLOPE MAP
  - SLOPE FOR EACH FLIR PIXEL
  - CAN BE USED BY ATR TO DETERMINE ASPECT RATIOS

FEATURE DATA ANALYSIS

PRODUCTS

* FEATURE MAP
  - FEATURE CODES FOR EACH FLIR PIXEL
  - CONFIDENCE CODE FOR EACH FLIR PIXEL
  - CAN BE USED TO ELIMINATE FEATURES AS TARGETS
* SUITABILITY MAP
  - SUITABILITY RATING (E.G. 1-9) FOR EACH FLIR PIXEL
  - HOW LIKELY IS A TARGET TO BE AT THAT PIXEL?
  - FOR EXAMPLE, 1 FOR A TANK IN A LAKE, 9 FOR A TANK ON A ROAD
* SIGNATURE MAP
  - EXPECTED SIGNAL INTENSITY FOR EACH PIXEL
  - ADJUSTED FOR: TEMPERATURE, TIME OF DAY, AND ATMOSPHERE

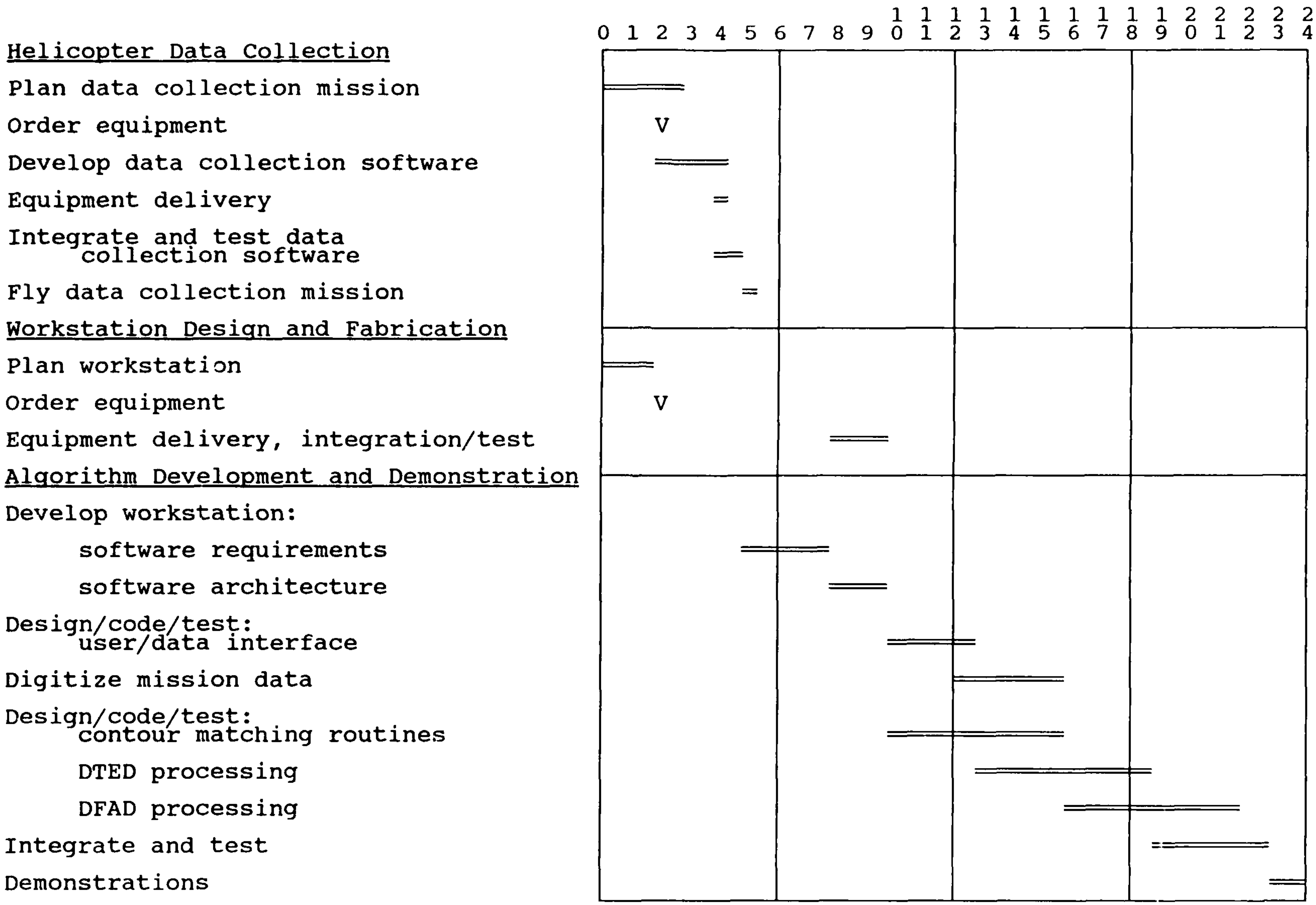
DEMONSTRATION



14020-08

TENTATIVE SCHEDULE AND COST

Phase II Schedule



COST ESTIMATE
FLIR/MAP PROGRAM STEP I

LABOR

CLASSIFICATION	HOURS	COST
Program Manager	60	$4,220
Staff Scientist	220	$15,970
Senior Engineer	600	$26,230
Engineer	460	$16,810
Engineering Aide	60	$1,500
Total Labor	1400	$64,730

OTHER DIRECT COST

Reproduction	$20
Equipment Lease	$0
Travel	$0
Misc, Material	$44,570
Other Direct Cost Subtotal	$44,590

LABOR + OTHER DIRECT COST $109,320

COST ESTIMATE
FLIR/MAP PROGRAM STEP II

LABOR

CLASSIFICATION	HOURS	COST
Program Manager	10	$710
Staff Scientist	120	$8,770
Senior Engineer	120	$5,280
Engineer	120	$4,420
Engineering Aide	20	$500
Total Labor	390	$19,680

OTHER DIRECT COST

Reproduction	$20
Equipment Lease	$0
Travel	$0
Misc, Material	$127,330
Other Direct Cost Subtotal	$127,350

LABOR + OTHER DIRECT COST	$147,030

TOTAL ESTIMATED COST

DATA COLLECTION	$109,320
WORKSTATION DEVELOPMENT AND FABRICATION	147,030
ALGORITHM DEVELOPMENT AND DEMONSTRATION	243,220
	$499,570

COST ESTIMATE
FLIR/MAP PROGRAM STEP III

LABOR

CLASSIFICATION	HOURS	COST
Program Manager	280	$20,430
Staff Scientist	1320	$99,400
Senior Engineer	360	$16,310
Engineer	2620	$99,340
Engineering Aide	280	$7,250
Total Labor	4860	$242,730

OTHER DIRECT COST

Reproduction	$490
Equipment Lease	$0
Travel	$0
Misc, Material	$0
Other Direct Cost Subtotal	$490

LABOR + OTHER DIRECT COST $243,220

NEXT MEETING

REVIEW PROPOSAL