Section 6 INTEGRATED PRODUCT & PROCESS DEVELOPMENT (IPPD)

6.1 Background on Concurrent Engineering and IPPD

During the past ten years the U.S. automobile industry has done a lot of soul-searching to understand the differences between its products and processes and those of the Japanese automobile industry. Over time some great distinctions were uncovered. One key distinction was the inordinate amount of planning and consensus-seeking by the Japanese at the outset of a new project. The Japanese attempted to anticipate and resolve design, manufacturing, test, reliability, and other quality issues to the greatest extent possible at the outset of a program. They sought to eliminate costly downstream design changes. In contrast, American industry focused initially on design, with producibility and reliability issues deferred until later in the development and production process. While this leads to an earlier start (and completion) of prototype design, it usually leads to more downstream design changes after the initial automobiles are tested. Redesign and retooling introduces delays and extra cost and a longer total time to market in comparison to the Japanese. Further, it was finally realized that quality could not be "tested in" during production. This results in high scrap rate and further redesign. Rather, quality must be "designed in" from the outset, as the Japanese have been doing.

American automobile makers have been changing their product development approach and are experiencing improved quality, reduced time to market, and profitability at lower production levels (the ability to pursue small, niche markets). The result is that American automobile customers have begun to swing back to more purchases of American automobile products.

Concurrent Engineering and Transition to IPPD

Many aspects of concurrent engineering have been practiced in the U.S. aerospace industry since the days of Sputnik, when they had top (DX) priority and almost unlimited funding (by today's standards). The weapons programs were viewed as a matter of national survival (they might well have been) and the rush to operationally deploy them spawned innovative management techniques such as concurrent engineering and Program Evaluation & Review Technique (PERT) for program control.

In order to let weapon system development proceed at maximum speed on all fronts, tight interfaces were defined and maintained between all subsystems. Then, development of all subsystems proceeded in parallel. As the subsystems were developed they were connected in conformance with the earlier-established interface definitions. This approach had great risks because most of the key technologies (nuclear weapons, solid propulsion, inertial guidance, thrust vector control, and rugged, high reliability electronics) were all in immature development status. There were many intense negotiation sessions when suppliers could not meet their interface constraints. Some were too big, exceeding the physical envelope constraint. Some were too heavy, exceeding their weight allocation, etc. Project management adapted as best possible to minimize schedule and performance impacts. These activities were concurrent engineering, but fall short of the intent of modern concurrent engineering programs.

The DoD has defined concurrent engineering as "... a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support." The stated rationale for this definition of concurrent engineering was to "... cause developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements." As can be seen from the above two quotes, the present definitions of concurrent engineering involve more than

Prepared by San Francisco Bay Area Chapter
International Council on Systems Engineering
Edited by Jim C. Robertson

just engineering; they involve the whole project, including manufacture and support. Therefore, some U.S. companies adopted the terminology *Integrated Product Development* as more descriptive of this concurrency. Integrated product development implies the continuous integration of the entire product team, including engineering, manufacturing, test, and support, throughout the product life cycle. Later, as the importance of *process* was recognized, the terminology was modified to *Integrated Product and Process Development,* or IPPD.

A comparison of a concurrent/integrated product development program with a traditional or series development program is shown in Figure 6-1A, Concurrent Development. Historically, traditional development took place in series with one activity starting as the preceding one was completed. This a low risk approach for system development and compatibility, but it is a very lengthy process. The product could become obsolete before it is completed. With good interface definition and control, integrated product development, involving the entire team, can speed up the development process, as shown in the figure. Integrated or concurrent development could introduce *more* risk into a development program because downstream activities are initiated on the *assumption* that upstream activities will meet their design and interface requirements. But the introduction of a hierarchy of cross-functional product teams, each developing and delivering a product has been found to actually reduce risks and provide better products faster - as will be discussed.

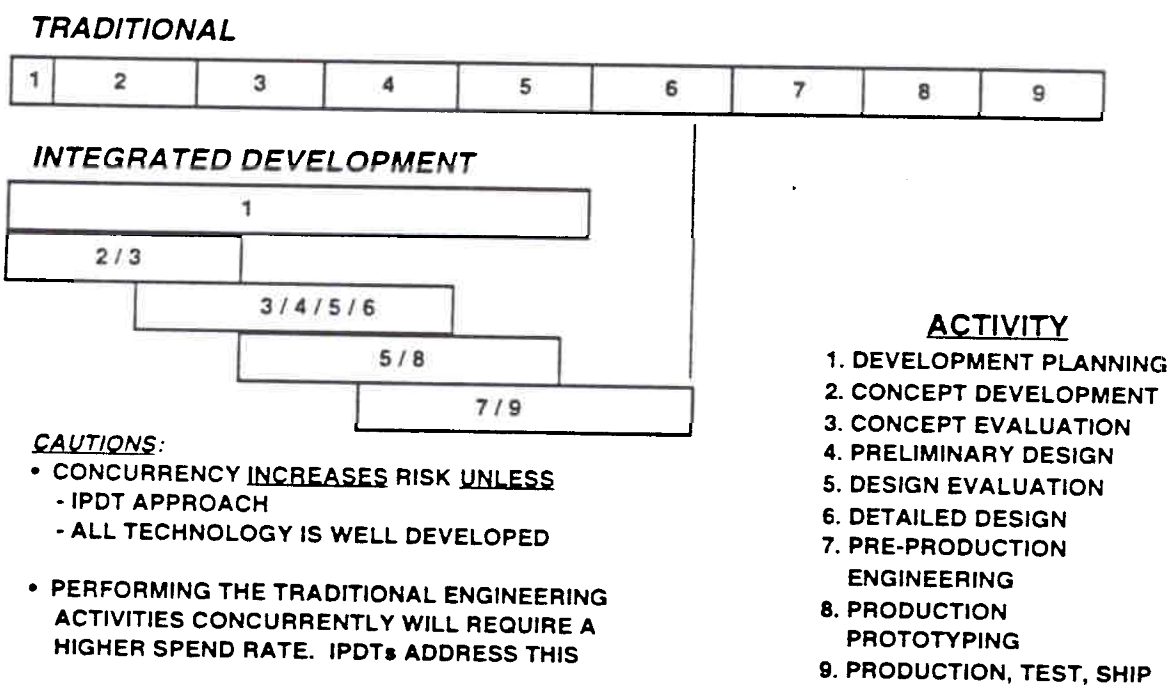


Figure 6-1A Concurrent Development vs. Traditional

6.2 Overview of Integrated Product & Process Development

What are Integrated Product Development Teams (IPDTs)?

IPDTs are a process-oriented, integrated set of cross-functional teams (an overall team comprised of many smaller teams) given the appropriate resources and charged with the responsibility and authority to define, develop, produce, and support a product (and/or service). Process orientation means they are staffed with all the skills necessary to complete their assigned processes-- which may include all or just part of the development and production steps.

Although the teams are organized on a process basis, the organizational structure of the team of teams may approach a hierarchical structure for the product, depending upon the way the product is assembled and integrated.

Different members of a cross-functional team may have primary, secondary, or minor support roles during different phases of the project cycle. For example, the manufacturing and test representatives may have minor, part-time advisory roles during the early product definition phase, but will have primary roles later, during manufacture and test. The idea is to have them participate to the degree necessary from the outset to insure their needs and requirements are reflected in overall project requirements and planning to avoid costly changes later.

The team must be given both responsibility and authority to get the job done. If no one is in charge, things don't get done. The team should be empowered with authority to do the job. It shouldn't be looking to higher management for its key decisions. It should, however, be required to justify its actions to others, including interfacing teams, the system integration team, and project management.

Why IPDTs?

Fierce global competition in the marketplace is driving companies in four major areas:

- Lower cost products and services
- Leaner corporate staffs (The horizontal corporation)
- Higher quality products and services
- Shorter development and production times (Time to market)

The tight schedule pressure essentially forces concurrent (overlapping) development, where components are developed almost in parallel, not in series. Concurrent development usually ***increases*** risks of development problems, because tight interfaces must be negotiated between components ***before they are developed.*** If problems are encountered with one component, it could affect others, resulting in redesign, schedule slips, and extra development costs.

To reduce the risks inherent in concurrent development, U.S. industry has learned that IPDTs, using best practices and continuous improvement, have been achieving significant ***process*** improvements, resulting in:

- Seamless interfaces within the teams
- Reduced engineering design time
- Fewer problems in transition from engineering to manufacturing
- Reduced development time and cost

The above have led to improved product features, performance, quality, and customer satisfaction.

In the early 1990s companies began to discover that they really could be more productive if they moved away from the hierarchical management structure and organized into product development teams. These teams each mimic a small, independent project to produce its product. Some of the greatest productivity gains have come in three areas:

- Unleashing the team's ingenuity through decentralized processes
- Avoidance of previous problems through new, creative approaches
- Better integration between engineering and manufacturing

Some examples of success through IPDTs

In early use of IPDT techniques, Boeing said they have reduced the delivery time for a small satellite from 36 months to 18 to 24 months, and that costs could be halved relative to previous government formula pricing estimates.

In an early application by Rockwell, on a missile program, their costs and delivery schedule were reduced about thirty percent lower than the competition.

Loral Corporation, now part of Lockheed Martin, took one of their very successful vice-presidents out of line management temporarily to run a small process action team of about 12 core members. Their purpose was to review how they developed communication satellites and to define process changes they could introduce for major improvements in cost, quality, and competitiveness.

The dedicated Loral team, segregated from the day-to-day fire drills, came up with major changes in standardization, integration practices, supplier teamwork, and modular hardware and software that reduced their long lead items, schedules, and costs. Some examples are: a focus on low cost, light weight, common products; a standard 15-pin connector for all electronics - same harness for every box. Although each of their satellites is usually somewhat different (in order to meet unique requirements), designers are limited to one of ten design templates. Result: satellite is always 85 percent designed (vs. a new start).

A. What Needs To Be Done?

6.3 The IPDT Process

A basic principle of IPDT is to get all disciplines involved at the beginning of the development process to ensure that requirements are completely stated and understood for the full life cycle of the product. This up-front activity is considered part of the system engineering process. Historically, the initial development of requirements has been led by systems engineers. In IPDTs, the systems engineers still lead the requirements development process, but now more (all) disciplines participate in it.

Requirements are developed initially at the system level, then successively at lower levels as the requirements are flowed down. Teams, led by systems engineers, perform the up-front systems engineering functions at each level. *This is different* from the previous, classical development approach where systems engineers did the up-front work and passed the requirements along to development engineers who passed their designs on to manufacturing, thence to test, etc.

The general approach is to form cross-functional product/process teams for all products and services, plus a Systems Engineering & Integration (SE&I) team to cover systems issues, balance requirements between product teams, and help integrate the teams. This process is illustrated in Figure 6-1B. Each of the teams may have members representing the different areas indicated on the left side of the chart.

These team members' participation will vary throughout the product cycle, as the effort transitions from requirements development to conceptual design, through preliminary design and detail design, to manufacturing, assembly and test, to delivery, operational support, and finally retirement (and possibly replacement). It is good for at least some of the team to remain throughout the product cycle in order to retain the team's "corporate memory".

The product teams do their own internal integration. A SE&I team representative belongs to each product team (perhaps several), with both internal and external team responsibilities.

There is extensive iteration between the product teams and the SE&I team to converge on requirements and design concepts. This effort should slow down appreciably after the preliminary design review, as the design firms up.

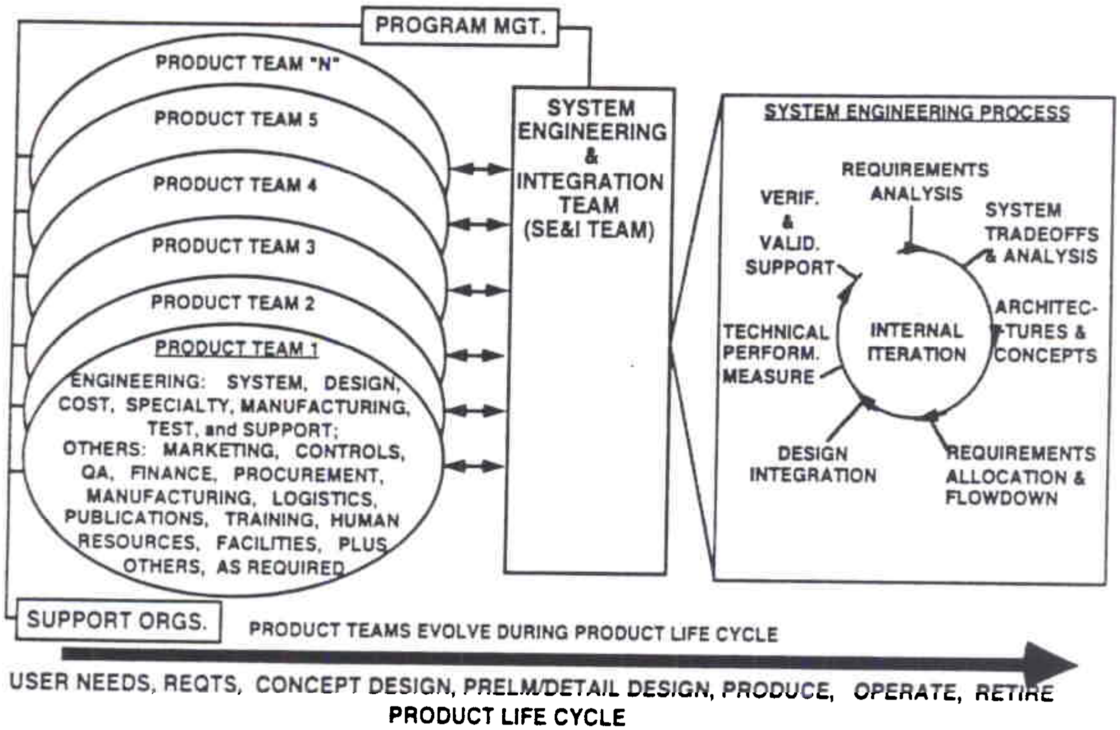


Figure 6-1B, IPDT Process Overview

There are typically three types of IPDTs. These are:

- System Engineering & Integration Team (SE&IT)
- Product Integration Teams (PITs)
- Product Development Teams (PDTs)

The focus areas for the three types of IPDT teams and their general responsibilities are summarized in Figure 6-2. This arrangement is often applicable to large, multi-element, multiple subsystem programs. It must obviously be adapted to the specific project. For example, on smaller programs, the number of PITs can be reduced or eliminated. In service-oriented projects, the system hierarchy, focus, and responsibilities of the teams must be adapted to the appropriate services.

Note that the teams are **process** oriented, focusing on components or their integration into more-complex subsystems and elements. A SE&I team is used to focus on the integrated system, system processes, external and system issues, which, by their nature, the other teams would possibly relegate to a lower priority.

SYSTEM HIERARCHY	TEAM TYPE + FOCUS & RESPONSIBILITIES
	SYSTEM ENGINEERING & INTEGRATION TEAM (SE&IT)
EXTERNAL I'FACE & SYSTEM	• INTEGRATED SYSTEM AND PROCESSES • EXTERNAL & PROGRAM ISSUES • SYSTEM ISSUES & INTEGRITY • INTEGRATION & AUDITS OF TEAMS
	PRODUCT INTEGRATION TEAMS (PITs)
ELEMENT & SUBSYSTEM	• INTEGRATED H/W AND S/W • DELIVERABLE ITEM ISSUES & INTEGRITY • SUPPORT TO OTHER TEAMS (SE&IT and PDTs)
	PRODUCT DEVELOPMENT TEAMS (PDTs)
COMPONENTS, ASSEMBLIES, & PARTS	• HARDWARE AND SOFTWARE • PRODUCT ISSUES & INTEGRITY • PRIMARY PARTICIPANTS (DESIGN and MFG.) • SUPPORT TO OTHER TEAMS (SE&IT and PITs)

THESE MULTI-FUNCTIONAL TEAMS HAVE LIFE CYCLE (CONCEPT-TO-DISPOSAL) RESPONSIBILITY FOR THEIR PRODUCTS and THE SYSTEM

Figure 6-2, Types of IPDTs, their focus and responsibilities

The choice of the number and composition of the PDTs and PITs is flexible, but should be based on natural work products and deliverable configuration items. Each team is responsible for integrating its product and the product's integrity -- the all-up system test and buy-off of its product. As problems occur in this assembly and integration process, the team must resolve them.

Systems engineers will participate heavily in the SE&IT and PIT teams and to a much lesser extent in the PDTs. The systems engineering processes described in this handbook are just as applicable by all teams in the IPPD environment as they were in previous styles of organization. The iterative systems engineering process is still used. In fact, its easier to apply the process throughout the program because of the day-to-day presence of systems engineers on all teams.

All product teams have many roles. Their integration roles overlap, based on the type of product team and the integration level. Some examples are shown in Figure 6-3 for various program processes and system functions.

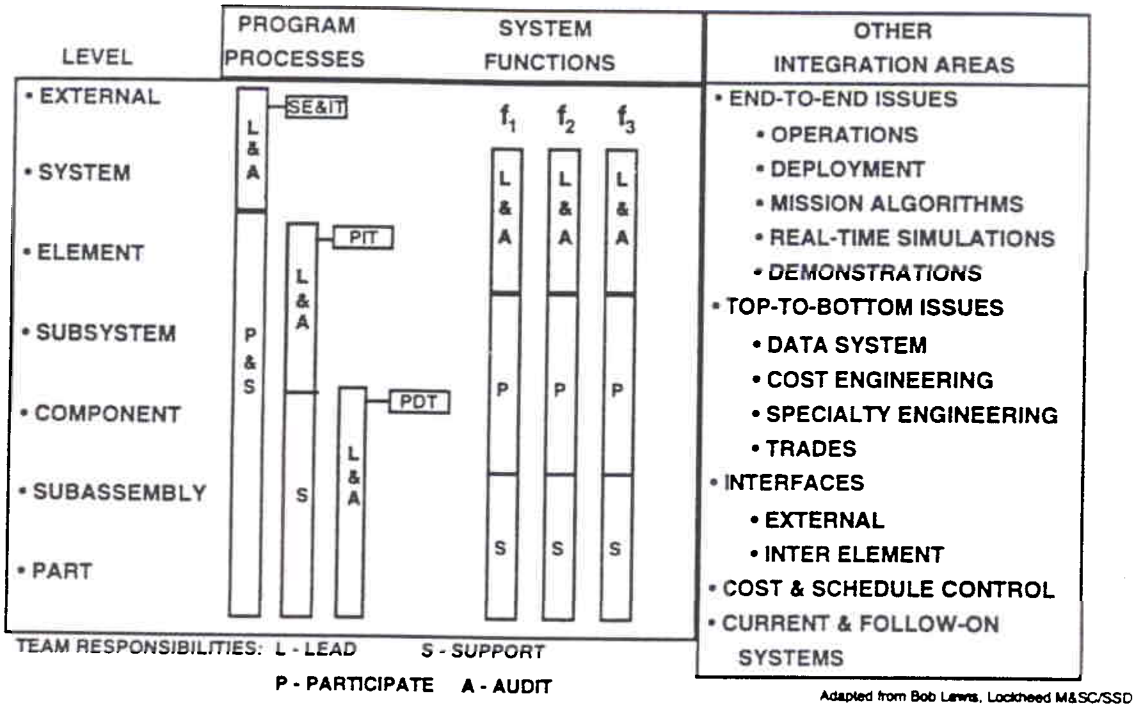


Figure 6-3, Examples of Complementary Integration Activities of PDTs

In this figure, Program Processes covers just about anything required on the program. The three bars on the left side show the roles of the three types of product teams at different levels of the system. Note for example that the SE&I team **leads** and **audits** in external integration and in system integration activities, as indicated by the shaded bar. But, for those program processes involving components, subassemblies, or parts, the appropriate Product Development Teams (PDT) are the active participants, **supported** by the SE&IT and the PITs.

Basic system functions include system requirements derivation, system functional analysis, requirements allocation and flowdown, system tradeoff analysis, system synthesis, system integration, technical performance measurement, and system verification. The bars for functions 1, 2, and 3 in the chart show that the SE&I team **leads** and **audits** activities on different system functions while the component and subsystem teams actively participate. The lower level part and subassembly teams support, if requested.

The column at the right side of Figure 6-3 shows other integration areas where all teams will have some involvement. The roles of the various teams must also be coordinated for these activities, but they should be similar to the example.

B. How to do it

6.4 Steps in Organizing and Running IPDTs

The basic steps necessary to organize and run IPDTs on a project are listed in Figure 6-4. The steps cover the span from initially defining the IPDTs for a project through its completion, closure, and possible follow-on activities. Each step will be discussed in turn, usually with a chart summarizing the key activities that should take place during the step.

STEP	DESCRIPTION
1	DEFINE PDTs FOR THE PROJECT
2	DELEGATION of RESPONSIBILITY and AUTHORITY to PDTs
3	STAFF THE PDTs
4	UNDERSTAND THE TEAM'S OPERATING ENVIRONMENT
5	PLAN and CONDUCT THE "KICKOFF MEETING"
6	TEAM TRAINING
7	DEFINING TEAM VISION and OBJECTIVES
8	EACH TEAM'S EXPANDED DEFINITION OF ITS JOB
9	PROCESS ASSESSMENT and CONTINUOUS IMPROVEMENT
10	MONITOR TEAM PROGRESS - METRICS and REPORTS
11	SUSTAINING and EVOLVING the TEAM throughout the PROJECT
12	DOCUMENTATION of TEAM PRODUCTS
13	PROJECT CLOSURE and FOLLOW-ON ACTIVITIES

Figure 6-4, Steps in Organizing and Running IPDTs

STEP 1 - DEFINING THE PDTs for a PROJECT

A PROCESS-ORIENTED DIVISION OF EFFORT INTO NATURAL PRODUCTS - INCLUDING THEIR DESIGN, DEVELOPMENT, MANUFACTURING, TEST, DELIVERY, and OPERATIONAL SUPPORT

1. PRODUCTS (and PRODUCT TEAMS) CAN INCLUDE:
   - COMPONENTS
   - PARTS
   - ASSEMBLIES
   - SUBSYSTEMS
   - ELEMENTS
   - SYSTEM INTEGRATION & TEST
2. ORGANIZATION: THE TEAM OF PRODUCT TEAMS IS GENERALLY A HIERARCHICAL ORGANIZATION SUPPORTING THE ASSEMBLY AND SUPPORT OF THE FINAL PRODUCT, PLUS OTHER NECESSARY TEAMS, SUCH AS SYSTEM INTEGRATION & TEST
3. SOME GUIDELINES:
   - SELECT TEAMS SO THEY CAN BE AS SELF-CONTAINED AS POSSIBLE, WITH MINIMAL DEPENDANCE ON OTHERS TO GET THEIR JOB DONE
   - SELECT PRODUCTS/TEAMS TO MINIMIZE COMPLICATED INTERFACES BETWEEN THEM.
   - USE THE VENN DIAGRAM TO HELP VISUALIZE BEST DIVISION
   - AVOID TOO MANY TEAMS, WHERE INDIVIDUALS MUST CONTINUOUSLY SPLIT THEIR TIME
   - USE REPRESENTATIVES FROM PDTs ON THE PITs, AND PIT REPS ON THE SE&IT

Figure 6-5, Step 1

The first major task is organizing the IPDTs for the project, summarized as Step 1 in Figure 6-5. Management will do this very carefully, seeking a comprehensive team of teams that efficiently covers all project areas.

There are many alternative ways to organize the IPDTs. Figure 6-6 shows three examples from different size programs from different areas of the U.S.A. The small program example on the left side of the figure is a Boeing (Seattle, WA) arrangement for its small satellite programs. It uses a SE&I PDT and PDTs for major hardware assemblies and major functional areas, such as system test. The PDT Council, headed by a chief engineer, controls requirements and budget allocations and adjudicates interface contentions. Council members are leaders of the PDTs.

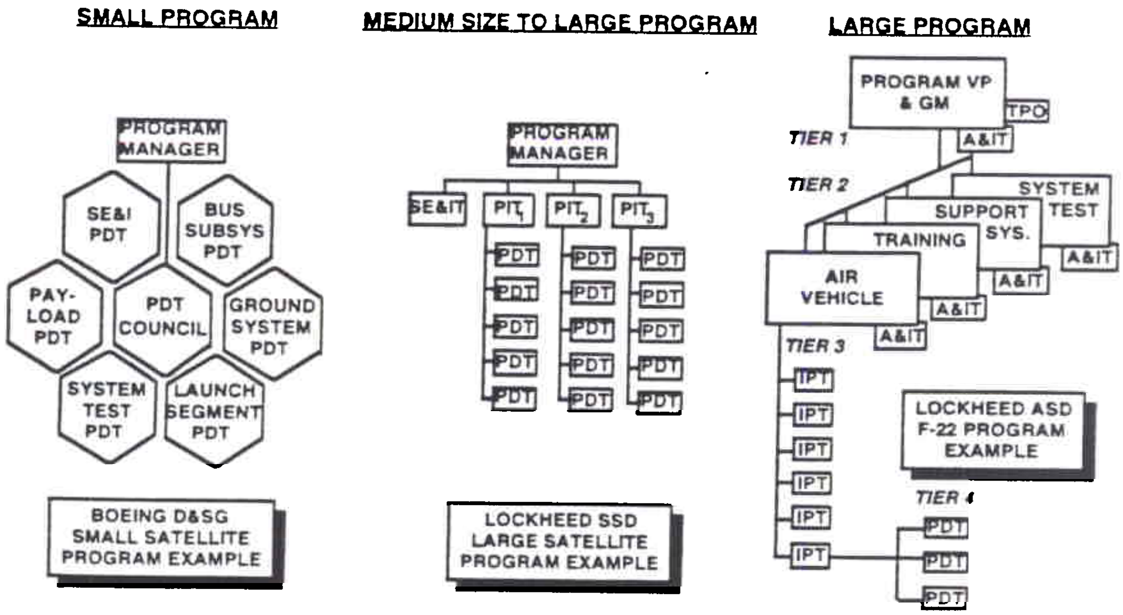


Figure 6-6, IPDT Organization Alternatives - Examples

In the center of the figure is a product team organization used by Lockheed Martin's Space System's Division (Sunnyvale, CA) on a large satellite program. Supporting organizations are not shown. This general model is used as the standard throughout this section.

On the right is the Lockheed Martin Aeronautical System Division's (Marietta, GA) F-22 program IPDT organization. At the Tier 1 level the program was managed by the program VP and General Manager with a Team Program Office (TPO) containing the senior program manager level representatives from all three major participating companies. The TPO includes major product managers as well as senior representatives from all the functional disciplines involved. The weapon A&IT consists of a director and 16 sub-teams that provide analytical support and/or integration that can not be provided by a lower level team. For example, design-to-cost analyses and allocations emanate from the Tier 1 level.

Although these three organization charts are greatly simplified, similarities between them are apparent. The A&IT teams on the F-22 program cover the system engineering functions that the other programs cover with their SE&I or SE&IT teams. The PIT teams on the large satellite program are similar to the F-22 IPT teams. The small satellite program doesn't need PITs.

The organizations on the left and right were discussed in detail in papers in the Proceedings of the 3rd annual NCOSE International Symposium, July, 1993. The Boeing paper was by M.J. Churchill, McPherson, and Weston. The Lockheed ASD paper was by J.D. Cox.

STEP 2 - DELEGATION of RESPONSIBILITY and AUTHORITY to THE PDTs

The "TEAM CHARGE"

1. THIS IS AN ESSENTIAL MANAGEMENT STEP. THE PROJECT MANAGEMENT, WITH SUPPORT FROM SYSTEM ENGINEERING AND OTHERS, AS NEEDED, SHOULD IDENTIFY THE TEAMS AND SELECT INITIAL TEAM LEADERS.
2. THE TEAM LEADER SHOULD NEGOTIATE HIS TEAM'S ROLE WITH SYSTEM ENGINEERING AND PROJECT MANAGEMENT. IT SHOULD BE WRITTEN DOWN; DRAFTED BY THE TEAM LEADER; REVIEWED AND COORDINATED WITH THE SYSTEM TEAM (SUCH AS SE&IT), THEN REVIEWED AND APPROVED BY PROJECT MANAGEMENT.
3. THE COMPLETED NEGOTIATION SHOULD INCLUDE:
   - A STATEMENT OF THE TEAM'S RECOGNIZED FUNCTIONS AND RESPONSIBILITIES (F&RS)
   - IDENTIFICATION OF TEAM LEADER
   - PRELIMINARY TASK STATEMENT (OVERVIEW)
   - PRELIMINARY SCHEDULE
   - PRELIMINARY RESOURCE ALLOCATIONS, WHICH SHOULD INCLUDE:
     - MANPOWER OR TOTAL BUDGET AVAILABLE vs. TIME
     - OTHER RESOURCES TRANSFERRED TO (OR AVAILABLE TO) THE TEAM
     - FACILITIES AVAILABLE FOR TEAM WORK AREAS
   - A STATEMENT OF TEAM LEADER APPROVAL AUTHORITY AND HIGHER LEVEL APPROVALS REQUIRED FOR SUPPLIER RELATIONSHIPS AND PROCUREMENTS EXCEEDING DEFINED THRESHOLDS
4. THE TEAM LEADER SHOULD ALSO SIGN, EVIDENCING HIS ACCEPTANCE

Figure 6-7, Step 2

Delegation of responsibility and authority to the IPDTs, is summarized in Figure 6-7. Management should select an experienced team leader. Then, a project management document identifying the team, its initial leader, functions and responsibilities (F&Rs), resources, project tasks and preliminary schedule, and limits on team authority should be approved by both the project manager and the selected team leader at the earliest possible moment in the program. This empowers the team and its leader and sets the stage for rapid, creative response to the assignment.

For lack of a better name, this document could be referred to as the "Team Charge", i.e., what the team is charged with doing.

Tasks, budget availability, and schedules must sometimes change frequently as company and project management adapt to the dynamic business environment. For continuity of effort and minimum loss of productive time, management should try to avoid unnecessary changes.

For companies and projects that routinely use the same subdivision of product teams, many of the items listed in the chart can be incorporated by reference to appropriate standard company/project management procedures.

STEP 3 - STAFFING the PDTs

THE CRITICAL ISSUE IS BRINGING THE NON-ENGINEERING ELEMENTS INTO THE PROCESS FROM THE OUTSET - TO GET THEIR INPUTS INTO THE DESIGN AND DEVELOPMENT PROCESS TO ACHIEVE GREATEST SAVINGS

CANDIDATE CROSS-FUNCTIONAL TEAM MEMBERS:

- Team Leader • System Engineering • Development Engineering • Manufacturing Engineering
- Procurement • Program Controls • Test • Logistics • Publications/Editorial
- Safety • Quality Assurance • Security • Facilities • Human Resources
- Training • Contracts/Legal • Human Engineering • Information Processing

STAFFING CONSIDERATIONS:

1. Competency and FULLTIME commitment of core team members
2. Competency and availability (when required) of part time members
3. Program stage in the development & support cycle
4. Issues critical to the team requiring additional emphasis or specialized expertise
5. Ability of a candidate individual to work well with the team
6. Budget

TACTICS:

- Inform all team members of meetings, subjects, and key results of prior meetings
- All members need not attend all mtgs.; Request attendance of those you think you need

Figure 6-8, Step 3

Most engineering team leaders know how to staff an engineering team. Even so, they would be wise to get management involved to help them get the right people for the job. Staffing problems are compounded when trying to staff a cross-functional team. The team leader and his management may not know qualified people from the other disciplines (especially on the first IPDT). They also may not know how much effort will be required from each discipline at each stage of the program.

In this vacuum, other specialty areas are usually tempted to "sell" more effort than the team really needs. Project management can keep the lid on staffing by holding the line on overall budget and forcing the team to make the tough decisions. No organization can afford to have unnecessary people on their teams. Therefore, the team, the team leader, and the various specialty support areas should be "challenged" to put together a lean, efficient team and evolve it as project needs change. Some key thoughts for staffing IPDTs are summarized in Figure 6-8.

STEP 4 - UNDERSTANDING the TEAM'S OPERATING ENVIRONMENT

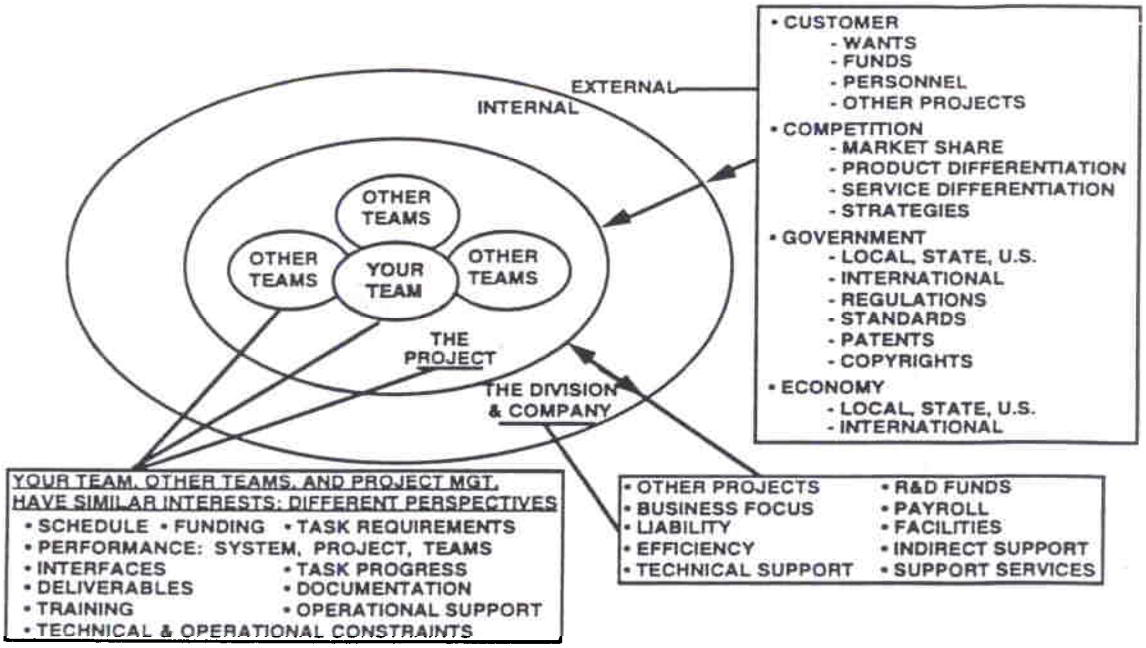


Figure 6-9, Step 4

There are many issues of the operating environment that influence the team. Many of these are indicated in Figure 6-9. Any team will be strongly influenced by the project and certain other teams. One should always try to understand and anticipate these influences and communicate them to team members.

The influence of other teams, other projects within the company, the company or division's current situation, and the external(outside the company) situation may be more indirect, but they can all have a strong influence on a team's situation. For example, the value of the U.S. dollar relative to the currency where your competitor produces may force you to produce key parts in a country with lower labor rates. Obviously, setting up this new factory would have a major impact.

The message of the figure is to recognize the position of the team in this nest of influences and be sensitive, not just to project influences, but to other indirect influences as well. For example, if your team plans to use some company test facilities that are also used by other projects, you must insure that they are reserved for you when needed or you'll have a schedule impact.

The better one can anticipate potential opportunities and impacts to the team, the better the team can adapt to do a good job. The failure of any team to accomplish its objectives imperils the other teams, the project, and the higher level organization. So, all of these organizations should support each other in the appropriate manner.

STEP 5 - THE "KICKOFF MEETING"

OBJECTIVE: ESTABLISH CLIMATE FOR SUCCESSFUL CONDUCT OF PROJECT; GET TEAMWORK GOING; ESTABLISH RAPPORT; LAUGH A BIT!

INCLUDE:

1. **Explain Project; Personnel**
2. **Explain "Team-of-Teams concept; Review Teams and Team Leaders**
3. **Explain general plan of operation and the operating environment (Step 4)**
4. **Review preliminary schedule and budget**

   After the kickoff meeting:
   - Each team does detailed breakout of its tasks, subtasks, personnel & budget needs
   - Each team validates or negotiates revised budget & schedule and commits to support
5. **Explain Meeting plans**
6. **Discuss the next steps that each PDT is expected to take (and due dates), including:**
   - Team Vision & Objectives
   - Detailed expansion and scheduling of team tasks, etc. (Last team in buys the beer!)
7. **Discuss training plans (to get each team up to speed)**
8. **Discuss basic items of project "Infrastructure" briefly, including:**
   - Computer systems, databases, control methods for: Reqts., Baseline designs, documents
   - Schedule and budget review and control procedures

Figure 6-10, Step 5

There are two "kickoff meetings", one for all project personnel, followed by each team's kickoff meeting. The project meeting obviously covers general project issues, but the team meeting focuses on team-specific issues.

The team kickoff meeting is identified as a specific step because of its importance to the success of the team effort. It is the culmination of preparation by the team leader and perhaps others to launch the team activity. The team leader should have a week or more of preparation for the meeting; working on staffing and getting briefing charts to cover topics on the chart shown in Figure 6-10.

For some of the team, the Kickoff Meeting will be their first exposure to the leader and other team members. It is important that the team leader appear to be organized and competent. The leader must extract loyalty, dedication, and quality outputs from the team. While the leader need not know all the answers, he/she should have a strong idea of where the meeting is going and see that it gets there (while getting everyone to participate!).

The team kickoff meeting is very important in setting the stage for professional team conduct. It should move fast, in a business-like manner. It, and all future team meetings, should have a posted (or regular) agenda (that attendees know in advance). The next meeting can be a short training session, discussed next as step 6, to cover tools and techniques the team will use in its cooperative activities.

STEP 6 - TEAM TRAINING

OBJECTIVE: To prepare members to act as a team, using common terminology, techniques, and tools. To let them know what managers and team leader expect - and to provide the means to meet these expectations

1. Review project organization, product nomenclature, & terminology
2. Explain the "Team-of-Teams" concept
   - Handout a listing of all teams, leaders & tel. number
   - Discuss Functions & Responsibilities (F&Rs) of teams with which your team will primarily interface
   - Cover the responsibilities of your team vs. interfacing teams
3. Explain PDT Operating Procedures (You Define). These may include:
   - Time & place of regularly scheduled team meetings
   - Status reporting techniques & schedules
   - Project & team documentation requirements
4. Explain key techniques and tools to be used
   - Include requirements documentation, schedule formats, etc.

Figure 6-11, Step 6

Some of the items covered in this step may already have been covered at either the project or team kickoff meetings. If so, they may be simply reviewed or eliminated from any subsequent training. It is recommended that a booklet of these charts or other project/team direction material be maintained so that absent or new team members can brief themselves and rapidly come up to speed on a project. Incidentally, full-size copies of all these IPPD charts can be obtained through the San Francisco Bay Area INCOSE chapter.

The kickoff meeting and early team training sessions provide excellent opportunities to establish high standards for team performance by establishing creative procedures to let people work to their best capabilities with simple, well-defined controls that minimize interruption of their work.

Stretch out training on key techniques and tools such that an item is presented just prior to its need (when interest is highest) rather than a few lengthy (probably boring) sessions.

Procedures should be established for document and design drawing control and release, interface definition and control (consistent with project), requirements reviews and design reviews, maintenance of baseline schedule (for the team), maintaining documentation on the baseline design (accessible to all project personnel), etc. Establishing these items of project level "infrastructure" and training your team in their use are critical to project success!

STEP 7 - DEFINING TEAM VISION and OBJECTIVES

TEAM VISION or GENERAL OBJECTIVE (EXAMPLE):

DELIVER and SUPPORT THE "XYZ THINGAMABOB" ON SCHEDULE, UNDER BUDGETED COST, WITHIN (or EXCEEDING) ALL TECHNICAL SPECIFICATIONS and IN-PROCESS MILESTONES; TO EARN MAXIMUM INCENTIVES AND HAVE SOME FUN IN THE PROCESS.

EXAMPLE OBJECTIVES FOR *ALMOST ANY* PDT:

1. PROVIDE QUALITY PROGRAM PRODUCTS WITHIN NEGOTIATED SCHEDULE MILESTONES AND INCREMENTAL BUDGET ALLOCATIONS. THIS INCLUDES:
   - *INCLUDE TEAM-SPECIFIC OBJECTIVES HERE. THESE MIGHT INCLUDE ITEMS SUCH AS:*
   - A WORKING PROTOTYPE IN 45 DAYS PRODUCING 5 WATTS POWER
   - ALL FINAL DESIGN DRAWINGS COMPLETE WITHIN 125 DAYS
   - *MEET/EXCEED* ALL SPECIFICATIONS WITH A COMPONENT WEIGHING $\leq$ 8 Kg. AND HAVING A RELIABILITY OF $\geq$ 0.9990 AFTER 6,000 OPERATIONAL HOURS.
   -
2. RESPOND TO THE INFORMATIONAL NEEDS OF INTERFACING ELEMENTS, PROGRAM MANAGEMENT, AND CUSTOMERS IN A TIMELY, COURTEOUS, AND PROFESSIONAL MANNER.
3. MEET ALL DOCUMENTATION AND BRIEFING REQUIREMENTS WITH CLEARLY EDITED, PROFESSIONAL PRODUCTS WITHIN NEGOTIATED BUDGET AND SCHEDULE.
4. DEVELOP AND MAINTAIN BRIEFING MATERIALS GIVING A CLEAR OVERVIEW OF TEAM PRODUCTS, ACTIVITIES, AND CURRENT STATUS vs. COST AND SCHEDULE MILESTONES AND TPM PERFORMANCE METRICS WITH MINIMAL UPDATE EFFORT EXPENDITURES.
5. EARN MAXIMUM INCENTIVES FOR TEAM AND AWARDS FOR AN OUTSTANDING JOB.

Figure 6-12, Step 7

At the first private meeting of the team its good to spend an hour or so (not days) focusing on team vision and objectives. Make it a collaborative, brainstorming process to involve the entire team and get their input. It also provides the first opportunity to work together as a team and learn others' perspectives.

After a short general discussion, you could use an Affinity Diagram tool to quickly converge on important ingredients for the vision and objectives. Then summarize and restate them in an organized fashion.

The team can then use its new vision and objectives in constructing a detailed plan of action.

There is heavy interaction with other teams, management, and customers. Many of these meetings require overview briefings on team activities and status updates. If this recognized from the outset, the team leader can enlist team support in preparing and maintaining "road show" briefing charts, as described in item number 4, in Figure 6-12. This helps the team leader be more productive.

STEP 8 - EACH TEAM'S EXPANDED DEFINITION of its JOB

1. Review Vision & Objectives; Operating Environment - including constraints
2. Map out Plan of Attack (POA)
3. Prioritize & schedule activities
4. Review personnel needs & budget
5. Adjust plan as needed
6. Team Leader review plans with IPDT and next higher (Process) team
7. Establish reporting milestones for each task - with a responsible individual designated
8. Status & Follow-up/Adjust/Correct as needed

Figure 6-13, Step 8

In expanding the definition of the team's job, the operating environment constraints should include technical as well as budget/manpower and schedule. In mapping out a plan of attack a tree chart approach can be used to organize identified tasks and subtasks into greater detail.

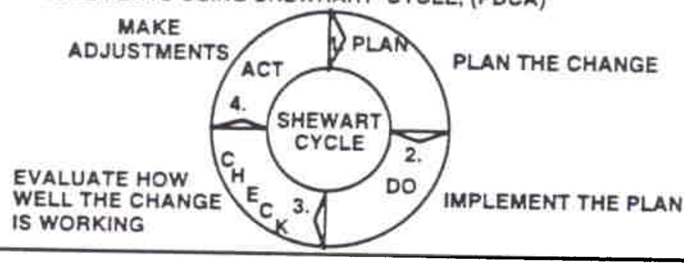
Once a breakout of tasks and subtasks has been developed, schedule them. Use Close-of-Business (COB) times, unless otherwise specified, on specific dates. Identify the responsible person on each activity; status at least weekly.

Now that a more-detailed plan has been developed, renegotiate budgets (more or less) as necessary to accomplish the tasks (or adjust the tasks for compatibility with the available budget). Resolve all budget problems quickly; the problems only increase with time.

Emphasize that team members <u>must</u> be accurate, factual, and quantitative in reporting status. Simply stating that "everything's fine" doesn't do it. Rather, "we have accomplished 85% of the items scheduled for this period; what's missing is ... and these items will be accomplished by XXX, which puts us two days behind plan, etc.".

STEP 9 - PROCESS ASSESSMENT and CONTINUOUS IMPROVEMENT

1. FROM THE OUTSET, INSTILL AN ATTITUDE IN THE TEAM FOR CONTINUOUS IMPROVEMENT.
2. ENCOURAGE INDIVIDUALS AND GROUPS TO COME FORWARD WITH IMPROVEMENT IDEAS
   - PROCESS IMPROVEMENTS
   - PRODUCT IMPROVEMENTS
3. SCHEDULE A BI-MONTHLY TEAM "SKULL SESSION" TO ASSESS HOW THE TEAM IS DOING AND HOW YOU COULD DO BETTER.
   - LIST YOUR KEY PROCESSES
4. ASSESS THE MATURITY OF YOUR KEY PROCESSES
5. IDENTIFY CANDIDATE IMPROVEMENTS
6. EVALUATE IMPROVEMENTS FOR GREATEST CONTRIBUTION TO TEAM OBJECTIVES
   - DEVELOP A SIMPLE SCORING SYSTEM
   - PARETO CHART PLOT of RESULTS
7. CONSIDER IMPLEMENTING THE IMPROVEMENTS
   - START WITH HIGHEST PARETO RANKING
   - CONSIDER COSTS vs. BENEFITS
8. SELECT IMPROVEMENTS TO BE IMPLEMENTED
   - REVIEW WITH PROJECT MGT. AS NECESSARY
9. IMPLEMENT IMPROVEMENTS USING SHEWHART* CYCLE, (PDCA)



* After Walter Shewhart

Figure 6-14, Step 9

A process is usually an integrated set of activities to accomplish a stated objective. Before you can improve processes you must identify the ones you are using. One way to do this is to use the Affinity Diagram technique to collect and group your activities into well-defined processes.

Next, assess the maturity of your processes. A detailed approach for this is given in Section 7, but, after reviewing Section 7, you can also perform quick subjective assessments as a team, ranking each process from 1 to 6 (or whatever) where 1 = initial level (undocumented processes), 2 = documented, .. and the highest level, 6 = optimizing.

To usefully focus your time, work on process improvements that appear to have high payoffs. Even though you may score some of your processes low, give them the "so what" test. If it's a big deal, work on it!

Evaluate candidate improvements. Include such factors as: schedule, cost, performance, quality, risk, personnel changes, facility/equipment changes, training required, impact on other project elements, impact on the customer, etc. Score as a team or separately then average, or discuss and reevaluate.

Remember, although you're looking for improvements, you must also consider the adverse consequences for your team and others. Some "improvements" have turned out to be disasters when a proven, reliable process was changed and process control was lost.

Step 4, "Act" in the Shewhart Cycle, in Figure 6-14, can also mean eliminate the proposed change, or adjust and try again. As you implement improvements, remember that, after PDCA, you start the process over -- to continuously seek useful improvements.

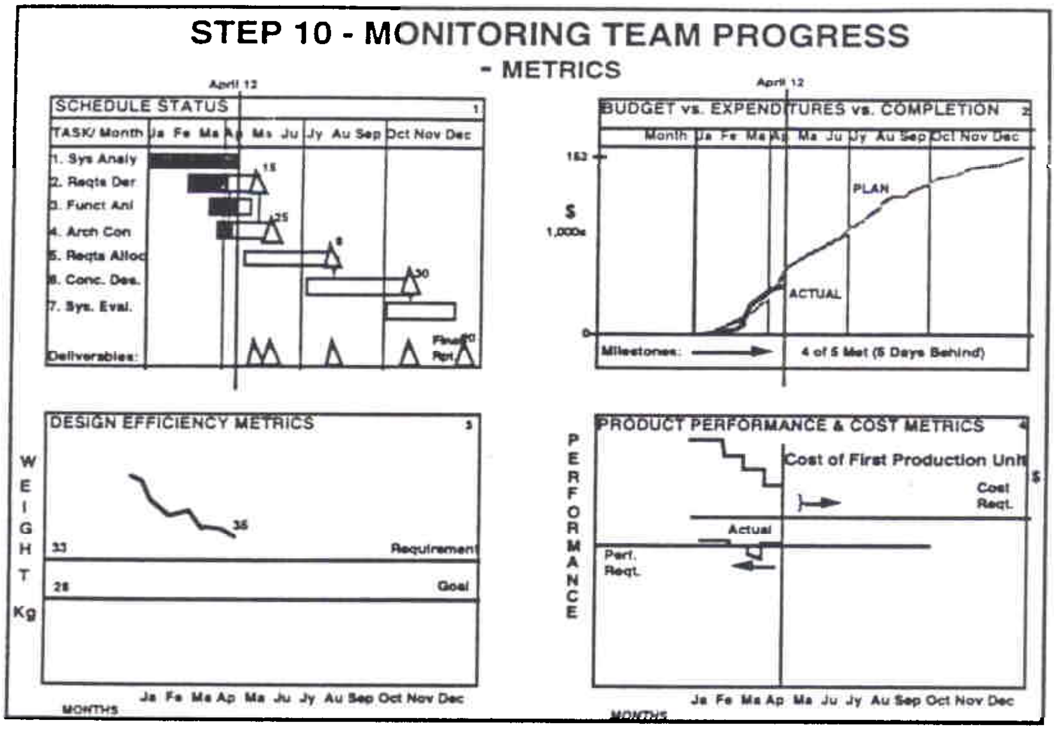


Figure 6-15, Step 10

Six categories of metrics that each product team can use to status its current and projected progress are illustrated in the four charts of Figure 6-15. Coordinate with the SE&I team on parameters, techniques, and units of measure to be used for commonality throughout the entire project so results can be quickly "rolled up".

Chart 1 shows team schedule status on each major task. The task bar is darkened to indicate percent completion, or days ahead (behind) schedule. The scheduled and actual completion dates (day and month) are shown by each task and milestone, including all deliverables. Lots of intermediate milestones should be shown.

Chart 2 gives status of actual team expenditures (including all commitments) vs. plan. At the bottom of the chart, the arrow shows milestone status. If the team is behind on some milestones, the arrow stops short of the current dateline by the number of days required to complete overdue milestones.

Chart 3 is representative of any number of design efficiency metrics, such as weight, required power, envelope dimensions (volume), errors per design drawing, or rework time, etc. Several may be required for adequate status.

Chart 4 gives another metric for design efficiency -- production cost of the first unit. Team status vs. its negotiated design-to-cost goal is shown. Also, performance status vs. key performance and quality measurements should be shown. This is a form of Technical Performance Measurement (TPM) for the team and should cover critical performance and quality parameters.

STEP 11 - SUSTAINING, EVOLVING TEAMS THROUGHOUT THE PROJECT

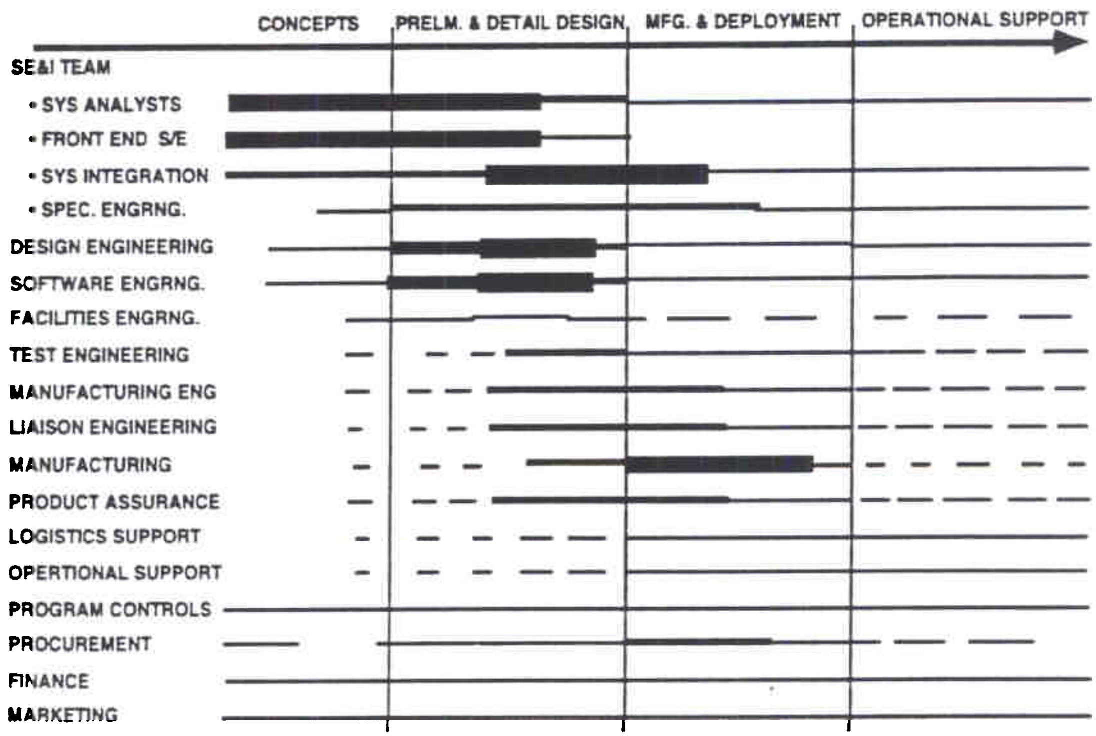


Figure 6-16, Step 11

The personnel assignments to a team will probably vary over the project cycle. If personnel adapt to the project's changing needs, perhaps they remain, but certainly the needs for skills varies during the cycle. The chart attempts to depict the relative emphasis for various skills on a project that has a heavy emphasis on both hardware and software.

Obviously, requirements development is critical during early conceptual design. Then note that many cross-functional disciplines are brought in beginning late in the conceptual design phase (wait until you have something to show them; its still early enough to make major changes with insignificant cost impact). These cross-functional specialists are identified with your team during conceptual design and continue periodic reviews of your progress, including detailed sessions with the other team members.

Specialty engineering may include reliability, maintainability, human factors, materials and processes, engineering standards writers, life cycle cost analysts, EMI/EMC, configuration management; etc.

Functions such as marketing, program controls, procurement, finance, legal, and human resources will generally support the team at a steady, low level of effort, or as required.

STEP 12 - DOCUMENTING TEAM PRODUCTS

IPD TEAMS STILL NEED LOTS OF DOCUMENTATION!

- IF ITS NOT DOCUMENTED, IT REALLY DOESN'T EXIST!
- HOW YOU DOCUMENT IS AN EFFICIENCY ISSUE
  - A COMPUTERIZED DATABASE IS GOOD – IF PEOPLE HAVE GOOD ACCESS TO IT

THE FOLLOWING NEED TO BE WRITTEN DOWN AND PRESERVED:

1. CUSTOMER INPUTS - ON WANTS, NEEDS, PROBLEMS
2. REQUIREMENTS AND SPECIFICATIONS - INCLUDING CRITICAL TIMELINE REQUIREMENTS
3. EXTERNAL I/F REQUIREMENTS AND I/F AGREEMENTS
4. INTERNAL I/F REQUIREMENTS AND I/F AGREEMENTS
5. CURRENT PROJECT/TEAM SCHEDULE
6. CURRENT TEAM ACTION ITEMS; WHEN DUE; WHO'S RESPONSIBLE
7. TEAM LEADER'S NOTEBOOK
8. CURRENT BASELINE DESIGN(S) OF TEAM'S END ITEM(S)
9. RATIONALE FOR SELECTION OF CURRENT BASELINE DESIGN
10. APPROVED PARTS LIST
11. TEST REQUIREMENTS
12. DEFICIENCY REPORTS
13. END ITEM COST PROFILE(S) AND SCHEDULE PROFILE(S) – PARETO FORMAT TO SUPPORT CI
14. DESIGN DRAWINGS
15. SOFTWARE DESIGN FLOWCHARTS AND SOURCE CODE
16. TEST RESULTS; DESIGN REVIEW RECOMMENDATIONS & DIRECTION
17. LRA AND MAINTAINABILITY PLAN, GENERAL LOGISTICAL SUPPORT PLAN; & MUCH MORE!

Figure 6-17, Step 12

The primary documentation requirements do not change significantly with the transition to IPD teams. What does change is the amount of cross-organizational correspondence required. Hopefully, it is greatly reduced or eliminated.

The items listed in Figure 6-17 and many more, must still be documented.

With cross-functional teams, there are many areas of expertise represented on the team. The team often has within its membership the capability to prepare the required documentation; delegating sections to various members, then integrating and editing the inputs to form the final document.

On documents that are likely to be updated, a person should be designated as the overall responsible author. This person is responsible for preserving the previous edition and collecting revisions for the next edition. Different people on the team should be designated as responsible for different documents.

STEP 13 - CLOSURE and FOLLOW-ON ACTIVITIES

CLOSURE	1. LEAVE A TRAIL ON FILE WITH THE PROGRAM OFFICE 2. INCLUDE TEAM LEADER'S NOTEBOOK(S) 3. PERMANENT CONTACT POINTS FOR TEAM LEADER & BACKUPS 4. INCLUDE FINAL ASSESSMENT OF PROJECT 5. INCLUDE TEAM ASSESSMENT OF LESSONS LEARNED (THESE SHOULD BE ROLLED UP TO PROJECT LEVEL)
FOLLOW-ON PROGRAM TYPE:	ACTIVITIES VARY WITH THE TYPE OF FOLLOW-ON PROGRAM
1. EXTENDED PRODUCTION	• MINOR MODS TO EXISTING PROGRAM • CONTINUE WITH SAME TEAMS
2. DESIGN IMPROVEMENT (MOD)	• MAY REVERT TO CONCEPT OR PRELIMINARY DESIGN STAGE • MUST ASSESS NEW REQUIREMENTS • PLAN HOW TO MEET REQTS. WITH MIN. MODS & COST
3. NEW APPLICATION	• THOROUGH ASSESSMENT OF NEW MISSION REQUIREMENTS • BRING IN CONCEPT TEAM BUT RETAIN PERSONNEL WHO KNOW THE PRESENT SYSTEM DESIGN, MFG., & OPS.

Figure 6-18, Step 13

In closing down a team, the main thing is to leave a team historical record on file with the project/program office. If the team leader kept his notebook(s) up-to-date during the program, there will be little left to do, except to possibly write a summary assessment of the team's activities and the status of things as the team's activity was discontinued.

The other items called for in Figure 6-18 should also be prepared, including lessons learned and how to contact key team members for several years in the future. The rationale for maintaining these records is to support analysis of in-service problems; to possibly assist other programs with similar situations; and to maintain records in case there is ever another startup of the team/project.

A follow-on activity could be anything from extended production of the same products, mods, or entirely new applications. This dictates how far back into the product life cycle the program must go and what type of product development teams it should have.

If extensive re-engineering is required -- as in design mods or new applications, problems can occur if the operational support teams attempt to address these without substantial engineering help.

SOME IPDT PITFALLS

1. SPENDING TOO LONG DEFINING VISION and OBJECTIVES
   (Converge and get on with it!)
2. PDT MEMBERS REQUIRED TO CHECK BACK WITH MANAGERS FOR AUTHORIZATION
   (Team leader responsibility – or put the manager on the team!)
3. PDT MEMBERS HAVE THE AUTHORITY, BUT AREN'T SENSITIVE TO MGT. ISSUES AND OVERCOMMIT or OVERSPEND
4. FUNCTIONALLY-ORIENTED TEAMS INSTEAD of CROSS-FUNCTIONAL, PROCESS-ORIENTED TEAMS
5. INSUFFICIENT CONTINUITY OF TEAM THROUGHOUT PROGRAM
6. TOO EARLY or TOO LATE TRANSITION TO NEXT PHASE TEAM SPECIALISTS
7. OVERLAPPING ASSIGNMENTS of SUPPORT PERSONNEL to TOO MANY TEAMS
   (Compromises their effectiveness)
8. LACK of GOOD REFERENCE DOCUMENTATION
   (For requirements, baseline schedule, baseline design, etc.)
9. INADEQUATE PROJECT INFRASTRUCTURE
   (Includes reqt. review & control process, configuration mgt., release center, etc.)

Figure 6-19, Some IPDT Pitfalls

There are some things teams should watch out for. Figure 6-19 describes nine. There are ample opportunities to get off track until team members and leaders go through several project cycles in the IPDT structure and gain the experience of working together.

Obviously, some things do require checking back with higher authority. Encourage team members to anticipate these from the outset. Functional managers/supervisors, if any, must stay aware of major team issues and coach/guide/train participants until they gain the requisite experience.

Project managers should review team staffing plans to ensure proper composition. Strive for continuity of assignments. The loss of a key team member who knows how and why things are done can leave the team floundering.

TEN TECHNIQUES FOR HIGH PERFORMANCE

1. CAREFUL STAFF SELECTION – GOOD PEOPLE DO GOOD THINGS
2. ESTABLISH & MAINTAIN POSITIVE TEAM INTERACTION DYNAMICS (MOST IMPORTANT!)
   - ALL KNOW WHAT'S EXPECTED
   - INFORMAL, BUT EFFICIENT
   - ALL STRIVE TO MEET COMMITMENTS
   - UPBEAT: NO BLAME FOR PROBLEMS
     - "LETS JUST FIX IT AND MOVE ON"
3. TEAM COMMITMENT AND "BUY-IN" TO VISION, OBJECTIVES, TASKS, & SCHEDULES
4. BREAKDOWN THE JOB INTO "BITE-SIZE" CHUNKS, SCHEDULE THEM, ASSIGN RESPONSIBILITY and FOLLOW-UP AT LEAST WEEKLY ON PROGRESS
5. DELEGATE, SPREAD OUT ROUTINE ADMIN. TASKS AMONG THE TEAM
   - FREES LDR. FOR MORE TECHNICAL STUFF
   - LIMIT TO ≤ 1 HR/WK per TEAM MEMBER
   - ADMIN./MGT. EXPERIENCE FOR TEAM
   - MAINTAIN TEAM GOAL CONSCIOUSNESS
6. "WORLD CLASS" ANALYSIS & SIMULATION CAPABILITY FOR REQTS. & PERFORMANCE
   - BE BETTER THAN YOUR CUSTOMER & COMPETITION
7. FREQUENT TEAM MEETINGS (DAILY 8:00 - 8:30 RECOMMENDED)
   - QUICK, EFFICIENT INFO EXCHANGES
   - ASSIGN ACTION ITEMS; MAINTAIN LIST WITH ASSIGNEE and DUE DATE
   - EVERYONE STAYS CURRENT
   - MANDATORY ATTENDANCE (UNLESS EXCUSED BY TEAM LEADER)
8. MAINTAIN A TEAM LEADER'S NOTEBOOK
9. ANTICIPATE! ANTICIPATE!! ANTICIPATE!!!
   SURFACE POTENTIAL PROBLEMS QUICKLY (INTERNALLY & EXTERNALLY)
   – THEN SWEAT THE DETAILS
10. ACKNOWLEDGE & REWARD GOOD WORK

Figure 6-20, Ten Techniques for High Performance

On product teams its important to have people who can work well together and communicate. But don't condemn your team to mediocrity by avoiding those outstanding technical/specialist people who can really make a difference.

General Abrahamson was at one time director of the DoD Strategic Initiative Program. His observation was that one fulltime (FT) person on the job was always better than "N" part time (PT) people. Generally this seems to be right.

Most of the items in Figure 6-20 are self-explanatory.

TEAM LEADER'S NOTEBOOK(S)

- THE TEAM LEADER'S NOTEBOOK CONTAINS THE HISTORY OF THE TEAM'S ACTIVITIES ON THE PROJECT.
- IT IS NECESSARY DUE TO THE TRANSITION OF PERSONNEL AND SOMETIMES TEAM LEADERS ON/OFF THE TEAM DURING THE COURSE OF A MULTI-YEAR PROJECT.
  - MINIMIZES LOSS OF CONTINUITY
  - REVIEW OF THE NOTEBOOK RAPIDLY BRINGS NEW MEMBERS/LEADERS UP TO SPEED
- CONTENTS WILL VARY WITH THE TYPE OF TEAM AND PROJECT BUT GENERALLY SHOULD INCLUDE:

1. THE "TEAM CHARGE"
2. TEAM MEMBERS NAMES, RESPONSIBILITIES, TEL., FAX, E-MAIL, BUILDING ADDRESS
3. REQUIREMENTS/SPECIFICATIONS
4. SCHEDULE (LATEST REVISION) AND TEAM'S CURRENT SCHEDULE STATUS
5. TEAM BUDGET (LATEST REVISION) AND TEAM'S CURRENT SPENDING STATUS
6. KEY DECISIONS, RESOLVED ISSUES, OR MANAGEMENT DIRECTION AND RATIONALE
7. CURRENT ACTION ITEMS
8. INTERFACE AGREEMENTS: SUMMARY; DETAILS MAINTAINED ON DWGS. &/or COMPUTER DATA BASE
9. SUPPLIER DATA; INDIVIDUAL NOTEBOOK FOR EACH SUPPLIER CONTRACT
10. DESIGN CHARACTERISTICS: SUMMARY CHARACTERISTICS OF TEAM PRODUCTS
11. KEY CONCERNS AND APPROACH
12. NOTES OF GENERAL INTEREST

Figure 6-21, Team Leader's Notebook(s)

Figure 6-21 summarizes the key items that should be considered for collection in the team leader notebook(s).

The team leader can/should delegate preparation and maintenance of various parts of the notebook to various members of his/her team. The team leader should periodically review the notebook to insure that it remains up-to-date and a viable reference resource.

REFERENCES

1) Paper by M.J. Churchill, McPherson, and Weston, The Boeing Corporation, Proceedings of the 3rd annual NCOSE International Symposium, July 1993.

2) Paper by J.D. Cox, Lockheed ASD, Proceedings of the 3rd annual NCOSE International Symposium, July 1993.