Chapter Two
Maintenance Organization

2.0 SUMMARY

This study recognizes the considerable strengths of the airline industry's maintenance flight safety efforts. It offers suggestions for additional research, and it describes some possible areas for further improvement. It represents a combined picture of maintenance management and organizational behavior in eight U.S. maintenance operations including small and large aircarriers and repair stations.

The sample used for this study was necessarily limited. The findings, therefore, must be understood as indicative only, and not conclusive.

The study was undertaken for the purpose of benchmarking: to estimate the effect current organization and management practice may be having on the work practices of mechanics, inspectors, and schedulers, and on their attitudes and morale, and how those, in turn, may affect safety and work quality. These factors do, in fact, show a close relationship one to the other.

While there was found considerable variation among these factors from one carrier to another, none was seen to have reached the point of compromising air-safety. This is an important finding for the industry, affirming its long-standing commitment to safe air travel.

Throughout the course of the study the people observed were seen as serious about their work, dedicated, well-meaning, and bright. Everywhere in the industry, employees clearly showed their desire to do their very best for air safety. Their commitment is reflected in their excellent performance record.

At several sites, employee morale and coordination of the work were found to be below the optimum. Based on the results of this study, the timely and careful adjustment of certain practices, structures, and norms might be an early prudent step to positively affect safety in the future.

For those who see in these findings confirmation of their own careful observations and conclusions, action may be taken with a fairly high degree of confidence. For others, only a more-broadly based, more thorough-going research effort or direct evidence of successful management changes and intervention will be convincing.

The present study sets the stage and suggests avenues for additional research and action.

2.1 INTRODUCTION

The excellent safety record of U.S. airlines is well established. A General Accounting Office (GAO) report states that "accident rate data . . . have improved over the last 20 years and that U.S. airlines have a lower accident rate than airlines in the rest of the world" (GAO, 1988).

Measuring the effects of maintenance on safety. Measures of safety other than accident rates have been applied with mixed results. Financial data may prove useful, but current reporting procedures for maintenance costs present difficulties in comparing companies within the industry. Airlines differ in their labor costs and accounting practices, and in the age of their fleets. Such differences make comparisons suspect. Because the Department of Transportation (DOT) does not require smaller airlines to report maintenance costs, these companies cannot be compared on this basis at all. New measures of current safety conditions would be useful.

Measuring and comparing airline maintenance quality is obviously important. The present major method of determining maintenance quality is to assess the degree of adherence to (or deviation from) the Federal Aviation Administration- (FAA) regulated maintenance programs. This approach does not measure the outcome of maintenance efforts, but instead relies on the assumption that if programs are followed quality will result -- in short, it is a measure of practice, not outcome.

Current interest in programs to measure and improve product quality (e.g., the Department of Defense (DOD) emphasis on "Total Quality Management") is beginning to be reported in the airline industry, (Doll, 1990), but such programs are apparently not widely applied yet. Comparable measures of maintenance quality, then, are still in the future. Measurement of maintenance related problems would provide a viable avenue to assess quality, but the available mechanical-reliability and unsafe-incidents data bases are designed to track short-term, not longer-term, trends (OTA, 1988). Thus, the currently available measures of maintenance on safety do not satisfy the need for measures except for historical accident data.

Measuring and comparing human factors. Despite recent conclusions that human factors in maintenance (and management practices specifically) can influence the judgement, attitudes and skill of aviation maintenance personnel (OTA, 1988) little research or action in this area has been reported. As will be described in further detail in the section on prior research, there is very little published about human factors in aircraft maintenance at either the individual worker or organizational levels.

This study is an initial effort to estimate the importance of organizational and management aspects of maintenance on morale and motivation, communication patterns, work-related behaviors, and quality of work for aircraft maintenance personnel (AMP). The results of this preliminary study suggest that links exist between organization, communication, attitudes and quality of work. Much more difficult to establish, but important to assess, is a link between quality of work and flight safety. That link was not intended to be validated within the scope of the present study.

2.1.1 Problem Definition - The Changing Environment for Aircraft Maintenance

Deregulation as a force increasing complexity for maintenance. During the initial years following airline deregulation (1979-1984), U.S. carriers' data reported to DOT indicated that a lower percentage of operating funds was spent on maintenance than had been the case in prior years (OTA, 1988). GAO noted recently that by 1988 the reported amount spent to maintain and repair aircraft was almost double the 1984 levels, and that current U.S. repair ability is operating at near full capacity (GAO, 1990). Such swings in maintenance expenditures, by themselves, place pressures on maintenance and inspection personnel. In another report, the GAO (1988) listed the following, among others, as "risk precursors" (their signs of problematic safety compliance) in U.S. air carriers: major route expansion, fleet expansion (due in part to mergers and acquisitions), industrial relations conflict (which can accompany mergers), and strained finances (complicated by intense competition and unstable fuel prices). Few U.S. carriers can claim the absence of these signs.

The additional problem of aging aircraft. Recent aging aircraft airworthiness directives (ADs) have been said to be an important stimulant to increasing short-term demand for airlines' need for maintenance (GAO, 1990). In the past decade the mean age of jetliners has risen 21% to about 13 years. With high altitude pressurized aircraft the number of flight cycles (one cycle includes a take-off and landing) is as important to age as years. Depending upon the specific model, aging aircraft are defined as those with more than 40,000 cycles. The GAO report notes that the cost of compliance with aging aircraft ADs may total $2 billion to sustain and extend the life of this aging fleet.

Inspectors and mechanics need to identify and deal with fatigue cracks in these old aircraft (especially myriad small cracks adjacent to one another, called "multi-site damage, or MSD") and corrosion in fuselage areas. This attention requires new information, skills, and time in addition to the normal work load. Demand for both airplanes and maintenance personnel continues to go up.

Organizational communication as it relates to maintenance. Attention to the human factor in maintenance is growing, and that human factor in aircraft maintenance is more than an individual who follows orders. In maintenance work, the human has often been characterized as "the technical system" - and this is not inappropriate. In this role, an inspector or mechanic ("inspecting") searches for flaws/ defects and decides when they have been found. After searching and locating it, the flaw is repaired in a planned sequence. This search-decide-plan-repair sequence is the "human factor as technical system" in maintenance systems of many industries.

With the importance and logic of this technical system view, a complementary view, that of the "human-factor-as-social-system" risks being ignored unless a conscious effort is made to include it. In this social systems view, the web of relationships among all the parties involved comes into focus in setting and strengthening expectations among them.

The social system is thus a set of expectations (sometimes positive and constructive, and sometimes conflictual and destructive) with others in the workplace, elsewhere in the organization, and with outsiders.

Management by design. Often managers (still) feel capable of making significant organizational decisions based on intuition and experience. But the tasks of organizing aircraft maintenance today have become extremely complex.

Among the organizational forms that have been used successfully in the past is assigning not only inspection and maintenance to separate departments, but separating materials, tools, shop repair of components, planning and scheduling from maintenance as well. Organizing into "functional silos" this way, strictly by application domain or function, may well affect maintenance system's ability to assure safety of flight through efficient, coordinated, motivated and informed action by people doing the work.

A parallel organizational form often found in aviation maintenance ignores functional differences altogether [except where required by Federal Aviation Regulations (FARs)] and relies on the "master craftsman's" technical skill and competence to determine and carry out the work. In today's complex maintenance environment, the functional silos, or master craftsman structures, that have proven adequate in the past may be breaking down in the present.

The safety record of the aircraft maintenance organization has been admirable. But it may be possible to achieve even higher performance, with higher morale and more efficient work coordination. To do so, however, would require more than minor improvements on the current system, which seems to already work about as it was designed to. Instead, the maintenance system would require redesign, eliminating or modifying sub-department boundaries so that the people could work more easily together in controlling key technical variances.

The central purpose for any such redesign would be to better enable maintenance personnel to control variances where they occur, and before they exceed stated limits. An effective redesign would save time, money, and effort as well. Prior research shows that such an approach, widespread in other industries, could usefully be applied to aviation maintenance (Taylor & Cotter, 1983).

2.1.2 Statement of Objectives

To improve safety, it is important to improve quality. To improve quality we must understand employees' state of mind and the organizational and management aspects most affecting that state. This study was directed at identifying these important aspects in aviation maintenance. With the support of the FAA, the study undertook field research as a rapid diagnostic tool to understand and describe the network of relationships, commitments, loyalties, and motivations of all roles in air carrier maintenance.

This study used observation and semi-structured interviews with a sample of members in significant roles in the heavy maintenance system. The non-management employees closest to the aircraft, during overhaul, are the airframe and powerplant (A&P) mechanic, the aircraft inspector, and the maintenance planner/coordinator. These three roles are of special interest in the present study. They are in contact with one another, and together with their supervisors, they have the front line responsibility for heavy maintenance. Throughout this chapter they will be referred to as aviation maintenance personnel (AMP).

The focus of the study includes not only AMPs but their contact with their unions, their supervisors, technical trainers, production planning managers, maintenance managers, engineers, and others such as manufacturers' representatives and FAA inspectors. The object of these observations and interviews was to begin to describe the systems of coordination and cooperation used to accomplish safe and effective aircraft maintenance.

If attitudes and state of mind are influenced by how the AMP are organized, directed, coordinated and communicated with, are the differences across the industry broad enough to cause notice? Such differences can further be used to identify some innovative, insightful and appropriate alternative styles, practices, and company cultures. The result of this study is general recommendations to the industry (where possible based on best practices), in the "normal" maintenance, scheduling, and inspection process, as well as in management style and support activities.

2.1.3 Prior Research

A recent search of published references from the 12 year period 1976-1988 yielded only 15 papers on human factors in aircraft maintenance. Of those found, many dealt with the physiology of human response. Examples of these include discussion of the effect of location, shape, or convenience of cockpit controls serviced by mechanics (Schmitt, 1983). A few studies discussed the whole person in context (Lock &Strutt, 1981; Strauch & Sandler, 1984).

A recent article described a maintenance system with dedicated teams for each 747 aircraft which Japan Air Lines (JAL) instituted in 1985. Individual ***kizuki*** teams (it means "airplane crazy"), typically 15 engineers and AMPs each, were reported to be responsible for overseeing the condition of one of JAL's 747 aircraft at all times, regardless of where it may be (Ramirez, 1989). Although reported in glowing terms no specific results or costs were related.

Accounts of successful team-based aircraft maintenance organizations have recently been reported in the U.S. Air Force (Rogers, 1991). Improvements in results measured through a series of maintenance effectiveness indicators are reported.

Use of new technology. One reference described and reported technical advances in military aircraft engine design that were developed to make field maintenance duties "soldier-proof" (Harvey, 1987). That reference to eliminating the human factor through technology (or at least as much as possible) is an alternative to the notion of a system of informed decision making and cooperation (cf., Diehl, 1990). Based on experience in other U.S. worksites (e.g., Sloane, 1991), it is assumed that radical automation which replaces human decision making with machines isn't necessary (and may be suboptimal) where AMPs can provide timely and informed judgements based on an understanding of the "big picture."

Technical advances can be adapted to strengthen the maintenance system's human response to its complex world. For instance, one air carrier reported reforming a rule-based maintenance software system, originally intended to direct mechanical work, into a supplemental decision support tool. The results included retaining the cost benefits of the former system while improving maintenance quality and mechanic satisfaction (Mayer, 1987). A spokesperson for the carrier said that this reform has changed the "expert [computer] system" into a [computer] "system for experts."

2.2 THEORY AND METHODS

2.2.1 The Research Methods - Procedures

Site visits. Eight U.S. air carrier and repair station maintenance operations were visited. The choice of U. S. maintenance sites was based on varied carrier size (including commuter line carriers), and varied location in the 50 states.

The specific focus of the study was the maintenance and inspection work process as it relates to structure (primarily fuselage) repairs in aging aircraft. This focus includes management practices as they may affect the practice of aircraft maintenance, particularly as they relate to the aging fleet. This sample included so called "heavy," or hangar maintenance only. In particular, the "C" level maintenance check proved to be the ideal intensity of overhaul for the present investigation. The C-check was ideal because it takes long enough (up to two weeks) to reveal patterns of communication (which are more difficult to observe with the varied and short jobs on the flight line), but short enough so that a visit of two to four days samples a sizable segment of it. The C-check is the third-level maintenance check for an aircraft, usually done once a year or after about 2,000 flight cycles.

Each company site visit lasted two to four days. Investigator impact on employees and management was purposefully as slight as possible. The investigator worked largely unsupervised and was present on night and evening shifts as well as during the day. Every effort was made to insure minimum disruption at the workplace.

The identity of results obtained from the individual companies agreeing to participate was promised to be held permanently confidential. In addition, data reports and summaries would not reveal the identities of individual persons interviewed or observed.

Developing the interview format. An observer/interviewer protocol was created to aid in collecting and understanding maintenance system communication data during site visits. This protocol was not intended to form a structured interview survey, since much of the data sought could be obtained through observation. This protocol formed the anchor or structure for obtaining the data described below.

Obtaining site access. The liaison to the Air Transport Association (ATA) Engineering Maintenance and Material Council helped provide access to six of the research sites used in the present study. Access to the FAR Part 145 repair station and one of the regional carriers was obtained through the cooperation of the FAA Office of Flight Standards.

Four additional maintenance sites were approached for participation in the study, but could not be visited in the time frame of the study. In all cases the airline executives approached were extremely busy during the period of the data collection and this preoccupation reflected intense activity in their organizations. This period of overload was the dominant reason that more heavy maintenance hangars were unavailable for observation.

Collecting the interviews. The interviews began with the first site visit in February 1990, and concluded in August 1990. Over 250 technicians, supervisors and managers were observed or interviewed. In total, 120 AMPs were observed and met with, 65 foremen or supervisors were observed and interviewed; and 80 other informal discussions were held with engineers (or other professionals), superintendents, managers, and higher executives at the sites. Most interviews were conducted at the workplace. All data collected are confidential and the names of the interviewees and the company were not discussed with others.

Accounting for Potential Sources of Error. The interested reader may wonder about the effects that observations of managers and AMPs have on the quality of the data collected in a study such as this one. Such contamination, when it is found, is often called the "Hawthorne effect" or "experimenter effect."

This concern can be addressed by describing the probable extent and severity of possible contamination. For instance, AMPs may want to say what they believe the investigator wants to hear, or behave in a way untypical of usual behavior at work.

The issue is whether the presence of an investigator on the hangar floor for several days does or does not substantially change work performance, or the manner or frequency of contact among mechanics, inspectors, planners, foremen, engineers and others. It needs to be emphasized that although respondents were asked to report events or results of events that had passed, the major focus of this research was the direct observation of what they were currently doing on the job, on a normal day, on an aging aircraft in the hangar for scheduled annual inspection.

With respect to the validity of the observations, it is difficult to believe that significant number of individual AMPs could substantially change their behavior during the visit. It seems even less likely that a foreman or manager could or would suddenly change the work assignment or coordination patterns of his crew. Finally it would not be likely that ingrained work habits could be postponed or deferred until after the investigator had left.

The validity of answers given to the investigator's questions is presumed high as well. Typically, questions had to do with the content of an interchange between people, and multiple parties were usually asked about the same transaction. Other questions related to motives or feelings about behaviors of self or others. Such motives and attitudes are expected to vary among people, but the interest in the present study is on commonalities among AMPs. Thus motives or attitudes are not reported unless the same or similar data had been collected from a number of people at the same site.

In each site visited, the investigator first introduced the purpose of the study to local management. That purpose was described as "establishing a baseline of technician behavior," as well as job and organizational characteristics. After that, foremen on each shift were in turn introduced to the study. Their cooperation in permitting the investigator to approach their subordinate technicians was sought. The purpose of these visits was continually enunciated. Considerable time was spent helping the respondent (AMP or foreman) feel comfortable with the approach. After several days of the investigator's return to the same shifts, most respondents expressed comfort with the investigator's presence and with the purpose of the study. Once at ease with the intent of the study, AMPs and foremen then carried on their jobs, with others, as on a normal day. They were very willing to explain or clarify the reasons or purpose of their acts, interactions or behaviors of themselves or others that the investigator could not or had not seen.

This data collection then, was typically seen as a neutral event and a mild change in routine for respondents. In some cases technicians, foremen or managers expressed interest in seeing the resulting report. Departures at the end of a visit were always warm or at least cordial. Call-backs were made to the managers at several sites. In no case was negative feedback obtained - the visit had been a neutral event.

There exists one coincidental source of data which confirms that the method of data collection used is not stressful or confounding. These data result from the occasional overlap in sites sampled between the present study and the Job Task Analysis (JTA) described in Chapter 3. The study described in the present chapter followed the data collection at three sites used in the JTA. In all three, special attention was paid to the possible effects of a slightly earlier visit by other field investigators. The JTA study had been of inspection departments only and the study in the present chapter deals with the total heavy maintenance system (as far as it includes "C" checks). Thus there is only partial overlap in the people interviewed or observed at a given site. When speaking with inspectors in these sites they said either that they remembered the previous visit with pleasure, or that they barely remembered it, or only recalled being told about it ("it was so brief," took so little of their time, didn't come up in conversation with others, or was just "one of many" distractions passing through the hangar). In no case was the JTA study visit recalled with suspicion or derision. It is extremely doubtful (given all of this) that technicians or foremen had been able or willing to substantially alter their usual behavior on the job simply because investigators were there, observing a typical day.

2.2.2 The Organizational Model - Socio-technical Systems (STS)

Socio-technical Systems (STS) is the organizational model used in this study to describe aviation heavy maintenance system. STS was developed to help understand purposeful work systems in complex, environments. STS assesses "goodness of fit" among people and technology as they respond to their environment in attaining systems success. STS analysis combines a technical systems view with a social systems view to capture the strength of both (Taylor & Asadorian, 1985). STS is a theory and practice of organizational development, in use over 40 years and applied in a wide variety of industries world-wide.

The phases of STS analyses. STS analyses adhere generally to a series of steps or phases. Although they may differ from project to project in precise terminology or serial order the phases may be described as follows:

1. Clearly defining the system's purpose, its values, its objectives, its boundaries, and its salient environment - **The System Scan.**
2. Identifying the critical or key variances in the product, or throughput, which most determine success in meeting objectives and thereby pursuing the basic mission - **The Technical Analysis.**
3. Examining the role relationships among the system members or employees in controlling the key variances and in cooperating otherwise for the survival of the system - **The Social System Analysis.**

STS begins in the system scan with the purpose or mission of the enterprise (in aircraft maintenance the purposes of the maintenance and engineering systems should be consistent with the overall mission of the company), and examines the degree to which there is a common language and common product for this purpose throughout the whole maintenance network. Examples of possible questions revealing mission include: Is the airline the "most profitable," "the biggest," "the cheapest," "the business flyer's airline," the "best value," the "safest," the "highest quality" (either in aircraft, or in service), the "most reliable," or perhaps the "most visible carrier in its market?"

Public statements of such mission statements (including communications to employees) are extremely rare in the sites sampled. Some airline missions are directly addressed by maintenance performance objectives, but many are not. Of course safety and aircraft quality are maintenance deliverables, but it is unlikely that any air carriers, in any country, single-mindedly and exclusively pursue these ends alone. It is logical to expect, in many cases, that maintenance remains "the place where highest mechanical safety is pursued at the most reasonable cost." If this is true, there is little to engage the average AMP with the company's overall mission and goals. He or she "belongs," then, only to a maintenance shop, divorced from the larger purposes of the airline - purposes which could help provide a sense of context, meaning, work priorities, and congruence between maintenance and the company as a whole.

An example is available to illustrate how a public, visible (and presumably believable) airline mission can be connected to heavy maintenance activities. The Japan Air Lines "kizuki" concept of a dedicated maintenance team per aircraft has received heavy advertising exposure during 1990. It is interesting to note from the magazine advertisements that JAL is proud of its "on-time departure record," and that "kizuki ... obsession with 747 performance has helped maintain that record." While similar mission-driven innovations have led to well-documented successes in Japan's auto industry - and to various industries in America and Europe as well - no hard numbers on JAL's kizuki system are yet in the public domain. Perhaps they never will be. Some U.S. companies (Proctor & Gamble, for one) hold the details and results of a team system approach very close to the vest, on the grounds that it gives them a distinct competitive advantage worth protecting.

Given purpose or mission, it is also necessary to be clear about the deliverable or output from maintenance. Is this output consistent with and in visible pursuit of company purpose, or is it at odds with the larger enterprise? These comparisons are made during the STS "technical analysis." The technical system analysis explores the question: "what happens to our aircraft as they pass through our maintenance systems again and again?" The answers are important to understanding the maintenance function as a system, because they focus on the results of the work instead of just the functional and organizational specialties surrounding the work.

Key variances (an STS concept defined as factors in the product throughput, which determine success in meeting objectives and thereby pursuing the basic mission) in aircraft overhaul, as in any technical system provide priorities for understanding complex work. They are often interrelated, they always reside in the system's throughput, and they can be expected in the process of a "normal" day.

Examples of technical variances in aircraft repair include the following:

> **Time required for repair** [the longer, the greater priority to start with it].
>
> **Parts availability** [identifying what needs replacing early enough to order it cheaply or preclude delay of repair beyond the norm].
>
> **Nature and/or extent of flaw, defect, or damage** [more complexity requires special skills, and coordination with other skilled members].
>
> **Visibility of flaw, defect, or damage** [less visible flaws are often detected later and can delay, prolong, or defer other priority work].

Once specific variances are identified in the technical system throughput, these are investigated to determine how they are controlled, by whom, using what information. This key variance control analysis provides an important opportunity to see the degree current ways of controlling these variances through effective thinking and behaving may show room for improvement.

The social systems analysis examines the work-related communication among people in an enterprise. It permits description of the social system as the coordinating and integrating buffer between the technical transformation process and the demands and constraints of a turbulent environment. The people who are in the most central or focal roles in the social system are those who are most involved in the control of key technical variances.

In the present study social systems analysis addresses the work-related interactions among people in the maintenance system. It is an evaluation of who talks to whom, about what, and how it's working. Social systems analysis is linked to the technical analysis because the most important communications documented are about the throughput and product, but the social system is also the wider mechanism for flexible response to a changing environment.

2.2.3 Analysis of the data

All data from observation and discussions were entered in a database, coded by "system scan" information, "technical system" information, "attitude or morale" data, and "social interaction." This last category was further coded by the type of social interaction specified above. These data were collated and analyzed by the investigator.

The social system analysis was conducted in the following manner. First, all of the data were combined and the responses to each topic discussed were consolidated. All of these responses to each of the topics were then tabulated by job title and summarized. The social system analysis focused on the concept of the social role as the basic link between organization demands and employee competence and understanding. The social system was defined as a network of work related actions and communications which are mediated by the reciprocal role expectations of individual employees. In this context, all relevant relationships in heavy maintenance were defined as including the following:

1. Superiors with subordinates,
2. Members of the same work group with one another,
3. Members of work groups with members of different groups within the heavy maintenance system, and
4. People inside the heavy maintenance system interacting with people outside that system.

In addition to these four relationships, attention was also focused on the relationship between role occupants (AMPs) and their jobs (or quality of working life), since job related feelings are strong determinants of morale.

The social system is further described as serving four organizational functions. The four functions that any social system fulfills are as follows:

1. Attaining the systems primary GOALS (G);
2. ADAPTING (A) to the external environment for immediate survival;
3. INTEGRATING (I) internal environment for management of conflict; and,
4. Providing for the development and maintenance of the system's LONG-TERM (L) needs.

These four functions (G, A, I, L) can be evaluated in terms of each of the four types of relationships described above, and the results displayed in a 4 X 4 grid (a 16-cell matrix of functions 4 relationships) where each cell in the grid is used to specify a particular type of social behavior.

The social analysis focuses specifically on the primary relationships of a "focal role." In this case the mechanics, inspectors, or planners and their foremen or managers became the focal roles around which the social analysis was developed.

Based on the responses surveyed, the investigator proceeded to evaluate the meaning of the data as classified in each of the 16 cells of the grid. A positive sign ("+") indicates a favorable rating by the investigator that the communication as observed was helpful or facilitative to the function or relationships. A zero ("0") means the communication as observed was neutral to the function or relationship. Finally a negative sign ("-") means that the communication was seen or reported to be detrimental to the function or relationship.

The social analysis was then continued by developing a "focal role network" (i.e., a map of relationships indicating who interacts with whom about what) that illustrates the activities taking place around the AMP and their supervisors. These networks were constructed basing the distance between the various roles on the frequency and importance of the interactions.

Defined this way, the social system is not mere friendship or informal support, but rather the source of adaptability and flexibility in coping with variances in the product, and with the system's complex environment. The demands of this environment go beyond merely satisfying a consumer market, or coping with supplies of raw materials, or the other aspects directly affecting the technical system. That environment is actually many environments - legal, legislative, labor, cultural, competitive, climatic, and so forth.

2.3 RESULTS AND DISCUSSION

2.3.1 Evolution of commercial aircraft maintenance, 1970 - 1990

During the course of the site visits for the present study a number of long-service heavy maintenance managers and supervisors described their views of the industry. What follows is the remarkably consistent picture which emerged, from these discussions, of the changes during the 1960s, the 1970s, and the 1980s in airline maintenance.

In the late 1960s and early seventies modern jet airliners (Boeing 707, and Douglas DC-8 in particular) were well established in the U.S. commercial fleet. Douglas DC-9 and Boeing 727 were newly introduced as smaller load, shorter trip, but still high altitude high speed aircraft. At that time the organization of hangar maintenance was guided by the skill and experience of general foremen. To them reported shift foremen and specialist mechanics prepared mainly by their duty tours in military aviation. Already included before the 1960s began were schedulers (or time-keepers) to monitor job assignment documents, and instructors to improve and broaden the mechanics' performance and skills on the newer aircraft. The oil crisis of 1973 sent fuel and ticket prices up, causing a reduction in passengers, and caused many airlines to lay-off newer, less experienced mechanics.

By the late 1970s and early 1980s the experienced mechanics and their supervisors had reached a high level of competence. Job cards for work assignment had been proven effective and the process of standardizing the work flow in hangar maintenance had created a need for a larger role for the "work planner." In 1979-1980 the further oil shortages, higher fuel prices, the air traffic controllers' work slowdown, and deregulation all converged to force many carriers to reduce costs further in face of increased competition. With aircraft maintenance technically under control with an ample and competent workforce, more AMP cuts were made.

Currently, in 1990, we find reduced numbers of experienced heavy maintenance mechanics and inspectors - the still-lingering result of AMP layoffs during the economic turbulence of 1979-83; coupled with the exodus of senior AMPs prompted by retirements, promotions, and interdepartment transfers to maintenance shops. Following the recession and deregulation, what we find are myriad signs of a cost-conscious industry - the most obvious signs of which are reduced parts inventories, and the lean AMP staffing levels. Finally, as we well know now, the fleet of new transport aircraft in 1970 has become "aging aircraft." Together these changes result in the typical 1990 hangar maintenance organization guided by shift foremen and/or planners. The latter are increasingly computer-literate and tasked with digitizing the job card and work planning/tracking system. With the hiring of new AMPs, and with the increasing complexity of new aircraft maintenance, training departments and their instructors have become once again an important aspect of maintenance effectiveness.

The current hangar maintenance AMP staff typically has a bimodal experience distribution of 30-plus years, and 3 or fewer years. There are relatively few heavy maintenance AMPs with company tenure between those two peaks. With the increase of aging fuselages and Airworthiness Directives (ADs) to attend to them, the greatest demand for new mechanics has been in sheet metal repair. Thus most sheet metal mechanics are new, and most of these are young. Many sheet metal mechanics hold an AP license, but are newcomers to the field, having done other work first. In many cases these new AP do not have military experience, and if they do, they are not necessarily immediately qualified for AMPs work with commercial transport category aircraft. For instance experience as a military aviation crew chief provides limited but deep experience in weight & balance; while repair in helicopters provides minimal understanding of repair on pressure cabins. There are also some AMPs who come into airline maintenance work after spending time in defense-related and/or commercial aircraft manufacturing. They usually know little about repair, although they are often very competent in sheet metal riveting. While some of them may know little about repair, many AMPs today are not hired as experts in aircraft repair, but to specialize in sheetmetal work only.

In summary: The prominent foreman role of the 1970s, reduced during the 1980s has reemerged in the 1990s in order to manage the many new AMPs in the heavy maintenance work force. An added complexity is that computerized planning systems (including the planners, schedulers, coordinators who operate them) constitute a challenge to the foreman's traditional authority, and the "authority of knowledge" held by the "master craftsman" in this industry.

The remaining results of the study will be presented as follows. First are the unfiltered results as obtained from the formal protocol developed for the visits. Next are the most frequent opinions, attitudes and feelings expressed by AMPs during the visits. These feelings or thoughts are specifically those dealing with company and maintenance system culture, mission, or values, and therefore contribute to important aspects of the system scan. Third, technical system data are described which deal with the aircraft and elements comprising the "critical path" of the overhaul. Fourth, the social system data are presented from the analyses described above.

2.3.2 Initial Results from the Observation/Interview Protocol

The following section describes the overall findings from the site visits, organized by the questions or items in the protocol. The descriptions reflect a norm for the sample studied, and not necessarily any carrier in particular.

1. **Contact among mechanics**

   a. How many mechanics are working together on this aircraft? About 25 mechanics work together per shift for a total of about 75 mechanics total on the average C-Check.

   b. How many subgroups are employed on various jobs on the same aircraft? Between four and six maintenance subgroups are employed on various jobs on the aircraft during overhaul. These subgroups consist of the occupational specialties of sheet metal mechanics, riggers/general A&P, cabin mechanics, cleaners; and sometimes painters, and contractors (specializing in particular repairs such as fuel tanks).

   c. Are subgroups involved in the overhaul that include occupations other than mechanics? Other regular subgroups or occupational specialties involved in the normal C-check are inspectors, parts or materials clerks (two or three to a group), and planners or coordinators (usually organized in groups of two to four).

   d. Did the subgroups meet together or reform themselves so that mechanics work with various others during the period of the visit? These groups were not observed or reported to meet together as such. The subgroups do not change themselves in composition during the check although they may change in membership as usual members rotate through their individual shift schedules, or work overtime on another shift. Occasionally a mechanic was reassigned by the foreman to work with mechanics in another subgroup, or a foreman would request all available members of a subgroup to assist in a task to which they normally would not be assigned.

   e. How often do the mechanics (or other AMPs) meet during the visit? What is the content of the meetings, How large are the meetings, How long are they, When do they fall in the shift, Who conducts the meetings? The frequency of formal meetings among mechanics during the visit varied widely by site. In one case, all mechanics on a crew are brought together daily (for about 10 minutes) at the beginning of the shift by their shift foremen. The content covers the range from the day's work and assignments, to what's new in the company, to personal items about people on the shift crew. In another site a weekly safety meeting was observed where the foreman spent a few minutes at the start of shift reading to all inspectors on that crew a safety memo prepared by the vice-president of operations. In another site, a shift inspection foreman arranged a brief meeting between all of his inspectors and the investigator. This was really an extension of the otherwise informal "get-togethers" inspectors held before each shift. These informal meetings of inspectors, and of mechanics, are described in more detail below. No formal meetings of mechanics was otherwise noted, although some sort of monthly (or less frequent) meetings with their AMPs were reported by foremen in nearly every site.

f. How much informal contact among mechanics (and other AMPs) is there during breaks and lunch? Considerable informal contact was observed among mechanics during breaks and meal times. Typically, this took the form of conversation among friends around the picnic style tables in the break areas. These groups did not often exceed six or eight people and were usually smaller. Regular cliques of larger and mutually exclusive groups were seen or reported only rarely. Even more informal contact was noted among inspectors. Their shift group size is smaller (about 6-10 in the typical carrier) and this makes it easier for the entire functional group to sit around the same table before shift, and "swap stories." Planners tended to stay to themselves and took breaks with neither inspectors nor mechanics.

g. How much contact is there among mechanics between shifts, Are meetings held between shifts, Who attends these meetings, Who conducts them? Little to no contact between mechanics on different shifts took place. In no case were meetings between mechanics from two shifts observed. Inspectors were much more likely to communicate with counterparts on other shifts. In several sites their shifts actually overlapped by an hour or more, so they could work together. Generally inspectors on the same shift took part in meetings (daily or less frequently) conducted by their foreman. Planners usually also met their counterparts, and the foremen, on other shifts to discuss work assignments.

2. **Contact with Foremen**

a. How often are foremen in contact with individual mechanics on a daily basis? Maintenance foremen are in contact with each mechanic an average of three times a day.

b. How much foreman contact during the visit is work assignment? How much is work guidance? How much is administrative (payroll, vacation scheduling, sick leave)? How much is training? How much is disciplinary? This daily contact primarily concerns work assignment (unless the labor contract restricts this task to lead mechanics, as it did in two of the eight sites). Other usual reasons for daily contact include work guidance or instruction, and administrative matters. In the typical case about half the foreman's contact with a mechanic is work assignment and reassignment during the shift; about one-third involves work guidance/instruction (especially in the smaller operations), and about one-sixth is administrative (payroll, vacation scheduling, and sick leave). A small proportion of time was observed in employee discipline.

3. **Contact with Inspectors**

a. Does this carrier have a separate inspection staff and department? If so how often do inspectors and mechanics talk together in general? Separate inspection departments and staff were found in all of the major airlines visited, the repair station, and one of the regional airlines. In the two smaller regional airlines (but operating aircraft large enough to be covered under FAR Part 121) a separate quality control (QC) department existed, but had no inspectors dedicated to it full time. In these sites certain mechanics were authorized to act as the inspectors for the QC department. These inspectors were usually the most experienced mechanics and often acted as lead mechanics or assistant maintenance foremen as well as inspectors. In the larger sites, mechanics usually try to speak directly with inspectors about quality matters. In the two smaller sites the contact is much more frequent because the inspectors are also a mechanic's colleagues or mentors.

b. How often do inspectors and mechanics talk together about the aircraft they are working on? What is the content of their conversation; if it is not advice or direction what is deliberated, and what is resolved? Mechanics' face to face contact with inspectors averages three times a day in the larger sites. These contacts are usually requests by the mechanic for the inspector to "buy back" or approve a repair. A mechanic following a non-routine defect report is in reality in indirect contact with an inspector who earlier determined that the defect required action. Sometimes the mechanic and foreman would contact the inspector or QC foreman to clarify the request, or to withdraw it for cause.

c. How much training do inspectors provide mechanics during the visit? Training varied greatly among the sites visited. In some large carriers, inspectors were sought out by mechanics for advice or instruction, while in others (particularly in larger carriers) the inspector's role was limited to inspection only, and mechanics were kept at a "social distance." Advice and instruction were clearly a part of the relationship between the combination inspector/mechanics' and the mechanics in the smaller carriers.

d. How much informal contact between inspectors and mechanics is there during breaks and lunch? Very little informal or non-work contact was observed in the larger sites.

4. **Contact with upper management**

a. How much contact was noted, during the visit, between AMPs and upper management (from maintenance management, or elsewhere in the company)? [This can include memos, video communication, electronic mail, and "waving as they pass through," as well as face to face communication.] In one large overhaul operation, multi-media communication from upper management was virtually continuous during the visit. This included video monitors outside the cafeteria showing current news stories of relevance to the company; a company newspaper was available; well organized bulletin boards containing announcements on a variety of topics; plus (during the time of the site visit) the president made a series of "hangar briefings" to personally inform employees and take questions about important upcoming events. In the other large operations visited, communication from upper management was limited to written announcements (posted on bulletin boards, or read out by foremen or supervisors in meetings), and in company newspapers. In more than one site, many AMPs could not remember the name of the company's president. In the smaller companies, upper management was visible in the hangar during the visit, and it was reported as normal for the owner or president, and his management staff, to drop in several times per week. Such visits were not reported to involve work-related communication between AMPs and executives.

5. **Contact with FAA Principal Maintenance Inspector (PMI)**

a. Is there a PMI on site? How often are AMPs and maintenance foremen in contact with the PMI during the visit? What is the content of their conversation? What is the setting (meeting, in the plane, in the break room, foreman's office, etc.) A PMI was seen in the overhaul area at two sites. In one case the PMI spoke with day shift inspectors, at the aircraft, about the non-destructive inspection (NDI) task they were doing. In the other the PMI discussed repair procedures with maintenance and inspection managers, both at the plane and in their offices. (The number and duration of the observation visits made it difficult to know how often the PMI was present)

6. **Contact with Trade Unions**

a. If employees are represented by a union, how much contact between AMPs and their union rep, and/or inspectors and their union rep was noted or reported during the visit? What was the content of the contact? In sites with trade union representation, AMPs were in informal contact with their local stewards often on a daily basis. In larger sites, where mechanics may not be able to sit at the same table with a union representative during breaks or lunch, the contact was less frequent. In the largest sites visited, the union officials had their own office space allocated near the hangar work area and tended to remain there. Few AMPs were seen in contact with officials in these offices during the visits.

b. How much contact was noted or reported between union representatives and management (including maintenance foreman) during the visit? Some contact by union officials or stewards to foremen was observed. The content included questions about work assignment and potential jurisdictional disputes, personnel issues and benefits.

7. **Contact with Trainers**

a. How much contact between trainers and mechanics, was noted during the visit? What was the nature of this contact? In several of the larger sites, experienced maintenance personnel (often close to retirement and recently transferred to training or planning departments) were assigned "On the Job Training" (OJT) duties. In only one of these sites were these OJT trainers observed in the hangar and in contact with mechanics. In that case mechanics reported benefiting from the OJT trainers' advice or hands-on instruction. Mechanics often doubled up for training, and the more experienced were directed by foremen, or sometimes requested by other mechanics, to provide OJT. The same relationship was noted among inspectors. OJT was requested by less experienced inspectors, directed by QC foremen, or offered by the more experienced AMP.

b. How much contact between trainers and inspectors, planners, and/or foremen was noted during the visit? No formal trainers were seen in contact with either inspectors or planners/coordinators during the visits, since formal training is conducted at the training site. Classroom training for new mechanics was usually going on in or near the hangar during the visits. Typically, formal trainers or teachers conducted these classes. Classroom trainers occasionally contacted shift foremen in the latter's office at the completion of a day's course or segment.

c. Was any kind of training provided during, or immediately preceding the visit? Was that training specific to the repairs on the visit aircraft? As noted above, nearly all the larger sites visited were in the process of aircraft orientation training for new mechanics. At some of these sites, other mechanics' classes were underway, dealing with more advanced topics or recurrent training. In all cases, this training was related to aircraft (as distinguished from safety training, personnel or communication, or administrative matters). In the smaller sites, no formal training was observed or reported. These sites had no training departments or dedicated specialists for instruction.

8. **Contact with Flight Crew(s)**

a. Was information passed from the flight crew or cabin crew to anyone in maintenance about this aircraft? If yes, who was the maintenance contact; and what was the content, form (formal report, note, face to face, etc.), and timing of the communication? In two cases in the larger carriers, was a flight crew observed in contact with heavy maintenance hangar personnel. These were cases where the finished aircraft was being released to the pilot and crew. Limited information about the overhaul was formally transmitted to the flight crew. In the smaller sites, frequent contact was noted between flight crews and AMPs. In addition to written communication in the aircraft logs, pilots would sometimes verbally describe the performance of the plane to a lead mechanic or inspector. Mechanics or inspectors sometimes accompanied the flight crews to the ramp for engine or systems run-ups; or actually joined the flight in cabin or cockpit. The information passed in these flights often dealt with cabin pressurization and door seals.

2.3.3 Common Attitudes and Opinions: The System Scan

There were similarities, across the various sites visited, in how AMPs saw things and felt about them. These common attitudes can help yield a systems scan of the "typical" heavy maintenance systems sampled in the present study.

Organizational purpose and mission. In all sites, a typical statement was, "everybody wants quick turnaround." Whether this was cause for AMPs' frustration, or stoicism, or pride depended on the degree to which they saw this as realistic and relevant. AMPs observed in this study consciously accepted safe and fast turnaround as relevant, but not always realistic. Most sites visited had no explicitly stated maintenance mission, beyond finding and fixing flaws as directed.

In one site visited AMPs' immediate work assignment and the larger mission seemed clearly connected. In this site, maintenance foremen held a brief start-of-shift meeting with their crew. In these meetings the foremen described the work to be done, the system's performance to schedule, and made (or explained) general assignments. Mechanics had usually obtained the job cards from the scheduling window before the meeting and would go on to gather materials and tools at its conclusion. During the meetings AMPs had the opportunity to query the day's assignment and the overall scope of current aircraft in for overhaul. This was the only one of the sites visited in this study which revealed a strategy of maintenance which was both acknowledged and successfully pursued by AMPs. AMPs and foremen at this site took pride in airworthy repairs **and** fast turnaround of the aircraft. They reported that they made a direct contribution to the efficient and timely delivery of quality aircraft.

In several other sites the work was arranged so that AMPs continued a job from one day to the next, without turning it over to another shift. Although their mission may or may not be clear in these locations (and rapid turnaround was never seriously believed as important by AMPs there) the AMP could usually feel secure in knowing what was the job at hand.

2.3.3.1 Organizational Culture

Hackman, (1990, p. 495) has reported that even though the advantages of teamwork in the cockpit are widely recognized in the airline industry, the culture of that industry still emphasizes individual rather than team aspects of cockpit work. In the present study it was found that this same culture influences the maintenance functions as well. Aircraft mechanics are proud of what is called their "macho" style. And individual licensure and personal liability has, in some cases, had an added effect of making AMPs and their supervisors less willing to share work across shifts, or with less experienced or less skilled colleagues. The resulting performance is slower (actually incurring delays when key employees are absent), and the ability of AMPs to exchange ideas or information is sometimes limited. This restricted communication further supports traditional emphasis on the individual contributor as the basic work unit.

Another part of aviation industry culture is the passion for flight. In the past, the aviation industry could aptly be called "boys' own airplane club," because the people who chose it loved airplanes, and flying. It was a boys' club, in heavy maintenance at least. Even today few women AMPs or managers were seen during the visits. The airplane passion, however, has largely gone the way of wooden propellers and fabric wings - held only by the long-time employees and few of the new-comers. From the top to the bottom jobs, people today join airlines for many reasons beyond the love of planes. This clear shift plus other changes in labor force confounds the long-service employee. Older AMPs are sometimes dismayed with the newer mechanics' acquired skills, their laissez-faire attitude, and their higher turnover. The new mechanics often profess to "like it okay here," but admit they are not "excited" about it. In some of the sites visited the company's reputation is of little concern to them, because many can see themselves as moving on to other companies or even other industries. These contrasting attitudes suggest a culture undergoing a considerable transformation.

2.3.3.2 Control over Work Assignment

An organization can have a clear locus of control, whether or not it has a mission or conscious purpose. Such control is invariably in the control of other peoples' activities, especially in the performance of the work. This control of behavior is sometimes structural, combined with behavioral norms, and sometimes the norms themselves, over time, can yield control in one group over the others. When control over one's actions is diminished, "ownership" or pride of work declines too. In the present study, this lower pride was sometimes associated with lower care/attention to the work - leading to slower work, fewer "buy-backs" by inspectors, lower morale and higher reported employee turnover. Usually the struggle for control over maintenance work was found between maintenance and planning.

Computers and control. The struggle for control takes on a different and more complex dimension as computerized planning becomes more common. Control by the computer can take on a life of its own, seeming to rise above both the maintenance and planning people in its rigidity and singular focus. In some sites both maintenance and planning seemed confounded by the computer-based system of work planning. Complaints were heard primarily about the quality of computer-produced job cards and the absence of associated graphics. Other complaints were voiced about the rigid decision models the computer used for scheduling.

Attitudes about training. Younger workers' attitudes toward recurrent training are mixed. In companies where some training is provided they wanted more; in those that didn't provide much training, the AMPs didn't complain (but they literally may not know what they're missing). Many older AMPs were able to describe the OJT procedure and its paperwork (they usually know it well), but they also say when they show younger guys something, it isn't long before they "think they know everything." Such younger employees' attitude toward training, if true, could work, over time, to stifle the amount and quality of OJT.

Occupational Safety Practices. Safety is important everywhere, but practices vary widely. At some sites, it was assumed that if no accidents have been reported, then the safety policy is okay. At one site, safety policy required leads completing a start-of-shift check list on housekeeping and safety each day. In another, the foremen reported that they hold 30-minute safety meetings with their AMPs once a month. Yet another site had a new operations vice president who, among his first official acts, required weekly safety reminder sessions. Another site used blanket rules such as not allowing tennis shoes on the base. In some sites there is much safety equipment around. Such equipment includes auxiliary lighting, overhead cables and harnesses for working on the aircraft crown, safety rails on scaffolding, protective clothing, rubber gloves, safety glasses, safety shoes, ear plugs, respirators. Some safety posters were in evidence. It was gratifying that at a personal level mechanics and inspectors were often seen to remind their co-workers to act safely. At several sites, foremen were observed refusing to assign work to their shift in unhealthy conditions (e.g., where painting or paint stripping was going on nearby).

In the main, personal safety in aviation maintenance is not always emphasized to the degree seen in other industries. Some examples are that AMPs were observed to take individual responsibility for spreading absorbent clay on oil spills, but only after somebody slipped. Several sites evidenced a variety of casual lightweight sport shoes. In others, few AMPs wore earplugs or muffs, were seen not to use overhead harnesses when working on the crown, and made little use of auxiliary lights (in favor of many flashlights). Some of the foremen observed were very attentive to safety issues during the visits and some were not.

Housekeeping in the overhaul area. In several of the sites visited, one can walk to stores or break areas only by passing through dimly lit, cluttered areas, with hoses and wires in profusion on the floor. Despite the frequent attention of janitorial crews, hangars at several of the sites visited were dirty, dusty, or oily not only on the floors but on other surfaces too. Work areas where AMPs demonstrated a pride in cleanliness or tidiness were noted in only about half the sites visited in the present study.

2.3.4 Technical System Findings

Planning the overhaul. How the work is planned and performed in heavy overhaul of aging aircraft varied among the sites visited. In about half the sites the day-maintenance foreman was responsible for assessing the extent of repair necessary, and managing the course of the overhaul, following the preliminary inspection by the quality control (QC) department inspectors. Sometimes the planning group, instead of the foremen, was responsible for scheduling and managing the overhaul. In one case QC had taken unwitting control for managing the "C" check, through close control of the issuance of job cards.

Key variances in aging aircraft. Large and complex repairs were often called the "critical path" for the overhaul. Defects such as cracked doors or door frames, or extensive corrosion of floor structures or pressure bulkheads were usually judged as critical items or key variances to plan the overhaul around. Key variances do not always require the most time consuming repairs, but they may demand exotic parts or special engineering planning, or intricate scheduling of other repairs.

Management in several carriers expressed particular pride in corrosion control programs they had developed in-house. Those programs were later confirmed by AMPs, who said that the company was willing to spend the extra time early, inspecting and treating corrosion-prone areas, to control these variances in advance which prevented "surprises" later. If used aircraft were acquired from other carriers, the special efforts to cope with their new-found corrosion demonstrated the quality of the original fleet and the positive efforts of corrosion prevention when it is employed.

At some other sites visited such variances were not as well prevented, and might not be detected in the preliminary inspection. Occasionally the extent of a defect detected during preliminary inspection (particularly hidden corrosion) would not be revealed until late in the overhaul. In a majority of the sites visited, corrosion (particularly when accompanied by fatigue cracks) and sometimes ramp-originated damage to skin, baggage doors and holds resulted in repairs that required more than the original estimated time. This optimistic time estimation (coupled with poor coordination or miscommunication between shifts or with shops, or from engineering or QC which led to rework at least some of the time) meant that there was some kind of regular "surprise" that thwarted AMP efforts to complete the overhaul on time or in budget.

Some key variances in aging aircraft [e.g., multi-site damage (MSD), or extensive corrosion to aircraft structure] demand special knowledge about structural repairs to adequately fulfill either "damage tolerance" or "fail safe" requirements. The existence of several such variances on the same aircraft were observed to require the simultaneous employment of very high (and scarce) AMP competence, and a considerable degree of engineering or shop support. During these special work reassignments progress on other aircraft in the hangar was sometimes delayed.

2.3.4.1 Organizational structure and work performance

A certain degree of coordination difficulty and miscommunication results from the way the systems were structured.

What differences do variations in the organization chart seem to have on maintenance performance? What structural similarities do companies in the sample share which may threaten to impair their currently enviable performance record?

Some heavy maintenance is organized with maintenance, materials, inspection, and planning/scheduling functions all reporting to separate vice presidents. In other companies, scheduling and maintenance report together at a lower organizational level. In yet others, materials department reports to the maintenance organization. These differences are reflected in the degree of cooperation among the departments and the degree of shared purpose felt and expressed by incumbents.

Differences were found among the sites in organizational structure (chain of command, span of control). Where strong functional chains existed, communications between AMPs in the separate departments were often limited. Stores, shop, and toolrooms were sometimes seen, or were reported, to act unsympathetically or unsupportively to maintenance's need for parts, components or tools. For instance urgent parts shipments were observed to arrive, and mechanics or their foremen were not notified of this by stores within the same shift. Communications breakdowns between those chains were never, during the present study, seen to compromise aircraft safety.

To minimize that possibility, however, the industry must continue to invest additional time, effort and money in cross-functional communication and controls.

Separate reporting structures were usually found to create struggles for power and authority among departments (e.g., maintenance, supply, shops, and planning). Such conflicts are resolved in a variety of ways, but they usually result in one department gaining a degree of control over the other. In those cases where maintenance retains control over planning, the foremen and mechanics often express a sense of triumph, and planners and coordinators feel some (usually minor) distress at their perceived decline in significance.

Where planning is the more powerful department, the planners were seen to act apprehensively (and often defensively), and QC and maintenance foremen and their AMPs feel confused and frustrated. In these cases, the planners and/or coordinators controlled job cards (and thus job assignment), and access to them by any others was strictly discouraged. In these several sites, high control of repair by planning was seen to diminish the pride of ownership and competence that mechanics, inspectors, and their supervisors felt. Planners described their major function as "responsible for the aircraft," while maintenance was seen as merely responsible for completing repairs. Associated with mechanics feeling of lower pride was lessened care/attention to work performed. "Good enough to be safe is all we can manage," was heard from several mechanics in the sites where planning controlled work assignment.

2.3.4.2 Differences in behavioral norms and work performance

Norms are customary behaviors, not necessarily based on policy. Norms of work assignment, or of managing AMP absences and overtime can have advantages and disadvantages simultaneously for maintenance effectiveness. Mechanic overtime and high use of temporary labor in several sites were both observed to be effects of a lack of planning. Mechanics in turn felt part of an "ad hoc" organization with little ability to forecast or plan for overtime. Occasionally foremen were observed not to notify their shift replacements of AMPs who had called in sick - sometimes hours before. The resulting lack of control of initial work planning for maintenance foremen and scheduling supervisors caused them confusion and frustration.

Many of the sites visited displayed effects of expectations of maintenance about stores. Typically, AMPs expected storekeepers to be uncooperative, unfriendly, or slow; and maintenance supervisors expected stores to be often out of stock, and slow to reorder frequently used parts and supplies. Whether by self-fulfilling prophesy, policy considerations, or by structural arrangements, the materials functions were often in a defensive posture in management meetings and at the parts counter because parts and supplies were not available when needed.

2.3.5 Social System Analysis Results

The social analysis involves the examination of the roles and relationships within the whole work process. This activity actually includes mapping both the persons who have work-related interactions in the system and the reasons for that contact. Because a comprehensive analysis of all positions would be too time consuming, the social analysis focuses upon the role or roles most involved in the control of key variances, based on the assumption that every organization exists in order to meet the short-term goal of producing its product. This is the social system analysis, which maps the cooperation and coordination undertaken between the focal roles and others within and outside the work process. The focal roles identified in the heavy maintenance operation are the mechanic, the planner, or the inspector.

Every organization exists in order to meet the short-term goal (G) of producing its product. However, in doing so it must not adversely impact its capacity to survive as an organization. To do so it must adapt (A) to, and be protected from short-term changes and pressures in its immediate environment. It must also combine or integrate (I) activities to manage internal conflict and to promote smooth interactions among people. Finally, it must ensure the long-term (L) development of knowledge, skills and motivation to cope with goal-related, environmental and systems requirements in the future. In the social analysis, the letters G, A, I, L are used to indicate what type of functions are affected in contacts among people.

Many organizations have separate departments to perform these functions. For example, industrial engineering, planning, personnel, and training departments can have the formal responsibilities for one or another of the four basic functions. Typically this specialization acts to narrow and limit the ability of other employees to act appropriately when a response from them in that function is required. The only clear exception to this are training specialties because the expert trainer serves to enlarge the roles and response repertoires of individuals without complicating lines of command or the allocation of responsibility. Not surprisingly, perhaps, a good many of these functional behaviors are performed through informal activities at the level of the focal role. Not only are these behaviors informal, they are often unrecognized even though they may be more frequent and more influential in affecting performance than the existing formal methods and policies. The task for the social analysis is to better understand the ways that these necessary social system functions actually get carried out, and to evaluate how effective these methods are for satisfying the human and technical requirements of the organization.

2.3.5.1 The Social System Grid

The examination of the presence or absence of a fixed set of functional relationships in a social system is aided by charting them in a way that combines both the four functional requirements (G, A, I, L), and the particular relationships (vertical and horizontal, internal, and cross boundary contacts) describing the work process. This combination is charted in a 4 X 4 table or "grid" of social relations.

Table 2.1 shows an overall evaluation of information summarized from interviews and observation classified by the four essential social functions. Table 2.1 presents evaluations of those typical contacts observed, and an approximation of the relative frequency of those contacts.

Table 2.1
Summery of Communication Analysis
" G, A, I, L " Functions Against Four Types of Social Contacts
Airline Maintenance Personnel / Heavy Check Service

	1. Contact Between Supervisors and Suborcinates	2. Contact Among Peers in the Same Work Groups	3. Contact Between Groups in the Same Mainten. Systems	4. Contact Between Maintenance Systems and the Outside
" G: " GOAL ATTAINMENT	+++++ 0000000000 -------	++ 0000 --	++++++ 0000000000 000000000 ==========	+++ 000 ==========
" A : " ADAPTION TO ENYIRONMENT	+ 0 -	000	+ 000 --	00 --
" I: " SYSTEM INTEGRATION	+++++ 0000000 ----------	++ +++++ 00000 ----------	++++++ 0000000 ----------	++++ -------
" L:" LONG-TERM DEVELOPMENT	+ 0000 ---------	+++ 0000 -------	+++ 000 --	0 --

Legend :

"+" = Communication as observed is helpful or facilitative to the function or relationship

"0" = Communication as observed is nuetral to the function or relationship

"-" = Communication as observed is helpful or facilitative to the function or relationship

Table 2.1, row "G," reveals that communication about goal attainment is frequent (many contacts were coded "G"), but effective only to some degree (about 20% of the total goal attainment contacts were evaluated by the investigator as positive, while about 40% each were evaluated either neutral or negative in their contribution to maintenance performance).

Mechanics and inspectors play a central role in accomplishing the essential task or mission of maintenance. The results in Table 2.1 indicate that these AMPs play this central role with considerable guidance from their foremen, with some cooperation from others in their work group, and much direct contact (although some of it is negative in outcome) with other employees in the maintenance system.

Row A (Table 2.1) reveals that there is very little contact among focal roles and other members of the maintenance system about matters dealing with relevant outside environments. Some foremen mentioned that cooperation in borrowing or lending spare parts is good between the maintenance departments of different carriers.

The same pattern, found in Row G, of frequent but less than effective communication between mechanics or inspectors and others in the maintenance system is repeated for row "I." Those contacts affecting systems integration (coded "I" in Table 2.1) had a larger proportion of negative evaluations in peer group and supervisory communications than did contacts for goal attainment. Rows "G" and "I" in Table 2.1 provide evidence for the observation that AMPs work with strong support and guidance from foremen and other members of the maintenance system, but their work relations with co-workers in the same occupation is less developed. Mechanics do talk to one another about opportunities and requirements for employment at other carriers, which if it helps an AMP make a decision to resign could surely be considered "disintegrative" for the current employer.

Row L in Table 2.1 reflects a need for formal training programs, a small management role in on-the-job training, and a limited, though high impact role for AMPs in training co-workers in their same occupation. Most mechanics and inspectors said they obtained OJT from senior employees. However, in some situations there may not be enough experienced technicians to ensure that there is enough high-quality OJT for the junior personnel.

2.3.5.2 Focal Role Network

The "focal role analysis" maps the work-related communication between the focal role(s) and others in the work process.

The first figure that follows shows the general role network (displaying the common pattern) for all sites visited. Subsequent figures show specific differences in three different situations revealed during the site visits. The networks each reflect a norm for the sample studied, and not necessarily any carrier in particular. The focal roles identified in the heavy overhaul maintenance system sampled in the present study are the mechanics (both sheet metal and A&P), or the planners or coordinators, or the inspectors involved in a "C" check equivalent on an aging aircraft.

In all cases their leads, foremen, or supervisors are also considered focal roles. In the role networks displayed here (Figures 2.0, 2.1, 2.2, and 2.3), the shorter length of the lines between roles reflects a higher frequency of communication observed. The arrows indicate one-way or two-way communication observed. Double arrows pointing in opposite directions (e.g., Figure 2.2) denote equally-frequent initiation of essentially one-way communications.

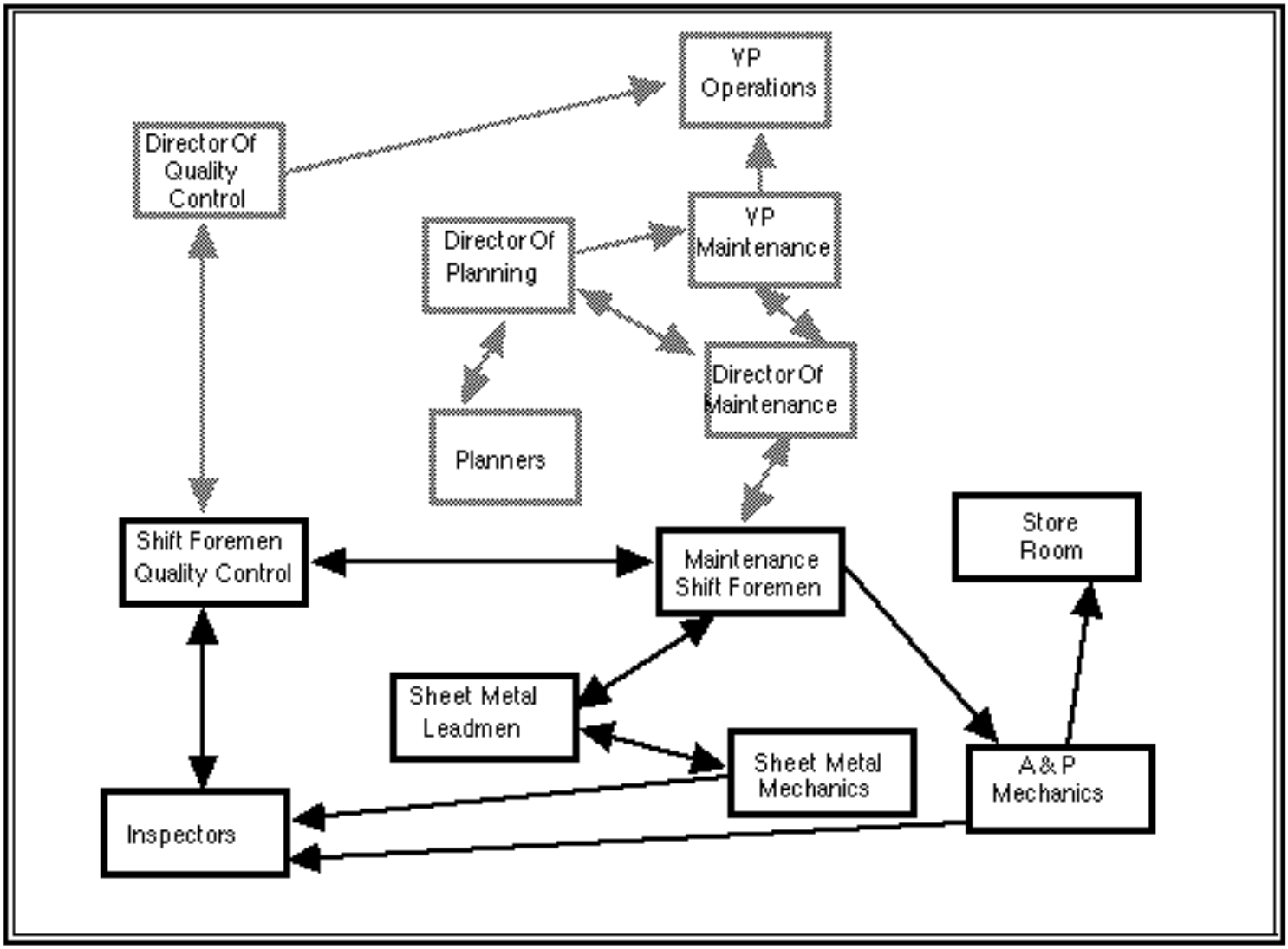

Figure 2.0 Common Communication Pattern - All Sites

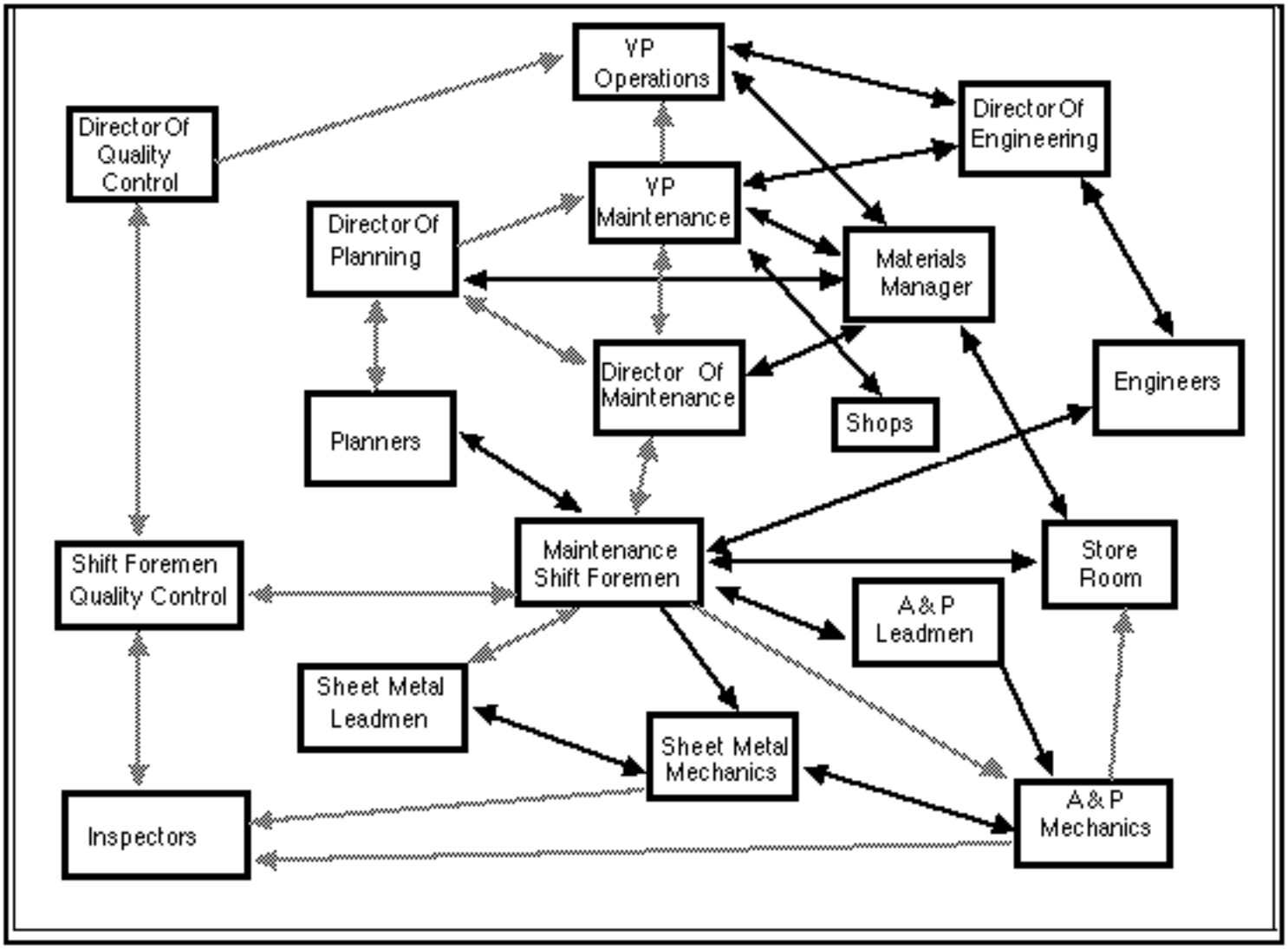

Figure 2.1 Maintenance in Control of Work Assignment

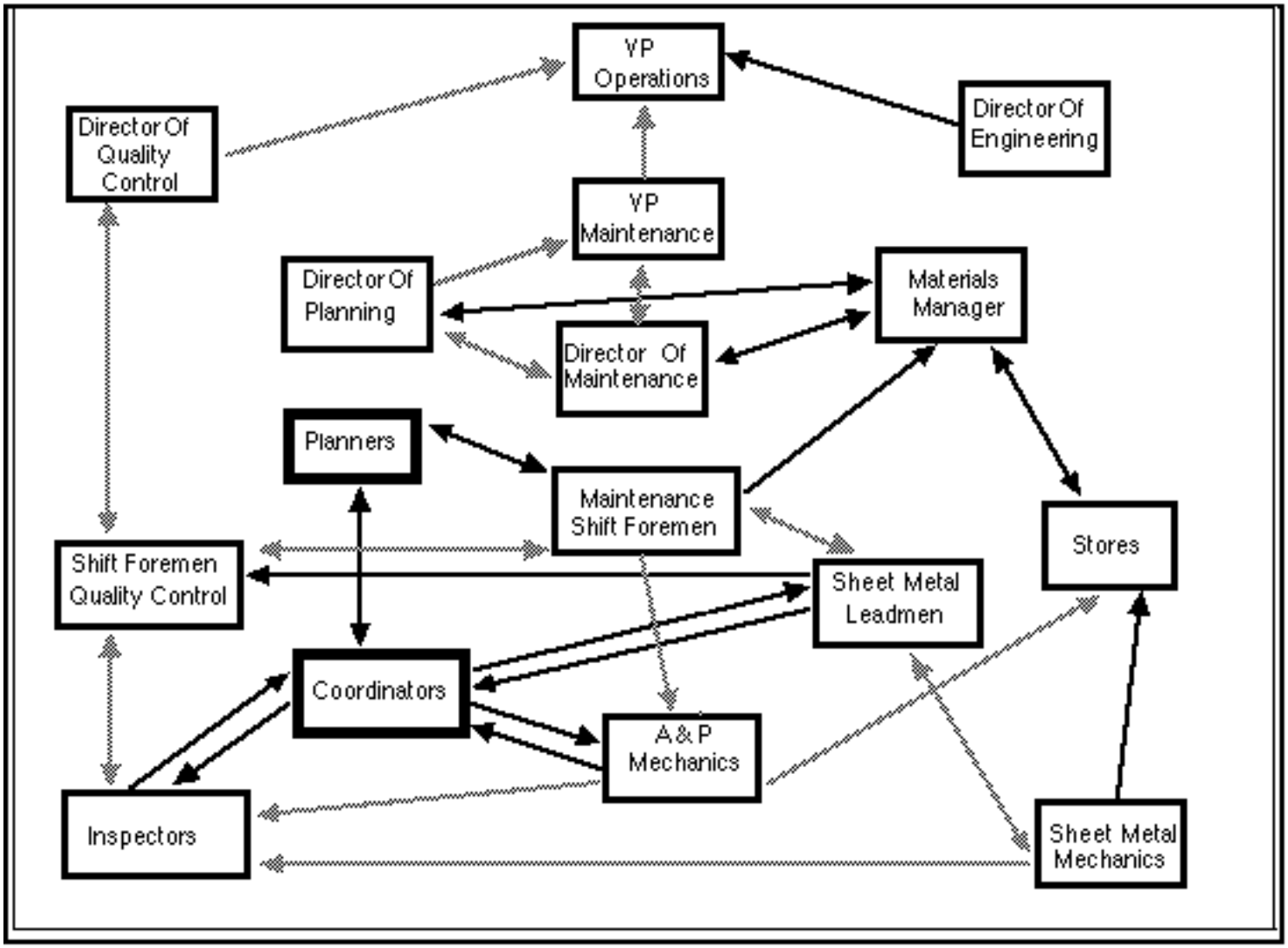

Figure 2.2 Planning in Control of Work Assignment

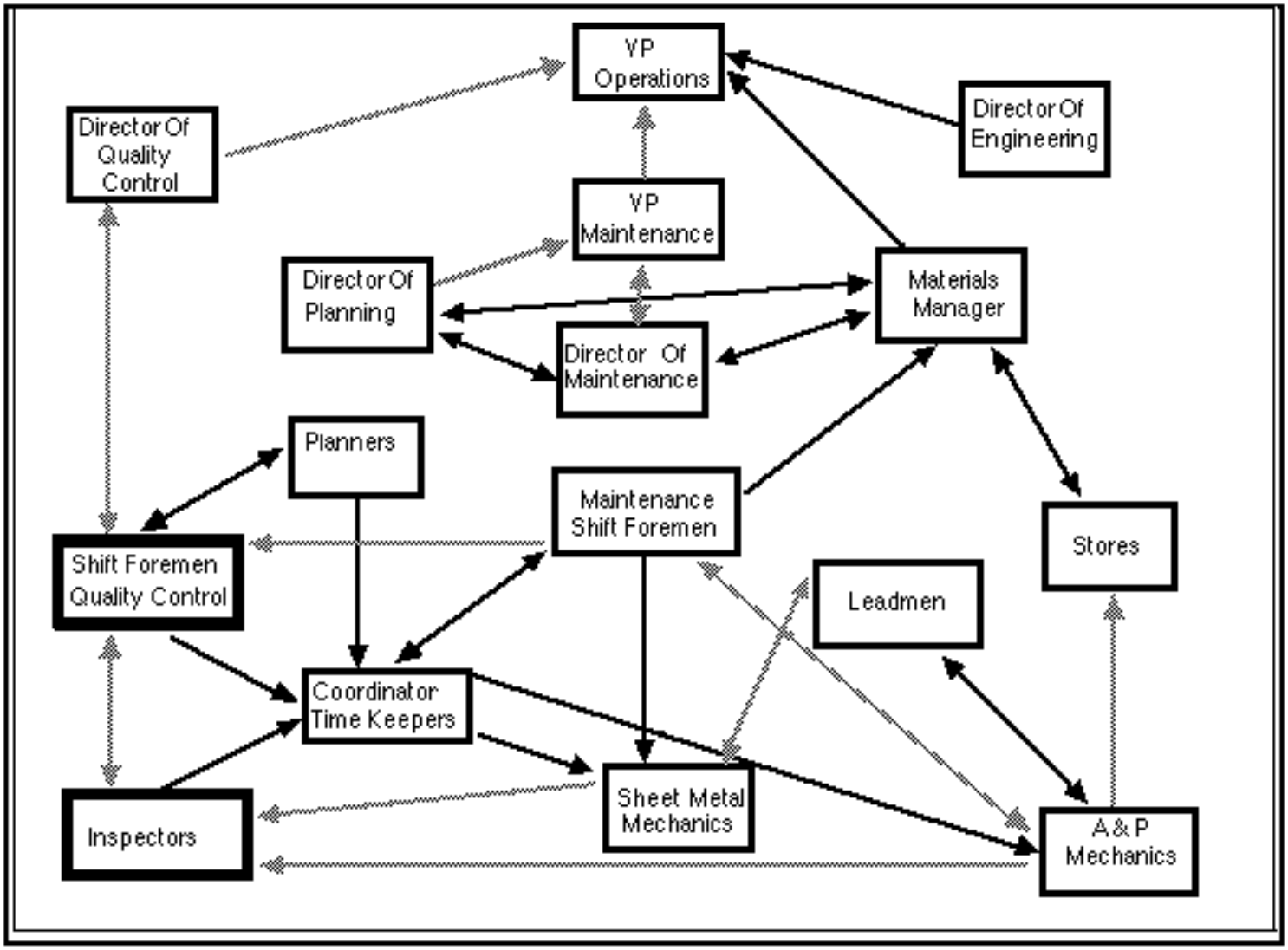

Figure 2.3 Inspection in Control of Work Assignment

The relationships depicted in Figure 2.0 (the common pattern of communication found in all sites) are repeated in the following three figures, but in lighter contrast to enable the reader to more readily see the unique communications depicted in each figure.

The Figures 2.1 and 2.2 display two major communication patterns observed during the present study, and Figure 2.3 displays one unique pattern (observed in only one site during this study), for contrast. Figure 2.1 depicts the web of frequent contacts in several sites where the maintenance department (maintenance foremen and their managers) are in control of the AMP work assignment process. Figure 2.2 shows an alternate network of frequent communication in sites where the planning department played a major role in mechanic and inspector work assignment. Finally, Figure 2.3 displays the unusual case described earlier in which the QC department controlled work assignment.

Figure 2.1 portrays a composite of typical communications patterns in the sites where maintenance is in control of AMP work assignment. Figure 2.1 shows frequent contact between maintenance foremen, leads, and mechanics. In addition it shows close coordination between maintenance and QC foremen. Finally, Figure 2.1 reveals a close (daily) interaction among all executive managers responsible for supporting the maintenance effort.

This kind of communication pattern is particularly effective in maintaining aging aircraft when there is a clear maintenance mission that is supported from above, and when foremen are in close touch with AMPs.

Use of pre-shift briefings. In one site visited, AMPs and foremen were proud of their on-time and high quality "C" check completions and this mission was supported by upper management. This site is the model for the network shown in Figure 2.1. At this site the foremen hold a brief meeting with their AMPs at the beginning of each shift, in which a focus on purpose is maintained by describing status of the aircraft in the hangar, the critical aspects for timely completion of those aircraft, and briefly explaining work assignments. In this case, mechanics have usually already obtained the job cards from the scheduling window, and immediately following the meeting, they go on to the storeroom for material and tools.

These shift foremen were trained in how to conduct meetings. In general the meetings kept AMPs informed of the unit's performance to goal, and of their own role in the overhaul. The AMPs in turn took pride in successful accomplishment. Lead mechanics kept their foremen informed of progress throughout the shift. Occasionally, the leads or planners would also tell foremen of AMPs whose performance was below standard. Foremen acted to guide and reward good performance, and to understand and correct substandard performance. Maintenance foremen also kept in close touch with QC foremen to discuss approval of complex repairs.

Less effective use of goals and communication. Several examples of less effective maintenance systems were observed during the visits. These were systems also typified by the network in Figure 2.1, where maintenance was in control of work assignment. In one of these less effective sites, a mission for maintenance (beyond airworthy repair of aircraft) was unknown to AMPs: little urgency for timely work completion was observed, and management urged expense containment.

In other less effective sites, disparate goals were set for the various departments in the maintenance system. For repair, overhaul turn-around times were set too high for a largely inexperienced work force to meet without an unusual degree of cooperation from materials department and the shops. Materials departments and shops in turn were given goals to contain costs, and therefore could not respond to maintenance demands by always having needed parts in ready inventory.

Inspection goals could also conflict with maintenance as illustrated by the number of rejected, "non-routines" allowed by QC management reported in several sites. Some inspectors required engineering variance authorizations (EVAs) for reportedly minor deviations from structural repair manual (SRM) repairs. Where multiple and conflicting goals and missions were set, and management continues to press for them, time and/or cost performance would necessarily slip. Besieged by conflicting demands foremen tended to ignore AMP training, or coordination between shifts, or forward planning for spare parts acquisition, almost all of which alienated AMPs, and were reported as leading to lower cost and performance-to-time results. The cycle, once established, apparently continues in these sites without resolution.

The effectiveness of these sites could be hampered even further if lead mechanics were (by labor contract) in strict charge of work assignment of AMPs. Where this situation was found, Figure 2.1 would have to have been redrawn to show less frequent contact between AMPs and foremen. This system resulted in generally less effective coordination between shifts because foremen, not now in direct contact with AMPs, would make the face-to-face transition between shifts. In some cases also, high seniority AMPs would bid into lead jobs without sufficient breadth of technical experience to always understand the work they were assigning to AMPs and the results of which they were describing to foremen.

There were other examples of how communication in an inexperienced workforce created errors involving miscommunication. The combination of inexperienced mechanics and long tenure foremen often caused the former to be unassertive with the latter. These subordinates are reported to seldom voice their uncertainty or their lack of experience when assigned to a job, except at sites where there are strong sanctions against remaining quiet. There were also accounts of new AMPs who did not report problems when they occurred. Cases were reported of relatively inexperienced employees being assigned to work beyond their abilities-with ensuing repair errors. Those errors reported were discovered and safety of flight was not compromised, but extra expense and time were incurred and in some cases little positive was seen to be learned by foreman or AMPs. In most cases of serious errors or incorrect repairs, the AMPs involved were said to have quit or were dismissed from the firms shortly thereafter.

Figure 2.2 portrays a composite picture of the communication pathways in sites where the planning department or function closely controlled the work assignment and job cards. In these cases, the planners and/or coordinators kept access to job cards strictly controlled. Planners described their major function as "responsible for the aircraft," while maintenance and inspection were seen as merely responsible for using the tools and undertaking assigned repairs. In these sites, high control of repair by planning was seen to diminish the pride of ownership and competence that mechanics, inspectors, and their foremen felt.

The algorithm often used by planning, in the sites visited, to set priorities is based on length of time required for repair; with little or no attention paid to the complex interactions among a number of repairs (both "routine" and "non-routine") called for in the typical overhaul. Both maintenance and inspection foremen in these sites claimed that the planners lacked maintenance experience with repairs or with aircraft to enable them to effectively prioritize a series of complex repairs. This arrangement frustrated foremen and caused them to lose confidence in their own abilities. This, and lower pride was often associated by interviewees with lower care/attention to work performed - and with slower work, lower quality work, fewer "buy-backs" by inspectors, and more rework. For AMPs, the visible absence of control their foremen had over the order in which work was performed, and the ambiguity about what was to be done next, was reported to lead to diminished job satisfaction.

Figure 2.3 shows the communications patterns for one site in which inspection took control of work planning at the beginning of a maintenance check. In this case the inspection foreman closely controlled the overhaul planning by rewriting all routine job cards dealing with opening (and subsequently closing) the aircraft for inspection as specific non-routine orders to only open access areas. Separate non-routine orders were subsequently issued to close all access locations only after QC inspectors had scrutinized those areas. For the Boeing 727 aircraft observed at the site during the visit, over 400 extra non-routine orders were created for this purpose.

This unusual behavior presumably was based on a mistrust of the many inexperienced mechanics employed by this company to read and understand the routine cards as written. Although that solution worked, and all inspection locations were checked by QC, the "cure" was almost as painful as the "disease." The resulting lack of control of initial work planning by maintenance foremen and by scheduling supervisors created confusion and frustration. For instance, when parts were received and the planners and maintenance foremen were notified, they were unable to locate the associated job card to begin work if that work (and card) was still under QC control. These parts were often set aside until they could be identified, and sometimes became lost or misplaced. Sometimes, because job cards were "missing," parts were not ordered on time. Waiting for QC to schedule "closing-up," the aircraft sat with fuel tanks open and vulnerable control joints and bearings exposed to airborne contaminants. Because of management pressure to complete the overhaul on a timely basis, mechanic overtime and high use of temporary labor were both among the unwanted "products" of this system. Mechanics in turn felt part of an "ad hoc" organization with little ability to forecast or plan for overtime.

Summary of Role Networks.

One of the major findings of the role network analysis is that many of the roles closest to one another on the network chart (Figures 2.1, 2.2, and 2.3) are between people in different occupational groups (except for AMP and foremen or lead). Thus the people in close contact with each other are not only the foreman and the mechanic, but also the mechanic and the planner/coordinator, the mechanic and the inspector, the mechanic with other employees in stores, and the foreman with production control, the various support shops, and engineering. These are all examples of people communicating between functional silos.

2.3.6 Organization, Attitudes, and Performance

2.3.6.1 Linkage between management practices and attitude

Three of the eight sites visited exhibited higher levels of communication than the rest. These three sites include the large carrier in which foremen conducted pre-shift meetings; and the two smallest carriers where inspectors were also the senior mechanics. Communication in these three sites included a great deal of "technical" or goal-related contact/communication within and between occupational groups and hierarchical levels, as well as expressions of employee good-will and personal support for one another. These communications were observed in frequent or regular group meetings as well as in individual face-to-face contacts. These three sites also evidenced the clearest maintenance and company missions. The large carrier among these three reported consistently high levels of timely completion of "C" checks. Finally managers, and AMPs in all three of these sites expressed the greatest individual satisfaction with their timely performance and/or high quality as was expressed in any of the sites studied.

The other five sites varied in the amount of communication and contact observed and reported. All of the five had less frequent communication than the three sites already reported. Among the five sites, lower levels of communication were associated with greater observed and reported conflict between shifts and occupational groups. Whether past conflict reduced present contact, or if conflicts arose through misunderstandings caused by inadequate or incomplete communication, is impossible to say with the data available - a combination of both is most likely. Expressions of personal satisfaction were lower among AMPs in these five sites. AMPs were less likely to say they planned to stay with that employer, and in a few sites mechanics and/or planners said they were considering leaving aviation maintenance altogether.

2.3.6.2 Quality Performance Information for heavy maintenance ("C" check)

"Hard numbers" were not available to AMPs at most sites visited, but the following indicators were often at the core of their concerns and discussion with others about final results - "getting safe aircraft out on time."

1. **Maintenance.**

   Doing it right the first time. Indicated by the time (and/or iterations) required to perform a repair that will be approved by inspection; this includes rework of completed work rejected by inspection, as well as "false starts" caught by lead mechanics, foremen, engineers or inspectors, and begun again during the repair process. **Underestimated repair severity.** Includes severe defects identified as minor, or identified after initial inspection, indicated by underestimated repair time or adjusted coordination of repair jobs to accommodate for omissions or optimistic assessments of defects identified early.

2. **Inspection.**

Absence of Turnbacks. Involves the assessment of severity of a defect such as corrosion or fuselage cracks - less severe defects that were identified were indicated by the presence of some number of non-routine defect "turnbacks" to inspection by maintenance.

3. **Planning.**

Dynamic but realistic schedules. Measured by the ability to adjust the maintenance schedule and spare parts ordering so that revised check completion dates can be realistically met. This performance relies on being able to account for complex interrelations among the individual repair jobs contained in the heavy check.

2.3.6.3 Linkages between Practices, Attitudes, and Performance

Quality performance, as measured above, was highest in the three sites described earlier as having higher levels of communication. The high degree of "technical" or goal-related communication within and between occupational groups and hierarchical levels in these sites contributed to a focus on timeliness of repair and/or quality.

In the two small sites of the three, scheduling changes were performed by the foreman in consultation with lead mechanics, while in the larger site the maintenance foremen stayed in close touch with planning and QC as work progressed and the schedules changed. In association with the less frequent communication and contact observed at the remaining five sites, AMPs displayed and reported greater conflict between shifts and occupational groups. The five sites also displayed or reported lower quality performance as measured above.

2.4 CONCLUSIONS

Among the accepted causes of work quality is the committed attitude, the high level of knowledge, and the positive state of mind of employees performing that work. Conversely, negative attitudes, lack of knowledge, and disquieted mind relate to poor quality and a reduction of safe conditions and outcomes. This study obtained measures of the amount of communication about the work and interpersonal support, the levels of trust, and the degree of frustration or facilitation of human needs. Important sources of employee attitude and state of mind in aviation maintenance were found. The conclusions to follow are directed at stressing these important aspects.

2.4.1 MAJOR ORGANIZATIONAL COMPONENTS Identified as a Result of the System Scan Analysis

DEDICATION: It is not an exaggeration to state that all employees and managers of the heavy maintenance systems visited in the course of the present study are dedicated to safety of flight. To their credit, most mechanics, inspectors, planners and their managers want to be able to see the "big picture," and to have real competence in complex detection and repair technologies. Throughout the course of this study, the people observed were serious about their work, well meaning, and bright. These are people who want to do their best for safety.

ENJOYMENT OF WORK: It is also true that an overwhelming majority of mechanics truly enjoy maintenance work and mechanical repair.

RESPECT FOR COWORKERS AND MANAGERS: In the main, AMPs also like and respect their co-workers and managers. In the smaller, regional carriers in particular, the relationship between inspectors and mechanics is mutually respectful and professionally useful for both parties. These mechanics learn advanced repairs and detection from the more experienced inspectors, and the latter learn by and from the teaching.

PARTICIPATORY MANAGEMENT: Excellent and well proven management practices, and resulting high performance, were observed in the course of the present study, but they were not the norm. Participatory management in combination with high performance organization, was observed consistently in just one site, and noted to a lesser extent in two others.

In the one truly excellent site visited, shift foremen behaved quite differently than in the other companies. These foremen had been trained in, and encouraged to hold, daily work-related meetings with their AMPs. They met at least weekly with other foremen and their superior. In addition, they were responsible for the pursuit of a conscious and public maintenance mission and for setting and achieving measurable objectives. They were expected to provide work direction, encouragement for high AMP performance, as well as insight and action when performance was poor.

Many of the other sites observed reflect a pattern of management practices and results that roughly matches the American national norm for completely standard practices: functional organization, firm goals, traditional supervision, and sufficient controls to guarantee minimal required outcomes. These practices do not seem to measure up in the current environments for motivating or developing employees; even as they may continue to turn out acceptable repairs.

MISSION

1. **Definition:** An effective mission - published, discussed, internalized and acted upon - is no mere slogan. It can be the driving force in ensuring worksystem excellence. It guides and unites the people of the organization in their pursuit of product "perfection," and it thereby also helps to cement the link between the organization and its customers.
2. **Findings:**

a. **Most sites had no explicit mission, for Maintenance or the Company.** None of the AMPs interviewed had participated in developing a written mission statement for their department or for their company. Nor did any report having seen or heard of any such formal statement. As to their own understanding of their mission, two statements were typical. The usual statement was: "We all want safe aircraft." In addition, some AMPs reported that "the Company wants fast turnaround." Combined - and with a course of action specified - these two statements might serve as the nucleus for a truly effective mission, serving and uniting the interests of workers, managers, passengers, shareholders and even regulators. Yet only in three of the sites visited was such an integrative mission and action plan observed in print, speech or practice.

b. **Having two sub-missions is not seen as realistic.** The AMPs observed in this study clearly accepted the dual "mini-missions" of quality repairs for aircraft **safety,** and **speed** of turnaround as relevant. They know that both of these aims are important. But which way to lean? Without a sense of success in achieving both, the essential unity of these aims is replaced by feelings of organizational confusion, psychological stress and interpersonal strain. Most of the time, in many of the sites, the expectation that they will fulfill both sub-missions at the same time is felt by the AMPs as clearly unrealistic.

c. **Most choose safety as their mission; in conflict with speed.** In response to their conflicting-aims dilemma, the AMPs interviewed and observed favored safety (quality/accuracy) as their everyday work priority. Under the normal demands for fast turnaround, they did make their best efforts to move the work along however, but not so quickly that flight safety was put at risk. And, of course, that is the right thing to do. But doing the right thing leaves many AMPs in conflict over the **other** right thing. It makes their private choice in favor of safety of flight feel inconsistent, and it leaves them feeling at odds with their management's rightful demands for speedy turnaround.

d. **Under pressure, the mission reverts to fixing things.** When the workload went up, with considerably more turnarounds and repairs expected, AMPs at several sites were observed to wait passively for their work assignments to be handed out by the supervisor. Their "mini-mission" then could be seen as neither safety nor speed. Instead, their guiding rule was clearly to "just fix things (safely), as assigned."

As the work was assigned, the AMPs performed their allotted tasks with all the care, skill and effort required. But their aim had dropped: from the safety mission (with an awareness of the clock), to merely doing the immediate task at hand (with flight safety still in mind, and the inescapably clanging clock considerably more in mind than usual).

CULTURE

The prevailing culture in heavy maintenance contains an individualistic attitude among mechanics, combined with a cooler passion for airplanes and flight among the newer employees than was common with an earlier generation.

Increasingly, people are taking airline jobs at both the top and the bottom levels for more prosaic reasons than a love of airplanes. Employees today seem to be generally less willing than their counterparts in the past to share responsibility by working closely with others. The obligations an individual A&P mechanic takes with the AMPs license, and the personal liability that entails, were reported to have the effect of making AMPs and their supervisors less eager to share work across shifts, or with less experienced or less skilled colleagues. One result of this is slower turnaround (incurring delays when key employees are absent). Another result is a considerable limitation of the opportunities for AMP to effectively exchange ideas or information. Learning was therefore hampered, too, and with it, skill development so important to the quality of work performed.

AMP EXPERIENCE

Most heavy maintenance sites visited had AMPs with very long service, very short service, and very few in the middle. The "younger" AMPs (those with less experience) were often specialists in the large sheet metal repairs or laborious inspections called out by recent airworthiness directives (ADs). Many of the AMPs with less experience had less than complete advance preparation for complex structural repairs thus OJT and formal training were necessary.

Most of the companies studied hire new mechanics and planners directly from A&P schools. These new employees learn model-specific information about large passenger aircraft in formal classroom training conducted by their employers. For more specific details of airframe technical repairs, new AMPs mainly learn on the job.

Although many companies encourage AMPs to hold A&P licenses, there remain A&P who do not, especially among the sheet metal mechanics. Sheetmetal mechanics who do have an NDI license report they received little preparation for this specialty at school. Few AMPs in the study felt well prepared from either school or subsequent training to undertake complex structural repairs or use complex NDI equipment. Such skill is developed on the job.

CONTROL OF WORK ASSIGNMENT

A struggle for control over maintenance work was observed between maintenance and planning in several sites. This struggle is beginning to take on a different and more complex dimension as computerized planning becomes more common. Where such a system is not very carefully managed and designed, it can become "control by computer," with a rigidity and singular focus that can act against the intentions of its sponsors and creators.

2.4.2 MAJOR ORGANIZATIONAL COMPONENTS Identified as a Result of Technical System Analysis

Key Variance Control

Early key variance corrections have reduced costs and raised morale. Not getting the needed cross-department cooperation sometimes blocks the path.

Maintenance foremen in some sites could not always obtain the coordination and cooperation they needed from other departments in order to attend to "critical path repairs." Critical path items were those minimum critical repairs (in particular kinds of flaws, defects, fatigue wear, and damage to the aircraft) which determined the course of the overhaul: These particular defects in aircraft condition were understood as the "key variances" in overhaul. When key variances were detected early and repaired correctly the first time, long-term maintenance costs were reported to go down while maintenance morale rose.

Sometimes these variances were not detected during the preliminary inspection, and occasionally the extent of fatigue damage (particularly corrosion) would not be revealed until late in the overhaul. Apparently this latter situation is not unusual. In many of the sites visited, the aircraft observed had corrosion or (less frequently) ramp damage that required more than the original estimated time to repair. This situation meant that there was a regular, but nasty "surprise" that defeated efforts to complete the overhaul on time or within budget.

2.4.3 MAJOR ORGANIZATIONAL COMPONENTS Identified as a Result of Social System Analysis

Organizational and Group Teamwork

Individuals and groups at several sites did not always work together effectively. Several factors appear to be contributing to this less-than-ideal state of cooperation and coordination.

Interviewees listed difficulties with work organization, guidance, and training in the face of an increasing work load along with the increasing complexity of repair for aging aircraft. AMPs at several sites reported that they were too often unable to obtain parts in a timely manner. This contributed to an uneven work flow complicating work coordination and creating additional frustrations for mechanics and supervisors. Fairly frequent and sometimes even heated discussions with others about the correctness of repairs, when no prior standard seemed to exist, was also reported as disconcerting to everyone involved. In summary, despite the best efforts of all concerned, a truly effective level of teamwork was not the norm at several of the maintenance work systems studied.

In some cases, more experienced mechanics questioned the motives and performance of younger mechanics. In these sites, mechanics and inspectors on a given shift did not approve of work performed on a preceding shift and/or would not trust their own work to the oncoming shift.

Although there appeared to be some misunderstanding and negative feeling between mechanics and inspectors, the main feeling was one of mutual respect for the separate roles and a civilized agreement to disagree. Mechanics in some sites said that they did whatever work the inspectors required. Foremen and mechanics in other sites said that inspectors were inconsistent, and this caused them to over-process and unnecessarily replace parts. Sheet metal foremen in many sites felt that the inexperience of new inspectors was a major issue. Inspectors said that there were occasional issues between themselves and the mechanics over the interpretation of standards in the structural repair manual (SRM). Inspectors in many sites reported requiring more engineering variance authorizations (EVAs) before approving non-SRM repairs. Inspectors in some sites said that the quality of the mechanics' work needed to be improved.

The production control or planning group was often identified by respondents in the sample (including planners and coordinators themselves) as the least salient, most overstaffed unit. They reported having (and were reported to have) less training and less well-defined standards than they would need to best contribute to an effective hangar maintenance system. When the planning group obtained, or was granted, control over work assignment, the results on productivity and hangar morale were usually described in negative terms.

Internal Maintenance System Boundaries

Existing organizational boundaries are not appropriately drawn in several sites. Their current boundaries tend to create separate organizations within the same system, encourage finger-pointing, and promote more politics than productivity. The necessity to cross these boundaries (for example between materials and maintenance or between shops and maintenance) has built-in difficulties in negotiating demands in support of the systems requirements. When these separate departments have conflicting goals, and diverging or incomplete understanding of the maintenance and company mission, these difficulties would occasionally escalate near the limits of the system's ability to cope.

In a number of the sites visited, both management and AMPs reported that morale was lower than it had been in the past, and that absence and turnover among AMPs was increasing. Respondents said turnover caused by poor morale was in part the outcome of frustration over work coordination, concerns about being asked to do more than can be done, and lack of cooperation and communication among separate departments.

Despite all this, mechanics and inspectors said they liked aircraft maintenance work and most of them expected to remain in the industry. Many, however, were not sure if they would stay with their present employer. Planners, on the other hand, said they were less likely to stay in maintenance at all. They reported that their jobs were less challenging and, as a group, felt they were held in low esteem by other AMP groups.

2.5 RECOMMENDATIONS

2.5.1 Guidelines for Management

Based on the results of the general overview produced by this study, it is important to strengthen the relationship between AMP technology, coordination and cooperation, and performance.

The goal of this first set of recommendations is to create guidelines which draw conclusions about the effective use of the human factor - in patterns of communication for effectively getting work done, together with satisfying the AMP work force; and to use these findings to create guidance to maintenance managers and supervisors for improvement of such communication in the maintenance function. It is recommended, therefore, to develop management guidelines for improving communication in maintenance work. In particular, the guidelines should emphasize communication styles and techniques useful in applying new or known effective AMP technologies.

Outlines and draft guidelines should be field tested with maintenance managers for feedback of those outline materials. From this feedback the guidelines for effective communications within maintenance organizations would be developed.

Guidelines as created should be consistent with the development of maintenance teamwork training derived from cockpit resource management (CRM) experience in the industry. Further, the guidelines should be written in a style and format for use by maintenance management personnel.

1. Deliver an outline for communication guidelines which
    a. specifies: AMP attitudes about the local organization. Maintenance management style. Maintenance organization purpose, long-term objectives, and short range goals. Maintenance organizational structure. Job design for applying the technology. Patterns of coordination and communication in applying the technology. Success in attaining goals and objectives in pursuit of purpose.
    b. Describes the outline topics in terms of case study and observations already collected in AMP studies described in this report.
2. Present this outline to maintenance managers in the industry and obtain feedback of topics and concept. Deliver an interim report describing the results of analyses of data collected received during feedback and field tests. The deliverable at this interim stage will provide further elaboration of the outline topics based on field test of the previous case studies and observations and added illustrative material obtained during the field tests.
3. Deliver a final and detailed report of the Communication Guidelines for effective communications within maintenance organizations. The Guidelines shall be written for maintenance management personnel.

2.5.2 Industry Validation of the Findings from the Present Study

The present study, as described, was intended to provide a rapid diagnostic picture of current U.S. experience. The study necessarily focussed on a narrow slice of aircraft maintenance, it employed informal measures of collecting data, and it was produced from a small sample rather than from the comprehensive population of companies comprising the industry.

The second major recommendation suggests more formal and comprehensive measurement by and for the commercial aviation maintenance industry itself. For a permanent and definitive record of the industry it would be valuable to quantify and expand the present study through the development of a formal survey questionnaire, designed and administered by the industry itself. For such a questionnaire a larger and representative sample of companies and their employees and managers nationwide would be drawn, and the area of interest would be extended from heavy maintenance of fuselage to all heavy maintenance activities in all areas of the aircraft, and to maintenance at the flight line as well. The data collected should also include the experience of working with newer aircraft.

Specific steps to quantify and expand the present study:

Develop a formal survey questionnaire from the findings reported here.

Extend the area of interest from heavy maintenance of fuselage alone, to at least all heavy maintenance activities in all areas and systems of the aircraft.

Specify questions the answers to which can be quantified into scaler values.

Obtain response and advice about the questionnaire items from both management and labor representatives of the commercial aviation maintenance industry.

Pretest the resulting survey instrument with a representative sample of airline maintenance employees, and correct or change items as required. Promote the support and cooperation of the industry's leaders for the survey.

Encourage company managements, local union representatives, and relevant professional societies to support the survey.

Draw a large and representative sample of companies and their employees and managers nationwide for an initial administration of the survey.

Make the preliminary results available to the sponsoring parties for aid in interpretation of findings.

Publish and distribute the final report within one year of the survey.

Develop and conduct a series of industry-wide meetings to discuss the results of the survey and plan changes to be made on the basis of those discussions.

2.5.3 Undertake Changes in Maintenance Organization and Management

This study may, in itself, provide sufficient validation of the state of maintenance safety efforts to prompt some managers and executives to take action based on its findings. The third set of recommendations therefore includes the following.

Increase the workforce competence. Increase and improve on the job (OJT) training by using experienced AMPs or qualified trainers who have themselves been trained in approaches to effective learning. Improve and expand company sheet metal and composites training for inspectors as well as mechanics. In addition to better OJT, new intelligent tutoring systems should lend themselves to efficiency in this recurrent training. Expand and emphasize teamwork training. Extending the effective training methods and curricula of cockpit resource management to maintenance managers, foremen, and AMPs is suggested.

Emphasize and support maintenance system centrality in company purpose. Each company should concentrate on developing a clear company mission statement, and help the maintenance system enunciate its role in it. Maintenance mission for each company should likewise be developed, for which clear-cut goals and objectives can be created and pursued. All maintenance personnel should be able to describe their role in achievement of these objectives and how these fit with company purpose.

Develop commitment to human values which reflects the desired practices of management and employees, and which enhances the logic of those practices. Each company and maintenance system should have a statement of values about people, including (at least): employees, managers, shareholders, contract personnel, competitors, passengers, and the travelling public. These values should be able to link with management practices, and the rationale for them.

For example, if an AMP closes out the current job card close to the end of the work day, why should the use of personnel time clocks also be required? Dedicated workforce attendance and timekeeping for personnel systems is neither required by labor law, nor is it the only effective way to acquire such data. AMPs are inconvenienced at the time clocks by waiting a second time each end of shift for the convenience of personnel departments. Time clocks may not be in keeping with values which announce trust in employees and respect for their abilities.

Another example of the logic of human values relates to policies and practices of employee furlough, or lay-offs. The value statement that claims employees are a most prized resource is difficult for AMPs to reconcile with past lay-offs. Of course a management cannot guarantee lifelong employment, but such value statements invite the creation of a logical and visible set of steps to be taken by a company before any employee is laid off. Consistency in values and practice and an open attitude to communication with employees creates greater commitment to the company.

Create and endorse teamwork in the maintenance system. Eliminate or modify the boundaries between the various function specialties in the maintenance system. This would include planning, shops, and certain parts of engineering and materials groups. Even inspection can be designed to enhance cooperation with maintenance while continuing to comply with FARs for a separate QC department which reports, independently, to top management.

Reduce the emphasis on the individual contributor as the basic work unit in aviation maintenance, in favor of greater teamwork among AMPs. Consider enhanced company role in *ab initio* AMP orientation training. Surely the current experiments with aircarrier operated A&P schools will prove effective in imparting up-to-date technical knowledge and skills.

Promote excellence in management performance. Encourage foremen to hold daily meetings with their AMPs. Encourage maintenance managers to hold at least weekly with their foremen. Emphasize management and foreman responsibility for the pursuit of a conscious and public maintenance mission and for setting and achieving measurable objectives. Expect foremen to provide work direction, and encouragement for high AMP performance, as well as insight and action when performance is below par. Involve AMPs in decision making and problem solving about matters that affect them at work. Ensure that communication throughout this management system is two way.

2.5.4 Communication Guidelines

The first year of this research was focused on identification and observation of communication practices in maintenance organizations. During 1991 a handbook will be developed to provide practical advice to improve such communication practices.

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