digital

engineering handbook

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office of development
digital equipment corporation
maynard, massachusetts 01754

ENGINEERING HANDBOOK

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CONTENTS

PREFACE

The *Engineering Handbook* is designed to be used primarily by design and project engineers who work under the Office of Development (Central Engineering). It may be useful to other engineers and support people in the company, but second person pronouns (you, your) refer to Office of Development engineers.

Chapter 1, WHY, is intended to give the flavor of the company. Chapter 2, HOW, traces the typical life of a project from concept to installation. Chapter 3, WHO, details the relationships between design and project engineers and the various groups they have to work with.

New people may find the best way to read this book is to read Chapters 1 and 2, and skim Chapter 3. Later on, sections of Chapter 3 can serve as a reference when dealing with particular groups.

CHAPTER 1
WHY

1.1 PHILOSOPHY

Honesty
Not only do we want to be technically honest, but we also want to ensure that the implications of what we say and the impressions we leave are correct. We feel that any commitment to customers or employees must be honored.

Profit
We are a public corporation in which stockholders invest for profit. Success is measured by profit. With success comes the opportunity to grow, the ability to hire talented people, and the satisfaction that comes with meeting goals. We feel that profit is in no way inconsistent with social goals.

Quality
We aspire to be a quality organization performing quality jobs so that we can be proud of our product and our work for years to come.

The product we sell incorporates the engineering, the software, the manufacturing, and the services, which include field service, software support, sales, order processing, training, and manuals.

Responsibility
Plans, which may be rejected until they fit corporate goals or until there is confidence in them, are proposed by managers or teams. The impetus for a plan may come from outside the group making the proposal, but the accepted plan is the responsibility of those who proposed it.

Line Management
We particularly want to be sure that line management jobs are clearly defined. Because many people are dependent on the plans of line managers, it is important that the plans have regular automatic measurements of success built into them. Profit is only one measure of a plan; other measures are customer satisfaction, career advancement for Digital personnel, achievement of long range corporate needs, development of new products, and exploration of new markets. We believe that our commitment to planning assures our freedom to act.

Civic Responsibilities
We are committed as a corporation to take affirmative action to provide equal opportunity for employment and promotion for all persons – regardless of race, color, creed, or sex. We encourage all employees to take responsibility in community, social, and government activities and we will always entertain ideas for corporate or individual (on corporation time) participation in these areas. However, activities involving company time or with company funds may require a formal proposal including ways of regularly measuring progress toward goals.

Environment
As good citizens, we believe we have the responsibility to keep our environment free from pollution.

Customers
We must be honest and straightforward with our customers to be sure not only that they are told the facts concerning our products and services, but also that they understand these facts.

To the best of our ability, we want to be sure that the products we sell solve the needs of our customers. When we sell a product to a customer, we want to be sure the corporation fulfills the obligations we assumed with the sale.

Competitors
We never publicly criticize the competition; we sell by presenting the positive features of our own products. We want to be respectful of all competition and collect and analyze all public information about competitors. When we hire employees from competitors, we should never press them for confidential, competitive information, nor should we use confidential literature they may have taken with them.

Simplicity and Clarity
We want all aspects of Digital to be clear and simple. We want simple products, proposals, and organization, literature that is easy to read and understand, and advertisements that have a simple, obvious message.

We have thousands of employees and many thousands of customers. We have to keep things simple to be sure that we all work together. Our decisions must always consider the impact on the people – both customers and employees – who will be affected by them.

OEMs (Original Equipment Manufacturers)
Standard products are the base of our business. At times, in certain areas, we will develop and invest in software and hardware for special markets. But we should never lose sight of the fact that the base of our business is our standard products.

We are very dependent on sales to OEMs. There are more applications for our products than we could ever develop. In addition, the development of many new fields presents risks that we cannot afford to take. Therefore, we are very dependent on OEMs, and when they take the risks and are clever enough to be successful, we should respect their risks and their effort and neither compete with them nor hurt them otherwise. When our OEMs are in trouble with a customer we should help solve their problem.

End Users
We make products for the end users. If our products do not solve their problems, we have failed in our job. We strive always for good understanding of the end users' needs.

Personnel Development
We encourage employees to develop technical skills, breadth of knowledge, and expertise in a specific area. We also encourage them to develop supervisory and management skills. We believe that individual discipline should be self-generated.

Promotion
We promote people according to performance, considering not only technical ability, but also the ability to get the job done and to take the responsibility that accompanies the job. Ability is measured by attitude and desire to succeed as well as by past results. Performance results are also used to decide whether a person should remain in his or her current job.

Hiring From Customers
We should be exceedingly careful when hiring employees from customers. Sometimes this is reasonable and desirable, but we should do it with caution to be sure that the employee first tells the customer and allows the customer the chance to compete with us.

First Rule
When dealing with a customer, a vendor, or an employee, do what is "right" in each situation.

1.2 STRUCTURES AND PERSONS

Like other large organizations, Digital has a structure that helps us channel our energies. Our structures are abstractions built upon real people. We let the structures survive only so long as they help us get our job done. These are the important things to remember about our corporate structure:

1. It influences the way we work, but it never takes responsibility for what we do; only people can take responsibility.

2. It is there to help get the job done. It works well for things like policy decisions. When ideas and problems are involved, however, people are encouraged to talk with anyone in the organization who should be informed or who can help. Don't let structure bar the way.

3. We always try to push decisions down to the lowest level where all information is available.

One-by-One
In your area of responsibility, your job is to find out what is right, and then do it. Digital's products are used in critical applications where malfunctions can be expensive for our customers, and, in some cases, can cause injury to property and human life. We must focus on decisions that affect these kinds of applications. *You* are the only one who understands your product completely; that is why we focus responsibility on you.

One of the most difficult adjustments at Digital is realizing that you may have little authority over many aspects of your product even though you are responsible for all of it. Hence, it is *not* sufficient to do what is right; you have to convince others of what's right. This is in part a check on your ideas. You should begin to wonder about your decisions when you cannot convince others to work with you. It also forces clarity in your thinking.

Good communication is a very important part of what is right. You *must* understand how your specifications will be interpreted. You must make sure that sales personnel and customers understand the limits of a product's specifications. Malfunction due to misuse by a customer is an acceptable excuse only if our customer can be made aware of that misuse through clear and accurate communication.

Two-by-Two

The two-by-two method for product development is an important new concept for Digital. Essentially, it proposes that every project be managed by a two-person team – one from engineering, and one from manufacturing. Each person is jointly responsible for introducing a new product into production.

Engineering responsibilities include:

- Planning
- Design
- Testing
- Documentation
- Startup (jointly with manufacturing)
- Support of production and field
- Meeting cost goals
- Shipping on schedule

Manufacturing responsibilities include:

- Product introduction plan
- Influence design to ensure manufacturability
- Capacity forecasting
- Volume production – documentation and successful implementation

The principal advantage of the two-by-two concept is the focus of joint responsibility on two people and the granting of a certain amount of freedom to do what is right for a particular product.

The two-by-two concept can have problems:

1. You must avoid using the freedom to re-invent the wheel, i.e., to re-learn lessons previously learned (often the hard way).

2. You may be tempted to go off and do your own thing ignoring the strengths of people with in-depth experience and knowledge in specific areas. This would make the team only as strong as the team members.

Both engineer and manufacturing manager have total project responsibility, but each is subject to existing "business" disciplines and operates within existing charters. Thus, you should involve metals people in metals decisions, module people in module decisions, and so on.

The details of the two-by-two relationship cannot be defined. Our concepts are changing as we gain more experience, and each engineering group and manufacturing facility is different. They make different products and work in different ways.

You can think of the two-by-two concept as a silly management game. If so, it won't succeed any better than any other game. If you really buy into the relationship, however, if you bring honesty, integrity, and love to your partner, you will succeed where others playing games fail. *It is up to you.*

Three-by-Three

The three-by-three concept is developing more slowly than two-by-two. Three-by-three says marketing is just as important as design and manufacturing. It says that you can design and build the best thing in the world, but unless we tell our customers about it, they won't buy it, and the product will fail. The best products of the future will be managed by a partnership of three.

If you think of yourself as a vendor of products, the product manager is your customer. But realize that a product is more than hardware. It is documentation, marketing, software, manufacturing, and support. It is reliability and, above all, it is profitability.

We all work together toward a common goal, but we should be aware of the needs and perspectives that each of us brings to the job. By the nature of things, the product manager is likely to be more keenly aware of the needs of the market than of the problems of development. It is your responsibility to make sure he or she does not try to overcommit you. On the other hand, you owe the product manager the best product money can buy.

In short, you owe the product manager and the manufacturing manager cooperation in your common goal, and awareness and respect for the needs of the market as reflected by the product manager, and for the needs of manufacturing as reflected by the manufacturing manager. You also owe respect to the engineer – yourself.

It is not always possible to identify a product manager. If you cannot identify one for *your* product, *you* are it.

Matrices

Figure 1-1a and b illustrate the latest organization chart for the corporation. The Appendix gives a detailed chart for Office of Development. It can be used best as a guide around the company to let you get in contact with appropriate people quickly.

Notice that the figure implies the traditional pyramid structure. As such, it shows only half of the story. We really operate with a so-called matrix structure. Engineering projects cut horizontally across the organization lines using people from many groups throughout the company. Figure 1-2 illustrates what this means. In a sense, the vertical structure is responsible for people and policies; the horizontal structure worries about products.

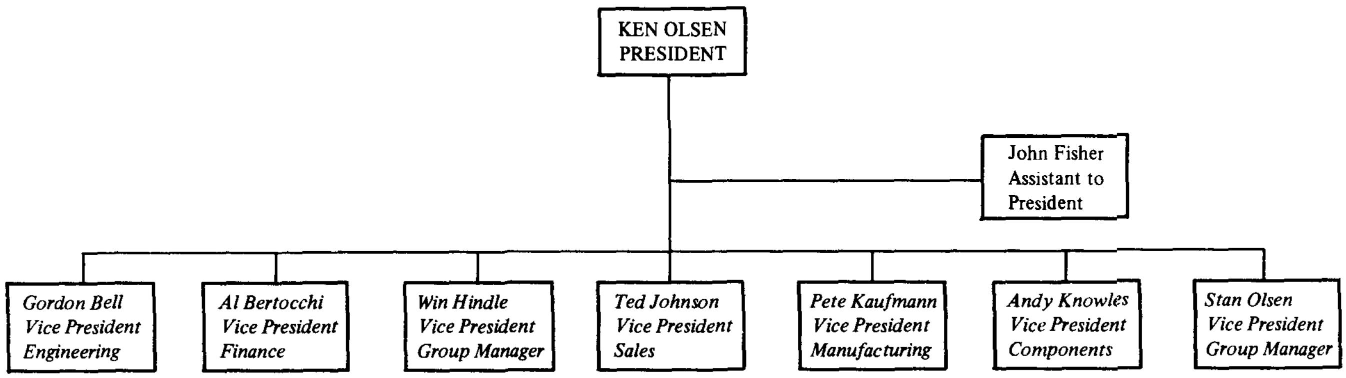


Figure 1-1a
Corporate Organization

STAN OLSEN
VICE PRESIDENT
GROUP MANAGER

Irwin Jacobs
Product Line Manager,
Business Products Manager

Bob Lane
Traditional Products
8 & 11 Typesetting
Manager

Julius Marcus
Vice President
Data Communi-
cations Group

TED JOHNSON
VICE PRESIDENT
SALES

Bruno Duerr
Corporate
Software Services Manager

Gerry Moore
Vice President
N. A. Sales

J-C Peterschmitt
Vice President
Europe

Ron Smart
General International
Region Manager

Jack Shields
Vice President

Gene Smith
Corporate
Public Relations/
Advertising Manager

Craig Zamzow
Sales Training Manager

WIN HINDLE
VICE PRESIDENT
GROUP MANAGER

Dennis Burke
Personnel/OD
Manager

John Holman
CSS
Manager

Ed Kramer
LDP/BIO
Group Manager

John Leng
Vice President
DECsystem-10,
PDP-15

Bill Long
Vice President
OEM Group

Charlie Spector
EPG/ECP
Group Manager

Brad Vachon
IPG
Manager

Figure 1-1b
Corporate Organization

	Engineering	Documentation	Model Shop	Manufacturing	Product Lines
New CPU Project Product Manager A					
New Tape Drive Product Manager B					
New Disk Product Manager C					

Figure 1-2
The Matrix Organization

CHAPTER 2
HOW

This chapter presents an overview of the life of a project. Figure 2-1 illustrates the phases most projects pass through.

2.1 DECIDE WHAT TO BUILD

Objective:

To identify a problem or set of problems our customers have and propose a solution that will help them and bring profit to the corporation, as well.

People Involved:

Engineering (hardware and software)
Customers
Marketing
Product Manager

Tools:

Engineering Proposal (essentially, a functional specification)
Marketing (or Business) Plan

When most engineers start on a project, this step has already happened. Many groups have a five year plan for development. Major decisions on new products are usually made during formulation of these plans.

It is often hard to tell when this phase ends, but two things usually mark the end: project approval, in the form of official funding, and a design review of the functional specification.

Most engineers start their involvement when the functional specification has already been written. Keep in mind that the specification may be (1) incomplete, (2) inconsistent, or (3) impossible for reasons you may discover during the design. In such cases, the specification should be updated with the concurrence of at least the Engineering and Marketing Managers.

2.2 DESIGN IT

Objective:

To translate the functional requirements into a design that manufacturing can use to build.

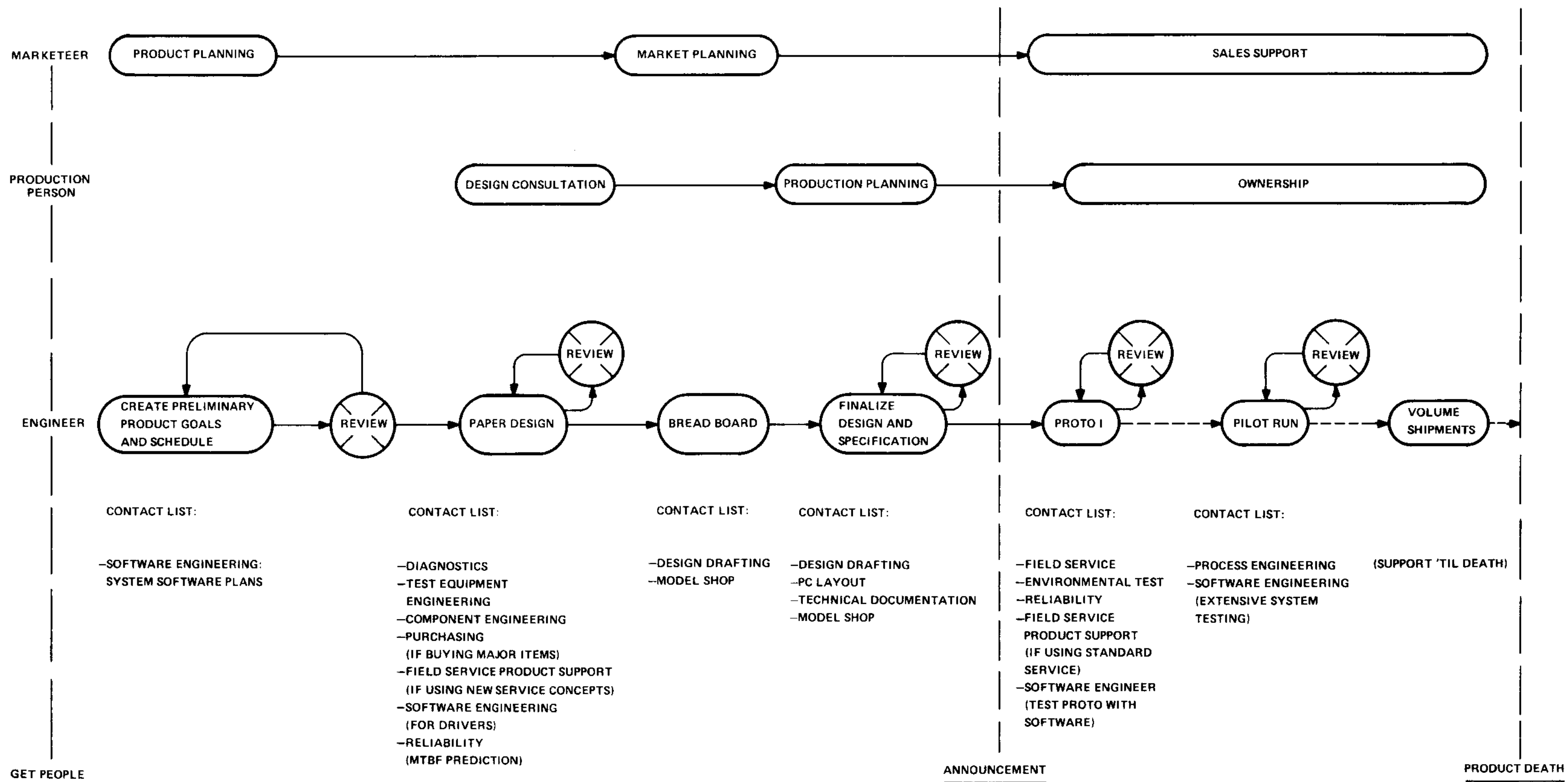
People Involved:

Design Engineer } Principals
Manufacturing Project Manager }
Software Engineering
Component Engineering
Purchase Specification Control
Purchasing
Design Drafting
Diagnostic Engineering
Model Shop
Technical Documentation
Mechanical Engineering/Industrial Design
Field Service Product Support
Stockroom
Reliability Engineering
Central Test Engineering
Process Engineering

Tools:

Functional Specification
Engineering Project Plan
Manufacturing Plan
DEC standards 002, 004, 007, 008, 009, 030, 055, 092, 102

The Design Engineer and the Manufacturing Project Manager are the focus for design decisions. The rest of the people and groups just listed have developed special expertise in their own areas. The assistance they can offer is outlined here briefly. Chapter 3 details the interaction between the engineer and the various supporting groups.



THE LIFE OF A PROJECT

Software Engineering: You should identify a designated consultant who can help you define the software interface. The Software Planning Group can identify such a person. The Software Product Manager's Group should interface with the Hardware Product Manager.

Component Engineering: A component engineer will help you research and specify your component needs.

Purchase Specification Control will provide purchased parts information, vendor information, and DEC standards information.

Purchasing will help with vendor selection, sourcing, and problem solving.

Design Drafting provides manual and automatic design drafting assistance; does manual and automated P.C.* design, provides information about DEC standards, documentation, and corporate guidelines; watches spending; and acts as a communications link for all engineering services.

Diagnostic Engineering can assist in hardware/software tradeoffs and logic partitioning decisions; they also make diagnostics for your product.

Model Shop supplies fabrication in metal, plastic, wood, clay, and foam; assembles prototype modules, small sub-assemblies, and cable harnesses; and provides P.C. board models, hand-testers, odd jobs, and quality testing.

Engineering Stockroom stocks company-preferred components.

Technical Documentation provides documentation planning, technical writing services, publication services, printing, and distribution services.

Mechanical Engineering/Industrial Design can help with industrial design (appearance and product design concepts – panels, colors, etc.) and mechanical engineering (packaging design, materials evaluation, connector tests, heat transfer/flow casting and molded parts design).

Field Service Product Support is a part of field service. They can help you design in supportability features and plan for field support.

Reliability Engineering: Provides early mean time between failure prediction.

Central Test Engineering works with the engineer and the diagnostics people to ensure testability of the product.

Process Engineering will consult with the engineer on our way of manufacturing and the manufacturability of the product. When necessary, they can design jigs and tools to facilitate manufacture.

You should not end this phase without a logic, circuit and/or mechanical design review. Design reviews bring in senior people from outside the project. They help you find problems and can give you advice.

2.3 REVIEWS

A series of design reviews aids the engineer in conceiving and developing the project in a logical and practical manner.

Specification and Equipment Concept Review assures that the specification completely describes the equipment to be designed, including interfaces (physical and electrical) and a functional relationship between inputs and outputs; demonstrates the planned implementation of the design (block diagrams, flow diagrams, analysis, specifications for sub units, etc.); includes mechanical, packaging, test and maintenance, thermal and power requirements, and concepts.

Preliminary Mechanical Design Review should be held prior to generating a complete set of drawings so that the inputs from manufacturing, field service, etc. can be considered. The engineer should show sufficient detail in the project specification or a separate mechanical specification to assure that the design will meet all requirements. He or she may include sketches, models, mock-ups and/or assembly type drawings, analysis, and calculations to show thermal and structural integrity.

Preliminary Logic Design Review should be held as soon as possible after completion of the design and prior to the generation of board layout. The data should include the logic diagrams, some form of specification, preliminary map of the locations of chips and pins, timing diagrams of critical paths, etc.

Preliminary Circuit Design Review should be held as soon as the circuit is designed and the supporting analysis and critical portions have been breadboarded, and prior to the generation of artwork and detailed packaging. The data available should include the schematic, parts lists, stress calculation, stability analysis, power requirements, MTBF estimates and supporting test data.

Prototype Test Review is held to examine the results of prototype testing and conclusions drawn from the test data. It should include the planned corrective action in as much detail as possible. The data supplied to the reviewers should include summaries of the test data and conclusions drawn.

*Printed Circuit

Final Specification Design Review is held to assure that the specification is correct, complete, and acceptable prior to release to Documentation Control. The data supplied to the reviewers is a complete specification.

Pre-Release Mechanical, Logic, and/or Circuit Design Reviews are held to examine the details of changes found desirable or necessary in the prototype manufacture and evaluation prior to limited release for pilot production. The reviews may be combined if the changes are minor.

Final Mechanical, Logic and/or Circuit Design Reviews are held to examine the problems and corrective actions found desirable during pilot production prior to release to full production.

2.4 PROTOTYPE EVALUATION

Objective:

To shake the bugs out of your design; to document what it can *and can't* do.

People Involved:

- Engineering
- Component Engineering
- Model Shop
- Diagnostics
- Environmental Testing
- Reliability

Tools:

DEC Standard 102

Your test strategy depends on the intended market, the intended manufacturing process, and the object itself. Component engineering, test equipment engineering, and reliability can help with a test strategy. Reliability can also help in statistical analysis.

You will need diagnostics to help test your product. Make sure diagnostic engineering's schedules mesh with your own.

Here is a partial list of the kinds of test equipment we use:

ICs

Teradyne J384s
Macrodata 100s

System Testers

ACT11A
ACT11B

Module Testers

CMT
XOR
DD11
General Radio

We have test chambers for environmental testing for heat, humidity, and supply voltage and frequency. These factors can be isolated or coupled. Outside testing facilities are used for additional testing as required.

When you are satisfied with your design and have signed off the print set, Reliability will make some very long tests under controlled, realistic environments. They do this with engineering prototypes and early production models. Total testing in the prototype and early production stages runs between 10,000 and 40,000 unit hours for major, high-volume products.

In order to build a prototype, you will probably need to use the model shop. They have facilities for everything from rough boxes made from early sketches to limited release and production release.

Environmental Testing and Acton Labs do the testing required by DEC Standard 102. Refer to the standard for more information.

2.5 DOCUMENT IT

Objective:

To describe clearly, accurately, and completely the item you are trying to build.

People Involved:

Creators:

- Design Engineers and Technicians, Satellite Supervisor, Design Drafting, P.C. layout (manual and automated) — Internal Documentation
- Design Engineers and Technicians, Training, Technical Documentation — User Documentation

Users:

- Manufacturing
- Field Service
- Training
- Customers
- Software Engineering

Maintainers:

- ECO Control (Internal Documentation)
- Technical Documentation (User Documentation)

Tools:

Functional Specification
Field Service Philosophy
DEC Standards 003, 010, 012, 013, 014, 015, 018, 019, 020, 021, 022, 023, 024, 050, 054, 056, 100

Internal documentation is required to allow manufacturing to make your project and field service to service it. User documentation allows our customers to get the best use from your product.

You ought to contact the Technical Documentation Group and your satellite supervisor when you are setting up your schedule. They can help you with that, and with your budget.

In general, the more information you put into your specifications, drawings, and so on, the faster and better the documentation job. In the technical documentation area especially, the biggest problem is access to good information. Try to make yourself available for questions.

Good documentation allows our field service people to save money. Even more important, it makes our people more efficient. This is important when the supply of qualified people is limited. You can work a significant cost savings for your product by making sure you get the best documentation possible.

P.C. layout can be manual or automated. The manual job takes eight to ten weeks; the automated job takes less. For boards made to DEC Standard 030, with fewer than 100 ICs, automated P.C. layout takes four to five weeks, and there is no need for an extra week for GEMS* digitizing.

Once you authorize limited release of your product, your drawings go under ECO control, and you must sign off any changes made after that. DEC Standard 100 describes the ECO process. Make sure the Training Department is aware of your product and is scheduled to give courses at the appropriate time. They can give you feedback on how much documentation is necessary. Anything *you* don't supply that they need, *they* will have to write themselves – at greater expense (because they often have less information to work with) and with less general usefulness (because training materials do not get the same kind of distribution that standard user manuals get).

When you are ready to sign off your prints, you should hold a design review.

*GEMS is described in the paragraph on Design Drafting, Chapter 3.

2.6 TEST IT

Objective:
To make sure we have testing equipment and procedures for manufacturing and field fault detection and analysis.

People Involved:
- Engineering
- Manufacturing Manager
- Test Strategist (A representative of Test Equipment Engineering)
- Reliability
- Environmental Test
- Diagnostic Engineering
- Model Shop

Tools:
- Test Strategy
- Business Plan (For projected volume)
- Manufacturing Plan

The engineer, a person from the manufacturing team, the test strategist, and people from reliability, diagnostic engineering and Field Service Product Support should work out the manufacturing and field test strategy.

Test equipment engineering will take care of volume production of testers; the model shop will make testers in small quantities.

2.7 GETTING IT INTO MANUFACTURING

Objective:
To translate your design into objects our customers can use.

People Involved:
- Engineer
- Manufacturing Manager and Team
- Drafting
- Field Service
- Marketing
- Relevant Plant's Materials Manager
- Purchasing
- Component Engineering
- Purchase Specifications
- Process Engineering
- Central Test Engineering
- Diagnostics

Tools:
- Business Plan
- Manufacturing Plan
- Parts List, Purchase Numbers, and Purchase Specifications
- Product Line Forecast

Procedure

More important than anything else, you must identify the manufacturing facility that will build your product. The choice of manufacturing facility will influence the choice of your 2X2 partner. You should identify that person very early in the life of your project. Here are the kinds of things required for introducing a product to manufacturing:

Complete Documentation:

Complete parts list, including part numbers and purchase specs.

Manufacturing print set for all modules and testers.

Training for technicians

On-site support

Diagnostics and tester software. (Major systems use so-called ACT testers – Automated Computer Testing. Software for such systems must be budgeted separately.)

Models

Templates for insertion, or tapes

Multi-sourcing for new components

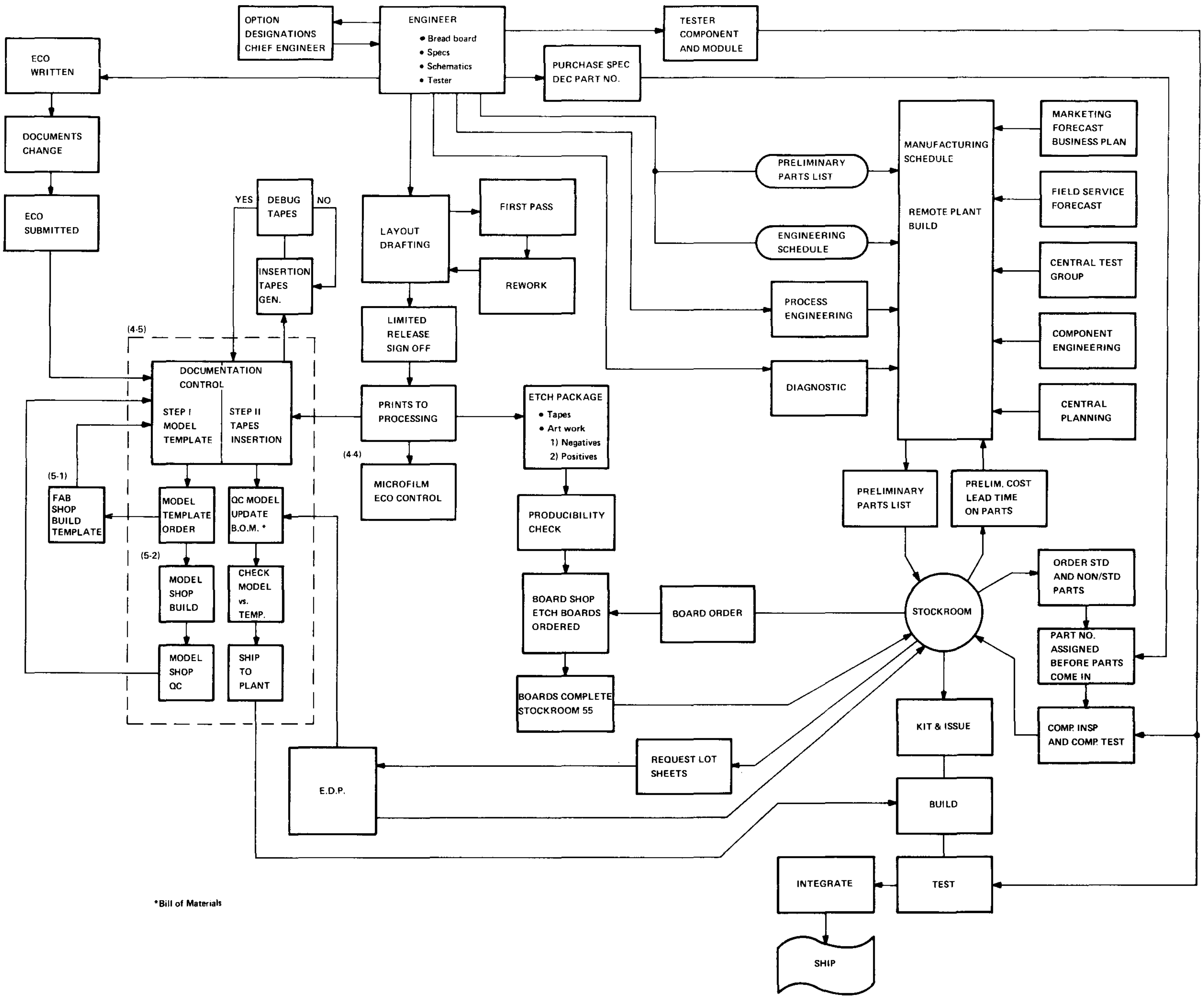
Incoming inspection procedures and test equipment

Testing procedures and equipment

If you are using new or unusual parts, be sure to allow enough time for the facility to stock them. Purchasing can help you with this kind of information. Figure 2-2 is a flow chart showing the steps for getting a product into manufacturing.

2.8 INSTALL AND ACCEPT IT

The engineer, field service product support person, and marketing manager, with the help of the systems programmers, diagnostic programmers and software support people, should work out any necessary installation procedures and a customer acceptance test upon completion of the system the customer pays for.



*Bill of Materials

Figure 2-2 Getting a Product into Manufacturing

CHAPTER 3
WHO

An engineer may not need the services of all the groups described in this chapter, but he or she should know what help they can offer and at what stage of product development an engineer should seek their help. The purpose of the planning stage is to forecast which groups will deal with the project and when. The project budget ensures that the engineer can get help when needed.

3.1 SOFTWARE ENGINEERING (Prime contact: Mel Woolsey)

The support that systems software gives to a product is a function of budget and negotiations between the hardware and software product managers. When software engineering supports a device, they do (potentially) all of the following:

1. Help define "functionality."
2. Help specify the implementation (bit layout).
3. Write I/O drivers for many operating systems.
4. Worry about the special conditions peculiar to so-called system devices (characteristics of system devices include random access and high speed).
5. Modify system generation procedures to include the new device.
6. Augment error-logging code, if needed.
7. Enhance stand-alone utility programs such as ROLLIN, if needed.
8. Write code for hardware bootstrap, if needed.
9. Worry about devices that may serve as distribution media (e.g., paper tape, DECtape, cassette, RK05, etc.), as follows:
   a. Distribution may affect packaging of the product.
   b. New order codes must be assigned for all affected software.
   c. The Software Distribution Center (software's equivalent for manufacturing) must obtain equipment to duplicate the software on the media.
   d. The Software Distribution Center's copy and verification software must be written.
10. Create on-line diagnostics, if needed.
11. Document all the above actions.
12. Create spooling programs, if needed.
13. Integrate this work into many, asynchronous schedules.

Currently, contacts with software engineering often happen on an *ad hoc* basis, and usually require persistence on the part of the engineer. If your product is affected by software, it is important to make this relationship.

In the early stages of product planning, this is what should happen:

1. The hardware product manager should see the software product managers' group leader in the early stages of the business plan.

2. That person should log the contact and redirect the request to the appropriate software product manager.

3. The product manager should establish the software end of the business strategy: "Will we support this device?" "In what systems?" "To what degree?", etc., and coordinate with the appropriate development manager(s) to obtain a commitment and resolve budgets, schedules, resources, etc.

4. This commitment, in the form of a formal revision to the software project plan, is conveyed by the software product manager to the responsible hardware manager for inclusion in the hardware manager's plan.

Software engineering primarily functions to create software for customer use. In carrying out that function, they use production equipment and expect a high level of reliability and service, as any customer would. Software engineering also supports new devices. In this role, the equipment they use is radically different. They need to test their systems on unproven prototypes and pilot run units. For such testing, the following issues must be resolved:

a. Who capitalizes the system?
b. Who services the system?
c. Who operates the system?

Not only should your prototype test configuration be able to contain the system software (i.e., with enough core and peripherals), but it also should be as well human-engineered as possible. For example, printers for listings and Teletypes should have an adequate supply of paper and ribbons. The system should be as clean as you can make it. Try to avoid hanging wires, etc.; try to be sure the console terminal is close to the console, not ten feet away.

In general, it is not sufficient to test hardware with diagnostics and functions exercisers. System software should be used to test new devices at the prototype stage. Before announcement, early models should be thoroughly tested with system software.

The software product managers' group can help you decide which operating systems should support your product and put you in contact with the proper people.

Software Engineering Standards
The Software Engineering Standards Committee is responsible for defining standards relating to data formats, file structures, and anything else pertaining to hardware/ software interfaces. If you think your product requires a new standard, or if it must conform to existing standards, contact engineering's representative on the committee.

Designated Consultants
There are people in software engineering who know a great deal about how software must interface with certain device classes, such as disks and terminals. If you cannot identify one for your area, the Software Planning Group will help you find such a "designated consultant."

When Should you Contact Software Engineering?

1. Contact the software product managers' group as soon as you have funding (or before).

2. Before you fix the design, contact your designated consultant.

3. When detailed specs are available, drivers for testing the prototype should be started.

4. When the prototype runs a function exerciser without errors, you should test it with system software.

5. When pilot run occurs, system tests should be planned and implemented.

What Software Engineering Can Supply an Engineer

1. A decision on which systems should support the device.

2. Commitments to support it on those systems on a date consistent with product line needs and software engineering's ability to schedule the Software Distribution Center.

3. Help in defining the software interface which will come from the designated consultant and must occur during the early functional design stage.

4. Drivers for testing the prototype with system software.

5. Extensive testing on pilot run units.

What Software Engineering Needs From the Engineer

1. Early contact.

2. Persistence.

3. Detailed specs from which to create drivers and define intelligent tests and standards.

4. Test configurations and any agreed-upon service, operation, and capitalization.

Management Tools that Help Make This Relationship

1. Business Plans to help decide which systems should support your product.

2. Specifications to allow drivers and standards to be created.

3. Project Plans. Software Engineering uses a fairly well-defined project plan outline. Each project leader must create a project plan for each project. This is probably a good vehicle for making sure you get the support you need. Either your device should be mentioned in a more general project's plan, or they should define a special project for supporting it.

4. Software Engineering Standards.

5. Test Plans. Formally or informally you should agree on a test plan that will wring out your product before customers can get their hands on it.

6. Engineering Functional Specifications to allow drivers to be created.

3.2 COMPONENT ENGINEERING (Prime contact: Dick Amann)

When Should you Contact Component Engineering?
As soon as you contemplate a new component. Description of the Purchasing/Component Engineering process is contained in Paragraph 3.4.

What Component Engineering Can Supply an Engineer

Documentation – Ensure technical content and accuracy of:

Purchase Specs

Qualified Vendor Lists (QVLs)

Component Index

Incoming Inspection Procedures

Master Parts File Descriptions

Generate:

Missing Incoming Inspection Documents

Incoming Inspection-Related Documents (Test Programs/Tester Documentation)

Component/Testing/Evaluation Audit Guidelines

Master Parts File Component Ratings

Purchase Spec Formats

DEC Alert Notes (Specifying Component Problems)

Component Testing – Component engineering also generates audit guidelines to ensure that component testing and component purchasing at all manufacturing locations are performed in accordance with standard Digital procedures.

- Select and specify test systems.
- Order and expedite tester hardware or software purchased outside.
- Generate component tester test programs per Digital specification and incoming inspection procedures.
- Perform a QC function on tester hardware and software purchased outside to ensure that it meets Digital's testing requirements.
- Distribute test hardware and software to the requesting plants.
- Maintain a status of test capability for all plants.
- Determine screens to be applied to purchased components.
- Specify and select equipment needed to perform screens.

Solution of Manufacturing Problems – Device and test problems.

Evaluations – The component engineering group provides resources to fight "crisis" component problems at all manufacturing locations, regardless of whether the problem is equipment or component related. This includes a commitment to hold periodic "Component Evaluation Consortiums" during which priorities of additional source evaluations will be set. Included in this item are failure analysis, correlation of vendor reject data, and initiation of corrective actions. Evaluations are made of:

- New parts
- New technology
- New suppliers, including companies with which Digital may enter into technology cross licensing.
- Additional sources.

Another function of the group is to perform evaluations on purchased parts including the development of a well equipped evaluation lab and the development of evaluation procedures.

The Lab – Component engineering will develop a lab to accomplish this charter:

- Support for manufacturing and engineering projects.
- Failure analysis.
- Evaluations of components and processes at package and chip level.

The 2 x 2 System of Bringing New Components or Technologies into Digital – Component engineering works with design engineering to introduce new parts and technologies into the corporation in a manner that will ensure successful application. As part of the project development costs, they are responsible for the following:

- Qualify each vendor's QC procedures and test plan.
- Evaluate the vendor's process and design.
- Generate a test plan for Digital and supervise its implementation.
- Qualify the vendor based on performance for some predetermined number of parts/lots shipped to Digital.
- Perform a failure analysis on failed parts during the qualification phase and feed the results back into the test plan.
- Continue to support the part or technology throughout its manufacturing life.
- Continue to monitor the test plan so that intelligent changes can be made that will reduce the testing cost.

Vendor Quality Measurement System – Component engineering initiates the periodic monitoring of shipments from our vendors and develops meaningful vendor rating schemes.

Generate Test Flow and Capability to Systems Integration Area for Highly Complex Devices Used in High-Volume Manufacturing – For certain highly complex, system-on-a-chip type devices used in high volume manufacturing, the component engineers' responsibility extends to providing test flow capability through to systems integration.

What Component Engineering Needs From the Engineer

1. Early consultation
2. Funding for projects to be undertaken

Management Tools that Help Make this Relationship

1. Part Number Request Forms for all new components must be signed by component engineering before parts are approved for use by Digital.
2. The *Component Index Book* and the *90 Class Index Book* are circulated.
3. Parts reviews of new products are made.
4. DEC Standards.

3.3 PURCHASE SPECIFICATION CONTROL (Prime contact: Bill Burns)

When Should You Contact Purchase Specification Control?
When engineering design is firm.

What Purchase Specification Control Can Supply an Engineer

Purchased Parts Information:

1. Assist engineer with purchase specification requirements.
2. Purchase specification writing and typing.
3. Purchase specifications – master file maintained.
4. *Multi-class Component Index Book* – available by request.
5. *90 Class Component Index Book* – available by request.
6. Incoming inspection procedures – file and distribute only.

Vendor Information:

1. VSMF – microfilm cartridges by vendor name and purchased commodity. Military specifications and standards are also available.
2. Selected vendor catalog files based on activity level.
3. Qualified vendor listings primarily for purchasing and incoming inspection use.

DEC Standards:

1. Administration and distribution.
2. Subject to engineering committee approval.

What Purchase Specification Control Needs From the Engineer

1. Good purchase specification inputs (known fixed requirements).
2. Positive response when requested to sign off a finished specification (i.e., same day).
3. Proper planning of design schedule to allow specification control sufficient time to process requests.

Management Tools that Help Make this Relationship

1. All purchased parts released to volume manufacturing must reflect a Digital-assigned part number (i.e., 10–99 classes) for control and identity.
2. Prior to part number assignment, a Part Number Request Form must be filled out and fully approved. A hand-written spec and/or vendor data sheet must accompany the part number request for approval signature and submission to spec control. Forms may be obtained by dialing our information desk at Maynard, Building 5-4, Ext. 2050.

3.4 PURCHASING (Prime contact: Andy Dufresne)

When Should You Contact Purchasing?

During the planning stage.

What Purchasing Can Supply an Engineer

Purchasing can provide the long term business picture in the component selection process: Is the usage of that component type a long term viable approach? Will Digital's existing and proposed usage outstrip the capability/willingness of the marketplace to provide? Is the cost structure of that component realistic relative to the actual quantity usage during prototype stages, pilot production, and high-volume production? Are we designing in specialty items that will limit Digital's multiple sourcing capability and its ability to grow? What has been the historical relationship between that vendor and Digital?

Specific purchasing engineer/analysts are assigned to general part classes to assist you and the buyers in vendor selection sourcing and problem solving.

Consortiums are formed to handle high-volume, repetitive, on-going requirements. The purpose of a consortium is to put Digital in the best possible position to achieve ultimate pricing and delivery performance from the marketplace. Consortiums are composed of part class buyers from each buying location, the component engineer, and the purchasing engineer/analyst with that commodity responsibility, headed up by a commodity manager with leadership responsibility for that commodity group.

What Purchasing Needs from an Engineer

1. Specification details
2. Quality standards

Management Tools That Help Make This Relationship Communication.

Purchasing Group Locations and Services in Maynard

Field Service Purchasing (PK 3-2) – This group services all the part service requirements for customer support in the field.

Maynard Manufacturing (Mill complex, 5-4) – This group services all the inventory and expendable material requirements of that organization.

Supplies and Services Purchasing (Mill complex, 5-4) – This group is responsible for supporting all other groups in the Maynard complex not mentioned specifically. Out of this group comes the support for the engineering world. Some of the major classifications of this group are capital equipment, chemicals, lab supplies, line printer paper, tools, consultant services, nonstandard office equipment and supplies, and the complete line of inventory class items in support of the engineering groups located in the Maynard complex.

Corporate Purchasing (currently located at Mill complex, 5-4) – This department functions as coordinator and policy maker, representing purchasing to the corporation and marketplace. Corporate purchasing provides the purchasing interface to Digital management (finance, legal, engineering, marketing, and others) and provides training, technical support, EDP tools, and analytical data to enable field purchasing groups to operate more effectively.

Purchase Orders (from *Office of Development Handbook*)

1. What is a purchase order?
   A purchase order is a document that indicates the company's commitment to take delivery of a product or service from a vendor outside the company. It also serves as an accounting document because it indicates the cost center, account, and, if applicable, the project to which the resulting expense is to be charged.

2. How to fill out a purchase order.
   Leave most shaded areas blank. A purchase order must be signed with an approval signature by a person authorized to sign purchase orders for at least the amount of the purchase order. Enter your badge number, cost center number, and the account number to be charged.

3. Accounts commonly used on purchase orders.

Expense charged directly to a project	Expense charged to cost center overhead	
8381	7326	
8384	7351	
	7353	
8389	7329	
	*2109	Typewriters
	*2105	Engineering test equipment

NOTE

An account from the left hand column (known as "80 range accounts") must be used to charge a project. If you enter an account number other than 80 range, the expense goes to your cost center overhead no matter what project number you put down.

4. ACT CODE
   This means activity code. In order to charge a project you must enter a letter that is an applicable activity code for your cost center. In general, these codes are:

Diagnostic Engineering	V
Software Engineering	P
Hardware Engineering	E

   ACT. CODE must be filled in if you used an 80 range account. If you did not use an 80 range account, leave ACT. CODE blank. Three boxes, labeled 1, 2, and 3, appear next. These boxes are used to indicate the project to be charged. Therefore, if you used an 80 range account, enter project number as follows:

1	2	3	
98	03112		The project number must be a valid one. Accounting publishes a list of valid numbers monthly.

   Box 3 is always blank for engineering cost centers. If you did not use an 80 range account, leave 1 through 3 blank.

---

*Capital Account used only for capital equipment, i.e., equipment with enduring value not to be used for purchase of services or software.

5. Additional Information
   Buyer code – Leave blank.

   Requested by – Enter your name.

   TEL EXT – Enter your phone extension.

   Location – Enter your office location, e.g., Maynard 1-3.

   Sales Tax – always check "taxable" unless it is to be used in units that will be shipped.

   Ship to – Since we use the same purchase order form in several locations, you must check off where you want the product delivered. For bulky or heavy objects, indicate a receiving dock close to where the equipment will be used. Receiving docks are located at:

   Maynard Mill Dock, 5-1 Thompson Street, 5-3 Thompson Street.

   Parker Street, PK 1, PK 3-1.

   In the body of the purchase order, indicate quantity, description, and part number (if known). Once the purchase order has been approved, send to the Purchasing Department at Maynard, Building 5-4.

3.5 DESIGN DRAFTING (Prime contact: Dick Reilly)
Design Drafting is decentralized so that the drafting and printed circuit design services can be closer to engineering. Engineering services and drafting satellites are located in the Mill, Buildings 1, 4, and 5, and in Marlboro.

These satellites perform five basic functions:

1. Provide manual and automated design drafting assistance.
2. Do manual and automated P.C. design.
3. Provide information about DEC Standards, documentation and its structure, and related corporate guidelines.
4. Watch spending for all engineering services.
5. Act as communications link for all engineering services.

Your principal interface with design drafting is the satellite group supervisor. If you are uncertain which satellite area services your group, call the prime contact.

When Should You Contact Design Drafting?
When you have official funding, contact your satellite supervisor. He or she will prepare a complete estimate of time, money, and necessary data or forms required for your project. Design drafting annually forecasts in June. Satisfactory results in providing support are heavily dependent upon forecasting, planning, and early interfacing with the satellite.

Engineering services satellites should be informed about project requirements as early as possible. Preliminary conversations should develop an awareness about a project's potential size and possible type of support so that proper planning and staffing can be arranged; the project definition can be developed through additional meetings.

What Design Drafting Can Supply an Engineer

Engineering Drafting – Design drafting's objective is to create the documentation needed to describe an engineering design and release it to production. Design drafting has a responsibility to follow generally accepted good drafting practices and, in particular, to follow DEC Standards and corporate guidelines.

If you are heavily involved in documentation, you should ask your satellite supervisor for a copy of the *Production and Engineering Services Drafting Manual*. This manual is distributed to a limited list of individuals involved in documentation and is under ECO control.

Existing documentation standards relate to numbering codes, drawing directories, documentation quality for microfilming, casting, harnesses, cables, lettering, dimensioning practices, schematics, and checking drawings. There are *no* standards in flow and timing diagrams. Design drafting personnel in the satellites know the general trends for the product lines they support and try to keep each product line internally consistent while always satisfying basic requirements of existing corporate standards.

P. C. Layout – Design drafting performs manual and automated printed circuit layout. The increasing use of automated techniques has improved both the turn-around time and quality control. CALDEC, the major automated system in use, allows board layout by a P.C. designer utilizing the GT15 graphic display unit controlled by a PDP-15. In 1974, almost one-third of the boards were done using CALDEC; in 1975, the proportion should double.

Manual P. C. layout uses the GEM system to digitize the manual drawing for line, hole, and component placement data. Boards designed using CALDEC and those digitized via GEMS both go through automated post processing for space and continuity checking, preparation of check plots, creation of numerical control tapes for drilling and component insertion, and creation of glass artwork.

To take advantage of the current automation capability, the engineer should design with CALDEC in mind; that is, component density should be kept down and the schematic and parts list kept clean and up-to-date. The present automated system is memory-limited in its ability to handle high-density boards. The effect of high density on design time is shown in Figure 3-1.

Any type of board can be made by manual design. The development time is dependent upon size, density and circuitry. In order of increasing difficulty, these types are:

1. DEC Standard 030 boards
2. Nonstandard boards
3. High-density boards
4. Multi-layer boards
5. Multi-layer, high-density boards

What Design Drafting Needs From an Engineer

1. Proper funding and project schedules.
2. Sketches.
3. Conversation and close interaction.
4. Engineering drawings.

3.6 DIAGNOSTIC ENGINEERING (Prime contact: George Plowman)

When Should You Contact Diagnostic Engineering?
It is extremely important for diagnostic engineering to participate in the very early conceptual stages of the development of the product. This allows time for incorporating hardware/software tradeoffs that are necessary to ensure a producible and maintainable product.

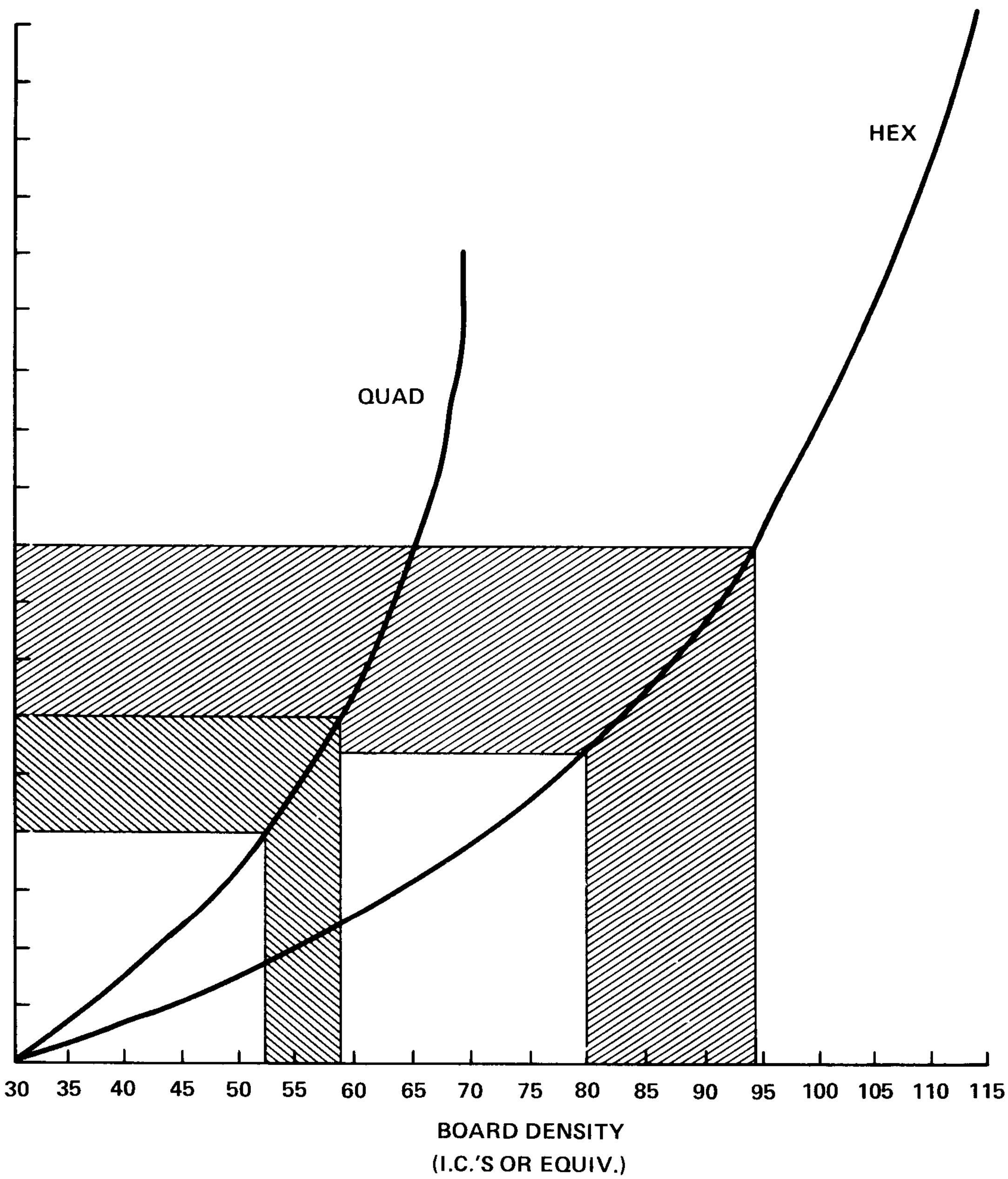
What Diagnostic Engineering Can Supply an Engineer
Diagnostic engineering is involved in a product from its conception through its entire life cycle and it is a tool that the engineer uses to meet the performance, producibility, and maintainability goals for the product. This is accomplished through an understanding of these goals and of the hardware/software tradeoffs that can be made to afford a practical solution to these goals. During the course of the engineer's involvement in the product, diagnostic engineering provides the following:

1. Product Concept and Project Planning Phase
   - Participate in the generation of engineering, manufacturing, field service, and diagnostic plans for the product.
2. Product Design Phase
   - Participate in product design and assist engineer in hardware/software tradeoffs and logic partitioning decisions.
3. Engineering Checkout Phase
   - Provide design check programs to validate hardware design per specification.
   - Provide special assistance during design checkout.
   - Provide test software to ensure that the product can be integrated into the systems environment.
   - Provide special evaluation programs as may be required by the engineer.
4. Release of Product to Engineering
   - Provide semiconductor and module test programs for manufacturing.
   - Provide device and system test programs for use by manufacturing to meet specified manufacturing goals.
5. Shipment of the Product to Customers
   - Provide maintenance programs to field service in accordance with specified maintenance goals.
   - Provide continued sustaining support for the diagnostic programs during the life of the product.

MAN–HRS VS. BOARD DENSITY

SYSTEM TIME

(Shaded areas indicates preferred limits)



What Diagnostic Engineering Needs From an Engineer

1. A project plan and project leadership to coordinate the efforts of the other project team members.

2. Concept review, design reviews, design specifications, schedules, project reviews, etc.

3. Funding to support product development and maintenance effort for diagnostic programs.

3.7 THE MODEL SHOP (Prime contacts: George Geralds, Manager; Sheila Farland, Material Controller)

When Should You Contact the Model Shop?

1. Machine shop, prototype assembly, and production model shop – whenever you need them. If they can't handle your job, you can talk with the engineer whose job they are working on and try to work something out.

2. For odd jobs and testers, they need a month's notice because these have low priority.

What the Model Shop Can Supply an Engineer

The model shop comprises four groups:

1. The machine shop fabricates sheet metal, plastic, wood, clay, or foam mock-ups, and furnishes machine shop services in general. They can tell you what is easy or hard to manufacture.

2. The prototype shop assembles prototype modules, small sub-assemblies and cable harnesses. They also can tell what is hard to manufacture; they look for errors.

3. The production model shop provides:

   - P. C. board models for limited release (LR) and production release (PR).

   - Sub-assembly models other than PC boards for LR and PR.

   - Hand testers for items that don't use AMT or CMT standard test equipment or low-volume items.

   - Odd jobs – anything at all, from wire wrap boards to show mock-ups to low-volume customer production to harnesses and cables that the prototype shop can't build.

   - Quality Control – this goes for all models (PR and LR) and anything made for a customer.

4. The engineering stockroom – stocks company-preferred components to avoid obsolete or non-preferred parts being designed into new units.

What the Engineer Must Give the Model Shop

Machine Shop – A valid charge number on a filled-out work order and some idea as to what is desired. The more details you supply, the more they are likely to build what you want. Sketches, blueprints, verbal instructions. This process almost always takes several passes. Please don't order more than you absolutely need until you know what you want.

Prototype Shop – A valid charge number on a filled-out work order; an assembly hole (AH) drawing; a parts list and a circuit schematic. The prototype shop works closely with design drafting. If you want a prototype from design drafting, they will forward the documentation to the shop, and the prototype shop will use their work order. The engineer must ensure that design drafting and prototype assembly do not get out of phase when changes occur in the design. The procedures are rather informal, to make changes easy, but that means *the engineer must be careful that everyone knows what is going on.*

Once in design drafting, more or less automatically the prototype shop makes up a prototype. If you need special work done outside of the design drafting loop, go to the materials controller and fill out a work order.

As with the machine shop, this process almost always takes several tries. Please don't order more boards (or whatever) than you need until you know what you want.

P.C. Boards – LR (limited release) and PR (production release):

1. Contact your satellite supervisor or the ECO layout group for LR or PR.

2. After that, work usually flows automatically to the model shop with the required documentation.

3. The engineer must sign the verification tag on *each* model before release.

Formal Print Sign-off:

1. Handled by ECO Layout group.
2. Required after QC for LR and PR.

Sub-assemblies -- LR and PR:

1. Contact model shop supervisor with formal or informal documentation to build from.

2. Must have Release Request Form signed by Dick Best (for power supplies or catalog items), and by drafting for anything else.

3. Engineer *must* sign verification tags on *each* item released.

Formal Print Sign-off:

1. Handled by model shop.
2. Required after QC for LR and PR.

Parts for LR or PR:
You will save time if you supply new and/or unique parts at time of release request.

For hand testers, all that is needed is a schematic, which may be formal or informal. Any critical areas, such as short wires or shielded wires etc., and any special notations must be on the print. Odd jobs for customers require formal documentation. Anything goes for other types.

Engineering Stockroom – The stockroom needs a valid charge number and lead time for parts they don't keep in quantity. When design drafting has made up a parts list for an option, they forward a copy to the engineering stockroom. The stockroom will usually try to buy time by ordering immediately, but for unusual cases, they will ask the engineer whether he or she really intends to use the part.

NOTE

Before parts can be ordered in quantity, before they can go through purchasing more than three times, and certainly before they get to the production model shop, they must have a purchase spec and a DEC number.

Management Tools That Help Make This Relationship

1. Work Order
2. Production Release Request Form
3. Parts List
4. Purchase Specs

Work Orders for Model Shop
The model shop in Building 5-3 (Mill complex), contains facilities for most sheet metal and milling operations. Some limited welding capabilities. Five men work in the mechanical part. (Prime contact: Ed Mayall)

Necessary steps to follow:

1. Come up with a sketch.

2. Take sketch to the woman in the office next to George Geralds (5-3).

3. She is responsible for typing out work order form (she will provide form).

4. Take order form with print to Ed Mayall for delivery date.

5. He will call when work is done.

NOTE

Delivery date is automatic; don't pay much attention to it. It can be negotiable with Ed.

Another model shop is located in Building 5-1 (Mill complex). The main function of this group is to make models for manufacturing. (Prime contact: Kevin Stankard)

Necessary steps to follow:

1. Fill out work order and submit sketch.

2. Check on them periodically.

3. You may have to supply materials at times, but generally they have everything in stock.

This shop is normally used for:

1. Large quantity items (10–20).

2. Complicated parts such as a panel with many holes or grill work.

The model shop in Marlboro is located in Building 1-1. (Prime contact: Arthur Huttla)

3.8 TECHNICAL DOCUMENTATION (Prime contact: Michael Moffa)

When Should You Contact Technical Documentation?

1. Prior to any formal periodic budgeting activity, with regard to current project costs and schedules.

2. To obtain hardware manual cost and schedule estimates for proposed new product design and development.

What Technical Documentation Can Supply an Engineer

1. Documentation planning and coordination.

2. Technical writing service.

3. Publication production service – Editing, illustrating, manuscript typing, typeset composing, and layout.

4. Coordinated printing, distribution, inventory, and revision control of the following types of hardware manuals:

   Site Preparation and Planning
   Installation Procedures
   General Description
   Theory
   Servicing
   Preventive Maintenance
   Illustrated Parts Breakdowns
   Operation/Programming
   System Reference Manuals (hardware-oriented)

What Technical Documentation Needs from an Engineer

1. A documentation plan that has been formulated by the product manager or project engineer, product support field service engineer, training course developer, and technical documentation writing group supervisor.

   The documentation plan should indicate the scope of the hardware manual project, schedule requirements, and the approved budget for the project.

2. Engineering drawings, equipment specifications, and any other technical information available.

3. Usually some engineering time for technical information and manuscript review.

3.9 MECHANICAL ENGINEERING/INDUSTRIAL DESIGN (Prime contact: Dave Nevala)

When Should You Contact Mechanical Engineering/Industrial Design?
Very early – prior to any hard design solution being fixed.

What Mechanical Engineering Can Supply an Engineer

1. Industrial Design, i.e., product appearance and product design concepts, panels, colors, etc.

2. Mechanical Engineering, i.e., packaging design, material evaluation, connector tests, heat transfer/flow casting, and molded parts design.

What Mechanical Engineering Needs from an Engineer

1. Description of the problem.

2. Market data.

3. Preliminary engineering specs and initial design concepts.

4. Production volume.

5. Estimated sales price or costs.

Management Tools That Help Make This Relationship
Only the understanding by engineers that service is available.

3.10 PRODUCT SUPPORT (Prime contact: Don Busiek)

When Should You Contact Product Support?
At least as soon as official funding starts – sooner for high volume or high cost items. For one-of-a-kind things, 3–4 weeks before shipment.

What Product Support Can Supply an Engineer

1. A responsible person.

2. Failure Data for existing products.

3. Ideas regarding maintainability (e.g., packaging and simplicity).

4. Design recommendations for maintaining machines.

5. Specifications for kinds and level of diagnostics.

6. Specifications of kinds and level of documentation.

7. Field cost per failure.

8. For cross-product peripherals, kinds of system diagnostics required.

9. Design tradeoffs, especially MTBF and MTTR for OEM vs commercial products.

10. System software considerations, especially for large machines.

What Product Support Needs from an Engineer

1. Understanding of field service costs.

2. Warning that product X is coming (big warning for big/high volume products, little warning for little/low volume products).

3. Data.

4. Product Plan.

5. Up-to-date specs.

Management Tools That Help Make This Relationship

1. Product Plan

2. "Maintenance Philosophy"

3. FSSP Statistical sort package (Call Faye Ibrahm)

4. Accounting Tools

5. Field Service Installation Quality Reports

Field Service Product Support Checklist

In general, with very high volume products such as the ones we make today, the more engineering helps the field service people, the lower the total cost to the corporation. You can reduce field service costs by doing your best to incorporate the following items into your design. Above all, try to continue working until you meet the goals set forth in the product support philosophy – especially the mean time between failures goal.

1. Is your error reporting as specific as possible? Avoid trapping multiple errors through the same register without having another one that gives more information.

2. Did you consider system needs when handling errors? Avoid creating limitations on system error diagnosis.

3. Did you incorporate maintenance features, such as data turn-around at key points in the logic?

4. Does your product have a fail-soft capability?

5. Are the diagnostics adequate for field service needs?

6. Are your specs complete and up-to-date?

7. Will your hardware react reasonably to common operator errors?

8. Does the documentation tell how to avoid such errors?

9. Did you use the *Digital* spec for your parts, not the supplier's spec? If the supplier's spec is different from the Digital spec, you may unconsciously rely on that difference. It is entirely possible that we will substitute another part that meets the Digital spec but won't do the job.

10. Is the site preparation documentation adequate? Did you give information on power surge, heat dissipation and electromagnetic interference?

11. Are the cables in either the option or the interface print set?

12. Were your vendor purchases made with an internal spec and design cycle to make sure we know what we are getting and we know how to fix it?

13. Are high-voltage terminals covered up so we avoid burns?

3.11 COURSE DEVELOPMENT (Prime contact: Mike Odom)

When Should You Contact Course Development?
Early in design development.

What Course Development Can Supply an Engineer
Complete educational package to train field service and other support personnel to properly maintain and support the engineer's product. Training is also given to customer students. Interfacing with the course developer, rather than with all instructors minimizes interruptions for education functions.

What Course Development Needs from an Engineer

1. Documentation
2. Consultation
3. Maintenance philosophy
4. Expected market quantities

Close working relationship, with early access to documentation helps course development progress smoothly. Technical critique assures accuracy of materials.

Management Tools that Help Make this Relationship
Recognition that the engineer should contribute to the educational package that supports the product.

3.12 INDUSTRIAL PACKAGE ENGINEERING (Prime contact: James Lawrence)

When Should you Contact Industrial Package Engineering?

1. During budget planning.

2. During mechanical packaging of components and thereafter.

What Industrial Package Engineering Can Supply an Engineer

1. Make sure the distribution function is well taken care of.

2. Make sure packaging cost can be minimal.

3. Help determine and design packages for rack-mountable add-on or OEM equipment. This enables a product to be shipped after DEC Standard 102 tests have been completed.

4. Design special pallets, if required.

5. Critiques and recommendations on vendor packing, if desired.

6. Aids and designs interplant packaging, as needed.

What Industrial Package Engineering Needs From the Engineer

1. Money (typical budget: $5 to 7K).

2. Projected quantities.

3. Definition of *all* parts that need packaging.

4. Manufacturing or flow plan for all materials.

5. As much information as possible about customers who will receive the product. For example, if we will never ship less than quantities of 100 in units of 10, we can save from $150K to 500K per year in shipping charges and packaging material.

Management Tools That Help Make this Relationship
DEC Standard 102.

3.13 RELIABILITY ENGINEERING (Prime contact: Donald Dawes)

Reliability Engineering is an organized engineering discipline using specialized techniques to make products more reliable. By reducing the number of failures in a product, we can:

1. Lower ECO activity.

2. Decrease amount of manufacturing testing.

3. Cut warranty costs.

4. Stock fewer spares.

5. Decrease field service manpower and dollar requirements.

6. Give customers more satisfaction and a better value.

When Should You Contact Reliability Engineering?
At inception of planning for a new product.

What Reliability Engineering Can Supply an Engineer

A Reliability Prediction – From a projected parts list and the known failure rates for these parts, they can make a mean time between failures (MTBF) prediction for the final product. This prediction does the following:

1. It shows what we can expect for an MTBF, if parts behave as experience has shown, and if there are no design errors.

2. It gives an early indication as to whether the product is even remotely likely to meet the product specifications.

3. It gives a baseline prediction to compare progress against.

4. It gives decision-tools for production strategy.

5. It underscores poor parts applications.

6. It helps in making business decisions (e.g., size and type of service organization, type of warranty) but it should not be used as an advertising tool.

The initial prediction may be made by the reliability engineering group. The detailed prediction is done by the designer with help from reliability engineering if necessary.

Reliability Maturity Test – The reliability engineering group has developed a test called a Reliability Maturity Test. Conducted by the reliability engineering group with the assistance of the product design group and the product manufacturing group, it certifies that the new design is ready for production. The test is conducted with prototype units to prove the design. It is repeated with early production units to check out the manufacturing system. Figure 3-2 illustrates how this test affects engineering and manufacturing.

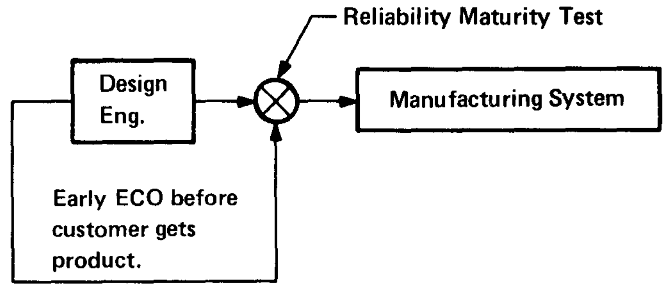


Figure 3-2 Reliability Maturity Test

For the engineering prototype, it measures whether the design is good and the parts are properly used. Long tests under controlled, realistic environments, with a large sample size (usually ten units) control:

Temperature
Humidity
Voltage and frequency
Combinations of the above

Sufficient test experience is accumulated to measure the MTBF to a confidence level of 90%. This measured MTBF can be compared to the product specification. The tests are largely functional, utilizing existing diagnostics and exerciser software. For the early manufacturing testing, they check:

1. Whether the manufacturing process has caused a problem.

2. Whether we should change the design to facilitate manufacturing, change the manufacturing process, or impose additional inspection or test.

Infant Mortality – They are studying mortality in products to:

1. Understand what factors affect the time it takes a newly-fabricated product to reach the low constant failure rate inherent in its design.

2. Help manufacturing and engineering groups to develop production test strategies that ensure that the customer receives a product free from latent defects.

3. Discover process-induced problems in specific products so the infancy period can be reduced.

Consultation in Statistical Engineering – They will help you write a test plan so that your results are statistically significant, checking:

1. Sample sizes.
2. Data analysis and interpretation.
3. The way the equipment is stressed.

What Reliability Engineering Needs From an Engineer

1. Scheduling: Product development schedule with milestones, particularly when hardware is available for test.

2. Money: Initial Reliability Estimate: $0–1000
   Reliability Maturity Test: $10,000–20,000

3. Product Specification

4. Design Specification

5. Hardware with software exerciser or diagnostic for test and operator assistance.

6. Technical assistance in diagnosing and correcting failures inversely proportional to product goodness.

Management Tools that Help Make This Relationship
None.

3.14 ENVIRONMENTAL TESTING (Prime contact: Frank Grimaldi)

When Should You Contact Environmental Testing?

1. Early in the project, to get acquainted.

2. During development, for consultation and design assistance.

3. 6 – 12 weeks of lead time are required for prototype testing.

What Environmental Testing Can Supply an Engineer

1. Dynamic Testing (DEC Standard 102 operational tests). They concentrate on vibration performance for transportation and in-service use – from the discrete product level to the board level. They do not, however, test rack-mounted items or perform random vibration tests because they do not have equipment for such testing.

2. Shock testing. They duplicate all "102" mechanical shock tests. For this purpose, they service the packaging group and product lines that do not go through packaging.

3. Temperature/humidity testing. They have a temperature/humidity chamber for DEC Standard 102 operational tests and engineering evaluation of prototypes.

4. Support for Action Lab testing.

NOTE

Procedures for Acton Lab and in-house testing and waivers are contained in DEC Standard 102.

In addition, they help in:

5. Developing added data analysis in vibration testing.

6. Developing thermal mapping capability for modules. This is a tool for development, reliability, and troubleshooting.

7. Acting as clearing-house for current status of all environmental testing.

8. Doing analysis for "102" testing and environment tracking for vans and railroad.

9. Reporting on the tests: they can supply pass/fail, raw data, or analysis.

10. Defining test plans to meet their test specs or goals.

11. Designing fixturing to hold down equipment to be tested.

12. Troubleshooting known field problems in established products.

What Environmental Testing Needs From the Engineer

1. Money: $1.5 – 2K for engineering evaluation tests. $1.5K for "102" operational tests for vibration, temperature and humidity, and mechanical shock. DEC Standard 102 specifies budgeting for Acton Lab testing.

2. Mechanical prototypes and (in very special cases) early line items.

3. Operating support *during* the test. *This is important.*

4. Test specifications or goals.

Management Tools that Help Make This Relationship

1. DEC Standard 102.
2. Test plan or test goals.

3.15 CENTRAL TEST ENGINEERING (Prime contacts: Dennis O'Connor, ICs and Modules; Russ Feener, Units and Systems)

Central test engineering coordinates the manufacturing test functions for all manufacturing plants. They are decentralizing most of their product-specific test equipment implementation functions to plant groups.

Centralized Functions:

1. New concepts
2. New test plans
3. New test methods
4. New test process generation
5. Project cost justification
6. Tester manufacture, installation, and training
7. Product test participation.

Manufacturing Plant Functions:

1. Project Coordination

   Design
   Specify
   Implement
   Build prototype

2. Monitor tester capacity (i.e., yields)

3. Manufacturing engineering support

4. ECO update

5. Fire fighting

They divide their work into four areas:

1. Incoming inspection of ICs (here, they work with component engineering)

2. Testing at module level

3. Sub-assembly testing

4. Final system integration and test

They are developing the idea of assigning a "test strategist" to work on the manufacturing half of the two-by-two team. Test strategists are essentially project leaders for manufacturing testing. Their responsibilities include:

1. Definition of test requirements for incoming inspection, module test, subsystem test and final system test.

2. Project design, implementation, and coordination for testing in all those areas.

3. Engineering support for the product's testing.

In general, central test engineering tries to:

1. Promote unattended testing capability – Digital is growing too fast to hire enough people to test everything.

2. Design-in self-diagnosis at the unit and system level.

3. Obtain "real estate" in custom LSIs for testing purposes.

4. Push testing and diagnosis to the most cost-effective level.

5. Screen and diagnose faults at module, unit, and system levels.

6. Reduce manufacturing and field costs through improved testing.

When Should You Contact Central Test Engineering?

1. Before the budget is fixed to allocate proper dollars.

2. Before design is started to develop a test plan.

3. Before P.C. layout to ensure proper partitioning for testability and diagnosability.

What Test Engineering Can Supply an Engineer

1. A test plan developed by the test strategist.

2. Direction in how to partition for testability and diagnosability.

3. Screening to stop untestable or unmanufacturable products from going to manufacturing.

4. If engineering and manufacturing are linked in a vertical structure, they will participate in design reviews.

What Test Engineering Needs From an Engineer

1. Funding, to support an agreed-upon level of test engineering participation.

2. Product specification.

3. Product performance specification.

4. The latest module, unit, or system drawings (depending on what is to be tested).

5. Goals for product volume (top and bottom figures).

6. Engineer's estimates of manufacturing cost.

7. Attendance at monthly test engineering status reviews to assure project coordination.

Management Tools That Help Make This Relationship

1. Product spec
2. Product performance spec
3. Test plan

3.16 PROCESS ENGINEERING (Prime contact: David Widder)

When Should You Contact Process Engineering?
At least before the electronics fabrication scheme is frozen. If you want dedicated help, they need three months warning.

What Process Engineering Can Supply an Engineer
Process engineering supplies information about manufacturing and testing. They will help you make financial and technical tradeoffs on:

Circuit boards
Modules
Interconnection systems
Cable harnesses
Wiring
Wire wrap
Basic systems

They will also consult on testing at the basic system, module, and incoming levels.

They will help you understand the benefits of design constraints imposed by high-volume manufacturing. Thus, if you want lower manufacturing cost through automated manufacturing, you will need standard board sizes, machine insertable components, standard pin spacings, component spacings, test techniques, and so on. They will suggest things like using two 1/2-watt resistors in parallel instead of a single 1-watt resistor, because the 1/2-watt resistors are machine insertable while the other isn't. They will advise you on the implications of DEC Standard 030 for your product.

They will explain how Digital manufactures things. They recommend that every engineer tour our manufacturing facilities, and that every design engineer consult with them before the electronic fabrication scheme is frozen. They are always available for a few hour's consultation. In some cases, they will dedicate an engineer to your problem or project, provided you set it up in advance and give them the funds.

Process engineering is charged with overseeing the entire manufacturing process. In this role they:

1. Improve efficiency in today's world. This sometimes involves making changes in the manufacturing process for current products. When a change affects the final product, they always obtain the approval of the project engineer. When it doesn't (for example, when they change from punch to slit), they do not seek engineering approval.

2. Plan for new facilities and manufacturing methods that will be cost competitive in the future.

What Process Engineering Needs From an Engineer
To provide you with consultation, they only need your presence. If you want one of their people dedicated to your project, they need lead time and money. They also need you to appreciate the fact that sometimes a seemingly painful restriction or requirement will cause a manufacturing saving that repeats itself thousands of times each month. Be sure to ask process engineers about differences among our high-volume plants.

Management Tools that Help Make This Relationship

1. DEC Standard 030.

2. Non-Standard Board Release Form: This is required whenever you use a non-standard component, pin spacing, or board size. You must obtain manufacturing approval of such boards via this form.

3.17 ECO (ENGINEERING CHANGE ORDER) GROUP
(Prime contact: Jim Gillette)

When Should You Contact ECO?
After prints have been signed off, changes must be made through this group *only*.

What ECO Group Can Supply an Engineer
A controlled method for updating engineering design.

What ECO Group Needs From the Engineer
Complete the ECO form (known as "yellow sheet"), then:

1. Submit ECO form to ECO Committee (meets every Friday at 9 a.m.).

2. Get approval of committee or appropriate engineering manager.

3. Turn ECO over to Arthur Vartanian (ECO Group).

4. After Arthur Vartanian has handled the ECO, you will be called in to look it over and sign it off.

5. ECO Group takes care of everything from this point on.

Management Tools that Help Make This Relationship
Engineering Change Order form.

3.18 ENGINEERING LIBRARY (Prime contacts: Renate Baptiste, Mimi Cummings, Sheila Wyatt)

When Should You Contact the Engineering Library?
Any time.

What the Engineering Library Can Supply an Engineer

1. Reference books

2. Periodicals

3. Newspapers

4. Proceedings of conferences

5. Vendor product catalogs

6. Competitive files (the EPAI Program – Exchange of Publicly Available Information. Participants are: Control Data, Hewlett Packard, Honeywell, National Cash Register, Univac, Varian, XDS, and IBM).

7. File of standards and specifications (EIA, ANSI, MIL, etc.)

8. Reference copies of:

   Master Spec Status Book
   Raw materials purchase parts list
   Components index
   Basic part number order

9. Borrowing facilities at MIT library

10. Assistance with specific research projects

11. Purchase order processing for printed materials and membership dues

12. Price and publisher information

13. Engineering Newsletter (monthly) lists new material and library development

What the Library Needs From an Engineer

1. Sign out borrowed materials.

2. Return material on time (loan period is two weeks; renewal available. Longer terms can be arranged.)

Library Hours
Library facilities and services are available to any Digital employee. Full-time librarians are on duty from 7:30–5:00, Monday through Friday. They will try to assist you with any of your questions. If you care to contact them by phone, their extensions are 2339 and 3824.

3.19 COMPUTATIONAL SERVICES (Prime contact: Sid Cronsberg)

When Should You Contact Computational Services?
Any time.

What Computational Services Can Supply an Engineer

Timeshared services on CS-2 (previously known as system 40) runs 7 days a week, 20 hours a day with operator support, and one more hour without operators. Field service operates CS-2 the other three hours.

They also support all standard DECsystem-10 software, including:

FORTRAN
COBOL
MACRO-10
BASIC
ALGOL
BLISS
MIMIC (a major simulation package)

Terminal clusters are in the Mill, Parker Street, and Marlboro. Parker Street and Marlboro will soon have Remote Job Entry Stations for output of *small* printouts. Large runs will still print out in the Mill (5-B), and come on a regular delivery. Access is also available via modems.

A *CS-2 User's Guide* is available from Sid Cronsberg's secretary. An update will be printed around December, 1974. Batch input through the terminal or via CS-2 operator work requests is possible, as is terminal time-sharing. CS-2 people will copy tapes, disk packs, and paper tapes, and make listings of files.

Time is also available on other DECsystem-10s in Marlboro on a limited basis. Computational services provides facilities management for some other computer systems, such as the small software engineering systems, the design automation system, and most DECsystem-10s in Marlboro.

A *Programming Staff* is available for consultation and some limited applications programming.

Software Preparation puts hand-written material into machine-readable form. Their services include:

1. Editing for RUNOFF output. (RUNOFF is a program that allows clean-looking printouts of ASCII files.)

2. Transcription

3. Assembly/compilation

There are satellite groups in the Mill, Parker Street, and Marlboro – and a night shift in the Mill.

What Computational Services Needs From an Engineer

1. A valid discrete project number.

2. Money allocated for the purpose.

3. An individual who wishes to get onto CS-2 must obtain an access number from computational services. A user's guide is available.

Management Tools that Help Make This Relationship
None.

CHAPTER 4
HARDWARE ENGINEERING REVIEW BOARD

4.1 CHARTER FOR HARDWARE ENGINEERING REVIEW BOARD

The Board's primary goal is to formally acknowledge all competent practicing engineers who otherwise would lack credentials.

Secondary goals include monitoring and accelerating the development of technical people at, or near the entry level. The Board will approve supervisors' proposals for promotions to engineering assistant, and will establish means for giving new engineers a working knowledge of key parts of the company (e.g., manufacturing) at minimum cost in time and failure.

We *don't* concern ourselves with B.S. degree holders; they don't need our acknowledgment. Neither do we concern ourselves with the level of supervisory or administrative responsibilities that proposed engineers may be carrying; other avenues exist for recognizing those contributions.

Our concerns are with the technical knowledge and ability and the engineering growth potential of the proposed engineer – *and* we evaluate both depth and breadth.

If the proposed engineer would be accepted as an engineer by careful engineering supervisors in other companies, we feel comfortable about saying yes. But we try not to impose standards higher than equivalence to fresh young B.S. graduates. Supervisors' inputs, peer evaluations (especially from groups other than the candidate's own), and personal interviews are always included in our evaluations. Specific engineering projects are discussed and supervisors (or prospective engineers through their supervisors) are encouraged to submit projects early so the board can help the supervisor plan a significant and measurable experience.

Monthly meetings are scheduled by a formula, and every member can mark his calendar to reserve this time months in advance. The secretary will notify each member by memo two weeks ahead, or by phone one week ahead to release those members whose presence is not specifically needed by the actual agenda. Members are expected to notify the secretary with these same lead times if they expect to be unavailable because a replacement may have to be selected to be fair to candidates.

4.2 THE PROCESS OF RECLASSIFYING AN EMPLOYEE TO ASSOCIATE ENGINEER

Identification of an Employee Who Has Engineering Potential

Engineering supervisors should always be on the lookout for technicians in their respective areas of responsibility who have demonstrated potential and interest in carrying out engineering responsibility.

Initial Discussion With Employees Who Have Engineering Potential

Once a technician with engineering potential has been identified, the supervisor should have a discussion with the employee concerning his or her personal ambitions/goals and determine whether or not the employee is interested in pursuing a career as a professional engineer. If the employee is interested in professional engineering, the supervisor should explain to him or her what is expected of an engineer and outline how the employee can achieve engineering status in the company. This initial discussion should also include a review of the employee's strengths and weaknesses and determine how the employee can work on areas of performance that need improvement.

Supervisor Plans Trial Assignment
If the supervisor feels that the employee is ready, a trial assignment will be developed which must be a legitimate test of the employee's engineering ability. This may mean a temporary transfer of the employee to another department if a trail assignment is not planned in the current department. The trial assignment must be developed in detail, including what the employee's responsibilities will be, a timetable for the trial assignment, and the performance criteria that must be met.

Discussion With The Employee About The Trial Assignment
After the trial assignment has been determined, the supervisor will outline the assignment in detail to the employee. This orientation to the trial assignment will include how the employee will be measured while performing the trial assignment, the documentation required, and a timetable for periodic reviews of the employee's progress by the supervisor during the trial assignment.

Preparation of Material for Engineering Review Board
Upon the employee's successful completion of the trial assignment, the supervisor will prepare a proposal to the Engineering Review Board requesting that the employee be considered for reclassification to associate engineer. This proposal will include:

1. An outline of the employee's overall qualifications:

   Education level
   Experience prior to Digital
   Experience within Digital

2. Outline the trial assignment. What was it? What was the goal?

3. What were the specific performance requirements and time schedules of the assignment, and specifically, how well did the employee perform against these requirements and time schedules?

4. What are the employees strengths? What is the assessment of his or her potential? Specific areas to be strengthened by schooling or other more sophisticated assignments should be outlined.

5. This proposal and supporting information should be forwarded to the appropriate personnel manager. The personnel manager and the engineering manager/supervisor review the material and jointly determine with the supervisor whether the employee meets the minimum requirements of the position of associate engineer. This may include a meeting with the technician and the personnel manager, or the engineering manager and the employee's supervisor.

When it is determined that the employee has met all of the requirements to be reclassified to associate engineer, the personnel manager will forward a copy of the proposal to the secretary of the ERB for inclusion on the next meeting agenda. Copies of the proposal will be forwarded to the ERB members in advance of the meeting.

Review By The Engineering Review Board
The supervisor will be scheduled to appear before the Board once the Engineering Review Board members have reviewed the proposal to reclassify an employee to associate engineer and are satisfied that the employee merits consideration by the Board. The supervisor will be asked to discuss the employee's technical performance on the trial assignment in detail, as well as the overall qualifications of the employee and his/her potential to advance in the engineering field. From this discussion, the ERB will reach a decision on the proposal.

The supervisor is then informed of the Board's decision. If the Board's recommendation is favorable, this recommendation is forwarded to the Salary Review Committee for final review and approval. If the Board's recommendation is unfavorable, a written report is provided to the supervisor outlining the reasons why the request was rejected and suggesting corrective action be taken.

The employee does not have to appear before the ERB in this phase of reclassification.

APPENDIX A
OFFICE OF DEVELOPMENT ORGANIZATION CHART

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        Updated: 10/10/74
         G. Bell

VICE PRESIDENT, OFFICE OF DEVELOPMENT (Gordon Bell)
!
!....PERSONNEL (Mark Abbett)
!    !----Software Senior Representative (open)
!         !----SOFTWARE PERS. REP. (Joe Underwood)
!    !----PERIPHERALS SR. PERS. REP. (Jerry Patton)
!    !----COMPUTER SYSTMS PERS.REP. (Dave Larson)
!    !----ADMINISTRATOR (Theresa Buckley)
!    !----PERSONNEL SERVICES ADMINISTRATORS
!         PERIPHERALS PSA (Jan Rodil)
!         SOFTWARE PSA (Patty Mercury)
!    !----CENTRAL RECRUITING SUPVR. (open)
!         !----Recruiter (open)
!         !----Recruiter (Leo McKiernan)
!         !----Associate Recruiter (Susan Coffey)
!         !----Associate Recruiter (Randi Love)
!
!----FINANCE (Phil Laut)
!    !----Planning (Al Sharon)
!    !....EDP (Arnie Goldfein)
!    !....SOFTWARE ANALYST ( Pat Spratt)
!    !....HARDWARE ANALYST (Irene Leary)
!    !....SYSTEMS ANALYST (Larry Smith)
!
!----CHIEF ENGINEER (Dick Best)
!    !----DESIGN REVIEW (Carl Noelcke)
!----TECHNICAL STAFF (vacant)
!....MEMORIES (Henry Lemaire)
!....COMMUNICATIONS OPTIONS (Vince Bastiani)
!....TERMINALS (Tom Stockebrand)
!....PDP-10 (Fred Wilhelm)
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!----VICE PRESIDENT, SOFTWARE DEVELOPMENT (Larry Portner)
!    !----MANAGER, SFT PRODUCTS GROUP Mgr. (Mel Woolsey)
!         !----MULTI-USER SOFTWR.Prod. Mgr. (Dick Angel)
!         !----REAL-TIME SOFTWR. Prod. Mgr. (Claiborne Neal)
!         !----LANGUAGES & UTILIITIES Prod. MGR. (Al Brown)
!         !----SMALL SYSTEMS SOFTWR. Prod. Mgr. (open)
!         !----SOFTWARE POLICIES Mgr. (Jim McKinley)
!    !----MGR. PDP-11 SOFTW.ENG. (Pete Van Roekens)
!         !----SMALL SYSTEMS SOFTWR ENG. (Ken Ellson)
!         !----LANGUAGEs (P. Van Roekens, acting)
!         !----NETWORK+Real Time (Frank Hassett)
!    !----DECSYSTEM 10 Softw. Eng. (Peter Conklin)
!         !----Decsystem 10 MARKET S.E. (J. Singer)
!         !----Decsystem 10 S.E. (C. Turley)
!         !----DECSYSTEM-10 LANG. PRODUCTS Mgr. (Jim Mills)
!    !----Mgr. Software APPLICATIONS (Ed Fauvre)
!         !----TYPESET-11 Prod. Sys. Dev. (T. Donovan)
!    !----Software Engineering  Support Mgr. (Bill Slack)
!          !----European Software Eng. Mgr. (Cary Wyman)
!          !----Software Documentation Mgr. (Bob Gafford)
!         !----SOFTWARE STANDARDS Mgr. (Pat White)
!         !----Hrdwr./Softwr. Tools Mgr. (John Xenakis)
!    !----RESEARCH & Dev. Mgr. (Jim Bell)
!         !----ADVANCED SYSTEMS RESEARCH Supr. (Bill Strecker)
!         !----SYS. TECH. & MEASUREMENT Supr. (Rollins Turner)
!    !----Administration & SERVICES Mgr. (Oleh Kostetsky)
!          !----Operations Analysis (Don Crowther)
!          !----Sftwr. Distribution Center (Tom Mullane)
!          !----MIS Systems, Cent. Admin. Doc. Svco. (Roy Lightfoot)
!    !----Diagnostic ENGINEERING Mgr. (George Plowman)
!          !----Automated Mfs. (Marv Horovitz)
!          !----PRODUCT LINE Diagnostics (Walter Manter)
!          !----STANDARDS & SYSTEMS (George Plowman, Acting)
!    !----Software Planning Mgr. (Larry Wade)
!          !----Departmental Planning Mgr. (Ed Wright)
!         !----HIRING & TRAINING Mgr. (Jim Murphy)
!    !----Networks Program Mgr. (Nat Teichholtz)
!    !----PERSONNEL MGMT. DEV. (open)
!    !----FINANCE (Pat Spratt)
!    !----SOFTWARE RELIABILITY ENG. Mgr. (Jack Mileski)
!
!
!----VICE PRESIDENT, COMPUTER SYSTEMS (Dick Clayton)
!    !
!    !----PDP-8 DEVELOPMENT Mgr. (John Clarke)
!         !----PRODUCT SUPPORT (Dave Brown)
!         !----8/A PROJECT ENGINEER (John Kirk)
!    !----SMALL PDP-11 SYSTEMS (Steve Teicher)
!         !----T↑2L 11/05's Supvr. (John Sofio)
!         !----RELIABILITY (Richard Olsen)
!         !----PRODUCT SUPPORT SUPVR. (Doug Rothenberg)
!         !----LSI (Dick Spencer)
!         !----MOS SYSTEMS (Mike Titelbaum)
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!    !----MEDIUM & LARGE 11 SYSTEMS (Bill Demmer)
!          !----LARGE 11 SYSTEMS Mgr. (Al Ryder)
!              !----Product Mgmt (John Misialek)
!              !----11/45 Supvr. (Bob Kirk)
!              !----MEMORIES (Sas Durvasula)
!              !----TECHNOLOGY (Dave Potter)
!              !----NEW SYSTEM(Steve Rothman)
!         !----MEDIUM 11 SYSTEMS Mgr. (Jega Arulpragasam)
!              !----PRODUCT PLANNING (Bob Gray)
!              !----11/40 (Jega Arulpragasam, acting)
!              !----NEW SYSTEM(John Levy)
!         !----11 FAMILY PACKAGING Mgr. (Dick Gonzales)
!         !----11 FAMILY SYSTEM ENG. Mgr.  (Ralph Platz)
!              !----ELECTRICAL RELIABILITY (Don Vonada)
!              !----SYSTEM TESTING (Ray Archambault)
!              !----SYSTEMS SUPPORT (Ed Permon)
!              !----SYS. DIAGNOSTICS & AVAIL.(Rick Fadden)
!    !----LARGE MINIS Mgr. (Bruce Delagi)
!         !----PRODUCT MANAGEMENT (Al Avery)
!         !----SYSTEM DESIGN (Len Hughes)
!    !----MKT. SERVICES, DEVELOPMENT Mgr. (Bill McBride)
!         !----TECHNICAL LITERATURE (Roger Dow)
!         !----PROMOTIONAL
!         !----COMPETITIVE PRODUCT EVALUATION
!    !----SYSTEMS PLANNING INTEGRATION (Robin Frith)
!    !----FINANCE (Larry Smith)
!    !----PERSONNEL (Dave Larson)
!
!
!----VICE PRESIDENT, HARDWARE DEVELOPMENT (Bob Puffer)
!    !
!    !----DISK ENGINEERING (Grant Saviers)
!          !----PROJECT MANAGEMENT
!          !----PLANNING & PRODUCT Mgr. (Paul Badum)
!         !----RP04 (Steve Orr)
!    !----TAPE ENGINEERING (Bob Peyton)
!          !----PROJECT MANAGEMENT
!          !----PLANNING & PRODUCT Mgr. (Paul Bauer)
!    !----LA36, UNIT REC.I/O (Ed Corell)
!          !----PROJECT MANAGEMENT
!          !----PLANNING AND PRODUCT Mgr. (Al Huefner)
!    !----LSI ENGINEERING (Lorrin Gale)
!          !----TOOLS (Bob Kusik)
!          !----CHIP DESIGN
!    !----POWER & PACKAGING (open)
!          !----POWER SUPPLY ENGINEERING Mgr. (Paul Rey)
!          !----MECHANICAL & INDST. DESIGN Mgr. (Dave Nevala)
!    !----ENGINEERING SERVICES (Phil Tays)
!          !----MODEL SHOP Mgr. (George Gerelds)
!          !----DESIGN SERVICE Mgr. (Leo Bennett)
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!               !----DRAFTING Mgr. (Dick Reilly)
!               !----CAD DEVELOPMENT Mgr. (Ed Vrablik)
!               !----CAD OPERATION Mgr. (Jack Murray)
!           !----INFORMATION SERVICES (Jim Gillett)
!          !----INFOR. PROCESSING & CORP. NETWORK DEV. MGR(Ron Rutledge)
!    !----FINANCE (Irene Leary)
!    !----PERSONNEL (Jerry Patton)
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