Challenges and Benefits to the Implementation of Integrated Product Teams on Large Military Procurements

by

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Submitted to the Alfred P. Sloan School of Management on May 8, 1995, in partial fulfillment of the requirements of the Requirements for the Degree of Master of Science.

Abstract

Ten's of billions of dollars will be spent by the United States Air Force, and Navy, over the next several years on the development and production of our country's top military weapon systems. The most senior leadership of these government agencies have committed their organizations to proceed with this development using a concept of management known as Integrated Product Development (IPD) using Integrated Product Teams (IPT).

Essentially, the majority of the US aerospace community is moving towards this new concept of management. Since this concept comes from the commercial industry, the underlying factors of the way commercial industry does business versus aerospace, need to be explored to ensure a model of IPD/IPT is developed which is optimized for the US aerospace industry.

This thesis looks at this issue for four, ongoing, major aircraft developments; B2 Bomber, C17 Transport, F/A-18 E/F Fighter, and F22 Fighter. These four programs are reviewed and contrasted to commercial business practices to bring out structural differences that may act as barriers to IPT Implementation. Several areas were identified that impede its implementation. These areas include: training, team budget control, and the need for balance between teams and functions. In addition, details of how benefits can be derived from the IPT concept are discussed. Current methods being used to measure these benefit are presented.

Thesis Supervisor: Dr. Janice A. Klein
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I wish to acknowledge the many people in industry that took time out of their schedules to talk with me and also made people from their organizations available as well. In this business, no one has spare time, so I know it was a sacrifice for them, and for that, I am grateful:

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Also, special thanks to Ed Smith and Jorge Diaz who both have taught me a great deal about the aerospace industry and it's challenges over the past 19 years.

However, the greatest recognition needs to go to my wife Dawn and my son Christopher, who have been a constant source of support and motivation over this past year. To them, I shall be eternally grateful.

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INTRODUCTION AND BACKGROUND

Ten's of billions of dollars will be spent by the United States Air Force, and Navy, over the next several years on the development and production of our country's top military weapon systems. The most senior leadership of these government agencies have committed their organizations to proceed with this development using a concept of management known as Integrated Product Development (IPD).

According to General Ronald W. Yates, Air Force Material Command, Commander:

> *"I believe Integrated Product Development (IPD) is the management initiative that will enable Air Force Material Command to operate most efficiently in this era of diminishing resources."*[1]

According to William C. Bowes, Vice Admiral, Nav Air Commander, US Navy:

> *"...lessons learned from Motorola, General Motors, Texas Instruments, Hughes Aircraft and the Air Force, which in turn have initiated some Nav Air methods.*
>
> *Those methods include integrated product teams, integrated weapon system management, cradle-to-grave management, flatter organizational hierarchies and co-location of team members which have collectively improved the service NAV AIR provides".*[2]

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[1] USAF/AFMC Commander's Policy-Integrated Product Development, 21-April-1993.

[2] Aerospace Daily, 25-July-1994.

Problem Description:

Essentially, the majority of US aerospace companies are is moving towards this new concept of management, Integrated Product Teams (IPT), as the primary component of IPD. Much of the theory behind IPT comes from the product development teams commercial industry has developed in recent years, as well as from the principles of concurrent engineering. However, the underlying factors of the way commercial industry does business versus aerospace needs to be explored to ensure a model of IPD/IPT is developed which is optimized for the US aerospace industry.

Approach to the Problem:

The approach to analyzing this problem was to look at four ongoing major development/production programs actively implementing the concept of IPD. The B2 Bomber, C-17 Transport, F22 Fighter, and the F/A-18 E/F Fighter, were reviewed relative to their implementation approaches. Each program was reviewed through structured interviews, and discussions with their program management and staffs. In reviewing these programs not all contractors were contacted due to logistical constraints. The contractors visited for each program are highlighted in Figure 1. The structured interview questions used in the program reviews were primarily based on challenges the B2 Bomber Program had in its attempts to implement IPD in 1993/94.

In addition to the four DOD programs, a commercial aircraft program, the Boeing 767-300ER Freighter, and an auto manufacture, the General Motors Cadillac and Luxury Car Division, were reviewed. These two reviews were to look for any significant differences in the way commercial business is conducted versus how the aerospace industry does business. Any identified differences would be analyzed for their impact to implementation.

A days worth of discussion on the topic of IPD was also conducted with personnel at WPAFB[3], who are charged with establishing standard approaches on IPD implementation for the Air Force.

Contractors Visited

	B2	C17	F/A18	F22
Northrop Grumman	Prime	Sub	Sub	
Boeing	Sub			Sub
Lockheed				Prime
MDA		Prime	Prime	

Figure 1

The results of the interviews and discussions were analyzed to determine if there were elements associated with the aerospace industry that may act as barriers or present major challenges to IPD. In addition, evidence of benefits from IPD was documented. This thesis also documents as background information, what IPD is and what its expected outcomes are .

What is Integrated Product Development?

The United States Air Force (USAF) has been a strong proponent of the management concept of Integrated Product Development (IPD). They have imposed it as a requirement on all Air Force personnel and have strongly encouraged industry to embrace this approach of management with them . They have made it a contracted

[3] Wright Patterson Air Force Base, is in Dayton Ohio, and home of the Air Force Material Command.

requirement on the F-22 Program, and the US Navy made it a contractual requirement on their F/A-18 E/F Program.

The USAF has spent a lot of time and effort defining and developing the concept of IPD. In May of 1993 they published a "Guide for Understanding and Implementing IPD throughout AFMC".[4] The definitions used below for IPD are taken from this guide.

[4] Air Force Material Command-is chartered to develop and procure all aircraft for the United States Air Force.

IPD as a Philosophy

IPD is looked upon by the USAF as a philosophy to managing Programs. They define it as follows:

"A Philosophy that systematically employs a teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce an effective and efficient product that satisfies customer's needs".

They go on to define a "product" as not only what is delivered to your customer but also processes like design, manufacturing and test which make the product possible.

IPD is made up of several tenets which are depicted in Figure 2, and are listed below:

IPD PHILOSOPHY	
CULTURE CHANGE	TEAMWORK & COMMUNICATIONS
PRODUCT FOCUS	EMPOWERMENT
UP-FRONT PLANNING	SEAMLESS MANAGEMENT TOOLS
RIGHT PEOPLE, RIGHT PLACE, RIGHT TIME	INTEGRATION THROUGHOUT LIFECYCLE

Figure 2

1) Culture Change - Embracing the IPD philosophy requires purposeful, multi-disciplined teamwork. The priority of focus for IPD should be:

a) The customer
b) The product
c) The process
d) Constraints,
e) Organizational structure

2) Product Focus - IPD requires a product focus and a complete understanding of the processes required to optimize the product.

3) Up-front Planning - The life cycle of a product or process will be integrated through comprehensive, up-front planning that must include all functions, customers, and suppliers.

4) Right People, Right Place, Right Time - All functions that impact the achievement of the customer's requirements should be applied concurrently, in a team fashion, throughout the life of a product or process.

5) Teamwork and Communications - People must function as a team. Team success, facilitated by rapid, open communications, must be emphasized and rewarded. Management relationships must be developed which are consistent with and focused on achieving the team's measurable goals and objectives.

6) Empowerment - Decisions must be driven to the lowest possible level commensurate with risk. Resources should be allocated at levels consistent with authority, responsibility, and the ability of the people.

7) Seamless Management Tools - A framework must be established which relates products and processes at all levels to demonstrate dependency and interrelationships. This hierarchical interrelationship must be understood and appropriate partnerships established to ensure that all decisions are optimized toward the ultimate user's end product.

8) Integration Throughout the Life Cycle - IPD will encompass all products and processes, regardless of the point in their life cycle.

IPD Structure

A model, from the AF IPD Guide is shown in Figure 3. The Model is based on an iterative process using special tools, teams, and process to assure that the product produced meets customer requirements.

GENERIC IPD MODEL

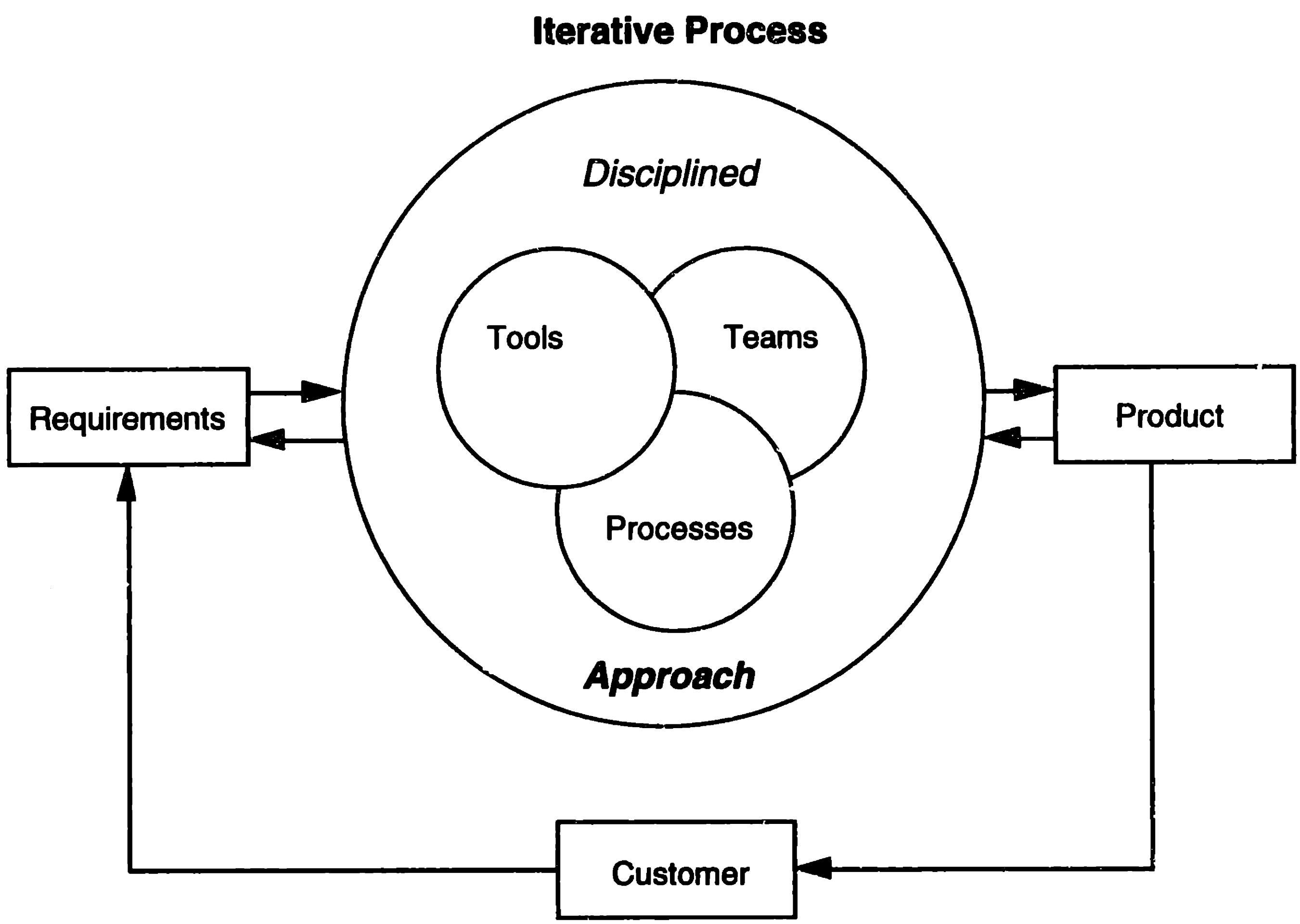

Figure 3

Why IPD?

The AF material Command, discusses the notion that a paradigm shift is taking place in corporate America today. They cite the successes that General Motors' Saturn Division has had by changing their culture and fostering a new organization which empowers workers. They speak of how the Ford Motor Company's Taurus division used a team of specialists to develop a car which could compete with the Japanese. Also mentioned is Motorola and how they have created a new culture by establishing department teams who focus on employee participation and not on organizational boundaries.

You can not pick up a piece of popular business literature today without reading about how one company or another is changing their culture, getting flatter, empowering the people, re engineering, and of course using teams to put them at the top of their industry, competitively. Unfortunately I think that when we read about these successes we often do not realize that there are far more penetrating organizational and industry related circumstances that allow these methods to work for one business and not another. This thesis will look at some of the issues associated with folding these popular management approaches into the military aerospace complex.

DATA COLLECTION METHODS

The purpose of this thesis was not to review programs implementing IPD and determine their effectiveness. But rather, to look at issues associated with implementing IPD in order to determine if unique barriers exist in the US military aerospace industry that would impede IPD implementation, since it was evolved from another industry.

Programs Visited

Provided here is a brief summary of the four military programs reviewed and where they are in the IPD implementation process. In addition, discussion is presented on how the commercial programs are structured.

B2 Bomber Program

The Northrop Grumman Corporation is under contract to develop, test, and produce the B2 Bomber for the USAF. Northrop Grumman and it's principle partners, Boeing, Vought, IBM, Hughes, and General Electric have been developing the B2 since the FSD contract was awarded in 1981. The current statement of work includes the production of 6 development and flight test aircraft, 2 Structural test aircraft, 20 operational aircraft, including all required support equipment, training and technical data.

The current development program status is: The B2 currently is meeting it's critical development milestones. The flight test activity has completed over 13,000 test points out of a planned 24,900. The flight test program also recently set new records for the number of flights in one month, 25, and number of flight hours in one month, 129. On the production contract, 6 aircraft have been delivered to Whiteman Air Force Base to date. These aircraft are of an early configuration and will be upgraded at a later time to the final configuration. The remaining aircraft are in final stages of production. The B2 program continues to be on schedule for critical logistical elements; like, technical data, training equipment and materials, support equipment, and spares.

The B2 Program began implementing the concept of IPD well after the program had started. The B2 adopted the concept of IPD in 1993 with the reorganization of its functions and program office. The concept adopted by the B2 team is shown in Figure 4. The basic idea is that the teams worried about the product and the functions provide services required to produce the products. The functional Vice Presidents were charged with performing their functional manager duties as well as acting as and Program Team Leaders (PTL). On the B2 Program there are six PTLs; Integration, Development, Air Vehicle Build, Air Vehicle Test, Systems Support, and Training. Below the PTLs were a series of Integrated Product Team (IPT) Leaders; such as Armament, Avionics, Production, Technical Data, Etc. Each IPT was made up of multiple disciplines as required for their statement of work.

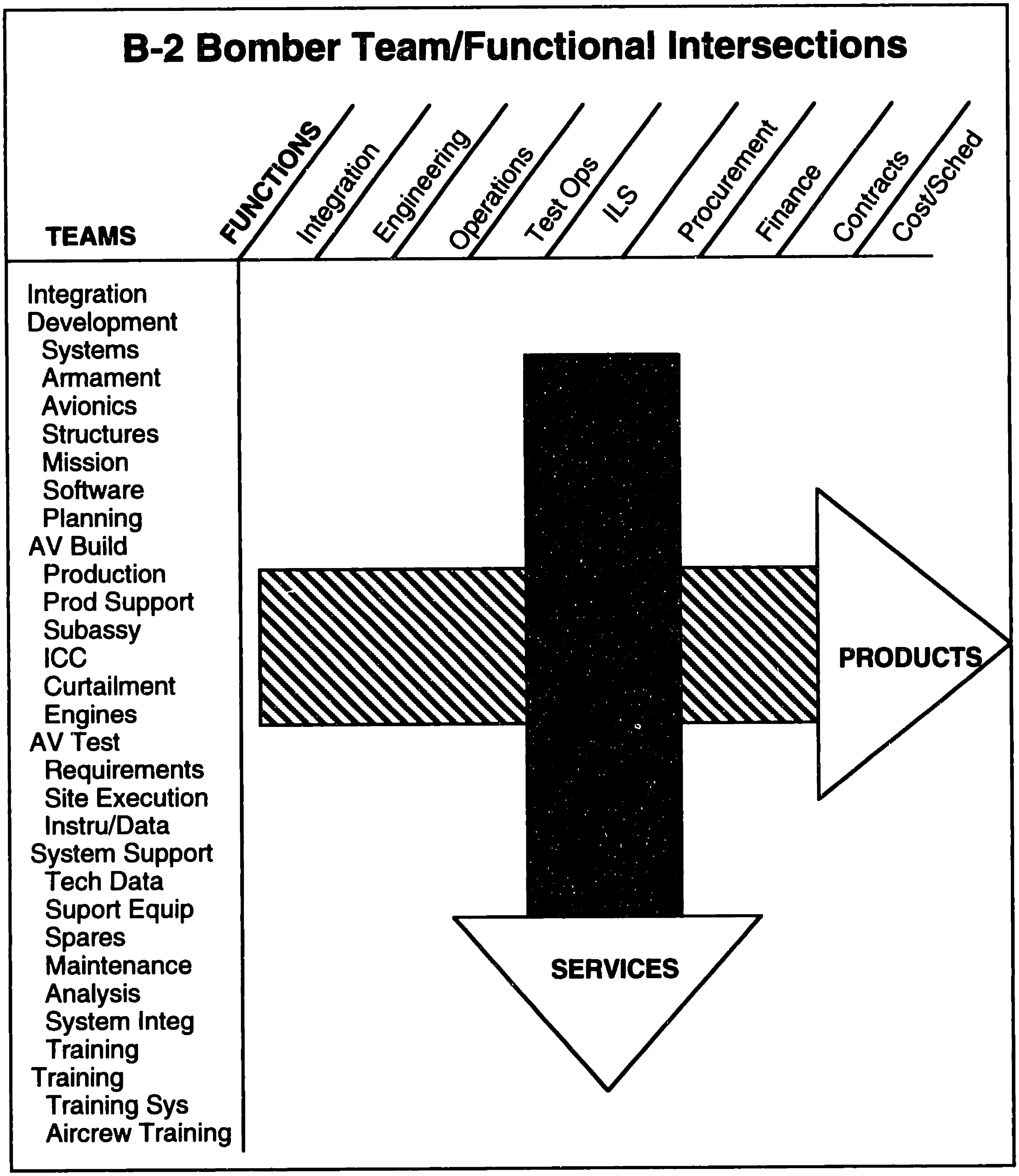

Figure 4

Each IPT was responsible for a particular segment of the Program. Efforts were made to try and get these teams cost and schedule data to aid in their product task responsibilities. The challenges associated with getting the team this data will be discussed further in the section on Cost Accounting and Budget Control.

Organizationally, the teams listed in Figure 4 reported to the Program Manager, as well as a functional manager/VP. For instance, all the Development IPTs reported to the VP of Engineering, and all the Air Vehicle Build IPTs reported to the VP of Operations. In a few cases an IPT leader had no other functional responsibilities, however, in most cases the IPT leader was also a second or third level functional manager.

On the Government side, teams were set up with counterparts to each of the Northrop Grumman team leaders. The government System Program Office (SPO) also facilitated participation from the using command (ACC)[5] and the Program Element Officer, USAF/HQ.

C-17 Military Transport Program

McDonnell Douglas received EMD authority to proceed with a slow-paced preliminary development order in July of 1982 for the C-17 Transport. They had been developing the C-17 aircraft since 1981. Their EMD contract was for three prototype aircraft, 1 flight test, and 2 ground based structural tests articles. They received a Low Rate Initial Production order in January of 1988, and have delivered approximately 20 aircraft under this contract. They had first flight of one of the prototype aircraft on 15 September 1991. By May of 1993, they had flown their 400th sortie. First paratroop drop in July 1993; established two new payload-to-altitude records in October of 1993, increasing their list of records to 21.[6]

The C-17 Program implementation of IPT was similar to that of the B2 Bomber program, in the sense that the concept was overlaid on an on-going program. They reorganized into Integrated Product Teams

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[5] Air Combat Command.

[6] Jane's, All the Worlds Aircraft, 1994.

in late 1993. Their Team structure is shown in Figure 5. They had a level I team-Weapon System, nine level II teams (7 product and 2 integration), and assigned approximately 2000 personnel to these teams. Deliverables, budgets, and program master schedule events were assigned to the teams. The SPO also had counterparts to these teams, and actively participates in team activities.

C-17 Weapon System Team Membership

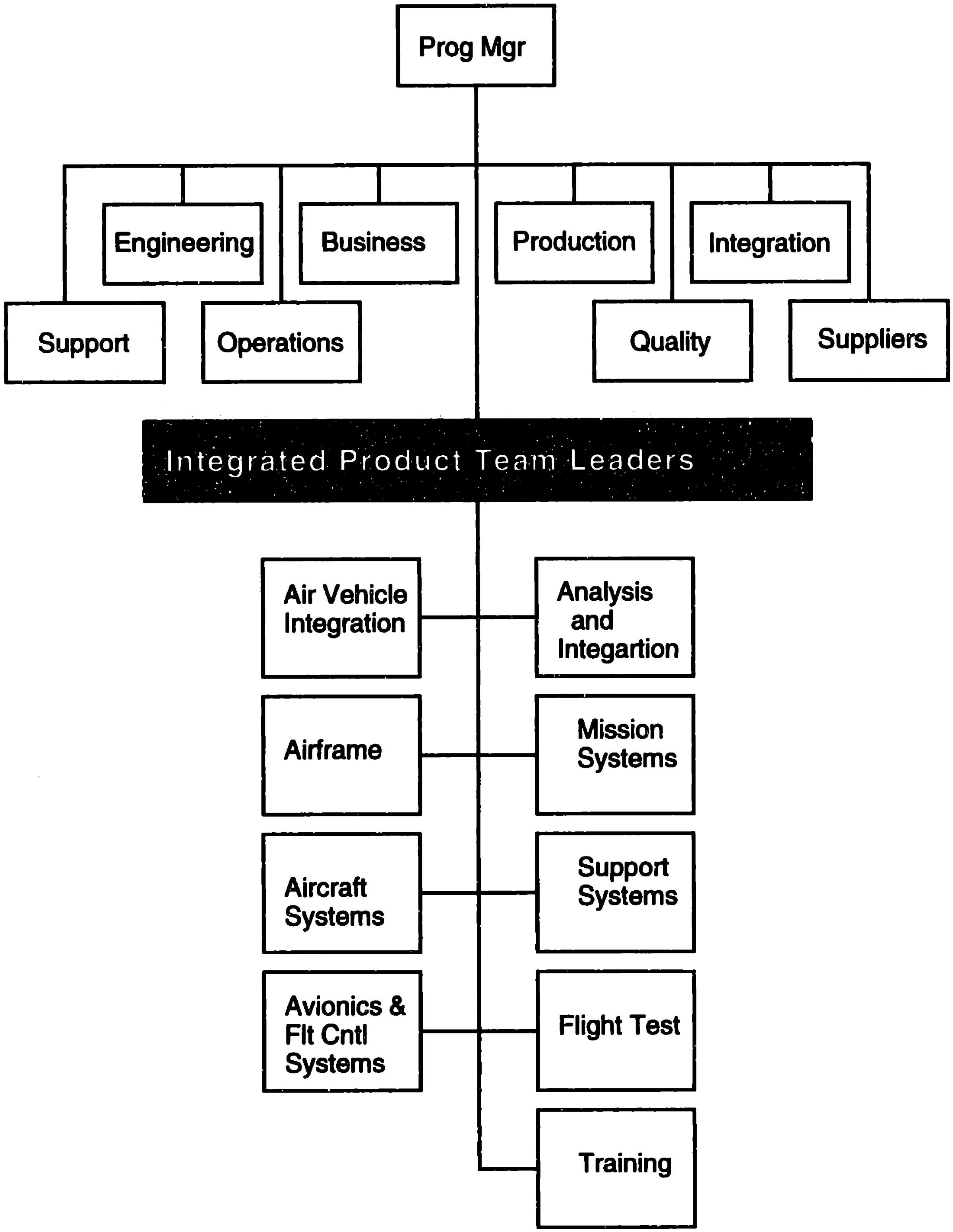

Figure 5

F-22 Fighter Program

The USAF Advanced Tactical Fighter (ATF) requirement is to develop a replacement for the F15 Eagle, incorporating low observables technology and supercruise (supersonic flight without using afterburners). The F22 will be the air superiority fighter meeting these ATF requirements. An EMD contract was awarded in August 1991 for nine flying prototypes, plus one static and one fatigue test airframes, to the Lockheed, Boeing contractor team. A preliminary design review was held in April 1993, critical design review was held in early 1995, and first flight is scheduled for mid-1996. A low rate production decision is expected in August of 1998.[7]

The F22 Program has IPD/IPT as a contractual requirement. The organization structure that evolved from this requirement is shown in Figure 6. Their team structure has one Weapon System Integration Team and four Product teams; Air Vehicle, Training, Support, and System Test.

The Boeing Company is responsible for wings, aft fuselage, power plant installation, auxiliary power generation system, radar, infra-red search and track system (if used on production) and avionics ground prototype. Boeing will also develop a 757 flying test bed and the F22 Training System.

The IPTs established at Boeing were based on the products they are responsible for and are made up of what ever resources are required to get the job done. The IPTs report to the Program Manager and have reporting to them people from all the required functions to make up the team. In addition, the Program Manager has three functional Directors; Business Management, Manufacturing, and Engineering reporting to him. These three have a dual reporting structure, to the program manager and to their functional VPs.

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[7] Jane's, All the Worlds Aircraft, 1994.

These Directors have the job of staying close to the program so as to ensure the right people are being used to staff the teams.

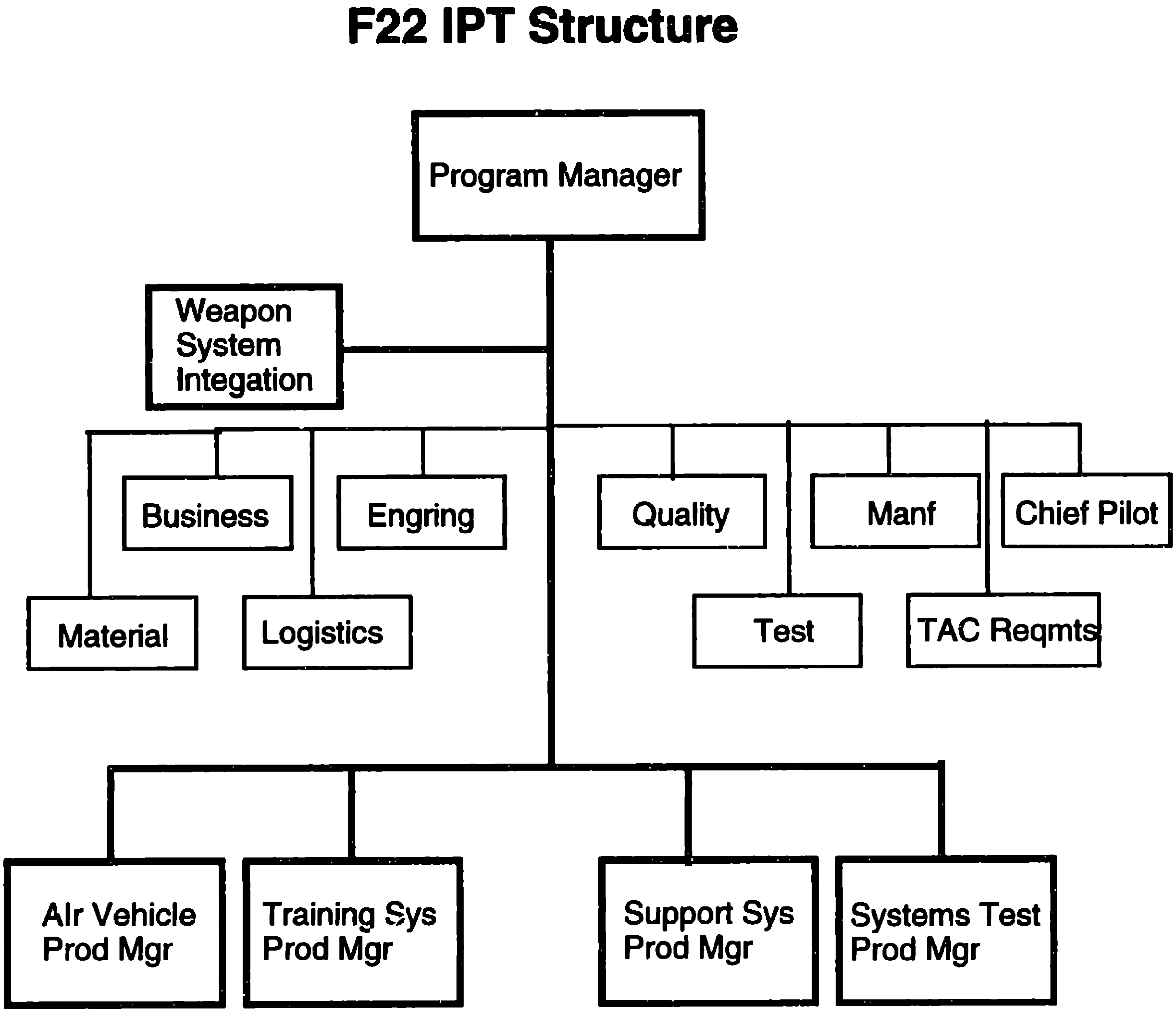

Figure 6

Each team leader has a deputy, usually a person with the functional background required for the next phase of program development. For instance, most of the Air Vehicle teams have manufacturing type personnel as deputy team leaders.

F/A-18 E/F Fighter Program

The F/A-18 E/F being developed by McDonnell Douglas and Northrop Grumman, was proposed in 1991 as a replacement for the canceled A12 and a follow on to earlier F/A-18As and other USN tactical aircraft as they retire. EMD began in December of 1992, which included development of seven test aircraft (five Es and two Fs) and three static airframes for structural testing. The F/A-18E/F will be equipped with the new GE F414 (35% higher thrust) engine. In addition the aircraft will have structural changes (25% larger wing, 34 inch center fuselage extension) and systems changes which give it longer range, (33% additional internal fuel) and more payload capability (light weight composite structures), greater carrier bringback, improved survivability, and growth capability.

First flight is planned for December 1995, and first production delivery in the late 1998 time period.[8]

Like the F22 Program, the F/A-18 program was proposed to be structured, organizationally, around the IPD/IPT concept. The concept the F/A-18 Program chose, was an outgrowth of the work performed by Northrop Grumman and McDonnell Douglas on the ATF program (YF23).

Their approach is different from the other programs in the sense that they have three phases of a program which create a backdrop under which their IPT's operate, see Figure 7; a Product Development Phase, a Product Delivery Phase, and a Product Support Phase. Under this concept there is to be a hand-off from segments of the teams in one phase to teams of the next phase. The concept is supported by having members from the downstream phases participating with the upstream phases.

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[8] Jane's, All the Worlds Aircraft, 1994.

F/A-18 E/F IPT Structure

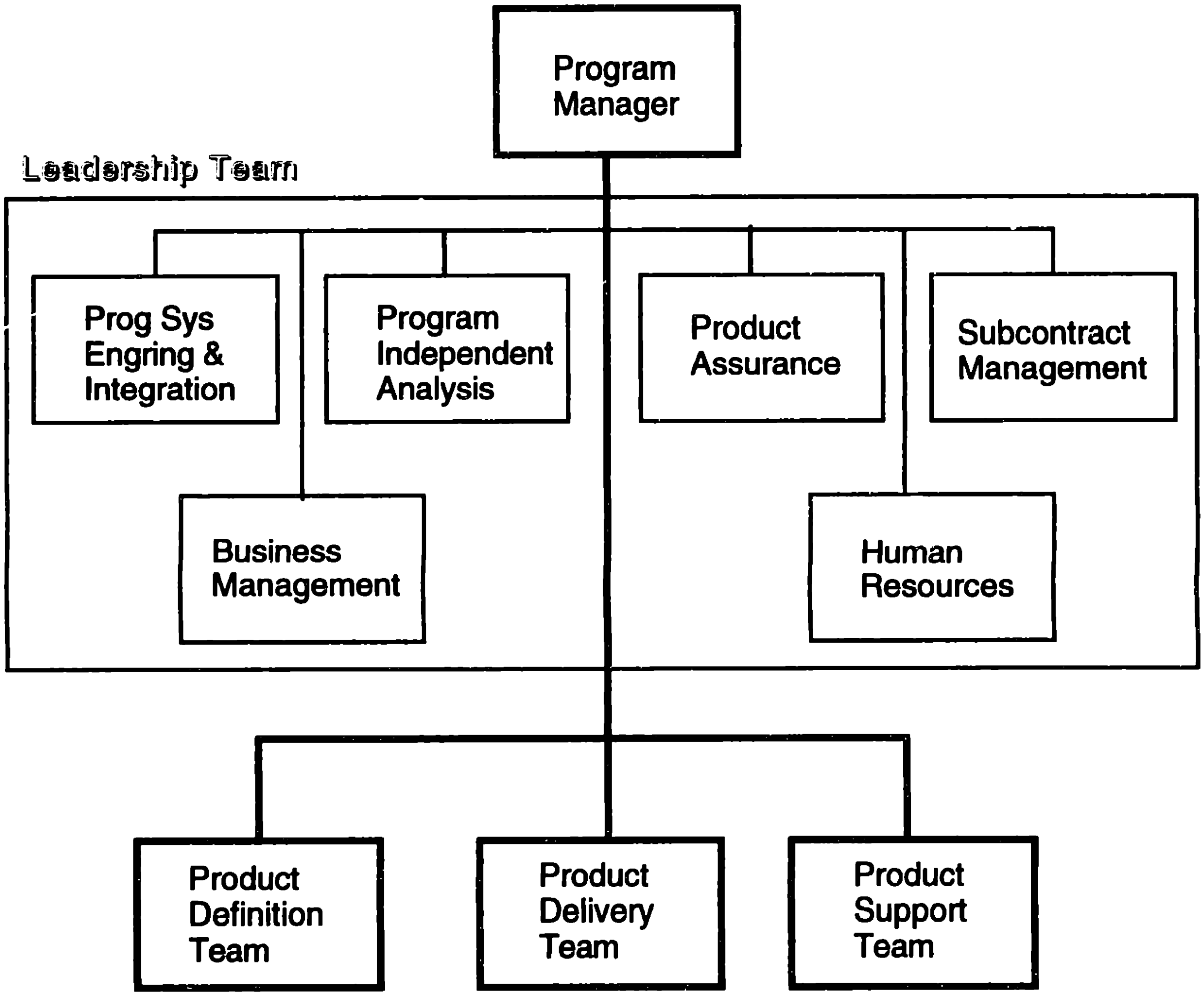

Figure 7

The F/A-18 E/F Program also has what they call, a Leadership Team. This team is made up of the key functional managers who report to their respective functional managers as well as the F/A-18 E/F Program Manager. The Leadership Team participates in the Product Team's goal setting, performance reviews, and reward processes. However, their primary job is to remove barriers such ht the Product Teams can get the job done.

The F/A-18 E/F program has been a very successful program. According to their Program Manager, they are meeting all technical performance measurements while operating at a schedule performance index (SPI) and a cost performance index (CPI) of 97%. They delivered the structural test article nine days early and the first flight article right on-time. This all is against a plan that was laid out over two years ago.

Boeing 767-300ER Freighter Program

Boeing Commercial Aircraft Company is undertaking a development of an all-cargo version of its 767 passenger transport with an order from United Parcel Service for 30 aircraft and options for 30 more. This freighter is a derivative of Boeing's 767-300 Extended Range passenger transport. It will have a 134 X 105 inch cargo door on the forward fuselage to meet UPS's needs. In addition, some strengthening in the landing gear and support structure is required for planned higher landing weight.

Flight test should begin in the second quarter of 1995, followed by certification, with deliveries beginning in October of 1995. Boeing plans to have five freighters to UPS by the end of November 1995.[9]

The 767 freighter Program Manager, in 1993, believed that the process improvements they have been studying for some time will allow them to deliver this derivative aircraft faster than in the past and at a lower price. These improvements include the use of cross-functional management teams for the program development. Two of their suppliers, Japan's Kawasaki Heavy Industries, and Mitsubishi Heavy Industries have agreed to support Boeing's efforts in this new management approach. Boeing created six "working together teams" around the major components/systems that would change on the 767 freighter, like doors, and floors.

These teams brought together they key functional representatives necessary to execute the change. These teams do not manage budget, they do however, have cost targets and are provided data to show

[9] "UPS Order Launches 767 Freighter Version", AW&ST, January 25, 1993.

how they are performing to these targets. Two of the six teams were collocated, and these same two teams were the only ones to exceed their cost reduction targets (i.e. did better performance). Customer involvement in Boeing's day-to-day activities is very limited compared to what is typical for a DOD procurement. UPS informed me that they only have five people overseeing the Boeing activity on a regular basis.

General Motors, Cadillac and Luxury Car Division (CLCD)

General Motors', Cadillac and Luxury Car Division, located in Flint, Michigan is responsible for developing and manufacturing large cars for the Buick-Oldsmobile-Cadillac and Pontiac Groups. GM's CLCD has adopted a form of cross functional product teams as a new way of developing luxury automobiles faster, at less cost, and with improved quality.[10]

One of the first things they did in creating this new culture was to merge the product engineers and process engineers into a single unit. This allows easy communications between the people who design and develop the thousands of parts that make up a car, with the people who are responsible for establishing the process methodology and sequence for assembling those parts on the factory floor. In 1987, they took this concept further. They realized that to foster truly simultaneous car development, they would have to bring into the process, people from all the division's critical functions; finance, materials, marketing, manufacturing, assembly-line operations, and external suppliers. Team participation for all members would be in addition to their functional responsibilities.[11]

The initial attempt at running this new structure, however, did not result in behavior they wanted. The teams never really operated like teams. The process was viewed, by many functions, as an

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[10] Wrubel, R., "GM Finally Fights Back", Financial World, November 26, 1991.
[11] Ibid.

Engineering operation since it was led and initiated by Engineering. The initial support required from the non-engineering functional organizations was not clear and team members from those areas maintained a functional focus and prioritized their functional responsibilities first. Management attempted to show support for the process by assigning special tasks to the teams to complete. However, since the teams were somewhat dysfunctional, they were unable to accomplish these tasks in many instances. Moral for all began to wane.

About the time CLCD was having it's teething pains in the new world of cross functional teams, they decided to re-examine the situation. A good deal of time was spent talking to those people involved in this new process and those affected by it. The conclusion reached was, that the division was a strongly focused functional organization, and to try and run it exclusively by teams was a mistake. It was also concluded that the advantages of teams could still be achieved, even if the functional organizations were to remain strong. The focus of the teams needed to be redirected, towards a process and structure that would facilitate cross functional communication in support of functional responsibilities. This refocused approach has turned out to be a real success for the CLCD Organization.

These new insights lead to the creation of a team structure which acted as an overlay to the functional organization. This team structure consisted of four levels within the organization; Core Simultaneous Management Team, Simultaneous Management Team, Product Management Teams (PMTs), and Product Development and Improvement teams (PDITs). This team structure is shown in Figure 8.

General Motors Cadillac, Luxury Car Division

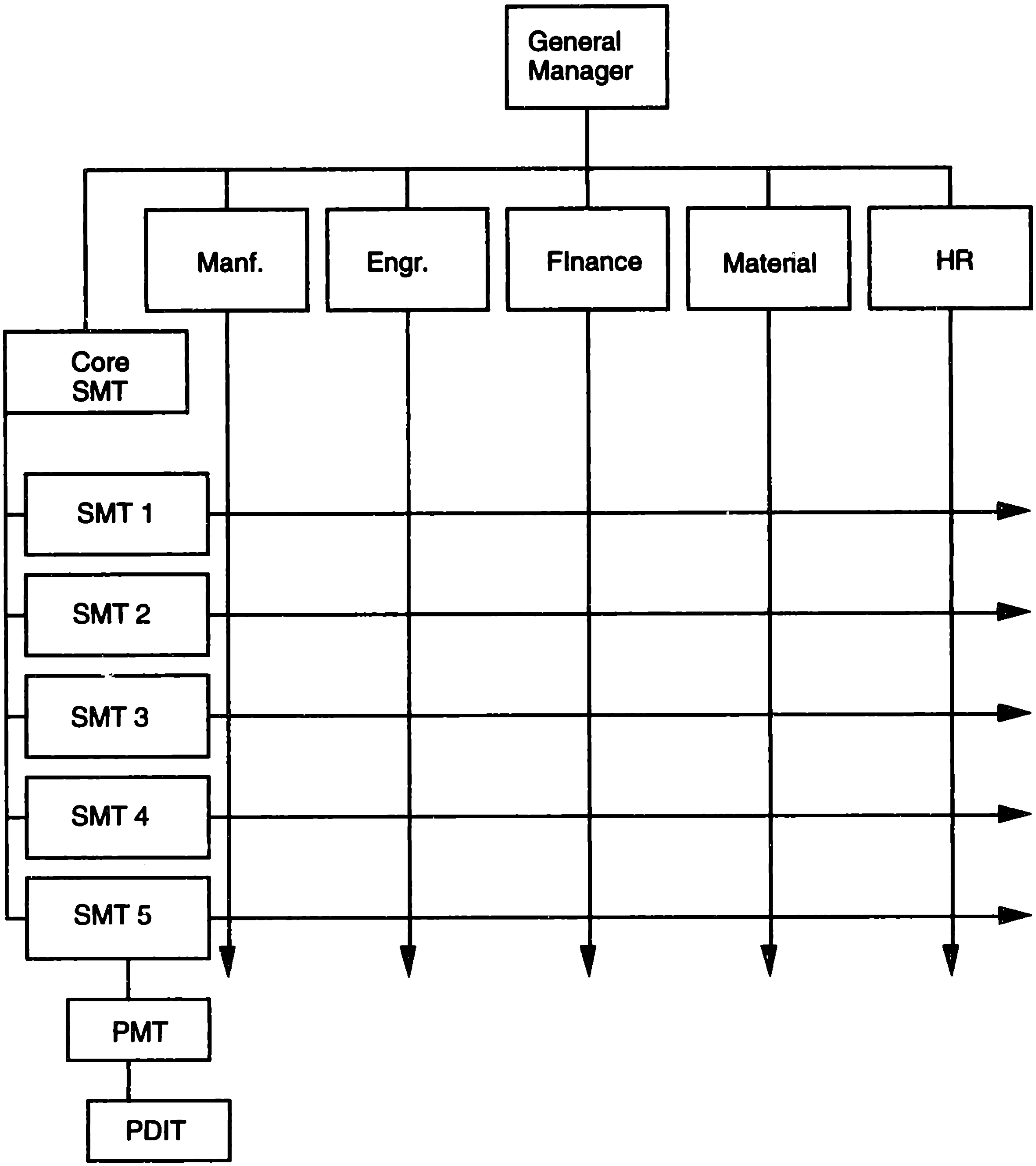

Figure 8

The core SMT is the most senior team, and is responsible for overall SMT process development and administration. They also act as an advisory group for the SMTs as required. They have six product

SMTs, structured around the key elements of a car, (i.e. chassis, interiors, etc.). They are chartered to provided leadership over the PMTs and to integrate all elements under their respective responsibility, and to ensure that activities are consistent with Division Business Plans. The PMT's are sub-teams to each of the SMTs. For instance, the interiors SMT might have several PMTs (i.e. seats, dash, etc.). The lowest level team would be the PDITs. These teams are created, as required, by a PMT to provide specific design/sourcing/process/manufacturing requirements.

ANALYSIS AND RESULTS

The results of the structured interviews with the four DOD Programs are listed in tabular form in appendix I. The discussions I had with the four major programs and the two commercial programs allowed me many insights into common challenges that the aerospace industry is facing with implementing IPD/IPT.

Structured Interview Results Summary

The structured interviews consisted of five categories; Organizational, Personnel and Training, Contracts, Control, and Process. The summary results of these categories are listed below.

Organizational

Item 1. All four programs stated the reason they adopted the concept of IPT/IPD was to "Reduce Cost". It was their belief that cross functional teams would help their programs control cost.

Item 2. Several of the programs felt that there was a great, but not quantified, advantage to have the IPT team members collocated. Having them sit side-by-side was believed to be the optimum physical location for the team. Although, many disciplines were only part time, and for them physical collocation was not practical. Physical space limitations also kept the teams for achieving the level of co-location they desired.

Item 3. The level of customer involvement varied from very involved to very limited involvement. On some programs the customer is actively involved in the teams activities through on-site visits and weekly video conferences.

Item 4. They all stated that it was the functions job to maintain personnel skills and processes however, it was not clear that any new initiatives were kicked off to make that happen other than what existed prior to IPD/IPT. Actually I got the impression that, to be a part of a function was not good, that the teams were the drivers.

Item 5. There was not adequate time spent defining the relative roles and responsibilities between team-to-team or team-to-functional organization. On some teams there was confusion as to who was doing what. Also, there were cases where it was not clear what the functions should be doing to support the teams.

Personnel and Training

Item 1. Very little time had been spent on training personnel for these new roles. In addition, no one program had an answer to the question on "How much was required?", or "What type is required?". The fact that the issues of how much training and what type of training is required remained unanswered may have contributed to the lack of training. However, as is explained in the section that follows on training, there may be structural forces at work in this area as well.

Item 2. Only the F/A-18 Program created a new job classification for the IPT Team Leader. Taking people out of the comfort of the functions and putting them on teams created fear as to what an individual's career path is. Creating new job classifications may alleviate these fears.

Item 3. Reward systems had provisions for team recognition, however, year end merit increases remained primarily individually based. Since team based incentive systems can be very challenging[12], this may be the right approach until the concept of these teams in military aerospace is further worked out.

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[12] Klein, J. A. and Maurer, P. M. ,"Integrators, not Generalists Needed: A Case Study of Integrated Product Development Teams", Interdisciplinary Studies of Work Team: Knowledge Team (Volume 2), M. Beyerlein and D. Johnson (eds.), Greenwich, CT: JAI Press, 1995.

Item 4. Performance evaluations of team members seems to be shifting towards a team leader task. Putting all the administrative responsibility for performance evaluations, and in some cases merit increases, on the team leader will take time away from their primary job of coordination/leading the team activities. The team leaders should be involved in the performance evaluation process since it's his memberships performance that is being evaluated, however, this could be accomplished just as well with dual signatures.

Contracts

Item 1. No Program's Work Breakdown Structure (WBS) was changed to support the desire to have teams control budgets. The issue of getting the teams budget control was being addressed by all four programs. Without restructuring the WBS to line up with the team structure this can be a very difficult task. However, changing the WBS can create a separate set of problems, which may be the reason the WBS's have not changed. This issue is discussed in detail later in this thesis.

Item 2. There was a common belief that the IPT concept has brought the government and the contractor closer in working contract changes. In looking for data to support the issue of the government having a advantage in change negotiations by being on both parties at the time of negotiations, I found just the opposite. What I learned was the contractors found having the government as part of the team made the task of creating the statement of work (SOW) much more timely and accurate. Also, having the government on the team did give them insight into the contractors soft numbers but it also gave them insight into the contractors hard numbers as well. This knowledge allowed for balance and fairness to remain.

Control

Item 1. Estimate To Complete (ETC) and change proposals were still done by functions to WBS structure, not team structure. All but one program was preparing their ETC's by functions, with the team input. All programs were preparing change proposals to a WBS structure.

Item 2. No program developed a method to review IPT processes against their existing policies and procedures for conflict. In putting the IPTs in place there was no process that reviewed the IPT approach for consistency with the existing divisions policies and procedures. The approach taken was to have the IPTs operate knowing they could not violate existing procedures, however, it they ran into a procedure that did not make sense they could go through a formal process to change it. This causes the IPTs to deal with these issues in real time rather than having them worked out in advance.

Item 3. IPT's have no control over indirect budgets. I found it peculiar that while there were ongoing efforts to try and get IPTs direct cost control, no effort was being expended to deal with the indirect labor cost, which can be a sizable amount. Although this was peculiar, it was not a pressing issue to research further, since later in this thesis an argument is presented that concludes, giving the team leader direct budget control may not be the right thing to do.

Item 4. IPT leaders did not acquire any new human resource management signature authority. In terms of the numerous forms that exist as part of the human resource management task as well as other forms within a firm, none of the IPT leaders received new signature authority. The only exceptions were if they were promoted to the "management ranks" as part of their new IPT leader responsibilities.

Detailed Analysis of Selected Issues

In this section several of the issues raised in the summary above will be explored further. This discussion is presented in two sections; Benefits, and Challenges. Some issues where there seemed to be consensus between the programs were selected for further discussion and analysis. Other issues were selected because all four programs were still struggling for answers to them.

Benefits

The Goal of Reducing Program Cost

Every one of the four major programs reviewed had "reducing cost" as the primary objective behind their implementation of the IPD/IPT concept. The AFMC Guide on IPD implementation also had reducing cost as one of the key objectives for the concept of IPD. Is it reasonable to think that this approach to management will have a significant affect on the cost of these type of major programs? This issue is explored here in more detail. First, the principles of why IPD/IPT should reduce cost are examined, and secondly a look at how many companies are trying to quantify this reduction.

It can be argued that the notion of IPD is heavily rooted in concurrent engineering. The examples below, which document improvements in the requirements integration process and reduced program cost, are based on concurrent engineering methodologies.

The value of better requirements integration is clearly depicted in John Hauser and Don Clausing's HBR article, "House of Quality".[13] They discuss the notion that if engineers and manufacturing people can get together to facilitate the design and manufacturing process why can't this process be carried further to include the marketing

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[13]Hauser, J. and Clausing, D., "House of Quality", Harvard Business Review, May-June 1988.

organization. Their article goes on to describe the significant reductions in setup costs and reduction in the number of changes required after initial release of engineering, due to early requirements integration.

In 1991, General Dynamics Convair Division set a goal of reducing their products life cycle costs by 40 percent. They felt that much of the 40 percent improvement would be achieved by improving their product definition and delivery processes. They further felt that the key to this goal was another goal they had set for themselves, which was to reduce the number of changes (internal) by an order of magnitude.[14]

In 1992, a team from the General Dynamics Space Systems Division set out to quantify the value of concurrent engineering. They bench marked several non-concurrent engineering programs to a similar program that used concurrent engineering. They found that concurrent engineering reduced the cost by 35 percent overall. Unplanned engineering changes were reduced 70 percent, and hardware discrepancies were reduced by 80 and 90 percent for (in house) and (out-house) respectively.[15]

Measuring the number of changes produced by engineering after initial drawing release to quantify the effectiveness of both concurrent engineering and IPD is becoming rather common. The Boeing 777 Program used drawing changes as a measure of engineering performance. They also used a parameter, "design errors reaching the factory", as a primary metric for the program.

"Design errors reaching the factory", consisted of "change, error and rework". These are errors that would show up on a rejection tag,

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[14] Rosenbaum, E. and Postula, F., "Computer-aided Engineering Integrates Product Development", 1991 AACE Transactions.

[15]Knodle, M., Kewley, S. and Zurawski, B., "Transition to Concurrent Engineering Environment", AIAA 92-4205, AIAA Aircraft Design Systems Meeting, August 24-26 1992,

such as, physical interference of two parts, and failure to fit (requires enlarged holes or shims). This category of change became their primary metric, with a goal of reducing it significantly from their previous major aircraft programs. Logic for making it the primary metric was based on analysis they performed to understand the components of a "program learning curve".

Boeing believes that change, errors and rework were the primary components of the Program Learning Curve, see Figure 9. The Basic Manufacturing Processes, Customer Driven Changes, and Learning stayed relatively flat compared to the Change, Error and Rework line. Boeing's goal was to reduce this line by 50% and achieve stability around the 100 th aircraft.

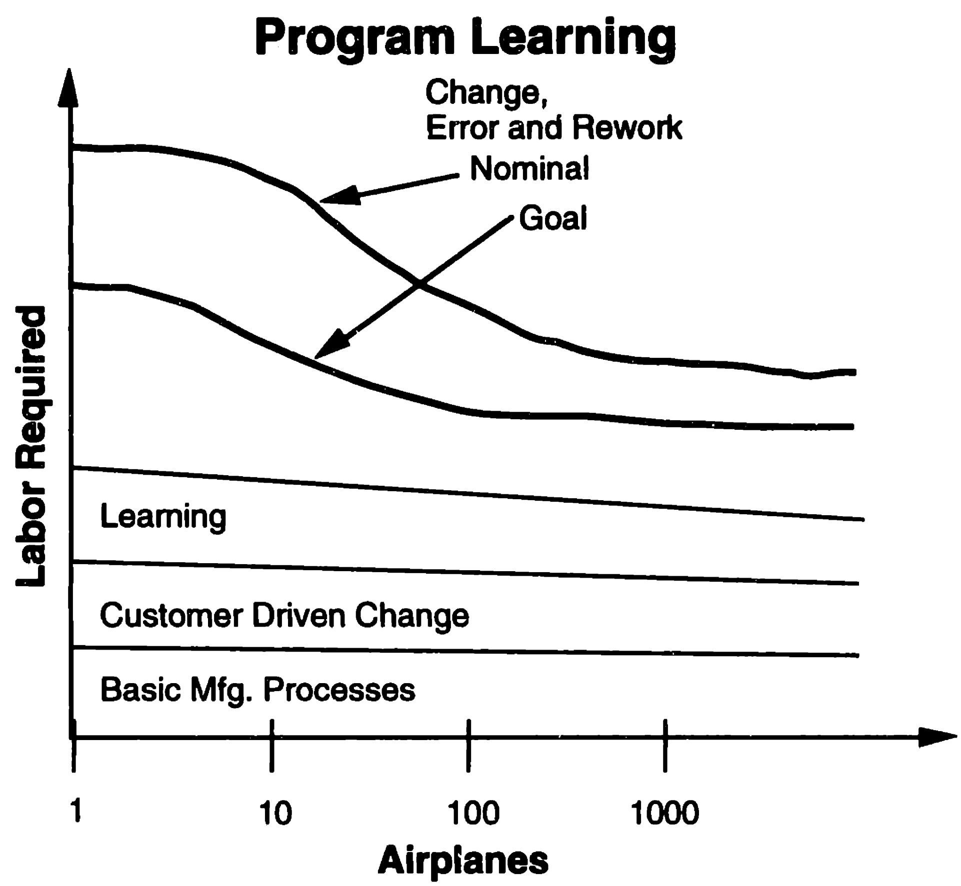

Figure 9[16]

[16]It should be noted that this Program Learning Curve is for Boeings commercial developments. Although the nature of these curves would be

To achieve this goal they established several new initiatives in aircraft development and production. One major initiative was the use of cross-functional design build teams (DBTs). The DBTs were made up of representatives from airlines, suppliers, and a number of internal organizations (engineering, manufacturing, procurement, facilities, customer services, etc.). In addition to the DBT organization structure, the use of digital design tools allowed these teams to perform 3-dimensional fit checks on parts and assemblies prior to release.

The 777 performance against the goal of a 50% reduction is shown in Figure 10. As of February 1995, a 63% reduction - 13% better than their goal -has been realized. Boeing attributes their success to three key elements of their development approach, co-located Design Build Teams, concurrent engineering, and digital pre-assembly via solid modeling.

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similar to one for a military development, the relative values might be different.

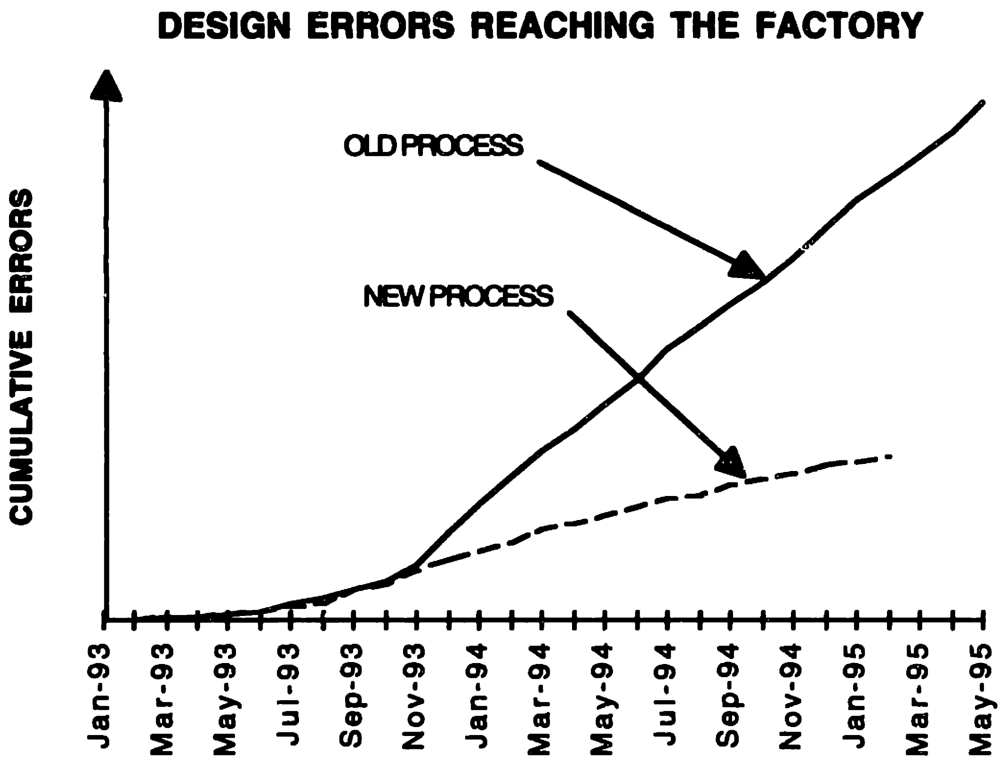

Figure 10

Reducing changes has a direct effect on the cost of a program. Change curves have been used on several major programs as a way of pricing out proposals for development and production. Although, reducing the absolute value of the number of changes is good, identifying these changes early is better. For programs like the four we are discussing in this thesis, time is a critical component of cost. Identifying errors early and incorporating them into the product quickly, can have a significant impact on your program cost.

As can be seen in Figure 11 the cost of incorporating even a simple change late in the production cycle can have a major cost impact because of the disruption it causes.

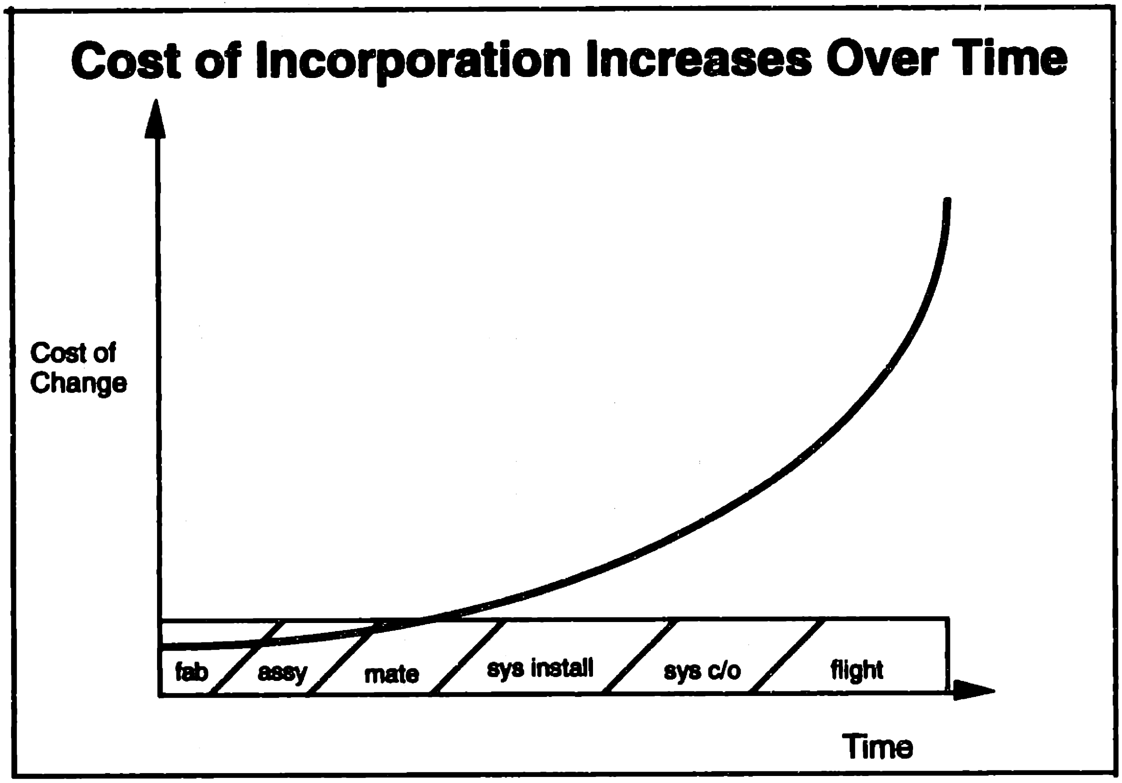

Figure 11

Incorporating a simple bracket change before aircraft systems checkout has occurred, can be a simple job. However, later in the production cycle, after systems checkout, if this bracket supports an electrical connector which has to be demated, the change can cause major regression testing and potentially stoppage of other parallel work.

The data above presents a case that shows correlation of cost reduction to a reduction in the number of changes after initial release of engineering drawings. Another set of data exists that correlates the number of rework cycles (changes) to the quality of the project.

Significant work has been done by Pugh Roberts Associates on what they call the "Rework Cycle".[17] They argue, perhaps correctly, that most programs are laid out with no allowance for rework that is a

[17]Cooper, K., pmNETwork, February 1993.

natural part of the design and development process.[18] After extensive study of over 60 large development programs, they developed an empirical graph of the correlation of number of rework cycles to typical quality. This graph is shown in Figure 12.

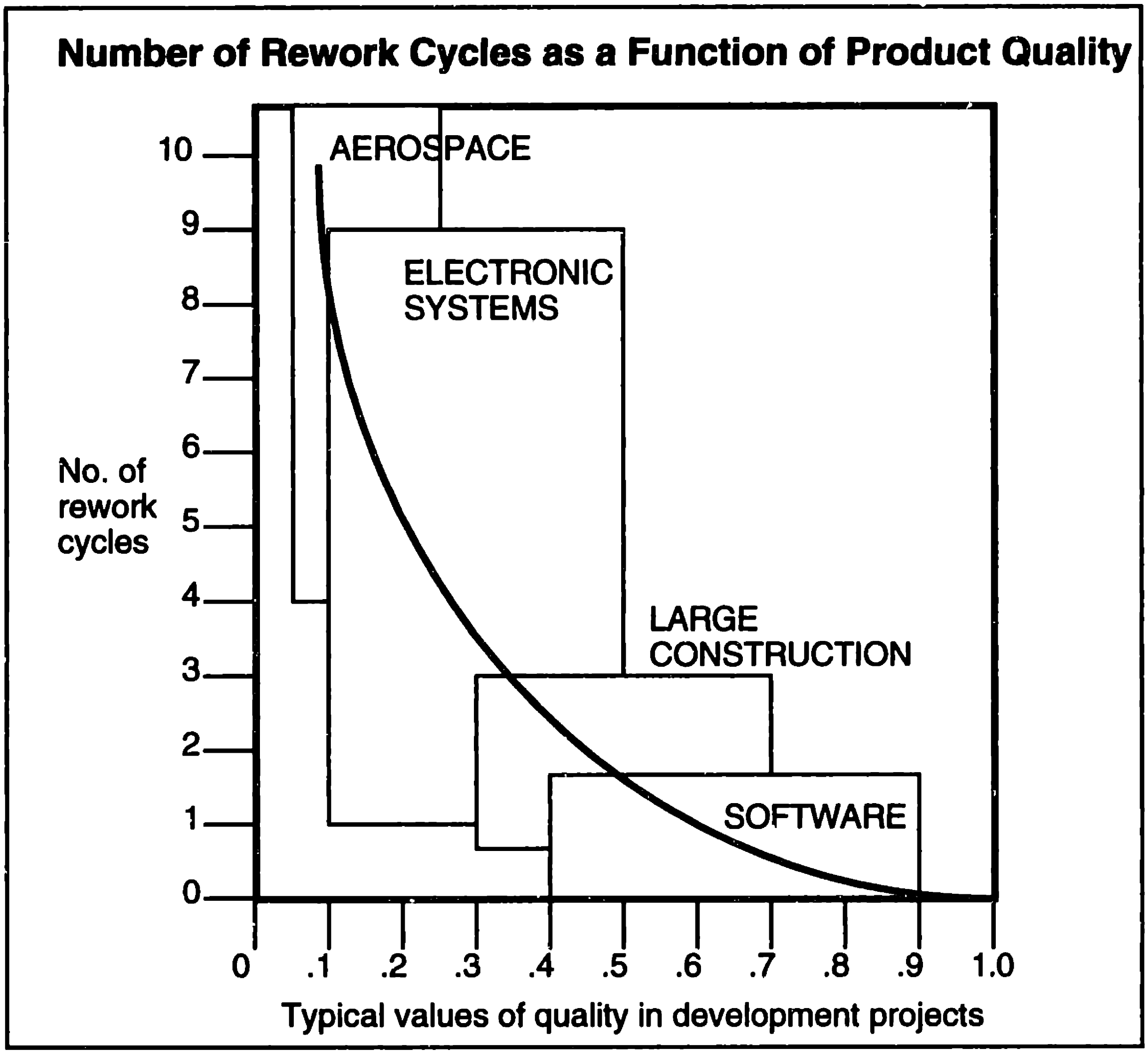

Figure 12

The Pugh-Roberts data gives an industry benchmark for the number of rework cycles relative to typical quality. Their data indicates that

[18]Cooper, K. G., "The Rework Cycle: Benchmarks for the Project Manager", Project Management Journal, March 1993.

aerospace projects experience a range of between 4 and 10 rework cycles[19] for quality ranging between 0.05 and 0.25%.

Using the Pugh-Roberts data on aerospace as a reference point we can locate the Northrop Grumman's B2 and F/A-18 Programs in terms of the number of rework cycles they have encountered to date. Based on the most appropriate data to date for these programs.

Figure 13 shows two curves for the Northrop Grumman part of the B2 Bomber program. One curve is the cumulative number of initial engineering drawing releases. The second curve is a cumulative release of changes to any released drawing. As of the end of 1994 there has been on average 4.44 engineering changes per initial drawing release, or 4.44 rework cycles.

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[19] The aerospace category consists of only a few data points. These data are from pre-1990 Full Scale Development programs (FSD). FSD being developmental may have expected more change.

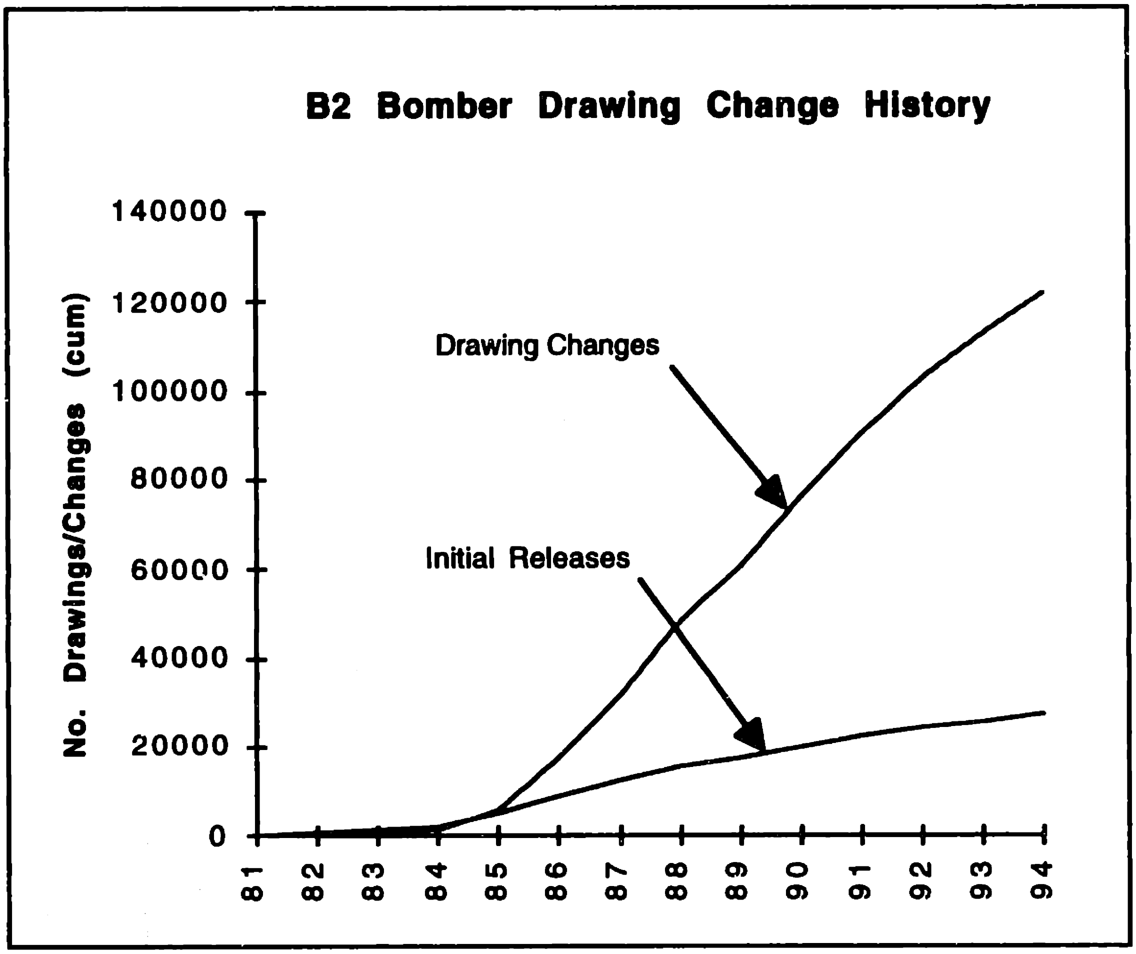

Figure 13

The F/A-18 E/F data shown in Figure 13 is the same as that for the B2, that is one line represents the cumulative number of initial releases, and the second line represents the cumulative number of changes to those drawings. On these plots, "Forward", and "Aft", refer to two different IPTs, the Forward Fuselage Team, and the Aft Fuselage Team, respectively.

The data shown in these two figures is based on a model (The F/A-18 E/F Program Dynamics Model) that Dr. J. J. Mc Ilroy and Pugh-Roberts developed for the F/A-18 E/F Program. The model is based on the concept of "Systems Dynamics" pioneered at MIT[20], using the

20 For further detail on Systems Dynamics see: Forester, J. W., Industrial Dynamics, MIT Press, Cambridge, MA. 1961.

rework cycle as a key element. The model is calibrated[21] quarterly with actual data, such that today, it is estimated to fall in to the 95-99% confidence range for forecasting accuracy.[22]

For the F/A-18 Program the number of changes after initial release varies by major component of the aircraft. In Figure 14 the number of rework cycles expected for these two structures IPTs is about 3 and 2. As of this calibration, for all teams on the F/A-18 E/F Program, the expected number of rework cycles was between 2.5 and 3.0 rework cycles.

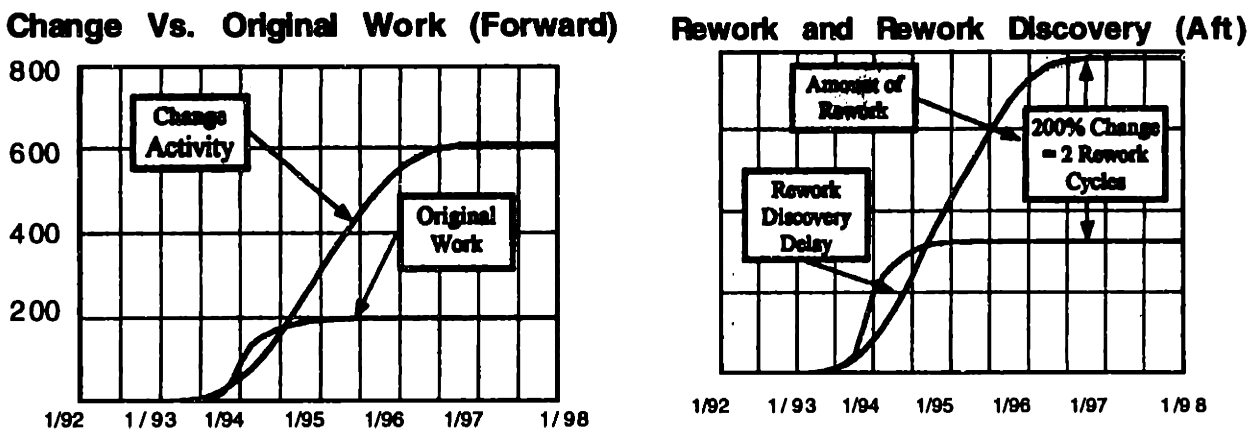

Figure 14

The 777 program also is tracking the number of engineering changes to initial drawing releases. Figure 15 shows their engineering performance as a ratio of changed drawing sheets to the number of original drawing sheets. The Old Process line is a benchmark from a previous Boeing program. The Goal line is their target, and the Actual line represents their progress to date. These lines are time synchronized by the aircraft's certification date.

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21 Since this is an ongoing project with future calibrations to be performed, it is possible that the forecasted numbers could change. However, based on the programs performance to date, it is not expected that this change would be significant.

22 Mc Ilroy, J. J., "Program Dynamics Model Change Activity Forecasts", Draft Working Paper dated 9/21/94.

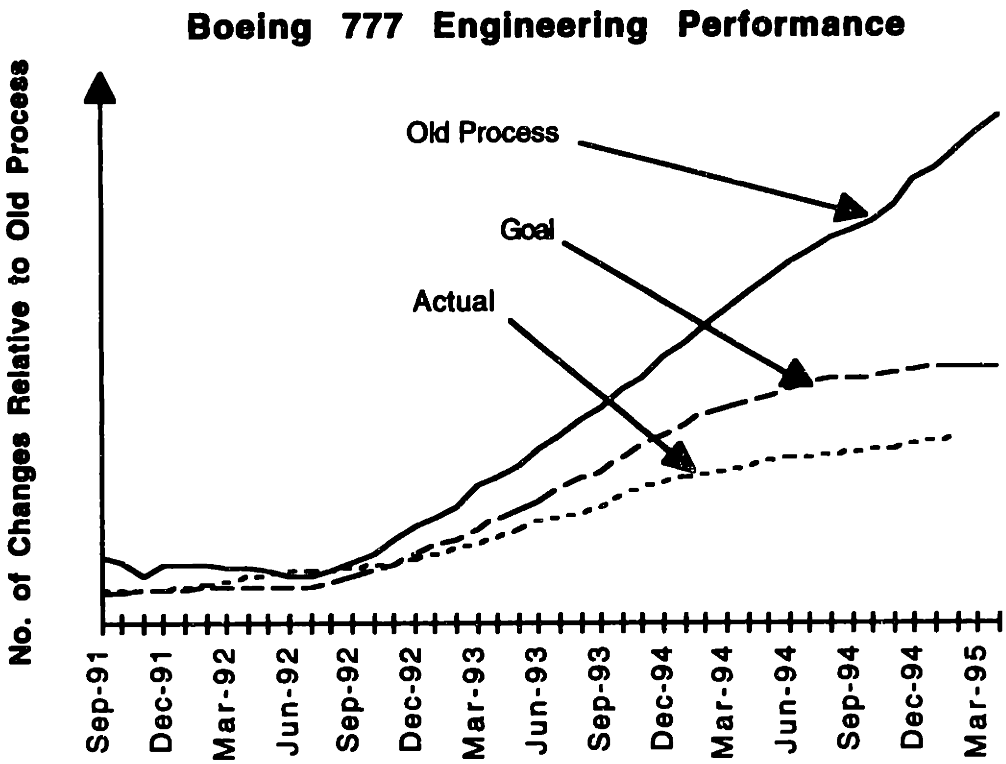

Figure 15

These data do not show absolute values, due to its proprietary nature, however, it is showing that Boeing is doing better than their goal by about 30%. It is my understanding that the number of rework cycles they have experienced to date, is less than 2.0.

A factor to keep in mind is that the data presented does not assign any value or magnitude to the "change". A given change could be as simple as enlarge a hole or a major redesign like those experienced on some of these programs.[23] Although the goal of reducing change is clearly a positive thing to do, there may be other factors that can drive your program just as much which are less quantifiable.

To summarize the rework data; B2 at 4.44 (all teams), F/A-18 E/F at 2.0 (forecast for structures teams), and the Boeing 777 at less than

[23] B2 aft deck redesign, or C17 wing redesign.

2.0. This puts the 777 and the F/A-18E/F Programs outside the "aerospace box" and the B2 Program very near the bottom of the box in Figure 12. All of these programs have had a version of IPT used in their development. The F/A-18 E/F Program explicitly embraced it from the beginning. The B2 program had "design build teams" in its very early days, prior to the concept of IPT, the 777 Program used design build teams as well.

These three programs also had integrated design databases and 3D modeling capability. The combination of teams and 3D modeling seems to have a powerful affect on reducing change. Unfortunately what we do not know at this time is what the mix of this combination should be. It is also not clear that reducing rework cycles is the most important element of a program's cost reduction. This is an area that will require further study.

Another, but similar approach to measuring the effects of IPD is being developed on the F/A-18 Program. Dr. J. J. Mc Ilroy, of the Northrop Grumman Corporation, is using an F/A-18 E/F Program Dynamics Model to study the progress of the program. This model includes some parameters for the effects of IPD (productivity, quality, and rework discovery). The impact of removing the effects of IPD is shown graphically in Figure 16.

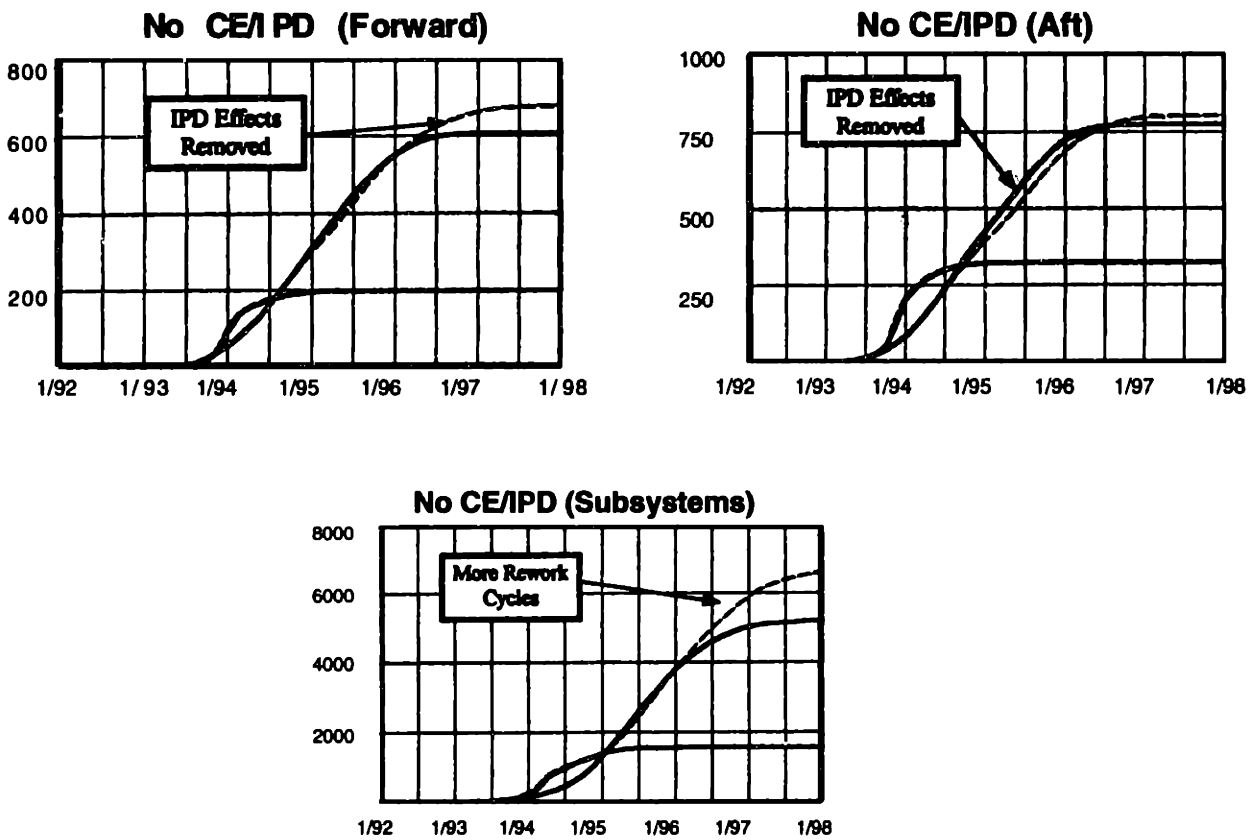

Figure 16

The dashed lines shown, represent the increased amount of rework cycles due to the absence of IPD. There is also a delay in the time required to discover the rework. The effect is more dramatic on the subsystems than on the structures. This would be consistent with the fact that the amount of coordination and complexity is greater with the subsystems than with structures.

<u>Reduced Development Time</u>

Another way that we might expect IPD/IPT to reduce cost is in the area of reducing development time. The value of development time reduction for programs like the B2, C17, F/A-18 or F22 can have a major payoff.

Concurrent Engineering

The concept of concurrent engineering has been around for a long time, and has been written up extensively. Here is a brief definition and a description on why it contributes to the reduction of product development time.

Concurrent engineering is defined in a 1988 Institute for Defense Analyses report (IDA Report R-338) as "a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause the developers, from the onset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements."[24]

There are several documented cases of where concurrent engineering principles have shortened a product's development cycle, for instance, General Dynamics Space Systems Division took out 40% of the time required to design, test, and fabricate it's payload adapters.[25] Also, General Electric cut the Afterburner and Exhaust Nozzle development time in half for it's F414-GE-400 Engine using a concurrent approach.[26]

The process of concurrent engineering is depicted in Figure 17. Here it can be seen that concurrent engineering is the method of pulling back, or in parallel, previously specialized functional processes. Along with this, the parties that own these processes are encouraged to communicate with each other on specific requirements and reach consensus type decisions with regard to the design. Since there are multiple requirements (testability, supportability, producibility) the specialists are given an opportunity to exchange the most critical

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[24] Lake, Jerome G., "Concurrent Engineering - Systems Engineering Revisited?", June 12, 1991, MORS Symposium at West Point, New York.
[25] Knodle, M., "AIAA 92-4205, Transition to Concurrent Engineering Environment", August 24-26, 1992, Hilton Head, S.C.
[26] Ruegg, R. G., Program Management Initiatives IPD Industry Symposium, Oct. 28, 1993.

elements of their requirements in order to seek the optimal design. In recent years this process has become very automated and more efficient with the advent of Groupware software applications, and common databases for design, tooling, numerical machining tapes, and support/training data.

Concurrent Engineering Process

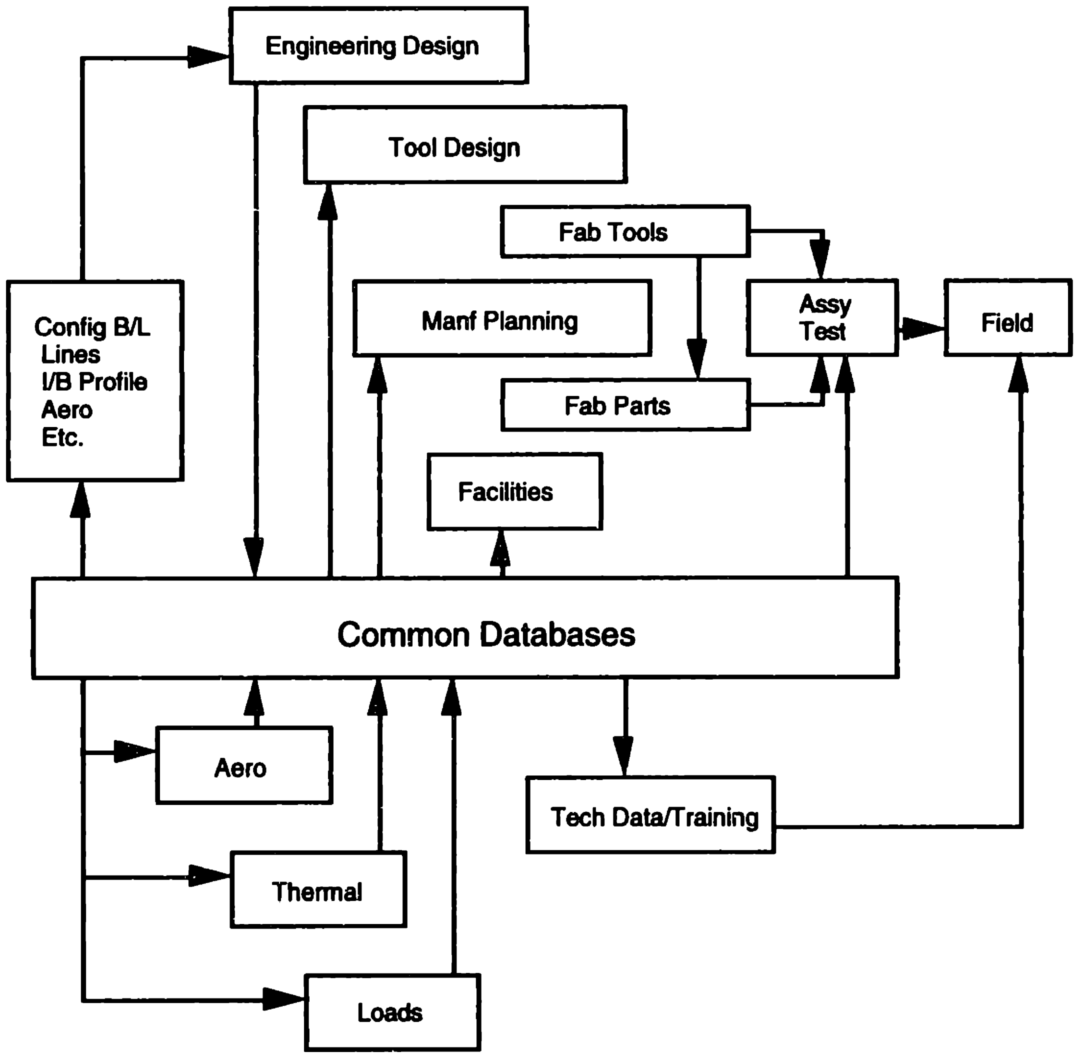

Figure 17

The B2 Bomber was one of the first programs to be essentially paperless in terms of engineering drawings. The Northrop Grumman Corporation along with their major subcontractors, Boeing and Vought, used NCAD/CADAM computer tools for design of the aircraft.

Today several programs have taken this concept even further. The Boeing 777 program has developed their aircraft with common data systems and the F22 and F/A-18 E/F programs are also in the early stages of development using common systems as well. More will be said about these new technologies in the section on Improved Communications.

In contrast to the concurrent engineering model depicted in Figure 17, past design efforts used a "throw it over the wall" approach. A particular functional group (engineering for instance) would finish their product (drawings), and release them to operations to figure out how to build them. In the concurrent process it is the norm for these two functions to get together and work out all problems well in advance of the actual engineering drawing release. With today's data systems it is common for the manufacturing engineer to be monitoring the engineers progress on the drawing and making inputs in parallel.

While visiting the F/A-18 E/F Program I learned that in order for their teams to get out of the mode of "throwing it over the wall", they changed the definition of the products produced to be consistent with their team approach. Instead of a set of drawings to be released by engineering, then a set of tools released by tooling, and a manufacturing plan by Planning, they have defined a new product, the "Build To Package". This package contains everything that is required for their Delivery Team (in-house manufacturing or out-house suppliers) to fabricate or assemble the end items. This package includes the drawings, manufacturing plan, quality plan, stress analysis, tool design, etc. and is signed off by all team members. This concept of changing the products that get produced to be the team's product has gone a long way in changing the attitude of the team members.

Concurrent engineering as a component of reduced development time is fairly straight forward in principle. The association to cost reduction is due to the size of major military aircraft programs. Any reduction in time will translate into some reduction in cost. Take the B2 Bomber Program for example, it has an estimated cost of about $44 billion. The program period of performance is expected to be about 16 years, that translates into about $7.6 million per day. Clearly reducing time can have very positive effects on Program cost.

Team Consensus Decisions

Why are empowered teams so great? Modern organizational theory suggests what is desired by business is "good decisions". It further assumes that good decisions are made by those with the greatest knowledge about the problem. This knowledge can be transferred to the decision makers who have the right to decide, or these decision makers can entrust those with the knowledge, to make the decisions, if the cost of transfer is too high.[27]

There exists many decisions that would be better made by those parties involved with them on a day to day basis rather than try and educate the organizational hierarchy to achieve the same. This is why empowered teams make sense in the development of complex aerospace systems.

Reduce Decision Making Time

The benefits of these empowered teams comes in two forms. For one, you save the cost of preparing the knowledge (usually a briefing) to go up the chain of command. You also save the time it takes to get this information up and back down. On the first count, preparing data for a decision from the hierarchy is a very time consuming process as many of us know. A lot of time can be spent compiling data to cover every contingency that our superiors may ask about, regardless of how germane it may be to the real problem. We do this for fear of looking bad in front of the boss. The boss on

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[27]Jensen, M.C. and Meckling, W. H., "Specific and General Knowledge and Organizational Structure," Ch. 9 in Contract Economics, Werin, L. and Wijkander, H. eds.. Oxford:Blackwell, 1992.

the other hand feels it is his job to apply experience and knowledge to the issue and find something that was not covered. This perception of what the manager's job is, creates a strong and genuine desire to add value to the process, by finding an issue that his subordinates had not considered.

Since you did not get the direction you wanted, you are now dealing with the time problem. You now have to go back to the drawing board and churn some more data. This takes more time. However, there is another more significant issue that comes along with this time element, that is did we loose sight of the problem with the passage of time. The cycle up the chain of command may go smoother the second time however, now you may be working on the wrong problem.

An even more complex twist to this knowledge transfer problem is when you have to prepare the data and the boss takes it up without you. Most of the time it will take longer to get your decision and if the answer comes back that misses the point or problem, it may be what you have to live with, since the boss will not be overly eager to go back and tell his superior that it is necessary to review the issue again.

Although these may be extreme examples, they do happen to someone every day. They are why pushing the decision making authority down to those people who have the knowledge is probably more economical than the traditional centralized approach to decision making via a hierarchy. There are certainly limitations on what you want your people deciding on. These limits need to be spelled out very carefully in order for the Empowerment to be economically effective.

Better Decision Making

Now that we have discussed the value of pushing the decision making down to the team or group, we should discus how that entity reaches decisions. Certainly a leader can be designated and make the decision with or without inputs of the other team members. However, studies[28,29,30] show that consensus decision making will provide better decisions and ones that can be implemented more quickly.

The concept of consensus decision making generally requires more time. However, in the long run, you may be getting better decisions. During the summer of 1994, I and my 54 other Sloan Fellow colleagues engaged in an experiment of sorts, to test the power of consensus decision making. In this exercise, we were given a list of things to take off a burning airplane that we would use to sustain our livelihood while we were stranded in the Canadian wilderness. We had to individually decide what was most important to get off the plane. Then we were put together in teams and asked to use a consensus approach to the decision problem. In every case the team scored better than any individual. This is true for our class and several Sloan Fellows classes that have taken the test for the past several years.

Collaborating and discussing the problem caused people to think of things they would not have on their own is my reason for why the results improved with the consensus approach.

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28 Schwartz, A. E., Group Decision-Making, CPA Journal, pp:60-63, Aug. 1994.
29 Reaching Consensus, Training, April 1994 pp:15.
30 Saturn's Rings Replace Typical Management Pyramid, Supervisory Management, pp:8-9, Aug., 1994.

Facilitates Implementation

Consensus decision making also has a lot of leverage on the implementation process. Especially in cases where teams are operating inside organizations where there are functional groups who have to participate in the implementation. Let's say that we have a team designing a new part. The team is made up of engineers, manufacturing personnel, finance, etc. Now the team makes a decision on how the part is to be made, and puts the drawings in the release cycle where others have to sign off on its release. If there was a party, lets say a manufacturing engineer, in this signature process who does not agree with the approach he could hold up the release. If there was no team he would be more likely to hold up than if there was a team where one of his own kind, a manufacturing person, has already signed off on the part. This may seem petty, but it happens all the time, and with the cost of time associated with major aerospace programs this is time you can not afford.

Improve Communications

Improved communications in every industry is occurring due to the ongoing computer revolution. Today, most large firms have networked PC's and workstations, email, voice mail, video conferencing, fax facilities, and, the latest, groupware. These technical marvels have allowed us to communicate faster, more efficiently and at any time of the day.

However, probably the biggest improvement to the aerospace industry is the advent of data systems to design and fabricate our products which talk to each other or better yet are the same system.

To look at this further review Figure 17. This figure is a schematic of the data systems we used on the B2 Bomber Program. The EMD program starts with a baseline configuration coming out of the

Dem/Val[31] phase of the program. This configuration will usually consist of loft lines, inboard profile drawings, aero data, etc. These data feed the engineering design process. Engineering design will use this data to create a structures schematic to begin the iterative process of defining the aircraft 's structural configuration. Also, systems groups will begin the layout process in parallel with the structure layouts. Here, the design community is using the same data system. As the design process continues and the aircraft configuration takes form and definition, tooling can start the process of roughing out the support structure for their tools, and making materials selection. In the past the tool design process would not start until the engineering drawings were released. This was to "protect" the tool designer from a lot of repeat work if the engineering design changed, which as we know it often does.

The value of this tight coordination and communication has been quantified for the automobile industry by Womack and Jones[32] . They describe how die-making in the auto industry is run in parallel with the car panel design. They indicate that since the die designers know the approximate size of the new car and number of panels they can go ahead and order blocks of steel required to make the dies. Then they will go ahead and make rough cuts in the steel so it is ready to move to final cut when the panel design is released.

This die making process involves close communication between the design and tool functions. It also requires that both functions understand the others job and critical requirements. And lastly, there is an element of trust that comes with working with each other on past projects.

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[31] dem/val is Demonstration/Validation phase that all major programs go through. It most often includes building an operating prototype of the product.

[32] Womack, J. P. and Jones, D. T., The Machine That Changes The World, New York, NY, HarperCollins, 1990.

The payoff for this working relationship is big. Die average development times for American and European car producers is about 25-28 months. In Japan, where the concurrent engineering process described above is used, the die average development times are about 13.8 months.

The concept of concurrent engineering acknowledges and accepts the fact that the engineering will go through several iterations. This does not mean the tool designer should shut down and wait until the engineer is done. The tool designer still has several things he can do to shortcut the process. One critical activity is to feed the engineer inputs on the design that is evolving to make allowances for the tooling. Because the tool designer is looking at the part being designed from a different perspective there are things that he will catch in this process, such as making sure all the surfaces are defined. The absence of all surfaces being defined in the model will require the tooling organization to define them during tool final design. Also, tooling can make inquires on where the critical design parameters are such that they can be accommodated. This process is especially critical in the design of composite materials where the whole industry is still learning the best way to produce this unique type of part..

In addition to the tool designer, several disciplines of the logistics community will also be involved at this stage by making inputs on how the aircraft will be supported to aid the designer. The fact that they all use the same data system makes this coordination and information exchange more efficient.

Numerically controlled tapes will come out of both tooling and engineering to feed machines that will cut the tools and parts. On the B2 Bomber Program tooling also had a three dimensional unwrap program that would take the three dimensional drawing for wire harnesses and lay them out in two dimensions. From this a two dimensional velum was created to build the electronic jig board used to lay-up the wire harness in the shop. The engineering wire design database can also feed the wire shop electronically to define wire sizes/types for cutting and also the automated test equipment to check out the finished product.

Manufacturing planning used the trimetric engineering drawings on the B2 for pictorial representations for factory floor technicians in their manufacturing plans. Process specifications could also be put on line to facilitate the planning process.

Test and check out processes used the engineering data bases to check out the wire configuration end to end in the entire aircraft. Here is were it becomes important to have common data systems with your major subcontractors. On the B2 we used the same 2D, 3D, and loft data system and had a common format for our wire data. This allowed the test engineers to pull up drawings, schematics, wire data and specifications to aid in their checking out of the aircraft.

In parallel with all this engineering activity, the integrated logistics group is using the same database to pull together the technical data manuals that will be used by the Air Force to maintain the aircraft. Also, the database supports the development of the training materials required by the air force.

This same 2D 3D database supported model development for wind tunnel testing. The loads group used the loft data directly to create NASTRAN models for their analysis. These models were easily updated if the outer mole lines changed.

The thermal analysis group also used the loft data to build up their mesh for thermal analysis. They also developed a FORTRAN model that would take the results of their CINDA[33] Thermal Model and put the temperatures back into structural X,Y,Z coordinates for the rest of the design team's use.

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[33] Chrysler Improved Numerical Diffrencing Analyzer.

Here communications have been significantly improved by use of a common data system.

Challenges

Training Appears to be a Shortcoming

Introduction

This section deals with the issue of training. For teams to be effective they will require various levels of training. The amount of team type training required to be successful will vary depending on what kinds of teams we are talking about and who you talk to. However, regardless of the kinds of teams, the large programs I reviewed would be hard pressed to say that they have done the right level of training for their teams to be effective. They are the first to admit this short coming. All four programs are struggling with the issue of training. The questions of "how much" and "what kind" are yet to be answered. One might think that the reason for this short coming in training is because the concept is still evolving and therefore what training is required and how much become critical questions. However, the how much question may be a problem due to unique characteristics of the aerospace industry.

This section will first discuss the different kinds of teams that exist in industry today. It will point out that for the most part, IPTs might be classified as "Project" teams according to definitions given. Data is presented on the various areas teams need to be trained, depending on what is expected of the team. Data are also presented on how much training might be required for the most demanding type of team, the "self-directed work team". These data point out how much training is required for "work" teams will be used to estimate how much training might be required for the other types of teams, including "project".

This section then describes how much training was performed on the four aerospace programs reviewed. As will be shown, very little training was invested. A theory on why little training is expended on large aerospace programs is then presented.

Types of Teams

The popular business literature talks a great deal about the wondrous "Team", but often does not clarify what kind of teams they are talking about. In general the most widely discussed types of teams these days are "work teams" of the self directed type. Next is probably the "product development teams", which seem to have been embraced by most consumer product developers, from Corning Glass to Ford Motor Company. Below is a brief discussion of these types and others to allow the reader to understand what we are talking about when we talk "team" in the context of the aerospace industry.

Susan Mohman[34] talks about teams as being on continuums with three dimensions. As shown in Figure 18 these continuums are temporal, task, and organizational environment oriented. Task Flow teams are what we popularly call work teams, and improvement teams are what is popularly know as continuous process improvement teams of TQM. Teams can be permanent or temporary. They can also act as self managed (intact) or as an overlay on the existing organization.

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[34] Galbraith, J. R., Lawler, E. E., III, and Associates, Organizing for the Future - The New Logic for Managing Complex Organizations, Jossey-Bass, San Fransisco, 1993.

Three Dimensions of Teams

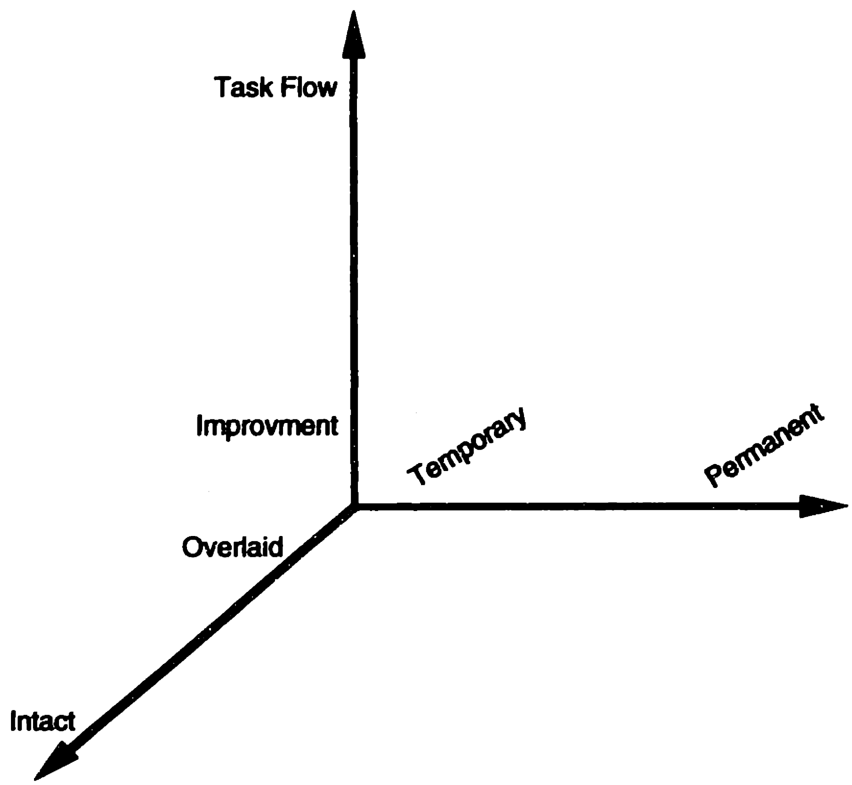

Figure 18

Susan Cohen[35] talks about four types of teams with variances about how far they go in several of their characteristics. Figure 19 lists her four teams and the types of training that may be required for each. None of the literature I found discussed the issue of "how much", but an attempt will be made to relate the amount of different types of training by team, to the issue of "how much" training later in this section.

The first type of team in Figure 19 is the Networked. This type is distinguished by the fact that is has no boundaries between the network and the parent organization. It's members cannot reliably identify the membership and although a project team may be made up of some of the networks nodes the network goes beyond that project team. Examples of this type are professional services like

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[35]Ibid.

investment banks and consulting firms. Training requires that the participants form ties and integrate their activities across the network. Problem solving skills and extensive skills in information management systems are usually required.

Team Type	Training
NETWORKED	Problem solving Conflict resolution Inter-Group resolution Information management systems
PARALLEL	Above-Plus: Specific organizational unique skills in processes for problem solving or process improvement Business and economic education
PROJECT	Above-Plus: Special training to allow participants an appreciation for the broad background/experience of the team's membership Scheduling and budgeting
WORK	Task trianing Social interaction skills Cross task training Business knowledge Team building activities Conflict resolution Problem solving Group interaction skills Information management systems skills Quality analysis or statistical process control Business and economic education Train managers on how to interface with self managed teams

Figure 19

The next type is called Parallel teams. These supplement the normal organization and are usually temporary. They carry out special tasks that the organization is not readily equipped to perform well. They also typically have no decision making authority, they must present recommendations to upper management. Examples of these types of teams include; quality circles, quality improvement teams, tasks forces, and productivity improvement teams. Their training is primarily on the existing processes and skills that the organization uses in problem solving and group interaction. They may also have some need for business and economic education if they are to develop recommendations that make business sense.

The next type of team is the Project or Development team. These are typically made up of professionals, like engineers, manufacturing engineers, researchers, or marketing, who are brought together to conduct a project which satisfies a user's (customer) needs. The project has a definite time period of performance but can be very extended. The project team will typically have a broad range of responsibility and authority. Examples are, new product development, information systems development, research and development, and new-factory design teams. Their training includes those skills we have seen in the other types of teams but also includes special training on how the membership can relate to each other based on the broad backgrounds and experiences the membership will most likely have. Also, skills in budgeting and scheduling, since these projects can last for several years.

The last type discussed is Work teams. These teams are responsible for producing specific products or services. They can be traditionally managed or self-managed. Self- managed teams may have control over their support services, like maintenance or purchasing, or certain personnel functions, like, hiring/firing or bonuses. Examples of these types of teams are usually found in manufacturing settings but are not limited to them. Other areas include, administrative support teams or customer sales/service teams. Training for these teams is the broadest of all that we have discussed. It includes task training and cross task training, all of the group type training we have mentioned in the other types of teams. In addition, it may require special skills in quality analysis or statistical process control. Many firms have found that the management of these types of teams may also require training of management on how to manage work teams.

Above we have discussed the different types of teams and the types of training they would require. Presented below are some industry data that define the amount of training in terms of hours or dollars for some of the different types of teams we have identified. These data are used in conjunction with Figure 19 to develop an estimate of how much training would be required for the type of teams we are interested in, namely the "project".

Amount of Training Required

Some data have been established on how much training may be required for certain types of teams. Most notably is the amount of training required by the "work teams", which is the most widely studied of the four types presented above.

Case studies by Kochan and Osterman, support the view that these new human resource management and production systems (self-directed work teams) require significant increases in training and skills over what industry has traditionally provided. They cite, for example, the investments in training made in new Japanese auto plants in the United States. "Studies of the Mazda plant in Michigan and the Toyota plant in Kentucky suggest that training costs account for as much as 10 to 20 percent of the total capital required to bring these facilities on line."[36]

They also point out that the Saturn Corporation of General Motors has a target for each employee to spend 5 percent of his or her working hours in training. In the start-up stage, operating technicians received approximately 300 hours of training, while skilled trade technicians received between 450 and 700 hours.[37]

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[36]Kochan, T. A. and Osterman, P., " The Mutual Gains Enterprise", Harvard Business School Press, Boston, Massachusetts, 1994.
[37] Ibid.

Further examples exist of the magnitude of training being performed in commercial industry.

Corning Glass found, after bench marking, that their commitment of 10 percent of an employee's time to training was insufficient compared to others who were spending 20 percent.[38]

More and more commercial firms are learning that training is not a one shot activity but rather a continuous process of enhancing your human resources. Certain divisions of Tektronics and General Electric have found that if you consider all variety of training (classroom, mentoring, cross-training, business meeting, team meeting, etc.), the sustaining requirement for training becomes about 10 to 20 percent of every employees work week. That is about one day out of every week dedicated to learning. On average today most companies are spending about 0.5 to 2 percent on training.[39]

These examples of the amount of training being expended on "work" teams, GM's 450-700 hours, and Tektronics and GE's 400 hours are extremes and most likely confined to certain divisions. However, in order to bound the amount of training that may be required for "project teams" these data will be used.

Using the data we have discussed so far a plot of training hours can be estimated, see Figure 20. The "Y" axis is non recurring training hours and the "X" axis represents the number of different teams outlined in Figure 19. For example, point "A" corresponds to a "Networked Team" which requires four types of training; Problem Solving, Conflict Resolution, Inter-Group Resolution, and Information Management Systems. Point "D" corresponds to a "Work Team", which requires twelve types of training; Task Training, Social Interaction Skills, Cross Task training, etc.

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[38]Fisher, K. "Leading Self-Directed Work Teams", McGraw-Hill, Inc. 1993.
[39]Ibid.

Using this approach two points become fixed, (0,0) and (12,400). The first point is self explanatory, the (12,400) point is defined as 400 hours spent on twelve types of training for "self-directed work teams".

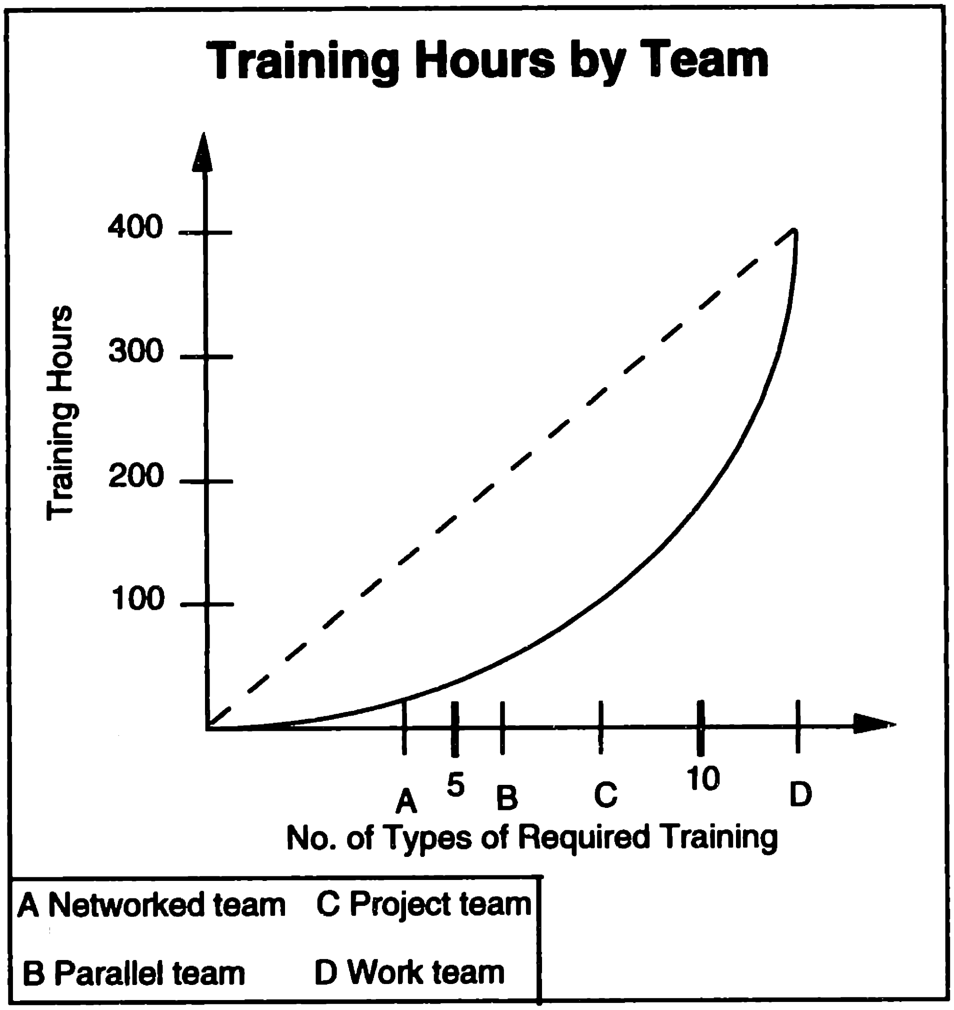

Figure 20

This is a very crude method of estimating the number of hours required for the three other teams, but is probably not far off if we look at a range. This range is established by drawing two lines between the two fixed points, one linear and one exponential. They will be used to set the range.

From the plot, Figure 20, we see that "project teams" may require from 90 hours (the exponential line) to 260 hours (the linear line). The 90 hours is probably a closer approximation, since, only the "work teams" training included "task" training, which is most likely the bulk of the estimated 400 hours of non recurring training. Task training would be the detailed technical training (e.g., equipment operation certification or soldering process certification).

Another approach to estimating the amount of training hours required for project teams would be to list the types of training and estimate the individual hours requirements for each type. Below, I made my own estimates with the exception of the 24 hours required for Scheduling and Budgeting. This number comes from the 3 days of training required to certify a cost account manager on the B2 Bomber Program.

For Project Teams:

Problem Solving	4
Conflict Resolution	8
Inter-group Resolution	8
Information Management Systems	8
Specific Org Unique Skills for Process Improvement	24
Business and Economic Education	8
Special Training to Allow Participants an Appreciation for the Broad Background/ Experiences of the Team Membership	16
Scheduling and Budgeting	24
Total	96 hours

We have used the "work team" training requirements as well as a bottoms-up estimate to derive an estimate for what might be required as non recurring training for "project teams". Now let us look at the investment in training the four major aerospace programs under study have actually made.

Training Performed on the Four DOD Programs

B2 Program

The B2 Program Executive Leadership Team (BELT) spent many hours discussing the issue of training. How much, by who, for who, and when were iterated in several long meetings. In the end the following approach was adopted:

> *"The Proposed approach involves a blend of team leader flow-down and subject-matter-expert trainers. A program decision was made early-on to do the training using internal trainers rather than external consultants. This strategy ensures team leader commitment and provides the opportunity for continual buy-in during every phase of the training process"*[40]

The final training plan consisted of a one day workshop with the SPO Program Director and the Northrop Grumman Program Manager, discussing the concept of IPT with the Program Team Leaders and the IPT Leaders, from both the government and contractor. This meeting also outlined a three day training session that was later held between IPT leaders and their team members. This three day session covered; Operations Concept Training, Team Development Training, Process Management/Metrics Training, and a training critique from the participants.

C17 Program

The C-17 Program was much like the B2 Program in that it was up and running when the notion of IPD was implemented. They had the same dilemma in determining what and how much training was to be given to the teams and others.

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[40] B2 Team Management Manual, First Edition.

They had only performed orientation type training for their team members. However, they are in the process of defining the training requirements and developing the training materials.

In preparing these materials they have taken an approach of "what should I train a Program Manger"[41], because the team leader is essentially a mini- program manager. With regard to what kind of training should the team as a whole get, they were still defining this.

F/A-18 Program

On the F/A-18 E/F Program Northrop Grumman ended up with a two day training session done by an outside consulting firm. In addition they use extensive coaching by leadership on an ongoing basis. In discussing their approach to training with Marc Schwarting indicated that more training would be beneficial to the teams. However, their program is on the backside of the headcount curve and therefore it would not be cost effective.

F22 Program

The F22 Program had a one day training session with the team and its membership.

Program Training Summary

The training outlined above for the four programs reviewed, is time spent in formal training settings. However, all of these programs have spent much more time working on getting the teams to function. For instance the F-22 Program spent about one day per week for a year on management training, IPTs spent a great deal of time defining process, tasks and responsibilities, and any new members to the teams received some program orientation. However, these types of education did not fit in my definition of non recurring

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[41] Discussion with personnel of McDonnell Douglas Aerospace.

team training so they were not rolled up into the training hours per program.

A summary of this training is shown in Figure 21 for the four programs. When comparing the average aerospace training of 12 hours to the range of 90 to 260 hours that was developed in Figure 20, we see there is a significant disconnect. Also, in two of the Programs I reviewed, no provision was made to repeat the training for new hires. The question becomes why? Hasn't the commercial world show the investment in training to be cost effective, or is there a deeper reason that is inherent in the nature of the business of Military aerospace industry?

LAI Survey Data[42]

Another data point indicated that training may not be up to the level desired comes from the LAI Survey feedback on Integrated Product Teams.

One of the survey questions was on the "Team Leader Understanding of Role". Responses could be from one to seven, with six or seven meaning fully understood. In the Airframe Sector, for the 13 teams surveyed, only 23% responded with a six or seven, that is they fully understood their role. The range of responses for these 13 were 2-7 and the mean was 4.8.

[42]Klein, J. A., and Susman, J., MIT LAI Working Paper 95-3, April 7, 1995.

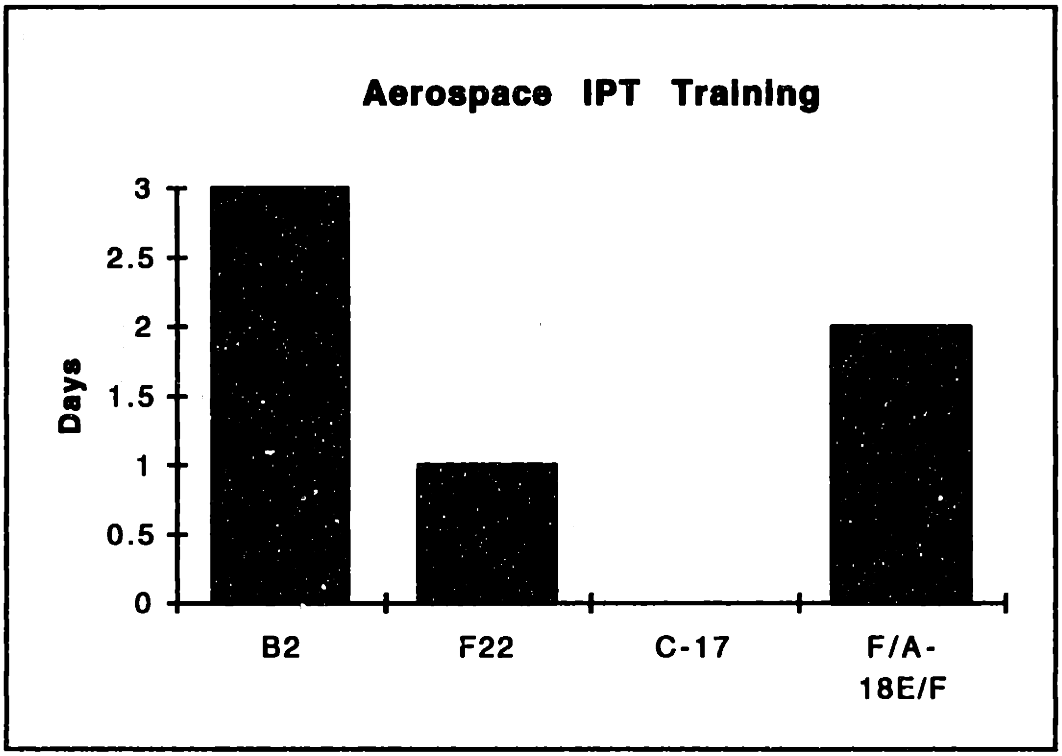

Figure 21

Analysis of Training Deficiency

One reason for the significant disparity on the amount of training provided may be the rate of turnover in the aerospace business. Training is considered to be an investment in capital, it just so happens in this case to be human. When a firm makes an investment in capital it expects a return on that investment, and makes no real distinction between PP&E[43] and human. In the case of the commercial firms, the investment they make in their people stays with the firm because the people tend to stay with that firm. In the case of aerospace the rate of turnover is staggering, a program can ramp up to 12,000 people and then be down to nothing in a ten year period[44]. This difference may be the reason that the aerospace industry is not making the same level of investment as the commercial segments of industry.

43 Plant, Property. & Equipment.

44 The level to which this occurs is dependent on other programs/work that the firm may have on going.

To support this concept I polled several companies to get their headcount profiles over time. In most cases I found that the headcount is relatively constant over time with the exception of swings due to market share or economics. From my discussions with the auto industry segment I was able to draw a figure that represents headcount profiles from two of the big three auto makers. There was one case where data was released, Caterpillar. The Caterpillar data is shown in Figure 22 & 23. Here it can be seen that over a ten year period their engineering headcount has had a slight positive trend to it, due most likely to their increases in sales over the same period.

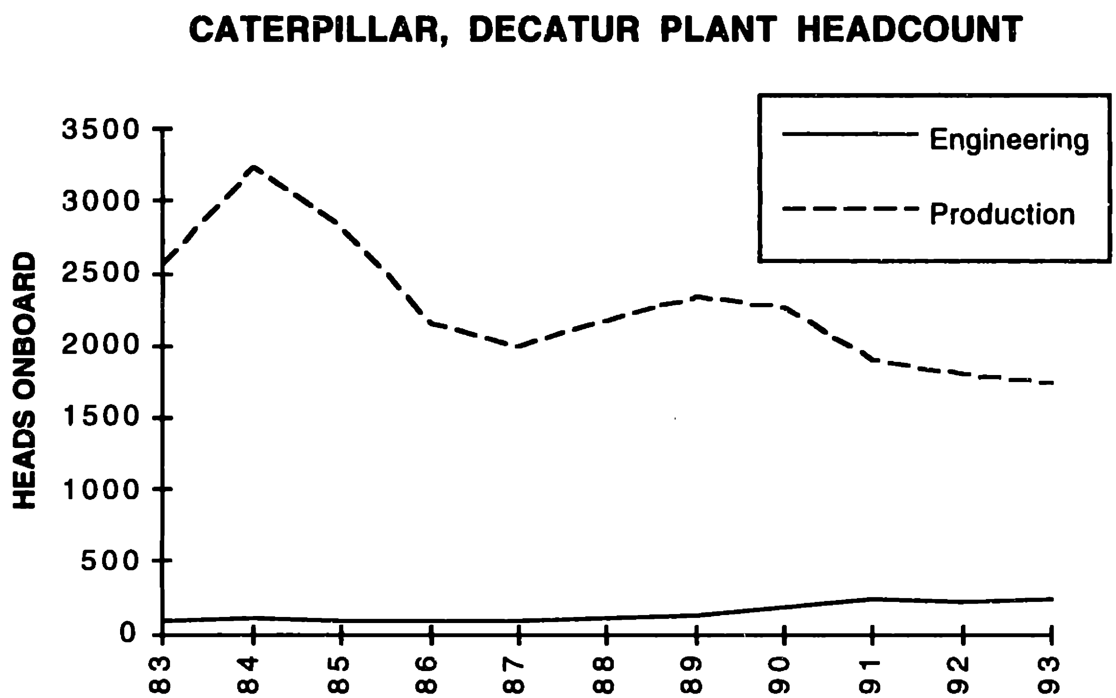

Figure 22

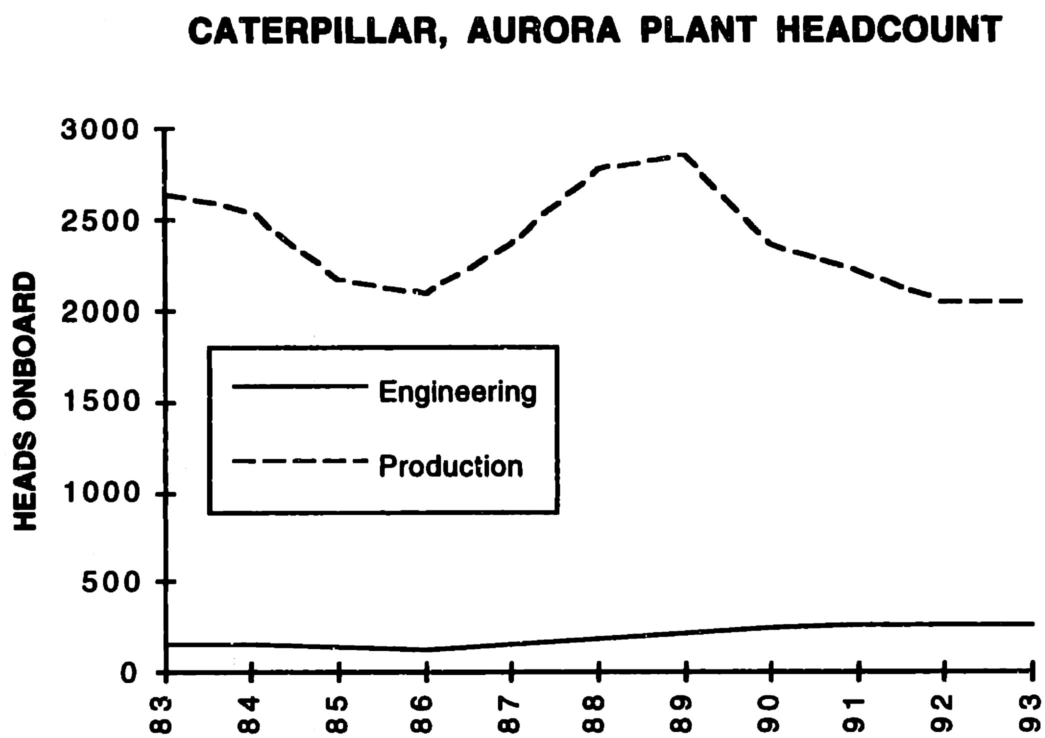

Figure 23

In Figure 24, we see data that are based on discussions with General Motors[45], and Ford Motor Company[46]. Here they go through a model cycle every year, ramping up and then ramping down their engineering staffs. This headcount cycle goes on indefinitely, so long as they are designing cars. This ramping up and down goes on for every new model car, however, if we integrate the area under these repetitive cycles you will essentially get a flat line. That is, they manage their people to these product cycles and essentially keep their headcount flat.

The point to these charts is to direct your attention to the fact that these commercial firms can afford to make larger investments in their people because they tend to stay around to give the return on that investment.

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45 Assistant Chief Engineer, CLCD.

46 World Class Training and Process Leadership, Ford Motor Company.

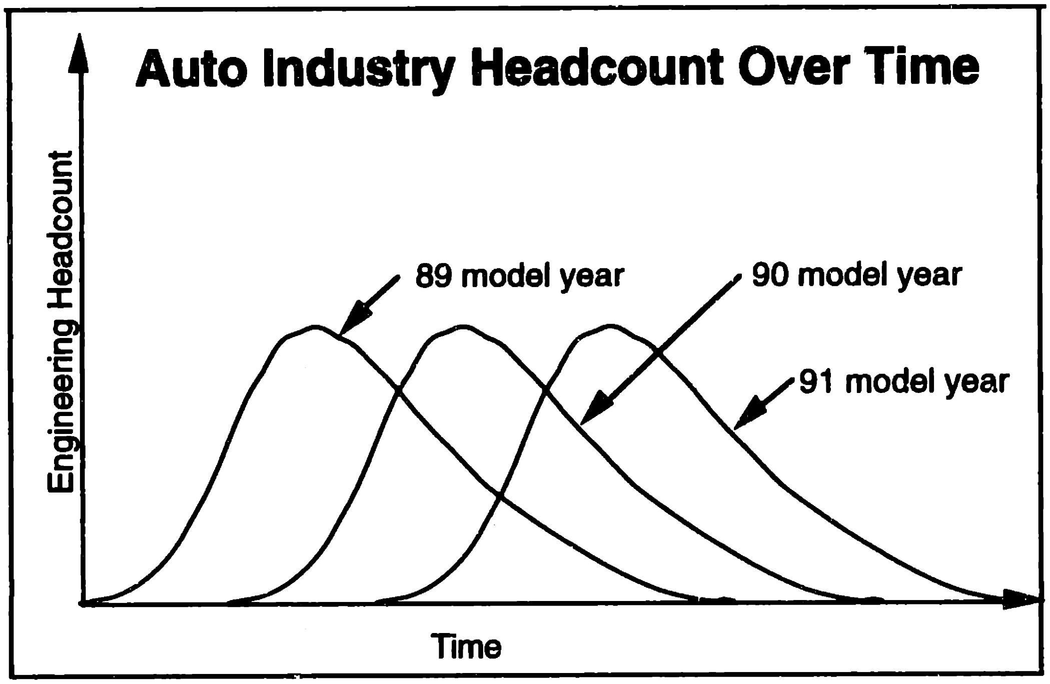

Figure 24

Now we will look at the aerospace curves. In Figure 25, we see that headcount data for the Northrop Grumman B2 Bomber and in Figure 26 the same data for the F/A-18 E/F EMD programs. Here we see there is a fast ramp up an then a sharp drop off of personnel. Although I could not access the data for the F22 or the C17, the nature of their curves would be very similar. The training problem may be related to the notion that a firm is less inclined to make the kinds of training investments in human capital, if it does not stay with the firm long enough to get an adequate return on the investment. What makes it worse, in the aerospace industry, is that when these natural workforce reductions take place, personnel will not typically go to another division in their same company. Most of the time they will go to another company or another industry. With today's decline in defense spending there will be more going into other industries.

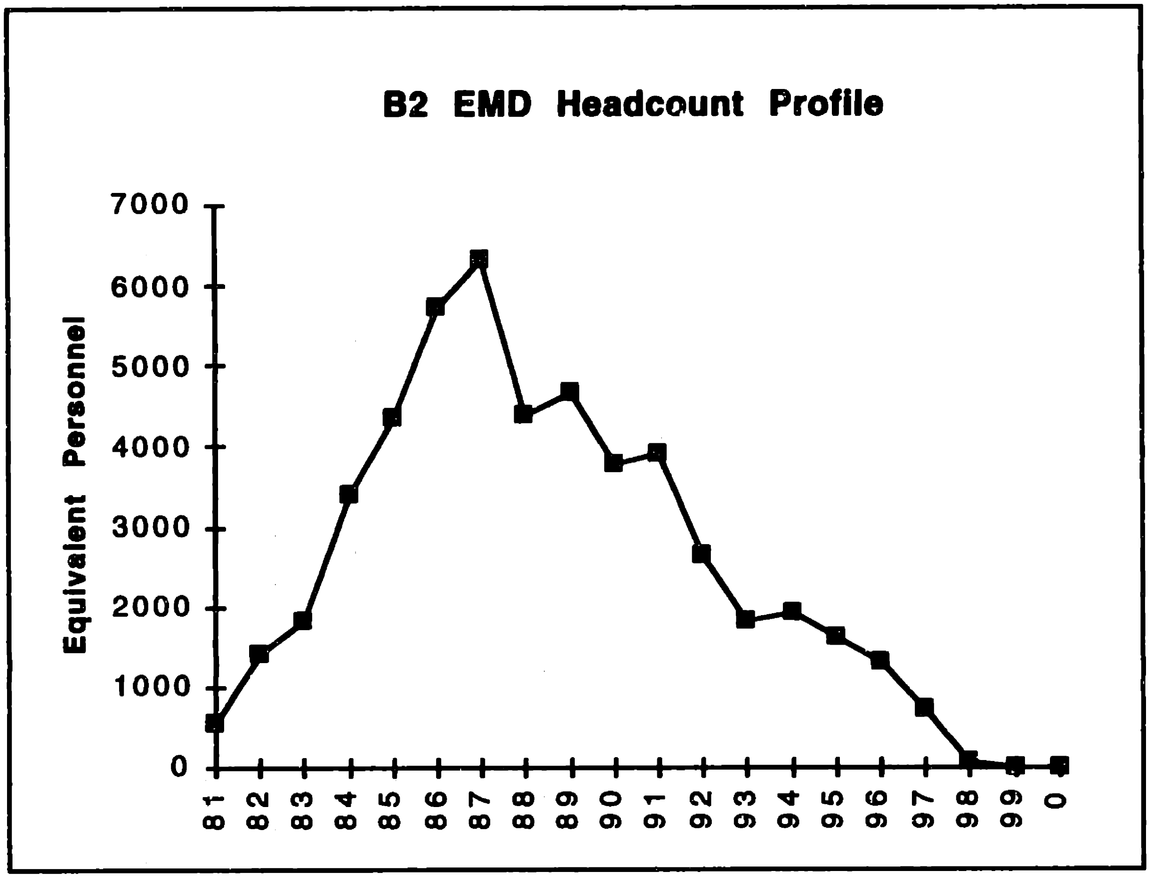

Figure 25

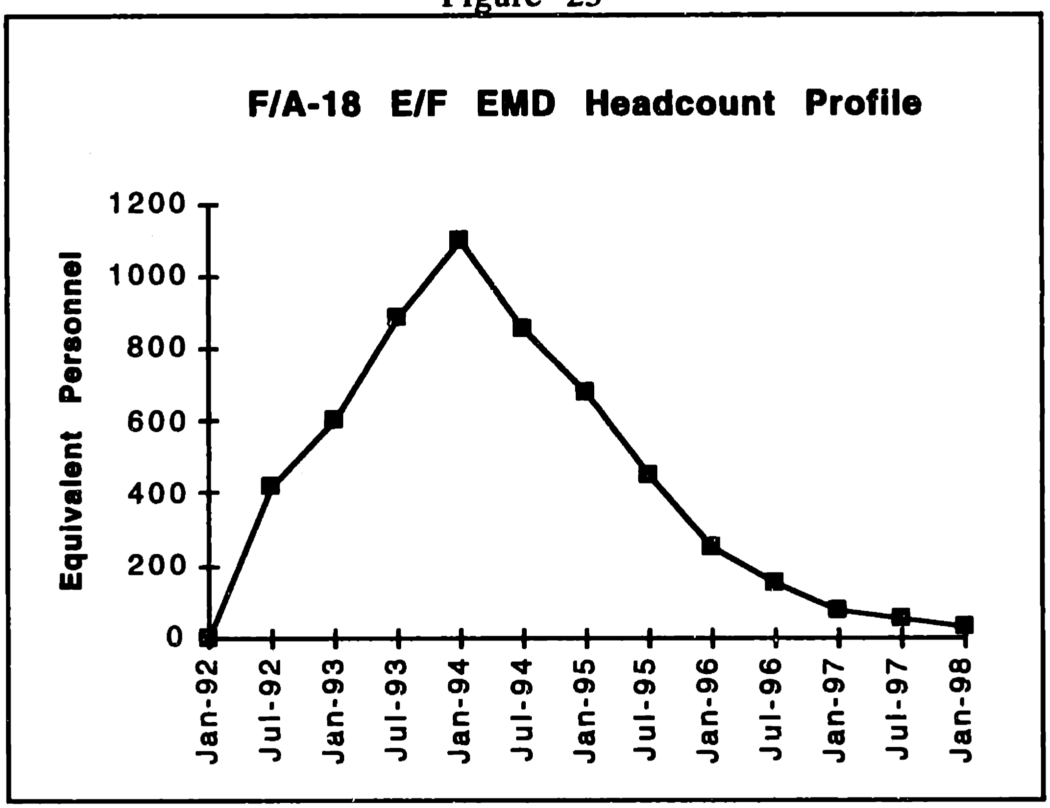

Figure 26

Problem Summary

Much more work is yet to be done in terms of defining what and how much training is required to make military aerospace IPTs to be as effective as they can be. Yet, it is clear that the amount of training performed to date may not be adequate. The issue of how this training should be paid for also requires investigation. At least one of the two programs that had IPT called out in their contract performed their training as a direct charge. If the amount of training that has been discussed here, is truly required, then many firms may have to relook their indirect rates. Also, the nature of the industry puts an incentive on not making large investments in training due to the rapid and high turnover of personnel.

Based on these realities it would seem appropriate for the aerospace industry to carefully analyze how much they spend on their IPD training.

A Potential Solution

Although the story presented above is not very positive, there is a reasonable solution to this dilemma. Not all the people leave the company during the downturns, there is about 30 percent that are your key personnel, in a variety of disciplines, with a varying skills plus your management and lead people. These people tend to stay on because conscious efforts are made to find them employment somewhere in the company because of their value. For these people you would want to make the investment in training, since you will reap the benefits on one or more of your programs over time. This will require you to institute a "critical skills" list and a key personnel list to identify who you will invest in. This would require you to clearly understand your strategic goals and what kinds of human resources those goals will require. Then you will need an active element of the organization to keep track of these people to coincide with your plan. This may sound complicated and it is, it would require a significant amount of time and effort, but it may be well worth it.

Since you would be moving people around from division to division under this scenario, it would also require that standard approaches to IPD be developed such that there is not a large retraining period for your people who move. This standard, if extended to all of industry would reduce the cost incurred by the government when someone moves from one company to another. More thought needs to be put into this subject before an industry standard could be worked out.

Some more thoughts on this subject. If we are trying to set up training to give our people the skills they need to execute programs in accordance with the concept of IPD, we may be able to get at least partly there by setting up an environment that supports some of the key elements of IPD. One of these elements is the notion of cooperation and communication between the functions. It would be of great value to a program if when it was ramping-up, the new hires saw that on this program there was a lot of open and honest communication between the functions, that people really cared about the product and doing what is right for the program first. This environment can be developed over time by those who are the long-term employees. The ones that have been identified to stay with the firm for the long-haul and have been receiving the right training.

If a firm was to have an environment in which the functions are pit against each other, the new hires will see it and emulate it. People tend to act like their management. If the operations VP and the engineering VP are at odds with each other it gets communicated quickly through out the organization. It also gets emulated though out the organization. The worker on the floor will be doing what he/she thinks is expected, after all, that is how his management acts and they assign the pay raises and decide who gets promoted.

Cost Accounting and Budget Control

All four programs are having problems with regards to the issue of team based cost control and cost accounting/reporting. In order to get into this discussion it is necessary to give some background on work breakdown structures and cost accounting in DOD procurements.

Mil-Std-881 (Work Breakdown Structures for Defense Material Items) is a DOD standard for how the item being procured should be broken up into elements and how cost within these elements will be segregated by categories.

A work breakdown structure (WBS) is a product-oriented family tree composed of hardware, software, services, data and facilities which results from systems engineering efforts during the acquisition of a defense material item. A work breakdown structure displays and defines the product(s) to be developed and/or produced and relates the elements of work to be accomplished to each other and to the end products(s).[47]

Although the WBS Mil-Std does not get into the details of "functional categories", it does state that for each work breakdown structure element there is a functional breakout. The cost of any specified work breakdown structure element at any level is composed of one or more functional categories. Functional categories include engineering, tooling, quality control, manufacturing, and purchase equipment, and are defined in the Contractor Cost Data Reporting (CCDR) System Pamphlet.

For aircraft systems the WBS standard is defined below in Figure 27.

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[47] Military Standard-Work Breakdown Structures For Defense Material Items, MIL-STD-881B, 25 March 1993.

Typical WBS For Aircraft System

Air Vehicle	**Data**
Airframe	Technical Publications
Propulsion	Engineering Data
A/V Application Software	Management Data
A/V System Software	Support Data
Communications/Identification	Data Depository
Navigation/Guidance	
Central Computer	**Peculiar Support Equipment**
Fire Control	Test & Measurement Equip
Data Display and Controls	Support & Handling Equip
Survivability	
Reconnaissance	**Common Support Equipment**
Automatic Flicht Control	Test & Measurement Equip
Central Integrated Checkout	Support & Handling Equip
Antisubmarine Warfare	
Amament	**Operational/Site Activation**
Weapons Delivery	System Assy, Instal, & C/O on Site
Auxiliary Equipment	Contractor Technical Support
	Site Construction
Systems Engineering/Program Mgmt	Site/Ship/Vehicle Conversion
System Test and Evaluation	**Industrial Facilities**
Devlopment Test & Eval	Construction/Conversion/Expansion
Operational Test & Eval	Equip Acquisition or Modernization
Mock-ups	Maintenence (Industrial Facilities)
Test & Eval Support	
Test Facilities	**Initial Spares and Repair Parts**
Training	
Equipment	
Services	
Facilities	

Figure 27

Once the contract is awarded the WBS is extended to lower levels by the contractor, with the governments approval, to further the definition of the work to be performed under the contract. This extension is called a CWBS, for contracted work break down structure. Traditionally, the CWBS and the contractors functional organization set up the configuration for how the work will be planned, tracked, managed, and reported. Figure 28 shows the relationship between the contractors organization and the CWBS.

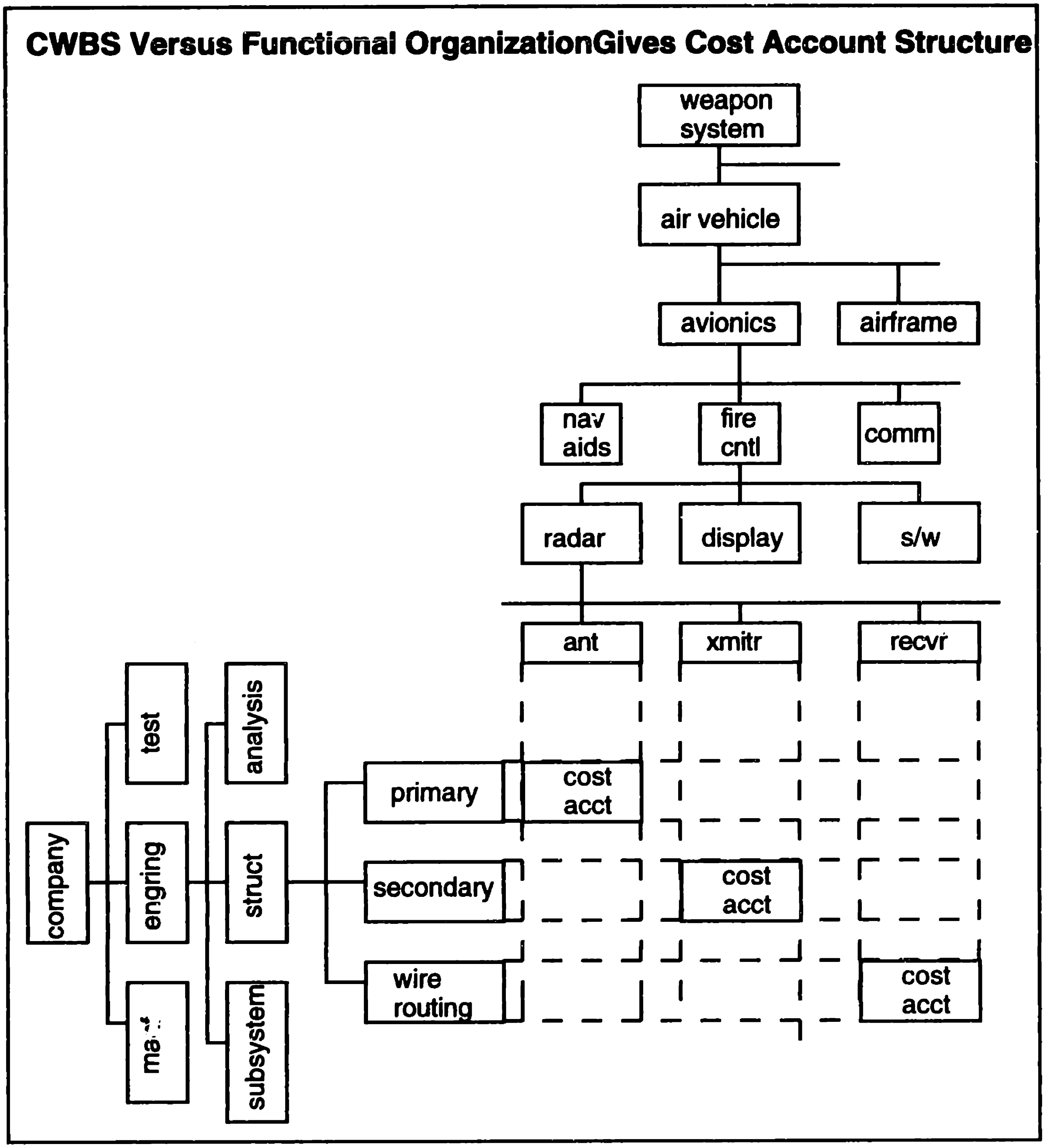

Figure 28

As the product is broken down, so is the organization to a point were there is a discrete measurable element of work that will be performed over a set period of time. This intersection is called a Cost Account. The cost account is the lowest level of control over cost and schedule, and is controlled by a cost account manager (CAM). The CAM is a functional manager, usually at least second level, who has direct responsibility over the people who will perform the work in his cost account. On large programs these cost accounts can be rolled up to a higher level WBS for reporting purposes to minimize the amount of data generated. The key point to notice in Figure 28 is that the intersection that creates the cost account is between "product", the CWBS, and "function", in this case, Engineering.

With the implementation of IPT, there is a move towards giving the IPT's cost & schedule control, that is responsibility over the cost accounts. If we were to install teams as cost account managers, the intersection with the CWBS would look something like that shown in Figure 29. Now instead of a "product-function" intersection, we have a "product-product" intersection.

While this "product-product" intersection would require a change to Mil-Std-881, the question becomes, is it worth it? Is there true value in giving the IPT leaders cost control over cost accounts? What is the non-recurring cost to change the contract and restructure all of the cost accounts? Lastly what does this change do to historical databases that are segmented by function? These issues are addressed individually below.

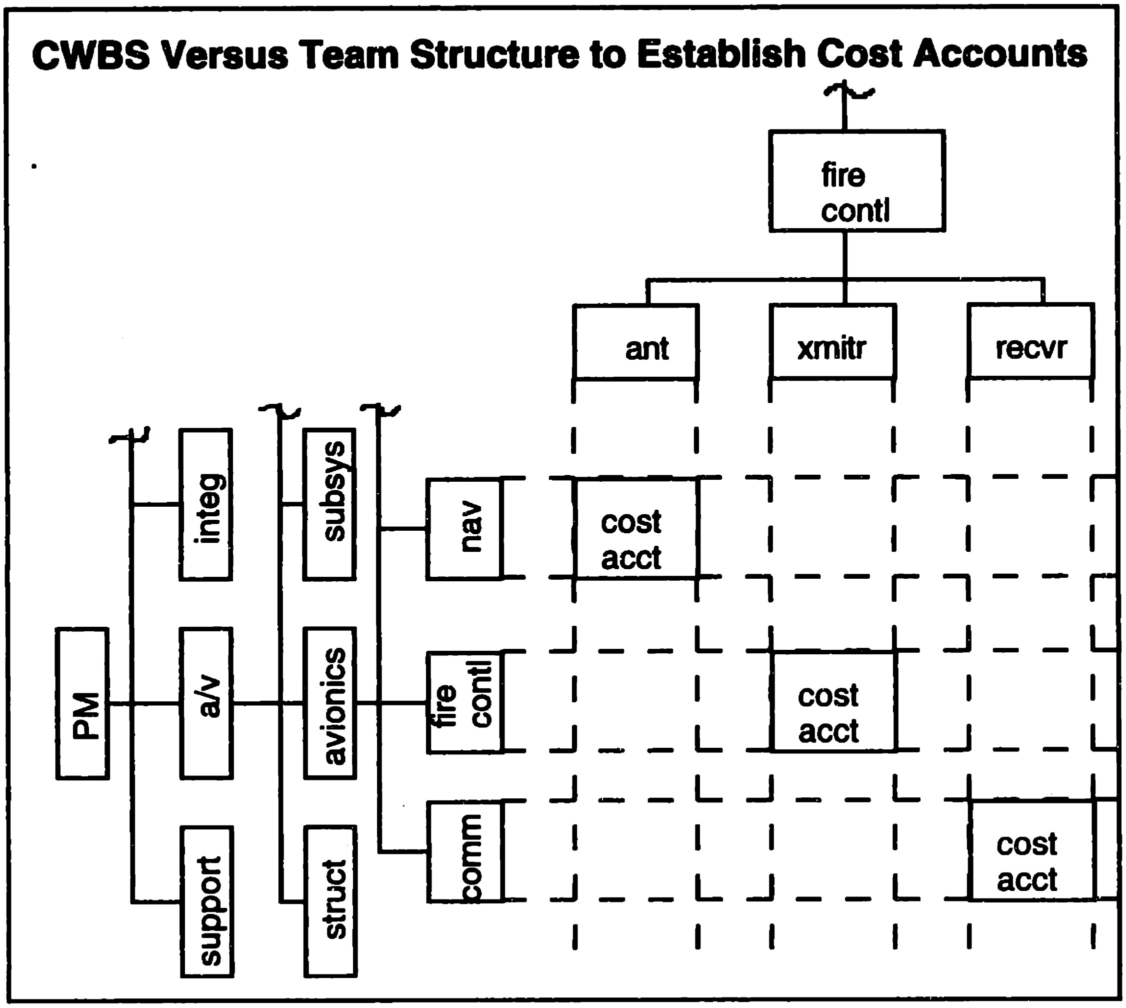

Figure 29

<u>Budget Control as a Part of Empowerment</u>

All the programs reviewed were under pressure to get budget control to the teams. On the B2 Program, it was felt that, as a part of "team empowerment", budget control and authority was required. In the commercial world, the team leaders commonly have budget control over their products, and I think this may be a source for the push to have IPTs control budgets. However, budget control in the commercial world has a different meaning than what is meant for DOD programs. These differences are explored below.

At General Motors', Cadillac Luxury Car Division, the SMT Captain for "Exteriors" will have budget control over all aspects of the components (parts) that are required for the exterior of the vehicle. The SMT captain is given a budget of, $400 for example, and she decides how to distribute these dollars within her area of responsibility, provided the product meets it's requirements. If she decides to spend $20 more on headlights and reduces the cost of bumpers, it was within her discretion to do so, provided that she does not violate her overall budget and also meets the overall performance requirements. She has several options as to how to get the $20 to headlights. She may have changed bumper-materials to reduce cost or made the bumper design more producible, or just negotiated a better deal with the supplier. Another option she has, is to barter with some of the other SMT captains. For instance she may have a surplus in her investment budget by $100,000[48], and negotiated a deal with the "interiors" SMT captain to trade this investment money for piece cost dollars. Here is were the teams often work together to make sure the total product is producible within the overall target, and helping each other out is part of the process. A final option might be to use a portion of her management reserve to get what she needed for the headlights and not touch the bumpers.

Here, there is clearly an advantage of giving budget control to the team leader. Since she has the greatest knowledge of her system and the mechanisms necessary to coordinate with the other SMT Captains, decisions are probably best made by her. Since she makes these decisions she should have the authority to make them happen, that is the budget control. This process provides her with the authority and responsibility over what she has been asked to do, which increases her level of dedication and commitment to the job.

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[48] Investment budget would cover items like tooling for assembly or piece part fabrication.

However, in DOD procurements under C/SCS[49] and Mil-Std-881 control, it is not as straight forward as in the example cited above. For one, no budget gets moved without a corresponding movement of A statement of work. Let say the avionics team leader wanted to cut the radar budget by 10% to transfer it to the communications sub team to get better performance on the communications system. Major systems like radars or communications are typically subcontracted items. So the team leader, working with the subcontract manger, would have to talk the radar subcontractor into modifying their estimate to complete (ETC)[50] without violating the procurement specification. Essentially, the subcontractor would have to admit that their was pad in his numbers, which no one likes to do.

Another option would be to take the budget from the radar and change some specification value or other parameter of the contract. If you change the supplier specification you have to make sure that it does not roll up and violate the specification the prime contractor has with the government. If it did bump a value in the primary specification and the contract was a cost type, the government would expect the prime contractor to give up fee or some other value for the relaxed requirement. Clearly, the prime contractor does not have an incentive to do this. Furthermore, changes to specifications like I have described take a long time, several months or instance. If this all sounds complicated, it is. So the value of giving the IPT leader budget control to provide them with a sense of ownership to achieve commitment and dedication, does not have the same affect as that of the General Motors SMT Captain. The SMT Captain can make the decision to transfer the budget in a matter of minuets if she uses her management reserve, in probably hours if she barters it with another SMT Captain, and may be days if she works with a supplier.

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[49]C/SCS is cost schedule and control system. It is a common methodology used by all government contractors to plan, track, and control a programs cost and schedule.

[50] ETC is a forecast of the cost to go to finish the contracted work.

Other distinctions between GM and the military programs, is the GM SMT captain is managing production cost, not development cost. The cost of engineering and other professionals at GM are treated as an overhead cost. What the SMT Captain is managing is the part-cost-per-unit of production. On the military programs, we are talking about trying to manage labor costs primarily, production costs do not have the same meaning and are not easily allocated to a team structure. In the case of the auto industry they produce hundreds of thousands of essentially identical cars. When a car rolls off the line, every minute, the cost of interiors is the sum of the parts plus a prorated share of the overhead. In the case of a B2 Bomber, the cost of any aircraft becomes very confusing if you try an allocate it to a team structure.

To illustrate this confusion let's say their is a change during production, which is a daily occurrence, that disrupts the flow of the build process. Is the time lost due to the disruption allocated to the team that is making the change, or equally shared by all teams? What if the disruption is not total stoppage by every work job, but rather, some completely stopped and others only partially stopped. How would you define this partial work that could be done and keep track of it such that the teams that were able to continue work are not fully penalized and the team that had total work stoppage, were appropriately penalized? It would take an army of staff people, industrial engineers, and manufacturing engineers to define it and then keep track of it.

If the B2, or any other major weapon system, went together in somewhat of a straight forward manner, like a car, it would become practical for the production costs to be allocated to a team structure. However, the production of 20 special purpose aircraft during a concurrent development program causes the production process to be continuously disrupted, and ownership of the disruption is not easily identifiable.

A Potential Solution

A typical aircraft development can create this continuous disruption due to engineering changes or re engineering of production processes. This highlights an area where it would make sense to give the teams control over a portion of the program budget, the portion designated for change management.

Let us go back to the example of the GM SMT Captain using her authority over the exterior's budget to get better headlights. Why she is making this change was not addressed. Her reason for making the change is most likely "customer" driven. Her marketing staff may have informed her that if she were to improve the intensity of the cars headlights they would sell more cars, as a simplified example. However, in the case of the avionics IPT leader, why is he trying to make the change to the communications system? It is most likely not because some marketing person told him that the end user would like a better communications system, although they may.

The customer requirements process is very different for military procurements. A statement of need is established, then requirements are developed, and over several years many studies a system is evolved that will satisfy the needs. Ultimately these studies are translated to a specification that a contractor signs up to perform. These types of developments are almost always "cost type".[51]

Since the contract calls for a radar, and it most likely has a detailed performance specification along with it, there is no mechanism to improve the radar above the specification because the customer might like it. A contractor spending government money to make a

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[51] Cost Type refers to the fact that the contractor will be reimbursed for his cost in developing the product and get some fixed fee as a function of cost. To prevent unnecessary costs there will usually be an incentive mechanism to encourage the contractor to keep the costs to a minimum.

product better than what the specification calls for, may find himself in court for unauthorized expenditure of government funds.

The avionics IPT is probably making the communications system change because he has to. He may have found out, in some recent test, that the output was not up to the level required by the specification, so he has to authorize the supplier to make a change to increase performance. Here is where the IPT, can have control over the budget to a degree. Changes like this are very common on complex developments, like any of the four aircraft we are discussing. Usually the program will set aside a relatively large sum of money to cover these expected development changes. This budget could be allocated to the IPT leaders to give them control over two elements of the program. One, to ensure that the money is spent only on things that are absolutely necessary, and two to ensure that the change is integrated with the rest of the program.

The magnitude of cost due to change is rather significant. In addition, according to Pugh-Roberts and Associates,[52] it is a major reason large complex programs, like aircraft, usually end up being late and over budget.

Significant work has been done by Pugh Roberts Associates on what they call the "Rework Cycle".[53] They point out the fact that most programs are laid out with no allowance for rework which are a natural part of the design and development process. However, the concept of using future inevitable changes as a part of your planning is being more widely used today. When the B2 Bomber Program was rebaselined, in 1993, the schedule that was developed allowed for three types of changes; Known-Knowns (K-K), Known-Unknowns (K-U), and Unknowns-Unknowns (U-U). The K-K are changes that engineering has identified and the change board has quantified the

[52] Cooper, K., "The Rework Cycle: Why Projects Are Mismanaged", pmnetwork, February 1993.
[53] Cooper, K., "The Rework Cycle: How It Really Works...And Reworks...",pmNETwork, February 1993.

amount of future work required to fix them. The K-U are changes that have been identified but have not been through the boards to determine the program impact. And the U-U's are the changes that you do not even know about yet, but are out there waiting for you to discover them.

Based on the history of change on the B2 program and some extrapolations from change curves on the B1 and F/A-18 programs a future forecast of change, by type, was developed along with an estimate of how many manufacturing hours would be required to incorporate these changes for the B2 Program.

The B2 Bomber change curve that resulted from this process is shown in Figure 30. This is a time plot of changes made to the weapon system after a program baseline was established in 1985. As can be seen, the magnitude of change and therefore corresponding cost is very large. Giving the IPT team leaders control over this budget may better achieve the objective of furthering their Empowerment.

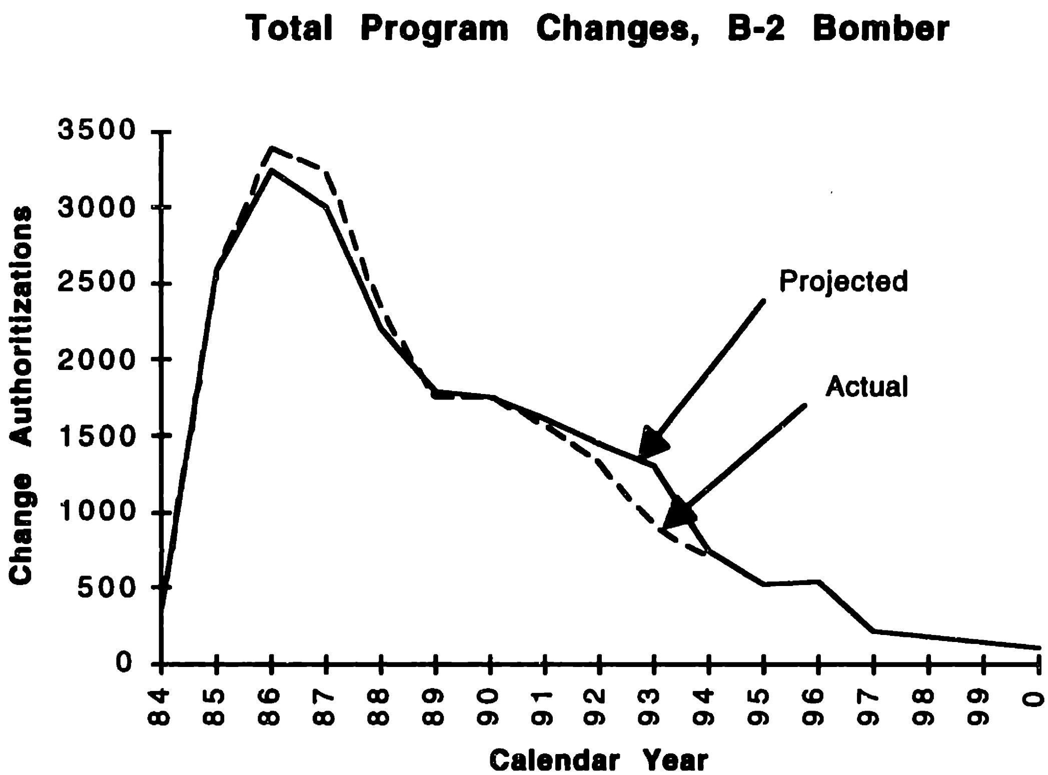

Figure 30

Cost of Restructuring a Programs Cost Accounts

The cost of restructuring the cost accounts of an ongoing major program can be rather large. These major programs will typically have hundreds of cost accounts distributed over the entire organization. These cost accounts would have to be pulled together and rebaselined to teams consistent with their statement of work. Each team would have to go through the very detailed and time consuming process of replanning these cost accounts to their schedules and priorities making sure all the effort remains integrated.

In addition to this there may be the need for major financial data systems changes since the reports and data structures are set to the functional organization. All in all, the challenge of restructuring cost accounts is by no means a small task.

Impact To Historical Databases

To facilitate giving the teams budget control, several of the programs reviewed are looking at ways to restructure their CWBS's. However, if a program moves away from the traditional WBS structure two problems surface, one for the government and one for the contractor. The problem for the contractor is one of cost estimating relationships and a historical cost databases. Most companies when bidding a new program or a major change will go out to all parties in the organization and collect inputs on the estimate to execute the change. The estimates are what we refer to as "grass roots".[54] If the number that rolls up from the grass roots estimate seems to high, the company can go to their parametric historical data and compare it with past changes. The problem is that these data are functionally cut by major organizations like engineering, production, material, logistics, etc.

If teams took over the control of cost accounts, estimates built up by them would be comparable to the historical data only after major recuts on the data by functions.

The government has the same problem but on the receiving end. They too have historical databases of estimated costs for a variety of tasks or programs. However, their databases are built up based on the functions defined by Mil-Std-881, that is, engineering, manufacturing, test, etc. If the bid comes in cut by team they would have nothing to compare it with, except a total value level.

For these reasons all four of the programs are still negotiating all changes or new contracts based on functional cost inputs. Also, cost

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[54] Grass roots refers to the fact that the estimate is built up form the lowest level in the organization.

reporting is still being formally submitted in the old format of functions. Even in the cases where the WBSC is close to the team structure, like the F/A-18 and F-22, they still report and negotiate by functional inputs. Essentially they have two cuts of their cost databases, one for formal reporting by function and another for management of the daily activities which is cut by team to a certain level.

Summary

What has been pointed out in this section is the impact associated with giving the IPTs cost account control. However, it was also pointed out that the reasons for trying to give the teams budget control (i.e. empowerment) may be ill founded. Lastly, a potential solution to the desire to giving the teams increased authority on the program may come in the form of change budget management.

Functions and Teams Working in Harmony

Several of the issues that were summarized from the structured interviews in the front of this document had to do with the relationship of teams and functions. They are repeated below:

1) The function's job is to maintain the personnel's skills and processes for the program.

2) Very little time was spent on defining the relative roles of the teams and functions

3) Performance evaluations seem to be migrating to the product team leader.

These points are all wrapped up in the complex organizational issues of trying to make teams and functions work in harmony. In this section these issues are explored in further detail. It will be demonstrated that both need to exist for the firm to sustain the critical skills that are necessary to be competitive. It will also be demonstrated that the advantages of teams can be lost if these issues are not well thought out and brought in line with your team approach.

The structure of this section is to first present the value teams and functions bring to organizations. Then the challenges of functions and teams are presented. Finally, the need for a balance of both is discussed and supported by data that has been recently collected under the Lean Aircraft Initiative (LAI).

The Advantages of Teams

Several advantages of teams were presented as examples in the front of this thesis. In this section, a broader more theoretical look at the advantages of teams is presented so as to be contrasted with the advantages of functions.

The advantages of teams is captured well by a lead in passage by Ancona and Caldwell,

" The cry has gone out to revamp our organizations-to move away from specialized jobs to broader work responsibilities, away from narrow functional perspectives to enterprise-wide views, away from rigid hierarchies to flexible arrangements that can be more responsive to technological, market, and competitive change".

They go on to say,

"In partial response to these demands, organizations have set up cross-functional teams in areas such as new product and new process development. These teams are designed to react quickly and nimbly from a broad perspective and to perform in parallel tasks that used to be performed sequentially. The payoff is presumed to be improved time to market, lower rework costs, and improved innovation and quality".

To be a little more specific about what it is we expect from cross-functional teams, Figure 31[55] lists some of the common expectations.

BENEFITS OF TEAMS
1) Increse capacity of entire organization to make more decisions more often.
2) Frees up managements time to work other issues.
3) Wider varity of decisions since whole org has potential of being involved.
4) Better and faster decisions.
5) Decisions implemented quicker with less friction.
6) Improved communications between fucntions required for task.
7) Improved integration between interdependent functions/skills.
8) Puts decision making in the hands of those close to the data who also have the expertise to interpret it and act on it.
9) Facilitate concurrent activities.
10) Improve members commitment through social identification with the team.

Figure 31

The essence of the first four items in Figure 31 is that team structures allow the organization to decentralize the decision making process. It is the notion that if you empower your people you can push the decisions down in the organization. This is a leveraging activity, to expedite the decision process. As an added benefit this decision-decentralization frees up the time of the traditional decision makers to do other activities.

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[55]Items 1-4 (Galbraith 1994), item 5 from Class lecture at MIT, Lotte Bailyn 1994, Items 6&7 (Klein & Maurer 1994), Items 8&9 (Cohen 1993).

A wider variety of decisions can be made because the team structure can be whatever the organization decides, based on the task the team is given. For instance, the team can make engineering decisions which is the most common, but can also make finance decisions, make-buy decisions, production process decisions, etc. Better and faster decisions come from the notion that the teams are closest to the information that is required to make the decision, so they are the most qualified. Faster comes from the absence of the time consuming tasks of getting data up and down the chain for a decision.

Decisions made by the lower levels of the organization tend to be implemented quicker because of the elimination of the time required to get a decision discussed above. Also, they tend to go faster because the principle people that need to implement were usually a part of the decision process.

Whether it be from co-location, information technology or just regular meetings, the members of the team have more opportunity to communicate. In the early stages of complex products like aircraft, there is a tremendous amount of interdependency between, first different engineering groups and later between engineering and the rest of the organization. Early on in the design you have a need for the avionics designer of the software or black box that will control the aircraft's doors, working with the engineers that are designing the mechanical controls of the doors.

The fact that the tooling engineer and the design engineer are working close together in common data systems, allows the tooling engineer to work in parallel with the design engineer. In purely functional configurations the tooling engineer would not start his task until the design engineer finished and released his drawing.

By organizing people into teams there is an intrinsic incentive and commitment to the group and therefore to the job. This commitment comes from the membership's personal identification with the work through social identification with the group. Members will have a tendency to feel like a part of the family with loyalties developing which focus on helping the team achieve it's common goals.

The Advantages of Functions

Corporations today are taking advantage of core competencies to get a competitive advantage. "Core competencies are the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies".[56]

The Northrop Grumman Corporation has a core competency in the area of stealth technology. The technology used on the B2 Bomber is a generation later than that used on the F117 Fighter developed by Lockheed. The Boeing company has a core competency in the area of large composite structure design and fabrication. The wings on the B2 Bomber developed by Boeing are some of the worlds largest aircraft composite structures. McDonnell Douglas Aircraft has a core competency in the area of designing aircraft suitable for aircraft carrier takeoffs and landings. This has come through two generations of F/A-18, F-4, and A4 design and development.

This is just a subset of the core competencies that these companies have. A key question to ask oneself is, where do these core competencies exist? They primarily exist in functions. Within the functions these competencies are refined and passed on to others of the same specialty. For example the B2 Division of Northrop Grumman has a function in engineering which manages all the stealth technology development and application. These engineers and scientists work together on similar problems talking about the science of stealth and figuring out ways to best apply it to aircraft. They have a bond between themselves and a loyalty to their field of engineering. If they were dispersed to several different teams and

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56 Prahalad, C.K.. and Hamel, G., "The Core Competence of the Corporation", Harvard Business Review, May-June 1990.

not given the forum they have today to interact, the synergy would be lost.

While at Boeing, I learned that one of the design teams (commercial) had developed a design for a pressurized door which was to be made out of a casting. They had done the design and received bids from the supplier and demonstrated that it would be cheaper than the conventional design. However, when it as reviewed by the senior functional management, it was abandoned. The Boeing company has a rule, "thou shall not make pressurized doors out of castings". This rule comes from having more experience and having built more aircraft than any other company in the world. They have learned that the risks of a cast part failing for this applications are not worth the savings in cost. This is an example of the corporate knowledge that resides within the function.

In their study of the global auto industry, Womack and Jones[57] addressed "three needs", that of the individual, the function, and the company. The needs of the individual included the need for a career to give one a mechanism for developing abilities and a sense of going somewhere. They also spoke of the need for individuals to have a "home", that defined where they were in the work lives. They go on to define the need for functions:

> *"In order to use and expand the knowledge of employees, companies must organize this knowledge into functions, such as engineering, marketing, purchasing, accounting, and quality assurance. But functions do much more that accumulate knowledge; they teach that knowledge to those who identify their careers with the function, and they search continually for new knowledge. In the so-called learning organization, functions are where the learning is collected, systematized, and*

[57] Womack, J.P. and Jones, D.T., "From Lean Production To the Lean Enterprise", Harvard Business Review, March-April 1994.

deployed. Functions, therefore, need a secure place in any organization".[58]

Womack and Jones also cite the need for functions to develop best practices and develop people, and teams to apply these to, in the development of products. They point out how Honda Motor Company will rotate their engineers from product teams to functions. They go back to functions to get education updates on their area of specialty, then back to a team to apply it. This seems to be a good approach. However, in the aerospace business the product development cycles for any given company do not allow a similar approach. This limitation will be discussed further in this section.

Essentially, these studies find that functions are the best repository, organizationally, for specialty knowledge and a place any professional can associate with in terms of career. Peter Drucker points out that functions have a great advantage of clarity. Everybody, has a "home". Everybody understands their own task, and it provides a high level of stability[59].

On the issue of specialty knowledge, it should be pointed out that it changes over time in aircraft development. As depicted in Figure 32, any given team will call on special knowledge as the program proceeds though it's life cycle. In the front end of the program the strength and leaning needs to be on the engineering team to sort out the design requirements, and define an optimum design that has a high probability of meeting the product performance specifications. Heavy coordination and integration takes place at this stage of a program. Many trade-offs are made between engineering design disciplines and between engineering and manufacturing and logistics. Special engineering skills will be necessary for the design of the pyrotechnic devices required for ejection systems, also special skills will be required from engineering to develop a cockpit that will meet

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58 Ibid..

59 Drucker, P. F., Management Tasks Responsibilities and Practices, New York, Harper & Row. 1974.

the mission needs as well as provide suitable space for the crew. Cockpit lighting is a specialty that will be required also.

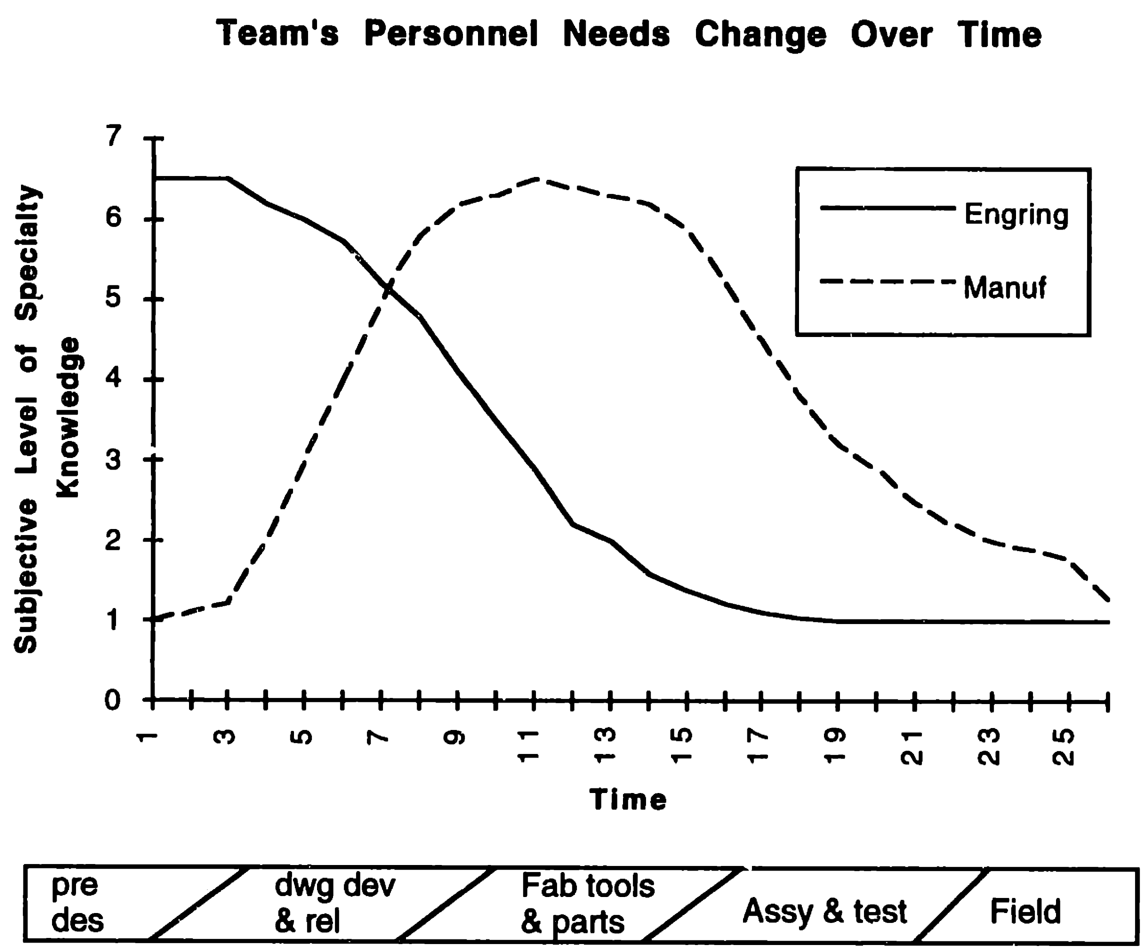

Figure 32

As time passes the team will need more and more support form production personnel and logistics and less engineering specialty knowledge. As the design group starts to layout the structural detailed design, tooling and manufacturing engineering will play a key role in the development of producible designs. Logistics will start to define support equipment and provisioning requirements.

The passage of time in Figure 32, depicts that the level of specialty for any of the skills listed above change over time. So what does the team or better yet, the firm do with the pyrotechnics expert when he is done with the cockpit? This is a skill that every company developing aircraft needs. It is one to be preserved and developed, but most importantly retained. That is where the function comes in. It is the home for these specialty skills, often called critical skills, that everyone in the aircraft design game must retain.

Challenges Team Structures Face

Team structures in organizations have many benefits as has been pointed out, however, they bring with them many challenges as well. From the Structured interviews I found that several programs are sorting through these challenges.

Who should do Performance Reviews?

There was a trend in the four Programs I reviewed to have the team leader do performance reviews for the members of his team. This creates a few problems in the context of what we have discussed thus far.

The reason the team was created was to provide a mechanism for the group to better integrate and coordinate. A key task of the team leader is to facilitate this activity, it will most certainly not happen all by itself. If the team leader is loaded up with a bunch of administrative tasks, he will not have time to do his primary task, integrate the team. Goal setting, interim reviews and the final performance review write-ups can eat up a big chunk of his time. A crude approximation of the amount of time required by the team leader is; 4 hours per employee for the goal setting, 2 interim reviews at 2 hours each, and 3 hours for the final review write-up. If he has 20 employees this will add up to about 220 hours, or about 11% of his working hours in a year. The 11% may or may not seem like a lot of time to you but this is further compounded by the fact that this time is bunched up at the beginning and end of the year, typically. So what it does, is effectively put the team leader on an administrative task for a month or so. This seems to be in conflict with what we want the team leader doing.

Another question to be addressed is whether the team leader is the best person to do the review. If the team members are hard lined to him I'd say yes, but if they are matrixed to him, then let the functional manager take the lead, and have the team leader countersign. The individual employees will feel better about being compared against a set of his functional peers versus a set of disciplines he knows little about.

Also, the individual performance review forms, not only document a person's goals for the year and how well they performed, these forms also document the individuals development goals and plans.

At least three of the aircraft programs reviewed, have within their performance review form the "space" for documenting an individual's personal development goals. Usually in this space a person will look at their career and decide what actions they may need to take to further themselves. It is usually worked out with their manager, and will include items like special assignments, advanced educational degrees, or training. These items would probably best be worked with a manger who is knowledgeable about the persons profession. Having the team leader do the performance review and another manager do the personal development portion of the review can be complicated, if they are on the same form. Not to say that it would be impossible, but certainly more complicated in terms of timing and coordination.

Natural Tendency for Conflict.

While the functional diversity on teams tends to foster communications between functions that are dependent on each other, it also tends to present problems within the team. These teams are made up with people from diverse backgrounds, education levels, expectations, and personal desires relative to the effort. This diversity can increase, and often does, the level of conflict, reduces cohesion, complicates internal communications, and hampers coordination within the team.[60] Small group literature indicates there is a challenge with putting together people with different cognitive styles, attitudes, and values, like those you would expect to find in a multi-functional teams.

For the aerospace industry, where the customer is also a member of the team, there is an added dimension to the concept of conflict. Provided the program is running smoothly and all requirements are being meet within the budget the team, including the customer, will most likely be OK. However, as soon as things do not go as planned, which is more often the case in complex aircraft developments, things become more stressed. Typically the responsibility for developing the product resides entirely with the contractor. So, when something goes wrong the contractor is obliged to figure out a way to solve it. However, differing opinions can develop when the customer is on the team. If the customer has one idea on how to fix the problem and the contractor has another there will be tension on the team. On the one hand the contractor has an obligation to the customer to do what the contractor thinks is best, that is what he was hired for. On the other hand the contractor has a duty to consider the customer's desires. It becomes a real dilemma for the team to sort it all out.

In most cases the team will sort it out and a solution to the problem will be reached via consensus, after all the customer is part of the team and its processes. However, I have seen cases where the contractor has been committed to one solution and the customer committed to another. In these cases the customer can, under the changes clause,[61] direct the contractor to do what they want. This

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[60]Ancona, D. and Caldwell, D., "Cross functional teams: blessing or curse for new product development", MIT Management/Spring 1991.

[61] Changes clause in most government contracts says , that the contractor is obligated to do what ever the government directs and its impact to the contract will be sorted out after the fact.

creates bad blood between the team, at that moment, and again when the negotiations for the change, if an impact was declared by the contractor, begin.

Another dimension to having the customer on the team is when they have to take action to ensure the interests of the US taxpayer are being served. The government has an obligation to raise issue when they feel there is a deviation to the contract. Let us assume they feel that there is no way that a contract milestone will be meet, or that the contractor fails to progress towards contract completion. Under these conditions the customer can take punitive action by withholding progress payments, requesting consideration or ultimately terminating the contract. By law these actions must be taken if appropriate, and the customer determines the appropriateness. However, after the C-17 insinuations about the customer being too close to the contractor in it's early development, everyone in the industry is being real careful not to give any of the outside audit agencies[62] something to point to and say, "the customer and contractor are in collusion".

At the most senior levels of a program it is understood when the government takes these kinds of actions that, this is a part of the business, and it is not taken personally. However, at the lower levels of the organization, where we are encouraging trust and cooperation, members of the team have a harder time understanding these actions. The result is that the trust that was built up between the contractor team members and the customer team members is presented with a set back.

The Level of Empowerment is a Function of Interdependency

According to Monaham (1991) " The importance and difficulty of integrating the various parts of an organization increase when the

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[62] The customer is constantly being watched by the GAO, or Congressional staffers, especially if the sponsoring member from congress feels he has a better idea on how to spend the money that is funding your program.

organization is required to make trade-offs, solve problems, and make adjustments to work on the basis of information from knowledge that resides in different parts of the organization".

In the development of advance aircraft there is very few elements of the product that do not affect the other elements in some way. There is almost always a certain level of interdependence that exists between the teams, internal and external. For example, let's look at our avionics IPT again, the one that wants to make a change to the Communications system. Let's say that they decide to get the output they need by increasing the power input, increase the size of the antenna, and have to add three pounds to the black box. They will need to coordinate with several other teams before they can proceed. They will need to get the structures team to OK the redesign of the antenna, and the increase in weight. They will need the subsystems team to OK the electrical power increase, and assure them that the current wire size is adequate, they will need the low observables team to OK on the increase in antenna size, and lastly they will need the program change boards to OK on the desired cut in point in production.

To accomplish this coordination most programs have and need a hierarchy of teams. Just as with the functional organizations, a process would exist to take up the chain all these parameters in order to make a decision on the proposed change, typically by the Program Manger.

These dependencies the Avionics team has with other teams is depicted in Figure 33. Here, the level of Empowerment will be a function of the amount of interdependency the team has with others[63].

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63 For a more detailed discussion of this phenomena see: Klein, J. A., "A Reexamination of Autonomy in Light of New Manufacturing Practices", Human Relations, Vol. 44, No. 1, 1991.

Another problem created by interdependency is a reduced level of program flexibility. Once you create empowered teams and they create their own master plan on how to achieve their objectives, the program's flexibility is reduced. The ability for the hierarchy of the program to change the course of the program due to some other teams problem/success which results in an impact to other teams will not be received well by the impacted team. The affected teams loyalty is to their team, and they will be reluctant to modify their plans due to some other teams.

Empowerment Diminishes With Interdependence

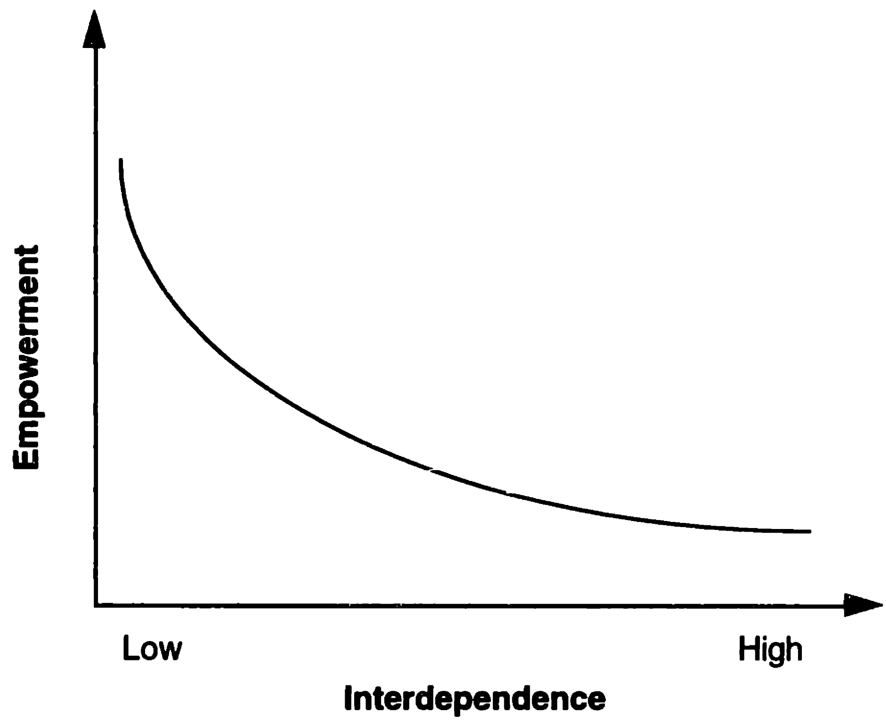


Figure 33

<u>Challenges Functions Face</u>

The problems with functions are that they tend to look out for themselves rather than the product. This creates barriers to good communication between the dependent parts of the organization.

Most decision making will require elevation to the highest levels of the organization because that is the only place that authority over all the elements exists. This not only causes slower decisions but as was explained in the section on "Decision Making", you may not get the decision you wanted or worse you may get a decision that is not relevant to the problem you were working.

Peter Drucker explains that the same advantages of functions are their problems. He points out that functions have the great advantage of clarity. That is everyone has a home and everybody knows and understands their task. Functional organizations provide a high level of stability for the workforce.

The price of this "clarity" and stability is that it is difficult for the members to understand the task of the whole and relate their sub task to it. Also, the stability keeps the organization rigid and very inflexible to change or adaptation. The clarity causes the functional managers to become very effort-focused. They tend to consider their function to be the most important element of the program or organization. This will cause the functional members to disregard the other functional groups, and to worry only about their own little element of the program.

Womack and Jones' notion of rotating your people between products and functions, as pointed out in the section "The Advantages of Functions" is an interesting one. However, it may not be all that practical for the developers of advanced aircraft for the government. The problem arises from the infrequency between major programs compounded by the further infrequency that your company is the one to win the few that exist. As shown in Figure 34, their has only been 8 major developments over the past 30 years and the average per company is about 2 (based on recent mergers and acquisitions).

Major Aircraft Developments Over Past 30 Years

(EMD Authorization Dates)

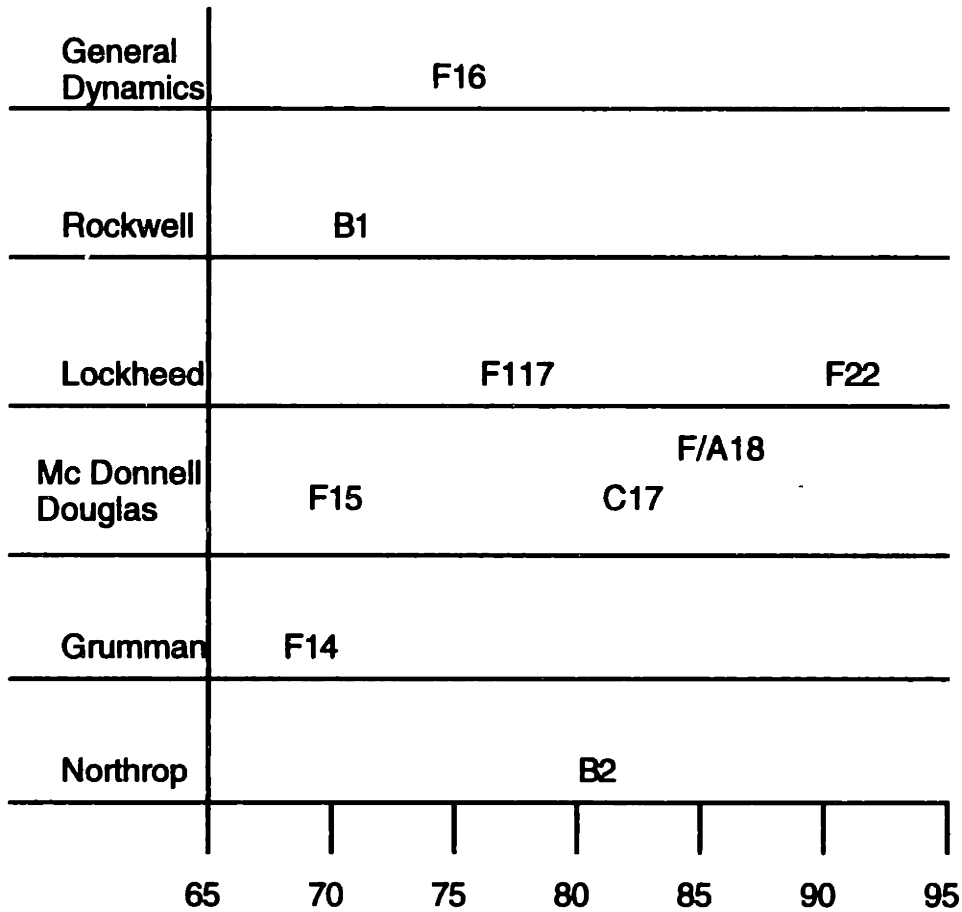


Figure 34

The fact that there is a certain level of subcontracting that goes on between these key players in the military aerospace industry helps this problem to a certain degree. For instance the Northrop Grumman Corporation has subcontract work from McDonnell Douglas on the C17, as well as the F/A-18. This allows a retention of certain skills, but only in certain areas, like structures and maybe some subsystems like power, hydraulics and electrical power generation.

Another approach to retaining critical skills is to selectively put them on IR&D projects until there is another major contract. This approach gets back to the issue of if you are to be a player in this game you have to very selectively pick the set of people that you expect to keep for the long-haul, an constantly develop them and keep them actively employed. Unfortunately, the rest of the staff will be forced to live with the normal industry swings in employment (see Figure 35).

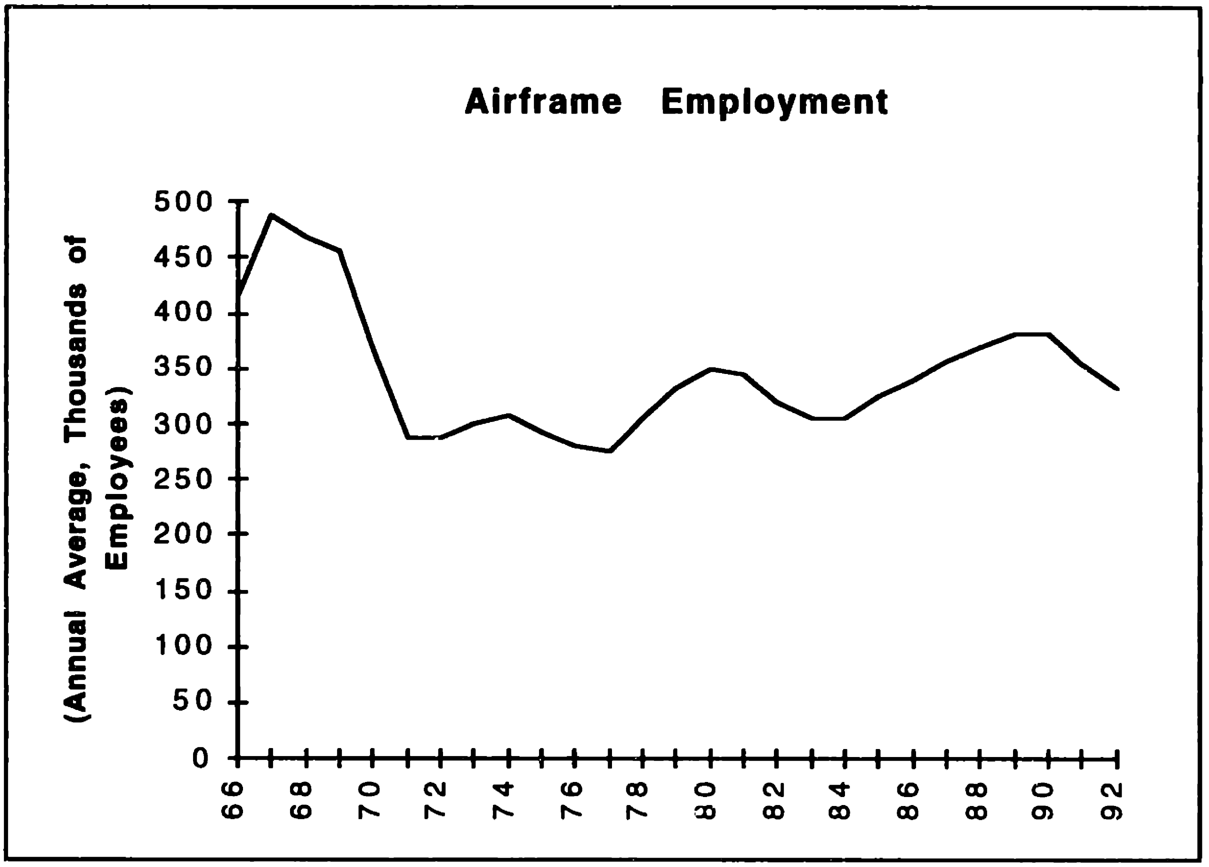


Figure 35

Summary

As has been discussed, there are clearly advantages to both teams and functions. In addition there are disadvantages to both as well. Teams can leverage the organization by putting decision rights with the people that are closest to the knowledge to make those decisions. However, if their interdependence with other elements of the organization is high, they will not be able to exercise total Empowerment and act on this knowledge without coordination with these other elements.

Functions, on the other hand, have been argued to be absolutely necessary to the sustainability of any organization, and even more so if the organization is involved in the development of high technology items. These functions provide security, and career growth paths for the critical skills required for the production of advanced technology products. However, these same forces of stability are counter productive to teamwork and cooperation. These strong functional bonds that develop tend to put focus on the function instead of the product.

The advantages of teams and functions has been discussed and shown to require a balance between the two. A factor that influences this balance is technical risk. Studies performed by the Lean Aircraft Initiative-Organization and Human Resources Team have shown that high versus low risk can influence the balance of teams and functions.

In the sample data collected by LAI the definition of high versus low risk was based on the answers to these three questions; 1) a product that was new to the world or the company, 2) incorporated any new technologies, and 3) incorporated any new process technologies. An affirmative response to two out of the three questions qualified a project as high risk.

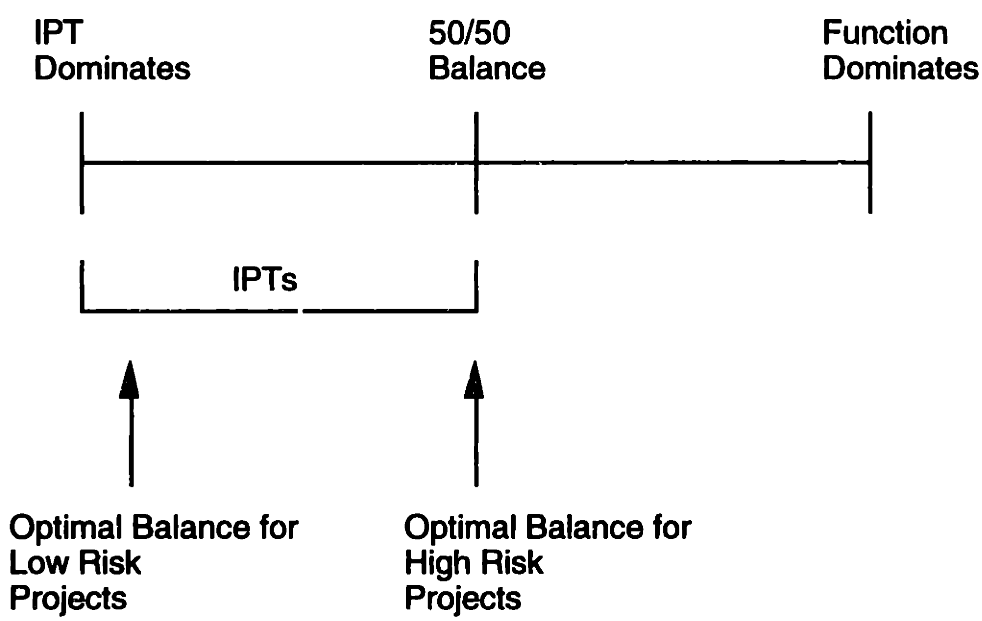
The LAI studies on team and functional balance point out that if technical problems exist in these high risk projects, very little simultaneous product and process design (i.e. concurrent engineering) may take place until the technical problems are solved. Once the technical problems have been overcome, there is a need for balance between the product based and functional based organizations.

As can be seen in Figure 36, the optimal point of influence between functions and teams in high risk projects is at the 50/50 point.

However, if the project is on the low risk end of the continuum, it may be better to have a bias towards team dominance.

The challenge for the military aircraft industry is to figure out what this balance should be for any given firm and project, as well as, how to structure it.

IPT versus Functional Influence



Source: Klein & Susman, MIT LAI Working Paper 95-3, April 7, 1995.

Figure 36

CONCLUSIONS

For all of the benefits associated with IPD/IPT there is a cost, and it can be a large one. Most large aerospace firms have a legacy of strong functional organizations. To overcome the inertia associated with this history will take investment in time, energy, and commitment. Implementing teams is a very complex task, it requires the integration of technology and sociology. Real people are involved who worry about pay increases, professional status, and career paths. Because of these worries employees will not commit to the team structure and process unless they see all elements of commitment by the firm. If the firm does not commit, the employees will see teams as just another passing fad that they can wait out, and in some cases accelerate its demise.

Implementing teams is hard. It is not something that you can say, let's do it, and it will happen. To be successful, the approach a firm or program takes, must be consistent with their strategy, supported by processes, and integrated with their human resource policies[64].

These statements are not intended to be discouraging. The data herein shows great promise for the concept of IPD/IPT. What is required to unleash these benefits is to further understand what limitations exist relative to incorporating IPT on large military aircraft programs and devise ways to work around them.

We cannot assume that a concept for product development in the commercial world can be directly transplanted into the military aerospace industry. As this thesis has pointed out, there are structural differences between the two industries that act as barriers towards this approach.

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64 Hax (1991) and Galbrith (1986).

The aerospace community should be making every attempt to capitalize on the positive aspects of IPTs which may work for large military aerospace programs. This thesis I believe, has only scratched the surface with regards to uncovering the barriers. Further study will be requited to dig deeper and unearth, potentially, other areas of uniqueness in the military aerospace industry that will have to be worked as well.

Several areas of further investigation were identified during this research, and should be considered as a starting point for further study:

Area 1. There is empirical data that suggests that a combination of common databases with 3D capability, multi-functional teams, and concurrent engineering have contributed to reductions in the number of rework cycles. However, it is not clear that we understand if there is a driver among these three.

Area 2. Since the customer is becoming an integral part of these teams a certain level of mutual trust develops. This trust only comes with time and experiences, and is an important factor in the teams effectiveness. However, the customer turnover is much higher than that for industry. Is this rate of turn over, and the impact to the team significant enough to warrant the government/industry potentially taking some action to keep individuals in place for longer periods of time?

Area 3. The data presented on change reduction indicates that the B-2 did better than the average of the Pugh-Roberts aerospace data set, and that the F/A-18 E/F did better than the B-2 and lastly that the 777 did better than all. There appears to be a trend with these three programs, that is, they are doing progressively better. Since their improvement is staggered consistent with their start dates, they may have learned from each other or they may have progressive generations of 3D software, or other tools. A more thorough study of these three and the Pugh-Roberts data may give us further understanding into this positive trend.

Finally, efforts like the LAI study can be a great facilitation device to getting industry and the government to come together and study IPT practices as well as other policy issues. Working these efforts through academic institutions brings to bear on the problem the rigors of structured research as well as an impartial third party to act as a balancing force.

Bibliography

Arnavas, D. P. and Ruberry, W. J., Government Contract Guidebook, Washington DC., Federal Publications. 1987.

Drucker, P. F., Management Tasks Responsibilities and Practices, New York, Haprper & Row. 1974.

Fisher, K., Leading Self-Directed Work Teams, A Guide to Developing New Team Leadership Skills, New York, NY. McGraw-Hill. 1993.

Galbraith, J. R.,Competing with Flexible Lateral Organizations, Second Edition, Reading MA., Addison Wesley, 1994.

Galbraith, J. R., Lawler, E. E., III, and Associates, Organizing for the Future - The New Logic for Managing Complex Organizations, Jossey-Bass, San Francisco, 1993.

Galbraith, J. and Kanzanjian, R. K., Strategy Implementation: Structure, Systems and Process. St. Paul, MN. West Publishing, 1986.

Hax, A. C. and Majluf, N. S. , The Strategy Concept and Process: A Pragmatic Approach. Englewood Cliffs, New Jersey, Prentice Hall, 1991.

Katzenbach, J. R. and Smith, D. K., The Wisdom of Teams, New York, N Y, Harper Business. 1994.

Klein, J. and Susman, J., Product Development Team Effectiveness, MIT Working Paper 95-3, April 7, 1995.

Klein, J. A. and Maurer, P. M., Integrators, not Generalists Needed: A Case Study of Integrated Product Development Team. in Interdisciplinary Studies of Work Team: Knowledge Team (Volume 2), Beyerlein, M. and Johnson, D. (eds.), Greenwich, CT, JAI Press, 1995.

Klein, J. A., Teams, The American Edge (eds. Klein, J. and J. Miller), Mc Graw-Hill, 1994.

Klein, J. A., Maintaining Expertise in Multi-Skilled Team, in Advances in Interdisciplinary Studies of Work Teams, Volume 1, Pages 145-165. JAI Press. 1994.

Klein, J. A., "A Reexamination of Autonomy in Light of New Manufacturing Practices". Human Relations, Vol. 44, No. 1, 1991.

Kochan, T. A. and Osterman, P., The Mutual Gains Enterprise: forging a winning partnership among labor, management, and government. Boston MA. Harvard Business School Press. 1994.

Milgrom, P. and Roberts, J., Economics, Organization & Management, Englewood Cliffs, New Jersey, Prentice Hall, 1972.

Swezey, R. W., And Salas, E. (eds.), Teams Their Training and Performance, Norwood, New Jersey, 1992.

Womack, J. P., Jones, D. T. and Roos, D., The Machine That Changed The World, New York, NY, HarperCollins, 1990.

Appendix I Interview Results Summary

Control continued

Question	B2	C17	F22	F/A-18
When schedule conflicts arise how are they resolved?	Teams work out or elevate.			Teams resolve it or it gets elevated.
Are your Program Review activites done by team, or by function? If by team where and how do the functions review where they are and how they are performing?	Reviews are done by team. Functions report at Quarterly Business Plan Review.			
Are your process groups like. IE, or Facilities, accountable to the teams or the fucntions?	Functions, however, suppot teams			IEs part of teh IPTs. Facilities and other broad groups belong to the functions.
Did you conciously change your signature authority documentation to be consistent with your team empowerment?	No.			No. The HR system does not recognize teh team leaders. System requires functional manager sign off.

Control continued

Question	B2	C17	F22	F/A-18
How do you account for the costs associated with systems that may cut across many IPTs like; Final assy, Flight Test, software, etc.?	These costs are collected by WBS by functions. No cut by IPT.	Collect cost by cost cahnge number and assign to each IPT.		
What decision making approaches do our IPTs use? Do they use different approaches for diffrent types of decisons (i.e. budget, program, personnel)?	Primarily consensus, however, team leader has final vote.			
Who decides what issues are to be worked by what IPT?	Teams try and work this out amoungst themselves.	Teams work it out amoungst themselves.		Because of structure it is rare to have this conflict.
How are conflicts between the functions (i.e. Chief Engineer) and the IPTs worked out?	Elevated to Program Manager who is hardlined above both.			
What process did you go through to ensure your IPT concept was integrated with the rest of your business systems and operating procedures?	None. IPTs must conform to existing procedures until they formally change them.			None. IPTs can not violate division procedures, but they can start a process to change them.
Who and how are your indirect budgets established?	Established by functional VPs and Approved by GM.			Indirect budgets are controlled by funcitons.

Interview Results

Control

Questions	B2	C17	F22	F/A-18
How is the Program ETC estimated and who controls the functional or IPT budgets?	ETC is generated by the functions & functions control it.	Functional Cost account managers (typically not IPT Leaders).		Functions, with input from IPT, generate the ETC.
Do your IPTs have an integrated schedule identifing the tasks they are responsible for and how they relate to other program activities? Who maintains the schedule?	In process of building schedules like this. Schedules maintained by central scheduling group.			
How do you IPTs integrate themselves, with other IPTs and the rest of the org?	Weekly meetings.	IPTs exchange liaison reps with other teams. Also, working meetings.		
What level of indenture does your cost account structure breakdown to, and how many cost account managers do you have? Are your cost account managers, IPT leaders?	In rare cases the IPT leader might be the CAM.	Cost accounts estab. at Level 4 of WBS with reporting at level 3. There are 200 CAM for each prod. lot. IPT leaders typically are not CAMs.		

Interview Results

Contractual	B2	C17	F22	F/A-18
Was your work breakdown structure tailored to support your IPT's?	No.	No. but cost account struct was realigned to satisfy IPT requiremets	No.	No. But WBS dictionary accounted for their needs
Was your contract tailored in any special way in support of your IPT implementation?	No.	No	IPT is a contract requirement.	IPT is a contract requirement.
What role do the IPT's play in contract change negotiations?	They support. Negotations done by contracts	Proprosal prep and pricing done by functions, but IPT participate in negotiations		Contract negotations done on WBS and functional basis.
Process				
How does your IPT work with your Change Process?	IPT leaders hav to sign off on change requests & demonstrate they have budget for change.	IPT's start changes, customer involved in about 90%. Change cut in negotiated with Assy Ops.		
Who is responsibel for configuration management, requirement verification, contract compliance, etc.?	The task belongs to Program Integration Team	Weapon Sys CM owns change process.		

Organization continued				
Question	**B2**	**C17**	**F22**	**F/A-18**
In establishing your IPTs how did you determine what the IPTs should be and their respective boundaries. How did you ensure that the whole program was being covered?	Negotiations with SPO, boundaries never clearly defined.			Teams do "what" and "when", functions do "who" and "how". some teams confused because they feel they should be in on the "how".
Are there separate functional departments within your company to do the care and feeding of personnel and processes, and if so how are they funded?	Yes.			Yes, they work on IR&D or Program, in which case the funding comes from Program.
What portion of your total program budget is controlled by your IPT's (including your indirect)?	A very small portion.			
How supportive of the concept of IPT has your functional departments been?	Moderately, not sure of respective roles.		More cooperative than not.	50/50, some very supportive, other not very supportive.
Do you consider your customer to be the Procurement element of the Govt. or the end user?	SPO is customer, however, ACC is involved in process			Mc Donnel Douglas

Organization continued

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Interview Results

Organizational

Question	B2	C17	F22	F/A-18
What is the objective of your IPT approach to management and how do you measure it	Cost and schedule reduction	Reduce Cost	Reduce rework(to reduce cost/schedule)	Trying to achieve CE to get better integration, improved quality, and quicker development times.
What citeria did you use to determine what functions would be represented on any given IPT?	Team leaders decided based on their needs	Team Leader/team decided who they needed	Team leaders decided what resources they needed to get job done. Most teams have an operations deputy.	Function of SOW plus ensured a Systems Engineer on every team.
What level of your org do your IPTs permeate and how did you determine that level	It varied, but most are at level 3	Varies by team. Top down was the method.		Level 5 - same as WBS
How do you define empowerment and how was that definition communicated to the teams	Defined in training curriculum	No written document, verbal from PM who lives by it.	Verbal	Program directives, IPD guide, training
Which memebers of your IPT's did you co-locate physically, and which did you not co-locate? For those you did not co-locate, how do they communicate	No co-location	Only A/V Integration IPT is collocated. More planned.	Did try and collocate within facility constrainints.	Many are collocated, and desks are available for those who are part time.

Interview Results

Training/Personnel	B2	C17	F22	F/A-18
What amount of training by type was expended on your teams and how was that amount determined?	3 days	No formal training completed yet. Putting together now.	1 day.	2 days of trianing by outside consultant. In house coaching. No way to determine how much is reqd.
Did your company create any special job clasifications for the IPT team members? What is the career path for an IPT member and do they understand this path?	No - career path through functional hierarchy.	No plans to do this.	No new classifications created.	Did create a job classification for team leader, only 2 grades so not much career growth. Team members faced with classic matrix management problem of career.
How has your reward system (individual vs team) changed since you started using teams as your primary method of performing work?	No changes. System allows for team recognition, but yearly merit prodominetly based on individual performance	Process is team oriented.	same as B2	No changes. Reward system supporttive of teams. Yearly merit based on individual performance.
Who does performance evaluations and what are they based on (team vs individual) ?	Done by functions and based on individual performance.	In 1995 IPT leader will buyoff on perf/merit.	IPT Leader	Joint sign off by functional and IPT leader on perf. eaval. In 1995 IPT leader will do it alone.
Was the training you recieved adequate and did it answer your questions on how your responsibilites and empowerment are different under the concept of IPT versus Functional?	NO.			NO.