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AUTHORITY

ABMDA D/A ltr, 30 Jan 1974

SYSTEM DEVELOPMENT CORPORATION

Real-Time Advanced Data Processing
Parallel Element Processing Ensemble (PEPE)

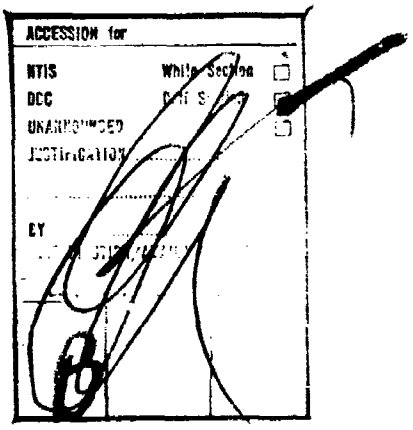
FINAL REPORT

FOR

CONTRACT DAHC-72-C-0031

CDRL B0005

Prepared by: System Development Corporation
4810 Bradford Boulevard
Huntsville, Alabama 35805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SERIES BASE NO. / VOL. / REISSUE
TM-HU-040 /204/00

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for G. J. Hansen

DATE 30 June 1973

TECH MEMO *a working paper*

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REAL-TIME ADVANCED DATA PROCESSING

PARALLEL ELEMENT PROCESSING ENSEMBLE

(PEPE)

FINAL REPORT

FOR CONTRACT
60-
DAHC-72-C-0031

CDRL B005

TABLE OF CONTENTS

1.0 INTRODUCTION

This document presents SDC's Final Report to ABMDA regarding technical status of the program: Real-Time Advanced Data Processing, Parallel Element Processing Ensemble (PEPE). The report is submitted in accordance with ABMDA Contract DAHC60-72-C-0031 and is supplied in compliance to ABMDA CDRL Item B005. Subsequent work will be executed under ABMDA Contract DAHC60-73-C-0060.

1.1 BACKGROUND

The PEPE Program which is subject of this report, was initiated in October 1971 and was completed in April 1973. This program was charged with designing an MSI Model PEPE and a full complement of real-time and support software, and represented the second increment of a three-stage PEPE development effort being sponsored by ABMDA. The first stage was a three-year (1969-1971) PEPE IC model feasibility demonstration program conducted by Bell Telephone Laboratories, with SDC and Honeywell assistance during the last year. The third stage, which has just been initiated, is aimed at fabricating a 36-element MSI Model PEPE and producing the required set of software. This last stage is being performed by SDC, employing the Burroughs Corporation as a subcontractor for PEPE fabrication.

The objectives of the PEPE MSI model design program were to:

(1) Complete the detailed functional and logical design of an MSI Model PEPE to be interfaced with a CDC 7600 Host computer for an implementation within a BMD laboratory environment.

(2) Complete a Version One Real-Time Operating System (RTOS) design for a PEPE/HOST implementation.

(3) Complete a Version One Process Construction system design for the MSI Model PEPE.

(4) Complete a Version One Utilities Package design for the MSI Model PEPE.

(5) Complete a Functional Simulation design for modeling and verifying the MSI Model, its RTOS, and BMD processes.

(6) Produce code and data for the basic components of the Process Constructive System, and the Functional Simulation System.

One year after initiating the PEPE MSI Model design phase of development, SDC was directed by ABMDA to undertake another set of tasks. In addition to continuing PEPE hardware and software design, SDC was to:

(1) Conduct a set of PEPE applications studies which would explore the feasibility of using PEPE: 1) with a small Host, 2) as a SETS processor, and 3) in a bulk tracking application.

(2) Develop a comprehensive program plan which would define an effective approach for completing the development of PEPE hardware and software for an ABMDA Research Center implementation.

(3) Select a qualified computer hardware manufacturer as a subcontractor for PEPE fabrication, test, and installation as specified by the PEPE Program Plan.

All objectives cited above have been achieved and have resulted in a design and planning base which will allow detailed system engineering, hardware fabrication, and software production to proceed.

1.2 SCOPE

In consideration of PEPE Program objectives listed under 1.1 above and requirements specified in the ABMDA statement of work, it may be noted that the PEPE Program has been charged with performing four categories of tasks which are defined as:

Hardware Development
Software Development
Program Planning
Special Studies

These task categories form the basis of this report and a succeeding section is devoted to each. Content and coverage of each section is based on the amount of formal documentation produced for component tasks during the report period. Hardware development, software development and program planning tasks have resulted in a considerable number of formal publications classed as Contract Data Requirements Items (CDRL). Accordingly, status for such well-documented tasks is presented in summary form. However, formal documentation for the set of tasks classed under special studies has not been required via CDRL and in these cases a detailed technical accounting is presented.

2.0 HARDWARE DEVELOPMENT

The hardware development effort included those activities required to design the PEPE MSI Model. The design was to specify the functions, logic interfaces, and physical interconnections of PEPE's major hardware components. These components included the control units, the processing elements, the power distribution subsystem, the signal distribution subsystem, and the mechanical and cooling subsystem. Accordingly, the task was organized into five distinct activites or subtasks which included:

- o PEPE Hardware Design
- o Control Unit Design
- o Processing Element Design
- o Power and Signal Distribution System Design
- o Mechanical and Cooling System Design

At the onset of the program, the hardware development effort was subcontracted to the Honeywell Corporation. The subcontract, which lasted one year (October 1971 - September 1972) was administered under SDC direction and resulted in a design which is reflected in the following specifications:

TM-HU-048/001/00,* PEPE System Functional Design Specification, Volume II, PEPE Logic Functional Specification System Development Corporation, 1 Sept 1972. (CDRL A007)

TM-HU-048/002/00,* PEPE System Functional Design Specification, Volume III, PEPE Hardware Design Specification, System Development Corporation, 1 Sept. 1972. (CDRL A007)

TM-HU-048/100/00,* PEPE/7600 Interface Specification, System Development Corporation, 1 Sept 1972. (CDRL A007)

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* Documents have been superseded.

TM-HU-041/000/00, PEPE Logic Design Report, System Development Corporation, 15 Sept 1972. (CDRL A008).

TM-HU-041/001/00, PEPE Signal and Power Distribution Specification, 1 Sept 1972. (CDRL A009)

TM-HU-041/002/00, PEPE Mechanical and Cooling Specification, System Development Corporation, 1 Sept 1972. (CDRL A010)

The above specifications formed the MSI Model PEPE baseline design. Subsequent to their issuance, SDC initiated an effort to upgrade (correct, improve, complete) the System Functional Design Specifications in order to provide a reliable source for initiating remaining development tasks. The upgraded documentation package consists of two volumes which supersede three previous system specifications. Current system specifications are identified following:

TM-HU-048/000/01, PEPE System Functional Design Specification, Volume 1, System Specification, 13 April 1973. (CDRL A007)*

TM-HU-048/001/02, PEPE System Functional Design Specification, Volume II Hardware Specification. (CDRL A008)**

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* Produced under contract DAHC60-72-C-0031.

**Produced under contract DAHC60-73-C-0060.

3.0 SOFTWARE DEVELOPMENT

The basic software objective set for the 18-month performance period was to specify a detailed design for a PEPE-oriented set of real-time and support software processes. Specifically, a detailed design was to be established for the following:

a. A Real-Time Operating System
b. A Process Construction System
c. A Functional Simulation System
d. A Utility Package
e. A PEPE Hardware Emulator

The design of the above software packages was accomplished, and is reflected in a formal set of documents. These documents were produced in compliance to ABMDA R&D standards. Types of documents produced for each software package, and their relationship to a particular stage of software development is depicted by Figure 2a.

Development objectives set for the Process Construction and Functional Simulation Systems additionally included the production of working code. This objective was realized for both software packages. The Software Deliverable File (SDF) for the Process Construction System was delivered to the ARC facility on 26 April 1973. The Functional Simulation System was formally demonstrated to ABMDA on 17 August 1972. Thereafter the system was used as a tool for demonstrating the performance of the MSI Model PEPE in BMD service through a credible functional simulation. (See Section 5.4 following.)

A complete bibliography of formal documentation produced as a result of the PEPE software effort follows:

DEVELOPMENT STATUS
PEPE SOFTWARE PROCESSES

SOFTWARE PACKAGE ID	DEVELOPMENT STAGE									
	REQUIREMENTS DEFINITION		COMPUTER INDEPENDENT DESIGN	COMPUTER DEPENDENT DESIGN		VALIDATION & TEST		IMPLEMENTATION		
	PRODUCT		PRODUCT	PRODUCT		PRODUCT		PRODUCT		
	SPR	SCD	SDS	SODS	PMM	TEP	TER	UM	IP	P&D
Real-Time Process										
a. RTOS	X	X	X	X	*	*	*	*	*	*
b. Tactical Process				*	*	*	*	*	*	*
Process Development Software										
a. Process Construction	X	X	X	X	X	*	*	X	NA	X
b. Functional Simulation	X	X	X	X	X	*	*	X	NA	X
c. Utilities Package	X	X	X	X	X	*	*			*
d. Hardware Simulator	X	X	X	X	*	*	*	*	NA	*

Legend

SPR: Software Performance Requirements document
SCD: Software Capability Description document
SDS: Software Design Specification
SODS: Software Organization and Detailed Specification
UM: Users Manual
TP: Test and Validation Procedures documentation
Demo: Formal ABNDA Demonstration
PMM: Program Maintenance Manual
P&D: Programs and Data
TEP: Test and Evaluation Procedure
TER: Test and Evaluation Report
IP: Installation Procedure

X: Completed (as of date of this document)

*: Planned

NA: Not applicable for type of software

FIGURE 2a

Task	Technical Memorandum Series Number	Deliverable Document Type
BMDOS Design and Development	TM-HU-043/000/00	Software Performance Requirements
	TM-HU-043/100/00	Software Capability Description
	TM-HU-043/200/00	Software Design Specification
	TM-HU-043/300/00	Software Organization and Detailed Specification
Process Construction Software Design and Development	TM-HU-042/000/00	Software Performance Requirements
	TM-HU-042/100/00	Software Capability Description
	TM-HU-042/200/00	Software Design Specification
	TM-HU-042/300/00	Software Organization and Detailed Specification
	TM-HU-044/400/00	Users Manual
	TM-HU-042/500/00	Program Maintenance Manual
Functional Simulation and Driver Design and Development	TM-HU-044/000/00	Software Performance Requirements
	TM-HU-044/100/00	Software Capability Description
	TM-HU-044/200/00	Software Design Specification
	TM-HU-044/300/00	Software Organization and Detailed Specification
	TM-HU-044/400/00	Users Manual
	TM-HU-044/500/00	Program Maintenance Manual
Utility Program Modification and Design	TM-HU-046/000/00	Software Performance Requirements
	TM-HU-046/100/00	Software Capability Description
	TM-HU-046/200/00	Software Design Specification
	TM-HU-046/300/00	Software Organization and Detailed Specifiation
	TM-HU-046/500/00	Program Maintenance Manual
Instruction Level Hardware Simulator Design	TM-HU-045/000/00	Software Performance Requirements
	TM-HU-045/100/00	Software Capability Description
	TM-HU-045/200/00	Software Design Specification
	TM-HU-045/300/00	Software Organization and Detailed Specification

4.0 PROGRAM PLANNING

As concerns this report, program planning tasks include those efforts aimed at defining and structuring the future course of the PEPE MSI Development Program. Tasks of this type conducted during the performance period focused on:

- o Software Development Planning
- o PEPE Program Planning
- o Hardware Subcontractor Selection

4.1 SOFTWARE DEVELOPMENT PLANNING

During the performance period, SDC was charged with the task of producing a Software Development Plan. This plan was to set forth an approach for designing, producing and implementing the PEPE/Host tactical software process. However, because the development of the tactical process is dependent on PEPE process development/support software, and because the tactical process must be compatible with the BMDOS, SDC chose to broaden the plan's scope. The expanded objective was to describe a coordinated approach for developing the entire software component of the PEPE MSI Model data processing system. By structuring the plan in this manner, it could also be utilized as a source for generating the PEPE Program Plan (See Section 4.2 following).

The PEPE Software Development Plan was produced as TM-HU-047/000/00 and was distributed on 15 December 1972, in compliance to ABMDA CDRL Item B021. Content of the plan was based on an interpretation of coverage requirements stated in the ABMDA Software Standards Manual. The requirements were accommodated by organizing the plan into three basic sections which respectively provided:

(1) A Program Overview - Identified specific software packages to be developed; provided references to baseline documentation; and defined current PEPE software status in terms of position within the typical ABMDA software development cycle.

(2) A Software Development Approach - Set forth an overview of the recursive software development concept, as well as a detailed description of the planned approach for developing PEPE software processes. Additionally, proposed software deliverables were identified and a relative schedule of development activities and deliverables was provided.

(3) Software Development Control Procedures - Described those internal SDC procedures which would be administered to facilitate effective program control throughout the software development cycle.

4.2 PEPE PROGRAM PLANNING

The objective of this task was to provide a comprehensive definition to a three-and-a-half year PEPE program, including plans for coordinated development of both the hardware and software elements of the PEPE data processing system. The deliverable to be evolved from this effort was a formal PEPE Program Plan, formatted as a proposal to ABMDA, for continuing and completing the PEPE MSI Model.

The plan was completed, and was delivered to ABMDA on 2 February 1973. The plan presented SDC's proposed technical, management, and cost approach to the PEPE Program and was based on a thorough evaluation of program requirements and objectives. The plan included the PEPE Hardware Subcontractor's Plan for PEPE MSI Model development, critical aspects of the Software Development Plan, and SDC's approach for conducting the Systems Engineering and management facets of the projected program.

4.3 SUBCONTRACTOR SELECTION

This task required the selection of a hardware subcontractor for the design, fabrication, test, and installation of the MSI Model PEPE.

Through a competative procurement, a hardware subcontractor was selected, namely the Burroughs Corporation, who in turn was placed under contract on 1 April 1973. A chronological sequence of events in the subcontractor selection process follows:

(a) A Bidders Conference was conducted by SDC on 1 September 1972 for representatives of 14 different hardware companies.

(b) Following the Bidders Conference, questions from prospective bidders were answered and consolidated in a uniform reply to all parties. The reply was transmitted on or about 7 November 1972.

(c) A preliminary Proposal Evaluation Plan was generated (October 1972).

(d) An RFP package was prepared and was transmitted to each of the companies showing interest in bidding the FEPE Hardware Subcontract. The RFP was prepared solely by SDC (RFP 73-5101R) and was transmitted on 7 October 1972.

(e) Responses to the RFP were received on 27 November from six companies. SDC immediately implemented the Proposal Evaluation Plan.

(f) Technical, Management, and Cost submissions were evaluated in conformance to the Proposal Evaluation Plan. The evaluations were completed 24 December.

(g) Negotiations with leading hardware subcontractor candidates were initiated 27 December, culminating with the selection of the Burroughs Corporation.

5.0 SPECIAL STUDIES AND ANALYSIS

During the performance period a group of special studies and analysis was conducted which examined the feasibility of utilizing PEPE in other BMD applications, and which evaluated the MSI Model design. Detailed results of these tasks are presented in succeeding sections which respectively present the following:

(a) A Small Host Study
(b) A SETS Application Study
(c) A Bulk Tracking Study
(d) An Analysis and Evaluation of the MSI Model Design.

5.1 SMALL HOST STUDY

The basic objective of the Small Host Study was to determine the feasibility of using a small Host in a PEPE-Augmented BMD System. Thus, if the PEPE/Small Host combination were feasible, a considerable cost reduction could be realized over those systems employing large stand-alone conventional computers.

The study considered a set of eight candidate Host machines, six of which were considered small (.5-4.0 MIP) and the other two in the large-scale range (> 4.0 MIP). The large-scale machines were included to offer a context for interpretation of study results. The candidate Hosts studied included the following:

Digital Equipment Corporation	PDP 11/45
Systems Engineering Laboratory	SEL 86
Control Data Corporation	CDC 6400
Xerox Corporation	SIGMA 8
International Business Machines	IBM 360/65
Univac	UNIVAC 1108
International Business Machines	IBM 370/165
Control Data Corporation	CDC 7600

5.1.1 Conclusions and Recommendations

The results of the study show it is quite possible to operate PEPE with a Host smaller than the CDC 7600. However, because of limitations in the model and because of the limited scope of the study, it was not possible to specify how much smaller (than the 7600); or to determine a minimum MIP range. Most of the limitations were caused by time constraints on the study which precluded exploring design options and trade-offs. Therefore, it is recommended that a more in-depth study be undertaken which additionally examines the effect of alternative functional mappings of BMD processes and which considers algorithms oriented to exploit the Host's potential.

5.1.2 Model Description

The functional simulation model used to conduct the Small Host Study is a modification of the System Verification Model (SVM) described in the references cited following and which accompany this report:

a. TM-HU-048/502/00; PEPE Functional Simulation, System Verification Model - Detailed Test Plans.

b. TM-HU-048/505/00; PEPE Functional Simulation Calibration Model and System Verification Model Descriptions.

The hardware facilities/configuration of the modified SVM model is shown in Figure 5a, and the mapping of the BMD process onto this hardware is shown in Figure 5b.

The only tactical functions performed in the Host computer in the model are farm communications and PEPE tactical-process scheduling. The model has a Real-Time Executive (RTE) and Real-Time Operating System (RTOS) in the Host which were designed for the CDC 7600 and timed to 7600 speeds.

To model each PEPE/Host configuration properly, an RTE and RTOS should be designed for each Host which takes advantage of the characteristics of the Host machine and is timed to the actual speed of the Host. Due to time constraints, this could not be done for this study. For each configuration, the Host functions were scaled based on a comparison of the MIP rating and data access time of the candidate Host with the CDC 7600. The numbers used are shown in Table 1.

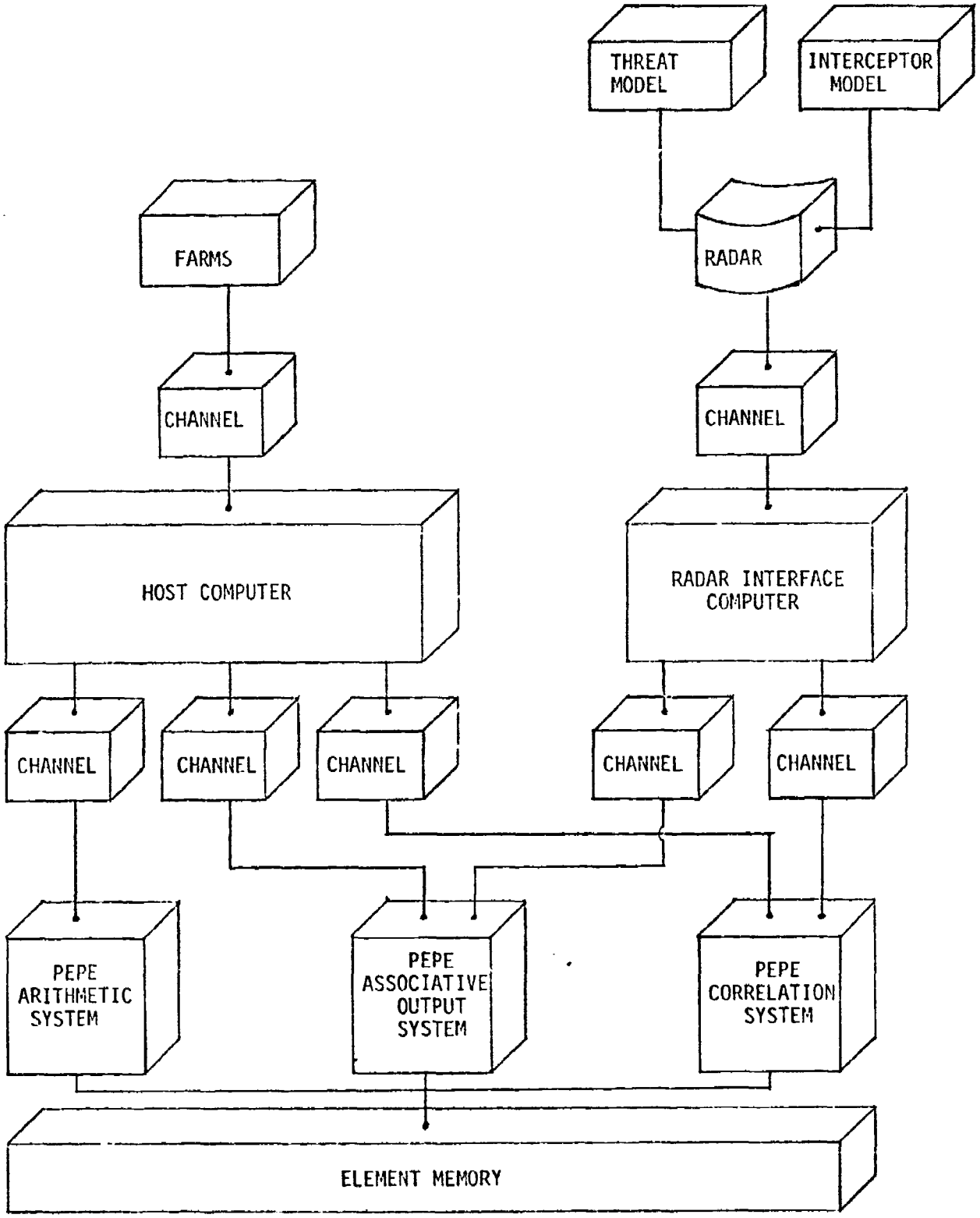

Figure 5a

SYSTEM VERIFICATION MODEL HARDWARE FACILITIES

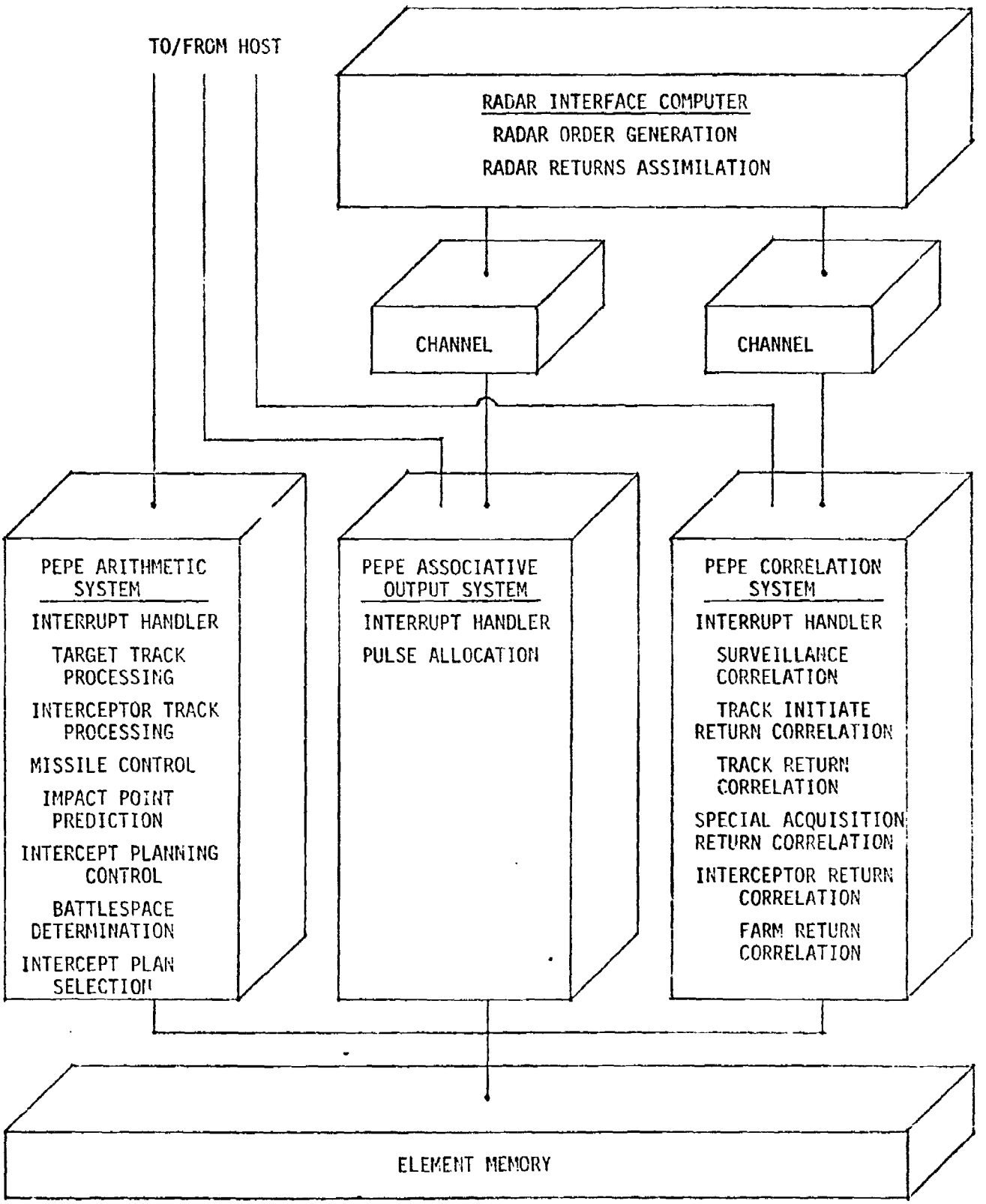

Figure 5b.

SYSTEM VERIFICATION MODEL BMD PROCESS MAPPING

Computer	MIP Scale	Data Access Time (nanoseconds)
PDP 11/45 (DEC)	0.5	1600
SEL 86	1.2	600
CDC 6400	1.2	800
SIGMA 8 (XDS)	1.5	900
IBM 360/65	2.4	750
UNIVAC 1108	4.0	375
IBM 370/165	6.0	250
CDC 7600	12.0	27.5

TABLE 1

Since Host utilization for the SVM is so small, it seemed desirable for the study to put a larger load on the Host. The most obvious functional choice was to place the netting function in the Host. However, since the netting function was not yet modeled, the RIC functions were moved to the Host instead. The characteristics of the two functions are somewhat similar consisting mainly of input/output. During the course of study, it became obvious that the timing of the RIC functions was very critical, probably much more so than the timing of a netting function.

During the early phases of the study, it became apparent that with the slower machines the PEPE scheduling algorithm used in the SVM would no longer work because of the amount of time it took to communicate between PEPE and the Host. Rather than change the algorithm, a hypothetical change was made in the PEPE hardware. An interrupt capability from the ACU to the AOCU was added. This change allowed the tactical process performed in PEPE to be scheduled in PEPE. The final structure of the small Host study model is shown in Figures 5c and 5d.

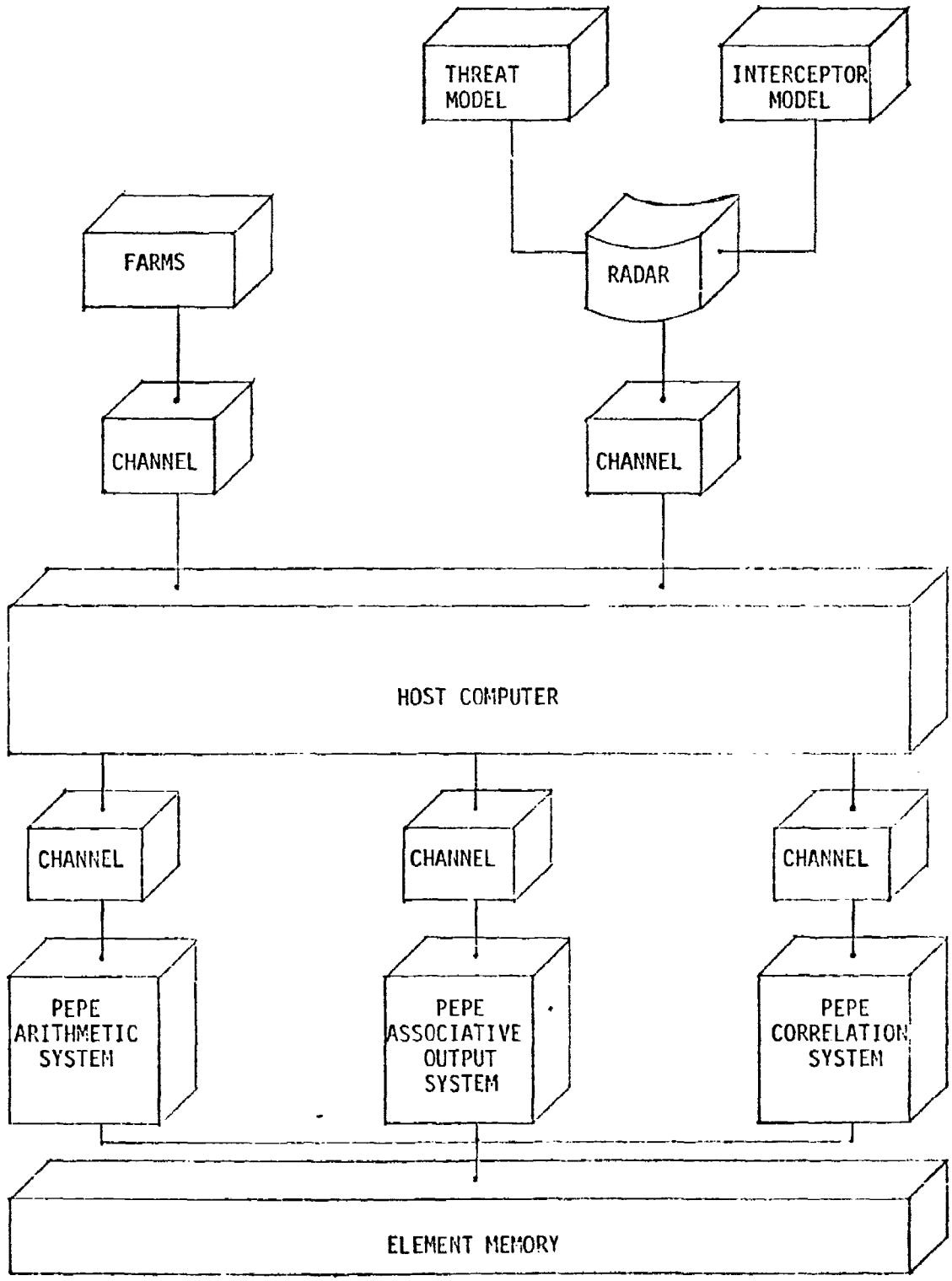

Figure 5c.

SMALL HOST STUDY MODEL HARDWARE FACILITIES

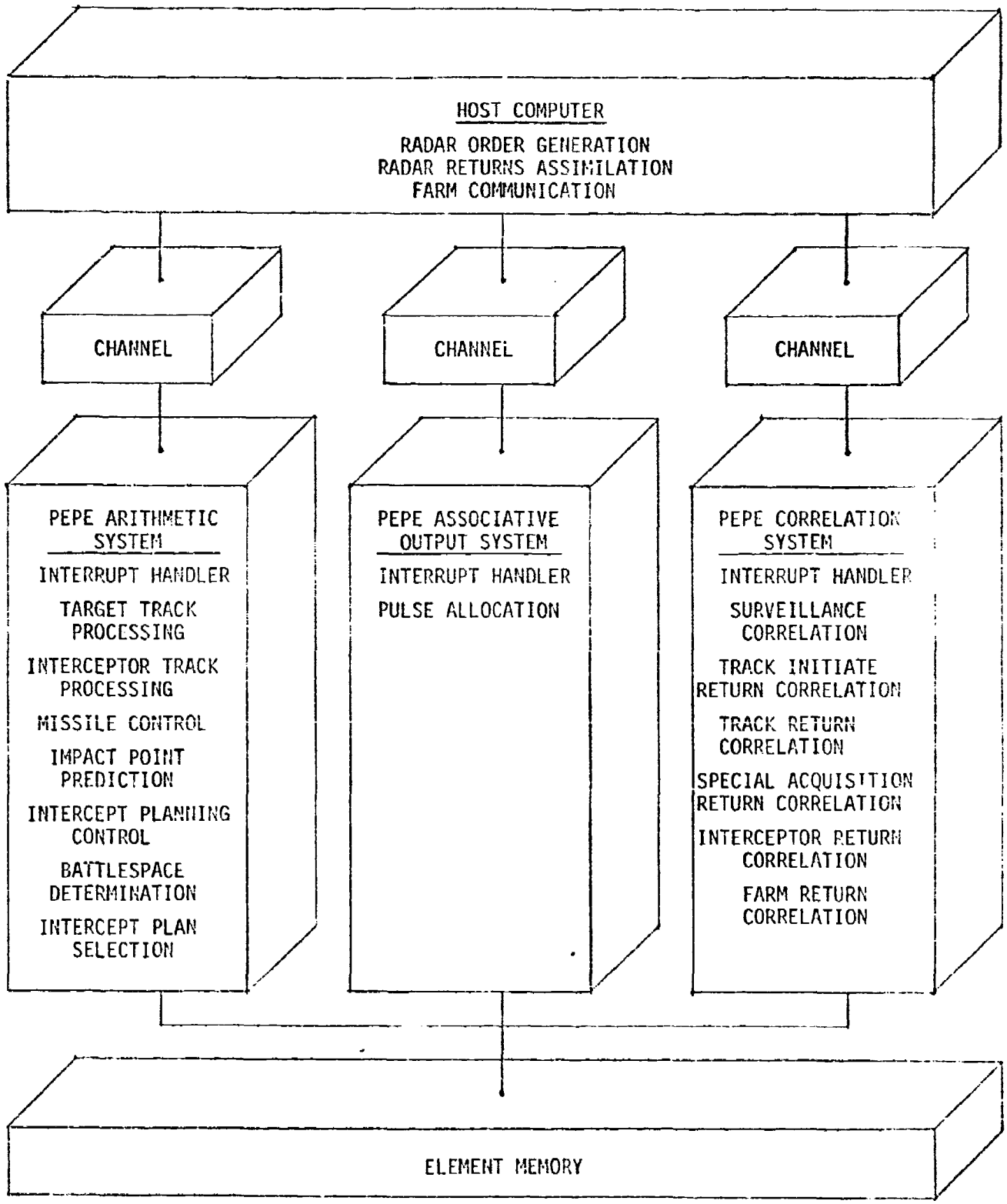

Figure 5d.

SMALL HOST STUDY MODEL BMD PROCESS MAPPING

5.1.3 Test Description

The vehicle used to test each PEPE/Host configuration is the Hardware Validation test described in the System Verification Model Test Plan (Reference a). The threat contains 144 objects which enter the search volume in 12 waves of 12 RVs per wave at 2.1 second intervals. The interceptor capacity is 200 missiles. Each engagement is scheduled to last 30 seconds. Maximum load is reached at about 15 seconds of engagement time. At this time, there are approximately 150 RVs and interceptors in track. After this time as new RVs enter the system and are assigned interceptors, RVs and interceptors from completed intercepts are dropped. This causes load to remain fairly constant for the balance of the test.

5.1.4 Test Results

PDP 11/45	failed at about .2 seconds
SEL 86	failed at about 8 seconds
CDC 6400	failed at about 10 seconds
SIGMA 8	failed at about 14 seconds
IBM 360/65	ran to completion - maximum utilization about 70%
UNIVAC 1108	ran to completion - maximum utilization about 50%
IBM 370/165	ran to completion - maximum utilization about 30%
CDC 7600	ran to completion - maximum utilization about 15%

The failures occurred after Host utilization reached 100%. They were the result of a backlog of unprocessed data in the Host which was larger than the amount of buffer storage provided. It would have been possible to increase the amount of buffer storage but it is unlikely that this would have done anything but postpone the failure for a short time.

The test results are presented graphically in Figures 5C-5L. In each diagram, Host utilization and number of track and interceptor pulses scheduled each period are shown. The number of pulses scheduled is a measure of activity and corresponds in this test to roughly half of the number of RVs and interceptors being tracked.

Figure 5c.

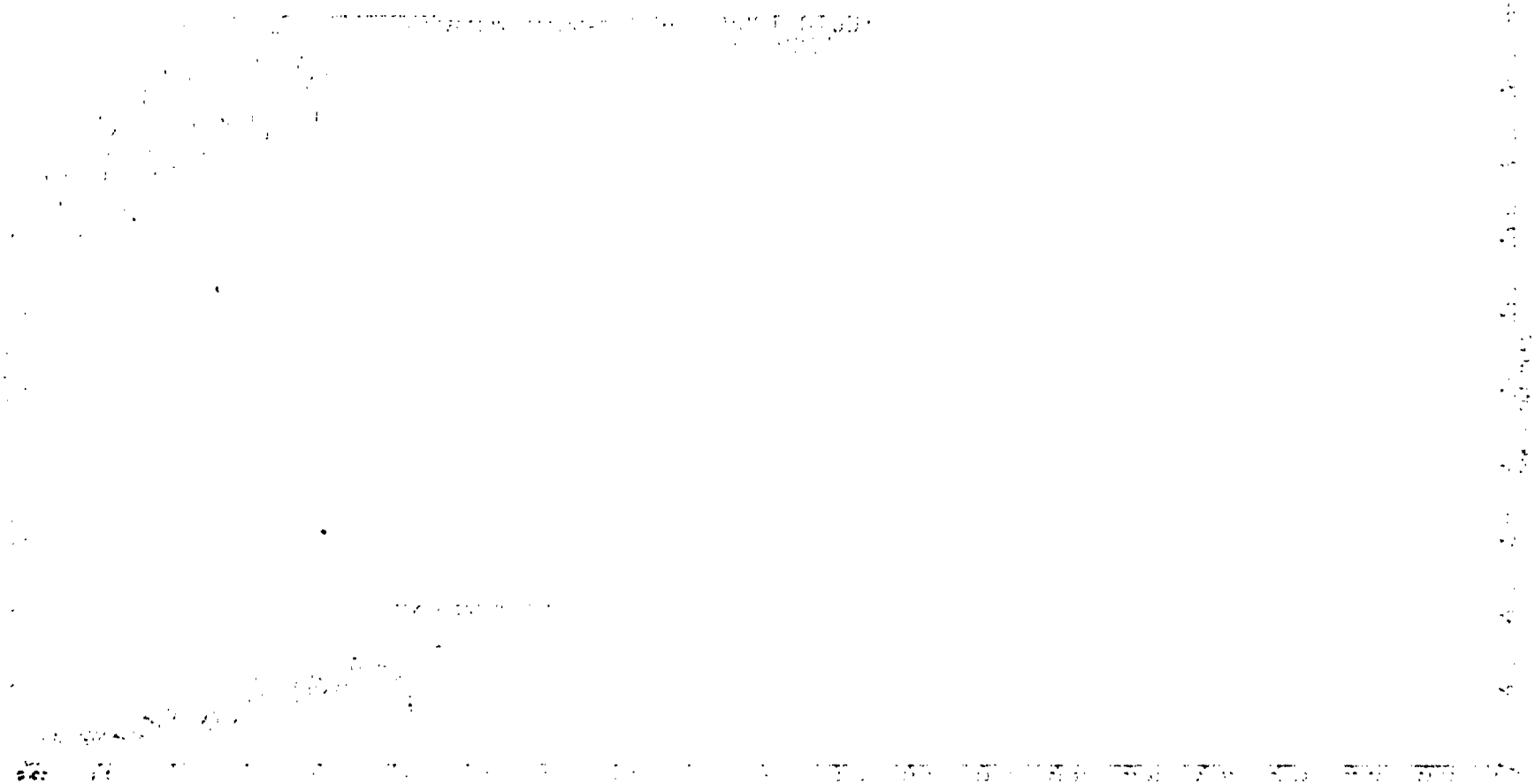

Figure 5f.

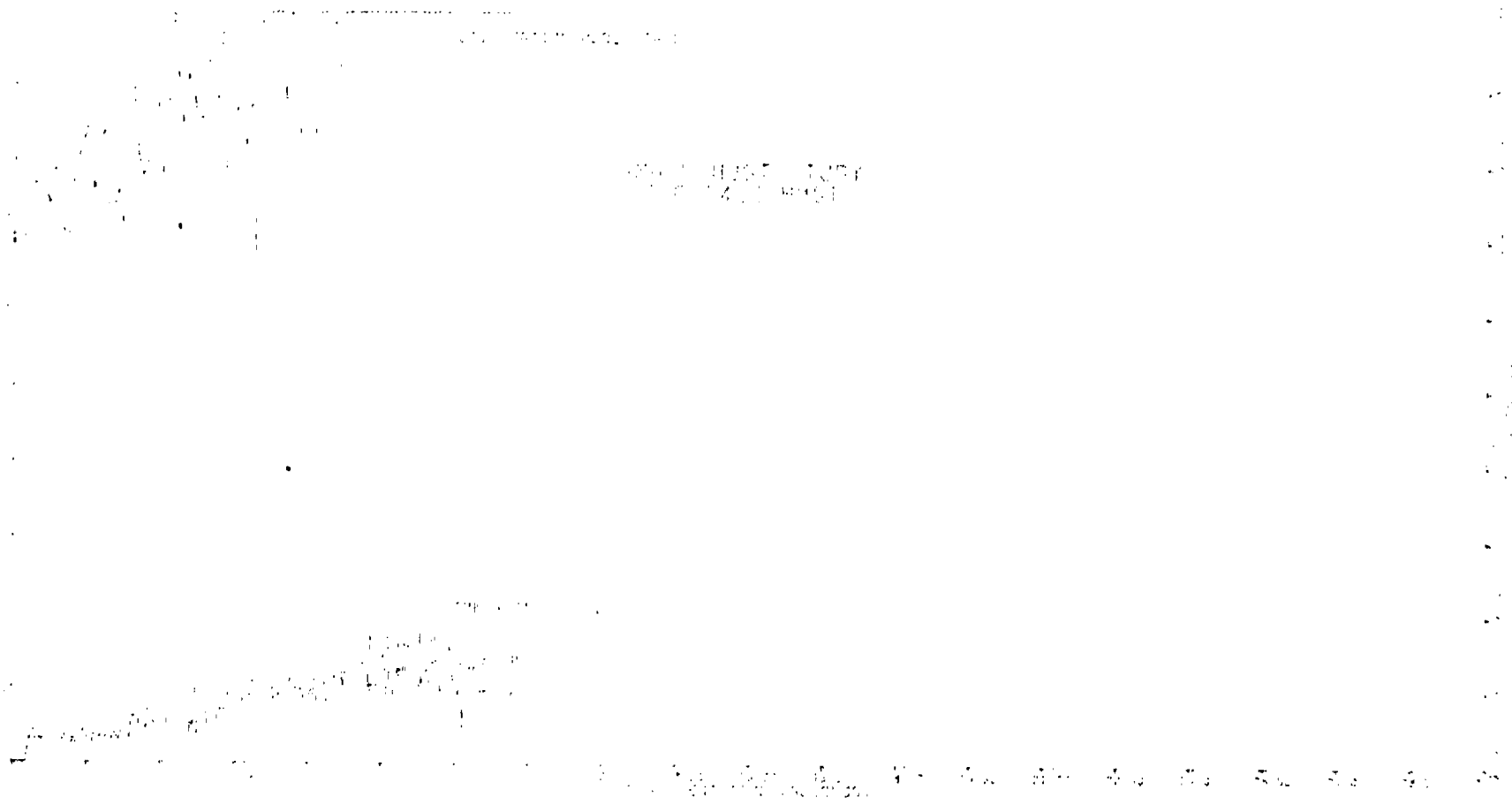

Figure 5g.

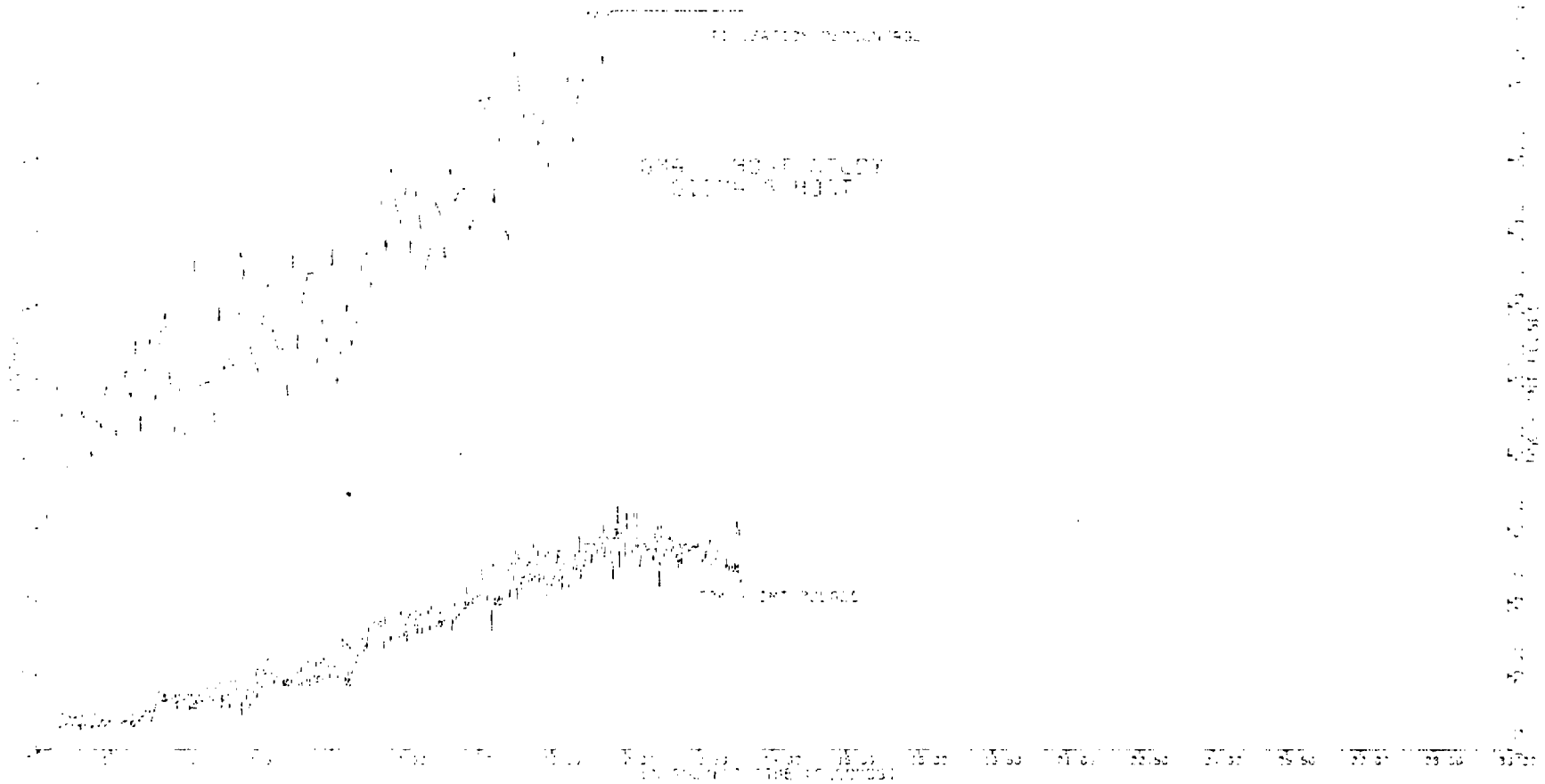

Figure 5h.

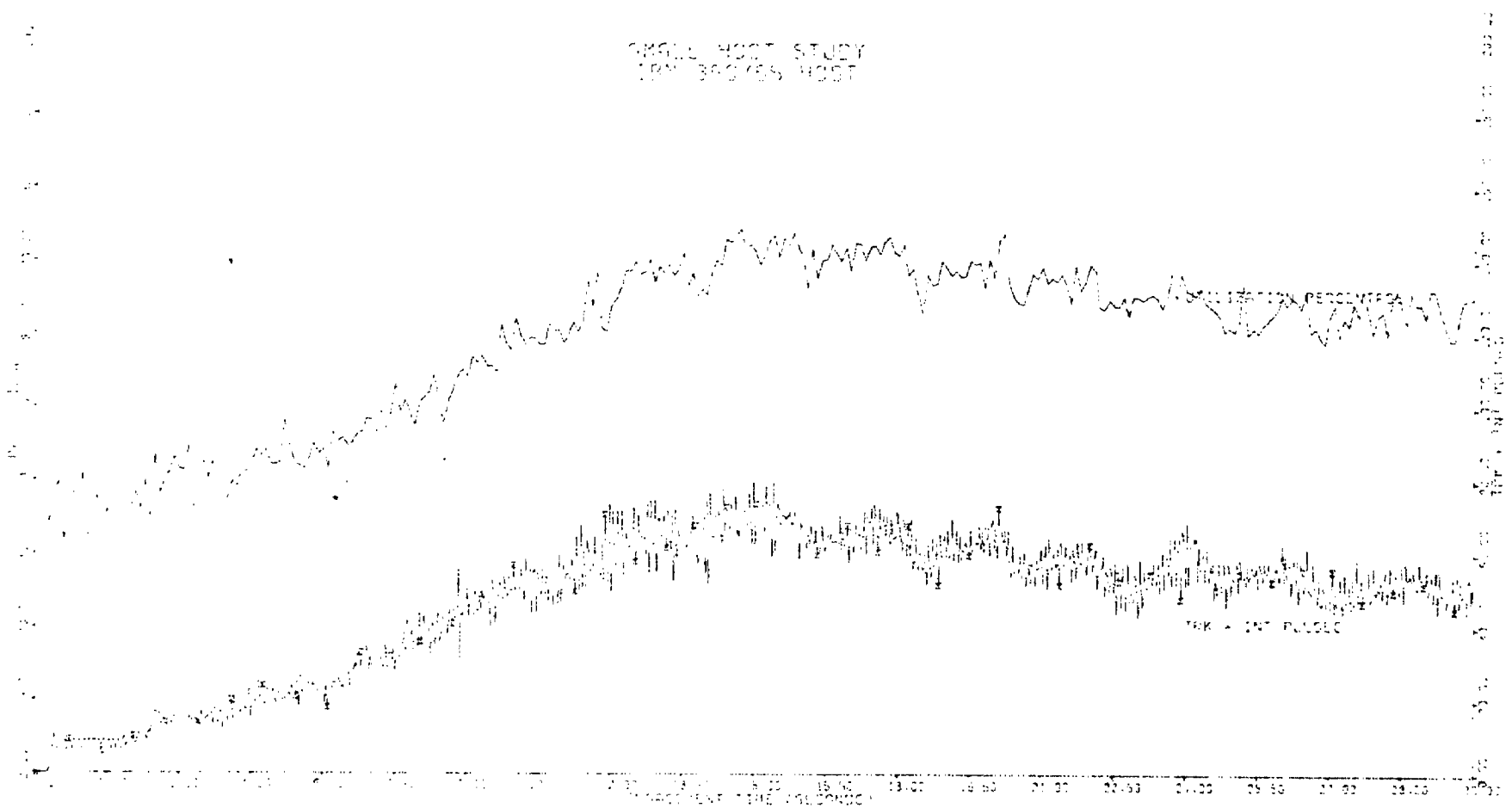

Figure 5i.

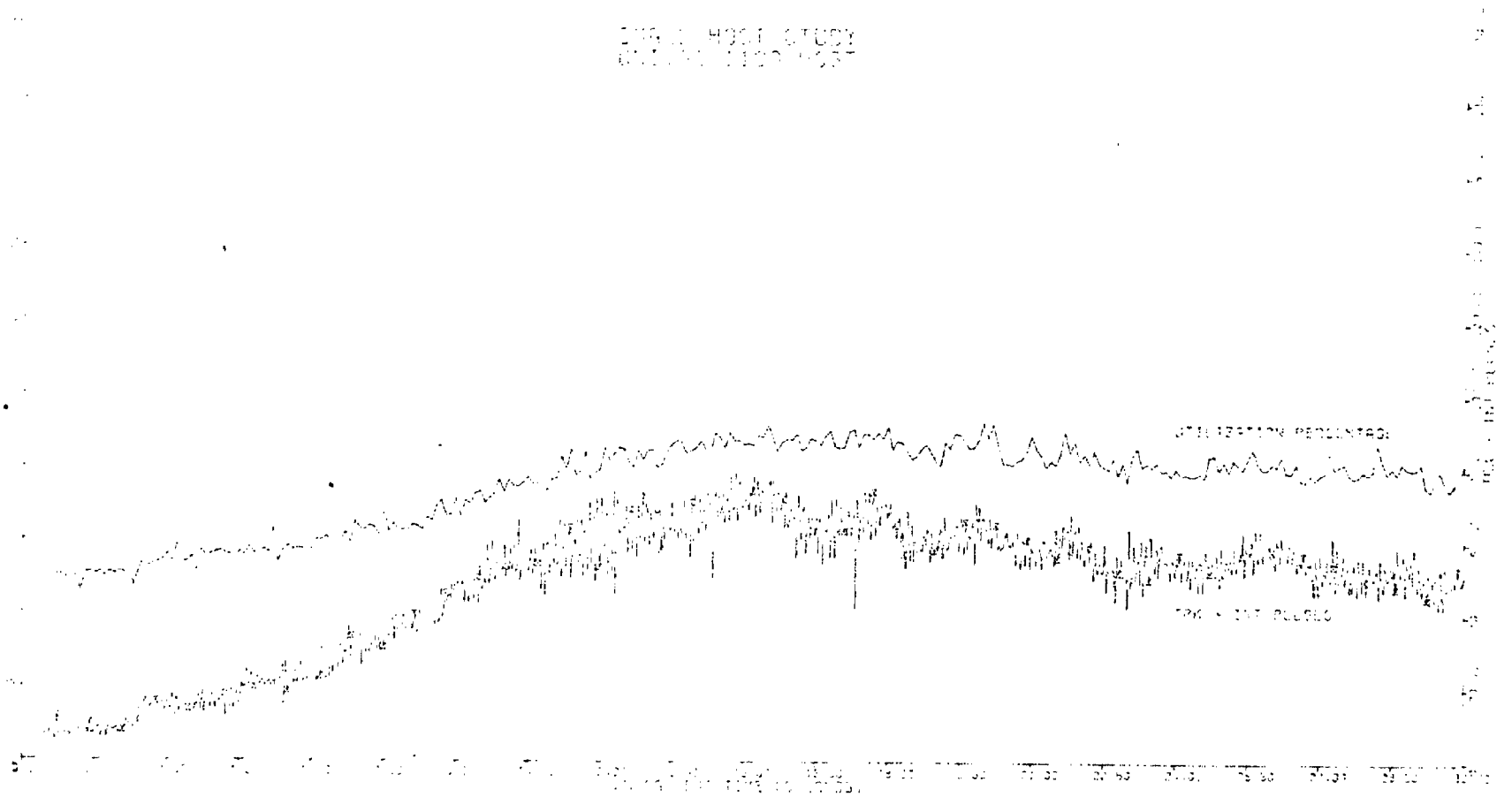

Figure 5j.

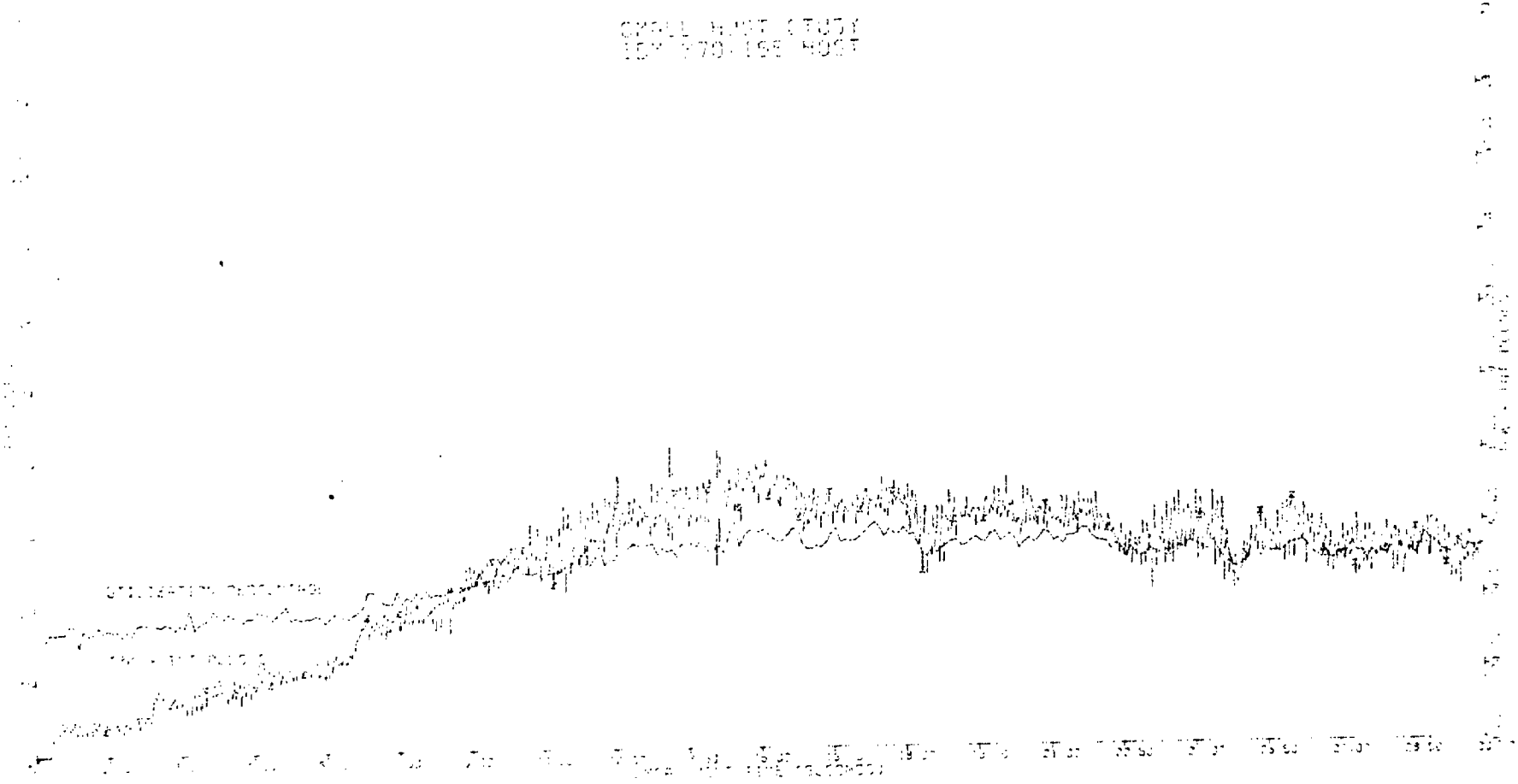

Figure 5k.

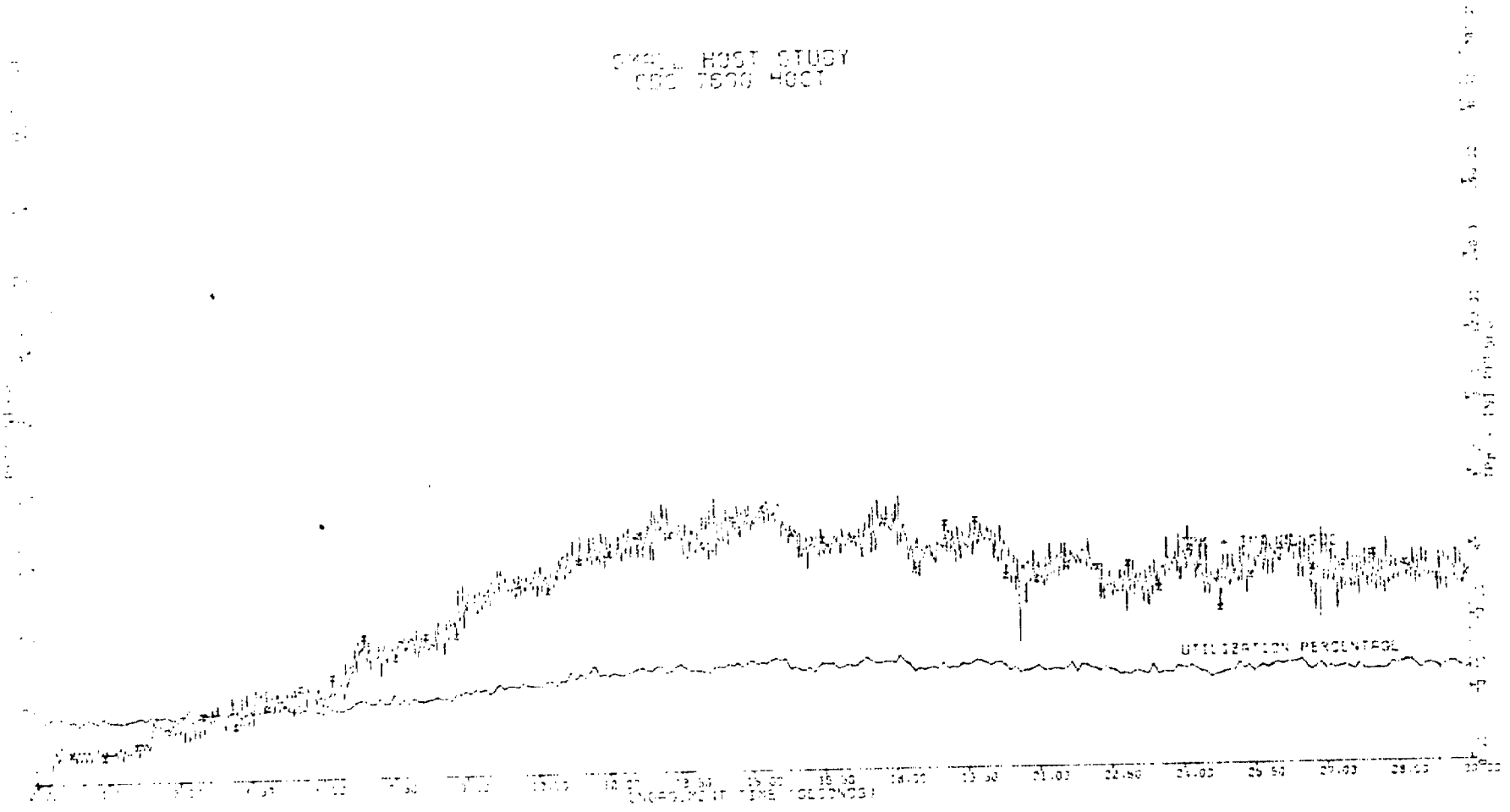

Figure 5L.

5.2 SETS APPLICATION STUDY

Described in a Classified Secret Appendix, "PEPE Report," CR-1-374, by P. Alexander, D. Beste, and G. Van Blaricum, General Research Corporation.

5.3 BULK TRACKING STUDY

Described in a Classified Secret Appendix, "PEPE Report," CR-1-374, by P. Alexander, D. Beste, and G. Van Blaricum, General Research Corporation.

5.4 MSI MODEL DESIGN EVALUATION AND VALIDATION

The development of the basic Functional Simulation capability (PEPSIE) was accomplished in August 1972, at which time it was successfully demonstrated to ABMDA. The next step was to apply the capability in a useful context. Specifically, the capability was to be used as a means for demonstrating the performance of the MSI Model PEPE in BMD service through a credible functional simulation.

To achieve this objective required a coordinated effort structured to accomplish the following:

a. Construction of a simulation model of the PHSD tactical process operating on the PEPE IC model equipment configuration.

b. Calibration of the model so that its performance would be the same (within prescribed limits) as was experienced through the PEPE IC Model design.

c. Modification of the simulation model to reflect the operation of the PHSD tactical process on the MSI configuration.

d. Evaluation of data output from simulation runs of the perturbed model for determining performance characteristics of the MSI Model PEPE executing the PHSD tactical process.

The above task elements formed the basis of a formal System Validation Demonstration presented to ABMDA and members of the BMD contractor community on 19 January 1973. Additionally, detailed results and

conclusions accompany this report in a five volume series*. Specific volumes in this series are identified following:

a. TM-HU-048/505/00, PEPE Functional Simulation Calibration Model and System Verification Model Descriptions.

b. TM-HU-048/500/00, PEPE Functional Simulation Calibration Model - Detailed Test Plans.

c. TM-HU-048/501/00, PEPE Functional Simulation Calibration Model - Calibration Test Results.

d. TM-HU-048/502/00, PEPE Functional Simulation System Verification Model - Detailed Test Plans.

e. TM-HU-048/503/00, PEPE Functional Simulation System Verification Model - SVM Test Results.

* See Attachment 1

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