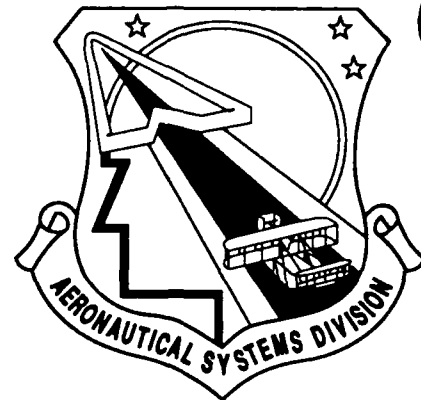


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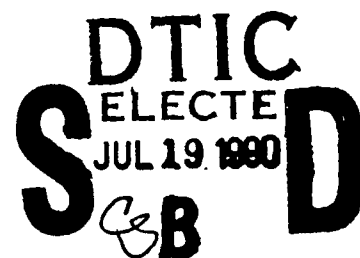
Joseph L. Weingarten

Deputy Chief of Staff

Integrated Engineering & Technical Management

Wright-Patterson AFB, OH 45433-6503

June 1990



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AIR FORCE SYSTEMS COMMAND

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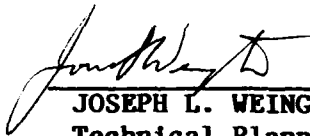
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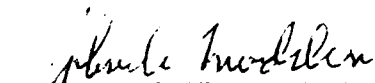
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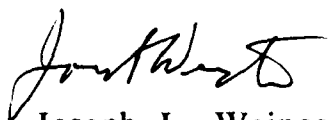
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FORWARD

The Deputy Chief of Staff for Integrated Engineering and Technical Management (DCS), Aeronautical Systems Division (ASD) has been operating under the current Matrix management concept since the mid 1960's. One of the major problems has not been the operation of this management technique but rather the mis-conception of how the system works both from within and out-side the DCS. The application of matrix management to other organizations with different missions and operating styles has also lead to the increase of confusion of how the system works. The object of this paper is to provide an overview of matrix management, from its inceptions to the current method of operation. This paper was originally published in May 1989 and updated in June 1990 to reflect the merger of Engineering, Configuration, Data Management and Manufacturing into a combined new organization.



Joseph L. Weingarten
June 1990



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Summary

The matrix management concept as practiced at ASD has proven itself to be an extremely effective and robust management tool. The Aerospace industry is credited with having founded and developed this method of management, since ASD was the first organization to use the technique, it can be called the founder. The matrix management techniques are an outgrowth of directed project management of the 1950's. To revert back to a project type of operation, however, that has been proven ineffective in the aeronautical/aerospace development environment would not be beneficial to Air Force Weapon System Development. The matrix was a revolution in American business structure and still today hard for many people to understand a one person two boss concept.

We must also view that matrix management and systems engineering are inexorably linked to each other.

In summary the statement made in the AFSC 1990's study best fits the combination of systems engineering, systems management and matrix: "Overall, the Wright-Patterson complex of ASD and AFWAL (WRDC) today is the result of a long term investment of a substantial portion of AFSC's resources. It has been an investment carefully tailored to the particular challenges of aeronautical systems which has paid off by producing a long string of outstanding combat aircraft."

Today that same complex continues to produce the best, most advanced aircraft in the world.

Introduction

On October 13, 1917 the War Department established the Airplane Engineering Division in Dayton Ohio. Five days later McCook Field was established as the nome for this new division. In those early years all aspects of engineering design were conducted under the umbrella of this one organization. The Division had under its control laboratory work as well as engineering production of the finished products and even its own school. (Air Force Institute of Technology started within the engineering function) With time the functions expanded as did the complexity of the work. In reality the complexity of the finished product can be cited for driving the structure of the organization and the work force. By World War II several departments had been formed to work in different technical areas. The basic concept of aircraft development was to built an airframe and then add guns, radios, etc to the frame. As systems became more complex the concept of just hanging on equipment began to get designers in trouble. For example, the B-47 required extensive integration of systems into this new complex aircraft, yet it was designed based on components. It was the first time that Air Force designers had to be concerned with the marriage of different systems that had to work together. It was these difficulties that resulted in the formulation of modern procurement method of the System Program Office and the utilization of the matrix management concept of personnel utilization. The B-52 was the first effort to view a more unified approach to development, which established the procurement concepts that are still in use today. It also started the firm road to matrix management with formal adoption of the concept in a organizational structure in 1962. The result was the integration of the engineering workforce in line with the integration of entire design process in building a weapon system.

One of the unique features of ASD is its organic engineering workforce and its ability to provide guidance to the entire American Aerospace Industry. Over the past few years the structure of the world markets has under gone a massive change. Our nation's leadership in the world markets has been lost in many consumer areas. In the area of aviation we still hold that lead but erosion has been steady as the Japanese continue to find new markets for their expanding economy. Both the growing concern on the part of American industry and that of the national defense has resulted in many studies on what to do better. Many of these activities viewed

the Japanese structure for systems development of new products and how to manage those developments. This is a misnomer in that the Japanese just took concepts that were developed by Americans and implemented them with a long range outlook while American industry was busy viewing short-term profits. Hence, the Japanese have been able to build their reputation for building a better product. It's not just the workers who build a better product. It's the engineering design coupled with a management style that views long-term growth, and respect for all employees. We must also remember the Japanese approach is to exploit capabilities of a technology which is a bottoms up approach. They do not practice systems engineering, and this may be part of the reason for their desire to enter into joint US/Japan ventures with our aerospace industries. From an overall perspective the bottoms up approach is the primary reason for the respect for the worker and the constant improvement of the building blocks in the areas they have chosen to develop. This is the basic Japanese style. They also permit joint ventures by many firms including the government as a partner.

In 1989, the Commander of ASD, as part of his efforts to instill a "total quality" culture within the organization established an ASD/Industry team to view how ASD was building products for its customer the Air Force. This team set out to view the development process relative to its changing environment both in technology and business structure. The team's recommendation was to restructure the way we conducted business at ASD. This paper provides an overview of matrix management and how this new concept fits into the matrix workforce.

The implementation of the teaming concept is not a radical departure from the way we were doing business. What was proposed in 1990 was a continuation of the evolutionary process of Systems Engineering. Just as in 1917, all parts of the design functions were under the direct control of the engineering workforce. It now became more and more apparent that we needed to combine more and more elements of the total design process into a single process and focus more effort in the early stages of design. Engineering is conducted under the direction of a Director of Engineering or Chief Engineer in the Program Office, but at the same time other technical elements were not. For example, manufacturing was a separate function; therefore, the designer could design a product that could only be built with great difficulty. Part of the Japanese technique was to view the entire process, we view the process in separate

parts. What caused this separation and what is needed to bring the system back into line? The answer is simple - the final product. Over the years, as aircraft became a system of parts, each design function became its own empire. We have now reached the point of where the process of putting together the end product may be more complex than the product itself. Another factor is that the care and feeding of that product has also become extremely complex. You can no longer pump in a few gallons of gas, and go flying. The "logistics" of an aircraft system also may be, if not, more complex than the aircraft itself.

Matrix management in its truest form is the construction of teams.

BACKGROUND

Before examining the current application of matrix management in development of Aeronautical Weapons Systems, it is important to understand why this concept of management came into being in the first place. While the current matrix was formed in 1964, the real reason for its need can be traced back to the early 1950's. Technological advances in the late 40's and early 50's exerted pressures on the Air Force for earlier and faster decisions on producing an aircraft. In January 1951 the B-47 office proposed the development of an independent unit to facilitate coordination and development of the project. The primary factor was that the B-47 office found it extremely difficult to develop an aircraft that did not follow the then traditional practices of designing components to be fit into an airframe. "The B-47 encountered difficulty in having a total aircraft system wherein all component parts functioned in unison for an acceptable length of time." The B-47 efforts were cited in a Rand Study "The Evolution of Air Force System Acquisition Management," completed in 1972, as one of the primary factors that changed the course of Air Force policies and formulated both the modern concepts of procurement.

A few months later the B-52 projects were combined into a "joint project office" and by January 1952 all efforts at Wright-Field had been converted into joint project offices. This resulted in a unified approach to development and proved to be more effective than the previous method of divided responsibilities. These new systems were just the start of a new era in aircraft design that called for more and more integration of complex systems. Major General D. L. Putt, Vice Commander, Air Research and Development Command, (predecessor to AFSC) in a letter to the Wright Air Development Center (predecessor to ASD) commander on 8 December 1952, established a doctrine that is still in effect today for establishing the systems engineering concept. He wrote "The complete weapon system-the aircraft or guided missile, its components, supporting equipment, and USAF preparation for its implementation as a weapon- should be planned, scheduled, and controlled, from design through test, as an operating entity. The objective is to insure,

insofar as possible within USAF management capabilities, that a balanced and complete combat-ready weapon system will be produced and ready for use when needed by the Air Force." In the 1953 - 54 time frame administrative procedures were established and a boarder project office called a Weapon System Project Office was started. This can be called the genesis of the current System Program Office (SPO).

During this period the laboratories at Wright-Field were providing support to the project offices, and at the same time they were doing advanced research. This resulted in a workload conflict of the engineer assigned to a particular area of expertise. The end result was that a project engineer had both applied research and systems development responsibilities. In some cases the research was slighted and in others the development effort was delayed or given a hasty analysis. In most cases the engineer supporting the project office from the labs had to operate on a crash basis in one or the other area. Another objection voiced during that time frame was the isolation of the engineers in the project office, from the engineering specialists in the laboratories. They also cited the lack of understanding of the interrelationships of his specialty with the increasingly complex aircraft systems.

In May 1959, Lieutenant General Bernard A. Schriever, Commander of the Air Research and Development Command, appointed a study group to examine purpose and structure of his command. They basically proposed in September 1959 that the principle of advanced technology ought to be directed toward integrated weapon systems and long range planning ought to be emphasized. The central issue that emerged from the planning meetings was, "should engineers be placed in a separate directorate or should they be controlled by the system managers?" The result was a proposal to separate the development work force into three functions - Systems Management, Advanced Systems Technology and Engineering. Major General Ferguson requested a second look with the objective of placing the engineers under the control of the systems managers to give the managers better, more direct control over all of the resources. It was concluded that management and engineering needed to be separate so that the engineers could support not only system development but also equipment, ground and operational programs. It was recommended that the most effective support would be to place the systems engineering project offices adjacent to the weapon system project offices. By having an

independent engineering directorate, they further stated that technical issues could be brought directly to the attention of the division commander. Otherwise, if the engineers were placed within the system management directorate, the management director would not only dominate advanced system technology but also restrict the division commander's authority. This new concept was approved by General Schriever on 30 November 1959. Early in 1960 the new engineering directorate started to support the weapon system project offices with engineering support as had been conceived. The engineering directorate also was beginning to function as a talent pool, providing experts to deal with specific problems as they appeared.

The engineers were officially assigned to the Directorate of Systems Engineering, however many were located in the SPO's. They were responsible for providing the program director with systems engineering and technical development support. One advantage was a capacity for quick reaction and improved support to the SPO's. Problems were encountered in that lines of authority tended to be confusing and the theory of movement of personnel did not always work in actual practice. The concept was that engineers would be assigned to a program office and as a system phased out they would be transferred to other systems or returned to a general engineering position. This was instituted to resolve an earlier problem of hiring and firing the engineering staff as each program finished and a new program started. However, a major problem that continued was that the government personnel system required any movement be accomplished on paper with position descriptions and job reviews to grade positions, etc. This process took as long as two years and in some cases resulted in the person selected for the job, due to their talents, could not meet the personnel systems requirements and were placed in positions of less responsibility. However, one extremely important factor continued - the theory and concept. It was realized that the concept was what was needed for effective systems management and development of weapons systems. Many of the problems encountered in the first few years of operation lead to a Capability Improvement Program, in the spring of 1964, to refine this new approach to engineering support.

The Capability Improvement Program(CIP) was aimed at eliminating certain organizational and managerial roadblocks to achieve the primary function of SPO engineering support. One of the reasons was a changing viewpoint that something had to be done to

achieve the most effective application of engineering resources. The concept of how to best use engineers appeared to be working yet the mechanics were not. Selection of individuals, agreement of supervisors, grade levels and reassignments were major stumbling blocks. The CIP efforts were in a large part directed at solving the paper-work barriers. So in essence, the formal movement of people was restructured into an informal process called matrix management. The key element was that all engineers were assigned to an overall engineering group, later to be called the Deputy for Engineering, and all organizational blocks within the SPO's were eliminated. The engineers would then be physically assigned to work in a SPO but never organizationally assigned. The engineers were forever assigned to their "home" office no matter where they worked. This operational arrangement allowed total flexibility to the engineering staff to move technical experts when and where they were needed either as a long term assignment or even for a few hours. At the time the CIP indicated that a contractor-customer relationship analogous to Aerospace and Space Division had been achieved, but without the contractual drawbacks.

In 1967 The Deputy for Engineering was created from the System Engineering Group. There was only one major change to the matrix concept from this action. While the basic concept of engineers had worked it was found that a "chief" reporting to the program director was needed for two reasons, the first to insure that an economy of manpower existed and only a chief could view the entire support to the SPO. The second was that the Program Director needed a single authority responsible for the engineering function and to further insure that the engineering positions were "harmonized." Thus the role of systems engineering was further emphasized within the SPO. The lack of organizational positions within the SPO also continued and with a few exceptions has continued to this date.

The engineering matrix remained basically unchanged from 1967 to April 1990. The "chief" position within each SPO remained as the only position truly identified "organizationally" the only other positions that fall within these categories were the secretarial positions. The primary factor has been the assignment of expert engineers rather than "engineers" to meet whatever the needs of the SPO has been. This was accomplished with the understanding of the real world of engineering. In real terms the engineers at Wright-Field, as well as most organizations, became specialized in a short

time, to where they work only in one narrow field. There is a concept outside of the engineering world that an engineer is an engineer. In reality engineers are even more specialized than doctors. The engineering specialization basically parallels those of the branch titles in an organization chart. For example, the landing gear branch mechanical engineers would not be able to provide the same level of expertise as the mechanical engineers in the aerial delivery branch. They do not even speak the same technical language. This resulted in a "home grown" special engineer called the integration engineer and the further refinement of the systems engineering concept. The integration engineer pulled together the technical experts into the overall design process and made sure that they interfaced with one another.

The manpower efficiencies that were found in the first years of the engineering matrix resulted in the adoption of the concept in 1976 by both the procurement, production, and comptroller functions. Lieutenant General James T. Stewart organizationally transferred all the specialists within the SPO's to these functions. The primary reason "aimed at more easily rotating these experienced specialists among the program offices as priorities, shifted during the development and production cycles."

In April 1990, Lieutenant General John M. Loh, reorganized the DCS for Engineering into a new organization incorporating all engineering, configuration and data management and manufacturing. The mission of the new organization was to develop and implement the concept of integrated product development. This presented a new challenge to the organization. The personnel in configuration and data management had been assigned to the program offices as part of their straight line staff and the new organization would over a period of time establish a matrix concept to allow the better utilization of these personnel. The manufacturing personnel had already been matrixed under the direction of a director of manufacturing within each system program office. The key element of this reorganization was to develop a new team concept within the program office with all the elements to achieve a comprehensive design unit aimed at total product development. Thus the system engineering concept was being further refined to include more elements of the design process. However, once again the incorporation of these new personnel proved to be harder than just a transfer on paper. Just as in the 1960's it took time to incorporate all the engineers into the matrix so will it take time and energy to draw

together these new elements. One of the most important factors will be the need within the SPO to obtain one voice for the engineering and technical community. Today there is a Director of Engineering, Director of Manufacturing and Chief of Configuration Control, in the future there needs to be one voice. This will be one of the main organizational challenges in the near term.

1964-1988

The two primary factors behind the matrix was efficient utilization of technical manpower and systems engineering. In a way the matrix is a unique technique that meets both of these requirements. There has always been pressure within the system to both reduce manpower and increase manpower at the same time.

1. MANNING--

Both the civil service and military system of assignment of personnel can be a trying task. From the perspective of trying to manage an engineering organization this can be a nightmare. The development of an aircraft system is not a steady state task, but rather a very dynamic one of ups and downs. The manning of such a system is also dynamic and is shown in actual engineering manpower usage in the development of the F-15 and B-1A aircraft shown in Figures 1 and 2 in appendix A. How would a manager provide for proper numbers and types of personnel? In a traditional organization they would either have far too few or far too many people while at the same time other programs would be in a similar situations. The type of engineer is also a major consideration. You do not need the same kind in the same technology at the beginning of a program as you might in the middle or in the end. Further in the traditional organization the manager could not respond fast to change. This is further complicated by the technical specialties required by the SPO and the possible lack of adequate personnel in that speciality to be provided to each SPO. For example, each aircraft SPO would want the best landing gear engineer available. It is possible that the total amount of landing gear engineers available doesn't even come up to the total number of aircraft programs. Yet by allowing the movement of the engineers they can support multiple programs to meet the peaks and be used elsewhere during the valleys and during different phases of the effort.

A 1968 review by Air Force System Command "ASD Requirements & Capabilities Panel FCRC Study" was part of an in-

depth study to determine the need for and role of Aerospace and Mitre Corporations in the Air Force environment. ASD was used as a base line in this study to determine if an "in-house" capability could be achieved to replace the two (Aerospace and Mitre) Federal Contract Research Centers (FCRC). It is important to first understand that these contractors perform a similar role as engineering does at ASD. They provide the technical support to the SPO at Space Division (predecessor to Space Systems Division (SSD)) and Electronic Systems Division (ESD). The panel found that "relative to the flexibility of the in-house vs. the FCRC capability for rapid task loading as noted previously, ASN's (predecessor to ASD/EN) operational concept provides extreme flexibility in terms of providing support to system programs. Usually operational response time, in terms of the ability to reallocate assigned personnel to adapt to changing workloads or program priorities, can be reduced to virtually zero." The panel did find that Air Force personnel and manpower policies hampered engineers ability to provide support. "Thus we have the paradoxical situation that in-house manpower critically required in order to develop a program to the point where formal program approval can be justified may not legally be applied until after the program is approved. In general, this particular constraint imposes greater limitations on the responsiveness of ASN (ASD/EN) than does the difficulty of hiring qualified new personnel." The engineering staff has started up one program after another within these limitations. For example, when President Reagan ordered the B-1B program start-up, the Deputy was able to put together an engineering team of over 100 people in less than two weeks. As a result some other programs lost people, but not all the people so that the organizations could continue until a build up of new people filled the gap. This is an extremely important asset of the matrix organization to meet priority needs of the system and ability to react.

The engineers of the DCS have developed a unique culture among its personnel that has resulted in the effectiveness of the matrix. The manpower within EN falls into three primary categories - administrative, home office and collocated.

2. ADMINISTRATIVE-

The administrative overhead function is required to manage the entire operation. During the FCRC panel studies it was found that the DCS had already reduced the ratio of engineer to overhead to a level far below the industry or even government standards. Prior to

the 1967 the ratio was at 5.3 to 1, in March 1968 the ratio stood at 8 to 1 and in 1989 it was approximately 7 to 1. The report stated industrial technical organizations should have a ratio of 6 to 1. In viewing the 1968 level they felt that "this indicates that we may have reached the practical limit of this standard. Further extension of this ratio may well result in a decline in productivity." Over the years the DCS has managed with a 7 to 1 ratio. This level has worked out in most cases because of a esprit de corp within the DCS. For example, each branch has only one secretary yet when one takes time off the work does not grind to a stop but rather this has resulted in the secretaries helping out each other. It is only because of this that the DCS has been able to manage with one secretary per branch. This low overhead has enabled the DCS to channel resources into the engineering workforce. As a result of the reorganization no change is envisioned in this area. Of major significance is the lack of administration required in the SPO engineering offices. Most of the administrative tasks are completed in the home office freeing up operating supervisors to assign and oversee engineering task rather than being burdened with paperwork. Further by having the home office supervisor view all the personnel in their area they can make judgements across the technical area rather than the broad area of one SPO. For example, in our landing gear branch the home office supervisor would view all landing gear personnel at ASD and they could determine training requirements for all of these personnel no matter where they work. If this were done in the SPO the chief engineer would only have one landing gear person and would compare them to other types of engineers and not to their peers.

3. HOME OFFICE-

A major strength of the matrix is the home office. However, it is not viewed as such, in some cases, by the Program Manager. They see the home office as a manpower pool whereas the DCS see it as a critical talent reservoir. In viewing the F-15 and B-1A Engineering Manpower charts, in Appendix A, the actual manpower expended on this program falls into two categories - collocated and home office support. The home office provides 25-35% of the work years of effort to the SPO. The reason is the technical specialist. Each and every SPO wants the world's expert to come and work in their office, under a non-matrix operation only one office would benefit from this person's expertise. Under the home office/matrix as run within the DCS, this person is available to assist each SPO as required and provide technical direction/assistance to engineers who work in that

technical area. This adds even more benefits than can be found on the surface, one of the most important is interchange of lessons learned from one program to another within the peer group of the individual engineers. Without the matrix this informal communication channel between SPO's would not exist. Much of the technical problems and solutions would never be transmitted from one office to another. This overall process has avoided the problems of isolation that plagued SPO's prior to the implementation of the matrix.

The home office personnel have an active part in SPO support, training of new personnel, developing specialty skills and providing planning/preparation for future systems. The two manning charts must once again be viewed. The number of manyears of effort in the collocated area move in a slower pace of change than the non-collocated area. This is the home office personnel coming into the SPO to provide surge assistance as required. They move from SPO to SPO as needed. Yet these people have viable jobs when not needed to help the SPO. This includes the development of the technical baseline, training of new engineers, and support of special studies. In essence, this is where the concept of a reservoir comes into being. A reservoir is a body of water that must be continuously filled to provide an output. The home office is continuously working in these areas, each of which will be discussed below. It is only because the home office personnel can move from one office to another that the matrix can efficiently provide work years of effort that otherwise could not be provided. One of the prime examples is source selections. These efforts require a large influx of personnel to evaluate the contractor proposals. If we were to provide full manning to each SPO, without the matrix, the manning requirements at ASD could increase by approximately 70%. In viewing the program manning charts it is clear one of the prime drivers would be the source selections. The increase to 70% would provide the same level of engineering support with only a need of 25-35% from the home office. This is caused by the role of the specialist. Each SPO would need more people because of the narrow specialist in today's complex technical world. The sharing of the experienced specialist from the home office helps keep the manning levels down. This level of total support could not be even conceived in this era of personnel reductions. The ability to provide surge manning has also been a trademark of the DCS. Should a crisis hit a program, the home office has always been ready to provide the technical manpower needed for that effort. In the short term some other programs would feel

the hurt but in the long term all are helped. If all personnel were collocated, some programs would have to suffer far more than any short term effects we see in today's environment.

The Technical Baseline has many factors and over the years has had different names of its many components, specifications, standards, lessons learned, etc.. The most important factor has been the movement of technology from the Laboratories into the system engineering process. In the AFSC 1990's study in 1982 the Development and Production Panel in discussing the relationship of ASD and the Air Force Wright Aeronautical Laboratories (AFWAL) (now Wright Research Development Center (WRDC)) stated "Together, these organizations constitute probably the largest concentration of aeronautical technical and allied business skills in the free world." ASD includes an internal organic engineering capability unique among AFSC organizations. The ease of interaction with the collocated AFWAL resources further strengthens that capability." The realignment of AFWAL in November 1982 into ASD further strengthens the ties between these research and development engineering organizations. In March 1984 these two organizations teamed together to insure transition of applicable advanced technology into ASD product developments. An aggressive plan was developed where Technology Transitions Plans were created as a contract between the researcher and end user. The DCS has the vital role of performing a technical assessment of new advanced development programs in the various laboratories. An important factor in the success of this effort is the personal interaction of the engineers at the working level with the laboratory personnel. The SPO engineer is too busy solving the day to day problems of getting the "rubber on the ramp" whereas the home office engineer is busy building the baseline for the future and getting the newly developed technology ready for use in the currently being procured systems and viewing future systems.

Another task is building the documentation needed for future systems. This area is often overlooked or not considered too important. One of the unique features of ASD versus ESD and SSD is the broad based technology for multiple systems and the concept of a production line. Aircraft development is totally different from one-of-a-kind spacecraft or ground radar systems. The development of the specification for aircraft systems is a never ending task requiring constant updates. In essence, the specifications become the "lessons learned" depository. To insure currency of these documents the

home office maintains a new type of specification called the Mil-Prime which not only has the tasking objective of a specification but also maintains its history. These documents contain the traditional requirements of a specification but in a different way. The requirements are based on mission needs, with the actual values blank. The home office engineering team provides, within the document, guidance on how to fill in the blanks and reasons behind the requirements and the lessons learned. When applied to a new development the SPO and home office engineer work together in development of the procurement specification. It is this high degree of cooperation between the SPO and home office that results in up-to-date and better written documentation for new efforts. Currently over 50 of the Mil-Primes are in constant review and up-date covering all aspects of aeronautical and subsystem development. This process has been repeatedly hailed as the way to procure new systems and as an effective method for streamlining.

The home office also provides the technical expertise to conduct independent reviews. The ability to conduct these reviews is critical to the development of new systems. For example prior to the first flight of a system, a team conducts a readiness and safety of flight review. This review is the Air Force's process of flight certification for a new aircraft and similar to the Federal Aviation Administration's certification process for civilian aircraft. It must be conducted by those outside the development of the aircraft to insure total independence. While this is one of the most critical types of reviews numerous other types are conducted by the home office. These reviews bring to the SPO an outside look without having to go outside the division and by personnel who are knowledgeable in the various technical areas. This also provides the ASD Commander the ability to have a review conducted at any point in a program development. In a way this provides him with the capability to have a "check and balance" in the system. At times the DCS has been called upon to conduct these types of reviews for agencies outside of ASD. They also review the new requirements of the operational commands in the form of looking at Statements of Operational Needs, to work with the user on what is going to be needed for our future defense, and can be accomplished.

The establishment of a home office in configuration and data management, in 1990, resulted in providing a focus for this work element and its personnel that was not present before. When viewing the population within this activity they had a distinctive

disadvantage in both the areas of policy development and personnel development. The above results in having a home office interested in its people and their work efforts from a total corporate viewpoint and not just within the individual SPO.

Supervision across a technical area is extremely important function of the home office. If you did not have a home office each SPO would tell you it had the best guy in the world in their technical area. This is just a normal organizational fact, that each organization is the best. The home office supervisor however can view all their personnel on a common technical baseline and determine ranking of the people. They can appraise all personnel in a technical area against one another and not against those in other areas. They can better determine who needs training, how much and what kind. They know who to call upon when a problem occurs and how to move people based on priority of programs. They also have the flexibility to move people as problems occur such as personality conflicts.

4. FUTURE

An engineer graduating from college can be viewed in the same light as a doctor. They have the theory, but not the practical knowledge necessary to treat the patient. The first years in the life of a new ASD engineer are spent in on the job training. The training program takes approximately 3 years to bring an engineer to the journeyman level. Without the home office the SPO engineers would have to spend time training the new engineers instead of working. The training is not just for the new engineer, but rather the home office is responsible for total career management of all personnel. Maintaining technical excellence requires continuous training of all the personnel. We live in an era of technology advances that move in leapfrogging advances. We also realize that in the area of aeronautics and electronics the work conducted within ASD must be at the forefront of technology. In fact, it must be at the forefront of technology world-wide. Part of career management is the allocation of the proper skills to do the job. The home office can view all programs across ASD in each technical area and can best allocate the right individual to accomplish the task. This factor is overlooked many times in assuming skill levels and types of skills needed to meet various technical problems are the same. The assignment and allocation of manpower is a constant tug of war between the home office and the director of engineering in the SPO. This is another

check and balance in the system and is one of the factors that keeps the allocation of manning "lean and mean." The major problem in allocation of personnel is the level of expertise provided. While each office can be provided engineers the level of program risk will increase as the level of engineering support decreases. Over the past 10-15 years the number of engineers has remained constant while both programmatic efforts and numbers of people that the engineer must answer has vastly increased. This is an area of major concern within the engineering community.

A critical part of the movement of the engineers and technical personnel back and forth is the interchange of information and skills. Technical information exchanges within the peer groups, but another form exchange exists due to the operation of the matrix. The promotion of personnel to levels of higher responsibility, a new branch chief may have been a senior engineer within a program office, or a newly assigned chief functional engineer may have just completed a tour of duty as a branch chief. This change of roles and movement back and forth provides the engineers the understanding and sensitivity needed to make the system work.

5. COLLOCATION

The primary function of the DCS is too provide total technical resources for development of all Air Force Aeronautical Weapons Systems. To meet this task approximately 65% of the DCS engineers and 90% of its configuration and data managers are collocated to the SPO's. These people are the core of system development. Within any SPO approximately one-third of the manning are engineers. One of the greatest pulls on the engineering community is there is never enough time or money to do everything that is required. The Director of Engineering is forever seeking additional resources, the home office is providing as much as possible and viewing all programs to try to match people with needs. This is a constant healthy tug of war of matching the right person with a particular job. Also the level of expertise will change as a program matures. While a formal structure does not exist within the SPO, the informal one has worked very well for a number of years. Currently, a SPO has a Director of Engineering and each functional area has a chief (i.e., Chief of Support Equipment) corresponding to the broad technical areas. Where many small offices are located in a SPO (basket type) the engineers move from program to program providing assistance. Where a SPO has only one product the engineers work on that

product. The change to incorporate configuration and manufacturing will in the long run cause a heightened interchange between these disciplines and a forcing function to tie the engineers to the remainder of the technical community, further the configuration and manufacturers will move closer to the engineers to increase their ability to influence the design process. The next step would be to force the logistics community to move closer to the design phase. This has been happening over the years and with the logistics community having an office in each SPO, the next step would be to have a closer relationship with the EN community.

The pull on these engineers not only comes from the Director of Engineering but also from the management side of the SPO. The ASD matrix is unique within the Air Force and in a way counter to the concepts of a military chain of command. It can be hard for a commander to have people working for him that he perceives that he does not command. It can be hard for a commander to have people move in and out of their organization without their knowledge. The matrix causes this to happen. The result has been over the years a conflict between engineering and SPO management over ratings and ownership of the engineers. Total SPO ownership would lead back to the 1950's and the inflexible personnel system that proved totally ineffective. Each commander of ASD over the years has recognized this and upheld the matrix to counter the past. Every time a new SPO was created, the need for additional engineers and overhead, has grown. Whenever SPO's were combined, the overhead was slightly reduced, however the savings for engineers was small to non-existent, because the work that needs to be accomplished did not change.

Level of technical effort is the key to the process within the SPO, how much or how little. If we add to or modify an already built product with no additional R&D it may not need much technical oversight. Whereas, the purchase of a totally new aircraft system is going to need considerable attention from the technical community. Further, how much review are you going to accomplish and how deep is the next question. Even on this totally new development you may choose to have only one engineer take a look at the total system and say yea or nay. While this is highly unlikely, it could happen.

Of major concern to the DCS is the isolation of the SPO engineer and the career development of these assets. The home office management, by retaining ownership is also responsible for

developing their people out in the SPO's. Part of the reason the matrix has been successful has been the basic structure is the same from SPO to SPO and the technical community has been able to build a career development program. The training and need to keep up to date is essential in the technical environment. The ability to replace a person in the SPO going to long term training allows us in many cases to send the best for additional training. This program is outlined in considerable detail, for civilian engineers, in a Deputy for Engineering pamphlet "Career Planning Guide for Civilian Engineers" and for the military engineers an internal program exists to provide training and counseling. The basic difference is that the civilian engineer is trained with the objective of being a part of the development design team for the next 30 years. The military engineer on the other hand is trained to assume program management in the future. Therefore they must be given the basic tools so that they have an understanding of the systems engineering process and how to effectively utilize the engineering work force when becoming a program manager. Similar efforts will be undertaken relative to the manufacturing and configuration communities. A good example of this isolation existed in the configuration community and was a reason for incorporation into this new structure. The technical personnel in configuration were in separate SPO's and did not have a common home office. The result was that a career program did not exist and training varied greatly from organization to organization. The movement of these assets into the new DCS will allow the establishment of the common training and then specialized training relative to the various positions.

The Matrix at Work and the Systems Engineering Process

The matrix concept, employeeed properly is a powerful management tool and operate with exceptional efficiency. It is a system that works very effectively at ASD. Part of the reason may be an unusual set of circumstances found at ASD and not elsewhere. ASD does not produce a product yet is responsible for a large number of extremely high tech products. The responsibility to work over 400 programs at once with a value of 20 billion dollars is not found in many areas either in industry or government. The system has proven itself by the products it has produced such as the best aircraft in the world. Yet it is a system that is under constant attack because it appears not to give total and complete authority to one person. Yet, it does, if you understand the process. What it does is provide a robust, flexible organizational structure with the ability to meet most needs. It provides a highly trained workforce that can take its experience from effort to effort. If you had unlimited manpower you would still benefit from a matrix organization in a highly technical environment.

There are three basic ways that you could structure the management within the ASD environment: Project -- Functional -- Matrix

The following is a description of the above three methods and why the Matrix is best suited for this type of operation.

1. PROJECT

Project management is a single point of contact management style within an organization that is responsible for directing and controlling the accomplishment of a specific project or goal. The director of such an organization has complete responsibility for supervision of all personnel and activities of the organization. This is a management style that the AFSC 1990's studies cited as being "well suited to manage programs that have complex technology, high priority, consume significant resources, have a beginning and an end,

and have high visibility." Other factors that enhance this style is that responsibility can be pinpointed, decision making is facilitated, and the organization has a high degree of self sufficiency.

If this style is "well suited" to manage a complex program, what are the problems? The 1990's study found the most significant area of concern was that this system is "expensive in demands on "experts" time." Manpower requirements are increased as the functional unit must duplicate efforts in the home office of building a technical base without knowledge of what is going on in the SPO. Manpower requirements are also increased due to the need to have an expert on each subject and the refusal to release personnel after they have completed their tasks in case you need them again. Technical problems will not surface until they are of major concern outside the SPO or until the product is delivered. Lessons learned are not transmitted to similar program efforts, as problems are worked within the SPO, there is a natural human trait not to broadcast you have a problem you can't solve. Likewise lessons learned from outside the SPO will not be transmitted into this closed loop. The ability to discuss problems with your peer group from the home office and other program offices does not exist under this environment. The closed loop is fostered within a closed environment. This type of project management can result in problems being "hidden" from the outside world with the premise that "hope that springs eternal" and that it will be solved before anyone finds out. Another problem within this closed environment is the "we know better" than anyone else and may result in a concept of operation and engineering design that is counter-productive to be advocated within the SPO. No check and balance exists because it is a closed system. The loss of lessons learned and closed environment also means a loss of corporate memory in the long term with a corresponding loss of expertise. Not only does this effect program being worked but also any other similar program.

2. FUNCTIONAL

Functional management is where all organizational structures are standardized for all similar operations. Activities are departmentalized into primary functions such as administration, engineering, accounting, personnel and contracting. Functional management is not an appropriate method for procurement of a system. The key word is system. A functional organization is appropriate when considering certain narrow functions such as

administration, supply and personnel. In these areas they perform an overhead function that is used by all. All the specialists are housed within that function and each person needing help can come to that function. For example, we could consider a supply function where each office needing paper and pencils could go to the store and pick up what they needed. To collocate a supply person in each office would substantially increase manning requirements, and add another layer between the person needing the pencil and the store. This is one case where you do not need a specialist, in fact, it would reduce efficiency. Most of the time the supply specialist would sit around waiting to be called upon to go get the pencil, with time the specialist would develop paperwork systems to requisition the pencil to justify their job. Then of course they would need an assistant to get the pencil because they are too busy handling the paperwork ordering the pencil, etc.

In engineering to only have a functional element, would cause the same isolation we have discussed relative to a project organization. The engineer working in his own little world would have no reason to go to the SPO to discuss his new invention. In fact, it goes back to the theory of when do you stop inventing and go into production on any item. If the functional engineer never had to communicate with the SPO, would he? This is a hard question to answer. In some cases, yes, and in some, no, is the only response. It was found after World War II and in the early 50's that in many cases the engineer in the functional elements did not. The organizational barrier between the SPO and functional element worked in both directions. Neither is at fault, it is part of the system and normal dynamics of an organization. A primary example of how this works is the technology transition program at ASD. Until a few years ago the personnel in the laboratories and engineering did not effectively communicate. They discussed the movement of technology on a hit and miss basis. The establishment of the Technology Transition Program and the merger of the Laboratories into ASD broke down some of the organizational barriers to where a program is functioning today. The biggest breakthrough was not in removing organizational barriers but rather the identification of individuals in both organizations as focal points for each area of technology and requiring them to meet one another. The personal contacts and interaction of the peer group has made this program work.

3. MATRIX

In the book *Organizational Choice* by Stanley M. Davis and Paul R. Lawrence, the matrix is defined as "any organization that employs a *multiple command system* that includes not only a multiple command structure but also related support mechanisms and an associated organizational culture and behavior pattern." The matrix therefore binds together project and functional management to meet two organizational needs: Organize specialized activities into functional departments that maintain expertise and have units that integrate activities on a project or system.

The matrix, when understood and properly used, is the most effective method to complete a job with limited resources. However, it is hard for many military commanders to understand the concept of a multiple command structure. We must remember that the role model for organizations and business' comes from the military and the church. These institutions were the first that provided an organizational structure and therefore were copied by business as it grew into larger entities. Both the military and the church maintained pyramid-type structures whose line of authority from the top down is the unity of command. It is therefore easy to see why business over the years adopted the lead of these organizations in developing the basic structure of American business. They were following a successful role model. It is also easy to see why the aerospace business of the United States once again followed the military in copying a matrix management concept in large R&D organizations. In *Organizational Choice* the authors point out that the matrix is now used in almost all facets of industrial and organizational types of operations. They also point out there is no standard matrix and that a matrix needs to be "grown" to your organization. The ASD matrix concept is the one that has grown and been practiced for a number of years.

What does a matrix achieve both in the short and long run? It has two primary functions. The first is efficient utilization of scarce resources and the second is communications. The number of engineers at ASD been basically constant for a number of years yet the job they have to do, gets more and more complex requiring more time. This is also true for other matrix organizations at ASD; continued increases in regulatory requirements make the job of the other functionals more complex. This has resulted in them needing

more specialists and more manpower to complete the more complex tasks. Just as they became matrixed a number of years after engineering they are following the same road the engineers have over the years of increased specialization. They have the same need to communicate from the home office specialists as do the engineers. The flow of concepts, and lessons learned are vital and often not recognized as benefits of the matrix. The "boss" never hears about the engineers at the lowest level talking about similar problems with engineers in other project or home offices. The communications from the labs to the home office and then to the SPO engineer, are all part of an informal chain that would not happen in a formal straight line structure. To a degree this can be viewed in the recent decision to incorporate Configuration and Data Management within the new DCS for two reasons. First to achieve a closer tie between the engineers and the configuration specialist and the second to cause a matrix of the configuration workforce. The only way a cross feed was achieved was when someone was promoted from one office to another. Further a bidding war for personnel via promotions would occur in an era of scarce resources. The matrix will allow the movement of those personnel and allow the cross communications that will develop with time from this movement.

What kind of problems have developed. The program manager "boss" starts to feel these people do not work for him and to be effective, they must report to him. This has been a battle since the start of the matrix. In 1967, to take care of this concern, a position of chief engineer was created in the SPO to oversee the functional personnel working in that organization. This has worked over the years as an effective way of meeting the single chain of command within the SPO. The senior collocate reports to the SPO director. The difference is that the people under the senior collocate report both to him and the home office supervisor. In essence, this would be the same as if we had no matrix, because the SPO chief would only talk to the senior collocate anyway. This has recently resulted in a high degree of concern by the SPO chief on who reports to who for ratings. The reporting concern has been blown out of proportion. A SPO chief or Commander never rates, in the real world, below the level directly reporting to him. In the matrix area the SPO chief rates the senior collocate. If the SPO were fully manned as a project office the SPO chief would still only rate the senior collocate. No difference! The only difference is in perception of who rates who. The senior collocate does most of the rating, what the home office does is measure each collocate against one another from a common technical

base. Therefore, each radar engineer is rated by his collocated boss and then a ranking is provided by the home office. Otherwise, the radar person would be measured against a radio or landing gear person. Looking again at the ratings, the SPO chief is only concerned that his senior collocate is getting the job done. If there is a problem with the senior collocate it will be reflected in their rating. The senior collocate then must accept the blame for program problems in their technical area. However, this second chain of command is extremely important in an R&D environment and when used by the overall commander, insures success of his products. It provides a check and balance and a measurement within that important peer group. In essence the senior collocate rates the person on a day-to-day basis whereas the home office supervisor rates a person on a long term outlook.

Corporate memory is another important facet of the matrix that also is not recognized as an outgrowth of this management technique. Corporate memory is knowledge of what we did right and wrong in the past and how we could improve the next time. The matrix, because of the flow of people, increases communications and therefore knowledge. The lack of this flow would cut off this knowledge, and also hamper the technology transition program now in being.

4. SYSTEMS ENGINEERING

How does the matrix fit into the systems engineering concept. Systems engineering, as does the matrix, has its firm roots in the B-47 development. In fact, prior to the B-47 in the B-29 development, systems engineering started to take hold. In the B-47 program the then traditional engineering development was taking place where all component parts were developed and just put onto the airframe. The using command had a hard time getting all parts of this aircraft to function at the same time for any length of time.

This was the starting point of true systems engineering, wherein, all parts of the system are viewed as one. What is of special concern is to insure that all parts of the system work in harmony. In today's aircraft, it is critical to the development. Everything must function together. To achieve systems engineering you must have an integrated workforce. The matrix moves you in this direction, whereas the direct reporting method isolates you. The program offices of B-47 and B-52 started the trend to make

engineering teams with all the specialists working together. Today we have in some cases only one or two specialist in a particular area out of the 1300 plus engineers in the DCS. Without the matrix and the flow of these people to support various efforts we could not provide total support to the SPO. As our technologies become more and more complex we will need the matrix more and more. If we view the system engineering process of today versus that of twenty years ago we also find it is changing. Today the process includes not only the actual development teams but also the configuration management and the training on how to use the finished product as well as the training on how to maintain and repair the delivered item. The complex systems have driven us to more specialization and this drive requires that the matrix provide the specialist when and where they are needed.

5. INTEGRATED PRODUCT DEVELOPMENT

In April 1990, the DCS for Integrated Product Development and Technical Management was formed. In the concept of a total systems engineering process, all elements of engineering design are fully integrated. Therefore the process at ASD was expanded to include the other functional elements that effect the design process. It was recommended that manufacturing, product support, testing, safety design, and security design were primary factors which needed to be added to the engineering process in the earliest design stages. It was further recommend the way to accomplish this change was to form "teams" to work on various projects. Each team is to be composed of technical experts necessary to design the total product including tooling, testing and maintenance.

How does this work within the matrix, without it, it couldn't. The concept is the formation of product teams that develop a product. In essence the entire SPO is a product team, we are now looking at smaller teams within the SPO aimed at specific areas, such as technical and business. On the technical side the team is viewing the product from inception to past delivery in actual usage. This allows the lines of communications to be shortened by pulling together the elements needed to design, build and deliver the product. To achieve the product team goal it is necessary to pull together personnel from the home office to provide the various technical experts? Not only is this true from an engineering viewpoint but also on the business side with experts from the

contracting and comptroller home offices. In developing this new concept two choices were available relative to the SPO structure. These are, the isolated teams of the 1950's or expand the current systems engineering concept. It was logical to expand systems engineering to include other technical elements and to strengthen those elements by placing them with the engineering workforce. What has happened is that the engineers, manufacturing specialists and configuration and data managers that were separate in the SPO's will with time become one unit. The interplay between these groups as one will cause the teams to come together, the togetherness will increase communication between the personnel and just as the engineering teams came together in the SPO from the separate functional home offices, so will the overall teams. By placing the technical elements under one technical director in the SPO we will achieve a higher degree of integration of product design and development.

A good example of this trend can be found in the logistics process and how it is moving in this direction. A few years ago one of the car manufacturers designed a bumper with its brake lights build right into the bumper. If a bulb went out, it cost 50 cents for the bulb and \$125 in labor to replace. The entire bumper assembly had to be removed from the vehicle. In designing any product the maintenance and repair of that product should be a prime consideration and incorporated in the initial design of the product. The increasing complexity of weapons systems has continued to push this need more and more to the forefront. In World War II our primary concern was to overwhelm the enemy with men and material. Gen Patton couldn't get enough gasoline to move forward, we built tanks and aircraft in vast numbers. Today the cost and time required to obtain and build an aircraft is far beyond the World War II concepts, we no longer live in a conventional warfare world.

To add to this concern is structure of development and service engineering in two different commands. While this is not bad in it does cause organizational roadblocks in achieving this new development process. Yet the flow of history shows us that the logistics engineering phase is ready for the next step and that step is towards integration with the development engineering community. In the past logistics, in the R&D environment was primarily concerned with the development of procedures to maintain and repair Air Force assets. They also became more and more involved in designing modifications to the systems as we began to own them

longer and longer and the missions changed due to threat changes. As the systems became more and more complex, the logistics engineers became more interested in making sure that the bumper didn't have to come off the car to change a 50 cents bulb.

It was recognized in the early 1970's that the program managers were so busy defending their programs they did not have time to be familiar with the details that needed to be finely tuned and structured within the program. The logistics community was concerned that its requirements towards maintenance and repair were one of those elements that were forgotten. During the early 70's they established an office within the command headquarters to start the process of recognition in this area and also established a new buzz word, "life-cycle costs." However these efforts failed because Air Force Logistics Command (AFLC) could not get the designers of new systems to be motivated to incorporate supportability in the design process. The primary cause for this failure was the inability of the AFLC personnel to have any fiscal authority to influence contractors. The conclusion was that without dollars and authority on how to spend the dollars, supportability would be just words. The overall basic concept was that a traditional program management was made up of three legs: Cost, Schedule and Performance. The AFLC view was that program management needed to be changed to four legs: Acquisition Cost, Schedule, Performance and Operating & Support Costs.

In a 1976 AFLC study it was found that there was a need for institutionalized recognition by both the Air Force and industry that Acquisition Program Management must encompass a broader perspective than was perceived. There was a need to increase the advocacy in engineering development of the logistics concerns along with other critical areas of procurement, contracting, budgeting, financial management, maintainability, reliability, supportability, mobility and legal sufficiency. The result of the studies was in 1976 the Air Force Logistics Command established the Air Force Acquisition Logistics Division (AFALD) with the basic mission to reduce the ownership costs of weapons systems. This new organization was charged with "reducing long term costs of ownership and operating support of weapon systems and related equipment." Of primary concern was the "constructive advocacy for controlling life-cycle operating costs and to assist AFSC program Managers during all phases of a systems design, validation, development, and production." This was the first time that the

logistics command structure moved to a more than handshake relationship and a single point of contact within the ASD System Program Office. To meet these objectives AFALD was structured to have five operating locations at the main Air Force Systems Command Product Divisions. This resulted in the placement of logistics personnel within the SPO's reporting to the SPO director. In 1976 when this organization was formed it was manned at a level of 519 personnel with an authorization of 707 positions this has grown to a current level of 784 positions. Once again the AFLC community was trying to move the concept of logistics need to the forefront of the design process. However, the logistics engineers while collocated, were still institutionally separate from the engineering community. They reported directly to the program manager and did not have the financial aspect of the program. In viewing earlier problems of the Program Manager, they had not changed in defending their program, to add logistics concerns would add in some cases cost and therefore was not truly adopted. The engineering community had no direct reason to add logistics to its already heavy workload. Therefore after all the years of trying to go to a four leg program management concept, in the real world it was still considered that a program had only three legs.

Logistics has come a long way towards achieving its goal, basically through the work of its people in the program offices. The concept of Integrated Product Development (IPD) gives the logistics community the opportunity to further advance its objectives. However to meet these objectives it would require the next logical step in the organizational placement of the logistics community. What is still lacking is the placement of the logistics advocate in the proper organizational context. If you want to influence front end design, the logistics engineer should sit next to the design engineer, not in the next office and they should have the same technical boss. We have been concerned with having influence at the high level and true measure of influence is at the lowest level. This type of change would be extremely simple to achieve. Within the System Program Office the logistics community should be separated into its two basic functions, design and supply. Those personnel involved in designing for logistics should be placed with the design engineers in their functional areas. This develops into a matrix within a matrix, but can be effectively utilized to achieve the end goals of the Air Force. Further the designer and logistician would have to report back through the same supervisor. Thus the logistics advocate would now be on the same level as the designer. They would talk together

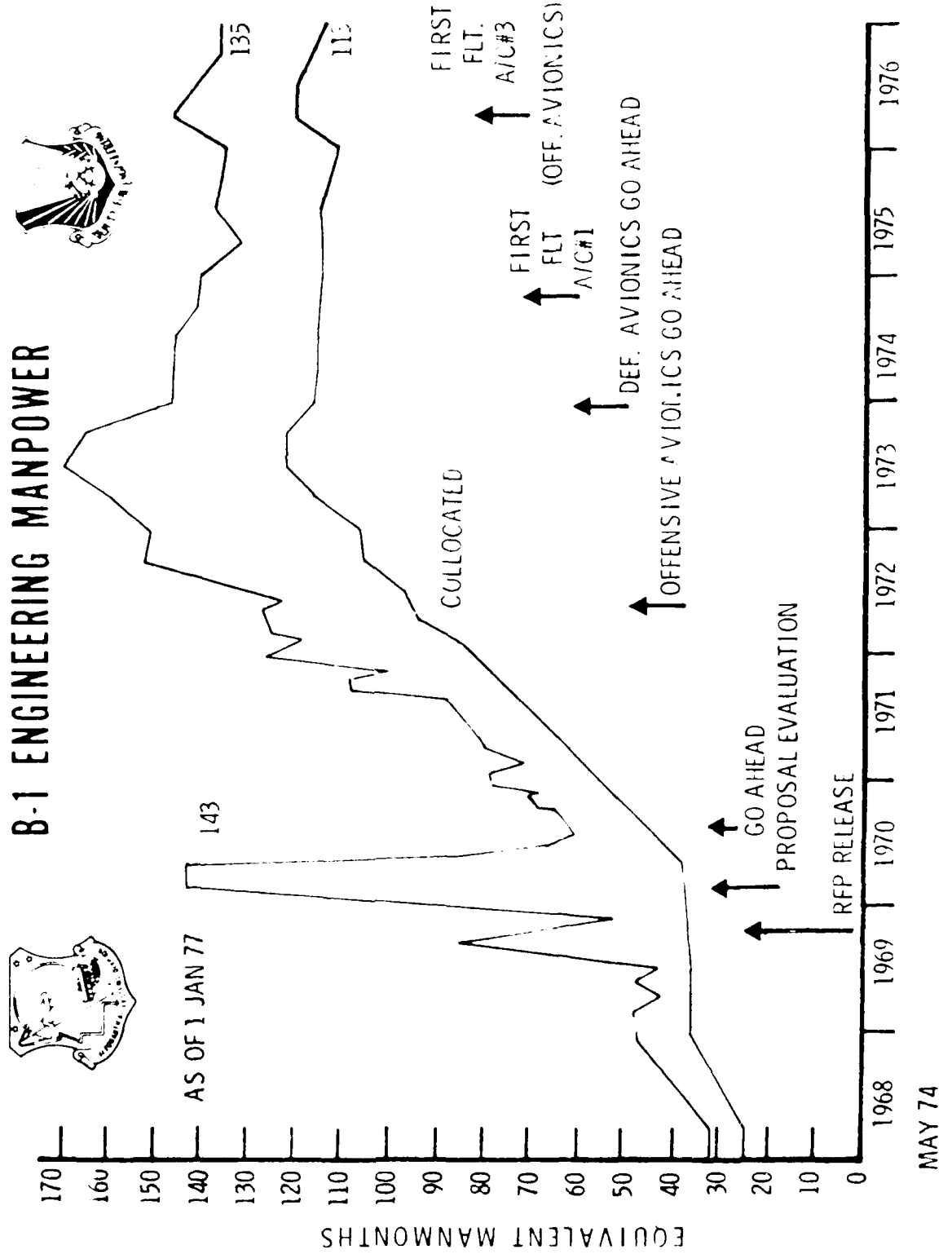
with the user from both an operational and a maintenance context. The removal of this organizational barrier would be an important step towards meeting the IPD goals.

Section Four

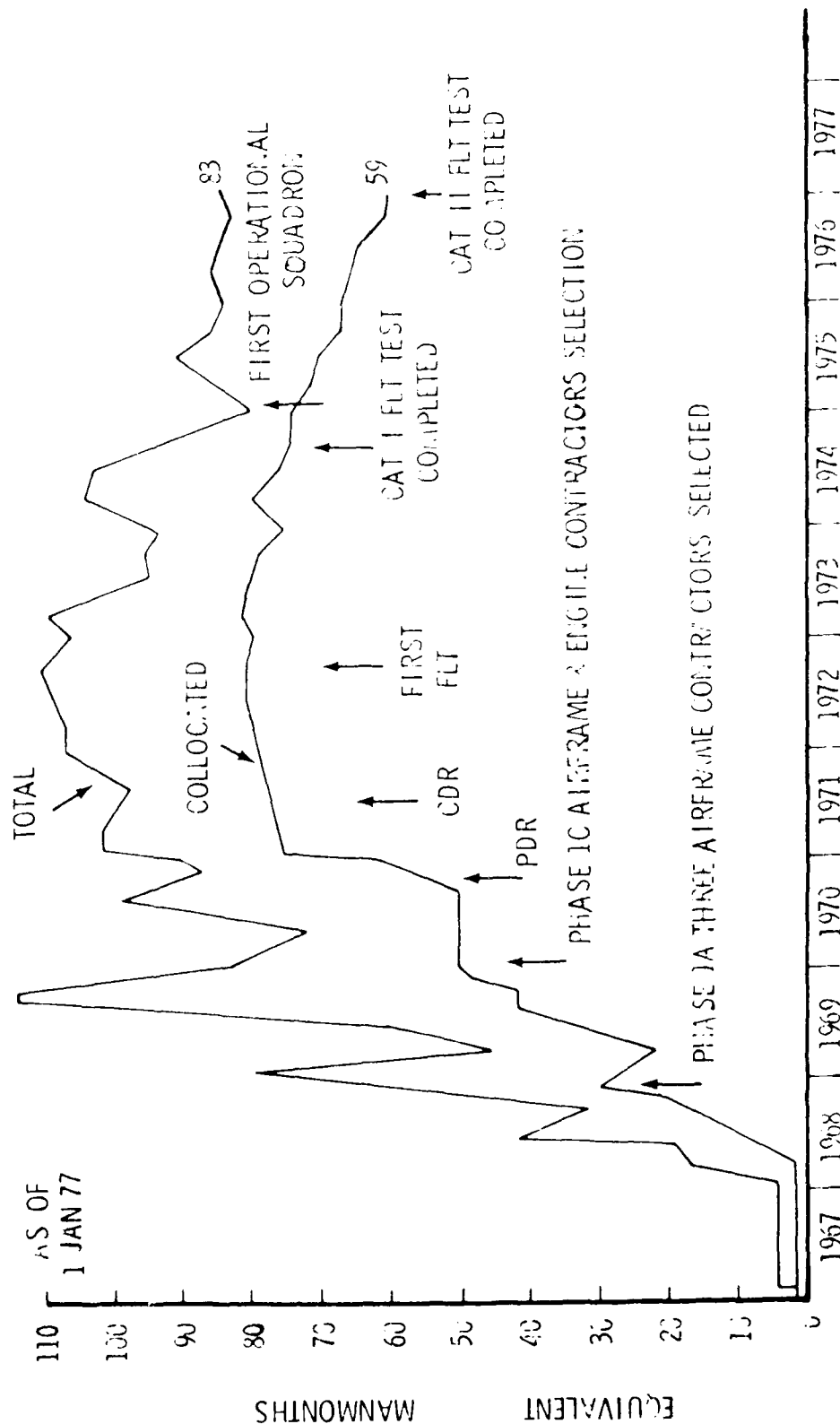
Conclusions

What would this look like in two years? This is an important consideration. With the matrix you have the ability to form highly effective technical specialists in the home office, this can be one person or even an entire organization or many groups, such as the new engineering organization and logistics from even another command. The primary function of these home offices is essential to building the technical base in their area of expertise. The System Program Office on the other hand must utilize the matrix to build highly effective product teams. Using the matrix the team structure can and will change as the program progresses and moves from phase to phase. It will have the ability to call upon the home office for the technical specialists it needs, to meet added requirements and the surge capability for problems, special work, etc. It also allows the workers to remain challenged as they can move from job to job, program to program.

Appendix A



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