A SYSTEM DYNAMICS MODEL OF A SMALL R&D OFFICE:

PRODUCTIVITY ENHANCEMENT

by

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ABSTRACT

The "Integrated Team" is an internal research and development alliance between a small project design office and a large laboratory complex. Both are government aeronautical research organizations. Its purpose is to enhance the laboratories ability to transfer the technologies it develops to a third government organization which is responsible for product development contracts with industry. The strategy is for the laboratory specialists to exhibit practical know-how gained by working in the small office's preliminary design environment. By becoming familiar with design integration and operational concept phases of their technologies, and the others with which they interface, they will collectively represent a significant pool of intellectual capital. When the product organization has need to develop a system involving advanced technology, the team of engineering scientists will be available.

The "Integrated Team," will be built over a 4 to 8 year period. Senior laboratory specialists shall be assigned to the small design offices for a 1½-year tour of on-the-job training and formal education by the office staff. Assignments of three to nine people will be made every three to six months. Team work and cross training shall be emphasized. Education and methodology development will work both ways. When a major product is to be developed, these people can be quickly reassembled into experienced teams.

After working such a project, the trained senior lab people will likely be more valuable to their home offices in terms of managing their technology. It is also hypothesized that direct technology transfer will be enhanced by quality documentation of in depth technology investigations which include practical design, manufacturing and operational considerations.

A system dynamics computer model has been developed to simulate the training of the "Integrated Team." Growth was found to be limited by the initial size of the small office and its ability to maintain a meaningful portion of its normal project studies.

The "Integrated Team's" capability was then compared to the manning requirements of an intense pre-contractual phase of an advanced tactical transport system development (a one- to two-year project). Based on a range of possible total RD&E costs, the team size is adequate for an in depth design effort but not one covering a broad range of concepts. This could possibly be corrected if the longer training phase and follow up laboratory efforts were also keyed directly to the tactical transport problems.

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CHAPTER I

INTRODUCTION

The objective of this thesis is to explore a multi-functional integrated team policy to enhance the technology transition productivity of a small R&D office and its parent organization, a large United States Air Force (USAF) research and development laboratory complex. The office, the Technology Assessment Division (~40 people, TXA office symbol), and the lab complex, the Wright Research & Development Center (~3,000 people, WRDC organization symbol), are located at the Wright Patterson Air Force Base, Ohio. The organizational size and functions and shown by Figure 1.1. In this investigation they are known as the TXA office and the WRDC lab complex; in the analysis section they are designated TXA and LAB. The abbreviations/acronyms used in this thesis are defined in Appendix A.

A second objective is to use the System Dynamics simulation methodology (see bibliography) to develop and test policies of work flow in and between these two units.

1.1 <u>The R&D Environment</u>

The Air Force Systems Command (AFSC), headquartered at Andrews Air Force Base near Washington, D.C., has a number of "product divisions" under its command. The one at Wright Patterson Air Force Base is the Aeronautical Systems Division (ASD). Its products are systems such as the F-15 fighter, the B-2 bomber, and the C-17 transport. It works with military aircraft manufacturers in the requirement, full-scale development and production phases. This includes the critical decision of the system's technology content.

The WRDC lab complex is part of ASD; its primary function is technology support of the future aeronautical system developments. The scale of its operation (people, budget, and facilities) is shown schematically in Figure 1.2. Each of the laboratories has a number of buildings, many converted to partitioned engineering offices.

WRDC has approximately fifteen major line divisions plus four directorates and a small (electric technology) laboratory (Figure 1.1). Each has two to four branches which are further split into groups. Many of the people (technologists) work individually or on small team projects within a discipline. The disciplines are usually independent of each other. The point is that WRDC has a technology portfolio filled with a large number of non-homogeneous projects. There are probably more than one per man on the "books" (greater than 3,000) and a good deal of these are active.

1.2 The TXA Office

TXA often serves as WRDC's technical staff in the exploration of future aeronautical systems concepts based on advanced technologies. It uses a mix of in-house and contract investigations that are termed "Technology Integration and Operational Evaluation" (TI&OE). These range from a quick two-day consultant response to an eighteen-month engineering study. At any given time its project portfolio will contain five to fifteen separate technical problems.

TXA is not large enough to provide total matrix support to other lab line organizations (aeronautics, propulsion, material, etc.); however, it often works with or requires information from such groups Its critical output is advanced technological requirements, hence its necessary input is technological information.

1.3 TXA Leverage and Limitations

The office acts as a pathfinder by limiting the rigor of its analysis in aircraft design and operations (sort of a computerized back-of-the-envelope). The payoff of this approach is suggested by Figure 1.3, where "Military Worth" represents a total force capability rather than the performance of a single aircraft within the force. Thus the decision-maker has a "vector" to guide any following, more rigorous (larger, more expensive) phase of the project.

Of the forty or so people in TXA, about half are in the Design Branch (designs, propulsion specialists, etc.), about a quarter are in the Analysis Branch (military operations), and the final quarter handle systems technology contracts (the Concepts Branch). When division supervision, secretaries, and contract people are discounted, there remain about twenty-five people doing in-house technical work. This thesis deals with the productivity of these 25 engineers and other WRDC technologists in a proposed integration policy.

1.4 Technology Development

Basic Research, Exploratory Development, Advanced Development, and Manufacturing Technology are the four primary categories of R&D at the

WRDC. The last three have the most emphasis. The last two are the most expensive (hardware), and the second, Exploratory Development (applied research), has the largest number of project work units. This applied research projects area is the focus of the TXA office.

1.5 Technology Assessment

Technologies take time and expense to develop, and are risky. Some, while contributing to an air group's combat effectiveness, actually degrade the performance of the individual aircraft (by adding weight or drag). Others, due to their great expense, would severely limit the size of the force which could be purchased. All must be considered carefully.

Many technologies, when considered incrementally, are an abstraction to the ultimate user (pilots, mechanics, generals, decision-makers). The technology integration process, such as used by TXA and other small design offices, results in conceptual aircraft designs which can be compared with existing aircraft types. The individual incremental technology contributions, however, are difficult to measure and are usually appreciated only by the designer or small design/evaluation team. Even then, since many technologies have been aggregated by a preliminary design methodology, the fine-grain definition is lost to empiricism.

Herein lies the problem for the TXA office. Their aggregated methods simplify and speed the synthesis task; however, to do this for a specific technology assessment situation, one must thoroughly understand the technological details used in a "full design office" approach. Hence the technologist's contribution is an integral part of an advanced design and it may also benefit by a feedback process. Only then can a technologist fully work, appreciate, and explain their concept to a decision-maker. And only then can the decision-maker act with a minimum risk-discount attitude for analysis credibility.

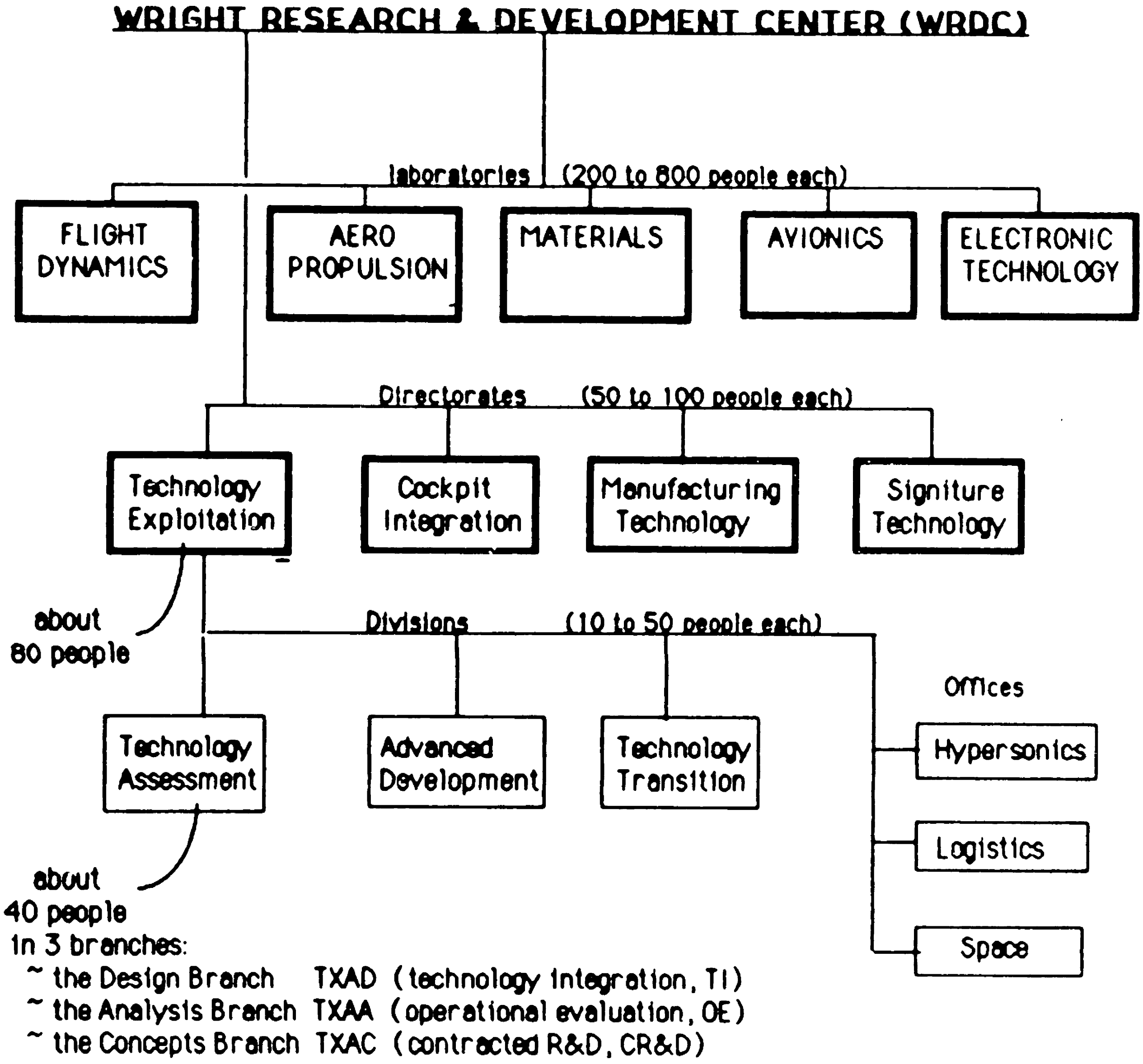


Figure 1.1 Wright Research & Development Center (WRDC) and the Technology Assessment Division (WRDC/TXA)

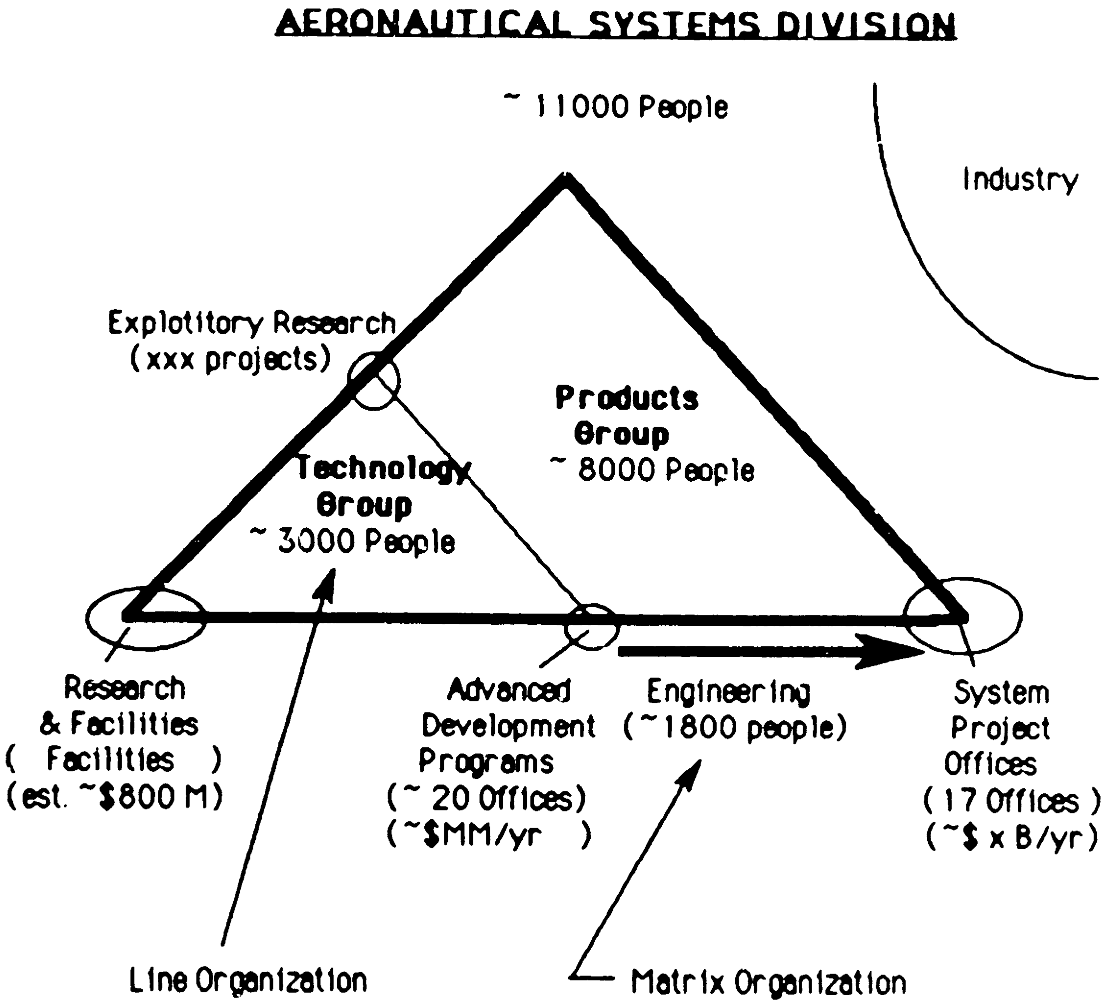
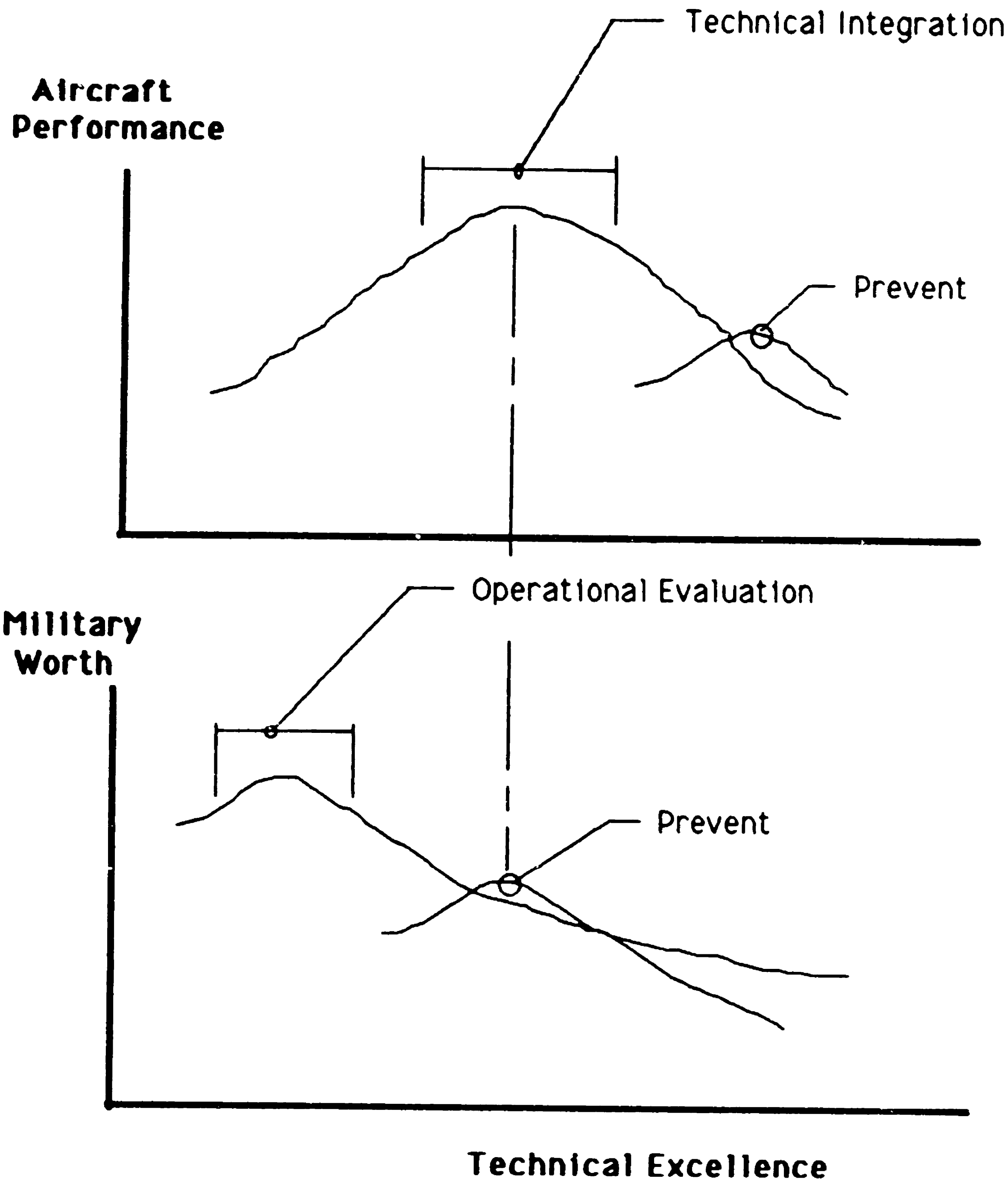


Figure 1.2 The Laboratory and the Product Groups



TI&OE - Technical Integration & Operational Evaluation

Figure 1.3 Analytic Leverage of the TXA Office

CHAPTER II

THE PROBLEM

As implied above, the management of technology is difficult. Which of the thousands of applied research projects has the most promise to improve future systems? In the short-run? In the long-run? Which projects should be increased? Which should be dropped? What critical ones are missing? What future systems, requiring particular technologies, will likely start first? Or never start at all? Should WRDC try to work all? If not, which?

Sheer numbers are impressive. If out of the 3,000 or so technology project work units, half are "good," a further half of these are applicable (cost effective) and the remaining are logically clustered (in half); the result is 375 technologies needing transition. If a factor of one-third replaces the one-half, the result is 100 technology clusters. How feasible, then, is it to transition 100 to 400 such good technologies to a new system of development?

2.1 Technology Transfer Investigations

The ultimate measure of the management of technology is the transition of technology. ASD Regulation 80-6 (January 1985) "explains" the term:

> Technology Transition - The transition of science and technology efforts from one R&D category to another. The most noticeable transition is from demonstrated technical capability to full-scale development or directly to operational capability (combat or support). Specifically, technology transition is the transfer of technology (a capability, method, process,. or technique) from Air

Force laboratory activities to development or production weapons systems and equipment.

Insightful investigations of LAB and SPO technology transition success have been made by a number of researchers. They have identified an ASD wide perception that WRDC has few direct transfers of technology to the System Project Offices (SPOs) of ASD.

The Herman Report. A government study team (Herman, 1982), directed by Dr. Robert Herman for the Under Secretary for Defense Research and Engineering, found that although "much good work is being done in the laboratories, ... there exists a disconnect between the laboratories and the operating forces, which exacerbates the problem of technology transition to the field."

2.2 **The Cormier/Salvucci Thesis**. An MIT thesis (Cormier & Salvucci, 1986) surveyed two Air Force product divisions on technology transition. It was noted that there are "...cases where a SPO [Systems Project Office] deals directly with a contractor without LAB/SPO interface ... and the SPO simply accepts or rejects the technology." They also noted that the laboratories and SPOs were funded by different mechanisms (separate budgets); a major disconnect.

In a survey of the LAB, SPO, and ENG (engineering Support) groups (but not outside contractors), they found:

1. At both divisions, the contractor was perceived as a major factor in the transition process.

2. XR organizations (Development Planning) were considered a minor influence on the successful transitions cited.
3. The informal transition mechanisms had a higher value than the formal ones.
4. The ENG group was a part of the technology policy.
5. There are problems in the relationships between the ENG and LAB groups.
6. The risk issue is a major factor in the technology transition process.

2.3 The Gummere Thesis

In an Air Force Institute of Technology thesis (Gummere, 1988), USAF Captain Robert J. Gummere studied the technology transition process at the Aeronautical Systems Division, but with a more focused look at the connection between the new Advanced Tactical Fighter (ATF) Systems Project Office and WRDC. This work also surveyed WRDC, ATF, SPO, and ASD/EN, plus the defense contractors involved in the development of the ATF. They also found the process ineffective:

> Five Investigative Questions guided the research: (1) How has the operating command contributed in the development and transition of technology? (2) How well have the official and unofficial technology transition processes worked as perceived by laboratory, SPO, EN, and contractor personnel? (3) What organizations are considered important sources of information on new technology, and what is the frequency of contact with those organizations? (4) What influence is the contractor perceived to have on the success or failure of moving technology from WRDC to the ATF SPO? (5) Is the perceived risk of new technology by the SPO a significant barrier in the transition process?
>
> This study found that the using command was perceived important in the transition process, although they have no official

involvement. The formal mechanisms and processes were not generally rated as effective, while the informal methods received an "effective" rating. There was a barrier identified in the general communications pattern between WRDC and the SPO, as well as WRDC and the product division engineering. The contractor was perceived to have a significant impact on the success or failure of transition. Respondents agreed that the willingness to accept risk was important to successful transition, and risk aversion by the SPO was to considered a barrier except by WRDC.

2.4 Patterson Thesis

In this thesis, Captain Richard Patterson (1989) thoroughly documented the history of technology transition, from 1904 to present. He summarized a number of negative perceptions similar to those noted above. His conclusion was that a lack of formal education programs had an adverse effect on the process of technology transition. Almost 70% of both LAB and ASD respondents indicated that they were not adequately trained. An outline of a national training program was included:

1. The importance of technology transition in meeting the users needs.
2. The importance of timing.
3. The documents that aid transition (i.e. regulations, statements of operational need, program management directives).
4. Successful/unsuccessful examples of how technology is transitioned.
5. The Senator Process.
6. Organizational structures of agencies established in technology transition and their purposes.
7. Interrelationships of users, laboratories, and product divisions.

8. The technology development process.

9. Contractor relationships.

10. The importance of good consumption.

Figure 2.1 is a national view of the direct and indirect technology transition process noted by the above researchers. As can be seen, there are a number of important players in the picture; not shown are others such as the operational Air Force (Users), political/congressional factions, lobbyists for industry, and upper-level DOD activities. This thesis recognizes these factors, but will not attempt to analyze or reconcile them.

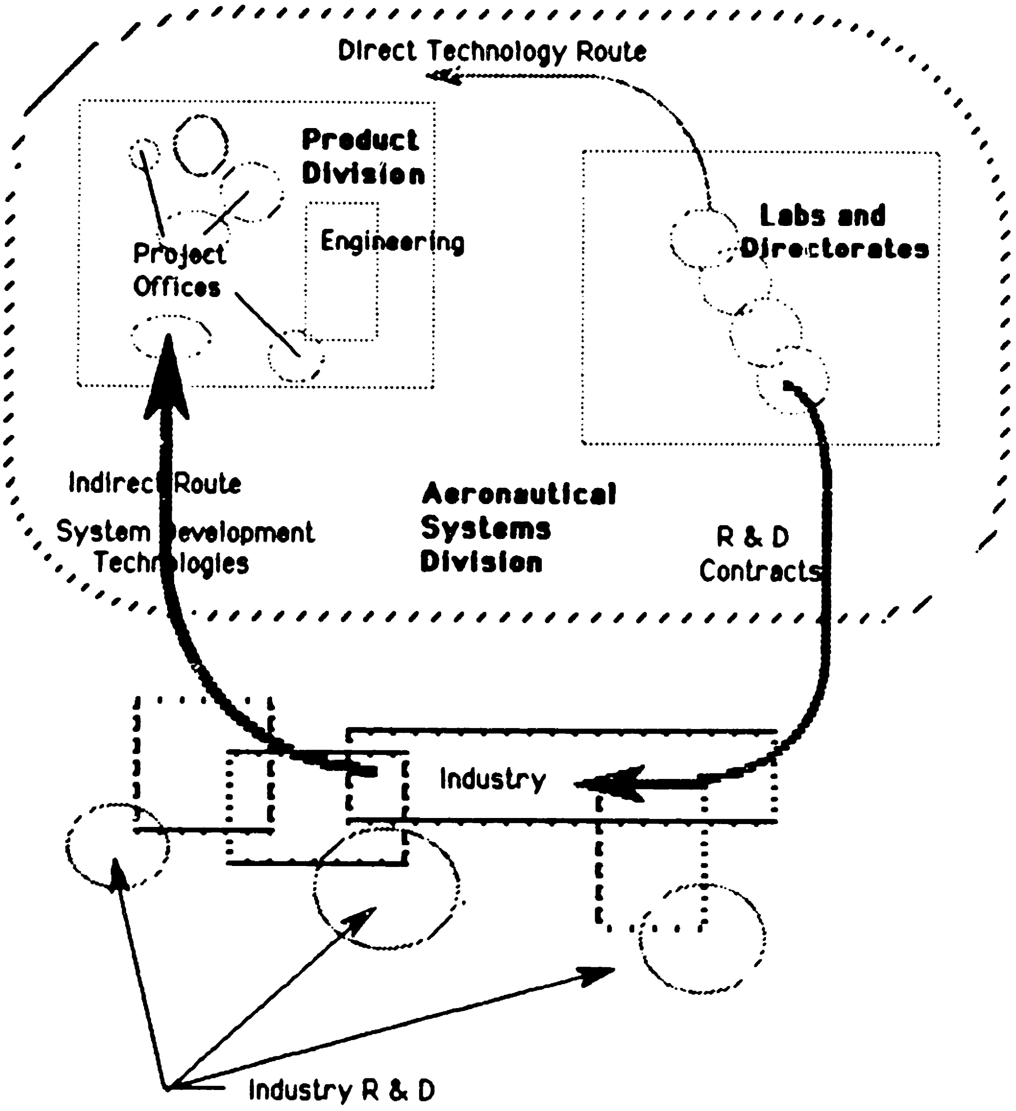


Figure 2.1 Technology Transition - Direct & Indirect Routes

CHAPTER III

SOLUTIONS

The laboratories have not been completely oblivious to the criticism noted in Chapter 2. Two general strategies implemented by the labs have helped the technology transition problem in certain, but not all, respects. These strategies are briefly outlined. Then following is an explanation of the proposed "Integrated Team" policy.

3.1 The Major Thrust Process

Four small but high-visibility offices were set up in the WRDC lab complex, in the early 1980s for the purpose of marketing technology. There were only four laboratories at the time, and although the technical responsibility of each office covered the total WRDC interest, each was attached administratively to a laboratory whose products closely matched the office focus:

Major Thrust Office	Administrative Laboratory
Sortie Generation	Flight Dynamics Lab
Supersonic Persistence	Propulsion Lab
Night-in-Weather	Avionics Lab
Space Applications	Materials Lab

A MITE report (MTR 9503, 1984) outlines the following management responsibilities.

1. Define MAJOR THRUST and technology capability goals.
2. Develop technology-relevant trees and road maps.

3. Lead technology capability goal planning.
4. Participate in transition planning and application reviews.
5. Lead preparation of technology plan.

Each MAJOR THRUST office was staffed with two high-level managers plus an *ad hoc* non-collocated technical staff of ten to twenty engineers drawn from various groups within the parent laboratory. Figure 3.1 shows the MAJOR THRUST operation; however, the primary strategy was external communication of technology since the MAJOR THRUST managers had access to top management outside the laboratory.

The weaknesses of the plan, however, was a lack of critical mass. In private industry the marketing office is organization size. It has a significant budget and staff to survey customer needs, then promote and advertize the firm's products, often through mass media. WRDC's informal approach was not successful, since the offices did not have their own budget (special items excepted) or control of the line organization budgets. The intangibility of their product and its fading from the mainstream of USAF focus also had a detrimental effect.

Nevertheless, the MAJOR THRUST managers were generally quite motivated people and served the lab's top management to "good stead." However, they acted more as assistants and less as distribution channels to move technology.

3.2 Laboratory Decentralization

In the 1960s, four laboratories independently reported to Washington (Air Force Systems Command). In the 1970s they were given a single commander who reports to the ASD commander. In 1988 the four labs were split into small units: five laboratories and four directorates (Figure 1.1).

The appeal of these smaller directorate units is that they have the critical technical mass (people, budget, and tangible products) that the MAJOR THRUST system lacked.

There are some weaknesses. First, splitting an organization into much smaller units (four went to nine in this case) causes the supporting staff, even a centralized one, to grow. In industry this hurts profits; in government it grows the negative aspects of a bureaucracy. Second, although three of the four directorates are "lean-an-mean" product focused line organizations, the remaining five laboratories still have a mixed project portfolio. The number may have shrunk from 100-400 case to a 75-300 one; however, still a great deal to manage effectively.

The third problem, which couples with the above one, is found in the TWA office: it now has a greatly expanded mission. Previously, TXA was part of the Flight Dynamics Laboratory, and in many cases that location restricted its investigations in avionics, propulsion, and materials -- all critical subsystems of a modern aircraft, but technological products of other labs. This limitation is now removed, however, a new responsibility is added to develop new technical capabilities and skills. Knowledge, data, methods, experience, and contacts should be brought up to the same standard as its past "Flight Dynamic" level. A new role may be necessary.

Even given that it can rise up to this expanded mission, it still has a critical mass problem. Previously it had difficulties supporting the four divisions of the Flight Dynamics Lab, it now faces a three- or four-times larger job.

3.3 The "Integrated Team" Proposal

This proposal involves the micro world of the TXA office and its relation to the rest of the WRDC laboratory complex in their dual pursuit of technology development and transition. The first precept is that a technology must be good (have significant military worth) before it can be considered transferable (Figure 1.4).

To contribute to this value added, the TXA office highlights the technological candidate(s) within its aircraft design synthesis process (Technology Integration -- TI) and then evaluates their incremental contribution to military success in various operational scenarios (Operational Evaluation -- OE). The design task (TI) and the operational evaluation (OE) task are highly iterative, both within and between each other.

TXA Capability. The office staff is knowledgeable and experienced in aircraft design and the military concept of operation. In a systems concept or straight aircraft design study, the various technological disciplines (aero, propulsion, structures) are aggregated and forecasted with historical data to support the analysis.

Figure 3.2 shows the project process in System Dynamics "causal-loop" format. This simply shows the behavior linkages between the elements of a system; the top figure, using generic "system state" terminology, represents an equilibrium-seeking system. The bottom (TXA project system process) is functionally identical to the top.

If the system is disturbed from equilibrium by the addition of new work (not on the schedule), the system achieves equilibrium by either increasing the work rate (people available) or by dropping lower priority projects. Note the latter technique can be equivalent to changing the schedule.

However, when specific technologies are the primary project focus, TXA needs help. When such a project is desired, lab technologists are assigned to support the TXA effort. The <u>communication cross-learning and team development is, in many cases, both long and imperfect</u>.

<u>Team Capability</u>. The "Integrated Team" proposal is a strategic alliance between TXA and the WRDC labs to temporarily co-locate senior lab technologists in the TXA small office work environment <u>before</u> major technology study is required. It is proposed that a mutual training and project syllabus would not only increase the knowledge and skills of staffs in both the design and operations research process, but also allow them to develop team leadership and consensus capabilities.

During this tour both staffs would adapt methods and concepts which dovetail in a new common process. The broad objective is for WRDC to have an "instant start" and "effectively run" capability for large complex system concept technology projects. Thus a pool of lab and TXA people who have previously trained together in specific team projects skills can be reunited in a critical mass to handle large high-priority projects. It amounts to a new role for both TXA and the participating engineers.

Figure 3.3 shows the Technology Integration (TI) type project which is similar to the System Concept type (Figure 3.2) but with an addition experience building loop. This phase *always* requires additional time, and the policy question then, is whether to do the training integration before or after the project starts. "After project start" is the status quo situation; "before" is the proposed "Integrated Team" strategy.

Team Payoff. A laboratory technologist must be able to discuss and quantify the increased performance capabilities of his candidate technology. The user is likely to believe the technologist's theory, but he has other practical concerns of operability that require answers. The technologist should be able to show the physical characteristics of a conceptual design (weight, shape, power, cost) and have worked and be conversant with the "ilities":

- reliability
- maintainability
- repairability
- durability
- manufacturability
- operability
- flexibility capacity
- survivability

The conceptual designers and TXA specialists should also have such knowledge; their function is to look across the spectrum of technology candidates to encourage synergism and solve misalignments. They become arbiters of symbiotic relationships.

Integration Team. Figure 3.4 shows the "Integrated Team" concept in terms of development time "windows." Key to the management of the concept is the location of the "window of opportunity." It is desirable to have a capable technical team in place when the window opens. When it shuts, the critical technologies of the aircraft subsystems are frozen to a "reasonable risk" level. This is referred to as the Technology Availability Date (TAD) and in peacetime it is usually set by a guess at time to develop and demonstrate a highly desired technology (such as a new engine or an advanced radar).

The "Integrated Team" concept has two strategic advantages. First, given the capability, a system development can be started sooner; or if the data is fixed, additional technology investigations can be made. Second, the credibility of the work is backed by a broad in-house project team with the skills and knowledge to do that specific job.

To develop the team there must be a period of low-key defense environment period much before the window opens. This allows time for the self development "training introduction" and "training window" phases to occur. Ideally, a significant size lab and TXA project office could be staffed from a training pool of people who have recently worked the specific aircraft system to be developed.

Their theoretical knowledge would be bolstered by practical engineering know-how embodied within the integrated team. Their productivity in the "system concept" window phase would be high, and ultimately they would represent significant leverage to the ASD commander as he formed the System Project Office (SPO), which officially begins the industry development phase. The Integration Team could consult, work for, or staff the SPO. The team would likely have significant technology exchange with their industry and EN counterparts. Opportunity for technology transition would be maximized. Analysis-free decisions and data-free analysis would be minimized.

The dynamic impact of this proposal is primarily a long-term disruptive one, as shown by the time frame in Figure 3.4b. There would be short-term oscillation due to delays and disruption, but the primary question to be answered here is, whether the immediate disruption of the training window can be regained and rebuilt to make an innovative impact in the "system concept" window phase.

Thus the TXA office has not been modeled from the micro productivity point of view, but rather from a LAB + TXA macro one. The questions to be answered are those of the gross feasibility of building an "Integrated Team."

- How quickly can a large pool be grown?
- How significant can an increase in capability be gained?
- How will this affect TXA's normal productivity?
- How can this process be introduced?
- How will the laboratories accept the concept?
- What are the measures of merit?

Expectations and Limitations. From the point of view of WRDC or industry, the "Integrated Team" proposal is evolutionary at best. From a WRDC prospective it would be a systematic shift (Tyre, 1990); a high change in the technology development process: "...it was not that the specific technical solutions were so hard to develop, but that we had to learn a whole new approach." This is also likely to be the perspective of the individual lab technologist assigned to the project.

From a TXA standpoint there is a question of just how far you can go without destroying its present "production" capability. Conceivably it could be completely turned into a training unit; practically speaking, such an end result is unprofitable. WRDC would lose a capability, and TXA staff would likely (rightfully) balk at a career change to teaching. The limits can be thought of in terms of maximum lab (students) training rate, minimum lab to TXA (student to teacher) ratio, and the loss of normal TXA production during the initial disruptive training phase. These factors are modeled by System Dynamics simulation in Chapters IV and V.

3.4 Scenario Requirement

The rate of pursuing an "Integrated Team" capability is scenario-dependent. "How soon and how large a new major project will be" will set the pace. If the project is fairly near term (one to three years after start) it will determine the magnitude of the role that a WRDC team can play. If the new project is far, the "Integrated Team" development rate and ultimate size will be determined by the relative scale of WRDC and TXA (should a team be 2x or 20x the size of the 25 TXA in-house engineers?); by cognitive capabilities (can a team be developed in 1½ years, ± six months?) and by the management of the program (how quickly will trained lab technologists "forget"?) -- should there be retraining (Red Flag) phases?. A real system development scenario (Advanced Tactical Transport) has been adapted (in Chapter VI) to help elevate the Integrated Team proposal.

3.5 Resistance

Resistance can be expected at various levels of management and staff. Initially the plan is personally and organizationally disruptive (Figure 3.4). it's a top-down policy decision and upper level management will need to take a long-term perspective on expected payback and profit.

Resistance - Staff. There will be a certain level of resistance from the respective staffs (TXA and LAB). Katz (1988) postulates that people in organizations go through three behavioral career phases. He describes the following:

- socialization -- six to eighteen months of getting to know the people and procedure (a rookie)
- innovation -- from socialization to six to twelve years; serious contributions and involvement in work.
- stabilization -- a secure niche, or "specialty," has been found, less willing to try new things, outside activities gain priority.

This last type often has the potential to contribute much due to their experience, but is motivationally limited by the (right) jobs within their present organization and position; career changes are not desirable.

Such a senior staff person may benefit from, as well as give benefit to, a team integration project: people with a high stage of knowledge in the product and process of the specific technology, who have skills, methods, and data to analyze, synthesize or completely model the technology. If this is the situation, they could interface with the design, operations, and other technologists in meaningful analytic ways. They would have the ability to let other team members know their needs (outputs, inputs) and also to be able to conceptualize design and adjust their technology to the needs of others. There may be an opportunity to develop an entirely new or expanded technology -- or they may discover a critical flaw in their present one. A careful screening should be made for such a candidate type.

Generally, the "Integrated Team" strategy allows candidates to learn new skills which complement their existing ones. It is motivational to contribute while at the same time to be re-energized by a new reachable challenge. It should not be a training program for new engineers.

Participating technologists should find themselves more marketable upon returning to their original organization. Their broadened view in the integration and operational aspects of the technology may put them in line for planning and leadership positions.

Finally, the whole purpose of the exercise is technology transition to a new or present operational system. Ultimately the technologist should be able to work for an SPO with a far better understanding of his candidate technology. His newly honed credibility will be recognized; his help should be sought.

Resistance - Supervision. How will lab supervisors react to co-locating their good senior people to such a project, even on a temporary basis?

- "The supervisor's supervisor won't let him/her go."
- "There is too much work" -- permanently or temporarily.
- "They may never come back."
- "It might interfere with their next promotion."

These and more creative ones will all be used. The decision shall have to be a top management one and a strategy to encourage cooperation shall have to be devised to keep mid-management from electing less than desirable candidates.

A short-term payback commitment to the contributing organization may help, e.g. including a favored technology in a training project, a special methodology development, etc.

The ultimate benefits of this plan are scenario-dependent and likely long term to WRDC. Contributing first and second level supervision will likely need to see several successful cycles before their resistance lowers.

Resistance - Upper-Level Management. Productivity is defined as the value of the goods manufactured divided by the amount of labor input. Manufacturing studies (Skinner, 1980) have suggested a "40-40-20 rule" as the best way to increase productivity:

- 40% - long-term decisions on capital and operations of the workforce and management.
- 40% - Equipment and process technology.
- 20% - Cost and efficiency concentration.

If the "Integrated Team's" R&D development process relates somewhat to a manufacturing process, then it is suggested that the leverage of the proposal is analogous to the first and perhaps second 40% strategies.

Upper-level management (of technology) must envision the "Integrated Team" capability as a value-added on the macro level. It should give management the ability to capitalize on a future opportunity either to initiate or accept a substantial start-up opportunity. It has much to do with risk-taking, and ultimately their reputation and fortune are at stake. It will take staying power.

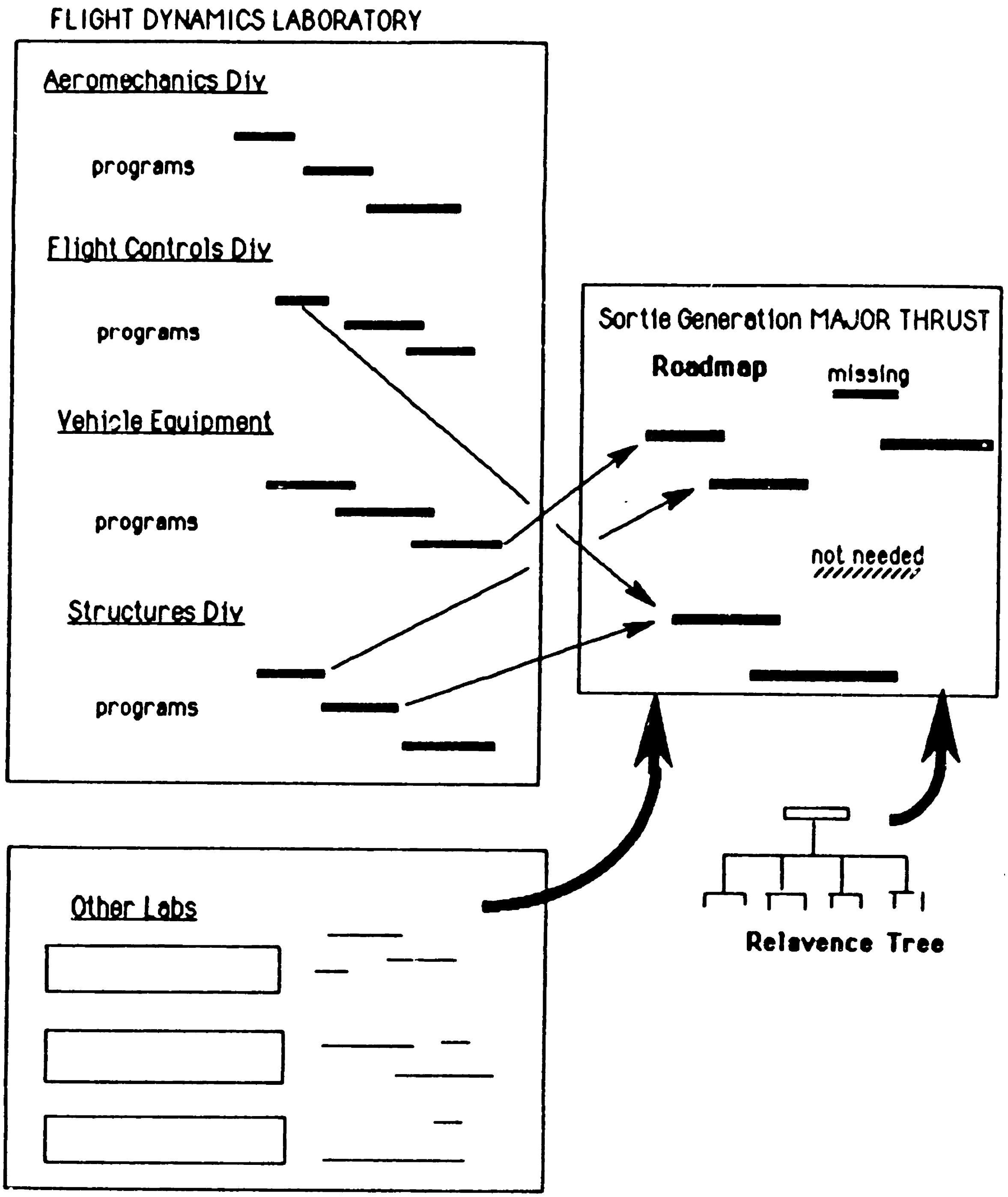
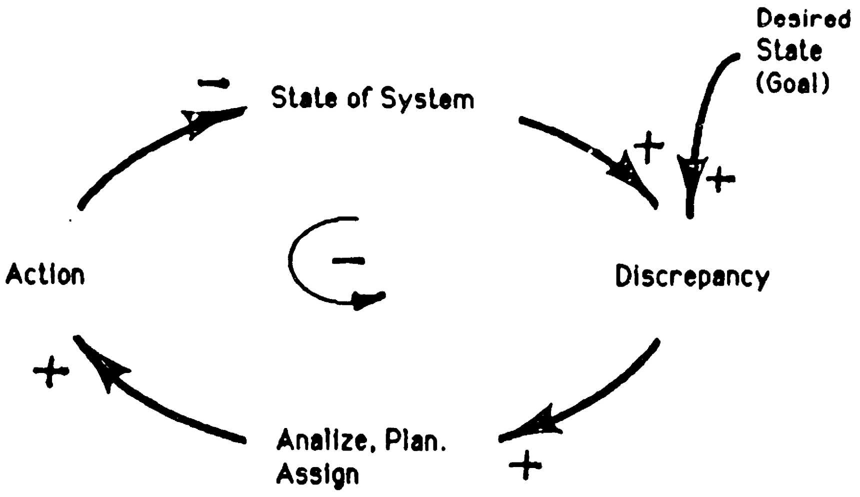
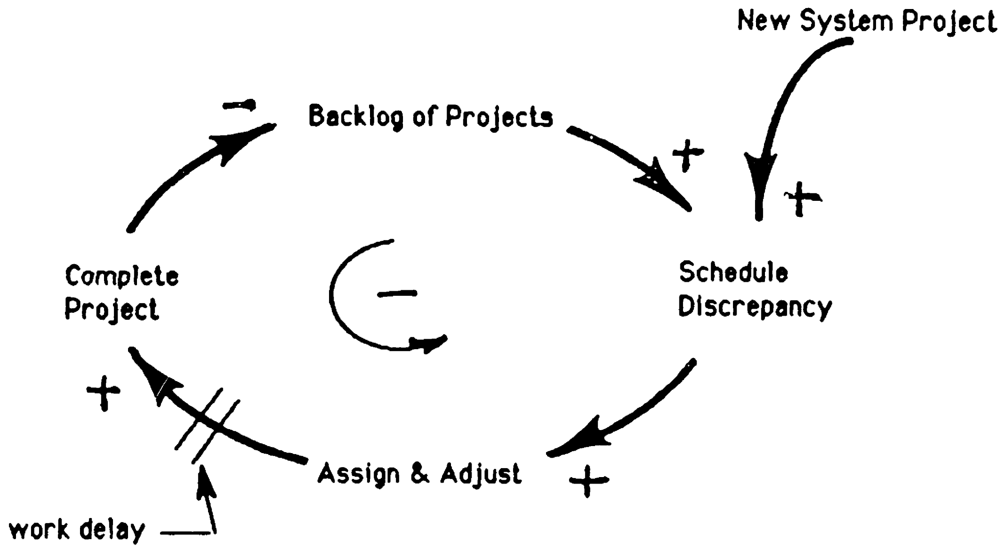


Figure 3.1 The MAJOR THRUST Ppocess



General Process of System Dynamics
(goal seeking)



System Concept Process

Figure 3.2 System Concept Process

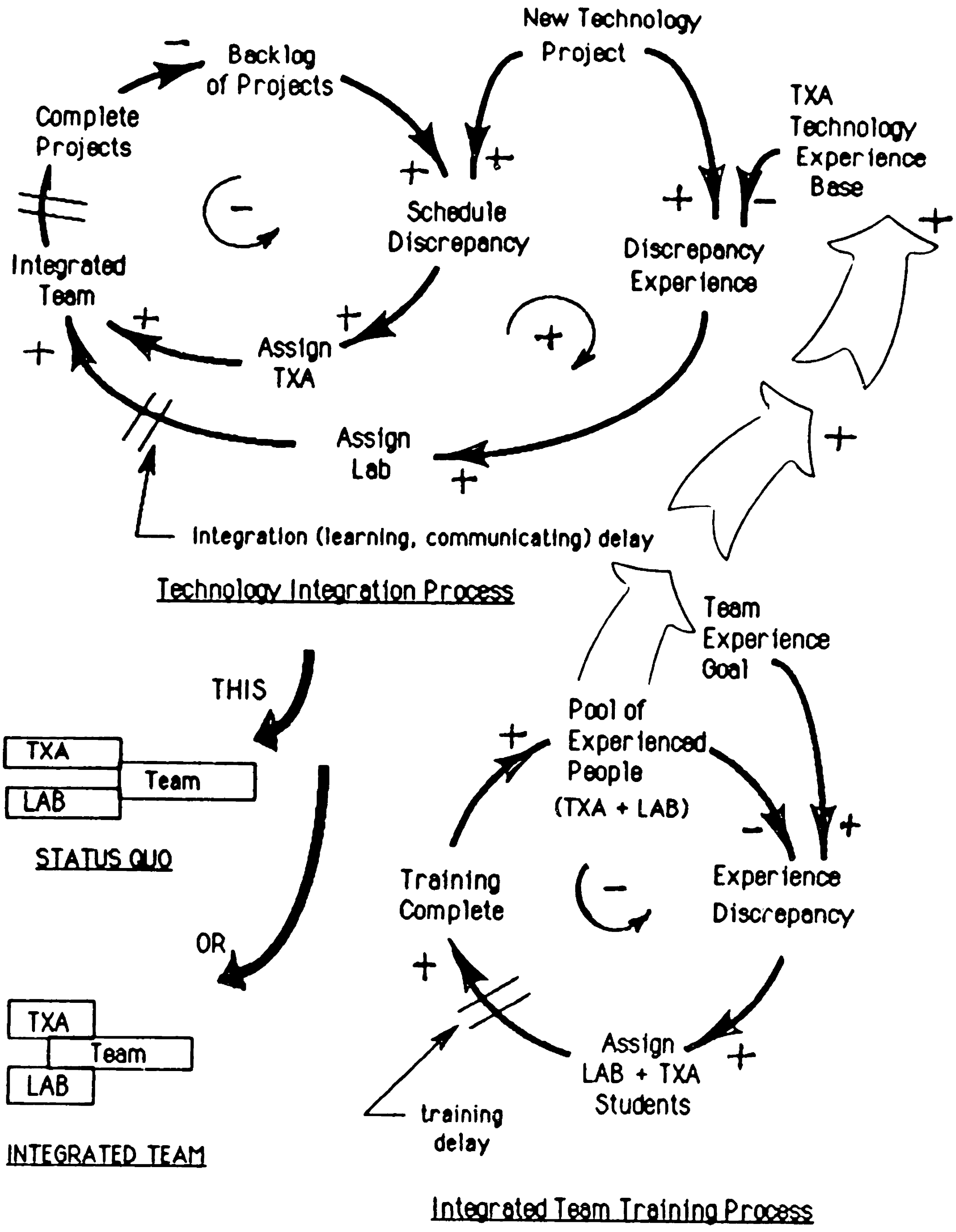
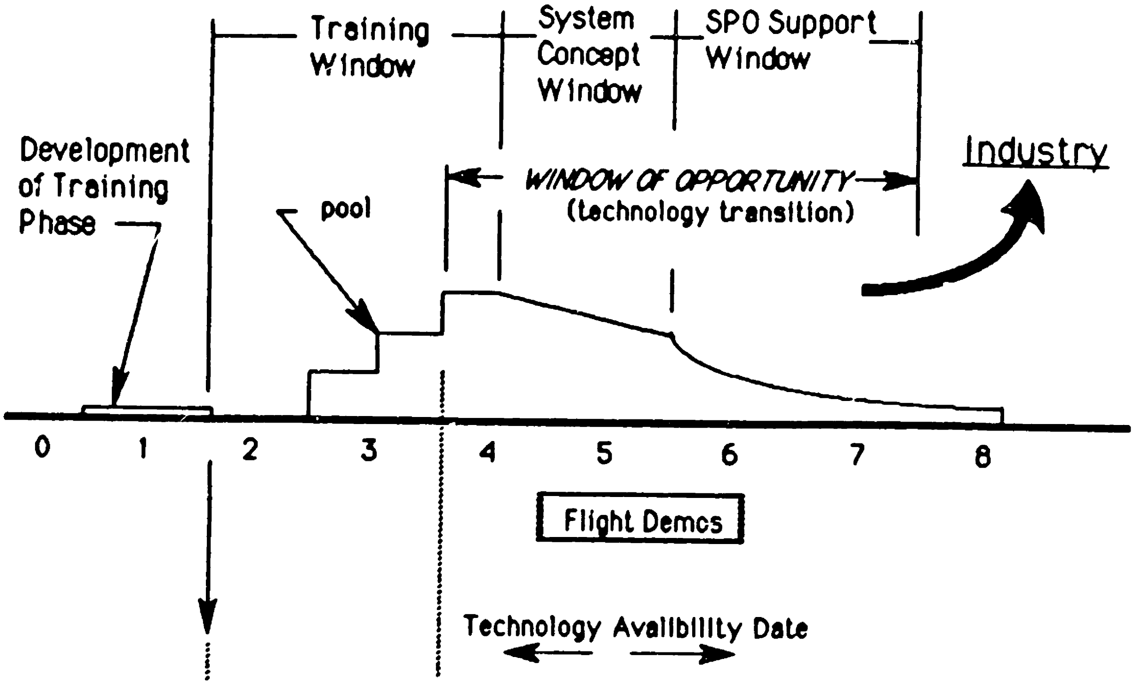


Figure 3.3 Technology Integration Project

fig 3.4a



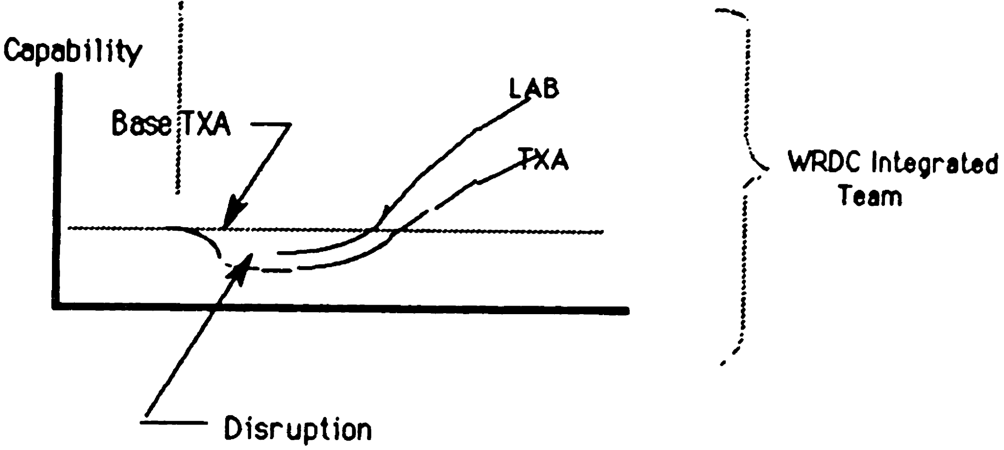


fig 3.4b

Figure 3.4 WRDC Integrated Team Time Horizon

CHAPTER IV

INTEGRATED TEAM PROCESS -- THE INTRODUCTION PHASE

Tyre (1990) focuses on the process of [successfully] introducing new production technologies into existing plants. The term "forums for change" is used to explain a process innovation that coexists with ongoing operations, and where the operator should "step back temporarily in order to reflect and build on their experience with the new technology." The introduction issue, of course, is the proposed WRDC "Integrated Team" R&D process.

A specific three-step introductory procedure was suggested and is further guided by some general management strategies to create an effective learning environment:

4.1 General Strategies

(1) Focus attention on learning and problem solving, e.g.:

- pre-introduction formal classes (local universities);
- mix of class work and "canned" projects and methods;
- consultations with lab home offices.

(2) Provide protected environments for developing and testing new ideas, e.g.:

- a classroom, a team room (Allen, 1986);
- maximum number of short-term, achievable projects;

(3) Bring diverse perspectives to problem definition and resolution, e.g.:

- the "right" mix of team people and technologies.

- More than one, but less than five technology candidates.

(4) Multiple resources, e.g.:

- TXA-administrated support (secretaries, supplies, phones, computers, ...)
- TXA technical support (methods and data availability, consultation, ...)
- Tap consultant expertise
- Technically qualified, charismatic leadership.

4.2 Start-up, Three Steps

Initial start-up steps are necessarily in the following sequence: "Preparatory Search," "Joint Search," and "Functional Overlap." The order in each section should be prioritized and put on a time line.

(1) Preparatory Search. This phase will identify and address the "Integrated Team" policy issues, i.e.: operational, organizational, development, and implementation.

- Facility arrangements
- Syllabus, initial draft
- Lab and TXA applicant screening process
- TXA Technical Team: tentative methodology and project objectives
- TXA/Lab initial planning team: draft plan, off-site meetings
- Thesis scenario (system starts) expansion
- Thesis simulation expansion (scale of possible growth rates)
- WRDC training office (announcement process and materials)
- personnel office support and approvals;

- draft of overall plan including ultimate goals and intermediate measures of merit;
- TXA "Integrated Team" Project: Project leaders, Principle Engineers, WRDC Staff Engineers (this may be a new TXA group with temporary TXA assignments plus permanent WRDC staff assignment(s));
- WRDC Steering Committee;
- preliminary meetings with WRDC and ASD management.

(2) Joint Search. Adds outside expertise to fully develop the process and its infrastructure.

- Contract special support
  - Project management consultant
  - Team building consultant
  - Academic critique of draft syllabus
- Meetings with specific management organizations to align and focus plan and to develop a support base
  - WRDC Laboratory and Division Heads
  - ASD EN (engineering) and SPOs (System Project Offices)
  - Top management (ASD and AFSC)
  - Liaison officers of Specified Commands
- TXA preparations
  - Assignment of initial instructor/integrationists
  - Development of technical materials
- Lab preparation
  - Assignment of initial student/technologists
  - Formal and informal course preparations

- "Integrated Team" update of draft materials

(3) Functional Overlap. Is a first trial, limited, on-site operation with actual participants, emphasis on fine tuning the plan for full go-ahead approval.

  - Small select initial team on a scaled-down syllabus
  - Weekly reports by members and WRDC staff engineer (progress, misalignments, innovations)
  - Management (TXA and Lab) technical review, personnel review
  - Revision of plan and syllabus for full "production" operations
  - WRDC management value review/due diligence:
    - Go-ahead decision
    - Scale and ramp up decision
    - Technology set decision

4.3 Start-up, Simulation Model

A "casual loop" diagram of the total process is shown in Figure 4.1, and diagrams of the individual three steps are shown in Figure 4.2. The casual loops are a means of providing a structure for study and learning. Ultimately quantitative simulations should be carried out to prove/disprove the model hypothesis.

The logic of Figure 4.1 gives reason to the 1-2-3 sequence of the introductory steps. The process starts at the outer "loop" and follows to the inner ones. A temptation to prematurely jump to an inner loop may eliminate a critical task, which will stall or derail the project at a later stage.

(1) Preparatory Search Algorithm. Figure 4.2a shows this phase to be a function of the number of in-house planners and their knowledge base. Management pressure (enthusiasm) could add to their productive hours, but is likely secondary, assuming a motivative staff. Existing similar plans (knowledge base), possibly available, would speed the completion. The model represents would represent the "plan" as a combination of documents (syllabus draft, methodology drafts, etc.) and knowledge (gained by the staff). A more complex model would represent these separately (disaggregated). This approach would be taken if one were interested in the planning process rather than in the plan itself.

(2) Joint Search Algorithm. Figure 4.2b is a more complex model by virtue of the added stock of outside planners. This phase cannot (should not) start until the inside planners have completed the work which supports this second phase. An amount of concurrence can be seen. Part of the time they must work jointly with the outside experts whereas part might be spent finishing other parts of phase one.

(3) Functional Overlap Algorithm. Figure 4.2C also has a dual set of people completing a common project, except in this case it is Lab people (learning, then working in TXA) and TXA people (teaching, then working in TXA). The speed of training and the degree of knowledge is a function of the quality and completeness of the syllabus. Another important but less obvious parameter (Allen, 1986; and Tyre, 1990) is the "Integrated Team" facility/mode of communication. A primary factor herein is co-location; a second

factor is the protection of the office from the distractions of the normal work of the surrounding office (TXA).

Figure 4.3 is a schematic which suggests this relationship. It contains three teaching sessions and two project phases. The projects are paced by a degree of difficulty which is pre-set (by the syllabus) in anticipation of the student learning rate.

This phase of the plan should have flexibility in the timing and difficulty of the three parameters. An adjustment of these amounts to a critical adjustment to the syllabus to maximize the "Integration Team" integration rate. The goal of the functional overlap task.

4.4 Causal Loop Behavior Analysis

The causal loops describing the model of the project team operation were shown by Figures 3.2 and 3.3. The basic job is shown by Figure 3.2; the normal work of TXA (or any organization) receiving a new job order that is within its capability. The assigned work must simply be adjusted for. Figure 3.3 is the case where the experience base is judged inadequate for the new job; e.g., a leading edge technology assessment assignment for TXA. As shown in the figure, an additional experiences building task is required, e.g., cross-training LAB and TXA staff. This phase always requires additional time, and the policy question, then, is whether to do the training integration before or after the project starts. "After project start" is the status quo situation; "before" is the proposed "Integrated Team" strategy.

Not shown by Figure 3.3 are some key issues:

(1) The experience building task can be done before as well as after the primary task is requested. The labor expended would likely be the same magnitude. If it is not, it means someone else is doing part of the work -- the front part. Leadership lost.

(2) If added after, specific information (data, questions) would likely be available for an efficient start-up. If added before, you may also have trained the wrong set of technologists and have to start anew. However:

- (a) Have you lost any ground? No.
- (b) Have the "wrong" technologists lost ground? Perhaps.
- (c) Are you in better shape if the right technologists were trained? Yes. You should be in much better shape in that the first tier of (straightforward) questions should have been addressed. The chance of arriving at a much better solution is improved (Figure 1.4). The start-up problem is likely to be more of one to educate the decision makers as to what the key questions "ought" to be (note: this is what technology transition is all about).

(3) Large and/or complex jobs are virtually directed to the firms with the labor and capital assets in place. Taking time to develop an experienced staff may be prudent, but it is equivalent to a "no bid" in the real world.

(4) Finally, although the process of Figure 3.3 is described from a TXA task perspective, the causal diagram is generic. It is perfectly adequate to address a lab technologist's project where TXA experience (in integration of systems) may be needed.

A simple estimate of the last Functional Overlap phase would be an adaptation of the "learning curve" (each time the repetition of a task is doubled, the time to accomplish this is decreased by a constant percentage -- say 75-95%). Thus only the first project + class time would have to be estimated. The problem is that each cycle would have to be identical, whereas in the desired learning situation it is likely desirable to increase the complexity of the cycle in order ultimately to achieve a high-level goal.

To accurately model this would be challenging. Partial theories on learning and behavior would be required. Intense work on these subjects is going on at MIT (Graham & Senge, 1990) including the impact of team organization and coordination on learning and performance. Allen (1986) has conducted a number of investigations on the impact of communications and facilities on project performance.

The general level of "degree of difficulty" can be estimated for particular jobs by people doing them (TXA and lab people). If learning can be compared to an athlete's conditioning program, a technique may be to short-cycle the intensity but with an upward long-term trend to "condition" the participants. This is the intent of alternating in-class knowledge building and on-the-job project work. Consensus building and cross-training are essential ingredients of the syllabus. Student aptitude and other non-measurable would have to be analyzed by a scenario approach. A range of time to achieve a capability could be forecasted, but the real payoff would be the increased understanding of the process, its difficulties, and the endogenous leverage points to increase the overall value added.

The next stage in this modeling process was to build and run a system dynamics simulation model. This proved both insightful and beneficial from an Integrated Team program understanding standpoint. Shifts in fundamental modes of behavior are possible. This could be a systemic shift for WRDC, and it is a major one for TXA.

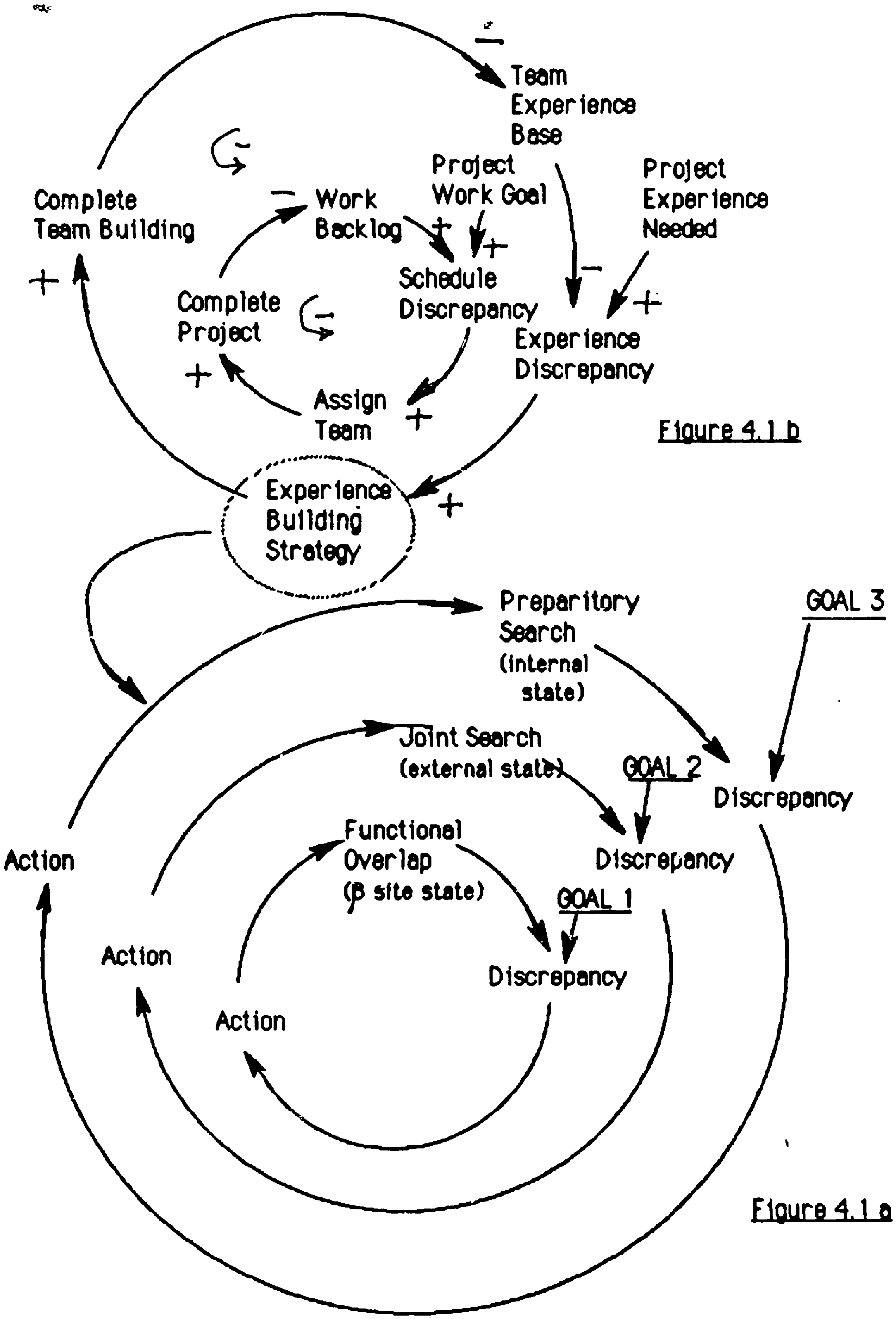


Figure 4.1 Introduction of Experience Building Strategy

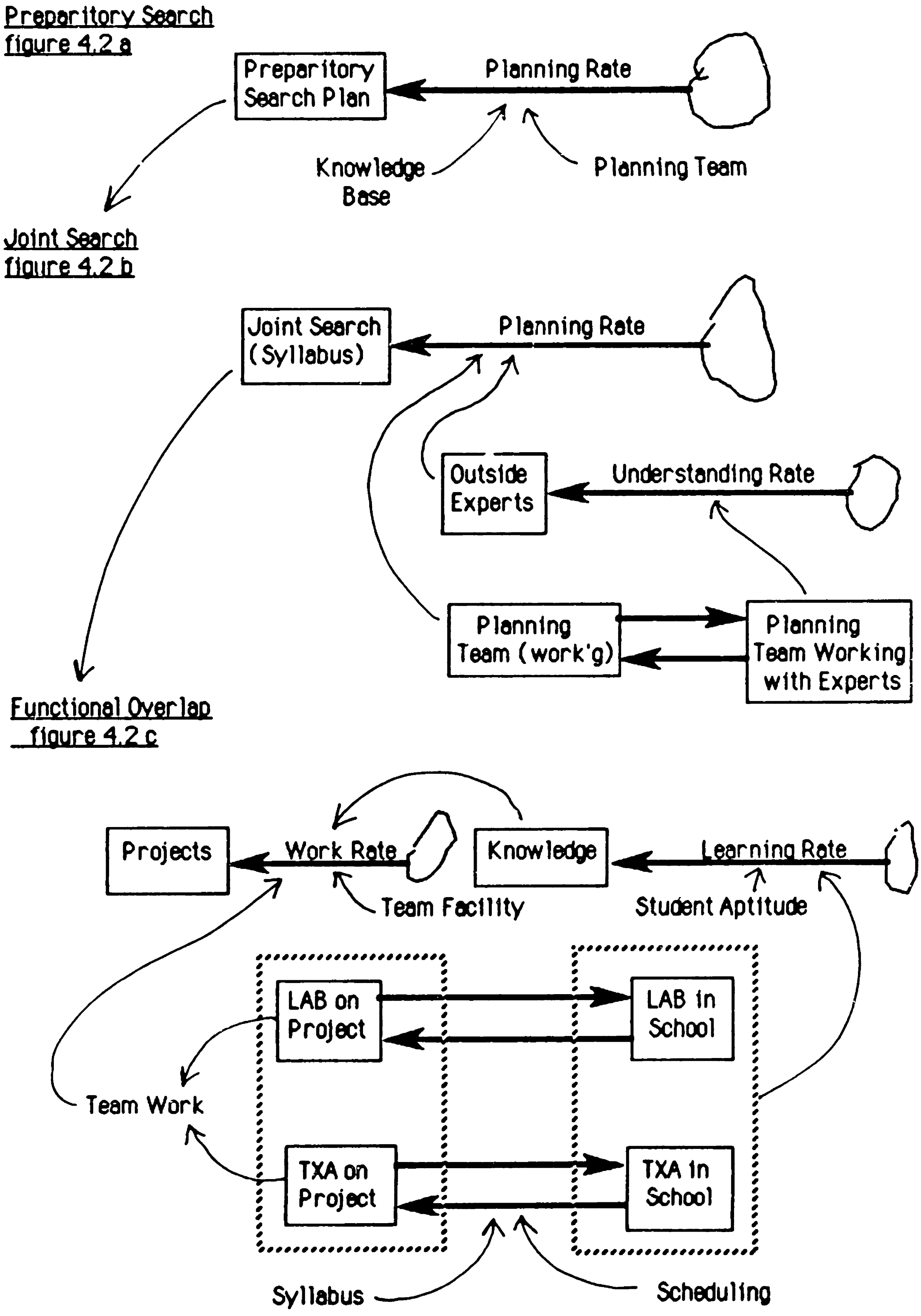


Figure 4.2 System Dynamics Diagram of Experience Building

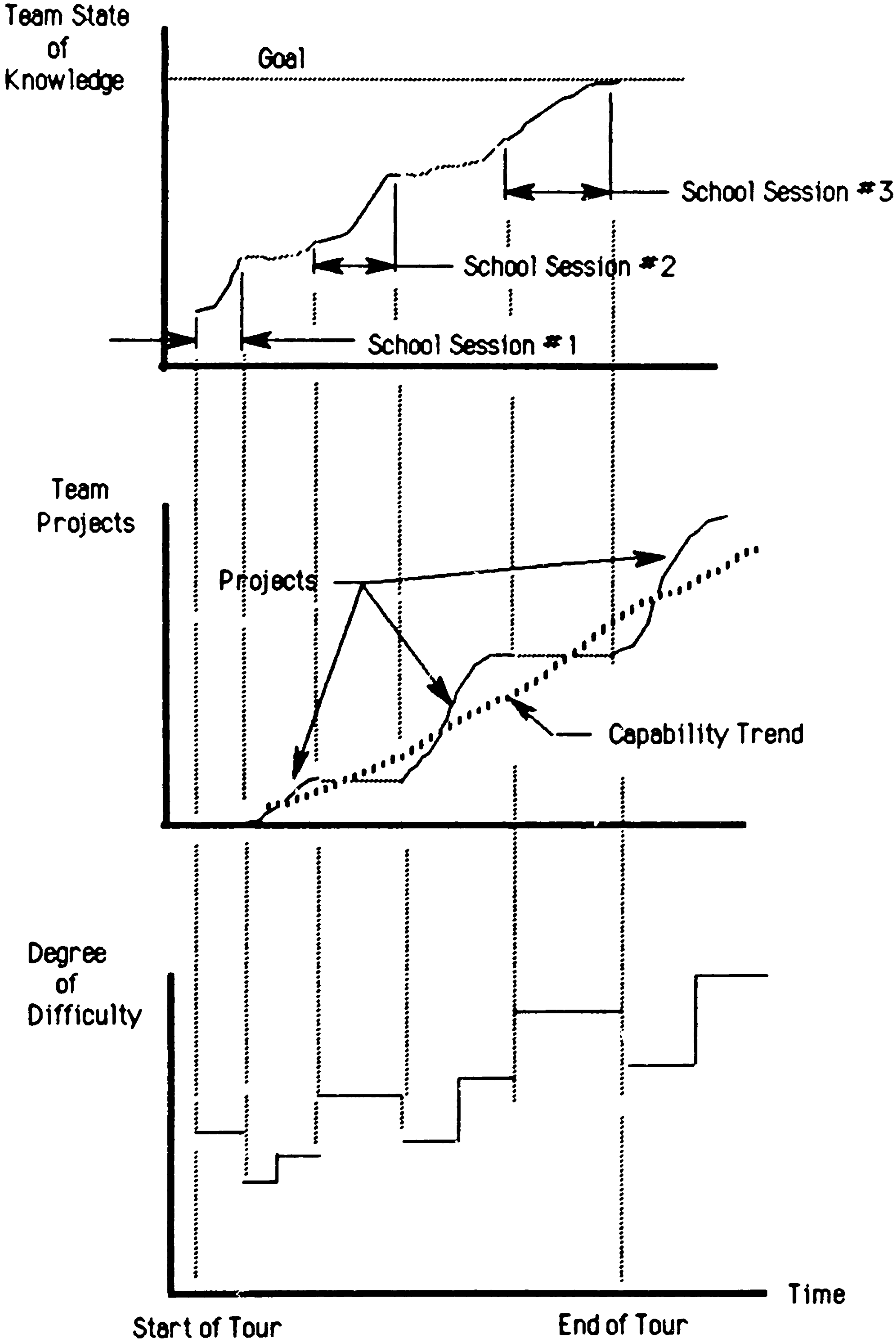


Figure 4.3 Functional Overlap Performance of Integrated Team

CHAPTER V

INTEGRATED TEAM: GROWTH SIMULATION

The problem is, "how to grow the Integrated Team?" Naturally, it is desirable to grow it as fast as possible without damaging the normal working integrity of the TXA office and without compromising the quality of the resulting WRDC team. A system dynamics simulation model of the process was built to help generate and answer the key questions. The underlying strength of this approach is that the model must both "run" and make sense. The questions (and answers) fit into three groups: basic program dynamics, issues of efficiency and validity, and major policy trade-offs.

5.1 Basic Dynamics

Time Horizons. As discussed previously (Figure 3.4), a four- to eight-year "Integrated Team" growth process is envisioned. Figures 5.1 and 5.2 show the expected mechanics of the short-term training periods and the long-term benefit of increased project capability. Also shown is the initial disruption in TXA capability due to its new role of "teacher." The following concept of operation shows the parameters and boundaries of the growth scenario:

> Small groups of "lab students" (one to ten) would periodically be assigned (every one to six months) to work with the TXA office for a training/working tour (one-half to two years). Eventually (four to eight years), when a large system development project appears on the horizon, the previously trained people would be recalled from the lab "pool," be reassembled into a large Integrated Team for in-

> depth engineering studies of the candidate technologies. This team would be "in place" at least a year before the System Project Office (SPO) was formed.

The object then was to capture this in a system dynamics simulation to highlight the real issues of Integrated Team growth, quantify the boundaries, and select a preliminary baseline growth plan.

Model Structure. A general diagram of the basic model was shown by Figure 5.3; the specific computer model (diagram and equations) are documented in Appendices C and D. The model simulates three separate actions taking place over a period of time. The first, in the uppermost diagram, represents work in progress, simply:

Products = Productivity * Integration Team

where: Productivity = Projects/Month/Man
Integration Team = TXA people + LAB people.
Products = interdisciplinary, multi-task projects

Productivity within the TXA office varied with the size of the project. Shorter jobs tended to be more of a simple question. They experienced fewer interruptions, less need for detailed knowledge, and short documentation. Figure 5.3 shows the range of values. A mix of large through small jobs was selected and a weighted average used for "product" calculations. The value, which is about 1, is shown in the code (Appendix D).

The lower diagram in Figure 5.3 or Appendix C represents the activities of the LAB and TXA people who are in the program. The links between the two are the lab and TXA people in the training (algorithm shown by Figure 5.4) and the "graduates" working on "products." The training function is shown graphically in Figure 5.4. The assumptions and rationale include:

- subject complexity (technology type and maturity)
- required capability and practical boundary
- teaching resources (student-to-teacher ratio)
- syllabus approach (Figure 4.3)

Student aptitude is inherently part of the structure.

The model is at the highest level of aggregation; its present simple structure is believed to be adequate to capture the primary dynamic of the growth operation. Additional "realisms" are added later for sensitivity reviews.

<u>Model Logic and Operation</u>. A manager or organizational scientist should understand the logic of the model in order to design or evaluate the results. It is controlled through the "assign" and "student-teacher-des" inputs:

- assign -- (laboratory people assigned per desired time period)
- student-teach-des -- (student teacher ratio desired)

Desired student-to-teacher ratio -> transfers TXA people into and out of the teaching role.

Actual student-to-teacher ratio -> determines the rate of Lab graduates.

These are duplicated on the lower diagram of Appendix C to represent a control panel.

A manager's goal may be to train a large "Integrated Team" both "quickly" and "smartly." This would mean a high assignment (assign) rate and a low student-to-teacher ratio (student-teach-des). Carried to the extreme, such an approach could drain TXA to provide desired teachers; the actual student-to-teacher ratio would climb, the graduation rate drop, and students would "stack up" in school.

In the real world it is likely that the system would simply graduate less capable students on time, thus passing its problem to the next phase of this activity (system development). Since the next phase happens in the distance and outside the model boundaries, the real cause of the problem, the aggressive training goal, is likely to go unobserved. The TXA normal production going to zero in the short term would be more obvious. A series of parametrics have been run to better understand the problem.

Model Behavior. The "Integrated Team" growth behavior should either fulfill management expectations or show where they are unreasonable, and why, and allow them to design a system that works. A small parametric study was made to examine the team size possibilities and the extreme of the control parameters where breakdown can be expected. The results are shown in Figure 5.5 and Table 6.1.

The magnitudes are "about right" but detailed modeling and analysis development would be needed before solid recommendations could be made (see "Issues of Efficiency"). The class size (number of lab students every three months) can seem to be the strongest parameter. The degradation of TXA "workers" to about half the office size (25 goes to 15) is a signal of trouble, and a detailed look at "lab-in-school" is shown by Figure 5.6. The problem is that the larger size of the class would probably interfere with the learning environment of the lab technologists. Note that the discontinuous shape of Figure 5.6is due to the "pulse" command in the computer logic. Each class assignment and graduation is actually a discontinuous pulse; the graphics simply connect the points to give a saw-tooth rather than a square-wave pattern. The important characteristics are the range of class size and whether they are stable or growing.

A "baseline" Integrated Team case was selected from the parametric study and its growth details are shown in Figures 5.7 through 5.10. It represents a class size of six student assignment (each 3 months), and a student-to-teacher ratio of 5. Although TXA does not collapse in this case, there is a penalty, namely, the projects lost due to the additional TXA teaching role. This is shown in Figure 5.10.

Preliminary Results and Conclusions. The model represents a start for additional analysis and strategy options. The model suggests that at least 48 to 60 lab and TXA people could be trained in four years, and 144 to 162 in eight years (Table 6.1). Their production capability (projects completed per year), including the TXA base of 28, would increase to the 148-186 range in four years, and 658-795 in eight. These capabilities are compared against a realistic system development scenario in Chapter VI.

The model thus represents a start for additional model development and strategy options.

5.2 Issues of Efficiency and Validity

The validity of the model's training function was discussed above. Obviously other important parameters could, and some should, be included in the model. As an example, a model modification was made which included a LAB "rookie" factor (Sterman's [1990] People Express Model), and a TXA disruption factor (Byrnes, 1990). The diagram and functions of this new model are appended (Appendix E). and a simulation is compared with the baseline case (identical inputs) in Figure 5.11. The degradation is subtle but realistic.

The new information is not necessarily more correct than the baseline, but it does point out the need for further model test and development. The following is a list of candidate model updates:

- Rookie factor
- Disruption factor
- Consensus & team bldg
- Technology complexity
- Team mix factor
- Forget rate
- Resistance
- Syllabus
- Experience base
- Burn-out

- Work pace and pressure

Data for some of the above factors may be unavailable, or even non-quantifiable, but if the modeler realizes (believes) they are critical, there are methods (STELLA, 1987) which should be used.

From the point of view of the system designer these model enhancements and updates can be made to obtain a creditable maximum lab pool growth and project work rate. Further, such efforts should be made in collaboration with the management "decision makers" and the follow-on system development System Project Office (SPO). The reasons are:

(1) Some of the non-material and/or non-quantifiable system behavior should include their perceptions and mental models of a risky world.

(2) Changes in model performance due to changes in these perceptions is a learning experience -- part of the decision process.

5.3 Major Policy Trade-Offs

The model validation point does not necessarily come with a single model or a single use of the model. If it is imperative to grow the system (Integrated Team) rapidly, other strategies can be tested with the aid of the (updated) model:

(1) The model can simulate periodic changes in the operating point by breaking the time horizon into a series of smaller segments and resetting the initial conditions at the beginning of each new period. For example, a maximum performance period could be alternated with a recovery period.

(2) A similar strategy would be a policy of transferring a portion of the trained lab people to TXA at the end of each tour. The growth in TXA would provide a compound growth effect in the succeeding training cycles. Table 5.2 shows such a scheme.

(3) Another strategy may be to set up mini TXA satellite organizations in some or all of the WRDC laboratories and directorates -- sort of a global operation within the world of WRDC.

These and other strategic or tactical possibilities have unique benefits and penalties, some of which can be measured with the aid of a simulation model, while some would be exogenous. Examples of the latter could be rigid organizational roles, political realities, personal operational standards, etc. These may set limits on the ranges of the variables or even which are or are not the variables. Ultimately the model(s) would have value only if it can correspond to the way things are actually done.

A realistic scenario set is outlined in the following chapter to provide growth goals and also an operational perspective for the "Integrated Team" R&D process as it enters possible variations of an Air Force system development program.

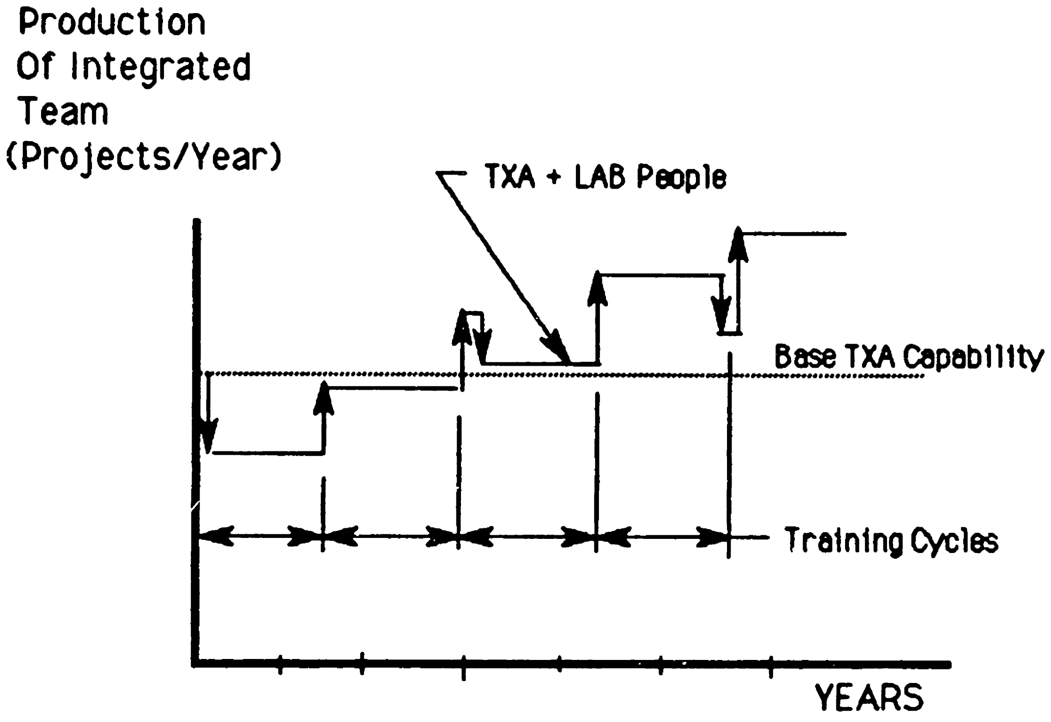


Figure 5.1 Integrated Team, Training Cycle

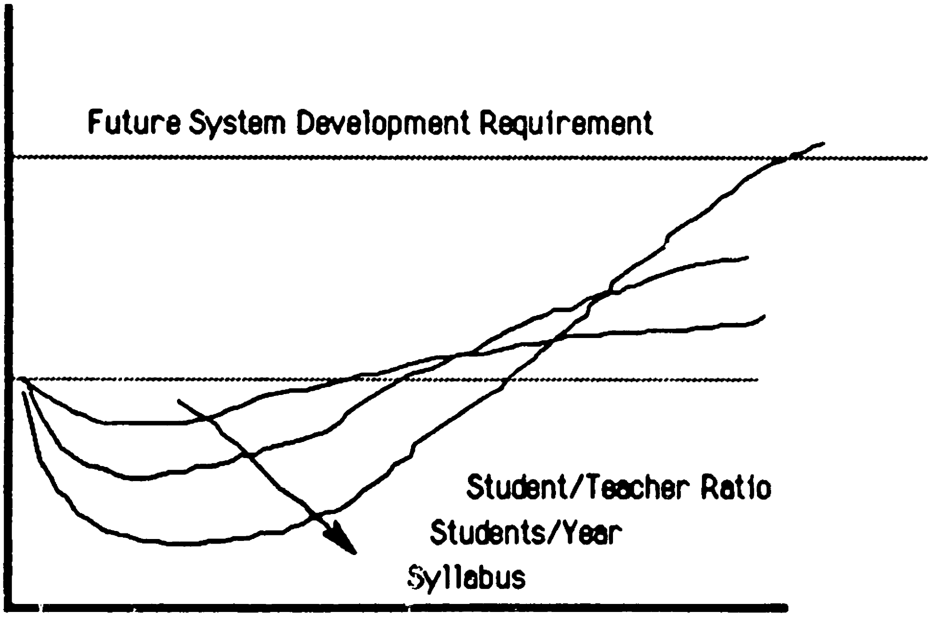


Figure 5.2 Integrated Team Management Control

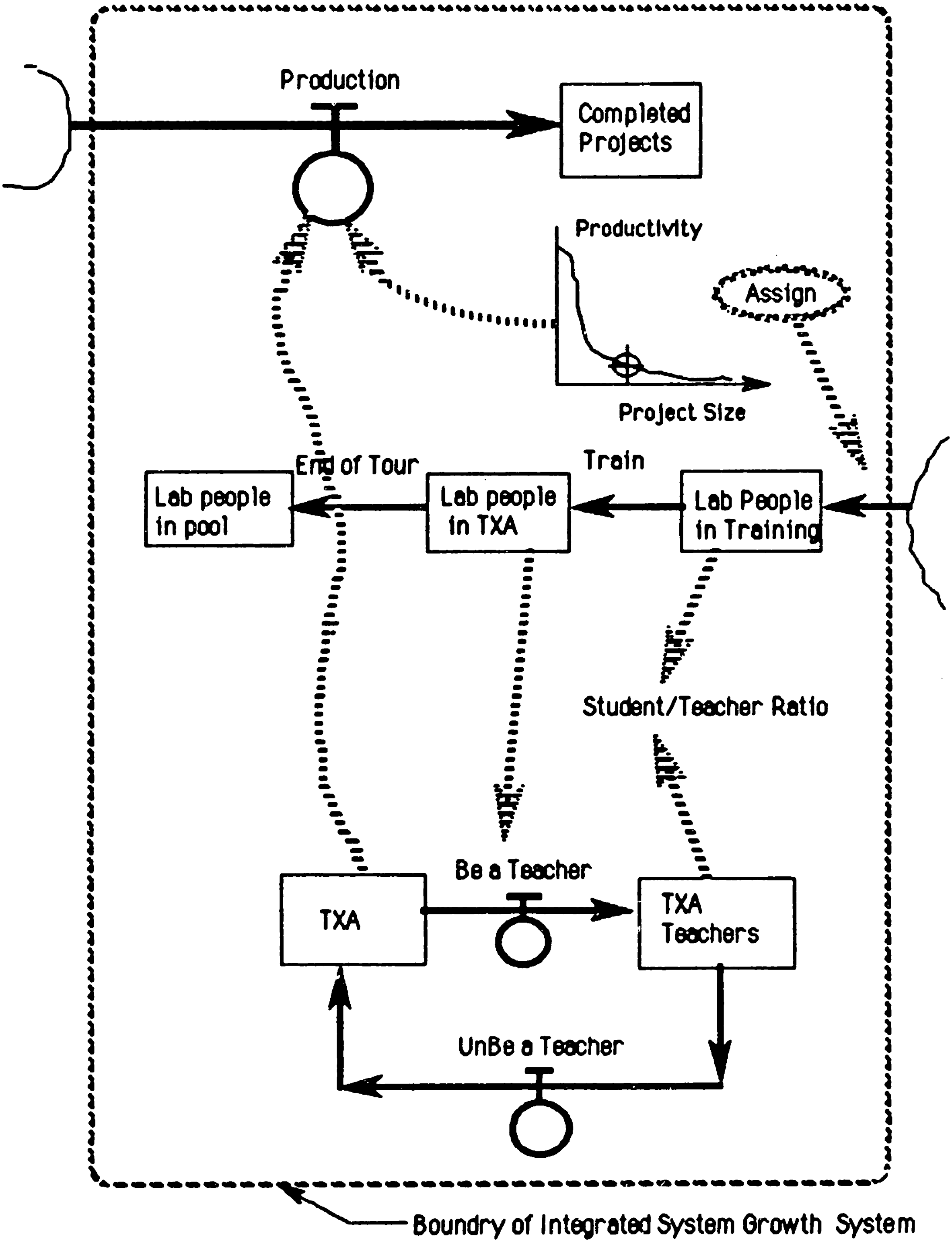
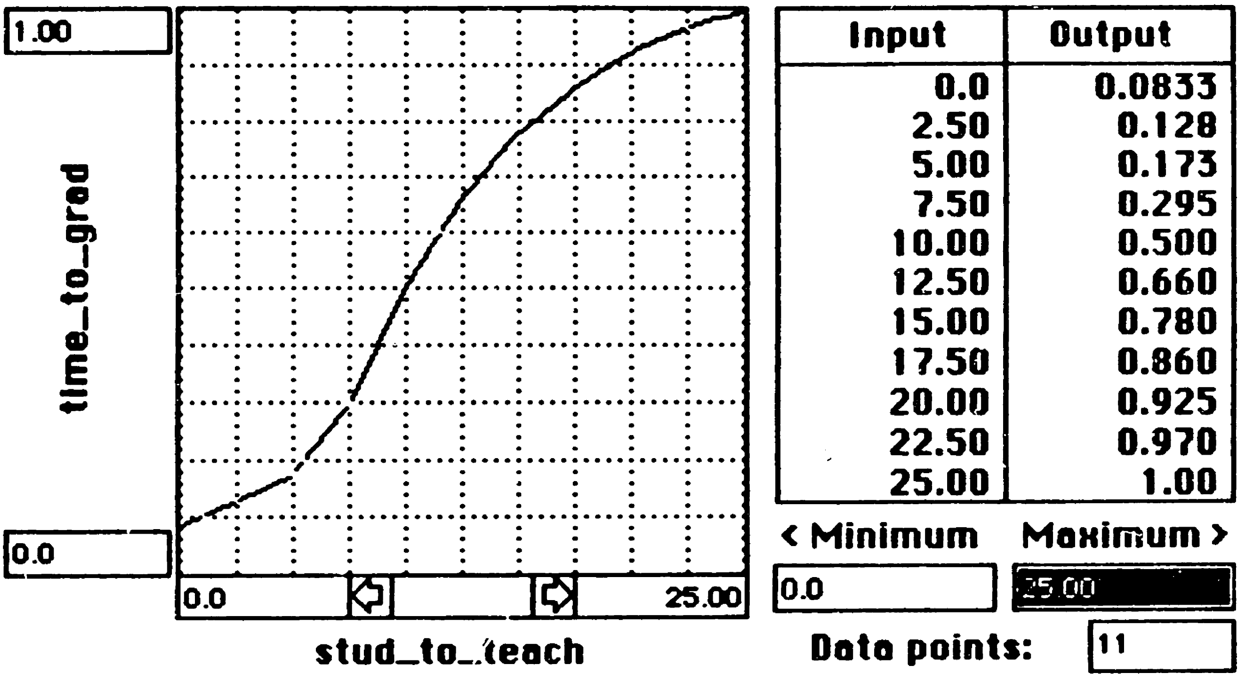


Figure 5.3 Integrated System Growth Dynamic Model



Input	Output
0.0	0.0833
2.50	0.128
5.00	0.173
7.50	0.295
10.00	0.500
12.50	0.660
15.00	0.780
17.50	0.860
20.00	0.925
22.50	0.970
25.00	1.00

< Minimum: 0.0
Maximum >: 25.00
Data points: 11

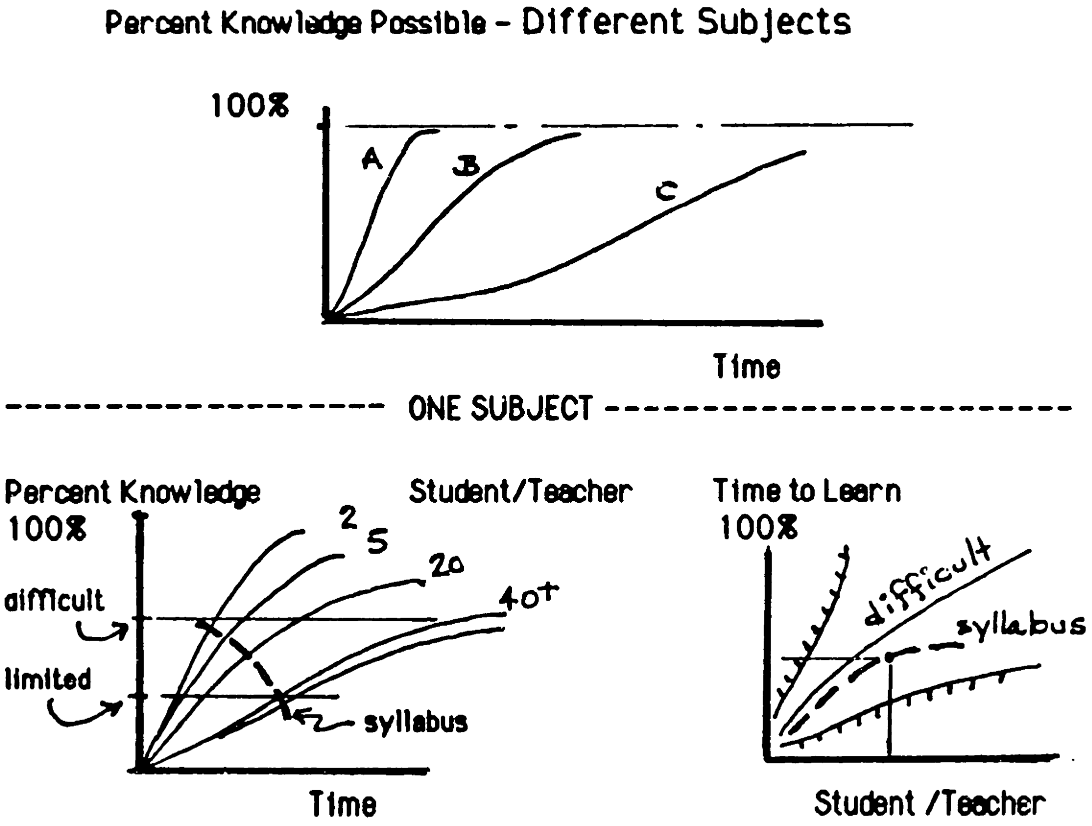


Figure 5.4 Training Rate Algorithm

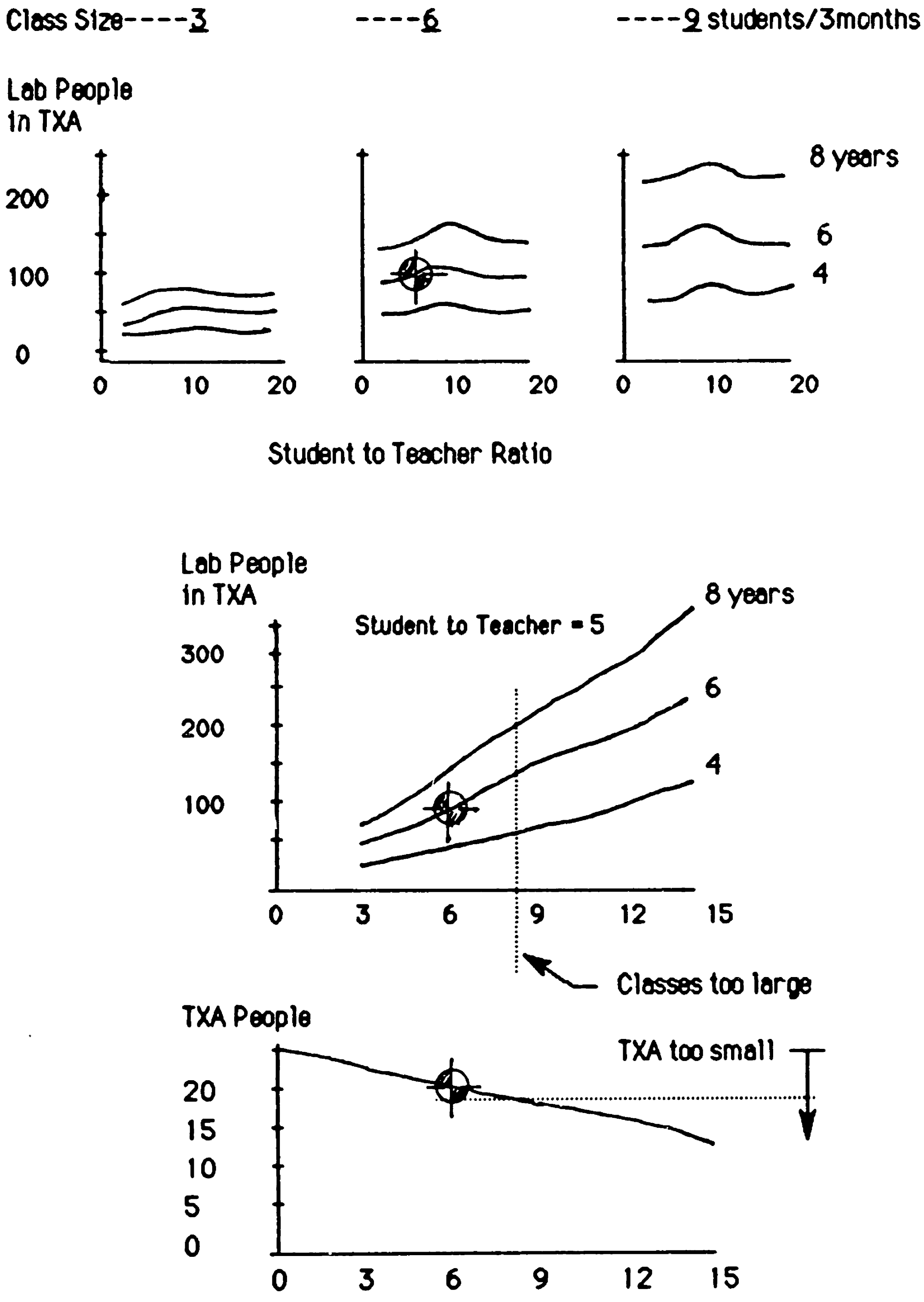


Table 5.5 Parametric Study, Integraded Team Growth

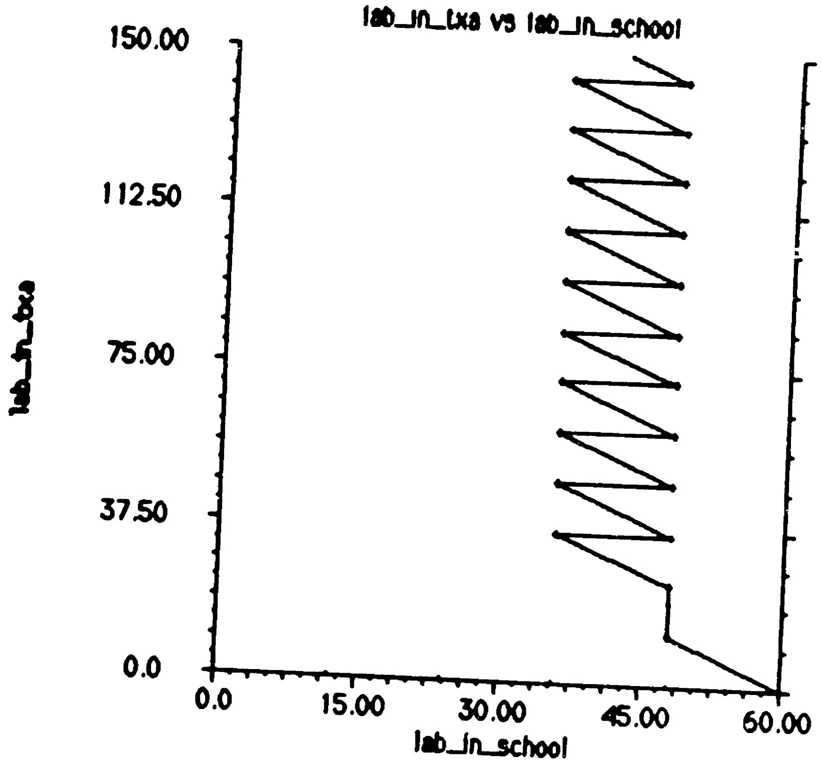


Figure 5.6

Lab in School - Oversize Case

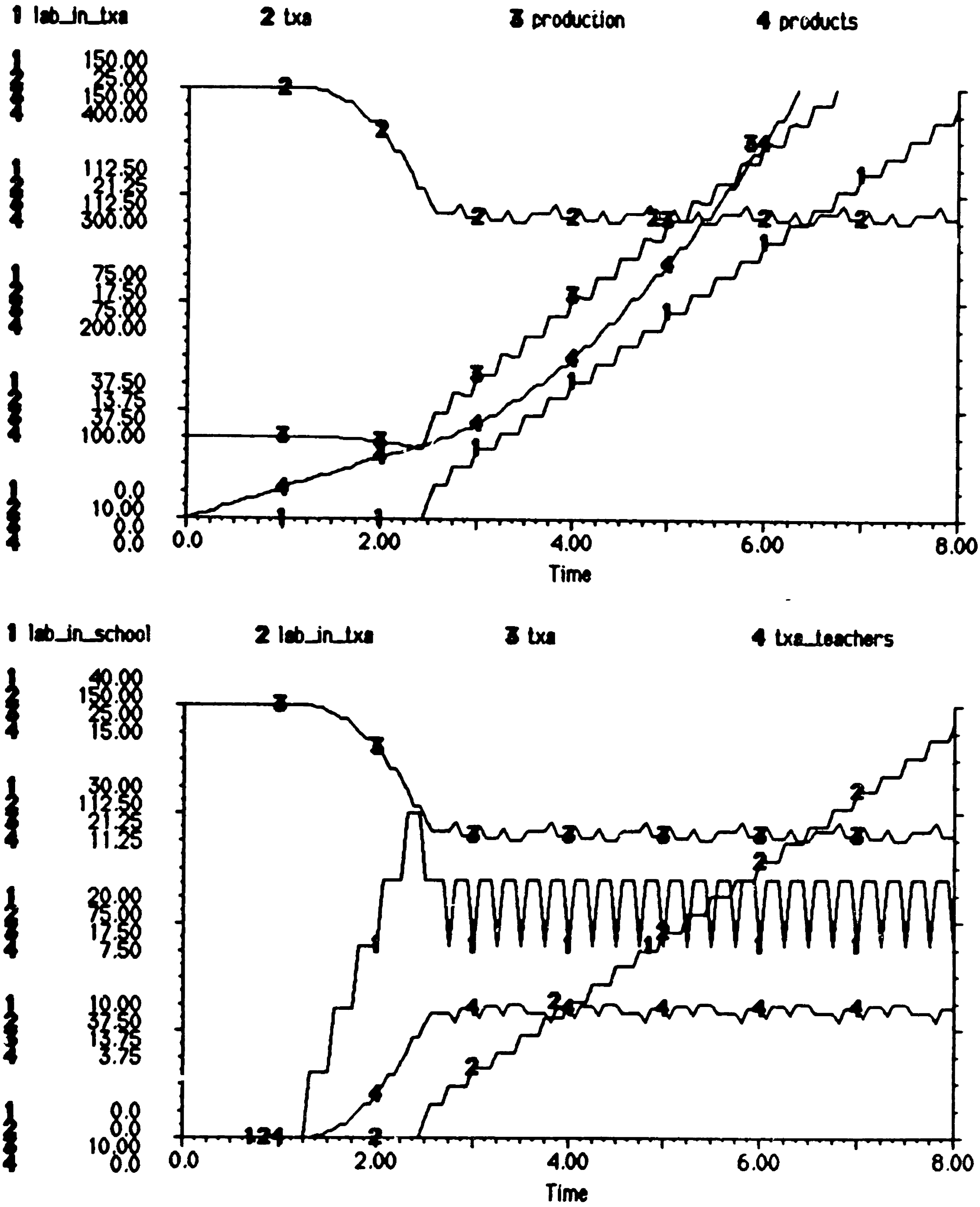


Figure 5.7

Baseline Integrated Team, Products and People

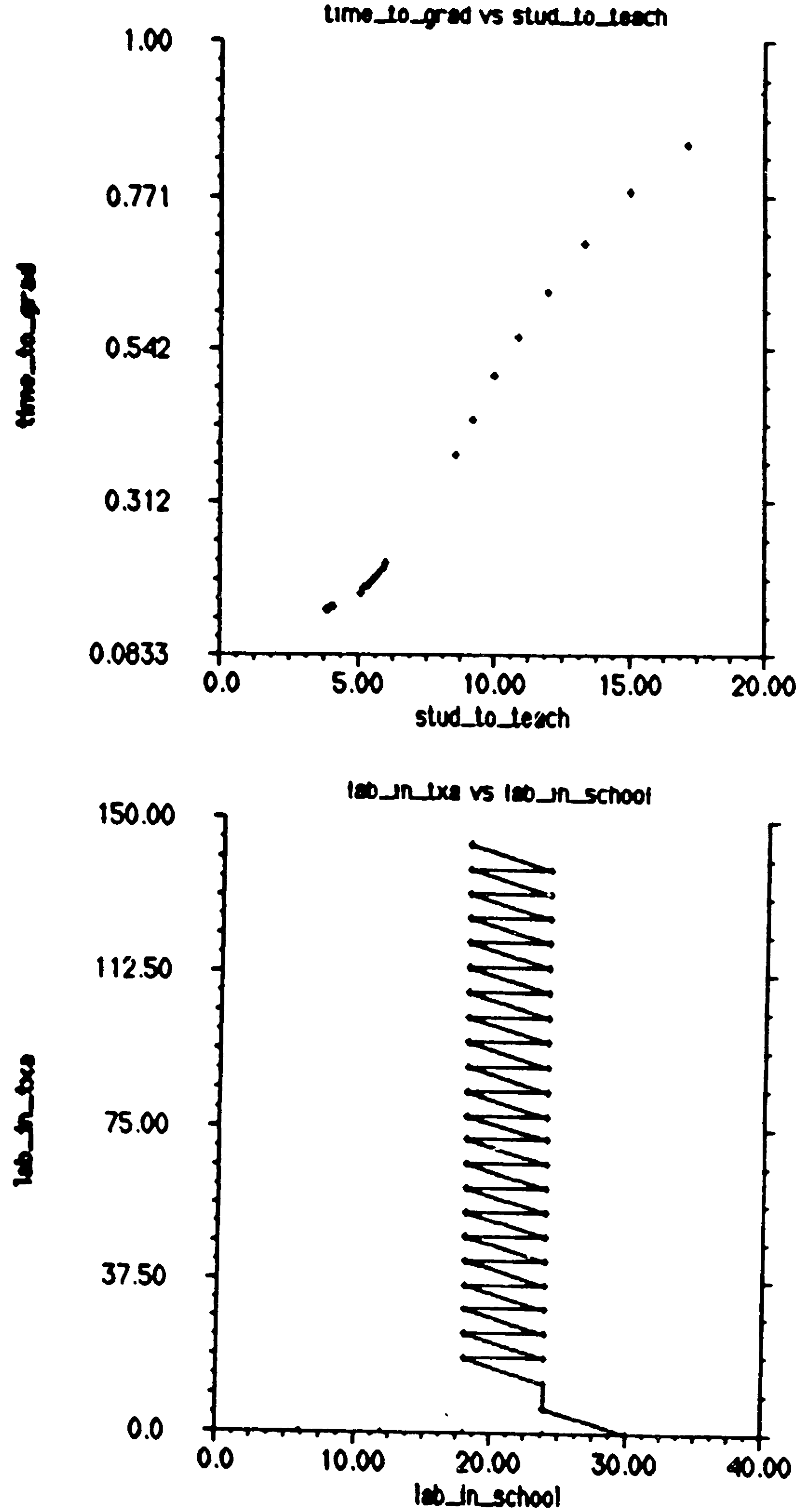


Figure 5.8

Baseline Integrated Team, Training and School

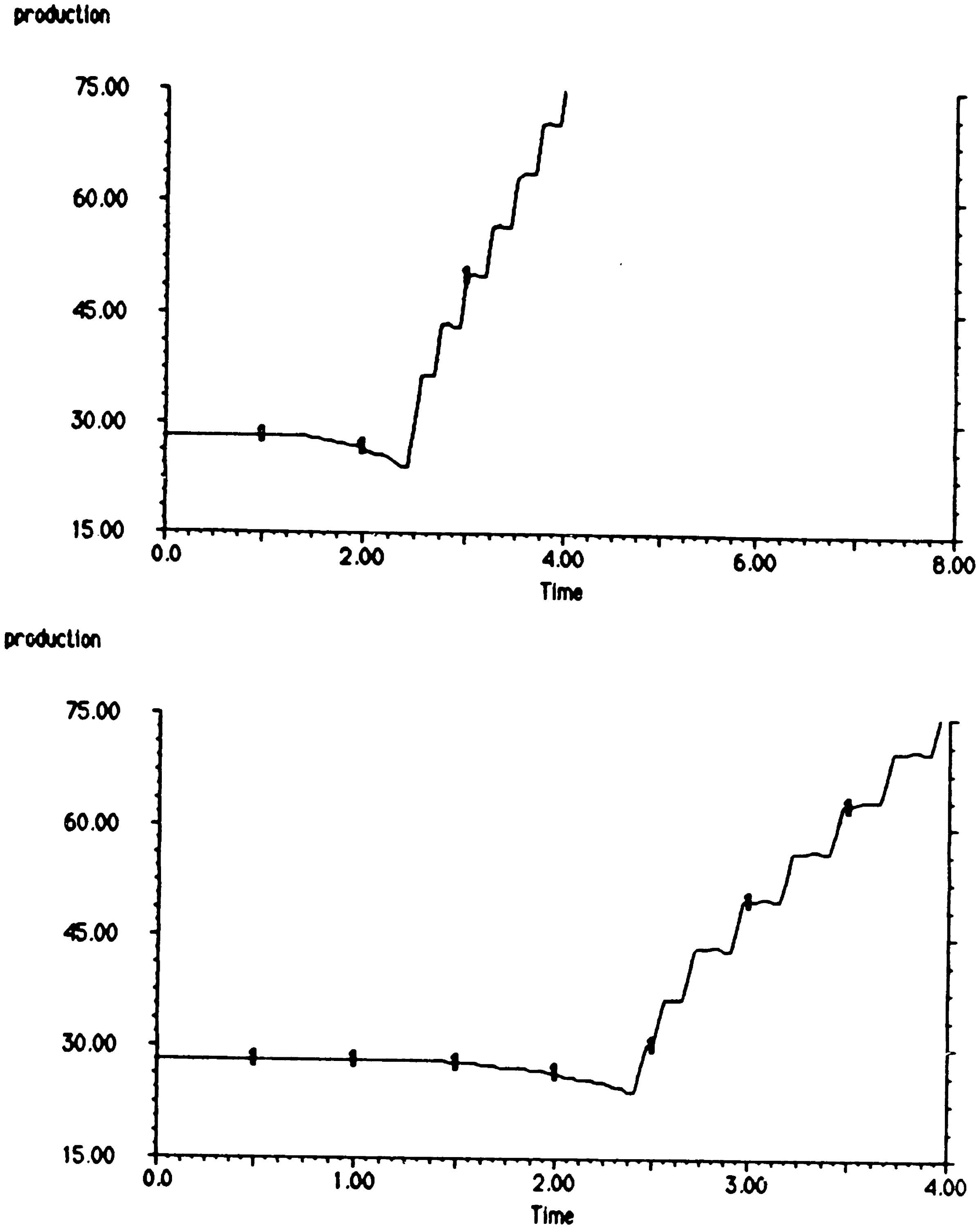
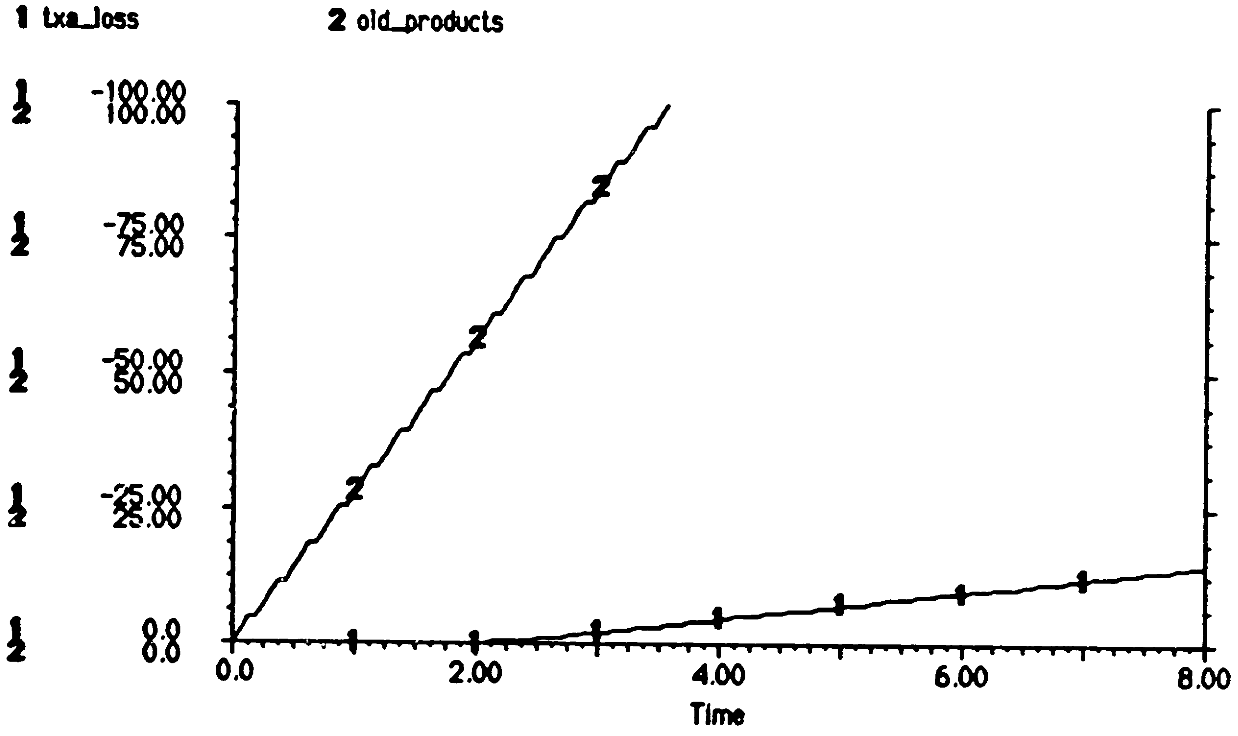


Figure 5.9

Baseline Integrated Team, Production



"TXA Loss"
Products are lost due to some TXA people assigned to teaching role

Figure 5.10 TXA Products Lost

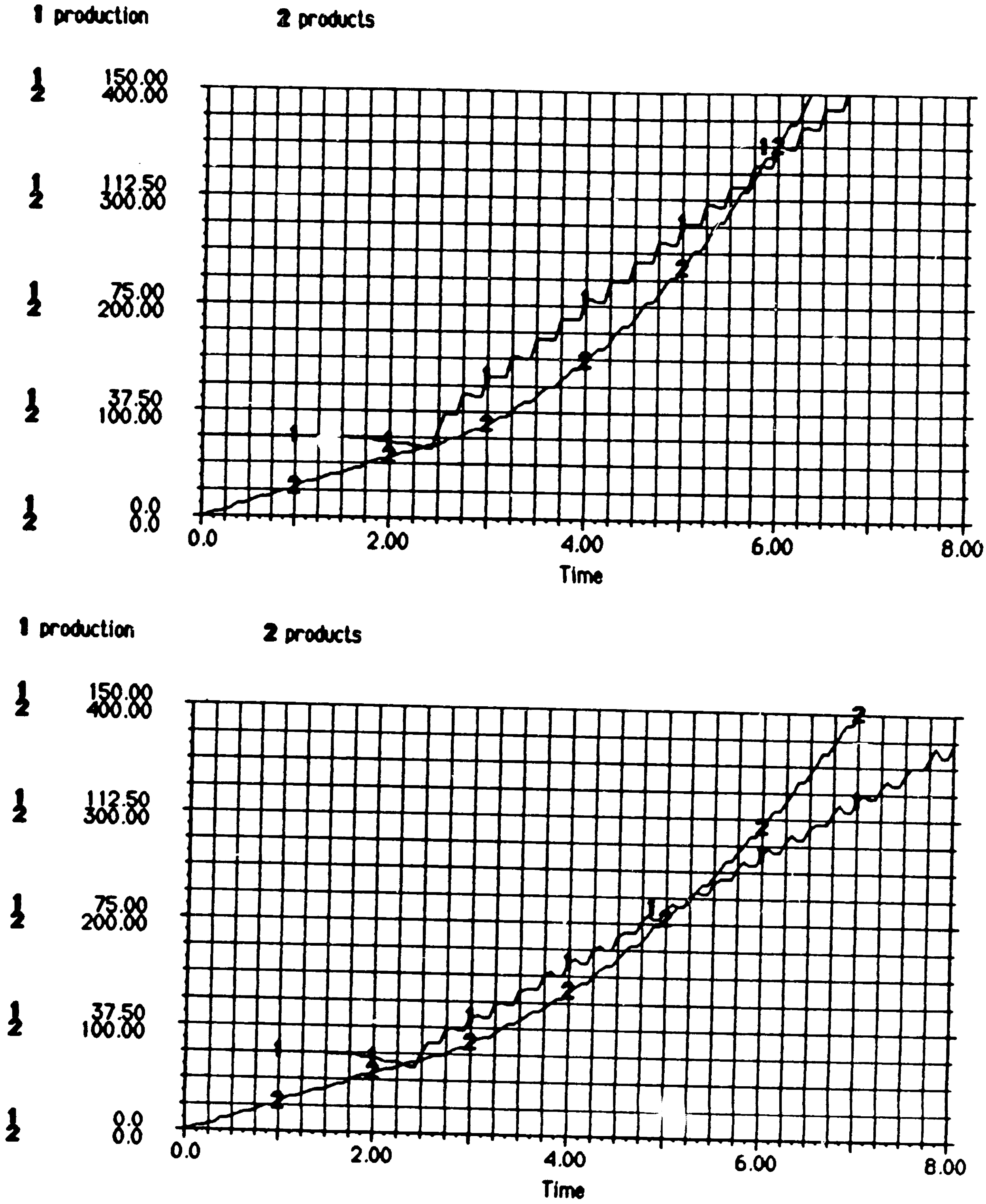


Figure 5.11

Integrated Team with Disruption and Rookie Factors

CLASS SIZE	STUDENT TO TEACH	GROWTH TIME LAB POOL 4yr	6yr	8yr	PRODUCTION 4yr	6yr	8yr
3	2	24	36	57	50	58	79
	5	24	48	72	53	80	106
	10	30	57	81	61	92	119
	15	24	48	72	55	81	108
	20	27	48	72	58	82	109
6	2	48	90	138	73	116	170
BASELINE	5	48	96	144	77	131	185
	10	60	114	162	95	156	208
	15	48	96	144	81	135	189
	20	54	96	144	88	135	189
9	2	72	144	216	95	176	256
	5	72	144	216	101	182	263
	10	90	171	243	127	219	300
	15	72	144	216	107	188	269
	20	81	144	216	118	189	269

Time	st_to_te...	lab_in_txa	txa	production	products	lab_in_sc...
0.0	5.00	0.0	25.00	28.10	0.0	0.0
1.000	5.00	0.0	25.00	28.10	28.09	0.0
2.00	5.00	0.0	23.50	26.41	55.81	18.00
3.00	5.00	24.00	20.50	50.01	87.97	18.00
4.00	5.00	48.00	20.50	76.99	148.13	18.00
5.00	5.00	72.00	20.50	103.96	235.26	18.00
6.00	5.00	96.00	20.50	130.93	349.34	18.00
7.00	5.00	120.00	20.50	157.90	490.39	18.00
8.00	5.00	144.00	20.50	184.88	658.40	18.00

Table 5.1 Parametric Study & Baseline Integrated Team

Time	st_to_te...	lab_in_txa	txa	production	products	lab_in_sc...
0.0	5.00	0.0	25.00	28.10	0.0	0.0
1.000	5.00	0.0	25.00	28.10	28.09	0.0
2.00	5.00	0.0	23.50	26.41	55.81	18.00
3.00	5.00	24.00	20.50	50.01	87.97	18.00
~~4.00~~	~~5.00~~	~~48.00~~	~~20.50~~	~~76.99~~	~~148.13~~	~~18.00~~

<u>End of Year 3</u>		→ accelerate →	= <u>Begining Year 4</u>
TXA	= 20.5	+ 8	= 28.4
TXA Teachers	= 4.5	+ 0	= 4.5
LAB In School	= 24	- 8	= 16
PRODUCTS	= 87.97	--------------	= 87.97
Assign Rate	= 6	+ 6	= 12

Time	st_to_te...	lab_in_txa	txa	production	products	lab_in_sc...
0.0	5.00	16.00	28.50	50.01	87.97	18.00
4.00	5.00	64.00	27.40	102.72	156.11	18.00
5.00	5.00	112.00	27.10	156.33	279.04	18.00
6.00	5.00	160.00	27.30	210.50	455.89	18.00
7.00	5.00	208.00	27.50	264.67	686.60	18.00

Table 5.2 Integrated Team Accelerated Growth Strategy

Chapter VI

SYSTEM DEVELOPMENT SCENARIO

The development and initial introduction phase of the "Integrated Team" R&D process was described in Chapter IV. Chapter V covered a simulation analysis of growth and productivity of the team. This chapter uses a scenario approach to describe the adequacy of the team size when it is ultimately involved in the start-up phase of a major system development project. Since the outcome possibilities in this phase are not within the boundaries of the system dynamics model, a scenario approach was used to capture the exogenous possibilities.

6.1 The Advanced Technology Transport (ATT) Scenario

The ATT project was started in the TXA office in the early 1980's. It quickly became a WROC lab wide program and ultimately a joint lab - ASD development planning program with participation by the user, the Military Airlift Command, cira 1984-86. The goal was to replace the large but aging C-130 (C-124, C-8) tactical transport fleet. Two problems arose which caused the program to be shelved. First the Air Force had a budget problem; it had two bomber plus a fighter start-up system development programs going. The second issue was that the C-130 fleet wasn't as old as originally thought. The aircraft was developed in the early 1950's; however production continued into the 1980's, reflecting a much younger average fleet age (also reflecting a successful design).

A revised start date was keyed to a production start-up near the turn of the century. Thus if 3 or 4 years are subtracted foe the detail design and manufacturing tolling phase, the ATT program may be matched with the "Integrated Team's" required growth and maturity period (4 to 8 years).

The mission analysis and technology application (front end) phase of the ATT project as of 1988 is briefly outlined in Appendix E (mission requirements, technology road maps and tasks). This information has been expanded to cover a greater range of technology candidates than envisioned in the mid 1980's. This expanded scope program was then the goal used to evaluate the proposed "Integrated Team" R&D process.

6.2 "ATT System Development" Development

The system development scenario is used to critique the planned growth of the "Integrated Team" R&D process. A primary question is how much time does the "Integrated Team" have to grow? Other questions are how many technologies are involved?, how difficult are they? how many organizations are involved?

The original ATT program data is the basis of a new plan which is suited to the "Integrated Team" operation (heavy front loading) in a System Development effort. The candidate aircraft concepts are increased from one to four (increasing the technology considerations) and the maximum effort is concentrated over a 1-1/2 year rather than 3 year time period. Man power wasn't included in the appendix data, so a notional "should cost" approach was used to estimate the size of the technology project effort. Since the numbers are fuzzy, the results are presented in parametric format.

The chart shown by table 6.1 is an aggregate of the critical technology groups listed in the appendix E data. The "Out of project" support performed by the functional lab organizations are not shown and, although important, will not be dealt with in this analysis. The original project emphasized 5 technology areas and the project task load varied from slightly under 4 group tasks per year to almost 6, over a 7 year period.

That level of effort was related only to the single base line aircraft candidate. Therefore in table 6.2, where four candidates are characterized, the effort was increased. The first two are conventional mission transports; the second two have added covert mission capability and are technologically more complex. The very 1st candidate (A) is a state of the art design. Shown at the bottom of the table is the estimated scale of the additional efforts due to the difference in technology content of each candidate.

The candidate expansion factors of table 6.2 were obtained through a subjective evaluation of the critical technologies impact beyond the original ATT front end (mission analysis and technology application). They are used to estimate a total program expansion factor. The table 6.2 factors were obtained as follows:

(1) Table 6.3 shows the structure of the design and the operational evaluation job. In a technology integration project only the critical technology branches of the tree are investigated in detail. The project technologists investigate their "branches" and the intersections with adjacent branches. At some point the detailed technology issues (symbolized

by the smallest, outermost branches) will move back to the functional laboratory organizations for detailed studies. The non-technology part of the tree is considered to be state-of-the-art and is handled by the TXA office's convention design methodology. In this analytic representation the design process was defined to contain 8 basic design branches.

(2) Table 6.4 shows the methods of judging the technology content of each candidate aircraft. Some technology tasks are more difficult than others and some teams or individuals are more productive in a given task. In this estimate the efforts are assumed to balance. The single triangle then denotes a "normal" technology" task; the double triangle represents a more complex problem and counts twice. These counts are added to the 8 basic "design branches" to estimate a full technology assessment effort for the particular aircraft candidate.

(3) Table 6.5 then uses the technology task sum from the previous table to calculate the critical technology contribution factor from each ATT candidate. Thus a total job for the "Integrated Team" would be 4.42 times the original ATT place shown by appendix E. However, with the help of early iteration between the design candidates and their military worth, this factor is reduced 60% or more; the final factor is 1.75. This represents one full competitive stage considering all 4 candidates, followed by 2 additional in depth technology integration and documentation stages for the "winner."

6.3 "Integrated Team" Manpower Requirements.

The proposed strategy of the "Integrated Team" R&D process is to sort out and solve the difficult technology tasks such that the best of these survives the System Development gauntlet and provide increased capability and quality to the operators (mechanics, pilots ... theater commanders). The implication then, is the System Development job will be no worse and possibly better in time and cost due to the revised R&D technology process.

The tactic then is to "front load" the technology activity in the pre-contractual phase of the System Development project in order to reduce the effort in the major later phases: contract award and post contract engineering. This is shown schematically by figure 6.1. Two hypothetical programs are compared; the front loaded (lower figure) is purposely sketched to be more successful than the upper figure. It has only 65% of the conventional program's engineering and manufacturing engineering loading (to dc equivalent work). However, its front load is 10% of the total, compared to 3% of the conventional's. The hypothesis is that the phased increase in the lower plan is more efficient than the sudden increase in loading (at JPO formation) in the conventional plan. The qualitative raticnal supporting this "best case" scenario is listed in table 6.6. All are substantial reasons, however, a full quantification is difficult to make and not available for the ATT case.

For this reason a parametric variation of cost has been used. A $1.2 billion dollar system development level was selected as the baseline RD&E

cost from the range of parametric values shown in table 6.7. The table was constructed for a broad view of cost, manpower and time values. Table 6.8 shows the required manloading for 3 cases. The most striking difference, given the assumptions, is the difference between the "conventional" R&D process and the "Integrated Team" proposal.

It is quite likely that a portion of the work (25%) would have been accomplished during the "Integrated Team" growth phase. Thus 160 people would be required for the $1.2 B size program, 80 for $600 M.

6.4 "Integrated Team" Manpower Available

The simulation analysis of chapter V was used to estimate a range of available team sizes as a function of time and syllabus. The base case projected 96 trained people in 6 years. Table 6.9 compares this with the requirements of two possible system development costs, $1.2 B and $600 M. Assuming that 100% of the effort is scheduled in the year and a half before SPO initiation, only 44 to 87% of the work can be planned on. Assuming 25% is completed earlier (in the growth phase), the capability is increased to 60 and 120%.

New technologies involve uncertainties in design, fabrication and operation; therefore are risky. However, if the process is investigated and tested before full commitment, the risk of impairing or constraining it is reduced by the amount of success in the verification effort. The risk reduction is projected by figure 6.2.

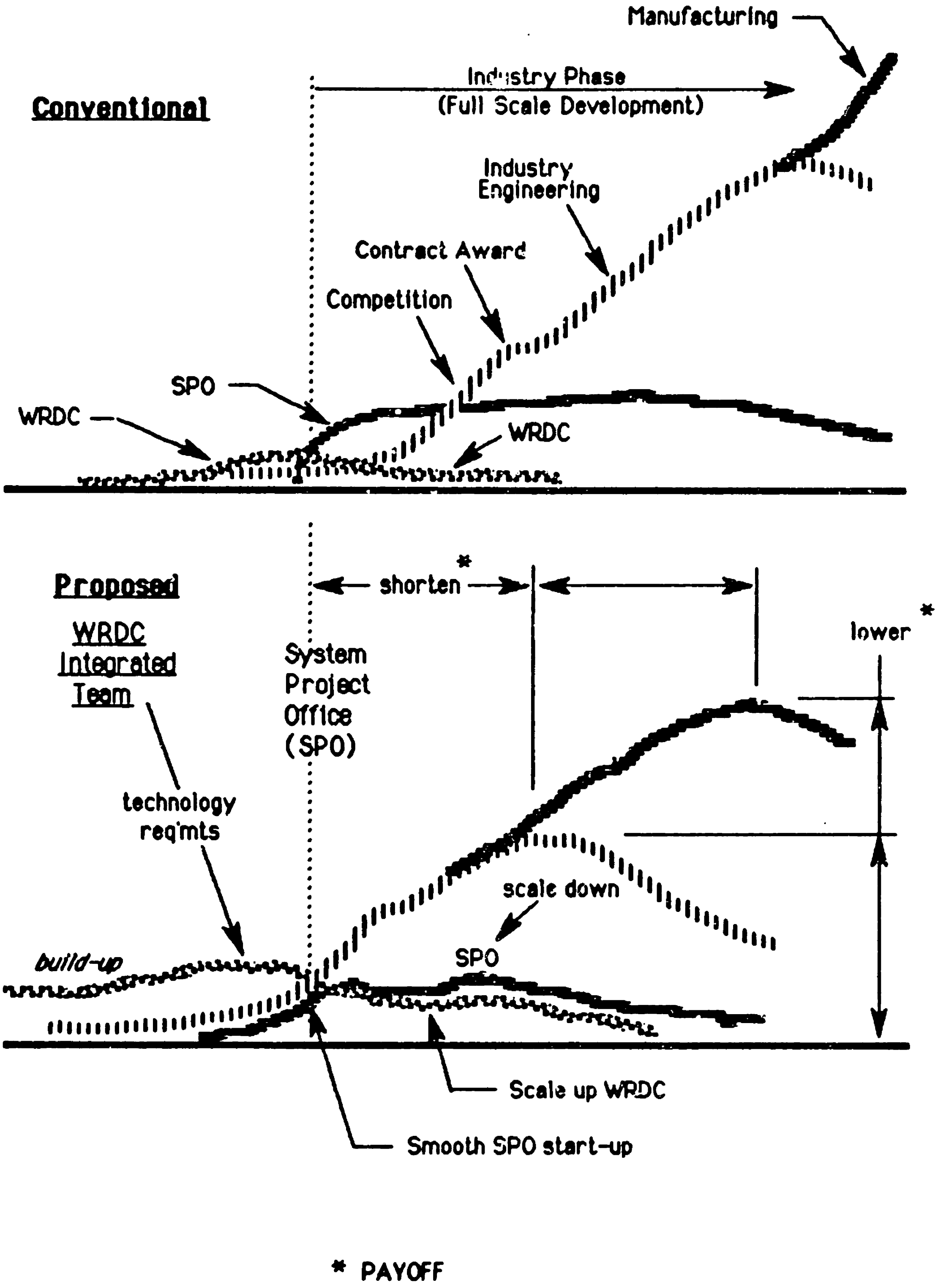
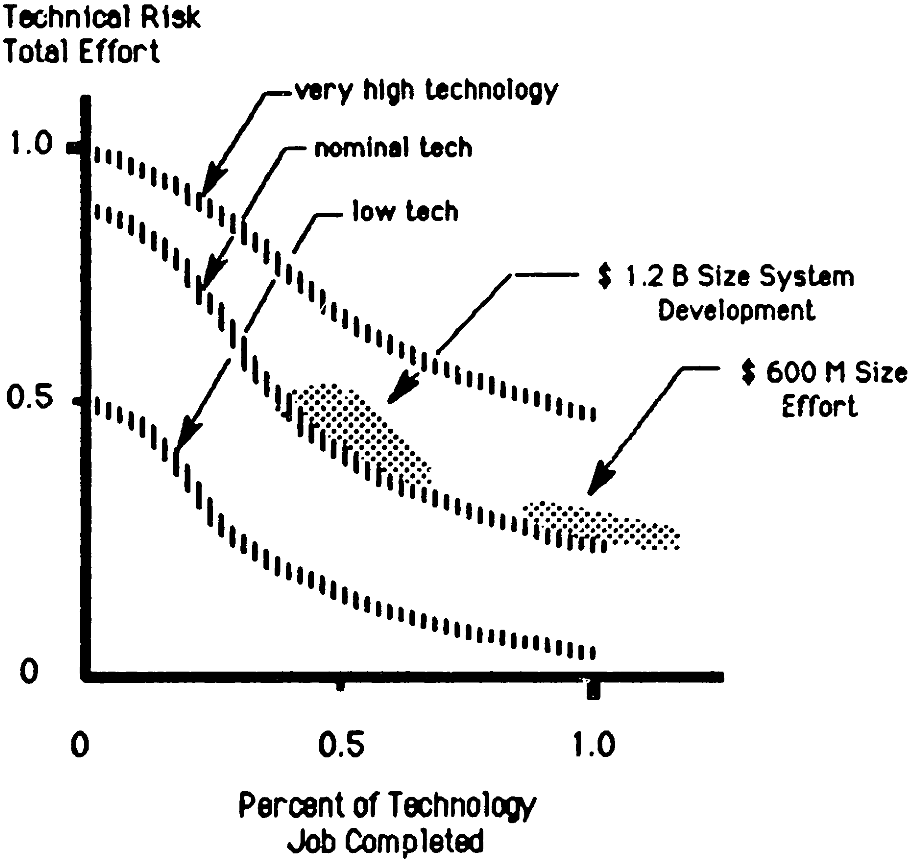
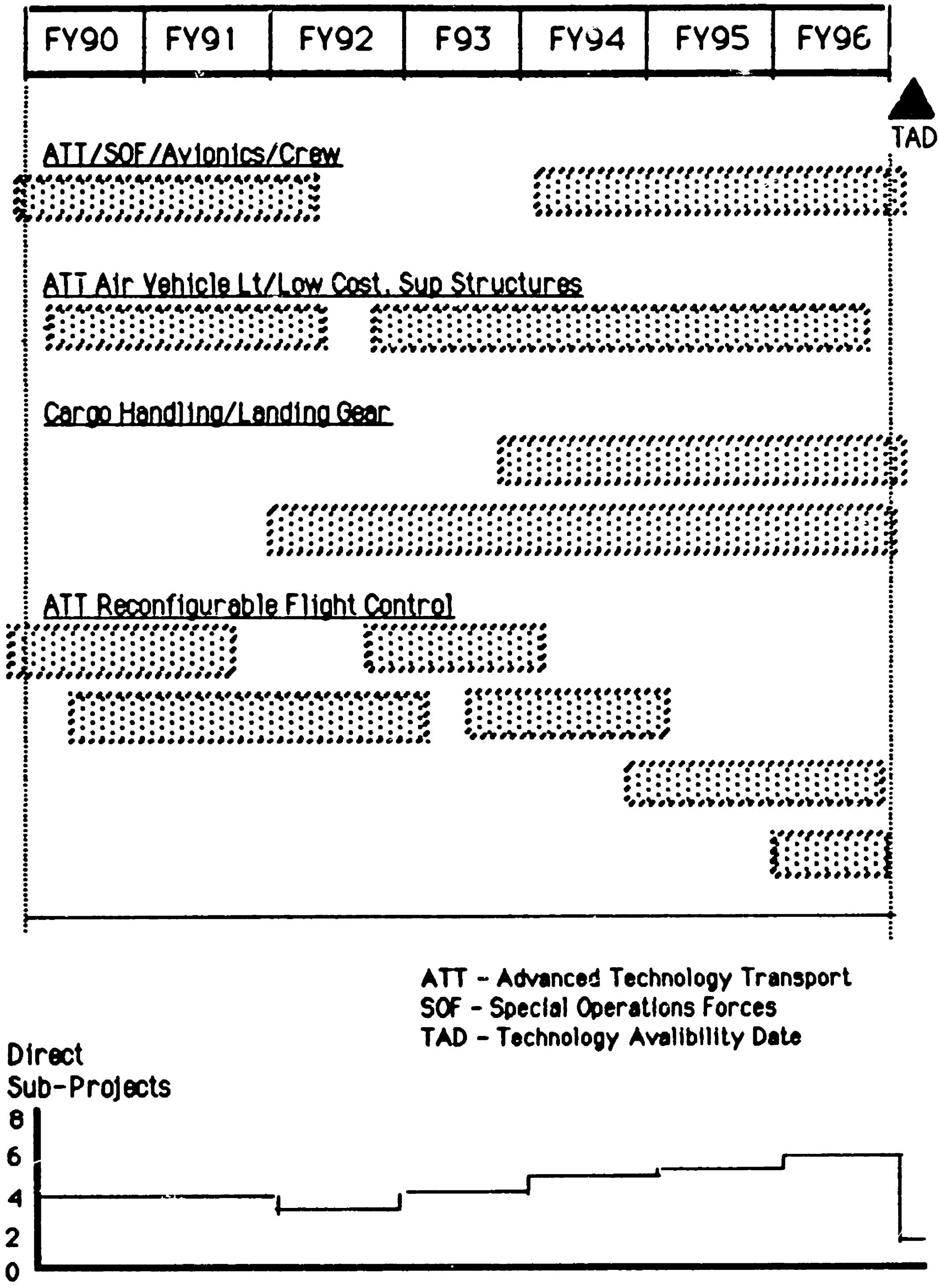


Figure 6.1 System Development Manpower Loading



STOVL & Low Signiture Cases
Integrated Team with 6 Year Growth
ref : table 6.9, p 83

Figure 6.2 Integrated Team Impact on Risk



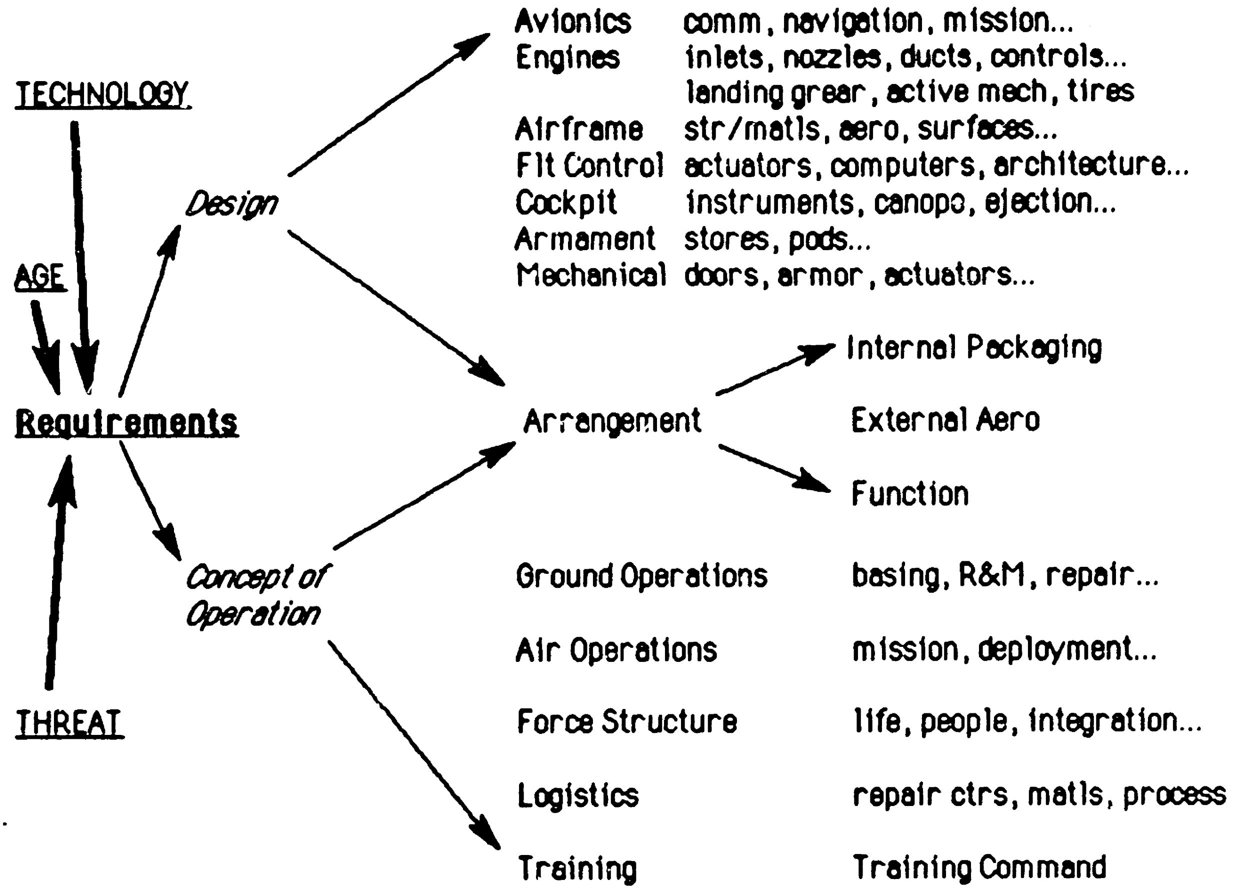
ATT - Advanced Technology Transport
SOF - Special Operations Forces
TAD - Technology Avalibility Date

Table 6.1 Origional Advanced Technology Transport Roadmap

CONCEPT ORGANIZATION	State of Art Jet C-130	Composite Jet C-130	Short Take-Off, Vertical (STOVL)	Low Signiture
Propulsion Lab	Comercial adoption	Comercial adoption	Modified ATF engine	Hi-By-Pass adoption
Materials Lab/ Signiture Dir	Alunimum	Composite	Composite	(Special)
Mfg Dir	Standard	(Special)	(Special)	(v. Special)
Avionics/ Electronics	Upgrade	Upgrade	Upgrade	(v. Special)
Flight Dyn Lab				
Inlets	Std	Std	(v. Special)	(v. Special)
Nozzles	Std	Std	(v. Special)	(v. Special)
Aero	Lo-Speed	Lo-Speed	(v. Special)	(v. Special)
Flt Controls	Std	Std	(v. Special)	(Special)
Structures	Std	(Special)	(Special)	(v. Special)
Equipment	Cargo Hand'g Rough Fld Vulnerability	Cargo Hand'g Jump Strut Vulnerability	Cargo Hand'g Rough Fld Vulnerability	Cargo Hand'g Jump Strut (v. Special)
Crew Sta Dir	Std	Std	(Special)	(v. Special)

ATF - Advanced Tactical Fighter
Dir - Directorate
Std - Standard
v. Special - very Special
Rough Fld - Rough Field Landing Gear
Jump Strut - Jump Strut Landing Gear
Hi-By-Pass - Jet Engine Type

Table 6.2 Advanced Technology Transport Concepts



comm - communications
active mech - landing gear type
str/matls - structures & materials
aero - aerodynamics
R&M - Reliability & Maintainability

Table 6.3 Aircraft Design & Evaluation

CONCEPT COMPONENT	State of Art Jet C-130	Composite Jet C-130	Short Take-Off, Vertical (STOVL)	Low Signiture
1. Engines			*	
2. Materials		*	*	**
3. Avionics		*	*	**
4. Arrangement			**	***
5. Airframe			**	**
6. Flt Controls			**	*
7. Land'g Gear		*	*	*
8. Mfg		*	**	**
Critical Technologies	0	4	12	13

Table 6.4 Advanced Technology Transport Critical Technologies

CONCEPT	Basic Comp-onents	Added Critical Tech'ies	Total Load	Load based on SOTA	Load based on Baseline
Low Tech	8		8	8/8 = 1	0.67
Composit Jet C-130	8	4	12	12/8 = 1.5	1.0
STOVL	8	8	16	16/8 = 2	1.33
Low Signiture	8	9	17	17/8 = 2.13	1.42
				Full Load Tech	4.42

Table 6.5 ATT, Technology Task Impact on Project Scope

Experience	The problem would have been previously worked in the training phase.
Knowledge	The technologists would previously have notified the labs of the tougher parts of the problem.
Timing	The technologists would be available to support the start-up System Project Office.
Industry	The management would be forewarned; hire, rearrange projects, set-up team, capital investments.
Motivation	A short initial investment to start-up period budgets, better cash flow, breakeven, profit, lower cost.
Intellectual Capital	A body of experienced people and their documented work.

Table 6.6

System Development Scenario Rationale

RD & E DEVELOPMENT COST *	TOTAL MANYEARS **	AVERAGE DEVELOPMENT MANLOADING					
		2yr		3yr		4yr	
		total	tech'y ***	total	tech'y ***	total	tech'y ***
$ 300 M	2000	1000	30	667	20	500	15
$ 600 M	4000	2000	60	1333	40	1000	30
$ 1.2 B	8000	4000	120	2667	80	2000	60
$ 2.4 B	16000	8000	240	5333	160	4000	120

* TECHNOLOGY + ENGINEERING + SYSTEM PROJECT OFFICE + MFG ENGINEERING

** $150 K / YEAR / MANYEAR

*** 3% of TOTAL (CONVENTIONAL PROGRAM)

Table 6.7 System Development Cost & Manpower Range

Technology Approach	Conventional	Integrated Team	
System Development Cost	$ 1.2 B	$ 1.2 B	$ 600 M
Technology Percent	3%	10%	10%
People/year (3 year project[1])	80	267	133
People/year (front load[2])	40	133	67
Max Scope of Work[3]	1.0	4.42	4.42
People/year (front load[4])	40	588	293
Actual Time Span (front load)	3year	1 1/2 year	1 1/2 year
Actual People/year (front load[5])	40	1175	587
Reduced Project Scope[6]	~	391-489	195-244
People in Project[7]	20	195-244	98-122
Average People in Project	20	219	110

1. Table 6.7 * percent; 2. 1/2 in front load; 3. Table 6.7; 4. People/year * Max Scope; 5. 3years/Time Span; 6. One concept of four "goes" 3 phases & the STOVL factor = 4/12, Low Sig. factor = 5/12; 7. 1/2 in Lab, 1/2 in Project

Table 6.8 Integrated Team Manpower Requirement, Two System Costs

RD & E COST	$ 1.2 B			$ 600 M		
Integrated Team Growth Time	4yr	6yr	8yr	4yr	6yr	8yr
Manpower Avalible	48	96	144	48	96	144
Manpower Required	219	219	219	110	110	100
Percent Job Complete	22%	44%	66%	44%	87%	131%
	Special "REDUCED SCOPE" Case[1]					
Manpower Required	160	160	160	80	80	80
Percent Job Complete	30%	60%	90%	60%	120%	180%

1. Assuming that 25% of the work was completed during the Integrated Team's growth stage.

Table 6.9 Integrated Team Manpower Capability, Two System Cases

CHAPTER VII

CONCLUSIONS

Several important conclusions can be drawn from the work done in this thesis.

7.1 System Dynamics

The system dynamic method represents an excellent approach to problem solving:

(1) It emphasizes the criticality of time as a system control variable as well as a limit.

(2) It guides the system investigator to the major elements of the problem: those which control the dynamic behavior modes.

(3) It provides strategic insights such as short-term loss to provide a long-term productivity gain.

(4) Families of similar models can be used to investigate different phases or behavior attributes of a system. The models can be used as engineering design tools.

(5) System dynamics modeling automatically leads to an enlarged system concept, when the answers are caused by factors outside the present model boundaries.

(6) As a system moves to an enlarged follow-on state, a scenario approach can be a first approximation. A scenario is simply a system dynamic model with manual feedback loops.

(7) As the modeling leads to areas of system unknowns, a strategy is to aggregate the parameters until valid information is found. Area experts should be enlisted in the modelling in such instances.

7.2 Integrated Team

the team consisted of the TXA design engineers in a symbiotic relationship with lab technologists.

(1) As the thesis investigation traversed various learning phases, it seemed more and more logical that the office might have originally been conceived for that very purpose.

(2) While the "Integrated Team" would seem to have a number of attractive benefits and features, its success is closely coupled to management capabilities and the acceptance of such an alliance by lab line organizations.

(3) A further level of detailed (disaggregation) investigation is recommended:

- to better understand the problem, test critical assumptions; and
- to bring management and key participants into the analysis.

7.3 The Technology Transition Problem

The labs have been criticized for a lack of technology transitioning to the product division. The criticisms are real, but not necessarily completely valid. A good deal of the lab efforts are in advanced development, i.e. hardware or flight demonstration. Such R&D is authorized and reviewed by a different set of people, Washington area planners rather than operational engineers at WPAFB. Also much of the technical process, refinements of interest to the operational engineers, is the responsibility of industry.

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APPENDICES

Appendix A

Abbreviations/Acronyms

Symbol	Term
AFSC	Air Force Systems Command
ASD	Aeronautical Systems Division
ENG	General symbol used to denote the Systems Engineering Organizations
IT	Integrated Technology
LAB	General symbol used to denote the laboratory organizations
OE	Operational Evaluation
RD&E	Research, Development, and Engineering
SPO	System Program Office
TI&OE	Technology Integration & Operational Evaluation
TXA	Office symbol used to denote the Technology Assessment Division
USAF	United States Air Force
WROC	Wright Research & Development Center (also called LAB)
XR	Symbol used to denote Development Planning Organizations

Appendix B

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System Dynamics

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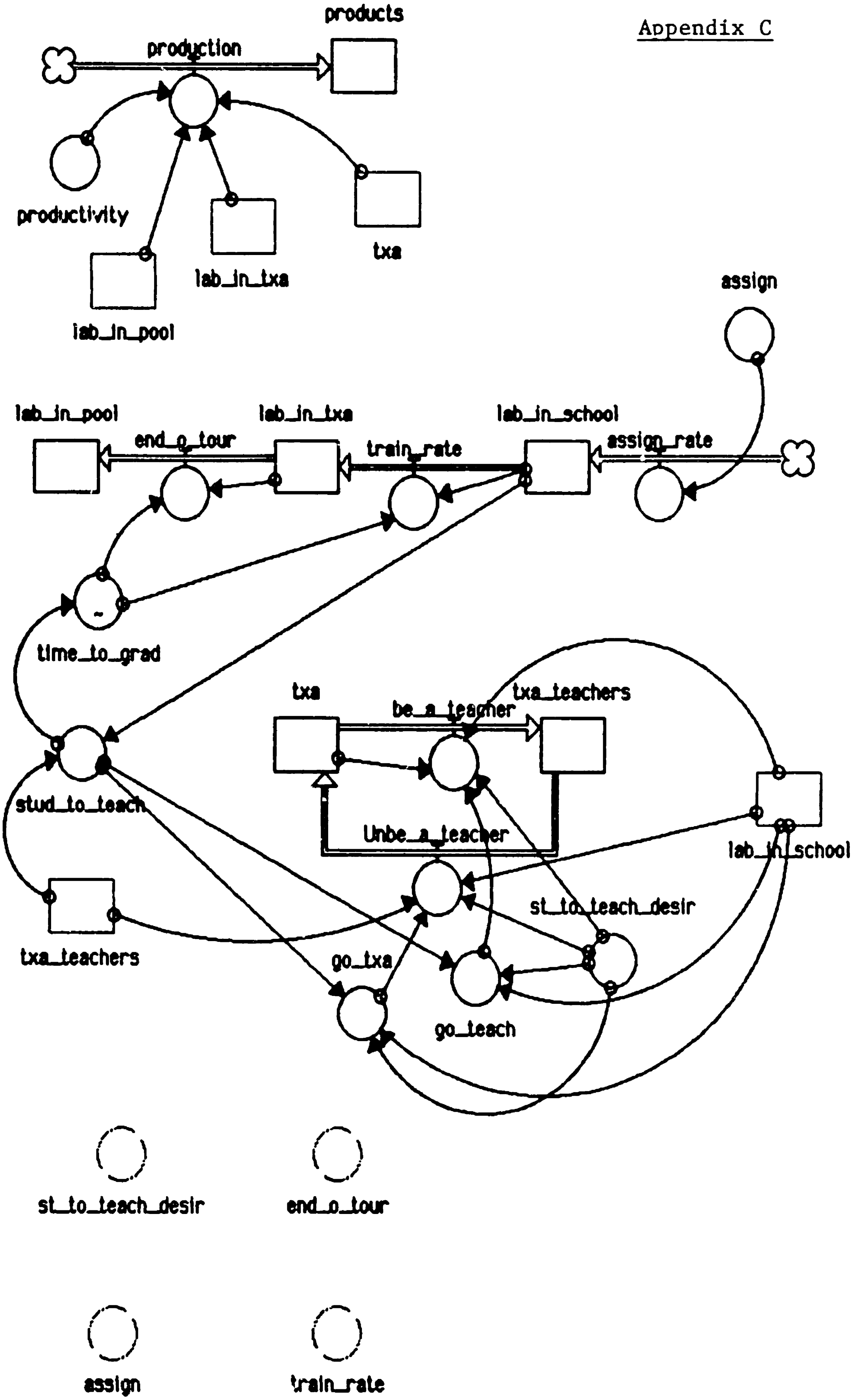
Appendix C


products
production
productivity
lab_in_txa
txa
lab_in_pool
assign
lab_in_pool
lab_in_txa
lab_in_school
end_o_tour
train_rate
assign_rate
time_to_grad
txa
be_a_teacher
txa_teachers
stud_to_teach
Unbe_a_teacher
lab_in_school
st_to_teach_desir
txa_teachers
go_txa
go_teach
st_to_teach_desir
end_o_tour
assign
train_rate

```
☐ lab_in_pool = lab_in_pool + dt * ( end_o_tour )
  INIT(lab_in_pool) = 0
  {Laboratory in Pool (people)
  lab technologists who have completed the TXA training tour}
☐ lab_in_school = lab_in_school + dt * ( -train_rate + assign_rate )
  INIT(lab_in_school) = 0
  {Laboratory in School (people)
  lab technologists in TXA training}
☐ lab_in_txa = lab_in_txa + dt * ( train_rate - end_o_tour )
  INIT(lab_in_txa) = 0
  {Laboratory in TXA (people)
  lab technologists working projects in TXA training tour}
☐ products = products + dt * ( production )
  INIT(products) = 0
  {Products (units)
  projects completed by TXA engineers and lab technologists}
☐ txa = txa + dt * ( -be_a_teacher + Unbe_a_teacher )
  INIT(txa) = 25
  {TXA (people)
  TXA is an office symbol for an in-house engineering staff}
☐ txa_teachers = txa_teachers + dt * ( be_a_teacher - Unbe_a_teacher )
  INIT(txa_teachers) = .001
  {TXA Teachers (people)
  TXA staff who have become full time teachers of lab tech-
  nologists on training tour}
○ assign = PULSE(3,1,.25)
  {Assign (people,first start-year,period-year),
  PULSE(3,1,.25) means 3 lab technologists are assigned after
  1 year and then 3 more every .25 of a year}
○ assign_rate = assign
  {Assignment Rate (people/year)
  lab technologists are assigned at a "assign" rate to the
  TXA training program}
○ be_a_teacher =IF (txa > (lab_in_school/st_to_teach_desir))
  THEN go_teach ELSE 0
  {Be a Teacher (people/month)
  rate at which TXA staff are assigned to be teachers, checks to see if
  TXA has enough people, then  assigns a "go-teach" rate}
```

```
○ end_o_tour = IF lab_in_txa > 0 THEN PULSE(3,2.5+time_to_grad,
  .25) ELSE 0
  {End of Tour (people/xx year)
  lab technologists end their tour at this rate,
  PULSE(zz,yy,xx) means zz people are released after yy years
  and then every xx years}
○ go_teach = IF (stud_to_teach > (st_to_teach_desir*1.1)) THEN
  MAX (0,lab_in_school/st_to_teach_desir) ELSE 0
  {Go Teach (people),

  TXA staff to be assigned to teaching if the student to teacher ratio is 10% greater than that
  desired}
○ go_txa = IF ((stud_to_teach*1.1) < (st_to_teach_desir)) THEN
  MAX(0,lab_in_school/st_to_teach_desir) ELSE 0
  {Go TXA (people),
  teachers that will be returned to TXA if 110% of the student to teacher ratio is less than that
  desired}
○ production = productivity*(txa+lab_in_txa)
  {Production (products/year)}
○ productivity = 1.12386
  {1.12386 products/year/person ,
  this is an weighted average for a mix of TXA project sizes}
○ stud_to_teach =(lab_in_school/txa_teachers)
  {Student to Teacher Ratio (dimensionless)}
○ st_to_teach_desir = 5
  {Student to Teacher Desired (dimensionless)}
○ train_rate = IF lab_in_school > 0 THEN
  PULSE(3,1+time_to_grad,.25) ELSE 0
  {Training Rate (people/ xx year),
  lab technologists are trained as a class "PULSE" rate,
  PULSE(zz,yy,xx) means zz people are first graduated at yy years and then every xx years}
○ Unbe_a_teacher = IF txa_teachers > (lab_in_school/st_to_teach_desir) THEN go_txa ELSE 0
  {Unbe a Teacher (people/month),
  a check is made to see if there are enough teachers to be released, then assigns a "go-txa" rate}
⊘ time_to_grad = graph(stud_to_teach)
  ( 0.0,0.0833),(2.50,0.128),(5.00,0.173),(7.50,0.295),(10.00,0.500),(12.50,0.660),(15.00,0.780),
  (17.50,0.860),(20.00,0.925),(22.50,0.970),(25.00,1.00)
```

APPENDIX E

ADVANCED THEATER TRANSPORT MISSION ANALYSIS AND TECHNOLOGY APPLICATION

ADVANCED THEATER TRANSPORT
MISSION ANALYSIS AND TECHNOLOGY APPLICATION

OBJECTIVE

- CONTINUE REFINEMENT OF MISSION/SYSTEMS REQUIREMENTS AND DEVELOPMENTAL OPTIONS
- APPLY EMERGING TECHNOLOGIES ,QUANTIFY TECHNOLOGY IMPACT AND DEFINE TECHNOLOGY PREDESIGN REQUIREMENTS
- QUANTIFY AFFORDABLE OPTIONS

APPROACH

- JOINT ASD/XR - WRDC/TX PROGRAM WITH MAC PARTICIPATION
- INHOUSE AND CONTRACTED
- WRDC LABORATORY AND DIRECTORATE PARTICIPATION
- TWO YEAR STUDY EFFORT

ATT TECHNOLOGY DRIVERS

NOTIONAL CHARACTERISTICS

TAD	• 1997 - 1998 (PRIOR TO MILESTONE II)
CONCEPT OF OPERATIONS	• OUT OF COUNTRY BASING • MULTI-STOP/SHUTTLE MISSION • AUSTERE/UNPREPARED SITES • NEAR AND ACROSS FLOT • NIGHT & WEATHER • 4000 FEET, 95° F • C-17 COMPANION
PAYLOAD	• BOX SIZE APPROXIMATELY C-130 • 25000 - 33000 LBS ASSAULT MISSION • 55000 LBS MAXIMUM PAYLOAD • 15000 LBS MINIMUM PAYLOAD @ 2600 OR 3200 N MI, DEPLOYMENT

ATT TECHNOLOGY DRIVERS (CONT'D)

NOTIONAL CHARACTERISTICS

INGRESS/ EGRESS	• CRUISE MACH ~ 0.7; ALT > 25000 FEET • PENETRATION ALTITUDE 200 FEET SPEED 300 KNOTS
SURVIVABILITY	• REAL TIME MISSION PLANNING • THREAT WARNING • TF/TA/TA • SELF PROTECTION COUNTERMEASURES (CHAFF, DECOYS, JAMMING, HARDENING) • LOW IR SIGNATURE • LOW VULNERABLE AREA • BATTLE DAMAGE TOLERANT/REPAIRABLE

ATT TECHNOLOGY DRIVERS (CONT'D)

NOTIONAL CHARACTERISTICS

DELIVERY SITE

- FIELD LENGTH ASSAULT RULES
  - STOL 1500 FEET
  - SUPER STOL 500 FEET (NO HOVER)
- SURFACE CBR 4 - 6
- AUTONOMOUS LANDING GUIDANCE
- GROUND MOBILITY/SPOT SIZE
- AUTONOMOUS / RAPID OFFLOAD
- LAPES / AIRDROP CAPABLE
- GET-HOME CAPABLE

CREW FACTORS

- 3 MAN CREW
- WORK LOAD CONTROL
- CHEM / BIO PROTECTION
- GOOD LOW ALTITUDE RIDE QUALITIES
- GOOD LOW SPEED HANDLING QUALITIES

ATT TECHNOLOGY DRIVERS (CONT'D)

NOTIONAL CHARACTERISTICS

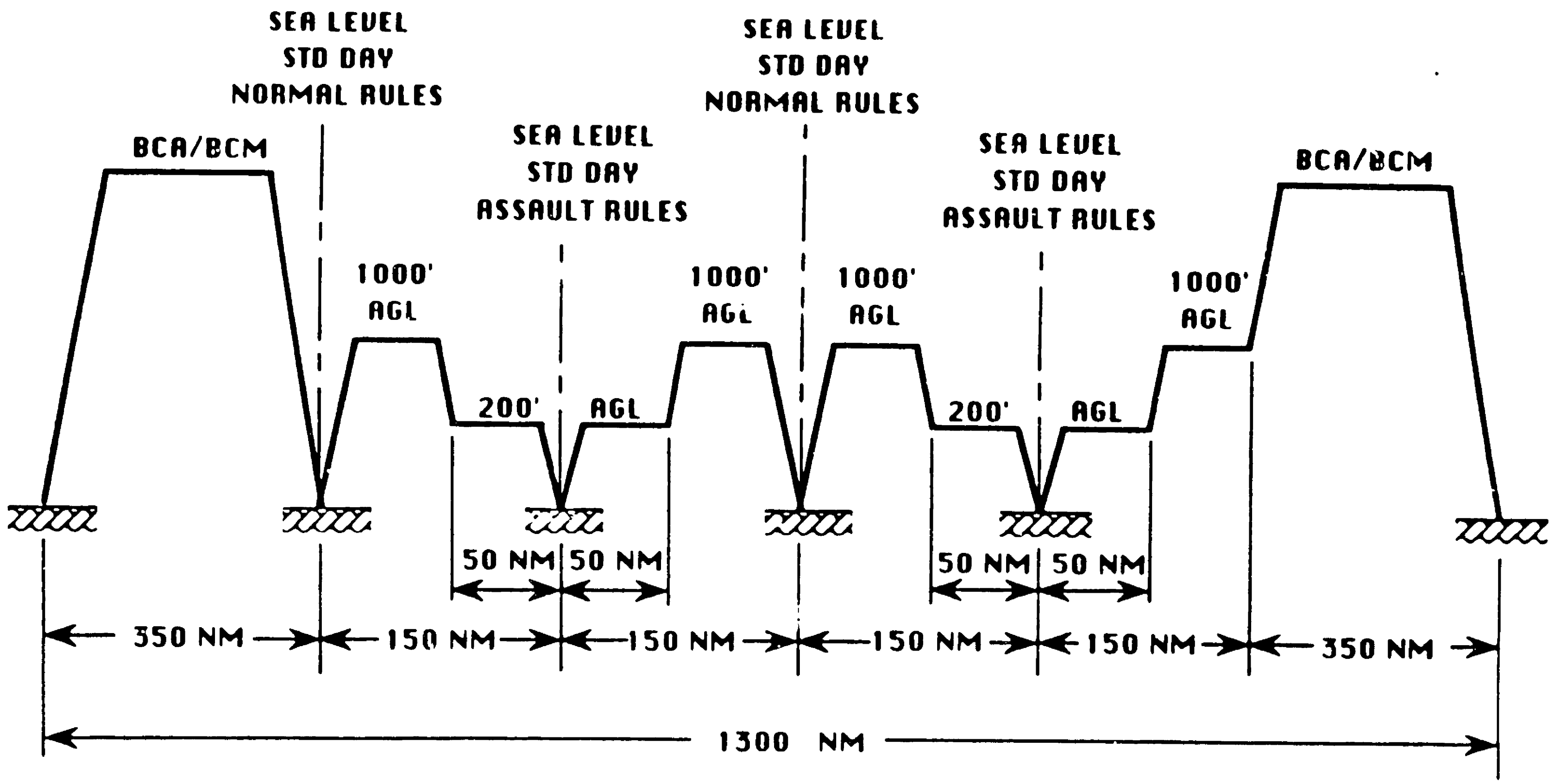
LOGISTICS

- AFFORDABLE
- LOW MAINTENANCE
- HIGH RELIABILITY
- HIGH SORTIE RATES

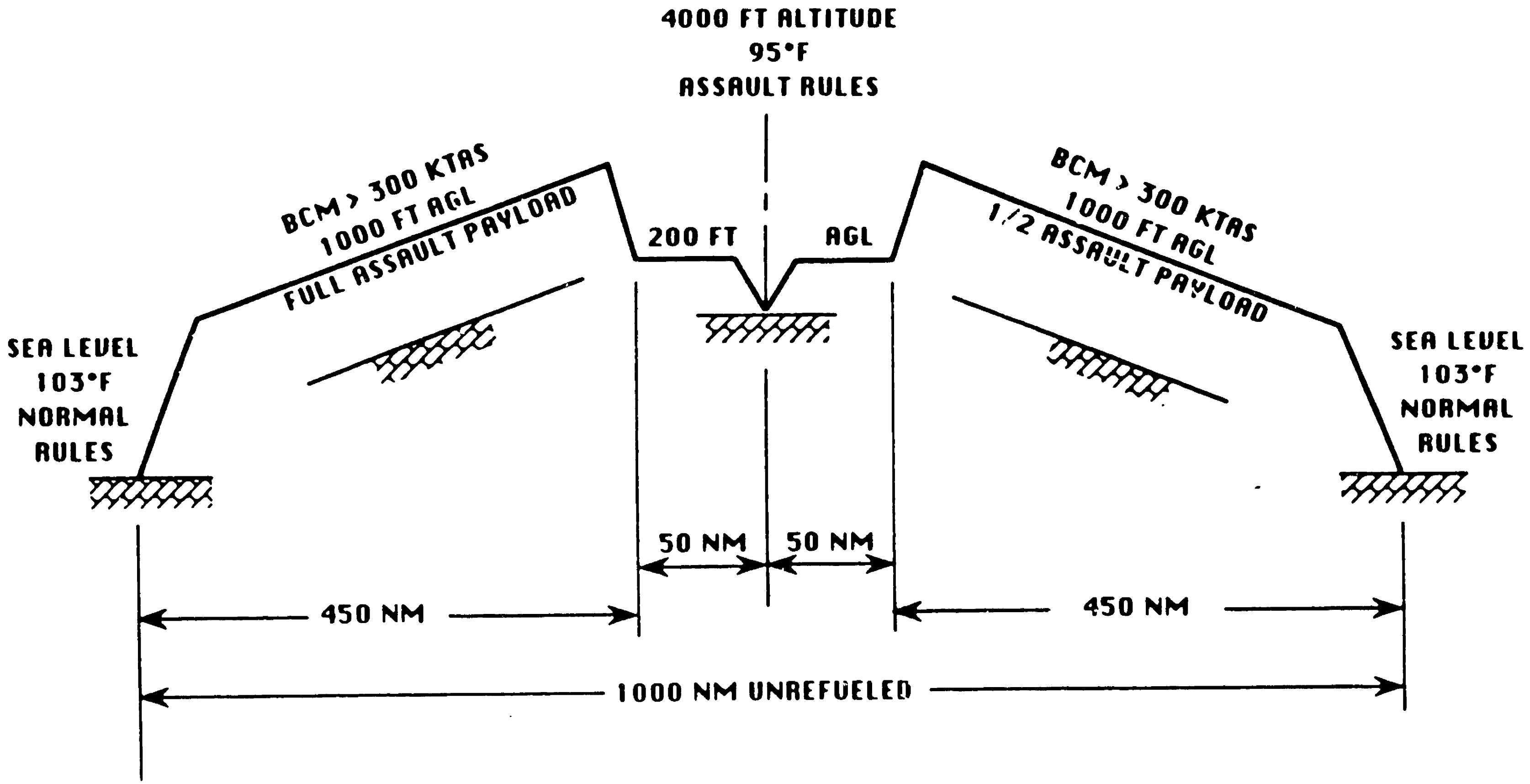
GENERAL

- INTEROPERABILITY
  - C-17 - C-130 - HELOs - ACA - TRUCKS
  - PLS - 463L - CONTAINERS
  - COMMUNICATIONS
  - CARGO TRANSFER / HANDLING
- JIAWG STANDARDS

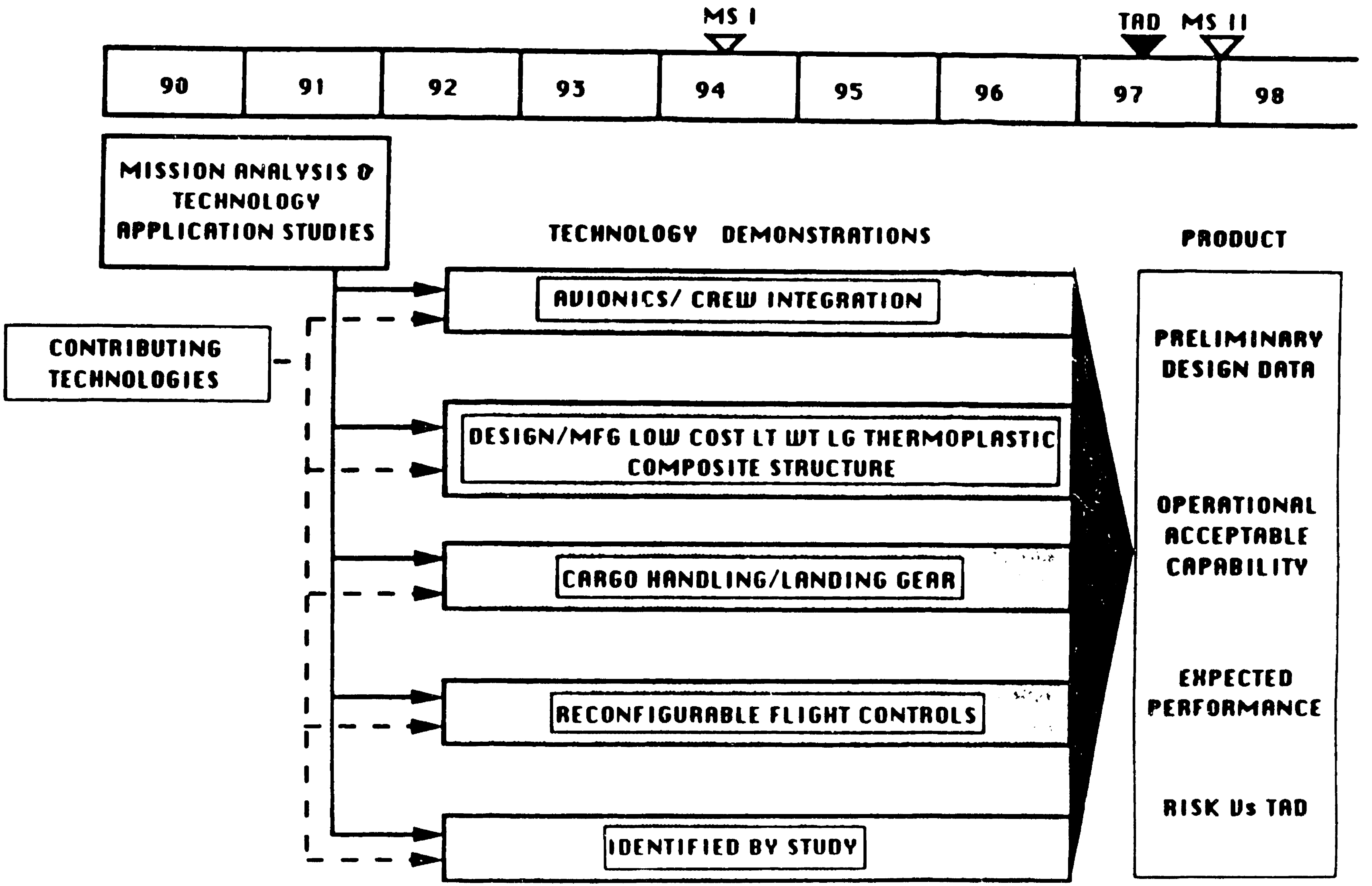
EUROPE ASSAULT MISSION



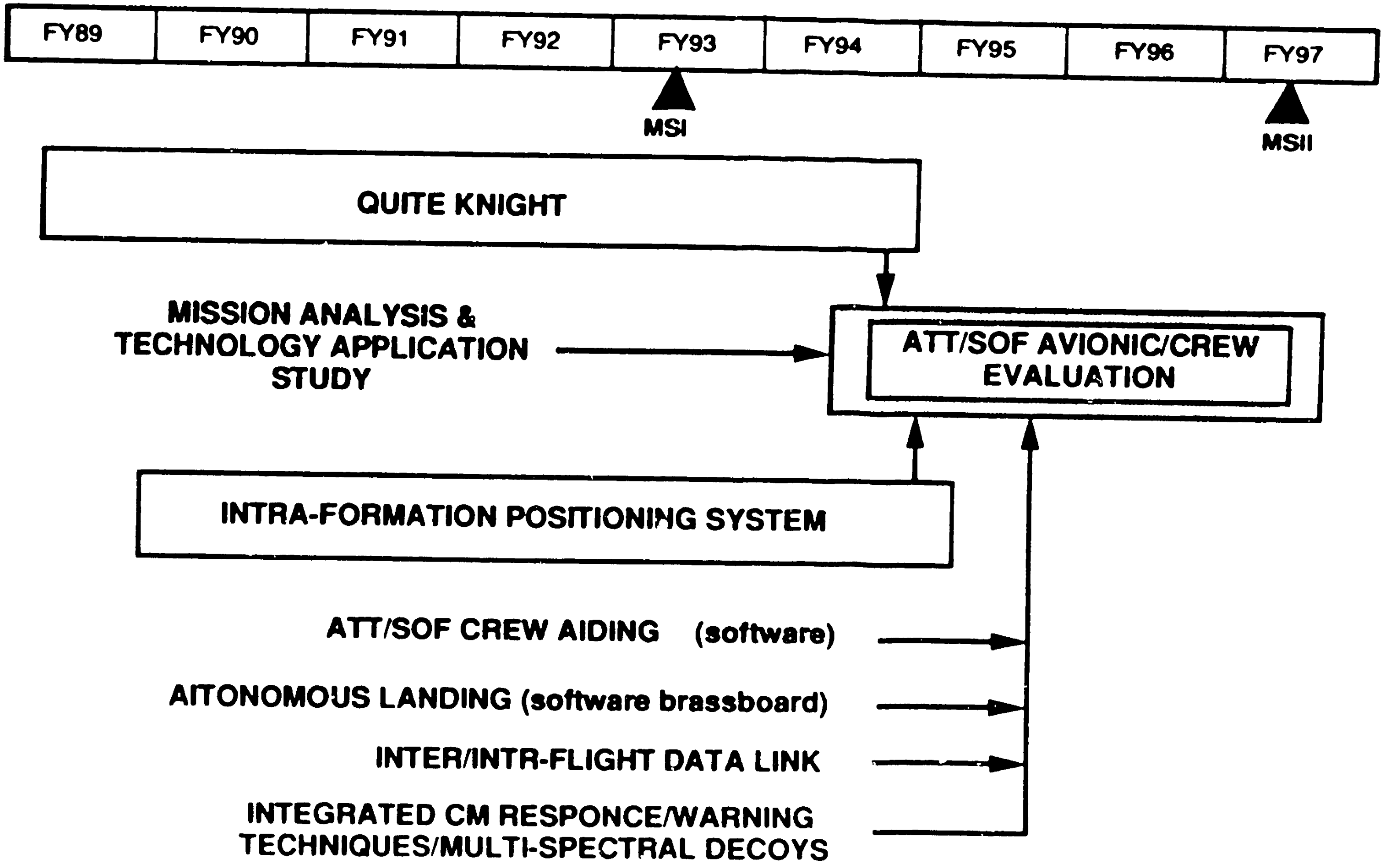
SWA ASSAULT MISSION



ATT 6.3 TECHNOLOGY ROADMAP
CRITICAL ADVANCED TECHNOLOGY TRANSITION DEMONSTRATIONS



ATT/SOF AVIONICS/CREW EVALUATION PROGRAM ROADMAP



FY89 FY90 FY91 FY92 FY93 FY94 FY95 FY96 FY97

MSI

MSII

QUITE KNIGHT

MISSION ANALYSIS & TECHNOLOGY APPLICATION STUDY

ATT/SOF AVIONIC/CREW EVALUATION

INTRA-FORMATION POSITIONING SYSTEM

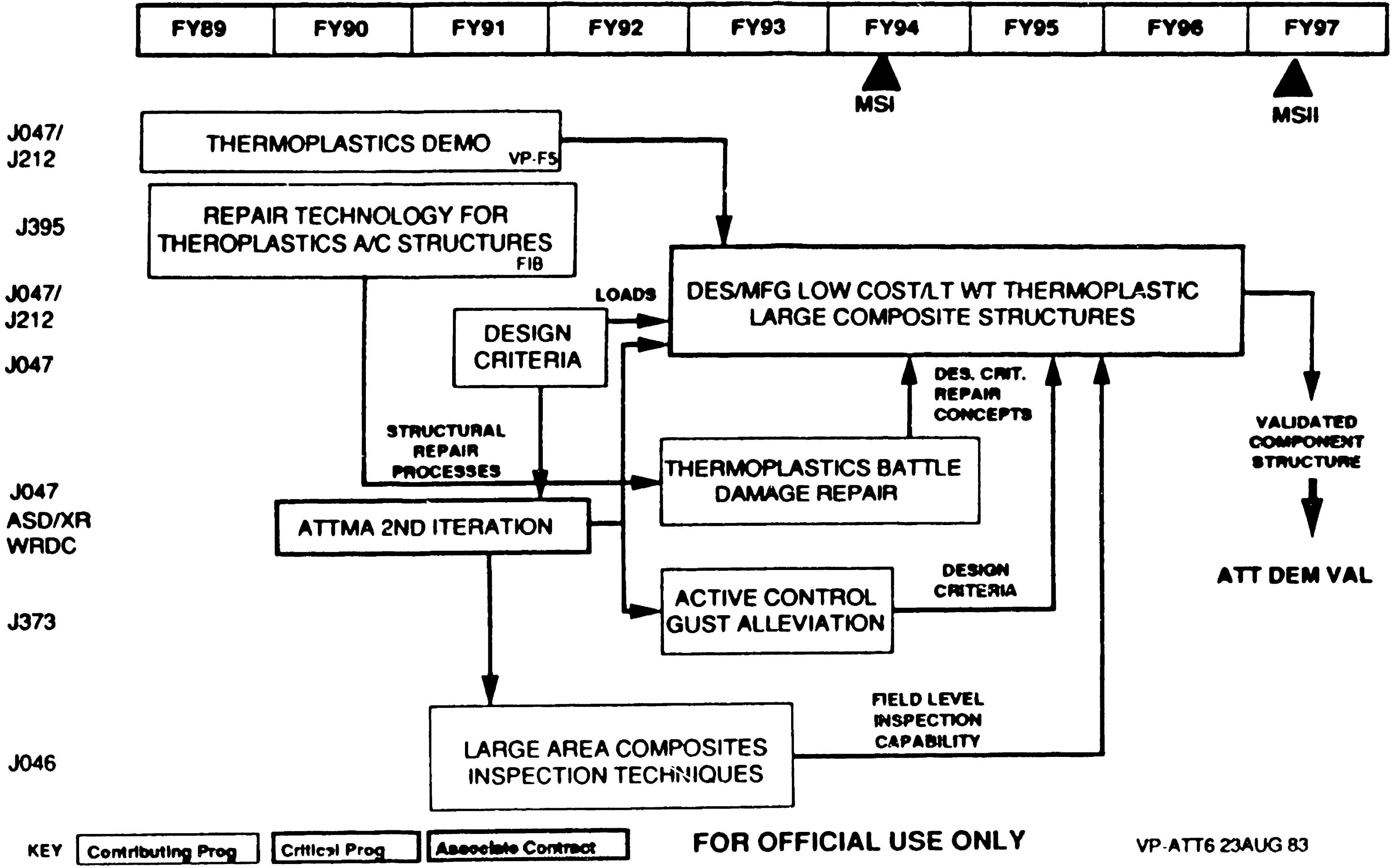
ATT/SOF CREW AIDING (software)

AITONOMOUS LANDING (software brassboard)

INTER/INTR-FLIGHT DATA LINK

INTEGRATED CM RESPONCE/WARNING TECHNIQUES/MULTI-SPECTRAL DECOYS

ATT Air Vehicle Lt/Low Cost, Sup Structures Critical Tdchnology Roadmap



FY89 FY90 FY91 FY92 FY93 FY94 FY95 FY96 FY97

MSI

MSII

J047/ J212 — THERMOPLASTICS DEMO VP-FS

J395 — REPAIR TECHNOLOGY FOR THEROPLASTICS A/C STRUCTURES FIB

J047/ J212 — DESIGN CRITERIA

J047 — DES/MFG LOW COST/LT WT THERMOPLASTIC LARGE COMPOSITE STRUCTURES

LOADS

STRUCTURAL REPAIR PROCESSES

J047 ASD/XR WRDC — ATTMA 2ND ITERATION

THERMOPLASTICS BATTLE DAMAGE REPAIR

DES. CRIT. REPAIR CONCEPTS

J373 — ACTIVE CONTROL GUST ALLEVIATION

DESIGN CRITERIA

J046 — LARGE AREA COMPOSITES INSPECTION TECHNIQUES

FIELD LEVEL INSPECTION CAPABILITY

VALIDATED COMPONENT STRUCTURE

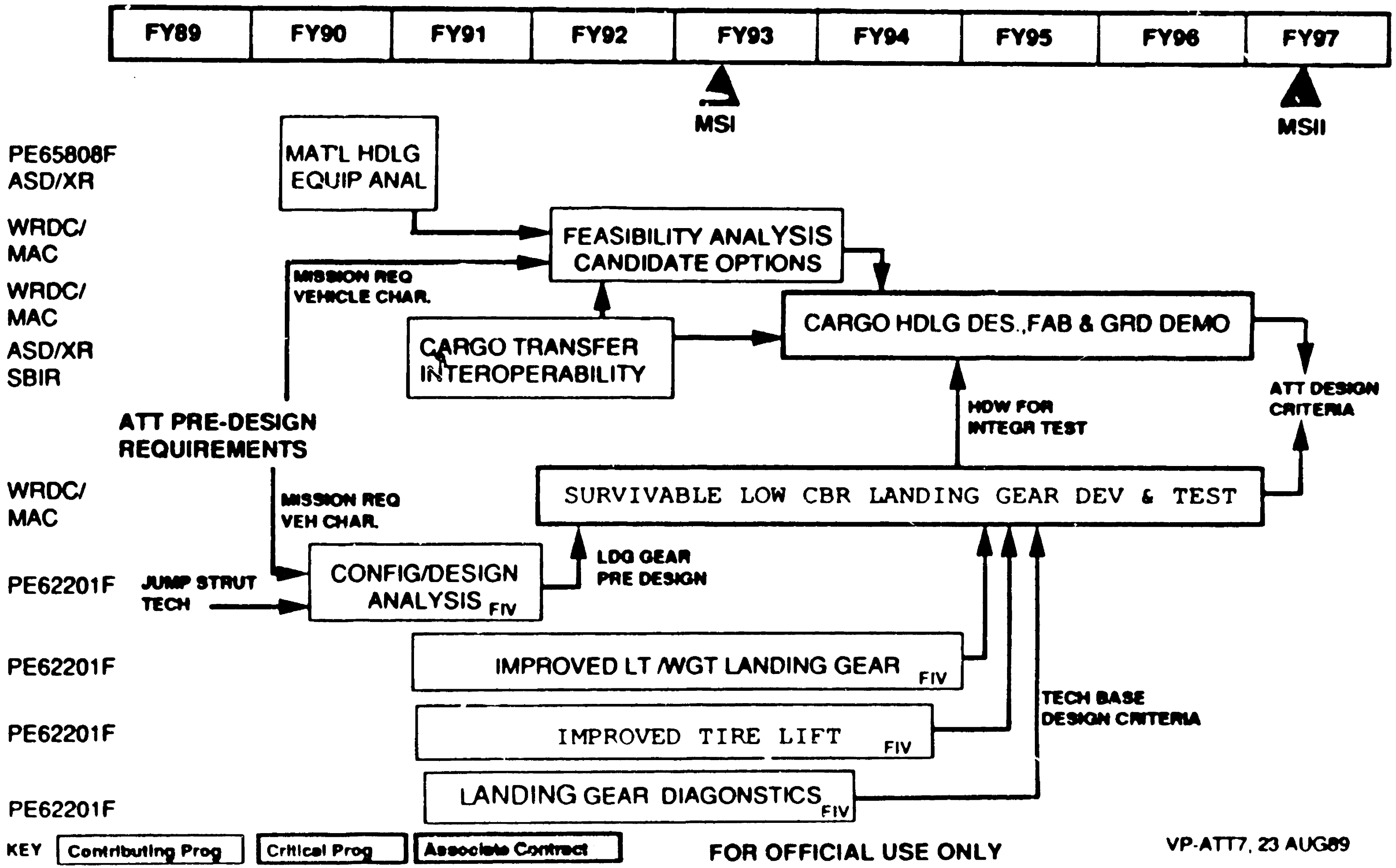
ATT DEM VAL

KEY Contributing Prog Critical Prog Associate Contract

FOR OFFICIAL USE ONLY

VP-ATT6 23AUG 83

Cargo Handling/Landing Gear Critical Technology Roadmap



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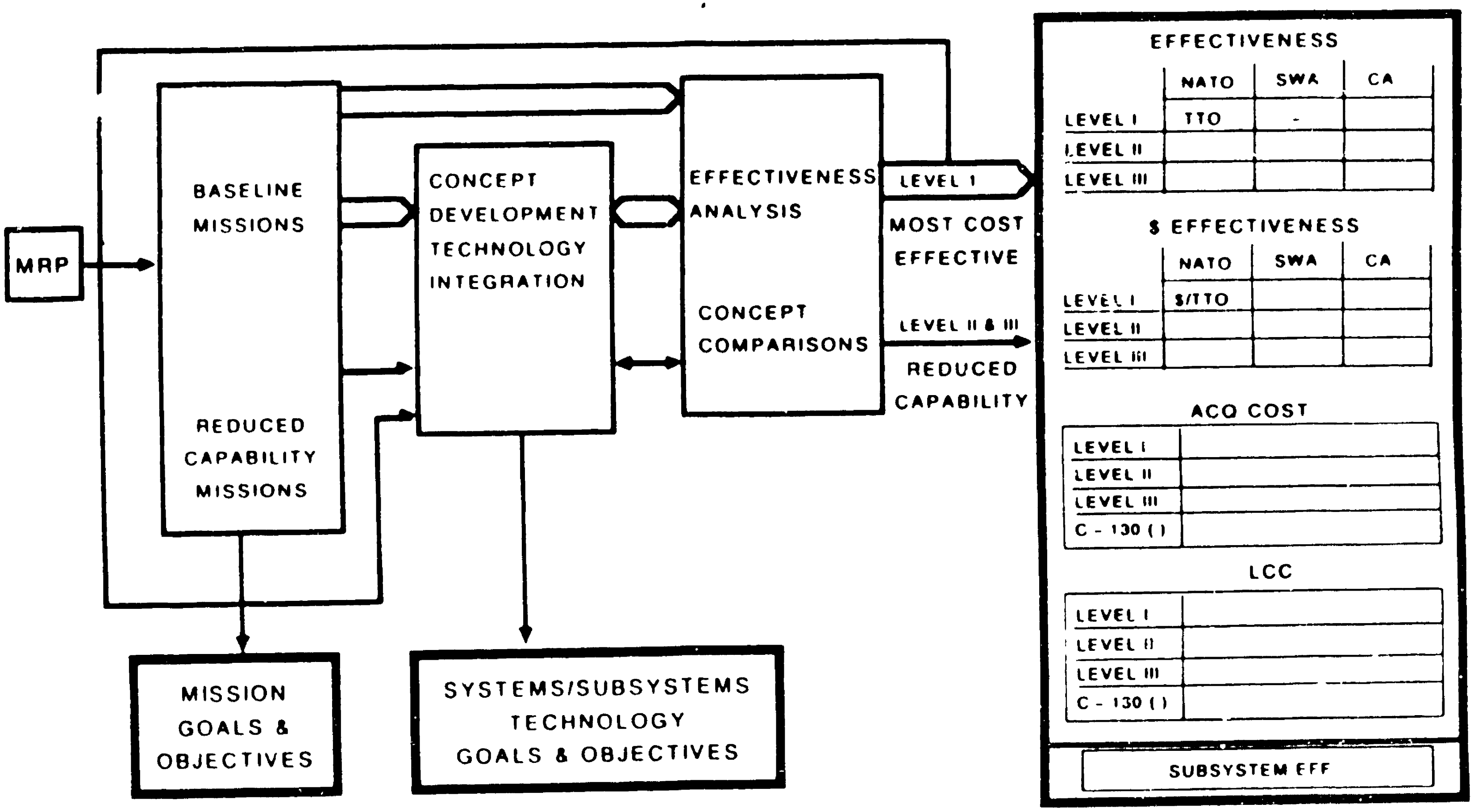
VP-ATT7, 23 AUG89

ADVANCED THEATER TRANSPORT
MISSION ANALYSIS AND TECHNOLOGY APPLICATION



MRP

BASELINE MISSIONS

REDUCED CAPABILITY MISSIONS

CONCEPT DEVELOPMENT TECHNOLOGY INTEGRATION

EFFECTIVENESS ANALYSIS

CONCEPT COMPARISONS

LEVEL I

MOST COST EFFECTIVE

LEVEL II & III

REDUCED CAPABILITY

MISSION GOALS & OBJECTIVES

SYSTEMS/SUBSYSTEMS TECHNOLOGY GOALS & OBJECTIVES

EFFECTIVENESS

	NATO	SWA	CA
LEVEL I	TTO	-	
LEVEL II			
LEVEL III			

$ EFFECTIVENESS

	NATO	SWA	CA
LEVEL I	$/TTO		
LEVEL II			
LEVEL III			

ACQ COST

LEVEL I	
LEVEL II	
LEVEL III	
C - 130 ( )	

LCC

LEVEL I	
LEVEL II	
LEVEL III	
C - 130 ( )	

SUBSYSTEM EFF

TASK

TASK I - DESIGN MISSION DEVELOPMENT

- NATO - SWA - CA
- ATT JOB ALLOCATION
- BASELINE PLUS REDUCED CAPABILITY
- MISSION PROFILES
- FUNCTIONAL MISSION DESCRIPTIONS

TASK II - SURVIVABILITY

- SUSCEPTABILITY AND VULNERABILITY
- THREAT LEVELS I, II, III (NATO, SWA, CA)
- AIR-TO-AIR, SURFACE-TO-AIR, ON-GROUND
- SUITE TRADES

TASK

(CONT'D)

TASK III - CONCEPT DEVELOPMENT / TECHNOLOGY INTEGRATION

- CONCEPT CATEGORIES
  - STOL
  - LDL VSTOL
- PREFERRED CONCEPT - BASELINE CAPABILITY
  - ONE PER CATEGORY
  - MOST EFFECTIVE SOLUTION - THREAT LEVEL I
- REDUCED CAPABILITIES CONCEPTS
  - TWO PER CATEGORY
  - FIRST ITERATION, BOX SIZE / PAYLOAD CONSTANT, THREAT LEVEL II
  - SECOND ITERATION, BOX SIZE / PAYLOAD VARIABLE, THREAT LEVEL III
- TRADES / SENSITIVITIES / RATIONAL

TASK
(CONT'D)

TASK IV - SUBSYSTEMS / TECHNOLOGY INTEGRATION

- DELINEATE SUBSYSTEMS OPERATION AND DESIGN REQUIREMENTS
  - MISSION AVIONICS
  - CREW STATION
  - PROPULSION
  - MATERIALS AND STRUCTURE
  - LANDING GEAR
  - CARGO HANDLING
  - FLIGHT CONTROL
  - VULNERABILITY REDUCTION TECHNIQUES

TASK
(CONT'D)

TASK V - CONCEPTS OF OPERATION

- THEATER ROLES C-17, C-130, ATT
- EXTERNAL SUPPORT
- INTEROPERABILITY

TASK VI - LOGISTICS

- USE PLAN
- R & M

TASK VII - SYSTEMS COMPARISIONS

- COST
  - MLCCM & CORE, 25 YEAR FY90$
  - 300 - 200 - 100 BUYS
- EFFECTIVENESS
  - THEATER / SCENARIO / CONCEPT
  - MIXED FLEET
  - FIXED FORCE & EQUAL EFFECTIVENESS
  - FOMS, TONS-ON-TIME, TOTAL TONS
    $ / TONS-ON-TIME, $ / TOTAL TONS

TASK
(CONT'D)

TASK VIII - PROGRAM SCHEDULE

- DEVELOPMENT PLAN / $ (6 OPTIONS)
- 6.3 DEMONSTRATOR PROGRAM PLANS

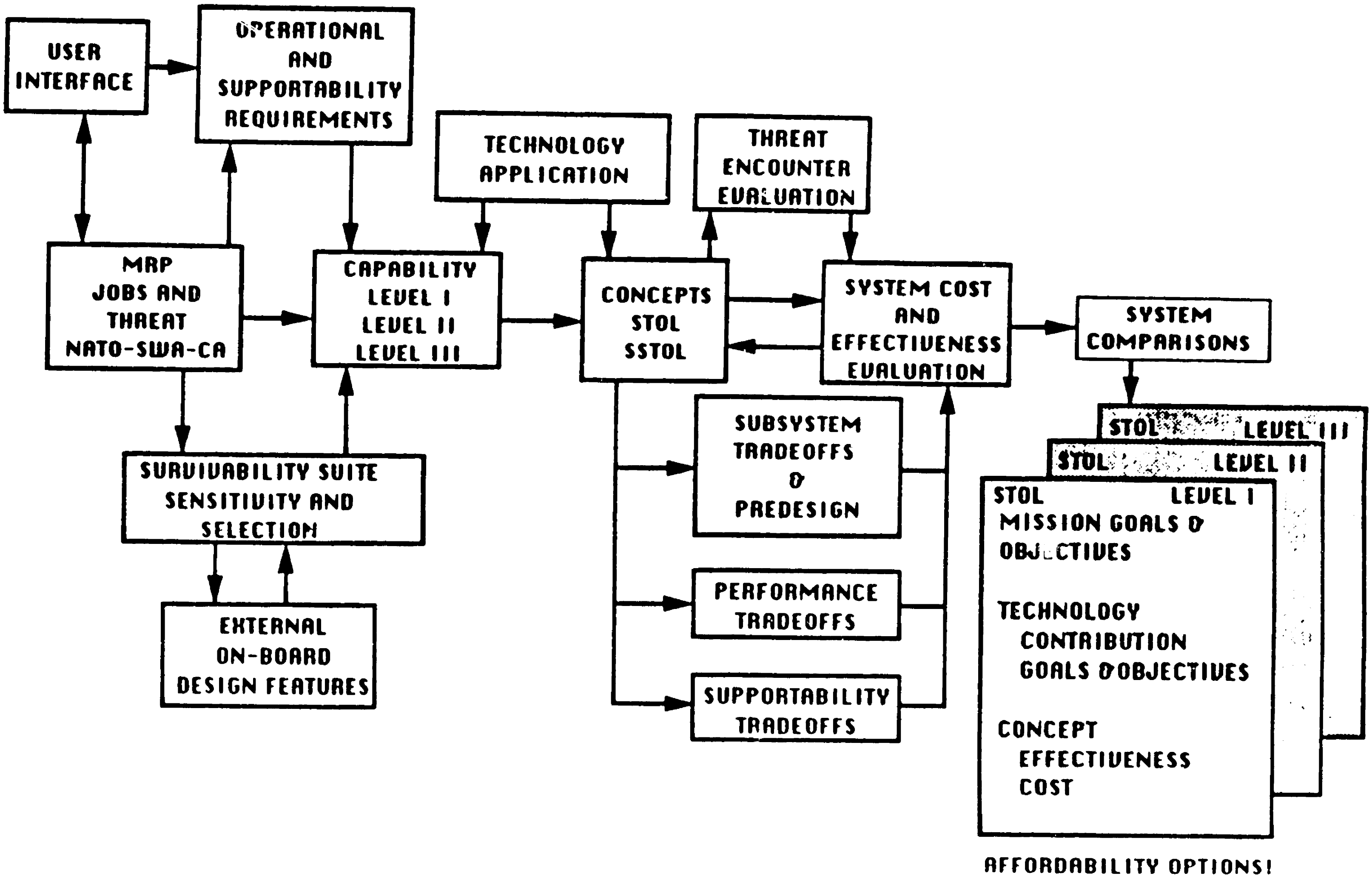
CAPABILITY PACKAGES

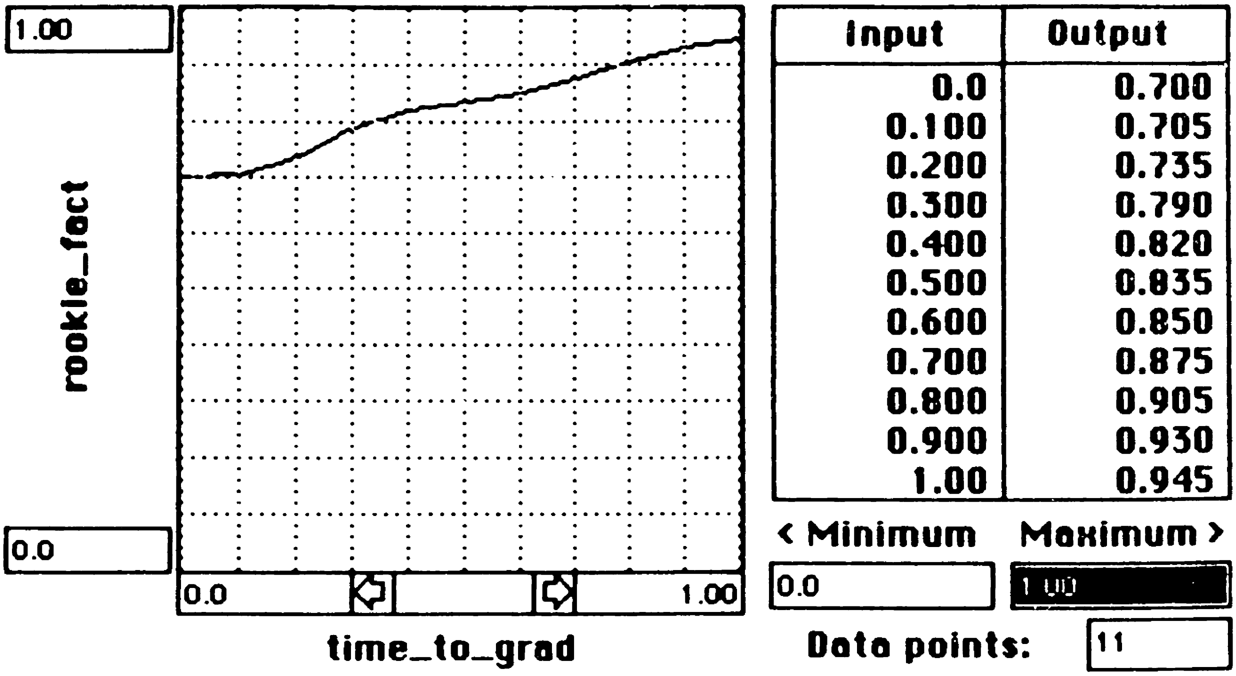
LEVEL I

LEVEL II

LEVEL III

ADVANCED THEATER TRANSPORT
MISSION ANALYSIS AND TECHNOLOGY APPLICATION



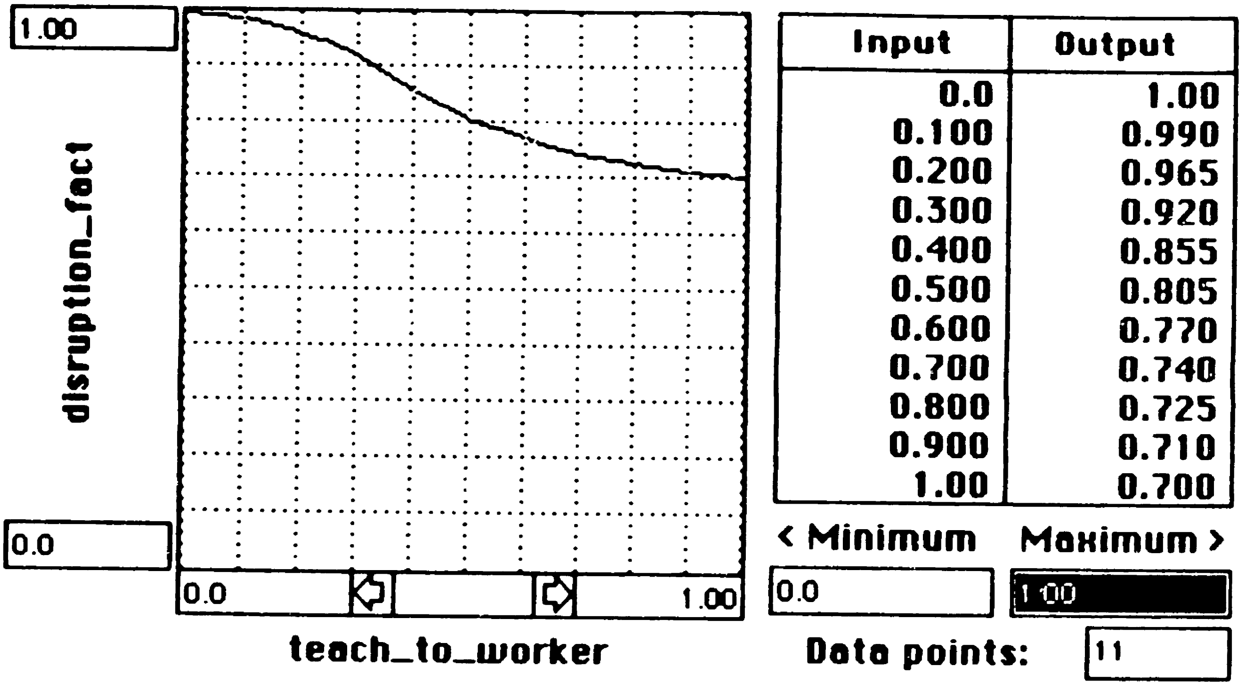


Input	Output
0.0	0.700
0.100	0.705
0.200	0.735
0.300	0.790
0.400	0.820
0.500	0.835
0.600	0.850
0.700	0.875
0.800	0.905
0.900	0.930
1.00	0.945

< Minimum 0.0

Maximum > 1.00

Data points: 11



Input	Output
0.0	1.00
0.100	0.990
0.200	0.965
0.300	0.920
0.400	0.855
0.500	0.805
0.600	0.770
0.700	0.740
0.800	0.725
0.900	0.710
1.00	0.700

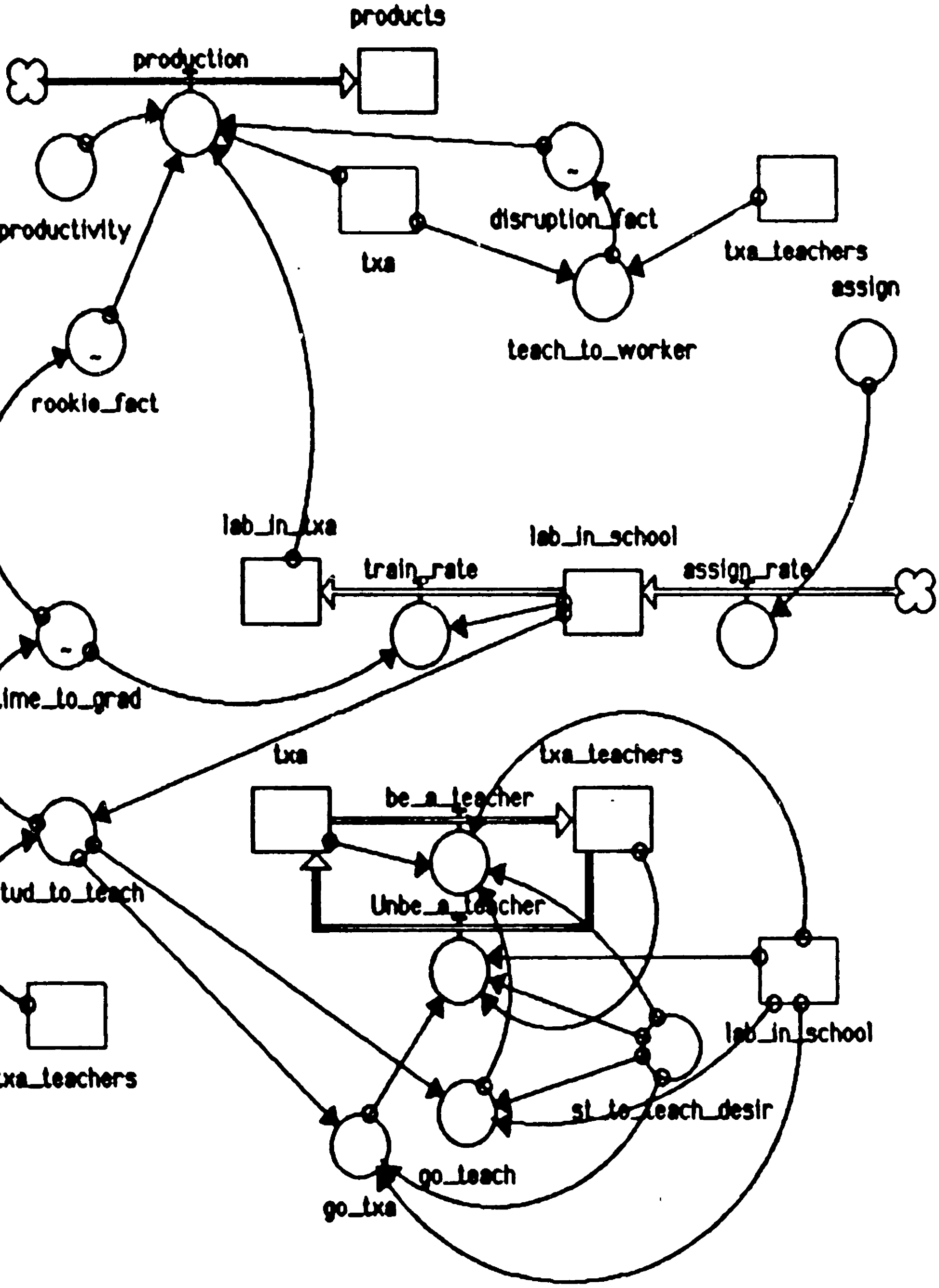
< Minimum 0.0

Maximum > 1.00

Data points: 11

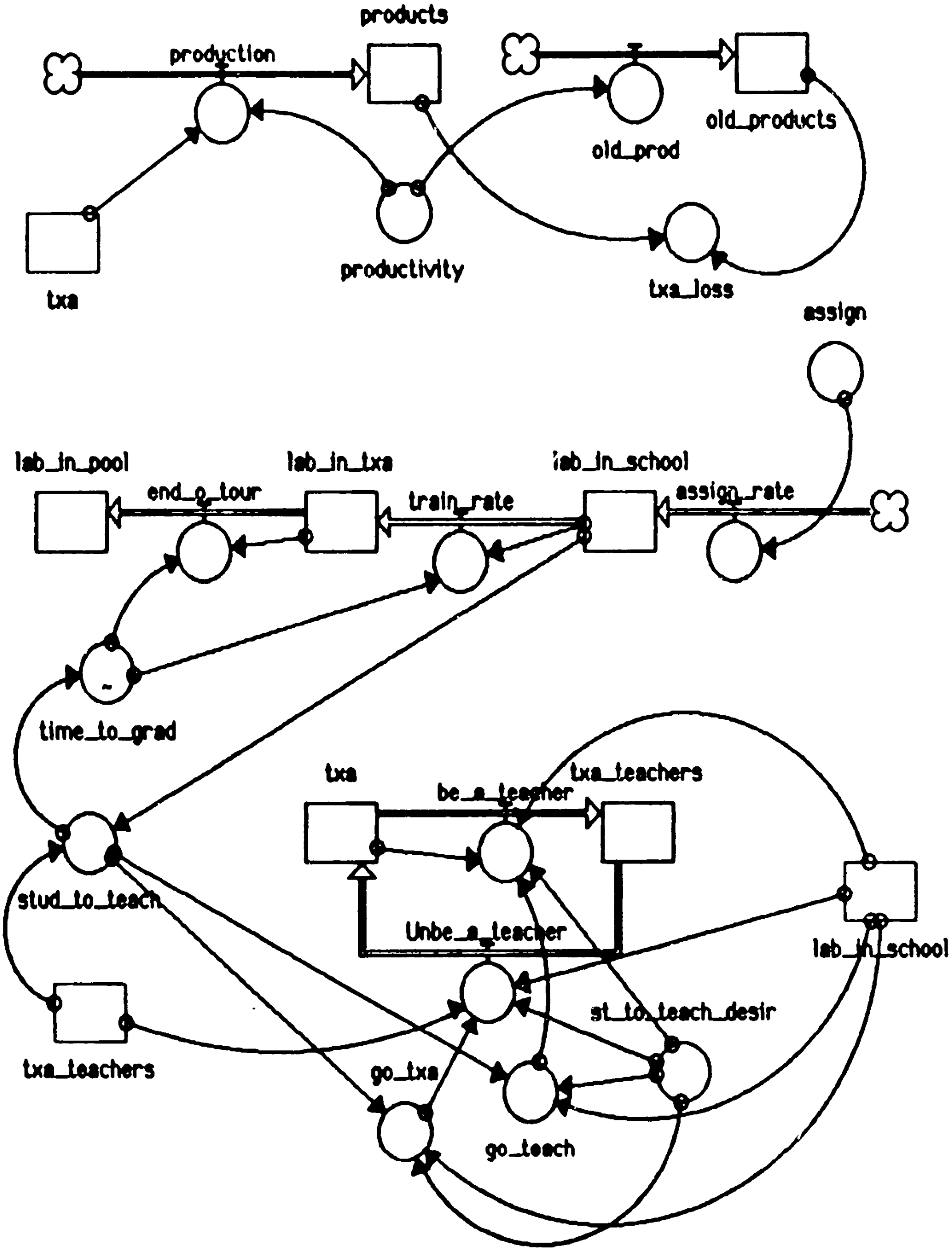
Appendix F

Appendix G



○ production = productivity*((disruption_fact*txa)+(rookie_fact*lab_in_txa))

Appendix H



☐ old_products = old_products + dt * (old_prod)

○ old_prod = productivity*25

○ production = productivity*(txa)

○ txa_loss = products-old_products