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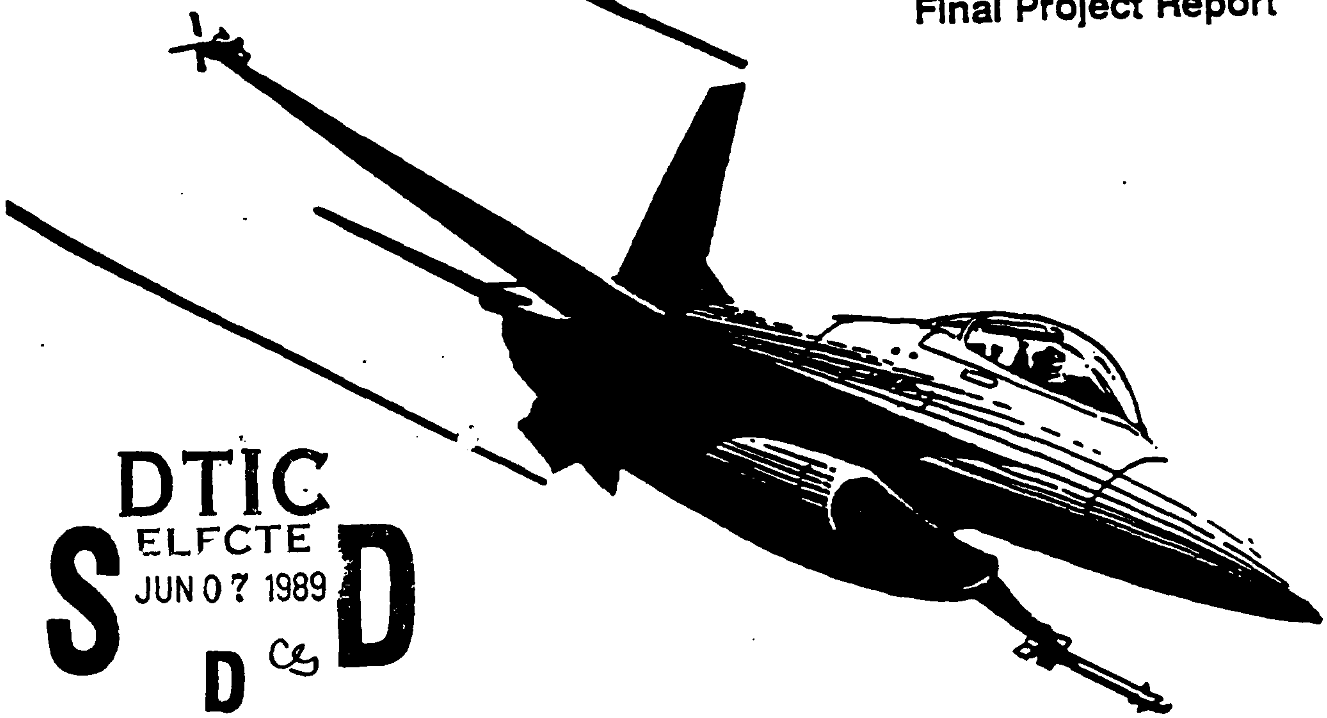
GENERAL DYNAMICS

FORT WORTH DIVISION

INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM

Phase 2

Final Project Report



PROJECT 82

INCREASE EFFICIENCY OF CARD/DEVICE TEST AREA BY THE USE OF MODERN MULTI-PURPOSE TEST EQUIPMENT

REVISION 1

Honeywell

Military Avionics Division

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Multipurpose test equipment in the printed circuit card and completed device test areas will be used for functional acceptance test, troubleshooting, and burn-in operations. The use of this more modern equipment will result in increased productivity and test yields by a reduction in test execution and fault isolation time and by providing enhanced data collection and analysis resources. Keywords:

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GENERAL DYNAMICS
FORT WORTH DIVISION

INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM

PROJECT 82 REVISION 1

PHASE 2 FINAL PROJECT REPORT INCREASE EFFICIENCY OF CARD/DEVICE TEST AREA BY THE USE OF MODERN MULTI-PURPOSE TEST EQUIPMENT

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PROJECT 82

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PROJECT 82

INCREASE EFFICIENCY OF CARD/DEVICE TEST AREA BY THE USE OF MODERN MULTI-PURPOSE TEST EQUIPMENT

SECTION 1

INTRODUCTION

The Flight Management and Targeting Systems (FM & TS) Production Department is chartered to manage and produce a variety of fixed and rotary wing aircraft electronics in support of the Flight Systems Operation (FSO).

The mission of FM & TS Production is to generate revenue and profit by executing production contracts in support of FSO profit and ROI objectives. FM & TS products are typically low volume, high technology devices built under specific customer contracts.

The Flight Management Area produces flight control systems for fixed and rotary-wing military aircraft for various customers. While the function of each of the systems is relatively similar in nature, each system is unique in the functions controlled on the aircraft, the quantity of devices (black boxes) which make up the system, as well as the specific customer build and test requirements.

As a rule, the component devices for a system are required to be interchangeable from one system to another and are therefore tested and shipped to the customer as individual devices. Most of these devices consist of a chassis into which printed circuit cards and other sub-assemblies are inserted to form a functional black box. The various devices contain from 10 to 25 printed circuit cards and are produced in relatively low quantities. Other devices which are part of the systems may contain fewer than 3 printed circuit or similar type devices and are also produced in low quantities.

The Targeting Systems Area produces an advanced helmet mounted sighting and display system. This system consists of several component devices which require unique skills to produce. Two of the "black boxes" are similar in nature to those described above for the Flight Management Area and require similar assembly and test techniques. However, the remaining component devices are unique to FM & TS. The display system utilizes a miniature cathode ray tube mounted on the pilot's helmet and requires precise assembly and test of optical and electronic devices. The sighting system consists of several components precisely mounted on the helmet and other sensor units which are mounted in the aircraft cockpit. These units also require unique assembly and test skills with very tight controls. As with the Flight Management Area, these systems are produced in relatively low quantities.

Project 82 was initiated to provide increased quality and efficiency by the use of modern multi-purpose test equipment for printed wiring cards and devices tested within FM & TS. These improvements include:

- New, highly automated assembly test station
- Continuation of the Fluke 3050B testing
- Comprehensive oven monitoring network

These additional improvements implemented under Project 82 will provide FM & TS with a significant increase in the efficiency of their manufacturing, help to reduce their overall manufacturing costs, and provide a higher quality product.

SECTION 2

PROJECT PURPOSE/OVERVIEW

The following section presents an overview of ITM Project 82. An overview of the FM & TS Production department and it's primary objectives is also presented along with a brief description of the Tech Mod efforts at Honeywell.

2.1 FM & TS Overview

Flight Management and Targeting Systems (FM & TS) Production is chartered to manage and produce a variety of fixed and rotary wing aircraft electronics in support of the Flight Systems Operation (FSO).

The mission of FM & TS Production is to generate revenue and profit by executing production contracts in support of FSO profit and ROI objectives. FM & TS products are typically low volume, high technology devices built under specific customer contracts. The FM & TS Production organization directly provides Production Engineering, Production Control, and operating capabilities to manage and execute production programs, support engineering programs, and provide specialized services to other product areas. Quality, Logistics, Procurement and Manufacturing Technical Services support is provided to FM & TS Production by Honeywell's Military Avionics Division (MAvD) central organizations.

The priority objective within FM & TS Production is to produce quality products within cost goals. Additional objectives include flexibility and dependability with the emphasis differing slightly in each of the focused factories.

2.2 FM & TS and Tech Mod

The USAF Tech Mod program was instituted to provide strategic planning and develop facility modernization projects that reduce manufacturing costs, improve product quality and reliability, and reduce manufacturing throughput time. In addition, the Tech Mod program has been chartered with assuring the capability for a rapid increase in production in the event of national emergency.

Under the guidance of the Tech Mod program, Honeywell has defined several areas for improving production in the Flight Management and Targeting Production facility in St. Louis Park, Minnesota. ITM Project 82 has been initiated with the purpose of upgrading the FM & TS Card/Device testing areas and is described in the following section.

2.3 Project 82 Strategic Goals and Objectives

FM & TS Production has defined several major objectives that are being incorporated in their future business planning. These objectives include increasing the flexibility of their operations and improving product quality, while maintaining a high degree of cost control.

Cost control is the overriding objective of FM & TS Production planning. This control must be maintained for both existing program production as well as for new programs. The cost control efforts underway in FM & TS Production are wide-ranging and are being applied at every level of the organization. Examples of this can be seen in the current implementation of the HMS/BOS MRPII system in St. Louis Park as well as the implementation of the Factory Data Collection System. In addition to controlling costs, the following objectives have been defined as critical to FM & TS's future production operations:

- **Increase flexibility of operations.** FM & TS will manufacture between six and ten products at any particular time and with the introduction of new programs which introduce both process and product changes, the current operations must remain flexible in adapting to these changes while still maintaining the capability of supporting existing programs.

- **Increase product quality.** By achieving 100% conformance with customer requirements, Honeywell will be viewed as the leading supplier of Military Avionics products. While this is of important strategic value from a marketing perspective, it can also have a direct effect on lowering the manufacturing costs in such areas as reducing rework and scrap.

- **Reducing production lead times.** Customer requirements dictate shorter production lead times and these will be accomplished through developing more streamlined process, material, and production flows. Improvements in information processing (such as HMS and FDC) will also aid in reducing production lead times.

ITM Project 82 has been defined by the Honeywell Tech Mod Project Team for implementation in Flight Management and Targeting Systems Production. This project, as defined by the Tech Mod Project Team, is described below.

ITM Project 82 addresses the modernization of multi-purpose test equipment in the printed circuit card and device test areas within the Flight Management and Targeting Systems (FM & TS) department. The new equipment will be used for functional acceptance test, troubleshooting, and burn-in operations on both new and existing programs/products. The benefits associated with the implementation of ITM Project 82 include:

- Faster, more comprehensive card and device program development
- Lower cost ATE hardware configuration for equivalent or better performance
- Improved diagnostic potential on faulty Units Under Test (UUT)
- Increased availability of digital circuit card assembly test equipment
- Upgrading of environmental chambers with micro-processor-based controllers
- Improved monitoring and control of environmental chambers via PC-based network

This project represents a significant part of the overall Tech Mod program currently being administered in Honeywell's Military Avionics Division.

SECTION 3

TECHNICAL APPROACH

The following subsections describe the general approach and methodology adopted by the Project 82 team for this project. The overall approach and methodology for performing an in-depth analysis of the FM & TS card and device area testing and burn-in operations are described as well as the methods employed in developing a structured design for more advanced operations. In addition, the evaluation methods used to establish technical requirements which define the areas for improvement within the card and device operations are presented.

The approach developed for selecting equipment is also described. This includes the methodology used to develop requirements for equipment, the selection criteria, and the high level evaluation matrices.

3.1 Overview of Project Approach and Methodology

This section describes the overall approach and methodology employed in the in-depth analysis of the FM & TS card and device testing and burn-in operations and presents the methods used by the project team in developing an automated testing and burn-in approach for more advanced operations with the introduction of newer programs. In addition, this section presents the evaluation methods used to establish technical requirements which define the areas for improvement within the card and device testing and burn-in operations.

The project team has developed an overall approach for performing ITM Project 82 which is summarized in Figure 3.1-1. During the initial phase of the project, this approach required the collection of a great deal of information, including:

- Project 82 Statement of Work
- Tech Mod Program Goals
- FM & TS Business
- FM & TS Products
- Personnel Interviews
- Facility Tours
- Card and Device Area Existing Test Equipment
- Card and Device Area Existing Burn-In Equipment
- Card and Device Area Existing Control and Monitoring Systems

This information was assimilated by the project team and presented in a series of meetings designed to assure that the team fully understood the various facets of the FM & TS card and device testing and burn-in operations. The analysis resulting from this exercise, along with the technological understanding of similar operations to that of FM & TS and the new systems,

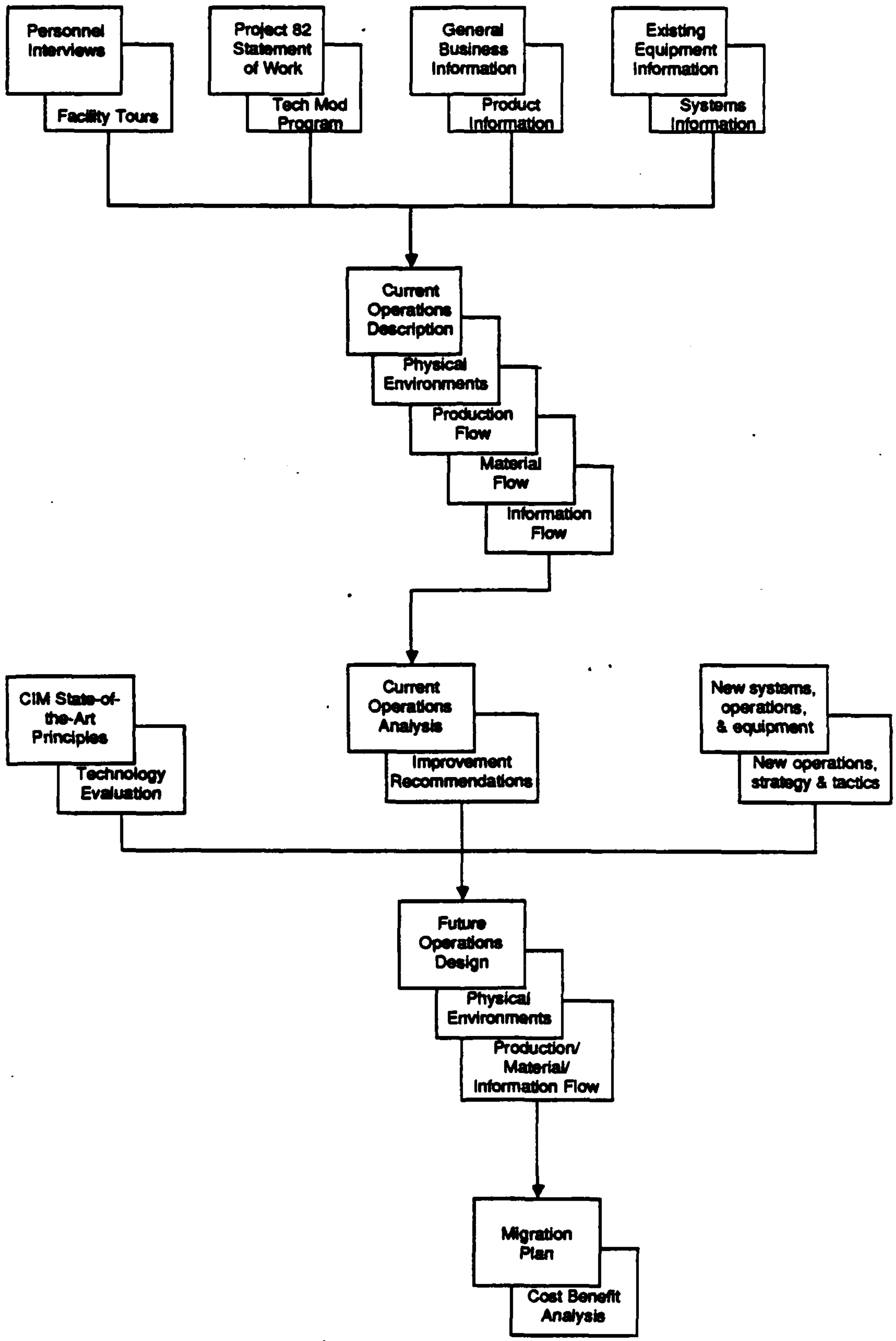


Figure 3.1-1 Project Approach and Methodology

operations, equipment, strategy, and tactics developed by the project team, were then utilized in developing the future operations design as well as the equipment specifications to provide a modern multi-purpose test and burn-in operation.

The final phase in this process is the development of a migration plan which outlines the implementation steps required to achieve the final plan and a cost benefit analysis which defines the benefits in respect to the necessary investment and the time required to realize a return on Honeywell's investment.

In utilizing the approach described above, the project team has found that an iterative process methodology would yield the best results in the creative process of designing systems and operations similar to the FM & TS operations. This methodology is particularly applicable in the type of environment, both from a physical perspective as well as a business and management perspective, that exists for the Honeywell project team.

In the early stages of the project, the iterative process consisted of the presentation of information collected and assimilated by the project team in a concise format. After an agreement as to the adequacy of the presentation was reached at this level, the process moved further into more detailed levels. This is the basis of the iterative process. Further iterations addressed the first initial conceptual levels of design and requirements development and, as more detail was agreed upon, more precise elements were put into place.

The feedback generated as a result of each of these presentations and the incorporation of this information into the final report assures that the results of the overall design process are compatible with the desires and ideas expressed by user's and management organization. The iterative design process is illustrated in a conceptual manner in Figure 3.1-2.

3.1.1 Operations Analysis

The goal of a comprehensive operations analysis is to first describe the current operations of Honeywell's FM & TS card and device testing and burn-in areas. Based upon this description, specific areas and operations are defined (in accordance with the statement of work) for further analysis as they significantly impact the direct or indirect costs of FM & TS production. This analysis then provides the foundation upon which the operations of the future is designed.

The absolute and definitive areas which are identified as cost drivers in the card and device operations lie in a multi-dimensional space with complex interrelated dimensions that are difficult to delineate. The primary task in the analysis phase is to determine the methods and approach required to define and analyze an issue which is extremely complex. As shown in Figure 3.1.1-1, this multi-dimensional space is characterized by the hierarchical levels existing within the FM & TS organization and the specific objectives of ITM Project 82.

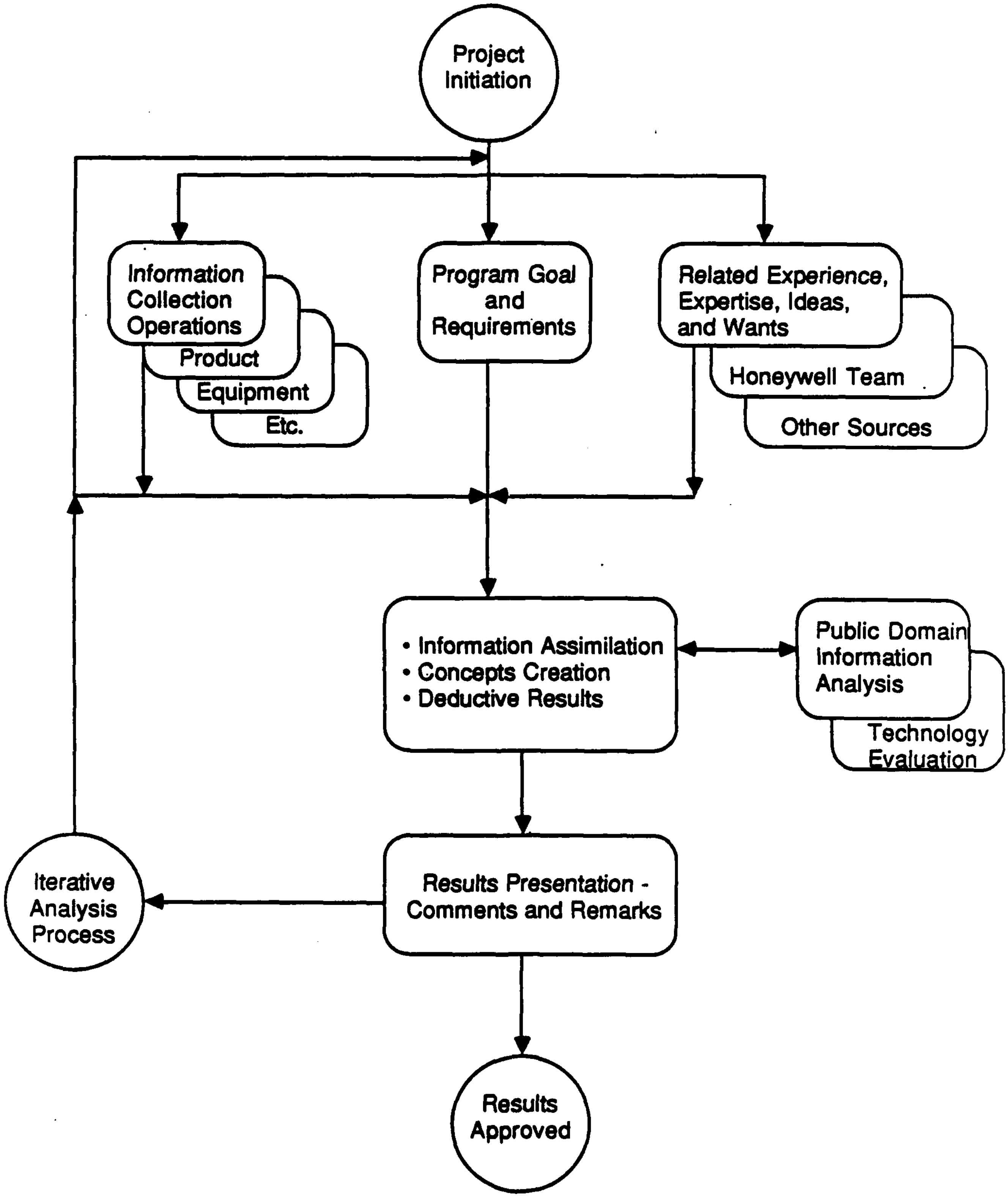


Figure 3.1-2 Typical Iterative Process

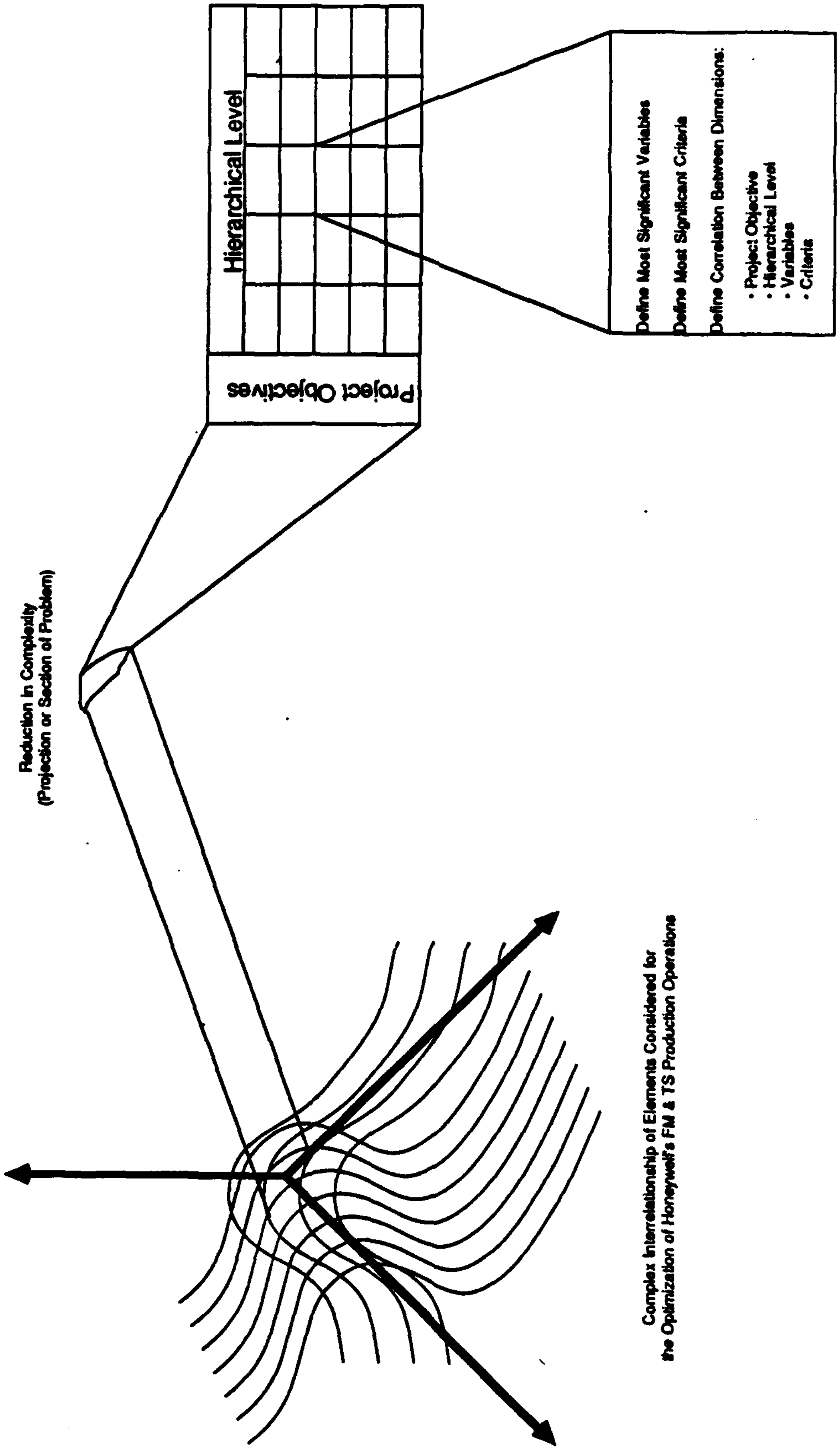


Figure 3.1.1-1 Multi-Dimensional Space Example

By specifying the general objectives to be achieved, it is possible to reduce the complexity of these interrelated dimensions and to define objectives for each of the levels of operations and analyze improvements to be made at each level. Once these objectives have been defined at a specific level, it is then necessary to establish the significant variables and criteria that will influence the analysis and recommendations made for each of these levels.

3.1.2 Structured Design Approach

The structured design approach employed by the project team is directly dependent upon a detailed analysis of the specific FM & TS operations for the card and device areas. The previous section described the methodology used to approach a large, complex, interrelated structure and "break down" that structure into discrete entities (i.e., specific equipment and resources). Once the operations have been analyzed at a discrete enough level to understand the processes and unique characteristics at each level, it is possible to rebuild each of the levels progressively to transform the operations into a more advanced manufacturing structure.

Large scale matrices were developed which correlated the Honeywell part number (of each assembly, sub-assembly, and component part of all products produced by FM & TS) with the operations (i.e., test, burn-in, etc.) and the standard hours required to perform these operations. These correlation matrices provided important information for defining the equipment required for each specific program.

A number of other factors (which are primarily concerned with the overall area layout, material handling requirements for these areas, and production volume) have influenced the general equipment requirements.

Once the equipment requirements for testing and burn-in are defined, it is necessary to present specific technical solutions that can be implemented in the most efficient and effective manner. The following section describes the project team's approach to evaluating the technical requirements that result from the analysis and design process and the selection tools that have been developed for the specific types of equipment that will be a part of the overall FM & TS solution

3.2 Equipment Selection Approach

The selection of equipment employed for ITM Project 82 was defined using a general approach and then a more refined methodology based on this approach was used for each specific piece of equipment. This general approach is described below and presented pictorially in Figure 3.2-1.

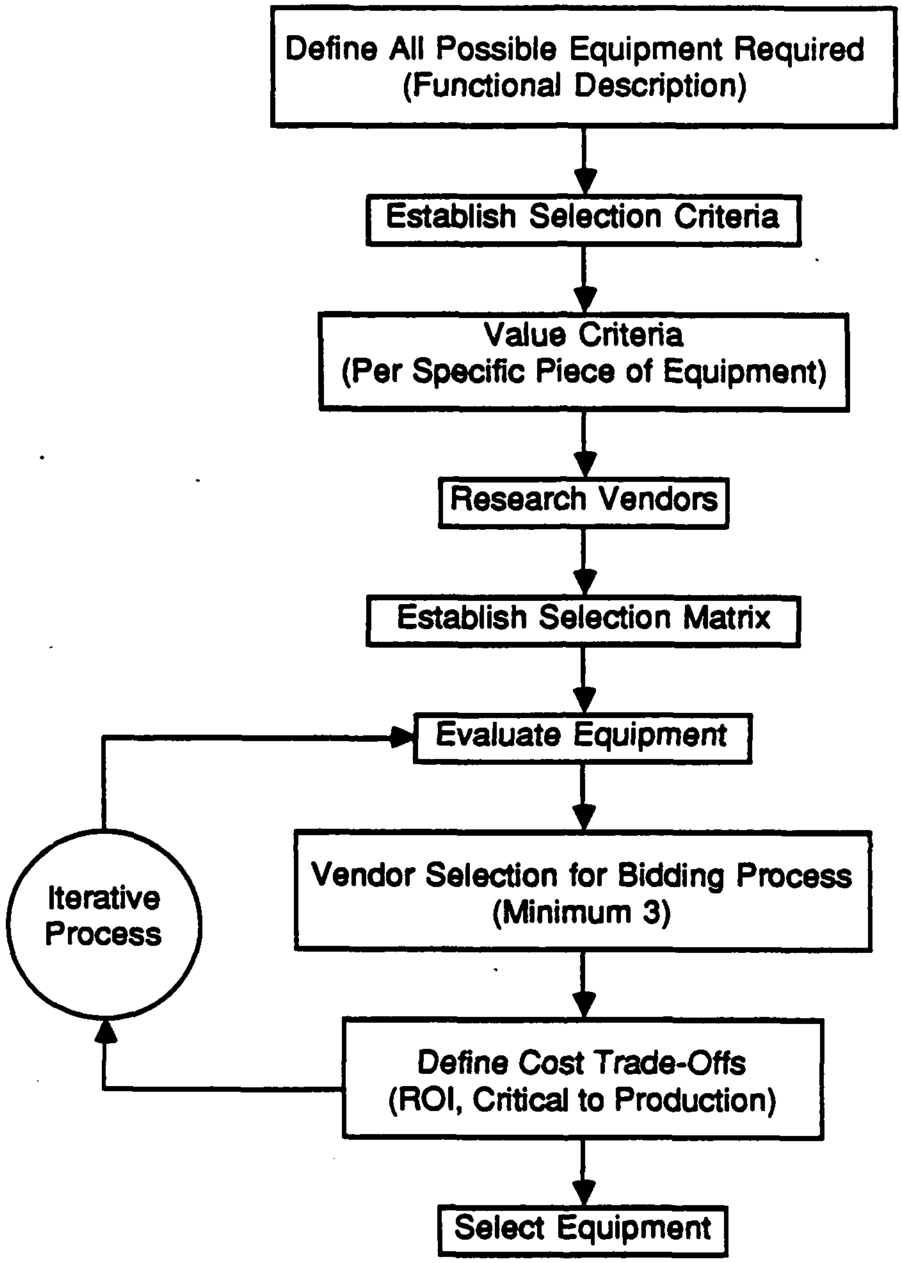


Figure 3.2-1 Equipment Selection Approach

The first step in the selection of equipment is to define all of the possible equipment required to perform the process necessary for production. This was approached from several different vantage points:

- Current equipment survey. All equipment currently used in a production area was reviewed for functionality, age, ease of repair and availability of spares, as well as several other factors specific to the unique piece of equipment.

- Production processes. The processes called out by the production layouts were reviewed to determine if current equipment could adequately perform those processes and what new available equipment could be used to perform production processes.

- Technology overview. Recent technological advances in production equipment were reviewed to ensure that during the equipment evaluation process that all applicable or substitutable technologies were understood in relation to the production area and the processes performed there.

Following the establishment of production equipment requirements, selection criteria were established to evaluate each individual piece of equipment. A general overview of these criteria includes:

Physical Criteria

Conformance to Requirements - Equipment meets (or exceeds) capabilities required, such as capacity, frequency, accuracy, MTBF.

Ease of Use - Required level of technical expertise/training necessary to effectively operate equipment.

Technology Level - Employment of state-of-the-art features or innovative application of technology that enables user to more effectively perform intended task.

Multiple Users - Ability to support more than one user simultaneously (either operating or programming).

Network Capability - Ability of equipment to be networked to other similar units or to centralized data files or controller.

Defect Detection and Reporting Capabilities - Effectiveness of reporting of defects on unit under test so as to permit repair in shortest possible time.

Support

Serviceability - Ease of maintaining equipment plus vendor's support capabilities/response level.

Technical Support Requirements - Level of technical expertise/training required to effectively support (program, maintain, etc.) equipment.

Cost of Programming - Relative effort required to develop operational programs for equipment.

Physical Characteristics

Portability/Moveability - Effect on critical adjustments/required participation of vendor.

Ease of Installation - Effects on installation due to physical size, mounting/isolation requirements, vendor or customer team required.

Ease of Upgrading/Modifications - Convenience of installing additional capabilities/features/options as well as field changes (both hardware and software).

Physical Interfacing - Relative level of ease in providing interface to unit under test (UUT) or other equipment being operated on.

Cooling Requirements - Special HVAC (Heating, Ventilation, Air Conditioning) requirements necessary for equipment due to operating temperature and range.

Environmental Impact - Provisions required due to equipment-generated heat, noise, vibration, etc.

Power Requirements - Exceptional or unusual power requirements equipment as compared to similar types of equipment being considered.

Special Environmental Requirements - Special environment requirements such as "clean" room, dark room, isolation mounting, etc.

Vendor Evaluation

Delivery - Availability of equipment in accordance to needs.

Vendor Reliability - Supplier's record in delivering and supporting equipment (evaluate by questioning other users).

Equipment Cost - Evaluated in relation to other similar pieces of equipment under evaluation for a given use (i.e., relative cost of unit).

It is then necessary (for each piece of equipment required) to "weigh" or value the criteria, selecting the most important criteria for a specific piece of equipment. The weighted factors associated with that equipment are then used to perform an initial vendor review.

The weighted criteria is ranked for level of importance or applicability to the decision making process and listed on one side of an equipment selection matrix (shown in Figure 3.2-2). This matrix is used to evaluate the vendor's product applicability and to screen out the vendor whose equipment is not suitably matched to the requirements.

The vendors whose products meet the initial requirements are sent specifications (RFQ's) to respond to. Once the initial cost of the equipment is established, the selection process then becomes an iterative process of defining the cost trade-offs involved, determining if the ROI is sufficient and reviewing the criticality of the new equipment and its effect on production. The final step in this process is the purchase of the equipment and the initiation of the program's implementation.

Equipment Selection Criteria	Vendor A	Vendor B	Vendor N
Conformance to Requirements			
Ease of Use			
Technology Level			
Multiple Users			
Network Capability			
Defect Detection and Reporting Capabilities			
Serviceability			
Technical Support Requirements			
Cost of Programming			
Portability/ Movability			

Figure 3.2-2 Tooling and Equipment Evaluation Matrix

Equipment Selection Criteria	Vendor A	Vendor B	Vendor N
Ease of Installation			
Ease of Upgrading/ Modifications			
Physical Interfacing			
Cooling Requirements			
Environmental Impact			
Power Requirements (Normal vs. Exceptional)			
Special Environmental Requirements			
Delivery			
Vendor Reliability			
Equipment Cost			

Figure 3.2-2 Tooling and Equipment Evaluation Matrix (cont.)

SECTION 4

"AS-IS" PROCESS

The following section presents a description of the "As-Is" condition of the FM & TS operations. This includes a brief description of the type of product currently in production and the organizational structure of Flight Management and Targeting Systems as well as the personnel involved in FM & TS Production. In addition, the test and burn-in equipment used in the card and device area is described.

An overview of the current "As-Is" process required to produce FM & TS products is depicted in Figure 4.0-1.

4.1 FM & TS Production Overview

FM & TS Production manufactures products for five major programs as well as producing spares for these and other older programs.

4.2 FM & TS Program Profiles

Flight Management and Targeting Systems Production assembles and tests high technology military flight control and targeting systems built under specific customer contracts. Therefore, while there may be several products within a particular program, each program must be managed and controlled to comply with a specific customer's requirements. The systems that are built under each of the program's currently under contract to FM & TS are typically made up of a variety of components, including:

- Computers
- Control Panels
- Sensors
- Control Sticks
- Electronics Units

The orders for any one of these program's products may be made for complete systems, modification packages, or spares.

In addition to the various programs which are in current production, a significant amount of FM & TS Production's business is made up of military spares and/or repairs on older programs.

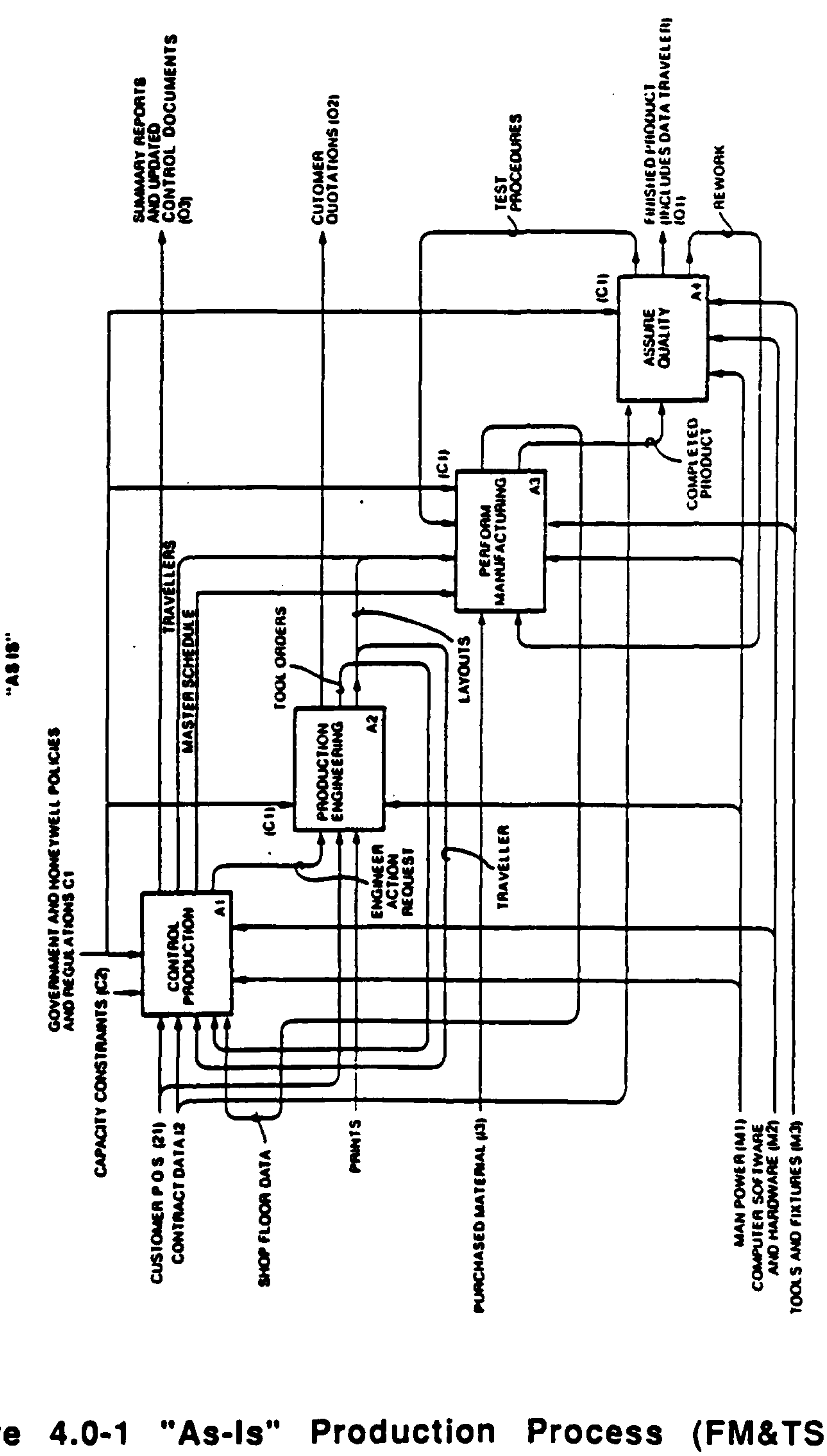


Figure 4.0-1 "As-Is" Production Process (FM&TS)

4.3 FM & TS Organizational Structure

The Flight Management and Targeting Systems (FM & TS) Production operations play a central role in Honeywell's Military Avionics Division's (MAvD) Flight Systems Operations (FSO) organization. The organizational structure of FSO is divided into several major functional areas, including:

- Production
- Program(s) Management
- Engineering
- Product Assurance
- Procurement

Each of the areas within FSO are structured as independent, function-oriented organizations that report to other areas on a "dotted line" basis. Within the Production area of FSO, the organizational structure is primarily high-level-product oriented. These high-level-product related areas are divided into:

- Flight Management and Targeting Systems Production
- Missile System Microwave Production
- Printed Wiring Assembly
- Aircraft System Microwave Production
- Advanced Systems
- Central Production Services

While the divisional distinctions within FSO are primarily high-level-product oriented, the products produced by each group are also significantly distinct from a manufacturing process perspective.

The Flight Management and Targeting Systems Production operations are functionally divided into several areas, including:

- Production Engineering
- Production Control
- Assembly

These areas, which are separated organizationally, are interrelated to work together in an overall manner to support each of the products manufactured by the FM & TS operation. In that respect, each of these divisions provide input and receive assistance from the other two areas.

While the organizational division at this level is functional, the inter-division communication is defined by specific product programs. While this requires comprehensive management by each of the supervisors, it allows for direct information exchange where it is most beneficial (i.e., for each of the FM & TS programs).

4.4 Test and Burn-In Operations Overview

The primary activities in the card and device production area are the test and calibration of circuit card assemblies (CCA) and the test, calibration, and environmental exercise of devices (black boxes). The activities of this organization are augmented by a special assembly group known as the Final Assembly Support Team (FAST) which includes modification, engineering order (E.O.) incorporation, and rework capabilities.

Within the FM & TS areas, the processing of electronic assemblies begins with card test and calibration. CCA's are received from an assembly area located at the St. Louis Park facility which is dedicated to that function. The cards are first tested and any operational faults are detected and repaired. If a card requires the addition of a component to calibrate a specific circuit, the value is determined and the component is installed.

Once the card is fully functional, it is transported to the Paint and Coating area for a conformal coat. Subsequent to the coating operation, the card is stocked in the area for later inclusion in a device chassis.

If a specific CCA is intended to be shipped directly to the customer as a spare, it is retested and, if fully functional, presented to the inspection department for final approval prior to shipment.

As orders for devices are released, area personnel select the correct card complement from the stocking cabinets and install them in the chassis for testing.

Each device is run through a programmed checkout or pre-ATP (Acceptance Testing Procedure) on ATE equipment to determine if it exhibits the correct functions in preparation for an environmental test (the exception to this is the major components of the Targeting Systems programs which are checked out in system configuration lashups instead of individual ATE adapters). An Acceptance Test Procedure has been developed which each device must correctly pass to be a shippable unit.

Once the device is working properly, it is installed in an environmental chamber that subjects each unit to temperature cycling over a program specific period. Depending on the specific program, each unit will be subjected to either sinusoidal or random vibration during this burn-in period. Units requiring random vibration are transported to the Development & Evaluation (D & E) Labs for testing since the capability does not exist within the FM & TS Production area.

Device performance is monitored periodically during environmental testing and any malfunction requires that the device be removed from the chamber and be repaired.

Once the device satisfactorily passes the environmental test, it is run through a final ATP and accepted by quality and/or customer representatives. Final labeling and packaging completes the pre-ship procedures.

4.5 Test Equipment

The following section describes the test equipment currently used in Honeywell's FM & TS Production area. This equipment includes:

- ATE Consoles
- Fluke Circuit Board Tester
- Manual Test Consoles
- Environmental Chambers
- General Purpose Test Equipment
- Adapters for Cards, Devices, and Environmental Burn-In

A detailed description of each of the major equipment types is presented in the following subsections.

4.5.1 Honeywell Automatic Test Equipment

The Honeywell ATE unit is a programmable, computer controlled tester designed to automatically test electronic modules of varying complexity for functional compliance with specifications for voltage type, frequency, amplitude, time duration, logic state, etc. Under program control, it is capable of providing the necessary stimulus to a Unit Under Test (UUT) so as to properly exercise specific operational functions which may be automatically measured.

4.5.1.1 Hardware

The Honeywell ATE has been in use for production testing on FM & TS assemblies for over eighteen years. The ATE is a computer-controlled tester utilizing a stored program to exercise both modules (printed circuit assemblies) and devices (card cages or "black boxes"). The computer acts as the control point of the operations of various instruments in the system that provide stimulus to and measure response from a unit undergoing test.

The ATE units in use in the FM & TS area are primarily configured as analog testers. The Honeywell ATE is a multi-bay cabinet consisting of rack-mounted measurement instruments and stimulus devices (e.g., power supplies, signal generators, waveform generators, etc.) controlled through an instrument addressing scheme with stimulus and measurement values transmitted back and forth to the H-316 controller via binary or BCD coding. The instrument stimulus output and measurement input points are wired to a main receiver chassis which provides interconnection to units to be tested via an interface patch panel as directed by the respective test program.

Typically, a unit under test is interfaced to the ATE via an adapter which contains the necessary interconnection hardware to both mate with the unit under test and the receiver (or main interconnection panel) of the ATE unit. An additional function of the adapter is to provide the signal terminations and routings (as well as power connections) which are required by the unit under test.

Typically, each of the ATE units has the following programmable instruments:

- DC Signal Sources
- AC Signal Sources
- Function Generator
- Pulse Generator
- Decade Resistance Panel
- DC Power Supplies
- Digital Voltmeter
- Threshold Detector
- Time and Frequency Digitizer
- Time Delay Generator
- AC/DC Converter

Additionally, power supplies are provided to energize units undergoing test. These include:

- 28 VDC
- 115 VAC, 400 Hz, 3 Ø
- 26 VAC, 400 Hz

4.5.1.2 ATE Central

All Honeywell ATE units in use by FM & TS are connected to a program storage facility known as "ATE Central". This facility is located in close proximity to the main FM & TS production area and is shown in Figure 4.5.1.2-1. The current area supporting FM & TS ATE Central is made up of approximately 960 square feet. The facility is on an eight inch raised floor and has both temperature and humidity controls with smoke alarms and other protective devices.

ATE Central is the repository for all test programs executed on units undergoing test in the card and device areas. Depending upon memory size requirements, programs are downloaded totally (or in blocks) to the requesting test station when the part number - dash number is provided at the respective station. This provides a central control of program configuration and eliminates the possibility of operator modification of the program. Additionally, the Honeywell computers located in Test Central provide control for all other Honeywell testers on site.

Data logging is also performed by the system which provides summaries of test results to satisfy the documentation requirements of various contracts. These log sheets are obtained from line printers located in Test Central and are included with the data packages associated with each device tested.

4.5.1.3 Fixturing

As indicated previously, adapters are required to interface the Honeywell testers and units requiring testing. These can be divided into two major categories:

- Card Adapters
- Device Adapters

Card Adapters

Card adapters permit printed circuit assemblies to be tested on the ATE. The adapters contain the necessary mating connectors to interface the card with the tester.

In some cases, a "family" of cards can be tested on an adapter or on a main adapter with "Piggyback" connector modules, thereby minimizing adapter costs and complexity. Adapters for the ATE's have been developed and are in use for many programs.

Figure 4.5.1.3-1 presents the physical outlines of the majority of these adapters.

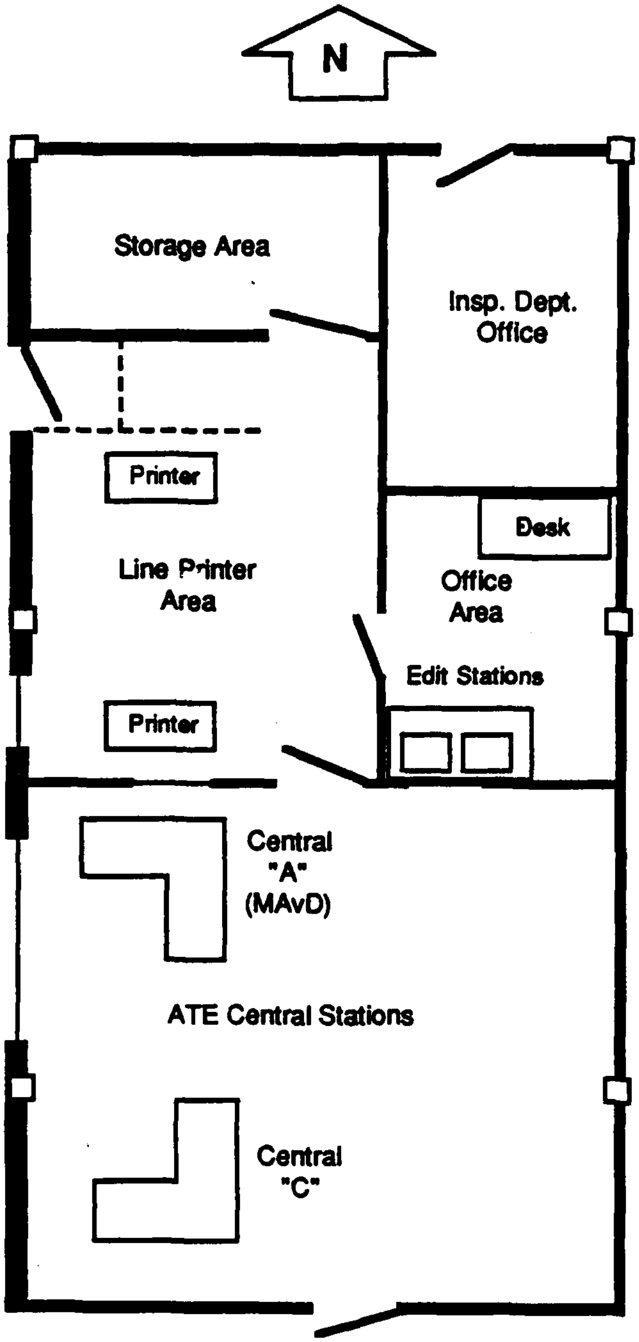


Figure 4.5.1.2-1 ATE Central "As-Is"

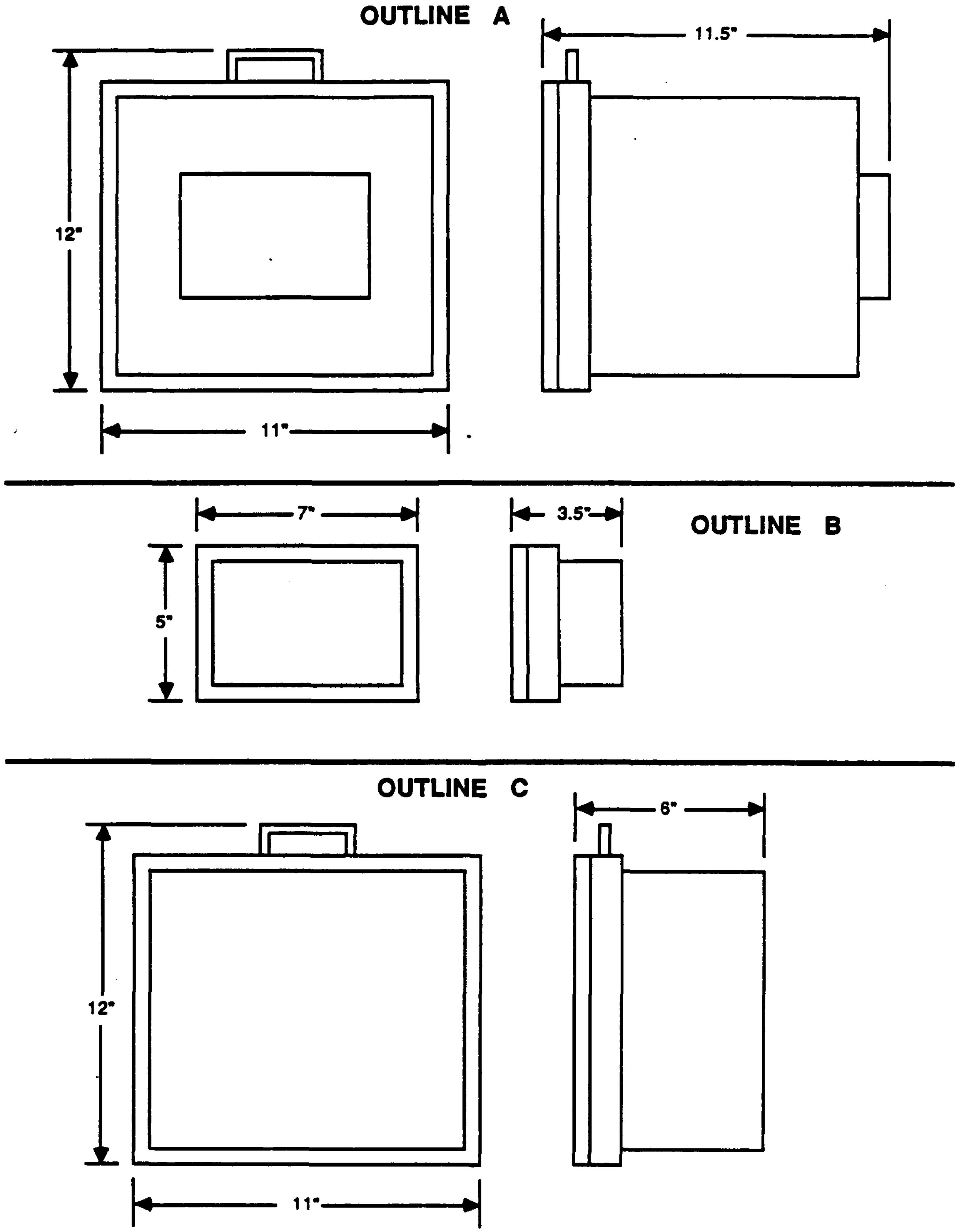
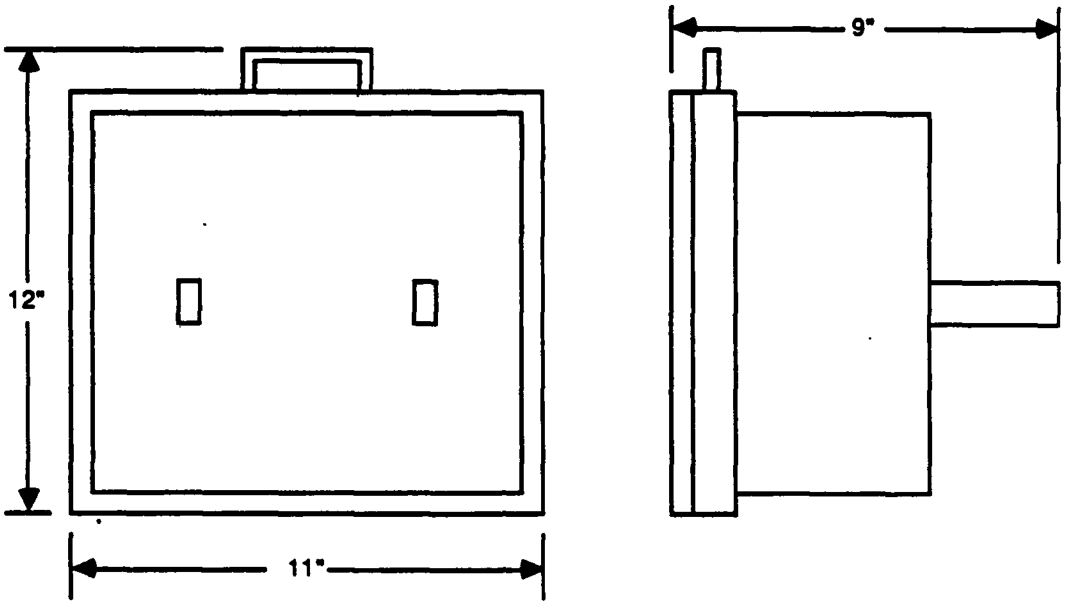


Figure 4.5.1.3-1 FM & TS Card Test Adapters

OUTLINE D



OUTLINE E

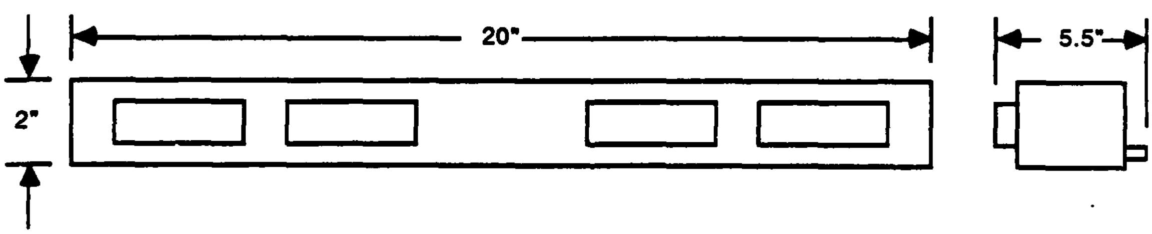


Figure 4.5.1.3-1 FM & TS Card Adapters (Cont.)

Device Adapters

Device adapters allow the "black boxes" (chassis loaded with cards) to be tested on the Honeywell ATE units. Programs for the devices are comprehensive and usually take from thirty minutes to an hour to execute to completion. The tests are loaded in blocks (or segments) because the tester memory is of limited capacity.

These tests are of considerable significance since they form the basis for the Acceptance Test Procedures (ATP) which must be successfully run on each device before and after environmental testing to permit final qualification and shipment. As indicated, printouts identifying the completion of a qualifying ATP run are produced by the ATE network and become part of the device documentation package.

4.5.1.4 Honeywell ATE Programming

Honeywell ATE programs can be divided into two basic categories: card programs and device programs.

Card programs tend to be shorter and less complex, requiring execution times ranging from seconds to a few minutes. In addition to testing card function, the tests allow circuit calibration by the insertion of a component value within a specific range to "trim" a circuit into the correct operational parameters. The operator can insert a value and run the test until the desired results are obtained.

Programs are generally straightforward and built up out of subroutines or subprograms which control the various signal and power sources within the ATE as well as the measurement modules which are provided. By inserting the specific conditions and values desired into the program coding, stimulus or measurement by the designated instrument is provided within the text sequence at the point desired.

For devices, the task is more complex. Since a device is a part of the Aircraft Flight Control System, the test program must simulate the environment, or range of conditions, the device will be expected to encounter while in operation. As a consequence, the ATE program must provide a complex variety of signal conditions to the device. Generally, these programs only require the operator to connect the unit to a properly functioning ATE station and start the program. As long as no failure occurs, intervention is unnecessary. While constant monitoring is not required, programs do not provide much more information upon failure than out-of-limits parameters. As a consequence, considerable experience with both cards and devices is necessary to effect rapid repairs.

In programming, the process is essentially manual, requiring the establishment of required parameters line-by-line in test station code. As previously indicated, instrument subroutines assist the programming effort, but coding, debug, and certification depend heavily on the expertise of the programmer.

4.5.2 Fluke Automatic Tester

Since the Honeywell ATE has limited digital card testing capabilities, FM & TS began digital card program development and testing on a Fluke Functional Test System in 1979. This tester was acquired by the Commercial Avionics Division and has been available to FM & TS on an off-shift basis for shared use testing of digital cards since that time. However, as the Commercial Avionics Division completes their move to a new facility, this tester will become unavailable.

4.5.2.1 Hardware

The Fluke Functional Tester is primarily a digital tester utilizing a comparison testing technique to determine the condition of a card of unknown functionality. This is accomplished by exercising a "known good" card of an identical type in parallel with the unknown card. Essentially, both cards are stimulated identically, in time and pattern, and the output response compared step-for-step. If no difference is detected, the unknown card is determined to be good.

The tester is basically a desktop console with display and control facilities capable of controlling cards with a maximum of 240 input and output pins (the Honeywell unit was configured for 128 pins). Zero insertion force connectors are provided to interface with adapters which in turn provide the interface with the UUT. The console has a built-in floppy disk unit to store the card test programs which can be prepared off-line. The disk drive also permits the testing of cards with a large number of test steps by linking program segments.

Two accessory units for the tester are available to FM & TS to assist in programming and testing cards:

- Analog Test Station
- Off-Line Programming Station

The analog test station is a rack-mounted group of instruments consisting of a counter/timer, multimeter, function generator, programmable power supplies, and a switch matrix module. This unit is interfaced with the Functional Tester to permit testing of cards with mixed digital and analog (hybrid) circuitry.

The instrumentation is controlled via an IEEE command set and programs are developed on a separate programming station.

The off-line programming station permits development of card test software and minimizes interference with testing activities. The unit is a desktop console with CRT and keyboard and has two floppy disk drives to allow program storage, transfer, and duplication. Once a program is developed, debugging and certification proceeds on the Functional Tester.

4.5.2.2 Networking

This equipment has the capability of being interconnected to a centralized program database similar to the Honeywell ATE's and ATE Central, however this function is not utilized at present. This activity could be performed via RS-232 protocol and interconnection.

4.5.2.3 Fixturing

All fixturing for the Fluke Functional Tester consists of adapters to interface the tester with various cards utilizing digital signal processing. The adapters contain the necessary internal wiring to correctly route signals to and from the card under test and the tester. They are relatively simple to wire and comparatively inexpensive to build.

4.5.2.4 Programs

Programs for the Fluke Functional Tester can be developed on the tester or on the off-line programming station. Selection of data rates, input and output pins, digital patterns, logic levels, etc. are set up to operate the card being tested under program control. Program options allow a wide variation in stimuli to ensure that all devices on the card are exercised sufficiently to detect any functional failures.

The Fluke tester, as opposed to the Honeywell ATE, is able to exercise digital circuits at much higher rates of speed which more closely approach those encountered in system operation. Moreover, the Fluke Functional Tester has much greater digital capability than any other card tester available to FM & TS operations at this time. The chief disadvantage to FM & TS is access to this equipment, since it resides in the Commercial Avionics Division card testing area and FM & TS Production receives a low priority for use of the system. Furthermore, this tester is scheduled to move with the Commercial Avionics Division to its new off-site location in the near future.

4.5.3 Manual Test Consoles

As part of program development, several consoles or test stations have been constructed to assist primarily in testing devices. The test consoles allow testing and troubleshooting of cards and devices without tying up the ATE units in prolonged diagnostic operations. As might be surmised, the testers are special purpose units with some having standardized test equipment such as oscilloscopes and digital multimeters built into the test racks.

4.6 Burn In Equipment

Typically, each contract for FM & TS systems has requirements for environmental testing which include time, temperature cycling, power application, vibrational conditions, etc. pursuant to applicable military standards. The equipment and processes described in this section are the primary means of ensuring contractual compliance in FM & TS environmental testing.

4.6.1 Environmental Chambers

As part of qualifying devices for the various programs currently in production in FM & TS, temperature cycling is required to verify performance under varying environmental conditions.

The ovens used to perform this testing are primarily units manufactured by Thermotron. Depending upon their acquisition date, the oven controllers range from paper tape-sequencer to microprocessor controlled units. The ovens have integral charting recorders to indicate program sequence and log temperature data as part of the historical records accompanying each device.

As the ovens are loaded with a device for a new run, the cycle is initiated and a new chart is mounted. Progress is periodically monitored to determine if device function is correct as well as oven performance. This is essentially a manual operation requiring the physical monitoring of each individual oven.

4.6.2 Vibration Testing

Some environmental chambers in the card and device area are equipped with sinusoidal vibration tables to provide a simulation of operational conditions during device burn-in. Periodically during device burn-in, the vibration tables are activated under sequencer control to vibrate the unit.

Some programs currently in production in FM & TS specify random vibration operation during burn-in. FM & TS utilizes environmental chambers in the D & E Labs to perform these functions as required by contract.

4.6.3 Fixtures

In addition to the control consoles which are connected to devices undergoing burn-in, FM & TS has a complement of fixtures which are used to burn-in spare cards and other sub-assemblies. These fixtures allow production personnel to perform the necessary environmental testing without the investment in a device chassis and complement of cards.

SECTION 5

"TO-BE" PROCESS

The following section describes the improvement of automated test and burn-in equipment that will be in place as a direct result of ITM Project 82.

5.1 "To-Be" Operations Overview

The "To-Be" operations can be characterized as consisting of more modern and advanced test and burn-in equipment for the FM & TS operations. Sub-assembly testing will be performed on a modular, multi-purpose tester such as the SigmaSeries manufactured by Summation. Additional digital testing will take place on a Fluke Functional Tester dedicated to the FM & TS operations.

Burn-in operations will benefit from the introduction of an oven monitoring network, which will record oven performance data automatically and provide a signal for out-of-tolerance conditions. The network also provides the groundwork for a future upgrade to automatic control of the ovens.

Figure 5.1-1 presents an overview of the "To-Be" processes required to produce FM & TS products.

5.2 Future Products Technical Overview

Technological advances through the use of greater density IC's with defined requirements (e.g., ASIC's) combined with surface mount technology (SMT) are making the eventuality of a flight control "computer-on-a-card" a very real possibility.

While the aircraft system's interconnections may be either hard wire or fiber optic, a very real need exists to comprehensively test these "devices" (cards) to ensure their functional adequacy. Since the effort to determine operational capability from the edge connector(s) will become increasingly more complex and difficult, means of accessing the internal workings of the assembly will take on greater significance.

While in the uncoated state, a card can be accessed by fairly typical means such as a vacuum "bed-of-nails" fixture. Once conformal coating is applied, this method is virtually eliminated, requiring specific physical test points (or connectors) to access the internal workings.

What is apparent here is that a close relationship with the system (card) designers is mandatory. It is not enough to appreciate just manufacturing / producibility needs. Designers need an awareness of total product cost, which includes after-delivery support and repair.

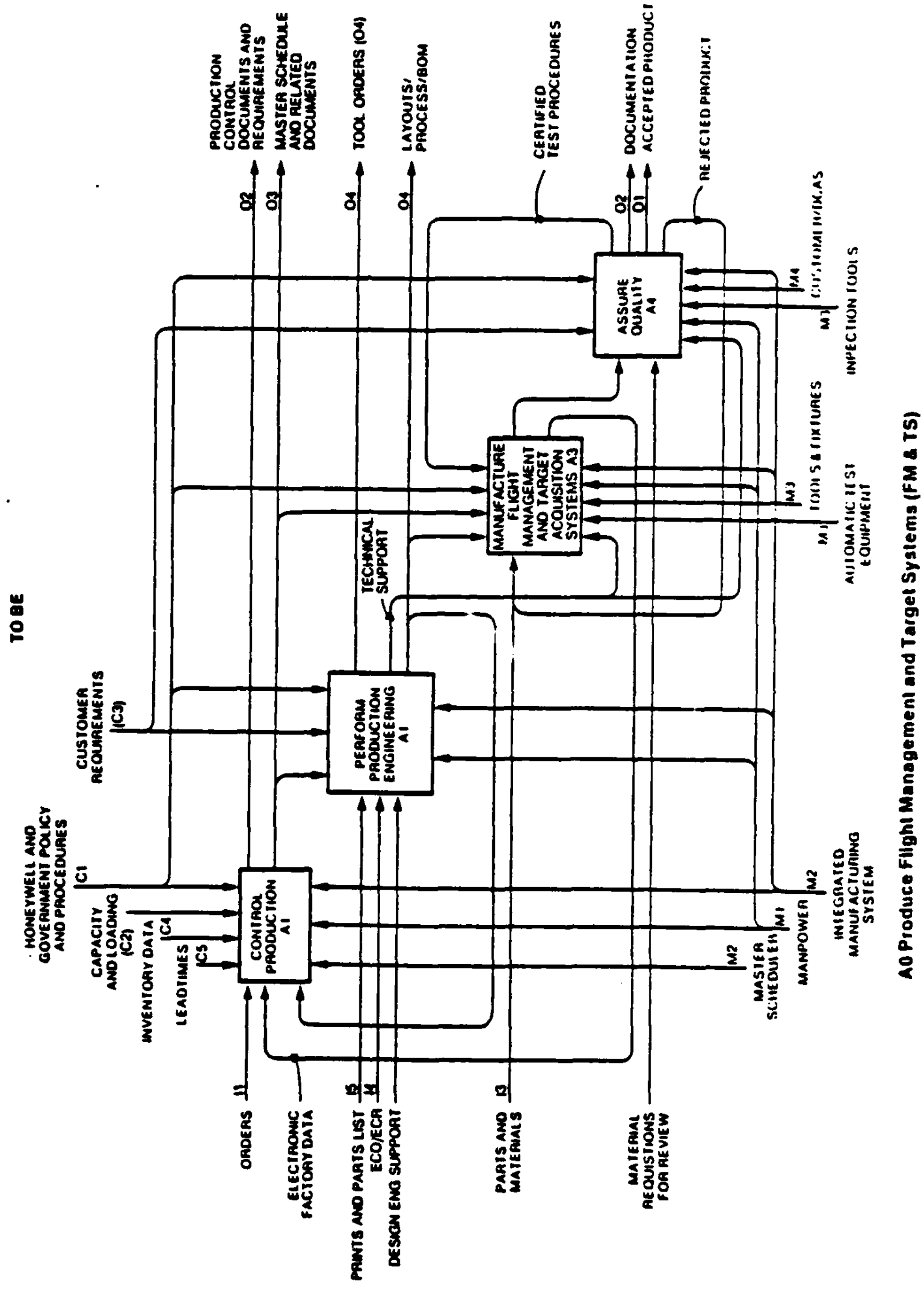


Figure 5.1-1 "To-Be" Production Process (FM&TS)

It is felt that the complexity of these future systems must include test "ports" as an integral part of the basic design. Moreover, the port has to be more than a hard-wire connection. What is envisioned here is an electro-optical link which inherently has the bandwidth/frequency capacity to couple the capabilities of a functional tester to the internal "workings" of the system.

The IC technology to accomplish the multiplexing and optical modem functions exists and is undergoing the same technological change the market is experiencing in general (i.e., increased complexity, density, capability, etc.). Additionally, this form of data "coupling" is electrically "quiet" and immune to non-coherent interference as well as having the capability of extremely high data rates.

In summary, what is proposed here is a combined design/testing approach which will encompass the capability for a high degree of expansion.

5.3 "To-Be" Equipment

Upgrades to equipment proposed for the FM & TS card and device test areas include:

- *Summation SigmaSeries modular multi-purpose test system*
- *Fluke Functional Tester*
- *Burn-In Oven Monitor Network*

The following sections describe briefly the equipment listed above. A more detailed description of the equipment itself as well as the requirements and specifications and vendor surveys which led to it's selection are contained in Sections 8, 9 and 11 of this document.

5.3.1 Summation SigmaSeries Test System Description

Summation's SigmaSeries™ Test System family fulfills the major requirements of the Computer Integrated Test (CIT) systems needed in today's manufacturing environments with:

- Complex analog and digital testing
- Simple straightforward operation
- Powerful software development tools
- Rapid test system reconfiguration
- Fast data feedback through networks

- Data reduction and statistical analysis
- Networking capability
- Management information system gateways

The system includes the MC68000-based modular TestStation™; proprietary TestWindows™ software, and a PC-based computer for system control. The basic structure of the SigmaSeries integrated test station is shown in Figure 5.3.1-1. As can be seen in this diagram, in addition to the cross triggering of modules within the Test Frame, the SigmaSeries can even accommodate other manufacturer's instruments which contain IEEE 488 standard interfaces. The modular design also allows for the addition of test functions as they are developed and the station to be reconfigured for testing new assemblies as needed without necessitating the purchase of a new system.

As configured, the SigmaSeries test station is primarily analog in nature, although it contains several times the digital capabilities of the Honeywell ATE stations now in use. It is therefore an ideal system for testing the analog and hybrid (containing both analog and digital circuitry) devices of both present and future design. It will be located in the FM & TS card and device test area and used primarily for the functional test of printed circuit board assemblies and various sub-assemblies prior to their being loaded into devices. The possibility also exists that in some instances devices (black boxes) will be tested on this equipment.

The SigmaSeries station is intended to be used for the test of assemblies and sub-assemblies primarily when new business is introduced in FM & TS requiring the creation of test programs for new cards and devices. This system offers an excellent opportunity for savings in the coding, debug, reprogramming, and documentation tasks necessary when new test programs are created. Additional savings will be realized due to the enhanced troubleshooting capabilities presented by this new equipment at the card and sub-assembly test level.

Although the station is intended for use in the test of new assemblies, the possible savings presented by the enhanced troubleshooting capabilities may present other opportunities. If it can be demonstrated that the troubleshooting savings realized can offset programming costs, the possibility exists that higher volume assemblies in current production will also be tested on the Summation equipment. This must be evaluated on a case by case basis by Production Engineering as the opportunities present themselves.

In summary, the Summation SigmaSeries test station offers several improvements over the present ATE test equipment. Principal among these improvements are:

- Enhanced analog and hybrid testing

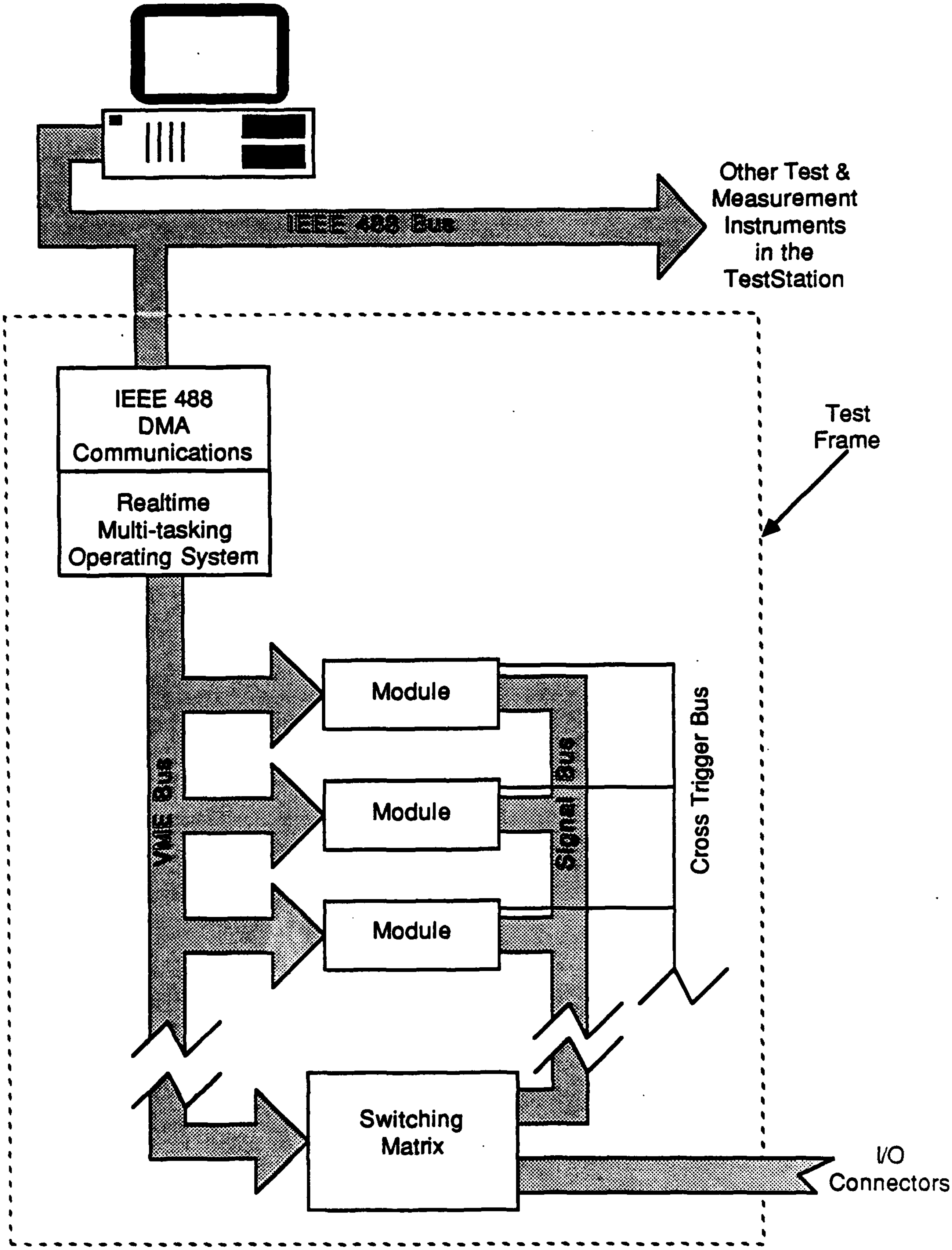


Figure 5.3.1-1 SigmaSeries Test Module Interfaces

- Simplified software programming and documentation
- Enhanced troubleshooting capabilities
- Rapid system reconfiguration

5.3.2 Fluke Functional Tester

Since the Honeywell ATE has limited digital card testing capabilities, FM & TS began digital card program development and testing on a Fluke Functional Test System in 1979. This tester was acquired by the Commercial Avionics Division and has been available to FM & TS on an off-shift basis for shared use testing of digital cards since that time. However, as the Commercial Avionics Division completes their move to a new facility, this tester will become unavailable.

Therefore, in order to maintain the present test capability and provide for improved test capability in the future, it is proposed that for the "To-Be" operation FM & TS purchase a dedicated Fluke 3050B for digital card testing. This will allow for the continued testing of products whose tests were originally developed on the Commercial Avionics Division's tester and assure that testing of the more complex digital designs of the future will be possible.

Additionally, a dedicated tester belonging to and controlled by FM & TS will provide efficiencies in scheduling which will promote more flow through testing of cards and devices. In the present situation, testing of FM & TS cards is limited to second or third shift operations and priority scheduling is given to the Commercial Division cards. In the "To-Be" operation, with control over a tester belonging to the department, the card test group leader will be able to optimize the schedule of test on the FM & TS equipment. Additionally it will allow the flexibility to alter the schedule when special situations arise (such as unexpected E.O. incorporation) in order to meet shipment deadlines.

5.3.3 Burn-In Oven Monitor Network

As part of acceptance testing of devices for the various programs currently in production in FM & TS, temperature cycling is required to verify performance under varying environmental conditions.

In the "To-Be" operation a monitoring system (shown in Figure 5.3.3-1) will allow a group leader to maintain constant awareness of system progress and oven performance. The oven network consists of a microprocessor-based controller installed in each oven, linked by an RS-232 interface to a personal computer which serves as the network monitor point. It is intended to have the ovens grouped together in an environmentally isolated structure located at one end of the FM & TS area (shown in Figure 5.3.3-2). The PC based monitor will be located conveniently to the group leader and operators such that oven status and/or device test parameters may be checked at any time. Consequently, once a device is started into burn-in, unless the device test parameters are altered, all environmental monitoring can be conducted remotely.

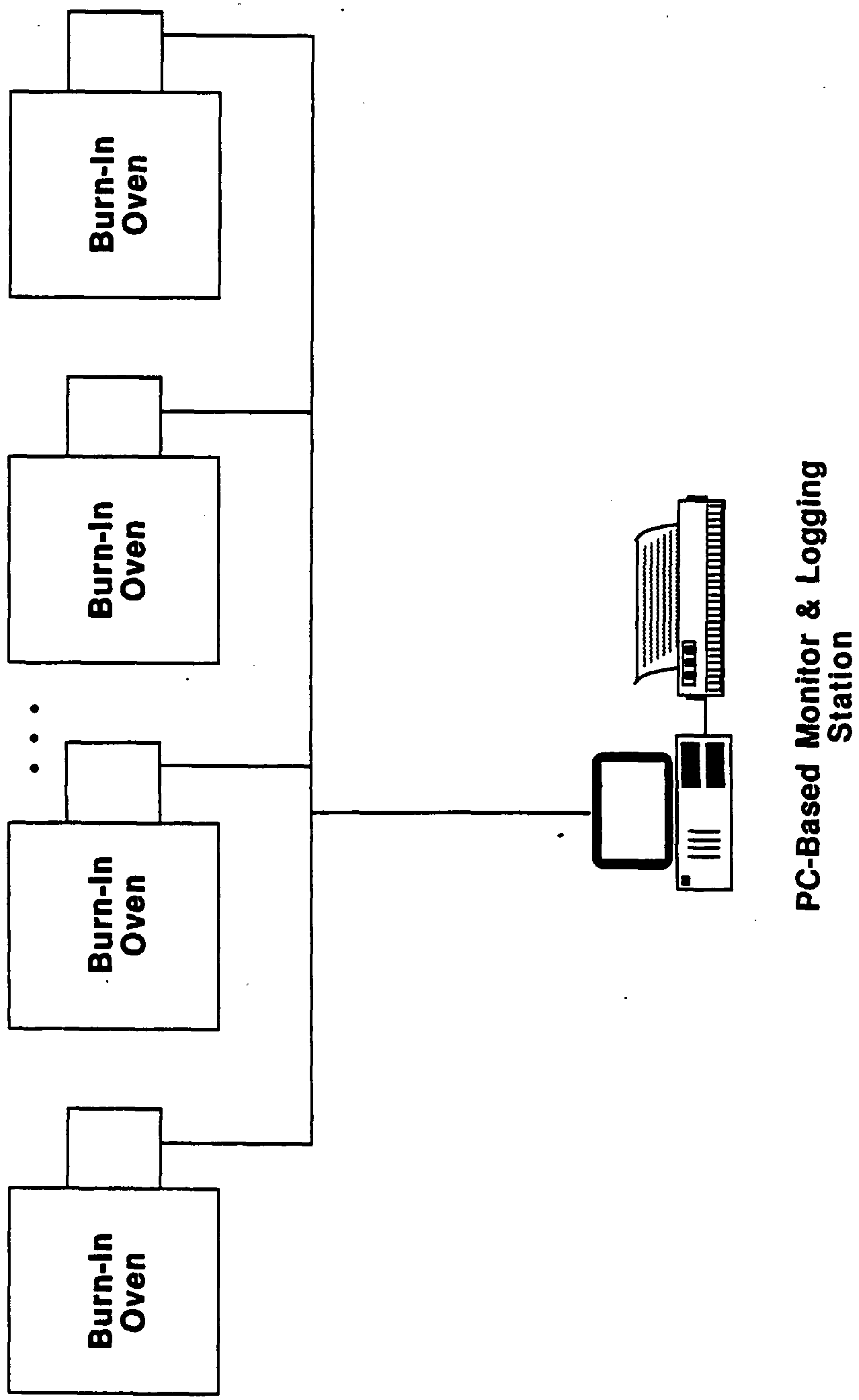


Figure 5.3.3-1 Oven Monitor Network

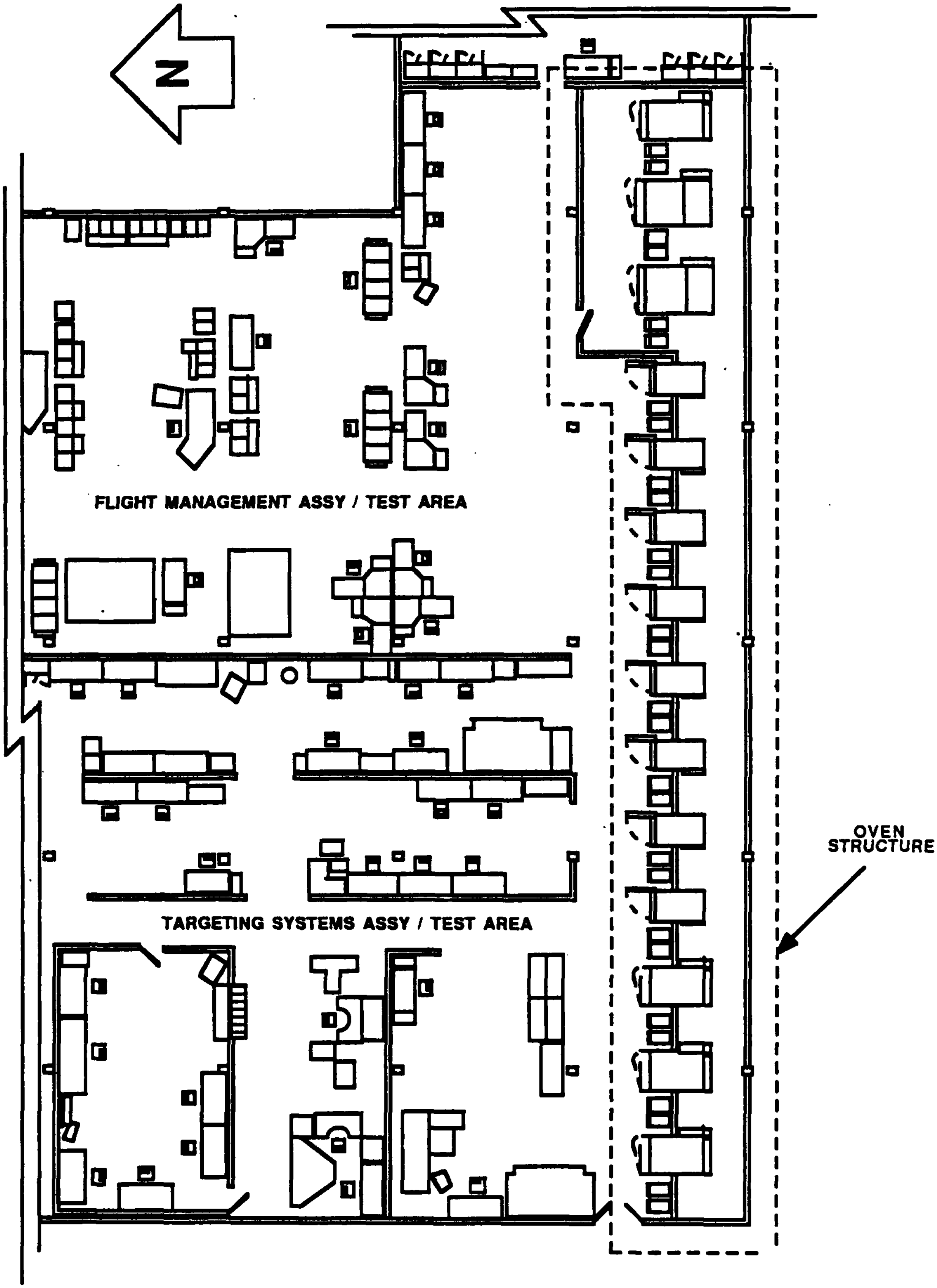


Figure 5.3.3-2 "To-Be" FM & TS Oven Isolation Structure

At the successful conclusion of the burn-in period, the environmental profile, complete with unit serial number, can be printed out and become a part of the device data package whenever this is a specific program requirement. Moreover, since the network is continuously monitoring the ovens connected to it, any conditions not conforming to the correct temperature profile will immediately be transmitted to the system monitor and annunciated to the group leader. This allows prompt correction of faulty equipment and greatly reduces lost time. An additional feature of the system allows for future upgrade to centralized control of all attached ovens if necessary.

SECTION 6

PROJECT ASSUMPTIONS

ITM Project 82 has proceeded with the following assumptions as fundamental guidelines. Project implementation could be impacted and schedules affected if alternative approaches or significant deviations to plan are executed.

- Capital funds will be available for equipment purchases beginning in fiscal year 1988.
- Sufficient internal resources will be committed to implement ITM Project 82.
- FM & TS Production Engineering will coordinate implementation efforts.
- Implementation will not be considered finalized until designated equipment is in place as depicted in the ITM Project 82 plan.
- As much as practical, software packages procured as part of the project implementation will be standard, off-the-shelf products so as to avoid on-going maintenance associated with customized packages.
- Build projections for card and device quantities are based on overall FM & TS revenue growth estimates.

SECTION 7

GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

No Group Technology analysis techniques were necessary in the development of the improvements during the course of ITM Project 82.

SECTION 8

PRELIMINARY/FINAL DESIGN AND FINDINGS

The following section describes the process of preliminary findings and design iterations as well as the Final Design that will be in place as a direct result of ITM Project 82 and the final design findings that led up to it. The primary emphasis of ITM Project 82 is on the improvement of automated test equipment and burn-in operations.

The approach to the development of the final design of the "To-Be" factory has been described in Section 3 of this document. In addition, the refined methods for arriving at the "To-Be" design are included as part of the justification and description of that design.

8.1 "To-Be" Operations Overview

The "To-Be" operations can be characterized as consisting of more modern and advanced test and burn-in equipment for the FM & TS operations. Sub-assembly testing will be performed on a modular, multi-purpose tester such as the SigmaSeries manufactured by Summation. Additional digital testing will take place on a Fluke Functional Tester dedicated to the FM & TS operations.

Burn-in operations will benefit from the introduction of an oven monitoring network, which will record oven performance data automatically and provide a signal for out-of-tolerance conditions. The network also provides the groundwork for a future upgrade to automatic control of the ovens.

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While the aircraft system's interconnections may be either hard wire or fiber optic, a very real need exists to comprehensively test these "devices" (cards) to ensure their functional adequacy. Since the effort to determine operational capability from the edge connector(s) will become increasingly more complex and difficult, means of accessing the internal workings of the assembly will take on greater significance.

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What is apparent here is that a close relationship with the system (card) designers is mandatory. It is not enough to appreciate just manufacturing / producibility needs. Designers need an awareness of total product cost, which includes after-delivery support and repair.

It is felt that the complexity of these future systems must include test "ports" as an integral part of the basic design. Moreover, the port has to be more than a hard-wire connection. What is envisioned here is an electro-optical link which inherently has the bandwidth/frequency capacity to couple the capabilities of a functional tester to the internal "workings" of the system.

The IC technology to accomplish the multiplexing and optical modem functions exists and is undergoing the same technological change the market is experiencing in general (i.e., increased complexity, density, capability, etc.). Additionally, this form of data "coupling" is electrically "quiet" and immune to non-coherent interference as well as having the capability of extremely high data rates.

In summary, what is proposed here is a combined design/testing approach which will encompass the capability for a high degree of expansion.

8.3 "To-Be" Automated Test Equipment

Assembly and sub-assembly testing will be performed on a modular, multi-purpose tester such as the SigmaSeries manufactured by Summation. It was determined that the selection of equipment for testing in conjunction with new product development would be a cost effective means to modernizing the automated test equipment and test development efforts at FM & TS while providing the necessary flexibility and functionality for future product test development.

The following subsections present a brief description of the ATE selection process performed for ITM Project 82. More detailed descriptions are presented in Sections 9 and 11 of this document.

8.3.1 ATE Requirements Development

Automated test equipment (ATE) utilized by FM & TS in the testing of card and device assemblies is performed by six multi-bay consoles, consisting of control and interface electronics, directed by an integral central processor executing stored programs specifically directed at functionally exercising the designated electronic assembly.

Programs utilized by the ATE consoles are stored in a centralized, computer controlled facility known as "ATE Central", which is linked to each tester over a communications buss. The appropriate program for the unit under test (UUT) is automatically accessed when the operator connects the test adapter to the station and initiates the test. The adapter contains coded information identifying the UUT which is interrogated by the station. Programs are then downloaded and executed at the respective console.

This equipment consists of a design now nearly 20 years old and has limitations in both application scope and capability which restricts testing to assemblies primarily analog in nature (digital card testing in FM & TS is performed on a tester configured for that purpose).

To provide future capabilities in FM & TS, as well as support existing applications where appropriate, the availability of suitable equipment was reviewed. This information was compared to the specifications detailing the Honeywell ATE performance characteristics to ascertain functional compatibility with existing equipment. In addition, Test Engineers in the FM & TS Production Engineering Department were consulted in an attempt to establish additional station requirements that would be necessary to test future designs.

A general specification was developed as a result of this process and is presented in Section 9 of this document.

8.3.2 ATE Vendor Survey and Selection

Among the vendors supplying Automated Test Equipment to the electronics industry, fourteen provided equipment specifications for review. A summary of the ATE manufacturers' survey is presented in Figure 8.3.2-1.

A comparison between the general specification described in Section 8.3.1 and published specifications for the surveyed equipment was performed and tabulated in an ATE Requirements Matrix. This assessment provided the basis for determining the appropriate course in future ATE selection. The list of ATE equipment manufacturers was then trimmed down to those which could meet the criteria set forth in the general specification. The list of likely equipment suppliers now included:

- ADATE 15XX Test System
- CompuGen ATS Series
- Digalog 2020 Series
- GenRad 2750
- HP 3065 AT
- Summation SigmaSeries
- Teradyne 210i

Manufacturer	Series	I/F	Type	Programming Language
ATE Systems Intl	Beaver	EC/BON	Functional	ATE Sys Internal
Compu Gen	Sleuth	EC/BON	Functional/ICT	Pascal
Computer Automation	Ironman	EC/BON	Functional	MAJICPLUS
Computest	8500	BON	Functional/ICT	MDG (MS-DOS)
Digalog	2020	EC	Functional	BASIC09 (UNIX)
Fluke	3050B	EC	Functional/Compare	TMS (ATLAS/Analog)
Gen Rad	227X	BON	Functional/ICT	CAPS
Hewlett-Packard	3065 AT	EC/BON	Functional/ICT	VCL/HP-BASIC
Marconi	Checkmate	EC	Functional/ICT	Pascal Based
Summation	Sigma Series	EC	Functional	Testwindows/TestBASIC
Talon	100	EC	Functional	BASIC
Teradyne	L210i	EC/BON	Functional/ICT	Pascal Based
Watkins Johnson	15XX	EC	Functional	COLT (UNIX)
Zehntel	800 Series	BON	ICT	Producer (UNIX)

Notes: I/F = Interface with UUT.
EC = Edge Connector
BON = Bed of Nails

Figure 8.3.2-1 ATE Manufacturer's Survey

Since FM & TS future requirements can consist of both the technology employed as it is at present as well as more complex designs, ATE selection was then narrowed to equipment which had flexibility through instrument configuration and programming integrating multiple types of functions (analog, digital, and hybrid) but not requiring a large initial investment. The systems exhibiting the ability to build around a lower cost system core included:

- CompuGen
- Digalog
- Summation

Cost effectiveness was a key consideration. A newer generation of equipment is emerging which integrates innovative programming techniques with a hardware approach that significantly lowers total costs. This equipment combines integral instrumentation (for common functions) with the traditional "rack and stack" approach, coupled with menu-driven programming to achieve both low cost and versatility. This overall combination of software and hardware, coupled with low costs, is presently available through one vendor, Summation, although there are indications that others are migrating toward this approach.

This entire vendor survey and selection process is presented in greater detail in Section 11 of this document. Included is a brief description of each of the ATE systems considered as well as a detailed description of the Summation SigmaSeries test system which was selected.

It should be pointed out that several ATE equipment vendors are still in the process of evaluating their equipment's responsiveness to the general specification developed by the project team. In addition, the ATE industry in general is at present experiencing much technological growth, presenting new and innovative testing techniques and hardware almost monthly. As a result, FM & TS Production Engineering is continually monitoring these developments for testing approaches which more closely fit future needs. This is an on-going process and if more appropriate equipment emerges prior to implementation, it will likewise be considered for purchase rather than the Summation system presently identified.

8.4 Additional "To-Be" Automated Test Equipment (Fluke 3050B)

Since the Honeywell ATE has limited digital card testing capabilities, FM & TS began digital card program development and testing on a Fluke Functional Test System in 1979. This tester was acquired by the Commercial Avionics Division and has been available to FM & TS on an off-shift basis for shared use testing of digital cards since that time. However, as the Commercial Avionics Division completes their move to a new facility, this tester will become unavailable.

Therefore, in order to maintain the present test capability and provide for improved test capability in the future, it is proposed that for the "To-Be" operation FM & TS purchase a dedicated Fluke 3050B for digital card testing. Other digital testers were considered, however the considerable investment in test software and card test adapters would have to be duplicated if any other tester were purchased with little or no additional capabilities gained. The acquisition of a Fluke 3050B tester will allow for the continued testing of products whose tests were originally developed on the Commercial Avionics Division's tester and assure that testing of the more complex digital designs of the future will be possible.

Additionally, a dedicated tester belonging to and controlled by FM & TS will provide efficiencies in scheduling which will promote more flow through testing of cards and devices. In the present situation, testing of FM & TS cards is limited to second or third shift operations and priority scheduling is given to the Commercial Division cards. In the "To-Be" operation, with control over a tester belonging to the department, the card test group leader will be able to optimize the schedule of test on the FM & TS equipment. Additionally it will allow the flexibility to alter the schedule when special situations arise (such as unexpected E.O. incorporation) in order to meet shipment deadlines.

8.5 Oven Monitor Network

As part of acceptance testing of devices for the various programs currently in production in FM & TS, temperature cycling is required to verify performance under varying environmental conditions.

The ovens used to perform this testing are manufactured by Thermotron. Depending upon their acquisition date, the oven controllers range from paper tape-sequencer to microprocessor controlled units. The ovens have integral charting recorders to indicate program sequence and to log temperature data as part of the historical records accompanying each device.

As the ovens are loaded with a device for a new run, a new chart is mounted and the cycle is initiated. Progress is periodically monitored to determine if device function is correct as well as oven performance. This is essentially a manual operation requiring the physical monitoring of each individual oven.

The Tech Mod project team, in reviewing this operation, determined that the ovens themselves are in good working condition and does not recommend replacement of any of them at this time. However, a remote monitoring system would allow a group leader to maintain constant awareness of system progress and oven performance.

The ovens that have paper tape-sequencers will require that a separate microprocessor-based controller be retrofitted into each oven in place of the existing control panel. This allows the function of each oven to be monitored from a central point via an RS-232 interconnection.

The monitoring system (shown in Figure 8.5-1) will allow the automatic maintenance of environmental records for each device being tested. Consequently, once a device is started into burn-in, unless the device test parameters are altered, all environmental monitoring can be conducted remotely. It is intended to have the ovens grouped together in an environmentally isolated structure located at one end of the FM & TS area (shown in Figure 8.5-2).

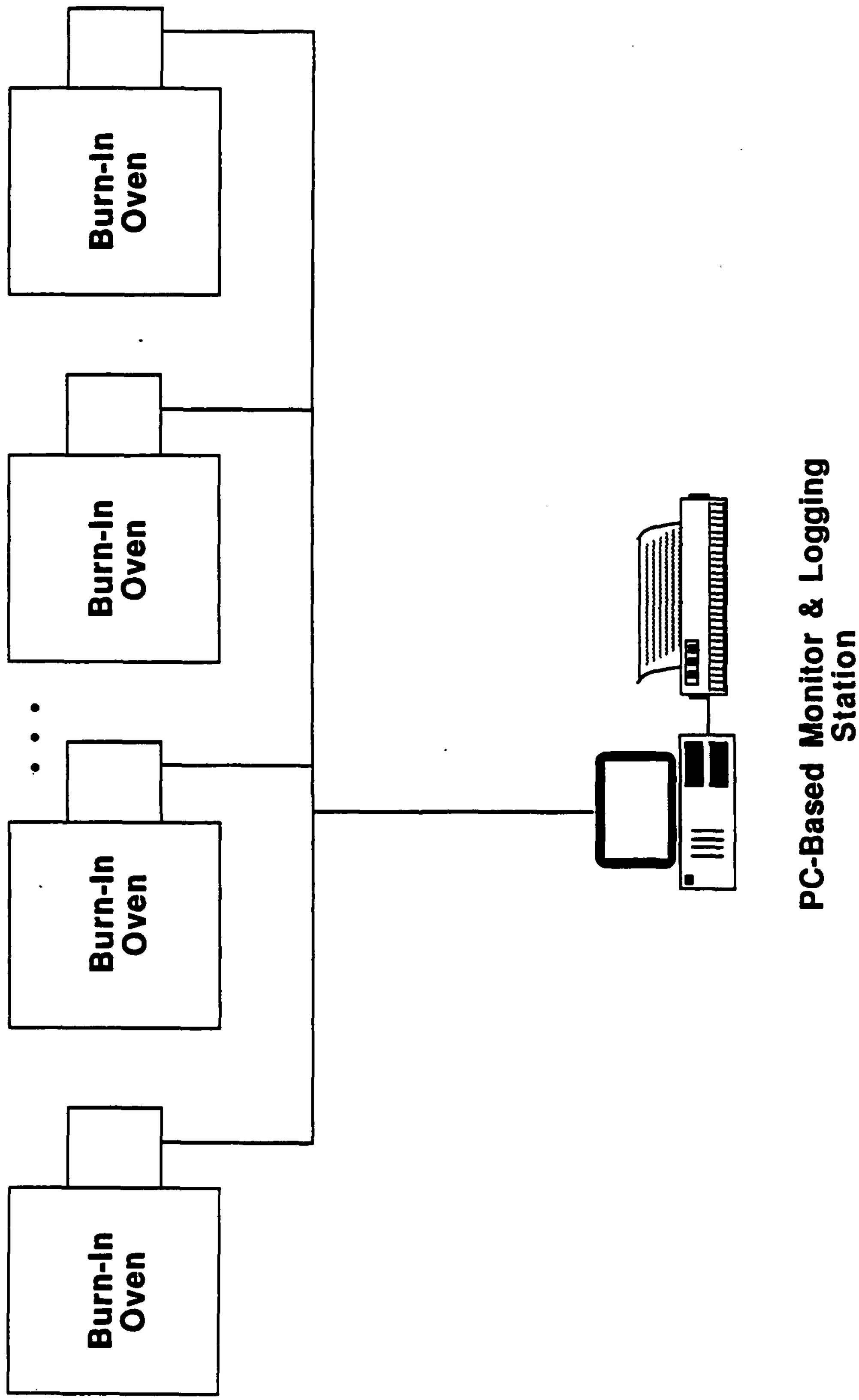

Figure 8.5-1 Oven Monitor Network

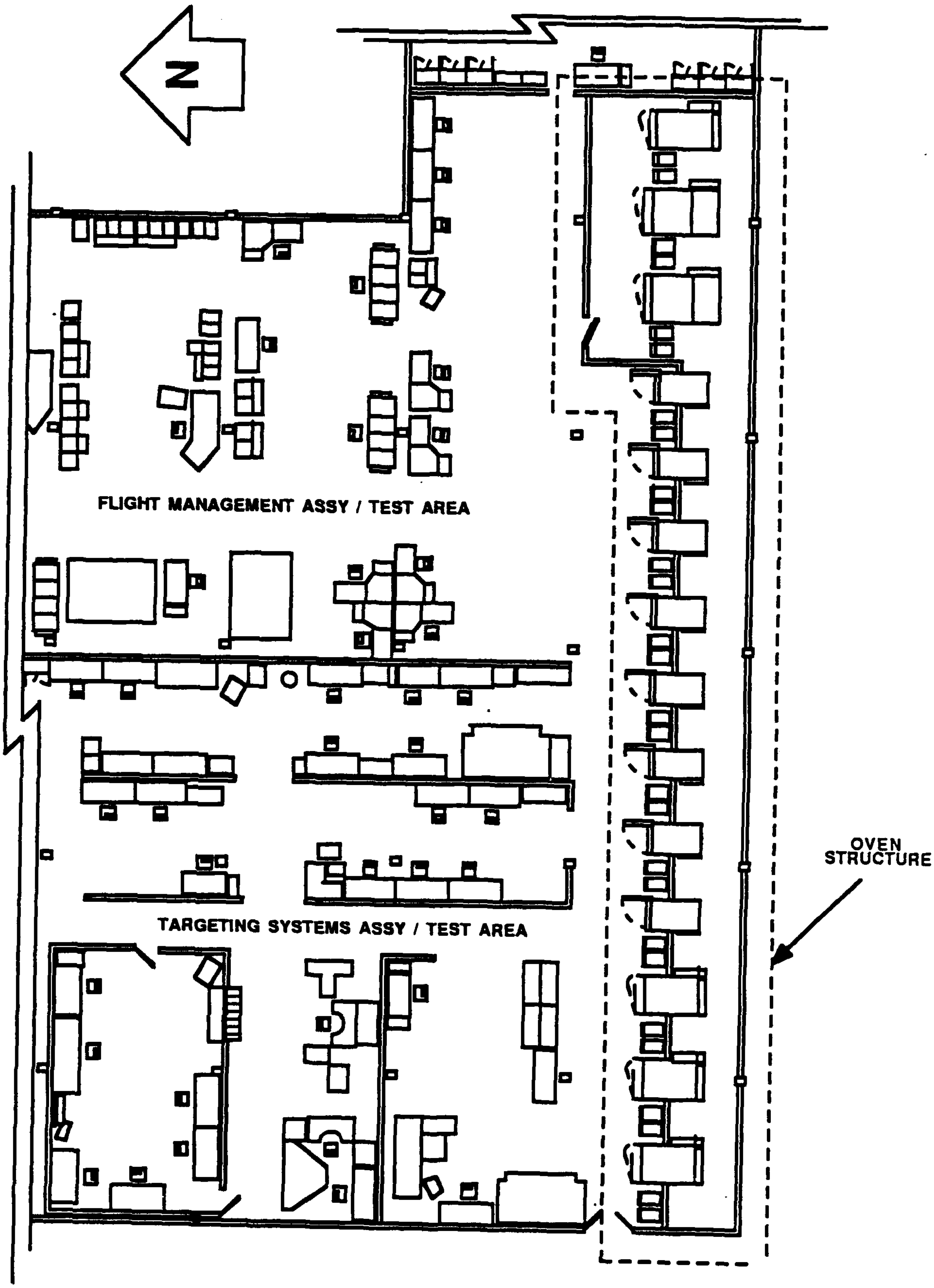

Figure 8.5-2 "To-Be" FM & TS Oven Isolation Structure

SECTION 9

SYSTEM/EQUIPMENT/MACHINING SPECIFICATIONS

The following sections present the detailed specifications that were developed as a result of the analysis and design performed for two areas within Honeywell's FM & TS operations under ITM Project 82. The system and equipment specifications are provided for test equipment as well as burn-in operations upgrading.

9.1 Assembly Test Station (ATE) Specification

This specification defines the minimum requirements for an ATE station intended to be used for the testing of various sub-assemblies including Printed Wiring Assemblies, Power Supplies, and other electronic assemblies. The station will be used for the functional testing via card edge connectors of these assemblies which may be analog, digital and hybrid (analog and digital mixed) in nature. The specification is presented in four sections:

1) General Station Specification describing the overall requirements of the station,

2) Instrumentation List listing the stimulus, switching, and measurement equipment necessary for the station to perform its intended task,

3) Instrument Specifications describing the intended purpose and the minimum requirements of each of the instruments listed in section 2), and

4) Additional Requirements/Options describing requirements and desirable options not covered elsewhere.

9.1.1 General Station Specification

It is intended that the ATE station be modular in nature in that it should consist of an overall system controller, a test system with plug-in instruments, and other additional instruments as necessary. The station input power shall be 115 VAC, 60 Hz.

System Controller

The system controller will be used as the overall controller and programming station. This could be an IBM-PC or compatible computer with monitor and keyboard. The controller will download a test program to the test system, accumulate test results, and print test results through a standard printer interface under program control. The controller should also have provisions for networking to other testers of the same type in the future through a VAX or other standard networking system.

Test System

The test system should contain its own processor to control the test according to the program downloaded from the system controller. The processor must control all test instruments in the station. As many of the instruments as possible should be contained on currently available plug-in cards/modules. Control of these instruments should be accomplished through an internal bus to maximize speed and accuracy. An internal bus system which allows the various instruments to communicate directly with one another to synchronize activities (i.e. an event complete signal from one instrument could trigger a voltage measurement by a Digital Multimeter) is also necessary. The test system must contain power supplies to support all of the plug-in cards/modules within its chassis.

The test system must be capable of providing power, grounds, and stimulus signals to the unit under test (UUT) through appropriate switches or other means under program control. UUT responses must be routed to the proper instruments and measurements made as required. The results must be compared against test limits and the data accumulated and sent to the system controller. A Zero Insertion Force (ZIF) connection system must be provided which routes power, grounds, inputs, and output measurement connections from the station instruments to standard connectors in the UUT interface panel. (A unique test adapter will provide the interface between the UUT and the ZIF connectors.)

Additional required features include a bar-code reader input, a minimum of (5) soft programmable operator interface keys, a footswitch wired in parallel with one of the soft programmable operator interface keys, and a minimum 80-character display under program control for operator instructions.

Other Instruments

All instruments necessary for the makeup of the system which are not available as plug-in cards/modules must be commercially available and fully controllable by the test system processor through a standard IEEE 488 bus. All interconnecting cabling between the test system and these external instruments must be provided. Input power for all external instruments shall be 115 VAC, 60 Hz.

9.1.2 Instrumentation List

The following is a list of all of the instrumentation required to meet the specification:

Qty	Instrument
6	DC Power Supplies
1	115 VAC, 400 Hz Power Supply
4	DC/AC Signal Sources
1	Function Generator
1	Pulse Generator
1	Digital Multimeter
1	Sample & Hold Module
1	Timer/Counter
2	Programmable Threshold Detectors
1	Time Delay Generator
60	General Purpose Switch/Relays
20	Signal Routing Switch/Relays
12	High Frequency Signal Routing Switches
64	Digital I/O Channels

9.1.3 Instrument Specifications

The instrument specifications are intended to define the minimum capabilities of the test system. Actual detailed specifications of instruments proposed by the vendor should be included with the description of the proposed system. If there are plug-in cards/modules available which combine two or more of the listed functions and still meet the requirements, the vendor should point out the combinations in the proposed system. The number in parentheses following the name of each instrument indicates the quantity required in the system.

DC Power Supplies (6)

The DC power supplies are intended to be used to provide steady UUT power during functional testing. The outputs shall be made available at the ZIF connectors in the UUT interface panel through switches/relays under station computer control. The voltage output level shall be remotely programmable throughout the output range (i.e. resistance programmable). The power supplies must have the following minimum characteristics:

Voltage Range	0 - 32 VDC
Current Range	0 - 1 Amp.

115 VAC, 400 Hz Supply (1)

The 400 Hz power supply is intended to be used to provide 115 VAC, single phase aircraft power to the UUT and as the primary AC reference. The supply shall also furnish 26 VAC to the UUT. Both outputs shall be made available at the ZIF connectors in the UUT interface panel through switches/relays under station computer control. The 400 Hz supplies shall have the following minimum characteristics:

Output Voltage	115 VAC	26 VAC
Output Current	2 Amp	0.5 Amp
Output Protection	Short Circuit	Short Circuit

DC/AC Signal Sources (4)

The programmable Signal Sources are intended to supply simulated DC or 400 Hz AC signals to the UUT. The signal sources shall be remotely programmable in both polarity and amplitude under station computer control. The DC signal sources could be used as AC sources by making use of an appropriate 400 Hz AC reference unit programmable in phase (0° or 180°). The outputs shall be available at the ZIF connectors in the UUT interface panel through switches/relays under station computer control. The signal sources (both DC and AC) shall have the following minimum characteristics:

Output Value	0 ± 15 volts in 1 mv increments
	0 ± 60 volts in 4 mv increments
Current Rating	0 to 1 A, short circuit protected

Function Generator (1)

The Function Generator is intended to provide simulated signals to the UUT of various forms. The function generator shall be remotely programmable in amplitude, function, frequency, and external trigger and synchronization under station computer control. The output shall be available at the ZIF connectors in the UUT interface panel through switches/relays under station computer control. The function generator shall have the following minimum characteristics when operating into a 50Ω load:

Waveforms	Sine, square, and triangle
Frequency Range	0.01 Hz to 10 MHz
Amplitude Range	5 mv to 10 V peak-to-peak

Pulse Generator (1)

The Pulse Generator is intended to provide simulated pulses to the UUT. The pulse generator output shall be remotely programmable in repetition rate, delay, pulse width, rise/fall time, and amplitude under station computer control. The output shall be available at the ZIF connectors in the UUT interface panel. The pulse generator shall have the following minimum characteristics when operating into a 50Ω load:

Repetition Rate	10 Hz to 10 MHz
Pulse Delay	10 nsec to 10 msec
Pulse Width	20 nsec to 10 msec
Amplitude	0 to ±10 volts
Rise/Fall Time	10 nsec to 70 msec

Digital Multimeter (1)

The Digital Multimeter (DMM) shall provide the means to make DC voltage, true RMS AC voltage, and resistance measurements. The DMM shall be remotely programmable for measurement type, trigger, and range (auto-range or specific range). The DMM shall have the following minimum characteristics:

DC Volts	0 to 500 VDC in (5) ranges and Auto-range

AC Volts	0 to 300 VRMS AC and AC+DC from 20 Hz to 100 KHz in (5) ranges and Auto-range
Resistance	0 to 20 Mohm 2 or 4 wire in (5) ranges and Auto-range
Readout Accuracy	4 1/2 Digit
Protection	500 VDC and 300 VAC for all measure types and ranges

Sample & Hold Module (1)

The Sample & Hold module is intended to be used for making instantaneous voltage measurements on a rapidly changing signal. It is set up in advance of the event to be measured, captures the voltage when triggered, and holds the data until the DMM reads the measurement. The Sample & Hold shall be used in conjunction with the DMM and therefore shall have the same programming requirements and minimum characteristics.

Timer/Counter (1)

The Timer/Counter is intended to be used for making frequency, period, pulse width, and time interval measurements (when used in conjunction with the Programmable Threshold Detectors described below). The Timer/Counter shall have two channels separately programmable for function and range. The instrument shall have the following minimum characteristics:

Frequency(A or B)	100μHz to 100 MHz
Period(A or B)	5 nSec to 25 Sec
Pulse Width(A or B)	5 nSec to 25 Sec
Time Interv.(A to B)	5 nSec to 25 Sec

Programmable Threshold Detectors (2)	The Programmable Threshold Detectors (PTD) are intended to be used to sense a signal excursion through a programmed threshold. The PTD threshold shall be independently programmable in level, range, slope, polarity, and AC or DC coupling. (Note: This function may be incorporated as a part of the Timer/Counter module.) The PTD's shall have the following minimum characteristics:

Trigger Level	0 to ±50 V in 2 ranges
Slope	+ or -
Coupling	AC or DC, programmable

Time Delay Generator (1)	The Time Delay Generator (TDG) is intended to provide an accurate indication of a programmed time delay with a "TDG complete" logic signal output. The TDG shall be programmable for time, range, and trigger. The TDG shall have the following minimum characteristics:

Time Delay	1μSec to 1000 Sec in 5 ranges

General Purpose Switch/Relays (60)	The General Purpose (GP) Switch/Relays are intended to be used for the application of power, grounds, and loads to the UUT as well as the switching of static signals to and from the UUT. The GP Switch/Relays shall be SPDT or DPDT latching type, independently programmable, with all the NO, NC, and Common contacts available at the ZIF connectors in the UUT interface panel. The GP Switch/Relays shall have the following minimum characteristics:

Contact Current	1 Amp (AC or DC) switched
Switched Voltage	200 Volts

Signal Routing Switch/Relays (20)	The Signal Routing Switch/Relays are intended to be used to route most of the signals from the UUT to the measurement instruments for processing. The SR Switch/Relays shall be of the SPDT type such that separate floating point measurements may be made. They must be independently programmable with the Common contacts available at the ZIF connectors in the UUT interface panel and the NO contacts connected to the internal test system bus(s). If the characteristics of the General Purpose Switch/Relays (as proposed by the vendor) described above are also suitable for this purpose the quantities may be combined and a single type of Switch/Relay specified. The SR Switch/Relays shall have the following minimum characteristics:

Contact Current	1 Amp (AC or DC) switched
Switched Voltage	200 Volts

High Frequency Signal Routing Switches (12)	The High Frequency (HF) Signal Routing Switches are intended to be used to route high frequency signals to and from the UUT. The HF Switches shall be independently programmable with the Common contacts available at the ZIF connectors in the UUT interface panel through coaxial connectors and the NO contacts connected to the internal test system bus(s). The HF Signal Routing Switches shall have the following minimum characteristics:

Voltage	100 VAC and 28 VDC
Current	0.5 Amp DC or AC
Bandwidth	50 MHz

Digital I/O Channels (64)	The Digital I/O Channels are intended to input test vectors and record output patterns from the UUT. The I/O channels shall be available at the ZIF connectors in the UUT interface panel with

the signal levels TTL compatible and tri-stateable individually or in a maximum of 8-bit groups under program control. The Digital I/O Channels shall have the following minimum characteristics:

I/O Rate	20 MHz
Data Depth/Channel	8 K

9.1.4 Additional Requirements/Options

The following additional requirements and/or options must be met by the vendor.

Software

The vendor shall describe in as much detail as possible the software requirements of the proposed system. It is mandatory that the programming language be of sufficiently high order and user friendly so as to avoid the necessity of programming in machine code, instrument specific ASCII strings, etc. The use of menus or similar programming aids in which the programmer specifies instrument parameters is desirable.

It is also desirable to be able to generate test programs off-line from the test station. The software system must also be able to support the programming of all the other instruments which are not internal to the tester and operate on the IEEE 488 bus. It is required that the system provide a hard copy of software programs and text descriptions/comments to document the test setup and procedure. Any programming aids or enhancements as well as any debugging tools which are available with the system should be described. Software training for two should be included as a part of the system cost.

Test Options

The system should provide the operator with a "stop on fail" option which will interrupt the test program execution to allow failure isolation while test conditions are maintained. This could make use of one of the operator interface keys such that, if selected, a failed condition will automatically cause an indication of the failure and interrupt the test. After isolating the failure, the operator should then have the option of continuing the test from that point by operating a push button or foot switch. If the "stop on fail" key is not selected the system should indicate the failure but continue execution of the test program.

Data Logging

During the course of test execution, the system must log all data (test No., test measurement, hi- and lo-limits, and pass/fail condition) to a data file in system memory which may be recalled and printed out at the operators discretion. The data file must be identifiable by part number and serial number of the UUT as well as the date and time of test.

System Calibration

All information, requirements, hardware, etc. which is necessary to maintain the calibration of the modules and instruments in the system by the customer must be included.

Other Options

Options available for the system (such as extended warranties, software services, hardware options, etc.) should be included.

9.2 Oven Network

The following sections present the specification required for the installation of the oven monitoring network.

9.2.1 Oven Controller

Application:	Thermotron Ovens Retrofit
Range:	-60° to + 160°C
Resolution:	0.1°C
Control:	RS-232C Port/2400 baud
Function:	Local/remote adjustment and monitor, program upload/download
Programming convention:	Modified Basic
Power:	115 VAC/60 Hz

9.2.2 Network Controller

Computer:	PC (or compatible) w/512K RAM, floppy disk
Display:	Monochrome (12")
Interface:	RS-232C (one port per channel) - 2400 baud
Printer:	80 column (min) dot matrix
Program Control:	DOS/Basic

SECTION 10

TOOLING

As a result of the nature of the design and development efforts , there is no unique tooling required for ITM Project 82.

SECTION 11

VENDOR/INDUSTRY ANALYSIS/FINDINGS

The Vendor/Industry Analysis/Findings for ITM Project 82 centered on two areas of improvement, as dictated by the project objectives:

- Automatic Test Equipment (ATE)
- Burn-In Oven Monitoring Network

The following sections describe the vendor search procedure, the equipment selection criteria and the resultant selection made by the project team in the execution of ITM Project 82.

11.1 Automatic Test Equipment (ATE)

This section describes the Vendor/Industry Analysis/Findings for a hybrid (analog/digital) test station to be used in FM & TS primarily for sub-assembly test.

11.1.1 ATE Vendor Survey

Among the vendors supplying Automated Test Equipment to the electronics industry, fourteen provided equipment specifications for review. A summary of the ATE manufacturers' survey is presented in Figure 11.1.1-1. A brief description of each of these ATE systems is provided in the following paragraphs.

ATE Systems International

Beaver, from ATE Systems International, is a low cost functional tester that can test a wide range of digital, analog, and mixed boards. Beaver has built-in analog and digital test facilities plus the ability to control external instruments. These can be mixed together freely on boards which require an analog input to give a digital output or vice versa.

Beaver programming is performed via an ATE System International-specific programming language which is menu driven.

The current cost for the Beaver system includes basic digital capabilities and programming support for IEEE 488 instrument add-ons.

Compu Gen

The Sleuth ATE Analog/Digital Test System, from Compu Gen, is a general purpose analog/digital functional and in-circuit test system. The system

Manufacturer	Series	I/F	Type	Programming Language
ATE Systems Intl	Beaver	EC/BON	Functional	ATE Sys Internal
Compu Gen	Sleuth	EC/BON	Functional/ICT	Pascal
Computer Automation	Ironman	EC/BON	Functional	MAJICPLUS
Computest	8500	BON	Functional/ICT	MDG (MS-DOS)
Digalog	2020	EC	Functional	BASIC09 (UNIX)
Fluke	3050B	EC	Functional/Compare	TMS (ATLAS/Analog)
Gen Rad	227X	BON	Functional/ICT	CAPS
Hewlett-Packard	3065 AT	EC/BON	Functional/ICT	VCL/HP-BASIC
Marconi	Checkmate	EC	Functional/ICT	Pascal Based
Summation	Sigma Series	EC	Functional	Testwindows/TestBASIC
Talon	100	EC	Functional	BASIC
Teradyne	L210i	EC/BON	Functional/ICT	Pascal Based
Watkins Johnson	15XX	EC	Functional	COLT (UNIX)
Zehntel	800 Series	BON	ICT	Producer (UNIX)

Notes: I/F = Interface with UUT.
EC = Edge Connector
BON = Bed of Nails

Figure 11.1.1-1 ATE Manufacturer's Survey

is highly programmable and reconfigurable. Both test programs for the system and the system software are written in the standard Pascal language. Higher cost system instruments have been avoided and measurement functions have been implemented using chip-level or board level modules.

System electronics resides on printed circuit and wire wrapped modules installed in an EXORbus cardrack. EXORbus compatible modules include custom relay multiplexer, relay driver and scaling/instrument-selection modules, custom wire-wrapped modules implementing a number of instrument and stimulus functions, custom interface modules, and D/A and A/D modules. Other components for providing stimulus are mounted outside the EXORbus rack and in the UUT-specific test heads.

The Sleuth ATE system with analog capabilities includes voltage and frequency measuring capabilities along with threshold comparators and a programmable function generator. All instrument drive is programmed via a Pascal derived IEEE language.

Computer Automation

Ironman, from Computer Automation (CA), is a completely integrated test system which is based on a CA concept called "testsharing." With testsharing, all of the elements of the test process - functional testing, test programming, logic simulation, board repair, and manufacturing management - are all designed to work together for optimum efficiency. At the same time, these individual capabilities are modular in design so that only the required elements need be purchased. This may range from a single test station to a complete multi-station system under the control of a central processor.

The Ironman is a functional tester which interfaces with an edge connector and/or bed of nails. The Ironman can be tailored to individual requirements through the selection of up to 1024 pins for digital functional testing at 10MHz test rates. 10MHz pins can be combined with static, 2MHz and 5MHz pins as needed according to the application. A mix of pins with fixed TTL, programmable logic levels, and analog pins are available. The system is also capable of external clock synchronization of up to 40MHz. Behind each of the high rate pins a 16K x 4 RAM allows the storage of large test programs.

The programming for the Ironman is performed using a language developed by Computer Automation called MAJIC PLUS. This language uses English-like statements which allow test engineers to describe test programs functionally. Logic simulation options as well as non-simulation option programming is also available.

This system is principally a digital tester with "add-on" analog capabilities.

Computest

The 8500 Performance Board Tester, from Computest, is a comprehensive functional/in-circuit test center with the principal features necessary to cause a digital or hybrid circuit card to perform at rated specifications for go/no-go testing and provides full automatic guided probe fault isolation for defective digital boards. A wide range of diagnostic tools are available for fault isolation including signature analysis, voltage, frequency, current probe, and others.

The operating system for the 8500 is an IBM PC/AT compatible MS-DOS operating system which allows any MS-DOS compatible computer to become a programming workstation. Test program generation is performed using MDG for writing functional tests in a matter of days which can be verified off-line using a simulator provided with the system.

The 8500 Performance Board Tester includes a digital bed-of-nails tester with 256 driver/receivers in addition to an instrumentation section with voltage, frequency, pulse catching, and signature analysis.

Digalog

The Digalog 2020 ATE system, manufactured by Digalog Systems Inc., combines digital and analog test to form a functional performance test system to handle complex VLSI board designs as well as sophisticated analog circuitry.

The digital test system uses dynamic bus emulation techniques for real-time testing of bus structured LSI/VLSI printed circuit board assemblies. The digital module can be configured to emulate microprocessor bus structures that have up to 32 address, 32 data, 16 control, and 8 clock lines. The analog test system is a self contained modular subsystem operated by the Testhead Controller located within the computer system. A library of functional calls, contained within a 32kByte EPROM, actually controls the analog system hardware (e.g., RUN DA[channel, voltage]).

Programming functions include the creation and loading of projects and memory modules, inter-project file copying, deletion of files, comments editing, and acce. ` to Basic09 (Pascal and C are optionally available). File development and handling are managed together to form a user-friendly digital test program development system.

The Digalog 2020 ATE system is available with variations from straight analog testing to a basic hybrid station capable of microprocessor control and emulation.

Fluke

The Fluke 3050B is described in Section 11.2 below and is proposed for implementation in the "To-Be" FM & TS operations for the test of assemblies which are primarily digital in nature.

Gen Rad

The GenRad Model 2750 series is a hybrid test system capable of testing both digital and/or analog circuitry in either functional or in-circuit modes. The system is configured by the addition of driver sensor cards for digital testing and analog function cards to allow measurement of AC and DC voltage, frequency, capacitance, inductance and resistance, internal sources of AC and DC voltage for circuit excitation as well as nine types of integral DC power supplies are configurable. For measurement of functions not handled by the internal instrumentation, an IEEE 488 interface is provided.

GenRad provides a series of high level programming methods including a package called Genesis which operates on an icon-driven user interface. Additionally, packages are available to provide transition for users of GR179X and 227X model testers.

The GenRad 2750 tester is a comprehensive system providing expandability for the user who needs a wide variety of digital capabilities coupled with analog testing.

Hewlett-Packard

The 3065 AT, from Hewlett Packard, is a combination in-circuit and functional tester capable of testing digital and analog circuitry. The system provides hybrid testing capabilities with on-board stimulus sources providing AC and DC voltage and current as well as sine, sequence, and triangle wave output. Analog detectors permit measurement of AC and DC voltage, resistance, frequency, and pulse width. The system can internally control up to eight programmable DC power sources and externally any IEEE 488 compatible device can be connected. Since the system is a rack-mount configuration, instruments can easily be physically located within the tester enclosure.

A large variety of software is available for the 3065 to provide both test programming capabilities in addition to networking and information systems support for quality and management data processing. Internally, test programs are developed using a BASIC-derived language in conjunction with both in-circuit and functional program generators. Several aids are available for automatically generating digital code via simulator and graphically displaying test results. Interfaces are available for input of testing patterns via computer aided engineering links. Testing software can also be assisted through integral signature analysis routines.

Marconi

Checkmate, manufactured by Marconi, is a comprehensive, low cost bench top configuration of Automatic Test Equipment. The range of functions provided is configurable by plug-in cards covering analog and digital testing, using in-circuit and functional test techniques together with logic and waveform analysis. Up to 21 cards are accommodated in one frame and can be used individually or in any combination.

The operating system for the Checkmate ATE is based on CP/M. All the facilities for each instrument card are contained in on-board firmware and are managed by an on-board microprocessor. Each instrument card downloads its own unique profile to Checkmate's operating system and provides the programmer with a menu of available facilities. This has the advantage that each instrument is under the control of its own processor, thus reducing the overhead on the main system processor and increasing the test execution speed.

The Checkmate system includes a basic digital capability which is the primary system feature along with analog instruments and an IEEE interface.

Summation

The Sigma Series Test System, from Summation, is a complex digital and analog functional tester. The system includes a MC68000-based modular test station and an IBM PC computer, in addition to the proprietary TestWindows software.

The high speed digital test system consists of function modules which plug into the Sigma Series TestFrame and a special software package that runs within TestWindows on the IBM AT. The TestFrame's MC68000 processor communicates with the IBM AT over the IEEE 488 bus and controls the test system. Other buses within the TestFrame provide inter-module triggering and analog signal switching capability. The TestFrame and all modules are at a single address on the IEEE 488 bus which operates at DMA rates up to 300 Kbyte/second.

Analog measurement and stimulus modules like waveform recorders, counter-timers, and function generators can be used right along-side the high speed digital test modules. The system's bus structure allows triggering between these modules. Static digital I/O modules and a variety of switching modules can be added if needed. Up to 23 instrument modules can be integrated into one compact test system.

Summation's TestWindows development system and TestBASIC language provide fast program development, debugging, and documentation for IEEE 488 instrument control applications. This is a menu-driven, very user friendly system which uses a "mouse" interface and highly sophisticated windowing software.

Talon

The Model 100, manufactured by Talon, is a compact, general purpose functional tester. The system contains twelve 16-channel "instruments", cross-triggered by any of four timing generators or controllers. The Model 100 may be used with other ATE instrumentation either via a host computer or through a Local IEEE Control Interface option which allows the Model 100 to directly control IEEE 488 compatible auxiliary instruments such as programmable power supplies, multimeters, etc.

The Model 100 has an on-line BASIC-like interpreter. The entire instruction set appears in pop-up windows to guide the user through each instruction entry. The resulting instruction is displayed on the CRT and is directly executed when commanded.

The Model 100 system includes the basic digital system of 192 I/O drivers with an IEEE 488 interface and software. Analog instrumentation and integration would be the responsibility of the user.

Teradyne

The L210i, manufactured by Teradyne, is an advanced, integrated in-circuit and functional test system which can achieve high fault coverage on VLSI boards. Internally, the L210i is organized around three major functional groups: the computer group, the digital subsystem, and the analog subsystem.

Within the computer group, a DEC PDP-11 serves as the supervisory processor. This communicates with the digital and analog subsystems where dedicated processors execute analog and digital instructions. The digital subsystem includes the Digital Command Processor, dynamic test controllers, digital channel cards, and system diagnostic tools. The analog subsystem, controlled by an Analog Instrumentation Processor, accommodates a wide variety of analog instruments and programmable power supplies. Analog instruments are switched over a Kelvin matrix to the board under test.

Test program generation is performed using a Pascal based language. This structured language makes it possible for programmers who may have different areas of expertise to work in parallel, developing distinct program segments separately, and finally merging them for efficient production test execution.

The fully configured L210i test systems provide extensive digital and analog hardware capabilities as part of the basic system configuration.

Watkins Johnson

The Automatic Dynamic Assembly Test Equipment (ADATE) Model 15XX, manufactured by Watkins Johnson, is a fully integrated analog and digital functional test system series configured to customer specifications.

The 15XX series follows a rack-and-stack approach around a core instrument module. The basic system controller utilizes a 68010 microprocessor with several RS-232 ports and a high-speed IEEE 488 instrumentation port. All equipment is contained in a multiple high-bay rack mounted console along with power, system, and operator control functions. As is typical with integrated multi-instrument systems, an interface assembly provides signal switching and interconnection between units undergoing test and the system.

Test sets are produced using a Watkins Johnson developed software system known as Conversational On-Line Translator (COLT) II. COLT II is a high-level test language which runs under the UNIX operating system. This permits system linking for multi-tasking and multi-user in the appropriate system and data management environment. IEEE instrument programming is accomplished via a "shorthand" notation which generates the detail instrument control coding sequence. Generally, programming is straightforward and sufficiently flexible to allow the integration of instruments, etc. in a comprehensive test program. In addition, test results can be stored and consolidated for various production, quality, and management reports.

An ADATE 15XX test system configured similarly to the Honeywell ATE includes the basic system and software plus the necessary "rack-and-stack" commercial type instrumentation and system integration to perform analog testing.

Zehntel

Zehntel testers are primarily in-circuit systems employing bed-of-nails interfacing as a means of routing signals to and from the circuit card under test. The equipment is based on an integral 68000 microprocessor CPU utilizing a UNIX-based operating system. The system allows a high degree of connectivity and networking between systems and a principal database.

Digital testing is primarily accomplished by a truth table exercise of various on-board devices. Analog testing with the integral instrumentation package is directed principally toward component verification via "guarded" measurement techniques. Multiple stimulus sources and special signal measurement functions such as waveform analysis is carried out by external instruments on an IEEE 488 bus controlled by the test system.

11.1.2 ATE Selection

The information provided by the ATE vendors was compared to the specifications detailing the Honeywell ATE performance characteristics to ascertain functional compatibility with existing equipment. This was done to assure that the specified equipment could perform tests on existing devices in the event Honeywell equipment was no longer available. In addition, Test Engineers in the FM & TS Production Engineering Department were consulted in an attempt to establish additional station requirements that would be necessary to test future designs. A general specification was developed as a result of this process and is presented in Section 9 of this document.

A comparison between the general specification and published specifications for the surveyed equipment was performed and tabulated in the ATE Requirements Matrix presented in Figure 11.1.2-1. This assessment provided the basis for determining the appropriate course in future ATE selection. The systems described in Section 11.1.1 which could meet these criteria included:

- ADATE 15XX Test System
- Compu Gen ATS Series
- Digalog 2020 Series
- GenRad 2750
- HP 3065 AT
- Summation SigmaSeries
- Teradyne L210i

Since FM & TS future requirements can consist of both the technology employed as it is at present as well as more complex designs employing fiber optics, high speed digital, etc, ATE selection was narrowed to equipment which had flexibility through instrument configuration and programming integrating multiple types of functions (analog, digital, and hybrid) but not requiring a large initial investment. The systems described in Section 11.1.1 and exhibiting the ability to build around a lower cost system core included:

- Compu Gen
- Digalog
- Summation

Current ATE Requirements Matrix

Manufacturer	Series	AC/DC Sig Gen	Func Gen	Pulse Gen	Prog DC PS	28 VDC	115 VAC 400Hz 10Supply	115 VAC 400Hz 30Supply	26 VAC 400 HZ Supply	DVM	Count Timer
ATE Systems Intl	Beaver	-	-	-	-	-	-	-	-	-	-
Compu Gen	Sleuth	I	X	I	A	A	A	A	A	X	X
Computer Automation	Ironman	I	I	I	I	A	A	A	A	I	I
Computest	8500	I	I	I	I	A	A	A	A	X	X
Digalog	2020	X	X	X	A	A	A	A	A	X	X
Fluke	3050B	A	A	A	-	A	-	-	-	A	A
Gen Rad	227X	A	A	A	A	A	A	A	A	X	X
Hewlett-Packard	3065 AT	I	I	I	I	A	A	A	A	X	X
Marconi	Checkmate	X	X	X	X	A	A	A	A	X	X
Summation	Sigma Series	I	X	I	I	A	A	A	A	X	X
Talon	100	-	-	-	-	A	A	A	A	-	-
Teradyne	L210i	X	X	I	I	A	A	A	A	X	X
Watkins Johnson	15XX	A	A	A	A	A	A	A	A	A	A
Zehntel	800 Series	X	X	X	X	A	A	A	A	X	X

Notes: X = Built-In Function
I = Available Via IEEE Interface
A = Add On

Figure 11.1.2-1 Current ATE Requirements Matrix

Current ATE Requirements Matrix

Manufacturer	Series	Time Freq Digt	Prog Thresh Det	Time Delay Gen	Sample & Hold	AC/DC Conv	G/P Relays	Crossbar Test Points	Digital Output	Digital Input
ATE Systems Intl	Beaver	-	-	-	-	-	-	Custom	192	192
Compu Gen	Sleuth	I	I	I	X	I	A	160	992	992
Computer Automation	Ironman	I	I	I	I	I	A	512	1024	1024
Computest	8500	-	-	-	-	-	-		256	256
Digalog	2020	I	I	I	I	I	A	192	1056	1056
Fluke	3050B	-	-	-	-	-	-	-	240	240
Gen Rad	227X	I	I	I	X	I	X	1024	1764	1764
Hewlett-Packard	3065 AT	I	I	I	I	I	A	1320	1320	1320
Marconi	Checkmate	I	I	I	I	I	-	900	320	320
Summation	Sigma Series	I	I	I	I	I	A	720	384	384
Talon	100	-	-	-	-	-	X	-	192	192
Teradyne	L210i	I	I	I	I	I	X	576	3000	3000
Watkins Johnson	15XX	A	A	A	A	A	A	Optional	Optional	Optional
Zehntel	800 Series	I	I	I	I	X	X	1024	1024	1024

Notes: X = Built-In Function
I = Available Via IEEE Interface
A = Add On

Figure 11.1.2-1 Current ATE Requirements Matrix (Cont.)

Cost effectiveness was a key consideration. Generally, ATE units with a high degree of flexibility carry significant costs, generally in hardware. However, a newer generation of equipment is emerging which integrates innovative programming techniques with a hardware approach that significantly lowers total costs.

This equipment combines integral instrumentation (for common functions) with the traditional "rack and stack" approach, coupled with menu-driven programming to achieve both low cost and versatility. The hardware extensions to the basic tester are accomplished through the use of the commonly accepted IEEE 488 buss convention allowing the use of virtually any instrument produced at present.

This overall combination of software and hardware, coupled with low costs, is presently available through one vendor, Summation, although there are indications that others are migrating toward this approach.

Typically, the Honeywell ATE configuration can be implemented in the Summation product line for far below estimated replacement costs and significantly less than other ATE manufacturer's equipment for equivalent functions. Additionally, there is no equipment presently in the marketplace employing the comprehensive programming approach found in Summation equipment which is as inexpensive and detailed.

Since programming can result in costs an order of magnitude higher than initial equipment costs, the approach which affects this expenditure area significantly reduces overall cost of ownership. The need to maintain existing test capabilities on higher volume spares could necessitate programming these devices on the replacement ATE system in the future. As indicated, this capability can be economically incorporated into the equipment acquisition.

The following section presents a detailed description of the Summation SigmaSeries test system.

11.1.3 Summation SigmaSeries Test System Description

Summation's SigmaSeries™ Test System family fulfills the major requirements of the Computer Integrated Test (CIT) systems needed in today's manufacturing environments with:

- Complex analog and digital testing
- Simple straightforward operation
- Powerful software development tools
- Rapid test system reconfiguration

- Fast data feedback through networks
- Data reduction and statistical analysis
- Networking capability
- Management information system gateways

The system includes the MC68000-based modular TestStation™, proprietary TestWindows™ software, and an IBM computer.

11.1.3.1 Summation Approach

Summation has a unique approach to ATE configuration and test development. Traditionally, final test systems were built from discrete instruments designed for engineering applications. These systems were custom built and programmed from instrument controllers via the IEEE 488 standard interface bus.

The SigmaSeries is the first testing system designed specifically for final test. It provides comprehensive testing benefits which include:

- Dramatically reduced development time
- Automated program documentation
- Combined analog/digital capability
- Combined integrated triggering and switching
- High speed communication
- Simplified data recording
- Straightforward operator interface

The SigmaSeries dramatically reduces the time and effort required to design, program, debug, and install a final test system. The modular TestStation contains all measurement, stimulus, and switching hardware. Therefore, test system design only requires function selection. TestWindows reduce programming time as much as 80% through innovative graphical techniques. Once the test procedure has been written, special TestBASIC™ features allow rapid revision and correction. Finally, the compact packaging (7-inch, rack mountable) and centralized fixturing mean quick implementation on the factory floor.

Test solutions are quickly documented. TestBASIC helps structure test procedure design for automated documentation. On command, the system prints clear, concise switching and triggering diagrams.

The SigmaSeries includes both analog and digital test. Each test station can be configured with up to twelve functions. Five analog, four digital, and three switching functions are currently available and new capabilities are planned. The basic structure of the SigmaSeries integrated test station is shown in Figure 11.1.3.1-1. As can be seen in this diagram, in addition to the cross triggering of modules in the test box, the SigmaSeries can even accommodate other manufacturer's instruments which contain IEEE 488 standard interfaces.

The SigmaSeries substantially eliminates ground loops and noise through proprietary CrossTrigger™ and TestPath™ signal buses integrated into the modular TestStation.

11.1.3.2 Shop Floor System Design

The SigmaSeries has features and functions which make it practical for the FM & TS manufacturing environment. These include:

- Versatile, reconfigurable hardware
- Clear display and audible signal
- Simple operator interface
- Reduced cabling and fixturing
- Compact, rugged design
- 100% reliability tested

The modular TestStation hardware is attractive for many difficult testing tasks. Final, sub-assembly, and design-environmental test are ideal applications. The system is completely reconfigurable: the operator can change test routines, system configuration, and data output options at the touch of a button. Therefore, one SigmaSeries system can perform multiple roles in the same location.

The SigmaSeries provides flexible options to prompt the operator. Messages can appear on the IBM computer monitor, the TestStation 80-character display, or they can be heard from the audible beeper. The IBM monitor serves best for complicated prompts, such as graphical representations or waveform displays. The simpler TestStation display is ideal for GO/NO-GO or other less complex testing. Also, whenever it would be inefficient for the

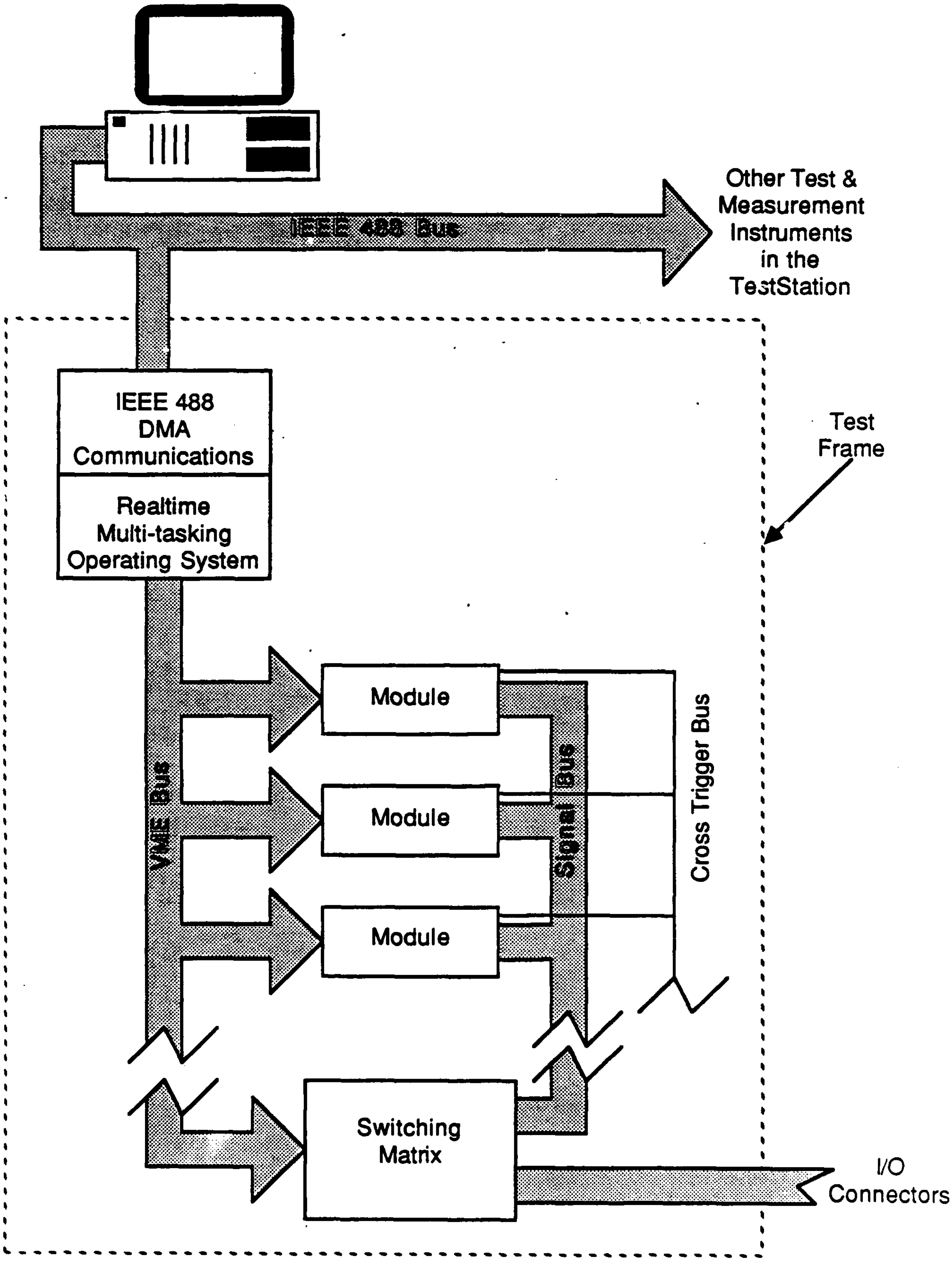

Figure 11.1.3.1-1 SigmaSeries Test Module Interfaces

operator to look away from the Unit Under Test, the audio annunciator provides the feedback.

The operator can respond to prompts in two ways: the TestStation keys or a footswitch. Seven keys on the TestStation (all soft programmable) allow the operator to change tests or configuration, select options, or halt testing. The footswitch is especially useful for incrementing to the next test step after making an adjustment or connection which requires the use of hands. In either case, fewer keys reduce operator confusion and errors.

The TestStation design minimizes the number of system cables and fixtures. The internal CrossTrigger and TestPath buses eliminate most intra-system connections while single-location patching precludes many additional UUT connectors.

The compact, rugged design of the SigmaSeries offers convenient options for test bench construction. The IBM computer and/or the TestStation can be placed in remote locations (for example, beneath the bench). The computer display is completely optional during test operation. A single, compact SigmaSeries system can free up much needed space by replacing several expensive, dedicated testers. A rack mount industrial computer, manufactured by IBM for Summation, is also available.

11.1.3.3 Data Analysis Capabilities

The SigmaSeries meets the growing demand for reporting of final test results. Its built-in features provide:

Reliable bar code data input. The bar code reader enters failure codes, UUT serial numbers, operator identification, or other important variable information for use under program control.

Strip and full-size printer output. A strip printer output can be attached to UUT's paperwork as a record of failures and aid in troubleshooting. Printing, rather than manually recording the failure, saves valuable test time. The TestStation has both RS-232C serial port and a Centronix-type parallel port to support a wide variety of printers.

Standard data format files. Data Interchange Format (DIF) files allow any one of hundreds of data reduction programs to analyze the data at the bench. Test data can be converted from the SigmaSeries to DIF automatically, and then analyzed using spreadsheets, plot programs, trend analysis programs, or other statistical programs which accept DIF information.

Compatibility with IBM and SigmaNet. Current SigmaSeries systems are completely compatible with the SigmaNet local area network (based on IBM-standard networking hardware and software). Therefore, data can be shared between test systems. Because the SigmaSeries uses a standard IBM computer, the system can utilize IBM-compatible software and hardware.

A conceptual view of the integration of the SigmaSeries test equipment is presented in Figure 11.1.3.3-1. As shown in this diagram, SigmaSeries test stations can be interfaced via network to a centralized program library in a similar manner as currently employed where the Honeywell ATE's are linked to ATE Central.

11.1.3.4 Programming Summation Equipment

Summation's TestWindows development system and TestBASIC language provide fast program development, debugging, and documentation for IEEE 488 instrument control applications. This advanced software system can be used with any IEEE 488 instruments from any vendor.

TestBASIC provides a DOS based PC/AT compatible computer with the same instrument control power as a dedicated instrument controller. TestBASIC also contains many features not found in typical instrument controllers, such as:

- Structured-programming constructs
- IEEE 488 command generator
- True sub-routines, libraries, and functions
- C language routine calls
- Paint and Draw generated graphics calls
- Trace, break, and single step debuggers
- Documentation tools

Simplified Programming Steps

The following steps represent the ease of programming using the SigmaSeries Tester. First, use the TestBASIC editor to outline the program. TestBASIC's highly structured environment and straightforward syntax makes the code highly readable.

The operator then selects the IEEE 488 instruments to perform each test. TestWindows includes a set of instrument windows and others can be added. With multiple windows on the screen, several instruments can be programmed simultaneously.

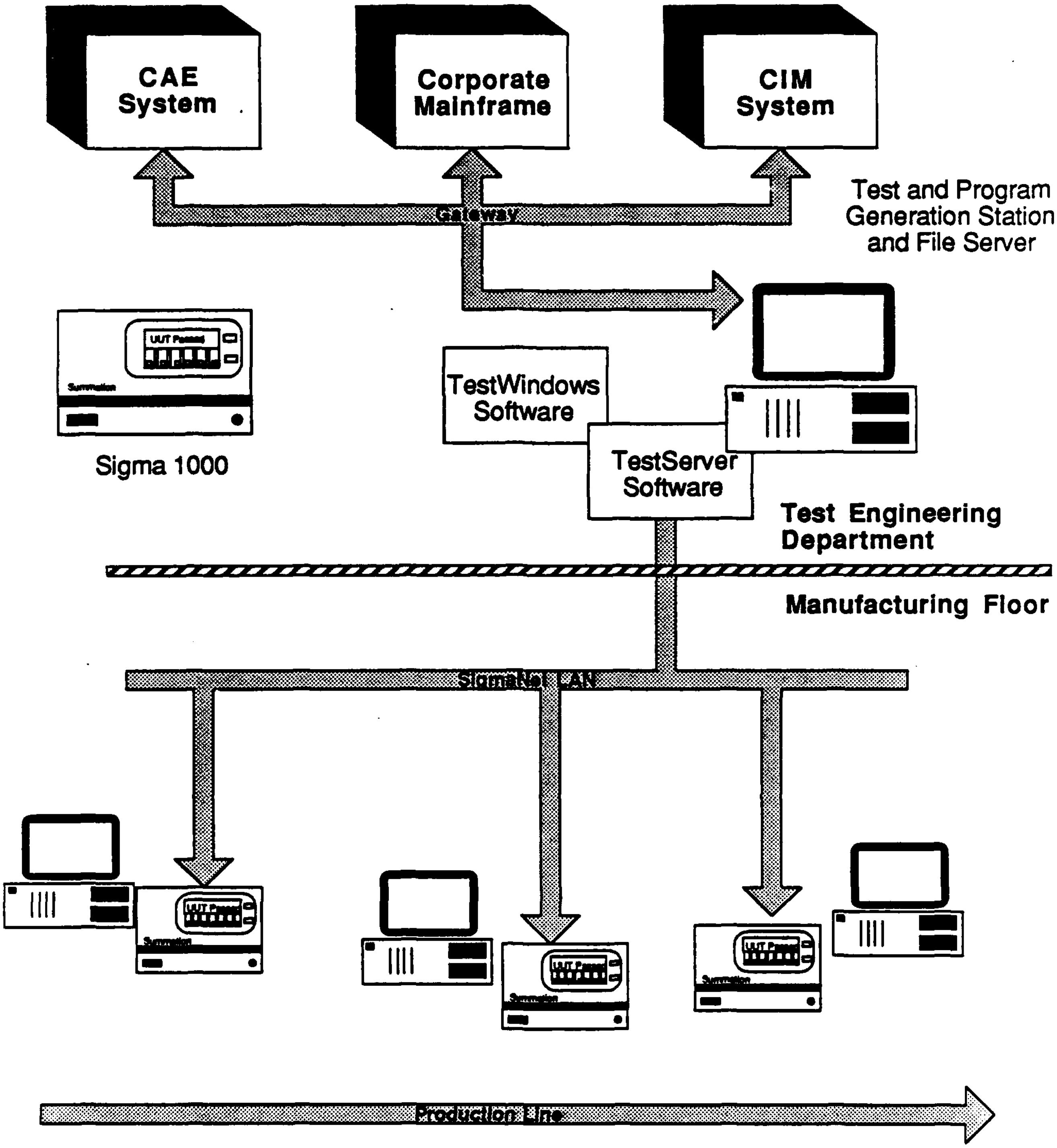

Figure 11.1.3.3-1 SigmaSeries Network Integration

As an aid to writing the program, TestWindows has an Import™ function to generate IEEE 488 code automatically, eliminating the need for manuals or reference cards. TestBASIC code is automatically generated and documented for each instrument set-up. Program variables, IEEE 488 bus traffic, source code execution can be traced using the TestBASIC runtime support feature.

The test program can then be documented and integrated. TestWindows allow for the use of graphics for guided-probe troubleshooting, documentation, and training. Other software packages can be integrated for word processing, spreadsheet analysis, and additional requirements.

TestWindows Automated Programming

TestWindows software provides the simplest user interface available. Function "windows", analogous to instrument front panels, control all displays and test settings. The user can "point and click" with a standard mouse interface to make selections, add functions, or program tests. Total proficiency is achieved in a matter of minutes.

Because of the completely integrated nature of the SigmaSeries TestStation, system configuration is programmable. The test engineer can modify switches, trigger lines, and function settings at the touch of a button.

TestWindows operates either in immediate mode, controlling the TestStation hardware interactively, or in programming mode, utilizing TestBASIC. However, both modes can operate simultaneously for automated program generation or modification. The TestBASIC editor window can be opened and used interactively with the "front panel" device windows. The user can also develop tests without the TestStation: only TestWindows and the IBM computer are required.

Automated function programming eliminates manual and mistakes from test development. After the windowed "front panel" settings are verified, a click on the mouse automatically generates the correct program line and the Import™ function transfers it to the TestBASIC program. Conversely, functions settings in a TestBASIC program can be transferred directly to a "front panel" window for graphic verification of program content.

Extensive built-in "debug" facilities reduce the time to perfect test programs. Trace functions highlight program execution while monitoring the value of a program variable, sub-routine location, and/or IEEE 488 bus activity on the screen. Conditional breaks can continuously test an expression for a true condition. The system can display TestStation hardware conditions at any time, allowing the engineer to check for errors in test set-ups.

TestBASIC solves the structure problems of BASIC programs which often lead to poor documentation and difficult maintenance. TestBASIC includes Autoindexing™ and true sub-routines with local variables and recursive entry.

These features promote top down design and allow automatic documentation. Autoindexing provides a test procedure flow outline in English (even before entering any executable statements). Common sub-routine constructs can be used over and over in different programs.

TestBASIC Development Language

TestBASIC simplifies test programming and includes a screen-oriented Editor Window, Output Window, and a variety of pull-down menus and pop-up windows. The CRT screen can be arranged with all of these interactive windows.

The editor window allows sub-routine, library, and function creation and manipulation. It also supplies cut/copy/paste and search/replace operations under an "Edit" menu. The Output Window contains text and graphics for run-time operator prompts.

Available memory is the only limitation to TestBASIC program size. However, program chaining and libraries allow virtually unlimited length.

TestBASIC incrementally compiles each line of code as it is entered. Thus TestBASIC immediately detects keystroke or syntax errors. TestBASIC creates both an ASCII source version and a binary version of each application program. Only the programmer's PC/AT needs to contain the source code.

TestBASIC is a powerful, complete programming language. Its comprehensive set of statements eliminate the need for specialized and confusing commands. It also allows the use of one BASIC language for all instruments, regardless of vendor.

TestBASIC constructs, such as DO-WHILE, IF-THEN-ELSE-IF, and SELECT-CASE allow Pascal-like structured programming. Labels and line numbers are optional.

Sub-routines provide a reusable format for commonly used software. General purpose routines can be written such as pass/fail tolerances verification, report generation, IEEE 488 service request handling, instrument error handling, timed interrupts, status checking, and instrument initialization.

These routines may be semi-independent sub-routines (CALL), independent library routines (LIBRARY), or dependent branches with returns (GOSUB). The sub-routines and libraries use local variables which are passed by reference. The GLOBAL command allows global variables to be defined for sub-routines.

An option allows programs to be written in "C" and Assembly Language routines and run from the TestBASIC program.

TestWindows Test Development Environment

A set of windows exists for each instrument. These instrument windows eliminate the need to reference instrument IEEE 488 programming manuals. The instrument window represents either a Summation SigmaSeries Test System module or any vendor's IEEE 488 instrument. The SigmaSeries instrument and switching module windows consist of a combination of graphics and English text. Mouse clicks on icons or "pushbuttons" manually control the module. Windows for other vendor's instruments consist of user-defined English set-up commands.

Summation provides windows for the TestBASIC editor, TestBASIC run-time system, DOS files, Summation SigmaSeries function modules, and the IEEE 488 Window Generator. Summation also supplies sample instrument windows for IEEE 488 instruments. The Summation Users' Group maintains a library of windows. With the TestWindows package comes a variety of Microsoft-supplied windows (Paint, Write, and Calculator functions are among those supplied).

The Summation IEEE 488 Window Generator™ provides unprecedented flexibility. Creating a window for an instrument of average complexity requires only a few hours. The process consists of equating each vendor-defined instrument command to an English command of your choice. One English command can be equated to an instrument set-up. The instrument programming manual is needed only during window creation.

11.1.3.5 Debugging and Documentation

Debugging

TestBASIC provides the only interactive , on-line debugging environment for instrumentation control. Advanced tools include:

- Trace Code
- Trace IEEE 488 bus
- Trace Variable(s)
- Trace Uninitialized Variables
- Trace (sub-routine) Stack
- Trace Break Conditions
- Set (unconditional) Breakpoint

- Single Step
- Next Step
- Continue At
- Continue

Trace code scrolls the executing program and highlights the executing line of code. Other windows can be tiled on screen to simultaneously monitor the status of the instruments, to Trace Variable values, and to Trace IEEE 488 bus traffic between the computer and all addresses. This unique interactive nature of Windows quickly isolates the problem area, making it possible to debug without listings.

Documentation

The TestWindows environment decreases documentation time. Ties between Microsoft and Summation Windows packages combine existing documentation, UUT measurements, and Paint generated drawings.

SigmaSeries instrument commands appear in English. Commands for other IEEE 488 instruments appear as specified by the manufacturer, and TestBASIC adds user-defined English equivalents as comments to the command. Clear variable names and branch labels make the BASIC language readable. The program can be listed in three ways:

- Comments only
- Executable code only
- Combination of both

Text and graphics can be easily combined. Summation's Camera window cuts any section of the screen contents. The screen contents could range from a waveform measured with a SigmaSeries waveform recorder to a cabling set-up diagram in the Microsoft Paint window. The Camera buffer can be pasted in a Microsoft Write file. The Write file could contain the corresponding TestBASIC program source or user written documentation text.

11.2 Additional "To-Be" Automated Test Equipment (Fluke 3050B)

Since the Honeywell ATE has limited digital card testing capabilities, FM & TS began digital card program development and testing on a Fluke Functional Test System in 1979. This tester was acquired by the Commercial Avionics Division and has been available to FM & TS on an off-shift basis for shared use testing of digital cards since that time. However, as the Commercial

Avionics Division completes their move to a new facility, this tester will become unavailable.

Therefore, in order to maintain the present test capability and provide for the future, it is proposed that for the "To-Be" operation FM & TS purchase a dedicated Fluke 3050B for digital card testing. This will allow for the continued testing of products whose tests were originally developed on the Commercial Avionics Division's tester and assure that testing of the more complex digital designs of the future will be possible.

The need for such a tester was identified early in the Phase 2 activity of ITM Project 82. Therefore Production Engineering began an immediate search for the equipment. As a result, an appropriate used Fluke 3050B tester was located and ordered in July, 1987 and received in September, 1987.

11.3 Burn-In Oven Monitoring Network

System criteria for the Burn-In oven monitoring network equipment consists of standardized controllers, simple programming, ease of networking, and reasonable cost. Since the existing Thermotron ovens are proposed for retrofitting, vendors with equipment which would easily interface with these ovens would be a requirement.

A review of vendors indicated that most network interconnection occurs via RS-232 (or similar protocol). This simplifies the interconnection of units since an easily fabricated cable consisting of a few conductors can interface between each oven and the system controller.

In addition, simplified programming was considered to permit ease of system maintenance and revision. In this area, most vendors supply a programming package consisting of a BASIC (or very similar) command set. Since this language has wide acceptance and ease of use, the monitor system does not require the constant services of a system programmer. Moreover, the use of a language with a common structure, in a PC MS-DOS environment, would allow future networking to be accomplished much more readily.

Three vendors were located that had equipment with the desired performance characteristics. They were:

- J.C. Systems
- Sun Systems
- Thermotron

J.C. Systems manufactures environmental controllers and various control panels adaptable to Thermotron ovens. The controllers are network adaptable and can be fitted into the existing physical locations. Programming is accomplished via BASIC-like commands and controlled by a standard PC.

Sun Systems provides a control panel for retrofit which interfaces ovens to a monitor point via RS-232. Control is via a standard PC (or PC compatible) utilizing a BASIC-derived command language.

Thermotron, which originally manufactured all the ovens utilized in FM & TS for device burn-in, produces a panel which can retrofit into the existing ovens and consists of the network, protocol, and language features required for this application. An additional benefit is Thermotron's maintenance of files covering all ovens sold to Honeywell. This permits an accurate assessment of the ovens and specifics about the peculiarities of each oven.

Response to requests for quotation for the monitoring system has been vary limited, with the only quotation coming from Thermotron. Therefore, the Thermotron system is the choice for this equipment at present. Because of the limited response additional vendor searches may be performed prior to implementation.

SECTION 12

EQUIPMENT/MACHINERY ALTERNATIVES

12.1 Summation Test System

In the event that the Summation Test System specified is not available or proves unable to satisfy FM & TS requirements, no clear alternative immediately presents itself. Since the ATE industry in general is at present experiencing such technological growth, additional equipment search and evaluation would be in order.

12.2 Fluke 3050B Test Station

The Fluke 3050B test station was ordered in July,1987 and delivered in September, 1987. Therefore, alternative equipment is not a consideration.

12.3 Burn-In Oven Monitor Network

If the monitoring scheme proposed proves unsatisfactory or is unavailable, the search for another vendor would be continued and/or expanded. If no comparable system were found, the present method of manual monitoring of the ovens would be continued. However, part of the proposed system consists of the upgrade of the individual oven controllers to microprocessor based units. There is no reason to believe that this portion of the proposed upgrade could not be accomplished since the controllers already exist and are readily available. This approach would eliminate the monitoring network but still extend the oven life by eliminating switches, motors, and assorted wear-prone mechanical equipment that presently exists in some of the ovens.

SECTION 13

MIS REQUIREMENTS/IMPROVEMENTS

The most significant improvements in the card and device testing area in respect to the Honeywell MIS department will be achieved with the introduction of the HMS/BOS system currently being modified for use at the St. Louis Park facility. HMS is a modular system comprised of the following modules:

- Master Production Scheduling (MPS)
- Inventory Records Management (IRM)
- Manufacturing Data Control (MDC)
- Material Requirements Planning (MRP)
- Capacity Requirements Planning (CRP)
- Purchase Material Control (PMC)
- Production Cost Accounting (PCA)

In addition to HMS, Honeywell is also implementing a process layout system which includes the Process Management System (PMS) and the Factory Data Collection (FDC) System.

The Factory Data Collection (FDC) system has been developed as a means of automatically recording hours an employee expends on a specific operation/part number. This provides important information to FM & TS management both for accounting purposes as well as monitoring the percentage of completion of a specific part being built. It is envisioned that in the future, the FDC system will be expanded to provide input to a system for location tracking of work-in-process as well.

Honeywell is also developing the specifications for a Work Center Manager System (WCM). While these specifications are still in the development phase, the improvements described in this document take into account the eventual implementation of these efforts and have been designed for future interface to a Work Center Manager System. The following paragraphs describe the basic functionality required of the Work Center Manager System.

A Work Center Manager System is typically a major piece of a hierarchically structured computerized factory control system. Residing at a higher hierarchical level than the WCM are the corporate systems and the MRP and MRP II systems such as HMS/BOS. Because MRP II systems are batch processing operations, the Work Center Manager has been assigned the responsibilities of direct, real time control of the factory floor. In this role, the system is responsible for short term, global scheduling tasks (during the operating day) and coordinating the inter-cell operations (such as material handling "hand-offs") that reside below it in the controls hierarchy.

It is also envisioned that the Work Center Manager will distribute graphics and textual process data to workstations and will maintain a process data library which will be accessed by various pieces of the process control hierarchy (such as PLC's and other automated equipment).

Implementation of the recommendation to upgrade ATE equipment will require the establishment of a data network to intorconnect test and programming stations along with development of a centralized database similar to ATE Central to maintain configuration control of test programs. As new systems are moved to production and additional test stations are placed into service, this network will gain in importance to FM & TS.

Since FM & TS will continue to support programs now in existence, the existing ATE Central and a complement of Honeywell ATE consoles will be required for several years to come. It is assumed programming will enter a "maintenance" phase and emphasis will shift to the newer equipment described previously.

SECTION 14

COST BENEFIT ANALYSIS AND PROCEDURE

In analyzing ITM Project 82, attention was focused on the methods and processes utilized in the FM & TS card and device areas. Activities reviewed included testing and production of cards, devices, and spares for the various FM & TS programs.

In the initial stages of the project, several areas were identified as cost drivers and reviewed for possible savings using the methodology shown in the process diagram of Figure 14.0-1. Those that exhibited the greatest potential for improvement were:

- Rework/Retest
- Programming Costs
- Troubleshooting Costs

Areas identified from the contract ledger data and foreman's cost control reports which did not result in significant benefit were:

- Scrap
- Standard Hours

The relatively low annual volumes in ITM Project 82 resulted in virtually no scrap. This is primarily because the effect of any scrap action would be the loss of a device or card and subsequent schedule impact. Consequently, rework is the preferred alternative.

14.1 ITM Project 82 Cost Drivers

The following paragraphs describe the cost drivers for ITM Project 82.

Rework/Retest

Examination of cost control records revealed that most of the Rework/Retest hours expended during 1986 were the result of retest due to E.O. (Engineering Order) incorporation and rework/retest due to component failure during testing and burn-in. Since neither of these cost drivers are affected by ITM Project 82, no rework/retest savings are projected as a result of implementation of the proposed equipment.

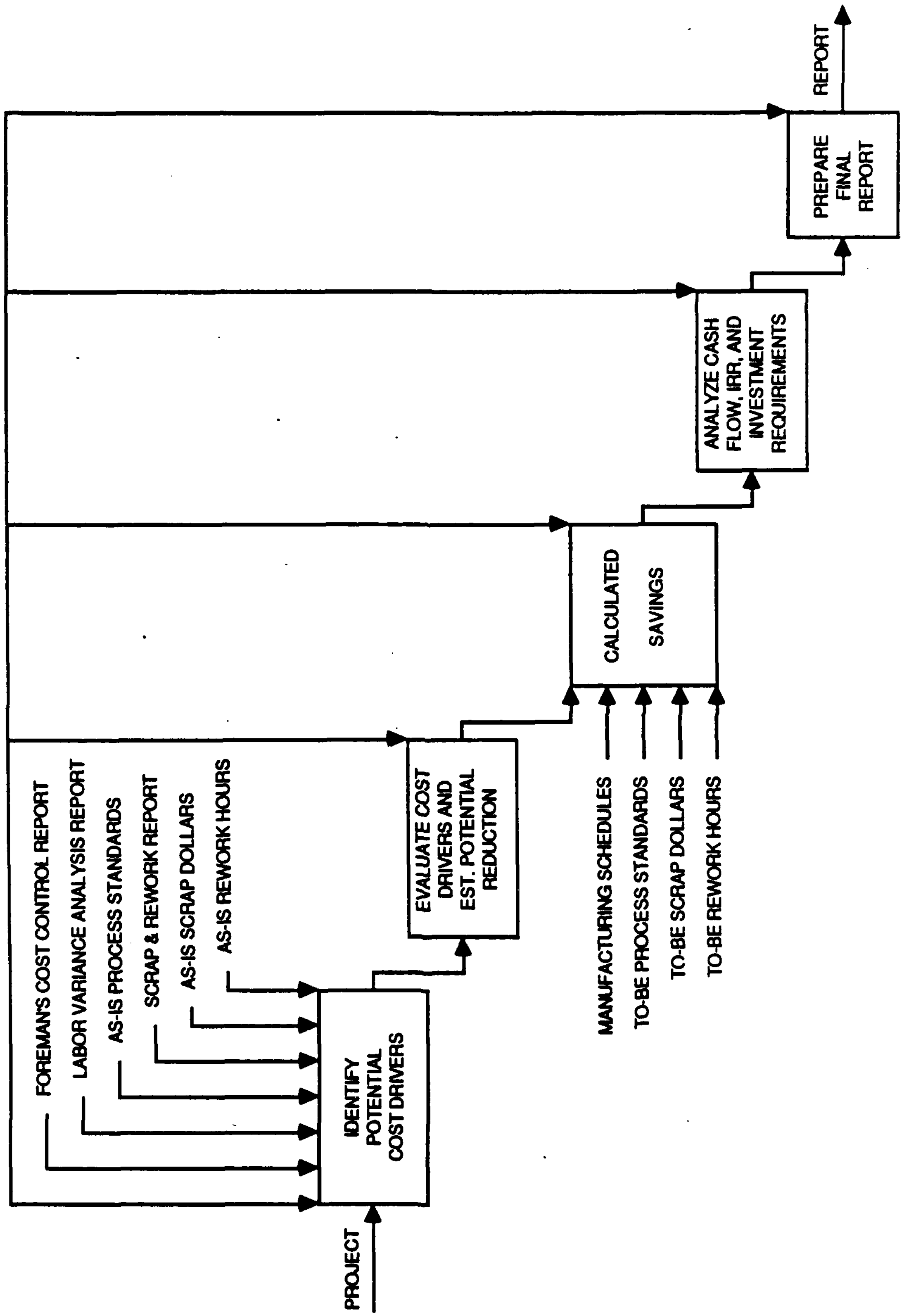

Figure 14.0-1 Cost Benefit Analysis Methodology

Programming Costs

Current FM & TS program testing is based on the fast development of test sequences for each device and the individual cards contained in them. With the exception of tests performed on certain Targeting Systems, all major systems have been programmed on Honeywell ATE units.

A typical device program will contain thirty to forty segments which are created and maintained by a production test engineer. Individual cards, numbering ten to twelve per device, require additional test engineering time for coding, debugging, and certification of the test program. As a result, the "typical" device consumes over 1-1/2 man-years in programming alone.

Because of efficiencies available in the programming systems which are part of the proposed ATE equipment, the typical programming effort can be reduced by as much as two-thirds. A conservative approach was taken for the calculation of savings by assuming that the reduction in effort would be only 50%. This benefit comes about primarily because coding, debug, reprogramming, and documentation using the new equipment are much more easily accomplished.

The savings to be realized will come about primarily when new business is introduced in FM & TS requiring the creation of test programs for new cards and devices. The project team estimates that savings in the programming effort will occur with the introduction of new programs in the 1989 - 1995 time frame based on projections obtained from Honeywell's Forecasting group. In addition, maintenance of these test programs is estimated to be 20% of the typical new programming effort per year in the 1996 - 1999 time frame.

Troubleshooting Costs

During device testing, the troubleshooting activity typically results in costs ten times higher than those at the card testing level. This is primarily due to the difficulty of isolating faults within a device as opposed to those on a single card.

Industry experience indicates that ninety percent of failures are caught at the printed circuit board level with the remaining ten percent surfacing at the device level using functional testing methods employed as they are in the FM & TS area. The result is an almost equal cost for finding and fixing failures at both levels. This is in agreement with FM & TS variance hours data taken from the contract ledger for 1986 for devices and cards on the higher volume programs.

Due to the enhanced troubleshooting capabilities presented by the Summation SigmaSeries test station it is estimated that fault isolation at the card and sub-assembly test level can be increased from ninety to ninety-five percent on new assemblies which come about as a result of new business introduced in FM & TS. By increasing detection of faults to ninety-five percent at the card test level, an annual savings of fifty percent will be realized in test at the device level.

In short, a fifty percent savings in device test costs can be achieved with a five percent increase in card test costs. For the savings calculations this was limited to new programs in FM & TS. There is a possibility for additional savings if it can be demonstrated that the troubleshooting savings realized can offset programming costs on higher volume assemblies in current production. However, since this must be evaluated on a case by case basis by Production Engineering as the opportunities present themselves, these potential savings were not included in the calculations.

Actual Hours

In determining savings for the card and device areas, actual operating ratios derived from Foreman's Cost Control reports were utilized. All standard hours were "normalized" to actual hours to perform "As-Is" versus "To-Be" comparisons on an area-by-area basis. This method is then able to take into account all operational factors not normally included in standards.

Assumptions

All calculations are tabulated for ten yearly periods by quarter, beginning with the implementation point. Generally, implementation commences during 1988, with savings not being realized until 1989.

Production rate increase/decreases are calculated based on the ten year marketing forecast for FM & TS revenue projected from factory production. This approach removes sources of revenue not directly attributable to products manufactured in the FM & TS production facilities addressed in ITM Tech Mod Project 82.

14.2 Capital and Expense

The capital, recurring and non-recurring expenses for Project 82 are shown in Figure 14.2-1.

14.3 Project Savings and Cash Flows

The savings to be realized in this project exceeds Honeywell's Military Avionics Division hurdle rate. The Project's cash flows are shown in Figure 14.3-1 with the assumption that capital will be available per the implementation plan.

PROJECT 82 EXPENDITURE SUMMARY

	GROSS COST	CAPITALIZATION YEAR
CAPITAL COSTS		
AUTOMATIC TEST EQUIPMENT (ATE) COST		
FLUKE ATE	$83,448	1987
SUMMATION ATE	$210,706	1988
SUB-TOTAL	$83,448	1987
	$210,706	1988
COMPUTER COST		
OVEN MONITOR SYS	$103,986	1988
SUB-TOTAL	$103,986	1988
	$83,448	1987
	$314,692	1988
TOTAL CAPITAL COST	$398,140	

	GROSS COST	YEAR EXPENSED
EXPENSE COST		
NON-RECURRING EXPENSES		
TRAINING		
	$1,700	1988
	$0	1989
SUB-TOTAL	$1,700	
PROCESS MODIFICATION		
	$6,400	1988
	$4,700	1989
SUB-TOTAL	$11,100	
OVEN MONITOR SYS. PROGRAMMING		
	$2,600	1988
	$1,600	1989
SUB-TOTAL	$4,200	
	$10,700	1988
	$6,300	1989
TOTAL NON-RECURRING COST	$17,000	
TOTAL CAPITAL AND NON-RECURRING	$415,140	
RECURRING EXPENSES		
ANNUAL MAINTAINANCE	$11,900	

Figure 14.2-1 Project 82 Expenditure Schedule

	1987	1988	1989	1990	1991	1992	1993
Capital	$83,448	$314,692	$0	$0	$0	$0	$0
Non-Recurring Expense	$0	$10,700	$6,300	$0	$0	$0	$0
Recurring Expenses	$0	$2,500	$11,900	$11,900	$11,900	$11,900	$11,900
Savings	$0	$0	$74,002	$105,989	$146,886	$284,479	$414,691
Depreciation	$10,431	$54,991	$80,580	$65,634	$54,425	$46,017	$31,914

	1994	1995	1996	1997	1998	1999	TOTAL
Capital	$0	$0	$0	$0	$0	$0	$398,140
Non-Recurring Expense	$0	$0	$0	$0	$0	$0	$17,000
Recurring Expenses	$11,900	$11,900	$11,900	$11,900	$11,900	$11,900	$133,400
Savings	$464,336	$527,183	$543,715	$592,076	$663,946	$338,608	$4,155,911
Depreciation	$24,429	$20,966	$8,753	$0	$0	$0	$398,140

Figure 14.3-1 Project 82 Cash Flows

SECTION 15

IMPLEMENTATION PLAN

The implementation plan for ITM Project 82 initially developed out of an earlier review of factory requirements and the recognition of a need to initiate modernization activities within the FM & TS Production area. ITM Project 82 concentrated attention on improvements in card and device test equipment used in the FM & TS area.

Since the equipment can be accommodated within the existing production area, acquisition can commence upon receipt of project approval.

15.1 Implementation Plan Activities

Implementation of ITM Project 82 is depicted in the Plan Schedule (Figure 15.1-1). The improvements scheduled for ITM Project 82 include the following:

- Installation of Summation ATE
- Installation of Fluke 3050B Digital Card Tester
- Installation of Oven Monitor Network

ITM Project 82 implementation will take place in three basic phases:

Phase	Activity
I	Program Planning
II	Acquisition, Installation, and Training
III	Operation and Validation

15.2 Summation ATE Implementation

Improved programming and operational testing methods will commence with the installation of the proposed up-to-date testing equipment. The technology represented by this equipment permits more comprehensive test sets complete with documentation depicting actual on-screen responses and graphics tied to the individual Unit Under Test.

15.2.1 Hardware

Equipment acquisition is anticipated for early 1989. Since the addition of this equipment is primarily predicated on new program development, the timing is geared to coincide with the introduction of new programs in the 1989 - 1995 time frame based on projections obtained from Honeywell's Forecasting group.

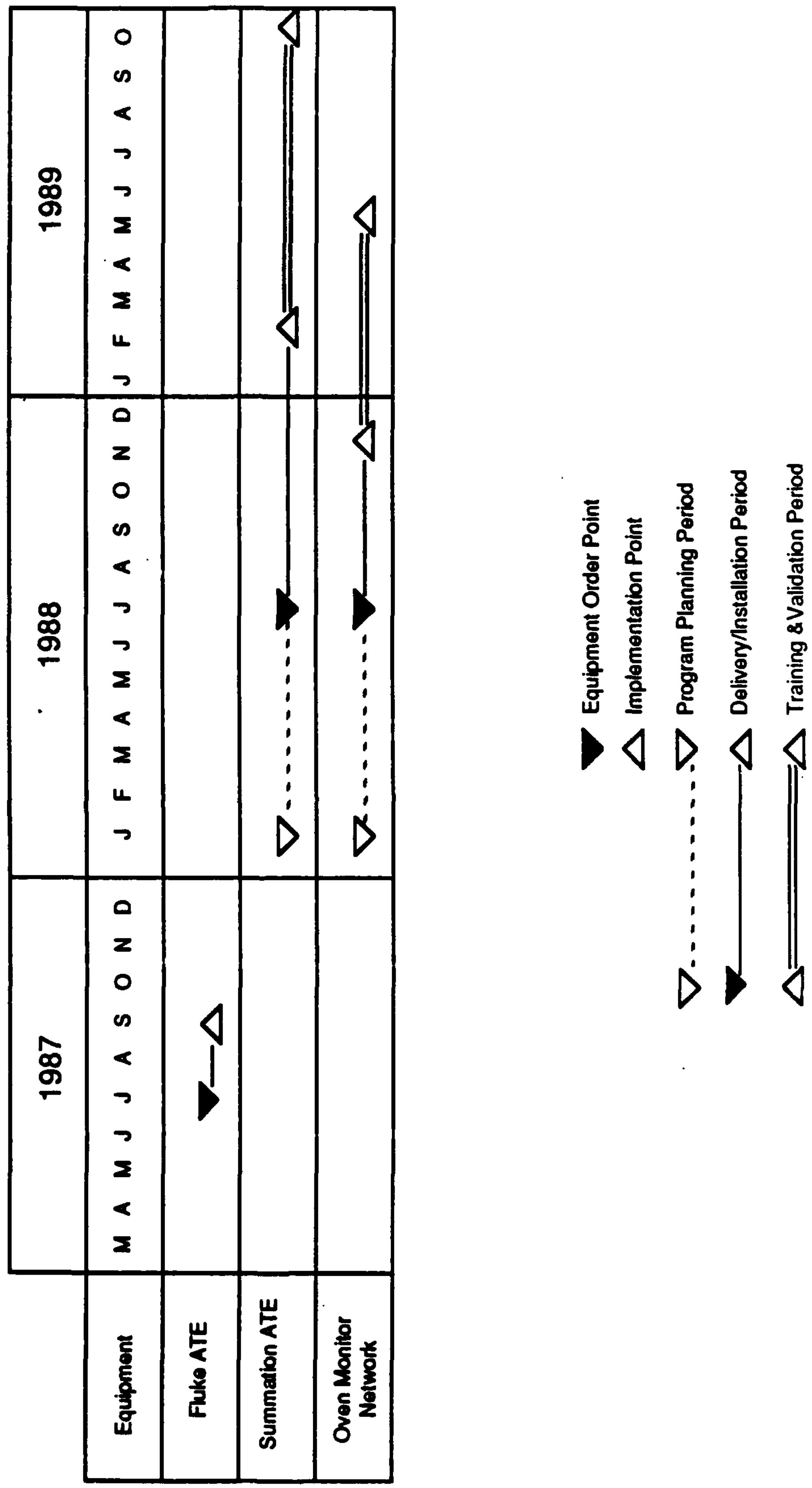

Figure 15.1-1 Project 82 - Implementation Plan

The Summation ATE is modular, allowing for the purchase of the basic control module and a complement of instruments, thus permitting training and familiarization at nominal cost. Early design of fixturing is also facilitated, as well as space planning and operational training.

The implementation should also provide for adapting the system to existing programs so that, at a future point in time, older programs may be added to the system when the present ATE equipment is phased out.

15.2.2 Programming

The most significant aspect of the proposed equipment is the substantial reduction in programming time when compared with former methods. The approach taken with the Summation equipment is a unique, menu-driven generation of coding, as opposed to the more traditional methods. The test engineer developing a program for a specific application virtually selects measurement and stimulus instruments from a list using a "mouse" as a pointing device along with range, amplitude, duration and many other parameters. These values are added to a file which automatically generates the appropriate instrument coding and avoids the usual input mistakes associated with instrument set-up and coding.

All signal routing in the system is handled in a similar manner. Screens are provided which permit the person developing the test program to graphically "route" signals to and from the unit under test to the respective instruments necessary to perform a measurement or provide signal or voltage stimulus. Once these tasks are performed, program execution can be tried to evaluate the results. In essence, the system eliminates what has been a major source of error in most ATE programming, typographical mistakes. By performing this function automatically from a graphics interface, the system allows the program developer to concentrate on the test plan and sequence, altering program development and facilitating the production of complete documentation.

Completing a program "package" normally involves the completion of documentation from a variety of sources. The Summation system materially assists this task by allowing the programmer to duplicate the actual "screens" which are displayed in the program along with all set-up and coding as well, so programs become self-documenting and require far less manually generated support documentation. The package can include all graphics which not only assist future program modifications, but can assist in operator training and troubleshooting. The majority of layouts dealing with card testing become documents directly related to what the operator sees and becomes less subject to interpretation and error.

15.2.3 Programming Implementation Plan

The system as proposed is supplied with all necessary software to facilitate program development and subsequent implementation in the production area. Programs are installed on IBM PC's or PC compatible micros equipped with the Microsoft "mouse" package which permits the utilization of the interactive functions present in the software.

Software for additional programming stations can be easily acquired so that program development can commence with several test engineers, accelerating the date on which the system will be operational in the factory. This feature will also permit greater facility with the system among the test engineers assigned to the project as well as allowing other personnel in Test Engineering to gain familiarity with the system.

15.3 Fluke 3050B Digital Card Tester Implementation

The Fluke 3050B tester was ordered in July, 1987 and received in September, 1987.

15.4 Oven Monitor Network Implementation

Oven Retrofit

Sufficient time has been provided to compensate for acquiring wiring diagrams if needed and fabricating any unforeseen control circuitry so that the modified ovens will perform all current functions employed in the testing process. In addition, the controller retrofit will take place over an extended period so as not to adversely effect the current production schedule.

Network Programming

The vendor has a basic software package which will require an initial configuration for FM & TS's specific needs. Test Engineering personnel familiar with PC BASIC will be able to easily set up the network and develop the BASIC coding to establish the monitoring function since it is a standardized package. Moreover, much of the system configuration can be accomplished while retrofit is going on, allowing the addition of ovens to the network as each individual modification is completed.

SECTION 16

PROBLEMS ENCOUNTERED AND HOW RESOLVED

Problem: Translating various FSO marketing projections of future revenue into growth figures applicable to FM & TS.

Solution: Figures were ultimately subjected to a process of review and scrutiny to ascertain those actually applicable to FM & TS Production.

Problem: Preliminary designs, while technically correct, did not reflect FM & TS preferred operational mode.

Solution: Subsequent designs were modified in a "working meeting" atmosphere so as to contain a maximum number of features desired by the operational personnel who would be implementing and using them.

Problem: Large quantities of parts related data presented a significant data reduction task to derive usable summaries.

Solution: Large data matrices were developed to integrate product description, operation, standards, and quantity data. This enabled accurate and comprehensive summaries to be developed.

Problem: Multiple locations were potentially available for future operations necessitating significant relayout efforts.

Solution: Area elements were entered into CAD database allowing easier update and relayout as revisions and relocations were proposed.

Problem: Significant amounts of tabular data developed and continually modified to reflect current rates, times, and quantities. This was potentially a large clerical task.

Solution: Data was linked and manipulated via powerful spreadsheet programs thus minimizing clerical effort.

Problem: Cost of reprogramming and acquisition of new ATE units not repaid from current operations.

Solution: New avionics programs programming and testing will determine acquisition point along with replacement requirements associated with existing ATE's.

SECTION 17

AREA FOR FUTURE CONCERNS/DEVELOPMENT

Future Concerns

- As implementation of Factory Data Collection (FDC) is considered and initiated, attention should be given to providing only those data elements which are necessary for specific area functions to be available in that area. This will reduce the "clutter" of data which could potentially impede the performance of the system. This, essentially, is the essence of hierarchically linking work centers, cells, stations, etc. so that each node has the key resources necessary to accomplish its task.

- Equipment has been proposed for this project in which capabilities exist for future inclusion in local factory networks. This will facilitate future factory modernization. It is important that any automated equipment under consideration be viewed as necessarily including this capability.

Future Development

- Any replacement test equipment should have the capability to interface or network so that data can be exchanged and configuration can be controlled.

- FM & TS should continue to advance the requirements for "design for manufacture" and "design for test" to facilitate future cost reductions.

- No future flight control or targeting systems should be released for production prior to the development of the capability to test any system element independent of others.

- Continuous evaluation of equipment coming into the marketplace will uncover price-performance "breakthroughs" that signal a cost effective solution to earlier, uneconomic alternatives.