PART 4

IMPROVING YOUR PERFORMANCE ON THE JOB AND STANDING OUT FROM YOUR PEERS

CHAPTER 20

THE ENGINEERING PROCESS IN YOUR COMPANY

LEARNING THE BUSINESS

The engineering process is simply the steps that companies go through to design, build, test, and deliver products to their customers. This engineering process can be subdivided into two processes that your company utilizes and that you must learn to be successful. The first is the product design and development process. This process defines the engineering steps involved in creating products. It is the sequence of tasks engineers follow to design products, build early units, and eventually turn over to manufacturing for production.

The second process is the department flow process. This process identifies the typical departments of the company that contribute or help build and test the product. Each department provides a special service or capability to support in the product development.

Therefore, the engineer must know (1) the sequence of steps in product development and (2) which departments perform these steps. Understanding both of these processes for your company is an essential prerequisite to career advancement. Once you have learned these processes as defined by your company, you can use this information in a multitude of ways to benefit your career. Learning these processes is often referred to as "learning the business."

PRODUCT DESIGN AND DEVELOPMENT PROCESS

The design process varies from company to company and from product to product. A generic product design and development process is shown in Figure 20-1. This process or sequence of steps is shown in a timeline diagram.

The Engineer's Career Guide. By John A. Hoschette

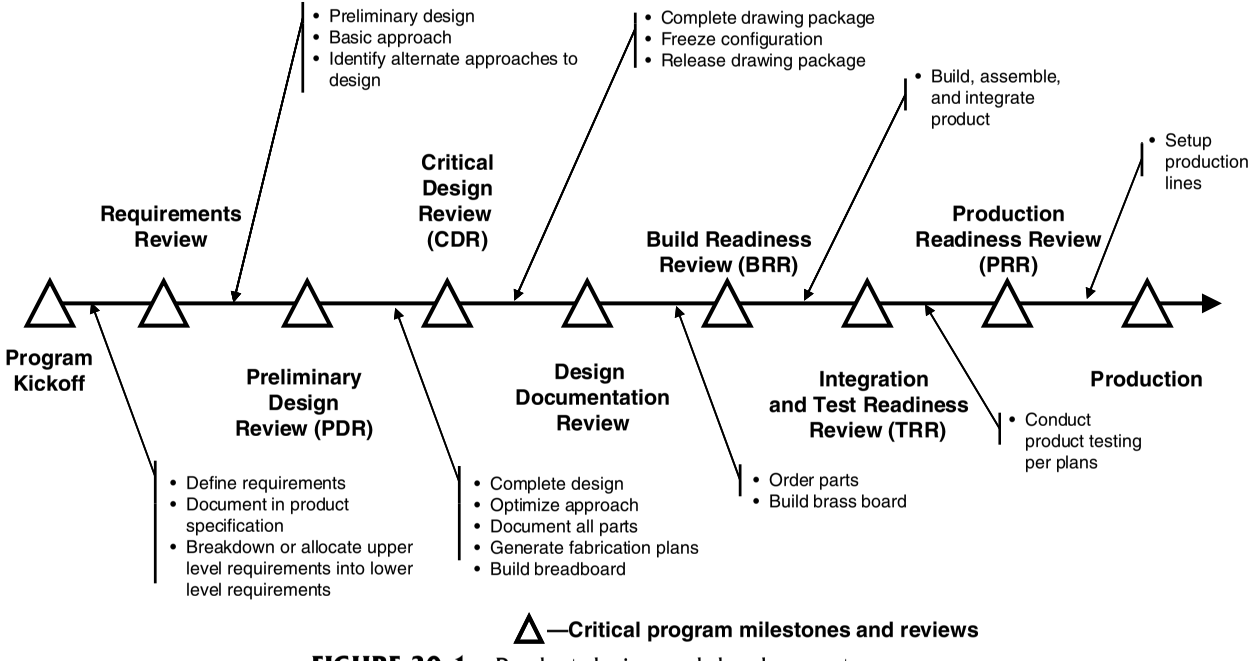

FIGURE 20-1 Product design and development process.

Major program events are planned to provide a system of checks and balances as the product progresses from design to production.

The timeline starts with the first major event, which is usually the program kickoff meeting. The program kickoff meeting signifies the official start of the effort. The purpose of the meeting is to get all the team members together, in the same spot at the same time, to review the plans for the program. Generally, the overall program schedule is reviewed with significant events identified. The team organization is identified and roles and responsibilities are agreed upon. And probably the most important is that the technical objectives are reviewed and agreed upon.

After the program kickoff, the next step is "requirements" development. At this stage in the program, the engineer defines all the requirements the new product will be required to meet. The standard practice is to document these requirements in a product specification. Oftentimes, only a few or top-level requirements are known. Therefore, the engineer is required to work with the customer and other engineers to further develop all the requirements. In addition to finding new requirements, the engineer will break down or allocate down the top-level requirements to lower-level requirements.

A good example of breaking down a top-level requirement into subrequirements might be a products power source. The top-level requirement is for the product to be powered by 120 V AC. The engineer knows the electronics cannot run directly on 120 V AC, therefore lower-level requirements are identified for the product to contain a power supply generating $+15$ V DC, GND, -15 V DC, and $+5$ V DC. And even these requirements can be broken down further into requirements such as nominal current required for each DC voltage, ripple voltage, turn on surge current, and maximum rated current. This is a simple example to illustrate the point. Actual product specifications can contain hundreds of pages and may include thousands of requirements.

Have you ever written a specification before? Does your company have special requirements on the form and content of specifications? One significant time-saving step might be to ask other engineers for a copy of specifications they have written on previous designs. It is much easier to modify an already existing specification than it is to create one from scratch. Maybe your company has an online process that describes how to write a specification. If so, this is a great starting point.

▶ ***Career Tip.*** Check with other engineers for copies of specifications they have written or go online in your company to see what guidelines and specifications might already exist.

Most specifications contain language that not only has technical meaning but legal implications also. For example, the industry standard interpretation

for use of the terms "will" and "shall." If the term "will" is used, it is taken to mean the requirement is a goal and it is not absolutely necessary the product meets the requirement. If the term "shall" is used, it is interpreted to mean the product must absolutely meet the requirement. A good example of the difference can be shown with a simple example. If the requirement is written, for example: the product will weigh less than 5 pounds. This is considered a goal and if the final weight comes in slightly over 5 pounds, it is not a problem. If the requirement is written, the product shall weigh 5 pounds or less. This is considered a hard and fast requirement. If the product comes in slightly over at 5.02 pounds, it means the product does not conform to the requirements and redesign is necessary. The difference between the use of "will" and "shall" is significant and can end up costing the company thousands of dollars.

Another significant and often overlooked skill the engineer must acquire is the ability to write a requirement that has a tolerance band and is easily measurable and verifiable. This may sound easy, but oftentimes it can be extremely difficult to do and can result in very expensive testing. A good example of a well-written requirement is the following: the product shall weigh 5.0 ± 0.2 pounds. The tolerance band of ± -0.2 pounds allows variance in the product weight with the hope all the products final weight will be within the tolerance band. Also, most scales can easily measure to an accuracy of 0.01 pound. Therefore no special or expensive weight scales will be required to verify performance.

A good example of an easily understood requirement that can be difficult to verify is automobiles' gas consumption or miles per gallon performance. It is easy to specify a requirement of so many miles per gallon (MPG) performance but testing to verify it meets the requirement can be very difficult and expensive. Many conditions must be considered when testing this requirement, including size of the engine, horsepower, size and weight of the car, number of passengers, road conditions, gasoline grade, accelerating and decelerating methods, idle time at stop light, and so on.

▶ ***Career Tip.*** Make sure the requirements you place on a product can be measured and easily verified through the simplest testing possible.

At the end of the requirements definition stage comes the requirement review or systems requirements review (SRR). This meeting is primarily run by the systems engineers of the program. Its main purpose is to systematically go through all the requirements the product will be built to, and get an agreement from the customer and/or management on these requirements. Generally, each engineer is asked to present a list of their requirements and the reasons behind selecting these requirements. This meeting may last only a few hours or could take as long as a week. It may be a very formal meeting with the customer or informal with just internal staff. The depth and style of the

meeting is generally left up to management and the customer to decide. The SRR signifies the end of requirements phase and the beginning of the product design.

The next step in the process is to create a preliminary design of the product or subsystem. This is only a preliminary design where you identify alternative means for accomplishing or meeting your design requirements. During the preliminary design stage, basic analysis of options is completed and a preferred approach is selected for further development and refinement. At this stage, the engineer has a good idea of the approach and completed some preliminary design with analysis and modeling to support the design. The design is usually documented in draft or preliminary sketches with basic modeling completed to support the conclusions presented.

Remember those lab notebooks the university tried so hard to get you to develop and maintain during the lab classes? You documented the design, showed analysis, identified equations you used to model performance, and finally, all the graphs you generated showing the simulation results. This is exactly what you should be doing to document your design. I have seen engineers who have taken the time to maintain incredible design notebooks and their efforts paid off when it came time to design reviews. They simply presented all the modeling and simulation results contained in their notebooks. They were organized and came across as technically in control.

▶ ***Lesson Learned.*** A well-documented and organized design notebook is worth its weight in gold.

I have also seen engineers who thought they could keep everything in their head and maintaining a good notebook was not necessary. Consequently, when it came time for the design review, these engineers were unprepared and appeared technically unorganized. These engineers generally crashed and burned during design reviews.

During the design phase, the engineer may have to go through one or more formal design reviews. The intent of the design reviews is for the engineer to present his design for review to make sure he or she is meeting all the requirements and that all parts will fit together when the product is assembled. Design reviews are often attended by senior engineers and management in the company. Their purpose is to review the design and ensure that ideas will work. They will provide helpful hints and suggestions on how to improve your design. They are also making sure that lessons learned from other products are being applied and that mistakes from other products are not repeated. Often the customer will participate in the design review.

The end of the preliminary design stage is usually culminated in a preliminary design review (PDR). The PDRs are often held at the beginning of the program to make sure it gets off to a good start. At PDRs, the engineers

present, to the customer, the plans for development and a preliminary design for the product. The purpose of the PDR is for all designers to review their design and show how the design is meeting the requirements of the specification. It is also to check that all designs are on track as well as a check that all subsystems and all interfaces will work. PDRs can be very short and informal lasting 1 or 2 hours or they can be very formal and lasting several days with customers in attendance.

Design reviews are an excellent opportunity to shine. A well-prepared PDR may contribute and shorten the time to your next promotion. It will make your supervisor look good and the team look good as well. It's worth the extra effort to make sure everything has been accounted for and the presentation is well organized. This is the time to show them your best. On the other hand, a poor PDR can significantly hurt your chances for a promotion. It's exactly the wrong time to look bad. So keep this in mind when you are preparing for a design review.

▶ ***Career Tip.*** A well-prepared and presented PDR presentation can help accelerate your career development. It will make you, your team, and your supervisor look good!

At most design reviews, there is usually a lot of heated discussion on what the correct approach should be. Your design will receive a lot of helpful criticism whether you like it or not. Remember not to take the criticism personally and remain calm! It's difficult when it's your hard work being criticized. But remember, others may have more experience and usually have good suggestions. The sign of a good senior designer is not taking the criticism personally and remaining calm. The best thing to do is find out from others how they would improve it and then use their suggestions. This will accomplish two things. First, you get them to participate in the design (this is especially good if a customer is participating). Second, you will show that you are cooperative and can deal with change. Both are excellent qualities for engineers to have.

▶ ***Career Tip.*** Gratitude expressed for suggestions or recommendations during a design review shows you have the right attitude.

If you really want to impress people, thank them for their suggestions! Everyone likes to hear the words "thank you." It makes them feel as if they have contributed something useful, a feeling even the most senior-level executives enjoy. Finally, when you are a senior engineer reviewing the design of a junior engineer, remember how it felt when you were in that position. Choose your words and criticisms carefully. You should be honestly trying to help the junior engineer and not just trying to make your importance known to others.

Oftentimes during the preliminary design stage, the engineer will be required to fabricate critical parts of the product to show that the concept they are proposing is feasible. One great design tool is use of prototype models of the final product. There are several different types of models that can be built. One prototype is called a nonfunctional mockup model that has the proper size and form factor of the product, but may contain little or no functionality. These models are great for determining size allocations and arrangement of major components and often used by the mechanical packaging engineers. Another prototype model is referred to as a breadboard prototype. Breadboard prototypes usually demonstrate functionality but may not be close in size, weight, and form factor. Finally, there is a brassboard prototype, which is as close as possible to the final product size, form factor, and functionality.

▶ ***Career Tip.*** Building and demonstrating a breadboard at the PDR is a career accelerator.

The next stage in the process is the critical design stage. During this time, the product design is completed and all the details are finalized. The approach has been optimized and all aspects of the design are modeled and documented. The drawing package or documentation package is completed. The documentation package contains all the formal or company-generated drawings and processes that will be needed to build and test the product. To document the design, part drawings and lists are generated. Plans are made for internal fabrication of parts or external procurement of parts. Everyone on the design team is finalizing their design to get it ready for build.

The critical design stage usually ends in what is referred to as the critical design review (CDR). At the CDR, the final design for the product is presented and approval is received from the customer and/or management to start the actual building and testing.

Once again the engineer must present his or her final design for review and approval to proceed into build. The CDR is the most critical review of the program; it marks the point where the program leaves the design stages and proceeds into product build stages. Or as we often say, it is the point where we leave the paper phase and enter the hardware build phase. Generally at this stage, the company is committing large amounts of funding to buy material and start fabricating parts. Therefore, the customer and management have a vested interest to make sure all aspects of the product performance and build plans have been covered.

Typically, management is looking to make sure the following has been completed:

1. All requirements are being met.
2. The design documentation is complete.
3. The design can be built and is testable.

4. All parts can be procured in a reasonable timeframe to meet the schedule.
5. Overly expensive parts are not required.
6. The customer is happy with the design.

Nearly every company I have interfaced with over the past 30 years has guidelines on how to hold and conduct CDRs. The companies have checklists and memos on lessons learned about conducting CDRs.

▶ ***Career Tip.*** To save time and significantly enhance your presentation, check into your company guidelines and policies regarding conducting a CDR. Review other programs' CDR packages.

Do you have a company website you could check? How about your mentors and other engineers who have participated in CDRs before; could you ask them for advice? Could you ask people on other programs for a copy of their CDR packages? Have you ever attended another programs' CDR? These are all time-saving and career advancement steps that you can take to help you when it comes time to present at CDRs.

Since the CDR is probably one of the most important reviews of a program and often the one review most attended by upper management, having an outstanding CDR presentation is critical for career advancement. Do not wait until the last minute to start on your charts. Complete your presentation early and then have your peers review the presentation. It is much better to discover your errors and left out items in private instead of in front of the customer and your management. Be prepared for the tough questions, and most of all, have action plans identified for any issues that might exist. As a senior reviewer for many CDRs, my danger alarms went off whenever the engineer was unprepared or claimed everything was great. The engineers I respected and knew had things under control were the ones who identified potential problems with the design and future risk reduction plans to mitigate the risks.

Critical design reviews are like combining senior labs, finals, and thesis dissertations all into one. Your work is reviewed in detail by everyone and your career depends on you getting approval or passing!

Granted that you pass the CDR, the next step is to complete the drawing or documentation package and start building and ordering parts. At this stage, the design portion of the program is over and the emphasis changes to build and assembly of the product. Some companies complete this documentation phase by having an official review of the drawing package to make sure all aspects of the design have been documented and we know what is going to be built. Oftentimes, the computer-aided design (CAD) department handles most of this and prepares the drawing package. Special notes are added to the drawings calling our standard processes and procedures to be

followed during fabrication of the parts. The drawing package is released by submitting the drawings to a standard review process and then getting everyone to sign off on the drawing package. This signing off is referred to as "release of the drawing package."

To release drawings, there are several engineering standards utilized in industry. These standards define what should be on the drawing and the levels of control. The control levels define who should review and sign it before it is released as well as who has the authority to change it. At the lowest level of control, it is signed by the engineer and CAD person only. At the highest level of control, the CAD person, the engineer, the supervisor, the program manager, quality control, manufacturing, and even the customer, review and sign drawings. Are you aware of your company's drawing release levels?

▶ ***Career Tip.*** Knowing and understanding your company's drawing release process and levels for release is an essential career skill.

Most engineers look upon a drawing release as a genuine nuisance and avoid it, if they can. My recommendation is not to avoid it, but use it to your benefit. Once all your drawings are complete, schedule some time with your supervisor to go through them and sign off on them together. This is an excellent opportunity to show him or her all that you have accomplished. A neat, well-organized drawing package is very impressive. It also gives you a chance to show all the problems you've solved. In addition, you identify how the suggestions made during design reviews were incorporated and how you have things under control. These are all things that can highlight your contributions as an employee and shorten the time to your next promotion.

▶ ***Career Tip.*** Showing your supervisor a neat and well-organized drawing package is well worth the effort and a career accelerating move.

The release of the drawing package is generally accomplished by what is referred to as a configuration control board (CCB) review. The CCB is comprised of the program manager, lead engineer, quality, CAD designers, and others. The engineer must present their drawing package for review and sign off. This is another career advancement opportunity if the engineer is well prepared with an outstanding drawing package. Having a thorough drawing package is clear indication that the engineer understands the processes and can perform. If you are required to present your drawing package at a CCB for release, are you thoroughly prepared?

▶ ***Career Tip.*** Have senior people in the company review your drawing package prior to presenting to the CCB.

Another tip is to check with other engineers on the program who have already presented to the CCB to learn what questions and changes the CCB is making to drawings. Having all the typical corrections and changes already in your drawing package prior to showing the CCB is another means of looking like a top performing engineer.

As shown in Figure 20-1, during the next stage in the process, the parts are placed on order, and once they arrive the build process is ready to start. Oftentimes, the company will hold just prior to the start of build of the first product a build readiness review (BRR). The purpose of the BRR is to make sure all the resources are in place to start the build. The parts will all arrive on time, the parts will be inspected and brought to assembly areas. The assembly instructions have been completed and the tools and people to build the products are in place.

Once the product build is complete, the next stage is testing the product. Prior to start of actual product testing, a test readiness review (TRR) is often held. The purpose of the test readiness review is to again make sure all the resources for testing are in place and the test plans and procedures have been completed. The test department and test team understand the testing to be completed, the type of test equipment needed, and the data to be collected.

Upon completion of the test stage, the program and management has a difficult decision to make. The decision of whether or not the product is ready to go into full-scale production. To aid in this decision, the process calls for conducting a production readiness review (PRR). The objective of the PRR is to review all test results to make sure the product is functioning as planned. It is also a means of reviewing and making sure the factory is ready to begin production. Are the resources in place to build and test the product, have all the assembly and test procedures been defined? Are the product packaging and delivery systems in place? Usually upon successful completion of the PRR, production is started.

The engineering product design and development process described here is generic and greatly simplified compared to what actually goes on in most corporations. The purpose of sharing this was to alert the engineer that all companies have some type of process for designing and developing products. Some companies have no formal processes written down, but just the same, you are expected to ask and learn the process. Other companies have very formal processes that are well documented and their manuals contain thousands of pages describing in detail every little aspect of the product development process for the company. No matter what the case, informal or formal processes, your challenge is to become familiar with every step in the company's engineering design and development processes.

One of the best resources outside of your company for getting information on the product development processes I have found is through engineering societies. One organization is the International Council on System Engineering (INCOSE) whose website is http://www.incose.org/.

Another great resource is the Program Management Institute and their website is http://www.pmi.org/.

PRESENTATIONS AT PROGRAM REVIEWS: CAREER ACCELERATORS OR BREAKERS

I would like to point out to you that the engineering product development process as described in Figure 20-1 has a minimum of six to eight reviews identified. The engineer is required to present his design and plans at each of these reviews. Therefore, I highly recommend that the engineer take several classes in making technical presentations. The reason behind this is what I refer to as the good charts–good engineer, bad charts–bad engineer syndrome.

This means that the audience forms an opinion of the engineer's capabilities on the basis of their presentation skills and charts. If the engineer has great charts and has excellent presentation skills, the audience generally considers the engineer's work to be excellent and the design excellent.

On the other hand, if the engineer has poor charts that are confusing and hard to follow and also does a poor job presenting the material, the audience naturally assumes the design is inferior and the engineer does poor quality design work.

▶ ***Career Tip.*** Poor charts are equated to poor engineering designs; great charts are equated to great designs.

I do not understand this phenomenon, but I have seen this affect my entire career as an engineer. A brilliant engineer with superior product designs gets dismissed all because they could not make a simple presentation to management or the customer. I have also seen engineers with poor design skills and inferior designs make great presentations with excellent charts and everyone in the audience clearly took the design to be impressive (Figure 20-2).

▶ ***Career Tip.*** Invest time in learning the use of proper software to create successful technical presentations. Take courses in making presentations.

GUIDELINES FOR BETTER PRODUCT DEVELOPMENT

The design process varies from company to company and from product to product. I can only share with you some generalized guidelines that will help you design a better product. The following design guidelines are very useful and should apply to most design situations. Simply reviewing this list as you develop your design should help eliminate mistakes and identify problem areas.

FIGURE 20-2 Let people see you at your best.

Guidelines for better product development:

1. Before you start the design, write down all the requirements placed on the design or product. Summarize them in a consolidated table or matrix so that it is easy to review.

   This list should include as a minimum:

Performance requirements	All inputs or outputs
Clearly defined interfaces	Size constraints
Weight constraints	Safety constraints
Operating constraints	Special conditions
Reliability (MTBF)	Safety
Power constraints	Test requirements
Customer use	Rework and repair requirements
Human engineering	Maintainability

2. Get agreement on the product requirements from your system engineer, project engineer, program manager, and/or your supervisor before you start designing. This is a must! If you design your product to the wrong requirements, you will stand little chance of having it approved and you will waste valuable company time and money.
3. Generate a list or table of different approaches that you might use for the design. The table should contain acceptable and poor points for each design. Remember there is always more than one way to do the design. By generating different approaches you can make trade-offs to determine which design is best. Also, by generating different approaches you are not locked into only one.
4. Now show the various design approaches to people in your organization and find out what they think. You will get some good tips along the

way. Also, by showing your approaches to people, you will get a feeling for what is good and bad. You should show these approaches to your supervisor. If he or she likes one and disapproves others, you have a good indication as to which approach to take. It is best to find out which approach stands the best chance of approval rather than spend a lot of time and energy on an approach that will never be approved.

5. Analyze every detail of your design. Model everything you can about the design. The modeling should quickly identify the problem areas for you. By modeling the expected performance of your product, you can show how the product meets every requirement on your list. Engineers will often start reinventing the wheel by generating all their own models. Before you start modeling, find out which models exist in the company. A good place to start checking is with the senior-level engineers in the company. Chances are they already have a model you can adapt to your needs with minor modifications.
6. Build a mockup of the design if possible. A mockup usually does not function but has the correct form or shape. It will help you to visualize how the product comes together. It has been said that one picture is worth a thousand words. I have found that one mockup is worth a thousand pictures! Mockups can identify problems in advance and help you correct them early in the design process.
7. Identify contingency plans in case something goes wrong. If you base your design on a specific part and the part is suddenly no longer available, what are you going to do? Check to make sure all the raw material and parts are available to build it the way you have designed it. A good practice is to find two different suppliers for each part. This way, if one goes out of business or no longer produces the part, you have a backup.
8. Keep track of product costs as you design it. A well-designed product is no good if you cannot sell because it is too expensive.
9. Before you commit to the design, develop a build and test plan. This will help you to quickly identify whether you have all the resources to build and test the product. If you don't have the resources, you had better let the company know in advance so that they can make arrangements to get them.
10. Put plenty of design margin into your design. If your product must survive a five-foot drop, design it to survive a seven-foot drop. If your product must operate within five seconds of turn on, design it to operate within three seconds of turn. Design as much margin into your product as it will allow you. This can save a great deal of expensive and unnecessary redesign later on.
11. Write down and document every aspect of your design. Keep good design notes. You are the only one who has a complete understanding of the design but remember your coworkers must build and test it.

They need good notes and documentation to do this. It is better to make a mistake on the side of too much documentation than too little. Take the time to make sure your documentation is accurate. Check all numbers twice.

12. Build prototype models before you start to build the final design. A prototype will allow you to see any problems in advance and give you time to change things. It will also alert you to possible potential problems.

Remember, these guidelines are very general and you have to adapt them to your particular company or product.

KNOWING WHAT TO DO WHEN IT COMES TIME TO BUILD AND TEST YOUR PRODUCT

Before starting to build your product, it is good to generate a checklist of everything that you might need during the build. Some companies actually hold a build readiness review prior to the start of building the product. The following is a good checklist to go through prior to commencing the build.

1. All parts have been received and are in the stockroom.
2. A build procedure has been written showing the build process flow step by step.
3. All inspections and tests to occur during the build are defined and agreed upon prior to start of build. Datasheets for recording results of inspections and tests are available.
4. All hazardous steps have been identified and people informed of any dangers.
5. Technicians are available and trained for every step of the process. Training or practice on scrap parts for the more difficult assembly steps is a good way to reduce rework.
6. All necessary documentation (drawings) is available for the technician.
7. Persons to contact in case of problems have been identified.

These are some of the concerns that should be addressed prior to start of build of your product. You will have to generate your own list and tailor it to your company's or product's need.

The test and evaluation phase of the program follows the build process. The best way to prepare for this step is to generate a complete checklist of everything that should be done to test the product prior to shipping. The following is a generalized checklist that should help you in preparing your own.

1. Generate a test requirements document that identifies parameters to be measured, requirements of test equipment, and pass/fail criteria.
2. Generate a test plan that calls for verifying every requirement listed in the design specification you generated. Get inputs from test personnel on the tests that you plan to run.
3. The test plan should show the order of the tests to be performed, requirements to be verified, plans in the event of failures, and data-collected plans.
4. Generate a test procedure that defines all the tests to be performed in the exact sequence.
5. For each test to be performed have the following been identified?

   Test facility available
   All test equipment in place and calibrated
   Test objectives for each test identified
   Datasheets for recording results completed
   All test, quality, and inspection personnel notified
   Test procedure written, reviewed, and approved

6. Identify the test director or someone responsible for each test.
7. Establish contingency plans should failure occur during the test.

▶ ***Career Tip.*** A good engineering practice is to witness and monitor all aspects of testing.

The engineer should be readily available to answer questions as they come up and provide direction to the test team as required. In addition, he or she should be comparing the test results against the modeling results obtained from the design modeling phase. A summary of the documentation identified in steps 1 through 3 is shown in Figure 20-3. Generating this documentation is highly recommended, as it will be needed to successfully control the testing phase.

Generally, there are four types of performance verification methods that are utilized during the test phase. These performance verification methods are:

1. *Analysis.* This is usually a mathematical modeling of the product to show compliance with requirements. (For example, safety analysis of product handles.)
2. *Inspection.* This is usually a physical and visual inspection to verify performance of the product. (For example, inspection of labels on the product to ensure correctness.)
3. *Certification.* This is verification of performance by receipt of certification from manufacturing. (For example, certification on how pure certain chemicals were that were used in the build.)

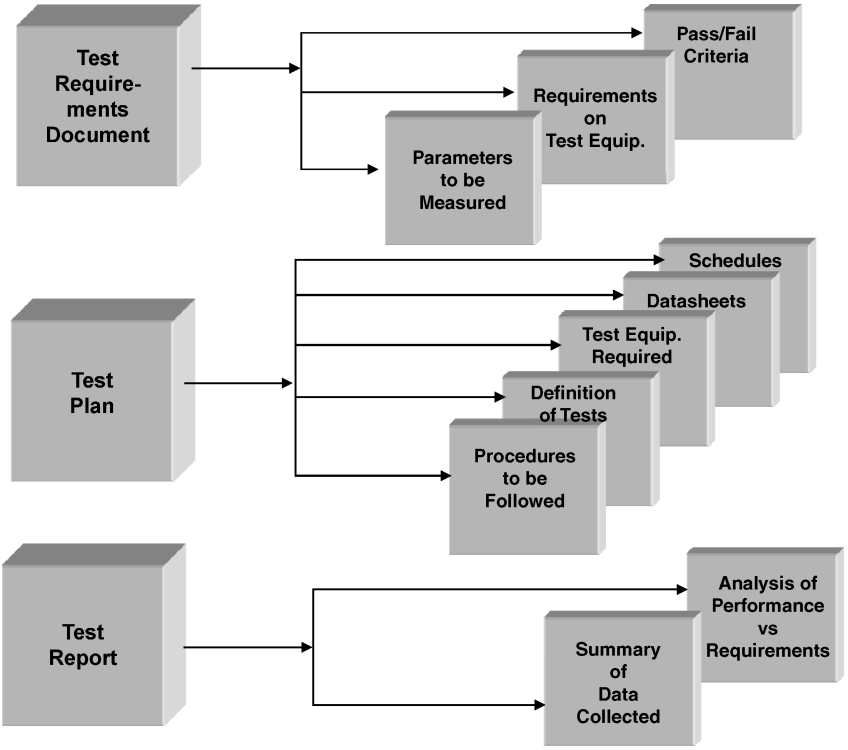

FIGURE 20-3 Test documentation.

4. *Test.* This is verification of product performance by operation and/or measurement of an item, usually requiring instrumentation to record and evaluate measured data. (For example, measuring the weight, size, or power consumption of a product.)

Documenting and Controlling Tests Are Essential

Often, it does not seem important to know exactly how the performance of a product is verified. However, if one considers the costs associated with the verification method, one quickly realizes how important the test method can be. Do not forget the cost factor associated with each test method. Usually, tests are most expensive and certifications are the least. Make sure you know the costs of performing the different tests in your company and minimize the cost of testing wherever possible.

In addition to defining what types of tests the product will be subjected to, there are different groups or combinations of tests that a product may be subjected to prior to shipping it to the customer. These groups of tests often include:

1. *Design Verification or Development Tests.* These are groups of tests that the engineer performs on the product to verify all aspects of the design. Most often, this is the largest group of tests. Some of the tests may be performed only once; since all the products are designed exactly the same, all others will pass it. Other tests in this group may be performed several times before the product is shipped and/or repeated for every product. (For example, measure the power consumed by each television set.)
2. *Qualifications Tests*. These are usually sets of tests that challenge the environmental performance of the product. (For example, vibration testing, drop testing, humidity testing, temperature testing, etc.)
3. *Acceptance Tests.* These are groups of performance tests that the customer usually specifies to be run on every product prior to shipping.
4. *Burn-in Tests*. These are groups of tests that the customer usually specifies to ensure that no instant or short-term failures will occur. These tests may include combining several tests into one. (For example, operate for 50 hours while cycling between hot and cold temperatures.)

A very good engineering practice is to develop a matrix showing exactly how and where every requirement of the specification will be met. An example of this is shown in Figure 20-4. The column on the left identifies the product specification requirement. The next four columns under "Test Method" identify the different test methods to be used to verify the specification requirement. The next four columns under "Test Group" identify the tests to be run. And the final column identifies the test plan paragraph that describes the test to be performed.

This type of table makes an excellent communication tool. It provides a condensed summary of all testing that is going to happen. It is great for the test team to have and can help clearly identify to the customer what is going to happen. Figure 20-4 is a generalized table that you should adapt and tailor to your product or company.

Finally, after the tests are completed, a test report and lessons learned summary should be written. The test report should contain a summary of the data collected as well as an analysis of performance versus requirements. Lessons learned should identify solutions to problems that were discovered during the test phase of the program.

▶ ***Career Tip.*** Taking the time to review test results with your supervisor can be very beneficial to your career.

Take the time to explain to him or her how the product performed against predicted results and the lessons learned. Make sure you point out to him or

Product Specification Paragraph	Test Method				Test Group				Test Plan Paragraph Describing Test
	ANALYSIS	INSPECTIOn	CERTIFICATION	TEST	DESIGN	QUAL TEST	ATP	BURN IN	
3.1 Power On/Off				X	X	X	X	x	4.1 Power On/Off
3.2 Paint Finish		X					X		4.2 Paint Finish
3.3 Material			X				X		4.3 Material
3.4 Hazard/Safety	X				X				4.4 Hazard/Safety

FIGURE 20-4 Requirements verification matrix.

her problems you overcame and the improvements you identified for future projects. Don't overwhelm him or her with data. Make sure it is neat and organized. Remember, they are forming ideas about your performance and your abilities. Take time to polish the report; now is the time to show your supervisor your best.

Career Benefits To Understanding How Your Company Does Business

Just as important as learning the engineering design process is learning how the product flows through the different departments of the company in its journey to your customers.

A typical department flow process is shown in Figure 20-5. This department flow process has been generalized and will vary from company to company as well as from product to product within any one company. The example was chosen since it is fairly typical of most companies. This example represents a starting point for determining the department flow process in your company. Study the example, then use it as a guide for developing your company's department flow diagram.

The engineering process starts with a product idea or a request for a proposal from the customer. If the product idea or business opportunity is worth pursuing, the company forms a proposal team. The team will write

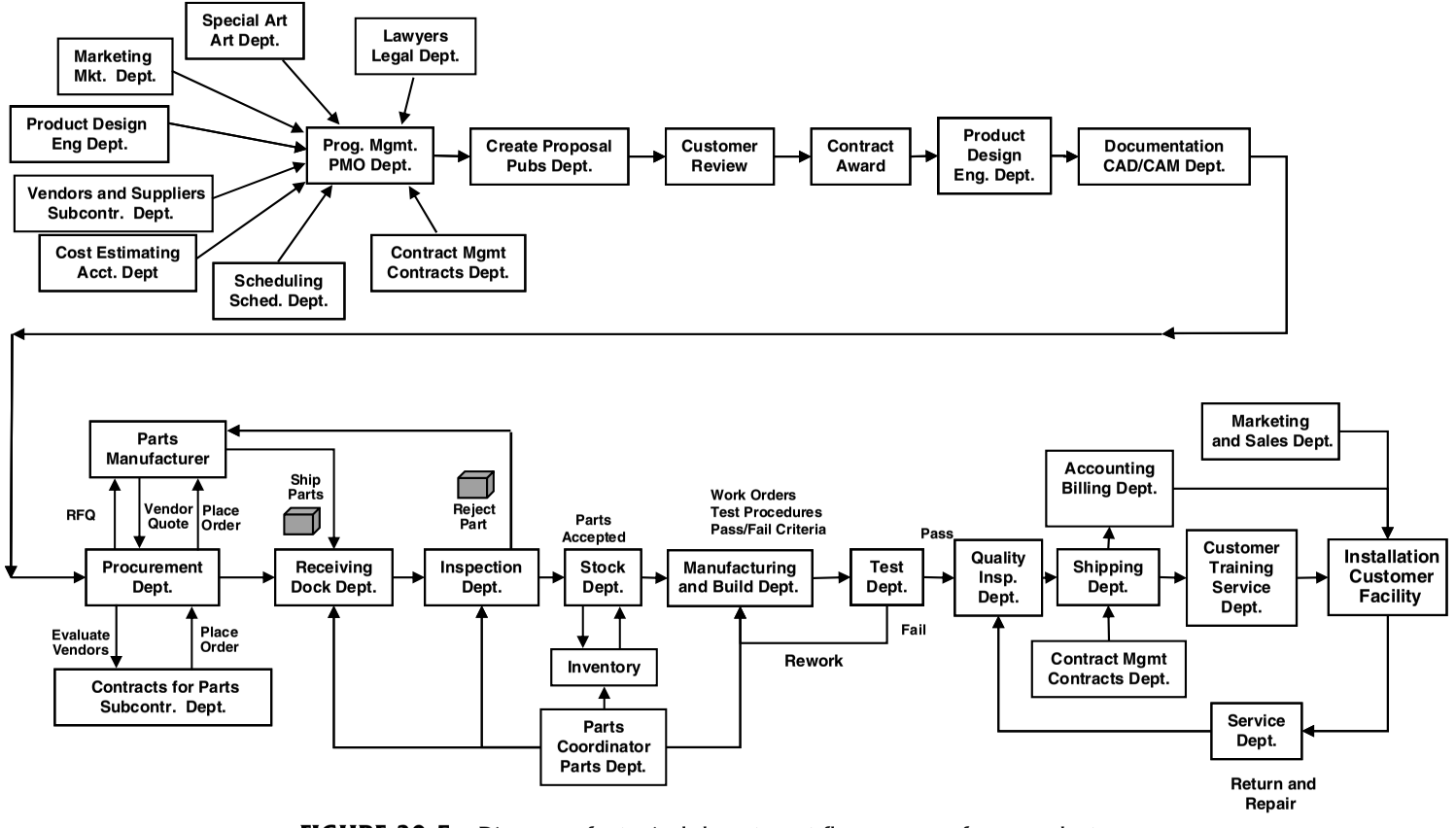

FIGURE 20-5 Diagram of a typical department flow process for a product.

a proposal to build a particular product for a certain customer, or to improve an existing product line, or to develop a new product. The proposal team includes people who are engineers, program managers, technical writers, accountants, lawyers, artists, contract specialists, and marketers, just to name a few. The marketing people provide information obtained from the customer about the product requirements and customer's desires. This information includes the customer's specifications and requirements, the time frame for completion, and the customer's budget. The engineers determine the technical approach to the product. The financial team assembles the cost associated with building the product.

The proposal is divided into various sections and the team members are assigned sections to write. Usually, the proposal effort is led by the program manager and run out from the proposal or publications department.

▶ ***Career Tip.*** If you become a proposal team member, your writing skills become critical. Take courses in technical and proposal writing. As a starting point, get copies of previous proposals for ideas on writing style, format, and technical data that need to be presented.

Once all the customer information is known, the team formulates a proposal to build a product to meet the customer's need for the least amount of money and deliver it within the time constraints. The engineers describe the product design and operation. The accountants compute all the costs associated with building the product.

Getting everyone to agree what should go into the proposal is no easy task.

Once the proposal is completed, it is submitted to the customer. The customer can then evaluate the proposal for its technical merit, cost, and schedule. This review process can take anywhere from several weeks for simple contracts to months and even years for large developmental programs.

If the proposal is accepted and your company is awarded a contract, the next step is the product design phase. For the product design phase, management organizes a team of engineers to develop the product. Often the teams are organized around a program management office (PMO). It is the responsibility of the PMO to execute the contract and make sure work is carried out as planned. These PMOs are led by a director who has profit and loss responsibility for the program. The director will have program managers to assist in running the program. The program managers are responsible for organizing the work. They determine the tasks to be accomplished, the order in which they are to be done, and the schedule for getting the work done by the design engineers.

After the program has been thoroughly planned out and the team members identified, the design work is ready to start. This step is known as product design. During this step, every detail of the product is designed

and performance modeled. Design trade studies are performed showing different ways to build the product. The pros and cons of the various methods are identified. During the design phase, the engineer is utilizing everything learned in school and then some.

Once the design is complete, the hand sketches and rough drawings are brought to the drafting or CAD/CAM department to draw up the parts of the product. The CAD department documents the design by creating a drawing package. The drawing package contains a complete set of drawings that document every part in the product, how it is built, and how it is to be assembled. Drawing packages may contain anywhere from 10 to 10,000 prints, depending upon the complexity of the product.

If you have an opportunity to choose with whom you work in the CAD department, try to get the most senior CAD person. The reason is that he or she has seen many designs in their time and knows what has worked and what has not. The senior CAD designer has a multitude of little tips to make the design more producible, perform better, and have a better chance of succeeding. If the CAD person finds something that improves the design, make sure to highlight their contributions by enlightening their supervisor of their input. Believe me, I've seen the CAD department find a lot more of my mistakes once they knew they were going to get credit for it.

▶ ***Career Tip.*** Select the most qualified CAD/CAM designers to work on your project. Solicit their inputs and highlight their contributions to management.

After drawing release, the prints are used by the procurement department or "purchasing" as it is sometimes called. The procurement department uses the drawings to obtain bids from other companies to build the parts. The procurement person contacts companies that are interested in building the part and requests a quote from them. This is referred to as a request for quote (RFQ). The manufacturer sends the bid or cost quote back to the procurement department for review and approval. Usually, the procurement department and the engineer decide whom the bid will be awarded to. When a decision is made, a purchase order is placed with the chosen company.

Getting the purchase order signed off is an exercise that will try any engineer's patience. A typical purchase order will usually require the signature of four to five different people: your supervisor, your supervisor's boss, your program manager, your procurement agent, and the parts manager, just to name a few. On larger programs, it may also require the production engineer, the quality engineer, and the program accountant.

▶ ***Career Tip.*** Make sure you understand all the steps and forms required to get a purchase order approved for your parts. Getting your part orders through the system first can significantly shorten your time to build.

For those parts fabricated within the company, a drawing is brought to the department that does the fabrication and the department normally starts work immediately. No purchase orders are necessary. This is much simpler, so most engineers will try to fabricate everything in house.

To keep track of all the parts being fabricated, most program managers utilize a "parts coordinator" to keep track of everything. The job of the parts coordinator is to place the orders, track delivery dates, push the parts through incoming receiving and inspection, and get them into the stockroom as quickly as possible. If you want to have your parts built, first it pays to make friends with the parts coordinator. Remember, all other engineers on the program are also trying to get that same parts coordinator to order their parts. I have been on programs where part coordinators are handling 5,000–10,000 parts. So getting the one part you forgot to order and desperately need may not be on the top of their priority list.

Parts coordinators can make or break you. If you get on their good side, they can make sure your parts always get top priority. If you get your parts first, you stand a better chance to finish first. If you get on their bad side, you can expect serious delays.

The point I'm making here is that other people in the company can affect your performance. You need to understand the function of each department and how it can affect you. You need to stop and think: if I win the argument and make an enemy, am I really winning?

There is a saying, choose your friends well. It's also good to choose your enemies well so that they can do the least amount of damage to your career. Chances are you can make enemies with some departments and your career will not suffer. But make an enemy in a department that is key to getting your job done and you may be greatly limiting your career.

When parts ordered from outside the company arrive, they are usually logged in and sent to inspection/receiving. In the incoming inspection and receiving department, the parts are usually inspected to make sure that all parts were built to the required specifications. Most companies do this for two reasons. The first is to detect bad parts before they are used to build the product. This can significantly reduce rework later on. Second, it gives the company a much stronger case for return and free replacement of bad parts by the manufacturer. This is especially true if lawsuits can be the result of poor inspections.

In order for the quality inspector to examine the incoming parts, they must know what to look for. To get this answer, the inspector usually obtains a copy of the part drawing from the company print room. This is called "inspecting the parts to drawings." These are the same drawings that you had the CAD/CAM department create and release. As most quality inspectors say, "No print to inspect, then no parts get through." It pays to have all your prints completed and released prior to inspection.

There is a very good reason for the incoming parts inspection even thought it might slow things up. If the parts are inspected and found to be

nonconforming to the requirements on the drawing, they are rejected. They are usually returned to the manufacturer for corrective rework. Sometimes this rework can cost a company significant overruns and result in large lawsuits that are settled in court. The legal judgments are often based on the drawings and whether or not they were fabricated to the drawing or not. Can you see why the documentation is now so important?

From receiving inspection the parts usually go to the stockroom where they are logged in and stored. Make sure your parts get to the right place once they leave the inspection department. Parts have been known to get lost between the inspection department and stockroom.

Most companies have an engineering build or manufacturing department that actually builds the product. These departments are often referred to as "model shops" for small quantity builds. This is where a breadboard or brassboard model of your product is first fabricated. Using the prints and assembly procedures that you have developed, these departments quickly assemble the product. There are two rules of thumb during assembly that can help you get through the build process easily and quickly. First, be available for the technician so that they can ask questions on how you want it assembled. Remember, if you are not around, the technician will assemble it the way they think you want it. This can lead to a lot of mistakes. Second, be ready to make changes if necessary during the assembly process. Chances are your design was not perfect and more than likely changes and modifications will be necessary.

▶ ***Career Tip.*** Make sure you are readily available during product fabrication. Check progress on a regular basis.

It's best if you are on the spot and can quickly remedy the situation; if you are not available and the technician has to go to your supervisor or other coworkers to find out how to solve the "glitch," it doesn't look good and can hurt your position. Solve problems quickly and as soon as you can. Spend as much time as possible in the assembly area during this time.

Just as in the CAD/CAM department situation, request the assistance of the most senior technician, if possible. He has seen a multitude of products and knows hundreds of shortcuts or helpful hints; make him your friend and not your enemy. Remember some technicians like to point out all the mistakes of the design without mentioning its good points. It may be tough to sit there and listen to criticism on your design, try not to take it personally, remain calm. Ask for ideas on what can be done to improve things. Be sure to give credit where credit is due. Again, it does help if you point out to the technician's supervisor all the good ideas that were contributed and how they are helping the design.

▶ ***Career Tip.*** Request the most qualified technicians support the build and test of your product. They bring a wealth of knowledge to your design.

At the completion of your product build, write up any lessons learned from the build process. Be sure to update your build process flow with any changes you have made to it. Updating and improving the build process flow is extremely helpful the next time you plan on building the product. Make sure you share the lessons learned with your supervisor and other people in the organization. This may save them from going through the same problems in the future. Also, as others share their lessons learned, you will learn faster and more efficient ways to build problem-free products.

After completing the build of the product, it is now ready to go to the test department. The test department typically has the responsibility for conducting all the tests you have specified. The test department will assign technicians to work with you to perform the majority of testing. Typically, the testing on the very first unit is done mostly by the engineer with the technician observing. By the third unit, the technician is generally doing the majority of the testing with little or no assistance from the engineer. Generating test plans and procedures from scratch is very difficult.

▶ ***Career Tip.*** Obtain copies of other test procedures developed and use as a model. Make sure you have datasheets showing the data to be collected during the testing.

Prior to shipping any products, the quality department joins the test team to witness and ensure quality products are going to be shipped. The quality department is usually required to witness all tests and sign off on all paperwork that the product is ready to be shipped. During my career, I have found that most companies require between 8 and 10 different types of paperwork to be filled out prior to releasing the product for shipment. Be prepared for this mountain of paperwork.

After successfully completing the testing of the product and filling out all the paperwork, it is time to ship it so that the company receives payment. Once you are ready to ship, several other support organizations get involved. As Figure 20-4 indicates, marketing, accounting/billing, shipping, and the service or installation departments get involved. Make sure they complete their job in a timely fashion so that you can still meet the schedule. The engineer should follow through and double-check everything.

▶ ***Career Tip.*** Team photos of the people who worked on the project generate an enormous amount of good will. Well worth the effort!

Here are some tips that may help company morale and benefit your career at the same time. First, before you ship the product, get photographs of the product for future customers. Second, if you can get the team together, have a team photograph taken. Give copies of the photograph to each team member.

See if you can have the company newspaper publish a story about the team and the product. Get a picture of the customer receiving the product if you can. And, finally, submit people who have helped you; they will be more willing to work with you the next time. Ask your supervisor for details on how to submit awards.

▶ ***Career Tip.*** Most companies have money for team awards. Submitting your team for an award is a very good career move and generates goodwill.

The product department flow discussed was a very general one. You can use it as a starting point for mapping out the product department flow in your company. By generating a flow diagram of the departments that become involved during a product development, you will have a better understanding of how your company does business, as well as which products and functions are key to its survival. By knowing the department flow process, you can contact other departments well in advance and schedule their help for your product. This allows you to get things done more efficiently, for less money, and on time, all good reasons for raises and promotions.

I have shadowed only three boxes in the department flow diagram. These were the only boxes/departments I had received training during my tenure at the university. Having to deal with all the other departments, people, and processes were all new to me. Learning what all these departments do and interfacing with all the people in these departments required I learn a complete set of new skills. Are you prepared to do the same?

You should have realized by now that 95% of product development is done outside your department and you must depend upon others to help you. Do you have the good interpersonal skills needed to make this happen? If not, take some classes.

▶ ***Career Tip.*** Take classes on dealing with difficult people. This is a skill required of all senior or lead engineers.

Pushing a product through large companies or organizations can seem impossible at times. Several senior engineers have shared this advice with me on occasions when I felt like giving up. Their words were

▶ ***Career Tip.*** "Don't let them wear you down; when you know you are right, keep on going."

Product design, build, and testing is a complex process. No one person can do it all, but with the help of teammates you can do it. Develop guidelines or checklists for each step to help you ensure that everything will be done. By generating guidelines or checklists jointly with your teammates, they get

involved with the work and help you more. Let support groups make contributions to the product to get their commitment; you'll need it. Who knows, their contribution may be just what is needed to make the product really successful.

▶ ***Career Tip.*** Guidelines and checklists are well worth the time and effort. They can save hours of work!

Don't ignore documentation. This is a very important part of the design process. It helps you keep track of the design as changes are made. It provides a means to communicate to others all that is involved in your design, and it provides a record of what was built after the product leaves the company.

▶ ***Career Tip.*** Overdoing the documentation never hurts; underdoing the documentation always causes problems.

One of the benefits to knowing the product flow through the company departments allows you to quickly identify the departments that are critical to the company's success. Are you working for a critical department that is absolutely necessary for the company's survival? Or are you working for a department that is only there to solve a short-term problem and will disappear shortly after the problem is solved? People in critical departments get raises and promotions. People in short-term departments usually get reassigned or laid off.

▶ ***Career Tip.*** The more critical the department is to the company product development, the more leverage you have for your career.

Another benefit of knowing the product flow process in your company is that you can contact other departments well in advance and schedule their help for your product. This allows you to get things done more efficiently, for less money, and on time—results that motivate companies to give raises and promotions.

By not learning the engineering process, you are doomed to trial and error methods that usually cause delays and cost overruns, results that do not lead to raises and promotions. Remember, no one likes to have an unexpected job dropped on them without notice or time to respond. By going to these departments well in advance, you give them the opportunity to schedule and complete your job in a timely manner. This makes both the company and you look good.

Knowing the engineering process will aid you in determining which projects are best to work on and which projects should be avoided. If you get reassigned to a project that has nothing to do with the mainline processes of

the company, you can be assured that you will also probably not be in the main line for career advancement.

By studying the engineering process and learning all the steps involved, you quickly become aware of the possible shortcuts and ways around all the red tape. In doing so, you should be able to accomplish assignments in a much shorter time.

▶ ***Career Tip.*** Getting assignments completed sooner and at less cost than expected usually assists in career advancement.

A side benefit to learning the engineering process is that you will also educate yourself about the company's products. Knowing both the company's products and the engineering processes provides a valuable insight into the company, a valuable insight that you can use to your advantage. For example, once you learn the products of your company, you can determine which product is best to work on for the betterment of your career.

To illustrate this point, let's assume you are working on the highest profit product in the company and you just figured out a way to produce it 10% cheaper. Chances are very good that someone is going to notice your improvement and reward you for it. Or you may be working on the most critical calibration and assembly process for the most profitable product of your company. Having knowledge of this is always great leverage when it comes time to ask for a raise. Supervisors like to reward key personnel who are absolutely essential for getting products out the door.

The point here is that you will not find out about these positions unless you study the engineering process and products of your company. You must analyze the process to determine which are the critical steps and which products are the most profitable.

▶ ***Career Tip.*** The optimum situation for your career is being responsible for the key process steps of the most profitable product of your company.

Failure to study and learn the engineering process and key products of your company will only sidetrack your chances for career advancement. A good example of this is working on a product that is about to become obsolete and phased out. Under these circumstances, you may soon be facing a layoff even if you do an outstanding job.

Another example of how ignoring the engineering process can hurt you is when changes are introduced into the process. Often companies will change the engineering processes to eliminate unnecessary steps, or they may send out the work to other companies that can do it cheaper. If you are working on a process step slated for being phased out, this will only hurt your chances for career advancement. Only by thoroughly understanding the process will you

be able to determine how changes will affect you. With this knowledge you should be able to sidestep trouble and keep your career on track.

Knowledge of the engineering process is essential for successful career advancement. It provides you with so much valuable insight into which jobs are critical and which jobs are not, which process steps are important and which steps are not.

The engineering processes are different from company to company. Not only is it different from company to company, it is continually changing within any one company. Therefore, you must be continually updating yourself on the changes. Never assume that once you have determined the engineering process for your company that you are finished. Learning and understanding the engineering process in your company is a never-ending career activity. Now that you understand the extreme importance of learning the engineering process, let's look at all that is involved in the engineering process.

Generally, it takes a team of people of various backgrounds to get a product out the door. The size of the teams varies anywhere from 15 to 150 people depending upon the product. In addition, it takes several different departments working together to design, build, and test the products. It is extremely important that you identify the different departments and people who become involved in producing your product and the order in which it is produced. You must determine all the steps a product must go through in your company to get out the door. Next, you need to diagram the product flow. While they normally exist in most companies, you may have to do some research to find one. If product flow diagrams are not available, then you need to generate one.

If you don't know how to generate a product flow diagram, simply ask for help. Ask your supervisor, as he or she generally has a good feel for what it takes to produce the product. Listen closely to what your supervisor tells you, for they will be sharing with you how things should operate. I am certain your supervisor will also tell you about all the pitfalls they encountered and how they overcame them. Try and do more listening than talking.

After you have mapped out your company's engineering process, you should quickly come to the realization that 95% of the work done on your product is actually performed outside your department. The engineer must call on the support of other departments to help him design, build, and test the product. What this means to you is that you must have good interpersonal skills as the utilization of work done by others is extremely important. This brings us to a very important question.

How well do you interface with other people? Can you easily convince other people to support you? If you find yourself having problems with this, don't panic. You can get help developing interpersonal skills. Guidance or career advice is available through many colleges and universities. Oftentimes, evening classes are offered to better accommodate people working and going back to school. Contact your local college or university to obtain a course

listing. Remember, career advancement depends on how well you interface with people. How good are you at requesting and receiving other people's help?

When dealing with other departments always try to create a win–win situation between your department and the department you are requesting help from. A win–win situation is one in which you get what you want and the department doing the supporting work gets what it wants. In other words, you both look good in accomplishing the work. Here's an example: you bring your job to the support department early enough so that they have time to respond and accomplish the work on time. You look good because you planned ahead and the work was completed on time and within the budget allocated. They look good because they were able to complete the work on time and with high quality.

▶ ***Career Tip.*** Win–win situations enhance your chances of a promotion or career advancement.

Stay away from a win–lose situation. This is where you win and the supporting department loses. A typical win–lose situation is where you are late bringing your job to the support group. You may even have to go over the head of the support group to get top priority for your product so that it is completed on time. The support group rearranges its priorities and gets your impossible job done, but this throws all other jobs in the department behind schedule. You win because you get your job done, but everything else looks bad and the support group loses. These win–lose situations will always come back to haunt you on the next project. That support group may put your job last and possibly keep it there. Unfortunately, I have seen this happen.

▶ ***Career Tip.*** Win–lose situations could possibly result in demotions or no career advancement

Sometimes projects require you to create a win–lose situation between departments. There are several ways around this situation. First, get the department supervisor to agree to rearrange the priorities in the department and try not to go over their head. Stay within the department to resolve the conflict. Raising it to higher levels usually creates more problems than it solves.

A great way to show your appreciation would be to nominate the work provided by the support team for a company award. This helps to smooth over ruffled feathers and will make it easier the next time you have to deal with the department. Still another suggestion is to apprise the upper management how the support department is handling your impossible situation. Nothing makes a support department move faster than knowing upper management is watching their efforts. It's their time to look good and they

want upper management to see them at their best. Finally, don't take credit for their work. Nothing makes people more irritated than someone taking credit for their work. Make sure you give credit where credit is due.

▶ ***Career Tip.*** If a support group did all the work, give them the credit.

SUMMARY

The engineering processes changes continuously. Departments come and go. Policies within departments change, people change, and new ways of doing things are continuously being implemented. Always watch how the engineering process changes. It is an important part of your job.

Learning all the products and processes of your company is not an overnight task. It may take months and maybe even years before you fully understand all the products and processes. Don't become discouraged, you will find it was worth the effort.

▶ ***Career Tip.*** A shortcut to learning the process sooner is to study your company's "Policies and Procedures Manual."

All larger companies have policies and procedure manuals and guidelines. These manuals define the policies and procedures that are to be followed by the employees regarding normal business operations. It is a simplified guide to how the company/corporation does business. While it may lag at times, it is well worth the effort.

To summarize, the benefits of understanding your company's engineering process are:

1. By identifying the steps that products go through during design, production, and testing, you gain valuable insights into the company's operations.
2. Understanding enables you to determine what products, functions, and departments are critical to the company's success.
3. Knowledge of other departments' functions leads to better productivity.
4. Awareness that business requires a cooperative effort.
5. Realization that 95% of the work is done outside your department.
6. Realization that interpersonal skills are important and the key to getting people to support you is through win–win situations.

Have you identified any career actions you want to take as a result of reading this chapter? If so, please make sure to capture these ideas before you forget by recording them in the notes section at the back of the book.

ASSIGNMENTS AND DISCUSSION TOPICS

1. Map out the engineering process in your company. How does your department fit in? Can you identify a name or person for each department or function in the engineering process?
2. What are the key products of your division? Rank them according to the profits they generate.
3. What are the critical engineering process steps for the product you work on? Who controls these steps?
4. Write up a specification for your product. List all the requirements.
5. List the models you have available in your department that you can access help that you model your product's performance.
6. Generate a requirements summary and test matrix for your product.