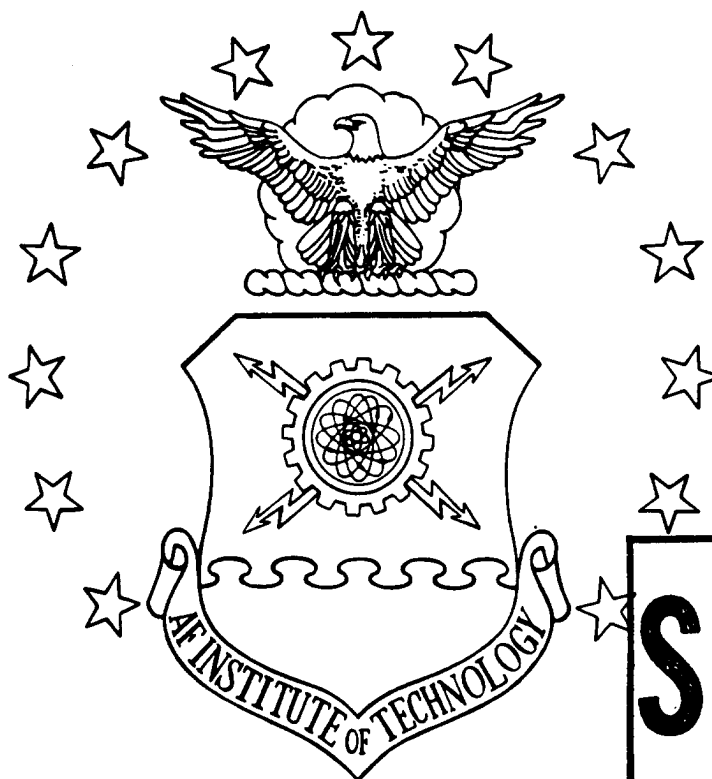


WHY SCHEDULES SLIP:  
ACTUAL REASONS FOR SCHEDULE PROBLEMS  
ACROSS  
LARGE AIR FORCE SYSTEM DEVELOPMENT EFFORTS

THESIS

William M. Cashman, Captain, USAF

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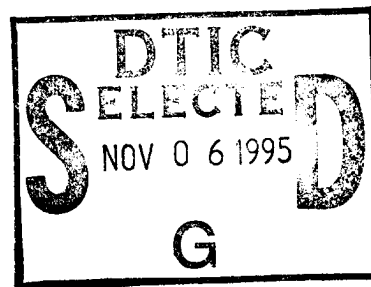
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**WHY SCHEDULES SLIP:  
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ACROSS  
LARGE AIR FORCE SYSTEM DEVELOPMENT EFFORTS**

**THESIS**

Presented to the Faculty of the School of Logistics and  
Acquisition Management  
Air Education and Training Command  
In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Systems Management

William M. Cashman, B.S., M.S.

Captain, USAF

September 1995

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William M. Cashman

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### *Abstract*

The three main objectives of this research were to identify the actual reasons for schedule problems across large Air Force system development efforts, to quantify the importance of each category of reasons in terms of frequency and severity, and to demonstrate that the reasons for schedule problems are not program unique, but are common across system development efforts.

To this end, this thesis contains a categorization and analysis of 549 reasons for schedule difficulties on 22 large Air Force Engineering and Manufacturing Development (EMD) programs from 1981 to 1994. These aircraft, missile, aircraft equipment, aircraft upgrade, and simulator programs had contract values ranging from \$40M to over \$10B. All reasons were extracted from narrative explanations of negative schedule variances contained in contractor generated Cost Performance Reports (CPRs).

Reasons for schedule problems were placed into categories, and categories were ranked by frequency of problems, total schedule variance (in dollars), and total schedule variance (in work days). Seven categories (technical problems, late subcontractors, manufacturing problems, design changes, late data, contracting, and staffing) accounted for 49 percent of the frequency, 57 percent of the schedule variance (in dollars), and 49 percent of the schedule variance (in work days).

**WHY SCHEDULES SLIP:  
ACTUAL REASONS FOR SCHEDULE PROBLEMS  
ACROSS  
LARGE AIR FORCE SYSTEM DEVELOPMENT EFFORTS**

***I: Introduction***

***General Issue***

Simply put, large defense systems take too long to develop (Drezner and Smith, 1990:i,1). Following project initiation, a typical system spends between one and six years in a preliminary design and prototype hardware phase. If approved for development, an additional three to ten years will typically pass before the first system is ready for delivery to an operational unit (Drezner and Smith, 1990:8-13). Thus, it can take as many as *sixteen years* before a validated system concept is developed into an operational military capability. In today's environment of advancing technology and changing national security concerns, the current practice of fielding 1979 weapon system concepts in 1995 systems simply does not make sense.

The idea that large defense system development takes too long is further supported by the fact that system development projects are typically late even by their own schedules. Specifically, the average defense system development effort requires one-third more time to complete than was originally scheduled (Augustine, 1983:115; Drezner and Smith, 1990:44).

There are four consequences of overly lengthy system development efforts. First, since a system's design tends to be "locked in" early in development, the longer it takes to field the system, the more likely the system will be based on old -- even obsolete -- technology. Such systems reduce the effectiveness of operational units, which rely on superior weapon systems to provide them with a combat advantage over enemy forces (Drezner and Smith, 1990:I,1). Second, a longer development effort increases the cost of a system in terms of inflation and overhead (Drezner and Smith, 1990:1). Third, a longer development effort provides more opportunities for introducing technical changes into, and new requirements for, the system (Drezner and Smith, 1990:1). These changes further lengthen the project and often lead to technical problems. Fourth, the longer a development effort, the more likely it is to be canceled prior to first system delivery (Augustine, 1983:203-204). One reason this last phenomenon may occur is because managers tend to associate schedule problems with project failure, and projects perceived to be failing are prime candidates for cancellation (Pinto and Mantel, 1990:273). In any case, a canceled development effort often represents a "lose-lose" proposition in which money is wasted and operational needs remain unfulfilled.

Thus, as was stated in the Packard Commission report on defense management, the length of the defense system development process is “a central problem from which most other acquisition problems stem.” (The President’s Blue Ribbon Commission on Defense Management, 1986:47).

### ***Specific Problem***

Clearly, there is a need for improving schedule performance in the development of large defense systems. Logically, such improvement could be realized by first identifying actual reasons for schedule problems on these efforts, then taking appropriate corrective action such as providing supplemental training, changing administrative procedures, or improving techniques. Unfortunately, very little research addresses the actual reasons for schedule problems on defense systems development efforts (i.e., late vendor selection or excessive engineering changes), and the research that does exist categorizes reasons at too high a degree of abstraction to enable the development of appropriate corrective actions. Without knowledge of these reasons, any attempt to improve schedule performance is little more than a “shot in the dark.”

### ***Thesis Objectives***

The objectives of this thesis are to:

- (a) identify the actual reasons for schedule problems across large Air Force system development efforts, describing those reasons at a level of detail that will allow the development of appropriate corrective actions;

- (b) quantify the importance of each category of reasons, in terms of frequency and severity, in order to determine the categories of reasons most and least deserving of management attention; and,
- (c) demonstrate that the reasons for schedule problems are not program unique, but are common across system development efforts, therefore schedule-related lessons learned from past and present efforts are likely to be relevant to future efforts.

### *Scope*

This thesis examines the reasons for schedule difficulties on 22 Air Force Engineering and Manufacturing Development (EMD) programs from 1981 to 1994. These aircraft, missile, aircraft equipment, aircraft upgrade, and simulator programs had contract values ranging from \$40M to over \$10B. All reasons were extracted from narrative explanations of negative schedule variances contained in contractor generated Cost Performance Reports (CPRs), a standard deliverable data item on large defense system development contracts. Frequency and severity data for each category of reasons were obtained from the same CPRs. The severity data was based on schedule variances associated with each observed reason for schedule problems. In order to ensure reasons were obtained *across* programs, data for each program were taken from the same number of CPRs as for all other programs.

## ***II: Literature Review***

### ***Introduction***

The literature contains very little research dealing directly with the actual reasons for schedule problems across large defense system development efforts. The literature does, however, contain two related areas: (1) theorized reasons for schedule problems, and (2) reasons for schedule problems observed on actual projects. These areas will be discussed in order, followed by an explanation of limitations in the current body of knowledge.

### ***Potential Reasons for Schedule Problems***

Table 2-1 summarizes some potential reasons for schedule problems. They have been synthesized from a variety of sources including: contract administration and materials management books (Contract Administration, 1975; Riemer, 1968; Ammer, 1974); surveys of project management instructors, practitioners, and headquarters personnel (Ketchum and McKenzie, 1976; Dunbar, 1980); a study of government/industry difficulties (Montgomery, 1978); a literature review and field interviews on reasons for construction project delays (Dawkins, 1987), and an examination of potential trouble areas on ten specific weapon system projects (Drezner and Smith, 1990). Note that these reasons are based on expert opinion, rather than on formal studies of schedule problems occurring on specific programs.

**TABLE 2-1: Potential Reasons for Schedule Problems**

| <u><b>Planning</b></u>                                                                                                                                                                                                                                             | <u><b>Procedures</b></u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Poor Support Planning<br>Poor Resource Planning<br>Poor Financial Planning<br>Backlog of Orders<br>Unrealistic Overall Schedule<br>Late Government Furnished Equipment<br>Late Receipt of Materials                                                                | Source Selection<br>Poor Quality Control Causing Rework<br>Failure to Inspect in a Timely Manner<br>Failure to Make Timely Progress Payments<br>Joint Service Project Management<br>Paperwork Processing Delays (Reviews/Approvals)<br>Poor Inspection/Acceptance Criteria<br>Poor Management Practices/Lack of Follow Up<br>Failure to Coordinate Multiple Contractors<br>Failure to Obtain Proper Approvals<br>Slow "Ramp Up" of Resources<br>Failure to Understand the Contract<br>Failure to Communicate<br>Inadequate Supervision<br>Micromanaging the Contractor |
| <u><b>Changes</b></u>                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Poor Management of Changes<br>Engineering Change Proposals<br>Design Changes<br>Inadvertent Constructive Changes<br>Government Directed Changes to Work Tempo                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <u><b>Execution</b></u>                                                                                                                                                                                                                                            | <u><b>External</b></u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| System Integration<br>Contractor Motivation<br>Technical Difficulties<br>Labor Problems<br>Defective Government Furnished Equipment<br>Default of Subcontractors<br>Program Complexity (Coordination Burden)<br>Contractor Performance<br>Program Manager Turnover | Political Influences<br>External Guidance<br>Concept Stability<br>External Event<br>Funding Stability<br>Major Requirements Stability<br>Economic Factors                                                                                                                                                                                                                                                                                                                                                                                                              |

(Adapted from Ammer, 1974:437; Contract Administration, 1975:161-171; Dawkins, 1987:7-8; Drezner and Smith, 1990:21-22; Dunbar, 1980:40; Ketchum and McKenzie, 1976:23; Montgomery, 1978:30; and Riemer, 1968:553)

There are three main points to note about the data in Table 2-1. First, in spite of the variety of sources, the reasons for schedule problems are fairly consistent. For example, "major requirements stability" is mentioned in four of the eight sources (Contract Administration, 1975; Dawkins, 1987; Drezner and Smith, 1990; Ketchum and McKenzie, 1976), "late/defective government furnished equipment" is mentioned three times (Dawkins, 1987; Dunbar, 1980; Montgomery, 1978), and "poor quality control" is

mentioned twice (Dawkins, 1987; Montgomery, 1978). Even though many reasons are only mentioned once, their similarity suggests that the actual reasons for poor schedule performance on large system development projects will resemble those listed in Table 2-1. Second, there are many reasons that could potentially impede schedule performance. Table 2-1 contains forty-three reasons, many of which need to be subdivided into still more reasons before they provide useful information on which to base corrective actions. Third, the literature that deals with theoretical reasons for schedule problems fails to provide any information on the frequency of these reasons or the severity of their consequences. This is significant, because it is impractical to implement corrective actions for all the reasons identified in Table 2-1. Thus, the theoretical literature fails to provide guidance as to which reasons most deserve attention.

#### ***Reasons for Schedule Problems Observed on Actual Projects***

Guidance as to which reasons deserve the most attention improves somewhat in the literature dealing with observed reasons for schedule problems. Specifically, two studies provide reasons for poor schedule performance, the amount of delay associated with each reason, and roughly how often each reason is encountered. The first study, summarized in Table 2-2, investigates delays in the development of ten major weapon systems and therefore applies well to this thesis. Unlike the theorized reasons for poor schedule performance presented earlier, the significance of the reasons in Table 2-2 has been identified. For example, “technical difficulties” account for more poor schedule performance than “external events.”

**TABLE 2-2: Significance of Reasons for Schedule Problems  
on Ten Major Weapon System Development Projects**

| <u><b>Reason</b></u>         | <u><b>Percent of Total Delay<sup>a</sup></b></u> | <u><b>Frequency (max is 10)<sup>b</sup></b></u> |
|------------------------------|--------------------------------------------------|-------------------------------------------------|
| Technical Difficulty         | 29.8%                                            | 5                                               |
| External Guidance            | 22.5%                                            | 5                                               |
| Unknown (could not identify) | 18.5%                                            | 1                                               |
| Funding Stability            | 16.7%                                            | 5                                               |
| External Event               | 7.6%                                             | 4                                               |
| Contractor Performance       | 2.5%                                             | 2                                               |
| Program Complexity           | 1.8%                                             | 1                                               |
| Concept Stability            | 1.5%                                             | 1                                               |
| Major Requirements Stability | -1%                                              | 2                                               |

<sup>a</sup> Total delay attributed to a reason  
divided by total delay across programs

(Adapted from Drezner and Smith, 1990:32-35)

<sup>b</sup> Reason observed on this number of projects

There are two difficulties associated with applying the results of the study to this thesis. First, the reasons listed in Table 2-2 are too abstract to serve as a basis for choosing corrective actions designed to improve schedule performance. For example, how does one actually go about improving “technical difficulty” or “contractor performance”? Unless these categories can be subdivided into more precise reasons, they are of limited usefulness. Second, there is very little information regarding how often each reason occurs. Although the study indicates whether or not a reason occurs on a development project, and provides the amount of delay associated with the reason, it does not identify how often that reason is observed in the development project (Drezner and Smith, 1990:32-34). Thus, important information for determining appropriate corrective actions to remedy poor schedule performance is missing from the study.

The second study, summarized in Table 2-3, examines the reasons for delay on forty-eight general building (aircraft hangars, military personnel housing, instructional

facilities, laboratories, modification/conversion/building addition projects, office buildings, and warehouse facilities) construction contracts (Dawkins, 1987:44-45).

**TABLE 2-3: Significance of Reasons for Schedule Problems on Forty-Eight General Building Construction Contracts**

| <u>Reason</u>                            | <u>Percent of Total Delay</u> | <u>Number of Changes<sup>a</sup></u> |
|------------------------------------------|-------------------------------|--------------------------------------|
| Design Error                             | 33.3%                         | 157                                  |
| Site not as Expected/<br>Unforeseen Work | 27.2%                         | 130                                  |
| Discretionary Owner Change               | 18.7%                         | 50                                   |
| Time Extension                           | 14.3%                         | 27                                   |
| Mandatory Owner Change                   | 5.4%                          | 21                                   |
| Claims Settlement                        | 1.1%                          | 1                                    |

<sup>a</sup> Total number of contract changes associated with each reason (Adapted from Dawkins, 1987:66,69)

Although there are many differences between building construction and major defense system development, there are also similarities. For example, “design error” in Table 2-3 (construction) could easily refer to “technical difficulty” in Table 2-2 (weapon systems). Likewise, “mandatory owner change” in Table 2-3 (construction) could easily refer to “major requirements stability” in Table 2-2 (weapon systems). Thus both studies are useful in identifying the general categories of reasons for poor schedule performance and in estimating the delays resulting from them.

The construction study, however, has a problem. As in Table 2-2 (weapon systems), the reasons for poor schedule performance in Table 2-3 (construction) are still too abstract to serve as a basis for choosing corrective actions designed to improve schedule performance. The author solved this problem by dividing the reasons listed in Table 2-3 into more specific sub-categories. For example, a “design error” may fall into a subcategory called “electrical” or “internal architecture” (Dawkins, 1987:66). If a large

percentage of reasons for poor schedule performance fall into the “design error - electrical” subcategory, electrical designers may need to receive supplemental training in this area. While the subcategories are construction-specific and would not provide appropriate guidance for large defense system development projects, this method seems very useful for providing detailed knowledge about reasons for poor schedule performance in general.

### ***Reasons Why Previous Research on Schedule Problems is Inadequate***

As presented earlier, the literature suggests forty-three potential reasons for poor schedule performance (See Table 2-1). It also attempts to identify the consequences associated with fourteen reasons observed on actual projects (See Tables 2-2,2-3). Unfortunately, it neither describes the reasons for schedule problems at a level of detail appropriate for determining corrective actions, nor does it quantify categories of reasons in a manner that allows management to determine which reasons are the most deserving of immediate attention. There are three probable reasons why previous research has not provided this information.

First, there is a prevailing attitude that poor schedule performance only occurs when an effort is completed later than its scheduled date (for example, see Drezner, 1990:17). If this were truly the case, the easiest way to improve schedule performance would be to *lengthen* the schedule. This is, in fact, what various schedule estimating methodologies accomplish (for example, Boyd and Mundt, 1993; Harmon and Ward, 1990; Harmon, Ward, and Palmer, 1989). By basing schedule predictions on historical data, these methodologies assume the mistakes and inefficiencies of the past will continue

into the future. When researchers take this stance, they fail to investigate ways to improve project execution. They also fail to look for signposts, such as the reasons for poor schedule performance, that would identify potential areas to improve.

Second, there is a belief that schedule performance on large defense system development projects is controlled primarily by factors external to the contractor and government project office. In fact, the previously mentioned study of ten major weapon system development projects found that five of the projects had between seventy and one-hundred percent of their delays caused by external factors. This result, however, must be viewed with some degree of skepticism, since three of the ten projects had over seventy percent of their delay caused by *internal* factors (Drezner and Smith, 1990:34-37). Further, studies in both the construction industry and in weapon system production found that a majority of poor schedule performance is due to the internal factor of poor management practice (Newmann, 1983:32; Dunbar, 1980:104). Finally, a recent survey of small architecture and engineering firms found that as the use of project management “best practices” increases, projects are more likely to meet or exceed their schedule objectives (Anderson and Tucker, 1994:40). Thus, there is a fair amount of evidence that the government project office and the contractor for a large defense system development project can improve their schedule performance through improving the effectiveness of their operations. Research into the reasons for schedule problems is necessary in order to pinpoint where improvements need to be made.

Third, there is a widespread belief that the reasons for schedule problems on one project will not apply to the next project. Therefore, research into reasons for schedule

problems is of little use. This view is understandable given the unique nature of projects. In his project management text, Nicholas states that “a project is a one time activity, never to be exactly repeated again” (Nicholas, 1990:4). Thus, it is not surprising that project managers tend to see the reasons for various project failures, including poor schedule performance, as isolated incidents that are not generalizable across projects (Pinto and Mantel, 1990:269). This perception is perpetuated through a lack of carry-over experience from one project to the next due to factors ranging from the breakup of project teams at the conclusion of a project, to the lack of training designed to preserve lessons previously learned for future projects (Bitner, 1985:73). Only through further research can this perception be altered. Just as Ketchum and McKenzie, in their formulation of fifteen weapon system acquisition case studies, found that “the method of dealing with acquisition management problems may differ, but the problems themselves seem to remain essentially the same,” (Ketchum and McKenzie, 1976:31) the study of reasons for schedule problems will most likely reveal similarities in these reasons across weapon systems. These reasons can then be used to determine generally applicable solutions to the problem of poor schedule performance.

### ***Conclusion***

The literature does not contain a single study, or collection of studies, that: (a) identifies actual reasons for schedule problems across large Air Force system development efforts, describing those reasons at a level of detail that allows the development of appropriate corrective actions; (b) quantifies the importance of each reason in terms of its frequency, and severity in a manner that allows the determination of the categories of

reasons most and least deserving of management attention; and, (c) demonstrates that the actual reasons for schedule problems are not program unique, but are common across system development efforts. This thesis will build upon the related research summarized in this literature review, and expand the existing body of knowledge dealing with the actual reasons for schedule problems in order to satisfy (a), (b), and (c) above.

### ***III: Methodology***

#### ***Introduction***

This research had three main objectives. The first was to identify the actual reasons for schedule problems across large Air Force system development efforts, describing those reasons at a level of detail that will allow the development of appropriate corrective actions. The second was to quantify the importance of each category of reasons, in terms of frequency and severity, in order to determine the categories of reasons most and least deserving of management attention. The third was to demonstrate that the reasons for schedule problems are not program unique, but are common across system development efforts, therefore schedule-related lessons learned from past and present efforts are likely to be relevant to future efforts. This chapter provides a detailed description of the manner in which the research was conducted in order to satisfy the above objectives. It discusses the overall research approach, the appropriateness of the data source, the pilot study conducted to determine the data collection methodology, the specific data to be collected along with the rationale for choosing those particular data, the use of schedule variance in this study, the sampling frame, the sampling process, the data collection process, and the method of data analysis.

#### ***Overall Research Approach***

Because studies identifying and quantifying the reasons for schedule problems on large defense system development efforts do not currently exist, this research is intended

to provide the missing foundation upon which project managers can build schedule problem insight and researchers can base investigations into more specific schedule-related management questions. This research, then, is a descriptive study (Emory and Cooper, 1991:148) in which the goal is to provide information on observed reasons for schedule problems on defense system development efforts that will be useful in preventing those problems in the future.

Although this research is neither focused on determining causal relationships nor on answering specific management questions, it is still a formal study (Emory and Cooper, 1991:140) in that it has well-defined objectives related to identifying and quantifying the reasons for schedule problems.

In order to identify and quantify the reasons for schedule problems in an unbiased manner, this research uses an observational, *ex post facto* approach (Emory and Cooper, 1991:140-141) in which all data are taken from official reports. Because these reports are prepared by people familiar with the schedule problems and are recorded soon after the problems occur, their use helps to ensure that reasons for the problems are neither distorted nor omitted. If this approach were not taken, it would be likely that only reasons associated with the more memorable or more recent schedule problems would be captured (Emory and Cooper, 1991:402).

Another fundamental aspect of this research is that it examines many system development efforts, rather than one or two in depth. This approach helps to ensure that the results of this research reflect the variety of reasons for schedule problems encountered across system development efforts, and that these results will most likely

apply to similar development efforts not specifically studied. This approach also satisfies the research objective of demonstrating that the reasons for schedule problems are not program unique, but are common across programs.

Finally, this research is conducted using a longitudinal approach (Emory and Cooper, 1991:141) in that it examines the reasons for schedule problems on defense system development efforts over time. Compared to a cross-sectional study, which considers observations within a “snapshot” of one point in time,” (Emory and Cooper, 1991:141) this approach provides far more potential data. Given that system development efforts may experience different types of problems during various stages of development, this approach most likely also provides a better representation of the reasons for problems experienced within the development phase as a whole.

#### *Appropriateness of the Data Source*

The data source for this research is the Cost Performance Report (CPR), a standard deliverable data item typically required on large defense system development contracts. The CPR is an appropriate data source for the following reasons. First, CPRs contain information regarding both the reasons for schedule problems and the severity of those problems. Thus, they contain the type of information needed to satisfy the research objectives. Second, CPRs have been used on large defense system development contracts for many years. Thus, they provide a reasonably consistent source of data on a wide variety of development efforts for the duration of those efforts. Third, CPRs are prepared by the developing contractor at roughly the same time as the schedule problems being reported. This improves the credibility of the data because it is recorded by knowledgeable

individuals who are not relying heavily on memory to produce the reports. Fourth, CPRs are generated monthly. This helps to ensure the data are at the right resolution to help identify the reasons for schedule problems at a level of detail that allows the formulation of appropriate corrective actions. If the CPR were less frequent, the data may be too aggregated to suggest corrective actions. Regular monthly reports also facilitate the sampling of data across development efforts. Fifth, CPRs for large Air Force system development efforts managed by the Aeronautical Systems Center (ASC) are readily available in the ASC Cost Library. This is significant, because consistently recorded and archived schedule information on defense system development efforts is difficult, if not impossible to find otherwise.

### ***Pilot Study***

In order to determine data availability, the most appropriate data to collect, and the most effective method for data collection, a pilot study involving 77 CPRs from the C-17 system development effort was conducted. This study involved obtaining CPRs from the ASC Cost Library, recording narrative and numerical data associated with negative schedule variances (schedule variances will be explained in the next section), and evaluating the data and the data collection process in terms of the above pilot study objectives. The pilot study supported three conclusions. First, it was determined that sufficient data existed in CPRs to support this thesis effort. Second, although CPRs contain a wide range of cost and schedule data presented in a variety of ways, only a small subset of these data were relevant to this research. The specific data subset, described in the next section, was chosen based on insights gained during the pilot study. Third, data

collection for the thesis effort had the potential to be extremely time consuming. For this reason, a sampling methodology (described in a later section) would have to be adopted.

### ***Data Selection***

Based on the pilot study described in the previous section, specific types of data were selected from the CPRs for use in this thesis. This section both identifies these data, and provides justifications for their use.

**Data Identifying Schedule Problems.** In a CPR, each time the schedule variance (a concept that will be explained shortly) exceeds a predetermined threshold, the contractor is required to explain that variance in narrative form. Although thresholds vary from contract to contract, and can even vary during the length of a single contract, the threshold used on any given CPR has been chosen to ensure that only significant variances are reported. The fact that the CPR only explains variances significant to the corresponding system development effort increases the relevance of studies using CPRs as a data source. The narratives that accompany negative schedule variances (which correspond to behind schedule conditions) are the sole source of reasons for schedule problems on large defense system development efforts contained in this research.

**Measures of Schedule Problems Severity.** In addition to the narrative data, which identifies the reason for a given schedule problem, numerical data must also be collected to quantify the severity of that problem. While frequency data is obtained merely by counting the number of observed reasons for schedule problems, the magnitude of the problems associated with the reasons is obtained by collecting the schedule variance and

the Budgeted Cost of Work Scheduled (BCWS) for each collected reason (these terms will be explained shortly).

Before explaining what is meant by schedule variance and BCWS, and the appropriateness of these measures to this research, there are two important elements of data selection to be discussed: the use of current month rather than cumulative data, and the use of data associated with Work Breakdown Structure (WBS) elements rather than data associated with functional areas.

**Use of Current Month Data.** Although CPRs contain both cumulative and current month data, only current month data was collected. Part of the reason for doing this is to avoid double-counting schedule problems when sampling multiple CPRs on a given development effort. Another reason for collecting only current month data is that narratives associated with cumulative schedule variances generally contain many more reasons for the variance than do current month narratives. The more reasons per schedule variance, the more difficult it is to accurately separate and quantify the magnitude of the schedule problems associated with each reason. Also, cumulative data tends to be more sensitive to schedule variances early in an effort, and less sensitive towards the end of an effort. This is because explanations are only generated when schedule variance exceeds a predetermined threshold. This threshold may be in absolute terms (dollars), relative terms (percent), or a combination of both (AFSCP 173-4, 1989: Para. 4-3(c)(3)(a)). If the threshold is defined in relative terms, a given variance early in an effort may be of the same magnitude as a variance late in the effort, but only the early variance will exceed the threshold and be reported. This is because at the time of the earlier variance, less work

was scheduled to be completed than at the time of the later variance, and as a proportion, causes the same amount of variance to appear larger.

**Use of Data Reported Against WBS Elements.** Although CPRs identify schedule problems both by Work Breakdown Structure (WBS) element and by functional area, only data corresponding to WBS elements were collected. This approach was taken because in the C-17 pilot study, the reasons for schedule problems were better separated when reported against WBS elements. Functional area explanations tended to contain many reasons per reported variance, which, as was explained in the discussion of current month versus cumulative data, is an undesirable attribute. Also, as will be explained shortly, schedule variance is measured based on progress towards completing tasks defined by WBS elements. Because the determination of schedule variance is more closely tied to WBS elements than to functional elements, the collection of data organized by WBS element rather than by functional area is appropriate.

#### ***The Use of Schedule Variance in this Study***

This study relies on the use of schedule variance to quantify the severity of schedule problems on large defense system development efforts. In order to appreciate the usefulness and limitations of schedule variance as a measure, it is important to understand what schedule variance is, and how it is calculated on a CPR.

Schedule variance measures the difference between progress made over a given period of time (in the case of this research, a month) and progress scheduled to occur during that same period of time (The AFSC Cost Estimating Handbook: Para. 5.4.2). If

an effort is exactly on schedule, the schedule variance is zero. A negative schedule variance, however, indicates that the effort is behind schedule.

In order to calculate schedule variance, both the amount of progress scheduled to occur and the amount of progress that actually did occur must be defined. The amount of progress scheduled to occur during a given period is known as the Budgeted Cost of Work Scheduled (BCWS) (Nicholas, 1990:385). The BCWS is typically calculated at the start of an effort by defining the tasks required to complete the effort and estimating the amount of work (in dollars) involved in each task. The amount of work estimated for each task is then distributed over time, based on the schedule for the effort, to form a time-phased budget (Nicholas, 1990:355-356). The amount of work in this time-phased budget that is planned to occur during a given period is that period's BCWS. The current month BCWS, then, represents the amount of work that would occur during that month if the effort were on schedule.

Because large defense system development efforts are rarely, if ever, precisely on schedule, another measure, capturing the actual progress made during the current month, is necessary. This measure, known as the Budgeted Cost of Work Performed (BCWP) or "earned value," only takes credit for actual progress towards completing the effort (The AFSC Cost Estimating Handbook: Para. 5.4.2). The difference between the BCWP and the BCWS in a given month represents the difference between the amount of progress actually made during that month and the amount of progress scheduled to be made during that month. This difference, known as the monthly schedule variance, is negative if less progress occurred than was scheduled (Nicholas, 1990:387-388). By collecting the

negative schedule variance associated with a schedule problem, the magnitude of that problem in terms of progress not made can be quantified.

Note, however, that schedule variance is measured in dollars rather than in time. This is because it is a measure of deviation from scheduled progress, and progress is measured against the time-phased estimated *cost* of the tasks comprising the development effort. Although negative schedule variance measured in dollars implies a behind schedule condition, and by itself is a good quantitative indicator of schedule problem severity, it is also useful to view schedule problem severity in terms of time. The method used in this research to calculate schedule variance in terms of time is as follows. Because the current month BCWS represents the total progress scheduled to be made during the month, it can be said to represent one month worth of progress. Likewise, a negative current month schedule variance, which represents the amount of progress scheduled but not made during the month, can be said to represent between zero and one month worth of not making progress. Thus, when the negative schedule variance is compared to the current month BCWS, the resulting ratio (variance/BCWS) can be said to represent the fraction of a month in which progress is not being made (AFSCP 173-4, 1989: Para. 12-1(d)). This fraction of a month is what this research uses to represent schedule variance in terms of time.

Both measures of schedule variance (dollars and time) provide information useful in quantifying the magnitude of schedule problems. Schedule variance measured in dollars tends to characterize schedule problems on large efforts as much greater than problems on smaller efforts. This is because larger efforts tend to spend more money per month than

smaller efforts. A month of delay on a large effort may cause a \$1M schedule variance, while a month of delay on a smaller effort may only cause a \$50K schedule variance. Even though both tasks are a month behind, the task on the larger effort appears to have a much more severe schedule problem. This is consistent with the view that a delay to an effort such as the F-22 is far more significant than a delay to a smaller effort, such as a tactical communication system.

On the other hand, schedule variance measured in time views all task delays as equal, regardless of the size of the development effort. Thus, even though the schedule variance (in dollars) on a large effort may be 20 times the size of the schedule variance (in dollars) on a smaller effort, the schedule variance (in time) for both cases may be the same. This is consistent with the view that all development efforts are equally important, and that a delay to the F-22 is no more or less significant than a delay to a smaller tactical communication system effort. Depending on the reader's purpose and perspective, both this view and the opposing view, as described in the preceding paragraph, may be equally valid. For this reason, this research collects and presents both measures of schedule problem severity.

One final note on the use of schedule variance in this research. Although negative schedule variances, especially those stated in terms of time, may seem to imply that the overall development effort is experiencing a delay equal to the variance, this is usually not the case. In fact, only when tasks are on the critical path of a development effort do their schedule variances indicate delays to the overall effort (Nicholas, 1990:284). When tasks are not on the critical path, task delays indicated by negative schedule variances will

generally be absorbed by “slack” in the overall development effort’s schedule so as not to cause a delay in the overall effort. However, even if negative schedule variances often do not describe a delay in the development effort’s completion date, they are still a valid measure of schedule inefficiency, and therefore pertain directly to this research. Further, the fact that an observed schedule problem is not associated with a task on the critical path of an effort does not mean that a similar problem will not occur on a critical path task in the future.

### *The Sampling Frame*

The following criteria were used to select the system development efforts that are included in this research. First, for ease of access, only system development efforts whose CPRs were available in the ASC Cost Library were considered. This includes most large Air Force system development efforts managed by program offices at ASC.

Second, only efforts with a target price of over \$40M were considered. This selection criteria originates from the fact that in general, CPRs are applied to larger efforts, and reports known as Cost Schedule Status Reports (C/SSRs) are applied to smaller efforts (AFSCP 173-4, 1989: Para. 3-4(a)). As explained previously, CPRs are the sole source of data for this research. C/SSRs were not used because although they contain similar information, they require only cumulative, rather than current month reporting. Also, unlike the CPR, where BCWS and BCWP for a task must be calculated by directly summing subtask BCWS and BCWP, C/SSRs do not have a standard approach for calculating these parameters (AFSCP 173-4, 1989: Para. 3-4(b)). Because these parameters are used to calculate schedule variance, variances taken from CPRs should be

more able to be consistently compared across development efforts than variances taken from C/SSRs. Also aiding in consistency is the fact that C/SCSC (Cost/Schedule Control Systems Criteria) is required on contracts using the CPR, but is not necessarily applied to contracts using the C/SSR (The AFSC Cost Estimating Handbook: Para. 5.4.2). Because contracts applying C/SCSC have accounting and reporting systems that meet the same criteria, cost and schedule data from these contracts are more consistent than among contracts not applying C/SCSC. In any case, limiting the sampling frame to efforts with a target price of over \$40M also controls for the fact that small efforts may have different reasons for schedule problems than large efforts. Eliminating this potential moderating variable (small versus large efforts) increases the credibility of the results of this research.

Third, this research only considers Engineering and Manufacturing Development (EMD), previously known as Full Scale Development (FSD), efforts. The reason for this criteria is to exclude basic research and exploratory development efforts, which tend to be neither planned nor managed with the same emphasis on schedule as EMD efforts.

Fourth, this research only considers development efforts that are ongoing, or that have ended after 1984. This timeframe is based on a compromise between obtaining a wide variety of data on a number of types of development efforts, and ensuring the results are relevant to current and future efforts. With a large timeframe, more efforts are included, providing a wider variety of data. With a smaller but more recent timeframe, fewer efforts are included, however the schedule problems observed are more likely to represent those encountered on efforts operating under today's management practices.

Based on the above criteria, the ASC Cost Library document catalog indicated 39 system development efforts described by 1850 CPRs would comprise the sampling frame. After an examination of several CPRs from each of these efforts, five development efforts were removed for not containing any negative schedule variances, four were removed for not reporting explanations for schedule variances, three were removed because they were not currently available, two were removed for not reporting current month variances, one was removed for a lack of data due to a late contract definitization, one was removed for not presenting data in a format conducive to identifying reasons for schedule problems, and one was removed for reporting variances against functional areas rather than by WBS elements. In addition, the number of usable CPRs on four efforts was less than anticipated because reports early or late in the efforts lacked variance explanations. Table 3-1 displays the final sampling frame of 22 system development efforts described by 973 CPRs.

**TABLE 3-1: Description of Sampling Frame**

| <u>Effort Type</u> | <u>Number of Efforts</u> | <u>Specific Effort Types</u>                                                     | <u>Years Covered</u> | <u>Number of CPRs</u> | <u>Contract Value</u> |
|--------------------|--------------------------|----------------------------------------------------------------------------------|----------------------|-----------------------|-----------------------|
| Aircraft/Missile   | 7                        | Fighters (3)<br>Bomber (1)<br>Transport (1)<br>Cruise Missile (1)<br>Trainer (1) | 1982 - 1994          | 316                   | \$ 15,277 M           |
| Aircraft Upgrade   | 6                        | Fighters (2)<br>Elec Warfare (2)<br>Bomber (1)<br>Special Msn (1)                | 1984 - 1994          | 190                   | \$ 819 M              |
| Aircraft Equipment | 5                        | Recon (2)<br>Engine (1)<br>Launcher (1)<br>Transponder (1)                       | 1981 - 1991          | 290                   | \$ 580 M              |
| Simulator          | 4                        | Elec Warfare (2)<br>Aircrew (2)                                                  | 1984 - 1994          | 177                   | \$ 358 M              |

Note that in Table 3-1 , the actual system development effort (program) names have been replaced with generic program types, and data regarding the development effort duration and cost have been aggregated in order to allow unrestricted dissemination of this research. By omitting clues that tie the data to specific defense programs, sensitive information is properly safeguarded, yet the ability to fully understand and appreciate this research is preserved.

### *The Sampling Process*

Based on the previously mentioned C-17 pilot study, a census of all 973 CPRs in the sampling frame would be too time consuming for a limited scope research effort such as this. In addition, because of the wide variation in the number of CPRs associated with the efforts in the sampling frame, a census would represent efforts unequally. In order to satisfy the research objective of demonstrating that the reasons for schedule problems on large defense system development efforts are common across efforts, it is important to ensure efforts are represented equally. For these reasons, a sampling approach randomly selecting an equal number of CPRs from each effort in the sampling frame for examination was adopted.

Specifically, nine CPRs were randomly selected from each sampling frame system development effort, using random number tables (Kendall and Smith, 1938:147-166) to choose among the CPRs available for each effort. The reason for selecting nine CPRs per development effort is that the effort with the fewest CPRs had only nine CPRs associated with it. Thus, nine was the maximum number of CPRs that could be examined per effort given the intent was to examine an equal number of CPRs per effort. In addition, the

resulting number of CPRs (198) was deemed, based on the C-17 pilot study, to represent an ambitious yet reasonable data collection and analysis effort given the scope of this research. The exception to the rule of examining nine CPRs per effort occurred towards the end of the data collection effort, when only eight reports in a usable format were available on one of the fighter aircraft development efforts. In this case, only eight CPRs were examined, however there is no evidence that this discrepancy significantly affects the results of this research.

### ***The Data Collection Process***

Data collection for this research was a two-step process. In the first step, relevant data was copied from all sampled CPRs. Specifically, for each sampled CPR, every page containing either schedule variance or narrative related to an explained current month negative schedule variance reported against WBS elements (contained in Format V of the CPR) was copied either with a standard office or microfiche copier. In addition, Format I of each CPR, which contains BCWS values for the WBS elements, was copied in the same manner.

In the second step, the CPR pages copied in step one were examined such that each explained current month negative schedule variance reported against a WBS element generated an entry in a computer database. For each entry, the program name, reason for the schedule variance (extracted from the narrative), schedule variance, BCWS, and CPR date were recorded. In recording this information, the following guidelines were followed. First, only negative schedule variances that represented a true behind schedule condition for a task generated a data entry. Variances resulting from accounting errors or

late billing for completed work were not included. Similarly, false negative variances resulting from work completed early or out of planned sequence were not included. An example of how a task actually completed early can generate a false *negative* schedule variance is as follows. Suppose a task is scheduled to occur in the month of May, but instead occurs in April. Because no effort was scheduled for April, the actual progress made during April will cause a positive schedule variance (as expected). However, because the effort was originally scheduled for May, and no progress occurs in May (because the effort is complete), a false negative schedule variance is reported. If only the May report is sampled, the negative variance will appear to indicate a behind schedule condition when in fact it does not. For this reason, data associated with such false variances has been excluded from this research.

Second, the narratives associated with explained negative current month schedule variances were often written in paragraph form. In order to facilitate data collection and analysis, these paragraphs were summarized in one-line descriptions of 75 characters or less. Where possible, explanations were recorded verbatim, although most explanations were paraphrased. In summarizing the explanation, the primary focus was on preserving the actual reason for the schedule variance, while a secondary emphasis was on capturing how the schedule problem impacted the development effort.

Third, in many cases, the explanation associated with a single schedule variance reports multiple reasons for that variance. Although this occurs more often in explanations of cumulative variances and variances reported against functional areas, it occurs often enough in explanations of current month schedule variances reported against

WBS elements that the following rules were adopted for use in this research. First, if more than one reason was associated with a single schedule variance, a data entry was created for each reason. Thus, a single reported schedule variance on a CPR could result in multiple entries in the database supporting this research. This, however, created a problem in deciding how to divide the variance among its associated reasons, hence the second set of rules. On occasion, the narrative will identify, either in dollars or in percent, the amount of variance associated with each included reason. In these cases, variance was divided accordingly. More often, the narrative will state that the variance was caused primarily by one reason, but other reasons contributed. In these cases, the variance was divided in a ratio of 3 to 1 if there were two reasons, and 3 to 1 to 1 if there were three reasons. Most often, the narrative contains no indication of one reason being any more significant than another. In these cases, variance was divided equally among each reason.

The final rule for dividing quantitative information among reasons for schedule problems is that when multiple reasons are associated with a single variance, and hence a single BCWS, on a CPR, the BCWS is *not* divided among the reasons. Instead, the total BCWS associated with the reported variance is applied to each recorded reason. At first, there may appear to be an inconsistency between dividing variance and not dividing BCWS. The reason for the apparent discrepancy is that while variance is fully described by the reasons listed in the narrative, BCWS is based on the completion of tasks that may or may not be listed in the narrative. Recall that BCWS reflects all work that is scheduled to occur on a given WBS element, and schedule variance only reflects work not accomplished. When variance is divided, it merely is an attempt to distribute a known

amount of inefficiency, relative to the completion of a WBS element, among known reasons for that inefficiency. If BCWS were to be divided in the same manner, it would imply that each reason for schedule variance was creating a given amount of inefficiency against its very own lower level WBS element. While this is possible, it certainly is not expected. Given the absence of information on how multiple reasons associated with a single reported schedule variance impact lower level WBS elements, this thesis has applied the full BCWS associated with each reported variance to each reason associated with that variance.

### ***Method of Data Analysis***

It is necessary to group data associated with similar reasons into categories in order to analyze the collected data in a manner that allows meaningful identification of the reasons for schedule problems across system development efforts, quantification of the severity of the problems associated with those reasons, and demonstration that those reasons are common across efforts. Because this research is descriptive in nature, no attempt was made to force the data into pre-defined categories. Instead, categories were developed to reflect the data. A discussion of the method for categorizing the data is as follows.

The initial categorization of the data into groups having similar reasons for schedule problems was conducted in parallel with the entry of CPR data into the computer database. As each reason for schedule problems and associated quantitative information was extracted from the CPR, the reason was categorized based on its wording and the researcher's five years of experience as an Air Force project manager. This categorization

was intended to represent the reason at a high enough level of generality to allow the reduction of hundreds of data entries into a manageable and understandable form, while preserving the descriptive nature of the original reason. For each data entry, if the reason for the schedule problem was similar to an existing category, the reason was placed in that category. In the event that a reason did not fit into any categories, a new category was defined based on the above method.

Once all the data was entered into the computer database and grouped according to initial categories, the researcher conducted two separate reviews to ensure appropriate categorization of the data. The first review was to ensure the reasons for schedule problems truly belonged in their assigned category. This review also was to ensure the categories themselves were at similar levels of detail. Based on this review, several reasons were recategorized, and several categories at too low a level of detail were divided into more detailed categories. As an example of the latter, a category named “development problems” was divided into “technical problems,” “technical definition,” and “manufacturing problems.”

The second review was conducted primarily to ensure that the categories focused on the reason for the schedule problem, and not what the problem impacted (such as integration), or where the problem occurred (such as at the subcontractor’s facility versus prime contractor’s facility). Based on the review, several categories were eliminated, and their reasons were assigned to other categories. Following this reassignment, the review reexamined whether each reason belonged in its assigned category. This time, only four

reasons were recategorized, demonstrating that the categories were now stable enough to allow meaningful analysis.

Following the grouping of reasons for schedule problems on large system development efforts into descriptive categories, the reasons within each category were further grouped into subcategories. These descriptive subcategories were determined in the same manner as the categories. Their purpose is to provide a level of detail between the fairly general categories and the detailed data entries. This additional detail allows greater insight into the reasons for schedule problems by identifying the types of reasons that make up each category. In addition, the subcategories allow for a more orderly grouping of data entries in the full listing of the computer database in the appendix.

After fully categorizing and subcategorizing the data, the data was analyzed by category in terms of the previously discussed schedule problem severity measures of frequency, schedule variance (in dollars), and schedule variance (in time). The data was also analyzed to demonstrate that the reasons for schedule problems are common across system development efforts. The details of these analyses are presented in Chapter 4.

## ***IV: Data Description and Analysis***

### ***Introduction***

This research had three main objectives. The first was to identify the actual reasons for schedule problems across large Air Force system development efforts, describing those reasons at a level of detail that will allow the development of appropriate corrective actions. The second was to quantify the importance of each category of reasons, in terms of frequency and severity, in order to determine the categories of reasons most and least deserving of management attention. The third was to demonstrate that the reasons for schedule problems are not program unique, but are common across system development efforts, therefore schedule-related lessons learned from past and present efforts are likely to be relevant to future efforts. The following chapter presents a characterization of the data collected in this research, and an analysis of that data with the intent of satisfying the above research objectives.

Specifically, it discusses the number of schedule problem observations obtained from each type of development effort, the number of observations per development effort, the number of observations by year of occurrence, the categories into which the reasons for schedule problems were grouped, and the types of reasons composing each category. The chapter then compares the categories of reasons for schedule problems in terms of frequency, total schedule variance per category (in both dollars and work days), and average schedule variance per category (in both dollars and work days). The chapter

concludes with a summary ranking of each category in terms of the above measures, and an analysis demonstrating that the reasons for schedule problems are common across system development efforts.

### ***General Description of Data***

Using the methodology addressed in Chapter 3, 549 instances of reasons for schedule problems across 22 system development efforts were observed. In order to provide a context within which to assess the results of this research, the following section broadly characterizes these reasons in terms of where and when the reasons occurred.

Figure 4-1 provides a graphical representation of the proportion of reasons for schedule problems observed on each of the types of system development efforts (programs) defined in Chapter 3, Table 3-1.

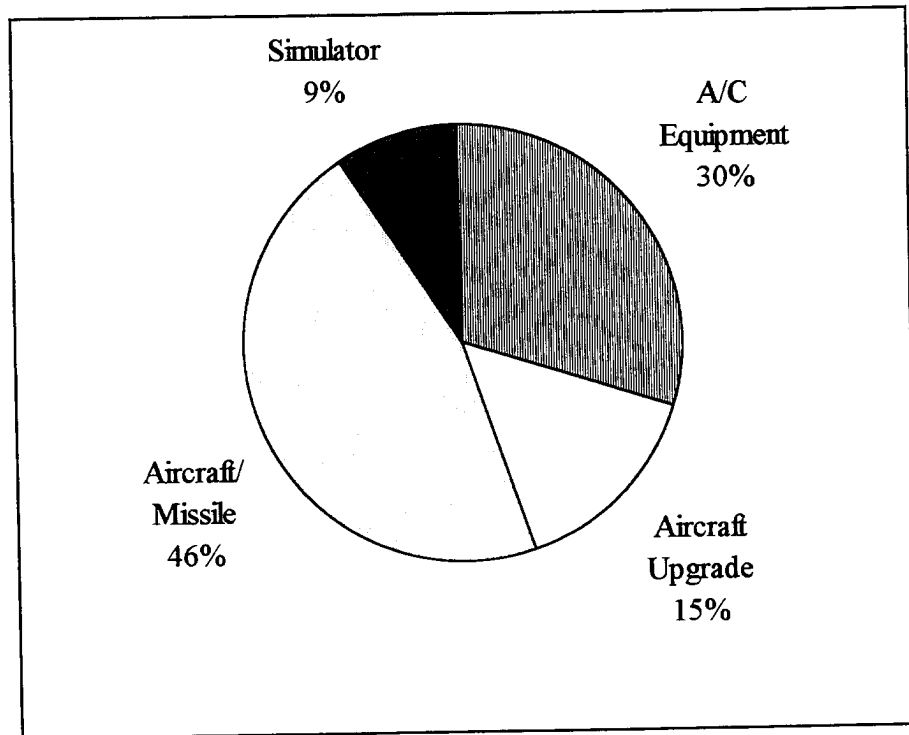


**FIGURE 4-1: Proportion of Reasons from Each Development Effort Type**

Although Figure 4-1 may appear to imply that schedule problems are more likely to occur on one type of development effort than another, this research neither supports nor refutes that conclusion. As explained in Table 3-1, the number of efforts, size of efforts, and length of efforts is not consistent across development effort types. For this reason, comparisons among the effort types in this research is not appropriate. Instead, the utility of Figure 4-1 is that it assists in understanding the origin of the data underlying this research so that results of this research can be correctly interpreted.

To further assist in understanding the origin of the data, Figure 4-2 presents the number of observed reasons for schedule problems per sampled development effort.

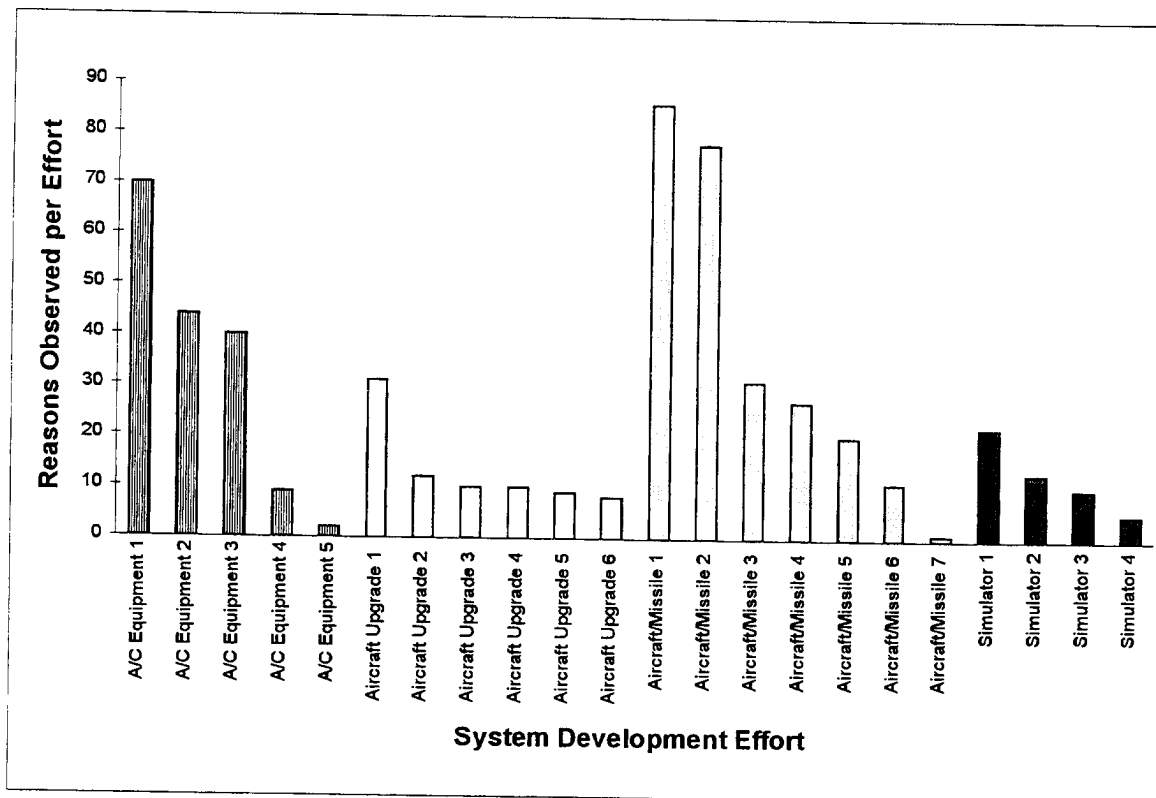


**FIGURE 4-2: Reasons Observed per Development Effort**

From Figure 4-2, it is clear that not all development efforts provided the same number of reasons for schedule problems. This is despite the fact that, as explained in Chapter 3, the data was collected from an identical number of monthly Cost Performance Reports (CPRs) for each development effort. Although the cause of this variation was not investigated in this research, potential reasons could include varying schedule problem reporting thresholds among programs and varying schedule-related success among programs. In any case, for the purposes of this research, it is important to note that certain development efforts influence the results more than others, but that most efforts provided a reasonable contribution. Overall, the average number of reasons for schedule problems observed per effort was roughly 25, with a standard deviation also of roughly 25.

Finally, Figure 4-3 presents the number of reasons for schedule problems observed in all CPRs sampled in a given year.

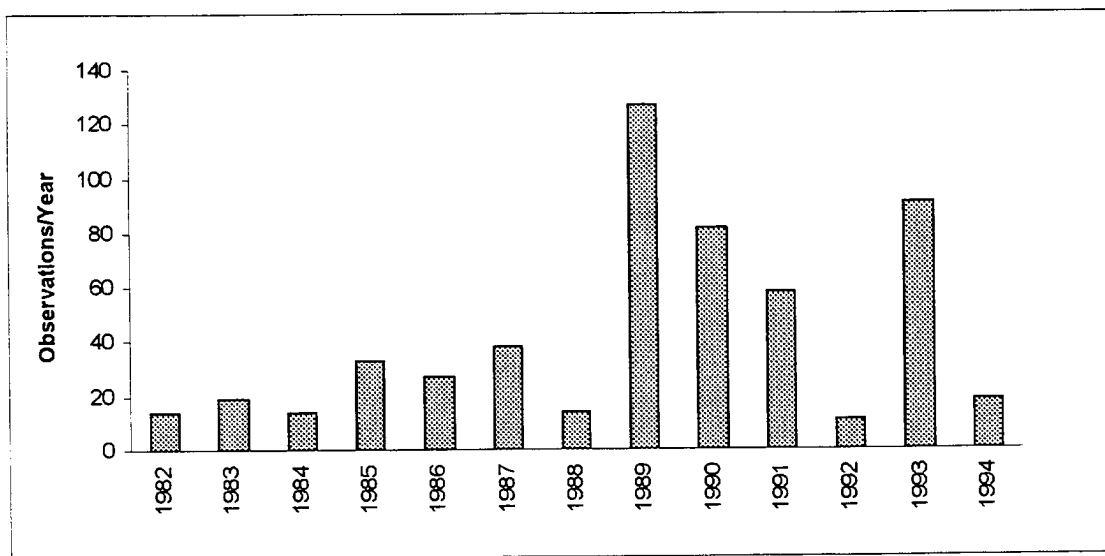


**FIGURE 4-3: Reasons Observed by Year of Occurrence**

Although Figure 4-3 may appear to imply that schedule problems are more likely to occur on recent efforts than on efforts prior to 1989, this research neither supports nor refutes that conclusion. In the research, there was no attempt to sample data equally across years, and as such, conclusions regarding the prevalence of schedule problems by year are not appropriate. Instead, the utility of Figure 4-3 is that it assists in understanding the origin of the data underlying this research in order that results of this research can be correctly interpreted. For example, based on Figure 4-3, it is clear that a significant proportion of the data underlying this research reflects recent schedule problems (experienced since 1989), which should provide managers with added confidence that the results of this research will apply well to current efforts, and to efforts in the near future.

#### ***Categorization of Reasons for Schedule Problems***

In order to make sense of the 549 reasons for schedule problems observed in this research, these reasons have been grouped into descriptive categories according to the methodology specified in Chapter 3. Because these categories are intended to reflect the descriptive nature of the original reasons, albeit at a lower level of detail, the best way to describe these categories is through examples of the actual reasons they summarize. In this manner, Table 4-1 provides a brief description of each of the 20 categories used in this research.

**TABLE 4-1: Categories of Reasons for Schedule Problems**

| Category             | Examples                                                                                                             |
|----------------------|----------------------------------------------------------------------------------------------------------------------|
| Contracting          | Contract not yet signed with vendor for wing slat package<br>Late source selections delaying H/W & S/W design        |
| Changed Plans        | Minor changes in several functional responsibilities<br>Rescheduled design effort                                    |
| Design Changes       | Design changes due to weight reduction activities<br>Tech manuals delayed due to frequently changing tech data       |
| Estimating           | Number of detail parts to be custom designed more than planned<br>Overly aggressive material plan could not be met   |
| Facility Problems    | Facility design behind schedule<br>Design mods/layouts behind due to late test area completion                       |
| Gov't Added Work     | Gov't directed more detailed specifications than anticipated<br>Support for VIP demo flights impacting test effort   |
| Gov't Not Supportive | Delay in obtaining source data from Gov't for tech manuals<br>Late final test plan due to delayed customer comments  |
| Gov't Stopped Work   | Gov't directed work stoppage impacting other areas<br>Stop work order slowed vendor tasks                            |
| Inventory Mgt        | Delays in recognition of receipt of vendor deliveries<br>Parts shortages impacting test article fabrication          |
| Late Data            | Lack of imagery data to validate algorithms<br>Late engineering drawing releases                                     |
| Late Reviews         | Delayed fabrication due to slip of CDR<br>Additional effort required to close out CDR                                |
| Miscellaneous Delays | Delay in shipment overseas impacts test<br>Site activation meeting delayed                                           |
| Manufacturing Probs  | Delays in fabrication of major assembly tooling fixtures<br>Delay in defining/releasing production bill of materials |
| Quality              | Vendor testing not satisfactory for acceptance<br>Flight station shipped in an incomplete condition by subktr        |
| Req'ments Changes    | Changing specifications impacting effort<br>Change in harness board requirements                                     |
| Staffing             | Inadequate systems engineering staffing delaying specifications<br>Reassignment of personnel to more critical areas  |
| Subcontractor Late   | Late material deliveries delaying STE effort<br>Subcontractor delays in reaching development milestones              |
| Test Problems        | Unplanned instrumentation modification delaying flight test<br>Component difficulties during qual testing            |
| Technical Definition | Delay in specification generation<br>Incorrect envelope definition to sub delayed CDR                                |
| Technical Problems   | Difficulties in analyses and monte carlo simulation<br>Technical difficulties associated with H/W algorithms         |

The categories listed in Table 4-1 identify the reasons for schedule problems across Air Force system development efforts at fairly general level. It is at this level that comparisons of reasons in terms of frequency of observation and severity of associated problems have been made. These categories have also been used to demonstrate the commonality of reasons across development efforts. Prior to making these comparisons and demonstrations, however, it is essential that the above categories are fully understood. In the following subsections, each category listed in Table 4-1 is described based on subcategories (as explained in Chapter 3) of reasons assigned to each category. By understanding the categories in these more detailed terms, the likelihood of formulating appropriate corrective actions for schedule problems based on the results of this research is increased.

**“Contracting” Category.** This category includes reasons related to contractual actions and the process of awarding subcontracts. In the assignment of reasons to this category, most did not contain sufficient information to determine whether or not the associated schedule problems were caused by contracting functional procedures and staff. Consequently, this category includes contracting-related reasons for schedule problems that were likely caused not only by the contracting department, but by other departments failing to provide information or generate requests in a timely manner, and by management actions resulting in lengthy contracting-related approval cycles. Specific subcategories of reasons for schedule problems within the “contracting” category are as follows:

- (1) source selection of subcontractors and vendors (including request for proposal (RFP) preparation and proposal receipt),

- (2) placing subcontractors and vendors on contract,
- (3) processing purchase orders, and
- (4) terminating subcontractors.

Figure 4-4 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “contracting” category.

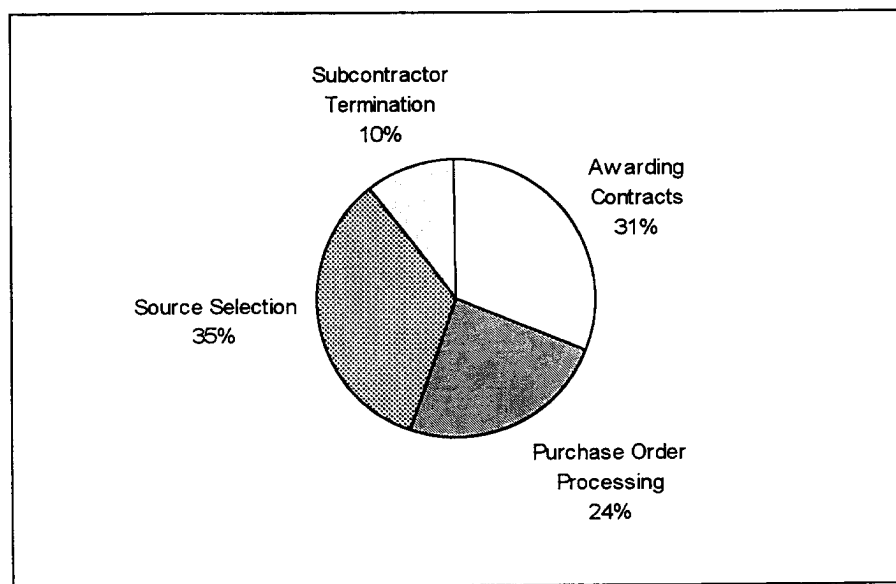


**FIGURE 4-4: “Contracting” Subcategories**

**“Changed Plans” Category.** This category includes reasons related to revised schedules and work plans. Specific subcategories of reasons for schedule problems within the “changed plans” category are as follows:

- (1) new design schedules,
- (2) new delivery schedules, and
- (3) changes in work responsibilities among functional departments.

Figure 4-5 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “changed plans” category.

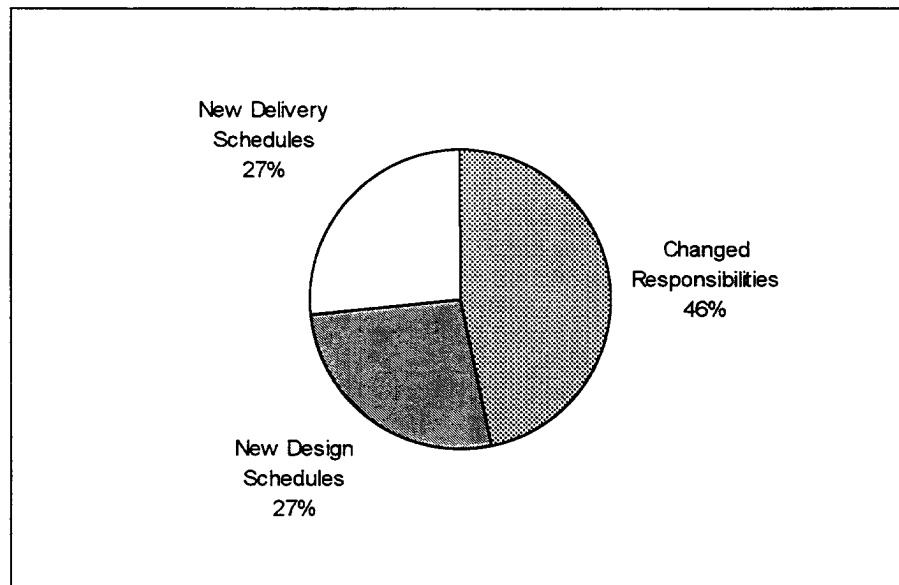


**FIGURE 4-5: “Changed Plans” Subcategories**

**“Design Changes” Category.** This category includes reasons related to changes in system or component designs, typically undertaken to fix problems or to improve performance. Quite often, in addition to requiring time to implement, these changes also impact other, related tasks that depend on stable, defined designs for their continued progress. Specific subcategories of reasons for schedule problems within the “design changes” category are as follows:

- (1) changes affecting generation of data, such as that needed for engineering drawings or technical manual preparation;
- (2) changes affecting manufacturing activities, such as mockup construction, component fabrication, and system assembly;
- (3) changes affecting subcontractor deliveries (deliveries delayed due to the need to incorporate changes);
- (4) changes affecting testing (tests that must wait for redesigned components);
- (5) general delay, including changes limited to affecting design efforts, or changes whose affect is unspecified; and,
- (6) changes to reduce the weight of the system.

Figure 4-6 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “design changes” category.

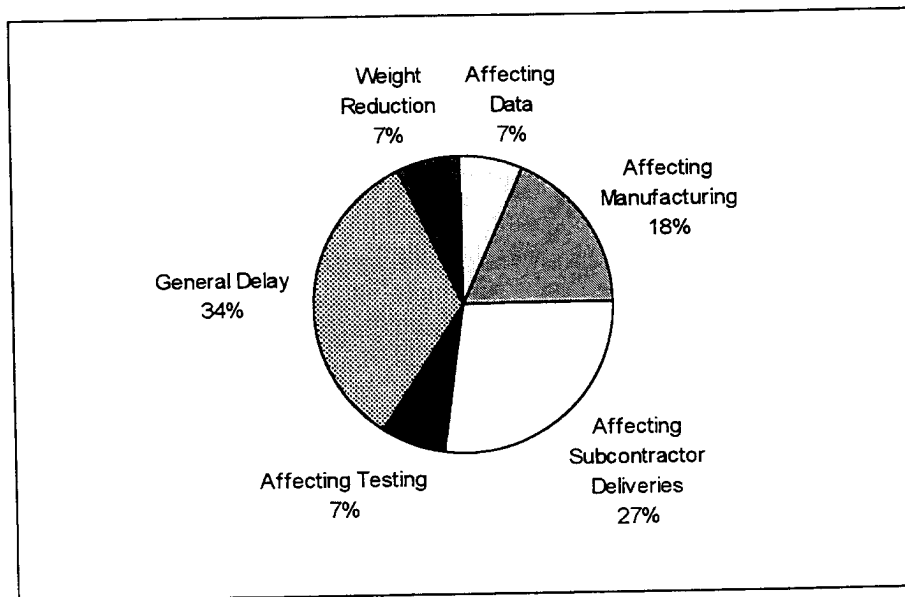


**FIGURE 4-6: “Design Changes” Subcategories**

**“Estimating” Category.** This category includes reasons related to the underestimation of time or effort required to complete tasks on schedule. Although many of the 549 observed reasons for schedule problems may indeed have been caused by poor schedule estimating, the reasons included in this category are only those that mention, either directly or indirectly, a problem in schedule planning or estimating. Specific subcategories of reasons for schedule problems within the “estimating” category are as follows:

- (1) overly ambitious schedules,
- (2) optimistic material budgets (based either on using more material during the observed month because the effort was planned to be further towards completion, or on overly optimistic supply predictions),
- (3) planning to an incorrect schedule,
- (4) underestimating the time required to order materials,
- (5) lack of integrated schedules resulting in disconnects among tasks,
- (6) misplanning (poor planning) of tasks,
- (7) underestimating the time needed to complete tasks, and
- (8) underestimating the amount of work required to complete tasks.

Figure 4-7 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “estimating” category.

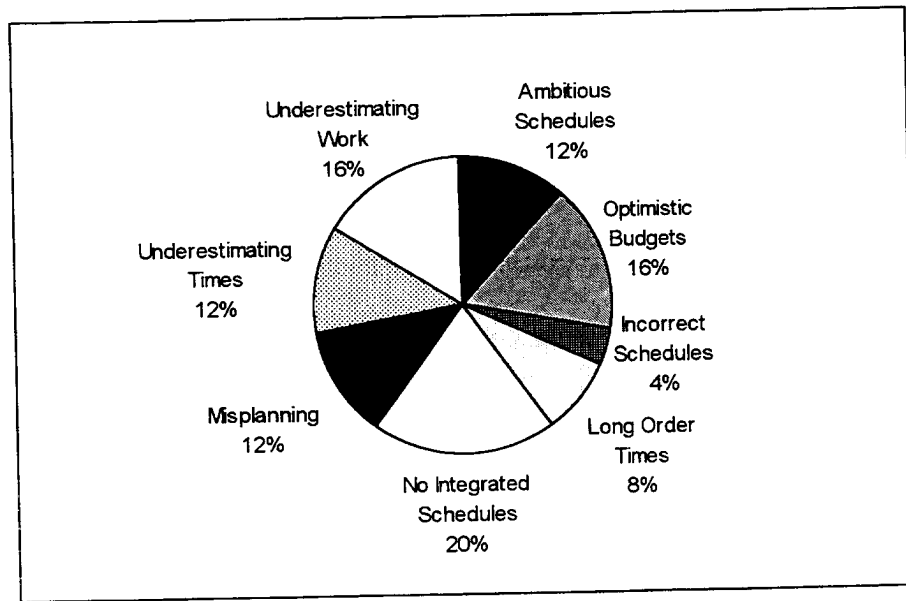


**FIGURE 4-7: “Estimating” Subcategories**

**“Facility Problems” Category.** This category includes reasons related to the design, fabrication, and renovation of facilities required for development effort completion. Because only three reasons have been included in this category, two of which are included in Table 4-1, no further description of this category is necessary.

**“Government Added Work” Category.** This category includes reasons related to government direction that resulted in additional, unplanned effort for the contractor. Specific subcategories of reasons for schedule problems within the “government added work” category are as follows:

- (1) additional unplanned government review of contractor efforts,
- (2) government directed changes in design and documentation,
- (3) government comments at reviews generating contractor action items,

(4) government requested marketing support to help “sell” the development effort to higher-ups, and

(5) government rescheduling of reviews causing inefficiencies in the work schedules of those supporting the reviews.

Figure 4-8 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “government added work” category.

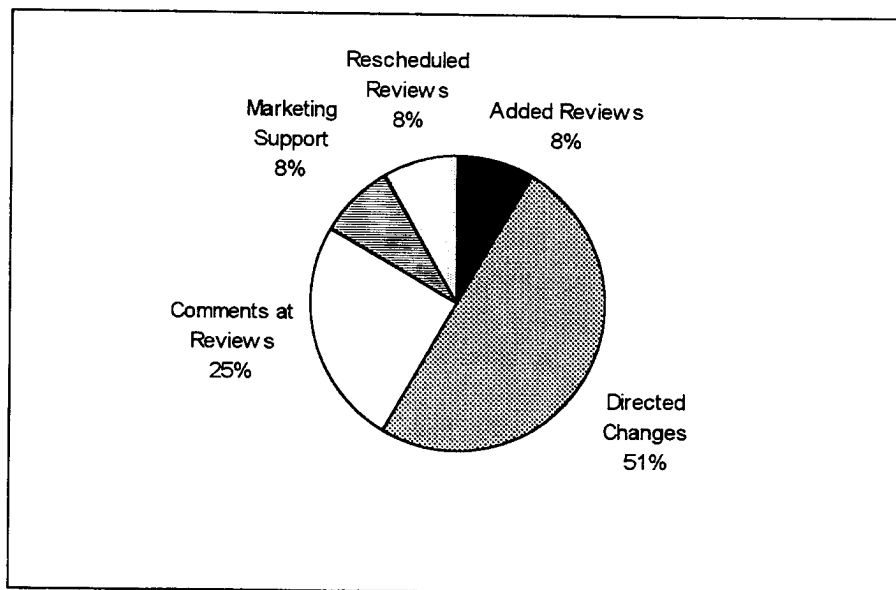


**FIGURE 4-8: “Government Added Work” Subcategories**

**“Government Not Supportive” Category.** This category includes reasons related to a government failure to provide an appropriate level of support to the contractor. Specific subcategories of reasons for schedule problems within the “government not supportive” category are as follows:

- (1) late data item approval (government was late in approving submitted data items),
- (2) failure of the government to provide required data to the contractor (includes classified and unclassified operational, threat, and design-related data that requires government collection or release),
- (3) government funding shortfalls impacting contractor task completion,
- (4) incomplete or late government furnished equipment or property, and
- (5) late direction from the government (including comments, approvals, inputs, and decisions).

Figure 4-9 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “government not supportive” category.

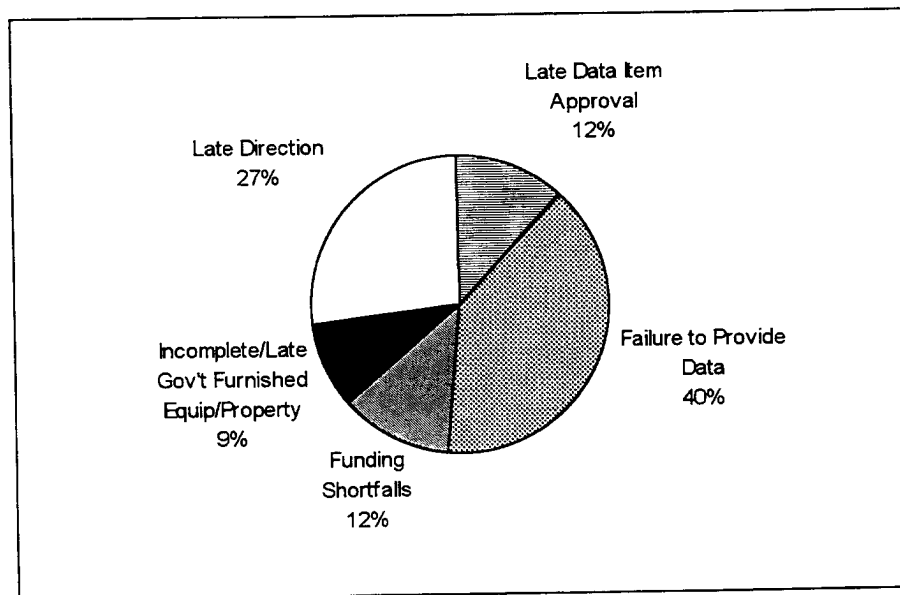


**FIGURE 4-9: “Government Not Supportive” Subcategories**

**“Government Stopped Work” Category.** This category includes reasons related to a government-directed stop work order. Reasons in this category reflect schedule variances both in stopped tasks, and in tasks related to the stopped tasks. Because the reasons included in this category are very similar, Table 4-1 is sufficiently descriptive of this category that no further elaboration is required.

**“Inventory Management” Category.** This category includes reasons related to inventory problems. Specific subcategories of reasons for schedule problems within the “inventory management” category are as follows:

- (1) ineffective controls for materials being ordered, delivered, or stored, such as being unaware of delivered material, or having parts in stock that do not match the bill of materials; and,
- (2) parts shortages.

Figure 4-10 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “inventory management” category.

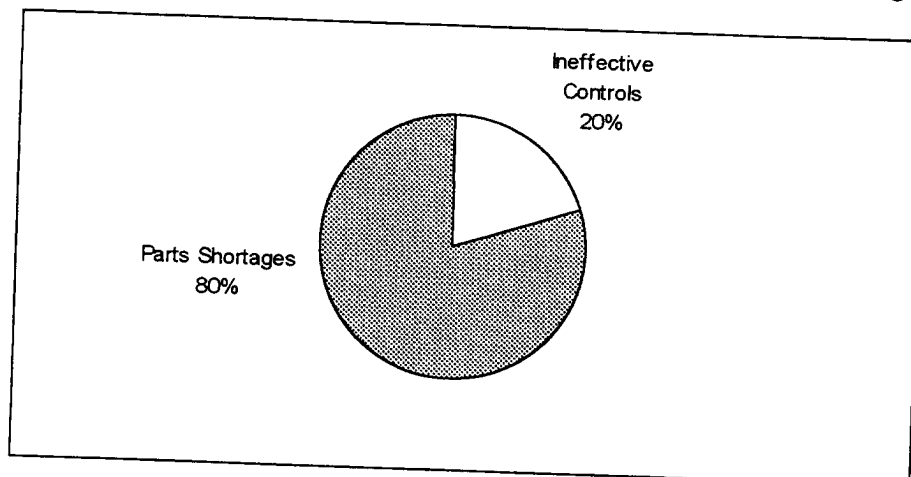


**FIGURE 4-10: “Inventory Management” Subcategories**

**“Late Data” Category.** This category includes reasons related to the late receipt or generation of required information either within the contractor’s organization, or between contractor and subcontractor. Specific subcategories of reasons for schedule problems within the “late data” category are as follows:

- (1) incomplete data items (late completion of specifications and other documents required for delivery to the government);
- (2) late engineering release of drawings and other design data required for manufacturing and other activities; and,
- (3) late or incomplete information (such as specifications, reports, and data) impacting areas such as design, manufacturing, training, provisioning, technical publications, test, facilities, and material orders.

Figure 4-11 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “late data” category.

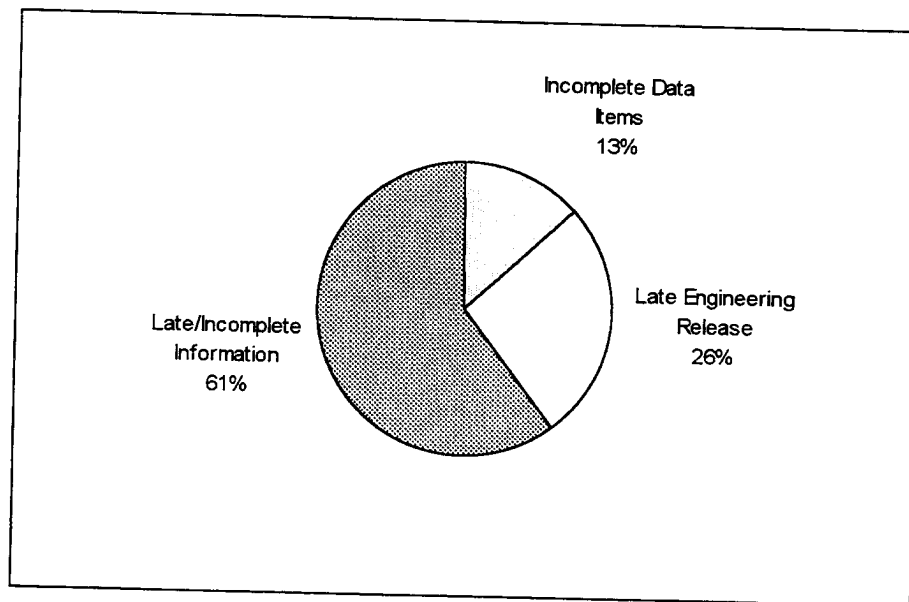


**FIGURE 4-11: “Late Data” Subcategories**

**“Late Review” Category.** This category includes reasons related to technical or management reviews that have been either lengthened or postponed by the contractor or subcontractor. Specific subcategories of reasons for schedule problems within the “late review” category are as follows:

- (1) review completion (more than the anticipated amount of time was required to conduct the review and address issues that surfaced during the review); and
- (2) late start (“slip”) of scheduled requirements or design reviews, often impacting activities such as design, fabrication, and test.

Figure 4-12 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “late review” category.

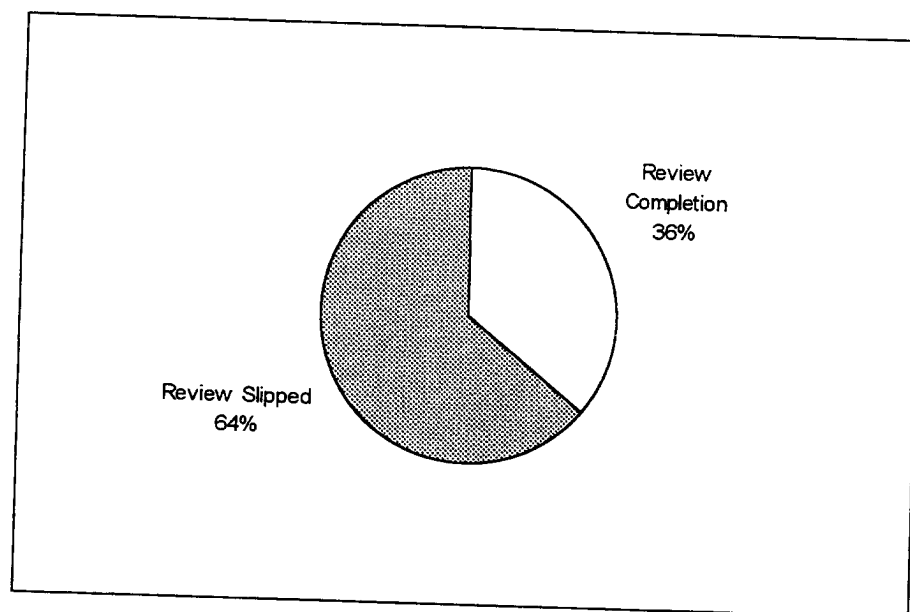


**FIGURE 4-12: “Late Review” Subcategories**

**“Miscellaneous Delays” Category.** This category includes schedule variance explanations that failed to state the reason for a particular schedule problem, and reasons that did not fall neatly into another category. The explanations include various schedule problems whose reason was unspecified, impacting activities such as design, logistics, deployment, test, and manufacturing. The reasons in this category include delays in overseas shipments and an inefficient management process. Because of the diverse nature of the reasons and explanations in this category, subcategorization is not particularly useful in this case, and as such, has not been conducted.

**“Manufacturing Problems” Category.** This category includes reasons related to problems building hardware, both in the development and preparation for production of a system. These problems, described below, are those encountered in translating an engineering design into developmental and production hardware. Specific subcategories of reasons for schedule problems within the “manufacturing problems” category are as follows:

- (1) miscellaneous problems, such as late requisitioning of inventory, a slowdown due to a new computer system, and design problems discovered during fabrication;
- (2) fabrication problems on breadboards, system components, tooling, and test equipment;
- (3) late receipt of material impacting fabrication and assembly;
- (4) late start of tooling;

- (5) manufacturing design problems in developing the bill of materials, releasing tooling, and providing articles required for development;
- (6) machine proofing problems and delays impacting fabrication and assembly; and,
- (7) manufacturing process problems, such as a fabrication process that produces system components that do not meet the specification.

Figure 4-13 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “manufacturing problems” category.

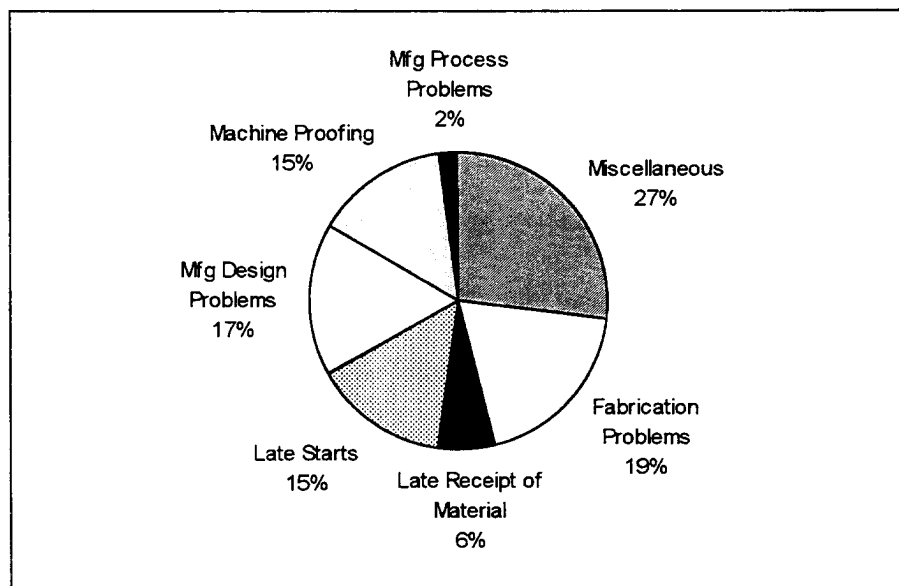


**FIGURE 4-13: “Manufacturing Problems” Subcategories**

**“Quality” Category.** This category includes reasons related to either a lack of quality (in terms of defective equipment/components, inadequate testing, and substandard personnel performance), or delays caused by quality assurance activities. Most of these

reasons deal with subcontractor or vendor problems. Specific subcategories of reasons for schedule problems within the “quality” category are as follows:

- (1) miscellaneous problems, such as poor subcontractor performance or inadequate preparation for testing;
- (2) inadequate testing, such as when vendor in-house testing is insufficient to determine whether or not a product is acceptable;
- (3) unacceptable items, that were either delivered with missing components or did not meet specifications; and,
- (4) acceptance procedures, such as inspections or approvals by the prime contractor, delaying subcontractor deliveries.

Figure 4-14 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “quality” category.

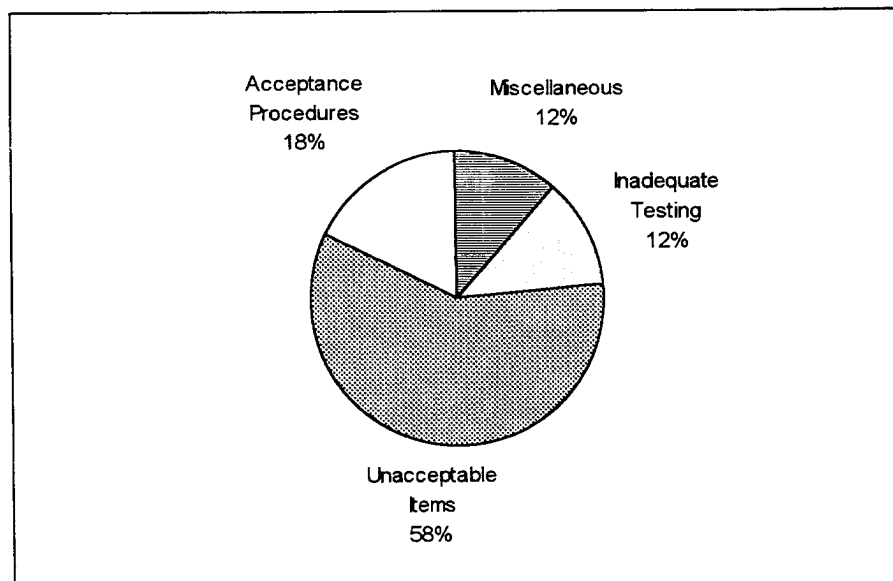


**FIGURE 4-14: “Quality” Subcategories**

**“Requirements Changes” Category.** This category includes reasons related to changes in security, test, and system component requirements, as reflected in specifications or otherwise. This category is different from the “design changes” category in that design changes are made in order to reach an objective, whereas requirements changes alter the objective. Although more of the 549 reasons for schedule problems may indeed belong in this category, only those reasons in which changing requirements were either directly or indirectly mentioned were included. Because “requirements changes” adequately captures the essence of all reasons included in this category, further subcategorization is of little value, and hence was not conducted.

**“Staffing” Category.** This category includes reasons related to having insufficient personnel assigned to tasks. Specific subcategories of reasons for schedule problems within the “staffing” category are as follows:

- (1) hiring delays, either during the initial ramp-up of personnel to conduct the effort, or in replacing personnel later in the effort;
- (2) inadequate staffing for the timely completion of tasks either at contractor or subcontractor facilities, impacting such activities as design, manufacturing, test, and technical publications;
- (3) receipt of security clearances taking longer than expected, causing delays until sufficient numbers of cleared personnel are available to work on the effort;
- (4) reassignment of personnel to higher priority or nearer term tasks, resulting in delays on the original tasks; and,

(5) wrong people assigned to a task, such as when subcontractors with either a lack of required expertise or with an inappropriate mix of personnel are working on a task.

Figure 4-15 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “staffing” category.

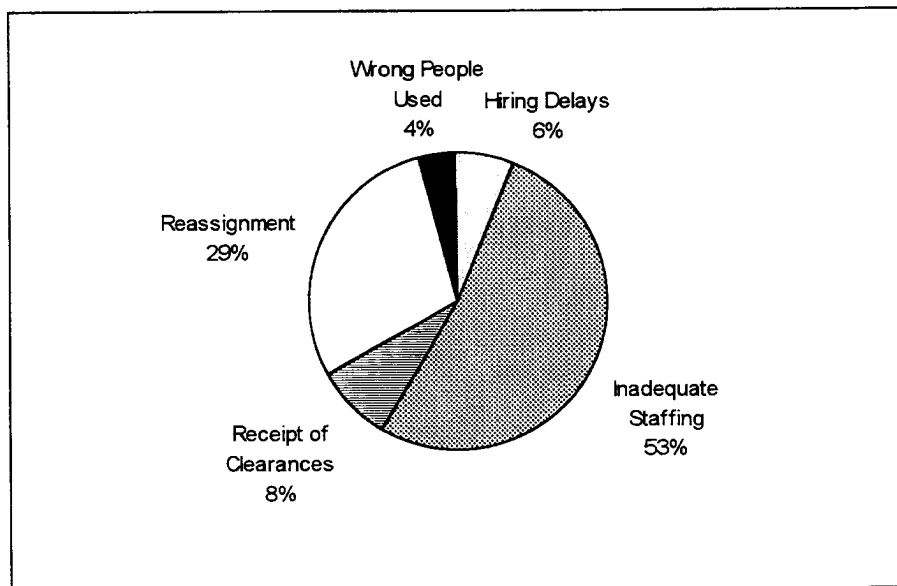


**FIGURE 4-15: “Staffing” Subcategories**

**“Subcontractor/Vendor Late” Category.** This category includes reasons related to late deliveries or slow progress by subcontractors or vendors. Specific subcategories of reasons for schedule problems within the “subcontractor/vendor late” category are as follows:

- (1) late deliveries of software, hardware (including anything from connectors to entire radar or head-up display units), and other miscellaneous products impacting prime contractor activities such as design, manufacturing, and test;
- (2) late deliveries by a subcontractor's subcontractor (essentially the same type of reasons as in (1) above, however delivery is late to subcontractor rather than to prime contractor); and
- (3) slow progress of a subcontractor toward meeting its planned schedule.

Figure 4-16 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “subcontractor/vendor late” category.

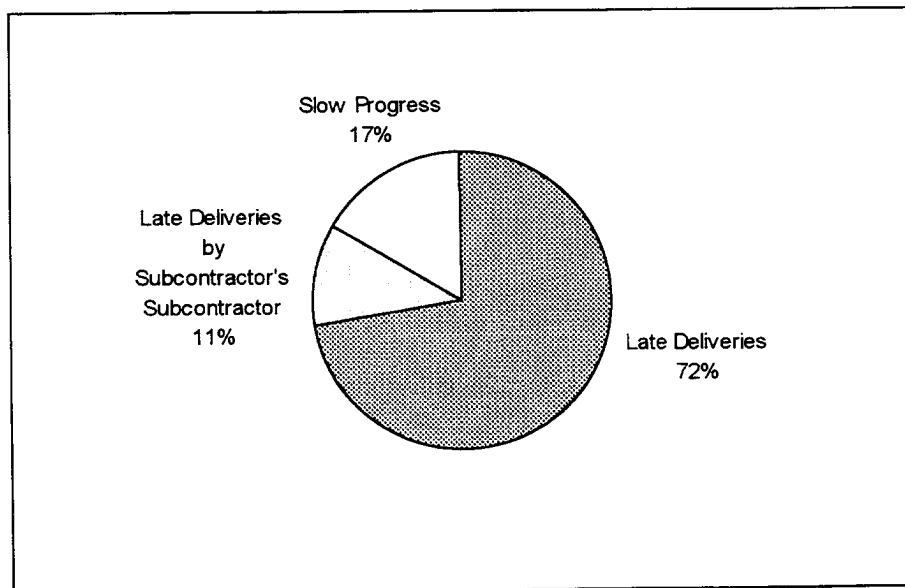


**FIGURE 4-16: “Subcontractor/Vendor Late” Subcategories**

**“Test Problems” Category.** This category includes reasons related to problems encountered in preparing for or conducting component or system ground or flight testing.

Included reasons are associated with schedule problems in simulation, instrument modification, and test asset receipt, as well as those encountered in environmental, transportation, qualification, component, and flight testing. Because the reasons in this category are adequately described as “test problems,” and because the varied specifics of each reason makes grouping below the category level extremely difficult, further subcategorization was not conducted.

**“Technical Definition” Category.** This category includes reasons related to defining requirements, interfaces, designs, and tasks to a level where work can proceed without being hampered by a lack of appropriate technical direction. Specific subcategories of reasons for schedule problems within the “technical definition” category are as follows:

- (1) finalizing requirements (ongoing definition of requirements and decision making causing delays to tasks awaiting technical direction); and,
- (2) poor requirements definition (incorrect or incomplete definition of requirements, interfaces, designs, and tasks).

Figure 4-17 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “technical definition” category.

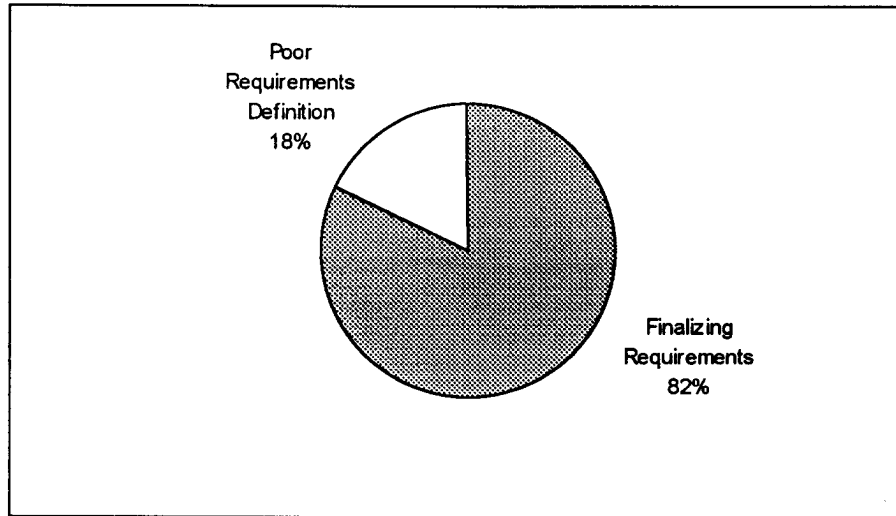


**FIGURE 4-17: “Technical Definition” Subcategories**

**“Technical Problems” Category.** This category includes reasons related to difficulties encountered in the design and development of components and systems. Specific subcategories of reasons for schedule problems within the “technical problems” category are as follows:

- (1) analysis problems (difficulties and delays conducting analyses or studies);
- (2) coordination and integration between system and related systems;
- (3) design problems (such as unresolved design issues, design errors, and design activities being more challenging than expected);
- (4) development problems (problems with acquiring or creating, and integrating both hardware and software into the system); and,
- (5) task growth (additional effort expended due to unexpected problems or the need for required improvements).

Figure 4-18 presents the relative contribution of reasons (in terms of number observed) within the above subcategories to the “technical problems” category.

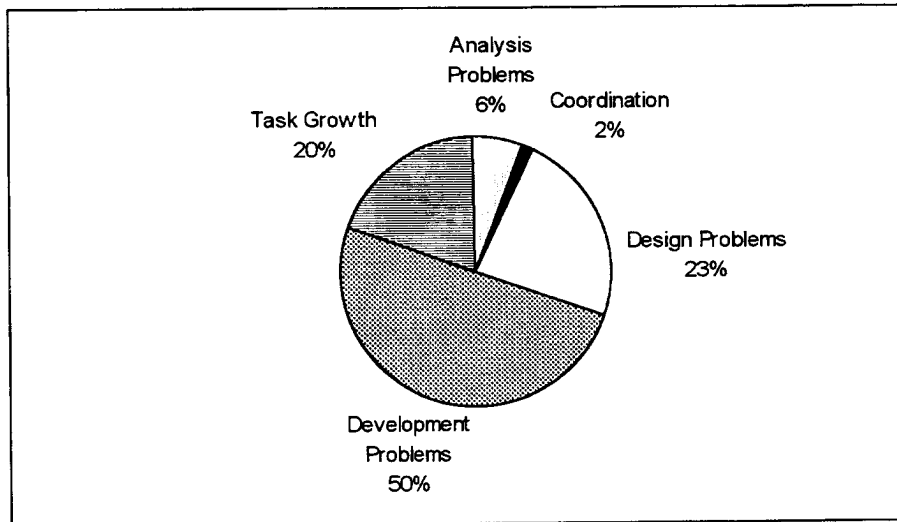


**FIGURE 4-18: “Technical Problems” Subcategories**

**A Final Word on Categorization of Reasons.** The above categories are useful for understanding and making comparisons among the major classes of reasons for schedule problems on system development efforts. In order to provide further detail, all 549 observed reasons for schedule problems have been listed in the appendix, where they are grouped in categories and subcategories identical to those described above. By identifying these categories, subcategories, and individual reasons, this research satisfies its objective of identifying the actual reasons for schedule problems across large Air Force system development efforts, describing those reasons at a level of detail (in this case, three levels of detail) that will allow the development of appropriate corrective actions.

In meeting this objective, it is important to note that there is no single “correct” manner in which to classify reasons into categories and subcategories. Certainly, other

schemes for defining categories and assigning reasons to those categories may be equally valid. What the above portion of the analysis provides is merely the data presented in a reasonable, consistent framework that allows the above research objective to be satisfied.

#### ***Comparison (by category) of Reasons for Schedule Problems***

The second objective of this research is to quantify the importance of each category of reasons, in terms of frequency and severity, in order to determine the categories of reasons most and least deserving of management attention. To this end, the following subsections quantify and compare the significance of the reasons for schedule problems in terms of frequency of occurrence, total schedule variance (in dollars and in work days), and average schedule variance (in dollars and in work days).

**Frequency of Reasons by Category.** Figure 4-19 presents the total number of observed reasons for schedule problems that fall within each category. Based on this data, it appears that on system development efforts, certain types of reasons are likely to occur far more often than others. Although frequency is only one of several measures of reason significance, the below figure provides important information for determining the types of reasons for which corrective action would provide the greatest benefit.

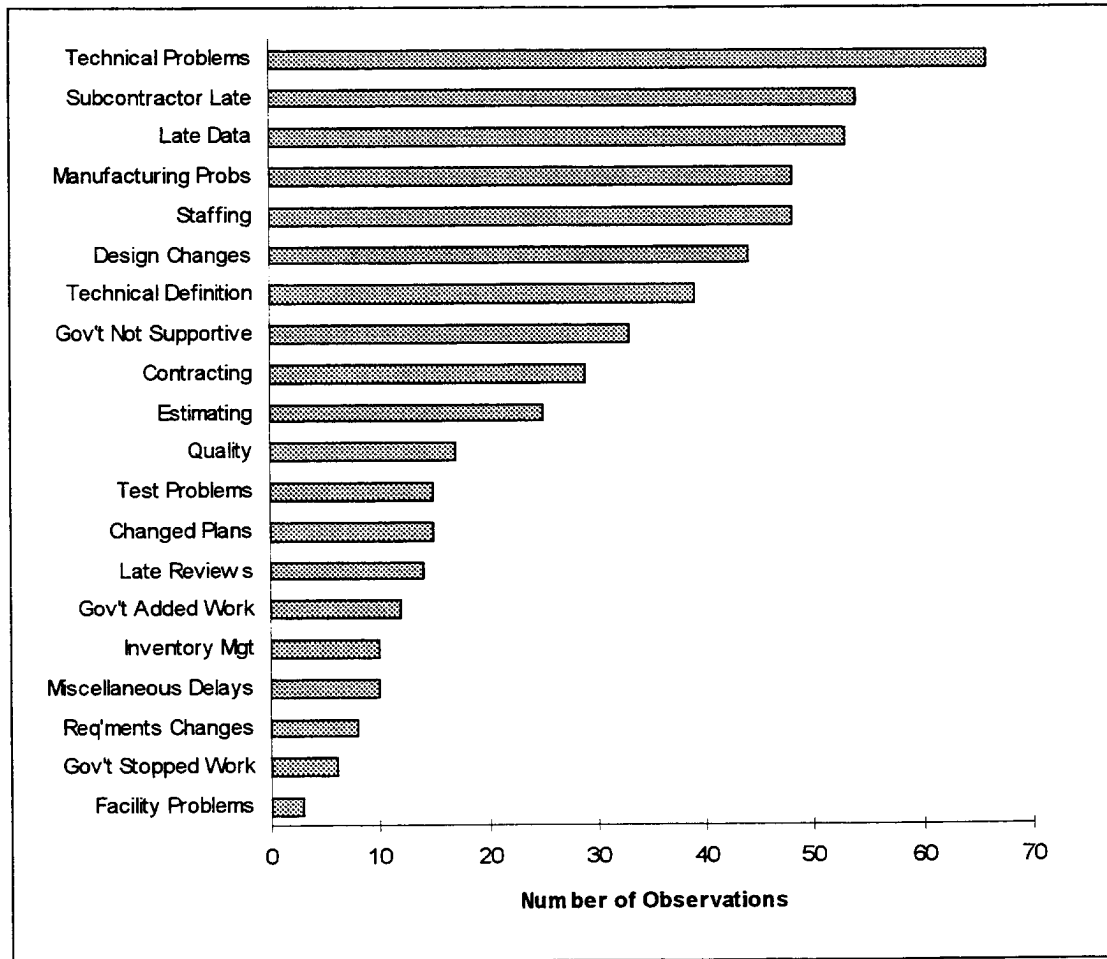


**FIGURE 4-19: Frequency of Reasons by Category**

**Total Schedule Variance (in dollars) by Category.** Figure 4-20 presents, for each category, the sum of the negative schedule variances associated with the reasons assigned to that category. This provides a measure of the total impact of the observed reasons on the development efforts. Because the below schedule variances are measured in dollars, they tend to bias the results towards reasons that occur on larger efforts, which tend to experience larger dollar schedule variances. For a more complete discussion of this topic, please refer to Chapter 3.

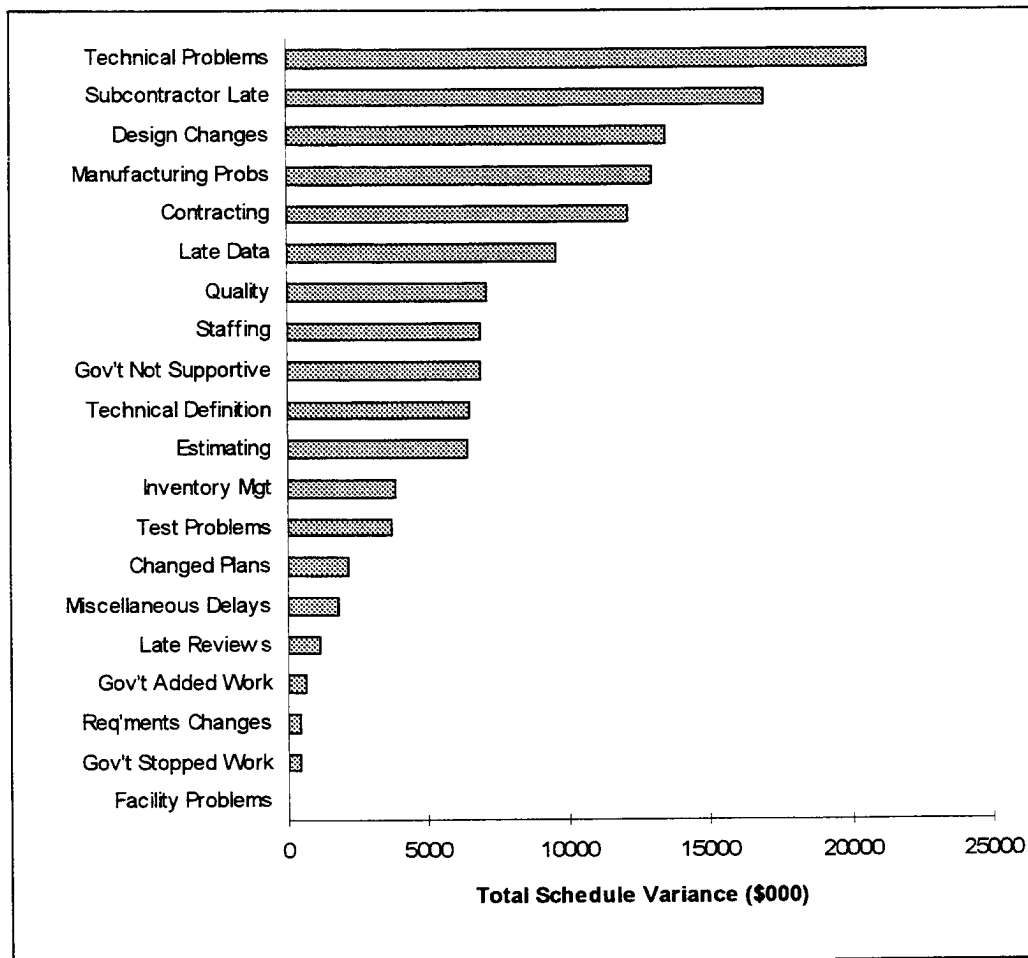


**FIGURE 4-20: Total Schedule Variance (in dollars) by Category**

**Total Schedule Variance (in work days) by Category.** Figure 4-21 presents, for each category, the sum of the negative schedule variances (in work days) associated with the reasons assigned to that category. Chapter 3 discusses the method used to convert schedule variances from dollar amounts to fractions of a month. Within each category, then, each reason's month fraction was converted to work days (assuming an

average of 22 work days per month), then summed to provide the totals in the below figure.

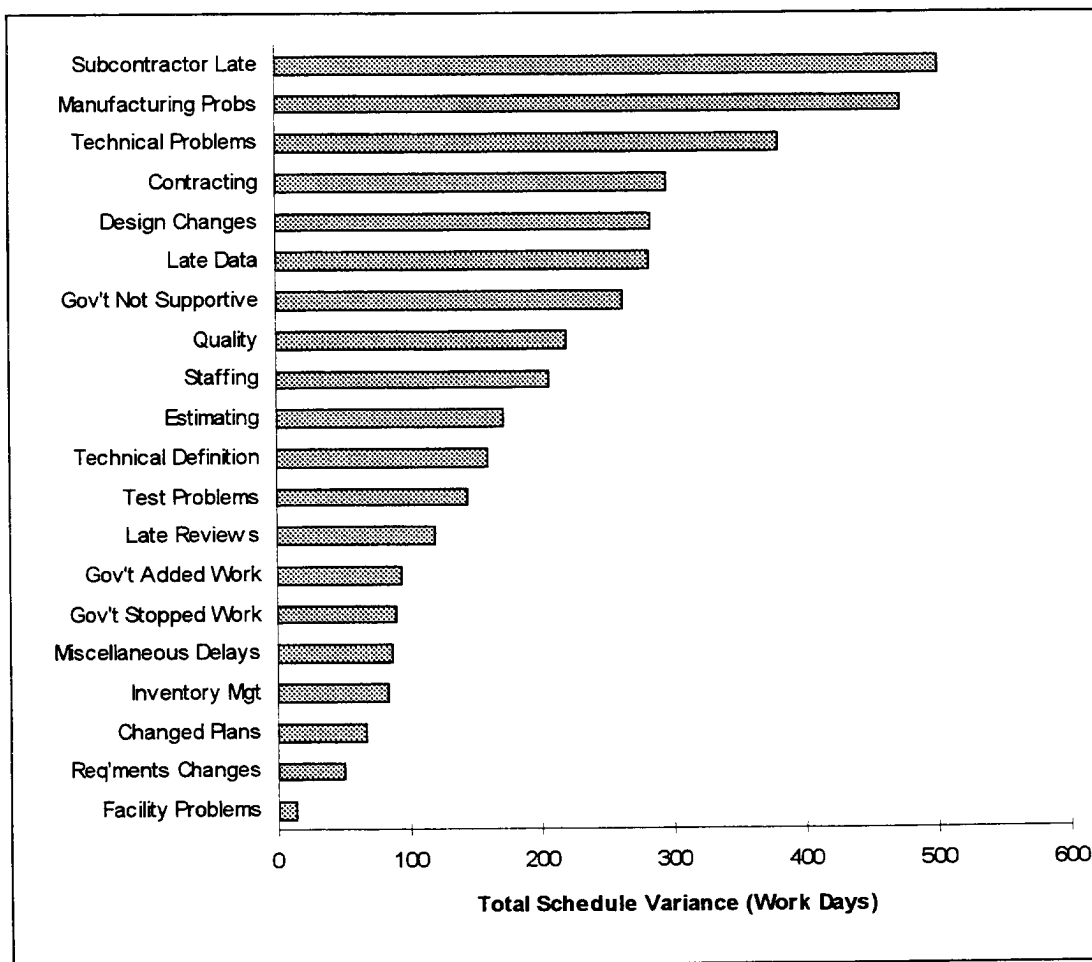


**FIGURE 4-21: Total Schedule Variance (in work days) by Category**

Like total schedule variance (in dollars), total schedule variance (in work days) provides a measure of the total impact of the observed reasons on the development efforts. As discussed in Chapter 3, however, schedule variance (in work days) represents a month of delay on small efforts the same as it represents a month of delay on large efforts. This tends to bias the results towards reasons found on smaller efforts, which would tend to get

less attention under normal circumstances. Thus, both types of schedule variances (in dollars and in work days) provide information useful in quantifying the severity of problems associated with various reasons.

**Average Schedule Variance (in dollars) by Category.** Figures 4-20 and 4-21 quantify the severity of schedule problems associated with categories of reasons for those problems. When using total schedule variances, however, there is an underlying assumption that the frequency distribution of reasons that occurred in the past will not change in the future. In the event that the frequency distribution of reasons is expected to change, the measures of problem severity should not be based on the observed (past) frequency distribution. Average schedule variance per category provides the required separation from the observed frequency distribution.

Figure 4-22 presents the average negative schedule variance (in dollars) for reasons within each category. In interpreting this figure, it should be noted that within each category there is a wide statistical variance among the observed schedule variances. In fact, across categories, the standard deviation of schedule variances observed within a category exceeded the mean value of the category's schedule variances by an average of 59 percent.

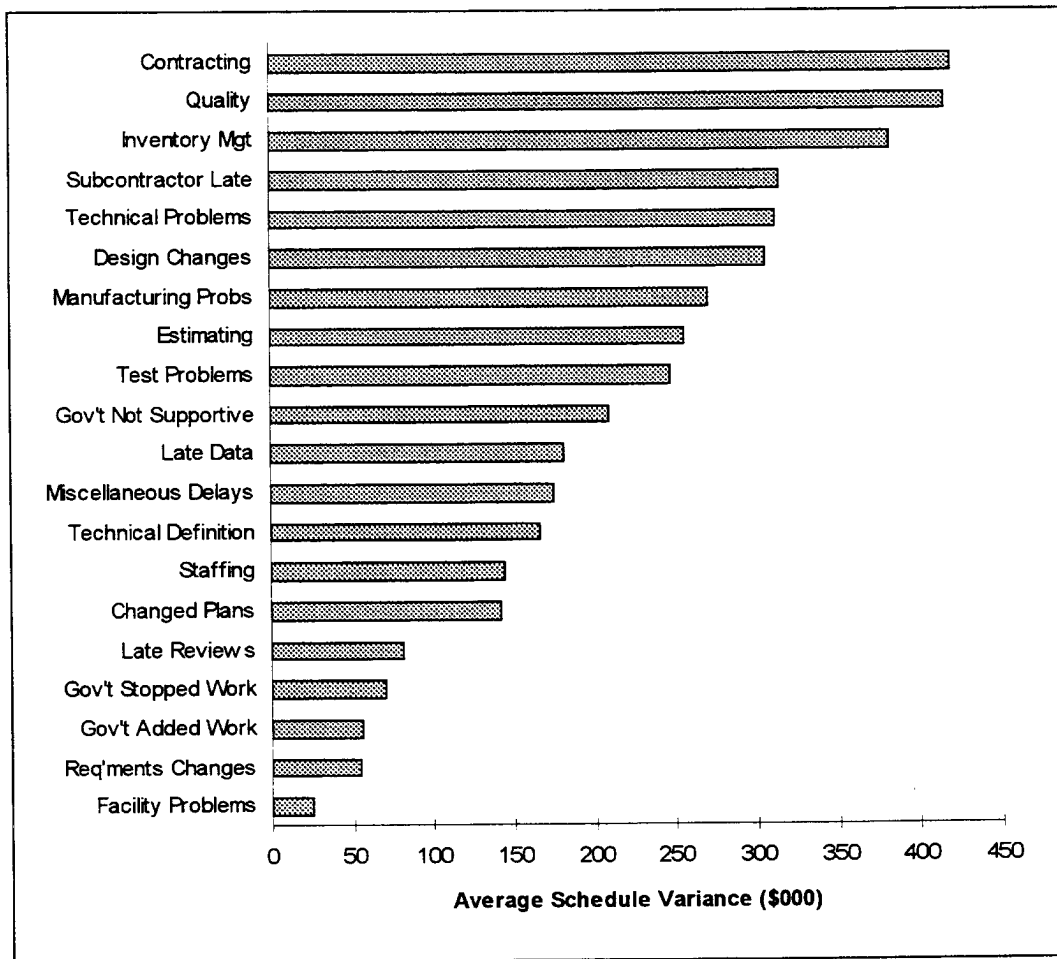


**FIGURE 4-22: Average Schedule Variance (in dollars) by Category**

**Average Schedule Variance (in work days) by Category.** As in Figure 4-22, Figure 4-23 presents the average negative schedule variance for reasons within each category. Figure 4-23, however, presents schedule variance in terms of work days rather than in terms of dollars. The conversion of individual schedule variances in dollars to schedule variance in work days, as well as the pertinent attributes of each of the two variance measures was explained in the above “Total Schedule Variance” subsections. Just as with average schedule variance (in dollars), there is a wide statistical variance

among the observed schedule variances (in work days) within each category. In fact, across categories, the standard deviation of schedule variances observed within a category exceeded the mean value of the category's schedule variances by an average of 2 percent.

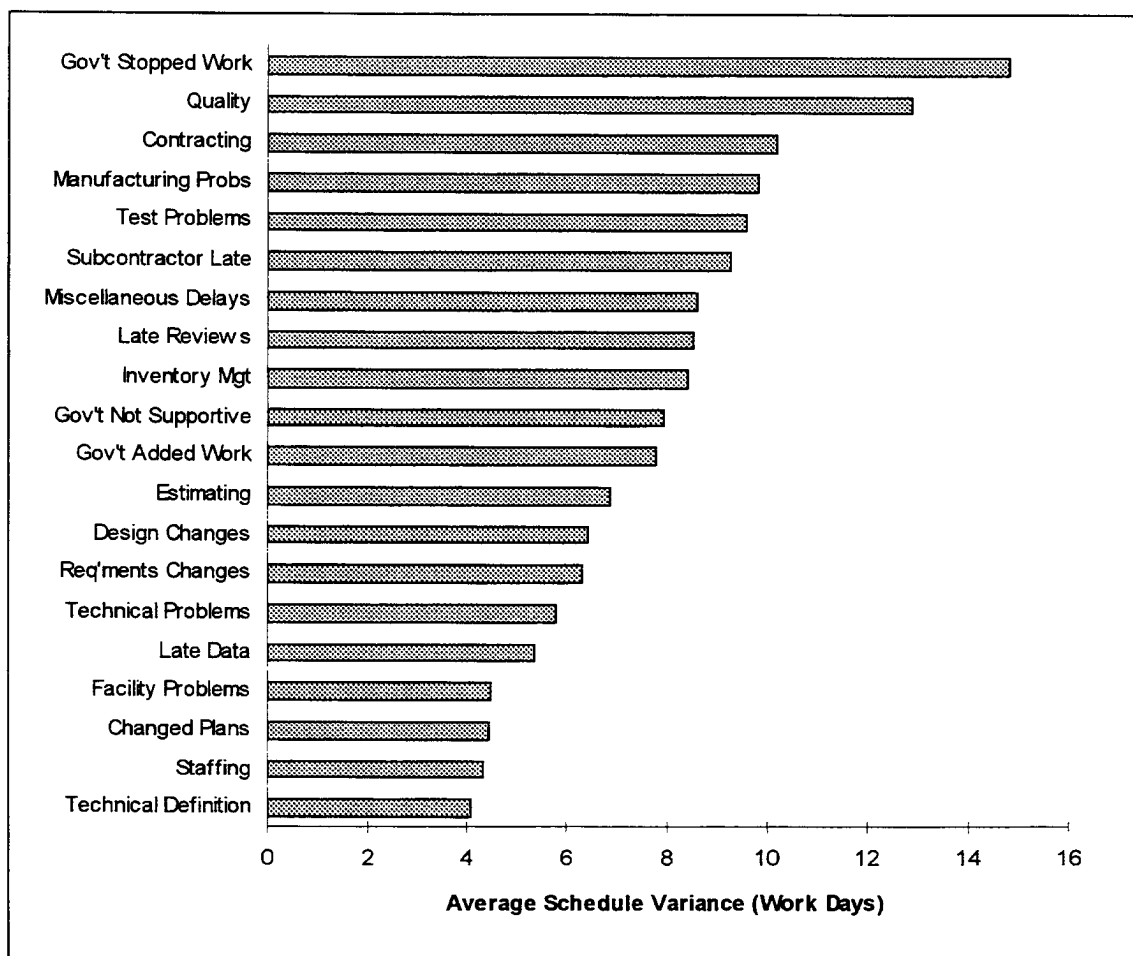


**FIGURE 4-23: Average Schedule Variance (in work days) by Category**

**Summary of Category Rankings by Comparative Measures.** Although the above subsections provide information about how each category of reasons for schedule problems compares to other categories for each of the five comparative measures

(frequency, total schedule variance in dollars, total schedule variance in work days, average schedule variance in dollars, and average schedule variance in work days) individually, Table 4-2 presents the ranking of each category of reasons in terms of all five comparative measures simultaneously.

**TABLE 4-2: Summary Ranking of Categories**

| Category             | Frequency | Total Variance |        | Average Variance |        |
|----------------------|-----------|----------------|--------|------------------|--------|
|                      |           | (\$)           | (Days) | (\$)             | (Days) |
| Technical Problems   | 1         | 1              | 3      | 5                | 15     |
| Subcontractor Late   | 2         | 2              | 1      | 4                | 6      |
| Manufacturing Probs  | 4         | 4              | 2      | 7                | 4      |
| Design Changes       | 6         | 3              | 5      | 6                | 13     |
| Late Data            | 3         | 6              | 6      | 11               | 16     |
| Contracting          | 9         | 5              | 4      | 1                | 3      |
| Staffing             | 4         | 8              | 9      | 14               | 19     |
| Gov't Not Supportive | 8         | 9              | 7      | 10               | 10     |
| Quality              | 11        | 7              | 8      | 2                | 2      |
| Technical Definition | 7         | 10             | 11     | 13               | 20     |
| Estimating           | 10        | 11             | 10     | 8                | 12     |
| Test Problems        | 12        | 13             | 12     | 9                | 5      |
| Late Reviews         | 14        | 16             | 13     | 16               | 8      |
| Changed Plans        | 12        | 14             | 18     | 15               | 18     |
| Inventory Mgt        | 16        | 12             | 17     | 3                | 9      |
| Gov't Added Work     | 15        | 17             | 14     | 18               | 11     |
| Miscellaneous Delays | 16        | 15             | 16     | 12               | 7      |
| Gov't Stopped Work   | 19        | 19             | 15     | 17               | 1      |
| Req'ments Changes    | 18        | 18             | 19     | 19               | 14     |
| Facility Problems    | 20        | 20             | 20     | 20               | 17     |

In Table 4-2, categories have been ranked from one to twenty for each measure of schedule problem significance, with lower numbers indicating the more significant categories (categories having the same number within a column are “tied” for a given rank). The categories have been presented in order of significance, based on a simple

aggregate ranking scheme, where the three rankings to the left of the double line have been summed. Again, the lower the sum of the category's ranks, the more significant the category. Note that this ordering scheme is merely a useful tool for presenting the data, and does not imply that this scheme is the "correct" way to interpret category significance in all cases. Rankings to the left of the double line are those that should be considered if the frequency distribution of reasons is not expected to change from that observed in the data. If another frequency distribution of reasons is expected to occur in the future, rankings to the right of the double line should be considered, along with the expected future distribution. In any case, the rankings in Table 4-2 enable informed decisions to be made regarding the categories of reasons for which corrective action would provide the greatest benefit.

#### ***Commonality of Reasons Across System Development Efforts***

The third and final objective of this research was to demonstrate that the reasons for schedule problems are not program unique, but are common across system development efforts. The achievement of this objective enables schedule-related lessons learned from past and present efforts to influence schedule performance in future efforts. Figure 4-24 demonstrates this commonality of reasons by presenting the number of efforts on which reasons within each given category occurred.

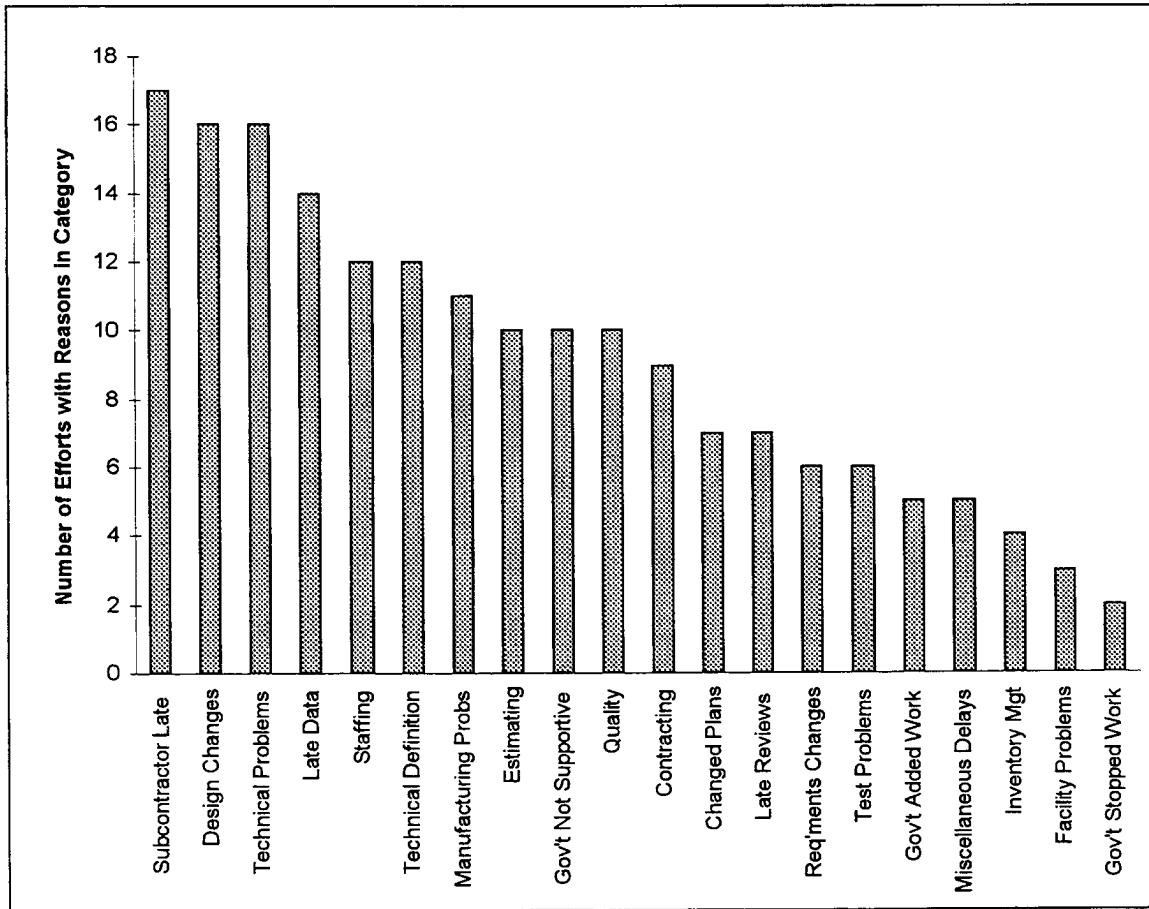


**FIGURE 4-24: Commonality of Reasons Across Development Efforts**

From Figure 4-24, it is clear that in general, reasons for schedule problems on system development efforts are not unique to a given effort. While all 22 development efforts did not experience all 20 categories of reasons for schedule problems, no category appeared only on one effort, and on average, categories appeared on 9.1 efforts. Certainly, this is compelling evidence supporting the further study of lessons learned from past schedule problems so that these problems (which *will* recur without intervention) can be avoided in the future.

The evidence for commonality of reasons for schedule problems across system development efforts would most likely be even stronger if reasons were classified under fewer categories. This approach, however, was not taken because in order to satisfy the first two objectives of this research, reasons needed to be explained in sufficient detail (hence the need for a greater, not a fewer number of categories) to allow the development of appropriate corrective actions.

## ***V: Findings and Conclusions***

### ***Introduction***

This research had three main objectives. The first was to identify the actual reasons for schedule problems across large Air Force system development efforts, describing those reasons at a level of detail that will allow the development of appropriate corrective actions. The second was to quantify the importance of each category of reasons, in terms of frequency and severity, in order to determine the categories of reasons most and least deserving of management attention. The third was to demonstrate that the reasons for schedule problems are not program unique, but are common across system development efforts, therefore schedule-related lessons learned from past and present efforts are likely to be relevant to future efforts. The following chapter summarizes the findings of this research related to these three objectives, comments on the differences between the results of this research and results found in the literature, provides observations regarding the collection of meaningful schedule-related data from system development efforts, and suggests areas in which future related research would be appropriate.

### ***Findings Related to the Research Objectives***

**Identified Reasons for Schedule Problems.** In order to satisfy the first objective of this research, the reasons for schedule problems on large Air Force system development efforts were identified. All 549 observed reasons (see Appendix) were categorized (see Table 4-1) and subcategorized (see pages 43-61) in order to facilitate understanding and

comparing those reasons at a level of detail that allows the development of appropriate corrective actions.

Although the categories and subcategories are useful in understanding classes of reasons and for making comparisons among reason classes, the 549 unsummarized reasons contained in the appendix may be of equal or greater value to managers. These reasons, grouped by category and subcategory, are essentially a database of lessons learned from 22 past and present system development efforts. The mere act of skimming through these actual reasons for schedule problems may provide managers with the “heads-up” reminder of things that have gone wrong before that will allow them to avoid these problems in the future.

**Relative Importance of Categories of Reasons.** In order to satisfy the second objective of this research, the identified reasons for schedule problems were compared in terms of frequency of occurrence and schedule variance (in dollars and in work days). The complete set of comparisons may be found in Figures 4-19 to 4-23, and in Table 4-2. Table 5-1 presents the top five and bottom five categories of reasons in terms of frequency, and total schedule variance (both in dollars and in work days). Although Chapter 4 also presented average schedule variance, in addition to the measures presented in Table 5-1, total schedule variance better describes the significance of the reasons in terms of the impact they actually had across the 22 sampled development efforts.

**TABLE 5-1: Most and Least Significant  
Categories of Reasons for Schedule Problems**

| <b>Top Five Categories<br/>(Rank Ordered)</b>                                                         |                                                                                                  |                                                                                                  |
|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| <b>Frequency</b>                                                                                      | <b>Total Schedule Variance<br/>(%)</b>                                                           | <b>Total Schedule Variance<br/>(Work Days)</b>                                                   |
| Technical Problems<br>Subcontractor Late<br>Late Data<br>Manufacturing Probs<br>Staffing              | Technical Problems<br>Subcontractor Late<br>Design Changes<br>Manufacturing Probs<br>Contracting | Subcontractor Late<br>Manufacturing Probs<br>Technical Problems<br>Contracting<br>Design Changes |
| <b>Bottom Five Categories<br/>(Rank Ordered)</b>                                                      |                                                                                                  |                                                                                                  |
| <b>Frequency</b>                                                                                      | <b>Total Schedule Variance<br/>(%)</b>                                                           | <b>Total Schedule Variance<br/>(Work Days)</b>                                                   |
| Miscellaneous Delays<br>Inventory Mgt<br>Req'ments Changes<br>Gov't Stopped Work<br>Facility Problems | Late Reviews<br>Gov't Added Work<br>Req'ments Changes<br>Gov't Stopped Work<br>Facility Problems | Miscellaneous Delays<br>Inventory Mgt<br>Changed Plans<br>Req'ments Changes<br>Facility Problems |

The seven categories listed in Table 5-1 comprising the “top five,” or most significant, categories of reasons for schedule problems account for 49 percent of the observed reasons (frequency), 57 percent of the schedule variance (in dollars), and 49 percent of the schedule variance (in work days). Clearly, these categories represent reasons more deserving of management attention than the eight categories listed in Table 5-1 comprising the “bottom five,” or least significant, categories of reasons for schedule problems, which account for only 7 percent of the observed reasons (frequency),

2 percent of the schedule variance (in dollars), and 8 percent of the schedule variance (in days).

**Where Management Attention Should Focus.** Based on the results of this research, management should focus its attention on the seven categories of reasons for schedule problems comprising the “top five” portion of Table 5-1. To this end, this subsection presents additional detail on the reasons in these categories and provides suggestions for improvement.

First, the “technical problems” category includes reasons related to difficulties encountered in the design and development of components and systems. These difficulties include: difficulties and delays conducting analyses or studies; coordination and integration between the system and related systems; unresolved design issues; design errors; design activities being more challenging than expected; problems with acquiring or creating, and integrating both hardware and software into the system; and, additional effort expended due to unexpected problems or the need for required improvements. In order to reduce the number of “technical problems” encountered, managers should ensure that adequate technical planning is conducted prior to the start of a project. In this planning, the integration of components and systems should be given high priority, because this aspect of planning is often neglected. By taking a methodical, systems engineering approach to project planning, many (though not all) “technical problems” can be eliminated.

Second, the “subcontractor late” category includes reasons related to late deliveries or slow progress by subcontractors or vendors. These difficulties include: late deliveries of software, hardware, and other miscellaneous products; late deliveries by a

subcontractor's subcontractor; and, slow progress of a subcontractor toward meeting its planned schedule. By being one of the top two categories of reasons for schedule problems in all three of the Table 5-1 measures of problem significance, subcontracting has been shown to be extremely important to the schedule success of defense system development efforts. In order to improve schedule performance in this area, managers need to increase visibility into subcontractor plans and procedures. In addition, better "early warning systems" are needed to allow managers to predict subcontractor delays in time to implement alternate work plans.

Third, the "manufacturing problems" category includes reasons related to problems building hardware, both in the development and preparation for production of a system. These problems, encountered in translating an engineering design into developmental and production hardware, include: late requisitioning of inventory; slowdowns due to new computer systems; design problems discovered during fabrication; fabrication problems on breadboards, system components, tooling, and test equipment; late receipt of material impacting fabrication and assembly; late start of tooling; manufacturing design problems in developing the bill of materials, releasing tooling, and providing articles required for development; machine proofing problems and delays impacting fabrication and assembly; and, manufacturing process problems, such as fabrication processes that produce system components that do not meet the specification. Just as in the "technical problems" category, much improvement could occur in the "manufacturing problems" area if management required a methodical, integrated, systems engineering approach to planning these activities.

Fourth, the “design changes” category includes reasons related to changes in system or component designs, typically undertaken to fix problems or to improve performance. Quite often, in addition to requiring time to implement, these changes also impact other, related tasks that depend on stable, defined designs for their continued progress. The key to mitigating problems in this area is for management to be aware that design changes often have a “ripple effect” throughout the system. Before permitting a design change, managers should insist on a thorough analysis of the potential impacts on the entire system.

Fifth, the “late data” category includes reasons related to the late receipt or generation of required information either within the contractor’s organization, or between contractor and subcontractor. These difficulties include: late completion of specifications and other documents required for delivery to the government; late engineering release of drawings and other design data required for manufacturing and other activities; and, late or incomplete information (such as specifications, reports, and data) impacting areas such as design, manufacturing, training, provisioning, technical publications, test, facilities, and material orders. The lesson of this category is that system development is a data intensive activity, and that efforts to speed the generation and flow of data will speed the overall development effort. Plans that incorporate the need for data generation and sharing, procedures that facilitate these actions, and computer based tools that enable these actions can all have a significant positive impact on development effort schedule performance.

Sixth, the “contracting” category includes reasons related to contractual actions and the process of awarding subcontracts. These difficulties include: source selection of

subcontractors and vendors (including request for proposal (RFP) preparation and proposal receipt); placing subcontractors and vendors on contract; processing purchase orders; and, terminating subcontractors. Improvements in this area could be realized by thoroughly planning subcontracting activities at the beginning of the development effort, and by further streamlining source selection procedures.

Seventh, the “staffing” category includes reasons related to having insufficient personnel assigned to tasks. These difficulties include: hiring delays, either during the initial ramp-up of personnel to conduct the effort, or in replacing personnel later in the effort; inadequate staffing for the timely completion of tasks either at contractor or subcontractor facilities; receipt of security clearances taking longer than expected, causing delays until sufficient numbers of cleared personnel are available to work on the effort; reassignment of personnel to higher priority or nearer term tasks, resulting in delays on the original tasks; and, having the wrong people assigned to a task, such as when subcontractors with either a lack of required expertise or with an inappropriate mix of personnel are working on a task. Improvements in this area could be realized by locating appropriate personnel prior to contract award, planning for an adequate number of personnel to meet the schedule demands of the effort, ensuring that the qualifications of personnel are matched to the tasks they are to perform, and allowing adequate time to both locate replacement personnel and to process security clearances.

The preceding suggestions for improvement only “scratch the surface” of potential corrective actions that could be applied to improve schedule performance on defense system development efforts. Indeed, a thorough investigation to identify corrective

actions based on the reasons for schedule problems identified in this thesis would be a significant research effort in and of itself. Hopefully, this research, by providing a starting point in terms of identifying the reasons for schedule problems and suggesting which categories of reasons most require management attention, will enable both researchers and practitioners to develop appropriate corrective actions to mitigate schedule problems in the future.

**Commonality of Reasons Across Development Efforts.** In order to satisfy the third and final research objective, the number of development efforts on which each category of reasons for schedule problems had been observed was analyzed to demonstrate that reasons were not unique to a given effort. According to this analysis, as presented in Figure 4-24, although all 22 development efforts did not experience all 20 categories of reasons for schedule problems, no category appeared only on one effort, and on average, categories appeared on 9.1 efforts. Certainly, this is compelling evidence supporting the further study of lessons learned from past schedule problems so that these problems (which *will* recur without intervention) can be mitigated in the future.

#### ***Differences Between the Results of this Research and Results in the Literature***

Overall, there is a remarkable similarity between the reasons for schedule problems found in the literature (see Tables 2-1, 2-2, and 2-3), and those observed in the course of this research (see Table 4-1, pages 43-61, and Appendix). The few exceptions are as follows.

First, several reasons for schedule problems mentioned in the literature were not observed in the data. One explanation for these discrepancies is that the data source (Cost

Performance Reports, or CPRs) is written from a contractor perspective, whereas some of the reasons found in the literature are stated from a government perspective. For example, poor management practices, a lack of “follow-up,” inadequate supervision, and a lack of motivation are all things that a contractor is unlikely to admit on a report being sent to the government (CPR). Similarly, there would be a tendency to downplay the effects of program manager turnover, and not to address political influences or economic factors on a CPR. In addition, there would be a tendency to not be too critical of the government, avoiding references to micromanagement, constructive changes, and problems with joint service project management. Finally, Engineering Change Proposals (ECPs) would probably not be listed as a reason for schedule problems on a contractor report because when ECPs modify the work to be accomplished, they also modify the baseline schedule against which progress on the development effort is measured. Thus, although the ECP may lengthen the development effort, it doesn’t typically cause a schedule variance (and thus is not reported) unless delays occur in conducting the work associated with the ECP.

Another explanation for reasons not appearing in the data is that some reasons in the literature may be reasonably rare, and therefore were not observed in the limited sample of development effort reports used in this research. Reasons such as labor problems, concept stability, and external events may fall into this category.

Second, several reasons for schedule problems observed in the data were not mentioned in the literature. These reasons, such as contractual actions, changed plans, facilities problems, late direction, technical definition, manufacturing problems, and test problems, tend to be more specific than many of the reasons in the literature. This is to be

expected in an initial descriptive study such as this one, where the desired outcome is to identify reasons not already expressed and to provide added detail such that the identified reasons are useful to managers for developing appropriate corrective actions.

Third and finally, unlike the reasons provided in the literature, the reasons for schedule problems identified in this research have been quantified in terms of the significance of their associated schedule problems so that managers can determine the categories of reasons most and least deserving of their attention.

### ***Obtaining Meaningful Schedule-Related Data from System Development Efforts***

Three observations regarding obtaining meaningful schedule-related data from large Air Force system development efforts are worthy of mention. First, it is difficult to find a usable source of this type of data. In the Air Force, and in the DoD in general, schedule has been of significantly less interest than cost. This is reflected in the fact that although there are numerous functional organizations throughout the DoD that focus on cost, there are few if any that focus primarily on schedule. The result is that unlike cost information, schedule information is rarely archived and seldom studied. Fortunately, due to the interest of the cost community, the Cost Performance Reports (which also *happen* to include schedule information) were a readily available source of data for this research. In order to properly preserve the schedule-related lessons of the past so that mistakes are not continually repeated, more schedule-related information needs to be archived and studied in the future.

Second, in general, the format of Cost Performance Report (CPR) has not been optimized for identifying and quantifying the reasons for schedule problems. This is partly

because the format of the CPR varies from contract to contract. Of the 22 development efforts examined, many had CPRs formatted such that reasons were easy to identify and quantify, however others made identification and quantification more difficult by presenting poorly organized, rambling narratives, and by grouping many reasons in a narrative without identifying the schedule variance associated with each reason. To remedy this problem, guidelines could be modified to call for contractors to explain variances in a way such that the root reasons for schedule problems are clearly and succinctly identified, followed by whatever narrative is necessary to understand the nature of the problems and associated consequences. Also, if a reportable schedule variance has several reasons, contractors should identify the amount of variance associated with each reason (as some contractors already do).

Third and finally, there needs to be a better measure than schedule variance for quantifying the severity of schedule problems. As explained in Chapter 3, negative schedule variance is based on a deviation from a time-phased budget, and while it is a reasonable indicator of schedule inefficiency, it does not usually equate with delay to the development effort. Any measure that more directly describes the delay to the overall effort, or at least the loss of “slack time” on tasks would be an improvement over the current schedule variance measure because it would better describe the real world management concern of project delay.

### ***Suggested Areas for Future Research***

Based on the experience gained and the results provided in this research, the following three areas are suggested for future exploration. First, as was stated earlier in

this chapter, the data source used in this research (the Cost Performance Report) is written from a contractor perspective. In order to gain additional insight into the reasons for schedule problems on system development efforts, it is highly desirable to also use a data source written from a government perspective. The Defense Acquisition Executive Summary (DAES) report is such a data source, which is similar to the CPR, yet is written by the government manager of the system development effort. The DAES reports are centrally archived by the Performance Management Branch of the Office of the Undersecretary of Defense for Acquisition and Technology in the Pentagon. The only complication with using the DAES as a data source is that portions of the DAES are classified. Although the data required to support further research into the reasons for schedule problems on system development efforts are generally *not* classified, the data would still have to be extracted from the classified reports. Once extracted, however, the data would allow a future effort to balance the contractor perspective contained in this research with a much needed government perspective.

Second, this research has provided a great deal of information about the reasons for schedule problems on past and present large Air Force system development efforts that can be used to help avoid these types of problems in the future. This information represents a host of lessons learned from previous efforts that provide managers with valuable insight into the types of problems that actually occur across development efforts. Given the value of these insights, it is important that this research approach not be limited to schedule-related problems. In fact, a very valuable contribution would be to apply the general approach of this research to the *cost* data contained in Cost Performance Reports.

This would allow managers a better understanding of the reasons for *cost* problems on system development efforts, which in general tend to be even more significant than schedule problems.

Third and finally, because of the lack of existing information regarding the reasons for schedule problems on system development efforts, this research necessarily focused on describing the reasons, rather than on determining causal relationships for explaining why reasons occurred as they did. Now that this research provides some insight into the reasons for schedule problems, future research can focus on specific management questions. For example, it may be interesting to investigate how reasons vary from one development effort type (such as fighter aircraft, or simulators) to another. Perhaps certain types of reasons are more likely to appear on certain types of development efforts. Also, it may be useful to investigate how reasons vary from one timeframe to another. Perhaps changed management practices, such as total quality management (TQM) or acquisition reform, impact the types and quantities of reasons for schedule problems that are experienced from one year to the next. In such future research efforts, great care would have to be taken to control for differences in potential moderating variables such as development effort size, type and level of completion (for example, it is important to avoid comparing efforts early in development with those late in development). Also, if reasons are being compared among timeframes, it is important to ensure that data is sampled equivalently among those timeframes. Given the need for careful, tailored data collection on these types of future research efforts, the more general research contained in this thesis

will most likely not *directly* apply, although it will certainly provide a source of future research questions and a context within which to assess future research results.

### ***Conclusion***

This research has filled a gap in the existing management body of knowledge regarding the reasons for schedule problems on system development efforts. By capturing the schedule-related lessons of past and present development efforts, and presenting them in a coherent framework, these lessons of yesterday can be used by the managers of today to solve the schedule problems of tomorrow. This research is not only valuable by itself, but provides a starting point from which more specific schedule-related management questions can be addressed in the future.

## ***Appendix***

### ***549 Reasons for Schedule Problems***

***Observed on 22 Large Air Force System Development Efforts***



| Category                 | Reason for Schedule Variance                                              | Variance (\$000) | Variance (Days) | Program            | Year |
|--------------------------|---------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| <b>Changed Plans</b>     |                                                                           |                  |                 |                    |      |
| Changed Responsibilities | Change in mgt office for component to get downstream efficiency           | 59               | 9.01            | A/C Equipment 2    | 1993 |
|                          | Minor changes in several functional responsibilities                      | 24               | 0.26            | Aircraft Upgrade 2 | 1993 |
|                          | Minor changes in several functional responsibilities                      | 63               | 0.77            | Aircraft Upgrade 2 | 1993 |
|                          | Minor changes in several functional responsibilities                      | 23               | 0.15            | Aircraft Upgrade 2 | 1994 |
|                          | Minor changes in several functional responsibilities                      | 171              | 5.87            | Aircraft Upgrade 3 | 1989 |
|                          | Minor changes in several functional responsibilities                      | 76               | 1.09            | Aircraft Upgrade 3 | 1991 |
|                          | Minor changes in several functional responsibilities                      | 34               | 1.46            | Aircraft Upgrade 3 | 1992 |
| New Design Schedules     | Rescheduling of large scale integration prototypes by sub                 | 134              | 0.27            | Aircraft/Missile 2 | 1993 |
|                          | Rescheduled design effort                                                 | 29               | 1.62            | Aircraft/Missile 5 | 1993 |
|                          | Revised drawing schedules                                                 | 30               | 0.41            | Aircraft/Missile 5 | 1993 |
|                          | Rescheduling of missile analysis task                                     | 19               | 1.53            | Simulator 1        | 1989 |
| New Delivery Schedules   | New subcontractor delivery schedule for better inventory management       | 113              | 0.71            | Aircraft Upgrade 2 | 1994 |
|                          | Rescheduled hardware delivery                                             | 1034             | 21.92           | Aircraft/Missile 4 | 1989 |
|                          | Rescheduled hardware delivery                                             | 39               | 10.21           | Aircraft/Missile 4 | 1989 |
|                          | Rescheduling of hardware delivery                                         | 276              | 10.92           | Aircraft/Missile 4 | 1989 |
| <b>Design Changes</b>    |                                                                           |                  |                 |                    |      |
| Affecting Data           | Tech manuals delayed due to frequently changing tech data                 | 92               | 10.02           | A/C Equipment 3    | 1991 |
|                          | Increased drawing changes leading to late drawing release                 | 150              | 2.04            | Aircraft/Missile 2 | 1993 |
|                          | Sub drawings behind schedule due to design changes                        | 62               | 0.93            | Aircraft/Missile 2 | 1993 |
| Affecting Manufacturing  | Significant rework due to engr request to relocate strain gauges          | 82               | 0.71            | Aircraft/Missile 1 | 1990 |
|                          | Late engr design/changes delay horiz/vert stabilizer build up             | 459              | 2.71            | Aircraft/Missile 1 | 1989 |
|                          | Engineering redefinition of mockups                                       | 40               | 8.38            | Aircraft/Missile 1 | 1987 |
|                          | Manufacturing experiencing heavy change traffic from Engrs                | 40               | 8.38            | Aircraft/Missile 1 | 1987 |
|                          | Delays in mockup construction due to engineering changes/late releases    | 83               | 16.16           | Aircraft/Missile 1 | 1986 |
|                          | Late receipt of material, tooling, and engr changes impacting integration | 1015             | 0.95            | Aircraft/Missile 1 | 1989 |
|                          | Design changes and redefinitions of mockups                               | 83               | 14.85           | Aircraft/Missile 1 | 1987 |
|                          | Engineering changes to cabinet caused installation delays                 | 61               | 1.74            | Simulator 2        | 1994 |

| Category                | Reason for Schedule Variance                                           | Variance (\$000) | Variance (Days) | Program            | Year |
|-------------------------|------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Affecting Subktr Delivs | Slowed sub effort due to potential design changes from PDR             | 55               | 10.00           | A/C Equipment 1    | 1990 |
|                         | Sub effort slowed pending design changes discussed at PDR              | 79               | 14.61           | A/C Equipment 1    | 1990 |
|                         | Sub slowdown due to PDR design/requirements changes                    | 56               | 6.96            | A/C Equipment 1    | 1990 |
|                         | Delays in subcontractor deliveries due to design changes               | 351              | 3.31            | Aircraft Upgrade 4 | 1994 |
|                         | Changes to test loading fixture design impacts parts deliveries        | 346              | 1.50            | Aircraft/Missile 1 | 1989 |
|                         | Design changes delaying material procurement by sub                    | 147              | 0.60            | Aircraft/Missile 2 | 1993 |
|                         | Material specification updates delaying material deliveries            | 530              | 5.00            | Aircraft/Missile 2 | 1993 |
|                         | Radar array design by sub slipped due to changes for vibe, ECCM, etc   | 335              | 0.74            | Aircraft/Missile 2 | 1993 |
|                         | Design changes delay subcontractor deliveries                          | 3237             | 22.00           | Aircraft/Missile 4 | 1989 |
|                         | Revised design delayed subcontractor delivery                          | 2756             | 22.00           | Aircraft/Missile 4 | 1989 |
|                         | Late vendor deliveries due to design changes                           | 39               | 11.00           | Aircraft/Missile 4 | 1989 |
|                         | Revised data impacts subktr ability to deliver                         | 222              | 22.00           | Aircraft/Missile 4 | 1989 |
|                         |                                                                        |                  |                 |                    |      |
| Affecting Testing       | Changes to development aircraft delayed test station fabrication       | 27               | 0.33            | Aircraft Upgrade 2 | 1993 |
|                         | Test fixture orders not placed by sub until designs stable             | 191              | 0.34            | Aircraft/Missile 2 | 1993 |
|                         | Development of new fuel bladder delaying testing                       | 50               | 6.43            | Aircraft/Missile 3 | 1991 |
| General Delay           |                                                                        |                  |                 |                    |      |
|                         | Incorporation of HW changes                                            | 6                | 22.00           | A/C Equipment 2    | 1982 |
|                         | Delay in card design - design instability                              | 26               | 4.50            | A/C Equipment 3    | 1989 |
|                         | Component design changes                                               | 107              | 8.20            | A/C Equipment 5    | 1986 |
|                         | Change in design approach to improve efficiency downstream             | 16               | 1.15            | Aircraft Upgrade 1 | 1985 |
|                         | Changes to loading system concepts on winglets                         | 49               | 0.21            | Aircraft/Missile 1 | 1989 |
|                         | Redesign of production winglet due to rejected previous design         | 82               | 0.71            | Aircraft/Missile 1 | 1990 |
|                         | Decision to integrate two systems into one                             | 272              | 0.48            | Aircraft/Missile 1 | 1987 |
|                         | Changes to LRU design delayed systems engineering tasks                | 96               | 4.31            | Aircraft/Missile 2 | 1993 |
|                         | Additional analysis required due to changed loads                      | 150              | 2.04            | Aircraft/Missile 2 | 1993 |
|                         | Incorporation of config change at sub delays electrical HW development | 603              | 13.55           | Aircraft/Missile 2 | 1993 |
|                         | Incorp of electrical power system design changes by sub                | 316              | 7.12            | Aircraft/Missile 2 | 1993 |
|                         | Changes in bus design by sub                                           | 228              | 0.40            | Aircraft/Missile 2 | 1993 |
|                         | Oper flight SW updates delaying completion of SW development           | 115              | 5.58            | Aircraft/Missile 6 | 1987 |
|                         | Unexpected design changes due to size of circuitry                     | 33               | 6.37            | Simulator 1        | 1989 |
|                         | Component redesign due to dev probs and perf improvement               | 59               | 9.01            | Simulator 4        | 1986 |
|                         |                                                                        |                  |                 |                    |      |
|                         |                                                                        |                  |                 |                    |      |
|                         |                                                                        |                  |                 |                    |      |
|                         |                                                                        |                  |                 |                    |      |
|                         |                                                                        |                  |                 |                    |      |

| Category                | Reason for Schedule Variance                                                                                                                                                                                                                                                                                                            | Variance (\$000)                 | Variance (Days)                         | Program                                                                                        | Year                                 |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------|--------------------------------------|
| Weight Reduction        | Changes required for weight reduction<br>Design changes due to weight reduction activities<br>Design concept changes to avoid increased aircraft weight                                                                                                                                                                                 | 146<br>561<br>40                 | 1.64<br>1.00<br>0.82                    | Aircraft/Missile 1<br>Aircraft/Missile 1<br>Aircraft/Missile 5                                 | 1987<br>1987<br>1982                 |
| <b>Estimating</b>       |                                                                                                                                                                                                                                                                                                                                         |                                  |                                         |                                                                                                |                                      |
| Ambitious Schedules     | Overly aggressive material plan could not be met<br>Delay in drawing completion - ambitious schedule<br>Aggressive schedule by sub led to delayed test equip design documents                                                                                                                                                           | 31<br>48<br>149                  | 4.04<br>6.00<br>0.82                    | A/C Equipment 1<br>A/C Equipment 3<br>Aircraft/Missile 2                                       | 1980<br>1989<br>1983                 |
| Optimistic Budgets      | Slower than expected demand for engineering materials<br>Original material budgets too optimistic<br>Material receipt scheduled too early<br>Material receipts not occurring as originally planned                                                                                                                                      | 35<br>42<br>511<br>82            | 4.50<br>7.39<br>6.45<br>0.71            | A/C Equipment 1<br>A/C Equipment 1<br>A/C Equipment 3<br>Aircraft/Missile 1                    | 1989<br>1989<br>1989<br>1990         |
| Incorrect Schedules     | Task baselined to incorrect schedule                                                                                                                                                                                                                                                                                                    | 23                               | 0.43                                    | Aircraft Upgrade 2                                                                             | 1992                                 |
| Long Order Times        | Poor planning of purchased items that required more time to order<br>Longer than sub planned lead times on radome material                                                                                                                                                                                                              | 128<br>53                        | 13.74<br>0.89                           | A/C Equipment 1<br>Aircraft/Missile 2                                                          | 1989<br>1993                         |
| No Integrated Schedules | Sub effort scheduled in parallel when should have been sequential<br>Planning based on non-integrated schedule (tasks out of sequence)<br>Parts late due to buy schedule out of synch with build schedule<br>Parts late due to buy schedule out of synch with build schedule<br>Schedule phasing mismatch between engineering & tooling | 110<br>58<br>1055<br>868<br>2388 | 9.03<br>17.72<br>18.73<br>20.00<br>5.31 | A/C Equipment 1<br>A/C Equipment 1<br>A/C Equipment 4<br>A/C Equipment 4<br>Aircraft/Missile 1 | 1990<br>1989<br>1984<br>1984<br>1986 |
| Misplanning             | Poor material planning<br>Misplanning of several design engineering test support tasks<br>Misplanning of several design engineering test support tasks                                                                                                                                                                                  | 43<br>13<br>38                   | 5.80<br>1.67<br>3.54                    | A/C Equipment 1<br>A/C Equipment 1<br>A/C Equipment 1                                          | 1989<br>1990<br>1990                 |
| Underestimating Times   | Integration schedule significantly underestimated<br>Design time underestimated<br>Development slower than anticipated                                                                                                                                                                                                                  | 476<br>17<br>40                  | 13.34<br>0.92<br>0.74                   | A/C Equipment 3<br>Aircraft Upgrade 1<br>Aircraft Upgrade 2                                    | 1991<br>1985<br>1992                 |

| Category             | Reason for Schedule Variance                                                                                                                                                                                                                                                                                   | Variance (\$000)                   | Variance (Days)                                 | Program                                                                                                                 | Year                                         |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Underestimating Work | Greater than anticipated effort for special test equipment<br>Component SRR work significantly more than anticipated<br>Number of detail parts to be custom designed more than planned<br>Underestimation of required effort                                                                                   | 44<br>27<br>70<br>35               | 2.49<br>2.79<br>20.53<br>3.76                   | Aircraft Upgrade 6<br>Aircraft/Missile 3<br>Aircraft/Missile 3<br>Simulator 3                                           | 1994<br>1991<br>1991<br>1990                 |
| Facility Problems    | Maintenance test slipped pending completion of building renovation<br>Facility design behind schedule<br>Design mods/layouts behind due to late test area completion                                                                                                                                           | 3<br>70<br>2                       | 8.25<br>4.81<br>0.40                            | A/C Equipment 2<br>A/C Equipment 3<br>Aircraft Upgrade 1                                                                | 1982<br>1990<br>1987                         |
| Gov't Added Work     |                                                                                                                                                                                                                                                                                                                |                                    |                                                 |                                                                                                                         |                                              |
| Added Reviews        | Gov't review of RFP not in original plan                                                                                                                                                                                                                                                                       | 54                                 | 1.63                                            | Aircraft Upgrade 6                                                                                                      | 1993                                         |
| Directed Changes     | Gov't directed tempest design changes<br>Gov't directed tempest design changes<br>Gov't directed tempest design changes<br>Gov't directed more detailed specifications than anticipated<br>Sub implementation of Gov't-directed HUD symbology changes<br>Sub implementing Gov't-directed HUD symbology changes | 24<br>17<br>26<br>56<br>136<br>142 | 2.54<br>2.05<br>3.14<br>13.84<br>22.00<br>22.00 | A/C Equipment 1<br>A/C Equipment 1<br>A/C Equipment 1<br>Aircraft/Missile 3<br>Aircraft/Missile 4<br>Aircraft/Missile 4 | 1990<br>1990<br>1990<br>1991<br>1989<br>1989 |
| Comments @ Reviews   | Specification work more than anticipated due to Gov't SRR comments<br>Additional specification work due to Gov't comments at SRR<br>Increased specification work due to Gov't comments at SRR                                                                                                                  | 23<br>25<br>19                     | 2.44<br>2.24<br>2.21                            | Aircraft/Missile 3<br>Aircraft/Missile 3<br>Aircraft/Missile 3                                                          | 1991<br>1991<br>1991                         |
| Marketing Support    | Support for VIP demo flights impacting test effort                                                                                                                                                                                                                                                             | 80                                 | 5.37                                            | Aircraft/Missile 6                                                                                                      | 1988                                         |
| Rescheduled Reviews  | PDR rescheduled by customer                                                                                                                                                                                                                                                                                    | 68                                 | 13.98                                           | Aircraft/Missile 3                                                                                                      | 1991                                         |
|                      |                                                                                                                                                                                                                                                                                                                |                                    |                                                 |                                                                                                                         |                                              |

| Category                                                   | Reason for Schedule Variance                                        | Variance (\$000) | Variance (Days) | Program            | Year |
|------------------------------------------------------------|---------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| <b>Gov't Not Supportive</b><br><br>Late Data Item Approval | Awaiting Gov't review of system test plan                           | 44               | 8.42            | A/C Equipment 2    | 1987 |
|                                                            | Gov't delay in approving qualification test plan                    | 125              | 8.57            | A/C Equipment 4    | 1984 |
|                                                            | Gov't approval of data item delaying structural analysis            | 4                | 0.22            | Aircraft Upgrade 1 | 1985 |
|                                                            | Specifications on hold pending Air Force review/comment             | 22               | 2.33            | Simulator 1        | 1989 |
| <b>Failure to Provide Data</b>                             | Sub non-receipt of classified documents                             | 17               | 1.70            | A/C Equipment 1    | 1990 |
|                                                            | Non-receipt of USAFE data base information                          | 34               | 6.13            | A/C Equipment 2    | 1982 |
|                                                            | Delay in obtaining source data from Gov't for tech manuals          | 76               | 5.11            | A/C Equipment 3    | 1993 |
|                                                            | Contractor waiting for Gov't data                                   | 47               | 2.81            | Aircraft Upgrade 1 | 1986 |
|                                                            | ALC waiting for SPO authorization to release data to subcontractor  | 98               | 10.57           | Aircraft Upgrade 5 | 1990 |
|                                                            | Lack of Gov't classified data / subcontractor access delayed RFP    | 54               | 1.63            | Aircraft Upgrade 6 | 1993 |
|                                                            | Late customer data causing design changes delaying H/W deliveries   | 77               | 22.00           | Aircraft/Missile 4 | 1989 |
|                                                            | Late receipt of customer design data                                | 71               | 8.40            | Aircraft/Missile 4 | 1989 |
|                                                            | Late customer data causing design changes impacting H/W delivery    | 77               | 22.00           | Aircraft/Missile 4 | 1989 |
|                                                            | Late interface data from customer                                   | 1010             | 21.93           | Aircraft/Missile 4 | 1989 |
|                                                            | Late customer data causes design changes impacting H/W deliveries   | 1252             | 22.00           | Aircraft/Missile 4 | 1989 |
|                                                            | Late receipt of customer interface data impacts H/W delivery        | 1837             | 8.66            | Aircraft/Missile 4 | 1989 |
|                                                            | Analysis delayed due to lack of intelligence data from customer     | 11               | 1.34            | Simulator 1        | 1989 |
|                                                            | Lack of funding delays study                                        | 50               | 6.51            | Aircraft/Missile 3 | 1991 |
| <b>Funding Shortfalls</b>                                  | Gov't funding shortfalls impacting piece part purchases             | 139              | 14.36           | Simulator 1        | 1991 |
|                                                            | Subcontractor failure to deliver simulator due to funding shortfall | 967              | 8.92            | Simulator 1        | 1991 |
|                                                            | Manpower shortage due to funding shortfalls                         | 105              | 12.69           | Simulator 1        | 1990 |
|                                                            | Awaiting GFP design packages supporting facilities design           | 33               | 4.43            | A/C Equipment 2    | 1988 |
| <b>Incomplete/Late GFE</b>                                 | Late GFE                                                            | 51               | 4.30            | A/C Equipment 3    | 1993 |
|                                                            | Incomplete Gov't furnished test equipment                           | 47               | 2.81            | Aircraft Upgrade 1 | 1986 |
|                                                            | Late final test plan due to delayed customer comments               | 13               | 1.67            | A/C Equipment 1    | 1990 |
|                                                            | Delayed NATO mtgs/lack of comments on draft docs                    | 35               | 3.44            | A/C Equipment 1    | 1990 |
| <b>Late Direction</b>                                      | Delayed customer comments delay final test plan                     | 38               | 3.54            | A/C Equipment 1    | 1990 |
|                                                            | Test requirements delayed due to non-receipt of Test SOW            | 16               | 1.15            | Aircraft Upgrade 1 | 1985 |
|                                                            | Awaiting Gov't decisions on flight test instrumentation             | 47               | 2.81            | Aircraft Upgrade 1 | 1986 |
|                                                            |                                                                     |                  |                 |                    |      |

| Category                  | Reason for Schedule Variance                                                                                                                                                                                                                                                                                                                                   | Variance (\$000)                                 | Variance (Days)                                                | Program                                                                                                                                                                   | Year                                                         |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
|                           | Sub HW on hold pending Gov't approval of accept tests/nonstandard parts<br>Late customer approval of component causes reconfiguration<br>HW deliv on hold pending Gov't approval of acceptance tests<br>Delay in inputs from Air Force to aircraft analysis task                                                                                               | 40<br>152<br>276<br>19                           | 10.48<br>19.00<br>10.92<br>1.53                                | Aircraft/Missile 4<br>Aircraft/Missile 4<br>Aircraft/Missile 4<br>Simulator 1                                                                                             | 1989<br>1989<br>1989<br>1989                                 |
| <b>Gov't Stopped Work</b> | Gov't directed work stoppage impacting other areas<br>ILS effort slowing due to stop work and program restructure<br>Gov't stop work<br>Stop work order slowed vendor tasks<br>Reduced sub activity due to partial stop work<br>Stop work order                                                                                                                | 219<br>57<br>41<br>11<br>67<br>26                | 13.20<br>19.00<br>8.93<br>14.24<br>22.00<br>11.44              | A/C Equipment 3<br>A/C Equipment 3<br>A/C Equipment 3<br>Aircraft Upgrade 5<br>Aircraft Upgrade 5<br>Aircraft Upgrade 5                                                   | 1991<br>1991<br>1991<br>1990<br>1991<br>1990                 |
| <b>Inventory Mgt</b>      |                                                                                                                                                                                                                                                                                                                                                                |                                                  |                                                                |                                                                                                                                                                           |                                                              |
| Ineffective Controls      | Parts received in stock do not concur with original Bill of Material<br>Delays in recognition of receipt of vendor deliveries                                                                                                                                                                                                                                  | 24<br>901                                        | 22.96<br>12.93                                                 | Aircraft Upgrade 1<br>Aircraft Upgrade 3                                                                                                                                  | 1986<br>1991                                                 |
| Parts Shortages           | Parts shortages / delay in card assembly delaying integration<br>Delinquent parts<br>Material shortages impacting manufacturing<br>Delinquent parts impacting test, STE, and modifications<br>Late availability of standard parts<br>Parts shortages<br>Parts shortages impacting test article fabrication<br>Part/material shortages for static test assembly | 37<br>20<br>2<br>311<br>49<br>645<br>1027<br>805 | 7.61<br>11.89<br>0.40<br>9.72<br>0.21<br>0.60<br>10.73<br>7.01 | A/C Equipment 2<br>Aircraft Upgrade 1<br>Aircraft Upgrade 1<br>Aircraft Upgrade 1<br>Aircraft/Missile 1<br>Aircraft/Missile 1<br>Aircraft/Missile 1<br>Aircraft/Missile 1 | 1983<br>1986<br>1987<br>1986<br>1989<br>1989<br>1990<br>1990 |
| <b>Late Data</b>          |                                                                                                                                                                                                                                                                                                                                                                |                                                  |                                                                |                                                                                                                                                                           |                                                              |
| Incomplete Data Items     | Delays in SSDD and Interface Specifications<br>Data items not yet approved or submitted<br>Late SW data items                                                                                                                                                                                                                                                  | 21<br>49<br>116                                  | 6.24<br>0.35<br>6.81                                           | A/C Equipment 1<br>Aircraft Upgrade 4<br>Aircraft Upgrade 4                                                                                                               | 1989<br>1991<br>1994                                         |

| Category                 | Reason for Schedule Variance                                           | Variance (\$000) | Variance (Days) | Program            | Year |
|--------------------------|------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Late Engineering Release | Sub interface control document not completed                           | 147              | 0.60            | Aircraft/Missile 2 | 1993 |
|                          | Non completion of data item                                            | 761              | 9.72            | Aircraft/Missile 6 | 1986 |
|                          | Awaiting document inputs                                               | 19               | 1.53            | Simulator 1        | 1989 |
|                          | Late delivery of review copies of SRS and IRS delayed prelim design    | 125              | 22.00           | Simulator 3        | 1989 |
|                          | Late release of engineering data                                       | 338              | 4.16            | A/C Equipment 2    | 1987 |
|                          | Delayed drafting efforts                                               | 48               | 5.62            | A/C Equipment 2    | 1988 |
|                          | Late engineering release impacting manufacturing start-up              | 510              | 6.44            | A/C Equipment 3    | 1989 |
|                          | Late STE design releases impacting manufacturing                       | 2                | 0.40            | Aircraft Upgrade 1 | 1987 |
|                          | Delayed releases from Electrical Engineering                           | 32               | 1.87            | Aircraft Upgrade 1 | 1985 |
|                          | Delays in engineering release of components                            | 12               | 0.65            | Aircraft Upgrade 1 | 1985 |
|                          | Engineering release not fast enough to support analysis                | 18               | 0.43            | Aircraft Upgrade 2 | 1992 |
|                          | Late engineering delaying subcontractors                               | 272              | 0.48            | Aircraft/Missile 1 | 1987 |
|                          | Late engineering drawing releases                                      | 263              | 22.00           | Aircraft/Missile 1 | 1986 |
|                          | Late engineering impacting tooling activities                          | 598              | 1.07            | Aircraft/Missile 1 | 1987 |
|                          | Delays in engr design/drawing release                                  | 610              | 4.39            | Aircraft/Missile 1 | 1989 |
|                          | Drawing release delaying test equipment development                    | 50               | 6.43            | Aircraft/Missile 3 | 1991 |
|                          | Late engineering releases                                              | 47               | 1.42            | Aircraft/Missile 5 | 1984 |
|                          | Late engineering releases                                              | 135              | 1.87            | Aircraft/Missile 5 | 1983 |
| Late/Incomplete Info     | Unavail of spec information delayed CSCI requirements analysis         | 14               | 4.22            | A/C Equipment 1    | 1989 |
|                          | Specifications not complete                                            | 35               | 4.50            | A/C Equipment 1    | 1989 |
|                          | Classified specifications impacting effort                             | 30               | 5.69            | A/C Equipment 1    | 1990 |
|                          | Lack of required information to begin drafting efforts                 | 21               | 2.31            | A/C Equipment 1    | 1990 |
|                          | Sub unable to proceed without interface control docs / specs           | 110              | 9.03            | A/C Equipment 1    | 1990 |
|                          | S/W requirements analysis delayed by lack of SSDD and I/F specs        | 12               | 3.26            | A/C Equipment 1    | 1989 |
|                          | Facilities design efforts delayed due to lack of drawings              | 15               | 1.78            | A/C Equipment 2    | 1987 |
|                          | Lack of imagery data to validate algorithms                            | 338              | 4.16            | A/C Equipment 2    | 1987 |
|                          | Lack of adequate vendor data to support ILS efforts                    | 132              | 7.17            | A/C Equipment 2    | 1987 |
|                          | Delays in data impacting provisioning effort                           | 12               | 4.80            | A/C Equipment 2    | 1983 |
|                          | Delay in specification completion                                      | 10               | 11.58           | A/C Equipment 2    | 1982 |
|                          | Lack of related system spec delays test planning (integration problem) | 2                | 11.00           | A/C Equipment 2    | 1982 |
|                          | Lack of sufficient data to complete tech manuals                       | 22               | 1.57            | A/C Equipment 3    | 1990 |
|                          | Training impacted by unavail of data and system access                 | 42               | 9.15            | A/C Equipment 3    | 1991 |
|                          | Lack of preliminary layouts delaying thermal analysis                  | 4                | 0.22            | Aircraft Upgrade 1 | 1985 |

| Category     | Reason for Schedule Variance                                                                                                                                                                                                                        | Variance (\$000) | Variance (Days) | Program            | Year |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
|              | Subcontractor SW development data items late                                                                                                                                                                                                        | 347              | 17.31           | Aircraft Upgrade 4 | 1992 |
|              | Delays in R&M engineering receiving FMECA data                                                                                                                                                                                                      | 146              | 1.64            | Aircraft/Missile 1 | 1987 |
|              | Late drawings and data                                                                                                                                                                                                                              | 33               | 0.36            | Aircraft/Missile 1 | 1985 |
|              | Lack of resource info delays raw material/purchase parts deliveries                                                                                                                                                                                 | 346              | 1.50            | Aircraft/Missile 1 | 1989 |
|              | Late loads info from engineering delayed deliveries                                                                                                                                                                                                 | 347              | 2.05            | Aircraft/Missile 1 | 1989 |
|              | Tech pubs behind schedule due to lack of source data                                                                                                                                                                                                | 191              | 9.13            | Aircraft/Missile 1 | 1989 |
|              | Unavailability of source data for tech pubs                                                                                                                                                                                                         | 153              | 4.22            | Aircraft/Missile 1 | 1990 |
|              | Late R&M analysis data for power plant                                                                                                                                                                                                              | 623              | 22.00           | Aircraft/Missile 1 | 1985 |
|              | Late loads info causes parts delivery delays impacting testing                                                                                                                                                                                      | 510              | 4.27            | Aircraft/Missile 1 | 1989 |
|              | Brassboard fab/assy delayed at sub due to late completion of studies                                                                                                                                                                                | 370              | 2.45            | Aircraft/Missile 2 | 1993 |
|              | Delays in receipt of drawings                                                                                                                                                                                                                       | 96               | 4.31            | Aircraft/Missile 2 | 1993 |
|              | Sub delay in detailed design data delayed acceptance tests                                                                                                                                                                                          | 442              | 1.80            | Aircraft/Missile 2 | 1993 |
|              | Sub drawings not meeting release schedule delayed H/W orders                                                                                                                                                                                        | 413              | 4.63            | Aircraft/Missile 2 | 1993 |
|              | Late drawings by sub                                                                                                                                                                                                                                | 431              | 4.52            | Aircraft/Missile 2 | 1993 |
|              | Design data for printed circuit boards not received on schedule                                                                                                                                                                                     | 39               | 5.72            | Simulator 1        | 1989 |
|              | Late design data for printed circuit boards slipping PDR                                                                                                                                                                                            | 45               | 6.11            | Simulator 1        | 1989 |
|              | Delays in sub obtaining final system data to freeze courseware design                                                                                                                                                                               | 68               | 5.50            | Simulator 2        | 1991 |
| Late Reviews | Additional effort required to close out CDR<br>End of non-recurring effort pending engineering validation<br>Awaiting closure of component CDR action items by sub<br>Detailed design task awaiting PDR completion<br>Delay in completing SW review | 204              | 10.84           | A/C Equipment 2    | 1988 |
|              |                                                                                                                                                                                                                                                     | 147              | 2.01            | Aircraft Upgrade 3 | 1992 |
|              |                                                                                                                                                                                                                                                     | 413              | 4.63            | Aircraft/Missile 2 | 1993 |
|              |                                                                                                                                                                                                                                                     | 14               | 4.46            | Simulator 1        | 1989 |
|              |                                                                                                                                                                                                                                                     | 24               | 2.20            | Simulator 3        | 1991 |

| Category             | Reason for Schedule Variance                                          | Variance (\$000) | Variance (Days) | Program            | Year |
|----------------------|-----------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Review Slipped       | Delay in SAW design & test due to late SSR                            | 41               | 12.36           | A/C Equipment 1    | 1989 |
|                      | Delayed SSR delaying SAW design and test                              | 35               | 9.51            | A/C Equipment 1    | 1989 |
|                      | Delay in SAW Specification Review                                     | 21               | 6.24            | A/C Equipment 1    | 1989 |
|                      | Delayed PDR impacts auxiliary equipment effort                        | 7                | 9.63            | A/C Equipment 2    | 1982 |
|                      | PDR slippage                                                          | 35               | 6.31            | A/C Equipment 2    | 1982 |
|                      | Delayed fabrication due to slip of CDR                                | 96               | 4.31            | Aircraft/Missile 2 | 1993 |
|                      | Slip of component SRR/PDR                                             | 56               | 22.00           | Aircraft/Missile 3 | 1991 |
|                      | Slipped PDR impacting detailed design tasks                           | 19               | 11.00           | Simulator 1        | 1989 |
|                      | Slipped PDR delaying SAW detailed design tasks                        | 24               | 13.89           | Simulator 1        | 1989 |
|                      |                                                                       |                  |                 |                    |      |
| Miscellaneous Delays | Late start of trade studies                                           | 33               | 5.58            | A/C Equipment 1    | 1989 |
|                      | Delays in common supt equipment effort                                | 49               | 14.57           | A/C Equipment 2    | 1983 |
|                      | Delay in shipment overseas impacts test                               | 174              | 10.94           | A/C Equipment 2    | 1985 |
|                      | Delay in shipment overseas impacts project mgt                        | 47               | 4.72            | A/C Equipment 2    | 1985 |
|                      | Delay in shipment overseas impacts site activation                    | 32               | 22.00           | A/C Equipment 2    | 1985 |
|                      | Other schedule slips impacting system testing                         | 22               | 10.30           | A/C Equipment 2    | 1983 |
|                      | Site activation meeting delayed                                       | 42               | 10.87           | A/C Equipment 3    | 1990 |
|                      | Availability of test article delayed                                  | 82               | 0.71            | Aircraft/Missile 1 | 1990 |
|                      | Tooling falling behind due to outside manufacturing delays            | 1197             | 0.86            | Aircraft/Missile 1 | 1988 |
|                      | Inefficiencies created by a multi-site development process by subtr   | 68               | 5.50            | Simulator 2        | 1991 |
|                      |                                                                       |                  |                 |                    |      |
|                      |                                                                       |                  |                 |                    |      |
|                      |                                                                       |                  |                 |                    |      |
|                      |                                                                       |                  |                 |                    |      |
|                      |                                                                       |                  |                 |                    |      |
| Manufacturing Probs  | Behind schedule requisitioning from inventory of equip. H/W, material | 942              | 16.90           | Aircraft Upgrade 3 | 1990 |
|                      | Behind schedule requisitioning of H/W from inventory                  | 115              | 4.53            | Aircraft Upgrade 3 | 1990 |
|                      | H/W interface problem discovered during build                         | 54               | 2.67            | Aircraft/Missile 3 | 1991 |
|                      | Delayed manufacturing activities impacting quality assurance          | 24               | 0.73            | Aircraft/Missile 5 | 1984 |
|                      | Material not being used as quickly as anticipated                     | 144              | 64.65           | Simulator 2        | 1994 |
|                      | Slowed material movement due to new manufacturing computer system     | 60               | 38.82           | Simulator 2        | 1994 |
|                      | New manufacturing planning computer slowed material usage             | 175              | 101.32          | Simulator 2        | 1994 |
|                      |                                                                       |                  |                 |                    |      |
|                      |                                                                       |                  |                 |                    |      |
|                      |                                                                       |                  |                 |                    |      |

| Category                 | Reason for Schedule Variance                                              | Variance (\$000) | Variance (Days) | Program            | Year |
|--------------------------|---------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Fabrication Problems     | Difficulty with breadboard fabrication                                    | 2                | 0.11            | Aircraft Upgrade 1 | 1985 |
|                          | Delays in fabrication of major assembly tooling fixtures                  | 80               | 4.07            | Aircraft/Missile 3 | 1991 |
|                          | Delays in fabricating major assembly tooling fixtures                     | 46               | 3.71            | Aircraft/Missile 3 | 1991 |
|                          | Mfg mock-up problems delayed fabrication of fuel sys test equipment       | 71               | 7.04            | Aircraft/Missile 3 | 1991 |
|                          | Delayed workstation integration & checkout efforts                        | 26               | 1.43            | A/C Equipment 3    | 1990 |
|                          | Delays in structural test specimen fabrication                            | 33               | 0.36            | Aircraft/Missile 1 | 1985 |
|                          | Delays in building test fixtures                                          | 217              | 0.63            | Aircraft/Missile 2 | 1993 |
|                          | Late fab of fixture by sub slips instrument landing system                | 60               | 0.11            | Aircraft/Missile 2 | 1993 |
|                          | Delays by sub in completion of RF test benches                            | 689              | 1.36            | Aircraft/Missile 2 | 1993 |
|                          | Detail parts not being built as quickly as expected                       | 163              | 8.06            | Aircraft/Missile 3 | 1991 |
|                          | Assembly tools taking longer than planned to manufacture                  | 36               | 2.34            | Aircraft/Missile 3 | 1991 |
|                          | Sub having difficulty fabricating fuel system bladders                    | 71               | 7.04            | Aircraft/Missile 3 | 1991 |
|                          | Problems with board fabrication / final installation                      | 61               | 1.74            | Simulator 2        | 1994 |
|                          | Cables not ordered because parts lists behind schedule                    | 42               | 20.09           | A/C Equipment 2    | 1983 |
|                          | Late receipt of breadboard parts                                          | 2                | 0.11            | Aircraft Upgrade 1 | 1985 |
|                          | Late tools/material for proof of production impacts test article assembly | 393              | 3.29            | Aircraft/Missile 1 | 1989 |
| Late Receipt of Material | Lack of adequate tooling availability to support assembly                 | 584              | 0.54            | Aircraft/Missile 1 | 1989 |
|                          | Late tools/materials for proof of production impacts test article fab     | 2022             | 8.75            | Aircraft/Missile 1 | 1989 |
|                          | Parts shortages due to engr changes, lack of raw material, capacity probs | 584              | 0.54            | Aircraft/Missile 1 | 1989 |
|                          | Late tools/material for proof of production impact test article fab       | 1426             | 8.43            | Aircraft/Missile 1 | 1989 |
|                          | Delayed engineering and late receipt of tools impacts fabrication         | 60               | 1.82            | Aircraft/Missile 5 | 1984 |
|                          | Delay in assembly of test article due to late main frame receipt          | 57               | 1.72            | Aircraft/Missile 5 | 1984 |
|                          | Late start of sheet metal and machine detail tools                        | 145              | 2.01            | Aircraft/Missile 5 | 1983 |
|                          | Late start of canopy tooling                                              | 13               | 0.53            | Aircraft/Missile 5 | 1984 |
|                          | Late start of conventional machine tool designs                           | 62               | 0.86            | Aircraft/Missile 5 | 1983 |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
| Late Starts              |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |
|                          |                                                                           |                  |                 |                    |      |

| Category             | Reason for Schedule Variance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Variance (\$000) | Variance (Days) | Program            | Year |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Mfg Design Problems  | Delay in defining/releasing production bill of materials<br>Production bill of materials not yet defined/released<br>Critical process tooling not released as planned<br>Tooling not released as planned<br>Late tool completion due to late releases, engr changes, and rework<br>Delays in sub completing range mock-up for elec warfare testing<br>Subcontractor slower than planned mfg process / tooling development<br>Delays in proof of concept article by sub                                                                                                                                                      | 57               | 17.66           | A/C Equipment 1    | 1990 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 54               | 17.22           | A/C Equipment 1    | 1990 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 76               | 21.16           | A/C Equipment 4    | 1985 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 185              | 20.87           | A/C Equipment 4    | 1985 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2042             | 1.91            | Aircraft/Missile 1 | 1989 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 238              | 0.54            | Aircraft/Missile 2 | 1993 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 707              | 1.29            | Aircraft/Missile 2 | 1993 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 226              | 0.40            | Aircraft/Missile 2 | 1993 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 138              | 11.12           | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180              | 12.38           | Aircraft/Missile 3 | 1991 |
| Machine Proofing     | Time required to revise data between proofing runs causing delays<br>Proofing delays impacting parts fabrication delaying assembly<br>Delayed machine proofing delayed fab of parts required for assembly<br>Mfg mock-up not yet started due to unanticipated machine proofing problems<br>Delays due to time required to revise data between proofing runs<br>Proofing delays impact parts fabrication delaying assembly<br>Assembly drawings late due to unanticipated level of support for proofing                                                                                                                      | 103              | 10.44           | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 36               | 2.34            | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 240              | 12.22           | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 132              | 12.25           | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 16               | 1.76            | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 109              | 12.62           | Aircraft/Missile 3 | 1991 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |                 |                    |      |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |                 |                    |      |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |                 |                    |      |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |                 |                    |      |
| Mfg Process Problems | Problem in curing process delayed receipt of bladder                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                  |                 |                    |      |
| Quality              | Sub test start delay due to insufficient parts/cables<br>Poor subcontractor performance<br>Vendor testing not satisfactory for acceptance<br>Seller in-house testing not adequate<br>Speed problems with sub's vendor's computer chips<br>Subcontractor data items rejected<br>Rescheduling of major forgings due to quality problems<br>Air data computer sys failure to pass test (sub)<br>Mechanical fit problem at sub discovered after PDR<br>Rejected HW delivery due to excessive test time on components<br>Rejection of subcontractor hardware<br>Subcontractor components required additional debug & integration | 80               | 10.35           | Aircraft Upgrade 4 | 1994 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1065             | 3.28            | Aircraft/Missile 1 | 1989 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 108              | 13.35           | Aircraft/Missile 4 | 1989 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 598              | 20.27           | Aircraft/Missile 4 | 1989 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 104              | 6.07            | Aircraft Upgrade 1 | 1986 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 98               | 10.57           | Aircraft Upgrade 5 | 1990 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 272              | 0.48            | Aircraft/Missile 1 | 1987 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1265             | 15.45           | Aircraft/Missile 1 | 1990 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 55               | 0.22            | Aircraft/Missile 2 | 1993 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 98               | 22.00           | Aircraft/Missile 4 | 1989 |
| Inadequate Testing   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 178              | 39.96           | Aircraft/Missile 4 | 1989 |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 61               | 1.74            | Simulator 2        | 1994 |
| Unacceptable Items   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |                 |                    |      |
|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |                 |                    |      |

| Category              | Reason for Schedule Variance                                    | Variance (\$000) | Variance (Days) | Program            | Year |
|-----------------------|-----------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Acceptance Procedures | Flight station shipped in an incomplete condition by subktr     | 2105             | 21.43           | Simulator 4        | 1986 |
|                       | Sub shipped H/W missing a component                             | 59               | 9.01            | Simulator 4        | 1986 |
|                       | Vendor components awaiting MRB approval                         | 106              | 8.13            | A/C Equipment 5    | 1986 |
|                       | Quality inspection delays in hardware deliveries                | 545              | 23.33           | Aircraft Upgrade 3 | 1992 |
|                       | Sub components awaiting Prime quality assurance approval        | 257              | 13.59           | Aircraft Upgrade 4 | 1994 |
| Req'ments Changes     | Potential spec changes have delayed sub component design        | 58               | 14.84           | A/C Equipment 1    | 1990 |
|                       | Changing specifications impacting effort                        | 30               | 5.69            | A/C Equipment 1    | 1990 |
|                       | Late sub definition/changes in requirements                     | 17               | 1.70            | A/C Equipment 1    | 1990 |
|                       | S/W requirements changes                                        | 16               | 2.21            | A/C Equipment 3    | 1989 |
|                       | Increased structural test complexity                            | 33               | 0.36            | Aircraft/Missile 1 | 1985 |
|                       | Expanded test requirements                                      | 54               | 4.70            | Aircraft/Missile 3 | 1991 |
|                       | Change in harness board requirements                            | 13               | 0.53            | Aircraft/Missile 5 | 1994 |
|                       | Changes to SCIF requirements                                    | 209              | 20.53           | Simulator 3        | 1990 |
|                       |                                                                 |                  |                 |                    |      |
|                       |                                                                 |                  |                 |                    |      |
| Staffing              | Subcontractor has slower staffing than planned                  | 98               | 10.57           | Aircraft Upgrade 5 | 1990 |
|                       | Slow manpower buildup by sub                                    | 1663             | 16.55           | Aircraft/Missile 1 | 1987 |
|                       | Delays in hiring/replacing engineers                            | 217              | 0.63            | Aircraft/Missile 2 | 1993 |
|                       | Manpower shortages in design areas                              | 21               | 2.31            | A/C Equipment 1    | 1990 |
|                       | Lack of initial staffing for trade studies                      | 33               | 5.58            | A/C Equipment 1    | 1989 |
|                       | Inadequate staffing for specification design                    | 46               | 2.13            | A/C Equipment 1    | 1989 |
|                       | Manpower shortage at sub delayed test article fabrication       | 74               | 2.36            | A/C Equipment 1    | 1990 |
|                       | Inadequate systems engineering staffing delaying specifications | 107              | 4.54            | A/C Equipment 1    | 1989 |
|                       | Understaffing in test engineering design area                   | 31               | 5.25            | A/C Equipment 1    | 1989 |
|                       | Shortage of manpower in shelter design                          | 6                | 8.25            | A/C Equipment 2    | 1982 |
|                       | Staffing shortages in H/W and S/W engineering                   | 237              | 3.32            | A/C Equipment 2    | 1987 |
|                       | Manpower shortages                                              | 266              | 4.71            | A/C Equipment 2    | 1988 |
|                       | Loss of software engineers                                      | 16               | 3.12            | A/C Equipment 3    | 1989 |
|                       |                                                                 |                  |                 |                    |      |
|                       |                                                                 |                  |                 |                    |      |
|                       |                                                                 |                  |                 |                    |      |
|                       |                                                                 |                  |                 |                    |      |

| Category              | Reason for Schedule Variance                                          | Variance (\$000) | Variance (Days) | Program            | Year |
|-----------------------|-----------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Receipt of Clearances | Shortage of illustrators and writers impacting tech manuals           | 67               | 4.79            | A/C Equipment 3    | 1990 |
|                       | SW development understaffed                                           | 16               | 2.21            | A/C Equipment 3    | 1989 |
|                       | Engineering resources not available to conduct study                  | 32               | 2.75            | A/C Equipment 3    | 1990 |
|                       | Sub late in supplying engr support                                    | 80               | 17.60           | Aircraft/Missile 1 | 1987 |
|                       | Shortage of personnel for structural test                             | 33               | 0.36            | Aircraft/Missile 1 | 1985 |
|                       | Inadequate staffing to support assembly                               | 584              | 0.54            | Aircraft/Missile 1 | 1989 |
|                       | Loss of experienced design team personnel                             | 561              | 1.00            | Aircraft/Missile 1 | 1987 |
|                       | Lack of personnel support to accomplish test                          | 215              | 2.25            | Aircraft/Missile 1 | 1990 |
|                       | Low experience levels of newly hired personnel                        | 82               | 0.71            | Aircraft/Missile 1 | 1990 |
|                       | Lack of staffing for technical publications                           | 126              | 8.56            | Aircraft/Missile 1 | 1988 |
|                       | Insufficient tech pubs staffing                                       | 153              | 4.22            | Aircraft/Missile 1 | 1990 |
|                       | Manpower shortages                                                    | 645              | 0.60            | Aircraft/Missile 1 | 1989 |
|                       | Manpower shortages                                                    | 294              | 2.25            | Aircraft/Missile 2 | 1993 |
|                       | Inadequate staffing for design and stress analysis tasks              | 146              | 1.32            | Aircraft/Missile 2 | 1993 |
|                       | Test vehicle design activities delayed due to manpower constraints    | 48               | 5.28            | Aircraft/Missile 3 | 1991 |
|                       | Delayed clearances/staffing problems                                  | 36               | 3.54            | A/C Equipment 1    | 1990 |
|                       | Staffing problems/slow receipt of clearances                          | 24               | 4.22            | A/C Equipment 1    | 1989 |
| Reassignment          | Slow design engineering startup due to understaffing/clearance delays | 56               | 9.78            | A/C Equipment 1    | 1990 |
|                       | Delayed clearances/staffing problems                                  | 13               | 1.67            | A/C Equipment 1    | 1990 |
|                       | Assignment of personnel by sub                                        | 17               | 1.70            | A/C Equipment 1    | 1990 |
|                       | Diversion of software resources to system engineering                 | 82               | 8.05            | A/C Equipment 2    | 1982 |
|                       | Reassignment of personnel to more critical areas                      | 61               | 4.97            | A/C Equipment 3    | 1991 |
|                       | Labor redirected from planned SW activities to system CDR prep        | 59               | 2.94            | Aircraft Upgrade 4 | 1992 |
|                       | Development startup diverted designers from mockups                   | 40               | 8.38            | Aircraft/Missile 1 | 1987 |
|                       | Reassignment of T&E personnel to higher priority tasks                | 82               | 0.71            | Aircraft/Missile 1 | 1990 |
|                       | Personnel reassignments                                               | 238              | 0.54            | Aircraft/Missile 2 | 1993 |
|                       | Diversion of manpower from one analysis to another                    | 19               | 0.83            | Aircraft/Missile 5 | 1984 |
|                       | Manpower diversion                                                    | 37               | 2.07            | Aircraft/Missile 5 | 1983 |
|                       | Manpower diversions                                                   | 26               | 0.36            | Aircraft/Missile 5 | 1983 |
|                       | Analysis delayed to focus on SRS update and PDR                       | 11               | 1.34            | Simulator 1        | 1989 |
|                       | Redirection of principal designer to an Ada study                     | 33               | 6.37            | Simulator 1        | 1989 |
|                       | Design personnel required to support non-design tasks                 | 14               | 2.37            | Simulator 1        | 1989 |
|                       | Test support effort reassigned from one group to another              | 72               | 8.61            | Simulator 4        | 1985 |

| Category                  | Reason for Schedule Variance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Variance (\$000)                                                                                                                                                                      | Variance (Days)                                                                                                                                                                                                                       | Program                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Year                                                                                                                                                                                                                                         |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Wrong People Used         | Subcontractor had wrong mix of technical personnel assigned<br>Subcontractor lack of critical subject matter expertise                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 25<br>68                                                                                                                                                                              | 8.46<br>5.50                                                                                                                                                                                                                          | A/C Equipment 2<br>Simulator 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1983<br>1991                                                                                                                                                                                                                                 |
| <b>Subcontractor Late</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                       |                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                              |
| Late Deliveries           | Delays in vendor shipments of engineering materials<br>Delays in vendor shipments of engineering materials<br>Delays in major H/W procurements<br>S/W delivery delays<br>Late delivery of H/W delays S/W and H/W integration<br>Hardware not delivered<br>Fuel controls not received as planned<br>Late receipt of material for DT&E flight test<br>Late material deliveries delaying STE effort<br>Late hardware deliveries<br>Delays in receipt of sub high speed memory units<br>Delays in RF synthesizer receipt from sub resulted in design issues<br>Late receipt of satellite simulator for GPS related modification<br>Late delivery of computer test units<br>Late receipt of parts from vendor for hydraulic system simulator<br>Late deliveries from subcontracts supporting airframe static testing<br>Electronic flight control sys not delivered as scheduled (sub)<br>Behind schedule receipt of materials for test station<br>Material not received from vendor<br>Late delivery of connectors from sub delays brassboard fabrication<br>Schedule slip on material<br>Late delivery of test equipment by sub<br>Materials for sub endurance test not delivered as planned<br>Delays in sub transporting panels to test facility<br>Continued timing variances by sub on purchased H/W<br>Late receipt of models needed for electrical simulation design by sub<br>Radar array material deliveries slipped<br>Late delivery of sensors from vendor | 38<br>13<br>52<br>39<br>77<br>73<br>84<br>57<br>10<br>673<br>449<br>449<br>450<br>1110<br>98<br>145<br>1706<br>146<br>505<br>437<br>134<br>134<br>62<br>53<br>110<br>55<br>335<br>841 | 3.54<br>1.67<br>2.40<br>11.75<br>9.68<br>12.26<br>19.45<br>10.81<br>1.98<br>8.18<br>4.91<br>4.91<br>14.37<br>18.89<br>0.86<br>12.91<br>17.30<br>1.29<br>1.17<br>3.87<br>0.27<br>0.27<br>0.93<br>0.89<br>1.20<br>0.22<br>0.74<br>25.04 | A/C Equipment 1<br>A/C Equipment 1<br>A/C Equipment 2<br>A/C Equipment 3<br>A/C Equipment 3<br>A/C Equipment 3<br>A/C Equipment 4<br>Aircraft Upgrade 1<br>Aircraft Upgrade 1<br>Aircraft Upgrade 2<br>Aircraft Upgrade 4<br>Aircraft Upgrade 4<br>Aircraft Upgrade 6<br>Aircraft/Missile 1<br>Aircraft/Missile 1<br>Aircraft/Missile 1<br>Aircraft/Missile 1<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 2<br>Aircraft/Missile 3 | 1990<br>1990<br>1983<br>1991<br>1990<br>1989<br>1985<br>1987<br>1987<br>1993<br>1993<br>1993<br>1994<br>1988<br>1989<br>1987<br>1989<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1993<br>1991 |

| Category                | Reason for Schedule Variance                                         | Variance (\$000) | Variance (Days) | Program            | Year |
|-------------------------|----------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Late Deliv by Sub's Sub | Late hardware deliveries (electrical system)                         | 1947             | 22.00           | Aircraft/Missile 4 | 1989 |
|                         | Late H/W delivery                                                    | 92               | 22.00           | Aircraft/Missile 4 | 1989 |
|                         | Late delivery of radar hardware                                      | 237              | 115.87          | Aircraft/Missile 4 | 1989 |
|                         | Delayed delivery of HUD units                                        | 232              | 10.05           | Aircraft/Missile 6 | 1987 |
|                         | Delays in equipment receipt and system req'mnts def'n from sub       | 90               | 5.64            | Aircraft/Missile 6 | 1987 |
|                         | Late delivery of equipment                                           | 51               | 8.63            | Simulator 1        | 1989 |
|                         | Late delivery of equipment items                                     | 64               | 14.22           | Simulator 1        | 1989 |
|                         | Late delivery of H/W items                                           | 76               | 8.89            | Simulator 1        | 1989 |
|                         | Did not receive SW & H/W from vendor                                 | 60               | 38.82           | Simulator 2        | 1994 |
|                         | Late receipt of materials                                            | 34               | 1.81            | Simulator 3        | 1991 |
|                         | Late receipt of vendor H/W                                           | 636              | 21.93           | Simulator 4        | 1985 |
|                         | Late delivery of connectors to subcontractor                         | 126              | 0.83            | Aircraft/Missile 2 | 1993 |
|                         | Late receipt of carriers/sockets/cable material at sub               | 570              | 1.04            | Aircraft/Missile 2 | 1993 |
|                         | Subcontractor material late                                          | 1743             | 4.61            | Aircraft/Missile 2 | 1993 |
|                         | Test station material not received at sub                            | 370              | 2.45            | Aircraft/Missile 2 | 1993 |
|                         | Late receipt of materials at subcontractor                           | 399              | 0.73            | Aircraft/Missile 2 | 1993 |
|                         | Late receipt of procured tooling at sub                              | 216              | 2.26            | Aircraft/Missile 2 | 1993 |
|                         | Slower than planned sub start up                                     | 17               | 2.05            | A/C Equipment 1    | 1990 |
|                         | Slower than planned sub start up                                     | 26               | 3.14            | A/C Equipment 1    | 1990 |
| Slow Progress           | Slower than planned sub start up                                     | 24               | 2.54            | A/C Equipment 1    | 1990 |
|                         | Disk storage subcontractor not maintaining schedule                  | 237              | 3.32            | A/C Equipment 2    | 1987 |
|                         | Vendor delay in bench qualifying fuel control unit                   | 125              | 8.57            | A/C Equipment 4    | 1984 |
|                         | Subcontractor behind schedule in computer H/W delivery               | 223              | 1.41            | Aircraft Upgrade 2 | 1994 |
|                         | Delayed milestone achievements by SW vendor                          | 316              | 4.37            | Aircraft/Missile 2 | 1993 |
|                         | Supplier material delays on alternate film selection                 | 53               | 0.89            | Aircraft/Missile 2 | 1993 |
|                         | Subcontractor delays in reaching development milestones              | 707              | 1.29            | Aircraft/Missile 2 | 1993 |
|                         |                                                                      |                  |                 |                    |      |
|                         |                                                                      |                  |                 |                    |      |
|                         |                                                                      |                  |                 |                    |      |
| Test Problems           | CI testing delays tech pub procurements                              | 48               | 3.85            | A/C Equipment 3    | 1989 |
|                         | SW testing difficulties                                              | 16               | 3.12            | A/C Equipment 3    | 1989 |
|                         | Test delays in hot/cold mission sim, hot endurance, vibe/shock tests | 149              | 17.16           | A/C Equipment 4    | 1986 |
|                         | Failure of elastomers/suspension system of system container          | 95               | 19.35           | A/C Equipment 4    | 1985 |
|                         |                                                                      |                  |                 |                    |      |

| Category                    | Reason for Schedule Variance                                       | Variance (\$000) | Variance (Days) | Program            | Year |
|-----------------------------|--------------------------------------------------------------------|------------------|-----------------|--------------------|------|
|                             | Sub simulation testing delays                                      | 110              | 1.20            | Aircraft/Missile 2 | 1993 |
|                             | L-band variances caused test time to slip for sub                  | 119              | 0.21            | Aircraft/Missile 2 | 1993 |
|                             | Slips in special testing                                           | 238              | 0.54            | Aircraft/Missile 2 | 1993 |
|                             | Delays in dielectric testing by sub                                | 53               | 0.89            | Aircraft/Missile 2 | 1993 |
|                             | DT&E problems                                                      | 68               | 2.54            | Aircraft/Missile 5 | 1984 |
|                             | Delay in receipt of test assets                                    | 13               | 0.53            | Aircraft/Missile 5 | 1984 |
|                             | Schedule delays in canopy jettison test                            | 31               | 1.26            | Aircraft/Missile 5 | 1984 |
|                             | Unplanned instrumentation modification delaying flight test        | 80               | 5.37            | Aircraft/Missile 6 | 1988 |
|                             | SWW problems during flight test                                    | 259              | 57.56           | Aircraft/Missile 6 | 1988 |
|                             | Non-completion of qual test line items                             | 761              | 9.72            | Aircraft/Missile 6 | 1986 |
|                             | Component difficulties during qual testing                         | 1675             | 21.01           | Aircraft/Missile 7 | 1989 |
| <b>Technical Definition</b> |                                                                    |                  |                 |                    |      |
| Finalizing Requirements     | Delays in requirement/specification generation                     | 21               | 2.31            | A/C Equipment 1    | 1990 |
|                             | Late definition of effort to sub                                   | 74               | 2.36            | A/C Equipment 1    | 1990 |
|                             | Late definition of sub requirements                                | 35               | 3.44            | A/C Equipment 1    | 1990 |
|                             | Unavailability of specs delaying S/W requirements analysis         | 39               | 9.98            | A/C Equipment 1    | 1990 |
|                             | Delay in specification generation                                  | 88               | 16.69           | A/C Equipment 1    | 1990 |
|                             | Delay in final design specifications                               | 54               | 8.08            | A/C Equipment 1    | 1989 |
|                             | Delay in requirements/specs                                        | 31               | 4.04            | A/C Equipment 1    | 1990 |
|                             | S/W delays due to late microprocessor selection                    | 14               | 4.22            | A/C Equipment 1    | 1989 |
|                             | Lag in microprocessor and design methodology selection             | 21               | 6.24            | A/C Equipment 1    | 1989 |
|                             | Delay in microprocessor/design methodology selection               | 12               | 3.26            | A/C Equipment 1    | 1989 |
|                             | Consolidating digital imagery operations concept                   | 237              | 3.32            | A/C Equipment 2    | 1987 |
|                             | Rework of requirements test allocations and methods                | 48               | 11.00           | A/C Equipment 2    | 1987 |
|                             | Interface specs not approved by associate ktrs or Gov't            | 33               | 4.43            | A/C Equipment 2    | 1988 |
|                             | Interface specification development delays                         | 15               | 1.78            | A/C Equipment 2    | 1987 |
|                             | Late design definition                                             | 266              | 4.71            | A/C Equipment 2    | 1988 |
|                             | Simulator not complete - must resolve interfaces                   | 45               | 3.85            | A/C Equipment 3    | 1989 |
|                             | S/W requirements not finalized                                     | 16               | 2.21            | A/C Equipment 3    | 1989 |
|                             | Subktr delays with top level design                                | 28               | 2.21            | Aircraft Upgrade 1 | 1985 |
|                             | Lack of flight test instrumentation definition                     | 13               | 1.75            | Aircraft Upgrade 1 | 1987 |
|                             | Vendor negotiations on spec control dwg defining antenna footprint | 16               | 0.42            | Aircraft Upgrade 2 | 1992 |

| Category                 | Reason for Schedule Variance                                               | Variance (\$000) | Variance (Days) | Program            | Year |
|--------------------------|----------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Poor Req'mnts Definition | Late identification/complexity of requirements                             | 45               | 2.55            | Aircraft Upgrade 6 | 1994 |
|                          | Late design definition                                                     | 645              | 0.60            | Aircraft/Missile 1 | 1989 |
|                          | Product definition changes causing parts shortages                         | 644              | 6.73            | Aircraft/Missile 1 | 1990 |
|                          | Continuing product definition changes causing parts/material shortage      | 862              | 7.50            | Aircraft/Missile 1 | 1990 |
|                          | Late engineering designs impacting test and evaluation                     | 1065             | 3.28            | Aircraft/Missile 1 | 1989 |
|                          | Late design definition impacting material orders                           | 252              | 3.03            | Aircraft/Missile 1 | 1990 |
|                          | Delayed receipt of test technical requirements                             | 82               | 0.71            | Aircraft/Missile 1 | 1990 |
|                          | Slip in spec/requirements definition for RF systems                        | 238              | 0.54            | Aircraft/Missile 2 | 1993 |
|                          | Security issues related to elec warfare aperture fabrication               | 238              | 0.54            | Aircraft/Missile 2 | 1993 |
|                          | Test effort suspension awaiting resolution of SOW issues                   | 20               | 2.80            | Aircraft/Missile 5 | 1982 |
|                          | Delay in system hardware requirements definition                           | 183              | 3.47            | Simulator 2        | 1991 |
|                          | Design issue resolution delaying effort                                    | 34               | 1.81            | Simulator 3        | 1991 |
|                          | Lack of line replaceable unit definition                                   | 30               | 5.69            | A/C Equipment 1    | 1990 |
|                          | Incomplete specifications                                                  | 43               | 5.80            | A/C Equipment 1    | 1989 |
|                          | Design reqmnts for LRU block diagrams / computer interface more than plan  | 6                | 0.45            | Aircraft Upgrade 1 | 1985 |
|                          | Incorrect envelope definition to sub delayed CDR                           | 347              | 3.45            | Aircraft Upgrade 2 | 1992 |
|                          | Changes in structural config due to systems integration                    | 146              | 1.32            | Aircraft/Missile 2 | 1993 |
|                          | Unplanned effort by sub to mount displays impacting analysis and test      | 446              | 2.45            | Aircraft/Missile 2 | 1993 |
|                          | Slip of Specs/PDR due to gov't needing more detailed specs than envisioned | 54               | 9.74            | Aircraft/Missile 3 | 1991 |
| Technical Problems       | Analysis Problems                                                          | 61               | 2.39            | Aircraft Upgrade 6 | 1993 |
|                          |                                                                            | 87               | 5.23            | Aircraft Upgrade 6 | 1993 |
|                          |                                                                            | 339              | 7.82            | Aircraft/Missile 2 | 1993 |
|                          |                                                                            | 60               | 0.11            | Aircraft/Missile 2 | 1993 |
|                          | Coordination                                                               | 26               | 8.80            | A/C Equipment 2    | 1983 |

| Category             | Reason for Schedule Variance                                      | Variance (\$000) | Variance (Days) | Program            | Year |
|----------------------|-------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Design Problems      | Open microprocessor spec/design issues                            | 59               | 18.54           | A/C Equipment 1    | 1989 |
|                      | Design errors delaying integration effort                         | 338              | 4.16            | A/C Equipment 2    | 1987 |
|                      | Digital design tasks more complex than originally envisioned      | 14               | 0.82            | Aircraft Upgrade 1 | 1985 |
|                      | Delayed vendor deliveries resulting from design problems          | 442              | 6.06            | Aircraft Upgrade 3 | 1992 |
|                      | Test equipment design not completed                               | 1273             | 9.04            | Aircraft Upgrade 4 | 1991 |
|                      | Delays in power supply design activity                            | 217              | 0.63            | Aircraft/Missile 2 | 1993 |
|                      | Power supply spec more challenging than anticipated               | 505              | 1.17            | Aircraft/Missile 2 | 1993 |
|                      | Sub design delays in GPS chip slipped test schedule               | 540              | 0.96            | Aircraft/Missile 2 | 1993 |
|                      | Late sub display H/W design delaying ordering of material         | 149              | 0.82            | Aircraft/Missile 2 | 1993 |
|                      | Delays in completion of electrical and packaging design by sub    | 689              | 1.38            | Aircraft/Missile 2 | 1993 |
|                      | Sub Radome design effort behind schedule                          | 53               | 0.89            | Aircraft/Missile 2 | 1993 |
|                      | Delays in printed circuit board layouts by sub                    | 335              | 0.74            | Aircraft/Missile 2 | 1993 |
|                      | Late engineering design                                           | 39               | 11.00           | Aircraft/Missile 4 | 1989 |
|                      | Vendor design problems delay autopilot task start                 | 86               | 14.67           | Aircraft/Missile 6 | 1987 |
|                      | Effort on other component delays this component's detailed design | 34               | 3.12            | Simulator 3        | 1991 |
|                      |                                                                   |                  |                 |                    | 1990 |
|                      | SW management tasks not complete                                  | 14               | 0.65            | A/C Equipment 1    | 1989 |
|                      | Delays in man-machine interface and graphics SW                   | 41               | 8.59            | A/C Equipment 2    | 1983 |
|                      | SW problems                                                       | 5                | 13.75           | A/C Equipment 2    | 1982 |
| Development Problems | Subcontractor SW coding difficulties                              | 16               | 0.82            | A/C Equipment 2    | 1983 |
|                      | SW code and test delays                                           | 34               | 1.75            | A/C Equipment 2    | 1983 |
|                      | Problems with calibration and geopotitioning SW and data bases    | 25               | 21.15           | A/C Equipment 2    | 1988 |
|                      | H/W & SW slips delayed QA activity                                | 65               | 2.92            | A/C Equipment 3    | 1989 |
|                      | Late completion of printed circuit boards - Engr probs            | 128              | 7.91            | A/C Equipment 3    | 1989 |
|                      | Difficulties with SW to SW integration                            | 16               | 3.12            | A/C Equipment 3    | 1989 |
|                      | H/W & SW slips delay system integration                           | 89               | 6.12            | A/C Equipment 3    | 1990 |
|                      | Delayed SW development impacts computer security task             | 32               | 2.75            | A/C Equipment 3    | 1990 |
|                      | SW development problems delay integration                         | 57               | 3.14            | A/C Equipment 3    | 1990 |
|                      | Tech manuals lagging due to late system development               | 91               | 9.91            | A/C Equipment 3    | 1991 |
|                      | Late CI Completion                                                | 51               | 6.27            | A/C Equipment 3    | 1989 |
|                      | SW development delays                                             | 16               | 1.15            | Aircraft Upgrade 1 | 1985 |
|                      | Sub behind in component development                               | 5066             | 16.20           | Aircraft Upgrade 3 | 1989 |

| Category    | Reason for Schedule Variance                                                | Variance (\$000) | Variance (Days) | Program            | Year |
|-------------|-----------------------------------------------------------------------------|------------------|-----------------|--------------------|------|
| Task Growth | Delayed detailed development of subsystem algorithms by subcontractor       | 18               | 0.79            | Aircraft Upgrade 5 | 1990 |
|             | Avionics simulation effort suspended due to mission computer delays         | 293              | 2.57            | Aircraft/Missile 1 | 1989 |
|             | Mission computer development problems (sub)                                 | 1800             | 19.01           | Aircraft/Missile 1 | 1989 |
|             | Late mission computer H/W and S/W development by sub                        | 2046             | 17.50           | Aircraft/Missile 1 | 1989 |
|             | Delay in electronic flight control units to support auto test equip develop | 935              | 13.45           | Aircraft/Missile 1 | 1989 |
|             | Mission computer effort falling behind schedule                             | 1952             | 21.68           | Aircraft/Missile 1 | 1988 |
|             | Slips in sub evaluating integrated circuits                                 | 335              | 0.74            | Aircraft/Missile 2 | 1993 |
|             | Sub delays in developing electrical components                              | 394              | 11.75           | Aircraft/Missile 2 | 1993 |
|             | Delays in component development by sub                                      | 303              | 0.55            | Aircraft/Missile 2 | 1993 |
|             | Sub power system development delays                                         | 110              | 1.20            | Aircraft/Missile 2 | 1993 |
|             | Delays in computer development by sub                                       | 111              | 0.20            | Aircraft/Missile 2 | 1993 |
|             | Not starting terrain following development as scheduled                     | 82               | 4.67            | Aircraft/Missile 6 | 1985 |
|             | Documentation more difficult than anticipated                               | 14               | 4.46            | Simulator 1        | 1989 |
|             | Progress on S/W code and test less than anticipated                         | 61               | 1.74            | Simulator 2        | 1994 |
|             | S/W code and unit test taking longer than expected - impacting integration  | 29               | 1.54            | Simulator 3        | 1991 |
|             | Delay in obtain, modify, and validate S/W                                   | 57               | 6.12            | Simulator 3        | 1990 |
|             | Difficulty finding parts to meet EMI and pulse shape specs                  | 24               | 2.20            | Simulator 3        | 1991 |
|             |                                                                             |                  |                 |                    | 1990 |
|             | Increase in sub component complexity to meet system spec                    | 88               | 10.19           | A/C Equipment 1    | 1990 |
|             | Technical difficulties associated with H/W algorithms                       | 13               | 6.09            | A/C Equipment 2    | 1982 |
|             | Problems with S/W automated test tool and code growth                       | 16               | 3.12            | A/C Equipment 3    | 1989 |
|             | S/W Code Growth significantly increased integration effort                  | 36               | 13.20           | A/C Equipment 3    | 1991 |
|             | Unplanned redesign due to tech problems                                     | 92               | 5.37            | Aircraft Upgrade 1 | 1985 |
|             | Unplanned software development                                              | 49               | 0.21            | Aircraft/Missile 1 | 1989 |
|             | Unplanned beam fabrication                                                  | 49               | 0.21            | Aircraft/Missile 1 | 1989 |
|             | Prep/support for weight reduction issues                                    | 146              | 1.32            | Aircraft/Missile 2 | 1993 |
|             | Complexities in loads, durability, and damage tolerance analyses            | 146              | 1.32            | Aircraft/Missile 2 | 1993 |
|             | Mockup/aircraft inconsistencies caused redesign (integration problem)       | 71               | 8.40            | Aircraft/Missile 4 | 1989 |
|             | Weight avoidance efforts delaying drawing release                           | 69               | 1.42            | Aircraft/Missile 5 | 1982 |
|             | Non completion of operational flight program S/W recode effort              | 94               | 9.53            | Aircraft/Missile 6 | 1987 |
|             | Unanticipated rework of graphics                                            | 68               | 5.50            | Simulator 2        | 1991 |

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## *Vita*

Captain William M. Cashman was born on 10 August 1967 in Boston, Massachusetts. In 1989, as a brand new Second Lieutenant commissioned through Air Force R.O.T.C., he graduated from Cornell University with a Bachelor of Science degree in Electrical Engineering. His first assignment was to Wright-Patterson AFB, where he joined the Joint Tactical Weapons System Program Office (SPO), first as a trainee in program control, then as the day-to-day project manager for the Tacit Rainbow anti-radar air-to-ground standoff missile Full Scale Development program. In 1992, he moved to the Electronic Combat SPO to become a project manager for the Joint Modeling and Simulation System (J-MASS), a software system designed to provide a common way to build, use, and reuse models and simulations throughout the DoD. In 1994, after completing Squadron Officer School in residence, he entered the Graduate Systems Management program of the School of Logistics and Acquisition Management, Air Force Institute of Technology (AFIT). In 1995, after completing his Master of Science degree in Systems Management at AFIT, he moved to Los Angeles AFB, where he is currently working as a project manager on advanced space systems.

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