AFIT/GSS/LSC/92D-5

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DEVELOPMENT OF A PROTOTYPE
AIR FORCE INSTITUTE OF TECHNOLOGY (AFIT)
RESEARCH MANAGEMENT SYSTEM (ARMS)

THESIS

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DEVELOPMENT OF A PROTOTYPE AIR FORCE INSTITUTE OF TECHNOLOGY (AFIT) RESEARCH MANAGEMENT SYSTEM (ARMS)

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Software Systems Management

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David N. Schaaf
Carl W. Scott

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Abstract

The goal of this study was to design, develop, test, and evaluate an initial prototype information system to enhance the conduct and management of research in the School of Systems and Logistics at the Air Force Institute of Technology (AFIT). To accomplish this goal, the authors developed the prototype system based on a methodology that was generally patterned after the milestones in a typical system development life cycle. The "proof-of-concept" nature of this research caused the researchers to map the study's seven major objectives into a second system development model called the Spiral Model (Boehm, 1988:61). This hybrid model provided better defined steps in a model that allows for iterative prototyping and served as the framework for this project.

This study's objectives were completed by collecting data using a structured interview, literature review, requirements validation effort, and a prototype evaluation questionnaire. The analytical portions of the research included: (1) an examination of alternatives to building the prototype; (2) the selection of automation requirements and prototype architecture; and (3) a determination of the prototype's technical adequacy and suitability.

The prototype AFIT Research Management System (ARMS) produced by this study is comprised of four major subsystems: the Research Topic Selection Subsystem, Research Products Reuse Subsystem, Research Management Subsystem, and Database Administration Subsystem. An operational test of the first three subsystems was completed using a

series of demonstrations that were attended by 47 graduate students and 11 faculty members. An analysis of the questionnaires completed by the testers validated the desirability of the system concept and provided many recommendations for improving it. Recommendations for research were developed concerning the follow-on development of the prototype and the conduct of corollary studies. The corollary studies listed in Chapter V represent a number of key issues that should be addressed prior to implementing an advanced prototype or operational system.

DEVELOPMENT OF A PROTOTYPE AIR FORCE INSTITUTE OF TECHNOLOGY (AFIT) RESEARCH MANAGEMENT SYSTEM (ARMS)

I. Introduction

General Issue

The goals of increased productivity and process improvement have received considerable attention during this century. The literature suggests that most of these efforts have concentrated on achieving immediate economic results in manufacturing operations, rather than "non-manufacturing" endeavors such as research (Tenner, 1991:27). However, research has been significantly enhanced during recent years through the increased use of computer technology (Straub and Beath, 1990:30). A major contributor to this progress was the application of computerized databases as "information delivery systems" (Straub and Beath, 1990:30). The general success of past automation efforts, combined with the dynamic nature of computer science, suggests that future gains in researcher productivity may be derived from the further application of information systems and other computer science techniques.

Background

The current state of research, in academe and industry, indicates a strong need for improvement. John Gilman, a forty-year veteran in the field of research, estimates that approximately ninety percent of all research conducted does not lead to recognizable benefits. Despite this bleak appraisal, research can still be profitable if the available resources (funds, personnel, facilities, and equipment) are managed effectively (Gilman, 1991:44).

The literature posits that good research management is practiced by facilitating researcher creativity and productivity rather than strictly directing results. A practical and proven approach to this situation is to build and cultivate a research environment that:

1. Creates new technical ideas by first assimilating existing ideas and combining them in new ways.

2. Remains focused during "failures" while striving for state-of-the-art results.

3. Possesses (or has access to) first-rate technical, analytic, library, and other services and equipment.

4. Provides for effective communications among researchers, between researchers and other members of the organization, and outward to sponsors. (Gilman, 1991:47)

In striving to meet similar objectives at the Air Force Institute of Technology (AFIT) School of Systems and Logistics (LS), the faculty has earnestly examined and is still evaluating several research program enhancements. The faculty's efforts have resulted in improvements within the areas of academic research education and informal guidance ("tips and techniques" newsletters) dissemination (Emmelhainz, 1991c).

One of the most significant enhancement efforts was the recent implementation of the "team thesis." Under this initiative, research teams of two students are guided by an advising committee with two or more faculty members. The goals of the team thesis include: the improvement of the students' capabilities to examine problems of greater scope and significance; the promotion of greater objectivity in research studies; and the enhancement of the thesis advising process (Emmelhainz, 1991c).

Despite the potential "manpower" benefits offered by the team thesis, this technique does not address many difficulties that inherently affect student researcher productivity (Emmelhainz, 1991c). A detailed description of the most important difficulties is provided in Chapter II. The intent of this study was to examine two such difficulties, research topic selection and research product reuse, and to develop a prototype system that would assist future student researchers by automating a portion of these functions. A prime consideration in the selection of these two items was their description in the literature as key tasks in the academic research process (Allen, 1973:viii,11, and 51; Madsen, 1983:21; Emory and Cooper, 1991:76).

Early in this study, the authors recognized that the detailed level of information contained in the proposed prototype system could be used to automate several AFIT LS research management tasks. This insight led the authors to include some rudimentary procedures for selected research management tasks. More importantly, it resulted in the development of a design to facilitate future incremental expansion as additional areas of the research domain are examined and automated.

Specific Research Goal

The goal of this research project was to design, develop, test, and evaluate an initial prototype information system to enhance the conduct and management of research in the School of Systems and Logistics at the Air Force Institute of Technology.

Research Objectives

This study's research objectives were generally patterned after the milestones in a typical system development life cycle (Senn, 1984:17). However, the "proof-of-concept" nature of this study led the authors to also view these objectives as part of a meta-model called the spiral life cycle model for system development (Boehm, 1988:61-72). By doing so, the authors were identifying this research as the initial phase in an effort that would require continued study. The specific application of the spiral model in this project and justification for its selection are further explained in Chapters II and III.

The following specific objectives guided the completion of this research project:

1. Describe the current AFIT research environment.
2. Define and validate the AFIT Research Management System (ARMS) requirements.
3. Analyze alternatives and select prototype constraints.
4. Design and develop the prototype system.
5. Perform an operational test of the prototype system.
6. Analyze and interpret operational test results.
7. Develop recommended path for follow-on research.

Each of these objectives involved the completion of two or more component steps, which are described in Chapter III.

Limitations

Due to time constraints, the initial prototype could not encompass all validated requirements. Therefore, the design of the ARMS contains only those requirements deemed necessary to determine the feasibility and suitability of the system. The selection process used to determine the representative capabilities for this version of the prototype strongly favored implementing the requirements related to student researcher productivity and proving the system's overall suitability to enhance the AFIT research environment.

Since the goal of this study was "proof-of-concept" oriented, a formal strategy for implementing and managing a "production-quality" system was not developed. However, a discussion of several practical recommendations is provided in Chapter V. Similarly, this study does not provide solutions to the problems associated with implementing and managing reuse programs, as described in Chapter II.

The development tools used to implement the prototype system were limited to those available at AFIT during the time of the study. This restriction was self-imposed to: (1) use the available "in-house" expertise within the AFIT Directorate of Communication and Computer Systems; (2) maximize the prototype's reusability for future research and improvement efforts; and (3) minimize the cost of the project.

Assumptions

In completing this study, the authors assumed that their status as student researchers qualified the contributions they made in formulating the requirements for the ARMS. Additionally, the authors based several prototype implementation decisions on their previous information systems development experiences. However, information system experts from the AFIT faculty and support staffs were consulted on some critical decisions related to the prototype's extendibility.

Contributions of the Research

Three specific areas of research were addressed during the development of the prototype ARMS: research topic selection, research products reuse, and research management. Each of these areas was treated as an equal subsystem of the prototype throughout the conduct of this research. A synopsis of the justification for, and benefits of, this study is provided in this section.

Research Topic Selection. The current method of researching potential academic research topics primarily involves the use of manual procedures. The available automated systems provide general access to a variety of past studies, but do not supply information concerning ongoing research or new requests for research. Within the context of the current AFIT research environment (described in Chapter II), the automation of these two key sources of information will help AFIT LS student researchers:

1. Begin the process of selecting and formulating a research topic earlier in their graduate program.
2. Review a broader range of research topics more expediently and efficiently.
3. Scope their selected research problem.
4. Select topics that lend themselves to longitudinal study.

The final implementation of the ARMS Research Topic Selection Subsystem (RTSS) could also increase the school's potential for qualitative and quantitative gains in the areas of continuing research studies and the communication of research needs.

Research Products Reuse. This study also adapted and applied an emerging computer science technique called software reuse. This technique is commonly defined as "the use of previously acquired or developed concepts and objects in a new situation" (Prieto-Diaz, 1987:7). In the area of software development, reuse concepts and objects are major components or products that comprise the overall system, such as source code modules, program architectures, and documentation (Jones, 1984:488-489). The analogous application of this technique to the academic research domain yielded the following types of reusable components: data collection instruments, data sets, statistical models, computer programs, and other products.

The current practice of cataloging only the thesis document inhibits the reuse of such components for two main reasons: (1) they are often difficult to locate, and (2) they normally require extensive manual effort to recreate. The Research Products Reuse Subsystem (RPRS) developed as part of this study represents an initial attempt at cataloging, tracking, and managing research products for the purpose of facilitating their location, review, and reuse by students. It was not possible to determine the quantitative value of the RPRS during this study, but the operational test results indicate that it could provide productivity gains similar to those experienced with software reuse.

Research Management. During early discussions of this project with the research director in each AFIT school, the authors became aware of an inherent need for a well-structured, reliable source of research program information. As focal points for summarizing and formally reporting each school's research efforts, the directors employ several unique automated and non-automated systems. The format, collection, and management of academic research information varies widely for each current system. In addition, the systems provide little or no trend-tracking capability and do not offer an integrated view of the respective research programs.

The prototype design for the ARMS Research Management Subsystem (RMS), combined with the two ARMS subsystems described above, integrates most of the data elements currently spread across several inflexible, single-purpose databases managed by the AFIT LS Thesis Program Administrator. The querying, reporting, and managing facilities implemented in the RMS provide a general framework which can be expanded and refined during future research efforts. The potential productivity gains offered by the RMS are not measurable at this time and could be tempered by the administrative overhead required to learn and maintain the system. Future research should examine the overall system in terms of a cost-benefit analysis.

Sequence of Presentation

This report is divided into five chapters. This chapter provided a description of the study's background, specific research goal, research objectives, and limitations. Chapter II contains a description of the current AFIT LS research environment and presents a literature review in the areas of research, reuse, and information systems. Chapter III describes the methodology used to meet the seven objectives of this study. Chapter IV reviews the specific research findings as they relate to each objective described in Chapter III. Chapter V provides conclusions and offers recommendations for further research.

II. Literature Review

Overview

The goal of this research was to design, develop, test, and evaluate a prototype information system to enhance the conduct and management of academic research at the Air Force Institute of Technology (AFIT) School of Systems and Logistics (LS). To support this end, the three major areas which comprise the study's problem domain and solution components--research, reuse, and information systems--were examined. This chapter begins with a review of the overall AFIT and LS-specific research programs, and then turns to a discussion of some major difficulties facing student researchers. The next section describes the concept of reuse and how it contributed to this project's theoretical foundation. The final section of this chapter discusses basic information system principles and the life cycle model employed to develop the prototype ARMS.

Research

The term "research" has diverse meanings depending on the situation and discipline of its practitioners (Lindsay and Neumann, 1988:32). As a result, the literature contains a variety of definitions and countless guidelines for conducting, managing, evaluating, and funding research. To gain an understanding of the research program at AFIT, the authors conducted a structured interview with the research director for each of AFIT's three schools. The interview results were analyzed in light of the current literature on research to complete this section and research objective one.

AFIT Research Program. The formal mission of AFIT is to "support national defense through graduate and professional education and research programs" (AFIT, 1990:I-1). At the start of this study, AFIT was comprised of several support directorates and three resident schools: the School of Systems and Logistics (LS), School of Engineering (EN), and School of Civil Engineering and Services (DE). Several changes have occurred in that organizational structure during the past year, but the overall mission of the Institute remains the same.

Research Environment. Research is an integral part of the AFIT mission and is conducted by both faculty and students. Faculty research ensures the currency of course content, promotes the continued intellectual growth of the faculty, contributes to a discipline's body of knowledge, and meets the specific needs of the United States Air Force (USAF) and Department of Defense (DoD). The primary purpose of student research is to enrich the overall educational experience by contributing to a discipline's body of knowledge and the missions of the USAF and DoD (AFIT, 1990:I-5).

Each resident school has a research director to coordinate ongoing research programs (AFIT, 1990:X-1). The directors have two sets of responsibilities; one for managing the external, or promotional, aspects of the research program, and a second for administering the internal aspects of the program. The main external responsibilities of these directors are:

a. to make [their school] an effective part of the problem-solving capability of the Air Force;

b. to make the Air Force fully aware of [their school's] capabilities in research and consultations;

c. to help obtain funding and other forms of research sponsorship; and

d. to serve as ombudsman for research bottlenecks. (Bridgman, 1991; Duncan, 1991; Emmelhainz, 1991a)

The research directors' internal responsibilities are discussed later in this section.

Similarities Among School Research Programs. Personal interviews conducted with the research directors highlighted several program similarities. All three directors strongly affirmed the need for research to be faculty-driven. Accordingly, they agreed that faculty consulting work with USAF and DoD agencies, as well as contacts with other professionals, should serve as the basis for both faculty and student research. However, two of the three research directors indicated that student research was not currently guided by this approach in their respective schools (Bridgman, 1991; Duncan, 1991; Emmelhainz, 1991a).

Another similarity among the DE, EN, and LS research programs was the "passive" internal management style practiced by the research directors. Each director espoused the often described approach in the literature of providing the needed resources and then letting the practitioners conduct their research studies with minimal oversight. In this role, the directors and their staffs serve as collection points, storehouses, and dissemination points for information (Bridgman, 1991; Duncan, 1991; Emmelhainz, 1991a).

Two of the more prolific "information handling" activities performed by the research directors and their staffs are the "call for thesis topics" and development of inputs for the annual report, "AFIT

Contributions to Air Force Research and Consulting." The first activity is conducted annually to canvass DoD organizations for pertinent research topics. Its purpose is to complement the supply of topics generated through faculty research and consulting. The latter activity is a post-academic year effort to summarize, assess, and formally report the contributions made by AFIT faculty and student researchers (Bridgman, 1991; Emmelhainz, 1991a).

The research directors' staffs perform many additional "information handling" tasks. These tasks include the maintenance of detailed records concerning research completion status, formal publication information, thesis advisor qualifications, and sponsorship statistics. Each school currently employs a number of manual and automated record-keeping systems to accomplish these functions; however, none offers a well-structured, integrated view of the information available within the respective research programs. In recognition of this fact, the DE and LS research directors strongly supported this study's goal of building a prototype system for integrating the varied sources of research information. They further stated that the system could greatly aid the conduct and management of their school's programs (Duncan, 1991; Emmelhainz, 1991a).

Differences Among School Research Programs. Personal interviews with the research directors revealed few significant differences among the three schools' research programs. The most important difference concerned the opposing philosophies that exist on thesis topic selection by students. In DE and LS, students may develop their own topics or select them from other sources (Duncan, 1991;

Emmelhainz, 1991a). EN students are required to complete their theses on funded, sponsored, or continuing research topics. As a result, very few student-derived topics have been approved over the last several years (Bridgman, 1991).

The differing philosophies on thesis topic selection have yielded somewhat predictable results in the area of continuing studies. DE and LS have conducted relatively few recent continuing studies (Duncan, 1991; Emmelhainz, 1991a), while EN has a long history of performing such studies (Bridgman, 1991). The DE and LS research directors both indicated that an increase in continuing studies could be realized if incoming students had an improved method for accessing information about previously completed and ongoing research studies (Duncan, 1991; Emmelhainz, 1991a). At the suggestion of these directors, the requirement for this capability was added to the prototype ARMS functional description.

Research Support Facilities. The overall AFIT research program is supported by a variety of campus and Wright-Patterson Air Force Base facilities. A major campus resource is the academic library, which provides a host of useful services. The library's current collections include over 85,000 books, 1,350 science and management journals, and 850,000 government-sponsored technical reports. These resources are augmented by a large audiovisual materials library and many computerized catalog systems. The automated support encompasses a number of major systems, such as those managed by the Defense Technical Information Center (DTIC), National Aeronautics and Space Administration (NASA), DIALOG Informational Service, and On-line Computer Library

Center (OCLC). In addition to its material resources, the library has a trained reference staff to assist researchers with bibliographic searches and other library-oriented services (AFIT, 1990:IX-2 - IX-4).

The AFIT campus is further complemented by a series of specialized research laboratories and an extensive network of computer systems. Modern laboratories are available to support the following EN disciplines: Aeronautics and Astronautics; Electrical and Computer Engineering; Navigation, Guidance, and Control; Robotics Systems; and Engineering Physics (AFIT, 1990:IX-7 - IX-12). Each school also maintains several computer laboratories that provide access to general purpose (word processing, database, communications) and specialized software applications (AFIT, 1990:IX-14).

AFIT's geographic location at Wright-Patterson Air Force Base, one of the Air Force's leading research and development facilities, provides researchers with access to numerous additional resources (AFIT, 1990:IX-7). The tenth edition of the Directory of Libraries and Information Centers at Wright-Patterson Air Force Base, published by the Wright Research and Development Center (WRDC), describes twenty-two major sources of information and reference material (Wright Research and Development Center, 1990). The base is also home to several research, development, test and evaluation laboratories, and a number of key procurement and materiel management agencies, such as the Air Force Materiel Command headquarters, Aeronautical Systems Center, and Foreign Aerospace Systems Technology Center (AFIT, 1990:IX-7).

LS Student Research Program. The LS student research program is governed by LS Operating Instruction (LSOI) 50-3, "Thesis Research Program." According to this document, the program's goals are to:

a. provide students the opportunity to gain experience in problem analysis, independent research, and written expression;

b. enhance student knowledge in one of six specialized areas: Logistics Management, Systems Management, Information Systems Management, Cost Analysis, Contracting Management, or Software Systems Management; and

c. identify military management problems and contribute to the solution of those problems. (LSOI 50-3, 1992:1)

Process-Oriented Focus. In line with this guidance, LS student theses are viewed as more than just a product. According to the LS research director, careful consideration and evaluation of the process used to derive and document results are essential aspects of conducting a quality research program. Figure 2-1 contains a general research process model that is presented to each incoming class of LS students in a thesis overview briefing by the LS research director. The model is intended to serve as a guide for new students; although it may require modification for use in specific studies (Emmelhainz, 1991c).

General Research Process Model

1. Select, define, and scope the problem.
2. Develop a concept map or organization chart.
3. Collect or create data.
4. Analyze data and determine problem solution.
5. Arrange material for report.
6. Produce the report (thesis text).

Figure 2-1. General Research Process Model (Emmelhainz, 1991)

Schedule. The LS student research program has a set of established milestones that guides students through the thesis process. Figure 2-2 shows the approximate schedule of major student research activities for the 1992 academic year. This schedule was generally applicable to most degree programs; however, some students completed COMM 687 and COMM 630 one academic quarter later than the indicated timeframe (LSOI 50-1, 1991). In addition, the Figure 2-2 example is normally supplemented by a more detailed, student-generated schedule that covers the execution of the specific thesis methodology and forms the basis for the agreement between the thesis committee and student team members (LSOI 50-3, 1992:2).

Responsibilities. Several people share responsibilities with students to assure the qualitative completion of theses. These individuals include personnel from the research director's staff (which is formally referred to as the Office of Research and Consulting), the degree program/option manager, and the thesis committee advisors. LSOI 50-3 describes their specific responsibilities as follows:

a. The Office of Research and Consulting (LSC) will:

(1) Administer and supervise the thesis research program.
(2) Collect potential research topics.
(3) Coordinate faculty review and screening of topics.
(4) Prepare faculty-approved topics for student review.
(5) Maintain a list of potential advisors with research interests and qualifications.
(6) Monitor selection of committee advisors for student teams.
(7) Prescribe format and administrative requirements for preparation of the final copy of the thesis.
(8) Review the final copy of the thesis to ensure compliance with the prescribed format.
(9) Supervise the publication and distribution of theses.

b. Program/Option Managers will:

(1) Collect potential research topics related to their program/option.

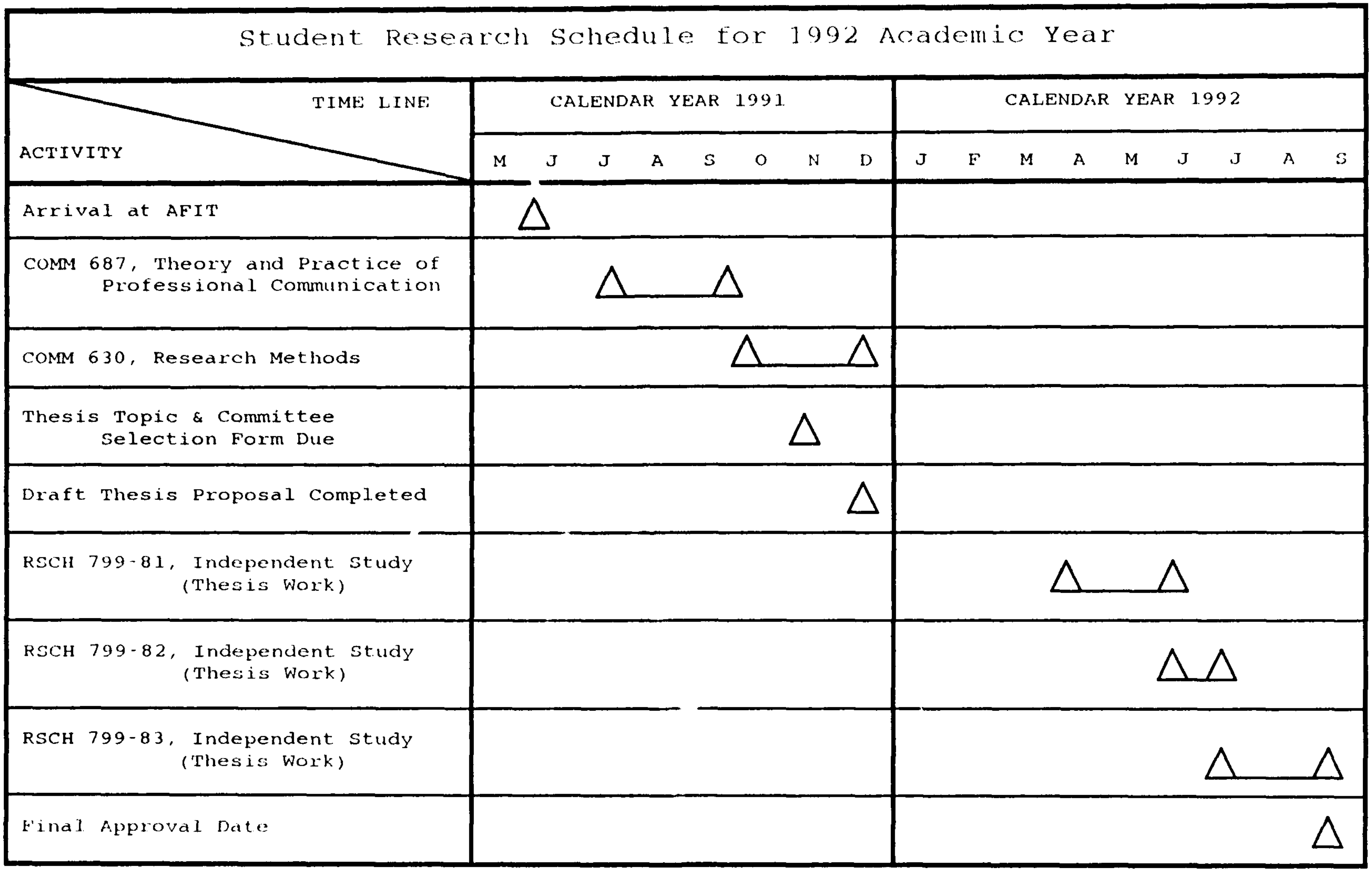

Figure 2-2. LS Student Research Schedule for 1992 Academic Year

(2) Assure that students in the program/option select appropriate topics and form committees by 1 Nov.
(3) Monitor thesis progress of students in their program/option.

c. Committee Advisors will:

(1) Assist Students in limiting and focusing topics to a researchable problem.
(2) Approve/disapprove the thesis proposal produced in COMM 630.
(3) Appoint one committee advisor as administrator to help the students schedule meetings and to facilitate administrative requirements.
(4) Review student travel requests and recommend approval to AFIT/LSG.
(5) Approve/disapprove data-gathering instruments and forward to AFIT/XPX for processing.
(6) Read, evaluate, and comment on student drafts and provide prompt feedback.
(7) Report thesis grades to LSC at each grading period specified in the student's education plan.
(8) Judge acceptability of content, organization, technical quality, and expression of thesis.
(9) Approve the final draft for publication in accordance with AFR 190-1, AU Sup 1, and pertinent DoD directives.
(10) Select the appropriate distribution option from the AFIT Style Guide for Theses and Dissertations. (LSOI 50-3, 1992:2-4)

The LSC responsibilities listed above represent the research director's "internal" responsibilities mentioned earlier in this section. They are administrative in nature and depict the research director's role as a "facilitator" of the process (Emmelhainz, 1991b).

Absent from the above list are the students' responsibilities. In a general sense, there are four: select a thesis partner, select a topic, select committee advisors, and do the work (Emmelhainz, 1991c; LSOI 50-3, 1992:2). However, the detailed execution of these responsibilities is an extensive effort and prone to the types of difficulties discussed later in this section.

Quality and Awards. The qualitative evaluation of a thesis' written expression and final format is incumbent on the committee advisors and LSC, respectively. According to the LS research director, thesis committee advisors are encouraged to stress quality throughout

THESIS GRADING FORM					
FACTOR	**A**	**A-**	**B+**	**B**	**B-**
INITIATIVE, CREATIVITY, INDEPENDENCE	self-directed	needed infrequent guidance	needed on-going minor guidance	required close supervision	required excessive supervision
CONTRIBUTIONS TO FIELD	ground-breaking	important	some	few	minor
ANALYSIS & DESIGN	innovative	refinement of existing methodology	appropriate for problem	shallow	inappropriate for problem
PROBLEM DIFFICULTY	extreme	moderate	average	minor	simplistic
PUBLISHABLE?	definitely	possibly	unlikely	no	file and forget
LEVEL OF EFFORT	exceptional dedication	high	appropriate to task	barely adequate	less than required
WRITING (Drafts)	virtually flawless	minor infrequent editing	minor ongoing editing	significant ongoing editing	extensive rework required
OVERALL DESCRIPTION	truly outstanding	clearly excellent	competent	acceptable	serious limitations

Figure 2-3. Thesis Evaluation Criteria (Emmelhainz, 1991)

the research process. Figure 2-3 provides advisors with sample criteria on which to base their assessment of a project. While these criteria are considered comprehensive, advisors may use their own judgment on how to evaluate student theses and assign grades (Emmelhainz, 1991a).

The thesis awards program is conducted under the auspices of LSOI 53-3, "Awards and Special Recognition for Students in Master of Science Degree Programs." This document describes four thesis awards that may be presented to LS students: the AFIT Commandant's Award, Dr. Leslie M. Norton Pride in Excellence Award, National Estimating Society Award, and National Contract Management Association Award. The first two awards are given to recognize exceptional contributions and outstanding quality; while the latter two honor exceptional studies in specific disciplines. To receive one or more of these awards, a thesis must be nominated by the study's advisors, recommended by the appropriate awards committee, and approved by a faculty vote (LSOI 53-3).

Student Researcher Difficulties. The student researcher potentially faces many difficulties in conducting a thesis or dissertation project. This review focuses on some of the more prevalent issues described in the literature, which can be grouped into the following categories: understanding research, managing time, selecting a topic, and locating and reusing available resources. Each of these categories is discussed below in terms of their attributes and context within the AFIT LS research environment.

Understanding Research. One source of difficulty for graduate students stems from their "lack of experience in thinking about problems as subjects for rigorous, systematic study" (Evans, 1991:3). The students' understanding of research may be further clouded by the many diverse meanings of research and the requirements each discipline employs for determining what constitutes an acceptable thesis project. Some key differences include the informal and formal expectations about data collection and analysis technique use, sampling quantification, measurement precision, and report length (Allen, 1973:3).

Despite these differences, student researchers can increase their chances for success by considering research as a process with steps leading from initiation to completion. It is equally important for them to approach the process in a proactive manner by anticipating and planning to minimize, or avoid, potential problems. Failure to do so could jeopardize the successful completion of their study (Allen, 1973:vii-viii).

To provide student researchers with an understanding of research, all LS graduate programs require the completion of two courses, Theory and Practice of Professional Communication (COMM 687) and Research Methods (COMM 630). COMM 687 instructs students on the areas of written and oral communication skills and introduces the AFIT Style Guide for Theses and Dissertations (Stibravy, 1991:2). This course also requires each student to complete a ten- to twelve-page literature review on a topic of the student's choosing, but preferably the student's thesis topic (Stibravy, 1991:2). COMM 630 provides students with an "understanding of basic research methods and concepts related to scientific inquiry" (Huguley, 1991:2). By the end of this course, each student or student team must complete a research proposal containing drafts of the first three thesis chapters (Huguley, 1991:2).

Managing Time. Time is an interesting and paradoxical aspect of the research process. While it is logical to expect quality research to require a significant amount of time and effort, spending too much time on a project can be counterproductive (Allen, 1973:vii; Madsen, 1983:21). In fact, many projects are extended by factors that "do not increase the quality of the final report or teach the student anything worthwhile about academic research" (Allen, 1973:vii). These factors include faculty (advisor) mobility and changes in the problem environment that impede the completion or negate the need for a study (Madsen, 1983:21).

Although the student researcher has little control over many delay-causing factors, "proper planning before research is started can significantly reduce the time required to produce high quality results"

(Allen, 1973:vii). Students should begin looking for a research topic soon after beginning their graduate work, as long as their selection is not made too hastily (Allen, 1973:14). By finding suitable topics early, students can select and optimally benefit from courses that increase their knowledge of the research project (Madsen, 1983:21).

Some aspects of the current LS research environment inhibit the early planning efforts of incoming research students. First, new students arrive at AFIT in May during the middle of the current students' research efforts. This significantly limits their access to both current researchers and advisors until early September, which is just after the thesis approval deadline date for graduating students. While new students can continue to research potential topics, they are delayed from obtaining valuable advisor feedback on new topics or information about ongoing research studies. The inability to hone in on a topic early can lead many students taking COMM 687 during the summer term (July-September) to complete their required literature review assignments on areas unrelated to their eventual theses. Students still learn about research when this occurs, but they are unable to optimally use their effort and time (Emmelhainz, 1991b).

Selecting a Research Topic. The literature indicates a plethora of research topics exists (Allen, 1973:11; Madsen, 1983:21). However, the selection and refinement of a topic that fulfills a department's unique criteria for contributing to a discipline's body of knowledge are still very difficult tasks (Allen, 1973:12). There are a number of recommended sources for research topics, some of which include: recently completed theses, professional journals, student associations or other local groups, research librarians, course lectures, published abstracts, and thesis and dissertation defenses (Allen, 1973:18; Madsen, 1983:21).

Theses and professional journals are especially beneficial if certain procedures are followed. When reviewing recently completed theses, researchers should consider the further research recommendations listed in award-winning, or other faculty-suggested reports. In conducting journal reviews, special attention should be given to lists of recently completed and ongoing dissertations or other research projects. These sources not only give student researchers insight into what other scholars think is important, but they also provide them with a valuable list of potential contacts (Madsen, 1983:21).

Similar to the diverse number and nature of sources for topics, there exists a wide range of criteria that can be used for selecting and refining a research topic. A "good" topic should:

1) be of current or future interest;

2) be narrow and specific (instead of broad and nebulous);

3) be of interest to, and in the knowledge area of, the selected faculty advisors;

4) be accessible (data is obtainable or available);

5) sustain interest and stimulate the researcher's imagination;

6) be within the researcher's range of competence;

7) permit the researcher to demonstrate independent mastery of both the subject and the appropriate research method; and

8) have the potential to make an original contribution to the sum of human knowledge. (Allen, 1973:12, Madsen 1983:23)

While each of the items on the above list are important, it is the last one that most often impacts the student's ability to decide on a research topic. It is particularly difficult for students learning the art of research to determine the potential "contribution" of a project since a formal policy rarely exists at their university. One view in the literature suggests that the circulation of any topic widely enough will garner a full range of opinions. To be successful, the student researcher must wisely consider this factor in the process of selecting a topic (Allen, 1973:13).

The LS research environment provides students with several resources for locating topics. As discussed earlier, some of the resources are automated systems. However, none of the systems identifies past or ongoing in-house research studies that merit further or cross-sectional study. Such topics are either informally passed on to incoming LS students, forgotten, or discovered incidentally (Emmelhainz, 1991a).

In addition to the options of "reviving" a previously completed study or continuing an ongoing study, LS student researchers may personally generate a topic or select one from the Thesis Topic Book maintained by the Thesis Program Administrator. The latter option involves manually searching through ordered groupings of new research requests that have been received from two major sources: 1) DoD organizations, as a result of the annual "call for thesis topics"; and 2) AFIT faculty members, who derive topics from their consulting responsibilities. Although this tool exists, its utility (in statistical or other terms) is unsubstantiated (Emmelhainz, 1991a).

During the interviews conducted with the LS and DE research directors, the requirement for an automated system to replace the current Thesis Topic Book was expressed. Besides its replacement role, the new system should have the ability to provide researchers with pertinent information on past and ongoing research efforts. It was also recommended that the system be capable of providing management with feedback on its utility. The requirements gathered during these interviews were incorporated into the ARMS functional description and formed the basis of the Research Topic Selection Subsystem (RTSS) (Duncan, 1991; Emmelhainz, 1991a).

Locating and Reusing Resources. One characteristic of a good research study is that its results are verifiable (Emory and Cooper, 1991:15). Consequently, a completed research project customarily yields a report that not only documents results, but contains details about the methodology and tools (surveys, questionnaires, statistic analysis models) employed during the study (Emory and Cooper, 1991:15-16, 374-375). Research studies may also yield output products, such as prototype system designs, computer software programs, or guidebooks. While these "components" are often well-documented in their respective theses, they are archived without consideration of their potential for further use, or the role they could play in promoting continuing studies (Duncan, 1991; Emmelhainz, 1991a). More detailed information about the potential benefits and pitfalls of reuse are described in the next section.

Reuse

Research is performed in many ways, but the common thread throughout all research is the need for information. Maurice Glicksman, in his address to the Conference on Information Resources for the Campus of the Future, discusses the goals of higher education. Glicksman explains that one goal is the "conservation of knowledge" (Glicksman, 1987:26) because "without the conservation process, we would go through a new learning process every generation. This would be highly inefficient for society" (Glicksman, 1987:30). Edgar Bright Wilson, Jr. further states:

> Science by its very nature is a structure which grows by the addition of new material on top of a great edifice formed by earlier workers. An individual completely ignorant of what was known before has little chance of making a worthwhile new contribution. Consequently, before beginning a new research project it is essential to find out the existing state of the field. (Wilson, 1952:10)

Therefore, in order for a research product to be successful, the researcher must be aware of the current state of knowledge and be able to reuse it.

Knowledge Reuse. Knowledge reuse is dependent upon researchers passing on knowledge which they have added to the field. Researchers are able to pass the knowledge to their colleagues directly or indirectly. Direct communication among researchers allows interaction to ensure the information is transferred correctly. Indirect communication occurs through journals and published papers but does not allow interaction (Glicksman, 1987:30). The computer has been introduced to enhance both direct and indirect knowledge reuse (Markoff, 1991:49).

Networks of computers provide researchers the ability to communicate with one another anywhere in the world. One such network is the Internet. The Internet was created in the 1960s by the Defense Advanced Projects Research Agency as a means to improve communication between researchers (Markoff, 1991:49). Additionally, in order to improve the United States' international standing in technology, the Congress has been debating the creation of a National Research and Education Network (NREN) which will enhance research by providing quicker transfer of information throughout the network (Fisher, 1991:182).

Computers can also store knowledge for researchers to access at a later time. In fact the Congressional Office of Technology Assessment found in 1990 that information gained through government funding should be stored in computerized databases to improve private companies' access to this information (Markoff, 1990:2).

Even with the increased importance of improving knowledge reuse, the greatest strides currently being made in the area of reuse are occurring in software development. The following examination of software reuse provides the basis for the authors' discussion of knowledge reuse.

Software Reuse. Ruben Prieto-Diaz and Peter Freeman in their paper, "Classifying Software for Reusability," state that the concept of software reuse has been studied for almost 25 years (Prieto-Diaz and Freeman, 1987:6). The main thrust of research on this topic is related to the classification and retrieval of software components.

Benefits. The employment of software reuse can benefit the software process in four main areas: programmers can increase their productivity by developing less new software and depending more on reusable software (Margono and Berard, 1987:63; Coomer and others, 1990:34); software products are more reliable because they have already been tested (Margono and Berard, 1987:63); total software costs are decreased because reused software components do not have to be redesigned, redeveloped, or retested (Margono and Berard, 1987:63, Dusink and van Kalwiyk, 1987:114); and the software products have expanded uniformity and quality because the components are retrieved from a standard set of software components (Margono and Berard, 1987:63).

Successes. Raytheon implemented software reuse in the late 1970s, and within three years, showed a great improvement in productivity. During this period, forty to sixty percent of the software in Raytheon applications was reused from previous programs. The practice of software reuse now has Raytheon's programmers producing software up to forty times faster with better quality, and higher maintainability characteristics. In addition, Raytheon's trainees are more productive after only three months of training than some experienced programmers who do not reuse software (Lanergan and Poynton, 1979:127-128).

Toshiba has increased productivity by eight to nine percent each year in the Fuchu Software Factory since 1977 by reusing code during software development. During this same time, Fuchu has maintained a low number of faults per thousand lines of code (Coomer and others, 1990:37).

NASA carried out a series of projects to determine the advantages of reusing software. By the end of the third project, reusable software accounted for forty percent of the total project, productivity increased by over fifty percent, and the number of errors decreased by over seventy percent (McGarry, 1989:57-58).

McDonnell Douglas performed a study on the missile packages they were developing for the Department of Defense to determine if software reuse could be employed effectively. McDonnell Douglas found that its missile software system contained over 200 reusable components. The researchers also determined that a software component which almost satisfied a requirement could be modified easier than developing a new component (McNicholl and others, 1986:104,106).

Computer Sciences Corporation developed guidelines for writing mission critical computer resource software based on reusable components (Gargaro and Pappas, 1987:51). Gargaro and Pappas state that, in order for software reuse to be effective, reuse must be considered throughout both the design and implementation phases (Gargaro and Pappas, 1987:43).

IBM introduced the concept of software building blocks which can be reused by their programmers to design and build new systems (Lenz, Schmid and Wolf, 1987:34). This concept was tested with NASA, and the results showed that the projects on which building blocks were used had ten to twenty-five percent reused software and produced better quality products (Lenz, Schmid and Wolf, 1987:42; Balda and Gustafson, 1990:42).

Drawbacks. Even with all of the successes, some firms are wary of instituting a reuse process within their organization. Biggerstaff and Richter catalog this concern into two areas: dilemmas and inhibiting factors (Biggerstaff and Richter, 1987:42-45).

A dilemma occurs when a positive gain in one area causes a negative gain in a second area. Biggerstaff and Richter's first dilemma addresses the fact that a software component will get reused more if it performs a general function. However, as a component's function becomes more general, the component must be modified in order to be effective in a specific application. The second dilemma deals with the size of the component. As a component gets larger, it becomes more effective because it performs a more specific function. On the other hand, as a component grows larger, its complexity increases as well as its maintenance cost. The final dilemma is that although a library is necessary to effectively reuse software components, the cost of creating this library is very high (Biggerstaff and Richter, 1987:42-43).

The inhibiting factors center on the people of an organization. First, programmers do not have a standard method of designing software that encourages reuse. Second, management normally does not provide a clear strategy for developing a reuse policy. Third, programmers are often unwilling to accept other programmers' work because the software may have problems which must be solved before it can be reused. This is commonly called the "not-invented-here" (NIH) syndrome. Finally, managers do not want to expend the capital required to institute a reuse program (Biggerstaff and Richter, 1987:45).

Other drawbacks include the fact that all programmers do not use a standard language, and project managers have very little, if any, training in the principles of software engineering (Coomer and others, 1990:33). Additionally, programmers could potentially develop a software module, using reused components, which is too specific to be reused itself. This would violate the principle that a software process should produce components which can be reused in future projects as well as reuse components from previous projects (Welch, 1987:86). Finally, the task of cataloging the components for reuse could be so difficult that any benefits gained would be overcome (Horowitz and Munson, 1984:481).

Sample Reuse Process. Prieto-Diaz states that a software reuse program must be structured and addressed systematically (Prieto-Diaz, 1991:62). In order for software to be reused, it must first be stored in a central location, called a software library (Burton and others, 1987:41). The software components stored in this library must be well-defined, useful in a number of different situations, and of proven high quality (Coomer and others, 1990:34-35). The software should also be cataloged to help distinguish one component from another (Prieto-Diaz and Freeman, 1987:7). To further enhance its reusability, the software could be cataloged in many ways to anticipate all of its possible uses (Mac An Airchinnigh, 1984:70).

Once the software has been cataloged and stored in the library, programmers can query an automated retrieval system for reusable components to use in current projects. The retrieval system, which is normally an information system, will take the specified software requirements, examine the library, and provide a candidate list of all components which meet those requirements. The retrieval system also provides information about each component. Based upon this information, the programmer can select a component which will be the easiest to reuse (Prieto-Diaz, 1987:6-7).

Domain Analysis. The first step in developing a reuse program should be a domain analysis (Holibaugh, 1989:267). The goal of a domain analysis is to describe the problems within the domain along with the software which solves these problems. This goal is achieved through the development of a domain model and software architecture. The domain model represents a picture of the domain while the software architecture describes the software currently available within the domain (Holibaugh, 1989:274).

Advantages. One advantage of a domain analysis is that it will capture expertise from an organization which can be tailored for use in a specific area. This expertise can identify common problems of past systems and develop methods of solving these problems. These solutions can then be applied to similar problems which arise in new systems. Also, knowledge from past systems can be used as a training aid for new employees (Holibaugh, 1989:267).

Disadvantages. The main disadvantage of domain analysis is in the area of assessment. benefits gained from a domain analysis cannot be fully measured until the new system has been implemented. Once the system is active, the productivity and reliability can be compared to previous results to determine if the domain analysis was successful. Other disadvantages of domain analysis are the lack of guidance for performing the analysis and the shortage of domain experts who supply the information to the domain analysts (Holibaugh, 1989:267).

Approach. Within the software environment, when a reusable component is required, the software architecture is examined to determine if software with similar functionality is available within the domain. The common traits from the existing components are identified and then reused in the development of the new component. If no similar component exists, efforts are made to determine if the new component should be developed for just the current project, or if it should be developed in a way to make it reusable for future projects as well (Balda and Gustafson, 1987:42-43).

Once the domain analysis has been performed, it is imperative that the domain model and software architecture are updated regularly. For every new development, the domain must be analyzed to identify any necessary changes. Some possible changes could be the addition of new software components or the removal of outdated components (Holibaugh, 1989:275-276; Prieto-Diaz, 1987:28).

Successes. As stated earlier, the success of a domain analysis cannot be determined until the system has been developed and tested (Holibaugh, 1989:267). Some organizations have already had an opportunity to validate the success of using the domain analysis technique. The recent software development successes of both Raytheon and McDonnell Douglas, as discussed earlier in this chapter, have been directly attributed to the performance of a domain analysis prior to initiating their reuse programs (Prieto-Diaz, 1987:23; 25-26).

Applicability to this Study. The authors' intent is to develop a domain model and software architecture that will enhance knowledge reuse within LS. The particular technique for this model is the entity relationship diagram (ERD) (Holibaugh, 1989:274). The ERD for the ARMS "knowledge domain" is described more fully in the design portion of Appendix K. The software architecture is comprised of the proposed AFIT Research Management System and the research facilities listed earlier in this chapter.

Current Research. Current reuse research is addressing more of the nontechnical issues related to software reuse: managerial, economic, legal, cultural, and social. Researchers have realized that the nontechnical issues form the foundation of a successful reuse program (Prieto-Diaz, 1991:61).

Information Systems

An information system is "an organized way to effect information transfer within a specific field" (Weisman, 1972:14). Information systems are able to maintain data for future use and process data to produce information and reports (Senn, 1984:15). Many times an information system does not allow the extraction of the information pertinent to the current project. After retrieving the information, further processing is required of the researcher to remove the unessential information (Tsichritzis and Lochovsky, 1977:26). A data base management system (DBMS) is a computerized form of information system which provides a more flexible interface between the researcher and the information (Senn, 1984:370-1). For the purpose of this thesis, the terms information system and DBMS are used synonymously to refer to a computerized system.

Data Base Management System Concepts. The smallest unit of data within a DBMS is called a data item, and a collection of data items comprises a record type (Tsichritzis and Lochovsky, 1977:21). To illustrate, Figure 2-4 shows a record type THESIS_INFO with four data items: THESIS_ID_NR, AUTHOR, SUBJECT, and COMPONENT. A particular group of these data items is called a record and a particular data item is called a data item value (Tsichritzis and Lochovsky, 1977:21).

	THESIS_ID_NR	AUTHOR	SUBJECT_AREA	COMPONENT
	AFIT/GEM/LSM/89S-6	David Clark	Vehicle Maintenance	Survey
Record →	AFIT/GLM/LSY/91S-27	Thomas Harkenrider	Hospital Supply	Software
	AFIT/GLM/ENY/89S-25	Dennis Green	Transport Aircraft	Survey
	AFIT/GIR/LSC/90D-2	Alan Constantian	Hospitals	Questionnaire

Figure 2-4. Record Type THESIS_INFO

The DBMS provides the flexibility of allowing the user access to the data in many different forms (Senn, 1984:367; Fleming and von Halle, 1989:4). A relational DBMS formats the data into a two-dimensional table. In this table, the rows can be regarded as records and the columns as data item values (Senn, 1984:375). The data is accessed using a primary key. A primary key is a data item which must uniquely identify each record (Fleming and von Halle, 1989:16). If one data item cannot uniquely identify one record, multiple data items can be used as the primary key. The multiple data items are collectively called a concatenated key (Martin, 1981:44).

The data stored in a data base can be used by multiple researchers with each researcher accessing only the portion or view of the data which is required for the particular research project (Martin, 1981:2). A view is the part of the data base which is visible to the user. Figure 2-5 shows a view, THESIS_VIEW, which is made up of a portion of the THESIS_INFO record type.

Record Type: THESIS_INFO

THESIS_ID_NR	AUTHOR	SUBJECT_AREA	COMPONENT
AFIT/GEM/LSM/89S-6	David Clark	Vehicle Maintenance	Survey
AFIT/GLM/LSY/91S-27	Thomas Harkenrider	Hospital Supply	Software
AFIT/GLM/ENY/89S-25	Dennis Green	Transport Aircraft	Survey
AFIT/GIR/LSC/90D-2	Alan Constantian	Hospitals	Questionnaire

View: THESIS_VIEW

THESIS_ID_NR	AUTHOR	SUBJECT_AREA
AFIT/GEM/LSM/89S-6	David Clark	Vehicle Maintenance
AFIT/GLM/LSY/91S-27	Thomas Harkenrider	Hospital Supply
AFIT/GLM/ENY/89S-25	Dennis Green	Transport Aircraft
AFIT/GIR/LSC/90D-2	Alan Constantian	Hospitals

Figure 2-5. View From Record Type THESIS_INFO

A view can also be composed of subsets from multiple record types. To continue the example from above, another record type, ADVISOR_INFO, contains three data items: THESIS_ID_NR, ADVISOR, and DEPARTMENT.

Record Type: THESIS_INFO

THESIS_ID_NR	AUTHOR	SUBJECT_AREA	COMPONENT
AFIT/GEM/LSM/89S-6	David Clark	Vehicle Maintenance	Survey
AFIT/GLM/LSY/91S-27	Thomas Harkenrider	Hospital Supply	Software
AFIT/GLM/ENY/89S-25	Dennis Green	Transport Aircraft	Survey
AFIT/GIR/LSC/90D-2	Alan Constantian	Hospitals	Questionnaire

Record Type: ADVISOR_INFO

THESIS_ID_NR	ADVISOR	DEPARTMENT
AFIT/GEM/LSM/89S-6	Robert McCauley	AFIT/LSM
AFIT/GLM/LSY/91S-27	Kevin Grant	AFIT/LSY
AFIT/GLM/ENY/89S-25	Robert Calico	AFIT/ENY
AFIT/GIR/LSC/90D-2	Larry Emmelhainz	AFIT/LSC

View: THESIS_TEAM

THESIS_INFO. THESIS_ID_NR	THESIS_INFO. AUTHOR	ADVISOR_INFO. ADVISOR
AFIT/GEM/LSM/89S-6	David Clark	Robert McCauley
AFIT/GLM/LSY/91S-27	Thomas Harkenrider	Kevin Grant
AFIT/GLM/ENY/89S-25	Dennis Green	Robert Calico
AFIT/GIR/LSC/90D-2	Alan Constantian	Larry Emmelhainz

Figure 2-6. View From Multiple Record Types

Figure 2-6 displays a view, THESIS_TEAM, consisting of data items from both THESIS_INFO and ADVISOR_INFO record types.

Advantages of Information Systems. Information systems allow for centralized control of the data by an administrator. The administrator can also enforce the standards for data handling and ensure the security of the data. Information systems provide a single location for storage of the data. By storing data in a single location accessible to everyone who needs the data, redundancy is reduced because multiple copies of the data are no longer needed. The decrease in redundancy also improves the integrity of the data, because it is more feasible to maintain only one copy. Finally, information systems allow different researchers to use the same data but access it with different views. This flexibility improves ease of use and enhances interaction between the researchers (Diehr, 1989:14-16).

Disadvantages of Information Systems. The costs of developing and operating an information system are its major disadvantages. The costs incurred from using an information system to manage the data can be measured by the cost of purchasing and setting up the system, converting the data to a format compatible with the information system, and upgrading the hardware on which the system will run. Additionally, the development, operation, and maintenance of an information system can be very expensive; however, the advantages listed above provide savings which outweigh the costs in almost all environments (Diehr, 1989:3).

Information System Development. Many information systems are created using the systems development life cycle described by James Senn in his book, Analysis and Design of Information Systems. The activities in Senn's model include preliminary investigation, determination of requirements, development of prototype system, design of system, development of software, systems testing, and implementation (Senn, 1984:18).

Preliminary Investigation. A preliminary investigation begins when a person or department has a requirement that can be satisfied with an information system. The investigation is comprised of clarifying the request, studying the feasibility of the request, and scheduling the development of the request (Senn, 1984:18-19).

Initially, the request must be clarified to ensure that the problem is understood by the users, managers, and analysts. Once the problem is understood, the analysts or managers must make sure that the proposed system is feasible (Senn, 1984:18-19). The feasibility can be determined through a careful analysis of the environment within which the information system will be used. The main question of feasibility is whether the needs of the user can be cost-effectively satisfied by using this system (Nijssen and Halpin, 1989:29). After the system has been judged feasible, the development process should be scheduled. The schedule is based upon the estimated cost, priority, completion time, and personnel requirements. These estimates determine which projects should be developed with current resources and which should be put on hold until more resources become available (Senn, 1984:19).

Determination of Requirements. As with any development, the requirements of a system must be determined before the design process can begin. This step consists of a thorough investigation of the current system. Analysts must talk to the people who use the system to get an idea of how it works. This also gives analysts a chance to find out what the new system should include. In addition to interviewing the personnel, the analysts must examine any documents or forms which further describe the process (Senn, 1984:20).

Development of Prototype System. Even after the preliminary investigation and determination of the requirements, the complete design of the system may remain unresolved. At this point, a prototype can be developed to evaluate possible solutions (Senn, 1984:20). A prototype can also provide the users with a hands-on version of the system. With this interaction, the user may think of other features which are needed in the new system (Lazinger, 1987:11-12). Additionally, the prototype can reduce the risk of using new or untested designs. A test of these designs can be performed with a prototype before beginning the development of the system. Another gain from prototyping is that any information gathered during the test of the prototype can be utilized in the development of the final system (Senn, 1984:20).

Design of System. The designing of the system creates a set of specifications that will be given to the programmers to develop the software. This specification contains the detailed structures of the input and output of the system. Preparation of the data needed to make it usable to the system must be addressed as well as the actual method of data entry into the system. Data can be entered from the keyboard or read from a document (Senn, 1984:287).

The output of the data should also be reviewed. The analysts must decide whether the output from the new system will be presented on the monitor or printed in a report. If the data is printed, the format of the report should be designed to enhance readability (Senn, 1984:231).

The system must be designed in modules representing the system's individual functions. These functions should be relatively small and self-contained (Humphrey, 1990:115). Because these modules are functionally independent, the system is easier to design and maintain (Pressman, 1987:230).

<u>Development of Software</u>. During this portion of the design, the programmers take the specification developed by the analysts and begin to write the software which makes up the information system. The programmers may also decide that some functions can be performed by buying commercial software and merging it with software they are writing. In some cases, it may be cheaper to buy the software instead of building it. If the programming staff is not large enough to handle the entire development process, or does not have time to complete the development, purchasing software becomes a very realistic way to save money and time (Senn, 1984:375).

<u>Systems Testing</u> Once the software is developed, the analysts begin to test each line of the program to determine if the requirements have been fulfilled (Senn, 1984:488). Other test cases examine the software against the specifications which were developed during the previous step (Senn, 1984:491). The lowest level of testing, unit testing, ensures that individual functions perform as they should (Pressman, 1987:501). As stated earlier, these functions are designed into separate modules of code. When modules complete testing, they are integrated to form a larger module, which in turn must be tested (Senn, 1984:491-494). This integration testing continues until all the modules have been integrated into the final product. The final product is then tested to ensure that it is complete and meets requirements (Senn, 1984:494-495).

Implementation. With testing complete, actions must be taken to implement the system. The implementation falls into three general categories: training, conversion, and review (Senn, 1984:525).

Training. Two groups need to be trained: the operators, or the personnel who will run the system; and the users of the system. The operators need training in how the system works and what steps need to be taken if an error occurs. The users need to be trained on how to use the system to enter and retrieve data. The source of training should also be explored. Training can be provided by vendors or in-house personnel. The quality and cost of the training will be a driving factor in the choice of the training source (Senn, 1984:525-530).

Conversion. Some method of converting from the current system to the new system must be devised. The conversion process can be performed using any of the following methods: (1) run both systems in parallel, allowing personnel to get accustomed to the new system and slowly transfer their work until the old system can be removed; (2) replace the old system, forcing personnel to use the new system; (3) install a pilot system in one department to test any new technology before making it available to the entire organization; or (4) implement the new system in phases to deal with the complexity of the system or the organization (Senn, 1984:530-535).

Review. After the system has been implemented, an evaluation is necessary to determine if: (1) the system is working correctly, (2) personnel are using the system, and (3) changes to the system need to be made. Maintainers of the system can also use the results from this review to determine what new capabilities need to be added (Senn, 1984:543).

Software Development Models. Senn's systems development life cycle is based on the waterfall model introduced by Royce in 1970. Currently, Royce's waterfall model (and its many variants) is the most widely accepted software development process model. However, the waterfall does have some problems (Humphrey, 1990:249). A review of the model and a major alternative to it are presented below.

Waterfall Model. Royce's original waterfall model was composed of seven steps: system requirements, software requirements, analysis, program design, coding, testing, and operations (Humphrey, 1990:250). The model is shown in Figure 2-7. The first three steps in Royce's model tie directly into the first two steps of Senn's model. The third step in Senn's model introduces prototyping to improve the developer's understanding of the problem and its solution requirements. Royce's form of prototyping calls for a "build it twice" sequence which is performed concurrently with the first three steps of the model (Kameny and others, 1989:6). The last four steps of the waterfall model correspond directly to Senn's final four steps.

Neither the waterfall model nor its derivatives encompass all aspects of software development. Although Royce and Senn recognized the need for prototyping, both limit the degree to which this technique is used. For instance, the development of software in an environment of rapidly changing, or undefined requirements, necessitates the use of a more flexible, iterative technique to ensure the system that is built meets the customers "real" needs. The next section examines a model

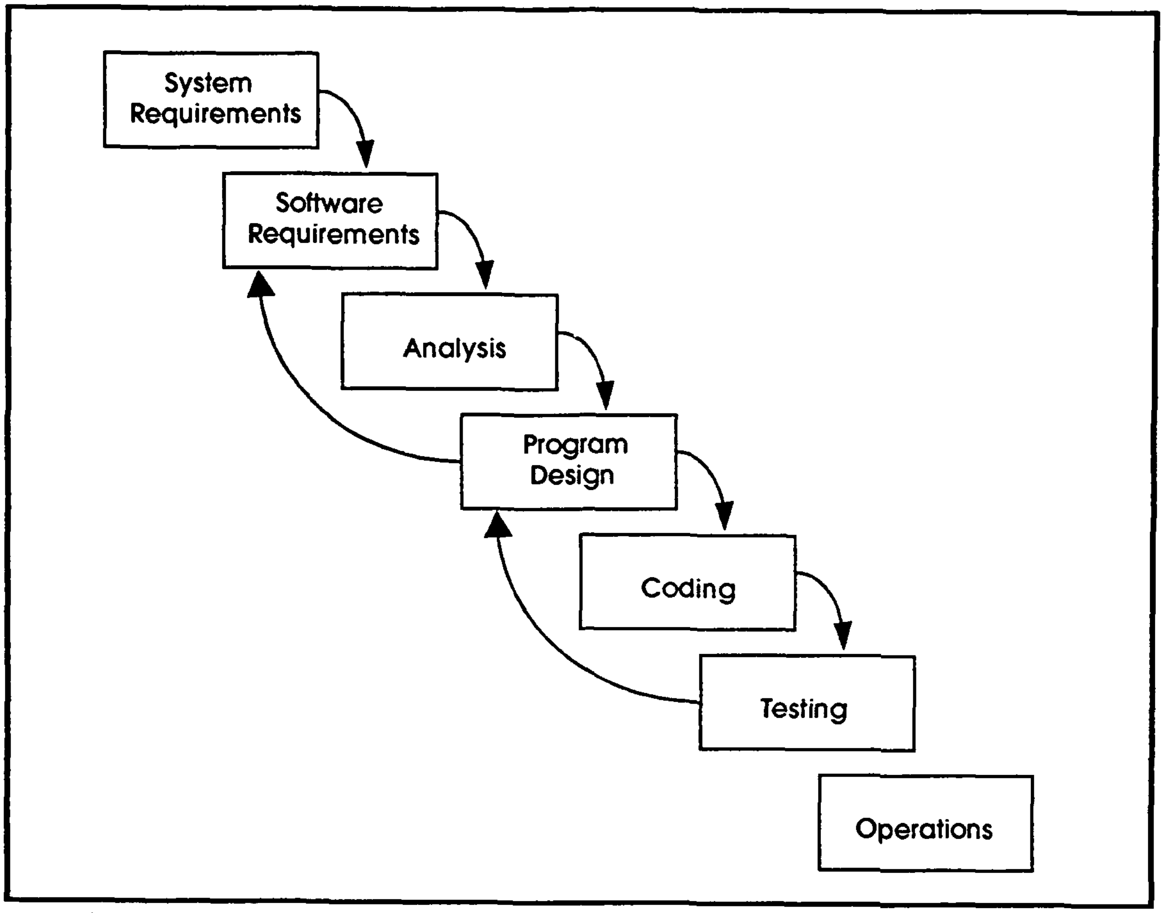

Figure 2-7. Waterfall Model of the Software Process (Humphrey, 1990:250)

that provides such a framework for software development (Boehm, 1988:63-65; Humphrey, 1990:249).

Spiral Model. The spiral model of software development evolved from the experience gained by using the waterfall model for large government software projects. It was developed to accommodate a variety of previous software development models as special cases and to provide guidance for modeling a given software situation (Boehm, 1988:64-65).

As its name implies, the spiral model approaches software development in a spiral fashion. Figure 2-8 provides an illustration of the model which should be viewed as starting at the innermost end and proceeding clockwise through a series of phases. The purpose of the spiral line's continuous movement away from the origin is to reflect the cumulative cost of the system's development. Similarly, the crossing axes are provided to show the amount of progress made at a given point in the program (Boehm, 1988:65).

Each new cycle of the spiral begins by defining the objectives of the software product in terms of its desired performance, functionality, and flexibility characteristics. Alternative implementations are then identified along with their associated constraints. Constraints may include such items as cost, schedule, and technical limitations (Boehm, 1988:65).

The upper and lower right quadrants of the model are described by Boehm as follows:

> The next step is to evaluate the alternatives relative to the objectives and constraints. Frequently, this process will identify areas of uncertainty that are significant sources of risk. If so, the next step should involve the formulation of a cost-effective strategy for resolving the sources of risk. This may involve prototyping, simulation, benchmarking, reference checking, administering user questionnaires, analytic modeling, or combinations of these and other risk-resolution techniques.
>
> Once the risks are evaluated, the next step is determined by the relative remaining risks. If performance or user-interface risks strongly dominate program development or internal interface-control risks, the next step may be an evolutionary development one: a minimal effort to specify the overall nature of the product, a plan for the next level of prototyping, and the development of a more detailed prototype to continue to resolve the major risk issues.
>
> If this prototype is operationally useful and robust enough to serve as a low-risk base for future product evolution, the subsequent risk-driven steps would be the evolving series of prototypes going toward the right in Figure 2-8. In this case, the option of writing specifications would be addressed but not exercised. Thus, risk considerations can lead to a project implementing only a subset of all the potential steps in the model.

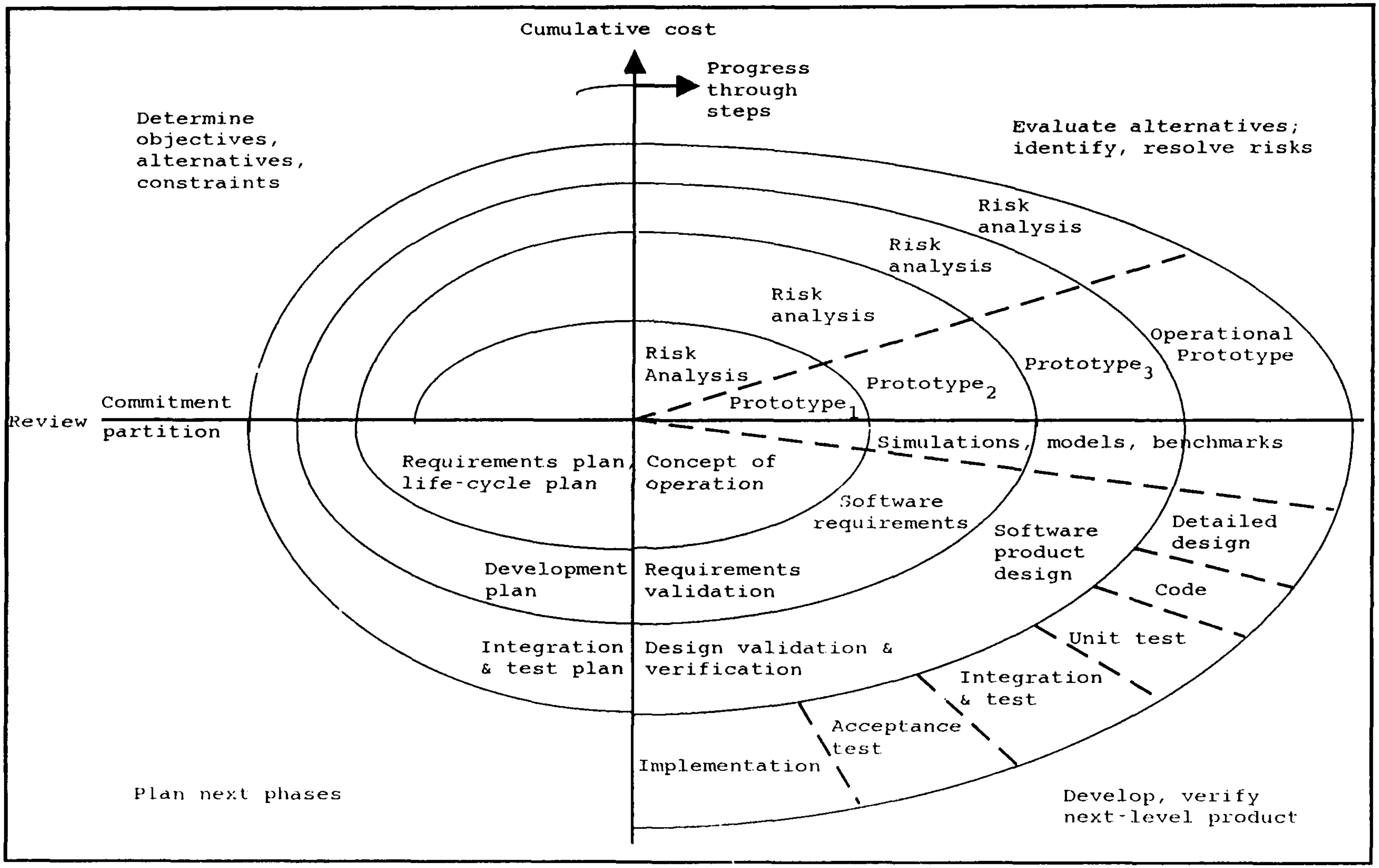

Figure 2-8. Spiral Model of the Software Process (Boehm, 1988:64)

> On the other hand, if previous prototyping efforts have already resolved all of the performance or user-interface risks, and program development or interface-control risks dominate, the next step follows the basic waterfall approach, modified as appropriate to incorporate incremental development. (Boehm, 1988:65)

During the last quadrant of the spiral model, plans are prepared for the next cycle. These plans could include the partitioning of the product into several components that may be developed in separate parallel spiral cycles. The final activity in this quadrant, and the cycle as a whole, is the "review-and-commitment" step. This step "may range from an individual walk-through of the design of a single programmer's component to a major requirements review involving developer, customer, user, and maintenance organizations." The ostensible end goal of the "review-and-commitment" step is to determine if future cycles through the spiral are needed and supported (Boehm, 1988:65).

Wolff used the spiral model for a system development and found that some areas of the model did not give a clear indication of what was occurring in the development. Wolff determined that as the knowledge base of the system grew, the spiral model was not able to keep up. In an effort to maintain a current knowledge base, Wolff modified the spiral model. The new spiral model contains two additional operations or activities: (1) gathering new knowledge and adding it to the knowledge base; (2) reviewing, analyzing and rationalizing what is in the knowledge base. These activities are followed by executing plans which may have been created during the cycle (Wolff, 1989:140).

Summary

Before one can solve a problem or make improvements to a current situation, it is important to understand your environment and alternatives. This chapter documented an exploration of the many topics considered germane to this study's problem and solution domains. It began with an overview of the area of research, which included a brief look at the AFIT and LS-specific research environments, and some major difficulties facing student researchers. The focus then shifted to the concept of reuse, its application in the software development arena, and its pertinence to this study. The final section reviewed some key information systems principles and software development models.

III. Methodology

Overview

The goal of this research was to design, develop, test, and evaluate an initial prototype information system to enhance the conduct and management of academic research in the School of Systems and Logistics (LS) at the Air Force Institute of Technology (AFIT). This chapter begins with an explanation of why the spiral life cycle model was chosen and how it was used to guide the activities of this study. The remaining sections describe how each of the following research objectives were satisfied:

1. Describe the current AFIT research environment.

2. Define and validate the AFIT Research Management System (ARMS) requirements.

3. Analyze alternatives and select prototype constraints.

4. Design and develop the prototype system.

5. Perform an operational test of the prototype system.

6. Analyze and interpret operational test results.

7. Develop recommended path for follow-on research.

Spiral Life Cycle Model

The spiral life cycle model was selected to guide this study for two primary reasons:

1. The model's iterative nature provides a flexible approach for developing and refining prototype systems.

2. The model's risk-driven review checkpoints allows for early termination of a project when it is becomes too risky or cost-prohibitive to continue. (Boehm, 1988:65)

As stated in Chapter II, these tenets of the spiral model allow developers to refine a system's requirements by completing several cycles before the production-quality system is built. This research completed an initial cycle through the spiral model and produced the results described in Chapters IV and V.

It is important to note that the spiral model was refined for use in this study. The authors' implementation represents an adaptation of both the spiral and Senn models into a hybrid approach. The new model supplies additional structure to the broad guidelines of the spiral by mapping a set of detailed steps, the research objectives for this study, into the original spiral model's initial cycle. As stated previously, the research objectives are generally patterned after Senn's model.

Figure 3-1 illustrates how this study's research objectives were mapped into the innermost cycle of the spiral model. The names used to describe the quadrants differ slightly from those presented in Chapter II, but the basic concept and goals of each phase remain the same.

Problem Analysis. The problem analysis phase of activities was mapped to quadrant I of the spiral model. During this phase, the authors conducted a literature review and completed research objectives one and two. The goal was to determine the objectives, alternatives, and constraints of this research effort. The outputs of this phase included the general understanding of the AFIT and LS research environments presented in Chapter II and a validated set of requirements for the prototype ARMS.

Risk Analysis/Prototype Development. The risk analysis/prototype development phase for this project corresponds to quadrant II of the

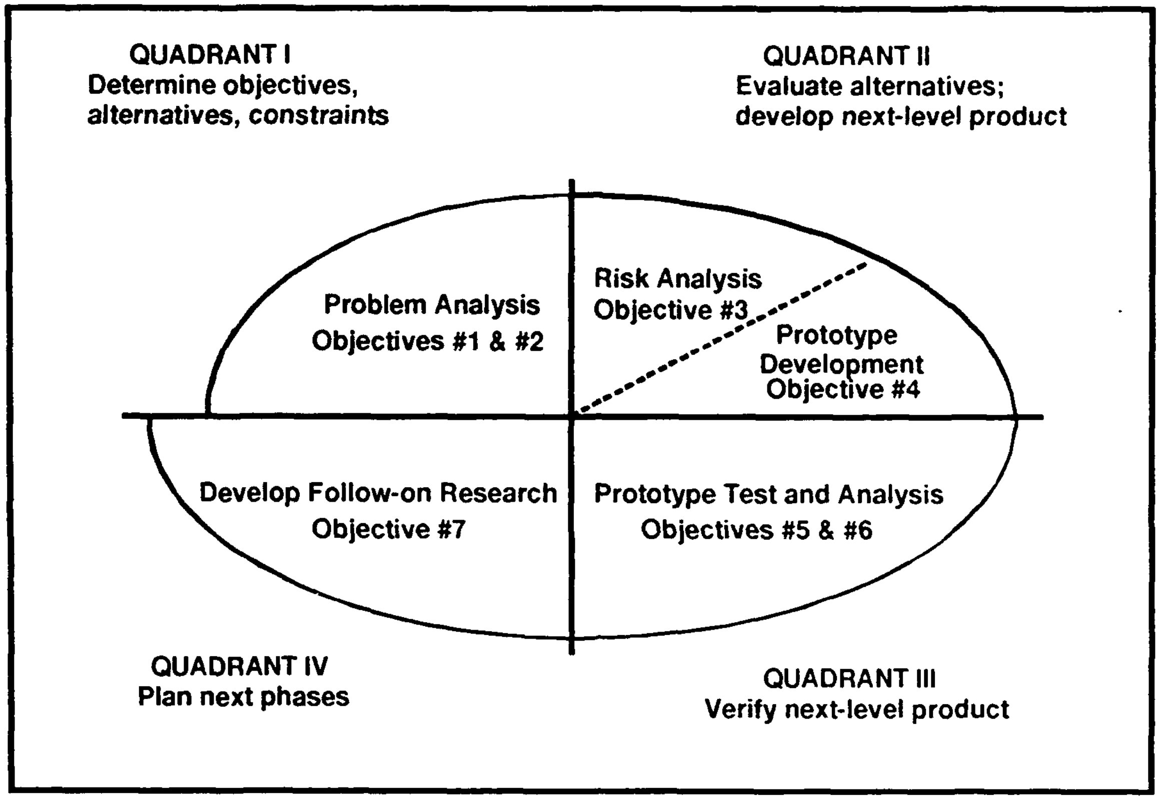

Figure 3-1. Adapted Initial Cycle of Spiral Model (Boehm, 1988:64)

spiral model and the goals of evaluating alternatives, and identifying/resolving risks. These goals were met by using the validated requirements document produced in the problem analysis phase to complete research objectives three and four. The major end products of this phase were the prototype system and documentation to operate and evaluate it.

Prototype Test and Analysis. Research objectives five and six were conducted during this phase to meet quadrant III's goal of verifying the next-level product. The analysis of the operational test conducted during this phase directly fed the follow-on research phase with information on how the prototype could be improved.

Develop Follow-on Research. The purpose of the spiral model's fourth quadrant is to develop plans for the next cycle through the model (Boehm, 1988:64). Research objective seven, which involved the development of recommendations for improving the prototype and conducting corollary studies, was completed to meet the goal of this phase.

Research Objective One - Describe the Current AFIT Research Environment

A detailed description of the current AFIT research environment was needed to clearly understand the objectives, alternatives and constraints of the research problem. The first step was to conduct a structured interview with the research directors for AFIT's School of Engineering (EN), School of Systems and Logistics (LS), and School of Civil Engineering and Services (DE). The interviews had the following three-fold purpose:

(1) to gain an understanding of the general structure, management philosophy, and overall strengths and weaknesses of each school's research program;

(2) to present the basic tenets of this research proposal and obtain general feedback on the intent of the overall project; and

(3) to solicit recommendations about desired requirements for the research products reuse program and the prototype information system.

Appendix A contains the outline used to conduct the structured interviews. Interview findings were divided into two major categories of information: (1) AFIT and LS-specific research programs, and (2) suggested requirements for the prototype ARMS. The information concerning the overall AFIT and LS-specific research programs is described in Chapter II, and the specific suggestions for the prototype ARMS are discussed in Chapter IV.

A literature review, including an examination of the major resources available tc student researchers, was also conducted to complete the overall view of the AFIT research environment. The review specifically investigated research guidance and resources available on the AFIT campus, as well as the facilities provided by research-sponsoring activities at Wright Patterson Air Force Base, Ohio.

Research Objective Two - Define and Validate the ARMS Requirements

The primary goal of this research objective was to produce a validated document that contained the requirements for the prototype ARMS. A chief concern of the researchers during this objective was to ensure that the system's many nonautomated requirements (particularly in the policy area) were not overlooked.

A proposed set of requirements for the prototype ARMS was developed based on the recommendations received during the interviews conducted in research objective one and the researchers' personal insights gained during the formulation of this research study. Due to the prototype nature of this study, most of the requirements for the ARMS were stated in general terms. It was anticipated that this approach would promote brainstorming by personnel reviewing and validating the prototype requirements. This approach also ensured that a pre-defined solution was not specified before the requirements were validated.

To facilitate an AFIT-wide faculty review of the proposed ARMS requirements, the authors developed a draft functional description (FD) for the prototype. Congruent with the approach discussed above, several sections of the initial FD (Appendix C) were not fully developed for the validation effort. Specifically, some portions of sections three, four, and five would have required a high degree of knowledge about the proposed system's design. The cover letter distributed with the draft document asked reviewers to validate and comment on the proposed requirements for the ARMS.

The results of the validation effort were analyzed and used to update the system's FD. The analysis accomplished during this step was centered on determining if any proposed changes or additions were consistent with the purposes of the ARMS. A description of the validation results and analysis is provided in Chapter IV . The updated ARMS FD is contained in Appendix K.

Research Objective Three - Analyze Alternatives and Select Prototype Constraints

Three major decisions were made to complete this objective. The first, and perhaps most important, action required the authors to analyze the alternative approaches for meeting the validated requirements developed in research objective two. The following three alternatives were considered for this study: do nothing, modify an existing system, and develop a prototype. As indicated earlier in this report, the alternative to develop a prototype was selected. The justification for this decision can be found in Chapter IV.

The second major decision involved paring down the ARMS requirements to a subset that could be implemented as part of the initial prototype ARMS. The first step in this process was to defer all nonautomated requirements needed to fully implement a research products reuse program. The second step involved an effort to decide which automation requirements to include in the initial design of the prototype. The goal of this step was to ensure that the selected requirements would demonstrate the potential usefulness of the system. Those requirements not selected for automation in this step were used to form the foundation for one of the recommended paths for follow-on research discussed in research objective seven.

The selection of a host computer system and development tools was the final decision needed before the prototype could be designed. To accomplish this task, an evaluation of available AFIT computing resources (hardware and software) was conducted with the assistance of personnel working in AFIT's Directorate of Communications and Computer Systems. The results of this decision are delineated in Chapter IV.

<u>Research Objective Four - Design and Develop the Prototype System</u>

Based on the decisions made in research objective three, the prototype system was developed. Specific emphasis was placed on documenting the system's design and operation to ensure the initial prototype could be efficiently operated during the operational test, and subsequently improved during follow-on research efforts.

The detailed system design for the ARMS was completed using a combination of software engineering techniques. The design approach included the use of context and entity relationship diagrams to model the current problem and solution environments. In addition, a set of revision control procedures was established and followed throughout the coding process to ensure the system's development was managed in an orderly manner. Chapter IV and Appendix K, Section 3, contain a summary and detailed explanation of the ARMS' design, respectively.

An initial set of operating instructions, in the form of a draft user's guide, was developed to help personnel use the system during the operational test. The development of a similar document for performing system administration functions, such as adding, deleting, or changing the data in the information system, was contemplated but deemed unnecessary for this study. The user's guide developed during this step is contained in Appendix F.

<u>Research Objective Five - Perform an Operational Test of the Prototype System</u>

In order to evaluate the technical adequacy and suitability of the prototype ARMS, an operational test of the system was conducted. The steps to meet this objective involved populating the information system with initial data, developing the evaluation tool, and conducting the test.

The effort to populate the prototype ARMS was conducted concurrently with the system's development. This approach permitted the use of the same data set for both pre-operational readiness and operational testing. Based on the implied quality of their content, award-winning theses were used to derive most of the information in the initial data set. A more precise criteria will likely be needed if a production-quality ARMS is placed into operational use.

Prior to conducting the operational test, the authors researched the availability of an appropriate evaluation instrument for assessing the technical adequacy and operational suitability of the ARMS. The evaluation questionnaire used by ARMS testers consisted of adapted questions from an instrument used in a 1990 AFIT thesis (McMurry, 1990:90-92). The specific structuring decisions employed in building the ARMS evaluation form (Appendix E) are discussed in Chapter IV.

A two-phased operational test was conducted using samples from the new student, current student, and LS faculty populations. During the first phase of testing, newly arrived students in the class of 1993 evaluated two major subsystems of the ARMS, the Research Topic Selection Subsystem (RTSS) and Research Products Reuse Subsystem (RPRS). This phase of testing was aimed at receiving feedback from evaluators who had not been influenced by a knowledge of the current environment. Additionally, the newly-arrived students were expected to be a source of fresh ideas.

Phase two of the operational test was conducted with LS faculty members and students in the class of 1992. During this phase, the prototype's RTSS, RPRS, and Research Management Subsystem (RMS) were evaluated by people considered experienced in the art of research and the AFIT research environment.

<u>Research Objective Six - Analyze and Interpret Operational Test Results</u>

During the conduct of the operational test, participating faculty members and students completed evaluation instruments. The evaluation tool's design was such that it facilitated assessments of the system's technical adequacy and operational suitability. For the purpose of this study, technical adequacy pertained to the relative maturity of the prototype's design and implementation. The suitability evaluation subjectively considered the applicability and desirability of the proposed system to serve as a productivity enhancement tool within the LS research environment.

To assess the technical adequacy of the system, an analysis was performed on the evaluation questions related to the basic performance characteristics of the system. Subjective ratings were requested on such factors as ease of use, speed of data retrieval, clarity of data presentation, and a number of other human-to-system interface considerations. Suitability was assessed by analyzing the evaluation responses about the proposed system's desirability and potential to enhance the AFIT research environment.

The assessment of the above factors had a two-fold purpose: 1) to determine what changes should be made to the prototype system; and 2) to decide if the project should be terminated at the end of this spiral model cycle or recommended for continued research.

<u>Research Objective Seven - Develop Recommended Path for Follow-On Research</u>

The exploratory nature of this study required the proper completion of this objective. Therefore, items for follow-on research were gathered and documented during the conduct of research objectives one through six. This approach reduced the documentation and completion of this objective to a minor effort of partitioning the issues into the two main categories described below.

Follow-on Development of the Prototype System. Items placed in this category focused on improving the capability of the prototype system. Specific candidate items included requirements not selected for automation during research objective three and the changes recommended by users performing the operational test described in research objective five.

Corollary Studies. This category contains suggested corollary studies to investigate how the nonautomated requirements and administrative oversight for the ARMS can be implemented. The primary items for this category were derived during research objectives two and three.

IV. Findings and Discussion

Overview

The structuring of this study's methodology in the form of a software development life cycle resulted in the completion of several objectives that did not bear traditional research "findings." Therefore, this chapter presents a more in-depth discussion of how the first five research objectives were accomplished and provides the findings for the sixth research objective. A discussion of the study's seventh, and final, research objective is deferred until Chapter V.

Research Objective One Results

The authors used the structured interviews (Appendix A) with the research directors and a review of the literature to document a general understanding of the current research environment described in Chapter II. A summary matrix of the research directors' responses to several interview questions is provided in Appendix B. The interviews were also used to obtain feedback concerning the requirements for, what was then termed, the research products reuse program (RPRP).

DE and LS research directors endorsed the RPRP and provided several recommendations that extended its functionality (Duncan, 1991; Emmelhainz, 1991). EN's research director primarily reserved comment on the proposal, but indicated that alternatives to building a new system should be considered (Bridgman, 1991). This suggestion was heeded and an evaluation of alternatives is described later in this chapter.

Besides confirming the need for the RPRP, the DE and LS research directors focused on a number of desired improvements in a second area of interest--the current topic selection process. The directors suggested that an increase in the number of continuing and sponsored studies could be realized if student researchers had access to an automated source of information on past and present thesis efforts. As noted in Chapter II, no current system specializes in providing this type of information. Along with the benefits of increasing certain types of studies, the DE and LS research directors felt that an automated topic information system could greatly enhance researcher productivity (Duncan, 1991; Emmelhainz, 1991).

The interviews also highlighted the need for a centralized source of information for monitoring and reporting a school's research program "health and status." Although automation is used to some extent for performing research management functions, many of the current systems provide a single function and, in most cases, contain duplicate data. The DE and LS research directors agreed that a system that integrated research program information would be a valuable resource, but they did not offer detailed recommendations on how such a system should be constructed (Duncan, 1991; Emmelhainz, 1991).

Research objective one's completion yielded two-fold results. First, the authors gained an understanding of the general structure, management philosophy, and overall strengths and weaknesses of each school's research program. Second, the authors obtained feedback on the prototype system. The feedback came in the form of several new requirements which extended this study's scope. Besides the initial goal of improving researcher productivity by adapting the reuse concept to research, the study incorporated the tasks of developing an aid for selecting research topics and a framework for monitoring the overall academic research program. To meet this challenge, the authors held several informal meetings with personnel in the LS Office of Thesis Research to develop a conceptual model of the current LS environment that could be used in developing the prototype ARMS.

Research Objective Two Results

Based on the structured interview results and the insights gained during the formulation of this study, the authors developed an initial set of requirements for the ARMS. As noted in Chapter III, the exploratory nature of this study limited the degree of quantification that could be used in specifying the system's requirements. This factor was not considered a problem since the underlying aim of this study was to determine if a formal ARMS is needed. Future research efforts to improve the prototype should address the need for a more measurable set of requirements that empirically show the system's effectiveness.

To facilitate an AFIT-wide review and validation of the proposed requirements for the ARMS, a functional description (FD) was developed using the format listed in DoD-STD-7935, "Automated Data Systems Documentation." The FD (Appendix C) provided an overview of the existing environment and addressed how the new system was expected to impact it. Sections 3, 4, and 5 in Appendix C were not fully developed because specific design and implementation details were unknown at that time. These sections were significantly updated in the FD produced at the end of this study (Appendix K).

Copies of the initial FD were distributed to the following personnel with a cover letter explaining some basic guidelines for reviewing and validating the document:

a. Directors of Research and Consulting for DE, EN, and LS;

b. Director of Library Services (LD);

c. Director of the LS Information Resource Center (LSI);

d. Department Head for Government Contract Law (LSL);

e. Department Head for Logistics Management (LSM);

f. Department Head for Contracting Management (LSP);

g. Department Head for Quantitative Management (LSQ);

h. Department Head for Communication and Organizational Science (LSR);

i. Department Head for System Acquisition Management (LSY); and

j. Chief of the Communications-Computer System Development Division (SCV);

In addition to imposing a 30-day suspense for responses, the cover letter specifically requested comments on the general requirements listed in paragraphs 2.4 through 3.1 of the FD.

Responses were received from DE, EN, LDE, LSI, LSR, and LSY for a response rate of 55 percent. EN's response expressed concern about the potential implications this study may convey about the quality and value of AFIT research. The authors discussed this issue with the EN research director and reaffirmed that the intent of this study was to enhance the AFIT research program.

The remaining FD validation responses were general in nature and are summarized in Appendix D. Several comments addressed implementation decisions that will need to be made before a production quality ARMS could be placed into operation. Some of these issues are discussed in Chapter V and could serve as follow-on research topics if this study is continued by other student researchers. An updated FD was not produced at the end of this validation effort due to the limited number of recommended changes. As stated earlier, the FD was updated at the end of this project and is contained in Appendix K.

Overall, the validation effort did not provide the authors with the type of detailed recommendations they expected. It was anticipated that the respondents would closely scrutinize the FD and provide potential low-level requirements for the major ARMS subsystems. As a result, the authors were forced to develop the low-level requirements for the subsystems based on the validated general concepts in the FD and their past experience. Section three of Appendix K contains the product of these efforts.

Research Objective Three Results

To complete this objective, the authors were faced with three major decisions. The first, and perhaps most important, involved evaluating the alternative approaches for meeting the requirements validated in research objective two. Given the decision to pursue prototyping, the remaining two decisions centered on the selection of specific requirements for automation and the prototype's target architecture. The results of these activities are summarized in the subparagraphs that follow.

Evaluation of Alternatives. Once the requirements for ARMS were validated, the authors needed to determine the best course of action to pursue. The first decision centered on the need to determine if further action was required. Three primary alternatives were evaluated and are explained in this section.

The first alternative was to do nothing. In this case, the existing methods for topic selection, research product reuse, and research management would have to be considered satisfactory. The selection of this alternative would have canceled the need for completing the remaining objectives and led to an early completion of this study. Based on the encouragement received from the DE and LS research directors to pursue improvements in these areas, this alternative was not selected.

The second alternative was to modify an existing system. This alternative required the authors to examine the feasibility of modifying such systems as the AFIT Integrated Library System (ILS) or Defense Technical Information Center (DTIC) database to include the capabilities defined in the ARMS functional description (FD). This option was likewise disregarded since these and many other systems in library are commercial products whose changes are not controlled by AFIT. The effort to modify one of these products could have been contracted through the appropriate manufacturer. However, this option was considered cost-prohibitive at that time because the concepts underlying the ARMS implementation were as yet untested.

The final alternative was to develop a prototype. This option called for the development of a limited system to evaluate the underlying concepts of the ARMS and determine the desirability of such a system. The authors' past experience with information system development, along with the support offered by the LS research director, were key factors that led to the selection of this alternative.

Automation Requirements Selection. The development of a prototype that incorporated all of the requirements contained in Appendix K, Section 3, would have been too great an effort to accomplish under the time constraint for this study. Therefore, the requirements for each of the ARMS' four subsystems were pared down to a feasible, but representative, subset for implementation in the prototype. Special emphasis was placed on including capabilities that would permit evaluators to assess the potential usefulness of a production quality ARMS. The detailed requirements selected and subsequently implemented in each subsystem are delineated in Table 4-1.

Table 4-1

IMPLEMENTED SUBSYSTEM REQUIREMENTS FOR INITIAL PROTOTYPE ARMS

SUBSYSTEM	**APPLICABLE ARMS FD PARAGRAPHS**
Research Topic Selection	3.2.2.1.1 subparagraphs A, G, and I; 3.2.2.1.2.A; and 3.2.2.1.3
Research Products Reuse	3.2.2.2.1.A and 3.2.2.2.2
Research Management	3.2.2.3.1 subparagraphs C, D, and E; and 3.2.2.3.2
Database Administration	3.2.2.4.1 and 3.2.2.4.2

Computing Resources Evaluation and Target Architecture Selection. The next task was to choose the development system (hardware architecture and software) for the prototype. Three common-user computing system architectures were examined during this effort. The first was the VAX Cluster, which was comprised of four Digital Electric Corporation (DEC) mainframes. The primary functions and software support provided by these mainframes included: student file storage, electronic mail services, administrative program applications, database management system development (using the ORACLE(TM) Relational Database Management System), and a variety of commercially developed packages.

Two UNIX operating system-based resources comprised the next hardware architecture evaluated during this study. The first system, nicknamed PHANTOM, runs the Q-Office(TM) software suite. It provides user service functions such as electronic mail, bulletin board, electronic calculator, and several other office automation capabilities. The second system was the EN graphics workstation laboratory, nicknamed SCGRAPH. The laboratory's workstations host a wide variety of graphically-based software packages that support EN's education, research, and administrative programs. At the time of this study, neither of the UNIX-based systems provided the capability to develop a multi-user database management system like the ARMS.

The personal computer (PC) local area networks (LANs) located throughout AFIT comprised the final architecture examined during this step. The PC LANs provide students with a diverse set of commercial and "in-house" developed software for meeting their educational and research needs. Of the 15 LANs at AFIT, none was accessible to all students. These systems, like the UNIX-based systems, also lacked the capability to develop a multi-user database management system.

The results described above led to the authors' decision to develop the ARMS prototype on the VAX Cluster using the ORACLE(TM) Relational Database Management System. Specific information concerning the software configuration used to develop the prototype is contained in the updated ARMS FD (Appendix K), paragraph 5.2.

Research Objective Four Results

The prototype's design and development took approximately four weeks to complete. This time period included the authors' efforts to learn the fundamentals of ORACLE's development tools and to draft an initial set of operating instructions for the prototype. A description of the results of this objective is presented below.

ARMS Design and Development. The design and development of the prototype followed a systematic approach that began by modeling several aspects of the current research environment. A review of the specific inputs and outputs of the current system yielded a list of "objects." Theses, students, advisors, topics, sponsors, and products (also referred to as components) comprised the list of objects and each became a candidate record type. The interactions between these objects are illustrated in the context diagram in Figure 4-1.

Each object was then examined to determine its defining characteristics or, in the information system terminology presented earlier, its data items. Certain special characteristics were derived from the requirements listed in the FD. For instance, several requirements implied the need for categorizing a thesis as ongoing, continuing, award-winning, or sponsored. Control data items for all of these conditions were embedded into the design of the thesis record type. Many general characteristics for each record type were equally easy to define. As an example, the advisor and student record types both relate to people and have data items for first name, last name, middle initial, and rank. A detailed data dictionary containing a

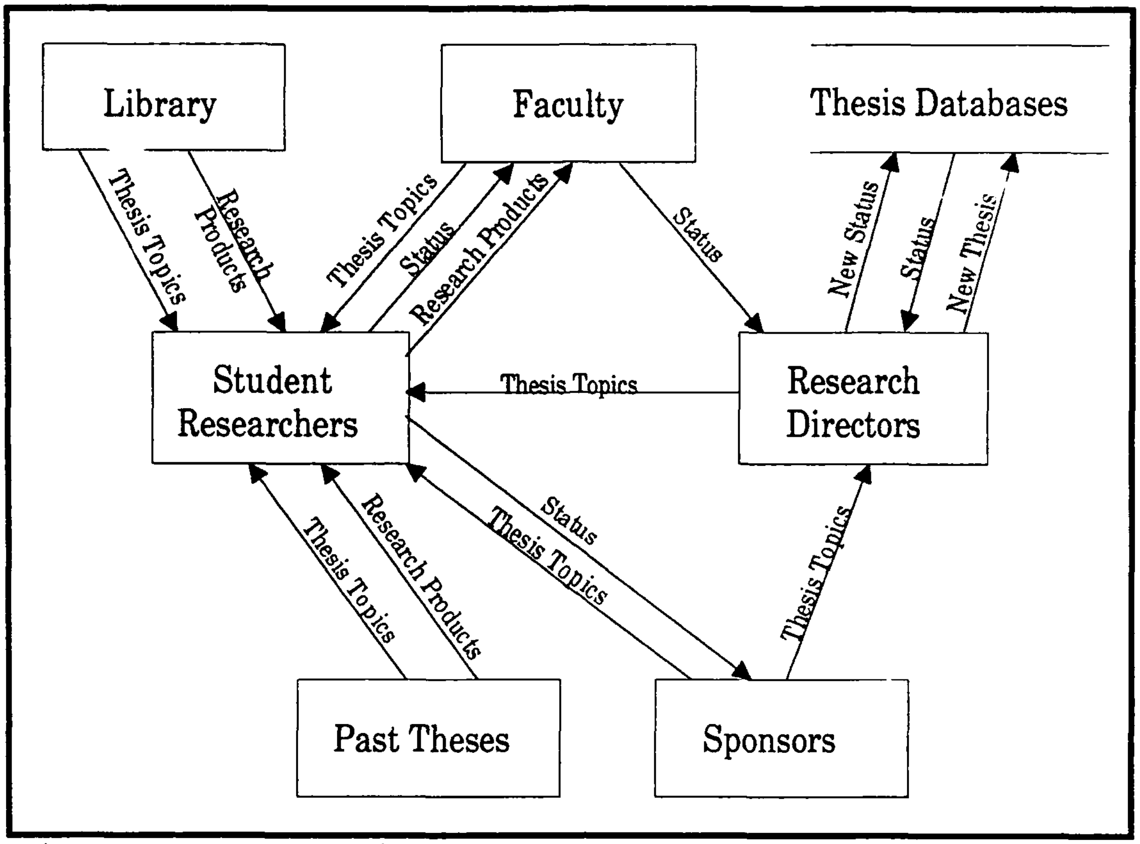

Figure 4-1. Context Diagram of the Current AFIT Research Environment

listing of each record type (also known as a table), its purpose, and its component data items is provided in Attachment 1 of Appendix K.

To manage the development of the prototype, the authors divided the system into logical subsystems. This provided them with a benchmark for gauging completion status and using standardized screen displays across different options within the same subsystem. The three subsystems (Research Topic Selection Subsystem (RTSS), Research Products Reuse Subsystem (RPRS), and Research Management Subsystem (RMS)) originally planned in the initial FD (Appendix C) were augmented by an additional subsystem to manage database administration functions. This fourth subsystem was aptly named the Database Administration Subsystem (DAS).

The next step involved the development of a menu structure that incorporated each subsystem and its associated functions. This effort was guided by the following general descriptions of each subsystem:

RTSS - Through the categorization of theses and automation of the current research topics book, the RTSS's goal is to provide student researchers with the capability to review available information in a more focused and expedient manner. The on-line information contained in the RTSS's tables allows researchers to review the complete abstract of an AFIT thesis and assists in determining if a more detailed review of the document is warranted. Four categories of theses and automated research requests can be queried and reviewed based on a variety of criteria.

RPRS - The RPRS represents an adaptation of the 'software reuse' concept, which is defined as the use of previously developed and/or acquired software components (such as source code modules, design descriptions, documentation, and so on) in a new development project. The application of this technique to the thesis yields several potential components for reuse. Currently, the process of locating such items is very tedious and time-consuming since only the thesis document is cataloged. The RPRS provides the framework for cataloging research components and allows for the on-line storage of an abstract describing the component, and in some cases, an electronic copy of the component itself.

RMS - The RMS is designed to provide a convenient source of management information concerning the AFIT/LS student research program. The initial capabilities of this subsystem include the ability to query and review information concerning continuing research studies, research sponsorship, and thesis advisor interests/ qualifications.

DAS - This subsystem is designed to provide personnel assigned database administration responsibilities with the capabilities to perform their job. Two primary sets of activities may be done in this subsystem: record manipulation and special queries.

Appendix F examines all of the menus developed during this phase and explains how each subsystem performs its required functions.

Three types of screen displays were then developed to meet the automation requirements selected during research objective three. The "query" screen, which provided the user with a "friendly" interface to find records of interest, was the first type of screen developed. The next step was to design the screens that would display information records retrieved by a user-provided query. The final step in this process involved providing the capability to view long text files, such as abstracts and electronic copies of components. Appendix F should be reviewed for more information about the screen layouts and procedures for using them. In addition, Attachment 2 of Appendix K should be consulted for details about the ORACLE SQLFORMS files that contain the screen display source code.

A limited help system was implemented with this version of the prototype. A user can get help from the system by pressing '0' on the keypad (<KP0>) during any menu, query, or information record display. Pressing <KP0> when a menu screen is displayed provides the user with information about menu options, while pressing <KP0> during the display of query or information records presents a layout of active keys for use within the current function. Additional help is provided on many of the screens in the form of "text boxes" and one-line messages that appear in the inverse video at the bottom of most screens. The ARMS User's Guide (Appendix F) contains some specific examples of the help information provided by the current prototype system.

Overall, the system's design was guided by the goal of integrating the plethora of information available within a research program. While the prototype built and evaluated during this study was somewhat

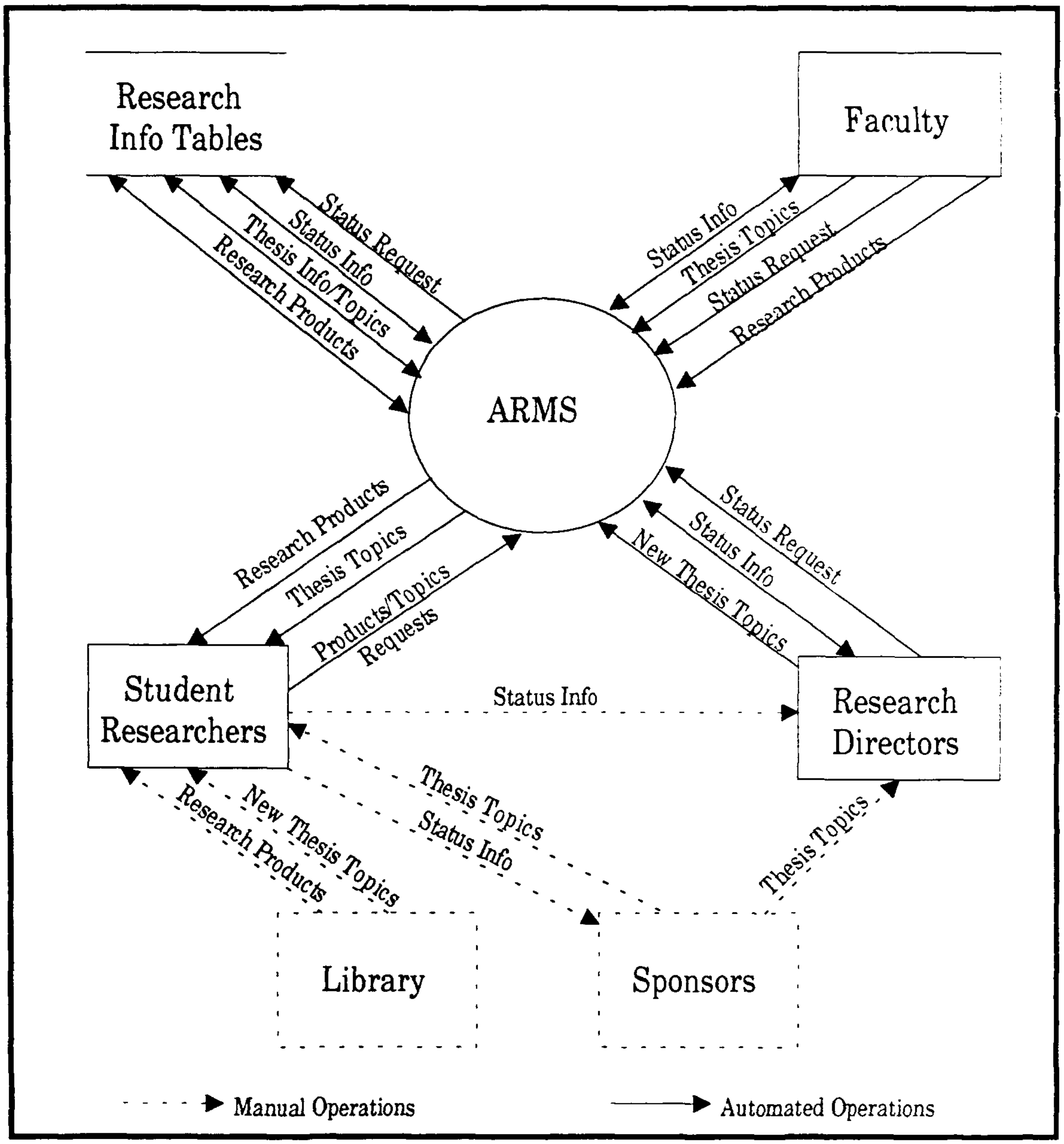

Figure 4-2. Context Diagram of the Proposed ARMS

limited, it does provide a modular framework that can be expanded. The context diagram in Figure 4-2 shows how the ARMS centralizes and potentially streamlines the flow of research information. As noted several times above, the interested reader is encouraged to review Appendices F and K to gain a better understanding of the prototype's design and operation.

User's Guide Development. In conjunction with the development of the prototype system, the authors drafted a user's guide (Appendix F) for use by personnel participating in the operational test. The guide begins with an introduction to the system and contains specific instructions on how to access, operate, and exit the system. It also contains specific examples that lead an ARMS user through queries in the research topic selection, research products reuse, and research management subsystems. The guide does not cover procedures for operating the database administration subsystem since access to it was limited to the authors for development and testing purposes.

Research Objective Five Results

Once the prototype ARMS was built, the next series of steps involved preparing for and conducting an operational test and evaluation. In completing this objective, the authors populated the prototype, developed an evaluation instrument, and conducted the test using the approach in Chapter III.

Prototype System Population. This step involved populating the prototype ARMS with an initial data set. Since most of the data were derived from theses, the authors recognized the need for qualitative criteria to select the documents for input into the system. It was decided that award-winning LS theses from the past three years would be used as the primary benchmark, since these studies had been judged by the faculty to be of superior quality. This criteria should be expanded for future prototyping efforts.

Information from a total of seventeen theses was placed into the ARMS thesis, student, advisor, sponsor, and component tables. Fifteen of the seventeen selected theses met the criteria listed in the above paragraph. One of the additional theses was selected because it was the source of a component reused by one of the award-winning theses. The final thesis was one that was needed to demonstrate the ARMS capability to provide ongoing thesis information. The text file abstracts for the completed theses were based on the abstracts contained in each document. A draft abstract was developed for the ongoing thesis effort.

A total of sixteen components were derived from the seventeen theses documented in the database. Component records and abstracts were developed by reviewing the applicable thesis text portions and extracting details. Seven of the sixteen components were reproduced for electronic storage and access through the ARMS RPRS. The remaining components were not entered because they were either too large or complex for inclusion in this version of the prototype. Table 4-2 provides a summary of the component types input into the ARMS.

Table 4-2

BREAKDOWN OF COMPONENTS TAKEN FROM THESES

COMPONENT TYPE	# CATALOGED IN THE DATABASE	# ELECTRONICALLY ARCHIVED
Documentation	1	0
Questionnaire	3	2
Survey	5	3
Interview	1	1
Statistical Models	6	1

Data on possible thesis topics available to incoming LS students was also included in the database. Nineteen topics were randomly selected from the LS Thesis Topics Book located in the library. The information used to complete each topic record was gathered solely from the applicable new research request forms. Seven of the selected topics were generated by AFIT faculty, while the remaining twelve were received from other DoD agencies.

Evaluation Instrument Development. The questionnaire used to evaluate the prototype ARMS was adapted from one developed by Captain Deanna McMurry for an AFIT thesis completed in 1990 (McMurry, 1990:90-92). McMurry's questionnaire contained twenty questions that were used to evaluate the technical adequacy and suitability of a prototype hypertext office reference system. Nine questions (numbers 1, 6a, 8, 9, 12, 13, 18, 19, and 20) were selected from the original set and modified to construct the evaluation instrument in Appendix E.

The evaluation instrument's first and last questions provided the authors with a means of evaluating each respondent's experience before the test and overall use of the prototype. Questions two through five addressed the user friendliness of the ARMS in terms of its on-line help and ease of use characteristics. The fifth and sixth questions allowed the test participants to subjectively assess the suitability of the ARMS and its potential to improve the research process. The remaining two questions provided the evaluators with the opportunity to annotate what they liked about the system and what they felt needed improvement. A space was also supplied to write additional comments about the ARMS or the project in general.

Operational Test Conduct. The ARMS operational test was conducted in two phases. Phase one was conducted with twenty-nine newly arrived students in the class of 1993, while the phase two included eighteen students in the class of 1992 and 11 LS faculty members. These sample sizes represented fifteen percent of the class of 1993, eighteen percent of the class of 1992, and six percent of the LS faculty, respectively.

The evaluation was conducted within the LS computer laboratories and was guided by a forty-five minute project orientation and system demonstration. The first fifteen minutes of each test were used to present an overview of the project, the prototype's major functions, and the evaluation instrument. The remaining thirty minutes were spent demonstrating the prototype ARMS' capabilities. During this period, the evaluators were encouraged to follow along on their personal computers. The example queries performed by the demonstrator are listed in the draft ARMS user's guide (Appendix F). Following the demonstration, evaluators were permitted to perform individual queries and complete the prototype ARMS evaluation questionnaire. The results of the test are discussed in the next section.

Research Objective Six Results

The two-phased operational test yielded the raw results contained in Appendices G, H, I, and J. This section discusses some of the significant results gained through an analysis of this data. It specifically addresses the technical characteristics of the current prototype and its overall suitability to meet the needs expressed in the ARMS FD.

Technical Adequacy Assessment. The technical adequacy assessment for this version of the prototype centered on the system's user friendliness and overall performance characteristics. Evaluator responses to questions two, three, four, seven, and eight in the prototype ARMS evaluation questionnaire (Appendix E) provided the necessary information to analyze these items.

A system's "user friendliness" is often difficult to judge. Some basic attributes of such systems include the availability of on-screen help, programmed function mapping to special keys, and error messages that describe what went wrong (Pfaffenberger, 1990:464). An analysis of questions two, three, and four showed that the prototype ARMS met each of these needs through the screen and form designs described above.

The menu help screens were highly rated by all three samples with satisfaction ratings of eighty-six percent by the new students, eighty percent by the faculty, and seventy-eight percent by the current students. In addition, Table 4-3 reflects that the subsystem-specific help facilities (which included context-sensitive help, function key mapping information, and error messages) received similar ratings. Although the ratings for the faculty sample were relatively lower for this question three, there were no apparent reasons for these deviations provided in the written comments on the evaluation forms.

Table 4-3

EVALUATION QUESTIONNAIRE RESULTS FOR QUESTION THREE

SAMPLE	RTSS	RPRS	RMS
New Students	83%	79%	Not evaluated
Current Students	89%	94%	89%
Faculty	80%	60%	70%

The questionnaire results for question four strongly support the "user friendliness" suggested above. Table 4-4 indicates that all three samples rated the subsystems as easy to learn and use.

Table 4-4

EVALUATION QUESTIONNAIRE RESULTS FOR QUESTION FOUR

SAMPLE	RTSS	RPRS	RMS
New Students	93%	87%	Not evaluated
Current Students	94%	83%	88%
Faculty	80%	70%	60%

In evaluating the responses to questions seven and eight, two other areas stood out as "well-liked" by all three samples. The screen displays garnered the approval of eighty percent of the faculty, seventy-eight percent of the current students, and seventy-two percent of the new students, while the functions performed by the subsystems were favored by 90 percent of the current students, 83 percent of the new students, and 60 percent of the faculty.

On the negative side, evaluator responses to questions seven and eight suggested improvements need to be made in the areas of processing speed and data breadth. The first improvement item was the result of some VAX Cluster system problems which caused interruptions during several demonstration sessions. This led several evaluators to suggest re-hosting of the ARMS to the LS PC LAN. The second improvement area was a factor induced by the authors' attempt to build such a large system in a short time period. Developing a more extensive data set for the initial prototype would have required trade-offs in other areas of the ARMS development and testing. To avoid this situation in future research efforts to improve the prototype, researchers should avoid simultaneously making many extensive enhancements.

Suitability Assessment. The suitability assessment for this version of the prototype was based on the subjective views of the operational test evaluators. In particular, the responses to questions five and six in the prototype ARMS evaluation questionnaire (Appendix E) provided the necessary information to perform this analysis.

Table 4-5

EVALUATION QUESTIONNAIRE RESULTS FOR QUESTIONS FIVE AND SIX

QUESTION/SUBSYSTEM	NEW STUDENTS	CURRENT STUDENTS	LS FACULTY
#5/RTSS	97%	95%	70%
#5/RPRS	96%	95%	70%
#5/RMS	Not evaluated	83%	80%
#6/RTSS	100%	100%	50%
#6/RPRS	100%	94%	50%
#6/RMS	Not evaluated	94%	60%

The results of evaluation questions five and six are summarized in Table 4-5. The two student samples expressed almost universal agreement concerning the need for the ARMS RTSS and RPRS. Interestingly, the faculty ratings for these questions was much lower than expected. A closer evaluation of the responses to these questions indicated that many faculty members elected to circle the 'neutral' or 'not evaluated' options. This might indicate that the phrasing of these questions should have been adjusted for the faculty population. As written, the questions specifically apply to the student researcher's role in the research process.

Overall, the ARMS prototype operational test demonstrated the desirability of having an automated tool that performs the functions described in the FD. Further research will have to be conducted before an informed decision can be made as to whether or not it is reasonable to implement a production-quality system. Accordingly, a number of further research recommendations are provided in Chapter V.

V. Summary, Conclusions, and Recommendations

Summary

The underlying impetus of this study was to enhance student researcher productivity through the use of automation. To scope this general issue down to a manageable research project, the authors performed a literature review and conducted an examination of the current academic research environment. These efforts resulted in the selection and further examination of two areas of difficulty that inherently impact student researcher productivity--research topic selection and research product reuse. A third area of the research domain, research management, was also investigated but to a lesser degree than the first two areas.

The modeling and subsequent implementation of the three selected areas into a "proof-of-concept" prototype information system were done using a hybrid software development life cycle model. An initial operational test of the developed prototype ARMS indicated strong support for the conceptual basis of the system and provided many recommendations for improving it. The time limitation placed on this study did not permit the authors to examine several key issues that should be considered before an informed implementation decision is made. These issues are discussed later in this chapter as part of the section on future research recommendations.

Conclusions

The accomplishment of this study yielded two groups of conclusions. The first group is of a general nature and reflects the insights gained during the execution of this study's methodology. The second group includes what the authors perceive as specific contributions to research.

General. A unique approach to system development was employed to complete this research. As described in Chapters I and III, the authors generally patterned the study's seven research objectives after milestones in a traditional system development life cycle with one exception--the planned final product was an initial prototype vice a production-quality system. To address the potential need for evolving the prototype into a well-defined, production-quality system, the authors then adapted and used a meta-model called the spiral life cycle model for system development (Boehm, 1988:64). The resultant model is a hybrid of the traditional and spiral models that not only supplied the initial framework for conducting this study, but established an approach that follow-on researchers can use to iteratively refine the prototype.

The use of a functional description (FD) to formally document and validate system requirements represented another unique aspect of this research. A review of recent AFIT thesis projects revealed that this approach has been infrequently applied by other researchers developing automated systems. However, the authors felt compelled to provide a document that would encapsulate their efforts and serve as a common baseline through subsequent development phases of the ARMS. As stated in Chapter IV, the FD validation effort did not produce the expected level of user participation. This may have been due to the inherent difficulty of describing an abstract entity like software in nontechnical terms. Despite its minimal early success, the FD should continue to be updated and used in follow-on studies to document and validate the ARMS requirements.

Research Contributions. A production-quality system that is similar to the prototype produced by this study has the potential to provide many potential benefits in the areas of research topic selection, research products reuse, and research management. A brief discussion of the conceptual contributions that each subsystem makes to researcher productivity and process improvement is provided below.

Research Topic Selection Subsystem (RTSS). The RTSS provides an additional automated method for reviewing information on "past" AFIT theses. It differs from current systems, such as the Integrated Library System (ILS) and Defense Technical Information Center (DTIC) catalog system, in three ways: (1) it provides a more detailed thesis information record; (2) it presents a textual abstract of unlimited length; and (3) it allows researchers to review theses that have been categorized as "continuing" or "sponsored" studies. These capabilities provide increased information to researchers and potentially assist them in determining if a further review of a thesis document is warranted.

The RTSS also allows researchers to review information and abstracts for theses that are still in progress when they are beginning their search for a thesis topic. Currently, researchers looking for a study that could be continued are dependent on the advisors and authors of ongoing research for information. As discussed in Chapter II, newly arrived student researchers within LS face a dilemma when they attempt to obtain and use this information to fulfill their research paper requirements for the COMM 687 course. The RTSS bridges the current information gap concerning ongoing studies and allows new student researchers to review and evaluate potential topics for continued study. In essence, they can begin the process of topic selection earlier in their graduate programs than the "unofficial" September availability date of thesis advisors.

The RTSS also automates the current research topics book. This new resource provides a more organized and traceable method of managing the topics generated by the faculty and received from other USAF and DoD organizations. In addition, a production-quality RTSS would theoretically furnish around-the-clock access (through the AFITNET computer network) to new research requests and allow students to search for a thesis topic at their convenience.

Research Products Reuse Subsystem (RPRS). The RPRS is possibly the most innovative aspect of the prototype ARMS. As described in Chapters I and II, many "reusable" research components and outputs are buried in completed theses. The current version of the RPRS represents an initial capability for cataloging, tracking, and managing these products so they can be located, reviewed, and reused in new or follow-on thesis efforts. This subsystem, used in conjunction with the RTSS, could potentially be used to promote the desirable goal of increased continuing studies. However, several policy and procedural details concerning the maintenance and use of the RPRS need to be resolved before it can be effectively implemented.

Research Management Subsystem (RMS). The time constraints of this study limited the RMS's design and development to the consideration of three information needs within the research management community. In its current form, the subsystem provides users with the ability to record and review continuing studies information, research sponsorship data, and thesis advisor qualifications. Of these three areas, only one, thesis advisor qualifications, is formally monitored in the current LS research program.

Despite its current primitive state, the RMS was well-received during the operational test. Personnel testing the system voiced many verbal recommendations on how to expand this subsystem but did not formally provide any in their written comments. The authors feel that future improvements to this subsystem are an essential aspect of making the overall ARMS a more viable tool for use in the AFIT research environment.

Recommendations

The authors encountered many related issues that could not be addressed as part of this research. Research objective seven was established and completed to ensure these issues were available for future research. As described in Chapter III, this objective called for the accumulation, documentation, and division of issues into two main categories: (1) recommendations related to follow-on development of the prototype system; and (2) suggestions for corollary studies.

Follow-on Development of the Prototype. There are three main sources of recommendations for follow-on development of the prototype. The first source is comprised of the subsystem requirements delineated in section three of the updated FD (Appendix K), excluding the paragraphs listed in Table 4-1. Table 4-1 contains the automation requirements that were selected for implementation in the initial prototype during research objective three. The two remaining sources of prototype enhancement recommendations are the contents of Appendix D and Appendix J. These appendices contain summarized written comments and recommendations from the FD validation and operational test efforts that were completed as part of research objectives two and five, respectively.

In addition to making the changes recommended in the above sources, follow-on research studies could also be conducted to:

1. Refine the ARMS one subsystem at a time. For example, the Research Topic Selection Subsystem could be considered as a stand-alone system, enhanced accordingly, and then implemented as a production-quality system.

2. Extend the current prototype to include one or more subsystems that deal with faculty research program. The goal of such a study would be to expand the conceptual basis of the current prototype to other research domain areas.

However, before proceeding with any enhancements to the current prototype, some consideration should be given to completing one or more of the corollary studies described in the next subsection.

Corollary Studies. The completion of this exploratory research project signals the need for several corollary studies. In particular, the relative success of this study's prototyping effort needs to be considered within the context of the numerous administrative and other factors that could impact its successful implementation. Three major corollary studies are described below.

Perform a Cost-Benefit Analysis. The aim of a cost-benefit analysis study would be to conclusively examine all potential alternatives for meeting the requirements in the ARMS FD. The first step would involve determining the projected costs and benefits of each alternative. The results of this step could then be used to compare the alternatives and select the best course of action. A study of this nature is strongly recommended in light of the ongoing efforts to trim the military's fiscal and personnel resources. The ARMS may indeed represent a desirable solution that AFIT cannot afford to sustain.

<u>Develop Qualitative Criteria for Reuse Components</u>. As discussed in Chapter II, one major obstacle to the widespread utilization of software reuse is the lack of a definitive quality standard for components. In practice, attempting to reuse poorly designed components can lead to serious project delays and negatively impact the system's overall quality. The subjectivity involved in evaluating academic work could pose a similar problem to the concept of research product reuse. The aim of a study in this area would be to develop a "consensus" set of criteria to use in evaluating items before they are placed in the Research Products Reuse Subsystem.

<u>Investigate Policy Decisions Required to Implement the ARMS</u>. A multitude of policy decisions are needed before a production-quality ARMS can be implemented. Some of the most important questions that need answers include:

1. What personnel resources are available to maintain and ascertain the system's data accuracy and currency?
2. Who should be responsible for determining if a research product is of sufficient quality to be cataloged in the research product reuse subsystem?
3. What data entry responsibilities, if any, should be delegated among students, thesis advisors, and research management personnel?

The organization and operational impact sections of the updated FD (paragraphs 2.4.2.1 and 2.4.2.2, respectively) provide some suggestions on how to approach these questions, but they are not conclusive. Rather than initiating a separate study to address the above concerns, one or more of these questions could be considered during the conduct of the other corollary studies listed above.

Appendix A: Structured Format for Research Director Interviews

ABSTRACT

The personal interviews conducted with the research director for each AFIT school followed the format listed below. In an effort to facilitate interviewee preparation and feedback, the researchers sent this three-part interview format and a short abstract describing the project to each research director one week before the scheduled interviews. These interviews had three primary goals:

1. to gain an understanding of the general structure, management philosophy, and overall strengths and weaknesses of each school's research program;

2. to present the basic tenets of the authors' research proposal and obtain general feedback about the project; and

3. to solicit recommendations about desired requirements for what was then termed the research products reuse program.

The questions listed below represent the minimal set deemed necessary to meet the above goals. Many other potential questions could have been asked if a more exhaustive study of the environment was needed. Actually, the research directors provided more information in answering these and unplanned follow-up questions than the authors needed to meet their goals for the interviews. Portions of the information derived from the interviews are recorded in Chapters II and IV, and Appendix B.

It should be noted that this structured interview was developed at a time when the authors were still fleshing out the details for their study. As described in Chapters II and IV, the results of this interview changed the scope of this research.

PART I. GENERAL QUESTIONS

A. What is the goal of research within your school?

B. Who is involved in the research process? What are their responsibilities?

C. What established timelines/milestones guide the thesis research program? Are they formally published and made known to the student researchers?

D. What types of external support/sponsorship are received?

PART II. MANAGEMENT QUESTIONS

A. How are certain types of research promoted within your school?

   1. How much of your school's research could be considered theory-building?

   2. How much of your school's research could be considered theory testing?

3. What are the typical focus areas of your school's research?

4. How are continuing studies promoted and managed within your school?

B. How is research evaluated in terms of quality and depth?

1. Are there any management indicators used to track: continuing studies, demand for faculty consultation in key research areas, or sponsorship trends?

2. If there are indicators, are they monitored by manual or automated systems?

3. In your opinion, what are the relative strengths and weaknesses of your school's research program?

4. Are there any on-going efforts to improve your school's research program?

<u>PART III. PROPOSAL PRESENTATION/FEEDBACK</u>

A. Proposal Outline

1. General Issue: The long-standing need for quality and utility in research is an issue that perpetually receives high-level interest within the academic, business, and government communities. Questions about how to establish and promote research programs with these attributes have guided many past and current initiatives. However, there is not a general consensus on a specific method to accomplish these tasks.

2. Specific Research Goal: The goal of this research is to design, develop, and test a prototype information system that will support the implementation of a research products reuse program within the Air Force Institute of Technology (AFIT) School of Systems and Logistics (LS).

3. Methodology/Research Objectives:

a. Describe the AFIT research environment.

(1) Interview research directors for each AFIT school.
(2) Investigate and document major research resources available to AFIT student researchers.

b. Define and validate the requirements for an AFIT research products reuse program.

(1) Develop a proposed list of requirements using the interview results and researchers' experiences.
(2) Design a requirements validation document for AFIT-wide faculty review and distribute it.
(3) Analyze validation results and update requirements list.

c. Determine the specific requirements for automation and select the prototype's target architecture.

d. Design/develop the prototype system and operating instructions for test users.

e. Prepare and conduct an operational test for the prototype system.

   (1) Populate the system with sample research products (surveys, questionnaires, statistical models, etc.) that could be used wholly, or modified and then reused in future research studies.
   (2) Select or develop an evaluation instrument.
   (3) Conduct tests with two random samples; one comprised of students and the other faculty.

f. Analyze operational test results.

   (1) Assess technical adequacy of the prototype system.
   (2) Assess the prototype's suitability and potential for contributing to the AFIT research environment.

g. Develop recommended path for follow-on research.

   (1) Provide suggestions for follow-on development of the prototype system.
   (2) Propose corollary studies to fulfill the requirements deemed unresolvable through automation, such as the policy structure needed to successfully implement the system.

B. Feedback Questions

1. What are your general impressions of the proposal?

2. What recommendations do you have about the requirements for the research products reuse program?

3. Would you be interested in assisting us with this study?

4. Would you be interested in evaluating the final product?

Appendix B: Matrix of Research Director Interview Results

The matrix below provides the major results derived from the personal interviews conducted with the research director for each AFIT school. The selected areas of interest listed in the first column were used to encapsulate answers from several questions. A more detailed discussion of results that pertain to the revised scope of this study are presented in Chapters II and IV.

AREA	DE	EN	LS
TYPE OF RESEARCH	Mostly applied; 10% theory	Mostly applied; faculty/sponsor-driven	Mostly applied; 10-20% theory-building
RESEARCH PROCESS	Well-defined timeline that incorporates formal research course work	Same as DE	Same as DE and EN
MANAGEMENT	Very few recent continuing studies; no formal tracking of indicators	Almost all are continuing or sponsored studies; thesis database used to track completion and cost avoidance data	Same as DE
RESEARCH PROGRAM IMPROVEMENT NEEDS	Better education of advisors on thesis process; capability to promote earlier problem identification	Lack of manpower is biggest limitation; extended tours for military faculty	Capability to promote continuing/sponsored studies and earlier problem identification
RECOMMENDATIONS FOR SYSTEM	Sections for topic selection, ongoing research review, sponsor information, and research management information	Should ensure alternatives to building a new system are examined	Same as DE

Appendix C: Initial ARMS Functional Description

INITIAL

FUNCTIONAL DESCRIPTION

FOR THE PROPOSED

AFIT RESEARCH MANAGEMENT SYSTEM (ARMS)

(Current as of: 27 Jan 92)

FUNCTIONAL DESCRIPTION
TABLE OF CONTENTS

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SECTION 7.	SYSTEM DEVELOPMENT PLAN	*

Note: Normal page numbering was removed to allow this document to be appropriately formatted into this thesis.

SECTION 1. GENERAL

1.1 Purpose of Functional Description. This Functional Description for the prototype AFIT Research Management System (ARMS) is written to provide:

A. System requirements which will serve as a basis for mutual understanding between the future users and the developers

B. Information on performance requirements, improvements, impacts, and system development processes

C. A basis for system test and evaluation

1.2 Project References

A. Draft Thesis Proposal: "Development of a Prototype Information System for Implementing a Research Products Reuse Program," 6 Dec 91, by Captains David Schaaf and Carl Scott

B. DoD STD-7935, "Automated Data Systems Documentation," 1 Nov 82

1.3 Terms and Abbreviations

A. ARMS - AFIT Research Management System

B. Automated Requirements - System requirements which can be implemented in the ARMS software suite

C. Component - A definable part of a system

D. Continuing Research Stream - Research which builds upon the results of previous studies

E. DE - School of Civil Engineering and Services

F. EN - School of Engineering

G. Faculty-Centered Research - research initiated, managed, and perpetuated by a faculty member

H. LS - School of Systems and Logistics

I. Nonautomated Requirements - System requirements which cannot be implemented as part of the ARMS software suite (for example, policy changes)

J. Prototype - A working model of a computer system which is used for testing the viability of a solution to a problem area

K. Research Product - component of the research process generated and used as part of a research project. (For example, data collection instruments, data, statistical models, computer programs, and computer program documentation)

L. Reuse - The application of existing solutions to the problems of systems development

M. Software - Computer programs, procedures, associated documentation, and data pertaining to the operation of a computer system and peripherals

N. Software Component - An element of software (code module, design document, etc.) that performs a definitive function

O. Software Reuse - The use of previously developed and/or acquired software components in a new development project

P. System - A collection of components organized to accomplish a specific function or set of functions

SECTION 2. SYSTEM SUMMARY

2.1 Background. The idea for this system was derived from the experiences of two students in the School of Systems and Logistics (LS). The difficulties of determining what research topics are important to the Air Force and DoD, as well as the complexity of scoping a workable research project, led them to initiate a research project that would aid future students.

This project is based on an emerging computer science technique called software reuse. This technique is commonly defined as the use of previously acquired and developed concepts and objects in a new situation. In the area of software development, this would include items such as source code modules, program architectures, software documentation, and a number of other products. The intuitive benefits of this technique are in the areas of productivity (cost and time avoidance), quality, and reliability. To be effectively implemented, reuse requires an extensive effort to determine what and how products should be cataloged into a library system. The library system then allows the products to be located, reviewed for applicability to a new project, and subsequently reused.

Current efforts in the area of reuse are focused on applying the technique to specific "domains." This project supports the intention of these efforts by adapting and evaluating reuse in the research domain. Using the original goal of building a research products reuse system, the student researchers found that there are many management benefits to be gained by employing such a system. This insight led them to expand the scope of the system's goals to those listed in the next paragraph.

2.2 Goals. The major goals of the prototype ARMS are to:

A. Enhance the student researcher's capabilities to select and scope a research problem which is vital to the Air Force and DoD.

B. Improve student researcher's productivity by adapting and evaluating the concept of reuse to the research domain.

C. Increase management efficiency by providing a collection of data which can be used to efficiently meet reporting needs.

D. Stimulate an increased conduct of continuing research streams within LS and DE.

2.3 Existing Methods and Procedures. Similar academic research processes are conducted by two of the three schools at AFIT. Currently, the Schools of Systems and Logistics (LS) and Civil Engineering and Services (DE) allow students to select their own research topics; while the School of Engineering (EN) employs an approach that fosters continuing research streams. Aside from this difference, the description of the existing methods and procedures provided below applies to all three schools.

It is important to note that modeling the entire academic research domain for the initial prototype ARMS would be an insurmountable task during the short research period afforded AFIT graduate students. Therefore, only three major facets of the domain will be examined during this project: research topic selection, research product reuse, and research management.

2.3.1 Topic Selection. AFIT graduate students researching possible thesis topics can refer to several resources. Many of these resources are found in the academic library, which contains a wide variety of services for conducting topical literature searches. Also, research directors and some faculty members formally and informally "advertise" potential topics. However, it is not always clear to the student researcher which topics are of vital interest to the Air Force and DoD.

The availability of thesis advisors during the critical initiation phase of new students' research activities is another area that impacts topic selection. At present, students in the initial period of selecting and scoping a suitable problem for research, compete for thesis advisors with students who are in the final stages of their projects. This situation not only impairs the progress of new researchers, but places an immense burden on the faculty. Hence, thesis advisors are not readily available for consultation until after Labor Day. By that time, students within the LS school (an' in some cases DE) are nearing completion of a literature review assignment for the mandatory COMM 687 (Theory and Practice of Professional Communications) course. Under the current system, the potential benefits of COMM 687 are not fully realized. Students without a well-defined topic may spend valuable time researching a subject unrelated to their thesis.

2.3.2 Research Product Reuse. During the process of completing their theses, student researchers generate a number of products to collect and analyze data. In addition, some student researchers develop software systems or other end products as a result of their efforts. The documentation of such items is embodied within theses and often archived without consideration for further use. (As noted above, the EN school has a program of continuing research streams that reuses products from past studies. However, such items are not cataloged or made available to students in other schools.) Therefore, research products reuse is inhibited in part by the difficulty that students face in locating the items which may benefit their research efforts. Once a suitable product for reuse is located, the researcher normally must recreate it using manual methods.

Based on the concept of reuse, student researchers potentially have a great deal to gain by locating, reviewing, and reusing (in part or as a whole) quality research products that are presently underutilized. The current methods of locating and manually reviewing theses might be more acceptable if students had a greater length of time to conduct their research. However, the current 12-15 month start-to-finish thesis process puts pressure on students to complete their research projects expediently. Improvements in locating and reviewing products could potentially relieve pressure by making validated products readily available for reuse.

2.3.3 Research Management. The process of managing academic research is accomplished at AFIT by the research directors for each school. As focal points for summarizing and formally reporting their school's research efforts, the directors use a number of automated and non-automated procedures. However, none of these procedures has a single collection point for data. Such a data base would offer many potential benefits.

Faculty members at each school who serve as thesis advisors share responsibility in the area of research management. In particular, the underlying basis for a quality program of continuing research streams is faculty-centered research. However, due to the short tenure of many military faculty members, the promotion and longevity of continuing research streams is somewhat restricted. The capability to track ongoing or review past continuing research streams could produce an improved environment for similar efforts in the future.

2.4 Proposed Methods and Procedures. This section outlines the improvements offered by the proposed ARMS and describes the system's impact on the present research process at AFIT.

2.4.1 Summary of Improvements. Student researchers, faculty members, and research directors will be provided with certain improvements due to the implementation of the ARMS. The improvements are grouped into four categories: general, research topic selection, research product reuse, and research management.

2.4.1.1 General Improvements. The automated portion of the proposed ARMS will use a data base management system to store and process the data needed to meet student researcher, faculty, and management requirements. As an automated and integrated source of data, the ARMS will offer an information sharing capability among the three AFIT schools. Additionally, the ARMS will provide intangible benefits of using a data base management system such as automated record-keeping, improved trend tracking, standardized/tailored reporting, and other capabilities.

2.4.1.2 Research Topic Selection Improvements. The ARMS will provide an expedient method for reviewing abstracts which describe past and on-going AFIT research projects. The system's implementation will potentially alleviate some of the constraints described above in section 2.3.1. The instinctive advantages of using an automated system, combined with the resources available in the current system, will help researchers:

A. Begin the process of selecting/formulating a researchable topic earlier in the academic year.

B. Review a broader range of research topics more expediently and efficiently.

C. Scope their selected research problem better.

D. Select topics that lend themselves to longitudinal studies.

E. Investigate the application of research designs and methodologies to specific types of studies.

F. Perform studies that are more relevant to the Air Force and DoD.

In addition to reviewing past and on-going AFIT research efforts, students will also be able to scan new topic suggestions using the ARMS.

2.4.1.3 Research Product Reuse Improvements. The ARMS will provide an efficient means of cataloging research products into a "library system" for future reuse. The resultant library system will allow researchers to expediently locate, review, and reuse research products from previous theses.

2.4.1.3.1 Locating Products. The ARMS will allow researchers to locate reusable research products in many different ways. The following is a list of key search methods that may be used individually or in a number of combinations:

A. Component Type.

1. Thesis documents
2. Data collection instruments such as surveys, interview formats, and questionnaires
3. Data from previous collection efforts
4. Statistical models developed to analyze collected data
5. Computer programs such as decision support systems, expert systems, and other application systems
6. Computer program documentation such as functional descriptions, design documents, source code, test plans, and user's guides

B. Research Category such as Acquisition Management, Contract Management, Software Engineering, and Environmental Management

C. School/Department

D. Author Name

E. Subject/Keyword(s)

The capability to locate specific products for reuse will be a major improvement over the systems that are now available to AFIT researchers. Currently, most of the systems only provide students with the capability to locate thesis documents and manually review them for available research products.

2.4.1.3.2 Reviewing Products. After the ARMS locates reusable products based on the provided criteria, the researcher will be able to review an abstract for each candidate product. Each abstract will provide both a description and a reuse history of the respective product. Researchers will also be able to further review a copy of the product to determine if it is reusable in their research project. Overall, the capacity to review abstracts and copies of research products immediately after locating them will save researchers' time.

2.4.1.3.3 Reusing Products. The current method of reusing research products normally requires the researcher to recreate the products manually. For example, researchers must either retype the product or become proficient at using an electronic scanner with optical character reading capability. To minimize this limitation, the ARMS will provide the researcher with an option to obtain an electronic media copy of the product. The ability to obtain a printed copy of the products and respective abstracts will also be available. Combined with the improved locating and reviewing functions, these features should further enhance the productivity of student researchers.

2.4.1.4 Research Management Improvements. The ARMS, by virtue of the detailed information it is to contain, will strongly support many management applications. The following is a representative list of functions that can be automated by employing this system:

A. Thesis status tracking data such as initiation date, personnel involved, topic, and completion date.

B. Thesis publication data to periodicals, DTIC, and other archives.

C. Research sponsorship data to include agency, point of contact, funding amounts, and cost-avoidance estimates.

D. Continuing research stream(s) monitoring.

E. New research topic screening/advertisement.

In designing the ARMS, the developers will review the structure of existing data base systems used by research management personnel to the extent that information is provided by the organizations administering such systems. The aim of this approach is to allow for the transfer of existing data into the ARMS.

2.4.2 Summary of Impacts. The ARMS will provide more timely and accurate information to support the conduct and management of the AFIT student research process. The following paragraphs discuss some of the system's major impacts in existing organizational and operational environments. In particular, the following paragraphs outline some of the major nonautomated requirements that must be addressed before the ARMS can be fully implemented.

2.4.2.1 Organizational Impacts.

A. A number of personnel (quantity to be determined) will be required to perform data entry operations. This effort could be minimized depending on how the policies and procedures for sustaining the system are structured. See paragraph 2.4.2.2.A.

B. A database/system manager should be appointed within each of the three schools to answer user questions and manage school-specific implementation details.

C. An application administrator should be assigned within AFIT/SC to maintain the ARMS application.

2.4.2.2 Operational Impacts. Several policies will need to be developed to ensure the system is implemented, operated, and maintained efficiently. Specifically, all operational areas (student researchers, faculty members (thesis advisors), and researcher directors) impacted by the ARMS should have defined responsibilities. The following suggestions should be considered before fully implementing the system:

A. Require student researchers to submit electronic media copies (diskette or other suitable means) of research products and abstracts along with completed theses. This requirement would impose a minimal workload on students, while significantly decreasing the data entry burden for the system.

B. Assign faculty members (thesis advisors) the responsibilities of:

1. Evaluating research products generated during student projects for inclusion in the research products reuse subsystem. This decision is similar to the one that is now made concerning thesis publication and distribution.

2. Reviewing research topics and generating new ones for input to the topic selection part of the ARMS.

C. Task the research management staff (each school's research director and their personnel) with overall ownership responsibilities for the system. Such responsibilities might include: monitoring the system's data accuracy and validity; acting as the liaison between users and the application administrator (AFIT/SC) for problem resolution and/or system improvements; and managing the access permissions for certain data within the system.

2.4.2.3 Developmental Impacts. Besides designing and implementing the data structures, control programs, and initial data set for the prototype ARMS, the developers will accomplish the following tasks as part of this project:

A. Training ('hands-on instruction') will be conducted for all personnel participating in the operational test of the prototype ARMS.

B. User guides/instruction sheets will be developed for the various ARMS applications (subsystems).

C. Program maintenance documentation will be developed to ensure the system can be enhanced in the future.

2.5 Assumptions and Constraints. The following key assumptions and constraints apply to this project:

A. The ARMS is a prototype development that will potentially undergo iterative refinement in future research efforts or be turned over to AFIT/SCV for maintenance. Therefore, coding and documentation conventions consistent with those used in other AFIT automation systems will be employed.

B. The project is limited to the use of existing AFIT computing hardware and software.

C. The prototype system will be developed to handle the storing and processing of unclassified information only.

SECTION 3.0 DETAILED CHARACTERISTICS

3.1 General Performance Requirements. The list below provides general performance requirements that the automated portion of ARMS must meet while providing the improvements and functions described in sections 2.4 and 3.2.

A. Provide formatted displays for interactive (on-line) data entry.

B. Minimize user entries by providing default values and range boundaries where possible.

C. Provide feedback when a transaction has either been completed or rejected.

D. Ensure that only completed transactions are stored in the database.

E. Provide an ad hoc query and reporting capability to users with special needs and advanced training.

F. Permit the generation of predefined reports.

G. Permit retrieval of data by the user from/to terminals or to printers.

H. Provide each user the authority to access records and data in their areas of responsibility.

I. Limit each user to specified processing functions based on assigned responsibilities.

J. Provide daily, weekly, and monthly database backup capability.

(NOTE: A detailed description of the following four sections will be developed during the design process. Any initial information available is provided in each paragraph.)

3.2 Functional Area System Functions. Based on the improvements listed in section 2.4, the automated portion of ARMS will have at least three major subsystems--the topic selection subsystem, the research products reuse subsystem, and the management subsystem. Additional subsystems will likely be required to permit database maintenance activities.

3.3 Inputs-Outputs. The data elements to be included in the construction of the ARMS will be defined and documented as required by the DoD-STD-7935 during the design process. The input of data will primarily be accomplished through the keyboard of a personal computer or other virtual display terminal connected to the AFITNET. The ARMS will also provide an interface for transferring data from selected disk drives of connected computers and terminals. Outputs from the system will include screen displays, printouts, disk files, or tape files.

3.4 Data Base Characteristics. As stated above, the data elements for the system will be defined and documented as required by DoD-STD-7935. Based on the requirement to use an already available relational database management system, all data elements will be represented within a set of tables. Casual users of the system will not need to know the details of how the data is stored and will be shielded from such information by a series of menu- and prompt-driven interfaces.

3.5 Failure Contingencies.

3.5.1 Types of Failures. Database failures for the ARMS can fall into three categories:

A. Transaction Failure: A failure of a single transaction of the database, usually caused by a data error.

B. Software Failure: A failure of the database management system itself, usually caused by a programming error.

C. Hardware Failure: A failure of the system hardware, either recoverable or catastrophic. Recoverable errors are typically power outages and catastrophic errors usually destroy data in the database requiring a complete recovery of the database from a backup copy.

3.5.2 Methods to Recover From Failures. To be determined based on the hardware and software systems selected to implement the system.

3.6 Security. The initial prototype ARMS will be developed to store and handle only unclassified data. Additional precautions for handling additional types of data may be required during future enhancement efforts.

SECTION 4. DESIGN DETAILS

The design details for the prototype ARMS will not be determined until the requirements listed in Sections 2 and 3 have been validated. In addition, the activities of this project's third objective (as outlined in paragraph 7.2.3) must be completed. This section will be written as part the project's fourth objective.

SECTION 5. ENVIRONMENT

The computer resources environment for the ARMS will be determined during the completion of the third objective of this research project (see paragraph 7.2.3.) This section will be written at that time.

SECTION 6. COST FACTORS

Cost factors are not addressed in this functional description because the initial version of the ARMS is being developed as a prototype under the auspices of a graduate student research project.

SECTION 7. SYSTEM DEVELOPMENT PLAN

7.1 Overall Approach. The development of the prototype ARMS will be accomplished using the seven research objectives described in the draft thesis proposal referenced in paragraph 1.2.A.

7.2 System Development.

7.2.1 Objective #1 - Describe/Define the Current AFIT Research Environment. A detailed description of the current AFIT research environment is needed to clearly understand the objectives, alternatives and constraints of the research problem. The following steps will be taken to accomplish this objective:

A. Interview Research Directors for the AFIT Schools of Engineering (EN), Systems and Logistics (LS), and Civil Engineering (DE) to:

   1) To gain an understanding of the general structure, management philosophy, and overall strengths and weaknesses of each school's research program.

   2) To present the basic tenets of this research proposal and obtain general feedback on the overall project.

   3) To solicit recommendations about desired requirements for the prototype ARMS.

B. Investigate and document the major resources available for conducting research.

7.2.2 Objective #2 - Define and Validate the Requirements for the AFIT Research Management System (ARMS). The primary goal of this research objective is to produce a validated requirements document for the ARMS. Since the system may require the implementation of many nonautomated requirements, the document developed below must not be constrained to only those tasks that can be automated. This fact will be emphasized throughout the process of completing the following steps:

A. Develop a Proposed Set of Requirements. A proposed set of requirements will be developed based on the interviews conducted in objective one and the insights of the students developing the system.

B. Design and Distribute a Functional Description (FD) of the System to Validate Proposed Requirements. The FD (which is this document) will allow future users of the system to influence the development of the prototype.

C. Analyze Validation Results and Update the FD. The results of the validation effort conducted in the above step will be analyzed and used to update the system's FD. The analysis accomplished during this step will focus on determining if the proposed changes or additions are consistent with the purposes of this system.

7.2.3 Objective #3 - Determine the Specific Requirements for Automation and Select the Prototype's Target Architecture. There are two primary sets of decisions that must be made to complete this objective. The first involves a determination of which requirements can be automated as part of the initial prototype system. The second set of decisions will involve an assessment of which computing hardware and software can be used to support the development and initial test of the prototype system. The final decisions in both of these areas will be affected by time and resource constraints that cannot be fully estimated at this juncture. The following steps will be accomplished to meet this objective:

A. Select Requirements for Automation. The first step in this process will be to defer all of the nonautomated requirements needed to fully implement the ARMS. The second and final step will require the developers to determine (based on time and resource restrictions) which automation requirements to include in the initial design of the prototype. The goal of this step is to ensure that the requirements selected will demonstrate the potential usefulness of the system. Those requirements not selected for automation in this step will form the foundation of the recommended path for follow-on research.

B. Examine AFIT Computing Resources and Select Target Architecture. The selection of a host computer system and development tools is required before the prototype can be designed. An evaluation of available AFIT computing resources will be conducted concurrently with the above research objectives.

<u>7.2.4</u> <u>Objective #4</u> - <u>Develop the Prototype System</u>. The prototype will be developed based on the results of the above research objectives. Detailed documentation on the design and operation of the system will be needed to ensure the initial prototype can be efficiently operated during the operational test, and subsequently improved during follow-on research efforts. These requirements, as well as the formal coding of the information system's data structures and control programs, will be fulfilled by completing the following steps:

A. Design and Program the Prototype System. The system will be designed using established software engineering principles. In particular, the system's design will be completed using a combination of data flow diagrams and program control structure charts before any computer programming is started. In addition, a set of revision control procedures will be established and followed throughout the programming process to ensure the system's development is properly managed.

B. Write Operating and System Administration Instructions. A set of initial operating instructions will be developed to help personnel use the system during the operational test. A set of instructions will also be developed on how to perform system administration functions (if deemed necessary). The documents developed to complete this step will be evaluated during the operational test of the system.

<u>7.2.5</u> <u>Objective #5</u> - <u>Operationally Test the Prototype System</u>. The steps performed to meet this objective involve populating the information system with initial data, establishing evaluation tools, and conducting an operational test of the system. The final step of this objective will require the cooperation of several departments within the three AFIT schools.

A. Populate Prototype System. During this step, the system will be populated with an initial set of data. The current plan is to have a minimum of fifty research products in the database for the operational test. These products will be derived from recent award winning theses.

B. Selection/Development of Evaluation Tools. Prior to conducting the operational test, a set of appropriate evaluation tools for assessing technical adequacy and operational suitability will be researched. If suitable tools are not found, they will be developed.

C. Conduct Operational Test. The formal operational test of the system will be conducted using faculty members and students from the School of Systems and Logistics. This testing limitation is being imposed to eliminate difficulties involved in coordinating a large formal test. A limited, informal test of the system may be commissioned to allow the research directors at the other two schools to assess the value of the prototype.

7.2.6 Objective #6 - Analyze Operational Test Results. During the completion of the operational test, test team members will use a set of predefined tools to document their evaluation of the system. The data gathered during the test will be used to perform the following steps:

A. Assess Technical Adequacy. To assess the technical adequacy of the system, a statistical analysis will be performed on responses to questions that relate to the basic performance characteristics of the system. Specifically, assigned subjective ratings will be evaluated for factors such as ease of use, speed of data retrieval, clarity of data presentation, as well as a number of other man-machine interface considerations.

B. Assess Operational Effectiveness/Suitability. The operational effectiveness of the prototype system will be assessed by performing a statistical analysis on responses to questions that pertain to the ability of the system to accomplish its operational mission. The assessment of operational suitability will involve making a determination on whether the prototype system should continue in the iterative improvement process.

7.2.7 Objective #7 - Develop Recommended Path for Follow-on Development/ Research. In light of this project's "proof of concept" nature, the proper completion of this objective is very important. Therefore, items for follow-on research will be gathered and documented during the conduct of objectives one through six. Following this approach will reduce the completion and documentation of this objective to partitioning the issues into the two main categories listed below.

A. Follow-on Development of the Prototype System. The research items in this category will focus on improving the prototype system. Known candidate items for inclusion in this category are:

1) Requirements that were not selected for automation during objective three.

2) Changes and additions recommended by the analysis results in objective six.

B. Proposed Corollary Studies. The follow-on research in this category will focus on the need for corollary studies to determine how the non-automated requirements for the system can be implemented. The primary items for this category will be derived during research objectives two and three.

Appendix D: Summary of FD Validation Comments

The summary below lists the comments provided by five of the six respondents to the FD validation effort. The EN director's comments are specifically addressed in Chapter IV and are not revisited in this appendix. A brief explanatory note that includes the item's final disposition is provided for each comment.

1. You may want to consider an off-line vice on-line archival system for electronic copies of components. (Reference paragraph 2.4.1.3.3.)

   Disposition: This alternative will be added to the next version of the FD.

2. It sounds like new manpower may be needed to manage the system. Can the job be handled by people already in place? (Reference paragraph 2.4.2.1.)

   Disposition: A follow-on study needs to assess this question and number of others that relate directly to a cost-benefit analysis.

3. If you are going to use the Oracle relational database management system, you may want to consider improving its user-interface by using embedded structured query language commands in a high order language. (Reference paragraph 3.1.)

   Disposition: For expediency purposes, the standard Oracle development environment was used for this initial prototype. Future improvements to the prototype or a contract effort to build a production system should consider this point.

4. You may want to consider making the human-machine interface resemble that of another commonly used system (like the library ILS) to minimize the student learning curve for a new system. (Reference paragraph 3.1.)

   Disposition: An attempt will be made to standardize the user interface with other existing systems. However, it would seem infeasible to be able to replicate an interface in the short time we have to develop the prototype, given the fact that it likely required a significant expenditure of resources by the commercial developers to develop the interfaces for the existing products. This factor should be examined during successive cycles of the spiral model.

5. AFIT/SCOS has previously looked at electronic archival of software, data, etc., from previous research. The students should check with them to see what has been done in this area. (Reference paragraph 2.4.1.3 and its subparagraphs.)

Disposition: This item was discussed with the personnel in the AFIT/SCOS branch. They advised that no formal study had been done on this issue or is planned at this time.

6. Some of the information planned for incorporation into the new system is a duplicate of what's already available in the Defense Technical Information Center's (DTIC) Defense RDT&E Online System (DROLS) data base. However, the actual computer models, programs, etc., which are a part of the thesis, are not separately indexed in DROLS. That aspect of the proposed ARMS would be a definite improvement over DROLS. (Reference paragraph 2.4.1.3 and its subparagraphs.)

   Disposition: Only a limited amount of data available within the existing library systems will be duplicated. For example, the thesis designator, title, and author information will be duplicated in the ARMS. However, detailed indicators concerning a thesis categorization as a continuing, sponsored, or award-winning study can not be found in these or any of the school-specific automation systems that track theses completion. There are a number of other examples of this fact located in the FD and the thesis. This issue should remain an area for future consideration and review.

7. Who would be responsible for inputting the data for retrospective theses? I don't see any organization willing taking on this added responsibility during the current environment of manpower downsizing. (Reference paragraph 2.4.1.3 and its subparagraphs.)

   Disposition: Similar to comment #2 above, a cost-benefit analysis should be conducted to determine if it would be worth-while to input past theses. This task is not within the scope of the current study.

8. Will the system include doctoral dissertations done here at AFIT, and those done at civilian schools with AFIT sponsorship? (General comment.)

   Disposition: This requirement will be added to the next version of the FD.

9. Section 2.4.1.3.1 should probably include the names of advisors.

   Disposition: This requirement will be added to the next version of the FD.

10. Section 2.4.2.2.A states that the tasking "would impose a minimal workload on students." This is probably not always the case with very long theses and dissertations.

   Disposition: This appears to be a misconception. This item will be better defined in the next version of the FD.

Appendix E: Prototype ARMS Evaluation Questionnaire

INSTRUCTIONS

Please rate the sliding-scale questions according to the following legend:

1 - strongly agree	4 - disagree
2 - agree	5 - strongly disagree
3 - neutral	6 - not applicable or evaluated

GENERAL INFORMATION

1. I consider myself knowledgeable about the general operation of computers and database management systems.

   1.......2.......3.......4.......5.......N

2. The menus' help screens were self-explanatory and provided me with enough information to begin using the system.

   1.......2.......3.......4.......5.......N

SUBSYSTEM EVALUATION

3. I felt confident operating this subsystem using only the on-screen help facilities (field/option-specific help bar, separate instruction blocks, etc):

   Research Topic Selection: 1.......2.......3.......4.......5.......N

   Research Products Reuse: 1.......2.......3.......4.......5.......N

   Research Management: 1.......2.......3.......4.......5.......N

4. I found this subsystem easy to learn and use:

   Research Topic Selection: 1.......2.......3.......4.......5.......N

   Research Products Reuse: 1.......2.......3.......4.......5.......N

   Research Management: 1.......2.......3.......4.......5.......N

5. I feel the type of automated information provided by this subsystem could help (or could have helped) me more efficiently conduct a research study:

   Research Topic Selection: 1.......2.......3.......4.......5.......N

   Research Products Reuse: 1.......2.......3.......4.......5.......N

   Research Management: 1.......2.......3.......4.......5.......N

6. I would use (or would have used) this subsystem for research work if it were fully operational:

Research Topic Selection: 1.......2.......3.......4.......5.......N

Research Products Reuse: 1.......2.......3.......4.......5.......N

Research Management: 1.......2.......3.......4.......5.......N

OVERALL SYSTEM EVALUATION

7. I liked the following features about the subsystems I used (circle all that apply):

   a. screen displays (screen organization).
   b. functions (what the subsystems do).
   c. processing speed (system response time).
   d. data (applicability, breadth).
   e. written instructions.
   f. on-line help instructions.

8. The following features of the subsystems I used need to be improved (circle all that apply):

   a. screen displays (screen organization).
   b. functions (what the subsystems do).
   c. processing speed (system response time).
   d. data (applicability, breadth).
   e. written instructions.
   f. on-line help instructions.

9. I used the AFIT Research Management System:

   a. less than 15 minutes.
   b. 15 to 30 minutes.
   c. 30 minutes to one hour.
   d. more than one hour.

CONCLUSION

If you have other comments, please record them below or attach a separate page. Thank you for your participation.

Appendix F: ARMS User's Guide

User's Guide

for the

Prototype

AFIT Research Management System (ARMS)

by

Captain Carl W. Scott
Captain David Schaaf

Current as of: 31 July 1992

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* The normal page numbering for this document was eliminated so that it could be incorporated into the thesis.

INTRODUCTION

The prototype AFIT Research Management System (ARMS) is a multi-user database that was developed as part of a graduate thesis project. The system's primary functions include storing and providing access to information which can aid student researchers in preparing for and conducting their thesis work. Specifically, the ARMS contains subsystems for assisting researchers with the tasks of developing a research topic, finding a thesis advisor, and locating a reusable component (such as a survey, questionnaire, program, or other applicable item) that could be used or modified for use in their projects. The ARMS is also intended to provide faculty and research management personnel with timely, accurate information about the school's research program.

The prototype system described in this guide was developed using the ORACLE database management system and associated tools. The man-machine interface is primarily menu-driven and requires the user to type in specific criteria on which to conduct queries. No knowledge of structured query language (SQL) is required by students or faculty to operate the ARMS. However, careful attention should be paid to the keyboard differences between the various types of computers available for use at AFIT. Specific examples detailing how to operate the system are provided later in this guide.

The goal of building this initial version of the prototype ARMS was to provide a method of evaluating the benefits and practicality of: (1) adapting the "reuse" philosophy to research, and (2) improving the research conduct and management processes through specialized automation. The present system is mature only to the extent that it demonstrates the conceptual gains which could be provided by a full production system.

ACCESSING THE SYSTEM

The prototype ARMS is currently hosted on the VAX Cluster and must be accessed through the AFITNET. For the purpose of the operational test, most personnel will only be able to view data. Privileges to add, delete, or change information in the system are reserved for the personnel developing the ARMS.

The following steps should be taken to access the ARMS:

1. Log into the LS_LAN NOVELL menu system and select the following options in succession 'A - Applications', 'F - Mainframe Connections', and 'A - Connect to the Mainframe Computers'.

2. Type **LANCER** and press **RETURN** when prompted for 'what system to connect to.'

3. Respond with your personal account information when presented with the VAX login prompts for 'Username:' and 'Password:'.

4. Once you receive the VAX prompt, type **CD GSS92D:[CSCOTT.ARMS]** and press **RETURN**.

5. Type **SQLMENU ARMS ARMS_USER/??????** (where the question marks represent the unique password which will be provided to you during the evaluation) and press **RETURN**.

You should now be at the ARMS main menu (Figure 4) where you can begin conducting queries based on the access privileges provided to you by the system administrators.

BASIC KEYBOARD COMMANDS

The prototype ARMS has several preset keyboard 'keys' which must be used to properly operate the system. Most of these keys can be found on the 'function key' row and 'numeric keypad' of your keyboard. Useful results of these keys and messages are provided on the 'help bar' located at the bottom of the screen. The most important keys and their meanings are summarized below.

FUNCTION KEY 1 (F1) - is the 'execute query' key which should be pressed after you have entered a search string to start a search. If the search is successful, the first record retrieved will be displayed.

FUNCTION KEY 3 (F3) - is the 'commit' key which is used to update a record. This key will be disabled for most operational test users.

FUNCTION KEY 4 (F4) - is the 'cancel/exit' key. Pressing this key will return you to the previous menu.

KEYPAD <0> (KP0) - is the 'help' key. This key is active while any 'menu', 'query', and 'information' screen is displayed and provides applicable help information to that screen.

KEYPAD <1> (KP1) - is the 'next block' or 'next page' key. It is active in certain multi-block or multi-page forms to provide access to different display screens or parts thereof.

KEYPAD <2> (KP2) - is the 'previous block' or 'previous page' key.

KEYPAD <3> (KP3) - is the 'display component' key. It is active only when a record in the 'Research Products Reuse Subsystem' is being displayed. If an electronic copy of the reusable component is available, pressing this key will display it in text-file format.

KEYPAD <4> (KP4) - is the 'get next record' key which can be used after you have executed a search and a record is displayed. The 'help bar' will notify you when no more records match the search criteria you provided. Pressing the **DOWN ARROW** accomplishes this same function.

KEYPAD <5> (KP5) - is the 'get previous record' key. The **UP ARROW** accomplishes the same function.

KEYPAD <6> (KP6) - is the 'display abstract text' key. It is active in all displays when an abstract is provided to further describe the record presented on the screen. A notice will appear at the bottom of the display when this key is available for use.

There are a number of other keys which have duplicate functions to those just described. However, the above keys should be used to ensure proper operation of the system.

HELP SYSTEM

A limited help system is provided with this version of the ARMS. As indicated in the above section, pressing KP0 while any 'menu', 'query', or 'information record' screen is displayed will present an appropriate help screen. (Note: Help is not active during the 'view abstract' and 'view component' operations because a VMS operating system command is used to perform them.) Figures 1, 2, and 3 illustrate the screens that will appear when KP0 is pressed with a menu, query, and information screen displayed, respectively. Additional help is provided on many of the screens in the form of 'text boxes' or one-line messages that appear in the inverse line block at the bottom of the page.

```
  A F I T   R e s e a r c h   M a n a g e m e n t   S y s t e m   ( A R M S )
                                   Main Menu

                  Help for Research Topic Selection Subsystem Option
                  ---------------------------------------------------
  This option provides access to the Research Topic Selection Subsystem
  (RTSS) menu.  The goal of the RTSS is to provide student researchers
  with an expedient method of reviewing information available on past,
  ongoing, and sponsored theses as well as new research requests.  The
  review of this information is intended to assist student researchers
  with the task of selecting and scoping a thesis topic.

                          Make your choice: 1

       *** Press 0 on the keypad <KP0> for help--ensure NUMLOCK is on ***
 ------------------------------------------------------------------------------
 v   Sun Jul 26 05:11:11 1992        OSC DBG        Replace      ARMS (ARMS )
 End of help info, type any key to return to menu...
```

Figure 1. Menu Help Screen Example

Press <F4> to return to main form

FUNCTION KEYS

F1 Execute Query	F4 Cancel/ Exit

OTHER KEYS

ESC-V--->Display Lookup Table

KEYPAD <KP> KEYS

7	8	9 Clear Field	- Redisplay Screen
4	5	6	,
1 Next Page	2 Previous Page	3	ENTER
0 Show Keys		.	

Char Mode: Replace   Page 1   Count: *0

Figure 2. Query Help Screen Example

Press <F4> to return to main form

FUNCTION KEYS

F1	F4 Cancel/ Exit

OTHER KEYS

Down Arrow-->Next Record
Up Arrow---->Previous Record

KEYPAD <KP> KEYS

7	8	9	- Redisplay Screen
4 Next Record	5 Previous Record	6 View Abstract	,
1 Next Page	2 Previous Page	3	ENTER
0 Show Keys		.	

Char Mode: Replace Page 1 Count: *0

Figure 3. Information Help Screen Example

SYSTEM OPERATION

A F I T Research Management System (ARMS)

Main Menu

--> 1 Research Topic Selection Subsystem
2 Research Products Reuse Subsystem
3 Research Management Subsystem
4 Database Administration Subsystem
5 Exit

Make your choice: 1

*** Press 0 on the keypad <KP0> for help--ensure NUMLOCK is on ***

v Sun Jul 26 04:34:21 1992 OSC DBG Replace ARMS (ARMS)

Figure 4. ARMS Main Menu

Figure 4 shows the menu displayed after a successful login to the ARMS. The four subsystems listed in the menu are designed to provide information that is intended to aid student researchers, faculty members, and research management personnel. A further discussion of each subsystem and its operation is provided below.

<u>Research Topic Selection Subsystem (RTSS)</u> - Through the categorization of theses and automation of the current research topics book, the RTSS's goal is to provide student researchers with the capability to review available information in a more focused and expedient manner. The on-line information contained in the RTSS's tables allows a researcher to review the complete abstract of an AFIT thesis and should assist them in determining if a more detailed review of the document is warranted.

The menu in Figure 5 lists four theses categories on which queries of theses and their abstracts can be based. The fifth menu option allows for the query and display of research topics which are either internally generated by faculty members or requests for research received from other DoD agencies. In each case, the search criteria for this version of the prototype is limited to subject term criteria.

Two examples of queries from this menu, one to review a thesis and its abstract and another to review a topic and its abstract, are provided to assist you in conducting your own queries. You are encouraged to exercise these examples in order to understand the operation of the system.

```
              R e s e a r c h   T o p i c   S e l e c t i o n   S u b s y s t e m
                                        Main Menu


                        --> 1  Review All Theses Records
                            2  Review Continuing Studies Records
                            3  Review Ongoing Theses Records
                            4  Review Sponsored Theses Records
                            5  Review New Research Requests
                            6  Return to Previous Menu



                            Make your choice: 1

     *** Press 0 on the keypad <KP0> for help--ensure NUMLOCK is on ***
 -----------------------------------------------------------------------------
 v   Sun Jul 26 04:40:18 1992        OSC DBG        Replace      ARMS (RTMAIN )
```

Figure 5. Research Topic Selection Subsystem Main Menu

<u>Querying/Reviewing a Thesis Record</u>

Step 1. Selection option 1 from the RTSS main menu. The query display in Figure 6 should be on the screen.

Step 2. You now have two choices: (1) enter a subject term (a one-, two-, or three-word descriptive phrase) to query the system on or (2) press **Esc-v** to reveal a look-up table with all possible values for thesis subject term. For the purpose of this example, press **Esc-v**. The look-up table in Figure 7 should appear on the screen.

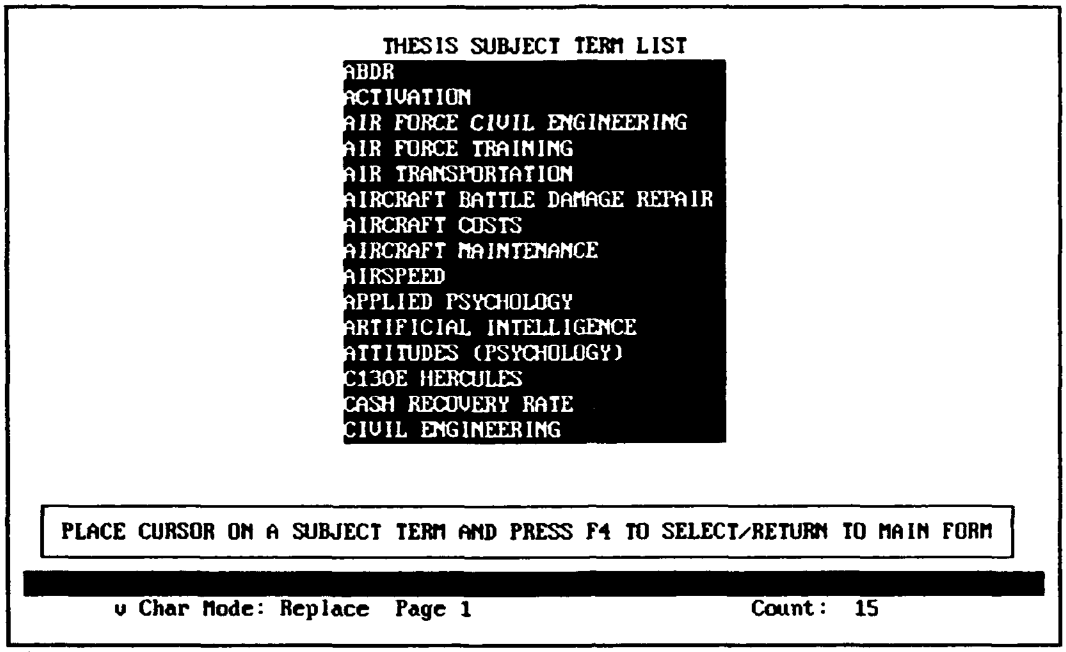
Step 3. Following the directions on the screen, use the **UP** and **DOWN ARROW** keys (or **KP4** and **KP5**) to move to the desired subject term. Press **F4** when ready to select an item and return to the main form. Select **SPARE PARTS** for this example and press **F4**. The display should match Figure 8.

Step 4. Press **F1** to execute the query on this subject term. The thesis information record in Figure 9 should appear on the screen.

Step 5. Press **KP6** to view the complete abstract for this thesis. The text screen shown in Figure 10 should now be on the screen. Page forward in this text file by pressing **RETURN**.

Step 6. Press **KP4** to see if there is another record matching this criteria. If there is not, you may return to the menu by pressing **F4** or you may request another query by pressing KP2 to return to the screen in Figure 8.

```
                ======== QUERY ALL THESES =========
                ========  SEARCH CRITERIA  ========

            SUBJECT TERM:

            DEGREE PROGRAM ID:

            AUTHOR'S LAST NAME:

            ADVISOR'S LAST NAME:

        THIS PANEL IS DESIGNED TO ALLOW YOU TO QUERY THESES
        BASED ON THE ABOVE SEARCH CRITERIA.  HOWEVER, THIS
        VERSION OF THE PROTOTYPE IS LIMITED TO JUST SUBJECT
        TERM SEARCHES.

         PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT

Enter SUBJECT TERM to query on or type Esc-v to select from a look-up table
      Char Mode: Replace  Page 1                        Count: *0
```
Figure 6. 'Review/Query All Theses' Search Criteria Block



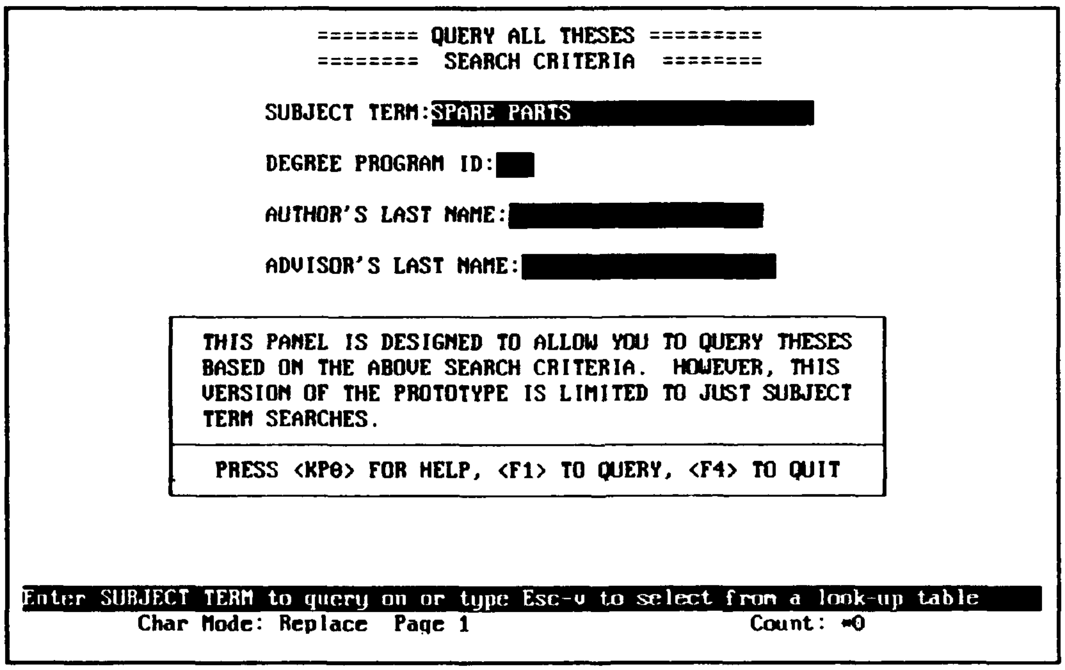
THESIS SUBJECT TERM LIST

ABDR
ACTIVATION
AIR FORCE CIVIL ENGINEERING
AIR FORCE TRAINING
AIR TRANSPORTATION
AIRCRAFT BATTLE DAMAGE REPAIR
AIRCRAFT COSTS
AIRCRAFT MAINTENANCE
AIRSPEED
APPLIED PSYCHOLOGY
ARTIFICIAL INTELLIGENCE
ATTITUDES (PSYCHOLOGY)
C130E HERCULES
CASH RECOVERY RATE
CIVIL ENGINEERING

PLACE CURSOR ON A SUBJECT TERM AND PRESS F4 TO SELECT/RETURN TO MAIN FORM

v Char Mode: Replace Page 1 Count: 15

Figure 7. Subject Term Look-Up Table Display



======== QUERY ALL THESES =========
======== SEARCH CRITERIA ========

SUBJECT TERM: SPARE PARTS

DEGREE PROGRAM ID:

AUTHOR'S LAST NAME:

ADVISOR'S LAST NAME:

THIS PANEL IS DESIGNED TO ALLOW YOU TO QUERY THESES BASED ON THE ABOVE SEARCH CRITERIA. HOWEVER, THIS VERSION OF THE PROTOTYPE IS LIMITED TO JUST SUBJECT TERM SEARCHES.

PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT

Enter SUBJECT TERM to query on or type Esc-v to select from a look-up table

Char Mode: Replace Page 1 Count: *0

Figure 8. 'Review/Query All Theses' Search Criteria Block
As Filled in by the Look-Up Table

```
======== THESIS INFORMATION ========

THESIS ID NR:AFIT/GLM/LSM/91S-7        DATE PUBLISHED:SEP 1991

THESIS TITLE:Performance Assessment of the Spare Parts for the Activation
             of Relocated Systems (SPARES) Forecasting Model

CONTINUING STUDY:N   SPONSORED STUDY:N   AWARD WINNER:Y   AWARD CODE:F

======== AUTHOR INFORMATION ========   ====== ADVISOR INFORMATION ======

LASTNAME                RANK           LASTNAME               ROLE
BUNKER                  CAPTAIN        SULLIVAN               ADVISOR
                                       BRESNAHAN              READER

PRESS <KP0> FOR HELP, <KP4> FOR NEXT RECORD, <KP6> TO VIEW ABSTRACT

Char Mode: Replace  Page 2                       Count: *1
```

Figure 9. Thesis Information Record

```
Abstract
     This research assessed the performance of the Spare Parts
for the Activation of Relocated Systems (SPARES) forecast model
used to develop the spares requirements forecast for the August
1988 activation of the 174TFW at Syracuse ANGB NY. SPARES was
developed by the Air Force Logistics Management Center in August
1988 to replace existing Standard Base Supply System (SBSS)
forecasting procedures. SPARES uses mission change data (MCD)
from five similar-size source bases to determine the
probability of future demand (PFD) for items at the gaining base.
Before implementing SPARES in the SBSS, forecast performance must
be measured and model weaknesses identified and corrected.
     SPARES correctly forecasted 72 percent of the demanded items
when a PPD of 20 percent was used; however, 58 percent of the
items forecasted did not have subsequent demands. SPARES
forecasted 692 items which had less than two customer demands at
the five source bases combined. This indicates either the
model's program coding is incorrect or deficiencies exist in
theoretical program logic. Deficiencies in the MCD collection
system also had an impact on SPARES performance. Based on these
findings, SPARES program coding and logic as well as the MCD
collection system must be reviewed before SPARES is implemented

Press RETURN to continue
```

Figure 10. Thesis Abstract Display

Querying/Reviewing a Topic Record

Step 1. Select option 5 from the RTSS main menu. The query display in Figure 11 should be on the screen.

Step 2. You have two choices: (1) enter a subject term (a one-, two-, or three-word descriptive phrase) to query the system on or (2) press **Esc-v** to reveal a look-up table with all possible values for thesis subject term. For this example, type in **MAINTENANCE MANAGEMENT**.

Step 3. Press **F1** to execute the query. The topic information record in Figure 12 should appear on the screen.

Step 4. Press **KP1** to view the second page of the topic information record (as shown in Figure 13). Note that you may return to page 1 from page 2 by pressing **KP2**.

Step 5. Press **KP6** to view the abstract for this topic. The text screen shown in Figure 14 should now be on the screen. Press RETURN to page forward through the displayed text file.

Step 6. Press **KP4** to see if there is another record matching the given criteria. If there is not, you may return to the menu by pressing **F4** or you may request another query by pressing KP2 to return to the screen in Figure 11.

```
                    ====  QUERY TOPICS   ====
                    ==== SEARCH CRITERIA ====

         SUBJECT TERM:

          TOPIC ID NR:

      EXTERNAL SOURCE:

        NOMINATOR ORG:

       THIS PANEL ALLOWS YOU TO QUERY RESEARCH TOPICS
       BASED UPON SELECTION CRITERIA.  THESE CRITERIA
       ARE SUBJECT TERM, TOPIC NUMBER, EXTERNAL SOURCE
       (Y/N), AND NOMINATOR'S OFFICE SYMBOL.

       THIS PROTOTYPE LIMITS THE SELECTION CRITERIA TO
       SUBJECT TERM FOR THE PURPOSES OF THIS TEST.

      PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT
Enter SUBJECT TERM to query on or type Esc-v to select from a look-up table
   Char Mode: Replace  Page 1                    Count: *0
```

Figure 11. 'Review/Query New Research Requests' Search Criteria Block

PAGE 1 OF 2

======== TOPIC INFORMATION ========

TOPIC NR: 92-8 DATE SUBMITTED: 24-JUN-92 EXTERNAL SOURCE: N

TOPIC TITLE: An examination of factors which impact the competitiveness of ALC Depots

FACULTY POC: GRANT FACULTY POC DEPARTMENT: LSY

======== NOMINATOR INFORMATION ========

NAME: Capt Kevin Grant

ORGANIZATION: AFIT/LSY

TELEPHONE (COMMERCIAL/DSN): 513-255-4845 / 785-4845

ADDRESS:

(PRESS <KP0> FOR HELP, <KP4> TO GET NEXT RECORD, <KP6> TO VIEW ABSTRACT)

Char Mode: Replace Page 2 Count: *1

Figure 12. Topic Information Record (Page 1 of 2)

PAGE 2 OF 2

========= TOPIC INFORMATION =========

TOPIC NR: 92-8 TOPIC USED: N

========= SUBJECT TERMS =========

1: LOGISTICS MANAGEMENT 4:

2: MAINTENANCE MANAGEMENT 5:

3: 6:

========= OTHER COMMENTS =========

(PRESS <KP0> FOR HELP, <KP4> TO GET NEXT RECORD, <KP6> TO VIEW ABSTRACT)

Char Mode: Replace Page 3 Count: *1

Figure 13. Topic Information Record (Page 2 of 2)

Depots are currently losing government contracts to industry. What factors make government depots less responsive and more expensive than our industrial counterparts? Background can address the changes that have led to this competitive environment. We are aware that OC-ALC recently lost an engine repair contract. Methodology may be conducted as a case study of contract efforts our depots have lost.

-- Press RETURN to return to SQL*Forms --

Figure 14. Topic Abstract Display

Research Products Reuse Subsystem (RPRS) - The RPRS represents an adaptation of the 'software reuse' concept, which is defined as the use of previously developed and/or acquired software components (source code modules, design descriptions, documentation, and so on) in a new development project. The application of this technique to the thesis yields several potential components for reuse. Currently, the process of locating such items is very tedious and time-consuming since only the thesis document is cataloged. The RPRS provides the framework for cataloging research components and allows for on-line storage of an abstract describing the component, and in some cases, an electronic copy of the component itself.

An example query is now provided to assist you in conducting your own queries. You are encouraged to exercise this example in order to understand the operation of the system.

Querying/Reviewing a Component Record

Step 1. Select option 2 from the ARMS main menu. The query display in Figure 15 should be on the screen.

Step 2. You now have two choices: (1) enter a component type or (2) press **Esc-v** to reveal a look-up table with all possible values for component type. Press **Esc-v** and the look-up table shown in Figure 16 should appear.

Step 3. Following the directions on the screen, use the **UP** and **DOWN ARROW** keys (or **KP4** and **KP5**) to move to the desired component type. Press **F4** when ready to select an item and return to the main form. Select **PROGRAM** for this example. The display should match the one in Figure 17.

Step 4. Press **F1** to execute the query on this component type A component information record should appear. For the purpose of this example, press **KP4** twice to move to the record shown in Figure 18.

Step 5. Press **KP6** to view the abstract for this component. The text screen shown in Figure 19 should now be on the screen. Page through the text by pressing **RETURN** until you return to the component information record.

Step 6. A copy of this component has been entered and is electronically stored on-line. Press **KP3** now to view it. The screen in Figure 20 should appear displaying a SAS program. Press **RETURN** to proceed through the text until you return to the component information record.

Step 7. Press **KP4** to see if there is another record matching the given criteria. If there is not, you may return to the menu by pressing **F4** or you may request another query by pressing **KP2** to return to the screen in Figure 15.

```
                    ===== QUERY COMPONENTS =====
                    ===== SEARCH CRITERIA  =====

               COMPONENT TYPE:


      THIS PANEL PRESENTS AN OPTION TO QUERY COMPONENTS
      ONLY BY TYPE.  FUTURE VERSIONS OF THE PROTOTYPE
      COULD INCORPORATE FURTHER SEARCH CRITERIA ITEMS
      SUCH AS: BY SUBJECT TERM, BY GRADUATE PROGRAM ID,
      AND A NUMBER OF OTHERS.

     PRESS <KP0> TO GET HELP, <F1> TO QUERY, <F4> TO QUIT

Enter component type to query on or type Esc-v to select from a look-up table
         Char Mode: Replace  Page 1                    Count: *0
```

Figure 15. 'Review/Query Components' Search Criteria Block

```
                         COMPONENT TYPES
                      DOCUMENTATION
                      INTERVIEW
                      PROGRAM
                      QUESTIONNAIRE
                      SURVEY


  PLACE CURSOR ON COMPONENT TYPE AND PRESS F4 TO SELECT/RETURN TO MAIN FORM

         Char Mode: Replace  Page 1                    Count: *5
```

Figure 16. Component Types Look-Up Table Display

```
===== QUERY COMPONENTS =====
===== SEARCH CRITERIA  =====

COMPONENT TYPE:PROGRAM

THIS PANEL PRESENTS AN OPTION TO QUERY COMPONENTS
ONLY BY TYPE.  FUTURE VERSIONS OF THE PROTOTYPE
COULD INCORPORATE FURTHER SEARCH CRITERIA ITEMS
SUCH AS: BY SUBJECT TERM, BY GRADUATE PROGRAM ID,
AND A NUMBER OF OTHERS.

PRESS <KP0> TO GET HELP, <F1> TO QUERY, <F4> TO QUIT

Enter component type to query on or type Esc-v to select from a look-up table
        Char Mode: Replace  Page 1                    Count: *0
```

Figure 17. 'Review/Query Components' Search Criteria Block As Filled in by the Look-Up Table

```
========= COMPONENT INFORMATION =========

COMPONENT TYPE:PROGRAM                DATE SUBMITTED:23-JUN-92

                  COMPONENT TITLE
SAS Program

COMPONENT POC:GRANT                   POC DEPARTMENT:LSY

THESIS ID NR: AFIT/GLM/LSY/91S-27     REUSED COMPONENT:N

                  OTHER COMMENTS

PRESS <KP0> TO GET HELP, <KP3> TO VIEW COMPONENT, <KP6> TO VIEW ABSTRACT

     ^ v Char Mode: Replace  Page 2                    Count:  5
```

Figure 18. Component Information Record

Program Abstract

The regression analyses performed by this program sought to identify the key relationships among the variables: Bed-Size, Annual Medical Supply Purchases, Medical Supply FTEs, Official Inventory, and Warehouse Size. Three separate categories (models) of analyses were performed for the dependent variables. These dependent variables were FTE (full-time-equivalent) reductions, official inventory reductions, and warehouse reductions.
-- Press RETURN to return to SQL*Forms --

Figure 19. Component Abstract Display

```
DATA VARS;
     INPUT BEDS PURCH PREFTE PREINV PREWHS POSTFTE POSTINV
           POSTWHS CHGFTE CHGINV CHGWHS PCTFTE PCTINV PCTWHS @@;
     ARRAY X {14} BEDS--PCTWHS;
     ARRAY L {14} LBEDS LPURCH LPREFTE LPREINV LPREWHS LPOSTFTE
                  LPOSTINV LPOSTWHS LCHGFTE LCHGINV LCHGWHS LPCTFTE
                  LPCTINV LPCTWHS;
     DO I =1 TO 14;
        L {I}=LOG(X {I});
     END;
     DROP I;
     CARDS;
575 20000000   12 554000  8000    5 20000 500    7    534000  7500
 .583  .963  .938
350  7000000   33 550000 13000   19 12000 300   12    538000 12700
 .364  .978  .977
176  1750909   14 250000  8000   12 40000 500    2    210000  7500
 .143  .840  .938
46    134037  1.5  55000   563  1.5  2000 100  .0001  53000   463
 .0001 .964  .822
40    120000    2 110000  2500  1.5  2800 150   .5    107200  2350
 .250  .975  .940

                    Press RETURN to continue
```

Figure 20. Text Display of a Component

<u>Research Management Subsystem (RMS)</u> - The RMS is designed to provide a convenient source of management information concerning the AFIT/LS student research program. The capability of this subsystem is limited in this version of the prototype due to a lack of detailed requirements. Figure 21 shows some examples of the types of information that the developers feel should be in a mature RMS.

The first three options in the menu shown in Figure 21 were developed for operational test purposes. The first item, 'Review Continuing Research Information' is similar to the capability provided in the RTSS and contains only one example record that may be queried. The second and third items on this menu provide information that might be equally valuable to student researchers, faculty members, and research management personnel. Example queries of these two options are provided to assist you in conducting your own queries.

```
            Research  Management  Subsystem

                         Main Menu

           -->  1  Review Continuing Research Information
                2  Review Research Sponsorship Information
                3  Review Thesis Advisor Qualifications
                4  Review Thesis Completion Status
                5  Review Research Publication Information
                6  Return to Previous Menu



                    Make your choice: 1

 *** Press 0 on the keypad <KP0> for help--ensure NUMLOCK is on ***
 ------------------------------------------------------------------
 v  Sun Jul 26 05:21:19 1992      OSC DBG      Replace   ARMS (RMMAIN )
```

Figure 21. Research Management Subsystem Main Menu

Querying/Reviewing a Sponsor Record

Step 1. Select option 2 from the RMS main menu. The query display in Figure 22 should be on the screen.

Step 2. You now have two choices: (1) enter a sponsor's organization and office symbol (SPONSOR_ORG_OFCSYM) to query on or (2) press **Esc-v** to reveal a look-up table with all possible values for SPONSOR_ORG_OFCSYM. Press **Esc-v** and the look-up table shown in Figure 23 should appear.

Step 3. Following the directions on the screen, use the **UP** and **DOWN ARROW** keys (or **KP4** and **KP5**) to move to the desired 'sponsor.' Press **F4** when ready to select an item and return to the main form. Select **HQ TAC** for this example and press **F4**. The display should match the one in Figure 24.

Step 4. Press **F1** to execute the query on this term. The sponsor information record in Figure 25 should appear on the screen.

Step 5. Press **KP4** to see if there is another record matching the given criteria. If there is not, you may return to the menu by pressing **F4** or you may request another query by pressing KP2 to return to the screen in Figure 24.

===== SPONSOR RECORD SEARCH CRITERIA =====

SPONSOR_ORG_OFCSYM:

FUNDING_PROVIDED: (INDICATE 'Y'es OR 'N'o)

THIS PANEL IS DESIGNED TO ALLOW YOU TO SPONSORSHIP INFORMATION BASED ON THE ABOVE SEARCH CRITERIA. HOWEVER, THIS VERSION OF THE PROTOTYPE IS LIMITED TO 'SPONSOR_ORG_OFCSYM' SEARCHES.

PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT

Enter SPONSOR_ORG_OFCSYM to query on or type Esc-v to select from a lookup table

Char Mode: Replace Page 1 Count: *0

Figure 22. 'Review Research Sponsorship Information' Search Criteria Block

SPONSOR ORGANIZATIONS/OFFICE SYMBOLS

AFLMC
HQ TAC
HQ TAC/LGS

PLACE CURSOR ON SPONSOR AND PRESS F4 TO SELECT/RETURN TO MAIN FORM

Char Mode: Replace Page 1 Count: *3

Figure 23. Sponsor Look-Up Table Display

===== SPONSOR RECORD SEARCH CRITERIA =====

SPONSOR_ORG_OFCSYM: HQ TAC

FUNDING_PROVIDED: (INDICATE 'Y'es OR 'N'o)

THIS PANEL IS DESIGNED TO ALLOW YOU TO SPONSORSHIP INFORMATION BASED ON THE ABOVE SEARCH CRITERIA. HOWEVER, THIS VERSION OF THE PROTOTYPE IS LIMITED TO 'SPONSOR_ORG_OFCSYM' SEARCHES.

PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT

Enter SPONSOR_ORG_OFCSYM to query on or type Esc-v to select from a lookup table

Char Mode: Replace Page 1 Count: *0

Figure 24. 'Review Research Sponsorship Information' Search Criteria Block As Filled in by the Look-Up Table

======== SPONSOR INFORMATION ========

SPONSOR POC: Col Van A. McCrea

SPONSOR ORG: HQ TAC

ADDRESS:

TELEPHONE: COMMERCIAL - DSN -

**** PROJECT INFORMATION ****

THESIS ID NR: AFIT/GLM/LSR/91S-17 FUNDING PROVIDED/AMOUNT: /

COST AVOIDANCE ESTIMATE: REQUESTED - RECEIVED - VALUE - 0

MISC COMMENTS:

(PRESS: <KP0> FOR HELP, <KP4> TO VIEW NEXT RECORD, <F4> TO RETURN TO THE MENU)

Char Mode: Replace Page 2 Count: *1

Figure 25. Sponsor Information Record

Querying/Reviewing a Thesis Advisor Qualification Record

Step 1. Select option 3 from the RMS main menu. The query display in Figure 26 should be on the screen.

Step 2. You have two choices: (1) enter a valid interest area that you want to query on or (2) press **Esc-v** to reveal a look-up table with all possible values for advisor interest areas. Press **Esc-v** and the look-up table shown in Figure 27 should appear.

Step 3. Following the directions on the screen, use the **UP** and **DOWN ARROW** keys (or **KP4** and **KP5**) to move to the desired 'interest area.' Press **F4** when ready to select an item and return to the main form. Select **ACQUISITION LOGISTICS** for this example and press **F4**. The display should match the one in Figure 28.

Step 4. Press **F1** to execute the query. The thesis advisor information record in Figure 29 should appear on the screen.

Step 5. Press **KP4** to see if there is another record matching the given criteria. If there is not, you may return to the menu by pressing **F4** or you may request another query by pressing KP2 to return to the screen in Figure 26.

```
                 =====  THESIS ADVISOR SEARCH CRITERIA  =====

                 INTEREST AREA:

                 ADVISOR'S LAST NAME:

                 ADVISOR'S ORG/OFCSYM:

                 ADVISING STATUS:

           THIS PANEL IS DESIGNED TO ALLOW YOU TO QUERY ADVISOR
           INFORMATION BASED ON THE ABOVE SEARCH CRITERIA. HOW-
           EVER, THIS VERSION OF THE PROTOTYPE IS LIMITED TO
           'INTEREST AREA' SEARCHES.

             PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT


Enter INTEREST AREA to query on or type Esc-v to select from a look-up table
       Char Mode: Replace   Page 1                     Count: *0
```

Figure 26. 'Review Thesis Advisor Qualification Information' Search Criteria Block

```
                 INTEREST AREAS
            ACCOUNTING
            ACQUISITION LOGISTICS
            ACQUISITION MANAGEMENT
            AIRLIFT OPERATIONS
            BEHAVIOR
            CONFIGURATION MANAGEMENT
            CONTRACT ADMINISTRATION
            CONTRACT MANAGEMENT
            COST ANALYSIS
            COST MODELS
            COST/SCHEDULE CONTROL SYSTEM
            DECISION MAKING
            DECISION SUPPORT SYSTEMS
            DEFENSE PLANNING
            DISTRIBUTION MANAGEMENT

 PLACE CURSOR ON INTEREST AREA AND PRESS F4 TO SELECT/RETURN TO MAIN FORM

    v Char Mode: Replace   Page 1                    Count:  15
```

Figure 27. Interest Area Look-Up Table Display

```
          =====  THESIS ADVISOR SEARCH CRITERIA  =====

          INTEREST AREA: ACQUISITION LOGISTICS

          ADVISOR'S LAST NAME:

          ADVISOR'S ORG/OFCSYM:

          ADVISING STATUS:

      THIS PANEL IS DESIGNED TO ALLOW YOU TO QUERY ADVISOR
      INFORMATION BASED ON THE ABOVE SEARCH CRITERIA. HOW-
      EVER, THIS VERSION OF THE PROTOTYPE IS LIMITED TO
      'INTEREST AREA' SEARCHES.

        PRESS <KP0> FOR HELP, <F1> TO QUERY, <F4> TO QUIT

Enter INTEREST AREA to query on or type Esc-v to select from a look-up table
     Char Mode: Replace   Page 1                    Count: *0
```

Figure 28. 'Review Thesis Advisor Qualification Information' Search Criteria Block as Filled in by the Look-Up Table

```
======== THESIS ADVISOR INFORMATION ========

LAST NAME:BRESNAHAN            FIRST NAME:PATRICK              MI:NMI
RANK:CIVILIAN    ORG/OFFICE SYMBOL:AFIT/LSM                PHONE:255-4149

ADVISING STATUS:I            STATUS DATE:1983             LAST ADVISED:1990

                         *** INTEREST AREAS ***
1:ACQUISITION LOGISTICS                  4:FINANCIAL MANAGEMENT
2:DISTRIBUTION MANAGEMENT                5:LEADERSHIP
3:EDUCATION                              6:LOGISTICS MANAGEMENT

  ADVISOR'S ADDRESS:
  (IF NOT FACULTY)

OTHER COMMENTS:LOGISTICS SUPPORT, MATERIALS, PERSONNEL MANAGEMENT,
               PROVISIONING, QUALITY, RESOURCE MANAGEMENT, TRANSPORTATION,
               WAREHOUSES

(PRESS: <KP0> FOR HELP, <KP4> TO VIEW NEXT RECORD, <F4> TO RETURN TO THE MENU)

    v Char Mode: Replace  Page 2                     Count:  1
```

Figure 29. Thesis Advisor Information Record

<u>Database Administration Subsystem</u> - This subsystem was designed to provide personnel assigned database administration responsibilities with the capabilities to perform their job. Two primary sets of activities, as shown in Figure 30, may be done in this subsystem--record manipulation and special SQL queries.

```
A R M S   D a t a b a s e   A d m i n i s t r a t i o n   S u b s y s t e m
                                Main Menu


                    --> 1  Add/Change/Delete Records
                        2  Perform Special Queries
                        3  Return to Previous Menu





                      Make your choice:  1

     *** Press 0 on the keypad <KP0> for help—ensure NUMLOCK is on ***

v   Sun Jul 26 05:26:52 1992        OSC DBG        Replace      ARMS (DAMAIN )
```

Figure 30. Database Administration Subsystem Main Menu

To ensure the integrity of the ARMS, only personnel with the proper level of access are capable of viewing the menus required to access the Database Administration Subsystem's capabilities. No operational test evaluators will have access to this subsystem.

EXITING THE SYSTEM

Pressing 5 at the ARMS Main Menu will allow you to reach the LANCER system prompt. At that time, you may either logout (by typing **LOGOUT**) or return to your home directory (by typing **HOME**). You'll be returned to the LS_LAN NOVELL menu after logging out of LANCER.

FINAL COMMENTS

Please ensure you document all of your comments on the prototype evaluation form. Your written comments will help the researchers appropriately document needed improvements or positive aspects of the system.

Appendix G: Prototype Test Results for New Students Test

INTRODUCTION

Questions were rated according to the following scale:

1 - strongly agree	4 - disagree
2 - agree	5 - strongly disagree
3 - neutral	N - not applicable

Evaluators were divided into two categories based on their answer to question one, inexperienced computer and database users (ratings 3, 4, and 5) and experienced computer and database users (ratings 1 and 2). Listed below are the questions provided to the new students, the number of individuals who gave the indicated rating, and the representative percentages for each rating per category.

GENERAL INFORMATION QUESTIONS

1. I consider myself knowledgeable about the general operation of computers and database management systems.

1	2	3	4	5
3(10%)	13(45%)	7(24%)	6(21%)	0(0%)

2. The menu's help screens were self-explanatory and provided me with enough information to begin using the system.

	1	2	3	4	5	N
Inexperienced User	1(8%)	10(83%)	1(8%)	0(0%)	0(0%)	0(0%)
Experienced User	2(13%)	11(69%)	1(6%)	2(13%)	0(0%)	0(0%)
Total	3(11%)	21(75%)	2(7%)	2(7%)	0(0%)	0(0%)

SUBSYSTEM EVALUATION QUESTIONS

3. I felt confident operating this subsystem using only the on-screen help facilities (field/option-specific help bar, separate instruction blocks, etc.):

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	1(8%)	9(69%)	1(8%)	2(15%)	0(0%)	0(0%)
Experienced User	1(6%)	13(81%)	2(13%)	0(0%)	0(0%)	0(0%)
Total	2(7%)	22(76%)	3(10%)	2(7%)	0(0%)	0(0%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	1(8%)	9(69%)	1(8%)	2(15%)	0(0%)	0(0%)
Experienced User	2(13%)	11(69%)	1(6%)	2(13%)	0(0%)	0(0%)
Total	3(10%)	20(69%)	2(7%)	4(14%)	0(0%)	0(0%)

4. I found this subsystem easy to learn and use:

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	6(46%)	6(46%)	1(8%)	0(0%)	0(0%)	0(0%)
Experienced User	4(25%)	11(69%)	1(6%)	0(0%)	0(0%)	0(0%)
Total	10(34%)	17(59%)	2(7%)	0(0%)	0(0%)	0(0%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	4(31%)	8(62%)	1(8%)	0(0%)	0(0%)	0(0%)
Experienced User	2(13%)	11(69%)	3(19%)	0(0%)	0(0%)	0(0%)
Total	6(21%)	19(66%)	4(14%)	0(0%)	0(0%)	0(0%)

5. I feel the type of automated information provided by this subsystem could help (or could have helped) me more efficiently conduct a research study:

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	9(69%)	4(31%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	10(63%)	5(31%)	1(6%)	0(0%)	0(0%)	0(0%)
Total	19(66%)	9(31%)	1(3%)	0(0%)	0(0%)	0(0%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	8(62%)	5(38%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	10(63%)	5(31%)	1(6%)	0(0%)	0(0%)	0(0%)
Total	18(62%)	10(34%)	1(3%)	0(0%)	0(0%)	0(0%)

6. I would use (or would have used) this subsystem for research work if it were fully operational:

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	11(85%)	2(15%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	13(81%)	3(19%)	0(0%)	0(0%)	0(0%)	0(0%)
Total	24(83%)	5(17%)	0(0%)	0(0%)	0(0%)	0(0%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	10(77%)	3(23%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	12(75%)	4(25%)	0(0%)	0(0%)	0(0%)	0(0%)
Total	22(76%)	7(24%)	0(0%)	0(0%)	0(0%)	0(0%)

OVERALL SYSTEM EVALUATION

7. I liked the following features about the subsystems I used (circle all that apply):

a. screen displays (screen organization)
b. functions (what the subsystems do)
c. processing speed (system response time)
d. data (applicability, breadth)
e. written instructions
f. on-line help instructions

	a	b	c	d	e	f
Inexperienced User	8(62%)	10(77%)	1(8%)	6(46%)	5(38%)	6(46%)
Experienced User	13(81%)	14(88%)	5(31%)	12(75%)	7(44%)	5(31%)
Total	21(72%)	24(83%)	6(21%)	18(62%)	12(41%)	11(38%)

8. The following features of the subsystems I used need to be improved (circle all that apply):

   a. screen displays (screen organization)
   b. functions (what the subsystems do)
   c. processing speed (system response time)
   d. data (applicability, breadth)
   e. written instructions
   f. on-line help instructions

	a	b	c	d	e	f
Inexperienced User	0(0%)	1(8%)	3(23%)	2(15%)	0(0%)	5(38%)
Experienced User	1(6%)	1(6%)	7(44%)	4(25%)	2(13%)	5(31%)
Total	1(3%)	2(7%)	10(34%)	6(21%)	2(7%)	10(34%)

9. I used the AFIT Research Management System:
   a. less than 15 minutes
   b. 15 to 30 minutes
   c. 30 minutes to one hour
   d. more than one hour

	a	b	c	d
Inexperienced User	4(31%)	7(54%)	2(15%)	0(0%)
Experienced User	1(6%)	12(75%)	3(19%)	0(0%)
Total	5(17%)	19(66%)	5(17%)	0(0%)

Note: 1. One inexperienced user did not answer question two.
2. The percentages listed in questions seven and eight are based upon the total number of respondents in each group.
3. Due to rounding, the percentage totals for several questions do not equal 100%.

Appendix H: Prototype Test Results for Current Students Test

INTRODUCTION

Questions were rated according to the following scale:

1 - strongly agree
2 - agree
3 - neutral
4 - disagree
5 - strongly disagree
N - not applicable

Evaluators were divided into two categories based on their answer to question one, inexperienced computer and database users (ratings 3, 4, and 5) and experienced computer and database users (ratings 1 and 2). All members of this sample indicated they were experienced users. Listed below are the questions provided to the current students, the number of individuals who gave the indicated rating, and the representative percentages for each rating.

GENERAL INFORMATION QUESTIONS

1. I consider myself knowledgeable about the general operation of computers and database management systems.

1	2	3	4	5
6(33%)	12(67%)	0(0%)	0(0%)	0(0%)

2. The menu's help screens were self-explanatory and provided me with enough information to begin using the system.

1	2	3	4	5	N
3(17%)	11(61%)	1(6%)	3(17%)	0(0%)	0(0%)

SUBSYSTEM EVALUATION QUESTIONS

3. I felt confident operating this subsystem using only the on-screen help facilities (field/option-specific help bar, separate instruction blocks, etc.):

	1	2	3	4	5	N
Research Topic Selection:	2(11%)	14(78%)	1(6%)	1(6%)	0(0%)	0(0%)
Research Products Reuse:	2(11%)	15(83%)	0(0%)	1(6%)	0(0%)	0(0%)
Research Management:	1(6%)	15(83%)	0(0%)	1(6%)	0(0%)	1(6%)

4. I found this subsystem easy to learn and use:

	1	2	3	4	5	N
Research Topic Selection:	5(28%)	10(56%)	1(6%)	2(11%)	0(0%)	0(0%)
Research Products Reuse:	4(22%)	11(61%)	1(6%)	2(11%)	0(0%)	0(0%)
Research Management:	4(22%)	10(56%)	1(6%)	2(11%)	0(0%)	1(6%)

5. I feel the type of automated information provided by this subsystem could help (or could have helped) me more efficiently conduct a research study:

	1	2	3	4	5	N
Research Topic Selection:	14(78%)	3(17%)	1(6%)	0(0%)	0(0%)	0(0%)
Research Products Reuse:	10(56%)	7(39%)	1(6%)	0(0%)	0(0%)	0(0%)
Research Management:	8(44%)	7(39%)	2(11%)	0(0%)	0(0%)	1(6%)

6. I would use (or would have used) this subsystem for research work if it were fully operational:

	1	2	3	4	5	N
<u>Research</u> <u>Topic</u> <u>Selection</u>:	15(83%)	3(17%)	0(0%)	0(0%)	0(0%)	0(0%)
<u>Research</u> <u>Products</u> <u>Reuse</u>:	13(72%)	4(22%)	1(6%)	0(0%)	0(0%)	0(0%)
<u>Research</u> <u>Management</u>:	10(56%)	5(28%)	1(6%)	1(6%)	0(0%)	1(6%)

<u>OVERALL</u> <u>SYSTEM</u> <u>EVALUATION</u>

7. I liked the following features about the subsystems I used (circle all that apply):

    a. screen displays (screen organization): 14(78%)
    b. functions (what the subsystems do): 16(89%)
    c. processing speed (system response time): 6(33%)
    d. data (applicability, breadth): 11(61%)
    e. written instructions: 9(50%)
    f. on-line help instructions: 13(72%)

8. The following features of the subsystems I used need to be improved (circle all that apply):

    a. screen displays (screen organization): 5(28%)
    b. functions (what the subsystems do): 0(0%)
    c. processing speed (system response time): 11(61%)
    d. data (applicability, breadth): 6(33%)
    e. written instructions: 2(11%)
    f. on-line help instructions: 6(33%)

9. I used the AFIT Research Management System:
    a. less than 15 minutes: 3(17%)
    b. 15 to 30 minutes: 9(50%)
    c. 30 minutes to one hour: 6(33%)
    d. more than one hour: 0(0%)

Note: 1. The percentages listed in questions seven and eight are based upon the total number of respondents in the sample.
2. Due to rounding, the percentage totals for several questions do not equal 100%.

Appendix I: Prototype Test Results for Faculty Test

INTRODUCTION

Questions were rated according to the following scale:

1 - strongly agree	4 - disagree
2 - agree	5 - strongly disagree
3 - neutral	N - not applicable

Evaluators were divided into two categories based on their answer to question one, inexperienced computer and database users (ratings 3, 4, and 5) and experienced computer and database users (ratings 1 and 2). Listed below are the questions provided to the new students, the number of individuals who gave the indicated rating, and the representative percentages for each rating per category.

GENERAL INFORMATION QUESTIONS

1. I consider myself knowledgeable about the general operation of computers and database management systems.

1	2	3	4	5
3(30%)	4(40%)	2(20%)	1(10%)	0(0%)

2. The menu's help screens were self-explanatory and provided me with enough information to begin using the system.

	1	2	3	4	5	N
Inexperienced User	1(33%)	1(33%)	0(0%)	1(33%)	0(0%)	0(0%)
Experienced User	0(0%)	6(86%)	0(0%)	1(14%)	0(0%)	0(0%)
Total	1(10%)	7(70%)	0(0%)	2(20%)	0(0%)	0(0%)

SUBSYSTEM EVALUATION QUESTIONS

3. I felt confident operating this subsystem using only the on-screen help facilities (field/option-specific help bar, separate instruction blocks, etc.):

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	0(0%)	3(100%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	2(29%)	3(43%)	2(29%)	0(0%)	0(0%)	0(0%)
Total	2(20%)	6(60%)	2(20%)	0(0%)	0(0%)	0(0%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	0(0%)	2(67%)	0(0%)	1(33%)	0(0%)	0(0%)
Experienced User	2(29%)	2(29%)	2(29%)	1(14%)	0(0%)	0(0%)
Total	2(20%)	4(40%)	2(20%)	2(20%)	0(0%)	0(0%)

Research Management

	1	2	3	4	5	N
Inexperienced User	0(0%)	3(100%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	1(14%)	3(43%)	3(43%)	0(0%)	0(0%)	0(0%)
Total	1(10%)	6(60%)	3(30%)	0(0%)	0(0%)	0(0%)

4. I found this subsystem easy to learn and use:

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	0(0%)	2(67%)	1(33%)	0(0%)	0(0%)	0(0%)
Experienced User	4(57%)	2(29%)	1(14%)	0(0%)	0(0%)	0(0%)
Total	4(40%)	4(40%)	2(20%)	0(0%)	0(0%)	0(0%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	0(0%)	1(33%)	2(67%)	0(0%)	0(0%)	0(0%)
Experienced User	3(43%)	3(43%)	1(14%)	0(0%)	0(0%)	0(0%)
Total	3(30%)	4(40%)	3(30%)	0(0%)	0(0%)	0(0%)

Research Management

	1	2	3	4	5	N
Inexperienced User	0(0%)	1(33%)	2(67%)	0(0%)	0(0%)	0(0%)
Experienced User	3(43%)	2(29%)	2(29%)	0(0%)	0(0%)	0(0%)
Total	3(30%)	3(30%)	4(40%)	0(0%)	0(0%)	0(0%)

5. I feel the type of automated information provided by this subsystem could help (or could have helped) me more efficiently conduct a research study:

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	2(67%)	0(0%)	0(0%)	0(0%)	0(0%)	1(33%)
Experienced User	2(29%)	3(43%)	1(14%)	0(0%)	0(0%)	1(14%)
Total	4(40%)	3(30%)	1(10%)	0(0%)	0(0%)	2(20%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	2(67%)	0(0%)	0(0%)	0(0%)	0(0%)	1(33%)
Experienced User	3(43%)	2(29%)	1(14%)	0(0%)	0(0%)	1(14%)
Total	5(50%)	2(20%)	1(10%)	0(0%)	0(0%)	2(20%)

Research Management

	1	2	3	4	5	N
Inexperienced User	2(67%)	0(0%)	0(0%)	0(0%)	0(0%)	1(33%)
Experienced User	2(29%)	4(57%)	0(0%)	0(0%)	0(0%)	1(14%)
Total	4(40%)	4(40%)	0(0%)	0(0%)	0(0%)	2(20%)

6. I would use (or would have used) this subsystem for research work if it were fully operational:

Research Topic Selection

	1	2	3	4	5	N
Inexperienced User	2(67%)	0(0%)	0(0%)	0(0%)	0(0%)	1(33%)
Experienced User	2(29%)	1(14%)	2(29%)	0(0%)	0(0%)	2(29%)
Total	4(40%)	1(10%)	2(20%)	0(0%)	0(0%)	3(30%)

Research Products Reuse

	1	2	3	4	5	N
Inexperienced User	1(33%)	0(0%)	2(67%)	0(0%)	0(0%)	0(0%)
Experienced User	4(57%)	0(0%)	1(14%)	0(0%)	0(0%)	2(29%)
Total	5(50%)	0(0%)	3(30%)	0(0%)	0(0%)	2(20%)

Research Management

	1	2	3	4	5	N
Inexperienced User	2(67%)	1(33%)	0(0%)	0(0%)	0(0%)	0(0%)
Experienced User	1(14%)	2(29%)	2(29%)	0(0%)	0(0%)	2(29%)
Total	3(30%)	3(30%)	2(20%)	0(0%)	0(0%)	2(20%)

OVERALL SYSTEM EVALUATION

7. I liked the following features about the subsystems I used (circle all that apply):

   a. screen displays (screen organization)
   b. functions (what the subsystems do)
   c. processing speed (system response time)
   d. data (applicability, breadth)
   e. written instructions
   f. on-line help instructions

	a	b	c	d	e	f
Inexperienced User	3(100%)	1(33%)	1(33%)	2(67%)	0(0%)	2(67%)
Experienced User	5(71%)	5(71%)	3(43%)	2(29%)	5(71%)	3(43%)
Total	8(80%)	6(60%)	4(40%)	4(40%)	5(50%)	5(50%)

8. The following features of the subsystems I used need to be improved (circle all that apply):

   a. screen displays (screen organization)
   b. functions (what the subsystems do)
   c. processing speed (system response time)
   d. data (applicability, breadth)
   e. written instructions
   f. on-line help instructions

	a	b	c	d	e	f
Inexperienced User	0(0%)	2(67%)	1(33%)	0(0%)	2(67%)	2(67%)
Experienced User	1(14%)	1(14%)	2(29%)	5(71%)	0(0%)	3(43%)
Total	1(10%)	3(30%)	3(30%)	5(50%)	2(20%)	5(50%)

9. I used the AFIT Research Management System:
   a. less than 15 minutes
   b. 15 to 30 minutes
   c. 30 minutes to one hour
   d. more than one hour

	a	b	c	d
Inexperienced User	1(33%)	1(33%)	1(33%)	0(0%)
Experienced User	0(0%)	3(43%)	4(57%)	0(0%)
Total	1(10%)	4(40%)	5(50%)	0(0%)

Note: 1. The percentages listed in questions seven and eight are based upon the total number of respondents in each group.
2. Due to rounding, the percentage totals for several questions do not equal 100%.

Appendix J. Summary of Written Comments from Test Evaluators

Over thirteen single-spaced pages of comments were received from the three samples of operational test evaluators. The topical lists below contain the most significant and prevalent comments.

1. Future Research Recommendations

a. Accessibility of data could be enhanced. Wildcard and keyword search capabilities would be beneficial. In addition, speed searching within the look-up tables (which involves the movement of the cursor to a set of records that match a typed letter) would increase the usability of this feature.

b. A personal computer (PC) version might be more practical and should be explored. Also, given the increasing use of compact disk read-only memory (CD-ROM), can the ARMS be placed on such a medium and used on a PC?

c. Provide users with the capability to print information they are viewing.

d. Research Management System:

(1) Provide capability under 'Thesis Advisor Qualifications' option to:

(a) search by advisor's last name;
(b) list all faculty with a matching interest area;

(2) List all known beneficiaries of a thesis study on the 'Sponsor Information Record' rather than just the sponsor.

(3) Add e-mail address data item field to the sponsor and advisor records.

e. Research Topic Selection Subsystem:

(1) Provide the capability to list all faculty members interested in a particular topic.

(2) Provide the capability to search theses by author's name.

2. General Comments

a. Faculty interface and comments concerning potential follow-on work would be valuable and provide "good" topics for study.

b. Great potential for saving time if the system is given adequate information to cover a wide range of topics and theses.

c. I liked the ability to view an abstract for a reuse product. Also, the availability of a look-up table to view a list of examples was exceptionally helpful.

d. I see promise in what you're trying to do. Key factors which will determine success include:

(1) Keeping the database current

(2) Ensuring proper abstracts are submitted with the thesis (plus components) on disk for easy entry into the system.

(3) Improving the user interface.

e. I'm not sure that the reuse feature is going to be a boon to AFIT research. I believe that a large part of the research learning is the development of these questionnaires. The "questionnaire-brand" research is not generally the kind of thing that will keep AFIT alive and respected as a research institution.

f. This program is only a small part of the research management task.

g. Without a solid, well-maintained database, this system is of limited utility. Even with a good database it still has holes.

h. Use of the ARMS could be extremely beneficial in selecting a thesis topic. The abstract and component lists are very helpful and informative.

i. This really sounds like something the library should/could manage effectively.

j. The on-line questionnaires, surveys, programs, etc, would be a strong asset as long as they could be easily converted to soft-copy format.

3. Help Screens

a. Suggest you add an opening information screen before the main menu explaining the purpose of the system.

b. On-line help was somewhat limited, but the list of keys and functions screen was useful.

c. Function/keypad keys' abbreviated definitions should be shown at the bottom of all applicable screen.

4. Policy

a. AFIT needs to provide better research support to students and the Air Force. Our ESC and ACC sponsors have provided close to two million dollars for AFIT research in our class, but I don't think AFIT will follow-up with them for future research. Students receive very little start-up support on topic selection or committee formation.

b. Policy considerations should be given to having AFIT students input the information into the system for their part of the thesis effort.

c. Is the ARMS worth it? What is the resource cost? Are the present methods totally inadequate?

d. The system seems valuable; particularly for the recall of reusable research "components." However, there will have to be strong input rules for consistency.

e. The key to the usefulness of this system will be its currency. A thorough consideration of policy issues along these lines is essential.

f. In order for this system to work, policy will need to be enforced at the student and faculty levels to ensure information is submitted and cataloged in the system.

5. Speed

a. System ran too slow to evaluate realistically.

b. Speed was fine with a limited database, but how will it be with 500 or more records?

6. User Friendliness

a. After the first few queries, using the system was almost second nature.

b. The "Thesis Information Record" award codes should be explained somewhere or listed out completely.

c. I think some of your key selections should be more "user friendly." Why use Esc-V, KP4, etc, when you could use just plain number or letter or function keys (e.g., N for next record, Q for inquiry, B for backup to previous display, M for main mer H for help, etc)?

d. Currently, the process of using Esc-V and F4, to display and select from a look-up table, does not automatically perform a query. Instead, I'm returned to the previous query screen where I must press another key, F1, to perform the query. The return to the query screen step should be removed unless it will perform some added function (like multi-field searches) in the future.

e. If keys could be used that don't require the "NUM LOCK" to be on, the system would be more user friendly.

f. The 'Component Information Record' doesn't include the title for the thesis it came from. Inclusion of this information would make looking for the thesis in library easier.

g. It would help if <KP#> and <F#> macros were dissimilar #'s. For example, KP4 and F4 are used a lot. I mixed up their uses a lot.

h. Users should have access to the thesis title and abstract anywhere they are looking at information about a specific thesis. This will give them idea where the item (such as a research product for reuse) came from (its context) or where it was used (its utility).

7. Written Instructions

a. Draft copy of user's guide was informative.

b. May want to consider putting all written instructions on-line.

c. User manual is okay, but could be more extensive.

d. Providing a simple list of all tables and fields in the user's guide would enhance the understandability and use of the system.

e. It would be nice to have a one-page "rosetta stone" help sheet. Face it, users won't take the time to read the manual.

Appendix K: Updated ARMS Functional Description

UPDATED

FUNCTIONAL DESCRIPTION

FOR THE PROPOSED

AFIT RESEARCH MANAGEMENT SYSTEM (ARMS)

(Current as of: 20 Aug 92)

FUNCTIONAL DESCRIPTION
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Note: Normal page numbering was removed to a ˉ-w this document to be appropriately formatted into this thesis.

SECTION 1. GENERAL

1.1 Purpose of Functional Description. This Functional Description for the prototype AFIT Research Management System (ARMS) was written to provide:

A. System requirements which will serve as a basis for mutual understanding between the future users and the developers

B. Information on performance requirements, improvements, impacts, and the system development status

C. A basis for system test and evaluation

1.2 Project References

A. AFIT Thesis: AFIT/GSS/LSC92D-5, "Development of a Prototype Air Force Institute of Technology (AFIT) Research Management System," by Captains David Schaaf and Carl Scott

B. DoD STD-7935, "Automated Data Systems Documentation," 1 Nov 82

1.3 Terms and Abbreviations

A. ARMS - AFIT Research Management System

B. Automated Requirements - System requirements which can be implemented in the ARMS software suite

C. Component - A definable part of a system

D. Continuing Research Stream - Research which builds upon the results of previous studies

E. Continuing Study - A research effort that serves as a follow-on to a previously conducted study.

F. DE - School of Civil Engineering and Services

G. EN - School of Engineering

H. Faculty-Centered Research - research initiated, managed, and perpetuated by a faculty member

I. LS - School of Systems and Logistics

J. Nonautomated Requirements - System requirements which cannot be implemented as part of the ARMS software suite (for example, policy changes)

K. Ongoing Thesis/Study - A study that is still in progress.

L. Prototype - A working model of a computer system which is used for testing the viability of a solution to a problem area

M. Research Product - component of the research process generated and used as part of a research project. (For example, data collection instruments, data, statistical models, computer programs, and computer program documentation)

N. Reuse - The application of existing solutions to the problems of systems development

O. Software - Computer programs, procedures, associated documentation, and data pertaining to the operation of a computer system and peripherals

P. Software Component - An element of software (code module, design document, etc.) that performs a definitive function

Q. Software Reuse - The use of previously developed and/or acquired software components in a new development project

R. System - A collection of components organized to accomplish a specific function or set of functions

SECTION 2. SYSTEM SUMMARY

2.1 Background. The idea for this system was derived from the experiences of two students in the School of Systems and Logistics (LS). The difficulties of determining what research topics are important to the Air Force and DoD, as well as the complexity of scoping a workable research project, led them to initiate a research project that would aid future students.

This project is based on an emerging computer science technique called software reuse. This technique is commonly defined as the use of previously acquired and developed concepts and objects in a new situation. In the area of software development, this would include items such as source code modules, program architectures, software documentation, and a number of other products. The intuitive benefits of this technique are in the areas of productivity (cost and time avoidance), quality, and reliability. To be effectively implemented, reuse requires an extensive effort to determine what and how products should be cataloged into a library system. The library system then allows the products to be located, reviewed for applicability to a new project, and subsequently reused.

Current efforts in the area of reuse are focused on applying the technique to specific "domains." This project supports the intention of these efforts by adapting and evaluating reuse in the "research domain." Using the original goal of building a research products reuse system, the student researchers found that there are many management benefits to be gained by employing such a system. This insight led them to expand the scope of the system's goals to those listed in the next paragraph.

2.2 Goals. The major goals of the prototype ARMS are to:

A. Enhance the student researcher's capabilities to select and scope a research problem which is vital to the Air Force and DoD.

B. Improve student researcher's productivity by adapting and evaluating the concept of reuse to the research domain.

C. Increase management efficiency by providing a collection of data which can be used to efficiently meet reporting needs.

D. Stimulate an increased conduct of continuing research streams within LS and DE.

2.3 Existing Methods and Procedures. Similar academic research processes are conducted by two of the three schools at AFIT. Currently, the Schools of Systems and Logistics (LS) and Civil Engineering and Services (DE) allow students to select their own research topics; while the School of Engineering (EN) employs an approach that fosters continuing research streams. Aside from this difference, the description of the existing methods and procedures provided below applies to all three schools.

It is important to note that modeling the entire academic research domain for the initial prototype ARMS would have been an insurmountable task during the short research period afforded AFIT graduate students. Therefore, only three major facets of the domain were examined during the initial study: research topic selection, research product reuse, and research management. Figure 1 provides an illustration of the major elements and their interaction within the current research environment.

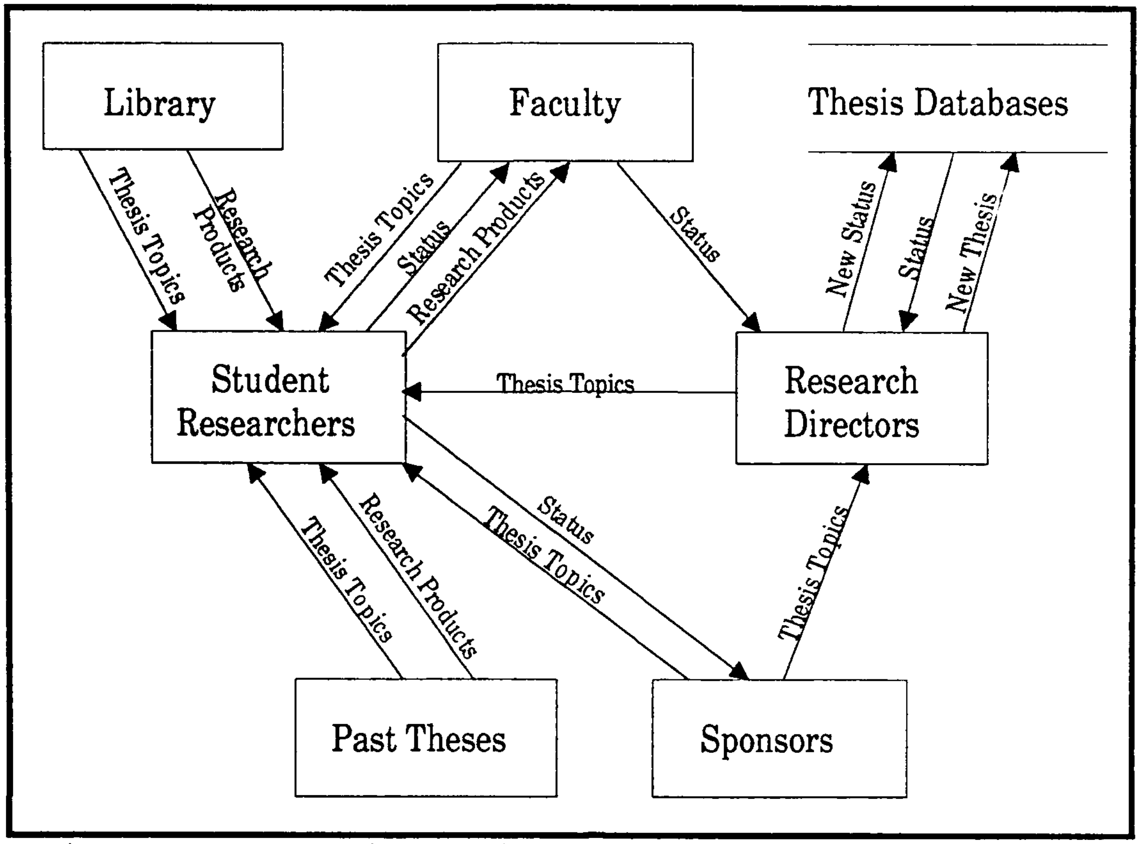

Figure 1. Context Diagram of the Current AFIT Research Environment

2.3.1 Topic Selection. AFIT graduate students researching possible thesis topics can refer to several resources. Many of these resources are found in the academic library, which contains a wide variety of services for conducting topical literature searches. Also, research directors and some faculty members formally and informally "advertise" potential topics. However, it is not always clear to the student researcher which topics are of vital interest to the Air Force and DoD.

The availability of thesis advisors during the critical initiation phase of new students' research activities is another area that impacts topic selection. At present, students in the initial period of selecting and scoping a suitable problem for research, compete for thesis advisors with students who are in the final stages of their projects. This situation not only impairs the progress of new researchers, but places an immense burden on the faculty. Hence, thesis advisors are not readily available for consultation until after Labor Day. By that time, students within the LS school (and in some cases DE) are nearing completion of a literature review assignment for the mandatory COMM 687 (Theory and Practice of Professional Communications) course. Under the current system, the potential benefits of COMM 687 are not fully realized. Students without a well-defined topic may spend valuable time researching a subject unrelated to their thesis.

2.3.2 Research Product Reuse. During the process of completing their theses, student researchers generate a number of products to collect and analyze data. In addition, some student researchers develop software systems or other end products as a result of their efforts. The documentation of such items is embodied within theses and often archived without consideration for further use. (As noted above, the EN school has a program of continuing research streams that reuses products from past studies. However, such items are not cataloged or made available to students in other schools.) Therefore, research products reuse is inhibited in part by the difficulty that students face in locating the items which may benefit their research efforts. Once a suitable product for reuse is located, the researcher normally must recreate it using manual methods.

Based on the concept of reuse, student researchers potentially have a great deal to gain by locating, reviewing, and reusing (in part or wholly) quality research products that are presently underutilized. The current methods of locating and manually reviewing theses might be more acceptable if students had a greater length of time to conduct their research. However, the current 12-15 month start-to-finish thesis process puts pressure on students to complete their research projects expediently. Improvements in locating and reviewing products could potentially relieve pressure by making validated products readily available for reuse.

2.3.3 Research Management. The process of managing academic research is accomplished at AFIT by the research directors for each school. As focal points for summarizing and formally reporting their school's research efforts, the directors use a number of automated and nonautomated procedures. However, none of these procedures have a single collection point for data. Such a data base would offer many potential benefits.

Faculty members at each school who serve as thesis advisors share responsibility in the area of research management. In particular, the underlying basis for a quality program of continuing research streams is faculty-centered research. However, due to the short tenure of many military faculty members, the promotion and longevity of continuing research streams is somewhat restricted. The capability to track on-going or review past continuing research streams could produce an improved environment for similar efforts in the future.

2.4 Proposed Methods and Procedures. This section outlines the improvements offered by the proposed ARMS and describes the system's impact on the present research process at AFIT. Figure 2 pictorially shows how a production quality ARMS is expected to interact within the research environment.

2.4.1 Summary of Improvements. Student researchers, faculty members, and research directors will be provided with certain improvements due to the implementation of the ARMS. The improvements are grouped into four categories: general, research topic selection, research product reuse, and research management.

2.4.1.1 General Improvements. The automated portion of the proposed ARMS will use a data base management system to store and process the data needed to meet student researcher, faculty, and management requirements. As an automated and integrated source of data, the ARMS will offer an information sharing capability among the three AFIT schools. Additionally, the ARMS will provide intangible benefits of using a data base management system such as automated record-keeping, improved trend tracking, standardized/tailored reporting, and other capabilities.

2.4.1.2 Research Topic Selection Improvements. The ARMS will provide an expedient method for reviewing abstracts which describe past and on-going AFIT research projects. The system's implementation will

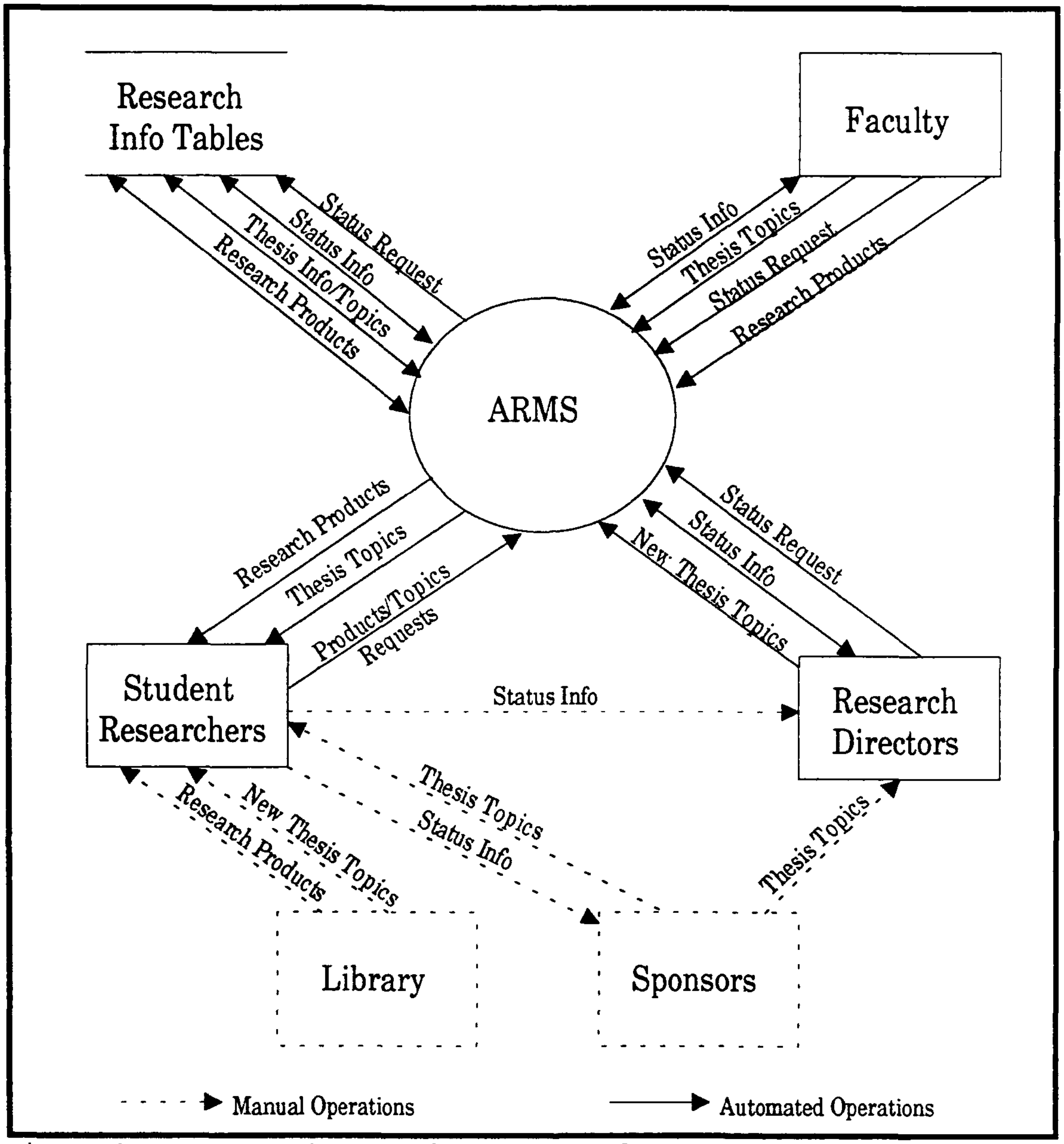

Figure 2. Context Diagram of the Proposed ARMS

potentially alleviate some of the constraints described above in section 2.3.1. The instinctive advantages of using an automated system, combined with the resources available in the current system, will help researchers:

A. Begin the process of selecting/formulating a researchable topic earlier in the academic year.

B. Review a broader range of research topics more expediently and efficiently.

C. Scope their selected research problem.

D. Select topics that lend themselves to longitudinal studies.

E. Investigate the application of research designs and methodologies to specific types of studies.

F. Perform studies that are more relevant to the Air Force and DoD.

In addition to reviewing past and on-going AFIT research efforts, students will also be able to scan new topic suggestions using the ARMS.

2.4.1.3 Research Product Reuse Improvements. The ARMS will provide an efficient means of cataloging research products into a "library system" for future reuse. The resultant library system will allow researchers to expediently locate, review, and reuse research products from previous theses.

2.4.1.3.1 Locating Products. The ARMS will allow researchers to locate reusable research products in many different ways. The following is a list of key search methods that may be used individually or in a number of combinations:

A. Component type.

1. Thesis documents
2. Data collection instruments such as surveys, interview formats, and questionnaires
3. Data from previous collection efforts
4. Statistical models developed to analyze collected data
5. Computer programs such as decision support systems, expert systems, and other application systems
6. Computer program documentation such as functional descriptions, design documents, source code, test plans, and user's guides

B. Descriptive subject term such as Acquisition Management, Contract Management, or Environmental Engineering

C. School/department

D. Author name

E. Subject/keyword(s)

The capability to locate specific products for reuse will be a major improvement over the systems that are now available to AFIT researchers. Currently, most of the systems only provide students with the capability to locate thesis documents and manually review them for available research products.

2.4.1.3.2 Reviewing Products. After the ARMS locates reusable products based on the provided criteria, the researcher will be able to review an abstract for each candidate product. Each abstract will provide both a description and a reuse history of the respective product. Researchers will also be able to further review a copy of the product to determine if it is reusable in their research project. Overall, the capacity to review abstracts and copies of research products immediately after locating them will save researchers' time.

2.4.1.3.3 Reusing Products. The current method of reusing research products normally requires the researcher to re-create the products manually. For example, researchers must either re-type the product or become proficient at using an electronic scanner with optical character reading capability. To minimize this limitation, the ARMS will provide the researcher with an option to obtain an electronic media copy of the product. The ability to obtain a printed copy of the products and respective abstracts will also be available. Combined with the improved locating and reviewing functions, these features should further enhance the productivity of student researchers.

2.4.1.4 Research Management Improvements. The ARMS, by virtue of the detailed information it is to contain, will strongly support many management applications. The following is a representative list of information/functions that can be automated by employing this system:

A. Thesis status tracking data such as initiation date, personnel involved, topic, and completion date.

B. Thesis publication data to periodicals, DTIC, and other archives.

C. Research sponsorship data to include agency, point of contact, funding amounts, and cost-avoidance estimates.

D. Continuing research stream(s) monitoring.

E. New research topic screening/advertisement.

In designing the ARMS, the developers will review the structure of existing data base systems used by research management personnel to the extent that information is provided by the organizations administering such systems. The aim of this approach is to allow for the transfer of existing data into the ARMS.

2.4.2 Summary of Impacts. The ARMS will provide more timely and accurate information to support the conduct and management of the AFIT student research process. The following paragraphs discuss some of the system's major impacts in existing organizational and operational environments. In particular, the following paragraphs outline some of the major nonautomated requirements that must be addressed before the ARMS can be fully implemented.

2.4.2.1 Organizational Impacts.

A. A number of personnel (quantity to be determined) will be required to perform data entry operations. This effort could be minimized depending on how the policies and procedures for sustaining the system are structured. See paragraph 2.4.2.2.A.

B. A database/system manager should be appointed within each of the three schools to answer user questions and manage school-specific implementation details.

C. An application administrator should be assigned within AFIT/SC to maintain the ARMS application.

2.4.2.2 Operational Impacts. Several policies will need to be developed to ensure the system is implemented, operated, and maintained efficiently. Specifically, all operational areas (student researchers, faculty members (thesis advisors), and researcher directors) impacted by the ARMS should have defined responsibilities. The following suggestions should be considered before fully implementing the system:

A. Require student researchers to submit electronic media copies (diskette or other suitable means) of research products and abstracts along with completed theses. This requirement would impose a minimal workload on students, while significantly decreasing the data entry burden for the system.

B. Assign faculty members (thesis advisors) the responsibilities of:

1. Evaluating research products generated during student projects for inclusion in the research products reuse subsystem. This decision is similar to the one that is now made concerning thesis publication and distribution.

2. Reviewing research topics and generating new ones for input to the topic selection part of the ARMS.

C. Task the research management staff (each school's research director and their personnel) with overall ownership responsibilities for the system. Such responsibilities might include: monitoring the system's data accuracy and validity; acting as the liaison between users and the application administrator (AFIT/SC) for problem resolution and/or system improvements; and managing the access permissions for certain data within the system.

<u>2.4.2.3</u> <u>Developmental</u> <u>Impacts</u>. Besides designing and implementing the data structures, control programs, and initial data set for the prototype ARMS, the developers will accomplish the following tasks as part of this project:

A. Training ("hands-on" instruction) will be conducted for all personnel participating in the operational test of the prototype ARMS.

B. User guides/instruction sheets will be developed for the various ARMS applications (subsystems).

C. Program maintenance documentation will be developed to ensure the system can be enhanced in the future.

<u>2.5</u> <u>Assumptions</u> <u>and</u> <u>Constraints</u>. The following key assumptions and constraints apply to this project:

A. The ARMS is a prototype development that will potentially undergo iterative refinement in future research efforts or be turned over to AFIT/SCV for maintenance. Therefore, coding and documentation conventions consistent with those used in other AFIT automation systems were and should continue to be employed whenever possible.

B. The project was limited to the use of existing AFIT computing hardware and software.

C. The prototype system was developed to store and process unclassified information only.

SECTION 3.0 DETAILED CHARACTERISTICS

3.1 General Performance Requirements. The list below provides general performance requirements that the automated portion of ARMS must meet while providing the improvements and functions described in sections 2.4 and 3.2.

A. Provide formatted displays for interactive (on-line) data entry.

B. Minimize user entries by providing default values and range boundaries where possible.

C. Provide feedback when a transaction has either been completed or rejected.

D. Ensure that only completed transactions are stored in the database.

E. Provide an ad hoc query and reporting capability to users with special needs and advanced training.

F. Permit the generation of predefined reports.

G. Permit retrieval of data by the user from/to terminals or to printers.

H. Provide each user the authority to access records and data in their areas of responsibility.

I. Limit each user to specified processing functions based on assigned responsibilities.

J. Provide daily, weekly, and monthly database backup capability.

3.2 System Functions/Requirements. To directly meet the general improvements listed in section 2.4, the automated portion of ARMS has three major subsystems: the research topic selection subsystem (RTSS), research products reuse subsystem (RPRS), and research management subsystem (RMS). A fourth subsystem, the database administration subsystem (DAS), provides system managers/monitors with the capability to maintain the ARMS.

3.2.1 Subsystem Descriptions. The following general descriptions guided the development of each subsystem:

3.2.1.1 RTSS. Through the categorization of theses and automation of the current research topics book, the RTSS provides student researchers with the capability to review available information in a more focused and expedient manner. The on-line information contained in the RTSS's tables permits researchers to review the complete abstract of an AFIT thesis to help them determine if a more detailed review of the document is warranted. Four categories of theses and automated research requests can be queried and reviewed based on a variety of criteria.

3.2.1.2 RPRS. The RPRS represents an adaptation of the "software reuse" concept, which is defined as the use of previously developed and/or acquired software components (such as source code modules, design descriptions, documentation, and so on) in a new development project. The application of this technique to the thesis yields several potential components for reuse. Currently, the process of locating such items is very tedious and time-consuming since only the thesis document is cataloged. The RPRS provides the framework for cataloging research components and allows for the on-line storage of an abstract describing the component, and in some cases, an electronic copy of the component itself.

3.2.1.3 RMS. The RMS is designed to provide a convenient source of management information concerning the AFIT/LS student research program. The initial capabilities of this subsystem include the ability to query and review information concerning continuing research studies, research sponsors, and thesis advisor interests/qualifications.

3.2.1.4 DAS. This subsystem is designed to provide personnel assigned database administration responsibilities with the capabilities to perform their job. Two primary sets of activities may be done in this subsystem: record manipulation and special queries.

3.2.2 Subsystem Requirements. A fully functional ARMS should meet the following automated requirements listed by subsystem.

3.2.2.1 RTSS Requirements.

3.2.2.1.1 Provide the capability to perform thesis queries based on the following types of user-provided criteria:

A. Subject term (Software Development, Supply, Maintenance, etc.)

B. School/department (LSC, LSR, etc.)

C. Degree program designator (GSS, GLM, etc.)

D. Author last name

E. Advisor last name

F. Title/subject keyword

G. Status (completed, ongoing, sponsored, and award-winning)

H. Date (completion year)

I. Continuing study designation (yes/no)

J. Research design/methodology type

K. Combinations of A through K above

3.2.2.1.2 Provide the capability to perform new research request (topic) queries based on the following types of user-provided criteria:

A. Subject term (Software Development, Supply, Maintenance, etc.)

B. Topic identification number

C. Title/subject keyword

D. Source designation (internal/external)

E. Nominating organization

F. Faculty POC last name

G. Usage status (previously used or still unused)

3.2.2.1.3 Provide screen listings of information records and associated textual abstracts for records retrieved by the queries described above in paragraphs 3.2.2.1.1 and 3.2.2.1.2.

3.2.2.1.4 Permit printing of screen displays to a user-designated printer. Provide the capability, where feasible, for printing summary lists of query results.

3.2.2.2 RPRS Requirements.

3.2.2.2.1 Provide the capability to perform thesis queries based on the following types of user-provided criteria:

A. Component type (Survey, Program, Interview, etc.)

B. Subject term (Software Development, Supply, Maintenance, etc.)

c. School/department (LSC, LSR, etc.)

D. Degree program designator (GSS, GLM, etc.)

E. Component POC last name

F. Title/subject keyword

G. Combinations of A through F above

3.2.2.2.2 Provide screen listings of information records, associated textual abstracts, and electronic copies of components for records retrieved by the queries described above in paragraph 3.2.2.2.1.

3.2.2.2.3 Permit printing of screen displays to a user-designated printer. Provide the capability, where feasible, for printing summary lists of query results.

3.2.2.2.4 When requested, provide researchers with an electronic copy of requested components that are stored on-line.

3.2.2.3 RMS Requirements.

3.2.2.3.1 Provide a menu of predefined options to review research program information concerning:

A. Thesis progress/completion tracking

B. External publication of studies (in periodicals, DTIC, etc.)

C. Continuing research streams (current and past)

D. Research sponsorship

E. Thesis advisor qualifications

3.2.2.3.2 Provide screen listings of information records and associated textual abstracts for records retrieved by the queries described above in paragraph 3.2.2.3.1.

3.2.2.3.3 Permit printing of screen displays to a user-designated printer. Provide the capability, where feasible, for printing summary lists of query results and other formatted reports.

3.2.2.4 DAS Requirements.

3.2.2.4.1 Provide a menu that permits the system administrator and other designated representatives to add, change, and delete records in the system's data tables.

3.2.2.4.2 Provide the system administrator and other designated representatives with the capability to perform specialized queries not covered in the system's menu structure.

3.2.3 Other Design Considerations. The system will validate inputs against look-up tables and ranges where possible. This will allow for the immediate rejection of invalid data before it can be stored in the database. The system will not permit the mistyping of character information or numbers in situations where validation is possible. When an error is detected, the user will be requested to re-enter the incorrect information or allowed to quit the input operation.

3.3 Inputs-Outputs. The input of data into the ARMS tables will primarily be accomplished through the keyboard of a personal computer or other virtual display terminal connected to the AFITNET. The ARMS will also provide an interface for transferring data from selected disk drives of connected computers and terminals. Outputs from the system will include screen displays, printouts, disk files, or tape files. (Note: Specific outputs for the initial prototype were limited to screen displays.)

3.4 Data Base Characteristics. There are seventeen types of records that contain the information needed to meet the streamlined set of requirements implemented in the initial prototype ARMS. A detailed description of the data elements for each record type is listed in the ARMS Data Dictionary (Attachment 1). The data dictionary is meant to provide the database administrator and other special users with an understanding of the system's data structures. Casual users of the system are shielded from such information by a series of menu- and prompt-driven interfaces.

3.5 Failure Contingencies. Database failures for the ARMS can fall into three categories:

A. Transaction Failure: A failure of a single transaction of the database, usually caused by a data error.

B. Software Failure: A failure of the database management system itself, usually caused by a programming error.

C. Hardware Failure: A failure of the system hardware, either recoverable or catastrophic. Recoverable errors are typically power outages and catastrophic errors usually destroy data in the database requiring a complete recovery of the database from a backup copy.

The methods used to prepare for and recover from these failures are as follows:

A. Backup. A daily, weekly, and monthly backup of the VAX Cluster is done by the operations branch of AFIT/SC. The scope of each type of backup is as follows:

1. Daily: All changes made to any files since the previous day.

2. Weekly: All changes made to any files since the previous week.

3. Monthly: All files on the VAX Cluster.

4. Weeknights: All data stored in the ORACLE database.

B. Rollback. ORACLE provides the ability to rollback incomplete transactions at the discretion of the user. Changes to the database are not permanent until the user commits them to the database.

C. Restart. Programs that are using ORACLE can be restarted after a catastrophic failure once the database is restored. In the case of a catastrophic failure, the changes which had not yet been committed to the database are automatically "rolled back."

3.6 Security. The initial prototype ARMS will be developed to store and handle only unclassified, nonsensitive data. Additional precautions for handling additional types of data may be required during future enhancement efforts.

SECTION 4. DESIGN DETAILS OF CURRENT VERSION

4.1 Implemented Requirements. Listed below are the paragraph numbers of the requirements implemented in each subsystem for the current version of the ARMS:

SUBSYSTEM	PARAGRAPH NUMBERS
Research Topic Selection (RTSS)	3.2.2.1.1 subparagraphs A, G, and I; 3.2.2.1.2.A; 3.2.2.1.3
Research Products Reuse (RPRS)	3.2.2.2.1.A; 3.2.2.2.2
Research Management (RMS)	3.2.2.3.1 subparagraphs C, D, and E; 3.2.2.3.2
Database Administration (DAS)	3.2.2.4.1; 3.2.2.4.2

In addition, the input validation requirements specified in 3.2.3 were implemented, where applicable, within the design for each subsystem.

4.2 Data Structures. As noted in paragraph 3.4, there are seventeen types of records that contain the information needed to meet the streamlined set of requirements implemented in the initial prototype ARMS. A detailed description of the data elements for each record type is listed in the ARMS Data Dictionary (Attachment 1). A pictorial view of the key relationships between the objects corresponding to the ARMS primary tables is provided in Figure 3.

4.3 Menus and Screen Displays. After completing the design for the ARMS data structures, a menu structure was developed to incorporate the selected automation requirements listed in paragraph 4.1. Attachment 2 provides a tree which lists the layout of the menu structure as well as the corresponding "forms" developed to manage the system. The "forms" are the file names ending with ".INP" listed under each action-oriented menu option. Three primary types of screens were developed for the system: the "query" screen that provides the user with a "friendly" interface to find records of interest; the "information record" display that presents the records retrieved by user-generated queries; and "text-format" layouts that list "information record" abstracts and electronic copies of components. All three of these screens types are encapsulated in the "QUERY_..." files listed in Attachment 2.

The "LIST_..."-type of forms shown in Attachment 2 were designed to provide the "look-up" table capability described in the ARMS User's Guide and required by paragraph 3.2.3 above. The "UPDATE_..."-type of forms provide the database administration personnel with the capability to add, change, and delete records from the ARMS' tables, as required by paragraph 3.2.2.4.1. The fourth and final form type, the "HELP_..."-series, is described below.

4.4 Help Facilities. A limited help system was implemented with this version of the prototype. Requesting help from the system is as easy as pressing "0" on the keypad (<KP0>) during any menu, query, or information record display. Pressing <KP0> when a menu screen is displayed provides the user with information about menu options, while pressing <KP0> during the display of query or information records presents a layout of active keys for use within the current function. Additional help is provided on many of the screens in the form of "text boxes" and one-line messages that appear in the inverse video at the bottom of most screens. The ARMS User's Guide contains some specific examples of the help information provided by the current prototype system. The "HELP_..."-type of forms shown in Attachment 2 contain the help screens for the individual menu options.

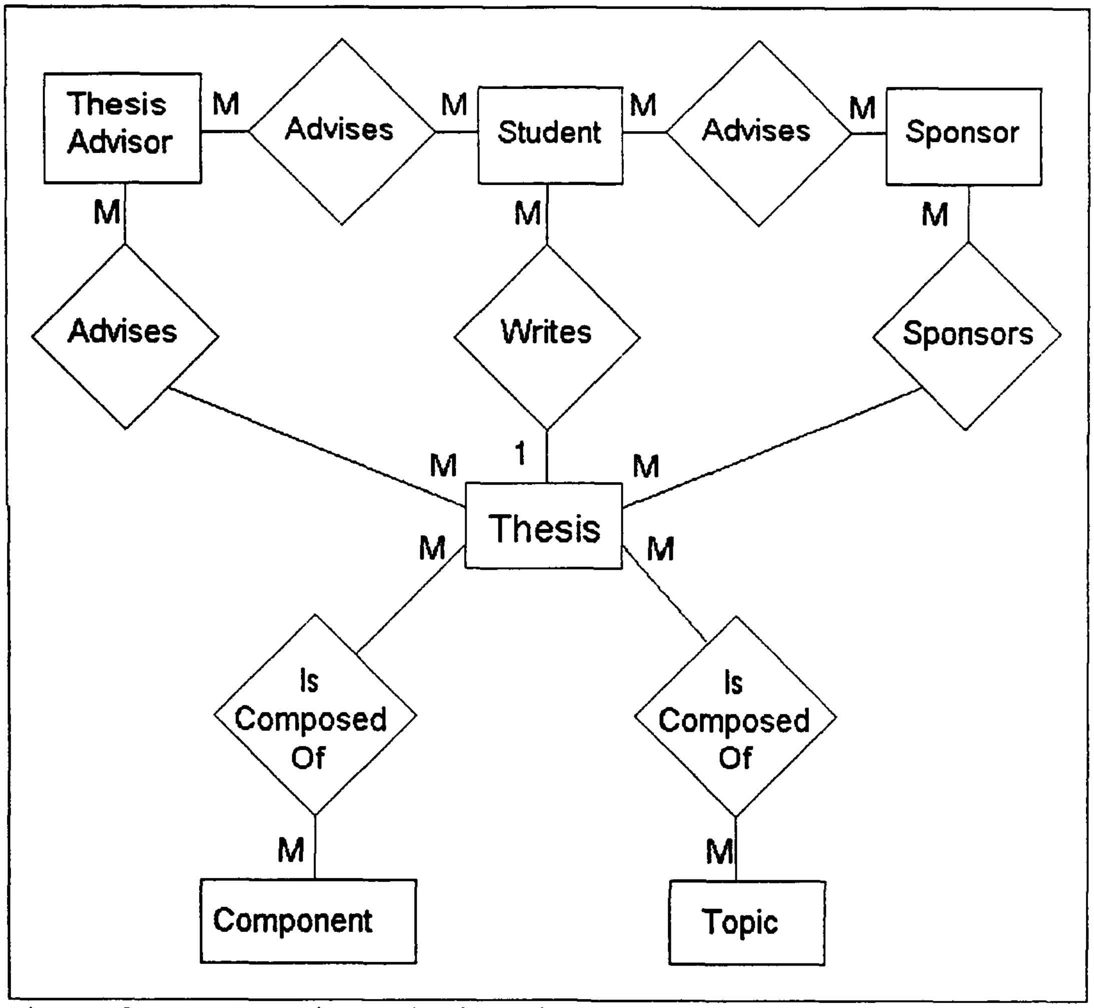

Figure 3. ARMS Entity Relationship Diagram

SECTION 5. ENVIRONMENT

5.1 Equipment Environment. The prototype ARMS is currently hosted on a Digital Electronics Corporation (DEC) VAX/VMS 8650 processor with 32 megabytes of internal memory. Other than a personal computer or other VT100-capable terminal connected to the AFITNET, there are currently no special peripherals required to access and operate the ARMS. Dedicated storage space and other system resources may be required in the future, but none have been determined to date.

5.2 Support Software Environment. The following software was used to develop the prototype system:

A. ORACLE, version 6.0

B. SQL*FORMS, version 2.3.31

C. SQL*MENU, version 4.1.16

D. SQL*PLUS, version 3.0.9.4.1

5.3 Interfaces. Currently, there are no other systems that interface with the prototype ARMS. If a production-quality system is eventually developed, links to the AFIT Student Information System (AFITSIS) and the Integrated Library System (ILS) should be considered.

5.4 Security. The ARMS is not designed to contain or process classified information. However, the current prototype provides the following information protection safeguards:

A. Users are required to "login" to the VAX/VMS Cluster using their personal "username" and "password."

B. Users are then required to enter their ORACLE "username" and "password."

C. Access to sensitive data elements is restricted to a specified set authorized personnel.

SECTION 6. COST FACTORS

Cost factors are not addressed in this version of the functional description because they could not reasonably be considered during the initial prototype development of the ARMS. One recommendation for future research includes the performance of a complete cost-benefit analysis to determine if a production-quality system should be pursued.

SECTION 7. SYSTEM DEVELOPMENT PLAN

7.1 Initial Prototype Development and Results. Development of the initial prototype ARMS was accomplished using the seven research objectives described in Chapter III of the AFIT thesis referenced in paragraph 1.2.A. While Chapters IV and V discuss the studies results and conclusions, respectively.

7.2 Follow-On Recommendations. Chapter V of the AFIT thesis referenced in paragraph 1.2.A also provides many recommendations for improving the current prototype system and performing corollary studies. The interested reader should thoroughly review the thesis and its appendices for additional information.

Attachment 1 - Prototype ARMS Data Dictionary

Listed below are the primary and supporting tables for the prototype ARMS. The tables under each category are listed in alphabetical order.

PART I - PRIMARY TABLES

Table Name: ADVISOR
Purpose: This table is used to store information about advisors of past and current thesis efforts. Data in this table is accessible through the Research Management System or Database Administration Subsystem.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
ADVISOR_LASTNAME	Character	20	Thesis advisor's last name
ADVISOR_FIRSTNAME	Character	15	Thesis advisor's first name
ADVISOR_MIDDLEINIT	Character	3	Thesis advisor's middle initial or may contain NMI (no middle initial)
ADVISOR_RANK	Character	8	Military rank or may contain CIVILIAN for non-military
ADVISOR_ORG_OFCSYM	Character	20	Thesis advisor's organization and office symbol
ADVISOR_PHONE_LOCAL	Character	8	Thesis advisor's local phone #
ADVISING_STATUS	Character	1	May contain: 'Q' for fully qualified, 'I' for intern, or 'A' for adjunct (See LSOI 50-11 for more information.)
STATUS_DATE	Character	4	Academic year assigned their advising status
LAST_ADVISED	Character	4	Academic year they last advised
INTEREST_AREA_1	Character	30	Area of interest to advisor
INTEREST_AREA_2	Character	30	Area of interest to advisor
INTEREST_AREA_3	Character	30	Area of interest to advisor
INTEREST_AREA_4	Character	30	Area of interest to advisor
INTEREST_AREA_5	Character	30	Area of interest to advisor
INTEREST_AREA_6	Character	30	Area of interest to advisor
ADVISOR_ADDRESS_L1	Character	50	Building/street address of advisor if not a faculty member
ADVISOR_ADDRESS_L2	Character	50	City or base, state, and zip code of non-faculty advisor
ADVISOR_COMMENTS_L1	Character	60	Space for miscellaneous comments
ADVISOR_COMMENTS_L2	Character	60	Space for miscellaneous comments
ADVISOR_COMMENTS_L3	Character	60	Space for miscellaneous comments

Table Name: COMPONENT
Purpose: This table is used to store information about thesis components (AKA research products). Data in this table is accessible through the Research Products Reuse Subsystem and Database Administration Subsystem.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
THESIS_ID_NR	Character	20	Thesis identification number (AKA thesis designator)
COMPONENT_POC_LASTNAME	Character	20	One of the thesis advisors for the study that produced the component product
POC_DEPARTMENT	Character	3	Thesis advisor's department
COMPONENT_TITLE_L1	Character	60	First part of component title
COMPONENT_TITLE_L2	Character	60	Second part of component title
COMPONENT_TITLE_L3	Character	60	Third part of component title
COMPONENT_TYPE	Character	20	Type of component (i.e. Survey, Questionnaire, Statistical Model, etc.)
DATE_SUBMITTED	Character	9	Date component formally placed into the ARMS for reuse
REUSED_COMPONENT	Character	1	Control field to indicate if the component was reused from another study ('Y'es or 'N'o)
COMPONENT_COMMENTS_L1	Character	60	Space for miscellaneous info
COMPONENT_COMMENTS_L2	Character	60	Space for miscellaneous info
ABSTRACT_LOCATION	Character	25	Name/location of text file containing the thesis abstract
COMPONENT_LOCATION	Character	40	Name/location of text file containing electronic copy of the component (if applicable)

Table Name: SPONSOR
Purpose: This table is used to store information about thesis sponsors. Data in this table is accessible through the Research Management System or Database Administration Subsystem.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
THESIS_ID_NR	Character	20	Thesis identification number (AKA thesis designator)
SPONSOR_POC	Character	50	Sponsoring agency's point of contact (POC)
SPONSOR_ORG_OFCSYM	Character	25	Organization and office symbol of sponsor
SPONSOR_ADDRESS_L1	Character	50	First part of sponsoring agency's address
SPONSOR_ADDRESS_L2	Character	50	Second part of sponsoring agency's address
SPONSOR_PHONE_COMM	Character	13	Commercial telephone number of sponsoring agency's POC
SPONSOR_PHONE_DSN	Character	8	DSN telephone number of sponsoring agency's POC
FUNDING_PROVIDED	Character	1	Control field to indicate if funding was provided ('Y'es or 'N'o)
FUNDING_AMOUNT	Character	6	Amount of funding received from sponsoring agency
COST_DEFER_RQSTD	Character	1	Control field to indicate if a cost avoidance estimate request has been sent ('Y'es or 'N'o)
COST_DEFER_RECVD	Character	1	Control field to indicate if the estimate has been received ('Y'es or 'N'o)
COST_DEFER_VALUE	Number	6	Estimate cost avoidance amount

(SPONSOR table definition continued)

SPONSOR_COMMENTS_L1	Character	60	Space for miscellaneous comments
SPONSOR_COMMENTS_L2	Character	60	Space for miscellaneous comments
SPONSOR_COMMENTS_L3	Character	60	Space for miscellaneous comments

Table Name: STUDENT

Purpose: This table is used to store information about graduate students (AKA thesis authors). Only a portion of the data items in this table is currently used. However, the type of information in this table could prove valuable as the Research Management Subsystem matures. Currently, the data in this table is primarily accessible through the Database Administration Subsystem.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
STUDENT_LASTNAME	Character	20	Student's last name
STUDENT_FIRSTNAME	Character	15	Student's first name
STUDENT_MIDDLEINIT	Character	3	Student's middle initial or may contain NMI (no middle initial)
STUDENT_RANK	Character	8	Military rank or may contain CIVILIAN for non-military
STUDENT_SSAN	Character	11	Student's social security #
DEGREE_PROGRAM_ID	Character	3	Student's three-letter degree program designator
PROGRAM OPTION	Character	25	Specific graduate degree program option, if applicable
GRADUATION_YEAR	Character	4	Academic year of student's scheduled graduation
GRADUATION_MONTH	Character	1	First letter of the student's scheduled month of graduation (may contain an 'S' for September or 'D' for December)
THESIS_ID_NR	Character	20	Thesis identification number (AKA thesis designator)
THESIS_APPROVED	Character	1	Control field to indicate if thesis is ongoing ('Y'es or 'N'o)
TEAM_THESIS	Character	1	Control field to indicate if the thesis was team effort ('Y'es or 'N'o)
FIRST_QTR_GRADE	Character	2	Field to contain student's grade for the first quarter of thesis work
SECOND_QTR_GRADE	Character	2	Field to contain student's grade for the second quarter of thesis work
THIRD_QTR_GRADE	Character	2	Field to contain student's grade for the third quarter of thesis work
STUDENT_COMMENTS_L1	Character	60	Space for miscellaneous comments
STUDENT_COMMENTS_L2	Character	60	Space for miscellaneous comments
STUDENT_COMMENTS_L3	Character	60	Space for miscellaneous comments

Table Name: THESIS

Purpose: This table is used to store information about each graduate thesis. Data in this table is accessible through all subsystems except the Research Products Reuse Subsystem.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
THESIS_ID_NR	Character	20	Thesis identification number (AKA thesis designator)
DATE_PUBLISHED	Character	9	Thesis publication date
THESIS_TITLE_L1	Character	60	First part of thesis title
THESIS_TITLE_L2	Character	60	Second part of thesis title
THESIS_TITLE_L3	Character	60	Third part of thesis title
SUBJECT_TERM_1	Character	30	Applicable DTIC subject term for the thesis (more than one may apply--as shown below)
SUBJECT_TERM_2	Character	30	Applicable DTIC subject term for the thesis
SUBJECT_TERM_3	Character	30	Applicable DTIC subject term for the thesis
SUBJECT_TERM_4	Character	30	Applicable DTIC subject term for the thesis
SUBJECT_TERM_5	Character	30	Applicable DTIC subject term for the thesis
SUBJECT_TERM_6	Character	30	Applicable DTIC subject term for the thesis
CONTINUING_STUDY	Character	1	Control field to indicate if thesis continues a previous study ('Y'es or 'N'o)
SPONSORED_STUDY	Character	1	Control field to indicate if the thesis was a sponsored study ('Y'es or 'N'o)
THESIS_APPROVED	Character	1	Control field to indicate if thesis is *ongoing* ('Y'es or 'N'o)
AWARD_WINNER	Character	1	Control field to indicate if the thesis was selected for an award ('Y'es or 'N'o)
AWARD_CODE	Character	1	First letter of award received, if applicable
CLASSIFICATION	Character	15	Security classification of thesis
DTIC_NR	Character	15	DTIC number assigned to thesis if it is archived through that agency
DISTRIBUTION_CODE	Character	9	Thesis distribution code assigned by the advisors
DISTRIBUTION_STMT_L1	Character	60	First part of distribution statement for the thesis
DISTRIBUTION_STMT_L2	Character	60	Second part of distribution statement for the thesis
DISTRIBUTION_STMT_L3	Character	60	Third part of distribution statement for the thesis
DISTRIBUTION_STMT_L4	Character	60	Fourth part of distribution statement for the thesis
OTHER_COMMENTS_L1	Character	60	Space for miscellaneous comments
OTHER_COMMENTS_L2	Character	60	Space for miscellaneous comments
OTHER_COMMENTS_L3	Character	60	Space for miscellaneous comments
ABSTRACT_LOCATION	Character	25	Name/location of text file containing the thesis abstract

Table Name: TOPIC

Purpose: This table is used to store information about new research requests (AKA topics). Data in this table is accessible through the Research Topic Selection Subsystem and the Research Management Subsystem.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
TOPIC_NR	Character	6	Topic identification number assigned by LSC using a year-sequential number format (YY-NNN)
TOPIC_TITLE_L1	Character	60	First part of topic title
TOPIC_TITLE_L2	Character	60	Second part of topic title
TOPIC_TITLE_L3	Character	60	Third part of topic title
DATE_SUBMITTED	Character	9	Date topic initially received by LSC
EXTERNAL_SOURCE	Character	1	Control field to indicate if the topic was generated from an agency outside of AFIT ('Y'es or 'N'o)
TOPIC_USED	Character	1	Control field to indicate if this request has been previously researched ('Y'es or 'N'o)
FACULTY_POC_LASTNAME	Character	20	Internal point of contact (POC) that has reviewed and volunteered to advise the topic
FACULTY_POC_ DEPARTMENT	Character	3	Three letter department/directorate of faculty POC
SUBJECT_TERM_1	Character	30	Applicable DTIC subject term for the topic (more than one may apply--as shown below)
SUBJECT_TERM_2	Character	30	Applicable DTIC subject term for the topic
SUBJECT_TERM_3	Character	30	Applicable DTIC subject term for the topic
SUBJECT_TERM_4	Character	30	Applicable DTIC subject term for the topic
SUBJECT_TERM_5	Character	30	Applicable DTIC subject term for the topic
SUBJECT_TERM_6	Character	30	Applicable DTIC subject term for the topic
NOMINATOR_NAME	Character	50	Nominating agency's point of contact
NOMINATOR_ORG_OFCSYM	Character	25	Organization name and office symbol of nominator
NOMINATOR_ADDRESS_L1	Character	50	First part of nominating agency's address
NOMINATOR_ADDRESS_L2	Character	50	Second part of nominating agency's address
NOMINATOR_PHONE_COMM	Character	13	Commercial telephone number of nominating agency's POC
NOMINATOR_PHONE_DSN	Character	8	DSN telephone number of nominating agency's POC
TOPIC_COMMENTS_L1	Character	60	Space for miscellaneous comments
TOPIC_COMMENTS_L2	Character	60	Space for miscellaneous comments
ABSTRACT_LOCATION	Character	25	Name/location of text file containing the topic abstract

PART II - SUPPORTING TABLES

Table Name: ADVISOR_HISTORY
Purpose: This table is used to store information about the theses the advisor has been involved with. This information is currently updated through the Database Administration Subsystem and is displayed by all subsystems that present information about theses. The foreign key 'THESIS_ID_NR' is what relates the advisor back to the appropriate thesis record and vice versa.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
ADVISOR_LASTNAME	Character	20	Thesis advisor's last name
THESIS_ID_NR	Character	20	Thesis identification number (AKA thesis designator)
ADVISOR_OR_READER	Character	7	Advisor's role for the specified thesis

Table Name: COMPONENT_TYPES
Purpose: This table stores a unique list of 'component types.' It is used as a look-up table by the Research Products Reuse Subsystem to assist in the formulation of queries by 'component type.'

FIELD NAME	FIELD TYPE	SIZE
COMPONENT_TYPE	Character	20

Table Name: CONT_STUDY_SUBJECTS_LIST
Purpose: This table stores a unique list of subject terms applicable to theses categorized as continuing studies. It is used as a look-up table by the Research Topic Selection Subsystem and Research Management Subsystem to assist in the formulation of queries by 'subject term.'

FIELD NAME	FIELD TYPE	SIZE
SUBJECT_TERM	Character	30

Table Name: CRITERIA
Purpose: This table is a dummy table used by several of the query forms. It serves only as a temporary storage location for user inputs.

FIELD NAME	FIELD TYPE	SIZE
SUBJECT_TERM	Character	30
DEPARTMENT	Character	20
DEGREE_PROGRAM_ID	Character	3
AUTHOR_LASTNAME	Character	20
ADVISOR_LASTNAME	Character	20
TITLE	Character	30
SPONSORED	Character	1
CONTINUING	Character	1
THESIS_DESIGNATOR	Character	20
DTIC_NR	Character	15
TOPIC_NR	Character	6
SOURCE	Character	1
NOMINATOR_ORG	Character	25

Table Name: INTEREST_AREA_LIST

Purpose: This table stores a unique list of advisor interest areas. It is used as a look-up table by the Research Management Subsystem to assist in the formulation of thesis advisor queries by 'interest areas.'

FIELD NAME	FIELD TYPE	SIZE
INTEREST_AREA	Character	30

Table Name: ONGOING_THESIS_SUBJECTS_LIST

Purpose: This table stores a unique list of subject terms applicable to theses categorized as ongoing. It is used as a look-up table by the Research Topic Selection Subsystem to assist in the formulation of queries by 'subject term.'

FIELD NAME	FIELD TYPE	SIZE
SUBJECT_TERM	Character	30

Table Name: SPONSOR_LIST

Purpose: This table stores a unique list of sponsor organization/office symbol values. It is used as a look-up table by the Research Management Subsystem to assist in the formulation of queries by 'sponsor organization.'

FIELD NAME	FIELD TYPE	SIZE
SPONSOR_ORG_OFCSYM	Character	25

Table Name: SPONSORED_STUDY_SUBJECTS_LIST

Purpose: This table stores a unique list of subject terms applicable to theses categorized as sponsored. It is used as a look-up table by the Research Topic Selection Subsystem to assist in the formulation of queries by 'subject term.'

FIELD NAME	FIELD TYPE	SIZE
SUBJECT_TERM	Character	30

Table Name: THESIS_SUBJECTS_LIST

Purpose: This table stores a unique list of subject terms applicable to all theses in the THESIS table. It is used as a look-up table by the Research Topic Selection and Research Management Subsystems to assist in the formulation of queries by 'subject term.'

FIELD NAME	FIELD TYPE	SIZE
SUBJECT_TERM	Character	30

Table Name: TOPIC_SUBJECTS_LIST

Purpose: This table stores a unique list of subject terms applicable to all topics in the TOPIC table. It is used as a look-up table by the Research Topic Selection Subsystem to assist in the formulation of queries by 'subject term.'

FIELD NAME	FIELD TYPE	SIZE
SUBJECT_TERM	Character	30

Table Name: TOPIC_HISTORY

Purpose: This table is used to store information on the use of specific topics. It is not currently used by any of the subsystems at this time, but could be used in future prototype enhancement efforts.

FIELD NAME	FIELD TYPE	SIZE	DESCRIPTION/POSSIBLE VALUES
TOPIC_NR	Character	6	Topic identification number
THESIS_ID_NR	Character	20	Thesis identification number that used the topic
NOMINATOR_NOTIFIED	Character	1	Control field to indicate if the topic's nominator has been notified that the topic will be used ('Y'es or 'N'o)
TOPIC_HISTORY_ COMMENTS_L1	Character	60	Line 1 of topic history comments
TOPIC_HISTORY_ COMMENTS_L2	Character	60	Line 2 of topic history comments

Attachment 2 - Prototype ARMS Menu/Forms Tree

Listed below is the menu structure for the initial prototype ARMS. A list of applicable SQL*FORMS(TM)-generated forms for each menu option is also included to provide an integrated view of the system.

ARMS Main Menu

- 1 - Research Topic Selection Subsystem Menu
  - 1 - Review All Thesis Records
    - HELP_CRITERIA_KEYS.INP
    - HELP_THESIS_KEYS.INP
    - LIST_THESIS_SUBJECTS.INP
    - QUERY_THESES_ALL.INP
    - QUERY_THESES_BY_SUBJECT.INP
  - 2 - Review Continuing Studies Records
    - HELP_CRITERIA_KEYS.INP
    - HELP_THESIS_KEYS.INP
    - LIST_CONT_STUDY_SUBJECTS.INP
    - QUERY_THESES_CONT_STUDY.INP
  - 3 - Review Ongoing Theses Records
    - HELP_CRITERIA_KEYS.INP
    - HELP_THESIS_KEYS.INP
    - LIST_ONGOING_THESIS_SUBJECTS.INP
    - QUERY_THESES_ONGOING.INP
  - 4 - Review Sponsored Theses Records
    - HELP_CRITERIA_KEYS.INP
    - HELP_THESIS_KEYS.INP
    - LIST_SPONSORED_STUDY_SUBJECTS.INP
    - QUERY_THESES_SPONSORED.INP
  - 5 - Review New Research Requests
    - HELP_CRITERIA_KEYS.INP
    - HELP_TOPIC_KEYS.INP
    - LIST_TOPIC_SUBJECTS.INP
    - QUERY_TOPICS_BY_SUBJECT.INP
  - 6 - Return to Previous Menu
- 2 - Research Products Reuse Subsystem Menu
  - HELP_CRITERIA_KEYS.INP
  - HELP_TOPIC_KEYS.INP
  - LIST_TOPIC_SUBJECTS.INP
  - QUERY_TOPICS_BY_SUBJECT.INP

(Continued on next page)

3 - Research Management Subsystem Menu

- 1 - Review Continuing Research Information
  - HELP_CRITERIA_KEYS.INP
  - HELP_THESIS_KEYS.INP
  - LIST_CONT_STUDY_SUBJECTS.INP
  - QUERY_THESES_CONT_STUDY.INP
- 2 - Review Research Sponsorship Information
  - HELP_CRITERIA_KEYS.INP
  - HELP_SPONSOR_KEYS.INP
  - LIST_SPONSORS.INP
  - QUERY_SPONSORS.INP
- 3 - Review Thesis Advisor Qualifications
  - HELP_CRITERIA_KEYS.INP
  - HELP_ADVISOR_KEYS.INP
  - LIST_INTEREST_AREAS..INP
  - QUERY_ADVISORS.INP
- 4 - Review Thesis Completion Status

  This option is diplayed on the menu as another example of the types of items that could be added to this subsystem. No forms were generated for this option, but the necessary data to generate them is contained in the existing ARMS tables.
- 5 - Review Research Publication Information

  This option is diplayed on the menu as another example of the types of items that could be added to this subsystem. No forms were generated for this option, but the necessary data to generate them is contained in the existing ARMS tables.
- 6 - Return to Previous Menu

4 - Database Administration Subsystem Menu

- 1 - Add/Change/Delete Records
  - UPDATE_ADVISOR_INFO.INP
  - UPDATE_COMPONENT_INFO.INP
  - UPDATE_SPONSOR_INFO.INP
  - UPDATE_THESIS_INFO.INP *
  - UPDATE_TOPIC_INFO.INP
- 2 - Perform Special Queries

  This option initiates a SQL*PLUS session and allows personnel knowledgeable of the ARMS tables to conduct complex SQL searches.
- 3 - Return to Previous Menu

5 - Exit (the ARMS)

* - The UPDATE_THESIS_INFO.INP form permits the database administrator to add, change, and delete records from the following tables: THESIS, ADVISOR_HISTORY, and STUDENT

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Vita

Captain David Schaaf was born on November 2, 1962, in Huntingburg, Indiana. He graduated from Heritage Hills High School, Lincoln City, Indiana, in May 1981 and then attended Purdue University. He earned a Bachelor of Science in Computer Science in May 1985 and received his commission through the Air Force Reserve Officer Training Corps program. Captain Schaaf was then assigned to Headquarters Strategic Air Command, Offutt AFB, Nebraska. He initially served as a systems programmer on the TRIAD Computer System (TRICOMS) and then as a contract manager for TRICOMS and the Joint Strategic Target Planning Staff (JSTPS). He entered the School of Systems and Logistics, Air Force Institute of Technology, in May of 1991.

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Vita

Captain Scott was born on 30 September 1959 in Framingham, Massachusetts, and graduated from Frankfort-Schuyler Central High School, Frankfort, New York, in 1977. He entered the Air Force as an enlisted member on 29 July 1977 and served 8 years as a communications-computer operations specialist. His enlisted assignments included tours at Torrejon AB, Spain; Langley AFB, Virginia; and the Pentagon.

He earned a Bachelor of Science Degree in Computer Science from Park College, Missouri--graduating Summa Cum Laude with a 4.0 grade point average in March 1985. After completing Officer Training School in June 1985, he was assigned to the 2147th Communications Wing, Royal Air Force Mildenhall, United Kingdom (UK). He initially served as the program manager for the 10-location, $40-million Scope Dial telephone switch replacement program and then as the Chief of UK Communications-Computer Operations. In October 1988, he was reassigned to Headquarters Tactical Air Command (TAC), Langley AFB, Virginia, as the Program Manager for Intelligence Systems Acquisition Logistics. In that position, he managed logistics support planning for 14 major command, control, communications, computer, and intelligence (C4I) programs valued in excess of $7 billion.

Captain Scott was a recipient of the Annual TAC Communications-Computer Professionalism Awards for 1989, and won both TAC and Air Force-wide honors for 1990. He entered the School of Systems and Logistics, Air Force Institute of Technology, in May of 1991.

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13. ABSTRACT *(Maximum 200 words)* The goal of this study was to design, develop, test, and evaluate an initial prototype information system to enhance the conduct and management of research in the School of Systems and Logistics at the Air Force Institute of Technology (AFIT). To accomplish this goal, the researchers developed and completed a methodology that was generally patterned after the milestones in a typical system development life cycle. The "proof-of-concept" nature of this research caused the researchers to also map the study's seven major objectives into a second system development model called the Spiral Model (Boehm, 1988:61). This hybrid approach provided better defined steps to a model that allows for iterative prototyping and served as the framework for this project. The prototype AFIT Research Management System (ARMS) produced by this study is comprised of subsystems that support research topic selection, research products reuse, research management, and database administration. An operational test of the system was completed and the results validated the desirability of the system concept and provided many recommendations for improving the ARMS. The recommendations for future research listed in Chapter V concern the follow-on development of the prototype and the conduct of important corollary studies.

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